National Aeronautics and Space Administration

SPACE SHUTTLE MISSION

STS-130

A Room with a View

PRESS KIT/JANUARY 2010

ZAMKA
VIRTS
HIRE
PATRICK
BEHNKEN
ROBINSON
STS-130

www.nasa.gov

United Space Alliance

CONTENTS

STS-130/20A MISSION OVERVIEW

Space shuttle Endeavour launches on the STS-127 mission to the International Space Station in 2009.

Endeavour's 13-day mission will deliver and assemble the last U.S.-built modules onto the International Space Station, giving the laboratory a room with quite a view. The mission kicks off the final year of shuttle flights, with five missions planned through September.

Node 3, known as Tranquility, will provide additional room for crew members and many of the space station's life support and environmental control systems. Attached to the node is a cupola, which is a robotic control station with six windows around its sides and another in the center that will provide a panoramic view of Earth, celestial objects and visiting spacecraft.

Tucked away inside Tranquility and Endeavour's middeck will be a ton of equipment, supplies and experiments for the space station. Included are a new distillation assembly and fluid control pump assembly for the urine processing assembly, an external filter assembly for the water processing assembly, a new bed for the carbon dioxide removal assembly, laptop computers, crew provisions, health care supplies, spacewalk tools and others.

Endeavour, commanded by spaceflight veteran George Zamka, is scheduled to lift off from Kennedy Space Center at 4:39 a.m. EST on Sunday, Feb. 7, and arrive at the orbiting complex in the early morning hours Tuesday, Feb. 9.

While docked to the station, Endeavour's crew will conduct three spacewalks and extensive robotic operations to install Tranquility and then relocate its cupola.

Zamka, 47, a U.S. Marine Corps colonel, served as pilot on STS-120 in 2007. He will be joined on the mission by pilot Terry Virts, 41, a U.S. Air Force colonel, who will be making his first trip to space. Mission specialists are Kathryn Hire, a U.S. Navy Reserve captain who flew on STS-90 in 1998; Stephen Robinson who flew on STS-85 in 1997, STS-95 in 1988 and STS-114 in 2005; Nicholas Patrick who flew on STS-116 in 2006; and Robert Behnken, a lieutenant colonel in the U.S. Air Force, who flew on STS-123 in 2008. Robinson, Patrick and Behnken all have doctorates in mechanical engineering.

Astronaut George Zamka, STS-130 commander, dons a training version of his shuttle launch and entry suit in preparation for a training session in the Space Vehicle Mock-up Facility at NASA's Johnson Space Center. United Space Alliance suit technician Joel Alvarado assisted Zamka.

The major tasks for the mission are to install, activate and checkout Tranquility, including connecting internal and external avionics, cables, and ammonia cooling system jumpers; relocating the Cupola from the end port of Tranquility to its Earth-facing port and then activating and checking out the Cupola; relocating the Pressurized Mating Adapter 3 (PMA 3) from the top of the Harmony node to the port side of Tranquility; and transferring water, equipment and experiments to the station.

The day after launch, Zamka, Virts, Hire and Patrick will take turns from Endeavour's aft flight deck maneuvering its robotic arm in the traditional day-long scan of the reinforced carbon-carbon on the leading edges of the shuttle's wings and its nose cap. This initial inspection, using a 50-foot-long robotic arm extension equipped with sensors and lasers, called the Orbiter Boom Sensor System (OBSS), will provide imagery experts on the ground a close-up look at the orbiter's heat shield following the dynamic liftoff. A follow-up inspection will take place after Endeavour undocks from the station.

Astronaut Terry Virts, STS-130 pilot, attired in a training version of his shuttle launch and entry suit, occupies the pilot's station during a training session in the Mission Simulation Development Facility at NASA's Johnson Space Center.

While the inspection takes place, Behnken and Patrick will prepare the spacesuits they will wear for their three spacewalks out of the Quest airlock at the station. Robinson will assist with spacewalk tool preparation that day as he will serve as the internal choreographer of the excursions. Docking preparations will occupy the remainder of the crew's workday.

On the third day of the flight, Endeavour will be flown by Zamka and Virts on its approach for docking to the station. After a series of jet firings to fine-tune Endeavour's path to the complex, the shuttle will arrive at a point about 600 feet directly below the station about an hour before docking. At that time, Zamka will execute the rendezvous pitch maneuver, a one-degree-per-second rotational "backflip" to enable station crew members to snap hundreds of detailed photos of the shuttle's heat shield and other areas of potential interest – another data point for imagery analysts to pore over in determining the health of the shuttle's thermal protection system.

Astronaut George Zamka (foreground), STS-130 commander; and astronaut Nicholas Patrick, mission specialist, work with an Extravehicular Mobility Unit (EMU) spacesuit during a training session in an International Space Station mock-up/trainer in the Space Vehicle Mock-up Facility at NASA's Johnson Space Center.

Once the rotation is completed, Zamka will fly Endeavour in front of the station before slowly closing in for a linkup to the forward docking port on the Harmony module. Less than two hours later, hatches will be opened between the two spacecraft and a combined crew of 11 will begin eight days of work. Endeavour's crew will be working with Expedition 22 commander NASA astronaut Jeff Williams and flight engineers cosmonaut Max Suraev, NASA astronaut T.J. Creamer and Japan Aerospace Exploration Agency astronaut Soichi Noguchi. Noguchi and Robinson flew together on the STS-114 space shuttle return-to-flight mission in 2005.

After a station safety briefing, Patrick and Creamer will operate the station's robotic arm to remove the OBSS from Endeavour's payload bay and hand it off to the shuttle robotic arm being operated by Virts and Hire.

The next day, Endeavour's crew will begin transferring supplies from the middeck to the station, including spacewalking equipment, and then will have the afternoon off.

That night, spacewalkers Behnken and Patrick will sleep in the Quest airlock as part of the overnight "campout" procedure that helps purge nitrogen from their bloodstreams, preventing decompression sickness once they move out into the vacuum of space. The campout will be repeated the night before each spacewalk.

Behnken (EV 1) will wear a suit with stripes. Patrick (EV 2) will wear a suit with no stripes. Behnken performed three spacewalks during the STS-123 mission in March 2008 totaling 19 hours and 19 minutes. The spacewalks conducted during STS-130 will be the first extravehicular excursions for Patrick.

The fifth day of the mission will focus on the first spacewalk and robotics work to install Tranquility. Spacewalkers Patrick and Behnken will prepare Tranquility for its removal from Endeavour's payload bay and then install avionics cabling once the new module is in place. Virts and Hire will operate the station's robotic arm to install Tranquility with the Cupola. The spacewalkers will also remove a tool platform from the station's special purpose dexterous manipulator while Tranquility is being maneuvered. Williams and Hire will begin a leak check of the interface to Tranquility.

The sixth day is available for focused inspection of Endeavour's heat shield, if mission managers deem it necessary. Zamka, Virts and Hire would conduct that survey in the crew's morning while Williams, Noguchi and Robinson continue the steps to open the hatch to Tranquility. Those five crew members will work together after the heat shield survey, continuing Tranquility checkout and opening the hatch into the Cupola. Patrick and Behnken will prepare their equipment for the next spacewalk.

Astronaut Robert Behnken, STS-130 mission specialist, gets help in the donning of a training version of his Extravehicular Mobility Unit (EMU) spacesuit in preparation for a spacewalk training session in the waters of the Neutral Buoyancy Laboratory (NBL) near NASA's Johnson Space Center.

Flight day seven will focus on configuring the new Tranquility module, inside and out, for its space operations. The spacewalkers will continue external outfitting of Tranquility by connecting fluid jumpers and remaining avionics cables, and installing covers as well as hardware to assist with future spacewalks, such as handrails and gap spanners. Virts, Hire, Williams and Noguchi will work on configuring avionics racks and the ventilation system inside Tranquility. At the end of the day they will close the hatch to the Cupola again and prepare it for its relocation. Virts and Hire will latch onto the Cupola with the station's robotic arm for the night.

The crew members will work inside the complex for two days before the final spacewalk. On the eighth day of the flight, Virts and Hire will move the Cupola to its permanent position on the Earth-facing side of Tranquility and then open the hatch again. Behnken and Robinson will grapple the PMA 3 with the station's robotic arm at the end of the day.

Astronauts Stephen Robinson and Kathryn Hire, both STS-130 mission specialists, read a procedure checklist during a training session in a fixed-base Shuttle Mission Simulator (SMS) training session in the Jake Garn Simulation and Training Facility at NASA's Johnson Space Center.

The ninth day includes moving the PMA 3 to the end of Tranquility to enhance micrometeoroid debris protection of the node, while Cupola internal outfitting continues. The crew will have the afternoon off.

The final planned spacewalk is on the tenth day to complete the work on Tranquility and the Cupola's exterior, including removing covers and launch locks. Inside, Noguchi will move a robotics workstation, which has served as a backup inside the Destiny lab, into the Cupola.

An additional docked day could be added to the flight, should Endeavour's onboard consumables support it. This day would be inserted as a new flight day 11 and would include transferring the station's regenerative life support racks, such as the water recovery system and oxygen generation system, from the Destiny lab into the Tranquility node. These racks were to have been moved earlier in the mission, but keeping them in Destiny longer will help recycling experts conduct tests following the planned repair work. If an additional docked day cannot be supported, the move may be completed after Endeavour departs.

The planned final full day of docked operations will include preparations for Endeavour's undocking and departure on the following day.

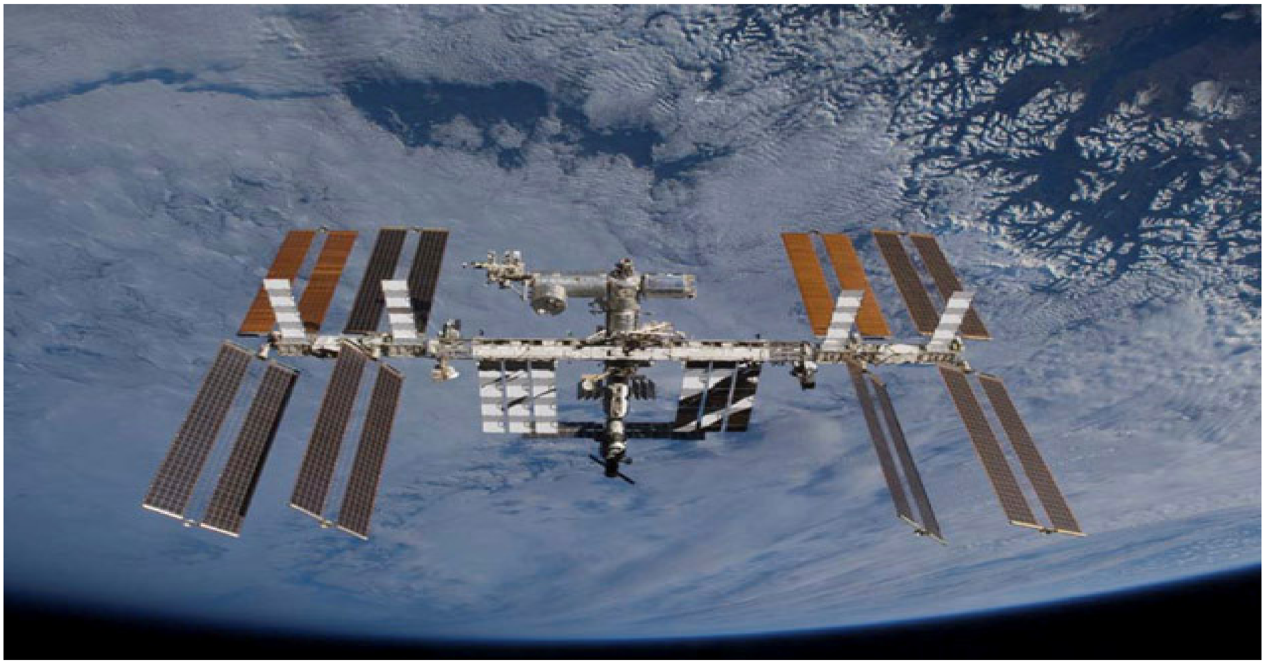
The crew will finish packing, reconfigure spacesuits and transfer them to Endeavour, and check out the rendezvous tools that will be used for undocking, flyaround and separation. The Endeavour crew will say farewell to the five-member station crew and close the hatches between the two spacecraft.

Endeavour's crew will leave the station approximately 90 percent completely assembled. The station will be in its final internal configuration, with most life support systems inside the nodes and workspace for research in the laboratories.

After Endeavour undocks the evening of Feb. 17, Virts will guide the shuttle on a 360-degree flyaround of the station so that other crew members can document the exterior condition of the orbiting outpost with its new additions. After the flyaround is complete, Zamka, Virts, Hire, Robinson and Patrick will conduct one last inspection of Endeavour's heat shield using the shuttle's Canadarm and the OBSS.

The last full day of orbital activities by the STS-130 crew will focus on landing preparations. Zamka, Virts and Robinson will conduct the traditional checkout of the shuttle's flight control systems and steering jets, setting Endeavour up for its supersonic return to Earth.

On the 14th day of the mission, weather permitting, Zamka and Virts will steer Endeavour to a landing at the Kennedy Space Center late in the evening of Feb. 19 to wrap up the 24th flight for Endeavour, the 130th mission in shuttle program history and the 32nd shuttle visit to the International Space Station.



Set against the background of a cloud covered Earth, the International Space Station is featured in this image photographed by an STS-129 crew member on Atlantis soon after the station and shuttle began their post-undocking relative separation.

STS-130 TIMELINE OVERVIEW

Flight Day 1

- Launch
- Payload Bay Door Opening
- Ku-Band Antenna Deployment
- Shuttle Robotic Arm Activation and Payload Bay Survey
- Umbilical Well and Handheld External Tank Photo and TV Downlink

Flight Day 2

- Endeavour’s Thermal Protection System Survey with Shuttle Robotic Arm/Orbiter Boom Sensor System (OBSS)
- Extravehicular Mobility Unit Checkout
- Centerline Camera Installation
- Orbiter Docking System Ring Extension
- Orbital Maneuvering System Pod Survey
- Rendezvous tools checkout

Flight Day 3

- Rendezvous with the International Space Station
- Rendezvous Pitch Maneuver Photography of Endeavour’s Thermal Protection System by Williams and Kotov of the Expedition 22 crew
- Docking to Harmony/Pressurized Mating Adapter-2
- Hatch Opening and Welcoming
- Canadarm2 grapple of OBSS and handoff to Shuttle robotic arm

Flight Day 4

- Spacewalk 1 preparations by Behnken and Patrick
- Crew off duty time
- Williams replacement and checkout of Distillation Assembly in the Water Recovery System
- Spacewalk 1 procedure review
- Spacewalk 1 campout by Behnken and Patrick in the Quest airlock

Flight Day 5

- Spacewalk 1 by Behnken and Patrick (Tranquility unberth preparations, tool stowage assembly removal from Dextre, launch to activation and avionics cable installation for Tranquility)
- Tranquility unberth from Endeavour’s payload bay and installation on port side of Unity
- Tranquility/Unity vestibule leak checks

Flight Day 6

- Focused inspection of Endeavour's thermal protection heat shield, if required
- Tranquility hatch opening
- Canadarm2 base change
- Cupola hatch opening
- Tranquility interior outfitting
- Spacewalk 2 procedure review
- Spacewalk 2 campout by Behnken and Patrick in the Quest airlock

Note: A decision on whether to transfer regenerative system racks to the new Tranquility Node 3 during docked operations is dependent on the required run time for the newly installed Water Recovery System hardware; if rack transfers are approved during docked operations, they would occur on an additional docked day, which would be a newly inserted Flight Day 11; a final decision would occur no earlier than the end of Flight Day 6; if rack transfers to Tranquility do not occur during docked operations, they would occur in stage operations for the station crew.

Flight Day 7

- Spacewalk 2 by Behnken and Patrick (install ammonia jumper cables, thermal insulation and other outfitting items on Tranquility)
- Opening of fluid lines for cooling of Tranquility's avionics
- Ground activation of Tranquility's systems
- Depressurization of the Cupola/Tranquility hatch interface
- Canadarm2 grapple of the Cupola

Flight Day 8

- Cupola unberth from forward end of Tranquility and installation to nadir port of Tranquility
- Cupola vestibule outfitting

Flight Day 9

- Pressurized Mating Adapter-3 (PMA-3) unberth from Harmony zenith port and installation on forward port of Tranquility for micrometeoroid debris protection
- Cupola interior outfitting
- Crew off duty time
- Spacewalk 3 procedure review
- Spacewalk 3 campout by Behnken and Patrick in the Quest airlock

Flight Day 10

- Spacewalk 3 by Behnken and Patrick (PMA-3 cable installations, Cupola thermal insulation removal, Cupola launch lock release, video cable installations, and worksite handrail installations)
- Cupola robotic work station installation
- PMA-3 repressurization

Flight Day 11

- Endeavour to ISS transfer operations
- Joint Crew News Conference
- Rendezvous Tool Checkout
- Farewells and Hatch Closure
- ISS reboost, if required

Flight Day 12

- Endeavour undocking from ISS and flyaround
- Final separation from the ISS
- OBSS late inspection of Endeavour’s thermal heat shield
- OBSS berth

Flight Day 13

- Cabin stowage
- Flight Control System checkout
- Reaction Control System hot-fire test
- Deorbit Preparation Briefing
- Ku-band antenna stowage

Flight Day 14

- Deorbit preparations
- Payload Bay Door closing
- Deorbit burn
- KSC Landing

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MISSION PROFILE

CREW

Commander:	George D. Zamka
Pilot:	Terry W. Virts Jr.
Mission Specialist 1:	Nicholas J.M. Patrick
Mission Specialist 2:	Robert L. Behnken
Mission Specialist 3:	Stephen K. Robinson
Mission Specialist 4:	Kathyrn P. Hire

LAUNCH

Orbiter:	Endeavour (OV-105)
Launch Site:	Kennedy Space Center Launch Pad 39A
Launch Date:	Feb. 7, 2010
Launch Time:	4:39 a.m. EST (Preferred In-Plane launch time for 2/7)
Launch Window:	10 minutes
Altitude:	122 Nautical Miles (140 Miles) Orbital Insertion; 185 NM (213 Miles) Rendezvous
Inclination:	51.6 Degrees
Duration:	12 Days 18 Hours 37 Minutes

VEHICLE DATA

Shuttle Liftoff Weight:	4,521,961 pounds
Orbiter/Payload Liftoff Weight:	267,470 pounds
Orbiter/Payload Landing Weight:	200,694 pounds
Software Version:	OI-34

Space Shuttle Main Engines:

SSME 1:	2059
SSME 2:	2061
SSME 3:	2057
External Tank:	ET-134
SRB Set:	BI-141
RSRM Set:	109

SHUTTLE ABORTS

Abort Landing Sites

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

LANDING

Landing Date:	No Earlier Than Feb. 19, 2010
Landing Time:	11:16 p.m. EST
Primary landing Site:	Kennedy Space Center Shuttle Landing Facility

PAYLOADS

Tranquility Node 3/Cupola

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MISSION OBJECTIVES

MAJOR OBJECTIVES

1. Dock Endeavour to Pressurized Mating Adapter (PMA)-2 and perform mandatory crew safety briefing for all crew members.
2. Transfer mandatory quantities of water from the shuttle to the International Space Station.
3. Transfer and stow critical items.
4. Install Tranquility (Node 3) to Unity (Node 1) Port Common Berthing Mechanism using the space station robotic arm.
5. Connect Node 3 internal and external avionics and ammonia jumpers.
6. Activate and check out Node 3.
7. Support space station dual docked operations for the following visiting vehicles, if required.
   - 20 Soyuz undocking from Multipurpose Research Module 2 (MRM-2)
   - 22 Soyuz docking to MRM-2
8. Relocate the Cupola from Node 3 port CBM and install on Node 3 nadir CBM.
9. Install, activate, and check out the Water Recovery System (WRS) Distillation Assembly (DA), Fluids Control and Pump Assembly (FCPA) and Recycle Filter Tank Assembly (RFTA).
10. Transfer remaining cargo items.
11. Relocate PMA-3 from Node 2 Zenith to Node 3 Port.
12. Activate and check out the Cupola.
13. Perform daily station payload status checks.
14. Perform Program-approved spacewalk tasks.
15. Perform daily middeck activities to support payloads.
16. Transfer, install, activate, and check out the following Node 3 racks:
    - Advanced Resistive Exercise Device (ARED)
    - Air Revitalization System (ARS)
17. Remove Integrated Stowage Platforms from Node 3.
18. Perform payload research operations tasks.
19. Perform Node 3 outfitting tasks.
20. Perform Cupola outfitting tasks.
21. Transfer oxygen from Endeavour to the station Airlock High Pressure Gas Tanks (HPGTs).
22. Perform Program-approved spacewalk get-ahead tasks.

23. Reboost the station with the orbiter if mission resources allow and are consistent with station trajectory analysis and planning.

24. Perform imagery survey of the station exterior during shuttle flyaround after undocking.

25. Perform payloads of opportunity: RAMBO-2, MAUI, SEITE, and SIMPLEX.

26. Perform Program-approved intravehicular get-head tasks (the crew will have the option to perform if time is available).
    - Transfer, install, activate and checkout the Regen ECLSS racks
    - Perform Node 3 fuel cell water bus fill and connection to station bus in Node 1
    - Repressurize PMA3
    - Perform Cupola window shutter functional test
    - Unstow and assemble the JEM Airlock Vacuum Pump and Driver
    - Install the JAXA CGSE valve unit
    - Install Carbon Dioxide Removal Assembly (CDRA) bed in Node 3 rack
    - Unpack 20A middeck and ISP cargo

27. Relocate the Special Purpose Dexterous Manipulator to the lab power data grapple fixture.

28. Perform SDTO 13005-U, ISS Structural Life Validation and Extension, during Node 3/Cupola and PMA3 berthing events.

29. Perform SDTO 13005-U, ISS Structural Life Validation and Extension, during shuttle mated reboost.

30. Perform SDTO 13005-U, ISS Structural Life Validation and Extension, during shuttle undocking.

MISSION PERSONNEL

KEY CONSOLE POSITIONS FOR STS-130

	Flt. Director	CAPCOM	PAO
Ascent	Norm Knight	Rick Sturckow Steve Frick (Wx)	Kylie Clem
Orbit 1 (Lead)	Kwatsi Alibaruho	Danny Olivas Rick Sturckow (Flight Days 3 and 12)	Kylie Clem
Orbit 2	Gary Horlacher	Mike Massimino	Brandi Dean
Planning	Chris Edelen	Shannon Lucid	Pat Ryan
Entry	Norm Knight	Rick Sturckow Steve Frick (Wx)	Kylie Clem
Shuttle Team 4	Paul Dye	N/A	N/A
ISS Orbit 1	Royce Renfrew	Robert Hanley	N/A
ISS Orbit 2 (Lead)	Bob Dempsey	Hal Getzelman	N/A
ISS Orbit 3	Mike Lammers	Kathy Bolt	N/A
Station Team 4	Dana Weigel		

JSC PAO Representative at KSC for Launch – Josh Byerly

KSC Launch Commentator – Allard Beutel

KSC Launch Director – Mike Leinbach

NASA Launch Test Director – Jeff Spaulding

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STS-130 CREW

The STS-130 patch was designed by the crew to reflect both the objectives of the mission and its place in the history of human spaceflight. The main goal of the mission is to deliver Node 3 and the Cupola to the International Space Station. Node 3, named "Tranquility," will contain life support systems enabling continued human presence in orbit aboard the space station. The shape of the patch represents the Cupola, which is the windowed robotics viewing station, from which astronauts will have the opportunity not only to monitor a variety of station operations, but also to study our home planet. The image of Earth depicted in the patch is the first photograph of the Earth taken from the moon by Lunar Orbiter I on Aug. 23, 1966. As both a past and a future destination for explorers from the planet Earth, the moon is thus represented symbolically in the STS-130 patch. The space shuttle Endeavour is pictured approaching the station, symbolizing the space shuttle's role as the prime construction vehicle for the station.

The STS-130 crew is commanded by George Zamka (seated, right) and piloted by Terry Virts (seated, left). Standing from the left are mission specialists Nicholas Patrick, Robert Behnken, Kathryn Hire and Stephen Robinson.

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

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

STS-130 CREW BIOGRAPHIES

George Zamka

George Zamka, a colonel in the U.S. Marines, will serve as commander of STS-130. In that capacity, he has overall responsibility for the safety and execution of the mission. His role includes overseeing the crew and ensuring mission objectives are met, and commanding the shuttle during dynamic phases of flight including launch, landing, rendezvous and docking to the space station. He was pilot of STS-120, which flew in 2007 to deliver the Node 2 “Harmony” module to the orbiting complex.

Zamka has more than 15 days in space and has logged more than 4,000 flight hours in more than 30 different aircrafts.

Terry Virts

Terry Virts, a colonel in the U.S. Air Force, will serve as pilot for STS-130, which will be his first trip into space. He was selected by NASA in 2000. Most recently, he served as lead Ascent and Entry CAPCOM. He will be responsible for orbiter systems and robotic arm operations. He will also be outfitting both Tranquility and the Cupola and will fly Endeavour during undocking and the flyaround. He has logged more than 3,800 flight hours in more than 40 different aircraft.

Nicholas Patrick

This will be the second flight for Nicholas Patrick, who will serve as a mission specialist. Selected by NASA in 1998, he flew on STS-116 in 2006. On that mission, he accrued more than 12 days and 20 hours of spaceflight experience.

Robert Behnken

Robert Behnken, a lieutenant colonel in the U.S. Air Force, will serve as a mission specialist on STS-130. He flew on STS-123 in 2008. During the mission, Behnken served as mission specialist 1 for ascent and entry, performed three spacewalks, and operated both the space station robotic arm and the Dextre robot. He earned more than 19 hours of spacewalk experience during the 15-day mission.

Stephen Robinson

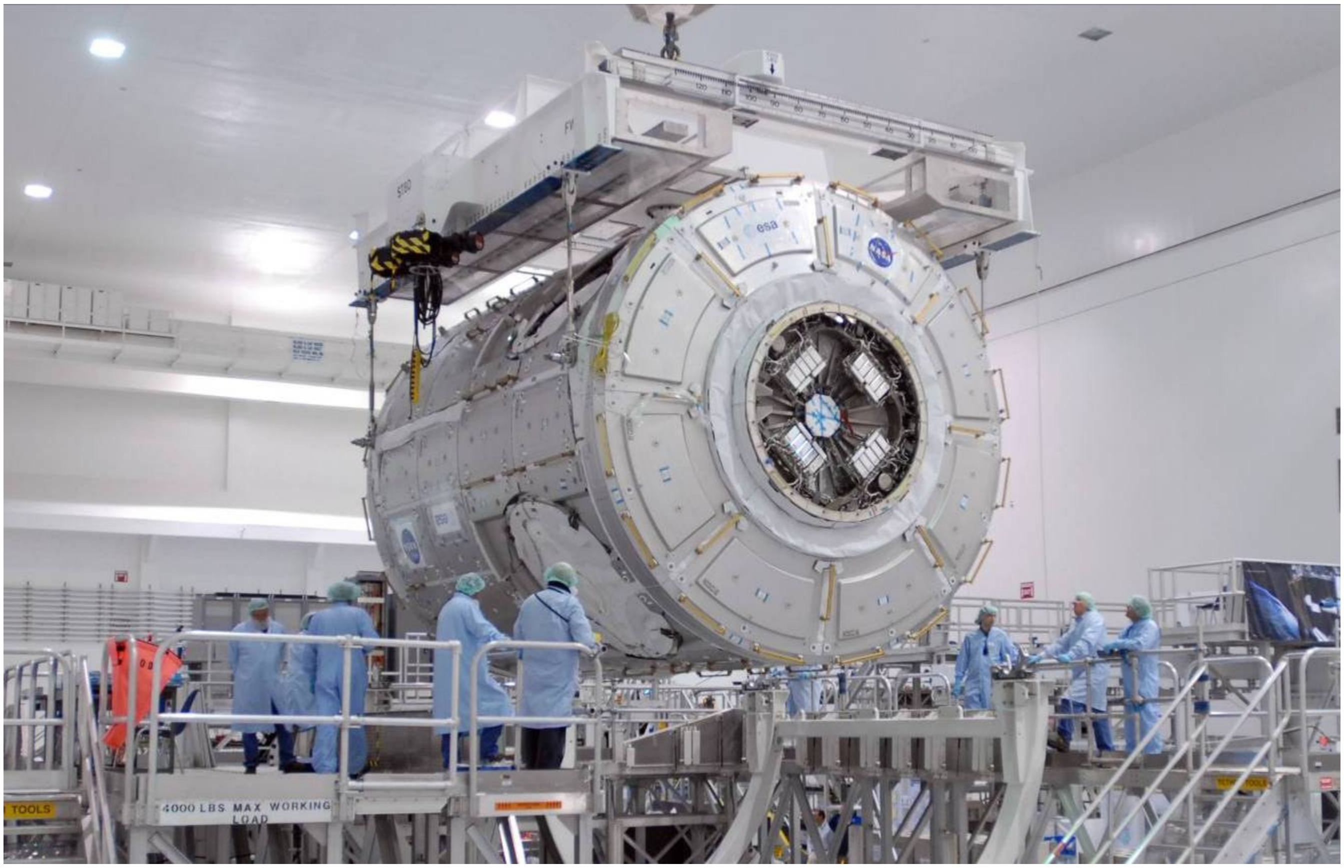
Veteran astronaut Stephen Robinson flew on STS-85 in 1997, STS-95 in 1998 and STS-114 in 2005. He has logged more than 831 hours in space, including more than 20 hours of spacewalking time. He has held various technical assignments within the Astronaut Office including testing space shuttle control software in the Shuttle Avionics Integration Laboratory and helping to develop the space station robot arm.

Kathryn Hire

On her second spaceflight, Kathryn Hire, a captain in the U.S. Navy Reserve, will be responsible for the shuttle robotic arm operations. She also will install and activate equipment in the Cupola. A former Kennedy Space Center engineer, she accumulated more than 15 days in space as the flight engineer on the STS-90 Neurolab mission.

PAYLOAD OVERVIEW

NODE 3

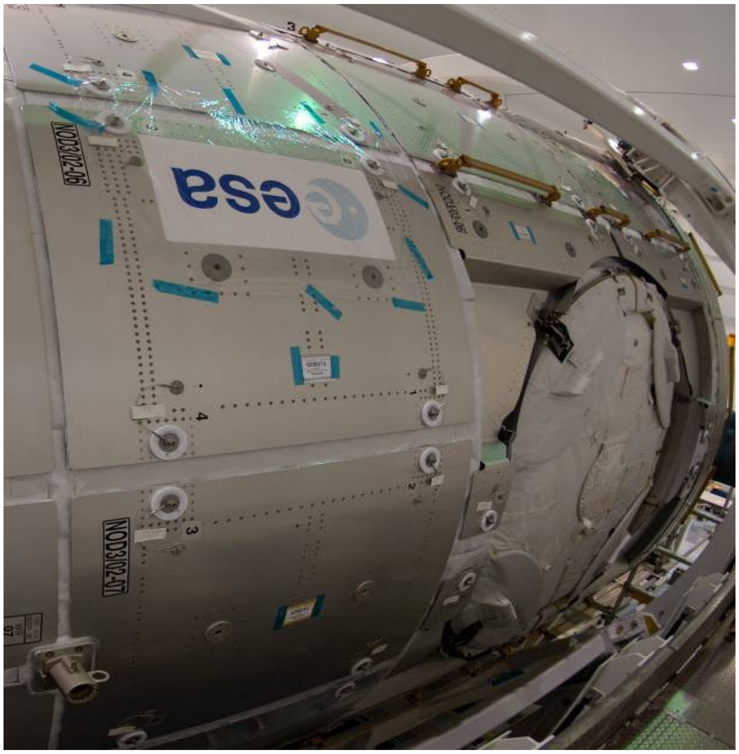


The European-built Node 3 being lowered onto a work stand in the Space Station Processing Facility at the Kennedy Space Center on May 26, 2009. This image shows a clear view of the uncovered docking mechanism to which the Cupola will be attached during its transport to the International Space Station in space shuttle Endeavour's cargo bay. (Image: NASA/Jim Grossmann)

The European-built Node 3 is the final one of the three International Space Station nodes, which will be launched into orbit. The nodes are the interconnecting elements between the various pressurized modules on the space station. They provide a shirtsleeve environment to allow the passage of crew members and equipment through to other station elements and provide vital functions and resources for the crew members and equipment.

Node 3 has systems, which provide many different functions and resources to the attached modules, and to itself, for maintaining a safe and ideal working and living environment on board the space station. Today's Node 3 is significantly different from the Node 3 that Europe initially agreed to develop back in 1997. It has evolved over the years from a connecting module into a very complex element, able to accommodate sophisticated crew and life support equipment, with many more capabilities than originally foreseen. Node 3 will support a six-member Expedition crew on the station by accommodating relevant hardware as well as supporting Node 3 cabin crew operations.

Node 3 consists of a pressurized cylindrical hull 4.5 meters (4.9 yards) in diameter with a shallow conical section enclosing each end. It is almost 7 meters (7.65 yards) long and will weigh together with the Cupola more than 13.5 tons at launch. The pressurized shell of Node 3 is constructed from aluminium alloys. This is covered with a multi-layer insulation blanket for thermal stability and around 75 sections of panelling to act as a protective shield against bombardment from space debris. This panelling is also constructed of an aluminium alloy, together with a layer of Kevlar and Nextel. Internal and external secondary structures are used to support the installation of equipment, piping and electrical harnesses. Two water loops (respectively low-temperature and moderate-temperature loops) allow the rejection of the heat generated inside the element to the station ammonia lines by means of two heat exchangers mounted on the external side of one end cone.



Side view of Node 3 clearly showing debris protection panels covering outer surface, one with inverted ESA logo, and one of the radial docking ports with its cover installed. (Image: ESA/S. Corvaja)

Node 3 can be considered in two halves. One half has a single docking port on one of the end cones where Node 3 will be docked to the station. This half also accommodates eight standard-sized racks, which will house relevant systems and equipment.

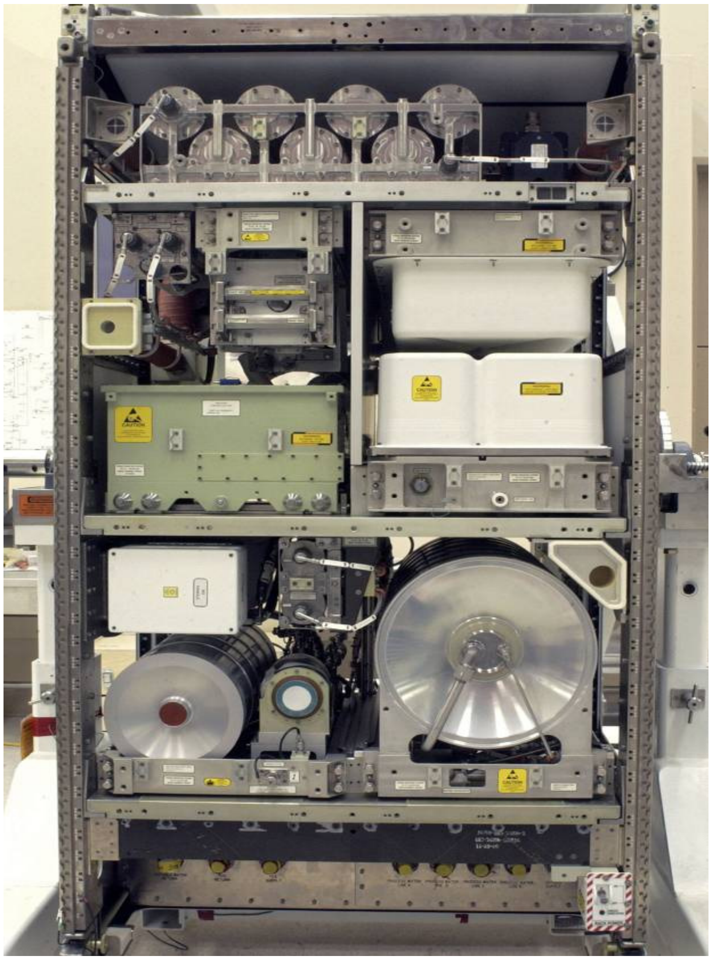
The other half consists of an additional five docking ports, one on the other end cone and four arranged around the circumference of the cylindrical main body of Node 3. Originally, the Habitation module, the Crew Return Vehicle and Pressurized Mating Adaptor 3 (PMA-3) were to be attached to Node 3 along with the Cupola. However, the first two elements were removed from the station configuration and PMA-3 will be moved to the port-side docking port of Node 3 once it is installed.

Internal view of Node 3 showing empty rack locations (bottom and right).
(Image: ESA/S. Corvaja)

In its launch configuration in the shuttle's cargo bay, Node 3 will have the Cupola attached to the end cone that will eventually face out from the station and be connected to PMA-3. Inside Node 3, the eight rack locations will be taken up with two avionics racks, three racks containing pallets with equipment and cargo for the station, with the three remaining racks remaining empty.

The Cupola berthed to Node 3 in launch configuration in the Space Station Processing Facility at the Kennedy Space Center in September 2009. (Image: ESA/S. Corvaje)

In its final in-orbit configuration Node 3 will look slightly different. The Cupola will be relocated to the Earth-facing port of Node 3 during the STS-130 mission. The three cargo pallet racks will be removed and returned on shuttle flight STS-131 in March 2010. In place of these three rack locations and the three empty rack locations will come six new racks which are already on the station. These include the second Air Revitalization System rack for air composition monitoring including carbon dioxide removal; an Oxygen Generation System rack for producing oxygen from water; Water Recovery System Racks 1 and 2 for urine and water processing; a Waste and Hygiene Compartment Rack for crew waste and hygiene processing and a second treadmill. Node 3 also will be outfitted with the Advanced Resistive Exercise Device for crew in-orbit physical exercise. All these racks and equipment are necessary since the station crew number was increased from three to six in the spring of 2009.



Water Recovery System rack 1 at the Kennedy Space Center on 17 October 2008 prior to launch. This rack is used as part of the systems to reclaim drinking-quality water from processing urine and waste water. (Image: NASA)

The atmosphere of Node 3's internal pressurized volume is controlled in terms of air pressure, temperature, humidity, velocity, particulate and microbial concentrations. Node 3 provides a piping network for the distribution of water (for fuel cells, drinking, waste and processes) between Node 1 and Node 3 and within Node 3. It also provides the line for the transfer of pretreated urine from Waste and Hygiene Compartment to Water Recovery System racks inside Node 3. Special lines and sectioning devices are adapted to distribute oxygen and nitrogen.

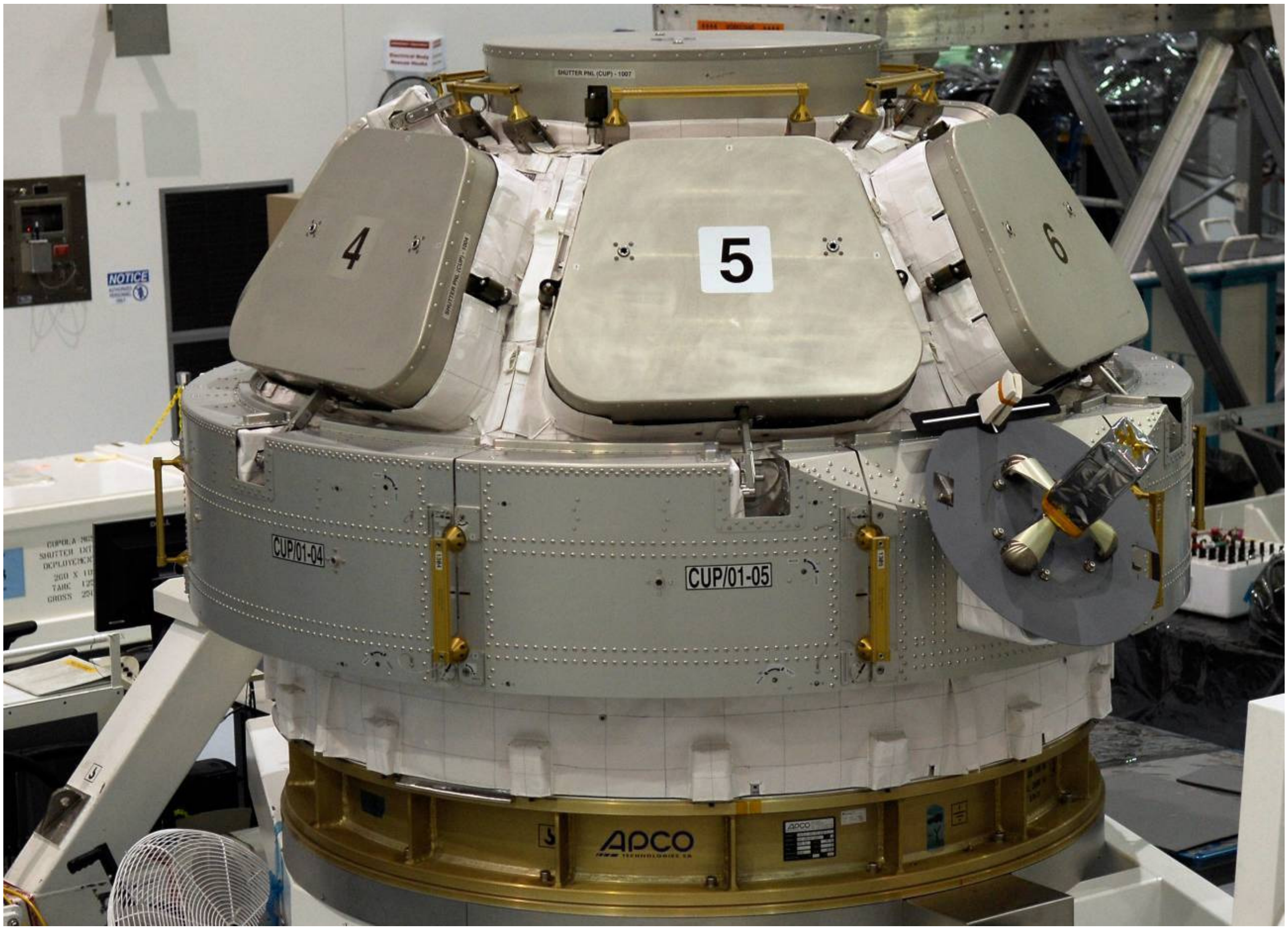
Fire detection is supported by two cabin smoke sensors and monitoring of electrical equipment. Other smoke sensors are used in particular racks. Fire suppression within predefined internal enclosures is by portable fire extinguisher.

Two avionics racks accommodate almost all the electronic units for the command and data handling, audio and video functions, and for the conversion and distribution of the electrical power from the station's solar arrays to the internal and attached elements. Command and control functions, as well as fault detection isolation and recovery algorithms, are supported by processing capabilities implemented in Node 3 computers.

Two of the three station nodes, Node 2 (Harmony) and Node 3, were made under a contract in Europe, while Node 1 (Unity) was made under a NASA contract in the United States. Node 1 has been in orbit since December 1998 while Node 2 has been in orbit since October 2007.

Nodes 2 and 3 are an evolution of Node 1. Thales Alenia Space put forward a design for Nodes 2 and 3, deriving from the experience with the Multi-purpose Logistics Modules that took into account new habitability requirements, making possible permanent crew quarters for four astronauts, with the capability to treat and recycle water, cater for personal hygiene and waste, jettison carbon dioxide and generate oxygen.

THE CUPOLA OBSERVATION MODULE



The European Space Agency-developed Cupola observation module at the Kennedy Space Center. (Image: NASA)

The Cupola will become a panoramic control tower for the International Space Station, a dome-shaped module with windows through which operations on the outside of the station can be observed and guided. It is a pressurized observation and work area that will accommodate command and control workstations and other hardware.

Through the robotics workstation, astronauts will be able to control the space station's robotic arm, which helps with the attachment and assembly of the various station elements, very much like the operator of a building crane perched in a control cabin. At any time, crew members in the Cupola can communicate with other crew members, either in another part of the station or outside during spacewalk activities.

Spacewalking activities can be observed from the Cupola along with visiting spacecraft and external areas of the station with the Cupola offering a viewing spectrum of 360 degrees.

Thus, the Cupola will have an important role in external space station activities.

However, the Cupola will operate as more than a workstation. With a clear view of Earth and celestial bodies, the Cupola will have scientific applications in the areas of Earth observation and space science as well as holding psychological benefits for the crew.

The Cupola is a 1.6-ton aluminium structure about 2 meters (2.18 yards) in diameter and 1.5 meters (1.64 yards) high. Its dome is a single forged unit with no welding. This gives it superior structural characteristics, which helped shorten the production schedule and lower overall costs.

The Cupola is a "shirtsleeve" module with six trapezoidal side windows and a circular top window of 80 cm (31.5 inches) in diameter, making it the largest window ever flown in space. Each window is built using very advanced technologies to defend the sensitive fused silica glass panes from years of exposure to solar radiation and debris impacts.

Produced from a single forging, Cupola's dome requires no welds. Shown is the actual flight unit dome just after machining in October 2002 at the Ratier-Figeac facility in Figeac, France. (Image: Thales Alenia Space)

The windows are protected by special external shutters, which can be opened by the crew inside the Cupola with the simple turn of a wrist. At the end of their tasks, the window shutters are closed to protect the glass from micrometeoroids and orbital debris and to prevent solar radiation from heating up the Cupola or to avoid losing heat to space.

Each window has three subsections: an inner scratch pane to protect the pressure panes from accidental damage from inside the Cupola; two 25 mm-thick (.98-inch) pressure panes to help maintain the cabin pressure and environment (the outer pane is a back-up for the inner pane); and a debris pane on the outside to protect the pressure panes from space debris when the Cupola shutters are open.

The 10-year in-orbit lifetime calls for user-friendly replacement of the windows while in orbit. The entire window or the individual scratch and debris panes can be replaced in space. To replace an entire window, an astronaut would first fit an external pressure cover over the window during a spacewalk.

NASA astronaut Terry Virts conducts a fit check of the robotic workstation of the Cupola observation module at the Space Station Processing Facility of NASA's Kennedy Space Center on 31 July 2008. (Image: NASA/Cory Huston)

Internally, the Cupola must provide functions to support the presence of two astronauts operating the instruments. Cupola's internal layout is dominated by upper and lower handrails around the inside of its cabin supporting most of the equipment and by "close-out" panels, which cover the harness and water lines attached to the Cupola. These internal panels form a pressurized air distribution system with the outer structure. These panels are removable to allow inspection and connection of different utilities.

Limited space for the crew and equipment means that the man-machine interfaces have to be optimized for entry and exit from the Cupola and carrying out workstation tasks and maintenance.

NODE 3 INTERNAL RACKS AND EQUIPMENT: ENVIRONMENTAL CONTROL

Two Water Recovery System racks delivered to the station in November 2008 and the Oxygen Generation System rack which was delivered in July 2006 will be relocated to Node 3 after its arrival. These racks make up the core of the Regenerative Environmental Control and Life Support System.

Water Recovery System Racks

The Water Recovery System racks use a series of chemical processes and filters to treat the astronauts' urine, perspiration and hygiene water, recycling about 93 percent of the fluid it receives to provide water clean enough to drink.

ESA astronaut Frank De Winne works with the Water Recovery System's Recycle Filter Tank Assembly in the Destiny laboratory of the International Space Station. (Image: NASA)

Recovering water from urine is achieved in the Urine Processor Assembly by spinning up a keg-sized distiller to create artificial gravity. Contaminants press against the side of the distiller while steam in the middle is pumped out. Water from the urine processor is combined with all other wastewaters and delivered to the Water Processor Assembly for treatment. The water processor removes free gas and solid materials such as hair and lint before the water goes through a series of multifiltration beds for further purification. Any remaining organic contaminants and micro-organisms are removed by a high-temperature catalytic reactor assembly.

This rigorous treatment creates water that meets stringent purity standards for human consumption. The purity of water is checked by sensors, with unacceptable water being reprocessed, and clean water being sent to a storage tank, ready for use by the crew. The Water Recovery System reduces the amount of water that needs to be delivered to the station by about 65 percent; i.e., about 2,850 liters over the course of a year.

The Expedition 19 crew with drink bags aboard the station in May 2009 after being given the all clear to drink water reclaimed by the Water Recovery System. (Image: NASA)

Oxygen Generation System Rack

The Oxygen Generation System produces oxygen for breathing air for the crew and laboratory animals, as well as for replacement of oxygen lost due to experiment use, airlock depressurization, module leakage and carbon dioxide venting. The system consists mainly of the Oxygen Generation Assembly and a Power Supply Module.

The Oxygen Generation Assembly electrolyzes, or breaks apart, water provided by the Water Recovery System, yielding oxygen and hydrogen as by-products. The oxygen is delivered to the cabin atmosphere, and the hydrogen is vented overboard. The Power Supply Module provides the power needed by the Oxygen Generation Assembly to electrolyze the water.

The Oxygen Generation System is designed to generate oxygen at a selectable rate and is capable of operating both continuously and cyclically. It provides up to 9 kg (19.8 pounds) of oxygen per day during continuous operation and a normal rate of about 5.5 kg (12 pounds) of oxygen per day during cyclic operation.

NASA astronaut Michael Barratt working with the Air Revitalization System (ARS) in the US laboratory in September 2009. (Image: NASA)

Air Revitalization System

The Air Revitalization System is one of the Environmental Control and Life Support Systems that will be relocated to the European-built Node 3 when it arrives at the station in February 2010. It provides carbon dioxide removal, trace contaminant control, and monitors the major constituents in the cabin atmosphere.

Crew-generated carbon dioxide is removed from the cabin atmosphere by sorbent beds that are designed to absorb carbon dioxide. The beds are regenerated upon exposure to heat and space vacuum. A Trace Contaminant Control System ensures that more than 200 various trace chemical contaminants generated from material off-gassing and crew metabolic functions in the habitable volume remain within allowable and safe concentration limits. The cabin atmosphere is analyzed by a mass spectrometer, measuring oxygen, nitrogen, hydrogen, carbon dioxide, methane and water vapour present in the cabin.

The Waste and Hygiene Compartment in the Destiny laboratory of the International Space Station on April 12, 2009. (Image: NASA)

Waste and Hygiene Compartment

The Waste and Hygiene Compartment in the U.S. Destiny laboratory was the second toilet facility to arrive on the station in November 2008 as part of the STS-126 mission. The first toilet facility is in the Russian Service Module.

This Russian-built toilet system is contained in a booth-like compartment and separately channels liquid and solid waste. While the solid waste goes to a holding tank, the Urine Processor Assembly, which forms a major part of the Water Recovery System racks delivered in November 2008, reclaims drinking water from crew members' urine.

ESA astronaut and Expedition 21 Commander Frank De Winne exercises on the COLBERT treadmill in the European-built Node 2 of the station in October 2009. (Image: NASA)

NODE 3 INTERNAL RACKS AND EQUIPMENT: CONDITIONING/EXERCISE EQUIPMENT

T2 COLBERT Treadmill

The T2 Combined Operational Load Bearing External Resistance Treadmill or COLBERT was temporarily installed in the European-built Node 2 in September 2009 as an important exercise device to keep the station crew healthy while in orbit and prepare them for return to Earth. It will be relocated to its permanent place in Node 3 after its attachment in February 2010. The T2 treadmill is adapted from a regular treadmill but designed so as not to shake the rest of the station. This vibration damping system does not use power and hence makes it more reliable.

The astronauts use elastic straps over the shoulders and round the waist to keep them in contact with the running belt and generate the foot force necessary to give the astronaut's bones and muscles a workout in the absence of gravity. The treadmill is also wider than the TVIS treadmill in the Zvezda Service Module of the station. Although it is built to handle 240,000 km (149,000 miles) of running, it will likely see about 60,000 km (37,282 miles) during its time in orbit.

Japan Aerospace Exploration Agency astronaut and Expedition 19/20 Flight Engineer Koichi Wakata exercising using the advanced Resistive Exercise Device (aRED) in Node 1 in May 2009. (Image: NASA)

Advanced Resistive Exercise Device

The advanced Resistive Exercise Device (aRED) will not take up a rack location in Node 3 but will be located in the new European-built module. It was developed to improve existing International Space Station exercise capabilities. It mimics the characteristics of traditional resistive exercises (weighted bars or dumbbells) by providing a more constant force throughout the range of motion. It offers traditional upper and lower-body exercises, such as squats, dead lift, heel raises, bicep curls, bench press, and many others.

The aRED uses vacuum cylinders to provide concentric workloads up to 270 kg (595 pounds), with an eccentric load up to 90 percent of the concentric force. The aRED also provides feedback to the astronaut during use and data to the NASA exercise physiologists. Flight surgeons, trainers and physiologists expect that the greater loads provided by aRED will result in more efficient and effective exercise, thereby preventing the muscle and bone loss that crew members sometimes experience during long space missions.

RENDEZVOUS & DOCKING

Space Shuttle Endeavour prepares to dock with the International Space Station during the STS-127 mission.

Endeavour's launch for the STS-130 mission is precisely timed to lead to a link up with the International Space Station about 220 miles above the earth. A series of engine firings during the first two days of the mission will bring the shuttle to a point about 50,000 feet behind the station. Once there, Endeavour will start its final approach. About 2.5 hours before docking, the shuttle's jets will be fired during what is called the terminal initiation burn. The shuttle will cover the final miles to the station during the next orbit.

As Endeavour moves closer to the station, its rendezvous radar system and trajectory control sensor will provide the crew with range and closing-rate data. Several small correction burns will place the shuttle about 1,000 feet below the station.

Commander George Zamka, with help from Pilot Terry Virts and other crew members, will manually fly the shuttle for the remainder of the approach and docking.

Zamka will stop Endeavour about 600 feet below the station. Once he determines there is proper lighting, he will maneuver the shuttle through a nine-minute backflip called the Rendezvous Pitch Maneuver, also known as a the R-bar Pitch Maneuver as Endeavour is in line with an imaginary vertical R-bar directly below the station. During this maneuver, station crew members Jeff Williams and Oleg Kotov will use digital cameras with 800mm and 400mm lenses, respectively, to photograph Endeavour's upper and bottom surfaces through windows of the Zvezda Service Module. The 800mm lens provides up to one-inch resolution and the 400mm lens up to three-inch resolution.

The photography is one of several techniques used to inspect the shuttle's thermal protection system for possible damage. Areas of special interest include the thermal protection tiles, the reinforced carbon-carbon of the nose and leading edges of the wings, landing gear doors and the elevon cove. The photos will be downlinked through the station's Ku-band communications system for analysis by systems engineers and mission managers.

When Endeavour completes its backflip, it will be back where it started, with its payload bay facing the station. Zamka then will fly the shuttle through a quarter circle to a position about 400 feet directly in front of the station. From that point he will begin the final approach to docking to the Pressurized Mating Adapter 2 at the forward end of the Harmony node.

The shuttle crew members will operate laptop computers that process the navigational data, the laser range systems, and Endeavour's docking mechanism.

Using a video camera mounted in the center of the Orbiter Docking System, Zamka will line up the docking ports of the two spacecraft. If necessary, he will pause the shuttle 30 feet from the station to ensure proper alignment of the docking mechanisms. He will maintain the shuttle's speed relative to the station at about one-tenth of a foot per second, while both Endeavour and the station are moving at about 17,500 mph. Zamka will keep the docking mechanisms aligned to a tolerance of three inches.

When Endeavour makes contact with the station, preliminary latches will automatically attach the two spacecrafts. The shuttle's steering jets will be deactivated to reduce the forces acting at the docking interface. Shock absorber springs in the docking mechanism will dampen any relative motion between the shuttle and station.

Once motion between the shuttle and the station has been stopped, the docking ring will be retracted to close a final set of latches between the two vehicles.

UNDOCKING, SEPARATION, AND DEPARTURE

At undocking time, the hooks and latches will be opened and springs will push the shuttle away from the station. Endeavour's steering jets will be shut off to avoid any inadvertent firings during the initial separation.

Once the shuttle is about two feet from the station and the docking devices are clear of one another, Virts will turn the steering jets back on and will manually control Endeavour within a tight corridor as the shuttle separates from the station.

Endeavour will move to a distance of about 450 feet, where Virts will begin to fly around the station. Virts will circle the shuttle around the station at a distance of 600 - 700 feet.

Once the shuttle completes 1.5 revolutions of the complex, Virts will fire Endeavour's jets to leave the area. The shuttle will begin to increase its distance from the station with each trip around the earth while ground teams analyze data from the late inspection of the shuttle's heat shield. However, the distance will be close enough to allow the shuttle to return to the station in the unlikely event that the heat shield is damaged, preventing the shuttle's safe re-entry.

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SPACEWALKS

Astronaut Robert L. Behnken, STS-123 mission specialist, participates in the mission's third scheduled session of extravehicular activity (EVA) as construction and maintenance continue on the International Space Station.

There are three spacewalks scheduled for the STS-130 mission.

Mission specialists Robert Behnken and Nicholas Patrick will spend a total of 19.5 hours outside the station on flight days 5, 6 and 8. Behnken, the lead spacewalker for the mission, will wear a spacesuit marked with solid red stripes. These will be his fourth, fifth and sixth spacewalk – his first three, during the STS-123 mission in 2008, totaled 19 hours and 19 minutes. Patrick , a first-time spacewalker, will wear an all-white suit.

When a spacewalk – also called extravehicular activity, or EVA for short – is going on outside, one crew member inside the International Space Station is assigned the job of intravehicular officer, or spacewalk choreographer. In this case, that crew member will be Mission Specialist Stephen Robinson, a veteran spacewalker with more than 20 hours of spacewalking experience under his belt. The first spacewalks will also require astronauts inside the station to be at the controls of the station's 58-foot-long robotic arm for the installation of the Tranquility Node. Pilot Terry Virts and Mission Specialist Kathryn Hire will be at the arm's controls for that operation.

Preparations will start the night before each spacewalk, when the astronauts spend time in the station's Quest Airlock. This practice is called the campout prebreathe protocol and is used to purge nitrogen from the spacewalkers' systems and prevent decompression sickness, also known as "the bends."

During the campout, the two astronauts performing the spacewalk will isolate themselves inside the airlock while the air pressure is lowered to 10.2 pounds per square inch, or psi. The station is kept at the near-sea-level pressure of 14.7 psi. The morning of the spacewalk, the astronauts will wear oxygen masks while the airlock's pressure is raised back to 14.7 psi for an hour and the hatch between the airlock and the rest of the station is opened. That allows the spacewalkers to perform their morning routines before returning to the airlock, where the air pressure is lowered again. Approximately 50 minutes after the spacewalkers don their spacesuits, the prebreathe protocol will be complete.

The procedure enables spacewalks to begin earlier in the crew's day than was possible before the protocol was adopted.

EVA-1

Duration: 6 hours, 30 minutes
EVA Crew: Behnken and Patrick
IV CREW: Robinson
Robotic Arm Operators: Virts and Hire

EVA Operations:

- Remove covers on Tranquility node berthing mechanism
- Disconnect Tranquility node cables in the shuttle cargo bay
- Move temporary storage platform from the special purpose dexterous manipulator to the P5/P6 truss segment
- Connect temporary Tranquility heating cables
- Connect Tranquility avionics cables

The first order of business, once Behnken and Patrick begin the first spacewalk of the mission, will be the preparation of the new Tranquility node for installation on the Unity node. Behnken will begin by moving to Unity and opening a flap that will expose Unity's centerline camera, which will be used to line up the two nodes during installation. He will then remove eight contamination covers from the port on Tranquility that will be docked to Unity.

While Behnken is doing so, Patrick will begin by installing an electric circuit on the avionics panel of Tranquility and removing cables that provide the node power from the shuttle before its installation.

After a trip back to the airlock to retrieve insulation and jumpers to be stored for use in a later spacewalk, both Behnken and Patrick will come together at the special purpose dexterous manipulator – or Dextre – to remove its orbital replacement unit temporary platform, a storage platform that allows the robot to carry spare parts. They will retrieve two handles from storage and install them on the robot and the platform, then work together to release the four fasteners connecting the platform to the robot. Behnken will carry the platform to a stowage bin on the left side of the station's truss, where it will be available for use as a backup to a new enhanced platform that will be installed on Dextre during the STS-132 mission.

While that work is going on, Virts and Hire will have unloaded Tranquility from Endeavour's cargo bay and installed it on the Unity node, at which point Behnken and Patrick can begin hooking it up. Patrick will begin by connecting Tranquility's heater cables to Unity to provide a temporary power supply. Behnken, meanwhile, will connect eight avionics cables between the nodes.

EVA-2

Duration: 6 hours, 30 minutes
EVA Crew: Behnken and Patrick
IV Crew: Robinson
Robotic Arm Operator: None

EVA Operations

- Install insulation covers on Tranquility trunnions and keel pin
- Connect Tranquility ammonia cables
- Install Tranquility atmospheric control and resupply system vent relief valve

Behnken and Patrick will spend the first four hours of their second spacewalk connecting the ammonia loops on the new Tranquility node to those of the Destiny laboratory. There are two loops, with two lines apiece, each of which must be connected to both Tranquility and Destiny and routed through a bracket on Unity, which connects Tranquility to Destiny. Behnken will open one of the loops so that ammonia will be allowed to flow to the node from the station's external thermal control system.

Once that task is complete, the spacewalkers will spend the remaining time outfitting Tranquility. Behnken will install insulation on the keel pin and four trunnions that connected Tranquility to the shuttle while it was in transit. He will also set up the centerline camera on the nadir, or Earth-facing, port of Tranquility and release the launch locks that held the petals of the port's berthing mechanism in place during launch. The Cupola will be moved to that port the following day.

While Behnken works on that, Patrick will install eight handrails and a vent valve on Tranquility. The handrails will be used by spacewalkers to move along the exterior of the node, and the vent valve will be part of the atmospheric control and resupply system.

That will be Patrick's final task of the spacewalk. Behnken will wrap up his duties by removing tape on five gap spanners that act as a bridge for astronauts between areas on Tranquility without handrails.

EVA-3

Duration: 6 hours, 30 minutes
EVA Crew: Behnken and Patrick
IV Crew: Robinson
Robotic Arm Operator: None

EVA Operations

- Connect pressurized mating adapter 3 heater and data cables
- Open ammonia flow to Tranquility
- Disconnect temporary Tranquility heating cables
- Remove Cupola insulation covers
- Release Cupola window covers launch locks
- Install Tranquility handrails, worksite interfaces and gap spanners

Tranquility outfitting will continue on the third and final spacewalk of the mission. Behnken will open the second of the two ammonia loops he and Patrick routed during the previous spacewalk, and disconnect the temporary power cables Patrick set up during the first spacewalk.

By this time in the mission, the Cupola will have been moved to its permanent home on Tranquility's nadir docking port, and the pressurized mating adapter 3 will have taken its place on the end of the node. That leaves Patrick and Behnken free to begin getting them into the right configuration. Patrick will connect the mating adapter's heater and data cables to Tranquility. Then he will work with Behnken to remove six panels of insulation over the Cupola's windows.

With the insulation out of the way, Patrick will be able release the three bolts on each of the seven window's covers; those bolts held the covers in place during Endeavour's launch. While he does so, Behnken will get back to outfitting Tranquility by installing four worksite interfaces and five more handrails.

At this point the two spacewalkers will come back together to route cables for the station's video signal converter, or VSC. The VSC is used with power and data grapple fixtures, of PDGFs, which provide locations on the exterior of the station's modules for the station's robotic arm to attach to.

Behnken and Patrick will wrap up the last of the spacewalk activities for the mission with two final tasks. First, they will close off the centerline camera that was used on the zenith, or space-facing, port of the Harmony node when the pressurized mating adapter 3 was attached it. And finally, they will each remove six clamps and the flex hose rotary coupler on the port 1 segment of the station's truss.

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EXPERIMENTS

The space shuttle and International Space Station have an integrated research program that optimizes the use of shuttle crew members and long-duration space station crew members to address research questions in a variety of disciplines.

For information on science on the station, visit

http://www.nasa.gov/mission_pages/station/science/index.html

or

http://www.nasa.gov/mission_pages/station/science/experiments/

Detailed information is located at

http://www.nasa.gov/mission_pages/station/science/experiments/Expedition.html

DETAILED TEST OBJECTIVES AND DETAILED SUPPLEMENTARY OBJECTIVES

Detailed Test Objectives (DTOs) are aimed at testing, evaluating or documenting systems or hardware or proposed improvements to hardware, systems and operations. Many of the DTOs on this mission are to provide additional information for engineers working for the Constellation Program as they develop requirements for the rocket and crew module that will return humans to the moon.

DTO 900 Solid Rocket Booster Thrust Oscillation

The Space Shuttle Program is continuing to gather data on pressure oscillation, or periodic variation, a phenomenon that regularly occurs within solid rocket motors through the remaining Shuttle flights. The data obtained from five flights designated to acquire pressure oscillation data have provided a better understanding of solid rocket motor dynamics. The collection of these additional data points will provide greater statistical significance of the data for use in dynamic analyses of the four segment motors. These analyses and computer models will be used for future propulsion system designs.

The pressure oscillation that is observed in solid rocket motors is similar to the hum made when blowing into a bottle. At 1.5 psi, or pounds per square inch, a pressure wave will move up and down the motor from the front to the rear, generating acoustic noise as well as physical loads in the structure. These data are necessary to help propulsion engineers confirm modeling techniques of pressure oscillations and the loads they create. As NASA engineers develop alternate propulsion designs for use in NASA, they will take advantage of current designs from which they can learn and measure.

In an effort to obtain data to correlate pressure oscillation with the loads it can generate, the Space Shuttle Program is continuing to use the Enhanced Data Acquisition System to gather detailed information.

EXPERIMENTS

The STS-130/20A mission continues the transition from a focus on International Space Station (ISS) assembly to continuous scientific research beginning in the fall of 2010.

Nearly 150 operating experiments in human research; biological and physical sciences; technology development; Earth observation, and educational activities will be conducted aboard the station, including several pathfinder investigations under the auspices of the station's new role as a U.S. National Laboratory.

In the past, assembly and maintenance activities have dominated the available time for crew work. But as completion of the orbiting laboratory nears, additional facilities and the crew members to operate them will enable a measured increase in time devoted to research as a national and multinational laboratory.

Among the new National Laboratory Pathfinder (NLP) investigations is a new experiment that will look at the effect of microgravity on cells of the *Jatropha curcas* plant. The purpose of the study is to assess the effects on cell structure, growth and development and breeding process for commercial use. Accelerated breeding could allow *J. curcas* to be used as an alternative energy crop (or biofuel) on Earth.

The National Lab plant experiment joins plant experiments from NASA, the Canadian Space Agency, the Japan Aerospace Exploration Agency and the Russian Federal Space Agency that are looking at plant development for potential use as resources for future long-duration spaceflights, fundamental research into plant growth and development, and horticulture and crop monitoring.

SHORT-DURATION U.S. INTEGRATED RESEARCH TO BE COMPLETED DURING STS-130/20A

Maui Analysis of Upper Atmospheric Injections (MAUI) will observe the space shuttle engine exhaust plumes from the Maui Space Surveillance Site in Hawaii. The observations will occur when the Space Shuttle fires its engines at night or twilight. A telescope and all-sky imagers will take images and data while the space shuttle flies over the Maui site. The images will be analyzed to better understand the interaction between the spacecraft plume and the upper atmosphere of Earth.

National Lab Pathfinder – Vaccine – 7 (NLP-Vaccine-7) is a commercial payload serving as a pathfinder for the use of the ISS as a National Laboratory after station assembly is complete. It contains several different pathogenic (disease causing) organisms. This research is investigating the use of space flight to develop potential vaccines for the prevention of different infections caused by these pathogens on Earth and in microgravity.

Ram Burn Observations – 2 (RAMBO-2) 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.

Shuttle Exhaust Ion Turbulence Experiments (SEITE) will use space-based sensors to detect the ionospheric turbulence inferred from the radar observations from a previous space shuttle Orbital Maneuvering System (OMS) burn experiment using ground-based radar.

Shuttle Ionospheric Modification with Pulsed Localized Exhaust Experiments (SIMPLEX) will investigate plasma turbulence driven by rocket exhaust in the ionosphere using ground-based radars by providing direct measurements of exhaust flow sources and developing quantitative models of plasma turbulence that degrades tracking and imaging radars. This is a payload of opportunity on every shuttle flight based on available OMS fuel, crew time, and overflight of ground sites.

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.

Spinal Elongation and its Effects on Seated Height in a Microgravity Environment (Spinal Elongation) investigation provides quantitative data about the amount of change that occurs in the seated height due to spinal elongation in space. Spinal elongation has been observed to occur in crew members during space flight, but has only previously been recorded in the standing position. The seated height data in microgravity is considered necessary to correctly identify the seated height projections of the crew in the Orion configuration. The projections of seated height will provide data on the proper positioning of the seats within the vehicle, adequate clearance for seat stroke in high acceleration impacts, fit in seats, correct placements of seats with respect to each other and the vehicle and the proper orientation to displays and controls.

Japan Aerospace Exploration Agency Research

Mycological Evaluation of Crew Exposure to ISS Ambient Air (Myco) evaluates the risk of inhalation of microorganisms when breathing and of adhesion to the skin, which is exposed to ambient air during a stay in the ISS. Samples collected from the nasal cavity, pharynx and the skin of crew members during the pre/in/post flight periods will be examined by teams on Earth, focusing on fungi, which act as strong allergens in a living environment.

SAMPLES/HARDWARE RETURNING FROM THE SPACE STATION:

U.S. Research

Bisphosphonates as a Countermeasure to Space Flight Induced Bone Loss (Bisphosphonates) will determine whether antiresorptive agents (help reduce bone loss), in conjunction with the routine in-flight exercise program, will protect station crew members from the regional decreases in bone mineral density documented on previous station missions.

Commercial Generic Bioprocessing Apparatus Science Insert – 03 (CSI-03) is the third set of investigations in the CSI program series. The CSI program provides the K - 12 community opportunities to utilize the unique microgravity environment of the ISS as part of the regular classroom to encourage learning and interest in science, technology, engineering and math. CSI-03 will examine the painted lady butterfly and Monarch butterfly in space.

Validation of Procedures for Monitoring Crew Member Immune Function (Integrated Immune) will assess the clinical risks resulting from the adverse effects of space flight on the human immune system and will validate a flight-compatible immune monitoring strategy. Researchers collect and analyze blood, urine and saliva samples from crew members before, during and after space flight to monitor changes in the immune system.

Materials Science Laboratory – Columnar-to-Equiaxed Transition in Solidification Processing and Microstructure Formation in Casting of Technical Alloys under Diffusive and Magnetically Controlled Convective Conditions (MSL-CETSOL and MICAST) are two investigations that support research into metallurgical solidification, semiconductor crystal growth (Bridgman and zone melting), and measurement of thermophysical properties of materials. This is a cooperative investigation with the European Space Agency (ESA) and NASA for accommodation and operation aboard the ISS. Microgravity offers a unique opportunity to obtain well-controlled solidification conditions for these alloys.

Nutritional Status Assessment (Nutrition) is the most comprehensive inflight 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.

National Aeronautics and Space Administration Biological Specimen Repository (Repository) is a storage bank that is used to maintain biological specimens over extended periods of time and under well-controlled conditions. Biological samples from the ISS, including blood and urine, will be collected, processed and archived during the preflight, inflight and postflight phases of space station missions. This investigation has been developed to archive biosamples for use as a resource for future spaceflight-related research.

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. Previous microbial analysis of spacecraft only identify microorganisms that will grow in culture, omitting greater than 90 percent of all microorganisms including pathogens such as Legionella (the bacterium which causes Legionnaires' disease) and Cryptosporidium (a parasite common in contaminated water). The incidence of potent allergens, such as dust mites, has never been systematically studied in spacecraft environments and microbial toxins have not been previously monitored.

Canadian Space Agency

The Cambium investigation is one in a pair of investigations which utilizes the Advanced Biological Research System (ABRS). Cambium seeks definitive evidence that gravity has a direct effect on cambial cells (cells located under the inner bark where secondary growth occurs) in willow, *Salix babylonica*. The Cambium research is needed to help understand the fundamental processes by which plants produce cellulose and lignin, the two main structural materials found in plant matter.

European Space Agency Research

Mental Representation of Spatial Cues During Space Flight (3D-Space) investigates the effects of exposure to microgravity on the mental representation of spatial cues by astronauts during and after space flight. The absence of the gravitational frame of reference during spaceflight could be responsible for disturbances in the mental representation of spatial cues, such as the perception of horizontal and vertical lines, the perception of objects‘ depth, and the perception of targets‘ distance. This experiment involves comparisons of preflight, inflight, and postflight perceptions and mental imagery, with special reference to spaceflight-related decreases in the vertical component of percepts.

Japan Aerospace Exploration Agency Research

RNA interference and protein phosphorylation in space environment using the nematode *Caenorhabditis elegans* (CERISE) is an experiment that addresses two scientific objectives. The first is to evaluate the effect of microgravity on ribonucleic acid (RNA) interference. The second is to study how the space environment effects protein phosphorylation (addition of a phosphate molecule) and signal transduction in the muscle fibers of gene knock-downed *Caenorhabditis elegans*.

Passive Dosimeter for Lifescience Experiment in Space (PADLES) measures radiation exposure levels onboard the ISS. PADLES uses passive and integrating dosimeters to detect radiation levels. These dosimeters are located near the biological experiment facilities and on the end of the Japanese Experiment Module, Kibo. The proposed research seeks to survey the radiation environment inside the Kibo by using Area dosimeter. The dosimeters measure absorbed doses, equivalent doses and Liner Energy Transfer (LET) distributions.

EXPERIMENTS AND HARDWARE TO BE DELIVERED TO INTERNATIONAL SPACE STATION

U.S. Research

Validation of Procedures for Monitoring Crew Member Immune Function (Integrated Immune) will assess the clinical risks resulting from the adverse effects of space flight on the human immune system and will validate a flight-compatible immune monitoring strategy.

Researchers collect and analyze blood, urine and saliva samples from crew members before, during and after space flight to monitor changes in the immune system.

National Lab Pathfinder – Cells – 3 (NLP-Cells-3) assesses the effects of microgravity on cells of the *Jatropha curcas* plant. The purpose of the study is to verify the potential effects of microgravity on improving characteristics such as cell structure, growth and development, for accelerating the breeding process of new cultivars of *J. curcas* for commercial use. Accelerated breeding could allow *J. curcas* to be used as an alternative energy crop (or biofuel). This would allow the inclusion of a major biofuel plant as an alternative energy crop for the United States.

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

Transgenic Arabidopsis Gene Expression System (TAGES) investigation is one in a pair of investigations that use the Advanced Biological Research System facility. TAGES uses *Arabidopsis thaliana*, thale cress, with sensor promoter-reporter gene constructs that render the plants as biomonitors (an organism used to determine the quality of the surrounding environment) of their environment using real-time nondestructive Green Fluorescent Protein imagery and traditional postflight analyses. The TAGES research is needed to help understand how plants perceive stresses in the spaceflight environment such as drought, inadequate light, or uneven temperature. Such genetically modified plants and imaging tools could be used as “biosensors” for characterizing other spacecraft environments. These same tools could also be used to further develop and analyze plants that could grow in either lunar or Martian bases.

Analysis of a Novel Sensory Mechanism in Root Phototropism (Tropi) will observe growth and collect samples from 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.

European Space Agency Research

The Long Term Microgravity: A Model for Investigating Mechanisms of Heart Disease with New Portable Equipment (Card) experiment studies blood pressure decreases when the human body is exposed to microgravity. In order to increase the blood pressure to the level it was on Earth, salt is added to the crew members‘ diet. To monitor this, blood pressure readings and urine samples are performed at different intervals during the mission. This study will examine the relationship between salt intake and the cardiovascular system when exposed to the microgravity environment. Results from this may lead to additional health safety measures for astronauts to protect them on long duration missions.

Japan Aerospace Exploration Agency Research

The effect of long-term microgravity exposure on cardiac autonomic function by analyzing 24-hours electrocardiogram (BioRhythms) will examine the effect of long-term microgravity exposure on cardiac autonomic function by analyzing 24-hour eletrocardiogram. The objective of this study is to examine the effect of long-term microgravity exposure on cardiac autonomic function by monitoring pre; in; and post-flight 24-hours electrocardiogram. The results will be analyzed for improving crew health care technology in long-duration space flight.

Educational Payload Observation (JAXA-EPO) aims to excite everyone's interest in microgravity research. Activities will include educational events and artistic activities with astronauts on orbit. These artistic activities will enlighten the general public about microgravity research and human space flight.

Production of high performance nanomaterials Nanoskeleton in microgravity (Nanoskeleton) clarifies the gravity effect such as the flotation of oil, sedimentation and convection on the generated TiO2 crystal on hexagonal arranged micelle tube structure.

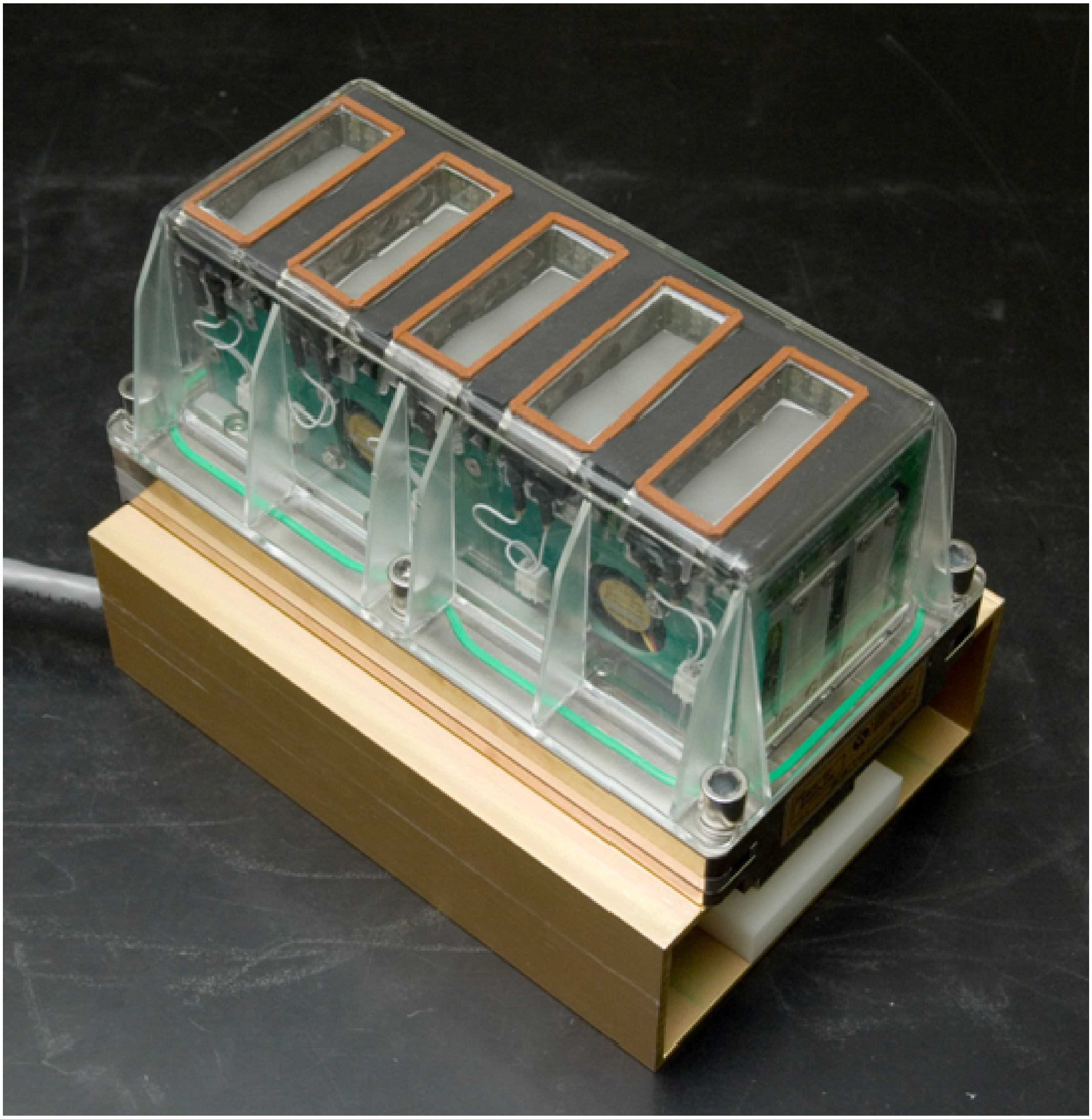
Passive Dosimeter for Lifescience Experiment in Space (PADLES) measures radiation exposure levels onboard the ISS. PADLES uses passive and integrating dosimeters to detect radiation levels. These dosimeters are located near the biological experiment facilities and on the end of the Japanese Experiment Module, Kibo. The proposed research seeks to survey the radiation environment inside the Kibo by using Area dosimeter. The dosimeters measure absorbed doses, equivalent doses and LET distributions.

TROPI-2: STUDYING PLANT GROWTH IN SPACE

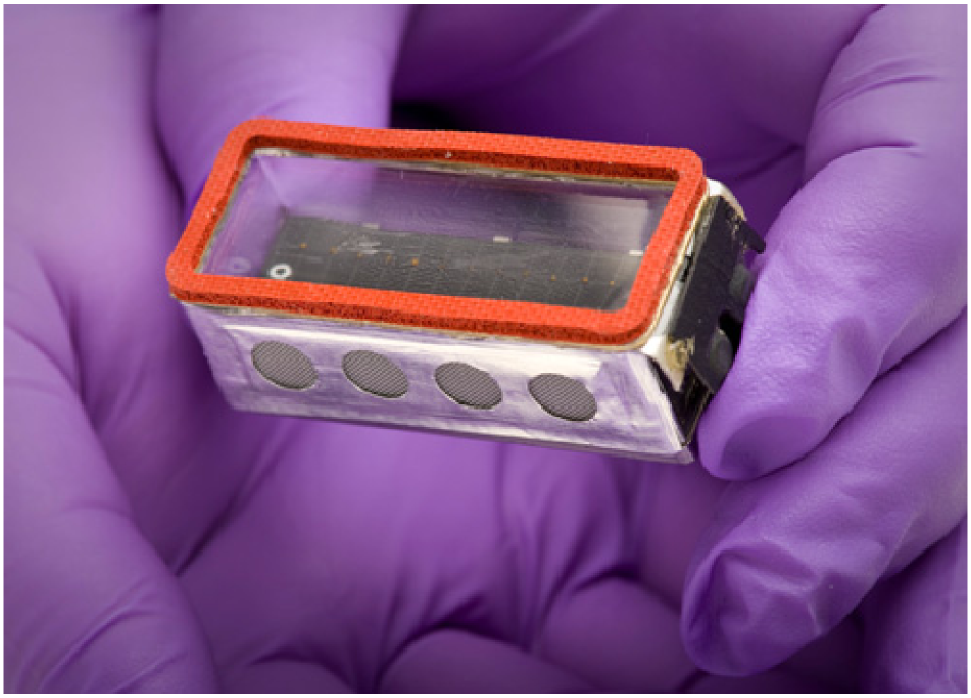
NASA scientists will send seeds into space to better understand how and why plants grow differently in microgravity than on Earth. In addition to carrying a third connecting-module, called Tranquility, and a seven-windowed control room for robotics to the International Space Station, STS-130 space shuttle Endeavour and its crew will deliver the Tropi-2 experiment to space. After running two six-day experiments studying the early stages of plant growth, Tropi-2 will return to Earth in STS-131 space shuttle Discovery. Scientists will use data from these experiments to better understand how light and gravity affect plant growth. Future astronauts may be able to grow plants as part of life support systems on long-duration space missions to the moon or Mars.

Mission Overview

Tropi-2 is a semi-autonomous space-based experiment to study *Arabidopsis thaliana* (thale cress) seedling sprouts to observe their response to light and gravity at a cellular level. Specifically, the seeds will be grown in microgravity – the weightlessness experienced on the station – or at gravity levels on Earth, the moon and Mars. Tropi-2 derives its name from the term "tropism." For example, phototropism is a plant's growth response to a direct source of light, and gravitropism is its growth in response to the pull of gravity.



European Modular Cultivation System (EMCS) Experiment Container with five Tropi Experiment Cards (ECs). Photo credit: NASA Ames/Tom Trower



A Tropi Experiment Card (EC) with seeds.
Photo credit: NASA Ames/Dominic Hart

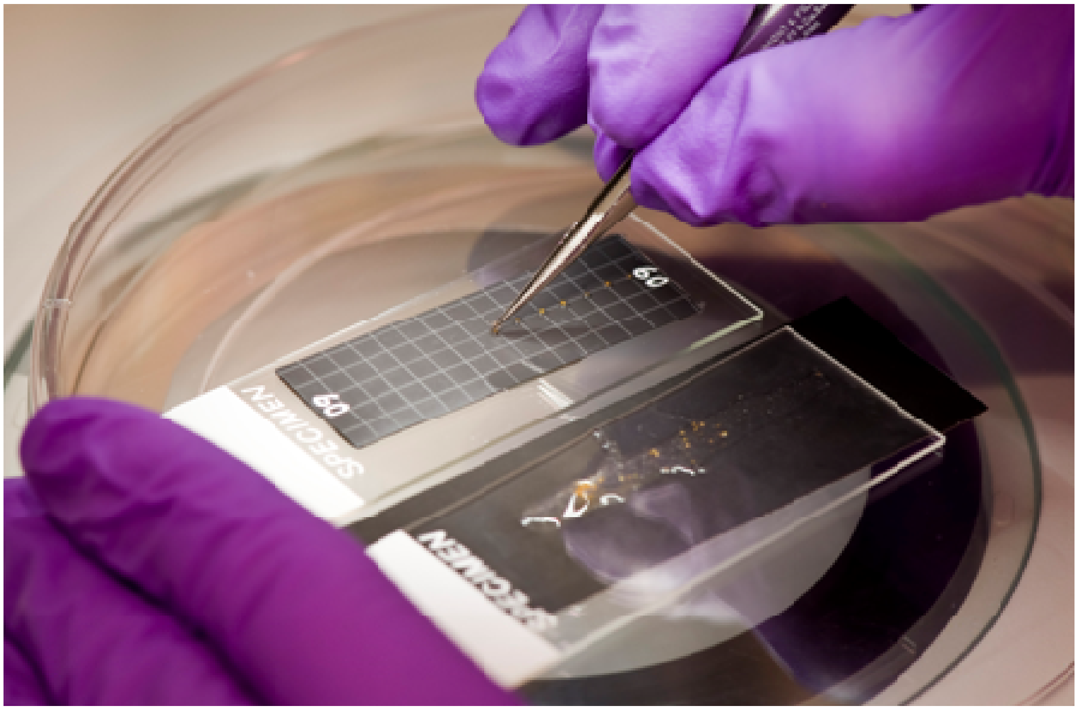
The International Space Station Non-Exploration Projects Office at NASA's Ames Research Center, Moffett Field, Calif., along with the principal investigator team at Miami University, Oxford, Ohio, prepared 16 Experiment Containers (ECs), each containing five seed cassettes, by inserting more than 1,000 tiny sterilized seeds crossways onto a gridded membrane. The gridded membrane has lines that measure 3 millimeters-by-3 millimeters to help scientists measure the plants' growth – approximately 10 millimeters during a six-day experiment. Using a microscope and tweezers, scientists precisely embedded the seeds, which are about the size of a grain of sand, into guar gum, an adhesive, to keep them in place during their launch, orbit and re-entry phase of the mission.

The European Space Agency (ESA) developed the European Modular Cultivation System (EMCS), a facility focused on plant biology research located on the station that can house up to eight experiment containers at a time. Once in orbit, NASA astronauts Jeff Williams and T.J. Creamer will place the Tropi-2 experiment containers in the EMCS incubator to conduct the experiment in a temperature, humidity, and atmosphere-controlled environment.

Once the experiment begins, the seeds will be continuously spun in centrifuges, to achieve varying levels of gravity, and given fresh water. The first three days are considered the "growth phase" of the experiment, during which the ECs will be exposed to gravity forces equivalent to Earth's. For the first 32 hours the seeds will remain in the darkness, with the exception of a four-hour exposure to red LED lights. From then until the end of the "growth phase," they will be illuminated with white LED lights. The last three days of the experiment are called the "stimulation phase," when they will be "photostimulated" – or constantly exposed to red, blue or a combination of red and blue LED lights and exposed to either microgravity, or levels of gravity found on Earth, the moon or Mars. During the final phase of the experiment, cameras in the centrifuges will take three images per minute to collect the majority of the scientists' data.

After the experiment is completed, Williams and Creamer will remove the containers from the incubator and take out the cassettes with seedlings. Then they will place the cassettes into the station's Minus Eighty (Degrees Celsius) Laboratory Freezer (MELFI) where they will remain until STS-131 space shuttle Discovery undocks. However, before Discovery undocks, astronauts will place the cassettes in precooled double cold bags as they transfer them from the MELFI to the Glacier freezer on the space shuttle. The samples are frozen to ensure they are preserved and to prevent any ribonucleic acid (RNA) degradation, prior to analysis on Earth.

Tropi-2 is based on an earlier gravitropism and phototropism experiment, Tropi, which flew to the station on STS-121 and STS-115 in 2006. While this earlier experiment successfully obtained data in microgravity, no moon or Mars gravity levels data were obtained.



Sterilized Arabidopsis thaliana seeds in guar gum adhesive are carefully positioned on a gridded membrane. Photo credit: NASA Ames/Dominic Hart

Relevance to Space Exploration and Earth Science

During long-duration space exploration, astronauts will need regenerative sources of food, as well as a method to recycle carbon dioxide into breathable oxygen. As new information about how plants grow in microgravity emerges, scientists will refine existing sustainable plant-based life support systems. Further understanding of how plants grow and develop at a molecular level can lead to advancements in agricultural production on Earth.

The Tropi-2 Team

NASA Ames' International Space Station Non-Exploration Projects Office will manage the Tropi-2 experiment for the Advanced Capabilities Division and Exploration Technology Development Program of the Exploration Systems Mission Directorate at NASA Headquarters, Washington. The Multi-Mission Operations Center at NASA Ames, along with the Norwegian User Support and Operations Centre in Trondheim, will provide mission operations support and receive Tropi-2 science data in real-time. John Z. Kiss, professor and chair of the Botany Department at Miami University, Oxford, Ohio, is the Tropi-2 principal investigator; Richard E. Edelmann of Miami University and Melanie J. Correll of the University of Florida, Gainesville, are Tropi-2 co-investigators; Kenny Vassigh of NASA Ames, is the Tropi-2 project manager; Marianne Steele of NASA Ames, is the Tropi-2 project scientist; Tom Luzod of NASA Ames is the Tropi-2 project engineer, David Heathcote of NASA Ames is the Tropi-2 operations lead.

For More Information

The Tropi-2 mission Web site is located at: http://spacebiosciences.arc.nasa.gov/STS130.html

ADDITIONAL STATION RESEARCH FROM NOW UNTIL THE END OF EXPEDITION 21/22

Human Research and Countermeasure Development for Exploration

Cardiovascular and Cerebrovascular Control on Return from ISS (CCISS) will study the effects of long-duration space flight on crewmembers' heart functions and their blood vessels that supply the brain. Learning more about the cardiovascular and cerebrovascular systems could lead to specific countermeasures that might better protect future space travelers. This experiment is collaborative effort with the Canadian Space Agency. (NASA/CSA)

Sleep-Wake Actigraphy and Light Exposure During Spaceflight-Long (Sleep-Long) examines the effects of space flight and ambient light exposure on the sleep-wake cycles of the crewmembers during long-duration stays on the space station. (NASA)

Nutritional Status Assessment (Nutrition) is the most comprehensive inflight 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. (NASA)

The National Aeronautics and Space Administration Biological Specimen Repository (Repository) is a storage bank that is used to maintain biological specimens over extended periods of time and under well-controlled conditions. Biological samples from the International Space Station (ISS), including blood and urine, will be collected, processed and archived during the preflight, inflight and postflight phases of ISS missions. This investigation has been developed to archive biosamples for use as a resource for future space flight related research. (NASA)

Validation of Procedures for Monitoring Crew Member Immune Function (Integrated Immune) assesses the clinical risks resulting from the adverse effects of space flight on the human immune system and will validate a flight-compatible immune monitoring strategy. Researchers collect and analyze blood, urine and saliva samples from crewmembers before, during and after space flight to monitor changes in the immune system. Changes in the immune system are monitored by collecting and analyzing blood and saliva samples from crewmembers during flight and blood, urine, and saliva samples before and after space flight. (NASA)

Cardiac Atrophy and Diastolic Dysfunction During and After Long Duration Spaceflight: Functional Consequences for Orthostatic Intolerance, Exercise Capability and Risk for Cardiac Arrhythmias (Integrated Cardiovascular) will quantify the extent, time course and clinical significance of cardiac atrophy (decrease in the size of the heart muscle) associated with long-duration space flight. This experiment will also identify the mechanisms of this atrophy and the functional consequences for crewmembers that will spend extended periods of time in space. (NASA)

Bisphosphonates as a Countermeasure to Space Flight Induced Bone Loss (Bisphosphonates) determines whether antiresorptive agents (help reduce bone loss), in conjunction with the routine inflight exercise program, will protect ISS crewmembers from the regional decreases in bone mineral density documented on previous ISS missions. (NASA)

The effect of long-term microgravity exposure on cardiac autonomic function by analyzing 24-hours electrocardiogram (Biological Rhythms) examines the effect of long-term microgravity exposure on cardiac autonomic function by analyzing 24-hour electrocardiogram. (JAXA)

SOdium LOading in Microgravity (SOLO) is a continuation of extensive research into the mechanisms of fluid and salt retention in the body during bed rest and spaceflights. It is a metabolically-controlled study. During long-term space missions astronauts will participate in two study phases, 5 days each. Subjects follow a diet of constant either low or normal sodium intake, fairly high fluid consumption and isocaloric nutrition. (ESA)

Observing the Earth and Educational Activities

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 dynamic events such as storms, floods, fires and volcanic eruptions. These images provide researchers on Earth with key data to better understand the planet. (NASA)

Earth Knowledge Acquired by Middle School Students (EarthKAM) an education activity, allows middle school students to program a digital camera on board the International Space Station to photograph a variety of geographical targets for study in the classroom. Photos are made available on the world wide web for viewing and study by participating schools around the world. Educators use the images for projects involving Earth Science, geography, physics, and social science. (NASA)

Physical and Biological Science in Microgravity

Foam-Stability examines the characteristics and stability of foam under microgravity conditions. (ESA)

Multi-User Droplet Combustion Apparatus – FLame Extinguishment Experiment (MDCA-FLEX) assesses the effectiveness of fire suppressants in microgravity and quantify the effect of different possible crew exploration atmospheres on fire suppression. The goal of this research is to provide definition and direction for large scale fire suppression tests and selection of the fire suppressant for next generation crew exploration vehicles. (NASA)

Selectable Optical Diagnostics Instrument – Influence of Vibration on Diffusion of Liquids (SODI-IVIDIL) studies the influence of controlled vibration stimulus (slow shaking) on diffusion between different liquids in absence of convection induced by the gravity field. This investigation aims help scientists to model numerically this physical phenomenon. (NASA/ESA)

Life Cycle of High Plants under Microgravity Conditions (SpaceSeed) uses *Arabidopsis thaliana* to determine if the life cycle of the plant can be achieved in microgravity. Additionally, this study will examine the specific genes in the cell wall of the plant that do not activate under microgravity conditions that normally activated in 1-g conditions. (JAXA)

Technology Development

Synchronized Position Hold, Engage, Reorient, Experimental Satellites (SPHERES) are bowling-ball sized spherical satellites. They are used inside the space station to test a set of well-defined instructions for spacecraft performing autonomous rendezvous and docking maneuvers. Three free-flying spheres fly within the cabin of the Space 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. (NASA)

Space Dynamically Responding Ultrasonic Matrix System (SpaceDRUMS) comprises a suite of hardware that enables containerless processing (samples of experimental materials can be processed without ever touching a container wall). Using a collection of 20 acoustic beam emitters, SpaceDRUMS can completely suspend a baseball-sized solid or liquid sample during combustion or heat-based synthesis. Because the samples never contact the container walls, materials can be produced in microgravity with an unparalleled quality of shape and composition. The ultimate goal of the SpaceDRUMS hardware is to assist with the development of advanced materials of a commercial quantity and quality, using the space-based experiments to guide development of manufacturing processes on Earth.

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.

Payload Operations Coordination

The work of more than 400 scientists, this research has been prioritized based on fundamental and applied research needs established by NASA and the international partners – the Canadian Space Agency (CSA), the European Space Agency (ESA), the Japan Aerospace and Exploration Agency (JAXA) and the Russian Federal Space Agency (RSA).

Managing the international laboratory's scientific assets, as well as the time and space required to accommodate experiments and programs from a host of private, commercial, industry and government agencies nationwide, makes the job of coordinating space station research critical.

Teams of controllers and scientists on the ground continuously plan, monitor and remotely operate experiments from control centers around the globe. Controllers staff payload operations centers around the world, effectively providing for researchers and the station crew around the clock, seven days a week.

State-of-the-art computers and communications equipment deliver up-to-the-minute reports about experiment facilities and investigations between science outposts across the United States and around the world. The payload operations team also synchronizes the payload time lines among international partners, ensuring the best use of valuable resources and crew time.

The control centers of NASA and its partners are

- NASA Payload Operations Center, Marshall Space Flight Center in Huntsville, Ala.
- RSA Center for Control of Spaceflights ("TsUP" in Russian) in Korolev, Russia
- JAXA Space Station Integration and Promotion Center (SSIPC) in Tskuba, Japan
- ESA Columbus Control Center (Col-CC) in Oberpfaffenhofen, Germany
- CSA Payloads Operations Telesciences Center, St. Hubert, Quebec, Canada

NASA's Payload Operations Center serves as a hub for coordinating much of the work related to delivery of research facilities and experiments to the space station as they are rotated in and out periodically when space shuttles or other vehicles make deliveries and return completed experiments and samples to Earth.

The payload operations director leads the POC's main flight control team, known as the "cadre," and approves all science plans in coordination with Mission Control at NASA's Johnson Space Center in Houston, the international partner control centers and the station crew.

On the Internet

For fact sheets, imagery and more on International Space Station experiments and payload operations, visit:

http://www.nasa.gov/mission_pages/station/science/

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SHUTTLE REFERENCE DATA

SHUTTLE ABORT MODES

Redundant Sequence Launch Sequencer (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, KSC, 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, after which 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 KSC. The powered RTLS phase begins with the crew selection of the RTLS abort, 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 KSC and achieve the proper main engine cutoff conditions so the vehicle can glide to the KSC 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 MCC 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, Calif.; or the Kennedy Space Center, Fla). 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 also may 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 are 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 identify which abort mode is (or is not) available. If ground communications are lost, the flight crew has onboard 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 onboard 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 onboard 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 onboard 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, MSFC 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 long, weighs about 7,000 pounds and is 7.5 feet in diameter at the end of its nozzle.

The engines operate for about 8.5 minutes during liftoff and ascent, burning more than 500,000 gallons of super-cold liquid hydrogen and liquid oxygen propellants stored in the external tank attached to the underside of the shuttle. The engines shut down just before the shuttle, traveling at about 17,000 miles 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, 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, 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, and 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, each engine generates 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 preburners, thus varying the speed of the high-pressure turbopumps and, therefore, the flow of the propellant.

At about 26 seconds into ascent, 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, known as 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, 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 until they achieve 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 two and one-half Boeing 747 airplanes.

The space shuttle main engine also is the first rocket engine to use a built-in electronic digital controller, or computer. The controller accepts commands from the orbiter for engine start, change in throttle, shutdown and monitoring of engine operation.

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, 2001 and 2007. 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.

The most recent engine enhancement is the Advanced Health Management System, or AHMS, which made its first flight in 2007. AHMS is a controller upgrade that provides new monitoring and insight into the health of the two most complex components of the space shuttle main engine – the high pressure fuel turbopump and the high pressure oxidizer turbopump. New advanced digital signal processors monitor engine vibration and have the ability to shut down an engine if vibration exceeds safe limits. AHMS was developed by engineers at Marshall.

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 (SRB)

The two solid rocket boosters required for a space shuttle launch and first two minutes of powered flight boast the largest solid-propellant motors ever flown. They are the first large rockets designed for reuse and are the only solid rocket motors rated for human flight. The SRBs have the capacity to carry the entire weight of the external tank, or ET, and orbiter, and to transmit the weight load through their structure to the mobile launch platform, or MLP.

The SRBs provide 71.4 percent of the thrust required to lift the space shuttle off the launch pad and during first-stage ascent to an altitude of about 150,000 feet, or 28 miles. At launch, each booster has a sea level thrust of approximately 3.3 million pounds and is ignited after the ignition and verification of the three space shuttle main engines, or SSMEs.

SRB apogee occurs at an altitude of about 230,000 feet, or 43 miles, 75 seconds after separation from the main vehicle. At booster separation, the space shuttle orbiter has reached an altitude of 24 miles and is traveling at a speed in excess of 3,000 miles per hour.

The primary elements of each booster are nose cap, housing the pilot and drogue parachute; frustum, housing the three main parachutes in a cluster; forward skirt, housing the booster flight avionics, altitude sensing, recovery avionics, parachute cameras and range safety destruct system; four motor segments, containing the solid propellant; motor nozzle; and aft skirt, housing the nozzle and thrust vector control systems required for guidance. Each SRB possesses its own redundant auxiliary power units and hydraulic pumps.

SRB impact occurs in the ocean approximately 140 miles downrange. SRB retrieval is provided after each flight by specifically designed and built ships. The frustums, drogue and main parachutes are loaded onto the ships along with the boosters and towed back to the Kennedy Space Center, where they are disassembled and refurbished for reuse. Before retirement, each booster can be used as many as 20 times.

Each booster is just over 149 feet long and 12.17 feet in diameter. Both boosters have a combined weight of 1,303,314 pounds at lift-off. They are attached to the ET at the SRB aft attach ring by an upper and lower attach strut and a diagonal attach strut. The forward end of each SRB is affixed to the ET by one attach bolt and ET ball fitting on the forward skirt. While positioned on the launch pad, the space shuttle is attached to the MLP by four bolts and explosive nuts equally spaced around each SRB. After ignition of the solid rocket motors, the nuts are severed by small explosives that allow the space shuttle vehicle to perform lift off.

United Space Alliance (USA)

USA, at KSC facilities, is responsible for all SRB operations except the motor and nozzle portions. In conjunction with maintaining sole responsibility for manufacturing and processing of the non-motor hardware and vehicle integration, USA provides the service of retrieval, post flight inspection and analysis, disassembly and refurbishment of the hardware. USA also exclusively retains comprehensive responsibility for the orbiter.

The reusable solid rocket motor segments are shipped from ATK Launch Systems in Utah to KSC, where they are mated by USA personnel to the other structural components – the forward assembly, aft skirt, frustum and nose cap – in the Vehicle Assembly Building. Work involves the complete disassembly and refurbishment of the major SRB structures – the aft skirts, frustums, forward skirts and all ancillary hardware – required to complete an SRB stack and mate to the ET. Work then proceeds to ET/SRB mate, mate with the orbiter and finally, space shuttle close out operations. After hardware restoration concerning flight configuration is complete, automated checkout and hot fire are performed early in hardware flow to ensure that the refurbished components satisfy all flight performance requirements.

ATK Launch Systems (ATK)

ATK Launch Systems of Brigham City, Utah, manufactures space shuttle reusable solid rocket motors, or RSRMs, at their Utah facility. Each RSRM – just over 126 feet long and 12 feet in diameter – consists of four rocket motor segments and an aft exit cone assembly is. From ignition to end of burn, each RSRM generates an average thrust of 2.6 million pounds and burns for approximately 123 seconds. Of the motor's total weight of 1.25 million pounds, propellant accounts for 1.1 million pounds. The four motor segments are matched by loading each 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 KSC on a heavy-duty rail car with a specialty built cover.

SRB Hardware Design Summary

Hold-Down Posts

Each SRB has four hold-down posts that fit into corresponding support posts on the MLP. Hold-down bolts secure the SRB and MLP posts together. Each bolt has a nut at each end, but the top nut is frangible, or breakable. The top nut contains two NASA Standard detonators, or NSDs, that, when ignited at solid rocket motor ignition command, split the upper nut in half.

Splitting the upper nuts allow the hold-down bolts to be released and travel downward because of NSD gas pressure, gravity and the release of tension in the bolt, which is pretensioned before launch. The bolt is stopped by the stud deceleration stand which contains sand to absorb the shock of the bolt dropping down several feet. The SRB bolt is 28 inches long, 3.5 inches in diameter and weighs approximately 90 pounds. The frangible nut is captured in a blast container on the aft skirt specifically designed to absorb the impact and prevent pieces of the nut from liberating and becoming debris that could damage the space shuttle.

Integrated Electronic Assembly (IEA)

The aft IEA, mounted in the ET/SRB attach ring, provides the electrical interface between the SRB systems and the obiter. The aft IEA receives data, commands, and electrical power from the orbiter and distributes these inputs throughout each SRB. Components located in the forward assemblies of each SRB are powered by the aft IEA through the forward IEA, except for those utilizing the recovery and range safety batteries located in the forward assemblies. The forward IEA communicates with and receives power from the orbiter through the aft IEA, but has no direct electrical connection to the orbiter.

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 V dc, with an upper limit of 32 V dc and a lower limit of 24 V dc.

Hydraulic Power Units (HPUs)

There are two self-contained, independent HPUs on each SRB. Each HPU consists of an auxiliary power unit, or APU; Fuel Supply Module, or FSM; 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 APU controller electronics are located in the SRB aft integrated electronic assemblies on the aft ET attach rings. The two separate HPUs and two hydraulic systems are located inside the aft skirt of each SRB between the SRB nozzle and 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 ET. The two independent hydraulic systems are connected to the rock and tilt servoactuators.

The HPUs and their fuel systems are isolated from each other. Each fuel supply module, or tank, contains 22 pounds of hydrazine. The fuel tank is pressurized with gaseous nitrogen at 400 psi to provide the force to expel via positive expulsion the fuel from the tank to the fuel distribution line. A positive fuel supply to the APU throughout its operation is maintained.

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, at which point all the fuel is supplied to the fuel pump.

The APU turbine assembly provides mechanical power to the APU gearbox, which 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 directing it 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. 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 (TVC)

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 TVC. 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 space shuttle ascent TVC portion of the flight control system directs the thrust of the three SSMEs and the two SRB nozzles to control shuttle attitude and trajectory during liftoff and ascent. Commands from the guidance system are transmitted to the ascent TVC, or 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. This permits 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 (RGAs)

Each SRB contains two RGAs mounted in the forward skirt watertight compartment. Each RGA contains two orthogonally mounted gyroscopes – pitch and yaw axes. In conjunction with the orbiter roll rate gyros, they provide angular rate information that describes the inertial motion of the vehicle cluster to the orbiter computers and the guidance, navigation and control system during first stage ascent to SRB separation. At SRB separation, all guidance control data is handed off from the SRB RGAs to the orbiter RGAs. The RGAs are designed and qualified for 20 missions.

Propellant

The propellant mixture in each SRB motor consists of ammonium perchlorate, an oxidizer, 69.6 percent by weight; aluminum, a fuel, 16 percent by weight; iron oxide, a catalyst, 0.4 percent by weight; polymer, a binder that holds the mixture together, 12.04 percent by weight; and epoxy curing agent, 1.96 percent by weight. 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 one-third 50 seconds after liftoff to prevent overstressing the vehicle during maximum dynamic pressure.

SRB Ignition

SRB ignition can occur only when a manual lock pin from each SRB safe and arm device has been removed by the ground crew during prelaunch activities. At T minus 5 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 pyrotechnic initiator controller, or PIC low voltage is indicated; and there are no holds from the launch processing system, or LPS.

The solid rocket motor ignition commands are sent by the orbiter computers through the master events controllers, or MECs, to the NSDs installed in the safe and arm device in each SRB. A pyrotechnic initiation controller, or PIC, is a single-channel capacitor discharge device that 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 V dc signals for the PICs. The arm signal charges the PIC capacitor to 40 V dc, minimum 20 V 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 igniter, which fires down the length of the solid rocket motor igniting the solid rocket motor propellant.

The general purpose computer, or GPC, launch sequence also controls certain critical main propulsion system valves and monitors the engine-ready indications from the SSMEs. The main propulsion system, or MPS, start commands are issued by the on-board computers at T minus 6.6 seconds. There is a staggered start – engine three, engine two, engine one – 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 3 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.

At T minus 0, the two SRBs are ignited by the four orbiter on-board computers; commands are sent to release the SRBs; 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.

SRB Separation

The SRB/ET separation subsystem provides for separation of the SRBs from the orbiter/ET without damage to or recontact of the elements – SRBs, orbiter/ET – during or after separation for nominal modes. 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 ET within 30 milliseconds of the ordnance firing command.

The forward attachment point consists of a ball on the SRB and socket on the 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 range safety system, or 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.

Redesigned Booster Separation Motors (RBSM)

Eight Booster Separation Motors, or BSMs, are located on each booster – four on the forward section and four on the aft skirt. BSMs provide the force required to push the SRBs away from the orbiter/ET at separation. Each BSM weighs approximately 165 pounds and is 31.1 inches long and 12.8 inches in diameter. Once the SRBs have completed their flight, the BSMs are fired to jettison the SRBs away from the orbiter and external tank, allowing the boosters to parachute to Earth and be reused. The BSMs 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.

Redesigned BSMs flew for the first time in both forward and aft locations on STS-125. As a result of vendor viability and manifest support issues, space shuttle BSMs are now being manufactured by ATK. The igniter has been redesigned and other changes include material upgrades driven by obsolescence issues and improvements to process and inspection techniques.

SRB Cameras

Each SRB flies with a complement of four cameras, three mounted for exterior views during launch, separation and descent; and one mounted internal to the forward dome for main parachute performance assessment during descent.

The ET observation camera is mounted on the SRB forward skirt and provides a wide-angle view of the ET intertank area. The camera is activated at lift off by a G-switch and records for 350 seconds, after which the recorder is switched to a similar camera in the forward skirt dome to view the deployment and performance of the main parachutes to splash down. These cameras share a digital tape recorder located within the data acquisition system.

The ET ring camera is mounted on the ET attach ring and provides a view up the stacked vehicle on the orbiter underside and the bipod strut attach point.

The forward skirt camera is mounted on the external surface of the SRB forward skirt and provides a view aft down the stacked vehicle of the orbiter underside and the wing leading edge reinforced carbon-carbon, or RCC, panels.

The ET attach ring camera and forward skirt camera are activated by a global positioning system command at approximately T minus 1 minute 56 seconds to begin recording at approximately T minus 50 seconds. The camera images are recorded through splash down. These cameras each have a dedicated recorder and are recorded in a digital format. The cameras were designed, qualified, and implemented by USA after Columbia to provide enhanced imagery capabilities to capture potential debris liberation beginning with main engine start and continuing through SRB separation.

The camera videos are available for engineering review approximately 24 hours following the arrival of the boosters at KSC.

Range Safety Systems (RSS)

The RSS consists of two antenna couplers; command receivers/decoders; a dual distributor; a safe and arm device with two NSDs; two confined detonating fuse manifolds; seven confined detonator fuse, or CDF assemblies; and one linear-shaped charge.

The RSS provides for destruction of a rocket or part of it with on-board explosives by remote command if the rocket is out of control, to limit danger to people on the ground from crashing pieces, explosions, fire, and poisonous substances.

The space shuttle has two RSSs, one in each SRB. Both are capable of receiving two command messages – arm and fire – which are transmitted from the ground station. The RSS is only used when the space shuttle violates a launch trajectory red line.

The antenna couplers provide the proper impedance for radio frequency and ground support equipment commands. The command receivers are tuned to RSS command frequencies and provide the input signal to the distributors when an RSS command is sent. The command decoders use a code plug to prevent any command signal other than the proper command signal from getting into the distributors. The distributors contain the logic to supply valid destruct commands to the RSS pyrotechnics.

The NSDs provide the spark to ignite the CDF that in turn ignites the linear shaped charge for space shuttle destruction. The safe and arm device provides mechanical isolation between the NSDs and the CDF before launch and during the SRB separation sequence.

The first message, called arm, allows the onboard logic to enable a destruct and illuminates a light on the flight deck display and control panel at the commander and pilot station. The second message transmitted is the fire command. The SRB distributors in the SRBs are cross-strapped together. Thus, if one SRB received an arm or destruct signal, the signal would also be sent to the other SRB.

Electrical power from the RSS battery in each SRB is routed to RSS system A. The recovery battery in each SRB is used to power RSS system B as well as the recovery system in the SRB. The SRB RSS is powered down during the separation sequence, and the SRB recovery system is powered up.

Descent and Recovery

After separation and at specified altitudes, the SRB forward avionics system initiates the release of the nose cap, which houses a pilot parachute and drogue parachute; and the frustum, which houses the three main parachutes. Jettison of the nose cap at 15,700 feet deploys a small pilot parachute and begins to slow the SRB decent. At an altitude of 15,200 feet the pilot parachute pulls the drogue parachute from the frustum. The drogue parachute fully inflates in stages, and at 5,500 feet pulls the frustum away from the SRB, which initiates the deployment of the three main parachutes. The parachutes also inflate in stages and further slow the decent of the SRBs to their final velocity at splashdown. The parachutes slow each SRB from 368 mph at first deployment to 52 mph at splashdown, allowing for the recovery and reuse of the boosters.

Two 176-foot recovery ships, Freedom Star and Liberty Star, are on station at the splashdown zone to retrieve the frustums with drogue parachutes attached, the main parachutes and the SRBs. The SRB nose caps and solid rocket motor nozzle extensions are not recovered. The SRBs are dewatered using an enhanced diver operating plug to facilitate tow back. These plugs are inserted into the motor nozzle and air is pumped into the booster, causing it to lay flat in the water to allow it to be easily towed. The boosters are then towed back to the refurbishment facilities. Each booster is removed from the water and components are disassembled and washed with fresh and deionized water to limit saltwater corrosion. The motor segments, igniter and nozzle are shipped back to ATK in Utah for refurbishment. The nonmotor components and structures are disassembled by USA and are refurbished to like-new condition at both KSC and equipment manufacturers across the country.

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.

EXTERNAL TANK

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 more than 530,000 gallons of liquid hydrogen and liquid oxygen in two separate tanks, the forward liquid oxygen tank and the aft liquid hydrogen tank. An unpressurized intertank unites the two propellant tanks.

Liquid hydrogen (fuel) and liquid oxygen (oxidizer) are used as propellants for the shuttle's three main engines. The external tank weighs 58,500 pounds empty and 1,668,500 pounds when filled with propellants.

The external tank is the "backbone" of the shuttle during launch, providing structural support for attachment with the solid rocket boosters and orbiter. It is the only component of the shuttle that is not reused. Approximately 8.5 minutes after reaching orbit, with its propellant used, the tank is jettisoned and falls in a preplanned trajectory. Most of the tank disintegrates in the atmosphere, and the remainder falls into the ocean.

The external tank is manufactured at NASA's Michoud Assembly Facility in New Orleans by Lockheed Martin Space Systems.

Foam Facts

The external tank is covered with spray-on foam insulation that insulates the tank before and during launch. More than 90 percent of the tank's foam is applied using an automated system, leaving less than 10 percent to be applied manually.

There are two types of foam on the external tank, known as the Thermal Protection System, or TPS. One is low-density, closed-cell foam on the tank acreage and is known as Spray-On-Foam-Insulation, often referred to by its acronym, SOFI. Most of the tank is covered by either an automated or manually applied SOFI. Most areas around protuberances, such as brackets and structural elements, are applied by pouring foam ingredients into part-specific molds. The other is a denser composite material made of silicone resins and cork and called ablator. An ablator is a material that dissipates heat by eroding. It is used on areas of the external tank subjected to extreme heat, such as the aft dome near the engine exhaust, and remaining protuberances, such as the cable trays. These areas are exposed to extreme aerodynamic heating.

Closed-cell foam used on the tank was developed to keep the propellants that fuel the shuttle's three main engines at optimum temperature. It keeps the shuttle's liquid hydrogen fuel at -423 degrees Fahrenheit and the liquid oxygen tank at near -297 degrees Fahrenheit, even as the tank sits under the hot Florida sun. At the same time, the foam prevents a buildup of ice on the outside of the tank.

The foam insulation must be durable enough to endure a 180-day stay at the launch pad, withstand temperatures up to 115 degrees Fahrenheit, humidity as high as 100 percent, and resist sand, salt, fog, rain, solar radiation and even fungus. Then, during launch, the foam must tolerate temperatures as high as 2,200 degrees Fahrenheit generated by aerodynamic friction and radiant heating from the 3,000 degrees Fahrenheit main engine plumes. Finally, when the external tank begins reentry into the Earth's atmosphere about 30 minutes after launch, the foam maintains the tank's structural temperatures and allows it to safely disintegrate over a remote ocean location.

Though the foam insulation on the majority of the tank is only 1-inch thick, it adds 4,823 pounds to the tank's weight. In the areas of the tank subjected to the highest heating, insulation is somewhat thicker, between 1.5 to 3 inches thick. Though the foam's density varies with the type, an average density is about 2.4 pounds per cubic foot.

Application of the foam, whether automated by computer or hand-sprayed, is designed to meet NASA's requirements for finish, thickness, roughness, density, strength and adhesion. As in most assembly production situations, the foam is applied in specially designed, environmentally controlled spray cells and applied in several phases, often over a period of several weeks. Before spraying, the foam's raw material and mechanical properties are tested to ensure they meet NASA specifications. Multiple visual inspections of all foam surfaces are performed after the spraying is complete.

Most of the foam is applied at NASA's Michoud Assembly Facility in New Orleans when the tank is manufactured, including most of the "closeout" areas, or final areas applied. These closeouts are done either by hand pouring or manual spraying. Additional closeouts are completed once the tank reaches Kennedy Space Center, Fla.

The super lightweight external tank, or SLWT, made its first shuttle flight in June 1998 on mission STS-91. The SLWT is 7,500 pounds lighter than previously flown tanks. 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 previously.

Beginning with the first Return to Flight mission, STS-114 in June 2005, several improvements were made to improve safety and flight reliability.

Forward Bipod

The external tank's forward shuttle attach fitting, called the bipod, was redesigned to eliminate the large insulating foam ramps as a source of debris. Each external tank has two bipod fittings that connect the tank to the orbiter through the shuttle's two forward attachment struts. Four rod heaters were placed below each forward bipod, replacing the large insulated foam Protuberance Airload, or PAL, ramps.

Liquid Hydrogen Tank & Liquid Oxygen Intertank Flange Closeouts

The liquid hydrogen tank flange located at the bottom of the intertank and the liquid oxygen tank flange located at the top of the intertank provide joining mechanisms with the intertank. After each of these three component tanks, liquid oxygen, intertank and liquid hydrogen, are joined mechanically, the flanges at both ends are insulated with foam. An enhanced closeout, or finishing, procedure was added to improve foam application to the stringer, or intertank ribbing, and to the upper and lower area of both the liquid hydrogen and liquid oxygen intertank flanges.

Liquid Oxygen Feedline Bellows

The liquid oxygen feedline bellows were reshaped to include a “drip lip” that allows condensate moisture to run off and prevent freezing. A strip heater was added to the forward bellow to further reduce the potential of high density ice or frost formation. Joints on the liquid oxygen feedline assembly allow the feedline to move during installation and during liquid hydrogen tank fill. Because it must flex, it cannot be insulated with foam like the remainder of the tank.

Other tank improvements include:

Liquid Oxygen & Liquid Hydrogen Protuberance Airload (PAL) Ramps

External tank ET-119, which flew on the second Return to Flight mission, STS-121, in July 2006, was the first tank to fly without PAL ramps along portions of the liquid oxygen and liquid hydrogen tanks. These PAL ramps were extensively studied and determined to not be necessary for their original purpose, which was to protect cable trays from aeroelastic instability during ascent. Extensive tests were conducted to verify the shuttle could fly safely without these particular PAL ramps. Extensions were added to the ice frost ramps for the pressline and cable tray brackets, where these PAL ramps were removed to make the geometry of the ramps consistent with other locations on the tank and thereby provide consistent aerodynamic flow. Nine extensions were added, six on the liquid hydrogen tank and three on the liquid oxygen tank.

Engine Cutoff (ECO) Sensor Modification

Beginning with STS-122, ET-125, which launched on Feb. 7, 2008, the ECO sensor system feed through connector on the liquid hydrogen tank was modified by soldering the connector’s pins and sockets to address false readings in the system. All subsequent tanks after ET-125 have the same modification.

Liquid Hydrogen Tank Ice Frost Ramps

ET-128, which flew on the STS-124 shuttle mission, May 31, 2008, was the first tank to fly with redesigned liquid hydrogen tank ice frost ramps. Design changes were incorporated at all 17 ice frost ramp locations on the liquid hydrogen tank, stations 1151 through 2057, to reduce foam loss. Although the redesigned ramps appear identical to the previous design, several changes were made. PDL* and NCFI foam have been replaced with BX* manual spray foam in the ramp’s base cutout to reduce debonding and cracking; Pressline and cable tray bracket feet corners have been rounded to reduce stresses; shear pin holes have been sealed to reduce leak paths; isolators were primed to promote adhesion; isolator corners were rounded to help reduce thermal protection system foam stresses; BX manual spray was applied in bracket pockets to reduce geometric voids.

*BX is a type of foam used on the tank's "loseout," or final finished areas; it is applied manually or hand-sprayed. PDL is an acronym for Product Development Laboratory, the first supplier of the foam during the early days of the external tank's development. PDL is applied by pouring foam ingredients into a mold. NCFI foam is used on the aft dome, or bottom, of the liquid hydrogen tank.

Liquid Oxygen Feedline Brackets

ET-128 also was the first tank to fly with redesigned liquid oxygen feedline brackets. Titanium brackets, much less thermally conductive than aluminum, replaced aluminum brackets at four locations, XT 1129, XT 1377, Xt 1624 and Xt 1871. This change minimizes ice formation in under-insulated areas, and reduces the amount of foam required to cover the brackets and the propensity for ice development. Zero-gap/slip plane Teflon material was added to the upper outboard monoball attachment to eliminate ice adhesion. Additional foam has been added to the liquid oxygen feedline to further minimize ice formation along the length of the feedline.

LAUNCH AND LANDING

LAUNCH

As with all previous space shuttle launches, Endeavour has several options to abort its ascent if needed after engine failures or other systems problems. Shuttle launch abort philosophy is intended to facilitate safe recovery of the flight crew and intact recovery of the orbiter and its payload.

Abort modes include:

ABORT-TO-ORBIT (ATO)

This mode is used if there is a partial loss of main engine thrust late enough to permit reaching a minimal 105 by 85 nautical mile orbit with the orbital maneuvering system engines. The engines boost the shuttle to a safe orbital altitude when it is impossible to reach the planned orbital altitude.

TRANSATLANTIC ABORT LANDING (TAL)

The 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)

If one or more engines shut down early and there is not enough energy to reach Zaragoza, the shuttle would pitch around toward Kennedy 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 90 minutes after liftoff.

LANDING

The primary landing site for Endeavour on STS-130 is the Kennedy Space Center's Shuttle Landing Facility. Alternate landing sites that could be used if needed because of weather conditions or systems failures are at Edwards Air Force Base, Calif., and White Sands Space Harbor, N.M.

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ACRONYMS AND ABBREVIATIONS

A/G	Alignment Guides
A/L	Airlock
AAA	Avionics Air Assembly
ABC	Audio Bus Controller
ACBM	Active Common Berthing Mechanism
ACDU	Airlock Control and Display Unit
ACO	Assembly Checkout Officer
ACS	Atmosphere Control and Supply
ACU	Arm Control Unit
ADS	Audio Distribution System
AE	Approach Ellipsoid
AEP	Airlock Electronics Package
AI	Approach Initiation
AIS	Automatic Identification System
AJIS	Alpha Joint Interface Structure
AM	Atmosphere Monitoring
AMOS	Air Force Maui Optical and Supercomputing Site
AOA	Abort Once Around
AOH	Assembly Operations Handbook
APAS	Androgynous Peripheral Attachment
APCU	Assembly Power Converter Unit
APE	Antenna Pointing Electronics
	Audio Pointing Equipment
APFR	Articulating Portable Foot Restraint
APM	Antenna Pointing Mechanism
APS	Automated Payload Switch
APV	Automated Procedure Viewer
AR	Atmosphere Revitalization
ARCU	American-to-Russian Converter Unit
ARED	Advanced Resistive Exercise Device
ARS	Atmosphere Revitalization System
ASW	Application Software
ATA	Ammonia Tank Assembly
ATCS	Active Thermal Control System
ATO	Abort To Orbit
ATU	Audio Terminal Unit

BAD	Broadcast Ancillary Data
BC	Bus Controller
BCDU	Battery Charge/Discharge Unit
	Berthing Mechanism Control and Display Unit
BEP	Berthing Mechanism Electronics Package
BGA	Beta Gimbal Assembly
BIC	Bus Interface Controller
BIT	Built-In Test
BM	Berthing Mechanism
BOS	BIC Operations Software
BSS	Basic Software
BSTS	Basic Standard Support Software

C&C	Command and Control
C&DH	Command and Data Handling
C&T	Communication and Tracking
C&W	Caution and Warning
C/L	Crew Lock
C/O	Checkout
CAM	Collision Avoidance Maneuver
CAPE	Canister for All Payload Ejections
CAS	Common Attach System
CB	Control Bus
CBCS	Centerline Berthing Camera System
CBM	Common Berthing Mechanism
CCA	Circuit Card Assembly
CCAA	Common Cabin Air Assembly
CCHA	Crew Communication Headset Assembly
CCP	Camera Control Panel
CCT	Communication Configuration Table
CCTV	Closed-Circuit Television
CDR	Space Shuttle Commander
CDRA	Carbon Dioxide Removal Assembly
CETA	Crew Equipment Translation Aid
CHeCS	Crew Health Care System
CHX	Cabin Heat Exchanger
CISC	Complicated Instruction Set Computer
CLA	Camera Light Assembly
CLPA	Camera Light Pan Tilt Assembly
CMG	Control Moment Gyro
COTS	Commercial Off the Shelf
CPA	Control Panel Assembly

CPB	Camera Power Box
CR	Change Request
CRT	Cathode-Ray Tube
CSA	Canadian Space Agency
CSA-CP	Compound Specific Analyzer
CTC	Cargo Transport Container
CVIU	Common Video Interface Unit
CVT	Current Value Table
CZ	Communication Zone

DA	Distillation Assembly
DB	Data Book
DC	Docking Compartment
DCSU	Direct Current Switching Unit
DDCU	DC-to-DC Converter Unit
DEM	Demodulator
DFL	Decommutation Format Load
DIU	Data Interface Unit
DMS	Data Management System
DMS-R	Data Management System-Russian
DPG	Differential Pressure Gauge
DPU	Baseband Data Processing Unit
DRTS	Japanese Data Relay Satellite
DYF	Display Frame

E-ORU	EVA Essential ORU
E/L	Equipment Lock
EATCS	External Active Thermal Control System
EBCS	External Berthing Camera System
ECC	Error Correction Code
ECLSS	Environmental Control and Life Support System
ECS	Environmental Control System
ECU	Electronic Control Unit
EDSU	External Data Storage Unit
EDU	EEU Driver Unit
EE	End Effector
EETCS	Early External Thermal Control System
EEU	Experiment Exchange Unit
EF	Exposed Facility
EFBM	Exposed Facility Berthing Mechanism
EFHX	Exposed Facility Heat Exchanger
EFU	Exposed Facility Unit

EGIL	Electrical, General Instrumentation, and Lighting
EIU	Ethernet Interface Unit
ELC	ExPRESS Logistics Carrier
ELM-ES	Japanese Experiment Logistics Module – Exposed Section
ELM-PS	Japanese Experiment Logistics Module – Pressurized Section
ELPS	Emergency Lighting Power Supply
EMGF	Electric Mechanical Grapple Fixture
EMI	Electro-Magnetic Imaging
EMU	Extravehicular Mobility Unit
EP	Exposed Pallet
EPS	Electrical Power System
ES	Exposed Section
ESA	European Space Agency
ESC	JEF System Controller
ESW	Extended Support Software
ET	External Tank
ETCS	External Thermal Control System
ETI	Elapsed Time Indicator
ETRS	EVA Temporary Rail Stop
ETVCG	External Television Camera Group
EV	Extravehicular
EVA	Extravehicular Activity
EXP-D	Experiment-D
EXT	External

FA	Fluid Accumulator
FAS	Flight Application Software
FCT	Flight Control Team
FD	Flight Day
FDDI	Fiber Distributed Data Interface
FDIR	Fault Detection, Isolation, and Recovery
FDS	Fire Detection System
FE	Flight Engineer
FET-SW	Field Effect Transistor Switch
FGB	Functional Cargo Block
FOR	Frame of Reference
FPMU	Floating Potential Measurement Unit
FPP	Fluid Pump Package
FR	Flight Rule
FRD	Flight Requirements Document
FRGF	Flight Releasable Grapple Fixture
FRM	Functional Redundancy Mode

FSE	Flight Support Equipment
FSEGF	Flight Support Equipment Grapple Fixture
FSW	Flight Software
GAS	Get-Away Special
GATOR	Grappling Adaptor to On-orbit Railing
GCA	Ground Control Assist
GLA	General Lighting Assemblies
	General Luminaire Assembly
GLONASS	Global Navigational Satellite System
GNC	Guidance, Navigation, and Control
GPC	General Purpose Computer
GPS	Global Positioning System
GPSR	Global Positioning System Receiver
GUI	Graphical User Interface
H&S	Health and Status
HCE	Heater Control Equipment
HCTL	Heater Controller
HEPA	High Efficiency Particulate Acquisition
HPA	High Power Amplifier
HPGT	High Pressure Gas Tank
HPP	Hard Point Plates
HRDR	High Rate Data Recorder
HREL	Hold/Release Electronics
HRFM	High Rate Frame Multiplexer
HRM	Hold Release Mechanism
HRMS	High Rate Multiplexer and Switcher
HTV	H-II Transfer Vehicle
HTVCC	HTV Control Center
HTV Prox	HTV Proximity
HX	Heat Exchanger
I/F	Interface
IAA	Intravehicular Antenna Assembly
IAC	Internal Audio Controller
IBM	International Business Machines
ICB	Inner Capture Box
ICC	Integrated Cargo Carrier
ICS	Interorbit Communication System
ICS-EF	Interorbit Communication System – Exposed Facility
IDRD	Increment Definition and Requirements Document

IELK	Individual Equipment Liner Kit
IFHX	Interface Heat Exchanger
IMCS	Integrated Mission Control System
IMCU	Image Compressor Unit
IMV	Intermodule Ventilation
INCO	Instrumentation and Communication Officer
IP	International Partner
IP-PCDU	ICS-PM Power Control and Distribution Unit
IP-PDB	Payload Power Distribution Box
ISP	International Standard Payload
ISPR	International Standard Payload Rack
ISS	International Space Station
ISSSH	International Space Station Systems Handbook
ITCS	Internal Thermal Control System
ITS	Integrated Truss Segment
IVA	Intravehicular Activity
IVSU	Internal Video Switch Unit
JAXA	Japan Aerospace Exploration Agency
JCP	JEM Control Processor
JEF	JEM Exposed Facility
JEM	Japanese Experiment Module
JEM-EF	Japanese Experiment Module Exposed Facility
JEM-PM	Japanese Experiment Module – Pressurized Module
JEMAL	JEM Airlock
JEMRMS	Japanese Experiment Module Remote Manipulator System
JEUS	Joint Expedited Undocking and Separation
JFCT	Japanese Flight Control Team
JLE	Japanese Experiment Logistics Module – Exposed Section
JLP	Japanese Experiment Logistics Module – Pressurized Section
JLP-EDU	JLP-EFU Driver Unit
JLP-EFU	JLP Exposed Facility Unit
JPM	Japanese Pressurized Module
JPM WS	JEM Pressurized Module Workstation
JSC	Johnson Space Center
JTVE	JEM Television Equipment
Kbps	Kilobit per second
KOS	Keep Out Sphere
LB	Local Bus
LCA	LAB Cradle Assembly

LCD	Liquid Crystal Display
LED	Light Emitting Diode
LEE	Latching End Effector
LMC	Lightweight MPESS Carrier
LSW	Light Switch
LTA	Launch-to-Activation
LTAB	Launch-to-Activation Box
LTL	Low Temperature Loop

MA	Main Arm
MAUI	Main Analysis of Upper-Atmospheric Injections
Mb	Megabit
Mbps	Megabit per second
MBS	Mobile Base System
MBSU	Main Bus Switching Unit
MCA	Major Constituent Analyzer
MCC	Mission Control Center
MCC-H	Mission Control Center – Houston
MCC-M	Mission Control Center – Moscow
MCDS	Multifunction Cathode-Ray Tube Display System
MCS	Mission Control System
MDA	MacDonald, Dettwiler and Associates Ltd.
MDM	Multiplexer/Demultiplexer
MDP	Management Data Processor
MELFI	Minus Eighty-Degree Laboratory Freezer for ISS
MGB	Middle Grapple Box
MIP	Mission Integration Plan
MISSE	Materials International Space Station Experiment
MKAM	Minimum Keep Alive Monitor
MLE	Middeck Locker Equivalent
MLI	Multi-layer Insulation
MLM	Multipurpose Laboratory Module
MMOD	Micrometeoroid/Orbital Debris
MOD	Modulator
MON	Television Monitor
MPC	Main Processing Controller
MPESS	Multipurpose Experiment Support Structure
MPEV	Manual Pressure Equalization Valve
MPL	Manipulator Retention Latch
MPLM	MultiPurpose Logistics Module
MPM	Manipulator Positioning Mechanism
MPV	Manual Procedure Viewer

MRM	Multipurpose Research Module
MSD	Mass Storage Device
MSFC	Marshall Space Flight Center
MSP	Maintenance Switch Panel
MSS	Mobile Servicing System
MT	Mobile Tracker Mobile Transporter
MTL	Moderate Temperature Loop
MUX	Data Multiplexer

n.mi.	nautical mile
NASA	National Aeronautics and Space Administration
NCS	Node Control Software
NET	No Earlier Than
NLT	No Less Than
NPRV	Negative Pressure Relief Valve
NSV	Network Service
NTA	Nitrogen Tank Assembly
NTSC	National Television Standard Committee

OBSS	Orbiter Boom Sensor System
OCA	Orbital Communications Adapter
OCAD	Operational Control Agreement Document
OCAS	Operator Commanded Automatic Sequence
ODF	Operations Data File
ODS	Orbiter Docking System
OGS	Oxygen Generation System
OI	Orbiter Interface
OIU	Orbiter Interface Unit
OMS	Orbital Maneuvering System
OODT	Onboard Operation Data Table
ORCA	Oxygen Recharge Compressor Assembly
ORU	Orbital Replacement Unit
OS	Operating System
OSA	Orbiter-based Station Avionics
OSE	Orbital Support Equipment
OTCM	ORU and Tool Changeout Mechanism
OTP	ORU and Tool Platform

P/L	Payload
PAL	Planning and Authorization Letter
PAM	Payload Attach Mechanism

PAO	Public Affairs Office
PAS	Payload Adapter System
PBA	Portable Breathing Apparatus
PCA	Pressure Control Assembly
PCBM	Passive Common Berthing Mechanism
PCN	Page Change Notice
PCS	Portable Computer System
PCU	Plasma Contactor Unit Power Control Unit
PDA	Payload Disconnect Assembly
PDB	Power Distribution Box
PDGF	Power and Data Grapple Fixture
PDH	Payload Data Handling unit
PDRS	Payload Deployment Retrieval System
PDU	Power Distribution Unit
PEC	Passive Experiment Container
PEHG	Payload Ethernet Hub Gateway
PFE	Portable Fire Extinguisher
PFRAM	Passive Flight Releasable Attachment Mechanism
PGSC	Payload General Support Computer
PIB	Power Interface Box
PIU	Payload Interface Unit
PLB	Payload Bay
PLBD	Payload Bay Door
PLC	Pressurized Logistics Carrier
PLT	Payload Laptop Terminal Space Shuttle Pilot
PM	Pressurized Module Pump Module
PMA	Pressurized Mating Adapter
PMCU	Power Management Control Unit
PMU	Pressurized Mating Adapter
POA	Payload ORU Accommodation
POR	Point of Resolution
PPRV	Positive Pressure Relief Valve
PRCS	Primary Reaction Control System
PREX	Procedure Executor
PRLA	Payload Retention Latch Assembly
PROX	Proximity Communications Center
psia	Pounds per Square Inch Absolute
PSP	Payload Signal Processor

PSRR	Pressurized Section Resupply Rack
PTCS	Passive Thermal Control System
PTR	Port Thermal Radiator
PTU	Pan/Tilt Unit
PVCU	Photovoltaic Controller Unit
PVM	Photovoltaic Module
PVR	Photovoltaic Radiator
PVTCS	Photovoltaic Thermal Control System
QD	Quick Disconnect
R&MA	Restraint and Mobility Aid
R-ORU	Robotics Compatible Orbital Replacement Unit
RACU	Russian-to-American Converter Unit
RAM	Read Access Memory
RBVM	Radiator Beam Valve Module
RCC	Range Control Center
RCT	Rack Configuration Table
RF	Radio Frequency
RGA	Rate Gyro Assemblies
RHC	Rotational Hand Controller
RIGEX	Rigidizable Inflatable Get-Away Special Experiment
RIP	Remote Interface Panel
RLF	Robotic Language File
RLT	Robotic Laptop Terminal
RMS	Remote Manipulator System
ROEU	Remotely Operated Electrical Umbilical
ROM	Read Only Memory
ROS	Russian Orbital Segment
RPC	Remote Power Controller
RPCM	Remote Power Controller Module
RPDA	Remote Power Distribution Assembly
RPM	Roll Pitch Maneuver
RS	Russian Segment
RSP	Return Stowage Platform
RSR	Resupply Stowage Rack
RT	Remote Terminal
RTAS	Rocketdyne Truss Attachment System
RTLS	Return To Launch Site
RVFS	Rendezvous Flight Software
RWS	Robotics Workstation

SAFER	Simplified Aid for EVA Rescue
SAM	SFA Airlock Attachment Mechanism
SAPA	Small Adapter Plate Assembly
SARJ	Solar Alpha Rotary Joint
SASA	S-Band Antenna Sub-Assembly
SCU	Sync and Control Unit
SD	Smoke Detector
SDS	Sample Distribution System
SEDA	Space Environment Data Acquisition equipment
SEDA-AP	Space Environment Data Acquisition equipment - Attached Payload
SELS	SpaceOps Electronic Library System
SEU	Single Event Upset
SFA	Small Fine Arm
SFAE	SFA Electronics
SI	Smoke Indicator
SLM	Structural Latch Mechanism
SLP-D	Spacelab Pallet – D
SLP-D1	Spacelab Pallet – Deployable
SLP-D2	Spacelab Pallet – D2
SLT	Station Laptop Terminal System Laptop Terminal
SM	Service Module
SMDP	Service Module Debris Panel
SOC	System Operation Control
SODF	Space Operations Data File
SPA	Small Payload Attachment
SPB	Survival Power Distribution Box
SPDA	Secondary Power Distribution Assembly
SPDM	Special Purpose Dexterous Manipulator
SPEC	Specialist
SRAM	Static RAM
SRB	Solid Rocket Booster
SRMS	Shuttle Remote Manipulator System
SSAS	Segment-to-Segment Attach System
SSC	Station Support Computer
SSCB	Space Station Control Board
SSE	Small Fine Arm Storage Equipment
SSIPC	Space Station Integration and Promotion Center
SSME	Space Shuttle Main Engine
SSOR	Space-to-Space Orbiter Radio
SSP	Standard Switch Panel

SSPTS	Station-to-Shuttle Power Transfer System
SSRMS	Space Station Remote Manipulator System
STC	Small Fire Arm Transportation Container
STR	Starboard Thermal Radiator
STS	Space Transfer System
STVC	SFA Television Camera
SVS	Space Vision System

TA	Thruster Assist
TAC	TCS Assembly Controller
TAC-M	TCS Assembly Controller – M
TAL	Transatlantic Abort Landing
TCA	Thermal Control System Assembly
TCB	Total Capture Box
TCCS	Trace Contaminant Control System
TCCV	Temperature Control and Check Valve
TCS	Thermal Control System
TCV	Temperature Control Valve
TDK	Transportation Device Kit
TDRS	Tracking and Data Relay Satellite
THA	Tool Holder Assembly
THC	Temperature and Humidity Control Translational Hand Controller
THCU	Temperature and Humidity Control Unit
TIU	Thermal Interface Unit
TKSC	Tsukuba Space Center (Japan)
TLM	Telemetry
TMA	Russian vehicle designation
TMR	Triple Modular Redundancy
TPL	Transfer Priority List
TRRJ	Thermal Radiator Rotary Joint
TUS	Trailing Umbilical System
TVC	Television Camera

UCCAS	Unpressurized Cargo Carrier Attach System
UCM	Umbilical Connect Mechanism
UCM-E	UCM – Exposed Section Half
UCM-P	UCM – Payload Half
UHF	Ultrahigh Frequency
UIL	User Interface Language
ULC	Unpressurized Logistics Carrier
UMA	Umbilical Mating Adapter

UOP	Utility Outlet Panel
UPC	Up Converter
USA	United Space Alliance
US LAB	United States Laboratory
USOS	United States On-Orbit Segment
UTA	Utility Transfer Assembly
VAJ	Vacuum Access Jumper
VBSP	Video Baseband Signal Processor
VCU	Video Control Unit
VDS	Video Distribution System
VLU	Video Light Unit
VRA	Vent Relief Assembly
VRCS	Vernier Reaction Control System
VRCV	Vent Relief Control Valve
VRIV	Vent Relief Isolation Valve
VSU	Video Switcher Unit
VSW	Video Switcher
WAICO	Waiving and Coiling
WCL	Water Cooling Loop
WETA	Wireless Video System External Transceiver Assembly
WIF	Work Interface
WRM	Water Recovery and Management
WRS	Water Recovery System
WS	Water Separator Work Site Work Station
WVA	Water Vent Assembly
WX	Weather
ZSR	Zero-g Stowage Rack

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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, or DVB-compliant Integrated Receiver Decoder, or IRD, with modulation of QPSK/DBV, data rate of 36.86 and FEC 3/4 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 De-coder, or IRD, to participate in live news events and interviews, media 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.

Television Schedule

A schedule of key in-orbit events and media briefings during the mission will be detailed in a NASA TV schedule posted at the link above. The schedule will be updated as necessary and will also be available at:

http://www.nasa.gov/multimedia/nasatv/mission_schedule.html

Status Reports

Status reports on launch countdown and mission progress, in-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.

More Internet Information

Information on the ISS is available at:

http://www.nasa.gov/station

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

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

Information on other current NASA activities is available at:

http://www.nasa.gov

Resources for educators can be found at the following address:

http://education.nasa.gov

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