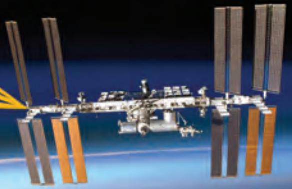
National Aeronautics and Space Administration

SPACE SHUTTLE MISSION

STS-131

Experiment Express

PRESS KIT/April 2010



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STS-131/19A MISSION OVERVIEW

Backdropped by a blue and white part of Earth, the International Space Station is featured in this image photographed by an STS-130 crew member on space shuttle Endeavour.

As the last round-trip for the Leonardo Multi-Purpose Logistics Module, Discovery’s 13-day mission will provide the International Space Station with not only some 8 tons of science equipment and cargo, but also one last opportunity to send a large load of cargo back to the ground.

Leonardo serves as basically a moving van for the space station, allowing the shuttle to, first of all, deliver shipments of equipment and supplies larger than any other vehicle could accommodate, and, second, to return science experiments, unneeded hardware and trash to the ground – all other cargo transfer vehicles burn up in the Earth’s atmosphere. And although Leonardo will return to the station once more on the last space shuttle mission later this year, this is scheduled to be its last round trip – Leonardo will remain permanently at the station after STS-133. So while it will deliver one more batch of goods, the cargo returning on STS-131 will be the last that it brings home.

And although there are only four shuttle missions left before the space shuttle fleet is retired, the program is still making some space "firsts" possible. With three female crew members arriving on board Discovery and one already at the station, the STS-131 mission will mark the first time that four women have been in space at one time. And as there is one Japan Aerospace Exploration Agency astronaut on each crew, the mission is also the first time for two JAXA astronauts to be in space at the same time.

Discovery, commanded by spaceflight veteran Alan G. Poindexter, is scheduled to lift off from Kennedy Space Center at 6:21 a.m. EDT on Monday, April 5, and arrive at the orbiting complex early on Wednesday, April 7.

While docked to the station, Discovery's crew will conduct three spacewalks and spend about 100 combined hours moving cargo in and out of Leonardo and the shuttle's middeck.

NASA astronaut Alan G. Poindexter, STS-131 commander, attired in a training version of his shuttle launch and entry suit, occupies the commander's station on the flight deck of the Full Fuselage Trainer in the Space Vehicle Mockup Facility at NASA's Johnson Space Center.

Poindexter, 48, a U.S. Navy captain, served as pilot on STS-122 in 2008. He will be joined on the mission by pilot James P. Dutton Jr., 41, a U.S. Air Force colonel, who will be making his first trip to space. Mission specialists are Rick Mastracchio, 50, who flew on STS-106 and STS-118 in 2000 and 2007, respectively; Dorothy Metcalf-Lindenburger, 34, a former teacher who became an astronaut in 2004; Stephanie Wilson, 43, who flew on STS-121 and STS-120 in 2006 and 2007, respectively; Naoko Yamazaki, 39, a Japan Aerospace Exploration Agency astronaut; and Clayton Anderson, 51, who spent 152 days on the space station as a member of the Expedition 15 crew in 2007, traveling to the station on STS-117 and returning to Earth on STS-120.

The day after launch, Poindexter, Dutton, Metcalf-Lindenburger, Wilson and Yamazaki will take turns from Discovery'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, 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 Discovery undocks from the station.

While the inspection takes place, Mastracchio and Anderson will prepare the spacesuits they will wear for their three spacewalks out of the Quest airlock at the station. Docking preparations will occupy the remainder of the crew's workday.

On the third day of the flight, Discovery will be flown by Poindexter and Dutton on its approach for docking to the station. After a series of jet firings to fine-tune Discovery'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, Poindexter 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.

Once the rotation is completed, Poindexter will fly Discovery 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 13 will begin nine days of work. Discovery's crew will be working with Expedition 23 commander, Russian cosmonaut Oleg Kotov and flight engineers T.J. Creamer and Tracy Caldwell Dyson, both of NASA; Soichi Noguchi, a Japan Aerospace Agency astronaut; and cosmonauts Alexander Skvortsov and Mikhail Kornienko. Anderson and Kotov were Expedition 15 crew members together, and Mastracchio visited during that time as part of the STS-118 mission.

NASA astronaut James P. Dutton Jr., STS-131 pilot, occupies the pilot's station during a training session in the shuttle mission simulator in the Jake Garn Simulation and Training Facility at NASA's Johnson Space Center.

After a station safety briefing, Wilson and Yamazaki will operate the station's robotic arm to remove the OBSS from Discovery's cargo bay and hand it off to the shuttle robotic arm being operated by Dutton and Metcalf-Lindenburger.

Wilson and Yamazaki will be back at the controls of the station's robotic arm the following day, flight day 4, as they unberth Leonardo and maneuver it into place for installation on the station's Harmony node. Anderson will then work with Noguchi to prepare Leonardo's hatch for opening near the end of the day.

That night, spacewalkers Mastracchio and Anderson 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.

Astronaut Clayton Anderson, STS-131 mission specialist, participates in an Extravehicular Mobility Unit spacesuit fit check in the Space Station Airlock Test Article in the Crew Systems Laboratory at NASA's Johnson Space Center. Astronaut Dorothy Metcalf-Lindenburger, mission specialist, assists Anderson.

On the fifth day of the mission, the station will be a hive of activity inside and out. Spacewalkers Mastracchio and Anderson will prepare the ammonia tank assembly brought up in Discovery's cargo bay to be removed by Dutton and Wilson at the controls of the station's robotic arm and temporarily stored on the arm's mobile base. They will also retrieve a science experiment on the Japanese Kibo Laboratory's exposed facility, replace a rate gyro assembly on the center segment of the station's truss and prepare the batteries on the station's P6 solar arrays for replacement later.

Mastracchio (EV 1) will wear a suit with stripes. Anderson (EV 2) will wear a suit with no stripes. Mastracchio and Anderson each have three spacewalks under their belt, one of which they performed together during the STS-118 mission.

While that is going on outside, inside Yamazaki and Noguchi will get to work unpacking some of the larger items brought up inside Leonardo, including a new Minus Eighty-Degree Laboratory Freezer for ISS, a new crew quarters rack and the Muscle Atrophy Resistive Exercise System, a piece of exercise equipment that allows astronauts to exercise seven different joints and scientists to study the strength of the muscles they use.

The sixth day is available for focused inspection of Discovery's heat shield if mission managers deem it necessary. Dutton, Metcalf-Lindenburger and Wilson would conduct that survey in the crew's morning while Mastracchio, Yamazaki and Anderson continued unpacking Leonardo. After lunch, Mastracchio and Anderson will begin preparations for their second spacewalk, while the rest of the shuttle crew, along with Kotov and Noguchi, carry on with the transfer work.

Among the items scheduled to make their way over to the space station on flight day 6 are the Window Observational Research Facility, which provides a set of cameras, multispectral and hyperspectral scanners, camcorders and other instruments to capture imagery of the Earth and space through the Destiny laboratory's window; and EXPRESS rack 7, which will provide power, data, cooling, water and other support to a number of experiments at the station.

NASA astronaut Rick Mastracchio, STS-131 mission specialist, participates in a training session in an International Space Station mock-up/trainer in the Space Vehicle Mock-up Facility at NASA's Johnson Space Center.

All Discovery crew members will participate in transfer of one form or another on flight day 7. For Mastracchio and Anderson, the work will occur over six and a half hours outside the station, as they remove a spent ammonia tank assembly from the starboard side of the station's truss and replace it with the new tank they removed from Discovery during the first spacewalk.

The following morning, the crew will have the first half of flight day 8 off to enjoy some well-earned off duty time, then it will be back to work in Leonardo and time to prepare for the third and final spacewalk of the mission on flight day 9. During that six-and-a-half-hour spacewalk, Mastracchio and Anderson will install in the shuttle's cargo bay the spent ammonia tank assembly they removed on the previous spacewalk. They'll also remove a piece of hardware used to attach equipment and experiments to the exterior of the Columbus laboratory and store it in Discovery's cargo bay; install a camera and remove an insulation blanket on the Special Purpose Dexterous Manipulator; and replace a light in a camera on the exterior of Destiny.

Crew members inside will perform more transfer work while the spacewalk is going on outside, and that work will finish up on the morning flight day 10 before the crews go off duty in the afternoon. All 13 members of the crew will also take some time out for the traditional joint crew news conference on this day.

The hatches between Harmony and Leonardo will be closed on the morning of flight day 11 in preparation for its removal from the station by Wilson and Yamazaki, who will use the space station's robotic arm to pack it back into Discovery's cargo bay for return home. With that done, Discovery's crew will say farewell to the Expedition 23 crew, and hatches will be closed between the two vehicles.

Discovery will leave the space station with more than 20,000 pounds of trash, hardware that's no longer needed and science experiments to return to Earth.

Japan Aerospace Exploration Agency (JAXA) astronaut Naoko Yamazaki (foreground) and NASA astronaut Stephanie Wilson, both STS-131 mission specialists, participate in a Thermal Protection System Orbiter Boom Sensor System training session in the Jake Garn Simulation and Training Facility at NASA's Johnson Space Center.

After Discovery undocks early in the morning of April 16, Dutton will guide the shuttle on a 360-degree fly-around of the station so that other crew members can document the exterior condition of the orbiting outpost. After that is complete, Poindexter, Dutton, Metcalf-Lindenburger, Wilson and Yamazaki will conduct one last inspection of Discovery's heat shield using the shuttle's robotic arm and orbiter boom sensor system.

The last full day of orbital activities by the STS-131 crew will focus on landing preparations. Poindexter, Dutton and Metcalf-Lindenburger will conduct the traditional checkout of the shuttle's flight control systems and steering jets, setting Discovery up for its supersonic return to Earth.

On the 14th day of the mission, weather permitting, Poindexter and Dutton will steer Discovery to a morning landing on April 18 at the Kennedy Space Center. When the shuttle's wheels roll to a stop, it will wrap up the 38th flight for Discovery, the 131th mission in shuttle program history and the 33nd shuttle visit to the International Space Station

STS-131 crew members, attired in training versions of their shuttle launch and entry suits, take a moment to pose for a crew photo prior to a training session in the Space Vehicle Mock-up Facility at NASA's Johnson Space Center. Pictured from the left are NASA astronauts Clayton Anderson and Stephanie Wilson, both mission specialists; James P. Dutton Jr., pilot; Alan G. Poindexter, commander; Dorothy Metcalf-Lindenburger, Japan Aerospace Exploration Agency (JAXA) astronaut Naoko Yamazaki and NASA astronaut Rick Mastracchio, all mission specialists.

STS-131 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 Hand-held External Tank Photo and TV Downlink

Flight Day 2

- Discovery’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 Discovery’s Thermal Protection System by Expedition 23 crew members Creamer and Kotov
- Docking to Harmony/Pressurized Mating Adapter-2
- Hatch Opening and Welcoming
- Canadarm2 grapple of OBSS and handoff to Shuttle robotic arm

Flight Day 4

- Leonardo Multi-purpose Logistics Module unberth from Discovery’s cargo bay and installation on Harmony module’s Earth-facing port
- Leonardo activation and ingress
- Spacewalk 1 preparations by Mastracchio and Anderson
- Spacewalk 1 procedure review
- Spacewalk 1 campout by Mastracchio and Anderson in the Quest airlock

Flight Day 5

- Transfer of cargo from Leonardo to ISS
- Spacewalk 1 by Mastracchio and Anderson (removal of depleted Ammonia Tank Assembly from S1 truss, replacement of a failed gyroscope unit in the S0 truss, retrieval of Japanese experiment from the Japanese Exposed Facility, preparations for replacement of batteries on the P6 truss on a later mission)

Flight Day 6

- Focused inspection of Discovery's thermal protection heat shield, if required
- Cargo and rack transfer from Leonardo to ISS
- Spacewalk 2 procedure review
- Spacewalk 2 campout by Mastracchio and Anderson in the Quest airlock

Flight Day 7

- Spacewalk 2 by Mastracchio and Anderson (install new Ammonia Tank Assembly on the S1 truss, temporarily stow the depleted ammonia tank on the truss' crew translation cart, install micrometeoroid debris shields on the Quest airlock)

Flight Day 8

- Crew off duty time
- Cargo transfer from Leonardo to ISS
- Spacewalk 3 procedure review
- Spacewalk 3 campout by Mastracchio and Anderson in the Quest airlock

Flight Day 9

- Spacewalk 3 by Mastracchio and Anderson (install depleted ammonia tank back in Discovery's cargo bay, installation of a lightweight plate adapter assembly on the Dextre robot, installation of a new light on a camera assembly on the Destiny laboratory, installation of a camera pan and tilt assembly on Dextre)
- Cargo transfer from Leonardo to ISS

Flight Day 10

- Final cargo transfer operations
- Joint Crew News Conference
- Crew off duty time

Flight Day 11

- Demate of the Leonardo Multi-purpose Logistics Module from the Harmony Earth-facing port and berthing back in Discovery's cargo bay
- Farewells and Hatch Closure
- Rendezvous Tool checkout

Flight Day 12

- Discovery undocking from ISS and flyaround
- Final separation from the station
- OBSS late inspection of Discovery'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:	Alan G. Poindexter
Pilot:	James P. Dutton, Jr.
Mission Specialist 1:	Rick Mastracchio
Mission Specialist 2:	Dorothy Metcalf-Lindenburger
Mission Specialist 3:	Stephanie Wilson
Mission Specialist 4:	Naoko Yamazaki
Mission Specialist 5:	Clayton Anderson

LAUNCH

Orbiter:	Discovery (OV-103)
Launch Site:	Kennedy Space Center Launch Pad 39A
Launch Date:	April 5, 2010
Launch Time:	6:21 a.m. EDT (Preferred In-Plane launch time for 4/5)
Launch Window:	10 Minutes
Altitude:	122 Nautical Miles (140 Miles) Orbital Insertion; 185 NM (213 Miles) Rendezvous
Inclination:	51.6 Degrees
Duration:	13 Days 2 Hours 14 Minutes

VEHICLE DATA

Shuttle Liftoff Weight:	4,521,749 pounds
Orbiter/Payload Liftoff Weight:	266,864 pounds
Orbiter/Payload Landing Weight:	224,957 pounds
Software Version:	OI-34

Space Shuttle Main Engines:

SSME 1:	2045
SSME 2:	2060
SSME 3:	2054
External Tank:	ET-135
SRB Set:	BI-142
RSRM Set:	110

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:	April 18, 2010
Landing Time:	8:35 a.m. EDT
Primary landing Site:	Kennedy Space Center Shuttle Landing Facility

PAYLOADS

Multi-Purpose Logistics Module

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MISSION OBJECTIVES

MAJOR OBJECTIVES

1. Perform middeck and Multi-Purpose Logistics Module cargo transfers.
2. Remove current Ammonia Tank Assembly on S1 and install new ATA (old ATA to be installed on Lightweight Multi-Purpose Experiment Support Structure Carrier).
3. Transfer and install the following racks:
    - Muscle Atrophy Research and Exercise System (MARES)
    - Window Observational Research Facility (WORF)
    - Minus Eighty-Degree Laboratory Freezer for ISS (MELFI-3)
    - EXpedite the PRocessing of Experiments to Space Station (EXPRESS) Rack No. 7
    - Crew Quarters No. 2
    - 2 Zero-g Stowage Racks (ZSR)
4. Retrieve Light Weight Adapter Plate Assembly payload.
5. Retrieve Japanese Experiment Module SEED payload.
6. Return three Integrated Stowage Platforms.

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MISSION PERSONNEL

KEY CONSOLE POSITIONS FOR STS-131

	Flt. Director	**CAPCOM**	**PAO**
Ascent	Bryan Lunney	Rick Sturckow George Zamka (Wx)	Brandi Dean
Orbit 1 (Lead)	Richard Jones	Rick Sturckow	Brandi Dean
Orbit 2	Mike Sarafin	Aki Hoshide	Josh Byerly
Planning	Ginger Kerrick	Megan McArthur/ Chris Cassidy	Lynnette Madison
Entry	Bryan Lunney	Rick Sturckow George Zamka (Wx)	Brandi Dean
Shuttle Team 4	Gary Horlacher	N/A	N/A
ISS Orbit 1	Courtenay McMillan	Mike Jensen	N/A
ISS Orbit 2 (Lead)	Ron Spencer	Stan Love	N/A
ISS Orbit 3	Ed Van Cise	Marcus Reagan	N/A
Station Team 4	Brian Smith		

JSC PAO Representative at KSC for Launch – Jenny Knotts

KSC Launch Commentator – Mike Curie

KSC Launch Director – Pete Nickolenko

NASA Launch Test Director – Steve Payne

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STS-131 CREW

The STS-131/19A crew patch highlights the space shuttle in the Rendezvous Pitch Maneuver (RPM). This maneuver is heavily photographed by the International Space Station crew members, and the photos are analyzed back on Earth to clear the space shuttle's thermal protection system for re-entry. The RPM illustrates the teamwork and safety process behind each space shuttle launch.

In the space shuttle's cargo bay is the Multi-Purpose Logistics Module (MPLM) Leonardo, which is carrying several science racks, the last of the four crew quarters and supplies for the space station. Out of view and directly behind the MPLM is the Ammonia Tank Assembly (ATA) that will be used to replace the current ATA. This will take place during three spacewalks. The 51.6Â° space shuttle orbit is illustrated by the three gold bars of the astronaut symbol, and its elliptical wreath contains the orbit of the station. The star atop the astronaut symbol is the dawning sun, which is spreading its early light across the Earth. The background star field contains seven stars, one for each crew member; they are proud to represent the United States and Japan during this mission.

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

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

The STS-131 crew is commanded by Alan G. Poindexter (seated, right) and piloted by James P. Dutton Jr. (seated, left). Standing from the left are Mission Specialists Rick Mastracchio, Stephanie Wilson, Dorothy Metcalf-Lindenburger, Naoko Yamazaki and Clayton Anderson.

STS-130 CREW BIOGRAPHIES

Alan G. Poindexter

A captain in the U.S. Navy, Alan G. Poindexter will command the STS-131 crew on its mission to the space station. This will be the second trip to space for Poindexter, who has more than 306 hours of spaceflight experience after serving as pilot of STS-122, which delivered and installed the European Space Agency's Columbus Laboratory in 2008.

Poindexter will be responsible for the execution of the mission and will oversee all crew and vehicle activities. As commander, he will fly Discovery during the rendezvous pitch maneuver. He also will fly the shuttle during docking and landing back on Earth.

Selected by NASA in 1998, Poindexter served as a CAPCOM and in the Astronaut Office Shuttle Operations Branch performing duties as the lead support astronaut at Kennedy Space Center.

James P. Dutton Jr.

Marking his first spaceflight journey, James P. Dutton, Jr., a colonel in the U.S. Air Force, will serve as pilot of STS-131. He will assist Poindexter with rendezvous and landing and will fly the orbiter during undocking and the fly-around. In addition, he will serve as lead shuttle robotic arm operator for the mission, will be responsible for airlock operations in preparation for EVAs and will assist Wilson with the station robotic arm operations.

Dutton graduated from the U.S. Air Force Academy in 1991. After being selected by NASA in 2004 and completing astronaut candidate training two years later, he was the ascent/entry CAPCOM for STS-122 and STS-123, both in 2008. He has logged over 3,300 flight hours in more than 30 different aircraft.

Rick Mastracchio

Veteran astronaut Rick Mastracchio will serve as mission specialist 1 on STS-131, marking his third trip to space. He joined NASA in 1990 as an engineer in the Flight Crew Operations Directorate. Before being selected as an astronaut he worked as an ascent/entry guidance and procedures officer in Mission Control supporting 17 missions as a flight controller. Selected as an astronaut in 1996, he has worked technical issues for the Astronaut Office Computer Support Branch, the Extravehicular Activity (EVA) Branch, and also served as lead for cockpit avionics upgrades. He flew as the ascent/entry flight engineer on STS-106 and STS-118 and participated in three spacewalks on STS-118.

Mastracchio, lead EVA crew member, will be on the flight deck for ascent and will perform three spacewalks with Clay Anderson.

Dorothy Metcalf-Lindenburger

A former teacher, Dorothy Metcalf-Lindenburger will serve as mission specialist 2 on STS-131. She is the intravehicular crew member, responsible for coordinating all spacewalk activities. She also will operate the shuttle robotic arm.

Selected by NASA as a mission specialist in 2004, Metcalf-Lindenburger has most recently served as the Astronaut Office Station Branch lead for systems and crew interfaces.

She spent five years teaching Earth science and astronomy, three years of coaching cross-country at the high school level and two years of teaching Science Olympiad. She also did undergraduate research in geology for two summers.

Stephanie Wilson

A Harvard engineering graduate and veteran of two spaceflights, Stephanie Wilson is assigned as mission specialist 3 for STS-131. She previously flew on STS-121 in 2006 and STS-120 in 2007. At the conclusion of STS-131, she will have flown on Discovery for all three of her spaceflights. Wilson's primary duties for the STS-131 mission include operating the space station robotic arm, operating the hand-held LIDAR and the rendezvous situational awareness tools during docking and undocking with the station, and managing the plan that transforms Discovery from a launch vehicle to an orbiting vehicle to an entry vehicle.

After being selected by NASA in 1996 from the Jet Propulsion Laboratory, Wilson was initially assigned technical duties in the Astronaut Office Space Station Operations Branch to work with space station payload displays and procedures. She then went on to serve in the Astronaut Office CAPCOM Branch, working in mission control as a prime communicator with in-orbit crews.

Naoko Yamazaki

Japan Aerospace Exploration Agency (JAXA) astronaut Naoko Yamazaki will serve as mission specialist 4 on STS-131, her first spaceflight. Loadmaster for the mission, she will be responsible for all payload and transfer operations, and she will also assist Wilson with MPLM install and berthing operations with SSRMS.

Yamazaki joined the National Space Development Agency of Japan (NASDA) in 1996 and was involved in the Japanese Experiment Module system integration and specifically assigned developmental tasks. For two years she was involved in the development of the station centrifuge (life science experiment facility) and conducted conceptual framework and preliminary design in the Centrifuge Project Team.

Selected by NASDA (currently JAXA) in 1999 as one of three astronaut candidates for the space station, five years later she arrived at Johnson Space Center where she initially served in the Astronaut Office Robotics Branch.

Clayton Anderson

Veteran of one long-duration spaceflight, Clayton Anderson will serve as mission specialist 5 for STS-131. In 2007, he launched to the station aboard STS-117 and replaced Suni Williams as the Expedition 15 flight engineer and returned home as a member of the STS-120 crew.

At Johnson Space Center, Anderson worked in the Mission Operations Directorate as a flight design manager leading the trajectory design team for the Galileo Planetary Mission, STS-34, while serving as the backup for the Magellan Planetary Mission, STS-31. In 1993, he was named chief of the Flight Design Branch. Anderson later then held the position of manager of the Emergency Operations Center. He was selected by NASA in 1998.

Anderson will be on the flight deck for entry. He will assist with rendezvous and undocking and will perform three spacewalks with Mastracchio.

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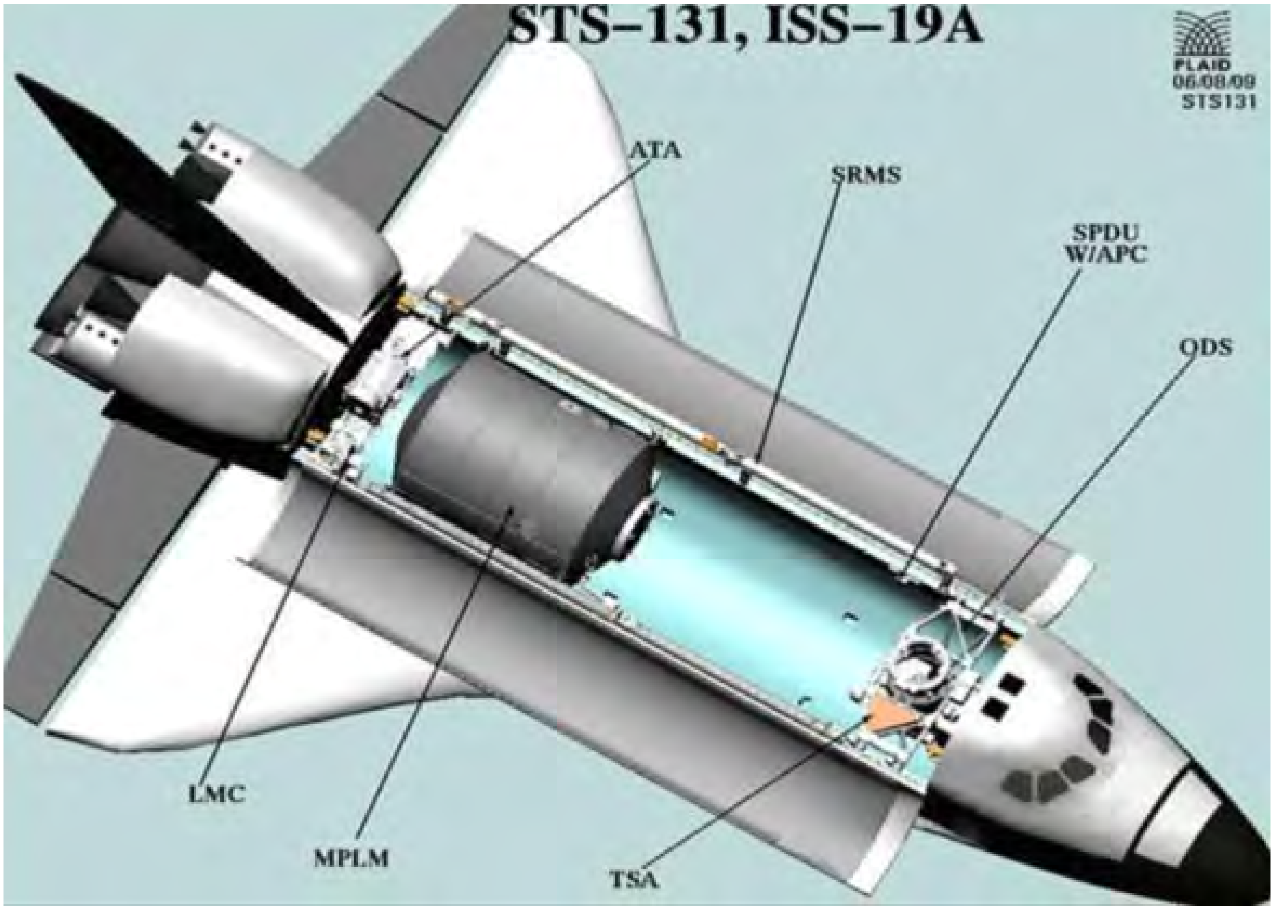
PAYLOAD OVERVIEW



The graphic depicts the placement of the primary STS-131 payloads in the shuttle's cargo bay.

Space shuttle Discovery's STS-131/19A payload includes the Leonardo Multi-Purpose Logistics Module (MPLM) and the Lightweight Multi-Purpose Experiment Support Structure Carrier (LMC). The total payload weight, not counting the middeck, is 31,130 pounds. The return weight is expected to be 24,118 pounds.

On the middeck of the space shuttle, it will carry GLACIER, which is a freezer designed to provide cryogenic transportation and preservation capability for samples. The unit is a double locker equivalent unit capable of transport and operation in the middeck and on-orbit operation in the EXPRESS Rack.

The space shuttle will carry on its middeck (ascent) the following items: GLACIER, MERLIN, Mouse Immunology, Space Tissue Loss, NLP-Vaccine-8, BRIC-16, APEX Cambium, ESA ECCO with WAICO2, JAXA 2D Nano Template, JAXA Myo Lab, JAXA Neuro Rad, Sleep. On its return, among the items carried on the middeck will include GLACIER, MERLIN, Mouse Immunology, Space Tissue Loss, NLP-Vaccine-8, BRIC-16, APEX-Cambium, Coldbag, JAXA Nanoskeleton, JAXA Space Seed, SWAB Return Kit, Sleep.

GLACIER

LEONARDO MULTI-PURPOSE LOGISTICS MODULE (MPLM) FLIGHT MODULE 1 (FM1)

The Leonardo Multi-Purpose Logistics Module (MPLM) is one of three differently named large, reusable pressurized elements, carried in the space shuttle's cargo bay, used to ferry cargo back and forth to the station. For STS-131, FM1 was modified by removing hardware to reduce the weight of the module so that more hardware could be launched for this mission. Approximately 178.1 pounds of noncritical hardware were removed from FM1.

Leonardo includes components that provide life support, fire detection and suppression, electrical distribution and computers when it is attached to the station. The cylindrical logistics module acts as a pressurized "moving van" for the space station, carrying cargo, experiments and supplies for delivery to support the six-person crew on-board the station. The module also returns spent Orbital Replacement Units (ORUs) and components that need maintenance for backup spares. Each MPLM module is 21 feet long and 15 feet in diameter – the same size as the European Space Agency's Columbus module.

MPLM

On the STS-131 mission, Leonardo will carry 16 racks to the station – four experiment racks, one systems rack, seven Resupply Stowage Platforms (RSPs), and four Resupply Stowage Racks (RSRs). The MPLM will also include the fully stocked Aft Cone Stowage (first used on STS-126/Flight Utilization Logistics Flight 2 on November 14, 2008). The aft cone modification allows 12 additional cargo bags, which are similar to the size of carry-on suitcases.

The four experiment racks carried in Leonardo are: Express Rack 7, Muscle Atrophy Research and Exercise System (MARES), Minus Eighty Laboratory Freezer 3 (MELFI-3), and Window Observational Research Facility (WORF). The station system rack is Crew Quarters 4 (CQ-4).

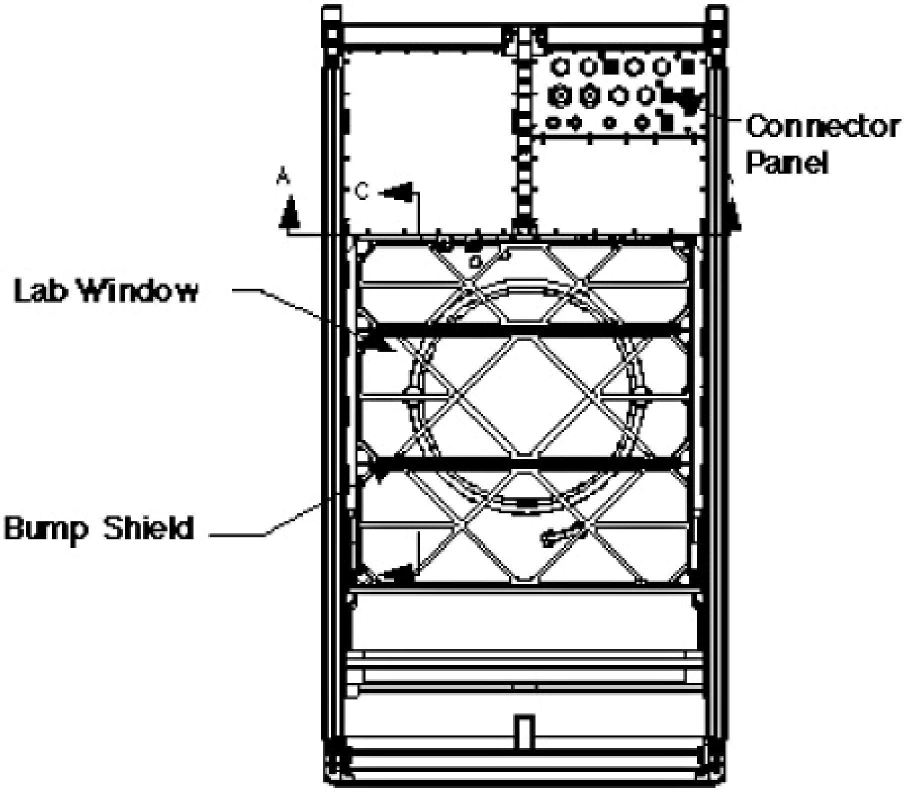
The following are more detailed descriptions on each of these racks:

WINDOW OBSERVATIONAL RESEARCH FACILITY (WORF)

The Window Observational Research Facility (WORF) provides new capability for scientific and commercial payloads and will be a resource for public outreach and educational opportunities for Earth Sciences (e.g., the EarthKAM, etc.). Images from space have many applications; i.e., they can be used to study global climates, land and sea formations, and crop and weather damage and health assessments. Special sensors can also provide important data regarding transient atmospheric and geologic phenomena (hurricanes and volcanic eruptions), as well as act as a test bed for collecting data for new sensor technology development

The WORF is located on the nadir (Earth facing) side of the U.S. Destiny laboratory module. The Lab window, which features the highest quality optics ever flown on a human occupied spacecraft, allows viewing of 39.5 degrees forward along the axis of the station, 32.2 degrees aft and 79.1 degrees from port to starboard.

WORF



Schematic of the WORF

The WORF design uses the existing EXpedite the PRocessing of Experiments to Space Station (EXPRESS) Rack hardware which includes a Rack Interface Controller (RIC) box for power and data connection, Avionics Air Assembly (AAA) fan for air circulation within the rack, rack fire detection, and appropriate avionics to communicate with the station data network. The WORF consists of a facility that provides protection for the interior of the Lab window and controls stray light exchange between the Lab interior and the external Station environment. The WORF will maximize the use of the Lab window by providing attachments for sensors (cameras, multispectral and hyperspectral scanners, camcorders and other instruments) to capture imagery of the Earth and space. It provides attachment points, power and data transfer capability for instruments to be mounted near the window. Multiple instruments can be mounted at the same time. The rack is designed to allow rapid changes of equipment by the crew. The WORF will have available a bracket for small cameras such as 35 mm, 70 mm and camcorders. Other larger payloads, which require a nonstandard attachment, or require additional instrument isolation, must supply their own brackets or platforms which mount to the WORF using the attachment points.

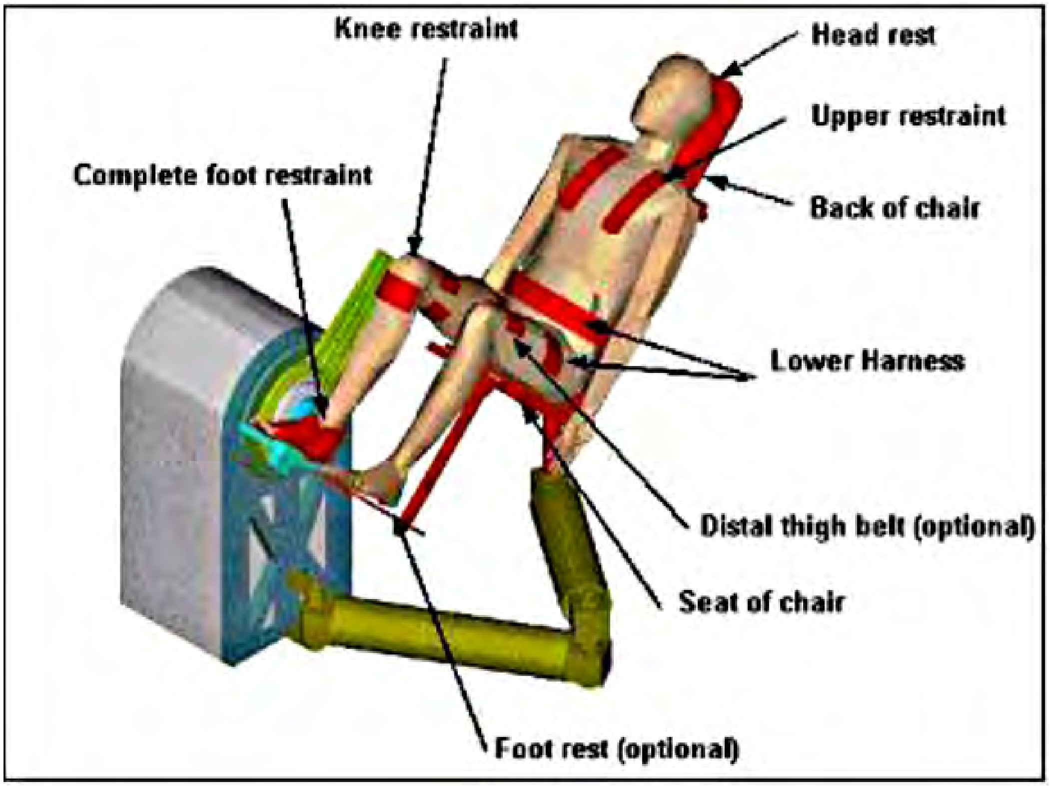
MUSCLE ATROPHY RESEARCH AND EXERCISE SYSTEM (MARES)

The Muscle Atrophy Research and Exercise System (MARES) will be used for research on musculoskeletal, biomechanical, and neuromuscular human physiology to better understand the effects of microgravity on the muscular system.

MARES enables scientists to study the detailed effects of microgravity on the human muscle-skeletal system. It also provides a means to evaluate countermeasures designed to mitigate the negative effect, especially muscle atrophy.

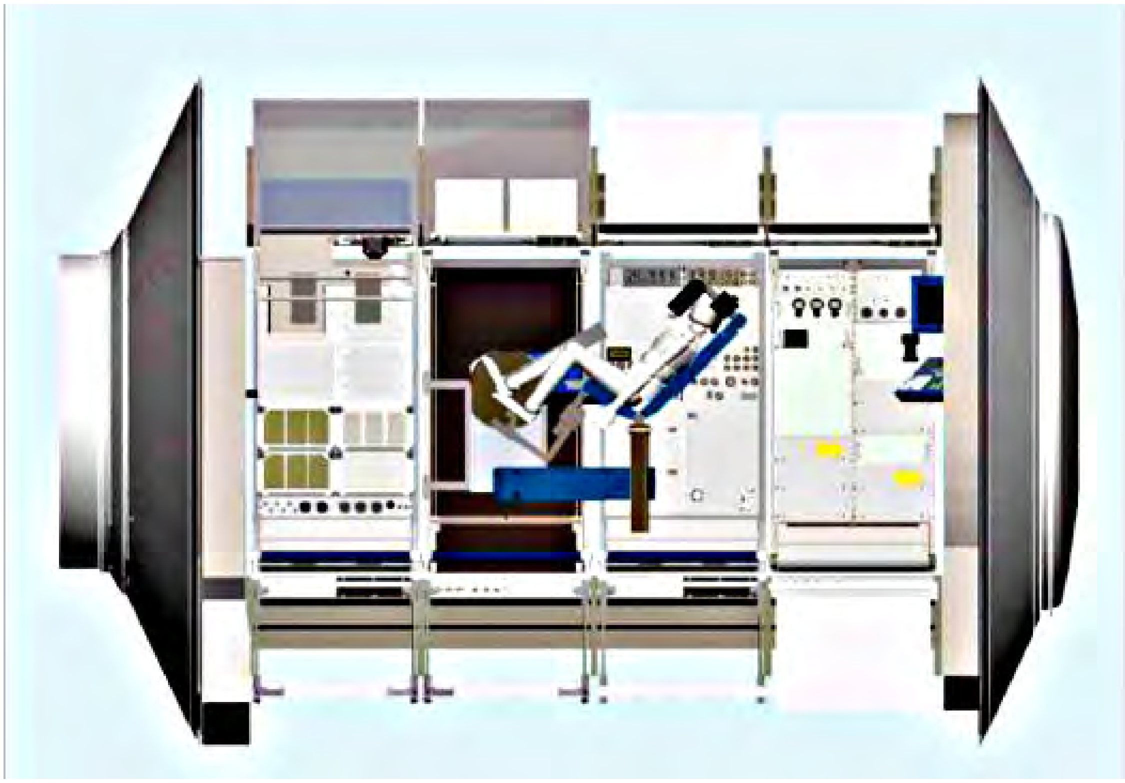
The MARES hardware is made up of an adjustable chair and human restraint system, a pantograph (an articulated arm supporting the chair, used to properly position the user), a direct drive motor, associated electronics and experiment programming software, a linear adapter that translates motor rotation into linear movements, and a vibration isolation frame.

MARES is capable of supporting measurements and exercise on seven different human joints, encompassing nine different angular movements, as well as two additional linear movements (arms and legs). It is considerably more advanced than current ground-based medical dynamometers (devices used to measure force or torque) and a vast improvement over existing station muscle research facilities.



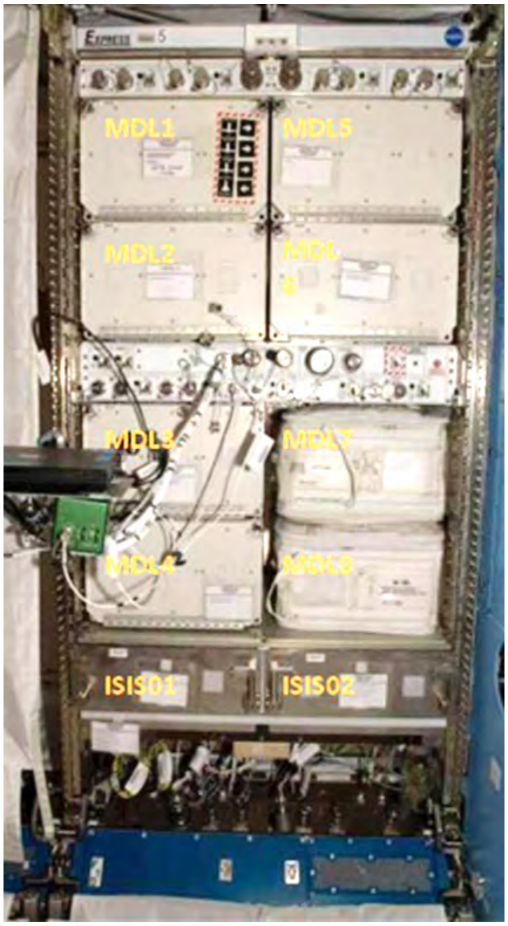
MARES

MARES is integrated into a single International Standard Payload Rack (ISPR), called the Human Research Facility (HRF) MARES Rack, where it can also be stowed when not in use. It may be used together with an associated device called the Percutaneous Electrical Muscle Stimulator (PEMS II).



MARES

EXPRESS RACK 7



EXPRESS rack

EXpedite the PRocessing of Experiments to Space Station Rack 7 (EXPRESS rack 7) is a multipurpose payload rack system that stores and supports experiments aboard the International Space Station. The EXPRESS rack system supports science experiments in any discipline by providing structural interfaces, power, data, cooling, water, and other items needed to operate science experiments in space.

With standardized hardware interfaces and streamlined approach, the EXpedite the PRocessing of Experiments to Space Station (EXPRESS) rack enables quick, simple integration of multiple payloads aboard the space station. The system is composed of elements that remain on the station and elements that travel back and forth between the station and Earth via the space shuttle. EXPRESS racks remain on orbit continually. Experiments are replaced in the EXPRESS racks as needed, remaining on the station for periods ranging from three months to several years, depending on the experiment's time requirements.

Payloads within an EXPRESS rack can operate independently of each other, allowing for differences in temperature, power levels, and schedules. The EXPRESS rack provides stowage, power, data, command and control, video, water cooling, air cooling, vacuum exhaust, and nitrogen supply to payloads. Each EXPRESS rack is housed in an International Standard Payload Rack (ISPR), a refrigerator-size container that serves as the rack's exterior shell.

Experiments contained within EXPRESS racks may be controlled by the station crew or remotely by the Payload Rack Officer (PRO) on duty at the Payload Operations and Integration Center at NASA's Marshall Space Flight Center in Huntsville, Ala. Linked by computer to all payload racks aboard the station, the PRO routinely checks rack integrity, temperature control, and proper working conditions for station research payloads.

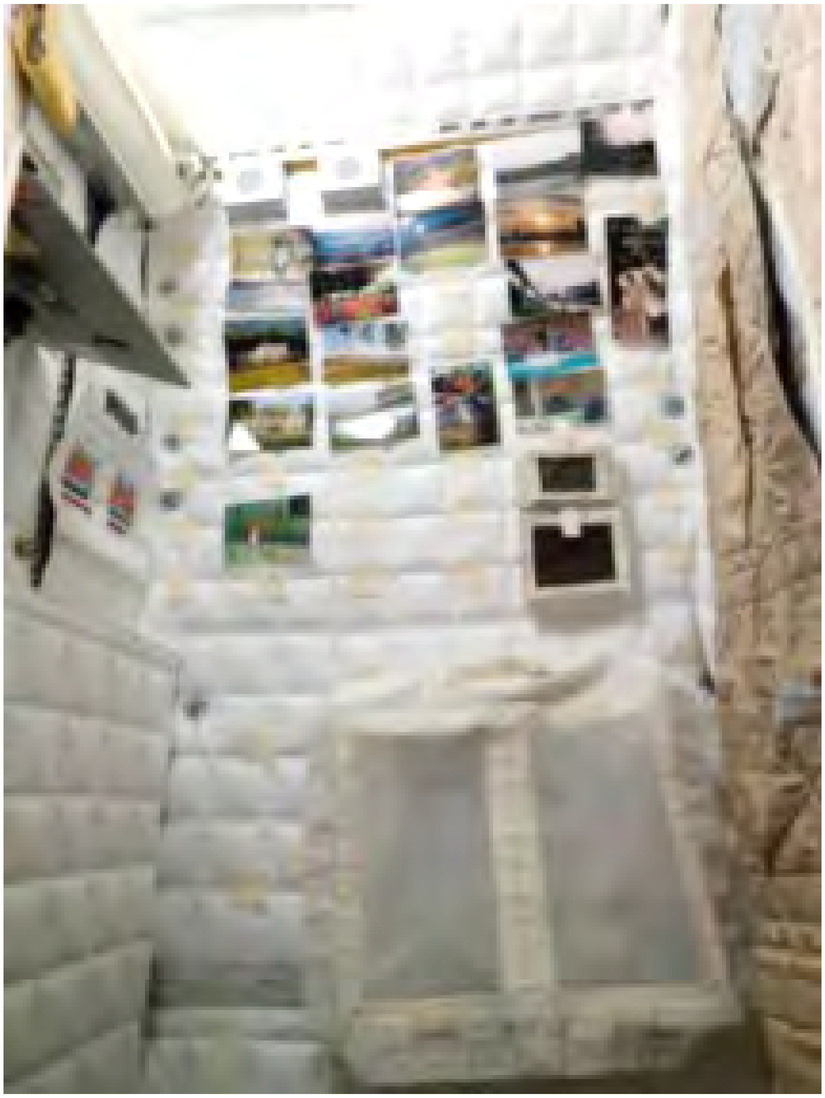
MINUS EIGHTY-DEGREE LABORATORY FREEZER 3 (MELFI-3)

Minus Eighty-Degree Laboratory Freezer for ISS (MELFI) is a European Space Agency-built, NASA-operated freezer that allows samples to be stored on the station at temperatures as low as -80 degrees centigrade. It comprises four temperature-controlled, insulated, independent containers called "dewars," which can be set to operate at different temperatures. Each dewar is a cylindrical, vacuum-insulated 75-liter container and can accommodate samples of a variety of sizes and shapes. The total capacity of the unit is 300 liters and can range in temperatures from refrigerated to "fast frozen." The first MELFI unit was flown to the station on STS-121 and the second MELFI unit was flown on STS-128.

MELFI

CREW QUARTERS (CQ) 4

The crew quarters delivered on STS-131/19A will be installed in the Harmony module (Node 2). The CQ provides private crew member space with enhanced acoustic noise mitigation, integrated radiation reduction material, controllable airflow, communication equipment, redundant electrical systems, and redundant caution and warning systems. The rack-sized CQ is a system with multiple crew member restraints, adjustable lighting, controllable ventilation, and interfaces that allow each crew member to personalize their CQ workspace.



Crew quarters

MPLM BACKGROUND INFORMATION

The Italian-built, U.S.-owned logistics modules are capable of ferrying more than 7.5 tons (15,000 pounds) of cargo, spares and supplies. This is the equivalent of a semi-truck trailer full of station gear bringing equipment to and from the space station. Equipment such as container racks with science equipment, science experiments from NASA and its international partners, assembly and spare parts and other hardware items for return, such as completed experiments, system racks, station hardware that needs repair and refuse from the approximately 220 mile-high outpost. Some of these items are for disposal on Earth while others are for analysis and data collection by hardware providers and scientists.

Leonardo was the first MPLM to fly to the station on STS-102 (March 8, 2002) and there have been nine flights total for the two modules. This will be the seventh Leonardo mission – Raffaello has flown three missions. Of the three MPLM modules, only two remain in active service to NASA for future flights.

The space shuttle flies logistic modules in its cargo bay when a large quantity of hardware has to be ferried to the orbiting habitat at one time. The modules are attached to the inside of the bay for launch and landing. When in the cargo bay, the module is independent of the shuttle cabin, and there is no passageway for shuttle crew members to travel from the shuttle cabin to the module.

The Leonardo logistics module will make its seventh trip to space.

After the shuttle has docked to the outpost, typically on the fourth flight day after shuttle launch, Leonardo is mated to the station using the station's robotic arm to the Node 2 NADIR port. In the event of a failure or issue which may prevent the successful latching of the MPLM to the nadir port, the zenith port can be used to mate the MPLM to the station. Nodes are modules that connect the elements to the station, and Unity was the first element launched to the station to connect the U.S. and Russian segments of the outpost. For its return trip to Earth, Leonardo will be detached from the station and positioned back into the shuttle's cargo bay.

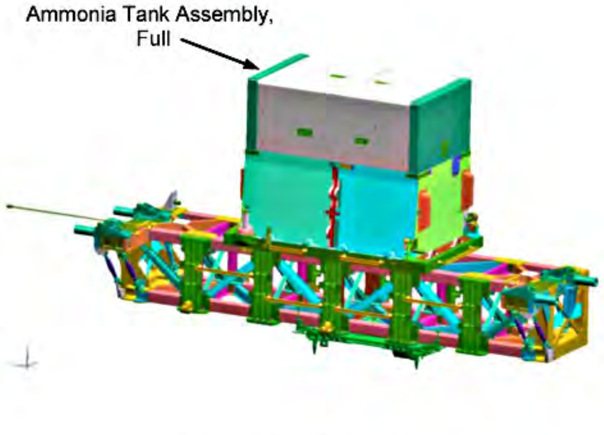
NASA solely owns the modules which were acquired in a bartered agreement between NASA and the Italian Space Agency for using the modules in exchange for allowing the Italians to have crew time on board station.

LEONARDO SPECIFICATIONS	
Dimensions:	Length: 21 feet Diameter: 15 feet
Payload Mass (launch):	27,274 lbs
Payload Mass (return):	20,375 lbs
Empty Weight:	9,632 lbs

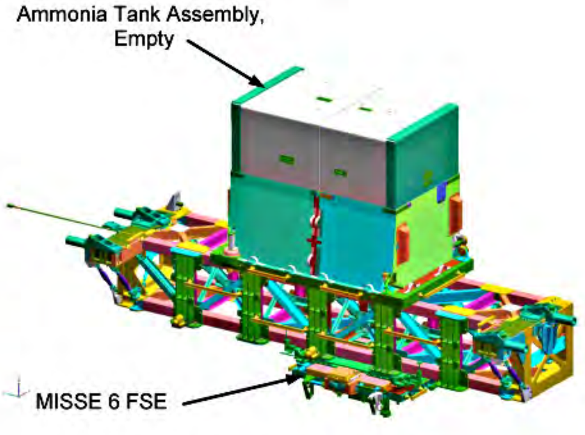
The MPLM Module Leonardo is named after the Italian inventor and scientist Leonardo da Vinci. It was the first MPLM to deliver supplies to the station. The two other modules are named Raffaello, after master painter and architect Raffaello Sanzio, and Donatello, for one of the founders of modern sculpture, Donato di Niccolo Di Betto Bardi. Raffaello has flown three times. Leonardo has flown the most because it is equipped with programmable heater thermostats on the outside of the module that allow for more mission flexibility. Donatello is not currently on the shuttle manifest to fly because of the cost associated with getting the module up to flight status code. STS-131 is the last MPLM flight scheduled before the station is complete and space shuttle retires later this year.

Boeing has the responsibility under its Checkout, Assembly and Payload Processing Services (CAPPS) contract with NASA, for payload integration and processing for every major payload that flies on each space shuttle flight. The Boeing MPLM and LMC processing team provides all engineering and hands-on work including payload support, project planning, receiving of payloads, payload processing, maintenance of associated payload ground systems, and logistics support. This includes integration of payloads into the space shuttle, test and checkout of the payload with the orbiter systems, launch support and orbiter post-landing payload activities including de-stow of the module.

THE LIGHTWEIGHT MULTI-PURPOSE EXPERIMENT SUPPORT STRUCTURE CARRIER (LMC)



Launch Configuration



Return Configuration

Located behind Leonardo in the space shuttle payload bay, is the Lightweight Multi-Purpose Experiment Support Structure Carrier (LMC), a nondeployable cross-bay carrier providing launch and landing transportation. The LMC is a light-weight Shuttle stowage platform that only weighs 1,100 pounds. The launch weight of the LMC is 3,890 pounds and the return weight will be 3,740 pounds. Goddard Space Flight Center and ATK Space provide the sustaining engineering for the LMC carriers, which have flown successfully on five previous missions.

During ascent, the LMC is carrying the Ammonia Tank Assembly (ATA), a critical spare Orbital Replacement Unit (ORU). During descent, the LMC will be carrying a spent Ammonia Tank Assembly (ATA).

RENDEZVOUS & DOCKING

Backdropped by a blue and white part of Earth, space shuttle Atlantis is featured in this image photographed by an Expedition 21 crew member as the shuttle approaches the International Space Station during STS-129 rendezvous and docking operations.

Discovery's launch for the STS-131 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, Discovery 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 Discovery 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 Alan G. Poindexter, with help from Pilot James P. Dutton, Jr. and other crew members, will manually fly the shuttle for the remainder of the approach and docking.

Poindexter will stop Discovery about 600 feet below the station. Timing the next steps to occur with 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 since Discovery is in line with an imaginary vertical R-bar directly below the station. During this maneuver, station crew members Timothy (T.J.) Creamer and Oleg Kotov will photograph Discovery's upper and bottom surfaces through windows of the Zvezda Service Module. They will use digital cameras with an 800mm lens to provide up to one-inch resolution and one with a 400mm lens that provides 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 Discovery completes its backflip, it will be back where it started, with its payload bay facing the station. Poindexter 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 Discovery's docking mechanism.

Using a video camera mounted in the center of the Orbiter Docking System, Poindexter 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 Discovery and the station are moving at about 17,500 mph. Poindexter will keep the docking mechanisms aligned to a tolerance of three inches.

When Discovery makes contact with the station, preliminary latches will automatically attach the two spacecraft. 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. Discovery'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, Dutton will turn the steering jets back on and will manually control Discovery within a tight corridor as the shuttle separates from the station.

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

Once the shuttle completes 1.5 revolutions of the complex, Dutton will fire Discovery's jets to leave the area. The shuttle will begin to increase its distance behind 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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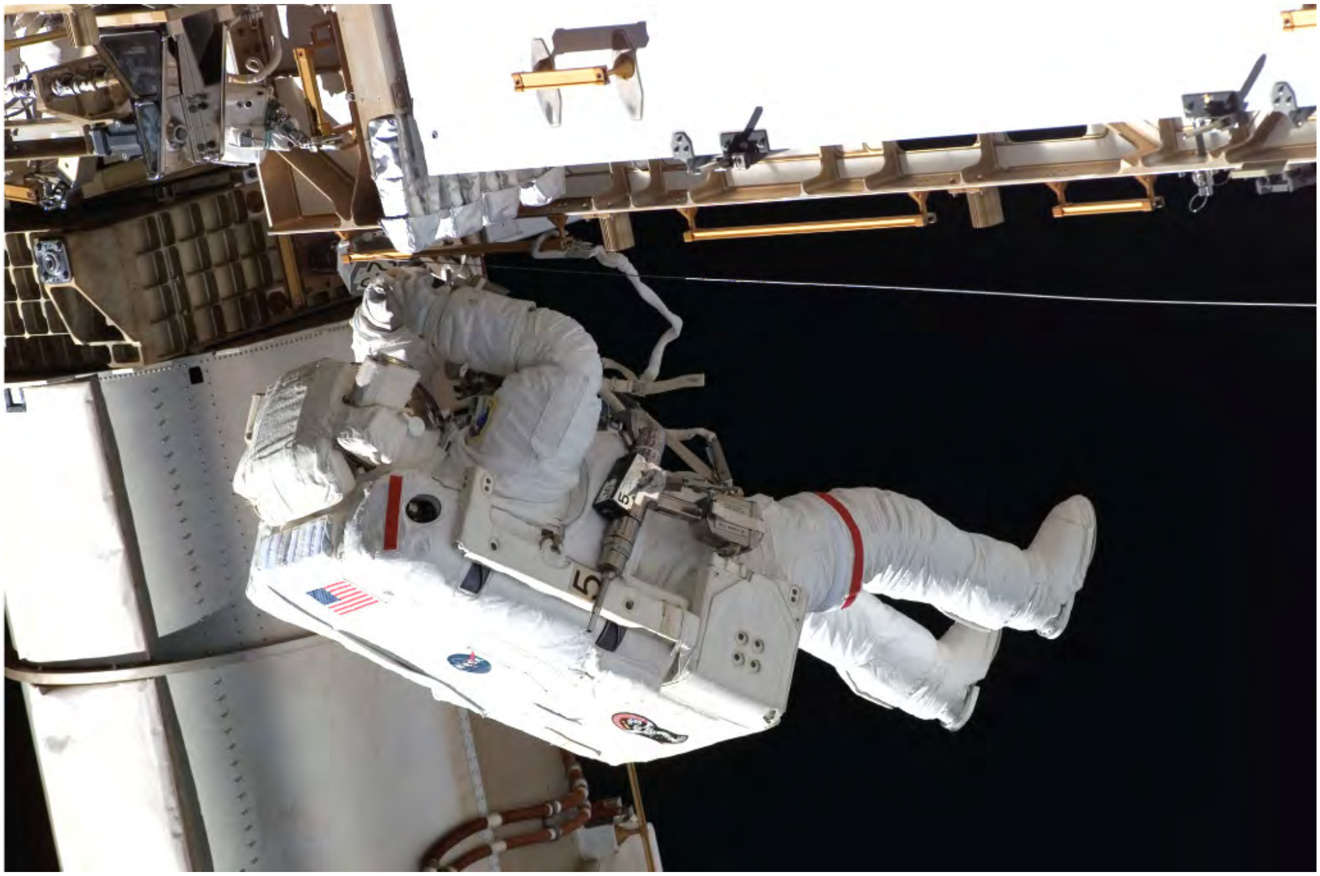
SPACEWALKS



Astronaut Rick Mastracchio participates in the STS-118 mission's first planned session of extravehicular activity, as construction continues on the International Space Station.

The complex choreography of the three spacewalks scheduled for the STS-131 mission will center around getting the ammonia tank assembly delivered by Discovery into place on the starboard side of the station's truss and getting the spent ammonia tank assembly into Discovery's cargo bay.

Because of the location of the old starboard ammonia tank assembly, the space station's robotic arm cannot reach it from the same location that it must be in to remove the new ammonia tank assembly from the shuttle's cargo bay. That means unpacking the new assembly, storing it, a base change for the robotic arm, removing the old assembly, storing it, installing the new, another base change for the arm and then packing the old assembly into the cargo bay. And all that work will take three spacewalks to accomplish, with some space here and there for get-ahead work.

Mission Specialists Rick Mastracchio and Clayton Anderson will spend a total of 19.5 hours outside the station on flight days 5, 7 and 9. Mastracchio, the lead spacewalker for the mission, will wear a spacesuit marked with solid red stripes, while Anderson will wear an all-white spacesuit. These will be the fourth, fifth and sixth spacewalks for both astronauts, and the second, third and fourth that they have performed together. Mastracchio performed three spacewalks during the STS-118 mission, and Anderson performed two during that mission and one during his stint as an Expedition 15 flight engineer.

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 Dorothy Metcalf-Lindenburger. The first spacewalks will also require astronauts inside the station to be at the controls of the station's 58-foot-long robotic arm to maneuver ammonia tank assembly and other pieces of hardware. Pilot James P. Dutton Jr. and Mission Specialist Stephanie Wilson will be at the arm's controls for those operations, with some help from Expedition 23 Flight Engineer Soichi Noguchi on the final spacewalk.

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: Mastracchio and Anderson
IV CREW: Metcalf-Lindenburger
Robotic Arm Operators: Dutton and Wilson

EVA Operations:

- Prepare new ammonia tank assembly for removal from the cargo bay
- Hand new ammonia tank to space station robotic arm for temporary storage
- Retrieve MPAC/SEED from Kibo exposed facility
- Replace rate gyro assembly
- Prepare P6 solar array batteries for replacement

The first leg of the ammonia tank assembly swap will start in the shuttle's cargo bay. After picking up a handle that the space station robotic arm will use to grasp the new tank, Mastracchio will move to the cargo bay and install it on the new tank then begin releasing the four bolts that hold it in place during its journey to the station.

Anderson, meanwhile, will move to the station's starboard truss segment and disconnect the old tank's four ammonia and nitrogen lines before meeting Mastracchio in the cargo bay to do the same on the new tank. Once the lines are disconnected and the bolts released, Anderson and Mastracchio will work together to lift it out of the cargo bay and into position for the robotic arm to grasp it and fly it to the external stowage platform 2 on the Quest airlock.

While it makes its way there, Anderson will clean up their work area while Mastracchio will move to the Kibo laboratory's porch – the Japanese Experiment Module's exposed facility – to retrieve the Micro-Particles Capture/Space Environment Exposure Device experiment and temporarily stow it outside of the airlock – he will move it inside later in the spacewalk.

They will meet the robotic arm back at the external stowage platform to install another handle on the new ammonia tank assembly, while it is still in the grasp of the arm. This second handle will be used to attach the assembly to a temporary storage location on the robotic arm's mobile transporter, where it will wait for installation on the second spacewalk of the mission.

Once that handle is installed, the robotic arm will fly the tank assembly to the storage location, and the spacewalkers will move on to other tasks. The first of the tasks will be the replacement of a rate gyro assembly on the center section of the station's truss. While moving the experiment inside of the airlock, Mastracchio will retrieve a new rate gyro assembly, then move to the center of the truss, where Anderson will have removed from inside the truss, two of the four bolts holding the old assembly in place. When Mastracchio arrives at the truss segment, he will open insulation protecting the assembly, disconnect two power cables and release the final two bolts. He will then remove the old assembly and slide the new one into place, engaging the first two bolts, connecting the power cables and then engaging the last two bolts.

Meanwhile, Anderson will have moved on to their final tasks of the mission: The preparation of the batteries on the farthest port solar array for replacement on a later mission. There are two sets of batteries, and the first set was replaced on STS-127, and some of the equipment used in that work – a gap spanner and a foot restraint – is still in place. Anderson will move it from the set of batteries replaced during STS-127 to the set of batteries he and Mastracchio will be working with. The spacewalker will be loosening the 12 bolts holding the six batteries in place before heading back inside the station.

EVA-2

Duration: 6 hours, 30 minutes
EVA Crew: Mastracchio and Anderson
IV Crew: Metcalf-Lindenburger
Robotic Arm Operators: Dutton and Wilson

EVA Operations

- Remove spent ammonia tank assembly and store temporarily
- Install new ammonia tank assembly on S1 truss segment
- Install two port radiator grapple fixture stowage beams
- Retrieve two debris covers from external stowage platform 2

Mastracchio and Anderson will begin the second spacewalk at the site of the spent ammonia tank assembly on the first segment of the station's starboard truss. Anderson will disconnect two electrical cables. Then he and Mastracchio will work together to release the four bolts holding the assembly in place, lift it off of the station's truss and hand it to the robotic arm.

Mastracchio will then move a crew and equipment translation aid cart – or CETA cart – into place to provide temporary storage for the old ammonia tank assembly. When the assembly arrives via robotic arm at the CETA cart via robotic arm, the spacewalkers will tie it to the cart with six tethers.

That frees the robotic arm up for the installation of the new ammonia tank assembly. While it is retrieving the new assembly from the mobile transporter system, Mastracchio and Anderson will take advantage of the time by installing two radiator grapple fixture stowage beams on the first port segment of the station's truss. These beams will be used temporarily to store handles that would be necessary if a radiator ever needed to be replaced.

By the time they are done with that, the new ammonia tank assembly should be in place. Mastracchio will first remove the handle that allowed it to be stored on the mobile transporter. Then he and Anderson will work together to install it, engaging four bolts and connecting six cables. Once the robotic arm is able to release its hold, the spacewalkers will be able to remove the handle it used to grip the assembly.

The next step will be to go back to the CETA cart, where Mastracchio will untie the old ammonia tank assembly and allow the robotic arm to grasp it. Then Anderson will install another handle on it that will allow the assembly to be stored on the mobile transporter until the final spacewalk, just as the new assembly was stored between the first and second spacewalks.

The final tasks of the second spacewalk calls for Mastracchio and Anderson to return to the external stowage platform 2 by the Quest airlock and retrieve two debris shields left there during STS-129.

EVA-3

Duration: 6 hours, 30 minutes
EVA Crew: Mastracchio and Anderson
IV Crew: Metcalf-Lindenburger
Robotic Arm Operators: Dutton, Wilson and Noguchi

EVA Operations

- Install spent ammonia tank assembly in Discovery's cargo bay
- Retrieve light-weight adapter plate assembly
- Install Dextre camera
- Remove Dextre insulation cover
- Replace Destiny camera light
- Install two starboard radiator grapple fixture stowage beams
- Install worksite interface extender on mobile transporter

The ammonia tank swapout will be more than halfway done by the beginning of the final spacewalk. Before they leave the airlock, the robotic arm will have retrieved the old ammonia tank assembly from the mobile transporter. They will meet the arm at external stowage platform 2 to remove the handle that held it in place there and stow the handle on the platform.

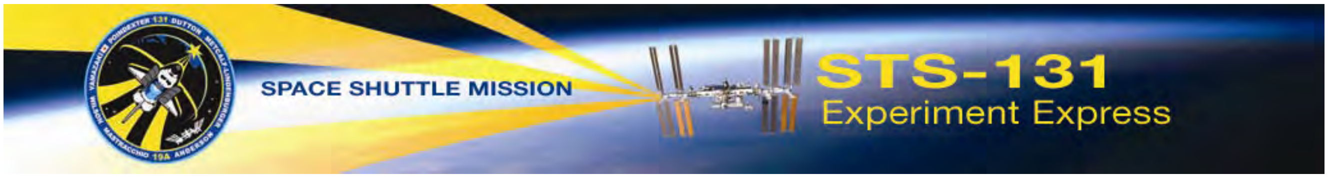
The next stop for the assembly will be Discovery's cargo bay. The spacewalkers will tighten four bolts to hold it in place for landing and remove the remaining handle that allowed the robotic arm to carry the assembly. That will wrap up the ammonia tank assembly work for the mission.

That will take about an hour of their time, and they will fill the rest of the spacewalk with get-ahead work for future missions.

Anderson's next tasks will take him to the Columbus laboratory. He will ride the robotic arm to the end of that module to pick up a light-weight adapter plate assembly, which has been used to attach experiments to the exterior of Columbus. Anderson will store it in the shuttle's cargo bay with help from Matracchio.

Then the robotic arm will fly Anderson to the Special Purpose Dexterous Manipulator, or Dextre. There he will install a second camera on the robot and remove an unnecessary insulation blanket. He will finish his work on the final spacewalk by removing the foot restraint that allowed him to ride the robotic arm.

Meanwhile Mastracchio will replace a light on a camera on the Destiny laboratory and install two more two radiator grapple fixture stowage beams, this time on the starboard side of the station's truss. His final spacewalking task of the mission will be to retrieve a worksite interface extender from the external stowage platform 2 and install it on the mobile transporter.



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://iss-science.jsc.nasa.gov/index.cfm

Detailed information is located at

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

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.

The Enhanced Data Acquisition System, or EDAS, is a data acquisition system that will record pressure data from one of the Reusable Solid Rocket Booster Operational Pressure Transducers, or OPT, and from accelerometers and strain gages placed on the forward skirt walls. These data will provide engineers with time synchronized data that will allow them to determine the accelerations and loads that are transferred through the structure due to the pressure oscillation forces.

DTO 854 Boundary Layer Transition (BLT) Flight Experiment

The Boundary Layer Transition (BLT) flight experiment will gather information on the effect of high Mach number boundary layer transition caused by a protuberance on the space shuttle during the re-entry trajectory.

The experiment is designed to further understand the high Mach number thermal environments created by a protuberance on the lower side of the orbiter during re-entry. The protuberance was built on a BRI-18 tile originally developed as a heat shield upgrade on the orbiters. Due to its geometry and re-entry profile, the Orion crew vehicle will experience a high Mach number boundary layer transition during atmospheric entry. By flying this protuberance during the orbiter's re-entry, a high Mach number transition environment will be created on a small zone of the orbiter's underside, which will aid in gaining an improved understanding of the heating in high Mach number environments.

STS-131 will be the third phase of the flight experiment and represents a repeat of the experiment flown on STS-128. The experiment on STS-128 in August of 2009 gathered data on a 0.35 inch protuberance at Mach 18 speed. The engineering team's goal is to refine its understanding of the Mach 18 environment before stepping up to a higher Mach number protuberance on currently planned for STS-134.

Boundary layer transition is a disruption of the smooth, laminar flow of supersonic air across the shuttle's belly and occurs normally when the shuttle's velocity has dropped to around eight to 10 times the speed of sound, starting toward the back of the heat shield and moving forward. Known as "tripping the boundary layer," this phenomenon can create eddies of turbulence that, in turn, result in higher downstream heating.

For the experiment, a heat shield tile with a "speed bump" on it was installed under Discovery's left wing to intentionally disturb the airflow in a controlled manner and make the airflow turbulent. The bump is four inches long and 0.3 inch wide. Ten thermocouples are installed on the tile with the protuberance and on tiles downstream to capture test data.

Additionally data from this experiment will expand the Aerodynamics and Aeroheating knowledge base and will be used to verify and improve design efforts for future spacecraft.

DTO 701A TriDar Sensor (Triangulation and LIDAR Automated Rendezvous and Docking)

This will be the second space shuttle flight for the TriDAR system. TriDAR is a rendezvous and docking sensor that has been integrated into the space shuttle orbiter to test this new technology in space. TriDAR provides critical guidance information that can be used to guide a vehicle during rendezvous and docking operations in space. Unlike current technologies, TriDAR does not rely on any reference markers, such as reflectors, positioned on the target spacecraft. To achieve this, it relies on a laser based 3D sensor and a thermal imager. Geometrical information contained in successive 3D images is matched against the known shape of the target object to calculate its position and orientation in real-time.

On its first test flight, TriDAR successfully demonstrated 3D sensor based tracking in real-time during rendezvous and docking to the International Space Station. Building on the success of this first flight, TriDAR's second test flight will focus on performance improvements, enhanced pilot displays as well as enhanced long range acquisition capabilities using passive thermal imaging.

Developed by Canada's Neptec Design Group Company, TriDAR's 3D sensor is dual sensing, multi-purpose scanner that builds on Neptec's Laser Camera System (LCS) technology currently used to inspect the space shuttle's thermal protection tiles. TriDAR's shape tracking technology is very flexible and can be adapted for multiple applications such as: robotic operations, planetary landing as well as rover navigation.

DTO 703 Sensor Test for Orion Relative Navigation Risk Mitigation (STORRM)

The first element of the STORRM test is being flown to the International Space Station on the STS-131 mission. STORRM, which is not slated for testing until the STS-134 mission, is designed to demonstrate the capability of relative navigation sensors developed for automated rendezvous and docking of Orion or other future spacecrafts. This DTO will test the Vision Navigation Sensor (VNS) flash LIDAR and high definition docking camera currently planned for the Orion crew exploration vehicle.

Light Detection and Ranging (LIDAR) is an optical remote sensing technology that measures properties of scattered light to find range and/or other information of a distant target.

The test is being performed because it is important that engineers gain a thorough understanding of the new sensors' performance on-orbit in order to validate ground simulation models and properly characterize sensor performance. STORRM will occur both during the space shuttle's approach to and departure from the station.

After Discovery docks to the station, the crew will install a set of reflective elements. The retro-reflectors are titanium clamping mechanisms that contain a small piece of reflective tape covered by Schott glass. The reflectors will augment the station docking target and stand-off cross used by the shuttle.

The reflectors are designed to prevent the shuttle Trajectory Control Sensor (TCS) from tracking the reflective elements at their wavelength, preventing any confusion for the shuttle crew during docking and undocking.

The reflective elements, which were built at Langley Research Center in Virginia, will be placed in a known pattern during STS-131. Having multiple reflectors in the sensor's field of vision at the same time allows the sensor to determine the relative attitude of the vehicle as well as relative position and velocity. This will provide six degrees of freedom for a future a vehicle's Guidance, Navigation and Control system.

The prototype VNS and docking camera will be mounted in an enclosure on the Orbiter Docking System truss next to the TCS.

The system was developed by Ball Aerospace and Technologies in Boulder, Colo., and provided to NASA by Lockheed Martin Corporation in Bethesda, Md.

Detailed Supplementary Objectives (DSOs) are space and life science investigations. Their purpose is to determine the extent of physiological deconditioning resulting from spaceflight, to test countermeasures to those changes and to characterize the space environment relative to crew health.

DSO 640 Physiological Factors

Astronauts experience alterations in multiple physiological systems due to exposure to the microgravity conditions of spaceflight. These physiological changes include sensorimotor disturbances, cardiovascular deconditioning, and loss of muscle mass and strength. These changes may lead to a disruption in the ability to walk and perform functional tasks during the initial reintroduction to gravity following prolonged spaceflight and may cause significant impairments in performance of operational tasks immediately following landing.

The objective of this study is to identify the key underlying physiological factors that contribute to changes in performance of a set of functional tasks that are representative of critical mission tasks for lunar and Mars operations. Astronauts will be tested on an integrated suite of functional and interdisciplinary physiological tests before and after short and long-duration spaceflight. Using this strategy, the investigators will be able to: (1) identify critical mission tasks that may be impacted by alterations in physiological responses; (2) map physiological changes to alterations in functional performance; and (3) design and implement countermeasures that specifically target the physiological systems responsible for impaired functional performance.

For more information, follow these links:

https://rlsda.jsc.nasa.gov/scripts/experiment/exper.cfm?exp_index=1448

https://rlsda.jsc.nasa.gov/docs/research/research_detail.cfm?experiment_type_code=35&researchtype=

EXPERIMENTS

The STS-131/19A mission continues the transition from a focus on International Space Station assembly to continuous scientific research in the fall of 2010.

Nearly 150 operating experiments in human research; biological and biotechnology; physical and materials sciences; technology development; Earth and space science, 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 multi-national laboratory.

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

On STS-131, research into how the human body is affected by long-duration stays in microgravity will be delivered to the space station by Discovery's crew. NASA's Integrated Cardiovascular experiment will continue on-going research into the documented decrease in the size of the human heart muscle and seek to determine the underlying causes for such atrophy. NASA's Integrated Immune experiment will look at how space flight changes the human body's ability to fight off disease and infection. ESA's Anomalous Long Term Effects on Astronauts' Central Nervous System – Shield (ALTEA-Shield) will assess the radiation environment inside the space station, and JAXA's Passive Dosimeter for Lifescience Experiment in Space (PADLES) will test a new, low-overhead method for measuring radiation exposure levels on the station.

Several experiments also will look at operational issues related to human health on orbit. The IntraVenous Fluid GENeration for Exploration Missions (IVGEN) experiment will look at methods for purifying fluids to be used in treating ill or injured crew members on long-duration missions, and the JAXA Mycological Evaluation of Crew Exposure to Space Station Ambient Air – 2 (Myco-2) experiment will support a detailed examination of the risk of crew exposure to allergens in the closed environments. The Vehicle Cabin Atmosphere Monitor (VCAM) investigation looks at potentially harmful gases that are present in minute quantities in the space station breathing air. And the Evaluation of Maximal Oxygen Uptake and Submaximal Estimates of VO2max Before, During, and After Long Duration International Space Station Missions (VO2maX) will look at how astronaut's ability to take in oxygen during exercise changes on long-duration missions.

In addition, Discovery will deliver the Window Observational Research Facility (WORF), which will provide support for Earth science remote sensing instruments using the highest quality optics ever flown on a human-occupied spacecraft; the EXpedite the PRocessing of Experiments to Space Station Rack 7, a multi-purpose payload rack system that stores and supports by providing structural interfaces, power, data, cooling, water, and other items needed to operate science experiments in space; the Muscle Atrophy Research and Exercise System, which provide equipment needed to investigate and measure the effects of microgravity on measurements and exercise on seven different human joints, and a third Minus Eighty-Degree Laboratory Freezer to the space station for storing experiment samples.

SHORT-DURATION U.S. INTEGRATED RESEARCH TO BE COMPLETED DURING STS-131/19A

Biological Research in Canisters – 16 (BRIC-16) germinates *Arabidopsis thaliana* seeds in microgravity to be returned to Earth for analysis by investigator teams. The *Arabidopsis* plant is the preferred model species for plant investigations in space. BRIC-16 contains *Arabidopsis* seeds from various experimenters to the space station. The seeds will germinate on orbit and subsequently be returned to Earth with the returning space shuttle. Investigators can make use of the in flight option for seedlings to be exposed to selected experimental treatments and subsequently fixed, or not, prior to return.

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.

Mouse Immunology will expand the knowledge base of the effects of space environment on mammalian immunology and provide fundamental knowledge for current applications that form a foundation for future long-duration space exploration missions.

National Laboratory Pathfinder – Vaccine – 8 (NLP-Vaccine-8) is a commercial payload serving as a pathfinder for the use of the International Space Station as a National Laboratory after space 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 (RAMBO) is an experiment in which the Department of Defense uses a satellite to observe space shuttle Orbital Maneuvering System engine burns. Its purpose is to improve plume models, which predict the direction the plume, or rising column of exhaust, will move as the shuttle maneuvers on orbit. Understanding the direction in which the spacecraft engine plume, or exhaust flows could be significant to the safe arrival and departure of spacecraft on current and future exploration missions.

Sleep-Wake Actigraphy and Light Exposure During Spaceflight-Short (Sleep-Short) will examine the effects of space flight on the sleep 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.

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 burn experiment using ground-based radars.

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 Orbital Maneuvering System fuel, crew time, and over-flight of ground sites.

Space Tissue Loss (STL) Space Tissue Loss advances research objectives for U.S. Army's Combat Casualty Care Research Program by defining cellular effects and growth characteristics in microgravity for immune system modulation, shock response abatement and directed tissue regeneration. The STL experiments using the Cell Culture Module (CCM) conduct cellular and regenerative medicine research. Exposure to microgravity causes cells to react in a destructive cascade similar to wounds. This breakdown of tissue and function present serious challenges to the health of humans in space. The STL/CCM modules allow for the controlled study of cell and tissue populations. Special emphasis is on the study of the resident population of regenerative cells that normally maintains and repairs tissue. These regenerative cells have demonstrated tremendous utility in wound repair, tissue repair and return to function of damaged organs. Special emphasis is placed on understanding and enhancing the repair activities of regenerative cells for improved health maintenance in space and corollaries on the ground.

Education Payload Operations – Robotics (EPO-Robo) creates an on-orbit video demonstration explaining robotic arm operations on the space shuttle and the International Space Station. EPO-Robo supports NASA's goal of attracting and retaining students in science, technology, engineering, and mathematic disciplines. EPO-Robo will be tied to an agency-wide ground-based robotic education plan revolved around STS-131/19A mission specialist and educator Dorothy Metcalf-Lindenburger. EPO-Robo will involve two on-orbit video demonstrations explaining robotic arm operations and scientific investigations. The robotic arm stations on space shuttle and space station will be used as show and tell items.

Mycological Evaluation of Crew Exposure to Space station Ambient Air (JAXA Myco-2) The purpose of Myco is to evaluate the risk of microorganisms via inhalation and adhesion to the skin to determine which fungi act as allergens on the space station. Samples are collected from the nasal cavity, the pharynx and the skin of crew before, during and after flight, focusing particularly on fungi, which act as strong allergens in the internal space station environment. It is well known that a living and working environment in the space station has been progressively contaminated by a number of microorganisms from the beginning of construction. These microorganisms can possibly cause serious life-threatening diseases and allergies if human immunity is compromised.

RESEARCH TO BE DELIVERED TO THE SPACE STATION

U.S. Research

Capillary Channel Flow (CCF) is a versatile experiment for studying a critical variety of inertial-capillary dominated flows key to spacecraft systems that cannot be studied on Earth. CCF results are immediately useful for the design, testing, and instrumentation for verification and validation of liquid management systems of current orbiting, design stage, and advanced spacecraft envisioned for future exploration missions.

Capillary Flow Experiment – 2 (CFE-2) is a suite of fluid physics experiments that investigate capillary flows and flows of fluids in containers with complex geometries. Results will improve current computer models that are used by designers of low gravity fluid systems and may improve fluid transfer systems on future spacecraft.

Coarsening in Solid Liquid Mixtures-2 (CSLM-2) examines the kinetics of competitive particle growth within a liquid metal matrix. During this process, small particles of tin suspended in a liquid tin-lead matrix shrink by losing atoms to larger particles of tin, causing the larger particles to grow (coarsen). This study defines the mechanisms and rates of coarsening in the absence of gravitational settling. This work has direct applications to metal alloy manufacturing on Earth, including materials critical for aerospace applications (e.g., the production of better aluminum alloys for turbine blades).

Cube Lab is a low-cost 1 kilogram platform for educational projects on the International Space Station. The lab is a multi-purpose research facility that interfaces standard modules into the space station EXPRESS Racks. The Cube Lab platforms are small modules that can be used within a pressurized space station environment in orbit, with a nominal length, width, and height of 100 millimeter and a mass of no more than 1 kilogram.

DEvice for the study of Critical LIquids and Crystallization (DECLIC) is a multi-user facility utilized to study transparent media and their phase transitions in microgravity on board the International Space Station. The Alice-Like Insert (ALI) portion of DECLIC studies the dynamics of near-ambient temperature critical fluids of sulfur hexafluoride (SF_6), a colorless, odorless, nontoxic and nonflammable gas and carbon dioxide (CO_2). ALI is one of the modules developed for DECLIC that will be used to continue the program on fluid physics and dynamics close to critical point.

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 also will identify the mechanisms of this atrophy and the functional consequences for crew members who will spend extended periods of time 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 will collect and analyze blood, urine and saliva samples from crew members before, during and after space flight to monitor changes in the immune system.

IntraVenous Fluid GENeration for Exploration Missions (IVGEN) will demonstrate the capability to purify water to the standards required for intravenous administration, then mix the water with salt crystals to produce normal saline. This hardware is a prototype that will allow flight surgeons more options to treat ill or injured crew members during future long-duration exploration missions.

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 thermo-physical properties of materials. This is a cooperative investigation with ESA and NASA for accommodation and operation aboard the International Space Station.

Preliminary Advanced Colloids Experiment (PACE) will characterize the capability of conducting high magnification colloid experiments with the Light Microscopy Module (LMM) to determine the minimum size particles which can be resolved.

Vehicle Cabin Atmosphere Monitor (VCAM) identifies gases that are present in minute quantities in the International Space Station breathing air that could harm the crew's health. If successful, instruments like VCAM could accompany crew members during long-duration exploration missions.

Evaluation of Maximal Oxygen Uptake and Submaximal Estimates of VO2max Before, During, and After Long Duration International Space Station Mspace Station (VO2maX) documents changes in maximum oxygen uptake for crew members onboard the space station on long-duration missions.

Canadian Space Agency

Cambium (Cambium) 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 experiment will provide an understanding of physiological processes such as gene expression, metabolism and general plant development that are affected in plant systems exposed to space flight. Following return to Earth the plants will be analyzed by microscopy and chemical methods.

European Space Agency Research

Anomalous Long-Term Effects on Astronauts' Central Nervous System – Shield (ALTEA-Shield) will provide an assessment of the radiation environment inside the space station. Astronauts in orbit are exposed to cosmic radiation that is of sufficient frequency and intensity to cause effects on the central nervous system. Radiation exposure represents one of the greatest risks to humans traveling on exploration missions beyond Low Earth Orbit (LEO). The experimental program makes use of the ALTEA detectors to perform a radiation survey on board space station and will improve the understanding of the effect of ionizing radiation on the CNS functions.

Waving and Coiling of Arabidopsis Roots at Different g-levels (WAICO) studies the interaction of circumnutation (the successive bowing or bending in different directions of the growing tip of the stems and roots) and gravitropism (a tendency to grow toward or away from gravity) in microgravity and 1-gravity of *Arabidopsis thaliana*. Specifically, verify that circumnutation of Arabidoposis roots is driven by an endogenous mechanism, that is independent of gravity as a cue.

Japan Aerospace Exploration Agency Research

Production of Two Dimensional NanoTemplate in Microgravity (2D-NanoTemplate) fabricates large and highly oriented nano-scale two-dimensional arranged peptide arrays by suppressing convection, sedimentation, and buoyancy. The arrangement generated will be used as the template of electronic materials on Earth.

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 of long-duration space station crew members. It has been demonstrated that space flight induces adverse consequences such as cardiovascular deconditioning and sleep disturbance which may be accompanied by disruption in circadian rhythms. As those consequences are closely related to autonomic function, cardiac autonomic function may be changed during long-term space flight. 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.

Chaos, Turbulence and Its Transition Process in Marangoni Convection (Marangoni) analyzes the behavior of a surface-tension-driven flow in microgravity. Marangoni convection is a surface-tension-driven flow. A liquid bridge of silicone oil (5 or 10 cSt) is formed into a pair of disks. Convection is induced by imposing the temperature difference between disks. Due to the fluid instability, flow transits from laminar to oscillatory, chaos, and turbulence flows one by ones as the driving force increases. We observe the flow and temperature fields in each stages and investigate the transition conditions and processes precisely.

Molecular Mechanism of Microgravity-Induced Skeletal Muscle Atrophy – Physiological Relevance of Cbl-b Ubiquitin Ligase (MyoLab) studies a rat muscle gene modified cell line to determine the effects of microgravity. The number of bedridden elderly people in Japan is remarkably increasing, which can be considered a serious social problem. However, there is no effective countermeasure for muscle atrophy (decrease in muscle mass), which is a main cause for bedridden conditions. The few countermeasures for unloading mediated muscle atrophy include: rehabilitation, diet and drugs. The MyoLab payload will focus on the inhibition of Cbl-b-mediated ubiquitination (enzyme found in humans) to improve IGF-1 (insulin-like growth hormone) resistance of skeletal muscle cells. Ubiquitin ligase Cbl-b is inhibited by focusing on the competitively inhibitory function of oligopeptides (molecules containing a small number of peptides).

Biological Effects of Space Radiation and Microgravity on Mammalian Cells (NeuroRad) studies the effects of space radiation on the human neuroblastoma cell (nerve cell containing a tumor) line in microgravity. NeuroRad will investigate the biological effects of space radiation on mammalian nerve cells using SK-N-SH (human neuroblastoma cell line). NeuroRad will evaluate the risk factors of long-term space flight by investigating the ability to recover from radiation damage acquired in microgravity. NeuroRad will also evaluate the effects of radiation accumulation as a result of long-term space flight missions. NeuroRad will focus on changes in the mitochondria-related gene expression, since the mitochondria is well known for having a crucial role in apoptosis (programmed cell death). After recovery, the effects of radiation in microgravity will be comprehensively analyzed using the following techniques: nuclear DNA microarray, western blotting, and mutation assays.

Mycological Evaluation of Crew Exposure to Space Station Ambient Air – 2 (Myco-2) evaluates the risk of microorganisms' via inhalation and adhesion to the skin to determine which fungi act as allergens on the space station. Myco-2 samples will be collected from the nasal cavity, the pharynx and the skin of crew during preflight, in flight and post-flight focusing particularly on fungi that act as strong allergens in our living environment. It is well known that a living and working environment in the space station has been progressively contaminated by a number of microorganisms from the beginning of construction. These microorganisms can possibly cause serious life-threatening diseases and allergies if human immunity is compromised.

Passive Dosimeter for Lifescience Experiment in Space (PADLES) measures radiation exposure levels onboard the space station using passive and integrating dosimeters to detect radiation levels. Passive dosimeter packages and an analysis system are developed by JAXA for supporting life science experiments. They provide environmental data for space radiation. Data reading can be done only on the ground after return. PADLES is a compact and battery-less Dosimeter, and has the advantage of no necessity of crew times and package for setting extremely close to biological samples.

Changes in Nutrient Contents in Space Food After Long-Term Space Flight (Space Food Nutrient) assesses the changes in nutrient contents in Japanese space foods after exposure to space station environment for long-duration space flight. Space Food Nutrient examines the effect of exposure to microgravity on the degradation of select of Japanese foods.

FACILITIES TO BE DELIVERED TO INTERNATIONAL SPACE STATION

NASA

Minus Eighty-Degree Laboratory Freezer for Space Station (MELFI) is an ESA-built, NASA-operated freezer that will store samples on space station at temperatures as low as -80 degrees C. This multi-purpose freezer significantly enhances the research capabilities of the U.S. Laboratory on space station. MELFI will support a wide range of life science experiments by preserving biological samples (such as blood, saliva, urine, microbial or plant samples) collected aboard space station for later return and analysis back on Earth. Samples from the space station Medical Project will be stored in MELFI and contribute to multiple studies of the effect of spaceflight on human health.

The Window Observational Research Facility (WORF) provides a facility for Earth science remote sensing instruments using the Destiny science window with the highest quality optics ever flown on a human-occupied spacecraft. The Window Observational Research Facility (WORF) provides a facility by which remotely operated payloads and crew members can perform Earth and space science research, including hand-held photography, at the U.S. Laboratory Science Window on the space station. WORF is based on an International Standard Payload Rack (ISPR) and utilizes avionics and hardware adapted from the EXPRESS Rack program. The rack provides a payload volume equivalent to 0.8 cubic meters, and will be able to support up to three payloads simultaneously, depending on available resources and space available at the window. The WORF will also provide access and equipment for crew Earth observations, such as crew restraints, camera/camcorder brackets, and condensation prevention.

EXpedite the PRocessing of Experiments to Space Station Rack 7 (EXPRESS Rack 7) is a multi-purpose payload rack system that stores and supports experiments aboard the International Space Station. The EXPRESS rack system supports science experiments in any discipline by providing structural interfaces, power, data, cooling, water, and other items needed to operate science experiments in space.

European Space Agency Research

The Muscle Atrophy Research and Exercise System (MARES) will be used for research on musculoskeletal, biomechanical, and neuromuscular human physiology to better understand the effects of microgravity on the muscular system. MARES enables scientists to study the detailed effects of microgravity on the human muscle-skeletal system. It also provides a means to evaluate countermeasures designed to mitigate the negative effect, especially muscle atrophy. The MARES hardware is made up of an adjustable chair and human restraint system, a pantograph (an articulated arm supporting the chair, used to properly position the user), a direct drive motor, associated electronics and experiment programming software, a linear adapter that translates motor rotation into linear movements, and a vibration isolation frame. MARES is capable of supporting measurements and exercise on seven different human joints, encompassing nine different angular movements, as well as two additional linear movements (arms and legs). It is considerably more advanced than current ground-based medical dynamometers (devices used to measure force or torque) and a vast improvement over existing space station muscle research facilities.

RESEARCH SAMPLES TO BE RETURNED ON THE SPACE SHUTTLE

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 space station crew members from the regional decreases in bone mineral density documented on previous space station missions.

Cardiovascular and Cerebrovascular Control on Return from Space Station (CCISS) will study the effects of long-duration space flight on crew members' 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 CSA.

Constrained Vapor Bubble (CVB) operates a miniature wickless heat pipe (heat exchanger) to understand the physics of evaporation and condensation as they affect heat transfer processes in microgravity. The thermophysical principles underlying change-of-phase heat transfer systems controlled by interfacial phenomena are not well understood under microgravity conditions and are less than optimized even under earth gravity conditions. As a result, related passive engineering systems for enhanced heat transfer such as heat pipes have not been optimized. The information obtained from CVB will be used to optimize the design and operation of passive heat transfer devices for Earth and microgravity environments and will be critically important for the successful completion of future long-duration missions beyond low Earth orbit.

DEvice for the study of Critical LIquids and Crystallization-High Temperature Insert (DECLIC-HTI) is a multi-user facility utilized to study transparent media and their phase transitions in microgravity onboard the International Space Station. The High Temperature Insert (HTI) portion of DECLIC studies water (H_2O) near its critical point. HTI is a thermostat for critical fluid experiments involving water between 350 degrees Celsius to 405 degrees Celsius. At around 374 degrees Celsius, close to its critical point, water shows a singular behavior, which is scientifically very interesting to investigate in absence of gravity. HTI is intended to enable the study of near-critical water, and later of other super-critical fluids.

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 crew members who will spend extended periods of time in space.

Validating Vegetable Production Unit (VPU) Plants, Protocols, Procedures and Requirements (P3R) Using Currently Existing Flight Resources (Lada-VPU-P3R) is a study to advance the technology required for plant growth in microgravity and to research related food safety issues. Lada-VPU-P3R also investigates the nonnutritional value to the flight crew of developing plants on-orbit. The Lada-VPU-P3R uses the Lada hardware on the space station and falls under a cooperative agreement between NASA and RSA.

Materials International Space Station Experiment – 6A and 6B (MISSE-6A and 6B) is a sample box attached to the outside of the International Space Station; it is used for testing the effects of exposure to the space environment on small samples of new materials. These samples will be evaluated for their reaction to atomic oxygen erosion, direct sunlight, radiation, and extremes of heat and cold. Results will provide a better understanding of the durability of various materials, with important applications in the design of future spacecraft.

National Laboratory Pathfinder – Cells – 3: *Jatropha* Biofuels (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.

Nutritional Status Assessment (Nutrition) is a comprehensive in-flight study being done to understand changes in human physiology during long-duration space flight. This study includes measures of bone metabolism, oxidative damage, and chemistry and hormonal changes, as well as assessments of the nutritional status of the astronauts participating in the study. The results will have an impact on the definition of nutritional requirements and development of food systems for future exploration missions to the Moon and Mars. This experiment also will help researchers understand the effectiveness of measures taken to counteract the effects of space flight, as well as the impact of exercise and pharmaceutical countermeasures on nutritional status and nutrient requirements for astronauts.

Dietary Intake Can Predict and Protect Against Changes in Bone Metabolism during Spaceflight and Recovery (Pro-K) investigation is NASA's first evaluation of a dietary countermeasure to lessen bone loss of astronauts. Pro-K proposes that a flight diet with a decreased ratio of animal protein to potassium will lead to decreased loss of bone mineral. Pro-K will have an impact on the definition of nutritional requirements and development of food systems for future exploration missions, and could yield a method of counteracting bone loss that would have virtually no risk of side effects.

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, including blood and urine, will be collected, processed and archived during the preflight, in-flight and post-flight phases of space station missions. This investigation has been developed to archive biosamples for use as a resource for future space flight related research.

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

Analysis of a Novel Sensory Mechanism in Root Phototropism (Tropi) studies *Arabidopsis thaliana* plants sprouting from seeds to gain insights into sustainable agriculture for future long-duration space missions. Tropi is a plant growth experiment that will investigate how plant roots from *Arabidopsis thaliana* (thale cress) respond to varying levels of light and gravity. Plant growth under various gravity conditions (0g to 1.0g) is achieved using a rotating centrifuge. Plants grown will be analyzed to determine which genes are responsible for successful plant growth in microgravity. This experiment will help gain insight into how plants grow in space to help create sustainable life support systems for long term space travel.

Evaluation of Maximal Oxygen Uptake and Submaximal Estimates of VO2max Before, During, and After Long Duration International Space Station Mspace Station (VO2max) documents changes in maximum oxygen uptake for crew members onboard the space station on long-duration missions. VO_2max, sometimes referred to as VO_2peak, is the standard measure of aerobic capacity and is directly related to the physical working capacity of an individual. VO_2max is related to the ability to perform an egress task while wearing a launch and escape space suit; therefore, decreased VO_2max may represent a safety concern in the event of an emergency during space flight. By understanding the changes in VO_2max that occur within space flight, necessary adjustments can be made to EVA exercise countermeasures.

Canadian Space Agency

Vascular Health Consequences of Long-Duration Space Flight (Vascular) determines the impact of long-duration space flight on the blood vessels of astronauts. Vascular Health Consequences of Long-Duration Space Flight determines the impact of long-duration space flight on the blood vessels of astronauts. Space flight accelerates the aging process and we must understand this to determine the need for specific countermeasures.

European Space Agency Research

Long Term Microgravity: A Model for Investigating Mechanisms of Heart Disease with New Portable Equipment (Card) experiment studies blood pressure decreases in the human body exposed to microgravity onboard the space station. In microgravity, the cardiovascular system relaxes causing a drop in the blood volume and pressure. This also causes the fluid and sodium retaining systems to be activated. One theory of this occurrence is that the body's level of sodium is decreased. This investigation will examine whether blood pressure and volume can be restored to the same levels that were measured during ground-based measurements by adding additional salt to the astronauts' food.

Japan Aerospace Exploration Agency Research

Japan Aerospace Exploration Agency – Education Payload Observation (JAXA-EPO) activities demonstrate educational events and artistic activities on board the space station to enlighten the general public and create enthusiasm about microgravity research and human space flight.

Leavenest – Information to be provided by JAXA at a later date.

Chaos, Turbulence and its Transition Process in Marangoni Convection (Marangoni) analyzes the behavior of a surface-tension-driven flow in microgravity. Marangoni convection is a surface-tension-driven flow. A liquid bridge of silicone oil (5 or 10 cSt) is formed into a pair of disks. Convection is induced by imposing the temperature difference between disks. Due to the fluid instability, flow transits from laminar to oscillatory, chaos, and turbulence flows one by ones as the driving force increases. We observe the flow and temperature fields in each stages and investigate the transition conditions and processes precisely.

Production of High Performance Nanomaterials in Microgravity (Nanoskeleton) aims to clarify the effect of gravity on oil flotation, sedimentation and convection on crystals generated in microgravity. Nanoskeleton will quantitatively investigate the effects of gravity during a chemical reaction process.

Passive Dosimeter for Lifescience Experiment in Space (PADLES) measures radiation exposure levels onboard the space station using passive and integrating dosimeters to detect radiation levels. Passive dosimeter packages and an analysis system are developed by JAXA for supporting life science experiments. They provide environmental data for space radiation. Data reading can be done only on the ground after return. PADLES is a compact and battery-less dosimeter, it has the advantage of no necessity of crew times and package for setting extremely close to biological samples.

Life Cycles of Higher Plants Under Microgravity Conditions (SpaceSeed) cultivates *Arabidopsis thaliana* (a small flowering plant) in microgravity to improve the productivity of crops in space as well as for understanding the role of gravity in regulating the life cycle of higher plants. The experiments with Arabidopsis under the microgravity environment on JEM will provide an abundance of important and useful information necessary for improving the productivity of crops in space, as well as for understanding the role of gravity in regulating the life cycle of higher plants.

EDUCATION ACTIVITIES

For STS-131 education activities, NASA Education selected two education themes aligned to the mission: robotics and women in Science, Technology, Engineering and Mathematics, or STEM, careers. The STS-131 crew will be heavily involved in complex robotic operations during its mission. Three of the mission specialists are women, excellent role models for young girls interested in STEM careers.

ROBOTICS

For STS-131, NASA Education developed a comprehensive robotics Web site – a one-stop shop for NASA K-12 education activities and resources related to robotics. While there are many ways to teach robotics, by design, this NASA Web site is focused on simple and inexpensive ways to introduce students to robotic concepts. Educators can find multiple lesson plans that use common materials and objects.

The Web site is found at:

www.nasa.gov/education/robotics

WOMEN IN STEM

Launch Conference

The NASA Office of Education will host an education forum in Florida in the days before the STS-131 launch. Focus for the launch forum will be on strategies to encourage young women to pursue STEM careers and robotics as an effective learning tool. NASA Education plans to bring together members of the K-12, higher education and informal education communities to discuss strategies to encourage young women to pursue STEM careers.

Dorothy Metcalf-Lindenburger

Before becoming an astronaut in 2004, Dorothy Metcalf-Lindenburger taught Earth science and astronomy for five years at Hudson's Bay High School in Vancouver, Wash. As a mission specialist on STS-131, she will operate the space shuttle's robotic arm and the 50-foot Orbiter Boom Sensor System.

IN-ORBIT EDUCATION ACTIVITIES

Education Payload Operations (EPO)

During the mission, Metcalf-Lindenburger and one of her crewmates, Japan Aerospace Exploration Agency astronaut Naoko Yamazaki, will conduct education payload operations to capture video on both the shuttle and the International Space Station for a NASA education film. The video will highlight robotic arm operations and NASA's diverse robotic missions; it also will explore the many career fields associated with robotics. It is not anticipated that the video will be downlinked during the mission. This video will be edited post-flight and will be posted to the robotics Web site.

In-flight Education Downlinks

If mission operations permit, members of the STS-131 crew will participate in two live in-flight education downlinks. During the education downlinks, crew members will answer questions from K-12 students. To select the downlink hosts, which are formal and informal education communities, NASA

Education released a call for proposals. After a highly competitive process, two education organizations were selected as downlink hosts.

On flight day 6, STS-131 Commander Alan G. Poindexter, Pilot James P. Dutton, Jr. and Metcalf-Lindenburger are scheduled to participate in an education downlink with K-12 educators and students gathered at the Naval Post Graduate School (NPGS) in Monterey, Calif. Education activities related to NASA and the mission are planned both before and after the downlink. Through social media and partnerships with media groups, the NPGS plans to share the downlink and related activities with a large off-site K-12 audience that could potentially include Department of Defense schools around the world.

On flight day 10, Poindexter and Mission Specialists Stephanie Wilson, Clayton Anderson and Metcalf-Lindenburger are scheduled to participate in an education downlink with educators and students at Eastern Guildford High School in Gibsonville, N.C. The high school plans to involve K-12 students from the entire school district in STEM education activities before, during and after the mission.

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, 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 NASA's 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 fuel tank, or ET, and orbiter, and to transmit the weight load through their structure to the mobile launcher 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 NASA's 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 Kennedy 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 Kennedy, 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 3 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 NASA's Michoud Assembly Facility, 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 NASA's 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, Discovery 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 NASA's Kennedy Space Center 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 Kennedy 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 Discovery on STS-131 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

2D-Nano Template	Two Dimensional Nano Template
A/G	Alignment Guides
A/L	Airlock
AAA	Avionics Air Assembly
ABC	Audio Bus Controller
ABRS	Advanced Biological Research System
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
ALI	Alice-Like Insert
ALTEA-Shield	Anomalous Long Term Effects on Astronauts Central Nervous System-Shield
AM	Atmosphere Monitoring
AMOS	Air Force Maui Optical and Supercomputing Site
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
ARS	Atmosphere Revitalization System
ASW	Application Software
ATA	Ammonia Tank Assembly
ATCS	Active Thermal Control System
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
BLT	Boundary Layer Transition
BM	Berthing Mechanism
BOS	BIC Operations Software
BRIC	Biological Research in Canisters
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
CAPPS	Checkout, Assembly and Payload Process Services
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
CCF	Capillary Chanel Flow
CCIS	Cardiovascular and Cerebrovacular on Return from Space Station
CCM	Cell Culture Module
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
CFE-2	Capillary Flow Experiment-2
CHeCS	Crew Health Care System
CHX	Cabin Heat Exchanger

CISC	Complicated Instruction Set Computer
CLA	Camera Light Assembly
CLPA	Camera Light Pan Tilt Assembly
CLSM-2	Coarsening in Solid Liquid Mixtures
CMG	Control Moment Gyro
COTS	Commercial Off the Shelf
CPA	Control Panel Assembly
CPB	Camera Power Box
CQ	Crew Quarters
CR	Change Request
CRT	Cathode-Ray Tube
CSA	Canadian Space Agency
CSA-CP	Compound Specific Analyzer
CTC	Cargo Transport Container
CVB	Constrained Vapor Bubble
CVIU	Common Video Interface Unit
CVT	Current Value Table
CZ	Communication Zone
DB	Data Book
DC	Docking Compartment
DCSU	Direct Current Switching Unit
DDCU	DC-to-DC Converter Unit
DECLIC-HTI	DEvice for the Study of Critical Liquids and Crystalization-High Temperature Insert
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
DSO	Detailed Supplementary Objective
DTO	Detailed Test Objective
DYF	Display Frame
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
EDAS	Enhanced Data Acquisition System
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
EPO	Education Payload Operations
EPO-Robo	Education Payload Operations – Robotics
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
EXPRESS	EXpedite the PRocessing of Experiments to Space Station
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
GLACIER	General Laboratory Active Cryogenic ISS Experiment Refrigerator
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
HRF	Human Research Facility
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
IVGEN	IntraVenous Fluid GENeration for Exploration Missions
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
LCS	Laser Camera System
LED	Light Emitting Diode
LEE	Latching End Effector
LEO	Low Earth Orbit
LIDAR	Light Detection and Ranging
LMC	Lightweight Multipurpose Experiment Support Structure Carrier
LMM	Light Microscopy Module
LSW	Light Switch
LTA	Launch-to-Activation
LTAB	Launch-to-Activation Box
LTL	Low Temperature Loop

MA	Main Arm
MARES	Muscle Atrophy Research and Exercise System
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
MERLIN	Microgravity Experiment Research Locker Incubator II
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	Multi-Purpose Experiment Support Structure
MPEV	Manual Pressure Equalization Valve
MPL	Manipulator Retention Latch
MPLM	Multi-Purpose Logistics Module
MPM	Manipulator Positioning Mechanism
MPV	Manual Procedure Viewer
MSD	Mass Storage Device
MSFC	Marshall Space Flight Center
MSL-CETSOL	Material Science Laboratory – Columnar-to-Equiaxcol Transition in Solidification
MSP	Maintenance Switch Panel
MSS	Mobile Servicing System
MT	Mobile Tracker
	Mobile Transporter
MTL	Moderate Temperature Loop
MUX	Data Multiplexer
Myco-2	Mycological Evaluation of Crew Exposure to Space Station Ambient Air-2
MyoLab	Molecular Mechanism of Micrograivty-Induced Skeletal Muscle Atrophy
n.mi.	nautical mile
NASA	National Aeronautics and Space Administration
NCS	Node Control Software
NET	No Earlier Than

NeuroRad	Biological Effects of Space Radiation and Microgravity on Mammalian Cells
NLP-Vaccine-8	National Lab Pathfinder-Vaccine-8
NLT	No Less Than
NPGS	Naval post Graduate School
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
OI	Orbiter Interface
OIU	Orbiter Interface Unit
OMS	Orbital Maneuvering System
OODT	Onboard Operation Data Table
OPT	Operational Pressure Tranducers
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

P3R	Plants, Protocals, Procedures and Requirements
P/L	Payload
PACE	Preliminary Advanced Colloids Experiment
PADLES	Passive Dosimeter for Lifescience Experiment in Space
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
PEMS II	Percutaneous Electrical Muscle Stimulator
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
PRO	Payload Rack Officer
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
RACU	Russian-to-American Converter Unit
RAM	Read Access Memory
RAMBO	Ram Burn Observations
RBVM	Radiator Beam Valve Module
RCC	Range Control Center
RCT	Rack Configuration Table
RF	Radio Frequency
RGA	Rate Gyro Assemblies
RHC	Rotational Hand Controller
RIC	Rack Interface 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
R-ORU	Robotics Compatible Orbital Replacement Unit
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	Resupply Stowage Platform Return Stowage Platform
RSR	Resupply Stowage Rack
RT	Remote Terminal
RTAS	Rocketdyne Truss Attachment System
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
SEITE	Shuttle Exhaust Ion Turbulence Experiments
SELS	SpaceOps Electronic Library System
SEU	Single Event Upset
SFA	Small Fine Arm
SFAE	SFA Electronics
SI	Smoke Indicator
SIMPLEX	Shuttle Ionospheric Modification with Pulsed Localized Exhaust Experiments
Sleep-Short	Sleep-Wake Actigraphy and Light Exposure During Spaceflight-Short
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
STEM	Science, Technology, Engineering and Mathematics
STL	Space Tissue Lost
STORRM	Sensor Test for Orion Relative Navigation Risk Mitigation
STR	Starboard Thermal Radiator
STS	Space Transfer System
STVC	SFA Television Camera
SVS	Space Vision System
SWAB	Surface, Water, and Air Biocharacterization

TA	Thruster Assist
TAC	TCS Assembly Controller
TAC-M	TCS Assembly Controller – M
TCA	Thermal Control System Assembly
TCB	Total Capture Box
TCCS	Trace Contaminant Control System
TCCV	Temperature Control and Check Valve
TCS	Trajectory Control Sensor 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
VCAM	Vehicle Cabin Atmosphere Monitor
VCU	Video Control Unit
VDS	Video Distribution System
VLU	Video Light Unit
V02maX	Evaluation of Maximal Oxygen Uptake and Submaximal Estimates of V02max Before, During, and After Long Duration International Space Station Missions
VNS	Vision Navigation Sensor
VPU	Vegetable Production 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
WORF	Window Observational Research Facility
WRM	Water Recovery and Management
WRS	Water Recovery System
WS	Water Separator Work Site Work Station
WVA	Water Vent Assembly
ZSR	Zero-g Stowage Rack

MEDIA ASSISTANCE

NASA TELEVISION TRANSMISSION

NASA Television is carried on an MPEG-2 digital signal accessed via satellite AMC-6, at 72 degrees west longitude, transponder 17C, 4040 MHz, vertical polarization. For those in Alaska or Hawaii, NASA Television will be seen on AMC-7, at 137 degrees west longitude, transponder 18C, at 4060 MHz, horizontal polarization. In both instances, a Digital Video Broadcast, 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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