National Aeronautics and Space Administration

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STS-116: POWER UP FOR SCIENCE

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STS-116 MISSION OVERVIEW: POWER RECONFIGURATION HIGHLIGHTS STATION ASSEMBLY MISSION

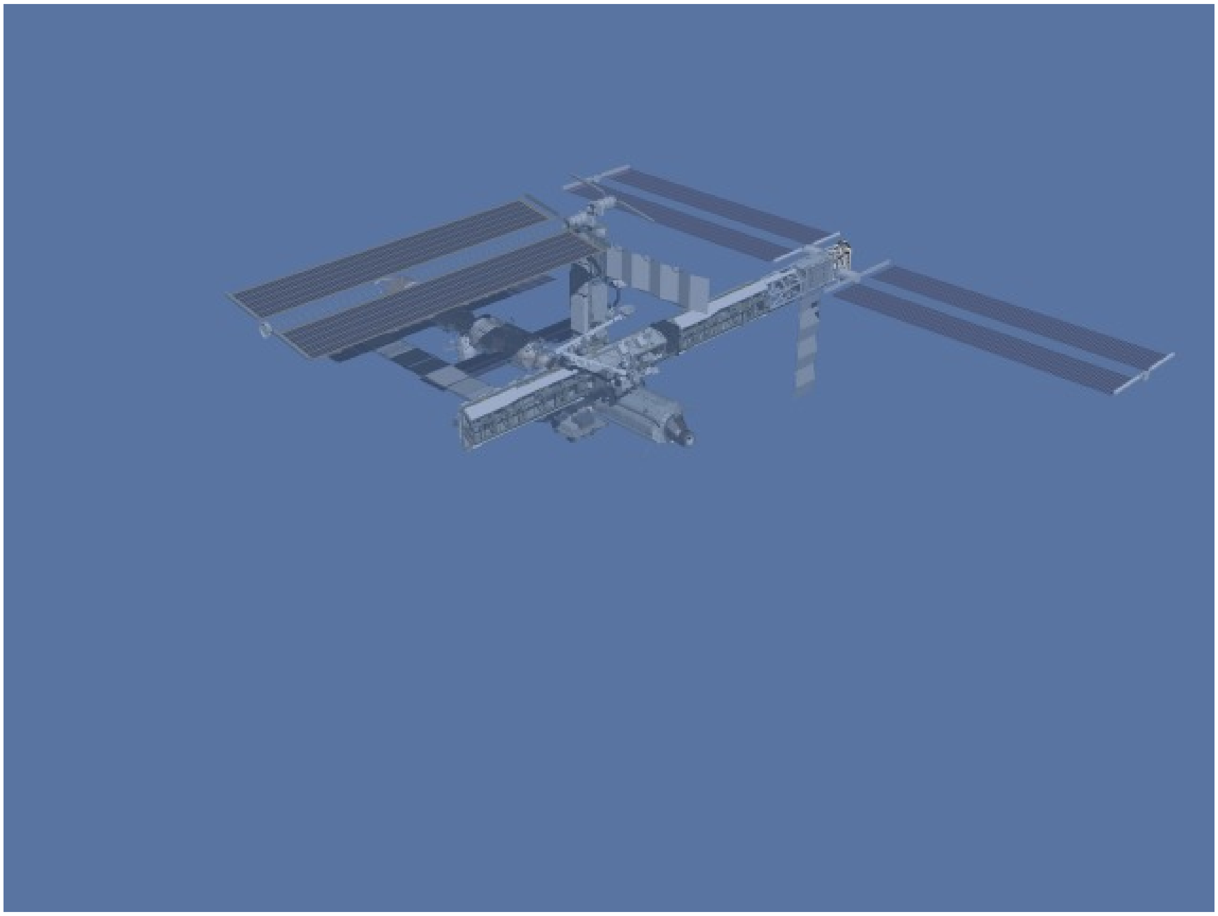
With its crane still attached, the orbiter Discovery was mated to the external tank and solid rocket boosters on the mobile launcher platform in high bay 3 of the Kennedy Space Center Vehicle Assembly Building.

Space Shuttle Discovery launches in December on its 33rd mission to deliver another truss segment of the International Space Station and begin the intricate process of reconfiguring and redistributing the power generated by two pairs of U.S. solar arrays.

The shuttle launches with seven astronauts—six shuttle and one long-duration station crew member. This is the first crew member rotation in four years involving a shuttle rather than a Russian Soyuz.

The primary assembly hardware Discovery will deliver to the space station is the $11-million Integrated Truss Segment P5, which measures 11 feet long by 15 feet wide by 14 feet high (3.3 x 4.5 x 3.2 meters). It will serve as a spacer and be mated to the P4 truss that was attached in September during the STS-115 mission of Atlantis.

Attachment of the 4,000-pound (1,800-kilogram) P5 sets the stage for the relocation to its final assembly position of the P6 truss and the pair of solar arrays that have been located temporarily atop the station's Unity module for six years.



A computer-generated artist's rendering of the International Space Station after flight STS-116/12A.1, following the delivery and installation of the third port truss segment (P5) and the retraction of the P6 port solar array wing and two radiators.

Three spacewalks (Extravehicular Activities or EVAs) spread across the seven days of docked operations will involve P5 installation and reconfiguration of cables so that flight controllers in Mission Control, Houston, can send commands to swap power generation and distribution from half of the P6 arrays to the newest P4 pair (power channel 2/3 moves to P4-2A and 1/4 moves to power channel P4-4A).

In addition to the P5 spacer, Discovery's payload bay also houses a small pressurized logistics module holding supplies and an integrated carrier delivering space station hardware and three small satellites to be deployed after the shuttle has undocked from the space station.

The 20th shuttle mission to the International Space Station represents the most choreographed assembly flight to date between the shuttle and station crew members and flight controllers in Mission Control, who will send all commands to carefully redistribute power and thermal management from one location to another. The STS-118 mission in the summer of 2007 will deliver an identical short spacer (S5) to the opposite end of the station's truss.

Discovery will launch with seven crew members, including Commander Mark Polansky, Pilot William (Bill) Oefelein (Commander, USN), and Mission Specialists Nicholas Patrick, Robert (Bob) Curbeam (Captain, USN), Joan Higginbotham, Christer Fuglesang representing the European Space Agency, and Sunita Williams. Williams will replace crew member Thomas Reiter (ESA) who will return to Earth aboard Discovery in her place. Williams will return home next summer following Endeavour's STS-118 mission.

Attired in their training versions of the shuttle launch and entry suit, astronauts Mark L. Polansky (left), STS-116 commander, and William A. Oefelein, pilot, occupy the commander and pilot's station during a training session in the fixed-base shuttle mission simulator (SMS) in the Jake Garn Simulation and Training Facility at Johnson Space Center.

The launch from complex 39B at the Kennedy Space Center, Florida, is timed precisely to occur within the same launch plane (similar to a lane on a highway) as the space station to maximize propellant savings and minimize rendezvous time.

Because of the excellent performance of the shuttle's external tank in minimizing foam shedding during ascent, and the ability to perform a 100 percent inspection of the orbiter thermal protection system for unlikely damage, the restriction for daylight-only launches has been lifted. This allows Discovery’s launch to take place at night for the first 10 days of its “window,” which opens no earlier than Dec. 7 and closes on or about Dec. 26 based on a sun beta angle constraint.

The first three days of the mission nearly mirror those of the previous three shuttle flights to inspect the thermal protection system tiles and the wing leading edge reinforced carbon-carbon panels, and rendezvous and dock with the International Space Station.

Patrick is the prime shuttle remote manipulator system (robotic arm) operator and will lead the inspection effort using the Remote Manipulator System (RMS) extension – the Orbiter Boom Sensor System. Polansky and Oefelein serve as backup shuttle arm operators.

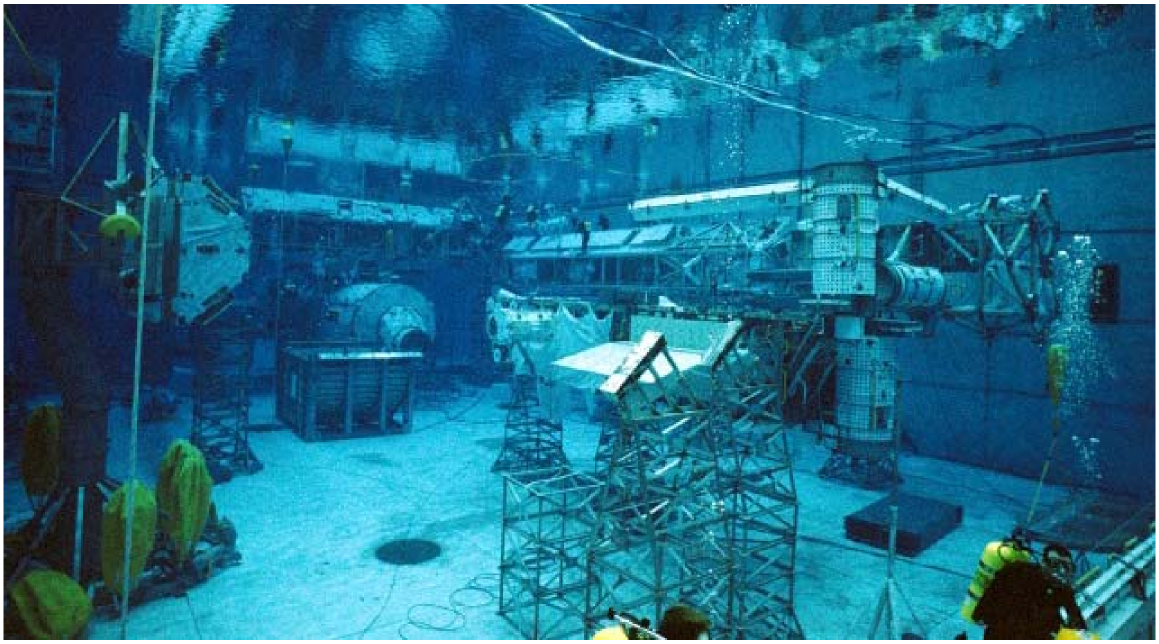
The highest priority tasks of the flight will be to transfer one station crewmember for another, install the new P5 short spacer, reconfigure the electrical power system and thermal control system and transfer extra oxygen to storage tanks on the outside of the U.S. Quest Airlock.

Astronaut Nicholas J. M. Patrick, STS-116 mission specialist, participates in a training session in the crew compartment trainer (CCT-2) in the Space Vehicle Mockup Facility at Johnson Space Center.

In the Kennedy Space Center Space Station Processing Facility, an overhead crane moves the P5 truss for mission STS-116 to the payload canister. The third port truss segment, the P5 will be attached to the P3/P4 truss on the International Space Station during the 11-day mission.

After docking, the first priority is to transfer form-fitting seat liners in the Soyuz spacecraft making Williams an official member of the Expedition 14 crew along with Commander Michael Lopez-Alegria and Flight Engineer Mikhail Tyurin. Reiter then becomes a member of the shuttle crew with which he will return home after a six-month stay on the station.

On flight day 3, Patrick will carefully lift the P5 spacer with the shuttle RMS and hand it to the waiting station arm. Higginbotham and Williams will control the station arm at the station's robotic work station in the Destiny Laboratory. The spacer will remain on the station's arm overnight in preparation for installation the next day during the first of three planned spacewalks.



Astronauts Robert L. Curbeam, Jr. and Christer Fuglesang, STS-116 mission specialists, wearing training versions of the Extravehicular Mobility Unit (EMU) spacesuit, participate in an underwater simulation of extravehicular activity (EVA). Curbeam and Fuglesang are dwarfed by station truss segments in this overall view of the simulation conducted in the Neutral Buoyancy Laboratory (NBL) near the Johnson Space Center.

The day after docking (flight day 4), Curbeam and Fuglesang will leave the Quest Airlock on a six-hour spacewalk to assist with installation and utility connections between the P5 short spacer and the P4 truss.

The connection tasks include removal of four launch locks with the two truss segments approximately 6-12 inches apart. The spacewalkers then will serve as on-the-scene observers for alignment and installation of P5 to P4. The installation is completed with the mating of six utility cables.

Astronaut Robert L. Curbeam, STS-116 mission specialist, attired in a training version of the Extravehicular Mobility Unit (EMU) spacesuit, awaits a training session in the waters of the Neutral Buoyancy Laboratory (NBL) near Johnson Space Center.

European Space Agency (ESA) astronaut Christer Fuglesang, STS-116 mission specialist, participates in an Extravehicular Mobility Unit (EMU) spacesuit fit check in the Space Station Airlock Test Article (SSATA) in the Crew Systems Laboratory at the Johnson Space Center. Astronaut William A. Oefelein, pilot, assisted Fuglesang.

Between the first and second spacewalks begins a process of power and thermal reconfiguration that has never been attempted before. Ground commanding removes power from one half of the P6 solar array followed by the retraction of its port array. A minimum of 40 percent of the array must be retracted to provide enough clearance for activation of the P4 solar array tracking rotary joint tested during the previous shuttle mission (STS-115). The starboard solar array of P6 will be retracted during STS-117 next March before installation of the S3/S4 set of solar arrays on the integrated truss structure of the station.

Though full retraction of the P6 port array is not necessary, it is planned in a three-step process budgeted for five hours, with retraction of three “bays” first. Then the port array will continue to be retracted to approximately 40 percent, and finally to one bay.

The next four hours includes filling one of the thermal control systems with ammonia before the final retraction of the solar array into its canister.

Once automatic sun tracking is confirmed for the new P4 arrays, the stage is set for the next day’s second spacewalk to reconfigure power to the outboard arrays. This requires precise coordination between the ground and crew to ensure electrical power is not flowing.

The United States Orbital Segment (USOS) electrical power system (EPS) is divided into three main subsystems: primary, secondary and support systems. The goal while Discovery is docked is to reconfigure the station's power system from the current temporary status to its “assembly complete” configuration.

The S0 truss segment sits in the middle position on the truss structure on top of the U.S. Destiny

Laboratory, flanked by the S1 and P1 truss elements. That truss and the S1 and P1 trusses contain the major electrical components of the permanent electrical system. Those are the Main Bus Switching Units (MBSUs) and large transformers called DC-to-DC converter units (DDCUs) that serve to modulate solar array power to the proper levels required to operate station systems.

S1 and P1 also house the station's two independent cooling systems, each of which include large ammonia tanks, a nitrogen gas pressurization system and a massive pump module to enable ammonia to flow through plumbing lines to radiators that will dissipate heat from the avionics systems on the station. There are three such radiators on S1 and three on P1. To facilitate that heat rejection, the radiators are mounted on a rotating beam that can point them toward deep space and away from the sun.

For the second time in three days, Curbeam and Fuglesang will head out of the Quest Airlock on the mission’s second spacewalk on the sixth day of the mission to reconfigure part of the power channel (2/3) by routing primary power through the MBSUs.

Williams joins Curbeam on the third spacewalk on the eighth day of the mission to do the same reconfiguration on the other half of the power channel (1/4). Oefelein will serve as the in-cabin choreographer for all spacewalks and spacesuit checkout.

Astronauts Sunita L. Williams (left), Expedition 14 flight engineer, and Joan E. Higginbotham, STS-116 mission specialist, use the virtual reality lab at the Johnson Space Center to train for their duties aboard the space shuttle. This type of computer interface, paired with virtual reality training hardware and software, helps to prepare the entire team for dealing with space station elements.

Mounted on the central truss segment (S0) launched in April 2002, these four MBSUs have never been activated, but were checked out during that mission and again in December 2002.

While the crew members prepare for the second and third spacewalks, a lengthy set of power-down commands will be executed by flight controllers to place all associated equipment in a safe configuration before opening the Direct Current Switching Unit remote bus isolators.

Because the MBSUs generate heat when current is flowing, they require cooling via the ammonia loops. Estimates show the MBSUs can run without cooling for about one hour, so well-choreographed commanding is planned to activate the ammonia pump module to provide cooling to the MBSUs within that timeframe.

Once the power reconfiguration is complete, the station's newest pair of solar arrays on the port side of the truss will be brought to life to provide electrical power to the station.

Throughout the mission, transfer of cargo from the pressurized module (SPACEHAB) in Discovery's payload bay takes place to resupply the station.

Hardware stowed in the module includes a Video Baseband Signal Processor, a Rotary Joint Motor Controller Assembly, an External TV Camera Group (ETVCG), Oxygen Generation System, Adjustable Grapple Bar; Remote Power Control Module(s), Nickel Removal Assembly Kit, Charcoal Bed Assembly, Desiccant/Adsorbent replacement unit, Control Moment Gyro Electrical Assembly and an Avionics Air Assembly.

After the outside work is completed and before Discovery departs, the station's Mobile Transporter will be relocated to the starboard end of the truss and will undergo a checkout in preparation for the next shuttle visit, scheduled for March 2007, to deliver another truss segment and the third pair of solar arrays – a mirror-image flight to that of Atlantis on the STS-115 mission in September.

On flight day 9, (the day after EVA 3), the Mobile Transporter will be moved to the starboard end of the truss and undergo a checkout in preparation for its support of the next assembly mission next March.

Once transfers are complete, the shuttle will undock from the station, conduct a flyaround and move to a station-keeping distance of about 40 miles.

Back on its own, Discovery's crew will oversee a final inspection of the orbiter's thermal protection system to ensure it has not sustained any damage from micrometeoroid debris before the shuttle is cleared for entry. The crew will also remotely deploy three small technology-demonstration satellites mounted inside canisters along an equipment carrier in the payload bay.

The carrier also holds the Service Module Debris Panels, 15 Adjustable Mass Plates and an ISS Passive Flight Releasable Attachment Mechanism.

Activities on the day before landing include stowage of gear and checkout of orbiter entry and landing systems, including the flight control surfaces and thruster jets used for on-orbit and entry steering.

Discovery is scheduled to land the following day at the Kennedy Space Center, completing the 117th shuttle mission.

STS-116 TIMELINE OVERVIEW

FLIGHT DAY 1:

- Launch
- Payload Bay Door Opening
- Spacehab Module Activation
- Ku-Band Antenna Deployment
- Shuttle Robot Arm Power Up
- External Tank Handheld Video, Umbilical Well Imagery and Wing Leading Edge Sensor Data Downlink

FLIGHT DAY 2:

- Shuttle Robot Arm Checkout
- Shuttle Robot Arm Grapple of Orbiter Boom Sensor System (OBSS)
- Inspection of Shuttle Thermal Protection System and Wing Leading Edge Reinforced Carbon-Carbon (RCC)
- OBSS Berthing
- Spacesuit Checkout
- Orbiter Docking System Outer Ring Extension
- Airlock Preparations
- Rendezvous Tool Checkout

FLIGHT DAY 3:

- Rendezvous Operations
- Terminal Initiation Engine Firing
- Rendezvous Pitch Maneuver and ISS Digital Photography of Discovery
- Docking to the International Space Station
- Hatch Opening and Welcoming by Expedition 14 Crew
- Suni Williams joins Expedition 14 crew with Soyuz seatliner transfer; Thomas Reiter joins shuttle crew
- Shuttle robot arm grapple of P5 spacer truss and handoff to station robot arm
- Curbeam and Fuglesang sleep in Quest Airlock for spacewalk pre-breathe campout protocol

FLIGHT DAY 4:

- Station robot arm installs P5 spacer truss installation on P4 truss attachment
- Curbeam and Fuglesang EVA # 1 to connect P5 / P4 power cables, release launch restraints and to change out TV camera on S1 truss
- Mobile Transporter moves from Worksite 7 to Worksite 3

FLIGHT DAY 5:

- P6 truss port array is retracted to enable Solar Alpha Rotary Joint activation and rotation on P4 truss
- P4 Solar Alpha Rotary Joint activation and autotracking of the sun
- Port side loop of External Active Thermal Control System is filled with ammonia
- Curbeam and Fuglesang sleep in Quest Airlock for spacewalk pre-breathe campout protocol

FLIGHT DAY 6:

- ISS power down of electrical channels 2 and 3
- Curbeam and Fuglesang EVA # 2 to reconfigure electrical channels 2 and 3, relocate Crew Equipment Translation Aid (CETA) carts 1 and 2
- ISS Treadmill Vibration Isolation System gyroscope replacement and maintenance
- Port side loop of the External Active Thermal Control System is activated to allow ammonia to flow
- ISS power up of electrical channels 2 and 3

FLIGHT DAY 7:

- Shuttle to ISS transfer work
- Joint Crew News Conference
- Crew off duty time
- Starboard side loop of External Active Thermal Control System is filled with ammonia
- Curbeam and Williams sleep in Quest Airlock for spacewalk pre-breathe campout protocol

FLIGHT DAY 8:

- ISS power down of electrical channels 1 and 4
- Curbeam and Williams EVA # 3 to reconfigure electrical channels 1 and 4 and transfer Service Module Debris Panels to Pressurized Mating Adapter 3
- Starboard side loop of the External Active Thermal Control System is activated to allow ammonia to flow
- ISS power up of electrical channels 1 and 4

FLIGHT DAY 9:

- Shuttle to ISS transfer work
- Mobile Transporter moves to Worksite 2 for S3 / S4 survey for STS-117, then returns to Worksite 4
- Rendezvous tool checkout in preparation for undocking

FLIGHT DAY 10:

- Final transfer work
- Farewells and Hatch Closing
- Undocking and ISS flyaround
- Final separation from ISS
- MEPSI pico-satellite deploy
- ANDE pico-satellite deploy

FLIGHT DAY 11:

- Flight Control System Checkout
- Reaction Control System Hot-Fire Test
- Cabin Stowage
- RAFT pico-satellite deploy
- Deorbit Timeline Review
- Recumbent Seat Set Up for Reiter in middeck
- Ku-Band Antenna Stowage

FLIGHT DAY 12:

- Deorbit Preparations
- Payload Bay Door Closing
- Deorbit Burn
- KSC Landing

MISSION PRIORITIES

1. Perform inspection of space shuttle reinforced carbon-carbon (RCC) and downlink sensor data for evaluation on the ground.

2. Document space shuttle tile during rendezvous with station using ISS imagery resources during the rendezvous pitch maneuver (RPM), followed by docking.

3. Complete ISS crew member swap (Expedition 14 Flight Engineer Suni Williams for Expedition 13 Flight Engineer Thomas Reiter).

    - Install the Soyuz seat liner, known as the Individual Equipment Liner Kit (IELK)
    - Check out the Russian launch/entry suit, known as the Sokol suit
    - ISS safety briefing
    - Transfer mandatory crew rotation items

    (a) Transfer required oxygen to ISS (~100 pounds).

    (b) Transfer and return Elektron.

4. Transfer water.

5. Install the P5 truss segment onto P4 using the shuttle and station robotic arms.

    - Remove P5 inboard launch locks (required for mating with P4)
    - Install four truss attachment bolts to structurally mate P5 to P4
    - Remove P5 grapple fixture and relocate to P5 keel (will allow P4 beta gimbal assembly to rotate)

6. Deactivate P6 2B loads and reconfigure U.S. segment loads to receive power distribution from P4 2A and P6 EB via main bus switching units 2 and 3. This includes establishment of active cooling for channel 2/3 MBSUs and DC-to-DC converter units via external active thermal control system loop B.

    - Retract P6 4B solar array wing to one bay and initiate P3/P4 solar alpha rotary joint tracking.
    - Remove P1-3A DC-to-DC converter unit-E thermal covers.

7. Deactivate P6 4B loads and reconfigure U.S. segment loads to receive power distribution from P4 4A main buss switching unit 1 and 4. This includes establishment of active cooling for channel ¼ MBSUs/DDCUs via external active thermal control system loop A. (P6 4B channel configured to dormant/parachute mode.

    - Remove S1-4B and S0-4B DC-to-DC converter unit-E thermal covers.
    - Uplink the D1 patch to portable computer system R9.

8. Transfer critical cargo items per transfer priority list.

9. Transfer Zvezda Service Module debris panels and adapter to pressurized mating adapter-3 aft grapple fixture.

10. Relocate both Crew and Equipment Translation Aid (CETA) carts from the starboard side to the port side.

    (a) Perform contingency spacewalk to complete primary mission objectives.

    (b) Perform late inspection of Discovery's wing leading edge and nosecap.

11. Perform minimum crew handover (12 hours) for rotating crew members.

    (a) Perform the Oxygen Recharge Compressor Assembly and Carbon Dioxide Removal Assembly removal and replacement and return removed hardware via shuttle.

12. Perform utilization activities to support experiments, including midodrine, ALTEA, Latent Virus, Sleep Short, and PMDIS.

13. Perform daily ISS payload status checks as required.

14. Transfer remaining cargo items per mission rules.

15. Perform external wireless instrumentation system power connections between P5 and P4.

16. Remove and replace External Television Camera Group (ETVCG) at Camera Port 3, Starboard 1 Outboard Lower.

17. Transfer the adjustable grapple bar from inside the station to the flex hose rotary coupler on external stowage platform-2.

18. Perform P6 4B final retraction and latching of the solar array blanket box.

19. Install power cables for S0 channels 1/4 2/3.

20. Perform payload operations to support STP-H2 (ANDE, MEPSI, RAFT).

21. Perform the following to allow return of on-orbit hardware:

    - Treadmill gyro removal and replacement
    - Charcoal bed assembly
    - Respiratory support pack checkout

22. Transfer nitrogen from the shuttle to the ISS Quest Airlock high pressure tanks.

23. Perform U.S. and Russian payload research operation tasks.

24. Perform an additional four hours of ISS crew handover (16 hours total).

25. Perform imagery survey of the ISS exterior from shuttle after undocking.

26. Perform payload operations to support Maui Analysis of Upper Atmospheric Injections (MAUI) and Ram Burn Observations (RAMBO)

27. Reboost ISS (altitude TBD based on available shuttle propellant).

28. The following tasks fit within the existing spacewalk timelines; however, they may be deferred if the spacewalk is behind schedule. The EVA will not be extended to complete these tasks.

    - Install station robot arm force moment sensor (FMS) insulation
    - Install the starboard and port fluid quick disconnect bags on the Quest Airlock

- Install S0/Unity Node primary power cable (S0 side only) and reconfigure Z1 patch panels and Russian power to operate from primary power (i.e., MBSU)

29. Perform program-approved spacewalk get-ahead tasks. The following get-ahead tasks do not fit in the existing spacewalk timelines; however, the team will be trained and ready to perform any of these tasks should the opportunity arise.

    - Connect P5 to P4 umbilicals (6)
    - Open P5 capture latch assembly (CLA) and partially close (~ 1 turn)
    - Remove P5 to P6 truss attachment system launch locks
    - Install the pump module jumper bag on the Quest Airlock
    - Install the vent tool extension bag on Quest

30. Perform:

    - Development Test Objective (DTO) 257 – Structural Dynamics Model Validation Flight Test and Supplementary Objectives Document (Internal Wireless Instrumentation System, known as IWIS, is required)
    - Perform ISS Structural Life Validation and Extension for the shuttle undocking (IWIS required).

LAUNCH AND LANDING

LAUNCH

As with all previous Space Shuttle launches, Discovery on STS-116 will have several modes available that could be used to abort the ascent if needed due to engine failures or other systems problems. Shuttle launch abort philosophy aims toward safe recovery of the flight crew and intact recovery of the orbiter and its payload. Abort modes include:

ABORT-TO-ORBIT (ATO)

Partial loss of main engine thrust late enough to permit reaching a minimal 105 by 85 nautical mile orbit with orbital maneuvering system engines.

TRANSATLANTIC ABORT LANDING (TAL)

Loss of one or more main engines midway through powered flight would force a landing at either Zaragoza, Spain; Moron, Spain; or Istres, France. For launch to proceed, weather conditions must be acceptable at one of these TAL sites.

RETURN-TO-LAUNCH-SITE (RTLS)

Early shutdown of one or more engines, and without enough energy to reach Zaragoza, would result in a pitch around and thrust back toward KSC until within gliding distance of the Shuttle Landing Facility. For launch to proceed, weather conditions must be forecast to be acceptable for a possible RTLS landing at KSC about 20 minutes after liftoff.

ABORT ONCE AROUND (AOA)

An AOA is selected if the vehicle cannot achieve a viable orbit or will not have enough propellant to perform a deorbit burn, but has enough energy to circle the Earth once and land about 9i0 minutes after liftoff.

LANDING

The primary landing site for Discovery on STS-116 is the Kennedy Space Center's Shuttle Landing Facility. Alternate landing sites that could be used if needed due to weather conditions or systems failures are at Edwards Air Force Base, California, and White Sands Space Harbor, New Mexico.

MISSION PROFILE

CREW

Commander:	Mark Polansky
Pilot:	Bill Oefelein
Mission Specialist 1:	Nicholas Patrick
Mission Specialist 2:	Bob Curbeam
Mission Specialist 3:	Christer Fuglesang
Mission Specialist 4:	Joan Higginbotham
Mission Specialist 5:	Suni Williams/ Thomas Reiter

LAUNCH

Orbiter:	Discovery (OV-103)
Launch Site:	Kennedy Space Center Launch Pad 39B
Launch Date:	No Earlier Than December 7, 2006
Launch Time:	9:36 p.m. EST (Preferred In-Plane launch time for 12/7)
Launch Window:	5 Minutes
Altitude:	123 Nautical Miles (142 Miles) Orbital Insertion; 190 NM (218 Miles) Rendezvous
Inclination:	51.6 Degrees
Duration:	10 Days 18 Hours 40 Minutes

VEHICLE DATA

Shuttle Liftoff Weight:	4,521,350 pounds
Orbiter/Payload Liftoff Weight:	265,466 pounds
Orbiter/Payload Landing Weight:	225,350 pounds
Software Version:	OI-30

Space Shuttle Main Engines:

SSME 1:	2050
SSME 2:	2054
SSME 3:	2058
External Tank:	ET-123
SRB Set:	BI-128
RSRM Set:	95

SHUTTLE ABORTS

Abort Landing Sites

RTLS:	Kennedy Space Center Shuttle Landing Facility
TAL:	Primary – Zaragoza, Spain. Alternates Moron and Istres, France
AOA:	Primary – Kennedy Space Center Shuttle Landing Facility; Alternate White Sands Space Harbor

Landing

Landing Date:	No Earlier Than December 18, 2006
Landing Time:	4:16 p.m. EST
Primary landing Site:	Kennedy Space Center Shuttle Landing Facility

PAYLOADS

Integrated Truss Segment (ITS)-P5, SPACEHAB Single Module

STS-116 DISCOVERY CREW

The STS-116 patch design signifies the continuing assembly of the International Space Station. The primary mission objective is to deliver and install the P5 truss element. The P5 installation will be conducted during the first of three planned spacewalks, and will involve use of both the shuttle and station robotic arms. The remainder of the mission will include a major reconfiguration and activation of the station's electrical and thermal control systems, as well as delivery of Zvezda Service Module debris panels, which will increase protection from potential impacts of micro-meteorites and orbital debris. In addition, a single expedition crew member will launch on STS-116 to remain on board the station, replacing an expedition crew member Thomas Reiter, who will fly home with the shuttle crew. The crew patch depicts the space shuttle rising above the Earth and the station. The United States and Swedish flags trail the orbiter, depicting the international composition of the STS-116 crew. The seven stars of the constellation Ursa Major are used to provide direction to the North Star, which is superimposed over the installation location of the P5 truss on the station.

These seven astronauts take a break from training to pose for the STS-116 crew portrait. Scheduled to launch aboard the Space Shuttle Discovery are, front row (from the left), astronauts William A. Oefelein, pilot; Joan E. Higginbotham, mission specialist; and Mark L. Polansky, commander. On the back row (from the left) are astronauts Robert L. Curbeam, Nicholas J.M. Patrick, Sunita L. Williams and the European Space Agency's Christer Fuglesang, all mission specialists. Williams will join Expedition 14 in progress to serve as a flight engineer aboard the International Space Station. The crew members are attired in training versions of their shuttle launch and entry suits.

Short biographical sketches of the crew follow with detailed background available at:

http://www.jsc.nasa.gov/Bios/

Commander Mark Polansky

A former Air Force test pilot, Mark Polansky will lead the crew of STS-116 on the 20th shuttle mission to the space station. Polansky served as the pilot on STS-98 in 2001. Making his second spaceflight, he has logged more than 309 hours in space. He has overall responsibility for the on-orbit execution of the mission, orbiter systems operations and flight operations including landing the orbiter. In addition, Polansky will fly the shuttle in a procedure called the rendezvous pitch maneuver while Discovery is 600 feet below the station before docking to enable the station crew to photograph the orbiter's heat shield. He will then dock Discovery to the station. Polansky will also be heavily involved in shuttle robotic arm operations for inspecting the orbiter’s heat shield, and transferring cargo to the station during the docked phase of the mission.

Pilot Bill Oefelein

William Oefelein (Oh'-fe-line), who has logged more than 3,000 hours flying more than 50 aircraft, will make his first journey into space as the pilot for the STS-116 mission. Selected by NASA in June 1998, Oefelein reported to the Johnson Space Center in Houston in August 1998. He has served in the Astronaut Office Advanced Vehicles Branch and CAPCOM (capsule communicator) Branch. He will be responsible for orbiter systems operations and assisting Polansky in the rendezvous and docking to the International Space Station. He will also serve as the choreographer inside Discovery and the station for the mission's three planned spacewalks, helping to suit up and direct the spacewalkers through their activities. Oefelein will undock Discovery from the station at the end of the docked phase of the mission and conduct a flyaround to enable his crewmates to photograph the station's configuration and assess its condition.

Mission Specialist Nicholas Patrick

A member of the 1998 astronaut class and a former flight instructor, Nicholas Patrick is assigned to STS-116 as mission specialist 1 (MS-1). He reported to NASA's Johnson Space Center in Houston for astronaut training in August 1998. His initial training included scientific and technical briefings, intensive instruction in shuttle and International Space Station systems, physiological, survival and classroom training in preparation for T-38 flight. Making his first spaceflight, Patrick will be the primary operator of the shuttle's robotic arm, using it to unberth the orbiter boom sensor system to survey Discovery's thermal protection system on flight day 2 and to grapple the station's P5 truss for a handoff to the station robotic arm operated by Mission Specialist Joan Higginbotham on flight day 3. He will be responsible for the shuttle's video and computer networks, and will assist with the transfer of cargo between the shuttle and the station. He will be seated on the flight deck for launch and on the middeck for landing.

Mission Specialist Bob Curbeam

A veteran of two space shuttle flights, Mission Specialist 2 (MS 2) Bob Curbeam conducted three spacewalks before being assigned to STS-116. He flew on STS-85 in August 1997 and on STS-98 in February 2001. He logged more than 19 hours over the course of three spacewalks during STS-98, completing delivery of the U.S. laboratory Destiny to the space station. He will conduct three spacewalks during STS-116. Curbeam, as EV 1, will conduct the first two spacewalks of the mission with Christer Fuglesang on flight days 4 and 6. During the first spacewalk, the two will install the P5 truss and attach all mechanical and electrical interfaces between it and the existing station truss. They also will change out a TV camera on the starboard 1 (S1) truss. During the second spacewalk, the duo will unplug station power channels 2 and 3 from the P6 power truss and connect them to the main truss (permanent) power system. They also will move the Crew and Equipment Translation Aid carts in preparation the next power reconfiguration to occur during the third spacewalk of the mission. Curbeam will conduct the third planned spacewalk of the mission on flight day 8 with Sunita Williams. They will unplug station power channels 2 and 3 from the P6 power truss and connect them to the main truss (permanent) power system. They also will transfer Service Module debris panels from the shuttle to the station. Curbeam will be seated on the flight deck for launch and landing, operating as the flight engineer to assist Commander Mark Polansky and Pilot Bill Oefelein.

Mission Specialist Christer Fuglesang

Making his first spaceflight, European Space Agency astronaut Christer Fuglesang (Fyu'-gel-sang) joins the crew of STS-116 as a mission specialist. Fuglesang is a member of ESA's European Astronaut Corps, whose home base is the European Astronaut Centre in Cologne, Germany. He entered the mission specialist class at NASA's Johnson Space Center in August 1996 and qualified for flight assignment as a mission specialist in April 1998.

Mission Specialist 3 (MS 3) Fuglesang, as EV 2, will conduct the first two planned spacewalks of the mission with Curbeam on flight days 4 and 6. Fuglesang is the lead for deploying three small satellites from the payload bay toward the end of the mission. Fuglesang will set up the recumbent seat returning Expedition 14 crew member Thomas Reiter will use for the trip home aboard the shuttle. Fuglesang will be seated on the middeck for launch and landing.

Mission Specialist Joan Higginbotham

Mission Specialist 4 (MS 4) Joan Higginbotham will be making her first flight into space aboard Discovery. To assist with the construction of the space station, Higginbotham's primary task on STS-116 will be to operate the station's robotic arm. Among other robotic tasks, she will use the station arm to install the P5 truss onto the P4 truss attachment on flight day 4. During the rendezvous, docking and undocking, she will manage the rendezvous navigation tools used to guide the shuttle's trajectory relative to the station. She will serve as the lead cargo transfer officer, overseeing the transfer of supplies and equipment between the shuttle and the station. She will oversee payload bay door closing operations. She will be seated on the middeck for launch and the flight deck for landing.

Mission Specialist/Expedition 14 Flight Engineer Suni Williams

Making her first spaceflight, Mission Specialist 5 (MS 5) Sunita (Soo-nee'-tah) Williams will join Expedition 14 in progress and serve as a flight engineer after traveling to the station on space shuttle mission STS-116. Williams, who goes by the name Suni (sunny), will join Expedition 14 on flight day 3, when her Soyuz seatliner is transferred from the shuttle 3. The transfer will mark the beginning of her scheduled six-month stay aboard the station. Williams, as EV 3, will join Bob Curbeam for the third planned spacewalk of the mission on flight day 8. She will be seated on the middeck for launch.

Thomas Reiter

International Space Station Flight Engineer Thomas Reiter (Toe-mahs' Rye'-turr) (FE 2) of the European Space Agency (ESA) flew to the space station aboard Discovery in July 2006 and became a member of the Expedition 13 crew. He will return to Earth aboard Discovery with the STS-116 crew. In September 2006, Expedition 13 Commander Pavel Vinogradov and Flight Engineer and NASA Science Officer Jeff Williams left the station aboard a Russian Soyuz spacecraft. Reiter was joined by Expedition 14 Commander Mike Lopez-Alegria and Flight Engineer Mikhail Tyurin. Reiter is the first crew member to serve on two expeditions. He spent 179 days in space in 1995-1996 for a mission to the Russian Mir space station during which he conducted two spacewalks and about 40 European scientific experiments. Reiter is the first ESA astronaut to live aboard the International Space Station for a long-term mission. Reiter worked on the station as part of an agreement between the Russian Federal Space Agency and ESA. Reiter will be on the middeck for landing in a specially designed recumbent seat to facilitate his adaptation to a gravity environment for the first time in six months.

MISSION PERSONNEL

KEY CONSOLE POSITIONS FOR STS-116

	Flt. Director	CAPCOM	PAO
Ascent	Steve Stich	Ken Ham Chris Ferguson (Wx)	Kelly Humphries
Orbit 1 (Lead)	Tony Ceccacci	Kevin Ford	Kyle Herring (Lead)
Orbit 2	Matt Abbott	Megan McArthur	Nicole Cloutier
Planning	Rick LaBrode	Shannon Lucid	John Ira Petty
Entry	Norm Knight	Ken Ham Chris Ferguson (Wx)	Kyle Herring
Shuttle Team 4	Richard Jones	N/A	N/A
ISS Orbit 1	Derek Hassmann	Terry Virts	N/A
ISS Orbit 2 (Lead)	John Curry	Steve Robinson	N/A
ISS Orbit 3	Joel Montalbano	Hal Getzelman	N/A
Station Team 4	Dana Weigel	N/A	N/A
Mission Control, Korolev, Russia	Kwatsi Alibaruho	N/A	N/A

JSC PAO Representative at KSC for Launch – Kylie Clem
KSC Launch Commentator – Bruce Buckingham
KSC Launch Director – Mike Leinbach
NASA Launch Test Director – Jeff Spaulding

RENDEZVOUS AND DOCKING

Discovery's final approach to the International Space Station during the STS-116 rendezvous and docking process will include the now-standard back flip pirouette maneuver to allow station crewmembers to take digital images of the shuttle's heat shield.

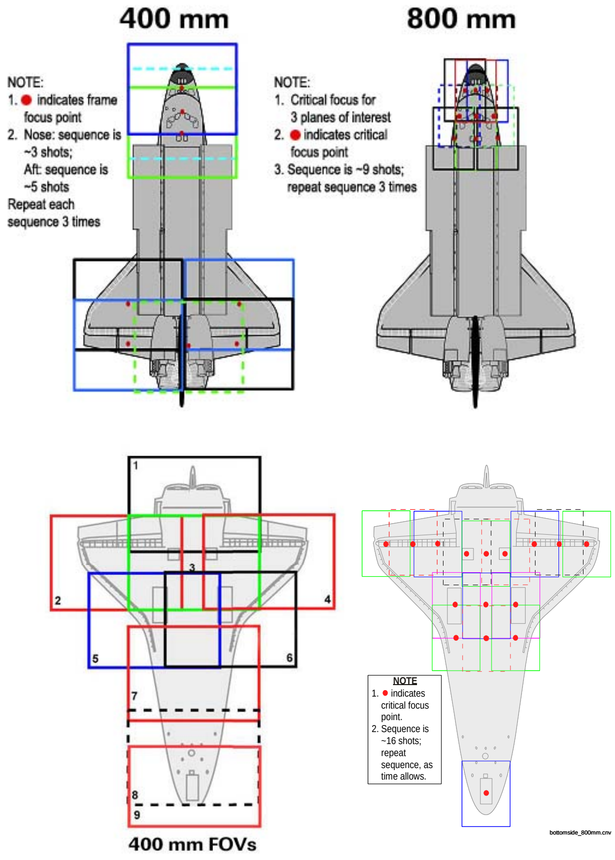
With shuttle Commander Mark Polansky at the controls, the shuttle will perform the circular pitch-around from a distance of about 600 feet below the station. The 9-minute flip offers Expedition 14 Commander Mike Lopez-Alegria and Flight Engineer Mikhail Tyurin time to document through digital still photography the required imagery of Discovery's thermal protection system.

The photos then will be transmitted to imagery experts in the Mission Evaluation Room at Mission Control, Houston, via the station's Ku-band communications system.

The photography will be performed out of windows 6 and 8 in the Zvezda Service Module with Kodak DCS 760 digital cameras and 400 mm and 800 mm lenses. The Rendezvous Pitch Maneuver (RPM) is one of several inspection procedures designed to verify the integrity of the shuttle's protective tiles and reinforced carbon-carbon wing leading edge panels.

The sequence of events that brings Atlantis to its docking with the station begins with the precisely timed launch of the shuttle, placing the orbiter on the correct trajectory and course

The sequence of events that culminate with Discovery's docking to the station actually begins with the precisely timed launch that places the orbiter on course for its two-day chase to arrive at the station. The 43-hour rendezvous includes periodic thruster firings that ultimately will place Discovery about 9 statute miles behind the station, the starting point for final approach.

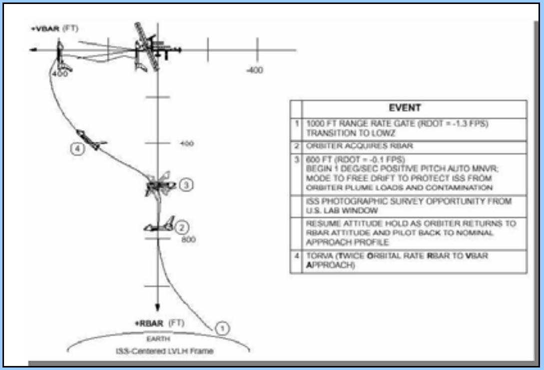


About 2.5 hours before the scheduled docking time on flight day 3, Discovery will reach a point about 50,000 feet behind the station. Discovery's jets will be fired in what is called the Terminal Initiation (TI) burn to begin the final phase of the rendezvous. Discovery will close the final miles to the station during the next orbit.

As Discovery moves closer to the station, the shuttle's rendezvous radar system and trajectory control sensor (TCS) will begin tracking the complex, and providing range and closing rate information to the crew. During the final approach, Discovery will execute four small mid-course corrections with its steering jets to position the shuttle about 1,000 feet directly below the station. From this point, Polansky will take over the manual flying of the shuttle up an imaginary line drawn between the station and the Earth known as the R-Bar—or radial vector.

He will slow Discovery's approach at about 600 feet and, if required, wait for proper lighting conditions to optimize inspection imagery gathering as well as crew visibility for the final rendezvous to docking.

Rendezvous Approach Profile



Space Shuttle Rendezvous Maneuvers

OMS-1 (Orbit insertion) - Rarely used ascent burn.

OMS-2 (Orbit insertion) - Typically used to circularize the initial orbit following ascent, completing orbital insertion. For ground-up rendezvous flights, also considered a rendezvous phasing burn.

NC (Rendezvous phasing) - Performed to hit a range relative to the target at a future time.

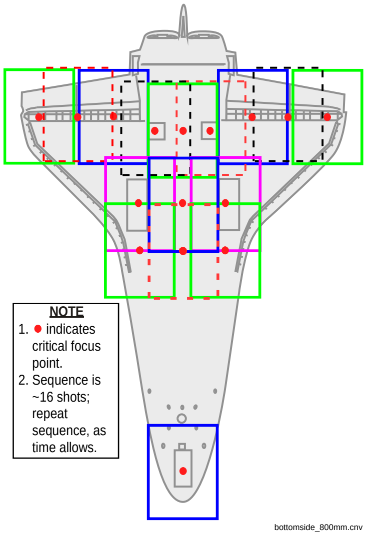
NH (Rendezvous height adjust) - Performed to hit a delta-height relative to the target at a future time.

NPC (Rendezvous plane change) - Performed to remove planar errors relative to the target at a future time.

NCC (Rendezvous corrective combination) - First on-board targeted burn in the rendezvous sequence. Using star tracker data, it is performed to remove phasing and height errors relative to the target at Ti.

Ti (Rendezvous terminal intercept) - Second on-board targeted burn in the rendezvous sequence. Using primarily rendezvous radar data, it places the orbiter on a trajectory to intercept the target in one orbit.

MC-1, MC-2, MC-3, MC-4 (Rendezvous midcourse burns) - These on-board targeted burns use star tracker and rendezvous radar data to correct the post-Ti trajectory in preparation for the final, manual proximity operations phase.



On verbal confirmation by Pilot Bill Oefelein to alert the station crew, Polansky will command Discovery to begin a nose forward, three-quarters of a degree per second rotational back flip. At RPM start, the station crew will begin a series of precisely-timed photography for inspection. The sequence of mapping optimizes the lighting conditions.

Both the 400 mm and 800 mm digital camera lenses will be used to capture imagery of the required surfaces of the orbiter. The 400 mm lens provides up to 3- inch resolution and the 800 mm lens can provide up to 1-inch resolution and detect any gap filler protrusions greater than 1/4 inch. The imagery includes the upper surfaces of the shuttle as well as Discovery's underside, nose cap, landing gear door seals and the elevon cove areas with 1-inch analytical resolution. The photography includes detection of any gap filler protrusions when the orbiter is at 145 and 230-degree angles during the flip. The maneuver and lighting typically offers enough time for two sets of pictures.

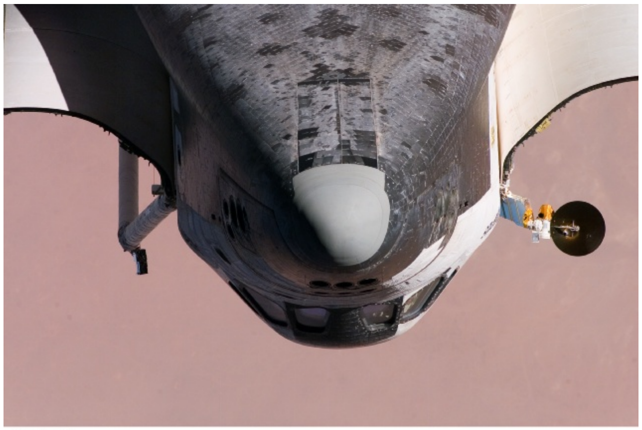
When Discovery completes its rotation, it will return to an orientation with its payload bay facing the station.

Polansky then will move Discovery to a position about 400 feet in front of the station along the V-Bar, or the velocity vector—the direction of travel for both spacecraft. Oefelein will provide navigation information to Polansky as the shuttle inches toward the docking port at the forward end of the station's Destiny Laboratory.

Oefelein will join Mission Specialists Nicholas Patrick and Joan Higginbotham in playing key roles in the rendezvous. They will operate laptop computers processing the navigational data, the laser range systems and Discovery's docking mechanism.

Using a camera view from center of Discovery's docking mechanism as a key alignment aid, Polansky will precisely match the docking ports of the two spacecraft and fly to a point 30 feet from the station before pausing to verify the alignment.

For Discovery's docking, Polansky will close the final 30 feet at a relative speed of about one-tenth of a foot per second (while both spacecraft are traveling 17,500 mph), and keep the docking mechanisms aligned within a tolerance of three inches.



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At contact, preliminary latches will automatically attach the two spacecraft. Immediately after Discovery docks, the shuttle's steering jets will be deactivated to eliminate forces acting at the docking interface. Shock absorber-like springs in the docking mechanism will dampen any relative motion between the shuttle and the station.

Once motion between the two spacecraft has been stopped, Mission Specialists Bob Curbeam and Christer Fuglesang will secure the docking mechanism, sending commands for Discovery's docking ring to retract and to close a final set of latches between the two vehicles.

UNDOCKING, SEPARATION AND DEPARTURE

With additional inspections of Discovery's heat shield expected to be scheduled after undocking, the orbiter will depart the station with the shuttle robotic arm and Orbiter Boom Sensor System (OBBS) in their stowed configuration. The OBSS will be unstowed to accommodate the inspections.

Once Discovery is ready to undock, Fuglesang will send a command to release the docking mechanism. At initial separation of the spacecraft, springs in the docking mechanism will push the shuttle away from the station. Discovery's steering jets will be shut off to avoid any inadvertent firings during the initial separation.

Once Discovery is about two feet from the station, with the docking devices clear of one another, Oefelein will activate the steering jets to very slowly move away. From the aft flight deck, Oefelein manually will control Discovery within a tight corridor as it separates from the station—essentially the reverse of the task performed by Polansky during rendezvous.

Discovery will continue away to a distance of about 450 feet, where Oefelein will guide the shuttle in a circular flyaround of the station. Once Discovery completes 1.5 revolutions of the complex, Oefelein will fire Discovery's jets to depart the station's vicinity for the final time.

Discovery will separate to a distance of about 40 nautical miles and remain there to protect for a return to the complex in the unlikely event the late inspection reveals any damage to the shuttle's thermal heat shield.

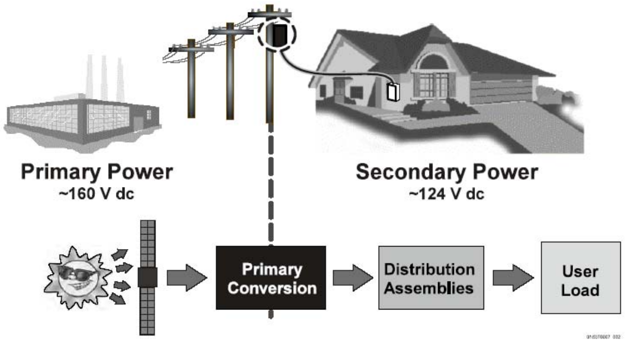
INTERNATIONAL SPACE STATION ELECTRIC POWER SYSTEM (EPS)

The International Space Station (ISS) electrical power system consists of power generation, energy storage, power management, and distribution (PMAD) equipment. Electricity is generated in a system of solar arrays. Besides the solar arrays on the Russian element, the station currently has two photovoltaic modules, a term that refers to a set of solar arrays, batteries and the associated electronics, on orbit, with two more scheduled for delivery.

The Electric Power System (EPS) provides all user loads and housekeeping electrical power and is capable of expansion as the station is assembled and grows. Eight independent power channels for high overall reliability supply the electric power.

A photovoltaic (PV) electric power generation subsystem was selected for the space station. A PV system uses solar arrays for power generation and chemical energy storage (Nickel-hydrogen) batteries to store excess solar array energy during periods of sunlight and provide power during periods when the station is in Earth's shadow (eclipse). The station orbits the earth every 90 minutes and for about 35 minutes, the station must run on batteries while the station is in eclipse.

Flexible, deployable solar array wings that are covered with solar cells provide power for the ISS. Each PV module contains two wings, and each wing consists of two blanket assemblies. The solar array wings are tightly folded inside a blanket for launch. They are deployed in orbit and supported by an extendable mast.



Analogy between municipal utility and the station's EPS

Nominal electrical output of each power channel is about 11 kilowatts (kW), or 20.9 kW per PV module. Four PV modules will supply approximately 83.6 kW.

The primary purpose of the Energy Storage Subsystem (ESS) is to provide electrical power during periods when power from the solar arrays is not enough to support channel loads. The ESS stores energy during periods when solar arrays can generate more power than necessary to support loads. The system consists of three nickel-hydrogen (Ni-H2) batteries per power channel and each battery consists of two battery Orbital Replacement Units (ORUs). Each battery also has a charge/discharge unit (BCDU). The Ni/H2 battery design was chosen because of its high energy density light weight and proven heritage in space applications since the late 1970s to early 1980s.

The entire EPS may be divided into two power subsystems. The primary power subsystem operates at a voltage range of 137 to 173 volts direct current (Vdc) and consists of power generation, storage and primary power distribution. The secondary power subsystem operates at a voltage range of 123 to 126 Vdc and is used to supply power to user loads. Direct Current-to-Direct Current Converter Units (DDCUs) are used to convert primary power to secondary power.

The U.S. power system is also integrated with Russian power sources, so that power from the American power bus can be transferred to the Russian power bus and vice versa. The Russian power system operates at a nominal voltage of 28 Vdc. American to Russian Converter Units (ARCUs) and Russian to American Converter Units (RACUs) are used to convert power from the American secondary power bus to the Russian power bus and vice versa.

SOLAR POWER

The most powerful solar arrays ever to orbit Earth capture solar energy to convert it into electric power for the ISS.

Eight solar array wings supply power at an unprecedented voltage level of 137 to 173 Vdc that is converted to a nominal 124 Vdc to operate equipment on the ISS. The Space Shuttle and most other spacecraft operate at nominal 28 Vdc, as does the Russian ISS segment.

The higher voltage meets the higher overall ISS power requirements while permitting use of lighter-weight power lines. The higher voltage reduces ohmic power losses through the wires. Some eight miles of wire distribute power throughout the station.

Each PV module contains two solar array wings. An individual wing is 110-feet long by 38-feet wide. Each wing consists of two array blankets that are covered with solar cells. The blankets can be extended or retracted by a telescopic mast which is located between the two blankets. Each solar array wing is connected to the ISS's 310-foot long truss and extend outward at right angles to it (P4 and P6 are currently on orbit). A series of 400 solar cells, called a string, generates electricity at high primary voltage levels while 82 strings are connected in parallel to generate adequate power to meet the power requirement for each power channel. There are a total of 32,800 cells per power channel or 65,600 solar cells on each PV module.

A solar cell assembly is about three inches square. The cells are made of silicon and have a nominal 14.5 percent efficiency for sunlight-to-electricity conversion. Cells are welded on to a flexible printed circuit laminate that connects cells electrically. The sun-facing surface of the cell is protected by a thin cover glass. Each group of eight cells, connected in series, is protected by a bypass diode to minimize performance impact of fractured or open cells on a string. Solar arrays are designed for an operating life of 15 years.

Two mutually perpendicular axes of rotation are used to point solar arrays towards the Sun. Each solar array wing is connected to one Beta Gimbal Assembly (BGA), located on each PV module, that is used to rotate that solar array wing. Another rotary joint, called Solar Alpha Rotary Joint (SARJ), is mounted on the truss and rotates the four solar array wings together. When the station is complete, there will be eight BGAs and two SARJs. These rotary joints are computer controlled and ensure full sun-tracking capability as the ISS goes around the earth under a wide range of orbits and ISS orientations.

ELECTRIC POWER SYSTEM OVERVIEW

Like a city's central power plant, the PV modules generate primary power at voltage levels too high for consumer use, ranging from 137-to-173 Vdc. The primary power is routed to BCDUs for charging batteries and to switching units that route it to local distribution networks.

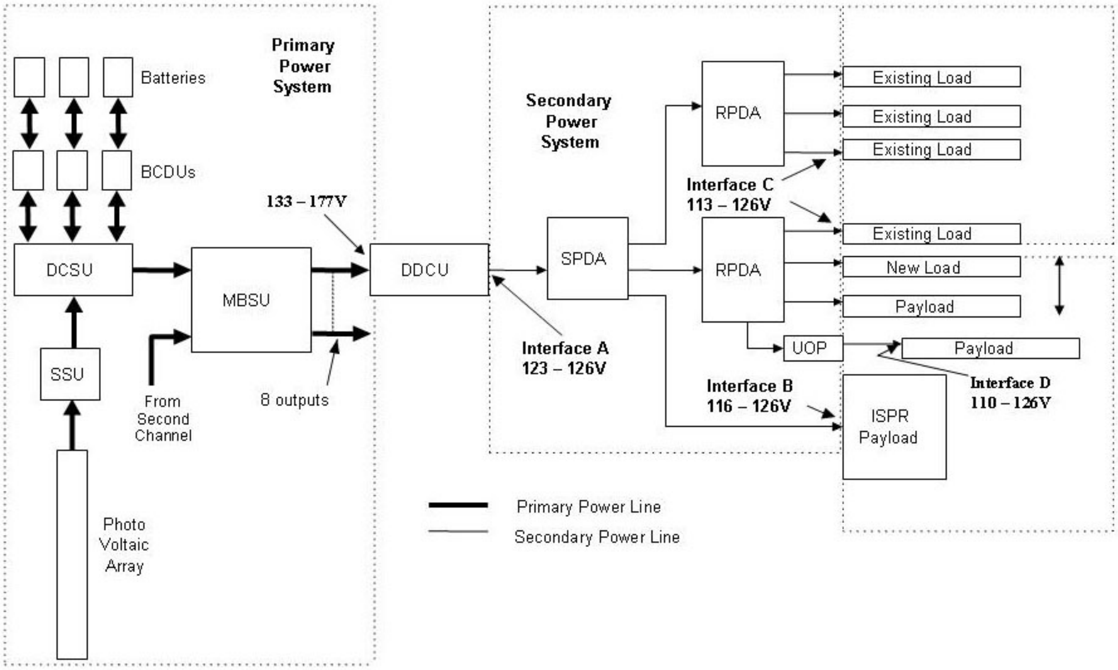
The DC-DC Converter Units, DDCUs, "step-down" the primary power to a more tightly regulated secondary power voltage, nominally 124.5 Vdc that is regulated plus or minus 1.5 Vdc, and distribute it to ISS loads. On Main Street, USA, the users would be shops and homes. On the ISS, they are laboratories, living quarters and other modules.

Even though the Station spends about one-third of every orbit in Earth's shadow, the electrical power system continuously provides usable power (about 84 kW at assembly complete) to ISS systems and users. When the ISS is in eclipse, the batteries that stored energy from solar arrays during the sunlit portion of the orbit supply power.

The power system is cooled by a thermal system through which excess heat is removed by liquid ammonia coolant in tubes that ultimately loop through radiator panels that radiate the heat to space.

Russia's segment of the ISS provides its own power sources, supplying 28-volt-dc to the Russian modules. Power is shared between the two segments when required to support assembly and operations for all ISS partners. Russian-to-American Converter Units (RACUs) and American-to-Russian Converter Units (ARCUs) step-up and step-down converters, respectively, deal with the difference between U.S. and Russian bus voltage levels. As ISS assembly continues, Russian solar arrays (a 72-foot pair on Control Module Zarya and a 97-foot pair on the Russian Service Module) will receive more shadow, which will diminish their power generation capability.

The overall design and architecture of the ISS EPS was managed by NASA’s Glenn Research Center in the early 1990s. Boeing’s Rocketdyne Propulsion and Power division (now Pratt & Whitney RPP) built most of the hardware for the electrical power system. Lockheed Martin built the solar arrays and the Solar Alpha Rotary Joint for Rocketdyne. Boeing, along with Pratt & Whitney RPP, as a subcontractor, continues to provide EPS sustaining engineering to NASA. Most EPS components and cargo assemblies undergo final acceptance testing at Kennedy Space Center before flight to ISS.



Electrical Power Distribution Overview

EPS BLOCK DIAGRAM OVERVIEW

This block diagram gives an overview of how the station's electrical system functions when assembly is complete. The Solar Array Wing (SAW) can generate power at a wide range of voltage, however, the Sequential Shunt Units (SSU), located close to the SAW in the Integrated Equipment Assembly (IEA), regulate the voltage that comes out of the solar arrays at an established setpoint of about 160 Vdc. When a solar array can produce sufficient power, then the surplus power is routed to the Battery Charge/Discharge Units (BCDU), which charge the batteries. When a solar array cannot produce sufficient power to satisfy ISS loads then the bus voltage starts to drop below the SSU setpoint, and when it drops below the BCDU setpoint, then the BCDUs start to discharge batteries to support ISS loads. The primary bus voltage varies between the SSU and BCDU voltage setpoints plus a small voltage regulation band.

The primary power is provided to the Main Bus Switching Units (MBSU) for subsequent distribution to ISS electrical loads. Four MBSUs are located on the S0 truss that is fed by eight independent power channels and the MBSU outputs supply all ISS loads. Under normal operations, each power channel supplies power to a specific set of loads. However, if that channel fails, the MBSU enables feeding power to those loads from another channel. This greatly enhances the failure tolerance of the EPS.

All EPS operations are computer controlled and controls can be exercised by the on-orbit crew or by operators on ground. Operators on the ground to free up crew time for more important on-orbit operations perform most of these functions. All control setpoints are stored on on-orbit computers and can be changed when needed.

The MBSUs route power to the DC-to-DC Converter Units (DDCUs). The DDCUs convert primary power to secondary power at 123 to 126 Vdc. Several DDCUs are located inside pressurized compartments, such as US Lab, while several are located externally on trusses. DDCUs supply regulated secondary power to Remote Power Controller Modules (RPCMs). RPCMs are boxes with multiple switches with several different load ratings to route power to user loads. The RPCMs provide remote switching of loads and over-current protection. An RPCM can also feed other RPCMs and can feed Russian power converters, outlet panels, etc. There will be thousands of individual switches in approximately 184 RPCMs on the station at assembly complete. There are about 119 RPCMs on the station currently.

The European and Japanese laboratory modules have their own internal power distribution system. Those modules will draw power from DDCUs, from Node 2. Their unique transformers and power control modules equivalent to U.S. RPCMs will handle power. NASA and Boeing have responsibility for distributing power to those elements, but the individual international partners will be responsible for power within their respective elements.

PRIMARY POWER DISTRIBUTION OVERVIEW

Primary Power Distribution provides a commandable interface between generated or stored power to loads that are located down stream. Power distribution within a power channel is performed by a DC Switching Unit (DCSU) and the power distribution to loads is performed by the MBSU. At ISS assembly complete, there will be eight DCSUs and four MBSUs involved in primary power distribution. The DCSUs and MBSUs use a network of high power switches called Remote Bus Isolators (RBIs) to direct the power flow. The RBIs do not physically control the direction of the current flowing through them but they do provide a means of isolating a current path in the event of a malfunction or if a repair is needed on the primary power system. The RBIs in both the DCSU and MBSU are fully commandable by on-board computers.

Each power channel contains one DCSU to perform power distribution on the Integrated Equipment Assembly (IEA). During insolation, the DCSU routes power from the arrays to an MBSU distribution bus, as well as to the BCDUs for battery charging. During eclipse, the DCSU routes battery power to the same MBSU distribution bus to satisfy power demands, and it also sends a small amount of power back to the SSU to keep the SSU firmware functioning in preparation for the next insolation cycle. In addition to primary power distribution, the DCSU has the additional responsibilities of routing secondary power to components on the PV modules (i.e., the Electronics Control Unit and other support components). This secondary power is provided by the DDCU located on the IEA. The DDCU receives primary power from the DCSU, converts it into secondary power, and sends it to Remote Power Controller Modules (RPCMs) for distribution. The PV module RPCMs are housed within the DCSU.

The MBSUs act as the distribution hub for the EPS system. The four MBSUs onboard the ISS are all located on the Starboard Zero (S0) truss. Each of MBSU receives primary power from two power channels and distributes it downstream to the DDCUs and other users including Service Module (SM) American to Russian Converter Units (ARCUs). In addition, the MBSUs can be used to crosstie power channels (i.e., feed one power channel loads with a different power channel source) to assist in failure recovery and assembly tasks.

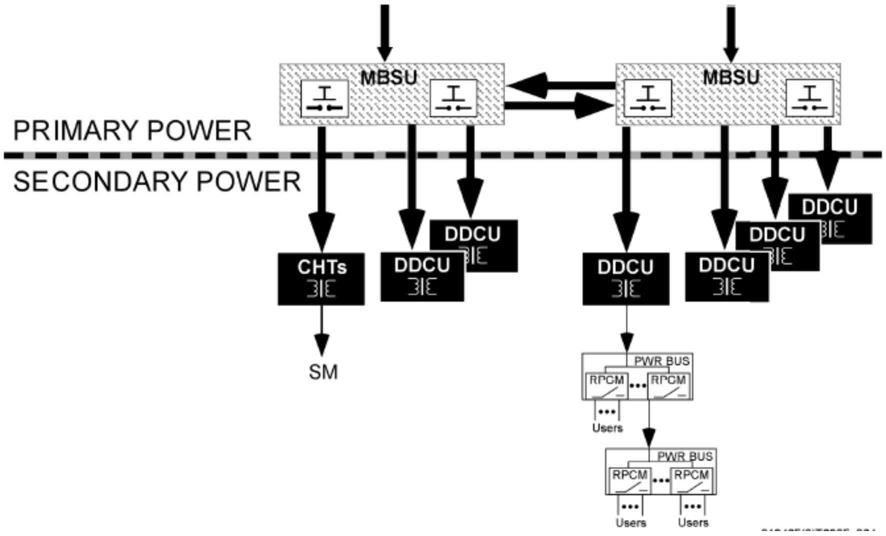
The BGAs and SARJs on the ISS also play a role in primary power distribution. The BGA provides for the transmission of primary power from the solar array wings to the IEA and the SARJ provides for transmission of primary power from the DCSUs to the MBSUs. The BGAs and SARJs incorporate a roll-ring design to provide conduits for power (and data), while allowing a continuous 360° rotation.

SECONDARY POWER DISTRIBUTION

The workhorse of the secondary power distribution system is the RPCM, an Orbital Replacement Unit (ORU), which contains solid-state or electromechanical switches, known as Remote Power Controllers (RPCs). RPCs can be remotely commanded, by on-board computers, to control the flow of power through the distribution network and to the users. There are different types of RPCMs, containing varying numbers of RPCs and varying power ratings. As shown above, secondary power flows from a DDCU and is then distributed through a network of ORUs called Secondary Power Distribution Assemblies (SPDA) or Remote Power Distribution Assemblies (RPDA). Essentially, SPDAs and RPDAs are housings that contain one or more RPCMs. The only distinction between SPDAs and RPDAs is the location downstream of a DDCU. RPDAs are always fed from other RPCMs inside SPDAs. Note that RPCMs have only one power input; thus, if power is lost at any level of the Secondary Power System, all downstream user loads will be without power.

There is no redundancy in the Secondary Power System; rather, redundancy is a function of the user's loads. For example, a critical user load may be able to select between two input power sources that use different power channels and thus different secondary power paths.

As with DDCUs, SPDAs and RPDAs may be located inside pressurized compartments or outside. Depending on their specific location, SPDAs or RPDAs may interface with the Lab Internal Thermal Control System (ITCS) or use heat pipes to dissipate heat. RPCMs are also located within the DCSU on the IEAs to provide secondary power-to-power channel components, as required.



REDUNDANCY

Each of the power channels is preconfigured to supply power for particular ISS loads; however, to provide a backup source of power for critical equipment, the assembly complete design provides for rerouting (i.e., cross-tying) primary power between various power channels, as necessary. At assembly complete, the ISS will have four PV modules containing eight power channels with full cross-strapping capability. However, it is important to note that only primary power can be cross-strapped. Once power is converted into secondary power, power flow through the distribution network cannot be rerouted.

As a result, if there is a failure within the Secondary Power System, there is no redundancy, and the entire downstream path from the failure is unpowered. Instead, user loads generally determine redundancy. There are three types of user redundancy schemes as listed below:

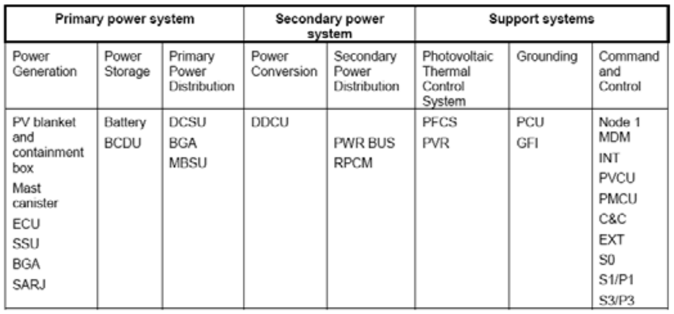
- Components may be wired with multiple power input sources, providing the capability of swapping among them.
- Two or more components that perform the same function can be fed by different power sources; thus, the responsibilities of one component can be assumed by another.
- Multiple components can work together to perform a function; with the loss of a single component, operational capabilities are degraded not lost.
- Set of available jumpers that can be used to temporarily regain power to a load until the secondary system can be fixed.

SYSTEM PROTECTION

The EPS is designed to protect equipment from power surges and overheating at several points along the power path from the source to the users. Current, voltage, and temperature sensors are located in nearly all the EPS equipment (ORUs) and are monitored by firmware located on the hardware or on-board computers, or both. If a voltage, current, or temperature is out of range, an appropriate safing action will be initiated either by the firmware or by computer software. The safing action is designed to limit the amount of time that the box is exposed to high power or high temperature. In case of power surges, it is also designed to limit the impact of that surge on other equipment along the power path.

The system protection function includes the architecture's ability to detect that a fault condition has occurred, confine the fault to prevent damaging connecting components, and execute an appropriate recovery process to restore functionality, if possible. This process is usually referred to as Fault Detection, Isolation, and Recovery (FDIR). For example, upon detection of a fault, components can be isolated, thereby preventing propagation of faults. In response to overcurrent conditions, the architecture is designed such that each downstream circuit protection device is set to a lower current rating and responds more quickly than the protection device directly upstream. This ensures that electrical faults or shorts in the system do not propagate toward the power source. Another function of the architecture's system protection shuts down the production of power when array output voltage drops below a specified lower-limit threshold. This prevents the PV cells from continuing to feed a downstream fault. In summary, all the various implementations of system protection work together to isolate faults or shorts at the lowest level. This approach minimizes impacts to the users of the EPS and protects the EPS from damage by low-level faults.

KEY EPS COMPONENTS



Primary power system			Secondary power system		Support systems		
Power Generation	Power Storage	Primary Power Distribution	Power Conversion	Secondary Power Distribution	Photovoltaic Thermal Control System	Grounding	Command and Control
PV blanket and containment box Mast canister ECU SSU BGA SARJ	Battery BCDU	DCSU BGA MBSU	DDCU	PWR BUS RPCM	PFCS PVR	PCU GFI	Node 1 MDM INT PVCU PMCU C&C EXT S0 S1/P1 S3/P3

SOLAR ARRAY WING (SAW)

The principle function of the SAW is to produce electrical power from solar energy. The SAW contains 32,800 solar cells, 16,400 per blanket, which can produce approximately 31 kilowatts (kW) of electrical power at Beginning of Life (BOL), and about 26 kW after 15 years, at their designed End of Life (EOL). However, it is important to note that power availability is influenced by ISS attitude, operational mode (e.g., proximity operations), Sun alpha and beta angle, shadowing, etc.

BETA GIMBAL ASSEMBLY (BGA)

The function of the BGA is to provide minor array pointing correction along the Beta Angle. The beta angle is the angle between the orbit plane and the solar direction (changes ~±4°/day)) to compensate for apparent solar motion induced by seasonal variations. There is one BGA associated with each SAW. The BGA provides one axis of rotation for a solar array wing. The BGA is capable of a full 360 degrees of rotation or may be commanded to a specific location via computer command. Electric power generated by the solar array wing is transferred through the BGA over the entire range of BGA axis rotation. The transfer of power is accomplished by a rotary coupling, the roll ring subassembly, which is mounted coaxially with the axis bearing and torque motor.

The BGA may be commanded to the following modes of operation:

- Angle Command Mode. BGA axis of rotation aligned to a commanded angle position.
- Latch Mode. The BGA axis of rotation is locked at specified location and prevented from further rotation.
- Manual Operating Mode. All non-essential functions are disabled and the drive motor is disabled. BGA axis may be rotated by manual action from the IEA side.
- Rate Mode. BGA may be commanded to rotate at a specified rate.

ELECTRONICS CONTROL UNIT (ECU)

The ECU is located on the BGA. It is the command and control link for the solar array wing and BGA. The ECU provides power and control for extension and retraction of the solar array mast, latching and unlatching of the blanket boxes, BGA rotation, and BGA latching.

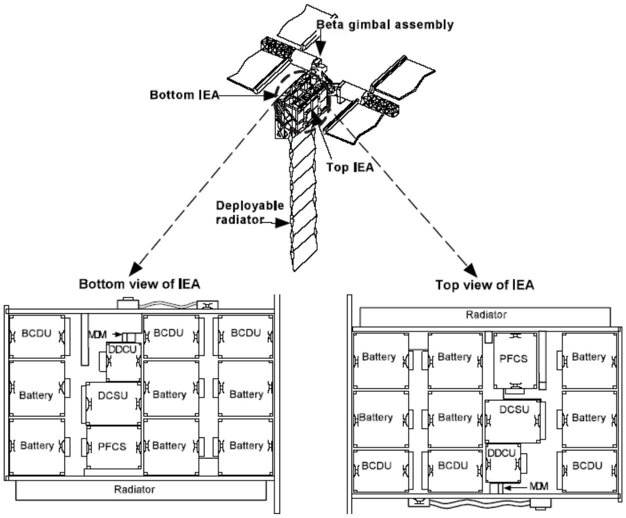
SOLAR ALPHA ROTARY JOINT

The purpose of the SARJ is to rotate the PVMs to provide alpha angle array pointing capability. The port SARJ and starboard SARJ are located at the outboard end of the P3 and S3 truss segments and provide 360° continuous rotational capability to the segments outboard of P3 and S3. The SARJ will normally complete one complete 360-degree revolution per orbit.

The SARJ transfer electrical power through a set of roll rings, which provide a continuous rolling electrical connection while rotating.

INTEGRATED EQUIPMENT ASSEMBLY (IEA)

Each IEA, located on P4, S4, P6 and S6, has many components: 12 Battery Subassembly orbital replacement units (ORUs), six Battery Charge/Discharge Units (BCDU) ORUs, two Direct Current Switching Units (DCSUs), two Direct Current-to-Direct Current Converter Units (DDCUs), two Photovoltaic Controller Units (PVCUs), and integrates the Thermal Control Subsystem which consists of one Photovoltaic Radiator (PVR) ORU and two Pump Flow Control Subassembly (PFCS) ORUs used to transfer and dissipate heat generated by the IEA ORU boxes. In addition, the IEA provides accommodation for ammonia servicing of the outboard PV modules as well as pass through of power, data to and from the outboard truss elements. The structural transition between the P3 and P4 (and S3 and S4 when launched next year) segments is provided by the Alpha Joint Interface Structure.



The IEA measures 16 feet (4.9 meters) by 16 feet (4.9 meters) by 16 feet ((4.9 meters), weighs nearly 17,000 pounds a (7,711.1 kilograms) and is designed to condition and store the electrical power collected by the photovoltaic arrays for use on board the Station.

The IEA integrates the energy storage subsystem, the electrical distribution equipment, the thermal control system, and structural framework. The IEA consists of three major elements:

1. The power system electronics consisting of the DCSU used for primary power distribution; the DDCU used to produce regulated secondary power; the BCDU used to control the charging and discharging of the storage batteries; and the batteries used to store power.

2. The Photovoltaic Thermal Control System (PVTCS) consisting of: the coldplate subassembly used to transfer heat from an electronic box to the coolant; the Pump Flow Control Subassembly (PFCS) used to pump and control the flow of ammonia coolant; and the Photovoltaic Radiator (PVR) used to dissipate the heat into deep space.

3. The computers used to control the P4 module ORUs consist of two Photovoltaic Controller Unit (PVCU) Multiplexer/Demultiplexers (MDMs).

The IEA power system is divided into two independent and identical channels. Each channel is capable of control (fine regulation), storage and distribution of power to the ISS. The two power modules are attached outboard of the AJIS.

Sequential Shunt Unit (SSU)

SEQUENTIAL SHUT UNIT (SSU)

The SSU is the primary power regulation device that controls SAW output. By design, the SSU provides a consistent source of power (typically ~160 V-dc), based upon a programmable setpoint. Regulation of the array output voltage is required because array output current, when illuminated with sunlight, is often greater than the ISS demands. To accomplish this, the SSU receives power directly from the PV array and maintains output voltage to a setpoint, by shunting and un-shunting solar array strings. Each string can be individually connected or disconnected from the primary bus and the power output from the SSU is the sum of all connected strings at any time. When the SSU power output exceeds the power demand, then the bus voltage starts to rise and that triggers SSU to shunt strings to reduce SSU power output, and vice versa.

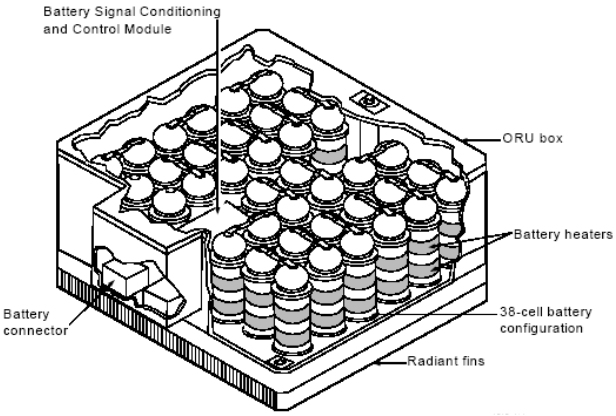
The voltage setpoint is provided to the SSU by the on-board computer. The setpoint is designed to maximize array power capability (maximum power point) while ensuring control stability. As solar arrays age, the voltage setpoint is adjusted to ensure optimum performance.

There will be eight SSU's on orbit when the station assembly is complete (two each per IEA, four IEAs when assembly complete). The SSU is located on the beta gimbal platform, at the bottom of the mast canister.

BATTERY SUBASSEMBLY ORBITAL REPLACEMENT UNIT

The battery subassembly consists of 38 lightweight nickel hydrogen cells and associated electrical and mechanical equipment, packaged in an ORU enclosure. When the sun is behind the Earth, all of the power is provided off the batteries, providing about a third of the station's power daily. The battery interfaces with a Battery Charge/Discharge Unit (BCDU), which provides charge and discharge control of electric energy. During isolation, solar electric energy, regulated by the SSU, will replenish energy stores in preparation for the next eclipse cycle. Two battery ORUs makes a battery set. There will be 24 battery sets on ISS at assembly complete.

The batteries have a design life of about seven years, but the actual life obtained on orbit is a function of how deeply the battery is discharged and the number of charge-discharge cycles (nominally 16 cycles per day).



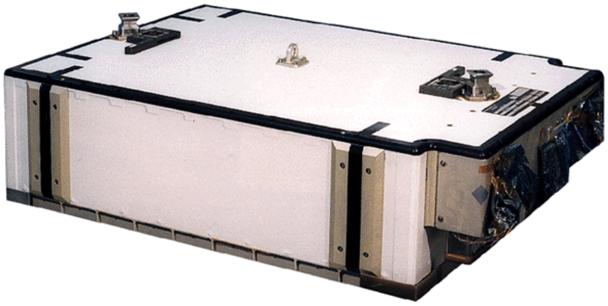
The battery ORUs can be changed out robotically using a special purpose manipulator on the end of the station's robotic arm. Each battery measures 41 inches (104.1 cm) by 37 inches (94 cm) by 19 inches (48.3 cm) and weighs 372 pounds (168.7 kilograms).

BATTERY CHARGE/DISCHARGE UNIT (BCDU)

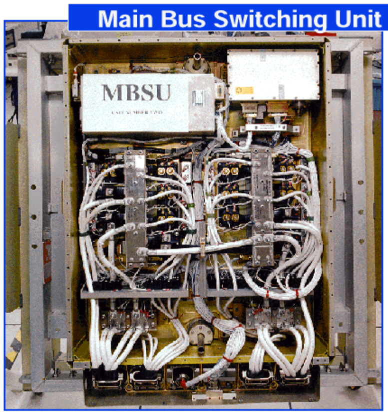
The BCDU serves a dual function of charging the batteries during isolation and providing conditioned battery power to the primary power busses during eclipse.

The Control Power Remote Bus Isolator (CPRBI) controls the flow of power to the DC control power output bus and also functions as a circuit breaker, limiting the load current during faults. The Fault Isolator (FI) limits the battery discharge current, in the event of a fault, to 85 to 127 amps. The BCDU also includes provisions for battery status monitoring and protection from power circuit faults.

Each BCDU measures 28 inches (71.1 cm) by 40 inches (101.6 cm) by 12 inches (30.5 cm) and weights 235 pounds (106.6 kilograms). The BCDU has an 8.4 kW battery charge capability with a 6.6 kW discharge capability. It provides 70 to 120 volts-dc control power output and can regulate power between 130 to 180 volts-dc. The power storage system consists of a BCDU and two Battery Subassembly ORUs.



Main Bus Switching Unit (MBSU)

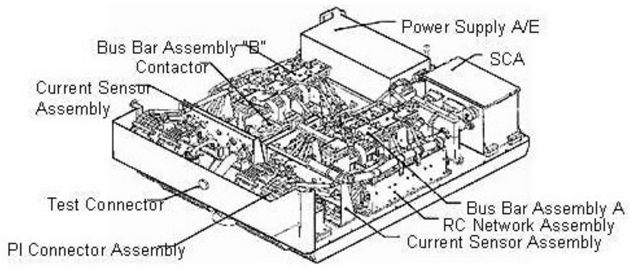


MAIN BUS SWITCHING UNIT (MBSU)

Located on the S0 truss, the four MBSUs distribute primary power from the power channels, downstream to the DDCUs, and other loads. They also provide the capability to cross tie Primary Power Channels to feed those DDCU loads in the event of a Primary Power Failure.

Command, communication, health monitoring, and RBI drive functions are provided by the Switchgear Controller Assembly (SCA). The MBSUs have a design life of approximately fifteen years. There is a spare MBSU located on orbit.

The system's design can accommodate the loss of PV modules and other problems by remotely accessing the MBSUs, by either the ground or on station, and internally redirecting power to by-pass faults or failures in the EPS. The four MBSUs themselves are not redundant. All MBSUs are required to power all station loads. However, MBSUs provide redundancy for power modules upstream. The MBSU output voltage range is from 133 to 177 V-dc.



The MBSU will be first used during STS-116/Assembly Mission 12A.1. All four MBSUs are activated during this mission. Each MBSU box is 28 inches by 40 inches by 12 inches and weighs 220 pounds.

DC SWITCHING UNIT (DCSU)

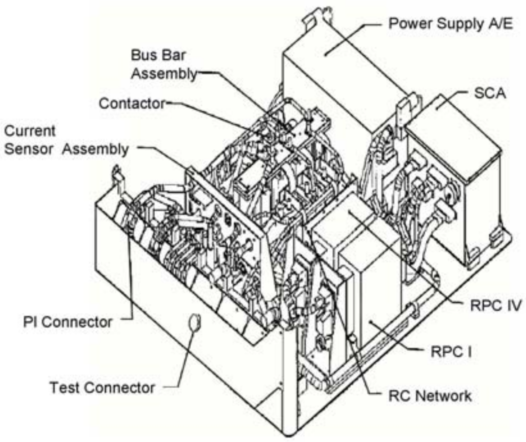
The DCSU is the electrical distribution box for a primary power channel. It provides fault protection for the many EPS ORUs, and numerous EPS support functions. The DCSUs primary function is to route power between the solar arrays, batteries, and downstream MBSUs and DDCUs.

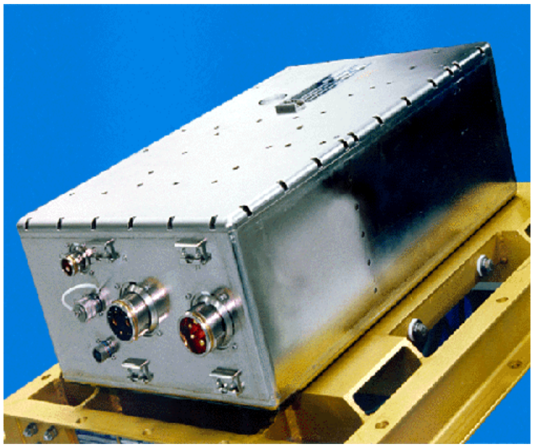
The DCSU is used for power distribution, protection and fault isolation within the Integrated Equipment Assembly. The DCSU uses remote-controlled relays (RBIs) identical to those on the MBSU to route primary power to the BCDUs, MBSUs and DDCU. The DCSU also routes secondary power (124 V-dc plus or minus 1.5 V-dc) through solid state switches to the ECU, SSU, and PFCS ORUs.

There will be a total of eight DCSUs on the ISS once S5/S6 is delivered in June 2008. To date, DCSUs have performed very well, with no failures. They have a design life of 15 years. Each DCSU box is 28 inches by 40 inches by 12 inches and weighs 238 pounds.

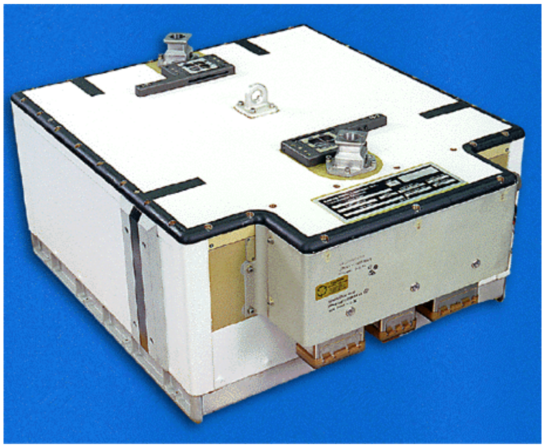
DIRECT CURRENT-TO-DIRECT CURRENT CONVERTER UNIT (DDCU)

The secondary power conversion function uses one type of ORU, the DDCU. The DDCU provides electrical isolation between the primary and secondary EPS. As the name implies, the DDCU is responsible for dc power conversion, in this case primary power into secondary power, using a transformer. Each DDCU has one primary power input and one secondary power output. The DDCU converts the coarsely regulated primary power (115 V-dc to 173 V-dc) to a voltage-regulated secondary power (124.5 V-dc nominal plus or minus 1.5 V-dc). The primary power on the ISS is like the main transmission lines in a city with the DDCU serving like a transformer on a utility pole that converts the power so it can be used in your home. The primary power voltage is typically 160 V-dc; however, voltage can vary over a wide range although the output is specified to be 124 V-dc, which is the prescribed voltage for all users of the Secondary Power System. If any other voltage level is required by user loads (such as payloads or crew equipment), it is the user’s responsibility to perform the conversion from 124 V-dc to its required voltage.





DDCU-I (internal)



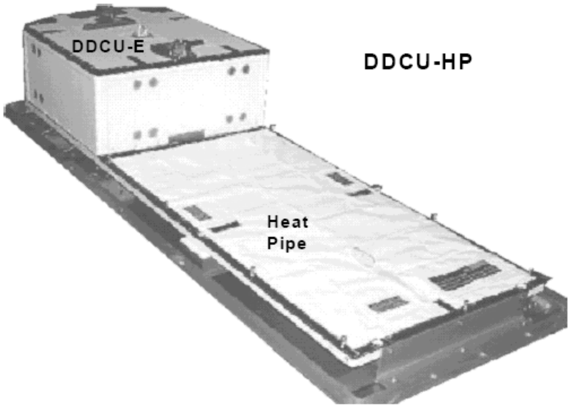
DDCU-I (external)

DDCUs come in three versions:

- DDCU-E (for external). These are used outside the habitable spaces on the station on the power module IEA, and Z1, S0, S1 and P1 trusses. There are four DDCU-Es on S0, and one each on S1 and P1.
- DDCU-I (for internal). These are used currently in the U.S. Laboratory and eventually in the Node 2 modules when those are delivered over the next several years. There are six DDCU-Is in the U.S. laboratory.
- DDCU-HP, The heat-pipe versions are currently located on the Zenith One (Z1) truss. There are two DDCU-HPs on Z1.

The only difference between the three types is the nature of the cooling system that transfers internal heat build up during operation to the surrounding space environment. The DDCU-Is are affixed to cold plates that transfer the heat to a water-cooled system inside the Lab and Node modules. This heat is then transferred by heat exchangers to the external ammonia cooling system where the heat is rejected into space via the large central radiators on the external S1 and P1 trusses (which will become active during this mission). The DDCU-Es are cooled via cold plates which interface directly to the external systems. The DDCU-HP are cooled directly by the radiator heat-pipe panel on which they are mounted.

To date, DDCUs have performed very well, with no failures. They have a design life of 15 years. There are already spare DDCUs (with the exception of DDCU-HP) on orbit. Each DDCU-E is 27 inches by 23 inches by 12 inches and weighs 129 pounds. Each DDCU-I is 27 inches by 18 inches by 10 inches and weighs 112 pounds. Each DDCU-HP is 68 inches by 25 inches by 14 inches and weighs 200 pounds.



REMOTE POWER CONTROLLER MODULE (RPCM)

RPCMs are the interface between the EPS and all non-EPS equipment onboard the ISS. The RPCM is a multi-channel, high power circuit breaker. The RPCM is the workhorse of the secondary power system. The RPCM has the following two purposes:

- To control the distribution of secondary power to downstream loads by opening or closing RPCs
- To protect the EPS against downstream faults by opening RPCs when overcurrents are sensed

Six types of RPCMs facilitate system protection, fault isolation and power flow control in the ISS Electric Power Systems. There are approximately 119 RPCMs currently located on the station and there will be a total of 184 when assembly is complete. There are multiple spare RPCM located on orbit. Several failed RPCMs have been replaced on the ISS.

RPCMs are located in the following modules: Integrated Equipment Assembly (Two each in DCSU or a total of 16), P1 (12), P3 (8), S1 (12), S3 (8), S0 (24), Z1 (4), Node 1 (12), Node 2 (18), Node 3 (27), Quest Airlock (4) and U.S. Destiny Lab (39). Each RPCM is 6.8 inches by 8 inches by 3.5 inches and weigh 10.5 pounds.

ELECTRICAL POWER SYSTEM (EPS) RECONFIGURATION

The space station will change from its early configuration to the beginning of the final assembly complete configuration. Since the P6 module has been on top of Z1, its power has been going directly to the DDCUs in the lab and Z1. Four MBSUs have been sitting on the S0 truss, but have not been getting any input power and are not feeding anything downstream. They have been sitting on a non-operating cooling loop. A series of bypass jumper cables and reconfigurable connections were initially installed that have allowed P6 to directly feed the DDCUs from the DCSUs. The initial configuration essentially bypassed the MBSUs. During STS-116, power will flow through the MBSUs for the first time since they have been on orbit, so that the main power from the trusses comes into the MBSUs first before going to the DDCUs. Each DCSU will feed one side of an MBSU.

To complete the reconfiguration, approximately 112 Extravehicular Activity (EVA) power connectors will be removed and reattached. Hundreds of commands from mission control will be issued to power up and down various components. This mission includes the largest number of EVA power connectors ever removed in a single assembly mission.

Two EVAs will be conducted to reconfigure the main power channels or paths. The purpose of the reconfigurations is to route power through the truss MBSUs and DDCUs. There are two channel domains over which electrical power travels across the truss and station elements called the 1 and 4, and 2 and 3 power domains, which comprises the basic numbering system for the power paths or domains. The four MBSUs are numbered 1 through 4. All the hardware downstream has a similar numbering system so you know which MBSU it came from. For example, when mission controllers refer to the 2/3 domain, they are referring to all the loads that go through MBSUs 2 and 3. In understanding the station power system, anything that receives a power feed from the 2/3 domain will have a “2/3” numbering scheme. Two separate thermal cooling loops on the ISS cool the 1/4 and 2/3 hardware. Each SAW on the IEA is labeled as A or B, so that each power channel has a power domain and a solar array designation. For example, the two power channels on the P6 module are 2B and 4B, and those on the P4 module are 2A and 4A. Similarly the channels on S4 are 1A and 3A and S6 are 1B and 3B.

During the first EVA during STS-116/Assembly Mission 12A.1, the P5 truss will be installed on the outboard side of P4. On the next day, NASA will remotely retract the 4B solar array, since there is a structural interference between the P6 4B array and the P4 arrays if rotated on the Solar Alpha Rotary Joint. Solar Array 4B on P6 will be retracted into its blanket boxes and the SARJ will be commanded into a solar tracking mode. P4 is not currently powering the rest of the space station, but will be brought on line during this mission.

During the second EVA during Flight Day 6, the entire 2/3 domain will be brought down for several hours while various power connectors are rewired. The remaining 1/4 path will support all the loads on the ISS, which means there will be no redundant power for the heaters and most of the equipment and systems (communications, guidance, navigation and control, etc.) throughout the station. They will power everything back up once the 2/3 domain is configured properly, and the MBSUs are brought on line. The MBSUs were checked on earlier spacewalks in 2002. NASA has provisions in place in case an MBSU fails when reconfigured. There will be an entire day, beginning when the crew begins their sleep shift following the first EVA, in which mission controllers will begin their procedures to transfer all the station systems from 1/4 to the 2/3 domain power path. Powering the DDCUs down, many of the systems that are being powered have been fed by DDCUs in the lab up to now, but after this reconfiguration, many of the DDCUs from the trusses will come alive for the first time. Two MBSUs and three truss DDCUs will be activated. On EVA 2, there are 15 umbilicals connected via EVA, and 6 Intra-Vehicular Activity (IVA). IVA activities consist of jumpers being connected inside the Lab, Node, and Airlock by the crew to provide backup power sources during the reconfigurations. There will be about 73 mates/demates of power connectors.

Two days later, a third EVA will be conducted on Flight Day 8 to reconfigure the 1/4 domain. For EVA 3, 20 umbilicals will be connected during the EVA and 9 IVAs, with a total of 81 mates/demates. Like on the earlier EVA, everything will run off the 2/3 domain power path while various connectors are removed and mission control powers items up and down. Two MBSUs and three truss DDCUs will be activated. Like the 2/3 domain reconfiguration, there will be limited power redundancy for several hours. The astronauts will do all of the reconfigurations on the 1/4 side while everything is powered down and then once all the connections are complete, then all four MBSUs will be on line and both cooling loops will be running and all the power is brought back up. Once NASA starts powering up after each 2/3 and 1/4 reconfiguration, they will know right away if any of the 2/3 or 1/4 hardware is not working. As each item is powered back up, the electronics will conduct an internal self-checking procedure. All of this data goes into mission control. There is a considerable amount of cleanup following an EVA to get all the systems back running and in a nominal configuration. It takes the entire night and next day following each EVA to verify those systems are operating nominally.

There will also be some minor reconfigurations on the Russian side when power converters are moved over to the U.S. primary side to where they are getting a higher voltage input. It is a seamless change and there are no changes in the major configurations on how the U.S. and Russians sides share power.

NASA conducted a large number of electrical power system simulations to prepare for this mission and is confident that electrical reconfiguration will go as planned. NASA has a number of contingency procedures since this reconfiguration operation is not without risks, especially if a problem should occur with the ammonia pumps for the cooling system that will be brought on line for the first time. Boeing and other industry engineers will be assisting NASA in the ISS Mission Evaluation Room, one of the primary backroom support centers to mission control, should any issues or problems arise.

EQUIPMENT REFERENCE

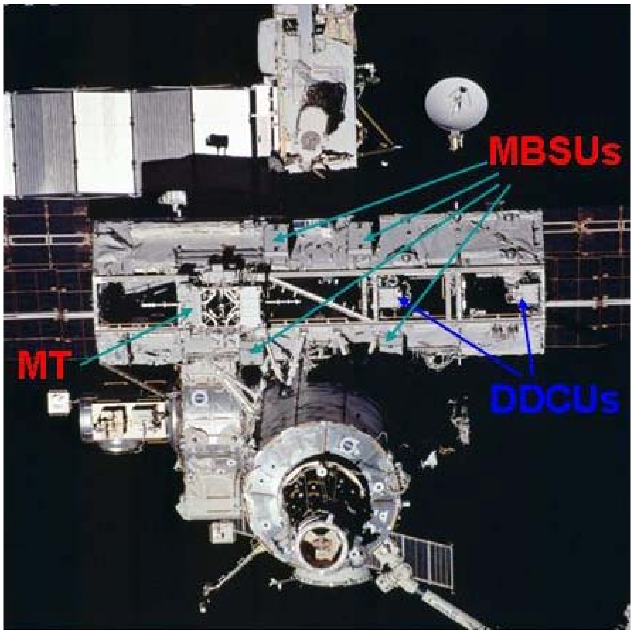


Image shows locations of the MBSUs and DDCUs on the SO truss element as part of the Electrical Power System

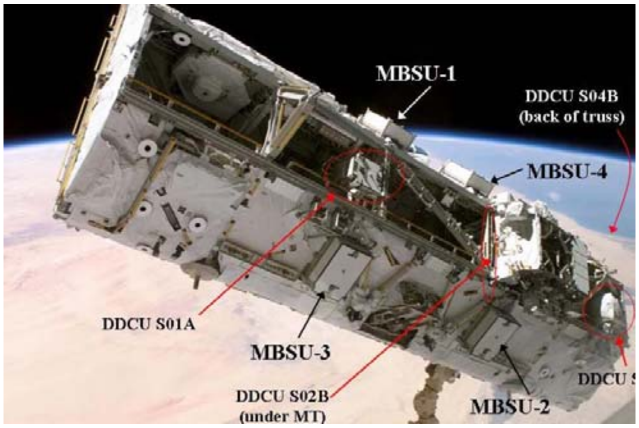
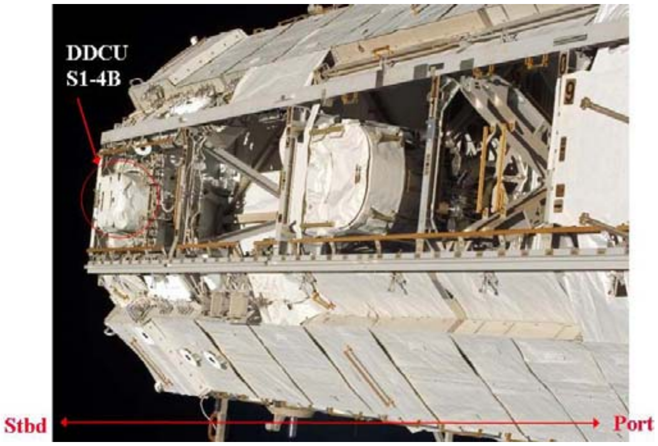
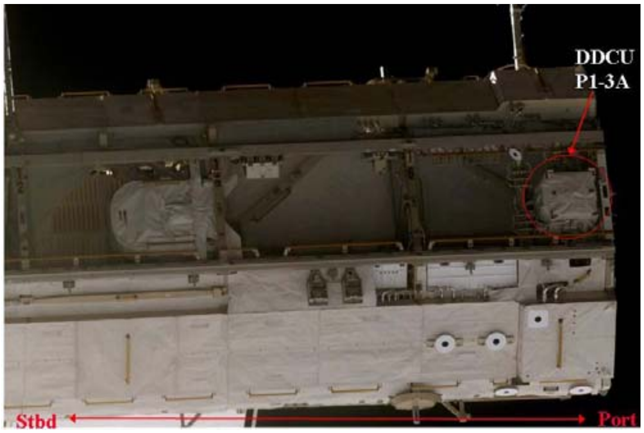


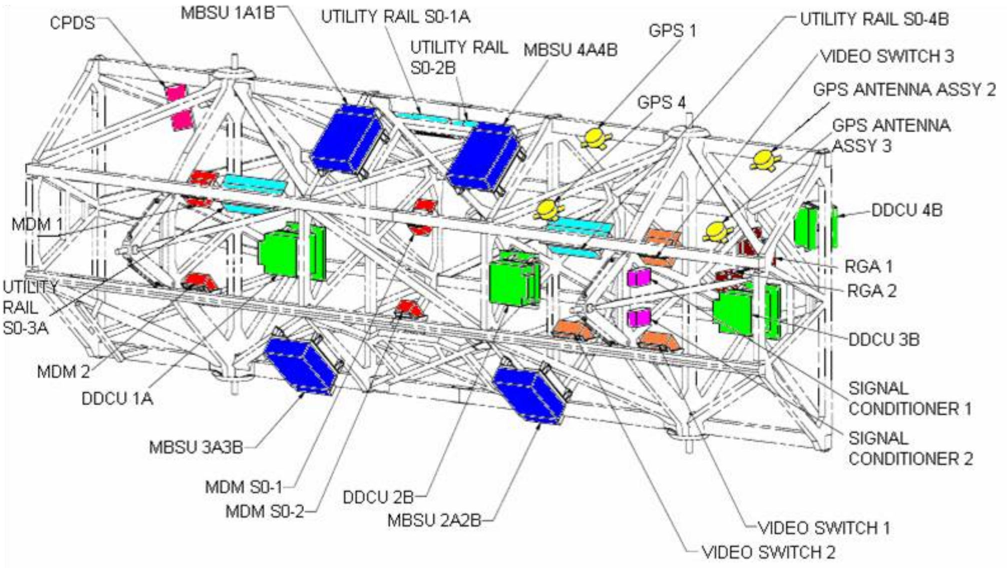
Image shows locations of DDCUs and MBSUs on the SO truss element to be activated



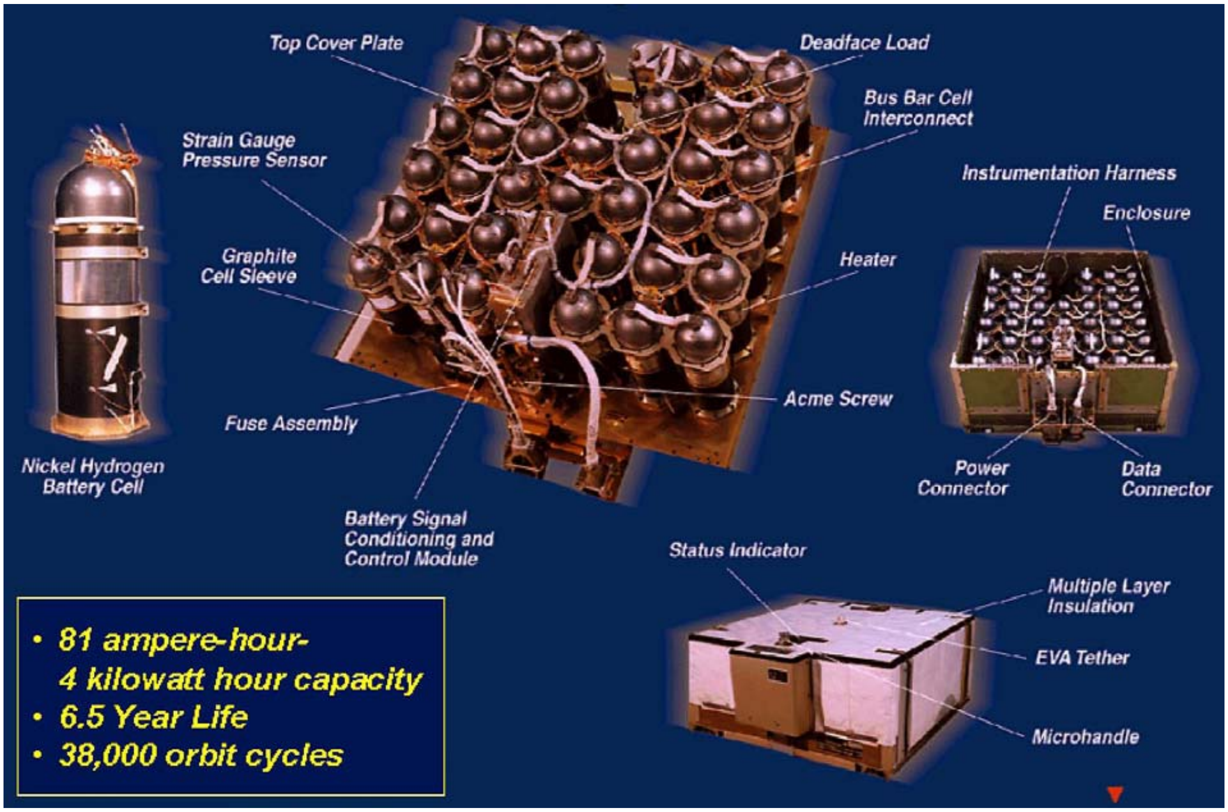
Location of DDCU to be activated on S1 truss



Location of DDCU to be activated on P1



EPS and other systems components on SO truss

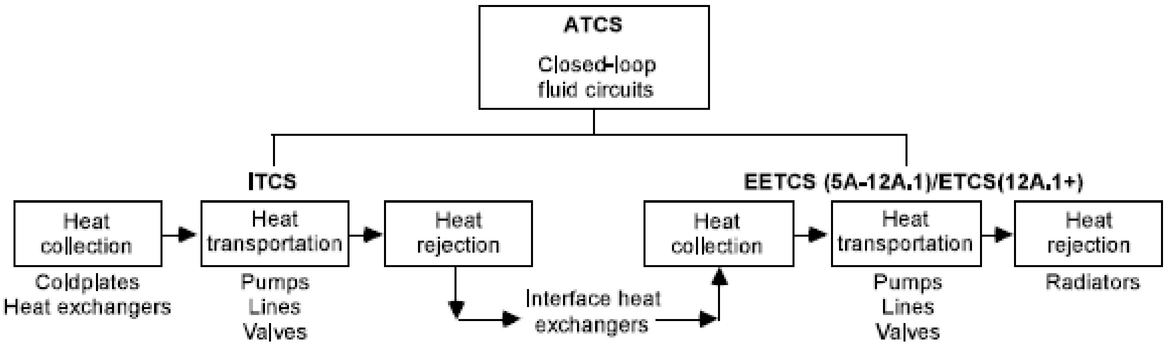


ACTIVE THERMAL CONTROL SYSTEM (ATCS) OVERVIEW

Most of the station's many systems produce waste heat, which needs to be transferred from the ISS to space to achieve thermal control and maintain components at acceptable temperatures. An Active Thermal Control System (ATCS) is required to achieve this heat rejection function when the combination of the ISS external environment and the generated heat loads exceeds the capabilities of the Passive Thermal Control System to maintain temperatures. An ATCS uses a mechanically pumped fluid in closed-loop circuits to perform three functions: heat collection, heat transportation, and heat rejection. Waste heat is removed in two ways, through cold plates and heat exchangers, both of which are cooled by a circulating ammonia loops on the outside of the station. The heated ammonia circulates through large radiators located on the exterior of the space station, releasing the heat by radiation to space that cools the ammonia as it flows through the radiators.

The ATCS consists of the Internal Active Thermal Control System (IATCS), External Active Thermal Control System (EATCS), the Photovoltaic Thermal Control System (PVTCS) and the Early External Active Thermal Control System (EEATCS). The IATCS consists of loops that circulate water through the interior of the U.S. Destiny Laboratory module to collect the excess heat from electronic and experiment equipment and distributes this heat to the Interface Heat Exchangers for transfer to the EATCS. At assembly complete, there will be nine separate ITCS water loops in the U.S. and International Partner pressurized modules.

The Photovoltaic Thermal Control System (PVTCS) consists of ammonia loops that collect excess heat from the Electrical Power System (EPS) components in the Integrated Equipment Assembly (IEA) on P4 and eventually S4 and transport this heat to the PV radiators (located on P4, P6, S4 and S6) where it is rejected to space. The PVTCS consist of ammonia coolant, eleven coldplates, two Pump Flow Control Subassemblies (PFCS) and one Photovoltaic Radiator (PVR).



Active Thermal Control System Architecture

The External Active Thermal Control System (EATCS), activated for the first time on this mission, consists of ammonia loops to collect heat from the Interface Heat Exchangers and external electronic equipment mounted on coldplates and transports it to the S1 and P1 radiators where it is rejected to space. In lieu of using the EATCS initially, the station hardware has been cooled by the Early External Active Thermal Control System (EEATCS). The EEATCS has provided heat rejection capability rejection capability for the U.S. Laboratory Interface Heat Exchangers (IFHX) since STS-98 through STS-116.

The EEATCS is the temporary system used to collect, transport, and reject waste heat from habitable volumes on the International Space Station (ISS). The EEATCS collects heat from the Interface Heat Exchangers (IFHX) located on the U.S. Laboratory module, circulates the working fluid, anhydrous ammonia, via the Pump and Flow Control Subassembly (PFCS), and rejects heat to space via two orthogonally oriented stationary radiators.

INTERNAL ACTIVE THERMAL CONTROL SYSTEM (IATCS)

The purpose of the U.S. Destiny Laboratory ITCS is to maintain equipment within an allowable temperature range by collecting, transporting, and rejecting waste heat. The ITCS uses water because it is an efficient thermal transport fluid and is safe inside a habitable module. The IATCS is a closed loop system that provides a constant coolant supply to equipment, payloads and avionics to maintain proper temperature.

The U.S. Laboratory contains two independent loops, a Low Temperature Loop (LTL) and a Moderate Temperature Loop (MTL). This approach allows for segregation of the heat loads, simplifies heat load management, and provides redundancy in case of equipment failure. The LTL is designed to operate at 40° F (4° C) and service systems equipment requiring low temperatures, such as the Environmental Control and Life Support System (ECLSS) Common Cabin Air Assembly (CCAA) and some payload experiments. The LTL contains approximately 16.64 gallons (63 liters) of fluid. The MTL nominally operates at 63° F (17° C) and provides most of the cooling for systems equipment (i.e. avionics) and payload experiments. The MTL contains approximately 52.83 gallons (200 liters) of fluid. The IATCS loops can be configured and operated as a single loop. This capability is used for a variety of purposes, including the reduction of wear on the pumps, reduction of pump power usage, or to compensate for a pump failure.

PHOTOVOLTAIC THERMAL CONTROL SYSTEM (PVTCS)

The PVTCS consist of ammonia coolant, eleven coldplates, two Pump Flow Control Subassemblies (PFCS) and one Photovoltaic Radiator (PVR). The coldplate subassemblies are an integral part of IEA structural framework. Heat is transferred from the IEA orbital replacement unit (ORU) electronic boxes to the coldplates via fine interweaving fins located on both the coldplate and the electronic boxes. The fins add lateral structural stiffness to the coldplates in addition to increasing the available heat transfer area. The PFCS is the heart of the thermal system. It consists of all the pumping capacity, valves and controls required to pump the heat transfer fluid to the heat exchanges and radiator, and regulate the temperature of the thermal control system ammonia coolant. The PVTCS can dissipate 6,000 watts of heat per orbit on average and is commanded by the IEA computer. Each PFCS consumes 275 watts during normal operations and measures approximately 40 inches (101.6 cm) by 29 inches (73.7 cm) by 19 inches (48.3 cm), weighing 235 pounds (106.7 kilograms).

The PVR—the radiator—is deployable on orbit and comprised of two separate flow paths through seven panels. Each flow path is independent and is connected to one of the two PFCSs on the IEA. In total, the PVR can reject up to 14 kW of heat into deep space. The PVR weighs 1,633 pounds (740.7 kilograms) and when deployed measures 10.24 feet (3.12 meters) by 44.62 feet (13.6 meters). When the station assembly is complete, there will be a total of four PVRs, one for each PV module (S4, P4, P6, S6).

EARLY EXTERNAL ACTIVE THERMAL CONTROL SYSTEM (EEATCS)

Function

Since the U.S. Laboratory became operational before the permanent External Active Thermal Control System (EATCS) was assembled, a temporary external cooling system was needed. External cooling from the Russian segment is not possible because there are no operational interfaces between the U.S. On-orbit Segment (USOS) and the Russian On-orbit Segment (ROS) thermal systems. Instead, a modified version of the Photovoltaic Thermal Control System (PVTCS) called the Early External Active Thermal Control System (EEATCS) acts as a temporary thermal system. The EEATCS consists of two independent, simultaneously operating ammonia cooling loops (ACL). These loops transport heat loads from the Interface Heat Exchanger (IFHX) located on the Laboratory module's aft endcone to the radiators located on truss segment P6.

The EEATCS is needed until the permanent EATCS is activated. Once the permanent EATCS becomes operational on mission, the EEATCS will be deactivated. After deactivation, portions of the EEATCS will be used as spare components for the PVTCS loops.

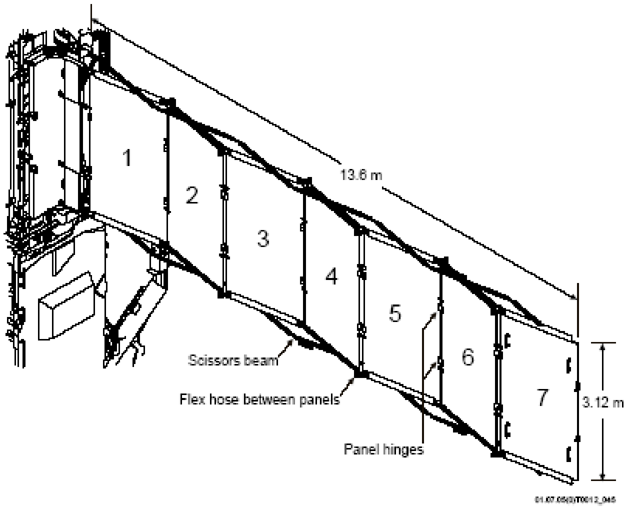
Hardware

Pump & Flow Control System (PFCS)

Each external loop contains a Pump & Flow Control System (PFCS) which contains most of the controls and mechanical systems that drive the EEATCS. There are two pumps per PFCS which circulate ammonia throughout the external coolant loops and a Flow Control Valve (FCV) which mixes cold radiator flow and warm IFHX return flow to regulate the temperature of the ammonia in the loop. The PFCS also contains the primary ammonia accumulator, which provides limited ammonia leakage makeup, protection against thermal expansion of the ammonia, and a net positive suction head greater than the minimum required to prevent pump cavitations. Additionally, all manner of pressure, temperature, flow, and quantity sensors used by the EEATCS are part of the PFCS.

Radiators

The EEATCS radiator ORU is a direct flow, deployable and retractable radiator system with two independent cooling loops. The EEATCS radiator consists of seven radiator panels, the deploy/retract mechanism, support structure, and the necessary plumbing. The EEATCS radiator has two channels (A & B) that acquire heat from the Lab Low Temperature (LT) and Moderate Temperature (MT) Loop Interface Heat Exchanger (IFHX) via liquid anhydrous ammonia. The ammonia flows from the PFCS to the associated IFHX, to the EEATCS radiator



manifold tubes, across the radiator panels and back to the PFCS. The radiator panels reject the excess heat to space via two non-articulating EEATCS radiator ORUs: one AFT (Trailing) and one Starboard (Normal). The two radiator ORUs are located on the P6 Long Spacer Truss Segment. The radiator measures 10.24 feet (3.12 meters) by 44.62 feet (13.6 meters).

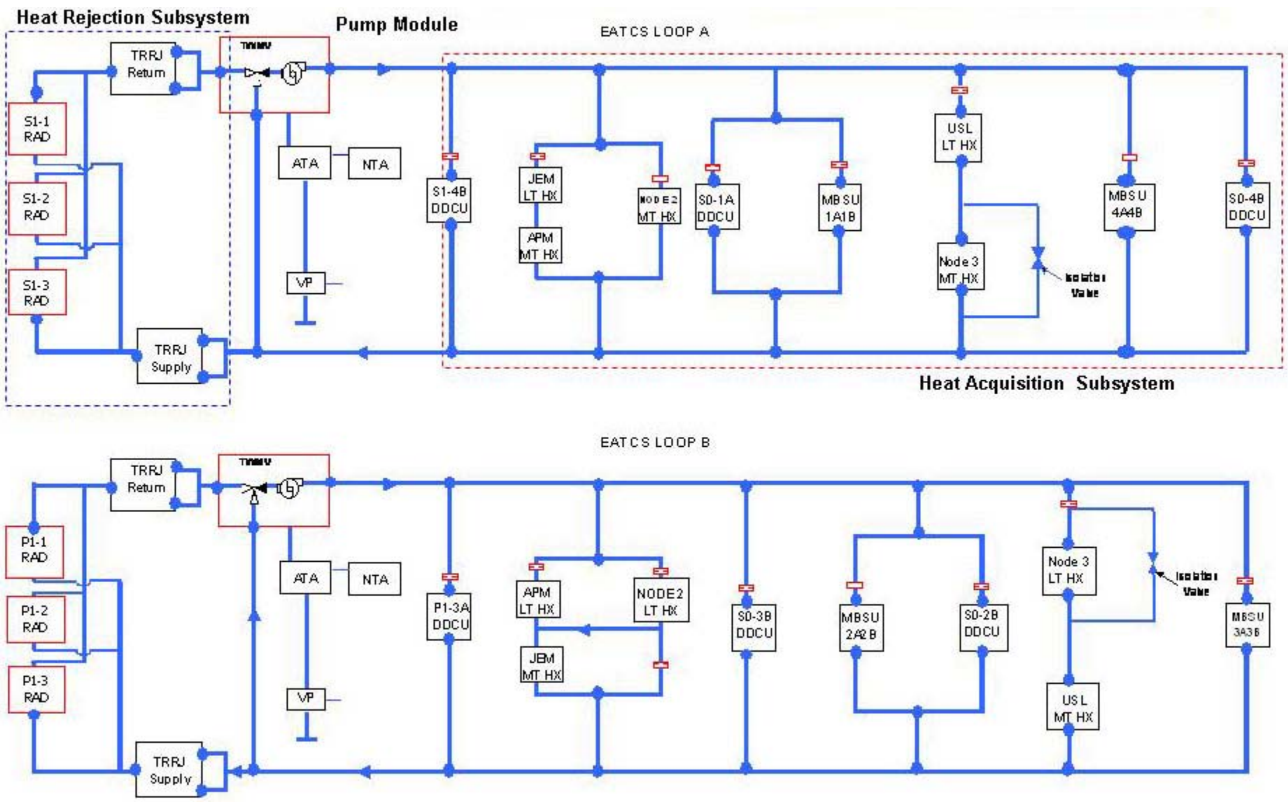
Interface Heat Exchanger (IFHX)

The Interface Heat Exchanger (IFHX) units accomplish heat transfer from the IATCS water coolant loops to the external ammonia coolant loops. When the station is complete, 10 interface heat exchangers will be in operation to provide heat transfer from the IATCS loops of the various habitable modules to the two external ammonia coolant loops. The IFHX units are located on the U.S. Laboratory, Node 2, and Node 3.

EXTERNAL ACTIVE THERMAL CONTROL SYSTEM (EATCS) OVERVIEW

The EATCS provides heat rejection capabilities for all U.S. pressurized modules and the main power distribution electronics on S0, S1 and P1. The system uses a single-phase anhydrous ammonia as its working fluid for its high thermal capacity and wide range of operating temperatures. Ammonia has an extremely low freezing point of -107 degrees ° F (-77 °C) at standard atmospheric pressure. The EATCS is comprised of two independent loops labeled loop A on S1 (Starboard) and Loop B on P1 (Port). The independent loops were designed so that a failure in one would not take down the entire EATCS system. Both loops are physically separated to prevent orbital debris from taking out the lines and the fluid transport lines are buried within the truss structure. If a loop does go down, the EATCS operates at a reduced capacity. Each loop collects heat from up to five Interface Heat Exchangers (IFHXs) mounted on the Node 2, U.S. Destiny Laboratory, and Node 3 as well as externally mounted coldplates. Most of the cold plates and plumbing to the pressurized modules are located on the S0 center truss. The EATCS is designed to provide 35 kW of heat rejection per loop for a total capability of 70 kW. The EATCS also provides ammonia re-supply capability to the Photovoltaic Thermal Control Systems (PVTCS) located on P4, P6, S4 and S6. All EATCS components are located outside the pressurized volumes to prevent crew contact with ammonia.

At assembly complete, each ammonia loop will supply coolant to five Interface Heat Exchangers (IFHX) and five cold plates (three Direct Current-to-Direct Current Units (DDCUs) and two Main Bus Switch Units (MBSUs). Two MBSU cold plates, each designed to remove 495 watts at 80 lbs/hr. Three DDCU cold plates are each designed to remove 694 watts at 125 lbs/hr. The cold plate interfaces with the component base-plate via radiant fins. IFHXs transfer thermal energy from the Internal Thermal Control System's (ITCS) water based coolant to the ETCS anhydrous ammonia coolant. Ammonia supply temperature is currently set at 37 °F (2.8 °C)



The ITCS supply temperature varies as a function of the modules' thermal load. IFHX can isolate and bypass the IFHX core on the ammonia side in the event a cold slug is detected at the pump outlet to prevent ITCS coolant from freezing.

Key Components

The External Active Thermal Control System (EATCS) is the primary permanent active heat rejection system on ISS. It acquires, transports, and rejects excess heat from all U.S. and International Partner modules except the Russian modules. The EATCS contains two ammonia coolant loops, which cool equipment on the S0, S1, and P1 truss segments. Capable of rejecting up to 70kW, the EATCS provides a substantial upgrade in heat rejection capacity from the 14kW capability of the Early External Active Thermal Control System (EEATCS).

Heat Acquisition Subsystem (HAS)

The HAS consists of the Interface Heat Exchanger (IFHX) Orbital Replacement Units (ORU), Main Bus Switch Unit (MBSU) and DC-to-DC Converter Unit (DDCU) cold plates ORU.

Heat Rejection Subsystem (HRS)

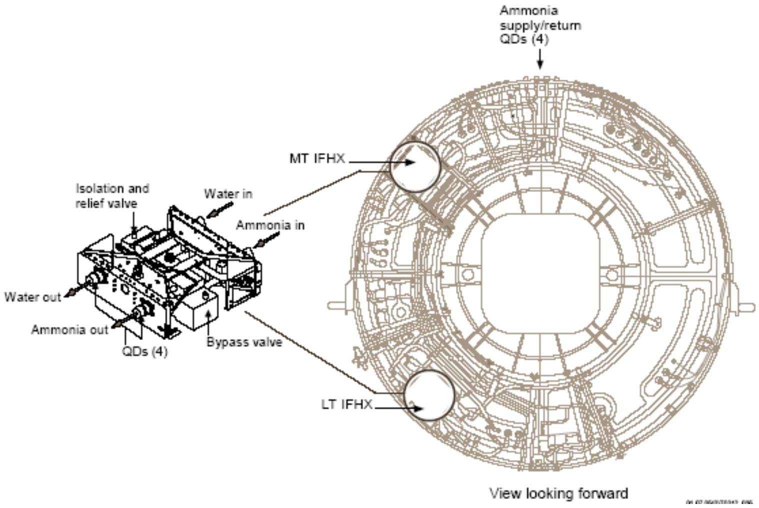
The HRS consists of the radiator ORU, which is a deployable, eight-panel system that rejects thermal energy via radiation. The HRS also consists of the Radiator Beam Valve Module (RBVM) that provides radiator isolating or venting, radiator beam which carries three radiators and connects to the Thermal Radiator Rotary Joint (TRRJ), which rotates to the radiator beam to provide radiator articulation. The EATCS allows the flow of ammonia through heat rejection radiators that constantly rotate to optimize cooling for the station.

Interface Heat Exchanger (IFHX)

The Interface Heat Exchanger (IFHXs) provides the interface between a module's internal TCS and the EATCS. The IFHXs transfer heat from the internal loops of the USOS modules to the EATCS ammonia loops. IFHXs are used to collect heat from USOS modules. There are five IFHXs for each EATCS loop. Some IFHXs are plumbed in series such that the cool ammonia flows through a module's Low Temperature Loop (LTL) IFHX prior to flowing though another module's Moderate Temperature Loop (MTL) IFHX.

The IFHX units accomplish heat transfer from the IATCS water coolant loops to the external ammonia coolant loops. Each IFHX core utilizes a counterflow design with 45 alternating layers. IATCS water flows through 23 of the layers, while EATCS ammonia flows through the 22 alternate layers in the opposite direction. These alternating layers of relatively warm water and relatively cold ammonia help to maximize the heat transfer between the two fluids via conduction and convection. The heat exchanger core is a simple flow through device with no command or telemetry capability. IFHXs are mounted on the Node 2, U.S. Laboratory, and Node 3. The U.S. Laboratory IFHXs have been connected to the EEATCS, until this flight, when the EEATCS ammonia fluid line quick-disconnect will be disconnected and reconnected to the EATCS. When Node 2 arrives on STS-120, it is equipped with six IFHXs designed to provide cooling for itself, the Columbus and Japanese Experiment Module. Node 3 also contains a set of IFHXs, which are connected to the EATCS when it arrives on a shuttle flight currently set for launch no earlier than January 2010.

When the station is complete, 10 interface heat exchangers will be in operation to provide heat transfer from the IATCS loops of the various habitable modules to the two external ammonia coolant loops. The IFHX units will be located on the U.S. Laboratory, Node 2, and Node 3. Because of the highly toxic nature of ammonia, IFHX ORUs are mounted external to the pressurized modules as a safety precaution. Each IFHX measures 25 inches (63.50 cm) by 21 inches (53.34 cm) by 8 inches (20.32 cm) and weighs about 91 pounds (41.28 kilograms).



Interface Heat Exchanger (IFHX) provide the interface between the ITCS and the EATCS

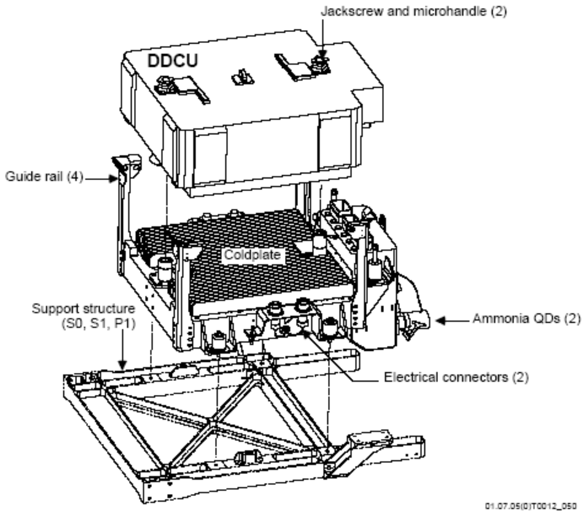
Heaters

Each EATCS loop has electrically powered heaters wrapped around the supply and return fluid lines on the S0 Truss to maintain the minimum operating temperature. These heaters are used during low heat load conditions and are turned on and off by software in the Multiplexer/Demultiplexer (MDMs). These heaters can be operated in closed-loop mode (temperature based) or open-loop mode (time based). Numerous heaters are located on the EATCS plumbing on the S1 (Loop A) and P1 (Loop B) truss segments to prevent ammonia freezing and flexible hose damage during nonoperational periods. These heaters are thermostatically controlled and have no software interface.

Cold Plate

Each ETCS loop provides cooling to externally mounted coldplates located on the S0, S1 (Loop A), and P1 (Loop B) truss segment. These coldplates contain Electrical Power System (EPS) equipment used to convert and distribute power to downstream ISS loads. Each ammonia loop contains four coldplates, two attached to Direct Current-to-Direct Current Converter Units (DDCUs) and two attached to Main Bus Switching Units (MBSUs).

Main Bus Switching Unit (MBSU) Coldplate



Direct Current-to-Direct Current Converter Units (DDCU) Cold Plate

Each MBSU coldplate measures 37 inches (93.98 cm) by 33 inches (83.8 cm) by 20 inches (50.8 cm) and weighs about 109 pounds (49.4 kilograms).

Each coldplate ORU is connected to the EATCS ammonia loop by self-sealing quick disconnect (QD) couplings and contains a finned coldplate, two or three strip heaters and temperature sensor. The coldplates are installed such that the fins of the coldplate are positioned adjacent to corresponding fins on either the DDCU or the MBSU to facilitate heat transfer by radiation between the cooled equipment and the coldplate. Each DDCU coldplate measures 35 inches (88.9 cm) by 28 inches (71.12 cm) by 31 inches (78.74 cm) inches and weighs about 96 pounds (43.54 kilograms).

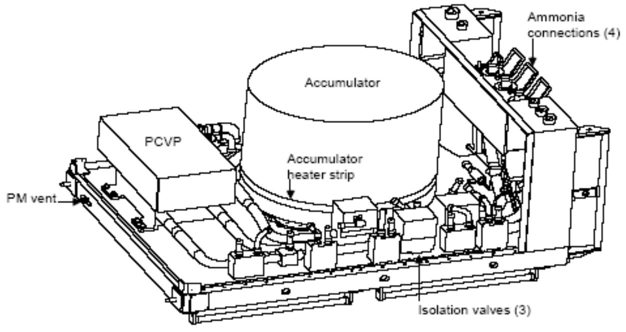
Pump Module (PM)

Circulation, loop pressurization, and temperature control of the ammonia is provided by the Pump Module (PM). Each ammonia loop contains a Pump Module Assembly (PM) ORU to provide flow and accumulator functions and maintains proper temperature control at the pump outlet. Each

PM consists of a single pump, a fixed charge accumulator, a Pump & Control Valve Package (PCVP) containing a firmware controller, startup heaters, isolation valves, and various sensors for monitoring performance. The accumulator within the PM works in concert with the Ammonia Tank Assembly (ATA) tanks to compensate for expansion and contraction of ammonia caused by the temperature changes and keeps the ammonia in the liquid phase via a fixed charge of pressurized nitrogen gas on the backside of its bellows.

The Pump Module (PM) provides fluid pumping, fluid temperature control and system pressure control. The PCVP provides flow control. A single pump in the PCVP provides circulation of the ammonia. The Flow Control Valve (FCV) located within the PCVP regulates the temperature of the ammonia. The FCV mixes "cool" ammonia exiting the radiators with "warm" ammonia that has bypassed the radiators.

Nominally, loop A will operate at 8,200 lb/hr and loop B at 8,900 lb/hr at 14,000 and 14,700 revolutions per minute, respectively.



Note: Enclosure removed for clarity.

The Pump Module ORU circulates liquid ammonia at a constant flowrate to a network of coldplates and heat exchangers located on the external trusses and U.S. modules, respectively.

For STS-116, initial activation with U.S. Laboratory IFHX where Loop A pump will run at 11,500 rpm, equivalent to 5,000 lb/hr while Loop B pump will run at 11,500 rpm which is equivalent to 5,200 lb/hr.

The accumulator located in the PM provides auxiliary pressure control. The accumulator resides upstream of the PCVP in each PM ORU. The accumulator keeps the ammonia in the liquid phase by maintaining the pressure above the vapor pressure of ammonia and provides makeup ammonia in case of a leak. The accumulator works in conjunction with the ATA to absorb fluctuations in the fluid volume due to varying heat loads through the expansion and contraction of its internal bellows.

Nominal operating pressure for the loops is 300 psia at the pump inlet; the pressure will be brought up to 390 psia for start up. The maximum system design pressure is 500 psia.

Each PM measures 69 inches (175.26 cm) by 50 inches (127 cm) by 36 inches (.91 cm) inches and weighs about 780 pounds (353.8 kilograms)

Low and High Pressure Flow Control Monitoring

Failure Detection, Isolation and Recovery (FDIR) for high and low pressure conditions are monitored and issued by the S1/P1 Multiplexer/Demultiplexers (MDMs). For an over pressure, gaseous nitrogen pressure is relieved down to 360 psia when pump inlet pressure reaches 415 psia (active control). The PVCP Inlet pressure, Radiator return pressure, and Bypass return pressure sensors are part of this system and two of three pressure readings are used to determine if an overpressure condition exists. The pump will shut down issued when the pump outlet pressure reaches 480 psia (active control). Various relief valves and burst disks at the IFHX, PM, and RBVM will relieve at approximately 70 psia (passive control)

Low pressure (current limit set at 170 psia) is monitored by two methods to determine a low pressure condition (chooses higher of the two values to determine the limit). Low pressure conditions are monitored using the PVCP inlet pressure, radiator return pressure, and bypass return pressure sensors.

Temperature Control

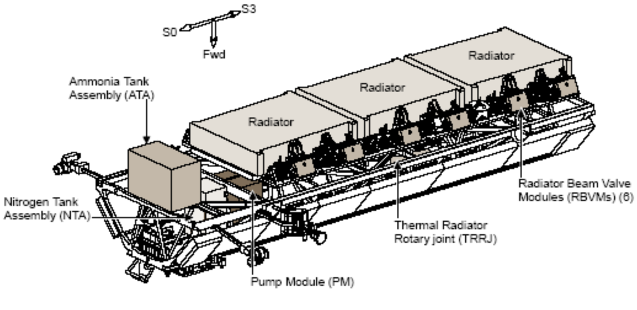
The PCVP also maintains temperature set point control of the ammonia supplied to the HAS. The PCVP has a temperature control capability of 36 °F (2.2 °C) to 43 °F (6.1 °C) and it will be set at 37 °F ± 2 °F (2.8 °C). The temperature control method is by three way mixing valve that mixes flow from the radiators and the HRS Bypass. Heaters on the HRS Bypass leg provide an additional level of control. Heaters are used to provide fluid conditioning in the event the thermal load on the loop is not sufficient to maintain set point control and to support temporary transient events. Total heater power of 1.8 kW is split across two heater strips mounted on the HRS bypass lines (900 watts each).

Pump outlet over temperature protection is provided by a Firmware Controller (FWC) in the PCVP that uses three PCVP outlet sensors to determine an over temp condition and issues zero pump speed. The S1/P1 MDMs use the PM outlet sensor to determine an over temp condition and pull power from the Solenoid Driver Output (SDO) card providing power to the PM.

Current limit is set at 65 °F (18.33 °C). Freeze Protection in the IFHX is detected by the PCVP firmware which shuts down the pump (first leg). When an under temperature condition is detected by the S1/P1 MDMs, it will pull power from the SDO card providing power to the PM (second leg). Under temperature detected by the S0 1,2 MDMs pulls power from the utility rail (third leg, leaves many things without power). The current limit is set at 35 °F (1.67 °C).

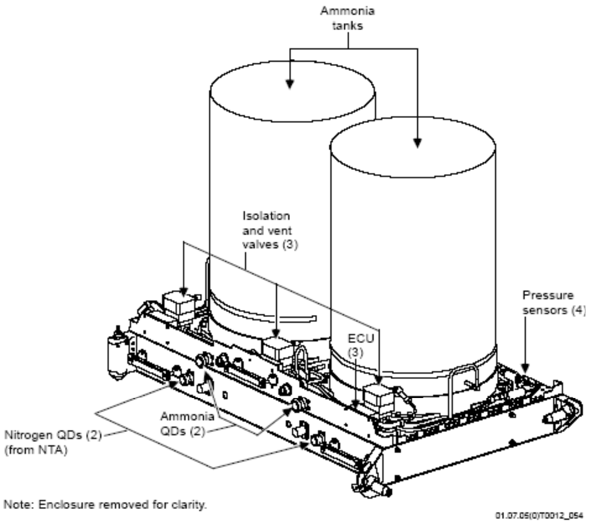
Fluid Supply

Each ammonia loop contains an ATA ORU to contain the heat transfer fluid (liquid ammonia) used by the EATCS loops. There is one ATA per loop located on the zenith side of the S1 (Loop A) and P1 (Loop B) truss segments. The ATA ORU will be used to fill the EATCS loop on startup, to supply makeup fluid to the system, to act as an accumulator in concert with the PM accumulator and provide the capability to vent the ammonia loops by way of a connection to an external non-propulsive vent. Each ATA primarily consists of two bellows ammonia tanks pressurized by an external nitrogen source, two internal survival heaters and two sets of quantity, differential pressure, absolute pressure and temperature sensors. The ATAs are isolatable and replaceable on orbit.



Note: Loop A components on the S1 Truss segment shown. Loop B components on the P1 Truss segment are identical; however, the orientation is reversed. All three radiators are retracted.

Ammonia re-supply capability for the EATCS and the eight PVTCS located on P6, P4, S4 and S6 is provided by the Ammonia Tank Assembly (ATA).

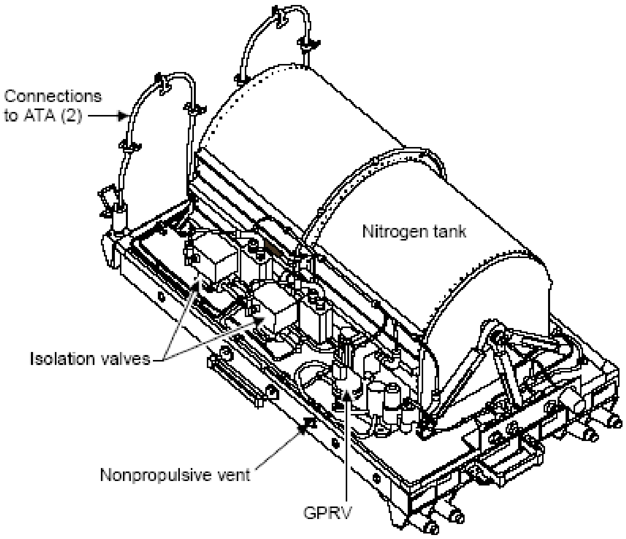


Note: Enclosure removed for clarity.

Multilayer Insulation (MLI) applied to the exterior surfaces of the ORU is provided to guard against excessive heat loss. The ATA ORU is protected against Micro-Meteoroid/Orbital Debris (MM/OD) by shielding on the exterior of each tank and the ORU itself. Each ATA measures 79 inches (200.66 cm) by 46 inches (116.84 cm) by 55 inches (139.7 cm) inches and weighs about 1,120 pounds (508.02 kilograms).

The ATA in combination with the Nitrogen Tank Assembly (NTA) provide fluid supply and primary system pressure control. A single ATA was launched on Flights 9A and 11A (ITS S1 and P1) with approximately 640 lbm ammonia in each ATA, 320 lbm per tank. ATA provides necessary plumbing connection to the ammonia vent system via the vent panel. Supply to outboard trusses is provided through the vent panel. The ATA acts as the primary accumulator for the EATCS in concert with the NTA. If required, it can also be used to replenish the PVTCS fluid lines.

Each ammonia loop contains a NTA ORU to provide storage for the high pressure nitrogen used for controlled pressurization of the ATA. The NTA mounts to the S1 (Loop A) and P1 (Loop B) truss segments and is connected to the ATA by self-sealing QDs. Each NTA ORU primarily consists of a nitrogen tank, a gas pressure regulating valve (GPRV), isolation valves and survival heaters. The nitrogen tank provides a storage volume for the high-pressure gaseous nitrogen, while the GPRV provides a pressure control function as well as nitrogen isolation and over pressure protection of downstream components. The NTA provides the necessary pressure to move the ammonia out of the ATA. The single high-pressure tank containing nitrogen at 2,500 psia (@70 °F, ground fill) and uses the GPRV to supply continuous pressure up to 390 psia in one psia increments. A back-up mechanical valve limits the maximum nitrogen pressure to 416 psia. The GPRV provides pressure control as well as high-pressure nitrogen isolation and overpressure protection of downstream components. The NTA has venting capabilities and over pressure controls. Each NTA measures 64 inches (162.56 cm) by 36 inches (91.44) by 30 inches (76.2 cm) inches and weighs about 460 pounds (208.65 kilograms).



Note: Enclosure removed for clarity.

Fluid Lines and Quick Disconnects (QD)

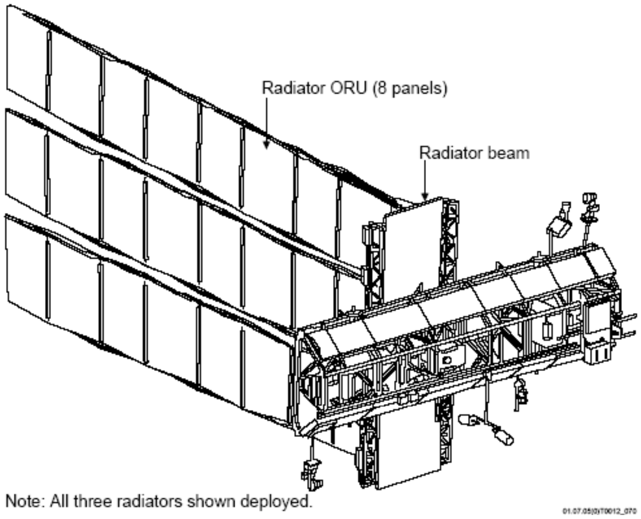
Fluid lines and external QDs provide the transportation path from the truss segments to the IFHXs. Connections between segments are made with flex hoses and QDs. There are flex hoses and QDs between each truss, and between the S0 truss and the various IFHXs.

Heat Rejection System

Heat collected by the EATCS ammonia loops is radiated to space by two sets of rotating radiator wings—each composed of three separate radiator ORUs. Each radiator ORU is composed of eight panels, squib units, squib unit firmware controller, Integrated Motor Controller Assemblies (IMCAs), instrumentation, and QDs. Each Radiator ORU measures 76.4 feet (23.3 meters) by 11.2 feet (3.4 meters) and weighs 2,475 pounds (1,122.64 kilograms)

Each ammonia loop contains one radiator wing comprised of three Radiator ORUs mounted on the Radiator Beam and six Radiator Beam Valve Modules (RBVM) and one Thermal Radiator Rotary Joint (TRRJ). The Radiator ORUs utilize anhydrous ammonia to reject heat from the EATCS.

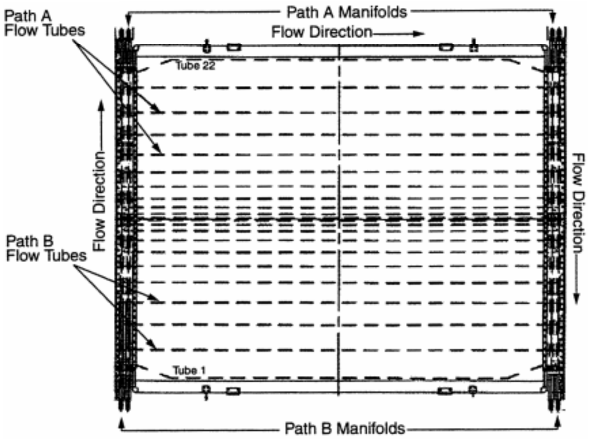
Heat Rejection System (HRS) Radiator during deployment testing at Lockheed Martin Missiles and Fire Control.



Each Radiator ORU contains a deployment mechanism and eight radiator panels. The deployment mechanism allows the Radiator ORU to be launched in a stowed configuration and deployed on orbit. Each radiator ORU can be remotely deployed and retracted.

Each individual radiator has two separate coolant flow paths. Each flow path flows through all eight radiator panels. Each panel's flow path has eleven flow tubes for a total of 22 Inconel flow tubes or passages (11 passages per flow path) per radiator panel; flow tubes are freeze tolerant. Flow tubes are connected along the edge of each panel by manifolds. Flex hoses connect the manifold tubes between panels. Each panel has a white (Z-93) coating which provides optimum thermo-optical properties to maximize heat rejection. Flow tube arrangement is designed to minimize ammonia freezing in the radiator.

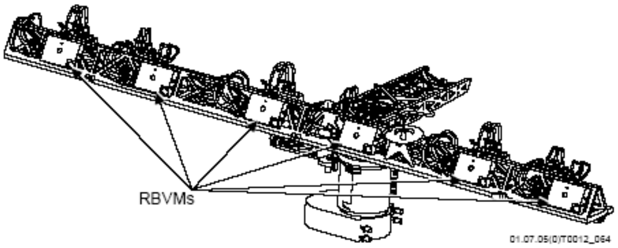
Each radiator path contains one Radiator Beam Valve Module (RBVM) as a part of the radiator wing. Six RBVMs are mounted on the radiator beams on the S1 and P1 truss segments. Two RBVMs service each radiator ORU. Each RBVM consists of an isolation relief valve, an isolation valve, an Integrated Motor Controller Assembly (IMCA), QDs, and pressure and



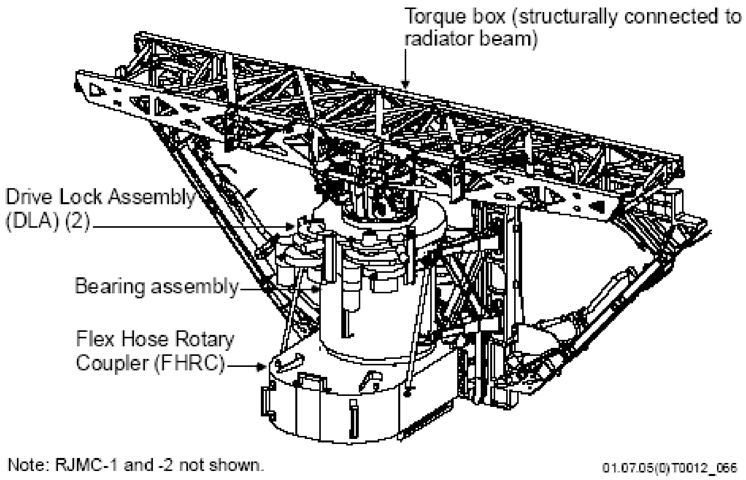
temperature sensors. The RBVM controls the transfer of ammonia between the Radiator Assembly ORU and the rest of the EATCS loop. Each RBVM contains sensors to monitor absolute pressure, temperature and valve position within the ORU. Remote control venting of the radiator fluid loop is also available through the RBVM to facilitate radiator replacement and prevent freezing of the ATCS coolant during contingency operations. The RBVM provides flow path isolation in the event that a panel suffers micro-meteoroid damage. Leak isolation FDIR functions are controlled by the S1/P1 MDMs monitoring large leaks via the STR/PTR MDMs. Additionally, the RBVM provides automatic pressure relief when the EATCS is over pressurized. Each RBVM weighs about 50 pounds (22.68 kilograms) and measures 24 inches (60.96 cm) by 20 inches (50.8 cm) x 5.4 inches (13.72 cm).

The rotation capability for each radiator assembly is provided through a **Thermal Radiator Rotary Joint (TRRJ)**. The TRRJ provides power, data, and liquid ammonia transfer to the rotating radiator beam while providing structural support for the radiator panels. Each TRRJ is composed of the following: a bearing assembly, two Rotary Joint Motor Controllers (RJMCs), two Drive Lock Assemblies (DLAs), a Flex Hose Rotary Coupler (FHRC), and a Power and Data Transfer Assembly (PDTA). The bearing assembly is the rotary interface and primary structural component of the TRRJ. The RJMCs provide control for the DLA system, which provides joint rotation and joint locking capability. The FHRC consists of four flex hoses, two supply and two return. The PDTA provides the data and power paths for transfer to and from the radiator beam.

TRRJ ORU provides rotation capability to the Radiator Beam to optimize the thermal environment of the radiators and to maximize heat rejection capability and prevent freezing in the radiator manifolds. Rotation angles are determined via the Radiator Goal Angle Calculation (RGAC) algorithm which commands the Radiator Beam to put the radiators either "edge to the sun" during isolation phase of the orbit or "face to the Earth" during the eclipse phase. The RGAC ensures the radiators stay cold enough so the heat can be rejected but warm enough so that the ammonia does not freeze. There is a temperature goal of –40 °F at the radiator outlet. The FHRC provides the transfer of liquid ammonia across the rotary joint and is capable of rotating 230 degrees, at ±115 degrees from its neutral position. (software command limit is ±105°); with a variable rotation speed of



There are two RBVMs (one per flow path) that allow or prevent the transfer of ammonia to and from the radiator panels.



Thermal Radiator Rotary Joint (TRRJ) provides controlled rotation of the EATCS radiators, allows the transfer of power, data, and ammonia across the rotating interface, and provides the structural support between the S1/P1 truss segments and the associated radiator wing assembly.

0 to 45 degrees-per-minute. Each TRRJ measures approximately 5.6 feet (1.7 meters) by 4.6 feet (1.4 meters) by 4.3 feet (1.3 meters) and weighs 927 pounds (420.5 kilograms).

System Performance Overview

Loop A and B operate at slightly different flow rates mainly due to differing system hydraulic resistance layout. Actual heat rejection will need to be planned and coordinated between all modules so as not to exceed the EATCS total heat rejection capability of 70 kW (at assembly complete), including S1/P1/S0 mounted electrical equipment.

Software

Thermal Control System (TCS) software is used to control and monitor the system. The TCS software executes actions such as system startup, loop reconfiguration, and valve positioning for flow and temperature control automatically or via commands from crew laptops or ground workstations. Telemetry from the various temperature, pressure, flow, and quantity sensors is monitored by TCS software and displayed on crew laptops or ground workstations. In addition, Fault Detection, Isolation, and Recovery (FDIR) software is used to monitor the performance of the TCS and, if there is a problem, alert the crew and flight controllers. In some cases, FDIR software initiates recovery actions.

EATCS Activation

With the solar arrays attached by the shuttle Atlantis' crew in September, NASA is ready with STS-116 to start generating enough power so that the permanent cooling system can be brought on line. NASA will have to bring up the permanent electrical power distribution system on line first before activating EATCS. The goal is to power up the MBSUs, route power through them to the cooling system and gets that system activated before the MBSUs can overheat. The EATCS has never been tested as an entire integrated system in its on-orbit configuration. However, NASA and Boeing engineers did conduct an entire loop test, but it did not have a rotating Radiator.

During STS-116/Assembly flight 12A.1, during the second and third spacewalks, the EATCS is activated as part of the entire reconfiguration. There are two major power domains, 1/4 and 2/3. During EVA 2, the 2/3 power domain reconfiguration takes place and loop B is activated and then on EVA 3, the 1/4 power domain reconfiguration takes place and loop A is activated. Both power-on and power-off are major reconfigurations, when half the station power is turned off for periods of time. NASA has implemented a large number of procedures to account for the situation where they are zero-fault tolerate. The key to each EVA is activation of the pump modules and getting the system started for the first time. Assuming a nominal activation, there are approximately 24 procedure steps to activate the EATCS for the first time.

Preparations to activate the EATCS start when the ground filled nitrogen pad is vented from the center radiators and the rest of the system (to be vented after STS-116 reaches orbit). The system is presently pressured with about 80 psia of nitrogen. The next step will be to introduce ammonia into the system with only one radiator ORU per loop plumbed, which will take several hours. Filling and activating the system will be one of the major challenges that mission controllers and engineers will face. Activation will take about an hour for each loop. If there were an anomaly during filling such as pressure begins to drop like a leak, then the entire reconfiguration would be interrupted. Mission controllers have thoroughly rehearsed their procedures to identify any potential leaks in the system. Some minor leaks are possible. Early activation will provide cooling to the MBSUs and DDCUs (their respective cold plates) on S1, S0 and P1. The activation sequence also allows for a through checkout of the EATCS loops prior to connecting the U.S. Destiny Laboratory IFHX to the EATCS. The US Laboratory IFHXs will continue to be cooled via the Early External Active Thermal Control System (EEATCS) located on P6 Long Spacer.

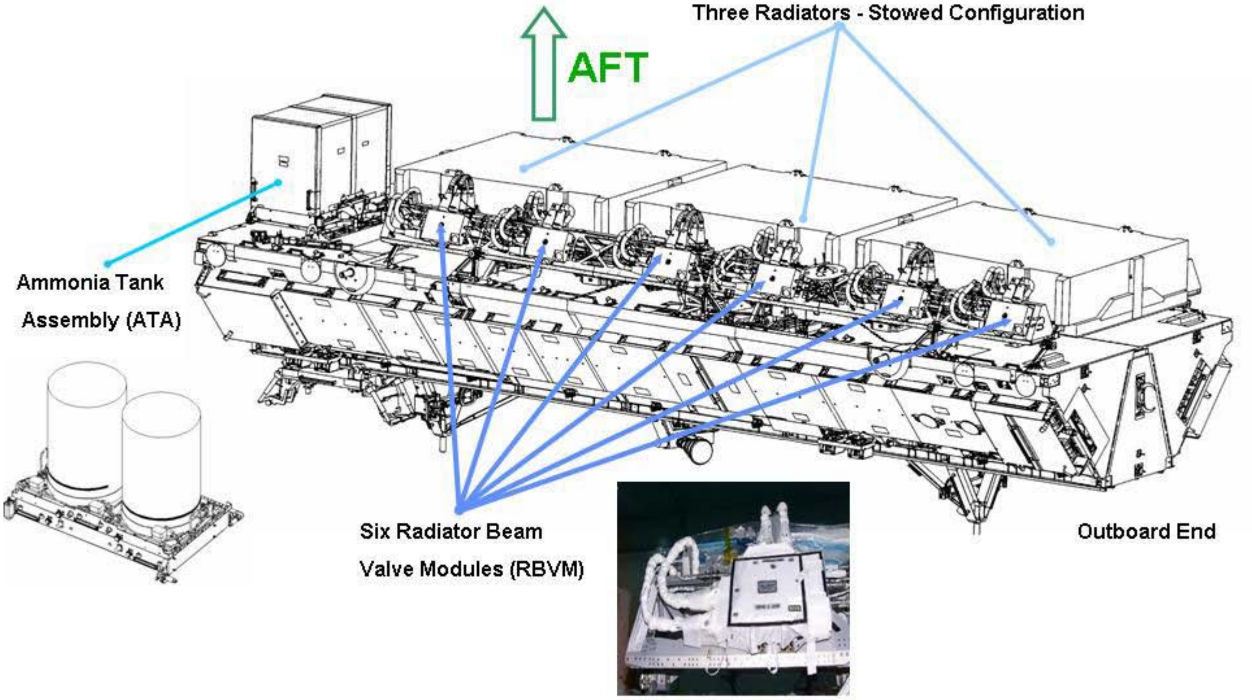
During the 12A.1 stage, EVAs will be conducted to connect the U.S. Laboratory IFHXs to the EATCS. After the IFHXs are connected to the EATCS, the EEATCS will enter a dormancy phase.

On STS-120, also known as Assembly Mission 10A, the two remaining radiator ORUs per wing are deployed and filled. Node 2 end-cones are connected to the EATCS via the starboard and port, boom trays located on the forward end of S0. Pump shut down will be required. All six IFHXs on Node 2 receive cooling from the EATCS: two for Node 2, two for Attached Pressurized Module (APM-Columbus), and two for Japanese Experiment Module (JEM-Kibo). The APM and JEM IFHXs remain in a bypassed and isolated configuration to prevent accidental freezing of the water side core of the IFHXs.

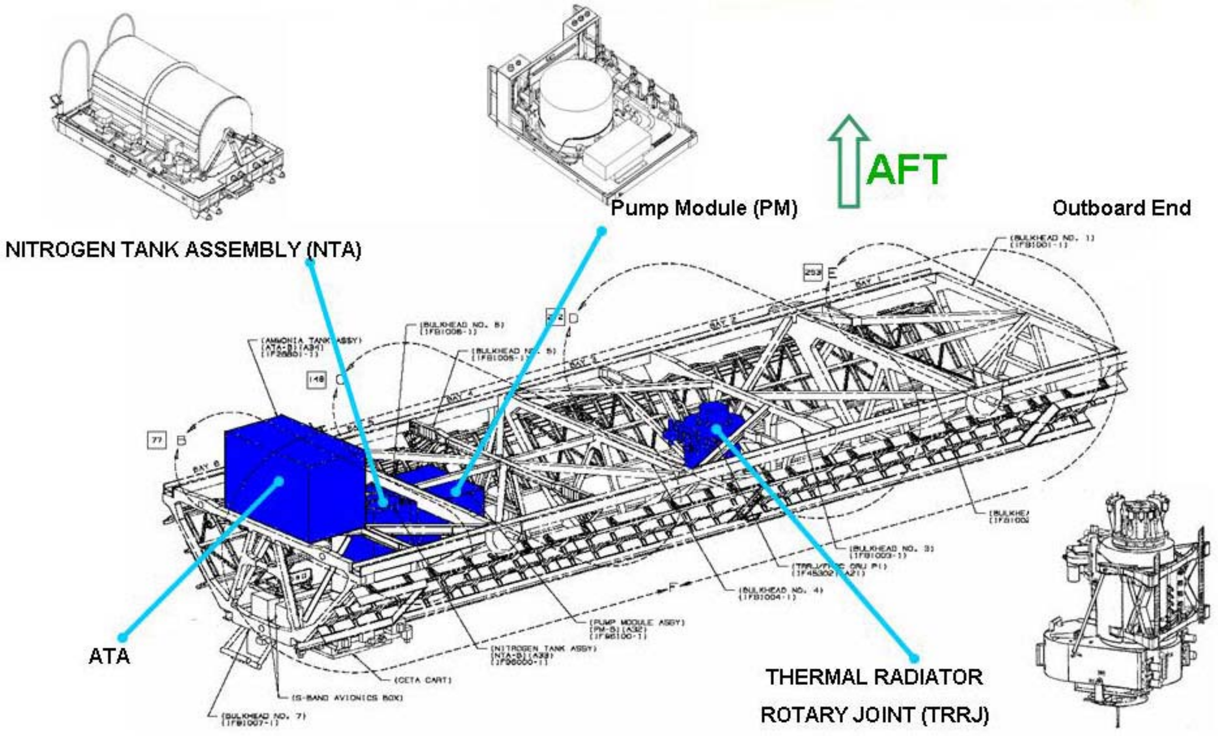
On Assembly Flight 20A, currently set for launch no earlier than January 2010, the Node 3 end-cone is connected to the EATCS via jumpers from the US Laboratory aft end-cone. A bypass line with an isolation valve on the US Laboratory Aft end-cone allows the fluid circuit to be completed prior to Node 3 arrival. Upon Node 3 arrival, the end-cone connection and activation the bypass-Isolation valves on US Lab end-cone are closed. This mission completes the EATCS loop architecture.

Boeing engineers in Huntington Beach, Calif. designed the EATCS as well as S0, S1 and P1 which contains most of the EATCS hardware. Major subcontractors to Boeing were Hamilton Sundstrand (PCVP, coldplates, core for heat exchanger), Honeywell (tanks, accumulator, RBVMs), Lockheed Martin (radiators) and Marotta (valves).

COMPONENT REFERENCE DRAWINGS



Component locations on S1/P1

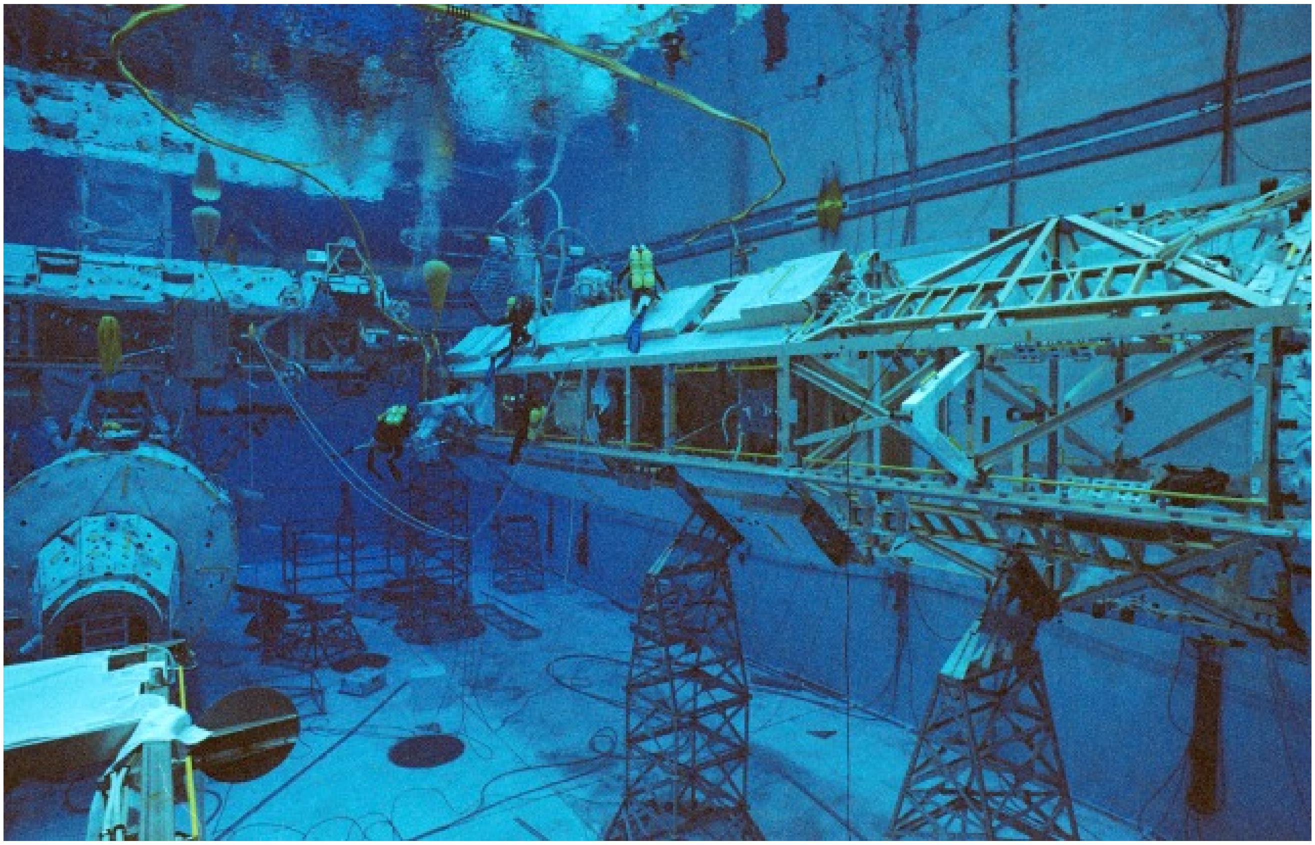


Component locations on S1/P1

SPACEWALKS

The major objectives of the three spacewalks on the STS-116 mission include: install the Port 5 (P5) truss segment; reconfigure the space station power system from its temporary to its permanent configuration and incorporate power from the P4 solar arrays for the first time: activate ammonia loops for cooling; relocate the Photovoltaic Radiator Grapple Fixture (PVRGF) and the Crew Equipment Translation Aid (CETA) carts; and transfer the Service Module Debris Panels (SMDPs).

The square-shaped P5 truss is about the length of a small compact car. It will provide structural spacing and utility connections between the P4 and P6 solar arrays after the P6 solar arrays are relocated during a shuttle mission next year. The station eventually will have 11 integrated truss segments joined together to stretch 356 feet end to end to support four solar array assemblies and radiators to power and cool the station.



Astronauts Robert L. Curbeam, Jr. and Christer Fuglesang, STS-116 mission specialists, wearing training versions of the Extravehicular Mobility Unit (EMU) spacesuit, participate in an underwater simulation of extravehicular activity (EVA). Curbeam and Fuglesang are dwarfed by station truss segments in this overall view of the simulation conducted in the Neutral Buoyancy Laboratory (NBL) near the Johnson Space Center.

During the three spacewalks, the astronauts and Mission Control Houston will power down equipment, transfer power to other redundant power channels and unplug and plug in electrical connectors.

The extravehicular activities (EVAs) are planned for flight days 4, 6 and 8, with each spacewalk estimated to last 6.5 hours. There will be several challenges during the spacewalks. On flight day 4, as the P5 spacer is being moved into position, it will come as close as 2.7 inches from the P4 truss in a move similar to parallel parking in a snug space. On flight day 6 and again on flight day 8, Mission Control, Houston, will power down half of the station as the crew prepares to rearrange the power system from the temporary system it has used to its permanent configuration. The process will activate several pieces of equipment for the first time. It also will allow the station to use power generated by the P4 solar arrays, added to the complex during STS-115 in September 2006, for the first time.

Mission specialists Bob Curbeam and Christer Fuglesang will conduct the first and second spacewalks. Curbeam and Mission Specialist Suni Williams will conduct the third spacewalk. Pilot Bill Oefelein will be the intravehicular lead for the spacewalks, assisting the spacewalkers from inside the spacecraft with their tasks. Williams will operate the station's robotic arm during the first two spacewalks and mission specialist Joan Higginbotham will operate the station's arm during the third spacewalk. Mission Specialist Nicholas Patrick will operate the shuttle's robotic arm.

Curbeam is a veteran of three previous spacewalks. This will be the first spaceflight and spacewalks for Fuglesang and Williams. Williams, who joins the station crew for a six-month stay, is slated to perform three spacewalks during her station flight.

Astronaut Bob Curbeam

On spacewalks 1 and 2, Curbeam will wear a spacesuit marked with red stripes around the legs and Fuglesang will wear an all-white spacesuit. On spacewalk 3, Curbeam will wear the spacesuit marked with red stripes, while Williams will wear all white. All of the spacewalks will originate from the station's Quest airlock.

EVA 1

There are three major objectives during EVA 1: First, install the P5 spacer; second, remove and stow the Photovoltaic Radiator Grapple Fixture—a handle used by the shuttle and station robotic arms during the P5 installation; and third, remove and replace a camera on the S1 truss that is needed to view clearances during future truss segment installations.

On flight day 3, the crew will use the shuttle's robotic arm to lift the P5 truss from the shuttle's payload bay and hand it to the station's robotic arm. It will remain "parked" at the end of the station arm while the crew sleeps that night. Then, on flight day 4, the station's arm—the Space Station Remote Manipulator System or SSRMS—will be used to move the P5 spacer to a pre-installation position on the left, or port, side of P4. Once the P5 is in position, Curbeam and Fuglesang will remove the locks that secured the spacer's hardware during its launch on the shuttle. Curbeam will remove the P5 launch locks from corners 3 and 1. Fuglesang will remove locks from corners 2 and 4.

Once the locks are removed, the two will provide verbally guide Williams as she maneuvers the station arm to align P5 to P4. The installation is completed by mating six utility cables.

Before the P5 is locked in place, Mission Control must take several measures to ensure nothing disturbs the operation. The station's thrusters will be turned off and the control moment gyroscopes will be in a mode that creates as little disturbance as possible until the crew has tightened three of the four Modified Rocketdyne Truss Attachment System (MRTAS) bolts. Mission Control also will configure the Solar Alpha Rotary Joint and Beta Gimbal Assemblies—used to swivel the solar arrays to allow them to track the sun—into the proper positions for P5 installation. All of the joints will be locked to ensure there is no unexpected motion.

After the P5 launch locks are removed, the station robotic arm will guide P5 into the soft capture position, with Curbeam and Fuglesang assisting by monitoring structural clearances. Once the P5 coarse alignment cone has captured the P4 soft capture pin, the spacewalkers will use a pistol grip tool—similar to a portable hand drill—to tighten the attachment bolts. First the bolts on corner 1 (forward/zenith) and 2 (forward/nadir) will be tightened, in that order, to an initial torque. Next, bolts on corners 3 (aft/zenith) and 4 (aft/nadir) will be driven to final torque. Finally, bolts 1 and 2 will be tightened to their final torque. After the bolts are driven, the crew will attach grounding straps on each corner and remove the soft capture pins.

Next, the crew will move the Photovoltaic Radiator Grapple Fixture (PVRGF) from the P5 to a place on the station's Mobile Base System. The grapple fixture will be temporarily stored there until it can be moved to the P6 aft radiator on a later spacewalk. The PVRGF is a handle that was installed on the top, or zenith, side of the P5 spacer and used by the shuttle and station arms to move the truss. It is being removed to provide enough clearance for the solar arrays to rotate and track the sun.

To accomplish this, Curbeam and Fuglesang will move to the grapple fixture, where Curbeam will use the pistol grip tool to begin removing fasteners. Meanwhile, Fuglesang will move a foot restraint to a new worksite interface. Once the foot restraint is in place, Fuglesang will begin removing grapple fixture fasteners. Once all the fasteners are removed, Fuglesang and Curbeam will perform an almost acrobatic transfer of the tethered grapple fixture from one to the other as they move to the station's keel.

The final task for this spacewalk is the removal and replacement of a camera located at port 3 of the station's starboard 1 (S1) truss. The camera is needed to view clearances during future installations and deployments. Curbeam will set up the worksite while Fuglesang retrieves the replacement camera from the airlock. Both will work to remove the failed camera and install the new one.

EVA 2

During EVA 2, there are two primary tasks and two secondary tasks for the crew. The first primary task is to reconfigure space station power to the permanent architecture and integrate P4 power beginning with the channel 2/3 side of the station's Electrical Power System. The second is to relocate two crew and equipment translation aid (CETA) carts from the starboard side of the station to its port side. This will clear the way for the station's Mobile Transporter to move to worksite 2 on the starboard 1 truss. Worksite 2 must be checked out prior to the STS-117 mission next year. On that mission, it will be used during installation of the starboard 3 and 4 (S3/S4) truss segments.

During the spacewalk, the crew also will install a thermal blanket for the force moment sensors on the station's robotic arm's latching end effector.

First, Curbeam and Fuglesang will reconfigure power on the Channel 2/3 side of the station's Electrical Power System to route it through the Main Bus Switching Units. The power reconfiguration requires that all power be shut down from Channel 2/3. To accomplish this, a lengthy set of power down procedures will be executed from the ground while the crew prepares for the spacewalk.

The Channel 2/3 power reconfiguration is expected to take Curbeam and Fuglesang about an hour and a half to complete. During the spacewalk, primary power from channels 2A and 2B will be connected to the main bus switching unit 2. The work will be done at the Starboard 0 (S0) truss segment near the forward S0-Lab struts. Curbeam will translate to the S0 to disconnect the lab's secondary power, install a cable to route power from the S0 truss to the P1 truss, and to reconfigure the S0-2B dc converter unit, the bypass jumper on the main bus switching, and the P1-3A dc converter.

Astronaut Christer Fuglesang

The S0 truss segment sits in the middle position on the truss structure on top of the U.S. Destiny Laboratory, flanked by the S1 and P1 truss elements. That truss, along with the S1 and P1 trusses, contain the major electrical components of the permanent electrical system, including the main bus switching units and the DC-to-DC converter units.

The power produced by the station's solar arrays is routed to batteries for storage and then to the main bus switching units. The main buses route power to DC-to-DC converter units (DDCUs) which then adjust the primary, 160-volt dc electricity it receives from the main buses to about 125 volts of power. The dc converters feed the station through the Remote Power Controller Modules (RPCMs). A simplified comparison is that the main buses are similar to a power substation, the dc converters are like transformers, and the controller modules are like the electrical switches inside a home.

While Curbeam is configuring power to the Unit 2 main bus, Fuglesang will be removing Circuit Interrupt Devices (CIDS) 3, 4, and 5. Once the main bus is operating, the circuit interrupt devices won't be needed. The circuit interrupts served as early "circuit breakers" for the crew. They will be returned to Earth. All three circuit interrupters are located at the lab's aft end cone panel, in an area known as "the rat's nest."

Because the main bus switching unit generates heat once it is activated, a pump module must also be activated to enable ammonia to flow through large cold plate loops that cool the bus. Prior to both the second and the third spacewalks, the station's External Thermal Control System (ETCS) ammonia loops will be filled so they are ready when the buses are activated. However, if the pump module doesn't work—it is powered by the bus—there is an estimated five-to six-hour window before the bus must be powered off and allowed to cool. If the pump isn't working because it failed, it will need to be removed and replaced. This procedure will require the crew to remove and replace the pump on the third spacewalk instead of completing the power reconfiguration to the P4 truss. That could result in an additional spacewalk to complete the station's power reconfiguration. The crew has trained for that possibility.

Another consideration is the possibility that the bus or a dc converter will fail and will need to be removed and replaced.

Once the EV crewmembers have finished the Channel 2/3 power reconfiguration, they will begin other tasks while Mission Control powers up the station. Curbeam and Fuglesang will relocate two crew and equipment translation aid (CETA) carts from their current locations on the S1 truss to the S0 truss to clear the way for Atlantis' astronauts to install the S3 and S4 truss segments on the STS-117 mission.

The crew also will install a thermal cover on the force moment sensors on the latching end effector on the station's robotic arm and reconfigure power to the Z1 truss electrical patch panel 6, which provides power to the Z1 truss as well as the Russian segment.

The electrical panel task must be conducted separately from the main power down because the S-band communication antennas powered by Channel 2/3 are sensitive to cold and should not be shut down for a protracted period of time.

While Curbeam is busy with this reconfiguration, Fuglesang will retrieve the starboard and port quick disconnect bags—stowage bags filled with maintenance hardware and tools—from the airlock and install the bags on top, or the zenith side, of the airlock.

EVA 3

The primary objective of the third spacewalk is to reconfigure power on the Channel 1/4 side of the station's Electrical Power System. The crew also will stow three Service Module Debris Panel bundles on a grapple fixture on the Pressurized Mating Adapter 3—a module attached to the port side of Node 1; reconfigure power on the Z1 truss patch panels 1 and 6; and install an Adjustable Grapple Bar (AGB) on the flex hose rotary coupler on the airlock's External Stowage Platform-2.

The third spacewalk on flight day 8 is basically a repeat of the flight day 6 power reconfiguration activities. During EVA 3, the Channel 1/4 side of the station's Electrical Power System will be reconfigured to route primary power through the Main Bus Switching Units. As on flight day 6, this spacewalk requires that all power be shut down—this time from Channel 1/4. Again, a lengthy set of power down procedures will be executed from the ground while the crew prepares for the walk. The reconfiguration task is also predicted to take about an hour and a half.

The work will again be at the Starboard 0 (S0) truss segment. Curbeam will reconfigure the S0 forward starboard avionics and the S1-4B and S0-1A dc converters, disconnect the secondary power Lab 4A dc converters, route the S0/N1 power cable, and reconfigure the bus bypass jumper.

While he is disconnecting and connecting cables, Williams will remove the 1 and 2 circuit interrupt devices and reconfigure the other half of the Z1 truss electrical patch panel 5. The circuit interrupters will be returned on the shuttle. Also, during the Z1 patch panel task, the crew will venture out to the Russian segment interface at Node 1 and reconfigure the Russian power feeds from the U.S. segment. This reconfiguration will allow the Russians to draw additional power from the U.S. segment by moving some of their power feeds to larger switches, capable of transferring more current, should that be needed.

As Curbeam and Williams reconfigure external power connectors, the crew inside will reconfigure an electrical patch panel in the Destiny lab. This new configuration will provide twice as much power for payload use.

Once power is reconfigured for Channel 1/4, Curbeam and Williams will move to the shuttle's payload bay to attach three Service Module Debris Panel bundles (SMDPs) on to an adapter. The three bundles and adapter were launched on the Integrated Cargo Carrier (ICC), a pallet located at the rear of the payload bay. Once the bundles are attached to the adapter, the assembly is referred to as "the Christmas tree."

Astronaut Sunita L. Williams prior to being submerged in the waters of the NBL. Astronaut William A. (Bill) Oefelein, STS-116 pilot, assisted Williams.

Williams will work from the shuttle arm to move the "Christmas tree" to stow it on the grapple fixture located on the aft side of the Pressurized Mating Adapter 3. The bundles are composed of individual panels that will be installed on the Service Module to provide additional micrometeroid debris protection. The panels will be moved to the Service Module during a Russian EVA currently slated for the summer of 2007.

While Williams completes clean-up of the task, Curbeam will move to reconfigure power to the Z1 truss electrical patch panel 1.

During the third spacewalk, Curbeam and Williams will also transfer the Adjustable Grapple Bar (AGB)—a portable handle that can be installed on objects to make it easier for the crew to move them around during spacewalks—to the Flex Hose Rotary Coupler (FHRC) on the airlock's External Stowage Platform-2, where it will be stowed for future use.

PAYLOAD OVERVIEW

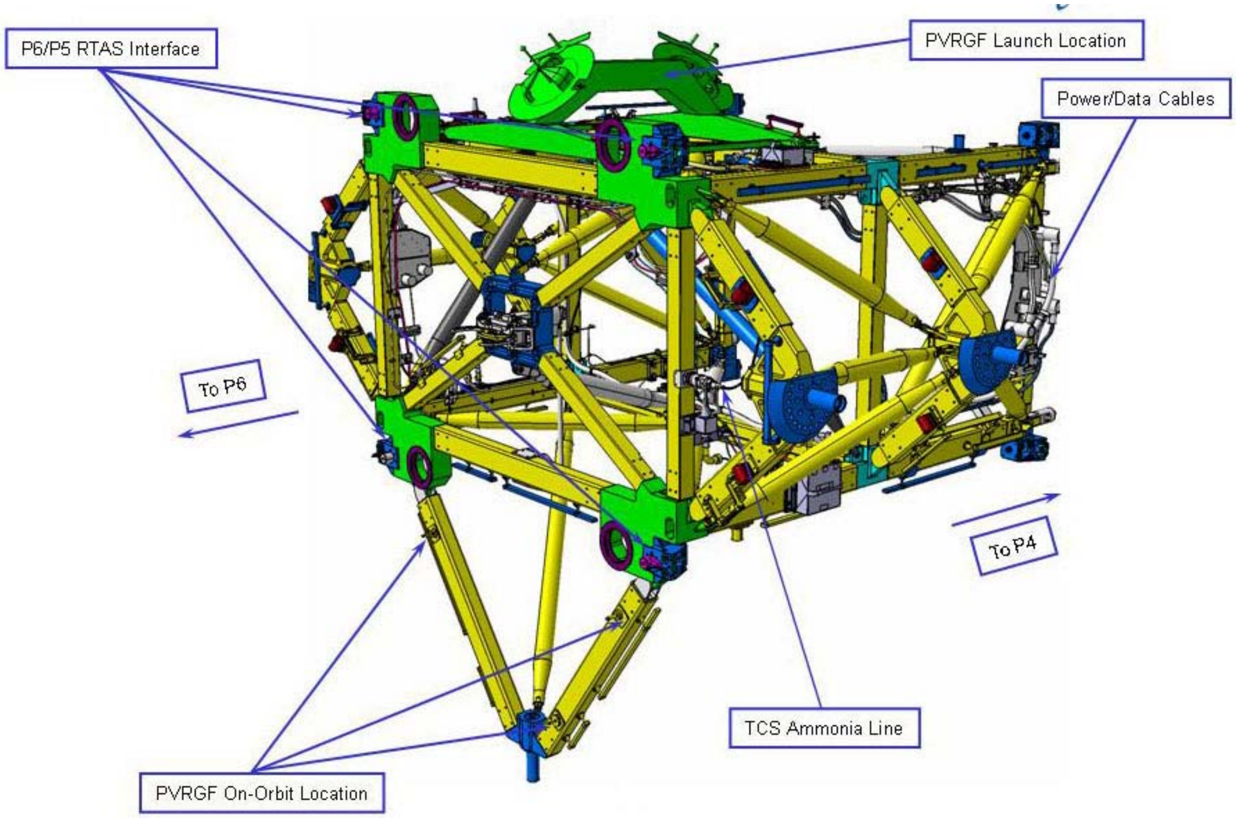
INTEGRATED TRUSS SEGMENT P5

STS-116 will deliver the square-shaped Port 5 (P5) truss segment to the International Space Station. P5 is part of the 11-segment integrated truss structure and the sixth truss element to be delivered. The truss structure forms the backbone of the International Space Station with mountings for unpressurized logistics carriers, radiators, solar arrays, other hardware and the various elements. Port 5 will be attached to the Port 4 truss element via the Modified Rocketdyne Truss Attachment System (MRTAS) interface. P5 is used primarily to connect power and cooling lines and serve as a spacer between the P4 photovoltaic module (PVM), or solar battery, and P6 PVM, which will be joined during a later assembly mission. P5 is very similar in construction to the long spacer located on P6. Without the P5 short spacer, the P4 and P6 solar arrays would not be able to connect due to the way the photovoltaic arrays (PVA) are deployed on orbit.

The P5 Short Spacer is shown in the Space Station Processing Facility at Kennedy Space Center.

The girder-like structure is made of mostly aluminum and provides several extravehicular aids, robotic interfaces, ammonia servicing hardware (as part of the station's External Active Thermal Control System that allows ammonia fluid to transfer from P4 to P6) and can also accommodate an external storage platform. The Enhanced Universal Trunnion Attachment System (EUTAS) allows platforms to be attached to P5 for the storage of additional science payloads or spare Orbital Replacement Units. P5 also has white thermal blankets on the structure, which help shade the P4 Solar Array Assembly ORUs.

P5 Specifications	
Dimensions:	**Length** is 132.813 inches or 11 feet and 0.813 inches (3.37 meters) **Width** is 179.014 inches or 14 feet, 11 inches (4.55 meters) **Height** is 167.031 inches or 13 feet and 11 inches (4.24 meters)
Weight:	**4,110 lbs or 2 tons (1,864.26 kg)**
Cost	**$10,972,000**

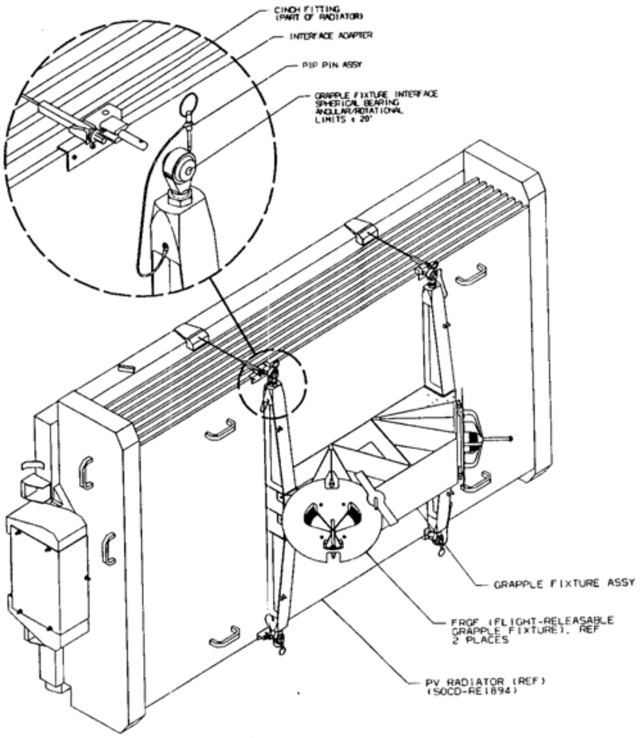


P5 is transferred using the shuttle arm from the payload bay to the Space Station Robotic Manipulator System (SSRMS), the station's robotic arm, where it will be placed into the install or soft-dock position. While being moved on the SSRMS, P5 will have about three inches of clearance as it passes the P4 Sequential Shunt Unit (SSU). The truss element is installed robotically with a crew assist. During the first spacewalk, astronauts will use the truss attachment system to connect P5 to P4 by using their portable hand tools to drive in four 3/4 inch diameter primary bolts in each corner. If a primary bolt cannot be secured, two contingency bolts at each corner on P5 can be tightened into the nut assemblies on P4.

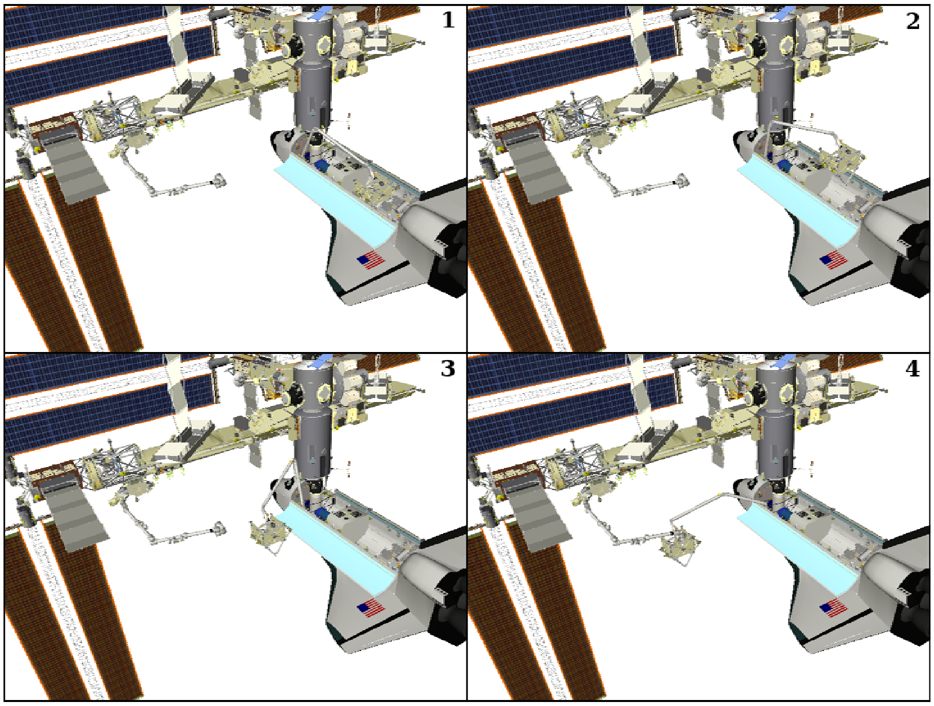
Another feature of P5 is the Photo Voltaic Radiator Grapple Feature (PVRGF). For launch, the PVRGF is stowed on top of P5 and is used by the shuttle and station robotic arms to grab P5 to lift if from the shuttle cargo bay and attach it to the station. After P5 is attached to P4, the PVRGF will be relocated to the truss' keel during the first spacewalk using four fasteners.

P5 also contains a remote sensor box, two tri-axial accelerators and two antenna assemblies as part of the External Wireless Instrumentation System (EWIS). EWIS will give engineers a better understanding of the actual response of the truss system on orbit to vibration and other stresses and help engineers predict the fatigue life and durability of the truss structure.

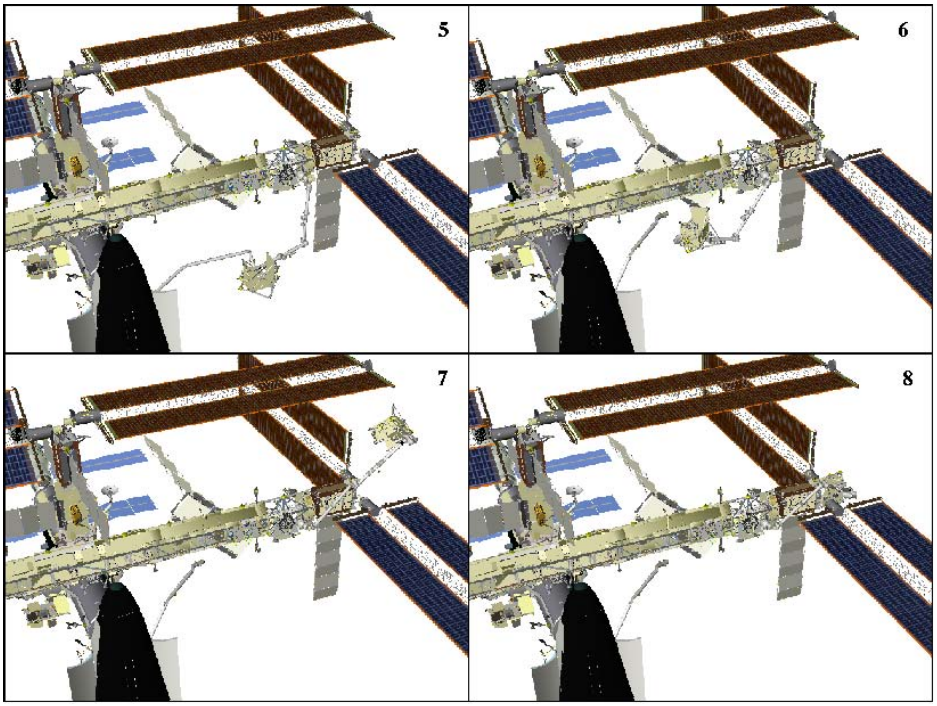
Boeing’s Rocketdyne Power and Propulsion (now Pratt and Whitney) designed P5. The component was constructed in Tulsa, Okla., in 2000. P5 arrived at Kennedy Space Center July 19, 2001, for final manufacture, acceptance and checkout. Boeing will continue to provide sustaining engineering of P5 and for the entire 310-foot integrated truss assembly.



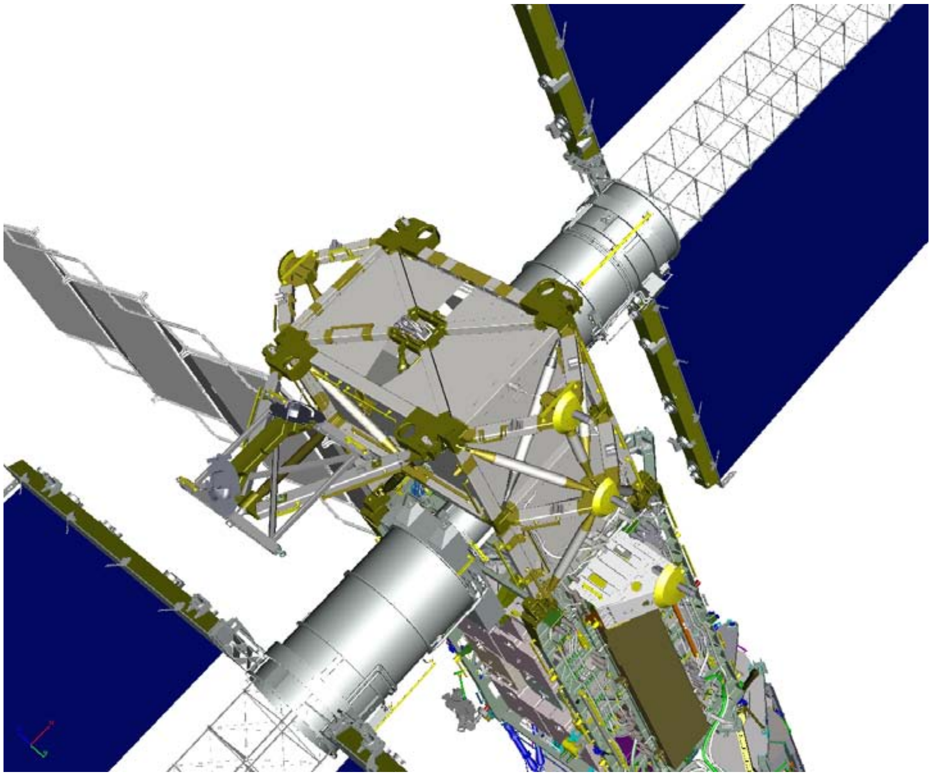
Drawing shows the Photo Voltaic Radiator Grapple Feature (PVRGF) attached to a folded photovoltaic radiator (PVR)



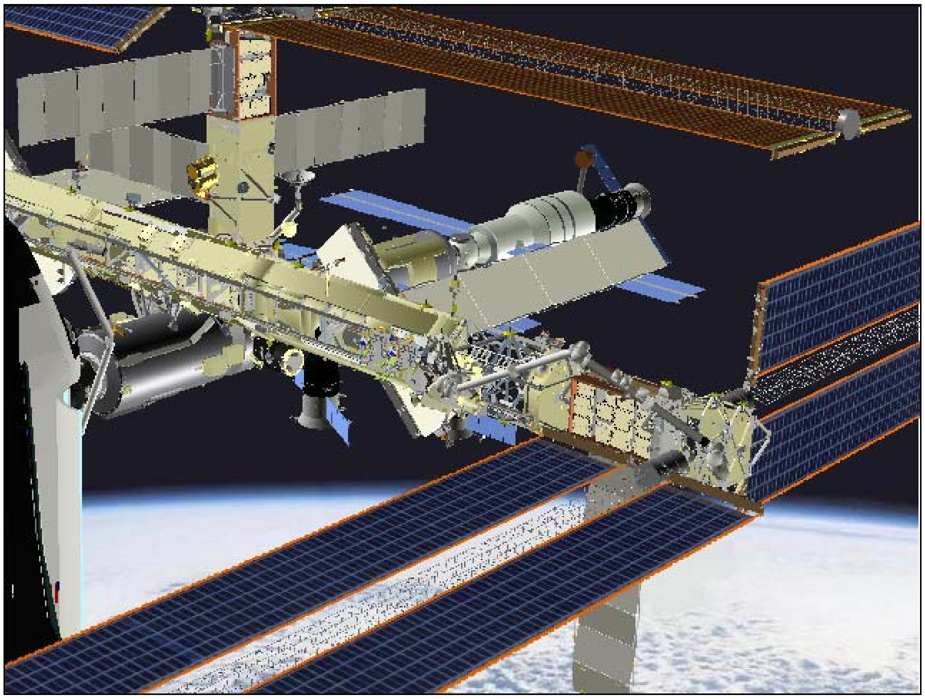
Sequence showing removal of P5 from the payload bay and transferred to the space station's robotic arm.



Sequence showing the movement and installation of P5 to the soft-dock position at the end of P4



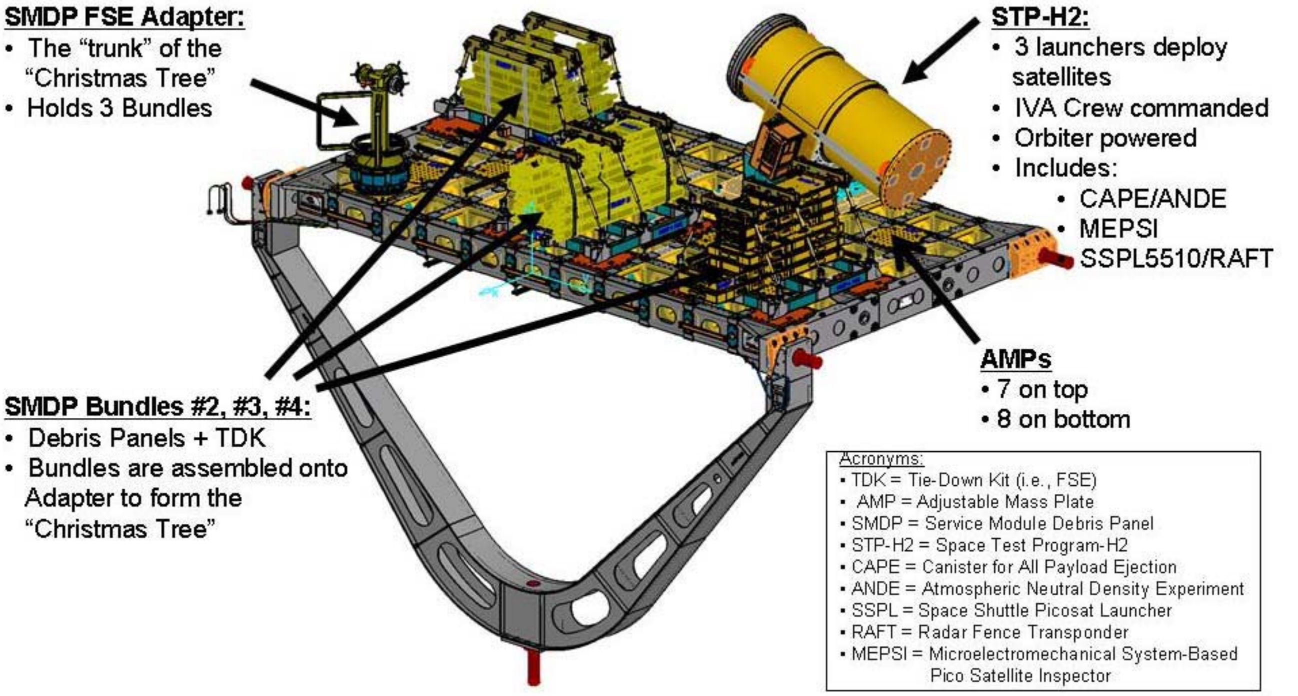
P5 shown installed on the ISS



INTEGRATED CARGO CARRIER (SPACEHAB)

The Integrated Cargo Carrier can carry up to 8,000 pounds of cargo on both faces of a pallet measuring 8 feet long, 15 feet wide and 10 inches thick. It carries cargo for transfer from the shuttle to the station and from the station to work sites on the truss assemblies. The carrier is an unpressurized, flatbed pallet and keel-yoke assembly housed in the orbiter's payload bay. It has no active interfaces (thermal, electrical or data) with the shuttle.

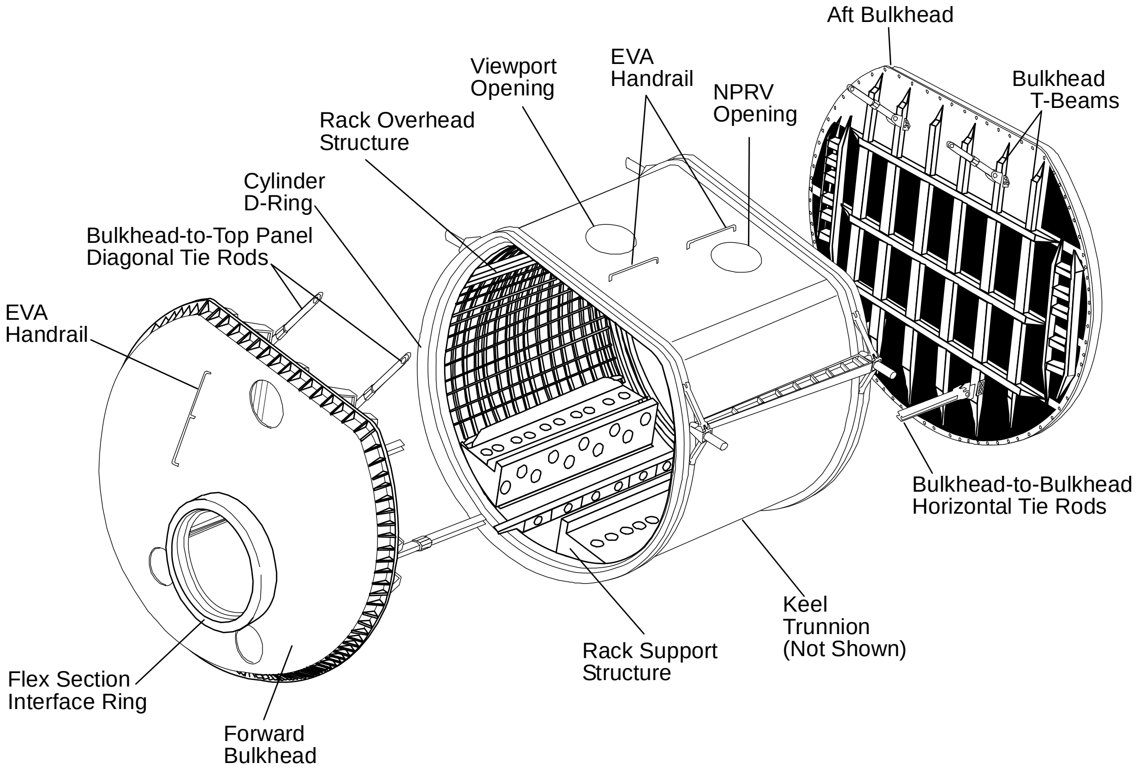
On STS-116, the ICC will carry the Service Module Debris Panels (SMDP), Space Test Program – H2 (STP-H2), 15 Adjustable Mass Plates (AMPs) and an International Space Station Passive Flight Releasable Attachment Mechanism (ICC PFRAM). The STP-H2 is a payload which deploys three satellites after the shuttle undocks from the space station. The ICC PFRAM is designed for a contingency return of a Pump Module Integrated Assembly (PMIA) should a pump module fail during the flight's second spacewalk. The SMDPs are transferred to space station and are temporarily stowed on PMA3.



Acronyms:
- TDK = Tie-Down Kit (i.e., FSE)
- AMP = Adjustable Mass Plate
- SMDP = Service Module Debris Panel
- STP-H2 = Space Test Program-H2
- CAPE = Canister for All Payload Ejection
- ANDE = Atmospheric Neutral Density Experiment
- SSPL = Space Shuttle Picosat Launcher
- RAFT = Radar Fence Transponder
- MEPSI = Microelectromechanical System-Based Pico Satellite Inspector

LOGISTICS SINGLE MODULE (SPACEHAB LSM)

In Discovery's payload pay, the small pressurized module known as the SPACEHAB Logistics Single Module provides cargo launch and return transportation. Some of the hardware stowed in the module on STS-116 are a Video Baseband Signal Processor (VBSP), a Rotary Joint Motor Controller (RJMC) Assembly, an External TV Camera Group (ETVCG), Oxygen Generation System (OGS), Adjustable Grapple Bar, Remote Power Control Module(s) (RPCM), Nickel Removal Assembly (NIRA) Kit, Charcoal Bed Assembly (CBA), Desiccant/Adsorbent ORU, Control Moment Gyro (CMG) Electrical Assembly (EA), an Avionics Air Assembly (AAA) and payloads.



EXPERIMENTS

DETAILED TEST OBJECTIVES

Detailed Test Objectives (DTOs) are aimed at testing, evaluating or documenting space shuttle systems or hardware, or proposed improvements to the space shuttle or space station hardware, systems and operations.

Such experiments assigned to STS-116 are listed below.

DTO 805 Crosswind Landing Performance (If Opportunity)

The purpose of this DTO is to demonstrate the capability to perform a manually controlled landing in the presence of a crosswind. The testing is done in two steps.

1. Pre-launch: Ensure planning will allow selection of a runway with Microwave Scanning Beam Landing System support, which is a set of dual transmitters located beside the runway providing precision navigation vertically, horizontally and longitudinally with respect to the runway. This precision navigation subsystem helps provide a higher probability of a more precise landing with a crosswind of 10 to 15 knots as late in the flight as possible.

2. Entry: This test requires that the crew perform a manually controlled landing in the presence of a 90-degree crosswind component of 10 to 15 knots steady state.

During a crosswind landing, the drag chute will be deployed after nose gear touchdown when the vehicle is stable and tracking the runway centerline.

SHORT-DURATION BIOASTRONAUTICS INVESTIGATION (SDBI)

Short-Duration Bioastronautics Investigations (SDBIs) are shuttle-based, life science payloads, experiments and technology demonstrations.

SDBI 1503S Test of Midodrine as a Countermeasure against Postflight Orthostatic Hypotension

Presently, there are no medications or treatment to eliminate orthostatic hypotension, a condition that often affects astronauts following spaceflight. Orthostatic hypotension is a sudden fall in blood pressure that occurs when a person assumes a standing position. Symptoms, which generally occur after sudden standing, include dizziness, lightheadedness, blurred vision and a temporary loss of consciousness.

Space alters cardiovascular function, and orthostatic hypotension is one of the alterations that negatively impacts crew safety. Susceptibility to orthostatic hypotension is individual, with some astronauts experiencing severe symptoms, while others are less affected. This countermeasure evaluation proposal, sponsored by the Countermeasures Evaluation and Validation Project, is in its second phase of the evaluation of midodrine. It is designed to give the greatest opportunity of measuring the maximum efficacy of the drug.

This experiment will measure the effectiveness of midodrine in reducing the incidence and, or, the severity of orthostatic hypotension in returning astronauts. Its effectiveness will be evaluated with an expanded tilt test.

SDBI 1493 Monitoring Latent Virus Reactivation and Shedding in Astronauts

The objective of this SDBI is to determine the frequency of induced reactivation of latent viruses, latent virus shedding and clinical disease after exposure to the physical, physiological and psychological stressors associated with spaceflight.

Induced alterations in the immune response will become increasingly important on long-duration missions, with one focus being the potential for reactivation and dissemination or shedding of latent viruses. An example of a latent virus is herpes simplex type-1, which infects 70 to 80 percent of adults. Its manifestation is classically associated with the presence of cold sores, pharyngitis and tonsillitis. It is usually acquired through contact with the saliva, skin or mucous membranes of an infected individual. However, many recurrences are asymptomatic, resulting in shedding of the virus.

SDBI 1634 Sleep-Wake Actigraphy and Light Exposure during Spaceflight

Subjects will don the Actilight watch as soon as possible upon entering orbit and will wear it continuously throughout the mission on their non-dominant wrists outside of their clothing/sleeve. The Actilight watch can be temporarily removed for activities such as spacewalks. Subjects will also complete a short log within 15 minutes of final awakening every morning in flight.

The experiment examines the effects of spaceflight on the sleep-wake cycles of astronauts during mission. This information could be vital in treating insomnia on Earth and in space.

SHORT-DURATION RESEARCH AND STATION EXPERIMENTS

Short-duration Research to Be Completed during STS-116

Incidence of Latent Virus Shielding During Spaceflight (Latent Virus) will determine the frequencies of reactivation of latent viruses—inactive viruses in the body that can be reactivated, such as cold sores—and clinical diseases after exposure to the physical, physiological, and psychological stressors associated with spaceflight. Understanding latent virus reactivation may be critical to crew health during extended space missions as crew members live and work in a closed environment.

Maui Analysis of Upper Atmospheric Injections (MAUI) will observe the exhaust plume of the Space Shuttle will lead to assessment of spacecraft plume interactions with the upper atmosphere.

Effect of Space Flight on Microbial Gene Expression and Virulence (Microbe) will investigate the effects of the space flight environment on virulence (ability to infect) of three model microbial pathogens: Salmonella typhimurium, Pseudomonas aeruginosa, and Candida albicans, that have been identified as potential threats to crew health based upon previous space flight missions.

Test of Midodrine as a Countermeasure Against Post-Flight Orthostatic Hypotension (Midodrine) measures the ability of the drug midodrine, as a countermeasure, to reduce the incidence or severity of orthostatic hypotension—dizziness caused by the blood-pressure decrease that many astronauts experience upon returning to the Earth's gravity.

Perceptual Motor Deficits in Space (PMDIS) will investigate why shuttle astronauts experience difficulty with hand-eye coordination while on orbit. This experiment will measure the decline of astronauts' hand-eye coordination during space shuttle missions. These measurements will be used to distinguish between three possible explanations: the brain not adapting to the near weightlessness of space; the difficulty of performing fine movements when floating in space; and stress due to factors such as space sickness and sleep deprivation.

Ram Burn Observations (RAMBO) is an experiment in which the Department of Defense uses a satellite to observe space shuttle orbital maneuvering system engine burns. Its purpose is to improve plume models, which predict the direction the plume, or rising column of exhaust, will move as the shuttle maneuvers on orbit. Understanding the direction in which the spacecraft engine plume, or exhaust flows could be significant to the safe arrival and departure of spacecraft on current and future exploration missions.

Sleep-Wake Actigraphy and Light Exposure During Spaceflight - Short (Sleep-Short) will examine the effects of spaceflight on the sleep-wake cycles of the astronauts during space shuttle missions. Advancing state-of-the-art technology for monitoring, diagnosing and assessing treatment of sleep patterns is vital to treating insomnia on Earth and in space.

Space Test Program –H2

Atmospheric Neutral Density Experiment (ANDE) consists of two microsatellites launched from the Shuttle payload bay will measure the density and composition of the low Earth orbit (LEO) atmosphere while being tracked from the ground. The data will be used to better predict the movement of objects in orbit.

Microelectromechanical System-Based (MEMS) PICOSAT Inspector (MEPSI) will demonstrate the use of tiny (the size of a coffee cup) low-power inspection satellites that can be sent out to observe larger spacecraft. The small inspection satellites are enabled by microelectromechanical systems (MEMS), and will test the functioning of small camera systems and gyros.

Radar Fence Transponder (RAFT) is a student experiment from the United Sates Naval Academy that uses picosatellites to test the Space Surveillance Radar Fence and experimental communications transponders.

Payloads Delivered on STS-116 to Be Used in Future Station Research

Cardiovascular and Cerebrovascular Control on Return from ISS (CCISS) will allow scientists to better understand the effects of spaceflight on cardiovascular and cerebrovascular functions of long duration crewmembers.

Commercial Generic Bioprocessing Apparatus Science Insert – 01 (CSI-01) is comprised of two educational experiments that will be utilized by middle school students. One experiment will examine seed germination in microgravity including gravitropism (plant growth towards gravity) and phototropism (plant growth towards light). The second experiment will examine how microgravity affects the model organism, Caenorhabditis elegans, a small nematode worm.

Elastic Memory Composite Hinge (EMCH) will study the performance of a new type of composite hinge to determine if it is suitable for use in space. The experiment will use elastic memory hinges to move an attached mass at one end. Materials tested in this experiment are stronger and lighter than current material used in space hinges and could be used in the design of future spacecraft.

Threshold Acceleration for Gravisensing (Gravi) will determine the minimum amount of artificial gravity needed to cause lentil seedling roots to start growing in a new direction. This work supports future efforts to grow sufficient edible crops on long-duration space missions.

Lab-on-a-Chip Application Development-Portable Test System (LOCAD-PTS) is a handheld device for rapid detection of biological and chemical substances on board the space station. Astronauts will swab surfaces within the cabin, add swab material to the LOCAD-PTS and within 15 minutes, obtain results on a display screen. Its purpose is to effectively provide an early warning system to enable crew members to take remedial measures if necessary to protect the health and safety of those on board the station.

Synchronized Position Hold, Engage, Reorient, Experimental Satellites (SPHERES) are bowling-ball sized spherical satellites. The first SPHERE satellite arrived on the station in April 2006 tucked inside a Russian Progress supply ship. Another arrived on STS-121 in July 2006 and a third will be carried to orbit by STS-116 in December 2006. They will be used inside the space station to test a set of well-defined instructions for spacecraft to perform autonomous rendezvous and docking maneuvers. Three self-contained free-flying spheres will fly within the cabin of the station, performing flight formations. Each satellite is self-contained with power, propulsion, computers and navigation equipment. The results are important for satellite servicing, vehicle assembly and formation flying spacecraft configurations.

Test of Reaction and Adaptation Capabilities (TRAC) will test the theory of brain adaptation during spaceflight by testing hand-eye coordination before, during and after the mission.

Space Station Research Samples Returned on STS-116

Long Term Microgravity: A Model for Investigating Mechanisms of Heart Disease with New Portable Equipment (Card) will examine the relationship between salt intake and the cardiovascular system when exposed to the microgravity environment.

Neuroendocrine and Immune Responses in Humans During and After Long Term Stay at ISS (IMMUNO) will provide an understanding for the development of pharmacological tools to countermeasure unwanted immunological side effects during long-duration missions in space.

The Optimization of Root Zone Substrates (ORZS) for Reduced Gravity Experiments Program is an international collaboration that will provide direct measurements and models for plant rooting media that will be used in future Advanced Life Support (ALS) plant growth experiments.

Passive Observatories for Experimental Microbial Systems (POEMS) is a demonstration of a passive system for growing microbial cultures in space and to observe genetic changes that occur in them as a result of living and growing in the space environment.

The **Renal Stone** experiment tests the effectiveness of potassium citrate in preventing renal stone formation during long-duration spaceflight. Kidney stone formation, a significant risk during long missions, could impair astronaut functionality.

Space Experiment Module (SEM) allows students to research the effects of microgravity, radiation and spaceflight on various materials. Some students will test for seed growth after microgravity exposure, while others will test how their materials protect against radiation exposure. The sample vials will be returned to Earth on a future mission for students to analyze further.

Stability of Pharmacotherapeutic and Nutritional Compounds (Stability) will study the effects of radiation in space on complex organic molecules, such as vitamins and other compounds in food and medicine. This will help in developing more stable and reliable pharmaceutical and nutritional countermeasures suitable for future long-duration missions to the moon and Mars.

A Comprehensive Characterization of Microorganisms and Allergens in Spacecraft (SWAB) will use advanced molecular techniques to comprehensively evaluate microbes on board the space station, including pathogens – organisms that may cause disease. It also will track changes in the microbial community as spacecraft visit the station and new station modules are added. This study will allow an assessment of the risk of microbes to the crew and the spacecraft.

Analysis of a Novel Sensory Mechanism in Root Phototropism (Tropi) will observe the growth and collect samples of plants sprouted from seeds. By analyzing the samples at a molecular level, researchers expect to gain insight on what genes are responsible for successful plant growth in microgravity.

Additional Space Station Research From Now Until the End of Expedition 14

Anomalous Long Term Effects in Astronauts' Central Nervous System (ALTEA) integrates several diagnostic technologies to measure the exposure of crew members to cosmic radiation. It will further our understanding of radiation's impact on the human central nervous and visual systems, and provide an assessment of the radiation environment in the station.

Crew Earth Observations (CEO) takes advantage of the crew in space to observe and photograph natural and human-made changes on Earth. The photographs record the Earth's surface changes over time, along with more fleeting events such as storms, floods, fires and volcanic eruptions. Together, they provide researchers on Earth with vital, continuous images to better understand the planet.

Space Flight-Induced Reactivation of Latent Epstein-Barr Virus (Epstein-Barr) performs tests to study changes in the human immune function. Using blood and urine samples collected from crew members before and after spaceflight, the study will provide insight for possible countermeasures to prevent the potential development of infectious illness in crew members during flight.

Behavioral Issues Associated with Isolation and Confinement: Review and Analysis of Astronaut Journals, using journals kept by the crew and surveys, studies the effect of isolation to obtain quantitative data on the importance of different behavioral issues in long-duration crews. Results will help NASA design equipment and procedures to allow astronauts to best cope with isolation and long-duration spaceflight.

Microgravity Acceleration Measurement System (MAMS) and Space Acceleration Measurement System (SAMS-II) measure vibration and quasi-steady accelerations that result from vehicle control burns, docking and undocking activities. The two different equipment packages measure vibrations at different frequencies.

Materials on the International Space Station Experiment 3 and 4 (MISSE – 3 and 4) are the third and fourth in a series of five suitcase-sized test beds attached to the outside of the space station. The beds were deployed during a spacewalk on STS-121 in July 2006. They will expose hundreds of potential space construction materials and different types of solar cells to the harsh environment of space. After being mounted to the space station about a year, the equipment will be returned to Earth for study. Investigators will use the resulting data to design stronger, more durable spacecraft.

Nutritional Status Assessment (Nutrition) is the most comprehensive in-flight study done by NASA to date of human physiologic changes during long-duration space flight; this includes measures of bone metabolism, oxidative damage, nutritional assessments, and hormonal changes. This study will impact both the definition of nutritional requirements and development of food systems for future space exploration missions to the Moon and Mars. This experiment will also help to understand the impact of countermeasures (exercise and pharmaceuticals) on nutritional status and nutrient requirements for astronauts.

Sleep-Wake Actigraphy and Light Exposure During Spaceflight-Long (Sleep-Long) will examine the effects of spaceflight on the sleep-wake cycles of the crew members during long-duration stays on the space station.

EUROPEAN SPACE AGENCY EXPERIMENTS

The majority of Christer Fuglesang's time at the station will be taken up with station assembly tasks. However, he will still be undertaking a number of experiments and additional activities during the mission. One experiment (Chromosome-2), one activity monitoring radiation dosimetry (EuCPD), and two education activities (ALTEA Filmed Lesson, Frisbee Competition) are supported by the European Space Agency (ESA). The Particle Flux Demonstrator is a Swedish National Space Board education experiment, and ALTEA is supported by ASI, the Italian Space Agency.

ALTEA (Human Physiology/Radiation Dosimetry)

The ALTEA project investigates the effects of cosmic radiation on brain function. The focus of the program will be on abnormal visual perceptions (often reported as ''light flashes'' by astronauts) and the impact that particle radiation has on the retina and visual structures of the brain under weightless conditions. ALTEA will also provide more information on the radiation environment in the station.

The ALTEA facility is a helmet-shaped device, which covers most of the astronaut's head. It consists of six particle detectors and will permit a 3-D reconstruction of cosmic radiation passing through the brain: measuring particle trajectory, energy and particle type. At the same time, a 32-channel EEG will measure the astronaut's brain activity and a visual stimulator and a pushbutton will be used to

ALTEA Flight Hardware.

determine visual performance and occurrence of light flashes. When not in use by an astronaut, the ALTEA device will be used to collect continuous measurements of the cosmic radiation in the U.S. Destiny laboratory on the station.

The ALTEA experiment follows on from the precursor Alteino experiment that took place during the European Marco Polo and Eneide missions (2002 and 2005), now continuing with the European ALTCRISS project.

The ALTEA experiment is particularly important with the increasing length of human operation on board the International Space Station and in the perspective of longer-term journeys to Mars. Results may also hold benefits on Earth in neuroscience in, for example, the use of Ion therapies to treat brain tumors.

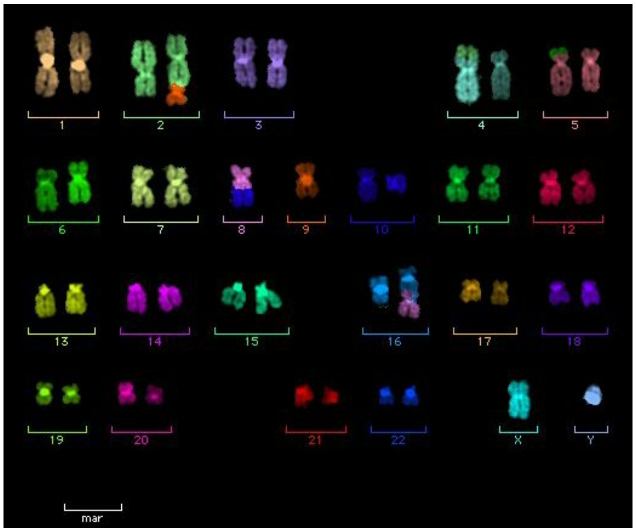
Chromosome-2
(Human Physiology)

During spaceflights, crew members are exposed to different types of ionizing radiation. To assess the impact of these radiations at a genetic level, an analysis will be made of abnormalities in chromosome number and structure in lymphocytes (white blood cells) of station crew members.

Venous blood samples will be taken a few days before launch and directly on return from the long-duration and short-duration missions. From these blood samples, whole blood cultures will be set up with a substance (phytohemagglutinin), which stimulates the lymphocytes to enter the cell cycle, i.e., to go through the cell division process.

Forty-eight hours after the start of the incubation period, the samples will be prepared for analysis. This consists of adding two substances to the samples. One (calyculin A) will cause the DNA strands to become tightly packed in the chromosomes, a process that occurs in cells at the beginning of the cell cycle. The other (colchicine) will prevent the chromosomes from dividing into two for cells at a later stage in the cell cycle.

Hereafter the preparations will be analyzed by one of two methods to determine the full spectrum of abnormalities in the chromosomes. This will either be by the fluorescence in vitro hybridization (FISH) method or classical Giemsa staining.



Multi-fluorescent chromosome map of a cell exposed to cosmic radiation

A small portion of the blood samples will be irradiated with X-rays. The frequency of abnormalities induced by this irradiation will provide information about the radiosensitivity of individual crew members and probable changes in sensitivity caused by spaceflight.

The Chromosome-2 experiment is planned to be carried out using eight subjects: four subjects from short-duration flights and four Expedition crew members.

European Crew Personal Dosimeters (EuCPD) (Radiation dosimetry)

ESA astronaut Fuglesang from Sweden will be equipped with passive personal radiation dosimeters to measure the radiation exposure during his flight. ESA astronaut Thomas Reiter has been using similar dosimeters since arriving at the station in July 2006.

The personal dosimeters have to be worn around the left-hand side of the waist and the left ankle for astronauts inside the station and at the same locations above the liquid cooling garment inside the spacesuit for astronauts undertaking spacewalks.

Each dosimeter is only 8 mm thick and consists of a stack of five different passive radiation sensors, i.e., sensors that provide a measure of the overall radiation dose rather than a measure of radiation with relation to time. The different sensors will measure different radioactive particles such as a range of neutrons (thermal, epithermal and fast), and heavy ions as well as measuring particle impact angles and energy transfer from particles.

The different sensors to be used will include a layer of thermo-luminescence dosimeters that are also used in the European Matroshka radiation dosimetry experiment that has been at the station since its launch on Jan. 29, 2004.

ESA astronaut Thomas Reiter wearing European Crew Personal Dosimeter during sample processing on the ISS

Two European Crew Personal Dosimeters will be worn by Fuglesang during launch. The others will be transported to the station as shuttle cargo.

Post-flight analysis of the different radiation sensors will be carried out in a laboratory environment according to standardized methods developed by the science team.

Particle Flux Demonstrator (Education)

This experiment aims to illustrate to students the difference in the radiation environment in space and on Earth. The Particle Flux Demonstrator will be used to measure the flux or flow of charged particles (cosmic rays) passing through the station. This will vary to the greatest degree with the variation of the latitude at which the station is flying.

Charged particles are detected in the Particle Flux Demonstrator using a plastic scintillator material connected to a photomultiplier tube. The charged particle generates a very faint flash of deep blue light in the scintillator material. This is converted to an electrical pulse by the photomultiplier tube. To trigger the Particle Flux Demonstrator, the charged particle must pass through two pieces of scintillator

Particle Flux Demonstrator hardware

separated by a few centimeters. This gives the Particle Flux Demonstrator some directional sensitivity. On the station, the majority of detected particles will be protons. However, by varying a requirement on the amount of light produced in one of the scintillators, it is possible to select much rarer charged ions also.

The Particle Flux Demonstrator is a portable device that can be carried through the station by the astronaut. It is expected to show how the flux varies in different parts of the station, depending on how much local shielding material there is. One will also see the change in flux with the orbital position: higher flux at high latitudes and lower near the equator, due to the interaction of the Earth's magnetic field. An additional aim is to demonstrate that the relative abundance of ions increases at high latitudes.

Special attention will be paid to the South Atlantic Anomaly, where the external particle flux is several orders of magnitude larger than elsewhere in the orbit due a dip in the Earth's magnetic field in the vicinity of the Brazilian coast. The behavior of the magnetic field means that a belt of particles approaches close to the Earth's surface. The particle flux inside the station will also increase drastically at this location. Additionally, it is expected to demonstrate the directionality of particles within the radiation belt

On ground, the Particle Flux Demonstrator will be able to detect muons (an elementary particle similar to the electron but with ~200 times the mass). These are produced by cosmic ray particles interacting with molecules high up in the atmosphere. However, the rate will be small—about 1 muon per minute (with the "telescope" orientated vertically).

The Particle Flux Demonstrator forms part of an education experiment at high school and university levels. Several education institutions, principally in Sweden but also in Norway and Denmark, will be taking part in this experiment using cosmic ray detectors to take readings on Earth during station flyovers. The readings from the institutions will be compared against readings from the Particle Flux Demonstrator on the station. Video footage of the on-orbit experiment with Fuglesang will be made available to students.

The Particle Flux Demonstrator was designed and built in the Particle and Astroparticle Physics research group at The Royal Institute of Technology (KTH) in Stockholm, Sweden. As part of a public relations event in Stockholm, Fuglesang will demonstrate the Particle Flux Demonstrator during a live video-link to the station.

ALTEA: Filmed Lesson on Radiation (Education)

This activity involves the filming of a mini documentary about the ALTEA experiment to

NASA astronaut Jeff Williams next to the ALTEA hardware in the U.S. Laboratory of the ISS during Expedition 13

form part of a lesson on radiation for 16-18 year olds. While ESA astronaut Fuglesang is undertaking the ALTEA experiment on the station as part of his mission, ESA astronaut Thomas Reiter, currently on the station as an Expedition 14 flight engineer, will film the experiment.

The footage will be recorded on video tape and returned to Earth. This footage will be combined with additional footage that was filmed during Fuglesang's training with ALTEA hardware at the Johnson Space Center in Houston before launch and accompanied with commentary from a member of the ALTEA science team and by Fuglesang himself. Fuglesang has been previously involved as a member of the scientific team for a similar experiment: SilEye, which investigated light flashes in astronauts' eyes on the Mir Space Station between 1995 and 1999.

The ISS Education Office will coordinate the development and content of the lesson together with the ALTEA science team. Once the production is complete, ESA will distribute the lesson to European secondary school teachers and their students.

Frisbee Competition (Education)

A little known fact about Fuglesang is that he was once a Swedish national Frisbee champion, holding the national title in 'maximum time aloft' in 1978, i.e., the longest time a Frisbee can stay in the air. He later competed in the Frisbee World Championship in 1981.

This activity is a competition for children up to 15 years of age that will stimulate the interest of children in space and culminate in a live linkup with the competition winner on the ground and Fuglesang on the station. During this in-flight call, Fuglesang will try to break the current world record for maximum time aloft, which stands at 16.72 seconds. This should not prove to be too difficult a prospect as Fuglesang has the advantage of weightlessness on his side.

The competition will be organized in Sweden by the national newspaper "Aftonbladet" and will be based on questions including the topics of space, space activities and Frisbee games. The competition winner will be announced during the in-flight call and they will present Fuglesang with the licence, necessary to be able to compete in professional competition. Once this has occurred, Fuglesang will begin his world record attempt.

The Frisbee that Fuglesang will take to the station with him is one of his personal Frisbees, which marks an Atlantic crossing he made.

The Frisbee that Fuglesang will be taking into space

SPACE SHUTTLE MAIN ENGINE ADVANCED HEALTH MANAGEMENT SYSTEM

The Advanced Health Management System (AHMS) will make its first flight in monitor-only mode on the STS-116 mission. When in monitor-only mode, the AHMS system collects and processes the turbopump accelerometer data, which is a measurement of turbopump vibration, and continuously monitors turbopump health but cannot shut down an engine. Data from the STS-116 flight will be collected and examined to ensure AHMS operates as intended before its subsequent flight in active mode.

When a NASA space shuttle lifts off the launch pad it does so with the help of three reusable, high performance rocket engines. Each space shuttle main engine is fourteen feet long, seven and one-half feet in diameter at the nozzle exit, weighs approximately 7,750 pounds and generates more than twelve million horsepower, which is equivalent to the output of more than seven Hoover Dams. The engines operate for about eight-and-one-half minutes during a shuttle liftoff and ascent – long enough to burn more than 500,000 gallons of super-cold liquid hydrogen and liquid oxygen propellants stored in the huge external tank attached to the underside of the orbiter. Liquid oxygen is stored at -298 degrees Fahrenheit and liquid hydrogen at -423 degrees Fahrenheit. The engines shut down just before the orbiter, traveling at about 17,000 mph, reaches orbit.

NASA is confident that this engine upgrade will significantly improve space shuttle flight safety and reliability. The upgrade, developed by NASA’s Marshall Space Flight Center in Huntsville, Ala., is a modification of the existing main engine controller, which is the on-engine computer that monitors and controls all main engine operations. The modifications include the addition of advanced digital signal processors, radiation-hardened memory and new software. These changes to the main engine controller provide the capability for completely new monitoring and insight into the health of the two most risky components of the space shuttle main engine – the high pressure fuel turbopump and the high pressure oxidizer turbopump.

The high pressure fuel and high pressure oxidizer turbopumps rotate at approximately 35,000 revolutions per minute and 28,000 revolutions per minute, respectively. To operate at such extreme speeds, the high pressure turbopumps utilize highly specialized bearings and precisely balanced components. The AHMS upgrade utilizes data from three existing sensors (accelerometers) mounted on each of the high pressure turbopumps to measure how much each pump is vibrating. The output data from the accelerometers is routed to the new AHMS digital signal processors installed in the main engine controller. These processors analyze the sensor readings 20 times per second looking for vibration anomalies that are indicative of impending failure of rotating turbopump components such as blades, impellers, inducers and bearings. If the magnitude of any vibration anomaly exceeds safe limits, the upgraded main engine controller immediately would shut down the unhealthy engine.

SHUTTLE REFERENCE DATA

SHUTTLE ABORT MODES

RSLS Aborts

These occur when the on-board shuttle computers detect a problem and command a halt in the launch sequence after taking over from the ground launch sequencer and before solid rocket booster ignition.

Ascent Aborts

Selection of an ascent abort mode may become necessary if there is a failure that affects vehicle performance, such as the failure of a space shuttle main engine or an orbital maneuvering system engine. Other failures requiring early termination of a flight, such as a cabin leak, might also require the selection of an abort mode. There are two basic types of ascent abort modes for space shuttle missions: intact aborts and contingency aborts. Intact aborts are designed to provide a safe return of the orbiter to a planned landing site. Contingency aborts are designed to permit flight crew survival following more severe failures when an intact abort is not possible. A contingency abort would generally result in a ditch operation.

Intact Aborts

There are four types of intact aborts: abort to orbit (ATO), abort once around (AOA), transoceanic abort landing (TAL) and return to launch site (RTLS).

Return to Launch Site

The RTLS abort mode is designed to allow the return of the orbiter, crew and payload to the launch site, Kennedy Space Center, approximately 25 minutes after liftoff.

The RTLS profile is designed to accommodate the loss of thrust from one space shuttle main engine between liftoff and approximately four minutes 20 seconds, at which time not enough main propulsion system propellant remains to return to the launch site. An RTLS can be considered to consist of three stages—a powered stage, during which the space shuttle main engines are still thrusting; an external tank separation phase; and the glide phase, during which the orbiter glides to a landing at the Kennedy Space Center. The powered RTLS phase begins with the crew selection of the RTLS abort, which is done after solid rocket booster separation. The crew selects the abort mode by positioning the abort rotary switch to RTLS and depressing the abort push button. The time at which the RTLS is selected depends on the reason for the abort. For example, a three-engine RTLS is selected at the last moment, about 3 minutes, 34 seconds into the mission; whereas an RTLS chosen due to an engine out at liftoff is selected at the earliest time, about 2 minutes, 20 seconds into the mission (after solid rocket booster separation).

After RTLS is selected, the vehicle continues downrange to dissipate excess main propulsion system propellant. The goal is to leave only enough main propulsion system propellant to be able to turn the vehicle around, fly back toward the Kennedy Space Center and achieve the proper main engine cutoff conditions so the vehicle can glide to the Kennedy Space Center after external tank separation. During the downrange phase, a pitch-around maneuver is initiated (the time depends in part on the time of a space shuttle main engine failure) to orient the orbiter/external tank configuration to a heads-up attitude, pointing toward the launch site. At this time, the vehicle is still moving away from the launch site, but the space shuttle main engines are now thrusting to null the downrange velocity. In addition, excess orbital maneuvering system and reaction control system propellants are dumped by continuous orbital maneuvering system and reaction control system engine thrustings to improve the orbiter weight and center of gravity for the glide phase and landing.

The vehicle will reach the desired main engine cutoff point with less than 2 percent excess propellant remaining in the external tank. At main engine cutoff minus 20 seconds, a pitch down maneuver (called powered pitch-down) takes the mated vehicle to the required external tank separation attitude and pitch rate. After main engine cutoff has been commanded, the external tank separation sequence begins, including a reaction control system maneuver that ensures that the orbiter does not recontact the external tank and that the orbiter has achieved the necessary pitch attitude to begin the glide phase of the RTLS.

After the reaction control system maneuver has been completed, the glide phase of the RTLS begins. From then on, the RTLS is handled similarly to a normal entry.

Transoceanic Abort Landing

The TAL abort mode was developed to improve the options available when a space shuttle main engine fails after the last RTLS opportunity but before the first time that an AOA can be accomplished with only two space shuttle main engines or when a major orbiter system failure, for example, a large cabin pressure leak or cooling system failure, occurs after the last RTLS opportunity, making it imperative to land as quickly as possible.

In a TAL abort, the vehicle continues on a ballistic trajectory across the Atlantic Ocean to land at a predetermined runway. Landing occurs about 45 minutes after launch. The landing site is selected near the normal ascent ground track of the orbiter to make the most efficient use of space shuttle main engine propellant. The landing site also must have the necessary runway length, weather conditions and U.S. State Department approval. The three landing sites that have been identified for a launch are Zaragoza, Spain; Moron, Spain; and Istres, France.

To select the TAL abort mode, the crew must place the abort rotary switch in the TAL/AOA position and depress the abort push button before main engine cutoff. (Depressing it after main engine cutoff selects the AOA abort mode.) The TAL abort mode begins sending commands to steer the vehicle toward the plane of the landing site. It also rolls the vehicle heads up before main engine cutoff and sends commands to begin an orbital maneuvering system propellant dump (by burning the propellants through the orbital maneuvering system engines and the reaction control system engines). This dump is necessary to increase vehicle performance (by decreasing weight), to place the center of gravity in the proper place for vehicle control and to decrease the vehicle's landing weight. TAL is handled like a normal entry.

Abort to Orbit

An ATO is an abort mode used to boost the orbiter to a safe orbital altitude when performance has been lost and it is impossible to reach the planned orbital altitude. If a space shuttle main engine fails in a region that results in a main engine cutoff under speed, the Mission Control Center will determine that an abort mode is necessary and will inform the crew. The orbital maneuvering system engines would be used to place the orbiter in a circular orbit.

Abort Once Around

The AOA abort mode is used in cases in which vehicle performance has been lost to such an extent that either it is impossible to achieve a viable orbit or not enough orbital maneuvering system propellant is available to accomplish the orbital maneuvering system thrusting maneuver to place the orbiter on orbit and the deorbit thrusting maneuver. In addition, an AOA is used in cases in which a major systems problem (cabin leak, loss of cooling) makes it necessary to land quickly. In the AOA abort mode, one orbital maneuvering system thrusting sequence is made to adjust the post-main engine cutoff orbit so a second orbital maneuvering system thrusting sequence will result in the vehicle deorbiting and landing at the AOA landing site (White Sands, N.M.; Edwards Air Force Base; or the Kennedy Space Center). Thus, an AOA results in the orbiter circling the Earth once and landing about 90 minutes after liftoff.

After the deorbit thrusting sequence has been executed, the flight crew flies to a landing at the planned site much as it would for a nominal entry.

Contingency Aborts

Contingency aborts are caused by loss of more than one main engine or failures in other systems. Loss of one main engine while another is stuck at a low thrust setting may also necessitate a contingency abort. Such an abort would maintain orbiter integrity for in-flight crew escape if a landing cannot be achieved at a suitable landing field.

Contingency aborts due to system failures other than those involving the main engines would normally result in an intact recovery of vehicle and crew. Loss of more than one main engine may, depending on engine failure times, result in a safe runway landing. However, in most three-engine-out cases during ascent, the orbiter would have to be ditched. The inflight crew escape system would be used before ditching the orbiter.

Abort Decisions

There is a definite order of preference for the various abort modes. The type of failure and the time of the failure determine which type of abort is selected. In cases where performance loss is the only factor, the preferred modes would be ATO, AOA, TAL and RTLS, in that order. The mode chosen is the highest one that can be completed with the remaining vehicle performance.

In the case of some support system failures, such as cabin leaks or vehicle cooling problems, the preferred mode might be the one that will end the mission most quickly. In these cases, TAL or RTLS might be preferable to AOA or ATO. A contingency abort is never chosen if another abort option exists.

Mission Control Houston is prime for calling these aborts because it has a more precise knowledge of the orbiter's position than the crew can obtain from on-board systems. Before main engine cutoff, Mission Control makes periodic calls to the crew to tell them which abort mode is (or is not) available. If ground communications are lost, the flight crew has on-board methods, such as cue cards, dedicated displays and display information, to determine the abort region.

Which abort mode is selected depends on the cause and timing of the failure causing the abort and which mode is safest or improves mission success. If the problem is a space shuttle main engine failure, the flight crew and Mission Control Center select the best option available at the time a main engine fails.

If the problem is a system failure that jeopardizes the vehicle, the fastest abort mode that results in the earliest vehicle landing is chosen. RTLS and TAL are the quickest options (35 minutes), whereas an AOA requires about 90 minutes. Which of these is selected depends on the time of the failure with three good space shuttle main engines.

The flight crew selects the abort mode by positioning an abort mode switch and depressing an abort push button.

SHUTTLE ABORT HISTORY

RSLS Abort History:
(STS-41 D) June 26, 1984

The countdown for the second launch attempt for Discovery's maiden flight ended at T-4 seconds when the orbiter's computers detected a sluggish valve in main engine No. 3.The main engine was replaced and Discovery was finally launched on Aug. 30, 1984.

(STS-51 F) July 12, 1985

The countdown for Challenger's launch was halted at T-3 seconds when on-board computers detected a problem with a coolant valve on main engine No. 2. The valve was replaced and Challenger was launched on July 29, 1985.

(STS-55) March 22, 1993

The countdown for Columbia's launch was halted by on-board computers at T-3 seconds following a problem with purge pressure readings in the oxidizer preburner on main engine No. 2 Columbia's three main engines were replaced on the launch pad, and the flight was rescheduled behind Discovery's launch on STS-56. Columbia finally launched on April 26, 1993.

(STS-51) Aug. 12, 1993

The countdown for Discovery's third launch attempt ended at the T-3 second mark when onboard computers detected the failure of one of four sensors in main engine No. 2 which monitor the flow of hydrogen fuel to the engine. All of Discovery's main engines were ordered replaced on the launch pad, delaying the shuttle's fourth launch attempt until Sept. 12, 1993.

(STS-68) Aug. 18, 1994

The countdown for Endeavour's first launch attempt ended 1.9 seconds before liftoff when on-board computers detected higher than acceptable readings in one channel of a sensor monitoring the discharge temperature of the high pressure oxidizer turbopump in main engine No. 3. A test firing of the engine at the Stennis Space Center in Mississippi on September 2nd confirmed that a slight drift in a fuel flow meter in the engine caused a slight increase in the turbopump's temperature. The test firing also confirmed a slightly slower start for main engine No. 3 during the pad abort, which could have contributed to the higher temperatures. After Endeavour was brought back to the Vehicle Assembly Building to be outfitted with three replacement engines, NASA managers set Oct. 2 as the date for Endeavour's second launch attempt.

Abort to Orbit History: (STS-51 F) July 29, 1985

After an RSLS abort on July 12, 1985, Challenger was launched on July 29, 1985. Five minutes and 45 seconds after launch, a sensor problem resulted in the shutdown of center engine No. 1, resulting in a safe "abort to orbit" and successful completion of the mission.

SPACE SHUTTLE MAIN ENGINES

Developed in the 1970s by NASA's Marshall Space Flight Center in Huntsville, Ala., the space shuttle main engine is the most advanced liquid-fueled rocket engine ever built. Every space shuttle main engine is tested and proven flight-worthy at NASA's Stennis Space Center in south Mississippi, before installation on an orbiter. Its main features include variable thrust, high performance reusability, high redundancy and a fully integrated engine controller.

The shuttle's three main engines are mounted on the orbiter aft fuselage in a triangular pattern. Spaced so that they are movable during launch, the engines are used – in conjunction with the solid rocket boosters – to steer the shuttle vehicle.

Each of these powerful main engines is 14 feet (4.2 meters) long, weighs about 7,000 pounds (3,150 kilograms) and is 7.5 feet (2.25 meters) in diameter at the end of its nozzle.

The engines operate for about 8½ minutes during liftoff and ascent—burning more than 500,000 gallons (1.9 million liters) of super-cold liquid hydrogen and liquid oxygen propellants stored in the huge external tank attached to the underside of the shuttle. The engines shut down just before the shuttle, traveling at about 17,000 mph (28,000 kilometers per hour), reaches orbit.

The main engine operates at greater temperature extremes than any mechanical system in common use today. The fuel, liquefied hydrogen at -423 degrees Fahrenheit (-253 degrees Celsius), is the second coldest liquid on Earth. When it and the liquid oxygen are combusted, the temperature in the main combustion chamber is 6,000 degrees Fahrenheit (3,316 degrees Celsius), hotter than the boiling point of iron.

The main engines use a staged combustion cycle so that all propellants entering the engines are used to produce thrust or power—more efficiently than any previous rocket engine. In a staged combustion cycle, propellants are first burned partially at high pressure and relatively low temperature—then burned completely at high temperature and pressure in the main combustion chamber. The rapid mixing of the propellants under these conditions is so complete that 99 percent of the fuel is burned.

At normal operating level, the engines generate 490,847 pounds of thrust (measured in a vacuum). Full power is 512,900 pounds of thrust; minimum power is 316,100 pounds of thrust.

The engine can be throttled by varying the output of the pre-burners, thus varying the speed of the high-pressure turbopumps and, therefore, the flow of the propellant.

At about 26 seconds into launch, the main engines are throttled down to 316,000 pounds of thrust to keep the dynamic pressure on the vehicle below a specified level—about 580 pounds per square foot or max q. Then, the engines are throttled back up to normal operating level at about 60 seconds. This reduces stress on the vehicle.

The main engines are throttled down again at about seven minutes, 40 seconds into the mission to maintain three g's – three times the Earth's gravitational pull – again reducing stress on the crew and the vehicle. This acceleration level is about one-third the acceleration experienced on previous crewed space vehicles.

About 10 seconds before main engine cutoff or MECO, the cutoff sequence begins; about three seconds later the main engines are commanded to begin throttling at 10 percent thrust per second to 65 percent thrust. This is held for about 6.7 seconds, and the engines are shut down.

The engine performance has the highest thrust for its weight of any engine yet developed. In fact, one space shuttle main engine generates sufficient thrust to maintain the flight of 2½ 747 airplanes.

The space shuttle main engine is also the first rocket engine to use a built-in electronic digital controller, or computer. The controller will accept commands from the orbiter for engine start, change in throttle, shutdown, and monitor engine operation. In the event of a failure, the controller automatically corrects the problem or safely shuts down the engine.

NASA continues to increase the reliability and safety of shuttle flights through a series of enhancements to the space shuttle main engines. The engines were modified in 1988, 1995, 1998 and 2001. Modifications include new high-pressure fuel and oxidizer turbopumps that reduce maintenance and operating costs of the engine, a two-duct powerhead that reduces pressure and turbulence in the engine, and a single-coil heat exchanger that lowers the number of post flight inspections required. Another modification incorporates a large-throat main combustion chamber that improves the engine's reliability by reducing pressure and temperature in the chamber.

After the orbiter lands, the engines are removed and returned to a processing facility at Kennedy Space Center, Fla., where they are rechecked and readied for the next flight. Some components are returned to the main engine's prime contractor, Pratt & Whitney RocketDyne, West Palm Beach, Fla., for regular maintenance. The main engines are designed to operate for 7.5 accumulated hours.

SPACE SHUTTLE SOLID ROCKET BOOSTERS

The two SRBs provide the main thrust to lift the space shuttle off the pad and up to an altitude of about 150,000 feet, or 24 nautical miles (28 statute miles). In addition, the two SRBs carry the entire weight of the external tank and orbiter and transmit the weight load through their structure to the mobile launcher platform.

Each booster has a thrust (sea level) of about 3,300,000 pounds at launch. They are ignited after the three space shuttle main engines' thrust level is verified. The two SRBs provide 71.4 percent of the thrust at liftoff and during first-stage ascent. Seventy-five seconds after SRB separation, SRB apogee occurs at an altitude of about 220,000 feet, or 35 nautical miles (40 statute miles). SRB impact occurs in the ocean about 122 nautical miles (140 statute miles) downrange.

The SRBs are the largest solid-propellant motors ever flown and the first designed for reuse. Each is 149.16 feet long and 12.17 feet in diameter.

Each SRB weighs about 1,300,000 pounds at launch. The propellant for each solid rocket motor weighs about 1,100,000 pounds. The inert weight of each SRB is about 192,000 pounds.

Primary elements of each booster are the motor (including case, propellant, igniter and nozzle), structure, separation systems, operational flight instrumentation, recovery avionics, pyrotechnics, deceleration system, thrust vector control system and range safety destruct system.

Each booster is attached to the external tank at the SRB's aft frame by two lateral sway braces and a diagonal attachment. The forward end of each SRB is attached to the external tank at the forward end of the SRB's forward skirt. On the launch pad, each booster also is attached to the mobile launcher platform at the aft skirt by four bolts and nuts that are severed by small explosives at liftoff.

During the downtime following the Challenger accident, detailed structural analyses were performed on critical structural elements of the SRB. Analyses were primarily focused in areas where anomalies had been noted during postflight inspection of recovered hardware.

One of the areas was the attach ring where the SRBs are connected to the external tank. Areas of distress were noted in some of the fasteners where the ring attaches to the SRB motor case. This situation was attributed to the high loads encountered during water impact. To correct the situation and ensure higher strength margins during ascent, the attach ring was redesigned to encircle the motor case completely (360 degrees).

Previously, the attach ring formed a C and encircled the motor case 270 degrees.

Additionally, special structural tests were done on the aft skirt. During this test program, an anomaly occurred in a critical weld between the hold-down post and skin of the skirt. A redesign was implemented to add reinforcement brackets and fittings in the aft ring of the skirt.

These two modifications added about 450 pounds to the weight of each SRB.

The propellant mixture in each SRB motor consists of an ammonium perchlorate (oxidizer, 69.6 percent by weight), aluminum (fuel, 16 percent), iron oxide (a catalyst, 0.4 percent), a polymer (a binder that holds the mixture together, 12.04 percent), and an epoxy curing agent (1.96 percent). The propellant is an 11-point star-shaped perforation in the forward motor segment and a double-truncated-cone perforation in each of the aft segments and aft closure. This configuration provides high thrust at ignition and then reduces the thrust by about a third 50 seconds after liftoff to prevent overstressing the vehicle during maximum dynamic pressure.

The SRBs are used as matched pairs and each is made up of four solid rocket motor segments. The pairs are matched by loading each of the four motor segments in pairs from the same batches of propellant ingredients to minimize any thrust imbalance. The segmented-casing design assures maximum flexibility in fabrication and ease of transportation and handling. Each segment is shipped to the launch site on a heavy-duty rail car with a specially built cover.

The nozzle expansion ratio of each booster beginning with the STS-8 mission is 7-to-79. The nozzle is gimbaled for thrust vector (direction) control. Each SRB has its own redundant auxiliary power units and hydraulic pumps. The all-axis gimbaling capability is 8 degrees. Each nozzle has a carbon cloth liner that erodes and chars during firing. The nozzle is a convergent-divergent, movable design in which an aft pivot-point flexible bearing is the gimbal mechanism.

The cone-shaped aft skirt reacts the aft loads between the SRB and the mobile launcher platform. The four aft separation motors are mounted on the skirt. The aft section contains avionics, a thrust vector control system that consists of two auxiliary power units and hydraulic pumps, hydraulic systems and a nozzle extension jettison system.

The forward section of each booster contains avionics, a sequencer, forward separation motors, a nose cone separation system, drogue and main parachutes, a recovery beacon, a recovery light, a parachute camera on selected flights and a range safety system.

Each SRB has two integrated electronic assemblies, one forward and one aft. After burnout, the forward assembly initiates the release of the nose cap and frustum, a transition piece between the nose cone and solid rocket motor, and turns on the recovery aids. The aft assembly, mounted in the external tank/SRB attach ring, connects with the forward assembly and the orbiter avionics systems for SRB ignition commands and nozzle thrust vector control. Each integrated electronic assembly has a multiplexer/demultiplexer, which sends or receives more than one message, signal or unit of information on a single communication channel.

Eight booster separation motors (four in the nose frustum and four in the aft skirt) of each SRB thrust for 1.02 seconds at SRB separation from the external tank. Each solid rocket separation motor is 31.1 inches long and 12.8 inches in diameter.

Location aids are provided for each SRB, frustum/drogue chutes and main parachutes. These include a transmitter, antenna, strobe/converter, battery and salt-water switch electronics. The location aids are designed for a minimum operating life of 72 hours and when refurbished are considered usable up to 20 times. The flashing light is an exception. It has an operating life of 280 hours. The battery is used only once.

The SRB nose caps and nozzle extensions are not recovered.

The recovery crew retrieves the SRBs, frustum/drogue chutes, and main parachutes. The nozzles are plugged, the solid rocket motors are dewatered, and the SRBs are towed back to the launch site. Each booster is removed from the water, and its components are disassembled and washed with fresh and deionized water to limit salt-water corrosion. The motor segments, igniter and nozzle are shipped back to ATK Thiokol for refurbishment.

Each SRB incorporates a range safety system that includes a battery power source, receiver/decoder, antennas and ordnance.

Hold-Down Posts

Each solid rocket booster has four hold-down posts that fit into corresponding support posts on the mobile launcher platform. Hold-down bolts hold the SRB and launcher platform posts together. Each bolt has a nut at each end, but only the top nut is frangible. The top nut contains two NASA standard detonators (NSDs), which are ignited at solid rocket motor ignition commands.

When the two NSDs are ignited at each hold-down, the hold-down bolt travels downward because of the release of tension in the bolt (pretensioned before launch), NSD gas pressure and gravity. The bolt is stopped by the stud deceleration stand, which contains sand. The SRB bolt is 28 inches long and 3.5 inches in diameter. The frangible nut is captured in a blast container.

The solid rocket motor ignition commands are issued by the orbiter's computers through the master events controllers to the hold-down pyrotechnic initiator controllers on the mobile launcher platform. They provide the ignition to the hold-down NSDs. The launch processing system monitors the SRB hold-down PICs for low voltage during the last 16 seconds before launch. PIC low voltage will initiate a launch hold.

SRB Ignition

SRB ignition can occur only when a manual lock pin from each SRB safe and arm device has been removed. The ground crew removes the pin during prelaunch activities. At T minus five minutes, the SRB safe and arm device is rotated to the arm position. The solid rocket motor ignition commands are issued when the three SSMEs are at or above 90 percent rated thrust, no SSME fail and/or SRB ignition PIC low voltage is indicated and there are no holds from the LPS.

The solid rocket motor ignition commands are sent by the orbiter computers through the MECs to the safe and arm device NSDs in each SRB. A PIC single-channel capacitor discharge device controls the firing of each pyrotechnic device. Three signals must be present simultaneously for the PIC to generate the pyro firing output. These signals—arm, fire 1 and fire 2—originate in the orbiter general-purpose computers and are transmitted to the MECs. The MECs reformat them to 28-volt dc signals for the PICs. The arm signal charges the PIC capacitor to 40 volts dc (minimum of 20 volts dc).

The fire 2 commands cause the redundant NSDs to fire through a thin barrier seal down a flame tunnel. This ignites a pyro booster charge, which is retained in the safe and arm device behind a perforated plate. The booster charge ignites the propellant in the igniter initiator; and combustion products of this propellant ignite the solid rocket motor initiator, which fires down the length of the solid rocket motor igniting the solid rocket motor propellant.

The GPC launch sequence also controls certain critical main propulsion system valves and monitors the engine-ready indications from the SSMEs. The MPS start commands are issued by the on-board computers at T minus 6.6 seconds (staggered start—engine three, engine two, engine one—all about within 0.25 of a second), and the sequence monitors the thrust buildup of each engine. All three SSMEs must reach the required 90 percent thrust within three seconds; otherwise, an orderly shutdown is commanded and safing functions are initiated.

Normal thrust buildup to the required 90 percent thrust level will result in the SSMEs being commanded to the liftoff position at T minus three seconds as well as the fire 1 command being issued to arm the SRBs. At T minus three seconds, the vehicle base bending load modes are allowed to initialize (movement of 25.5 inches measured at the tip of the external tank, with movement towards the external tank).

At T minus zero, the two SRBs are ignited under command of the four on-board computers; separation of the four explosive bolts on each SRB is initiated (each bolt is 28 inches long and 3.5 inches in diameter); the two T-0 umbilicals (one on each side of the spacecraft) are retracted; the on-board master timing unit, event timer and mission event timers are started; the three SSMEs are at 100 percent; and the ground launch sequence is terminated.

The solid rocket motor thrust profile is tailored to reduce thrust during the maximum dynamic pressure region.

Electrical Power Distribution

Electrical power distribution in each SRB consists of orbiter-supplied main dc bus power to each SRB via SRB buses A, B and C. Orbiter main dc buses A, B and C supply main dc bus power to corresponding SRB buses A, B and C. In addition, orbiter main dc bus C supplies backup power to SRB buses A and B, and orbiter bus B supplies backup power to SRB bus C. This electrical power distribution arrangement allows all SRB buses to remain powered in the event one orbiter main bus fails.

The nominal dc voltage is 28 volts dc, with an upper limit of 32 volts dc and a lower limit of 24 volts dc.

Hydraulic Power Units

There are two self-contained, independent HPUs on each SRB. Each HPU consists of an auxiliary power unit, fuel supply module, hydraulic pump, hydraulic reservoir and hydraulic fluid manifold assembly. The APUs are fueled by hydrazine and generate mechanical shaft power to a hydraulic pump that produces hydraulic pressure for the SRB hydraulic system. The two separate HPUs and two hydraulic systems are located on the aft end of each SRB between the SRB nozzle and aft skirt. The HPU components are mounted on the aft skirt between the rock and tilt actuators.

The two systems operate from T minus 28 seconds until SRB separation from the orbiter and external tank. The two independent hydraulic systems are connected to the rock and tilt servoactuators.

The APU controller electronics are located in the SRB aft integrated electronic assemblies on the aft external tank attach rings.

The APUs and their fuel systems are isolated from each other. Each fuel supply module (tank) contains 22 pounds of hydrazine. The fuel tank is pressurized with gaseous nitrogen at 400 psi, which provides the force to expel (positive expulsion) the fuel from the tank to the fuel distribution line, maintaining a positive fuel supply to the APU throughout its operation.

The fuel isolation valve is opened at APU startup to allow fuel to flow to the APU fuel pump and control valves and then to the gas generator. The gas generator's catalytic action decomposes the fuel and creates a hot gas. It feeds the hot gas exhaust product to the APU two-stage gas turbine. Fuel flows primarily through the startup bypass line until the APU speed is such that the fuel pump outlet pressure is greater than the bypass line's. Then all the fuel is supplied to the fuel pump.

The APU turbine assembly provides mechanical power to the APU gearbox. The gearbox drives the APU fuel pump, hydraulic pump and lube oil pump. The APU lube oil pump lubricates the gearbox. The turbine exhaust of each APU flows over the exterior of the gas generator, cooling it, and is then directed overboard through an exhaust duct.

When the APU speed reaches 100 percent, the APU primary control valve closes, and the APU speed is controlled by the APU controller electronics. If the primary control valve logic fails to the open state, the secondary control valve assumes control of the APU at 112 percent speed.

Each HPU on an SRB is connected to both servoactuators on that SRB. One HPU serves as the primary hydraulic source for the servoactuator, and the other HPU serves as the secondary hydraulics for the servoactuator. Each servoactuator has a switching valve that allows the secondary hydraulics to power the actuator if the primary hydraulic pressure drops below 2,050 psi. A switch contact on the switching valve will close when the valve is in the secondary position. When the valve is closed, a signal is sent to the APU controller that inhibits the 100 percent APU speed control logic and enables the 112 percent APU speed control logic. The 100 percent APU speed enables one APU/HPU to supply sufficient operating hydraulic pressure to both servoactuators of that SRB.

The APU 100 percent speed corresponds to 72,000 rpm, 110 percent to 79,200 rpm, and 112 percent to 80,640 rpm.

The hydraulic pump speed is 3,600 rpm and supplies hydraulic pressure of 3,050, plus or minus 50, psi. A high-pressure relief valve provides overpressure protection to the hydraulic system and relieves at 3,750 psi.

The APUs/HPUs and hydraulic systems are reusable for 20 missions.

Thrust Vector Control

Each SRB has two hydraulic gimbal servoactuators: one for rock and one for tilt. The servoactuators provide the force and control to gimbal the nozzle for thrust vector control.

The space shuttle ascent thrust vector control portion of the flight control system directs the thrust of the three shuttle main engines and the two SRB nozzles to control shuttle attitude and trajectory during liftoff and ascent. Commands from the guidance system are transmitted to the ATVC drivers, which transmit signals proportional to the commands to each servoactuator of the main engines and SRBs. Four independent flight control system channels and four ATVC channels control six main engine and four SRB ATVC drivers, with each driver controlling one hydraulic port on each main and SRB servoactuator.

Each SRB servoactuator consists of four independent, two-stage servovalves that receive signals from the drivers. Each servovalve controls one power spool in each actuator, which positions an actuator ram and the nozzle to control the direction of thrust.

The four servovalves in each actuator provide a force-summed majority voting arrangement to position the power spool. With four identical commands to the four servovalves, the actuator force-sum action prevents a single erroneous command from affecting power ram motion. If the erroneous command persists for more than a predetermined time, differential pressure sensing activates a selector valve to isolate and remove the defective servovalve hydraulic pressure, permitting the remaining channels and servovalves to control the actuator ram spool.

Failure monitors are provided for each channel to indicate which channel has been bypassed. An isolation valve on each channel provides the capability of resetting a failed or bypassed channel.

Each actuator ram is equipped with transducers for position feedback to the thrust vector control system. Within each servoactuator ram is a splashdown load relief assembly to cushion the nozzle at water splashdown and prevent damage to the nozzle flexible bearing.

SRB Rate Gyro Assemblies

Each SRB contains two RGAs, with each RGA containing one pitch and one yaw gyro. These provide an output proportional to angular rates about the pitch and yaw axes to the orbiter computers and guidance, navigation and control system during first-stage ascent flight in conjunction with the orbiter roll rate gyros until SRB separation. At SRB separation, a switchover is made from the SRB RGAs to the orbiter RGAs.

The SRB RGA rates pass through the orbiter flight aft multiplexers/ demultiplexers to the orbiter GPCs. The RGA rates are then mid-value- selected in redundancy management to provide SRB pitch and yaw rates to the user software. The RGAs are designed for 20 missions.

SRB Separation

SRB separation is initiated when the three solid rocket motor chamber pressure transducers are processed in the redundancy management middle value select and the head-end chamber pressure of both SRBs is less than or equal to 50 psi. A backup cue is the time elapsed from booster ignition.

The separation sequence is initiated, commanding the thrust vector control actuators to the null position and putting the main propulsion system into a second-stage configuration (0.8 second from sequence initialization), which ensures the thrust of each SRB is less than 100,000 pounds. Orbiter yaw attitude is held for four seconds, and SRB thrust drops to less than 60,000 pounds.

The SRBs separate from the external tank within 30 milliseconds of the ordnance firing command.

The forward attachment point consists of a ball (SRB) and socket (ET) held together by one bolt. The bolt contains one NSD pressure cartridge at each end. The forward attachment point also carries the range safety system cross-strap wiring connecting each SRB RSS and the ET RSS with each other.

The aft attachment points consist of three separate struts: upper, diagonal and lower. Each strut contains one bolt with an NSD pressure cartridge at each end. The upper strut also carries the umbilical interface between its SRB and the external tank and on to the orbiter.

There are four booster separation motors on each end of each SRB. The BSMs separate the SRBs from the external tank. The solid rocket motors in each cluster of four are ignited by firing redundant NSD pressure cartridges into redundant confined detonating fuse manifolds.

The separation commands issued from the orbiter by the SRB separation sequence initiate the redundant NSD pressure cartridge in each bolt and ignite the BSMs to effect a clean separation.

SPACE SHUTTLE SUPER LIGHT WEIGHT TANK (SLWT)

The super lightweight external tank (SLWT) made its first shuttle flight June 2, 1998, on mission STS-91. The SLWT is 7,500 pounds lighter than the standard external tank. The lighter weight tank allows the shuttle to deliver International Space Station elements (such as the service module) into the proper orbit.

The SLWT is the same size as the previous design. But the liquid hydrogen tank and the liquid oxygen tank are made of aluminum lithium, a lighter, stronger material than the metal alloy used for the shuttle's current tank. The tank's structural design has also been improved, making it 30 percent stronger and 5 percent less dense.

The SLWT, like the standard tank, is manufactured at Michoud Assembly, near New Orleans, by Lockheed Martin.

The 154-foot-long external tank is the largest single component of the space shuttle. It stands taller than a 15-story building and has a diameter of about 27 feet. The external tank holds over 530,000 gallons of liquid hydrogen and liquid oxygen in two separate tanks. The hydrogen (fuel) and liquid oxygen (oxidizer) are used as propellants for the shuttle's three main engines.

ACRONYMS AND ABBREVIATIONS

A/L	Airlock
AA	Antenna Assembly
AAA	Avionics Air Assembly
ABC	Audio Bus Coupler
AC	Assembly Complete
ACBM	Active Common Berthing Mechanism
ACO	Assembly and Checkout Officer
ACS	Atmosphere Control and Supply
ACSM	Attitude Control System Moding
ACU	Arm Computer Unit
ADO	Adaptation Data Overlay
ADSEP	Advanced Separation
ADVASC	Advanced Astroculture
ADVASC-GC	Advanced Astroculture—Growth Chamber
AEA	Antenna Electronics Assembly
AFD	Aft Flight Deck
AJIS	Alpha Joint Interface Structure
AKA	Active Keel Assembly
APAS	Androgynous Peripheral Attachment System
APCU	Assembly Power Converter Unit
APDS	Androgynous Peripheral Docking System
APFR	Articulating Portable Foot Restraint
APM	Attached Pressurized Module
APPCM	Arm Pitch Plane Change Mode
APS	Automated Payload Switch
AR	Atmosphere Revitalization
ARCU	American-to-Russian Converter Unit
ARIS	Active Rack Isolation System
ARS	Air Revitalization System
ASCR	Assured Safe Crew Return
ATA	Ammonia Tank Assembly
ATCS	Active Thermal Control System
ATU	Audio Terminal Unit
AUAI	Assemble Contingency System/UHF Audio Interface
AVU	Artificial Vision Unit
AVV	Accumulator Vent Valve
BA	Bearing Assembly
BBC	Bus Bolt Controller
BC	Bus Controller

BCDU	Battery Charge/Discharge Unit
BCU	Backup Controller Unit
BDU	Backup Drive Unit
BG	Beta Gimbal
BGA	Beta Gimbal Assembly
BGDTS	Beta Gimbal Deployment Transition Structure
BGHS	Beta Gimbal Housing Subassembly
BIT	Built-In Test
BITE	Built-In Test Equipment
BMRRM	Bearing Motor and Roll Ring Module
BONEMAC	Bone Marrow Macrophages in Space
BRS	Bottom Right Side
BSP	Baseband Signal Processor
BTS	Bolt Tight Switch
C&C	Command and Control
C&DH	Command and Data Handling
C&M	Control and Monitor
C&T	Communication and Tracking
C&W	Caution and Warning
C/A-code	Coarse/Acquisition-code
C/L	Crew Lock
CA	Control Attitude
CAS	Common Attach System
CBM	Common Berthing Mechanism
CBOSS	Cellular Biotechnology Operating Science System
CCAA	Common Cabin Air Assembly
CCASE	Commercial Cassette Experiment
CCD	Cursor Control Device
CCMS	Concentric Cable Management System
CCS	Communication and Control System
CCTV	Closed-Circuit Television
CDDT	Common Display Development Team
CDRA	Carbon Dioxide Removal Assembly
CDS	Command and Data Software
CETA	Crew and Equipment Translation Aid
CEU	Control Electronics Unit
CFA	Circular Fan Assembly
CGBA	Commercial Generic Bioprocessing Apparatus
CHeCS	Crew Health Care System
CHX	Condensing Heat Exchanger
CID	Circuit Interrupt Device
CIOB	Cargo Integration and Operations Branch

CLA	Camera and Light Assembly
CLPA	Camera Light and Pan/Tilt Assembly
CMG	Control Moment Gyroscope
CMG-TA	Control Moment Gyroscope-Thruster Assist
CO_2	Carbon Dioxide
COAS	Crew Optical Alignment Sight
COR	Communication Outage Recorder
COTS	Commercial-Off-The-Shelf
CP	Cold Plate
CPCG-H	Commercial Protein Crystal Growth-High
CR	Change Request
CRES	Corrosion Resistant Steel
CRIM	Commercial Refrigerator Incubator Module
CRIM-M	Commercial Refrigerator Incubator Module-Modified
CRPCM	Canadian Remote Power Controller Module
CSA	Computer Systems Architecture
CSA-CP	Compound Specific Analyzer-Combustion Products
CSCI	Computer Software Configuration Item
CSM	Cargo Systems Manual
CTB	Cargo Transfer Bag
CVIU	Common Video Interface Unit
CVT	Current Value Table
CVV	Carbon Dioxide Vent Valve
CWC	Contingency Water Collection
DAIU	Docked Audio Interface Unit
DAP	Digital Autopilot
DC	Docking Compartment
dc	direct current
DCP	Display and Control Panel
DCSU	Direct Current Switching Unit
DDCU	DC-to-DC Converter Unit
DDCU-CP	DC-to-DC Converter Unit-Cold Plate
DDCU-E	External DDCU
DDCU-HP	DC-to-DC Converter Unit-Heat Pipe
DDCU-I	Internal DDCU
DFL	Data Format Load
DLA	Drive Locking Assembly
DMCU	Docking Mechanism Control Unit
DMS-R	Data Management System-Russian
dp/dt	delta pressure/delta time
DPA	Digital Preassembly
DPS	Data Processing System

DTO	Development Test Objective
DTV	Digital Television
E/L	Equipment Lock
E-Stop	Emergency Stop
EACP	EMU Audio Control Panel
EAIU	EMU Audio Interface Unit
EAS	Early Ammonia Servicer
EATCS	External Active Thermal Control Subsystem
ECLSS	Environmental Control and Life Support System
ECU	Electronics Control Unit
ED	Engagement Drive
EDDA	External Maneuvering Unit Don/Doff Assembly
EEATCS	Early External Active Thermal Control System
EET	Experiment Elapsed Time
EETCS	Early External Thermal Control System
EFGF	Electrical Flight-releasable Grapple Fixture
EGIL	Electrical Generation and Integrated Lighting Systems Engineer
EIA	Electrical Interface Assembly
EMPEV	Emergency Manual Pressure Equalization Value
EMU	Extravehicular Mobility Unit
EOA	EVA Ohmmeter Assembly
EPCE	Electrical Power Consuming Equipment
EPG	Electrical Power Generator
EPS	Electrical Power System
ER	Edge Router
ESA	External Sampling Adapter
ESP	External Stowage Platform
ESSMDM	Enhanced Space Station Multiplexer/Demultiplexer
ESU	End Stop Unit
ETCS	External Thermal Control System
ETI	Elapsed Time Indicator
ETRS	EVA Temporary Rail Stop
ETSD	EVA Tool Storage Device
ETVCG	External Television Cameras Group
EUE	Experiment Unique Equipment
EV	Extravehicular
EV-CPDS	Extravehicular-Charged Particle Directional Spectrometer
EVA	Extravehicular Activity
EVR	Extravehicular Robotics
EVSU	External Video Switching Unit
EXPRESS	EXpedite the PRocessing of Experiments to the Space Station
EXT	Experimental Terminal

EWIS	External Wireless Instrumentation System
FAWG	Flight Assignment Working Group
FC	Firmware Controller
FCC	Flat Controller Circuit
FCT	Flight Control Team
FCV	Flow Control Valve
FD	Flight Day
FDA	Fault Detection Annunciation
FDIR	Failure, Detection, Isolation and Recovery
FDS	Fire Detection and Suppression
FET	Field Effect Transistor
FGB	Functional Cargo Block
FHRC	Flex Hose Rotary Coupler
FI	Fault Isolator
FPU	Fluid Pumping Unit
FQDC	Fluid Quick Disconnect Coupling
FRD	Flight Requirements Document
FRGF	Flight Releasable Grapple Fixture
FSE	Flight Support Equipment
FSS	Fluid System Servicer
FWCI	Firmware Configuration Item
GAS	Get Away Special
GC	Growth Cell
GCA	Growth Cell Assembly
GFE	Government-Furnished Equipment
GFI	Ground Fault Interrupter
GLONASS	GLObal Navigational Satellite System
GN&C	Guidance, Navigation and Control
GNC	Guidance Navigation Computer
GPC	General Purpose Computer
GPRV	Gas Pressure regulating Valve
GPS	Global Positioning System
GUI	Graphical User Interface
H_2	Hydrogen
HAB	Habitat Module
HC	Hand Controller
HCA	Hollow Cathode Assembly
HCOR	High-Rate Communication Outage Recorder
HDR	High Data Rate
HDRL	High Date Rate Link

HEPA	High Efficiency Particulate Air
HGA	High Gain Antenna
HHL	Handheld Lidar
HP	Heat Pipe
HPGT	High Pressure Gas Tank
HRF	Human Research Facility
HRF-PUF-DK	Human Research Facility Puff Data Kit
HRF-Res	Human Research Facility Resupply
HRFM	High Rate Frame Multiplexer
HRM	High Rate Modem
HRS	Hand Reaction Switch
I/F	Interface
I/O	Input/Output
IAC	Internal Audio Controller
IAS	Internal Audio Subsystem
IATCS	Internal Active Thermal Control System
ICC	Integrated Cargo Carrier
IDA	Integrated Diode Assembly
IDRD	Increment Definition Requirements Document
IEA	Integrated Equipment Assembly
IFHX	Interface Heat Exchanger
IFM	In-flight Maintenance
IMCA	Integrated Motor Control Assembly
IMCS	Integrated Mission Control System
IMU	Impedance Matching Unit
IMV	Intermodule Ventilation
INCO	Instrumentation and Communication Officer
INSTM	Instrumentation
INT	Internal
INTSYS	Internal Systems
IOC	Input/Output Controller
IOCU	Input/Output Controller Unit
IP	International Partner
IRU	In-Flight Refill Unit
ISA	Internal Sampling Adapter
ISL	Integrated Station LAN
ISO	Inventory and Stowage Officer
ISPR	International Standard Payload Rack
ISS	International Space Station
ISSSH	International Space Station Systems Handbook
IT	Integrated Truss
ITCS	Internal Thermal Control System

ITS	Integrated Truss Segment
IUA	Interface Umbilical Assembly
IV	Intravehicular
IVA	Intravehicular Activity
IVSU	Internal Video Switch Unit
IWIS	Internal Wireless Instrumentation System
JEM	Japanese Experiment Module
JEU	Joint Electronic Unit
kW	Kilowatt
LA	Launch Aft
Lab	Laboratory
LAN	Local Area Network
LB	Local Bus
LB-RWS	RWS Local Bus
LCA	Lab Cradle Assembly
LCC	Launch Commit Criteria
LCD	Liquid Crystal Display
LDI	Local Data Interface
LDR	Low Data Rate
LDU	Linear Drive Unit
LED	Light-Emitting Diode
LEE	Latching End Effector
LEU	LEE Electronic Unit
LFDP	Load Fault Detection Protection
LGA	Low Gain Antenna
LLA	Low Level Analog
LMC	Lightweight Multipurpose Carrier
LON	Launch On Need
LT	Low Temperature
LTA	Launch to Activation
LTL	Low Temperature Loop
LTU	Load Transfer Unit
LVLH	Local Vertical Local Horizontal
MA	Mechanical Assembly
MAM	Manual Augmented Role
MBE	Metal Bellows Expander
MBM	Manual Berthing Mechanism
MBS	Mobile Remote Service Base System
MBSU	Main Bus Switching Unit
MC	Midcourse Correction

MCA	Major Constituent Analyzer
MCAS	MBS Common Attach System
MCC	Mission Control Center
MCC-H	Mission Control Center-Houston
MCC-M	Mission Control Center-Moscow
MCDS	Multifunction CRT Display System
MCS	Motion Control System
MCU	MBS Computer Unit
MDA	Motor Drive Assembly
MDL	Middeck Locker
MDM	Multiplexer/Demultiplexer
MED OPS	Medical Operations
MEPS	Microencapsulation Electrostatic Processing System
MEPSI	Micro-Electromechanical System-based Pico Satellite Inspector
MER	Mission Evaluation Room
MET	Mission Elapsed Time
METOX	Metal Oxide
MFCV	Manual Flow Control Valve
MHS	MCU Host Software
MILA	Mode Indicating Light Assembly
MIP	Mission Integration Plan
MISSE	Materials International Space Station Experiment
MLI	Multi-Layer Insulation
MM/OD	Micrometeoroid/Orbital Debris
MMT	Mission Management Team
MOD	Mission Operations Directorate
MPEV	Manual Pressure Equalization Valve
MPLM	Multipurpose Logistics Module
MPM	Manipulator Positioning Mechanism
MRL	Manipulator Retention Latch
MRS	Mobile Remote Servicer
MSD	Mass Storage Device
MSFC	Marshall Space Flight Center
MSG	Microgravity Science Glovebox
MSS	Mobile Servicing System
MT	Mobile Transporter
MTCL	Mobile Transporter Capture Latch
MTL	Moderate Temperature Loop
MTS	Module-to-Truss Segment
MTSAS	Module-to-Truss Segment Attachment System
MTWsN	Move to Worksite Number

N_2	Nitrogen
n.mi.	nautical mile
NASA	National Aeronautics and Space Administration
NCC	Nominal Corrective Combination burn
NCG	Non Condensable Gas
NCS	Node Control Software
NCU	Network Control Unit
NET	No Earlier Than
NIA	Nitrogen Interface Assembly
NiH_2	Nickel Hydrogen
NIV	Nitrogen Introduction Valve
NSI	NASA Standard Initiator
NSTS	National Space Transportation System
NTA	Nitrogen Tank Assembly
O_2	Oxygen
OCA	Orbital Communications Adapter
OCAD	Operational Control Agreement Document
OCJM	Operator-Commanded Joint Position Mode
OCPM	Operator-Commanded POR Mode
OCS	Operations and Control Software
ODIN	Orbital Design Integration System
ODS	Orbiter Docking System
OI	Operational Increment
OIU	Orbiter Interface Unit
OIV	Oxygen Isolation Valve
OMI	On-Orbit Maintainable Item
OMS	Orbital Maneuvering System
OPCGA	Observable Protein Crystal Growth Apparatus
OPP	OSVS Patch Panel
Ops	Operations
OPS LAN	Operations Local Area Network
ORBT	Optimized RBar Targeting Technique
ORCA	Oxygen Recharge Compressor Assembly
ORU	Orbital Replacement Unit
OSE	Orbiter Support Equipment
OSO	Operations Support Officer
OSVS	Orbiter Space Vision System
OTD	ORU Transfer Device
OV	Orbiter Vehicle
P&S	Pointing and Support
P-code	Precision Code

P/L	Payload
P/TV	Photo/Television
P3/P4	Port 3/Port 4
PAS	Payload Attach System
PBA	Portable Breathing Apparatus
PC	Personal Computer
PCA	Pressure Control Assembly
PCAM	Protein Crystallization Apparatus for Microgravity
PCBM	Passive Common Berthing Mechanism
PCC	Power Converter Controller
PCG-STES	Protein Crystal Growth-Single Thermal Enclosure System
PCMCIA	Personal Computer Memory Card International Adapter
PCP	Pressure Control Panel
PCR	Portable Computer Receptacle
PCS	Portable Computer System
PCT	Post-Contact Thrusting
PCU	Plasma Connector Unit
PCVP	Pump and Control Valve Package
PDGF	Power and Data Grapple Fixture
PDI	Payload Data Interface
PDIP	Payload Data Interface Panel
PDRS	Payload Deployment and Retrieval System
PDTA	Power Data Transfer Assembly
PDU	Power Drive Unit
PEHG	Payload Ethernet Hub Gateway
PFCS	Pump Flow Control Subassembly
PFE	Portable Fire Extinguisher
PFMC	Pump/Fan Motor Controller
PGBA-S	Plant Generic Bioprocessing Apparatus-Stowage
PGSC	Portable General Support Computer
PGT	Pistol Grip Tool
PHALCON	Power, Heating, Articulation, Lighting, and Control Officer
PJAM	Pre-stored Joint Position Autosequence Mode
PLB	Payload Bay
PM	Pump Module
PMA	Pressurized Mating Adapter
PMCU	Power Management Control Unit
PMDIS	Perceptual Motor Deficits In Space
PMP	Payload Mounting Panel
POA	Payload/ORU Accommodation
POR	Point of Reference
POST	Power ON Self-Test

PP	Planning Period
PPA	Pump Package Assembly
PPAM	Pre-stored POR Autosequence Mode
ppO_2	partial pressure of oxygen
PPRV	Positive Pressure Relief Valve
PPT	Precipitate
PRD	Payload Retention Device
PRLA	Payload Retention Latch Assembly
Prox-Ops	Proximity Operations
PSN	Power Source Node
PSP	Payload Signal Processor
PTB	Payload Training Buffer
PTCS	Passive Thermal Control System
PTR	Port Thermal Radiator
PTU	Pan/Tilt Unit
PV	Photovoltaic
PVCA	Photovoltaic Controller Application
PVCE	Photovoltaic Controller Element
PVCU	Photovoltaic Controller Unit
PVM	Photovoltaic Module
PVR	Photovoltaic Radiator
PVRGF	Photovoltaic Radiator Grapple Fixture
PVTCS	Photovoltaic Thermal Control System
PWP	Portable Work Platform
PWR	Portable Water Reservoir
PYR	Pitch Yaw Roll
QD	Quick Disconnect
R/F	Refrigerator/Freezer
RACU	Russian-to-American Converter Unit
RAIU	Russian Audio Interface Unit
RAM	Random Access Memory
RAMV	Rheostat Air Mix Valve
RBB	Right Blanket Box
RBI	Remote Bus Isolator
RBVM	Radiator Beam Valve
RCC	Reinforced Carbon-Carbon
RCS	Reaction Control System
RDA	Retainer Door Assembly
RF	Radio Frequency
RFCA	Rack Flow Control Assembly
RFG	Radio Frequency Group

RGA	Rate Gyro Assemblies
RHC	Rotational Hand Controller
RHX	Regenerative Heat Exchanger
RIC	Rack Interface Controller
RJMC	Rotary Joint Motor Controller
RMS	Remote Manipulator System
ROS	Russian Orbital Segment
RPC	Remote Power Controller
RPCM	Remote Power Controller Module
RPDA	Remote Power Distribution Assembly
RPM	Rbar Pitch Maneuver
RPOP	Rendezvous and Proximity Operations Program
RS	Russian Segment
RSC	RMS Sideview Camera
RSP	Resupply Stowage Platform
RSR	Resupply Stowage Rack
RSTS	Rack Standalone Temperature Sensor
RSU	Roller Suspension Unit Remote Sensing Unit
RT	Remote Terminal
RT-Box	Reaction Time Box
RTAS	Rocketdyne Truss Attachment System
RTD	Resistive Thermal Device
RTL	Ready to Latch
RWS	Robotic Workstation
S	Starboard
S&M	Structures and Mechanisms
SA	Solar Array
SABB	Solar Array Blanket Box
SAGE	Space Arabidoposis Genomics Experiment
SARJ	Solar Alpha Rotary Joint
SARJ_C	SARJ Controller
SARJ_M	SARJ Manager
SASA	S-band Antenna Support Assembly
SAW	Solar Array Wing
SCA	Switchgear Controller Assembly
SCI	Signal Conditioning Interface
SCU	Service and Cooling Umbilical
SD	Smoke Detector
SDO	Solenoid Driver Output
SDS	Sample Delivery System
SEM	Shunt Electronics Module

SEPS	Secondary Electrical Power Subsystem
SFCA	System Flow Control Assembly
SFU	Squib Firing Unit
SGANT	Space-to-Ground Antenna
SHOSS	Spacehab Oceaneering Space System
SHOT	Space Hardware Optimization Technology
SIGI	Space Integrated Global Positioning System/Inertial Navigation System
SJRM	Single Joint Rate Mode
SLDP	Spacelab Data Processing
SLP	Spacelab Logistics Pallet
SM	Service Module
SMCC	Shuttle Mission Control Center
SMDP	Service Module Debris Panel
SOC	State of Charge
SOV	Shutoff Valve
SPCE	Servicing Performance and Checkout Equipment
SPD	Spool Positioning Device
SPDA	Secondary Power Distribution Assembly
SPDM	Special Purpose Dexterous Manipulator
SPG	Single-Point Ground
SRMS	Shuttle Remote Manipulator System
SSAS	Segment-to-Segment Attach System
SSBA	Space Station Buffer Amplifier
SSC	Station Support Computer
SSMDM	Space Station Multiplexer/Demultiplexer
SSOR	Space-to-Space Orbiter Ratio
SSP	Standard Switch Panel
SSRMS	Space Station Remote Manipulator System
SSSH	Space Shuttle Systems Handbook
SSSR	Space-to-Space Station Radio
SSU	Sequential Shunt Unit
STCR	Starboard Thermal Control Radiator
STES	Single Thermal Enclosure System
STR	Starboard Thermal Radiator
SVS	Space Vision System
TA	Thruster Assist
TAA	Triaxial Accelerometer Assembly
TAH	Tray Actuation Handle
TBA	Trundle Bearing Assembly
TC	Terminal Computer
TCCS	Trace Contaminant Control Subassembly
TCCV	Temperature Control and Check Valve

TCS	Trajectory Control Sensor
TD	Translation Drive
TDRS	Tracking and Data Relay Satellite
TDRSS	Tracking and Data Relay Satellite System
TEA	Torque Equilibrium Attitude
TFR	Translation Foot Restraint
THC	Temperature and Humidity Control
THOR	Thermal Operations and Resources Officer
TI	Terminal Phase Initiation
TORF	Twice Orbital Rate Flyaround
TORU	Teleoperator Control Mode
TORVA	Twice Orbital Rate +Rbar to +Vbar Approach
TPL	Transfer Priority List
TRAC	Test of Reaction and Adaption Capabilities
TRC	Transmitter Receiver Controller
TRRJ	Thermal Radiator Rotary Joint
TSP	Twisted Shielded Pair
TTCR	Trailing Thermal Control Radiator
TUS	Trailing Umbilical System
TVIS	Treadmill Vibration Isolation System
TWMV	Three-Way Mixing Valve
UCCAS	Unpressurized Cargo Carrier Attach System
UDG	User Data Generation
UF	Utilization Flight
UHF	Ultrahigh Frequency
UIA	Umbilical Interface Assembly
UIP	Utility Interface Panel
ULF	Utilization Logistics Flight
UMA	Umbilical Mechanism Assembly
UOP	Utility Outlet Panel
USL	U.S. Laboratory
USOS	United States On-Orbit Segment
UTA	Utility Transfer Assembly
VAJ	Vacuum Access Jumper
VBSP	Video Baseband Signal Processor
VCP	Video Camera Port
VDS	Video Distribution System
VDU	Video Distribution Unit
VES	Vacuum Exhaust System
VGS	Video Graphics Software
VRCV	Vent/Relief Control Valve

VRIV	Vent/Relief Isolation Valve
VRS	VES Resource System
VRV	Vent/Relief Valve
VSC	Video Signal Converter
VSSA	Video Stanchion Support Assembly
W/S	Worksite
WETA	WVS External Transceiver Assembly
WHS	Workstation Host Software
WIF	Worksite Interface
WRM	Water Recovery Management
WS	Water Separator
WVA	Water Vent Assembly
XPOP	X-axis Pointing Out of Plane
ZCG-SS	Zeolite Crystal Growth—Sample Stowage
ZSR	Zero-g Stowage Rack

MEDIA ASSISTANCE

NASA TELEVISION TRANSMISSION

NASA Television is carried on an MPEG-2 digital signal accessed via satellite AMC-6, at 72 degrees west longitude, transponder 17C, 4040 MHz, vertical polarization. For those in Alaska or Hawaii, NASA Television will be seen on AMC-7, at 137 degrees west longitude, transponder 18C, at 4060 MHz, horizontal polarization. In both instances, a Digital Video Broadcast (DVB)-compliant Integrated Receiver Decoder (IRD) (with modulation of QPSK/DBV, data rate of 36.86 and FEC ¾) will be needed for reception. The NASA Television schedule and links to streaming video are available at:

http://www.nasa.gov/ntv

NASA TV's digital conversion will require members of the broadcast media to upgrade with an 'addressable' Integrated Receiver Decoder, or IRD, to participate in live news events and interviews, press briefings and receive NASA's Video File news feeds on a dedicated Media Services channel. NASA mission coverage will air on a digital NASA Public Services ("Free to Air") channel, for which only a basic IRD will be needed. The schedule for television transmissions from the orbiter and for mission briefings will be available during the mission at Kennedy Space Center, Fla.; Marshall Space Flight Center, Huntsville, Ala.; Dryden Flight Research Center, Edwards, Calif.; Johnson Space Center, Houston; and NASA Headquarters, Washington. The television schedule will be updated to reflect changes dictated by mission operations.

Status Reports

Status reports on countdown and mission progress, on-orbit activities and landing operations will be posted at:

http://www.nasa.gov/shuttle

This site also contains information on the crew and will be updated regularly with photos and video clips throughout the flight.

Briefings

A mission press briefing schedule will be issued before launch. The updated NASA television schedule will indicate when mission briefings are planned.

Internet Information

Information on safety enhancements made since the Columbia Accident is available at:

www.nasa.gov/returntoflight/system/index.html

Information on other current NASA activities is available at:

http://www.nasa.gov/home

Resources for educators can be found at the following address:

http://education.nasa.gov

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