

Handbook of Space Shuttle Missions



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Chapter- 1

STS-1

STS-1

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Mission statistics

Mission name	STS-1
Space shuttle	<i>Columbia</i>
Crew size	2
Launch pad	Kennedy Space Center, Florida LC 39A
Launch date	12 April 1981 12:00:03 UTC
Landing site	Edwards AFB, Runway 23

Landing	14 April 1981 18:20:57 UTC
Mission duration	2d/6:20:53
Number of orbits	37
Apogee	156 mi (251 km)
Perigee	149 mi (240 km)
Orbital period	89.4 min
Orbital altitude	307 km (191 mi)
Orbital inclination	40.3 degrees
Distance traveled	1,728,000 kilometres (1,074,000 mi)

Crew photo



Crew members John W. Young (left) and Robert L. Crippen pose in ejection escape suits (EES) with small model of the space shuttle orbiter.

STS-1 was the first orbital flight of the United States Space Shuttle, launched on 12 April 1981, and returning to Earth 14 April. Space Shuttle *Columbia* orbited the earth 37 times in this 54.5-hour mission. It was the first US manned space flight since the Apollo-Soyuz Test Project on 15 July 1975. STS-1 was the only US manned maiden test flight of a new spacecraft system, although it was the culmination of atmospheric testing of the Space Shuttle orbiter.

Crew

Position	Astronaut
Commander	John W. Young Fifth spaceflight
Pilot	Robert Crippen First spaceflight

Backup crew

Position	Astronaut
Commander	Joe Engle
Pilot	Richard Truly

Mission parameters

- **Mass:**
 - *Orbiter Liftoff:* 219,256 lb (99,453 kg)
 - *Orbiter Landing:* 195,466 lb (88,662 kg)
 - *DFI payload:* 10,822 lb (4,909 kg)
- **Perigee:** 149 mi (240 km)
- **Apogee:** 156 mi (251 km)
- **Inclination:** 40.3°
- **Period:** 89.4 min

Mission highlights

The first launch of the Space Shuttle occurred on 12 April 1981, exactly 20 years after the first manned space flight, when the orbiter *Columbia*, with two crew members, astronauts John W. Young, commander, and Robert L. Crippen, pilot, lifted off from Pad A, Launch Complex 39, at the Kennedy Space Center — the first of 24 launches from Pad A. It was exactly 7 a.m. EST. A launch attempt 2 days earlier was scrubbed because of a timing problem in one of *Columbia*'s general purpose computers.

Not only was this the first launch of the Space Shuttle, but it marked the first time that solid-fuel rockets were used for a U.S. manned launch. (Note that all Mercury and Apollo astronauts had relied on a solid-fuel motor in the escape tower.) It was also the first U.S. manned space vehicle launched without an unmanned powered test flight. The STS-1 orbiter, *Columbia*, also holds the record for the amount of time spent in the Orbiter Processing Facility (OPF) before launch — 610 days, time needed for replacement of many of its heat shield tiles.

Primary mission objectives of the maiden flight were to check out the overall Shuttle system, accomplish a safe ascent into orbit and to return to Earth for a safe landing. The only payload carried on the mission was a Development Flight Instrumentation (DFI) package which contained sensors and measuring devices to record orbiter performance and the stresses that occurred during launch, ascent, orbital flight, descent and landing. All of these objectives were met successfully, and the Shuttle's worthiness as a space vehicle was verified.

During Day 2, the astronauts received a phone call from Vice President George H. W. Bush. President Ronald Reagan originally intended to visit the Mission Control Center

during the mission, but was still recovering from an assassination attempt two weeks before launch.

The STS-1 Shuttle reached an orbital altitude of 166 nautical miles (307 km). The 37-orbit, 1,074,567-mile (1,729,348 km)-long flight lasted 2 days, 6 hours, 20 minutes and 53 seconds. Landing occurred on Runway 23 at Edwards Air Force Base, California at 10:21 a.m. PST, 14 April 1981. *Columbia* was returned to Kennedy Space Center from California on April 28 atop the Shuttle Carrier Aircraft.

Mission anomalies



STS-1 touches down at Edwards Air Force Base

STS-1 was the first test flight of what was, at the time, probably the most complex spacecraft ever built. There were numerous problems – 'anomalies' in NASA parlance – on the flight, as many systems could not be adequately tested on the ground or independently. Some of the more serious or interesting were:

- A tile next to the right-hand External Tank (ET) door on the underside of the shuttle was incorrectly installed, leading to excessive re-entry heating and melting of part of the ET door latch.
- Inspection by astronauts while in orbit showed significant damage to the thermal protection tiles on the OMS/RCS pods at the orbiter aft end, and John Young reported that two tiles on the nose looked like someone had taken 'big bites out of them'. Post-flight inspection of *Columbia's* heat shield revealed that an overpressure wave from the Solid Rocket Booster (SRB) ignition resulted in the loss of 16 tiles and damage to 148 others.
- The same overpressure wave pushed the body flap below the main engines at the rear of the shuttle well past the point where damage to the hydraulic system would be expected, which would have made a safe re-entry impossible. The crew were unaware of this until after the flight, and John Young reportedly said that if they had been aware of the potential damage at the time, they would have flown the

shuttle up to a safe altitude and ejected, causing *Columbia* to have been lost on the first flight.

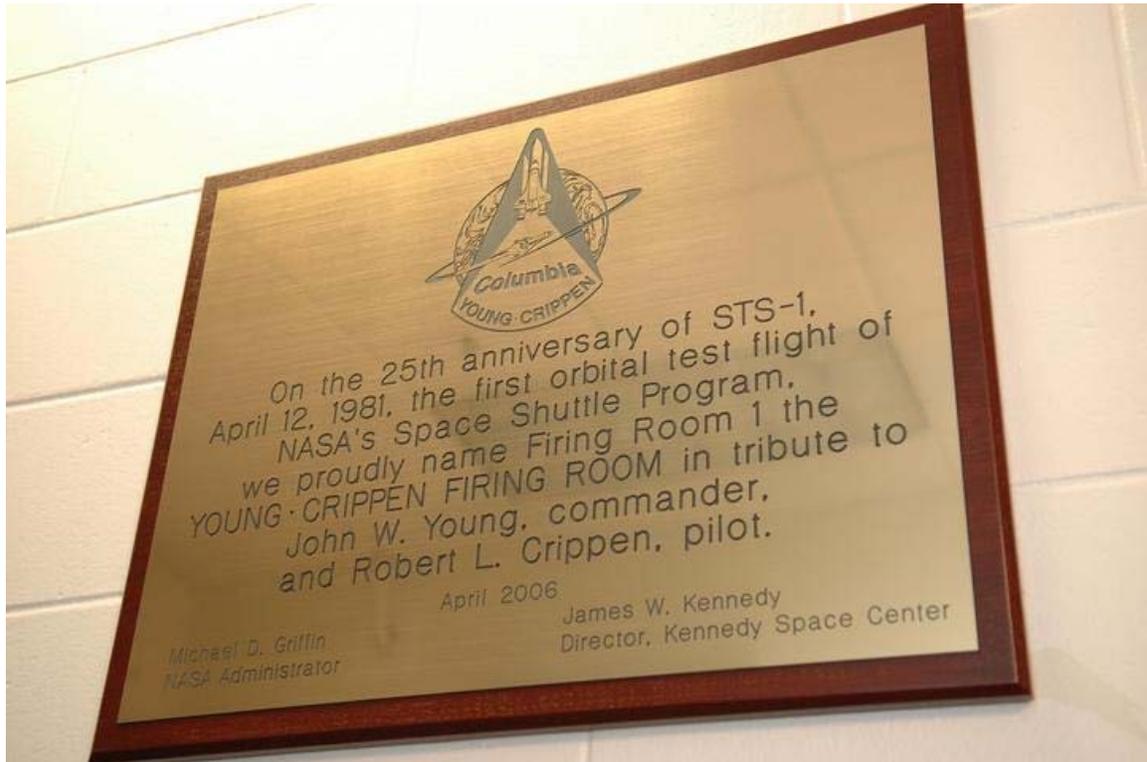
- Bob Crippen reported that all through the first stage of the launch up to SRB separation, he saw 'white stuff' coming off the External Tank and splattering the windows, which was probably the white paint covering the ET thermal foam.
- The toilet suffered from 'low urinal flow and a feces separation problem'.
- *Columbia*'s aerodynamics at high Mach number were found to differ significantly in some respects from those estimated in pre-flight testing. A misprediction of the location of the center of pressure (due to using an ideal gas model instead of a real gas model) caused the computer to extend the body flap by sixteen degrees rather than the expected eight or nine, and side-slip during the first bank reversal maneuver was twice as high as predicted.
- During remarks at a 2003 gathering, John Young stated that a protruding tile gap filler ducted hot gas into the right main landing gear well, which caused significant damage including buckling of the landing gear. Buckling of the door, but not the landing gear, is documented in the post-flight anomaly report.

Despite these problems, STS-1 was a successful test, and in most respects *Columbia* came through with flying colors. After some modifications to the shuttle and to the launch and re-entry procedures, *Columbia* would fly the next four Shuttle missions.

Mission insignia

The artwork for the official mission insignia was designed by artist Robert McCall. It is a symbolic representation of the shuttle. The image does not depict the black wing roots present on the actual shuttle.

Anniversary



The plaque of the Young-Crippen Firing Room in the Launch Control Center at Kennedy Space Center

The ultimate launch date of STS-1 fell on the 20th anniversary of Vostok 1, the first manned spaceflight. Another twenty years later, in 2001, Yuri's Night would be established to celebrate both events.

In tribute to the 25th anniversary of the first flight of Space Shuttle, Firing Room 1 in the Launch Control Center at Kennedy Space Center was renamed to the Young-Crippen Firing Room, dedicating the firing room that launched the historic flight and the crew of STS-1.

NASA described the mission as: *"The boldest test flight in history"*.

External tank

STS-1 was one of only two shuttle flights to have its External Tank (ET) painted white. In an effort to reduce the Shuttle's overall weight, all flights from STS-3 onward used an unpainted tank. The use of an unpainted tank provides a weight savings of approximately 272 kilograms (600 lb), and gives the ET the distinctive orange color which is now associated with the Space Shuttle.

Cultural references

The song "Countdown", by Rush, from the 1982 album *Signals*, was written about STS-1 and the inaugural flight of *Columbia*. The song was "dedicated with thanks to astronauts Young and Crippen and all the people of NASA for their inspiration and cooperation".

Hail Columbia!

IMAX cameras filmed the launch, landing, and mission control during the flight, for a film entitled *Hail Columbia!*, which debuted in 1982 and is now available on DVD. The title of the film comes from the pre-1930s unofficial American national anthem, also titled *Hail, Columbia*.

Wake-up calls

NASA began a tradition of playing music to astronauts during the Gemini program, which was first used to wake up a flight crew during Apollo 15. This special musical track at the start of each day in space was chosen, sometimes by their families, to have a special meaning to an individual member of the crew or to the day's planned activities.

Flight Day	Song	Artist/Composer
Day 2	"Blast-Off Columbia"	Roy McCall
Day 3	"Reveille"	Houston DJs Hudson and Harrigan

Chapter- 2

STS-126

STS-126

Mission insignia



Mission statistics

Mission name	STS-126
Space shuttle	<i>Endeavour</i>
Launch pad	LC-39A
Launch date	14 November 2008 19:55 EST (Nov 15, 2008, 00:55 UTC)
Landing	30 November 2008 13:25:06 PST (21:25 UTC)
Mission duration	15 days, 20 hours, 30 minutes, 34 seconds
Number of orbits	251
Orbital altitude	Orbital insertion: 122 nautical miles (226 km), Rendezvous: 190 nautical miles (350 km)
Orbital inclination	51.6 degrees

Distance traveled 6,615,109 miles (10,645,986 km)

Docking

Docking date 16 November 2008 22:01 UTC

Undocking date 28 November 2008 14:47 UTC

Time docked 11 days, 16 hours, 46 minutes

Crew photo



From left to right: Magnus, Bowen, Pettit, Ferguson, Boe, Kimbrough and Stefanyshyn-Piper

Related missions

Previous mission

STS-124 

Subsequent mission

STS-119 

STS-126 was a Space Shuttle mission to the International Space Station (ISS) flown by Space Shuttle *Endeavour*. The purpose of the mission, referred to as **ULF2** by the ISS program, was to deliver equipment and supplies to the station, to service the Solar Alpha Rotary Joints (SARJ), and repair the problem in the starboard SARJ that had limited its use since STS-120. STS-126 launched on 14 November 2008 at 19:55:39 p.m. EST from Launch Pad 39A at NASA's Kennedy Space Center with no delays or issues. *Endeavour* successfully docked with the station on November 16. After spending 11 days, 16 hours, and 46 minutes docked to the station, during which the crew performed four spacewalks, and transferred cargo, the orbiter undocked on 28 November 2008. Due to poor weather at Kennedy Space Center, *Endeavour* landed at Edwards Air Force Base on 30 November 2008 at 21:25 UTC (13:25 PST).

Crew

Position	Launching Astronaut	Landing Astronaut
Commander	Christopher Ferguson Second spaceflight	
Pilot	Eric A. Boe First spaceflight	
Mission Specialist 1	Heidemarie Stefanyshyn-Piper Second spaceflight	
Mission Specialist 2	Stephen G. Bowen First spaceflight	
Mission Specialist 3	Donald Pettit Second spaceflight	
Mission Specialist 4	Robert S. Kimbrough First spaceflight	
Mission Specialist 5	Sandra H. Magnus Expedition 18 Second spaceflight ISS Flight Engineer	Gregory Chamitoff Expedition 18 First spaceflight ISS Flight Engineer

Crew notes

Originally scheduled to fly on STS-126 was Joan E. Higginbotham, who was a mission specialist on STS-116. On 21 November 2007, NASA announced a change in the crew manifest due to Higginbotham's decision to leave NASA to take a job in the private sector. Stephen G. Bowen was originally assigned to STS-124 but was moved to STS-126 to allow *Discovery* to rotate Greg Chamitoff with Garrett Reisman.

Mission parameters

- **Mass:**
 - Orbiter liftoff: 266,894 pounds (121,061 kg)
 - Orbiter landing: 223,422 pounds (101,343 kg)
- **Perigee:** 185 nautical miles (343 km)
- **Apogee:** 190 nautical miles (350 km)
- **Inclination:** 51.6
- **Period:** 91.6 minutes

Mission payloads

Location	Cargo	Mass
Bays 1-2	Orbiter Docking System EMU 3005 / EMU 3011	1,800 kilograms (4,000 lb) ~260 kilograms (570 lb)
Bay 3P	Shuttle Power Distribution Unit (SPDU)	~17 kilograms (37 lb)
Bay 3S	APC/SSPL Picosat launcher PSSC Picosats	50 kilograms (110 lb) 7 kilograms (15 lb)
Bay 7S	ROEU umbilical	~79 kilograms (170 lb)
Bay 7-12	Leonardo (MPLM FM-1)	12,748 kilograms (28,100 lb)
Bays 13	Lightweight MPES Carrier (LMC)	1,495 kilograms (3,300 lb)
Starboard Sill	Orbiter Boom Sensor System	~382 kilograms (840 lb)
Port Sill	Canadarm 201	410 kilograms (900 lb)
	Total:	17,370 kilograms (38,300 lb)

STS-126 was scheduled to be a sixteen day mission with four spacewalks, largely dedicated to servicing and repair of the Solar Alpha Rotary Joints (SARJ). An additional docked day was added to the flight plan to give the crew more time to complete their tasks. The starboard SARJ had shown anomalous behavior since August 2007, and its use has been minimized pending diagnosis and repair. Both the starboard and port SARJs were serviced. In addition to lubricating both bearings, the remaining 11 trundle bearings in the starboard SARJ were replaced. Trundle bearing assembly five was removed during an Expedition 16 EVA for further examination in December 2007.

STS-126 included the *Leonardo* Multi-Purpose Logistics Module (MPLM) on its fifth spaceflight. *Leonardo* held over 14,000 pounds of supplies and equipment. Among the items packed into the MPLM were two new crew quarters racks, a second galley (kitchen) for the *Destiny* laboratory, a second Waste and Hygiene Compartment (WHC) rack (lavatory), the advanced Resistive Exercise Device (aRED), two water reclamation racks, spare hardware, and new experiments. Also included in *Leonardo* was the General Laboratory Active Cryogenic ISS Experiment Refrigerator, or GLACIER, a double locker cryogenic freezer for transporting and preserving science experiments. The shuttle also carried irradiated turkey, candied yams, stuffing and dessert for a special Thanksgiving meal at the station, as well as an Official Flight Kit with mementos for those who supported the astronauts and helped them complete their mission successfully.

Educational outreach

STS-126 carried the signatures of over 500,000 students that participated in the 2008 Student Signatures in Space program, jointly sponsored by NASA and Lockheed Martin. In celebration of Space Day last May, students from over 500 schools signed giant

posters, their signatures were scanned onto a disk, and the disk was flown on the STS-126 mission. The Student Signatures in Space project has been active since 1997, and has flown student signatures on seven other shuttle flights, starting with STS-86.

AgCam

Also aboard STS-126 was the Agricultural Camera (AgCam) which was installed in the *Destiny* module and is used to assist farmers and provide educational opportunities for students around the country. Students and faculty at the University of North Dakota built the Agricultural Camera (AgCam), that was to be delivered and installed on the International Space Station. The students will operate the camera from their campus and work with NASA engineers and station astronauts to take visible and infrared light images of growing crops, grasslands, forests and wetlands in the Great Plains and Rocky Mountains regions.

The information from AgCam will provide data to agricultural producers in North Dakota and neighboring states, benefiting farmers and ranchers and providing ways for them to protect the environment. AgCam imagery also may assist in disaster management, such as flood monitoring and wild fire mapping.

Cow embryos in space

STS-126 also flew the first bovine embryos on an American spacecraft for an experiment to evaluate effects of the environment of space on embryonic development. The project was a joint project of ZeroGravity Inc., University of Florida and USDA ARS.

Mission background

The mission marks:

- 155th American manned space flight
- 124th shuttle mission since STS-1
- 99th post-*Challenger* mission
- 11th post-*Columbia* mission
- 22nd flight of *Endeavour*
- 27th shuttle mission to the ISS
- 31st night launch

Shuttle processing



Endeavour at launch pad 39B prior to moving to pad 39A.

Space Shuttle Endeavour was moved from the Orbiter Processing Facility (OPF-2) at Kennedy Space Center to the Vehicle Assembly Building on 11 September 2008. Rollout to launch pad 39B took place overnight on 18 September 2008 and was completed at 07:00EDT on 19 September 2008.

Endeavour was originally moved to launch pad 39B ahead of the normal schedule to be on standby as the Launch on Need (LON) flight for STS-125. In the event that something happened to *Atlantis* during its flight to service the Hubble Space Telescope, a rescue

flight could be performed with *Endeavour*. With both *Atlantis* and *Endeavour* on the pads, it was the 18th time that two flight-ready orbiters were in position at both launch pads at the same time.

On 29 September 2008, NASA announced that due to a problem with the Hubble telescope, they would be revising the manifest to postpone STS-125 until 2009, so a solution to the issue with the telescope could be integrated into the flight plan. This moved STS-126 to the next flight, so on 23 October 2008 *Endeavour* was moved from launch pad 39B to 39A.

The payload for STS-126, including the MPLM *Leonardo*, arrived at launch pad 39A early on 22 October 2008.

Mission timeline

Launch preparations



Space Shuttle *Endeavour* as it lifted off to begin the STS-126 mission to the International Space Station.

The countdown to launch began on 11 November 2008 and the crew flew in from Johnson Space Center to the Kennedy Space Center to prepare for the launch. On 12 November 2008, Mission Management Team (MMT) Chairman LeRoy Cain announced that the MMT gave the official "go" for *Endeavour's* launch on 13 November 2008 and Ferguson and Boe practiced landings in the Shuttle Training Aircraft. Weather reports on 13 November 2008 gave a seventy percent chance of acceptable weather conditions for launch.

November 14 (Flight day 1, Launch)

Filling of the external tank with liquid hydrogen and liquid oxygen propellants started at 10:30 EST on 14 November 2008. After suiting up into the launch and entry suits, the crew left the Operations and Checkout building in the Astrovan and arrived at the launch pad at 16:22 EST. At 4:30 p.m., the crew began ingress into the orbiter, and by 17:25 EST, all crewmembers were in their seats and performed communications checks with the ground control personnel. At 18:00 EST, the closeout crew closed and locked *Endeavour's* hatch, and the orbiter's cabin was pressurized in preparation for launch. Despite a last minute issue with the white room closeout door not being fully secured, NASA Launch Director Mike Leinbach polled the team, determined the door did not pose a hazard to the orbiter or crew, and told the crew "Good luck, Godspeed and have a happy Thanksgiving in orbit." *Endeavour* lifted off on time at 19:55:39 EST (00:55 UTC). External tank separation occurred at 01:03 UTC.

After reaching orbit, the crew began working through the post-insertion timeline, which included opening the orbiter's payload bay doors, deploying the Ku band antenna, powering up and activating the shuttle robotic arm, and performing a burn of the Orbital Maneuvering System (OMS).

November 15 (Flight day 2)



On November 15, Kimbrough stops for a photo while working on the aft flight deck of *Endeavour*.

The second day in space for the crew was devoted to completing the initial inspection of *Endeavour's* heat shield. Using the shuttle's robotic arm and the Orbiter Boom Sensor System (OBSS), the crew took detailed images of the exterior of the orbiter for the image analysis team to review. The crew also continued to prepare for docking with the station on Sunday, by extending the docking ring, installing the centerline camera, and organizing the tools needed for rendezvous with the station. The crew also performed a checkout of the spacesuits that will be used for the spacewalks during the mission.

During the Mission Management Team briefing, LeRoy Cain noted that upon initial review of the ascent imagery, a small piece of thermal blanket appeared to come loose under the left Orbital Maneuvering System (OMS) pod, but explained that the area is not in an area of concern, as it does not experience high heat during reentry. During the Mission Status briefing, lead Flight Director Mike Sarafin said that after having the crew focus the camera on the left OMS pod, it did not appear that there was any damage, but the image analysis team would take a closer look at the area.

Two issues with the orbiter's Ku antenna were noted by Cain, although he stated they would not impact the mission. The antenna was not handing over from Ku to S-band automatically as it should, which meant that teams on the ground had to manually switch the antenna from Ku to S Band and back again. Sarafin noted that this was likely a

software issue, and would not affect the crew on board, or the mission. The other issue had to do with the antenna's failure to "lock on" to satellite targets after being given the pointing data. Instead, the antenna was drifting, which meant that the teams on the ground would have to use an alternate method of pointing the antenna. There was a possibility that the shuttle crew would need to use a backup procedure during rendezvous with the station, but it was not a concern, and would not change the timeline, Cain noted.

November 16 (Flight day 3)



Backdropped by a blue and white Earth, *Endeavour* prepares to perform the Rendezvous pitch maneuver prior to docking with the International Space Station.

After waking up, the crew set to work preparing for the rendezvous and docking with the station. The orbiter performed a final burn of the engines at 19:27 UTC to refine the approach, and by 21:00 UTC, the shuttle was in position below the station to allow the station crew to photograph the underside of the orbiter. Ferguson guided the shuttle manually through the Rendezvous pitch maneuver (RPM) while station crew used 400mm and 800mm cameras to take high-resolution images of the thermal tiles on *Endeavour*. The images were downlinked to NASA's image analysis team to assist in the evaluation of the thermal protection system of the orbiter. After the RPM was complete, Ferguson guided the orbiter into a safe docking at 22:01 UTC (17:01 EST), and the hatches were opened at 00:16 UTC (19:16 EST). Upon entering the station, Ferguson joked "Hey, we figured we'd go for a 10-year anniversary party for the space station, so that's what we showed up for." Ferguson was referring to the 20 November 1998 launch of Zarya, the first component of the International Space Station.

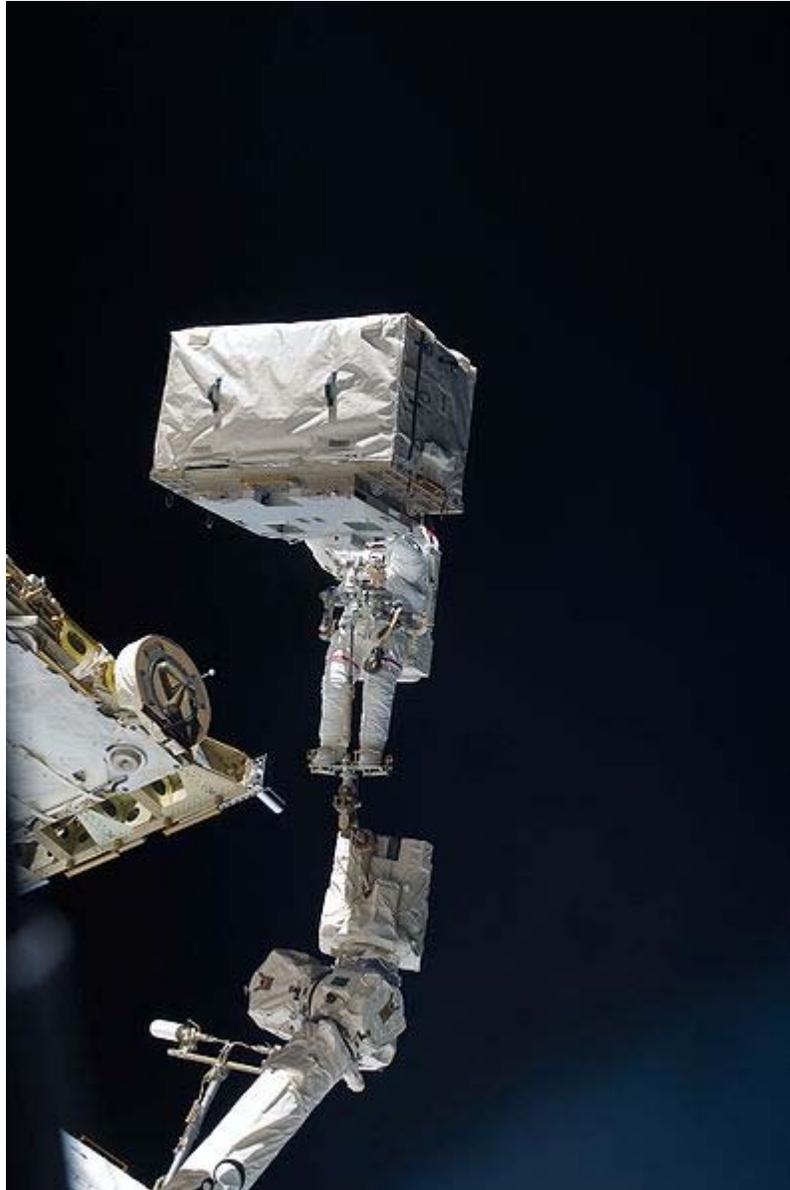
After the two crews exchanged greetings, they performed a safety briefing, and then set right to work, beginning transfers and preparing for robotic operations. At 02:50 UTC, Chamitoff and Magnus officially switched positions, with the swap of their Soyuz seatliners. Chamitoff joined the STS-126 crew as a Mission Specialist, and Magnus officially became the Flight Engineer 2 for Expedition 18.

During the mission status briefing, LeRoy Cain stated that the image analysis team was still evaluating the ascent imagery, but that the vehicle looked very clean, and the only event that was seen on launch, the area under the left OMS pod, appeared to have been ice. The images taken during the flight day two survey showed that all of the thermal blankets in that area were intact, as were the tiles. Cain stated that the item did not strike the orbiter, it was the only event that the Mission Management Team was still evaluating, and that the orbiter was in good shape. Mike Sarafin confirmed that the Ku band antenna performed properly in radar mode, and docking was carried out without any problems with the antenna.

November 17 (Flight day 4)



Following the docking of *Endeavour*, Expedition 18 crewmembers welcome the shuttle crew into the station.



Mission Specialist Stefanyshyn-Piper handles the Nitrogen Tank Assembly during EVA1.

Following the wake up call, the two crews began the procedures to move the *Leonardo* MPLM out of the orbiter's payload bay to install it on the Earth-facing port of the *Harmony* module. Using the station's robotic arm, Pettit and Kimbrough began maneuvering the 27,000 lb container around 16:45 UTC, and by at 18:04 UTC it was locked in place. After performing leak checks, the hatch was opened at 23:43 UTC. The crews took air samples and examined the container for any signs of condensation or shifting of the contents during launch. The container had no issues, and transfer of cargo between the container and the station began shortly after the hatch was opened. The team also worked on experiments that were flown with *Endeavour*, including one that involves observing spiders and butterflies in space. The experiment from Florida, Texas and

Colorado schoolchildren is being conducted to compare spider webs created in microgravity with those on Earth. The insects will be returned to Earth with the shuttle for additional study.

Later in the day, the crew members reviewed spacewalk procedures to prepare for the first of the four planned EVAs. Piper and Bowen began the protocol known as the "campout" prior to their sleep period. Camping out consists of spending the night in the *Quest* airlock at lower air pressure (10.2 psi) to lessen the time needed to acclimate to the environment in the spacesuits.

During the Mission Management Team briefing, LeRoy Cain confirmed that the orbiter's wing leading edge had been cleared, and that no focused inspection would be required. The time that was scheduled for that inspection on day six would instead be spent working on the station's new water reclamation unit. While the image analysis team was still reviewing the imagery from the day two inspection and RPM, Cain said the orbiter was "doing extremely well", and expected the image analysis team to clear it for re-entry within a day. Cain noted that the imagery from the external tank showed it to be extremely clean, with only three small areas of foam loss noted.

During the Mission Status briefing, ISS Deputy Program Manager Kirk Shireman noted the upcoming ten-year anniversary of the International Space Station. Shireman reviewed the progress and advancements that have come from the project, and reviewed some of the major milestones. Thirty Progress vehicles have visited the station, seventeen Soyuz vehicles, twenty-seven shuttles, and one Automated Transfer Vehicle (ATV). One hundred sixty-four people had visited the station from fourteen nations prior to STS-126, (167 once STS-126 docked) and on Thursday, the tenth anniversary, Shireman said the station will have orbited the Earth 57,509 times, for a total distance of over 1.3 billion miles.

November 18 (Flight day 5)



The crew lock bag holding tools floats away from the space station during EVA 1

Following their post-sleep period, the crews set to work preparing for the first spacewalk of the mission. Stefanyshyn-Piper and Bowen were suited up and in the airlock ahead of schedule, and the EVA started at 18:09 UTC, with Piper becoming the first female Lead Spacewalker. While Piper was preparing to begin work on the SARJ, she noticed a significant amount of grease in her tool bag, "I think we had a grease gun explode in the large bag, because there's grease in the bag," Piper reported to Kimbrough, who was working inside the shuttle to help coordinate the EVA. Mission Control managers instructed Piper to clean up the grease using a dry wipe, and while she was doing the cleanup, one of the crew lock bags floated away. "I guess one of my crew lock bags was not transferred and it's loose," Piper told Kimbrough. The bag floated aft and starboard of the station, and did not pose a risk to the station or orbiter. After taking an inventory of the items inside the lost bag, managers on the ground determined that Bowen had all those items in his bag, and the two could share equipment. While it extended the EVA duration slightly, the major objectives were not changed, and all EVA tasks were accomplished. The estimated value of the lost tool bag was \$100,000 USD. It was not the first time that equipment had got away from spacewalkers, items lost in the past include tools, nuts and bolts, glue guns, cameras, cloths, and even a robotic arm. The United States Space Surveillance Network constantly monitors over 12,500 items in orbit around the Earth.

During the Mission Status Briefing, lead ISS Flight Director Ginger Kerrick noted that there was no way to know what caused the bag to come loose. "We don't know that this incident occurred because they forgot to tether something. We don't know if perhaps the hook just came loose inside the bag," Kerrick said. "You've got to remember, we are working with humans here and we are prone to human error. We do the best we can, and we learn from our mistakes." Kerrick noted that the team would be taking extra precautions to avoid any further problems with the grease guns, by attaching them to the outside of the bags instead of inside to prevent the plungers from being inadvertently activated.

November 19 (Flight day 6)



Chamitoff and Magnus transfer one of the two new crew quarters racks. Visible on the back of the rack are the signatures of the members of the ground team that worked on the new equipment.

Flight day six was devoted to transfer operations, and the two crews worked through the morning to complete all the rack transfers. Magnus and Chamitoff successfully installed the two crew quarters racks into the *Harmony* node, and installed a rack with equipment to be returned to Earth into the MPLM. During the Mission Status briefing, Lead ISS Flight Director Ginger Kerrick noted that all the racks were now on station, and about 25% of the cargo transfers had been completed, which was slightly ahead of schedule. The two crews also began working on activating the Water Recovery System, so that samples of water from two areas could be taken and returned to Earth with *Endeavour*. The system's initial checkout was initiated, and water samples would be taken after

several days of operation. Later in the day, the two crews reviewed procedures for the mission's second EVA, and Stefanyshyn-Piper and Kimbrough would sleep in the station's airlock as part of the pre-EVA campout procedure.

November 20 (Flight day 7)



Following the traditional joint crew news conference, shuttle and station crews posed for a group photo.

On the tenth anniversary of the International Space Station, Stefanyshyn-Piper and Kimbrough successfully conducted the mission's second spacewalk. The EVA was 6 hours and 45 minutes in duration, and all tasks were accomplished without complications. Two crew equipment carts were relocated in preparation for the arrival of the final set of solar arrays, the station's robotic arm was lubricated, and the work on the starboard SARJ continued. Inside the station, crewmembers continued to transfer cargo from *Leonardo* to the station, items to be returned to Earth into the MPLM, and continued the activation of the Water Recovery System.

November 21 (Flight day 8)

Following the crew wake up call, the two crews set to work on the day's planned activities. Fincke and Magnus tested latches on the Exposed Facility Berthing Mechanism for the Japanese Kibo laboratory. Magnus continued with the installation of the Total Organic Carbon Analyzer (TOCA), while engineers on the ground worked through

troubleshooting of the Urine Processor Assembly. The component ran initially on Thursday evening, but shut itself down during that initial test, and shut down again the following morning after two hours of operations. Engineers were considering if the issue was a problem with the sensors, or with the centrifuge motor. At 17:10, Ferguson and Boe used the shuttle's engines to reboost the station's altitude, raising it by about one nautical mile to prepare for the next Progress arrival.

The two crews also participated in the traditional Joint Crew News Conference, answering questions from reporters around the world, and took the traditional crew photo. Cargo transfers continued between the vehicles, and the crew was about seventy-five percent complete with all transfers to and from the MPLM. After a bit of off-duty time, the two crews participated in an EVA review, in preparation for the mission's third spacewalk. Piper and Bowen spent the night in the *Quest* airlock for the campout prior to the next day's spacewalk.

November 22 (Flight day 9)



Bowen works on the SARJ during the mission's third spacewalk.

After awakening, the two crews set right to work preparing for the mission's third EVA, which began at 18:01 UTC. The entire spacewalk was devoted to completing the cleaning, lubrication, removal and replacement of the trundle bearings assemblies in the starboard SARJ. The final trundle bearing assembly installation was deferred to the fourth EVA, but all other tasks scheduled were accomplished without any issues.

Stefanyshyn-Piper's fifth EVA moved her to the twenty-fifth spot in cumulative EVA time with thirty three hours, forty two minutes.

On the station, the crews continued to work on transfer operations, and continued work on the water reclamation system. During the Mission Status Briefing, lead ISS Flight Director Ginger Kerrick noted that a sample was taken from the Water Processor Assembly that contained 10% urine and 90% condensate, and would be returned to the ground with the shuttle. Kerrick noted that if activation of the system continued on schedule, a sample from the potable water dispenser would be taken on flight day eleven. The ground crew continued to troubleshoot the Urine Processor Assembly, looking at whether there is a sensor touching part of the system's centrifuge as it rotates, which might be causing it to slow down.

November 23 (Flight day 10)



Mission Specialist Stephen Bowen during the mission's final spacewalk.

The two crews continued transfer operations, and Finke and Pettit worked together to reconfigure the Urine Processing Assembly (UPA) to try to dampen any vibration that may be contributing to the unit's shutting down prematurely. The unit has continued to operate sporadically, shutting itself down after two to three hours of operations, and the engineers on the ground are still evaluating the possible causes and solutions. Managers on the ground would make a decision Monday on whether to extend *Endeavour's* mission by one docked day, to help with the troubleshooting of the Water Recovery System (WRS). The *Endeavour* crew had several hours of off-duty time, and participated in media interviews.

November 24 (Flight day 11)



Continuing a long standing tradition, Pilot Eric Boe places the STS-126 patch onto a wall in the *Unity* node of the International Space Station.

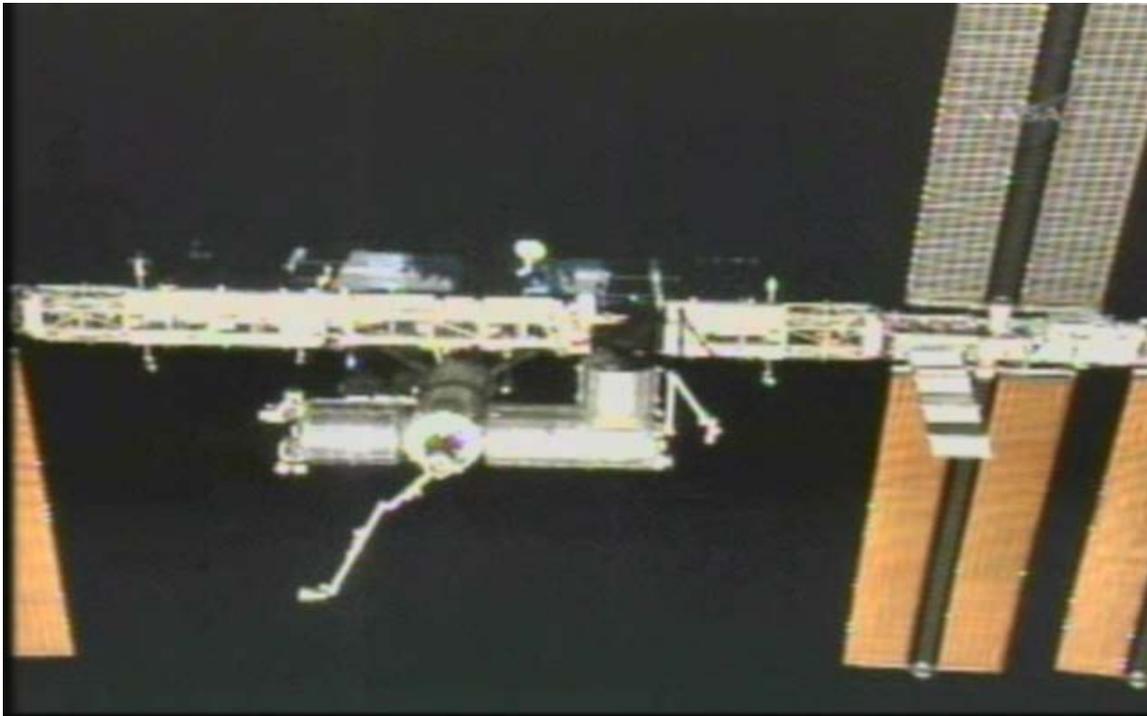
Following the wake up call, the two crews got to work preparing for the mission's final spacewalk. Bowen and Kimbrough officially began the EVA at 18:24 UTC. Shortly before the spacewalk began, managers on the ground radioed up to the crew that the Mission Management Team had approved an extra docked day of operations for the crews, extending the mission to sixteen days. The extra time was being given to allow the crews more time to resolve the issues with the Urine Processing Assembly. The spacewalk successfully concluded after 6 hours and 7 minutes, bringing the total time spent in EVA activities for the mission to 26 hours, 41 minutes.

November 25 (Flight day 12)

The crews dedicated most of the day to completing the transfer of supplies from the space station to *Endeavour* and *Leonardo*. The starboard Solar Alpha Rotary Joint was automatically tracking the sun for the first time in more than a year during a three-hour, two-orbit test that was initiated at 10:55 UTC. The Urine Processor Assembly completed its second full five hour run.

During the Mission Status Briefing, International Space Station Program Manager Mike Suffredini noted that the water recycling system appeared to be functioning normally after the modifications performed by the crew on orbit. Additional water samples were taken, and the crew would be bringing home approximately six liters of sample water for extensive testing. The crew on the station would not be drinking any of the water until the engineers and scientists on the ground had a chance to thoroughly analyze the samples taken. Suffredini also noted that while the goal of the EVA activities to perform maintenance on the starboard SARJ was to allow it to operate "periodically", the initial test showed encouraging results, and the lubrication and other work done by the spacewalkers may allow for more routine operations than originally expected. It would be weeks before a more complete assessment could be given, the joint would need to be put through more testing, as well as analysis of the results from engineers on the ground, but Suffredini was encouraged by the initial results.

November 26 (Flight day 13)



A frame taken from an animation of slow scan TV images taken on a flyaround inspection of the station by the shuttle.



Commander Chris Ferguson continued the long standing tradition of placing the cloth patch for STS-126 crew in the *Zvezda* module.

Pettit and Kimbrough used the station's Canadarm2 to move *Leonardo* from the *Harmony* module and placed in the shuttle's cargo bay at 21:52 UTC. Stefanyshyn-Piper packed up equipment and supplies used for the four spacewalks and moved them to Endeavour for return, while Magnus continued work on the station's new regenerative life support system. She drained a condensate collection tank to create the optimum ratio of condensate and distillate from the Urine Processor Assembly (UPA), and gathered additional water samples for testing.

November 27 (Flight day 14)

In their final day of joint operations, the two crews had some off-duty time, spoke to reporters, and shared a Thanksgiving Day meal together. Following the meal, the crews worked on last minute transfers, and gathered in the *Harmony* node to bid farewell. The hatches between the two vehicles were closed 23:31 UTC, with the crew of *Endeavour* reviewing the procedures and tools they would use the next day for undocking, scheduled for 14:47 UTC.

November 28 (Flight day 15)

Endeavour undocked from the International Space Station at 14:47 UTC. The total docked time was 11 days, 16 hours, and 46 minutes, making it the second-longest docked shuttle mission to the station, after STS-123's 11 days, 20 hours and 36 minutes. Pilot Eric Boe maneuvered the shuttle through a flyaround inspection of the complex, but the final separation burn was delayed to avoid bringing the shuttle near the remains of a Russian Cosmos satellite that broke apart in March. While the burn would have only brought them about eleven kilometers from the debris, Flight Director Mike Sarafin noted during the Mission Status Briefing that "Per the flight rules, it was the safe course of action to not perform that burn." The burn was instead completed at 23:23 UTC. After separating from the station, the crew of *Endeavour* conducted an inspection of the shuttle's heat shield with the robotic arm.

November 29 (Flight day 16)

Following the late inspection of *Endeavour*'s heat shield, the Mission Management Team officially cleared the orbiter for re-entry. The crew spent the day preparing for landing, performing inspections and checkout of the shuttle's flight control surfaces and reaction control system thrusters. Near the end of the crew's day, a Department of Defense satellite, Picosat, was deployed. The satellite will test two new types of photovoltaic solar cells, to determine their effectiveness for generating power.

Due to a less than favorable forecast for Kennedy Space Center on Sunday that was not expected to improve by Monday, mission managers decided to call up Edwards Air Force Base for the first day of landing opportunities. There were two KSC opportunities, with two more opportunities for Edwards later in the day. If the first two opportunities at KSC were called off due to weather, Bryan Lunney, Entry Flight Director stated during the Mission Status Briefing that they would take the Edwards opportunities; the weather was not likely to improve, so there would be no reason to delay landing for a day. The forecast at KSC called for thunderstorms within 30 miles of the landing site, as well as high crosswinds, both conditions that would violate the weather constraints for landing.

November 30 (Flight day 17)



Space shuttle *Endeavour* and the STS-126 crew land at Edwards Air Force Base, Calif. after completing a mission to the International Space Station.



Endeavour lands back at Kennedy Space Center atop the 747 Shuttle Carrier Aircraft

After awakening, the crew of *Endeavour* got to work preparing for reentry. While working through the deorbit timeline, Entry Flight Director Bryan Lunney, after reviewing the weather, waved off the first KSC landing opportunity due to excessive crosswinds on the runway. After evaluating the weather, the second KSC landing opportunity was also waived off, as the weather was "no go" and forecasted "no go" per the landing weather requirements. Lunney continued to watch the weather for possible changes in Monday's weather forecast prior to making the decision whether to land at Edwards, or wait one day to get a Kennedy landing, but following further analysis of the projected weather in Florida for Monday, Lunney decided to take the first Edwards Air Force Base landing opportunity. The deorbit burn was initiated at 20:19 UTC (12:19 PST), and the orbiter landed at Edwards Air Force Base at 21:25 UTC (13:25 PST).

Endeavour was the first and last orbiter to land on the temporary runway 04 at Edwards AFB, as the main runway was completing refurbishment. The use of the temporary runway required new braking and rollout techniques that have never been used before, as the runway is three thousand feet shorter than the normal runway.

Endeavour was returned to Florida on top of one of NASA's Shuttle Carrier Aircraft, arriving back at the Kennedy Space Center 12 December 2008 after a three day cross-country trip.

Extra-vehicular activity

Four spacewalks were scheduled and completed during STS-126. The cumulative time in extra-vehicular activity during the mission was 26 hours and 41 minutes.

EVA #	Spacewalkers	Start (UTC)	End (UTC)	Duration
EVA 1	Heidemarie Stefanyshyn-Piper Stephen G. Bowen	18 November 18:09	19 November 01:01	6 hours, 52 minutes
	Transferred an empty nitrogen tank assembly from ESP-3 to the shuttle's cargo bay, transferred a new flex hose rotary coupler to ESP-3 for future use, removed an insulation cover on the <i>Kibo</i> External Facility berthing mechanism, began cleaning and lubrication of the starboard SARJ, and replacement of eleven trundle bearing assemblies.			
EVA 2	Stefanyshyn-Piper Robert S. Kimbrough	20 November 17:58	21 November 00:43	6 hours, 45 minutes
	Relocated two Crew and Equipment Translation Aid (CETA) carts from the starboard side of the Mobile Transporter to the port side, lubricated the station robotic arm's Latching End Effector (LEE) "A" snare bearings, continued cleaning and lubrication of the starboard SARJ.			
EVA 3	Stefanyshyn-Piper Bowen	22 November 18:01	23 November 00:58	6 hours, 57 minutes
	Completed cleaning, lubrication, and replacement of all but one of the trundle bearing assemblies on the starboard SARJ. The final TBA will be replaced during EVA 4.			
EVA 4	Bowen Kimbrough	24 November 18:24	25 November 00:31	6 hours, 7 minutes
	Completed replacement of trundle bearing assemblies on starboard SARJ, lubricated the port SARJ, installed a video camera, re - installed insulation covers on the <i>Kibo</i> External Facility berthing mechanism, performed <i>Kibo</i> robotic arm grounding tab maintenance, installed spacewalk handrails on <i>Kibo</i> , installed Global Positioning Satellite (GPS) antennae on <i>Kibo</i> , photographed radiators, and photographed trailing umbilical system cables.			

Chapter- 3

STS-127

STS-127

Mission insignia



Mission statistics

Mission name	STS-127
Space shuttle	<i>Endeavour</i>
Launch pad	LC-39A
Launch date	15 July 2009, 18:03:10 EDT (22:03 UTC)
Landing	31 July 2009, 10:48 EDT (14:48 UTC)
Mission duration	15 days, 16 hours, 44 minutes, 58 seconds
Number of orbits	248
Orbital period	94 minutes
Orbital altitude	356 kilometres (221 mi) (221 statute miles)
Orbital inclination	51.6 degrees
Distance traveled	10,537,748 kilometres (6,547,853 mi)

Docking

Docking date 17 July 2009 17:47 UTC
Undocking date 28 July 2009 17:26 UTC
Time docked 10 days, 23 hours, 41 minutes

Crew photo



From left to right: Wolf, Cassidy, Hurley, Payette, Polansky, Marshburn, and Kopra

Related missions

Previous mission



Subsequent mission



STS-127 (ISS assembly flight **2J/A**) was a space shuttle mission to the International Space Station (ISS). It was the twenty-third flight of Space Shuttle *Endeavour*. The primary purpose of the STS-127 mission was to deliver and install the final two components of the Japanese Experiment Module: the Exposed Facility (JEM EF), and the Exposed Section of the Experiment Logistics Module (ELM-ES). When *Endeavour* docked with ISS, it set a record for the most humans in space at the same time in the same vehicle, the first time thirteen people have been at the station at the same time. It also tied the record of thirteen people in space at any one time.

The first launch attempt, on 13 June 2009, was scrubbed due to a gaseous hydrogen leak observed during tanking. The Ground Umbilical Carrier Plate (GUCP) on the external fuel tank experienced a potentially hazardous hydrogen gas leak similar to the fault that delayed the Space Shuttle *Discovery*, mission STS-119 in March 2009. Since a launch date of 18 June 2009 would have conflicted with the launch of the Lunar Reconnaissance Orbiter (LRO)/Lunar Crater Observation and Sensing Satellite (LCROSS), NASA managers discussed the scheduling conflict with both the Lunar Reconnaissance Orbiter project and the Air Force Eastern Range, which provides tracking support for rockets launched from Florida. A decision was made to allow the shuttle to attempt a second launch on 17 June 2009, allowing LRO to launch on June 18, 2009.

The second launch attempt on 17 June 2009 was also scrubbed due to hydrogen leak issues seen from the Ground Umbilical Carrier Plate. Due to conflicts with the launch of

the LRO, and due to a solar heating in space constraint, the next available launch opportunity was scheduled for 11 July 2009. A successful tanking test for leak checks was performed on 1 July 2009, with modified GUCP seals allowing launch preparations to proceed as scheduled. Because of lightning strikes near the launch pad during the evening of 10 July 2009, NASA scrubbed the launch for the third time and rescheduled for 12 July 2009. Due to a Return To Launch Site (RTL) weather violation on the evening of 12 July 2009, NASA scrubbed the launch for the fourth time.

STS-127's fifth launch attempt on 13 July 2009 was also scrubbed due to anvil clouds and lightning within 10 nautical miles (19 km) of the launch site, which violated launch safety rules. STS-127's sixth launch attempt was successful, on 15 July 2009 at 18:03 EDT. Pieces of foam were observed falling off of the External Tank during launch, as happened when the space shuttle Columbia was lost. In this instance Endeavour only received minor scuffs to the heat shield, which were found to be of no concern to a safe reentry. The shuttle landed at Kennedy Space Center at 10:48 EDT on 31 July 2009 after a 16 day mission.

Crew

Position	Launching Astronaut	Landing Astronaut
Commander		Mark L. Polansky Third spaceflight
Pilot		Douglas G. Hurley First spaceflight
Mission Specialist 1		Christopher J. Cassidy First spaceflight EV3
Mission Specialist 2		Julie Payette, CSA Second spaceflight Flight Engineer
Mission Specialist 3		Thomas H. Marshburn First spaceflight EV4
Mission Specialist 4		David Wolf Fourth spaceflight Lead Spacewalker EV1
Mission Specialist 5	Timothy Kopra Expedition 20 First spaceflight EV2	Koichi Wakata, JAXA Expedition 20 Third spaceflight

STS-127 marked the first time that two Canadian astronauts, Robert Thirsk and Julie Payette, were in space at the same time.

Christopher Cassidy was the 500th person to fly in space.

Mission payload



Payload bay of the shuttle being loaded.

Location	Cargo	Mass
Bays 1-2	Orbiter Docking System EMU 3003 / EMU 3018 SpaceX DragonEye LIDAR	1,800 kilograms (4,000 lb) ~260 kilograms (570 lb)
Bay 3P	Shuttle Power Distribution Unit (SPDU)	~17 kilograms (37 lb)
Bay 3S	APC/SSPL Dragonsat	51 kilograms (110 lb) 6 k

Bays 4-7	Kibo JEM Exposed Facility	3,820 kilograms (8,400 lb)
Bay 5P	APC/ECSH	~33 kilograms (73 lb)
Bay 5S	APC/PPSU	20 kilograms (44 lb)
Bay 6S	APC/PPSU	20 kilograms (44 lb)
Bays 8-9	Kibo ELM Exposed Section	2,453 kilograms (5,410 lb)
Bay 11	ICC-VLD	3,946 kilograms (8,700 lb)
Bay 13P	APC/ECSH	~33 kilograms (73 lb)
Bay 13S	SPA/CAPE/ANDE-2	265 kilograms (580 lb)
	ICU container	54 kilograms (120 lb)
	ANDE Active satellite	50 kilograms (110 lb)
	ANDE Passive satellite	25 kilograms (55 lb)
Starboard Sill	Orbiter Boom Sensor System	~382 kilograms (840 lb)
Port Sill	Canadarm	410 kilograms (900 lb)
	Total:	13,645 kilograms (30,080 lb)

Endeavour carried a wide variety of equipment and cargo in the payload bay, with the largest item being the *Kibo* Japanese Experiment Module Exposed Facility (JEM EF), and the *Kibo* Japanese Experiment Logistics Module - Exposed Section (ELM-ES). The exposed facility is a part of *Kibo* that will allow astronauts to perform science experiments that are exposed to the vacuum of space. The exposed section is similar to the logistics module on the *Kibo* laboratory, but is not pressurized. Once its payloads are transferred to the JEM EF, the ELM-ES will be returned to the payload bay.

Also inside the payload bay was a Integrated Cargo Carrier that contains a variety of equipment and spare components for the station. The carrier contained six new batteries for installation on the P6 truss, that was installed during two of the mission's spacewalks, as well as a spare space-to-ground antenna and a spare linear drive unit and pump module which was stored on an external stowage platform on the station's truss during one of the spacewalks.

Two satellites were also carried by the orbiter, for deployment when the mission ended. The Dual Autonomous Global Positioning System On-Orbit Navigator Satellite, called DRAGONSAT, gathered data on autonomous spacecraft rendezvous and docking capabilities, and consists of two picosatellites, the AggieSat2, and PARADIGM (BEVO-1), which acquire GPS data from a device at NASA and send it to ground stations at Texas A&M University and the University of Texas at Austin. After release, the two picosatellites remained attached for two orbits to collect GPS data, and separate during the third orbit.

A second satellite, the Atmospheric Neutral Density Experiment (ANDE-2), is part of a United States Department of Defense project flown by the Naval Research Laboratory to provide high-quality satellites, and will measure the density and composition of the low Earth orbit atmosphere while being tracked from the ground, to better predict the movement and decay of objects in orbit. ANDE-2 consists of two spherical

microsatellites, ANDE Active spacecraft (Castor) and the ANDE Passive spacecraft (Pollux), and will be tracked by the International Laser Ranging Service (ILRS) network as well as the Space Surveillance Network (SSN). One of the satellites, Pollux, is running Arduino libraries, with its payload programmed and built by students.

A set of experiments to be deployed on the ISS were carried by STS-127, namely Dosimetry for Biological Experiments in Space (ESA), Validation of Procedures for Monitoring Crew Member Immune Function, the student-made Image Reversal in Space (CSA/ISU), Nutritional Status Assessment (NASA), NASA Biological Specimen Repository and Tomatosphere-II (CSA).

The STS-127 Official Flight Kit (OFK) includes water samples from each of the five Great Lakes, a resin statue of a water droplet for the One Drop Foundation and a copy of Beethoven's Fifth Symphony for the Montreal Symphony Orchestra, among other mementos.

The docking module was also mounted with the DragonEye LIDAR ranging system by SpaceX. The module was launched to test the docking system which will be used by the commercial SpaceX Dragon re-usable cargo carrier to send supplies to the ISS during the post-shuttle era. The Dragon module is scheduled for its first launch in 2010.

Mission background



Mission poster

The mission marks:

- 158th American manned space flight
- 128th Space Shuttle mission
- 127th shuttle mission since STS-1
- 23rd flight of space shuttle *Endeavour*
- 29th shuttle mission to the ISS
- 102nd post-*Challenger* mission
- 14th post-*Columbia* mission
- 1st time that two Canadians have been in space at the same moment

Shuttle processing



Endeavour at Launch Pad 39A

Endeavour served as the STS-400 rescue vehicle for STS-125, and was prepared for a possible liftoff from Launch Pad 39B on 15 May 2009, four days after the launch of STS-125. After *Atlantis* performed the late inspection and was cleared for re-entry, *Endeavour* was officially released from stand-by status on 21 May 2009, and preparations for STS-127 were initiated.

Endeavour moved from Launch Pad 39B to 39A on 31 May 2009 in preparation for STS-127. The crew of STS-127 arrived at Kennedy Space Center on 2 June 2009, for the Terminal Countdown Demonstration Test (TCDT) that concluded with a full launch dress rehearsal. The Flight Readiness Review (FRR), a meeting during which NASA managers assess mission preparations and officially set the launch date, concluded on 3 June 2009. For the first time, live status updates about the FRR were published periodically during the meeting via NASA's Twitter stream.

Launch attempts



Close-up view of the Ground Umbilical Carrier Plate on STS-127's external tank during the first maintenance effort

The launch countdown began 10 June 2009, but on 13 June 2009, as tanking was underway, a gaseous hydrogen leak on a vent line near the Ground Umbilical Carrier Plate was observed, and the 13 June 2009 launch was scrubbed at 00:26 EDT. As liquid hydrogen fuel is pumped in, some of it boils off as the extremely cold liquid enters the warm external tank. The vent line valve controls the resulting buildup of gas pressure by allowing excess gas to escape into a ground-side vent line, which leads to a flare stack at a safe distance away from the pad. A similar leak situation was seen during the first launch attempt of STS-119. NASA managers met on 14 June 2009 and 15 June 2009 and evaluated the leak, discussed steps that had to be taken, and set a new launch date of 17 June 2009, at 05:40 EDT.

A second launch attempt was made on 17 June 2009 for which NASA moved the planned launch of the Lunar Reconnaissance Orbiter to a new date. On 17 June 2009 loading of the shuttle's external tank with liquid hydrogen and liquid oxygen was delayed three hours due to poor weather around the launch site, but tanking began once the weather cleared. Approximately two hours after tanking began, engineers saw leak indications in the GUCP similar to those seen during the first launch attempt. The launch was officially scrubbed at 01:55 EDT.

Following the launch scrub, Chairman of NASA's Mission Management Team LeRoy Cain noted that engineers would work to understand the hydrogen leak issue and come up with a solution to the problem. Cain said managers were hopeful that the issue could be resolved in time for the next available launch opportunity on 11 July 2009. Due to the delay of STS-127, managers noted that it was likely that the launch of STS-128 on 7 August 2009, would be pushed back slightly.



Lightning strikes *Endeavour's* Launch Pad.

On 1 July 2009, the shuttle managers conducted a new series of tanking tests to confirm a hypothesis that a misaligned vent port housing was the root cause of the leaks. The existing rigid seal was replaced with a flexible one in the hope that it would maintain a tight fit even under the cryogenic conditions that seem to cause the leak. The test was declared a success with no leaks detected on the GUCP. The mission was announced to be targeting a 11 July 2009 launch. On the evening of 10 July 2009 the launch pad region was hit by eleven strikes of lightning, which pushed back the 11 July 2009 launch time by at least 24 hours. Two of the strikes were strong enough to trigger an evaluation by NASA engineers. The inspections revealed that no damage had been done to the space shuttle.

NASA scrubbed *Endeavour's* 12 July 2009 launch attempt at T-minus 9 minutes and holding due to Cumulus clouds and lightning near the launch pad. During the final

Go/No-Go polls, Mission Control in Houston declared a "No-Go" due to unacceptable weather forecast for a possible Return-To-Launch-Site (RTL) abort, and planned for emergency scenarios when one or more engines shut down early leaving insufficient energy to reach the Transatlantic Abort Landing (TAL) sites. Similarly, during the 13 July 2009 attempt, RTL weather was also "no go." Meanwhile, shuttle weather officer Kathy Winters informed the launch director, Pete Nickolenko, that the launch pad weather had changed to RED as the Phase-1 Lightning warning was issued for the Kennedy Space Center. The launch was scrubbed at T-minus 9 minutes and holding and was quickly reset for 15 July 2009 (a 48 hours scrub turn around) due to weather concerns on the 14 July 2009 and the desire to replace the Tyvek covers over the forward Reaction Control System thrusters.

Attempt	Planned	Result	Turnaround	Reason	Decision point	Weather go %	Notes
1	13 Jun 2009, 7:17:19 am	scrubbed ---		technical	13 Jun 2009, 12:26 am	90%	gaseous hydrogen leak on a vent line near the Ground Umbilical Carrier Plate
2	17 Jun 2009, 5:40:52 am	scrubbed	3 days, 22 hours, 24 minutes	technical	17 Jun 2009, 1:55 am	80%	leak persisted
3	11 Jul 2009, 7:39:38 pm	scrubbed	24 days, 13 hours, 59 minutes	weather		40%	lightning strikes to launch pad
4	12 Jul 2009, 7:13:55 pm	scrubbed	0 days, 23 hours, 34 minutes	weather	(T-9:00 hold)	70%	RTL concerns, cumulus clouds and lightning near launch pad
5	13 Jul 2009, 6:51:24 pm	scrubbed	0 days, 23 hours, 37 minutes	weather	(T-9:00 hold)	40%	Phase-1 Lightning warning at the launch site

6	15 Jul 2009, 6:03:10pm	success	1 days, 23 hours, 12 minutes	60%
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Mission timeline

July 15 (Flight Day 1, Launch)



Liftoff of space shuttle Endeavour from Launch Pad 39A

On 15 July 2009 at 18:03:10 EDT, the launch was finally successful. Upon reviewing the launch video footage, imagery analysts noted eight or nine instances of foam shedding from the External Tank. The pictures of the external tank taken when jettisoning showed loss of foam in the intertank ribbing. The chairman of the Mission Management Team was not concerned and felt that the Space Shuttle would be cleared for re-entry on its return voyage—which it was a few days later. The payload doors were opened after reaching orbit followed by deployment of the K_u band antenna and activation of the shuttle's mechanical arm.

July 16 (Flight Day 2)



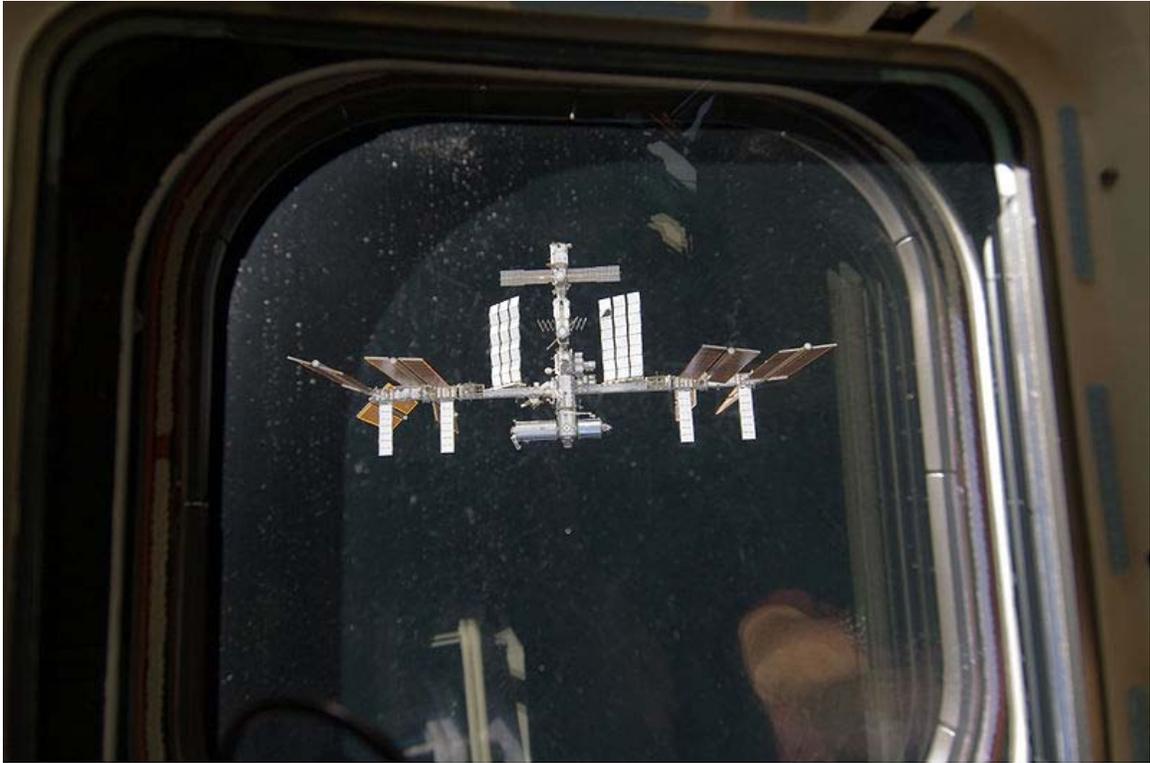
Julie Payette looks through an overhead window while operating controls on the aft flight deck of Endeavour during flight day two activities.

The thermal protection system was inspected with the Shuttle Robotic Arm/Orbiter Boom Sensor System (OBSS) and the voluminous data downlinked for analysis. The orbital maneuvering system pods were inspected for tile damage or protruding tiles. The extravehicular mobility units were checked in addition to the rendezvous system tests and centerline camera installation. In preparation for the docking, the docking ring was extended.

July 17 (Flight Day 3, ISS Docking)

The shuttle successfully docked with the station 220 miles (350 km) above Earth following a rendezvous pitch maneuver (RPM) photography of Endeavour's thermal protection system by the Expedition 20 Crew. During this procedure, the shuttle flips over on its back to the station so that the station crew can capture high resolution imagery of the underside of the shuttle. The docking happened on the ISS's PMA-2 (Pressurized Mating Adapter) on the Harmony module and the hatch was opened after leak checks. As part of the crew swap, station crew member Koichi Wakata was replaced with Tim Kopra. The two astronauts specially fitted seatliners were interchanged. As part of preparation for EVA 1, astronauts Wolf and Kopra camped out in the Quest airlock. A quick review of the RPM imagery showed no serious concerns beyond two instances of coating loss. Further analysis of the imagery will be done. A boost of the station was completed with the shuttles vernier thrusters to avoid a piece of space debris. The SRBs

were retrieved and their camera imagery is expected to give more detail on the ET foam shedding.



One of Endeavour's aft flight deck windows frames the nearby International Space Station.



Astronaut Christopher Cassidy uses a rangefinder to determine the distance to ISS before docking



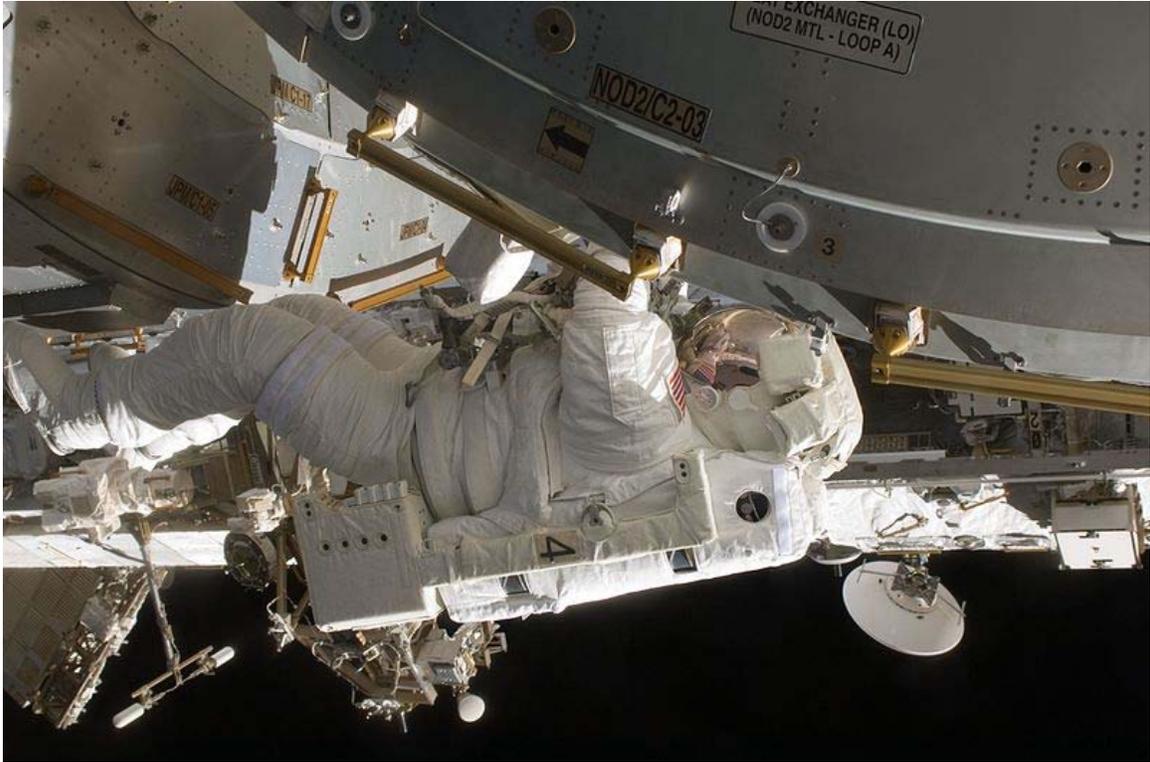
Endeavour as seen from ISS before docking. Payload including JEM and ICC-VLD visible in the shuttle bay



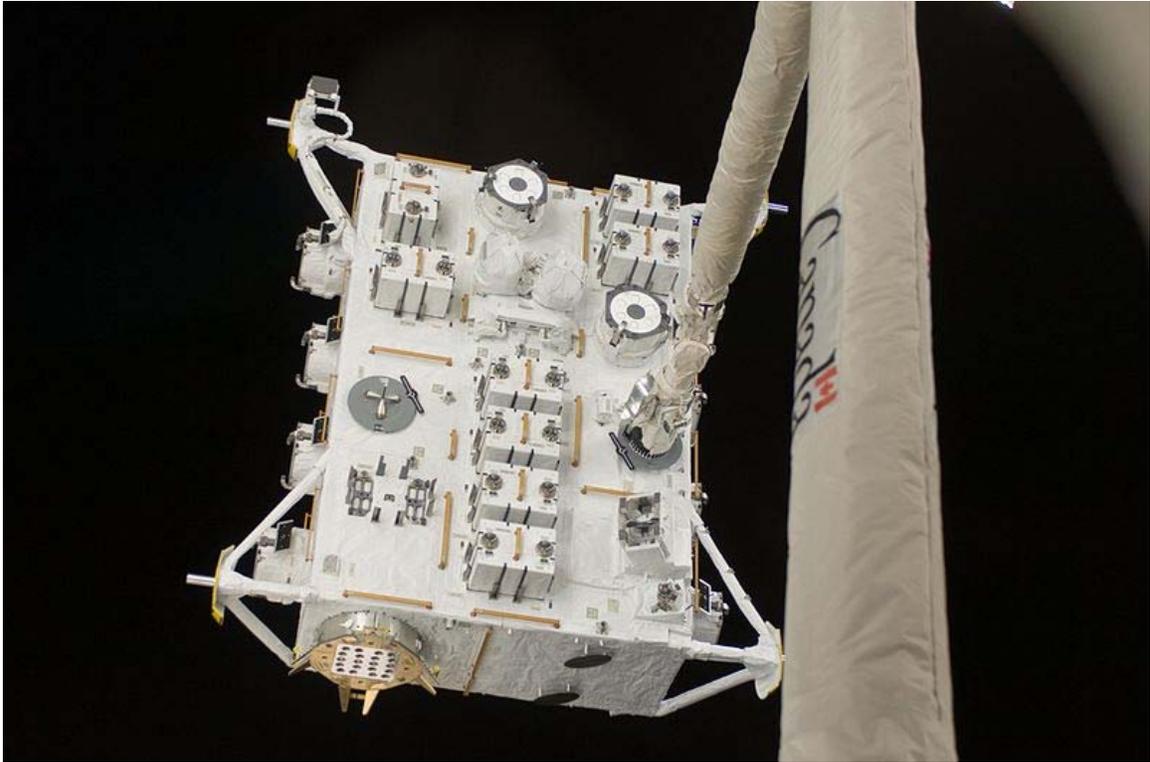
RPM image of Endeavour as taken from ISS

July 18 (Flight Day 4, Spacewalk 1)

EVA 1 started with astronauts Dave Wolf and Tim Kopra switching their spacesuit power to internal battery at 16:19 UTC. Despite a communication problem with the spacewalkers, the Japanese Exposed Facility was successfully installed on the Japanese Experiment Module by means of a complex series of steps involving the robotic arms of both the station and the shuttle. The JEF was first unberthed from the shuttle payload bay by the station arm following which the shuttle arm took the load. The station arm was then moved to the worksite on Node-2 (Harmony) from which it took the 4.1 ton facility back. The facility was then successfully latched on to the Experiment Module. As part of the EVA, the spacewalkers successfully deployed the port Unpressurized Cargo Carrier Attach System (UCCAS), which could not be completed during STS-119. During the prior mission, the deployment failed due to a jamming caused by a stuck detent pin. Engineers designed a custom tool to force the pin to release which was used to deploy the mechanism. Meanwhile the shuttle managers announced that there will be no need for a focused inspection of the heat shield. The nose cap and wing leading edge panels of the shuttle are cleared for entry as is but a reentry clearance was not given. Beyond one impact site having a gouge, the rest of the impacts were found to be mostly a loss of coating. The other activity scheduled for EVA 1, the deployment of a starboard side cargo carrier, was postponed for want of time. A fuel cell issue found before launch is still being analyzed, though it continues to function as expected with no impact to the mission.



Tim Kopra working to prepare the berthing mechanisms on the Kibo laboratory and the Japanese Exposed Facility (JEF) for the JEF installation on Kibo, during space walk 1.



JEF in the grasp of the shuttle's robotic arm.

July 19 (Flight Day 5)



ICC handoff by shuttle's robotic arm.

The installation of the Integrated Cargo Carrier-Vertical Light Deployable (ICC-VLD) on the port side of the station was successfully completed with the use of both the shuttle and station robotic arms. The cargo pallet, containing spares and fresh batteries for the station, was lifted out of the shuttle bay by the shuttle arm and handed off to the station's Canadarm2 which maneuvered it to its position. The pallet's contents will be setup in upcoming EVAs. A malfunction in a new toilet in the Destiny laboratory caused the crew to use the one in the Russian segment while attempts were made to identify the fault. Meanwhile the shuttle was cleared for reentry.

July 20 (Flight Day 6, Spacewalk 2)

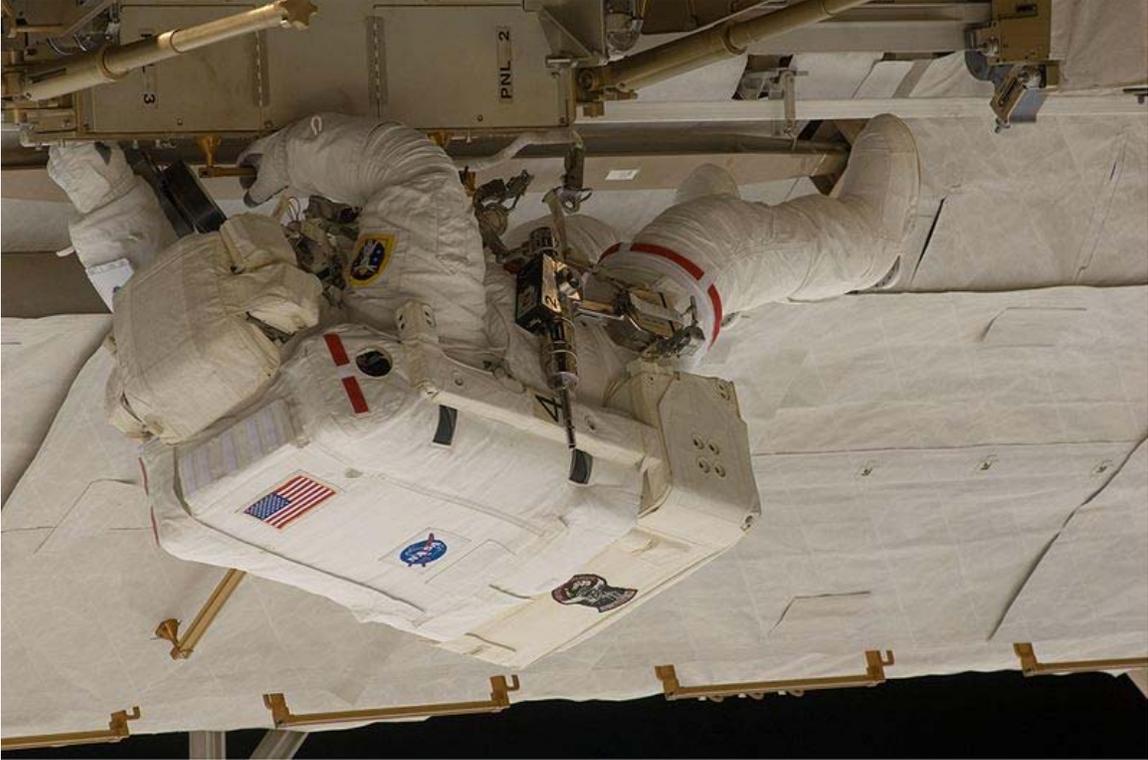
Astronauts Wolf and Marshburn began EVA 2 at 15:27 UTC out of the Quest airlock. The EVA was to transfer the spare components brought by the shuttle from the ICC-VLD to External Stowage Platform-3. The spares were handled by Wolf riding the station's robotic arm to the P3 truss stowage platform where he and Marshburn attached them for long term storage. The purpose of the spares was to provide redundancy to the station in the period following the shuttle's retirement. The spares unloaded include a Ku-Band Space-to-Ground antenna, a pump module for the coolant system and a drive unit for the station's robotic arm's mobile transporter. A planned installation of a camera on the Japanese Experiment Facility was postponed to a future EVA for want of time. Meanwhile the malfunctioning toilet was set right with the replacement of internal parts and cleared for normal use after tests.



Dave Wolf performs his second space walk, which is also the second of five scheduled space walks for STS-127.

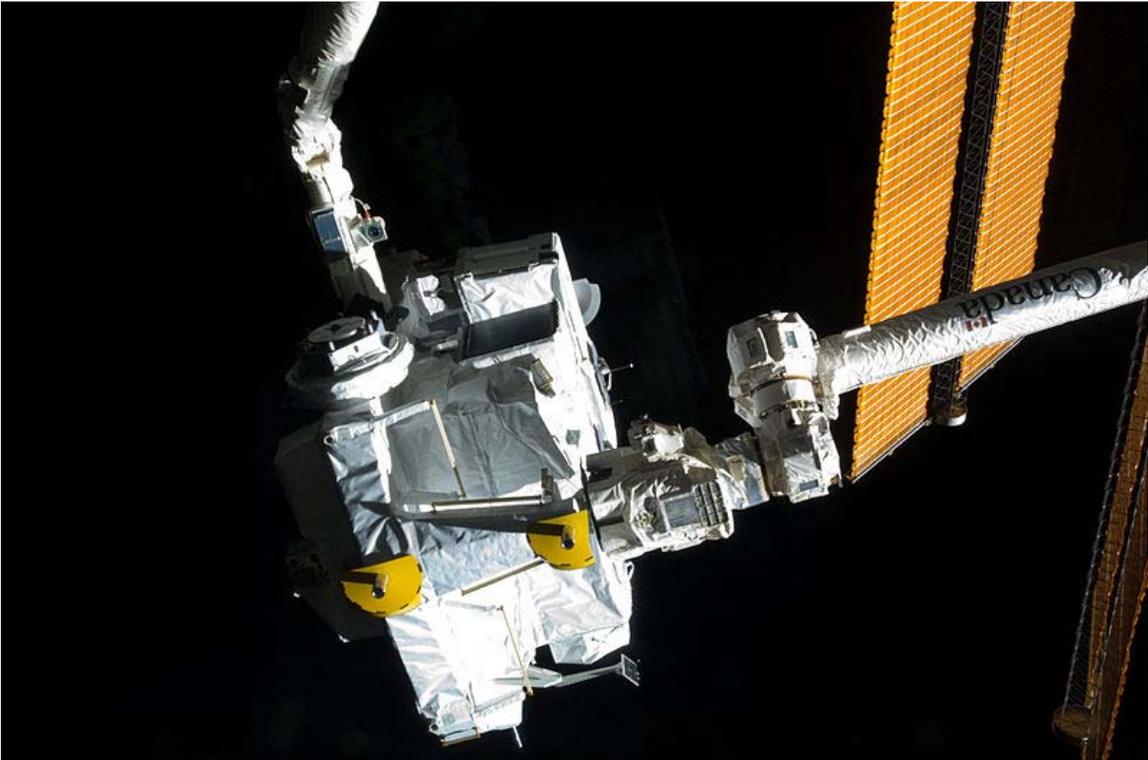


Tom Marshburn performs his first space walk, the STS-127 crew's second of the five scheduled.



Another view of Marshburn during his first space walk.

July 21 (Flight Day 7)



Japanese logistics carrier(JLE) handoff from shuttle to station.

In one of the more relaxed days, the Japanese logistics carrier was attached to the Japanese Exposed Facility. The cargo pallet was unberthed from the shuttle by the shuttle's robotic arm and handed to the station's robotic arm which then soft fixed it temporarily to the facility. After the experiments, containing an X-ray astronomy payload, a space environment monitor and a communications system, are installed the pallet will be returned back to Earth by the shuttle.

July 22 (Flight Day 8, Spacewalk 3)



Cassidy works near the JEF during space walk 3.

The spacewalk involving astronauts Wolf and Cassidy started at 14:32 UTC. As part of preparation for experiment installation on the Japanese external science deck, Cassidy removed the thermal covers off the experiment carrier. Meanwhile Wolf removed obstructions, consisting of a handrail and an equipment installation socket, from the Harmony node to clear the way for an upcoming Japanese automated resupply ship. The other task for EVA 3, involving replacement of four of the six batteries in the P6 truss, did not go as planned. Each 375 pound battery was to be removed and placed in a temporary stowage platform while a new one is taken from the ICC-VLD and fixed. The old ones will be returned to Earth. When two new batteries had been installed and three old ones removed, the CO₂ levels in Cassidy's suit showed an upward trend. Even though it never exceeded the safety limits, the EVA was called off with both astronauts returning

into the station. This left one old battery in a temporary flexible stowage position. The rest of the batteries will be installed in a future EVA with the rest of the EVAs being under replanning.

July 23 (Flight Day 9)

The Kibo robotic arm was inaugurated operationally with it being used to install experiments on to the Japanese exposed facility. The three experiments, transferred from the Japanese cargo pallet, consisted of Monitor of All-sky X-ray Image, Inter-orbit Communication System and Space Environment Data Acquisition Equipment-Attached Payload. As per the revised plan for EVA 4 astronauts Cassidy and Marshburn will replace the remaining four batteries on P6 and complete the already deferred installation of a camera on the Japanese experiment facility.

July 24 (Flight Day 10, Spacewalk 4)

The fourth spacewalk, by Cassidy and Marshburn, involved replacement of the final four of the six batteries on P6 truss integrated electronics assembly. After berthing the old batteries in the ICC-VLD, the cargo pallet was returned to the Endeavour's payload bay by the shuttle's robotic arm. The elevated levels of CO₂ in Cassidy's suit during EVA 3 was attributed to the astronaut working at a fast pace.

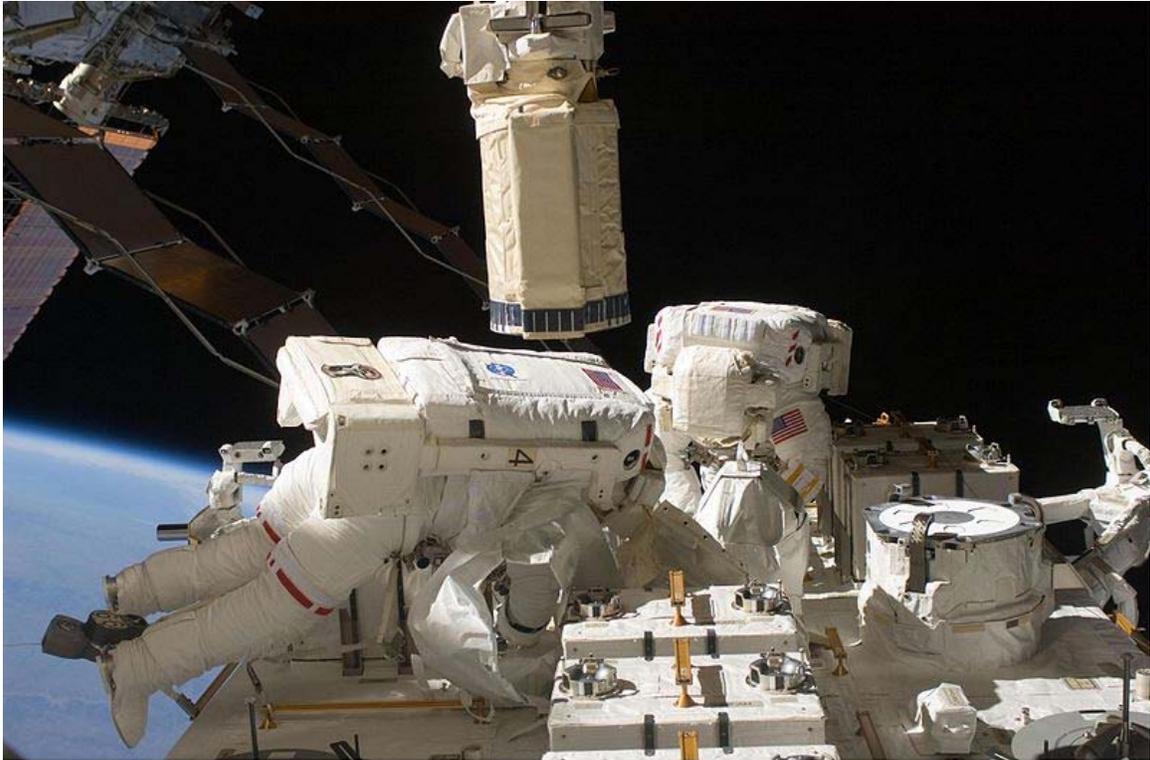
July 25 (Flight Day 11)

The crew of both the shuttle and station had a day off. The day was uneventful except for the station's American CO₂ removal system shutting down without any immediate impact.

July 26 (Flight Day 12)

The Japanese Exposed Section cargo carrier was berthed in Endeavour's payload bay by the shuttle's robotic arm after it was handed the pallet by the station's robotic arm. After this the crew of both the station and the shuttle held a joint news conference. Meanwhile the malfunctioning American CO₂ removal system has been transitioned to manual mode in order to keep it running.

July 27 (Flight Day 13, Spacewalk 5)



Marshburn and Cassidy during space walk 5.

Cassidy and Marshburn started EVA 5 at 11:33 UTC when they switched their suit power to internal battery. For this spacewalk, the CO₂ absorbent system in the suits were changed from Lithium Hydroxide to METOX due to problems with Cassidy's usage. Cassidy completed the reconfiguring of power channels in the Zenith 1 patch panel which are used for the control moment gyroscopes. Before the rewiring, two of the gyroscopes were fed by the same power channel. Since a failure of the channel can knock down two gyros and put the station in a degraded position the reconfiguration was made necessary. This rewiring made the two gyros to operate from separate power channels. Meanwhile Marshburn secured some multi-layered insulation on the Dextre. Later both the spacewalkers installed video cameras on the front and back of the Japanese exposed facility which will be used in dockings of the Japanese cargo crafts and normal operation. The cameras flew up in launch configuration and now have been installed in an operational configuration, thus completing the JEF assembly. Meanwhile due to Cassidy's METOX limitation, the deployment of the PAS was deferred to a future spacewalk. Instead some get ahead tasks were completed which included installation of handrails and a portable foot restraint.

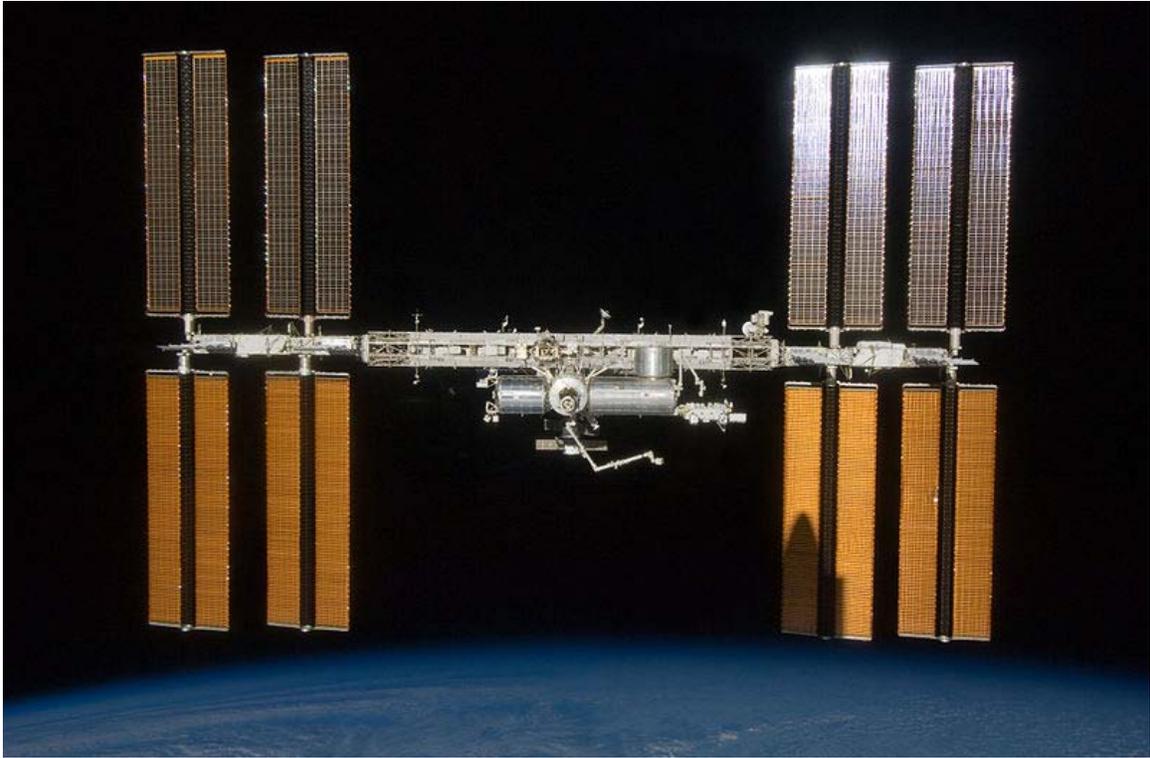
July 28 (Flight Day 14)

After a crew farewell Endeavour undocked from the ISS at 17:26 UTC. Unlike most other launches, hatch closure, which happened at 15:08 UTC, and undocking happened on the same day due to the extended delay in launching and the arrival of the Progress 34

cargo craft. After undocking Hurley began a fly around of the station giving the shuttle crew an opportunity to photograph the station's current configuration in all directions. Then a final separation burn was completed at 3:09 pm EDT.



Endeavour shortly after the shuttle and station post-undocking separation.



ISS shortly after the shuttle and station post-undocking separation with the JEF prominently seen.

July 29 (Flight Day 15)

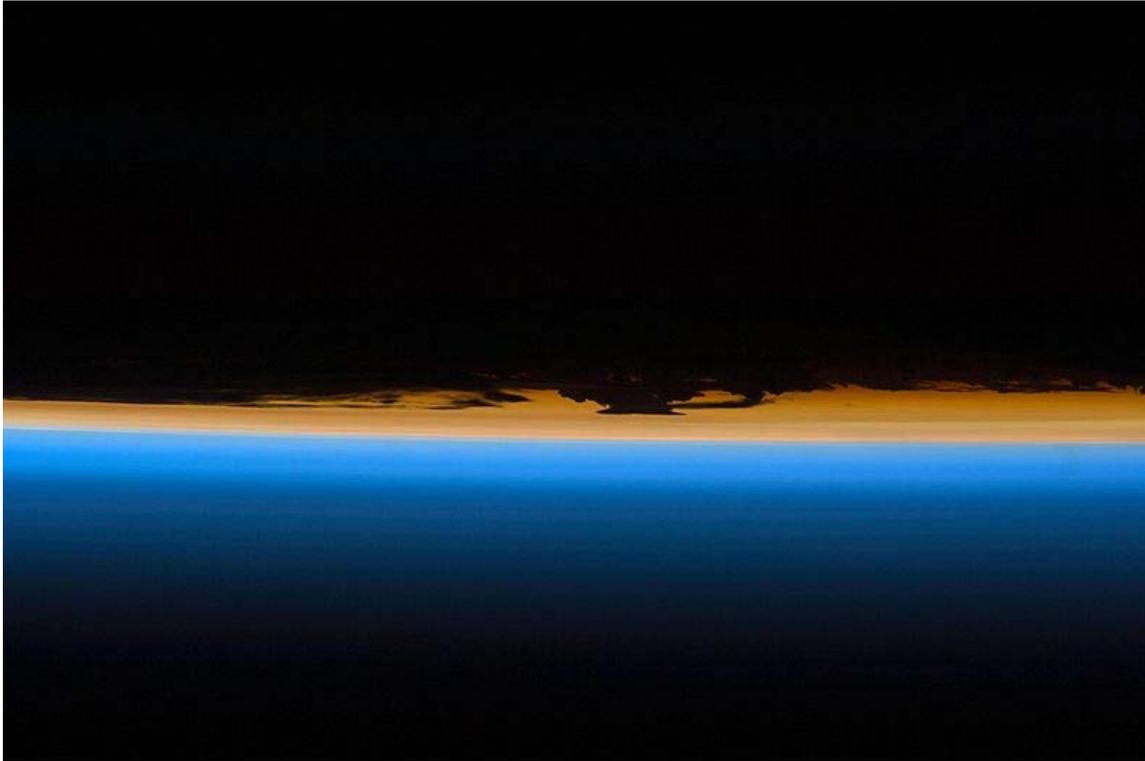


Image of orbital sunset taken from Endeavour one day before the shuttle landed.

The OBSS was grappled by the shuttle's robotic arm and used to inspect Endeavour's thermal protection system for damage from orbital debris. The imagery will be analyzed to clear the shuttle for reentry. Meanwhile the foam loss on the external tank was initially attributed to substrate contamination ahead of the application of the foam. Later during the processing of STS-128, voids in the foam was highlighted as a trigger for the shedding. The air trapped in the voids could have expanded due to the high temperatures generated during ascent thus breaking the foam.

July 30 (Flight Day 16)

The crew checked out the shuttle's systems for the landing and successfully deployed DRAGONSat and ANDE-2 satellites. The shuttle was also cleared for reentry with the TPS imagery showing no concerns. The shuttle will be tracking two chances of landing at KSC on Friday which has to be taken due to limitations of LiOH consumables.

July 31 (Flight Day 17, Landing)

After a 16 day mission, Endeavour landed at Kennedy Space Center at 10:48 EDT. The landing had to be done before Saturday due to CO₂ scrubbing Lithium hydroxide

limitations. There were two opportunities to land on 31 July 2009 of which the first was utilized.



Endeavour touches down at Kennedy Space Center.



Endeavour deploys the drogue chute to slow down

EVAs

Five spacewalks were completed in STS-127.

EVA #	Spacewalkers	Start (UTC)	End (UTC)	Duration
EVA 1	David A. Wolf	July 18	July 18	5 hours, 32 minutes
	Timothy Kopra	16:19	20:51	
JEF installed and P3 Nadir Unpressurized Cargo Carrier Attach System deployed. The S3 Zenith Outboard Payload Attachment System deployment was postponed due to time constraints.				
EVA 2	Wolf	20 July	20 July	6 hours, 53 minutes
	Thomas H. Marshburn	15:27	22:20	
Transferred Orbital Replacement Units (ORUs) from the Shuttle Integrated Cargo Carrier (ICC) to the External Stowage Platform-3 (ESP3). Transferred materials included a spare high-gain antenna, cooling-system pump module and spare parts for the Mobile Servicing System. The JEF Visual Equipment (JEF-VE) installation on the forward section was postponed due to time constraints.				
EVA 3	Wolf	22 July	22 July	5 hours, 59 minutes
	Christopher J. Cassidy	14:32	20:31	

JPM preparation work, ICS-EF MLI, and P6 battery replacement (2 of 6 units). EVA was cut short due to high levels of CO₂ in Cassidy's suit.

EVA 4	Cassidy	24 July	24 July	7 hours, 12 minutes
	Marshburn	13:54	21:06	
P6 battery replacement (final 4 of 6).				
EVA 5	Cassidy	27 July	27 July	4 hours, 54 minutes
	Marshburn	11:33	16:27	
SPDM thermal cover adjustment, Z1 patch panel reconfiguration, JEM visual equipment (JEM-VE) installation (forward and aft), and JEM-LTA reconfigurations. The S3 Nadir Payload Attachment System (outboard) deployment was postponed to a later mission.				

Wake-up calls

NASA began a tradition of playing music to astronauts during the Gemini program, which was first used to wake up a flight crew during Apollo 15. Each track is specially chosen, often by their families, and usually has a special meaning to an individual member of the crew, or is applicable to their daily activities.

Flight Day	Song	Artist	Played for	Links
Day 2	“These Are Days”	10,000 Maniacs	Timothy Kopra	WAV MP3 TRANSCRIPT
Day 3	“Here Comes the Sun”	The Beatles	Mark Polansky	WAV MP3 TRANSCRIPT
Day 4	“Home”	Marc Broussard	David Wolf	WAV MP3 TRANSCRIPT
Day 5	“Learning to Fly”	Tom Petty	Christopher Cassidy	WAV MP3 TRANSCRIPT
Day 6	“Thunderbirds March”	Barry Gray	Julie Payette	WAV MP3 TRANSCRIPT
Day 7	“Life Is a Highway”	Rascal Flatts	Tom Marshburn	WAV MP3 TRANSCRIPT
Day 8	“Santa Monica”	Everclear	Douglas Hurley	WAV MP3 TRANSCRIPT
Day 9	“Tiny Dancer”	Elton John	Mark Polansky	WAV MP3 TRANSCRIPT
Day 10	“Wish You Were Here”	Pink Floyd	David Wolf	WAV MP3 TRANSCRIPT
Day 11	“In Your Eyes”	Peter Gabriel	Tom Marshburn	WAV MP3 TRANSCRIPT
Day 12	“Dixit Dominus”	George Frederic Handel	Julie Payette	WAV MP3 TRANSCRIPT

Day 13	“On the Sunny Side of the Street”	Steve Tyrell	Mark Polansky	WAV MP3 TRANSCRIPT
Day 14	“Proud to Be an American”	Lee Greenwood	Chris Cassidy	WAV MP3 TRANSCRIPT
Day 15	“Yellow”	Coldplay	Doug Hurley	WAV MP3 TRANSCRIPT
Day 16	“I Got You Babe”	Sonny & Cher	Koichi Wakata	WAV MP3 TRANSCRIPT
Day 17	“Beautiful Day”	U2	Tom Marshburn	WAV MP3 TRANSCRIPT

Chapter- 4

STS-128

STS-128

Mission insignia



Mission statistics

Mission name STS-128

Space shuttle *Discovery*

Spacecraft Orbiter/payload liftoff mass:
mass 267,689 pounds (121,422 kg)

Launch pad 39A
August 28, 2009
23:59 EDT/
03:59 UTC August 29

Launch date

- Launch window: 9 minutes 45 seconds
- Shuttle liftoff mass:
4,522,852 pounds (2,051,531 kg)

Landing September 11, 2009
20:53 EDT (00:53 UTC)
Runway 22
Edwards Air Force Base, California

Mission duration 13 days 20:54:55

Number of orbits 219

Orbital period 94 min

Orbital altitude Insertion: 122 nautical miles (226 km);
Orbital: 188 nautical miles (348 km)

Orbital inclination 51.6 degrees

Distance traveled 5,755,275 miles (9,262,217 km)

Docking

Docking date August 31, 2009 00:54 UTC

Undocking date September 8, 2009 19:26 UTC

Time docked 8 days, 18 hours, 32 minutes

Crew photo



Seated (l-r) Ford and Sturckow. Standing (l-r) are Hernández, Olivas, Stott, Fuglesang and Forrester.

Related missions

Previous mission

STS-127 

Subsequent mission

STS-129 

STS-128 (ISS assembly flight **17A**) was a space shuttle mission to the International Space Station (ISS) that launched on August 28, 2009. Space Shuttle *Discovery* carried the Multi-Purpose Logistics Module *Leonardo*, as the primary payload. Leonardo contained a collection of experiments for studying the physics and chemistry of microgravity. Three spacewalks were carried out during the mission, which removed and replaced a materials processing experiment outside ESA's *Columbus* module, and returned an empty ammonia tank assembly. The first launch attempt was delayed due to weather concerns, including multiple weather violations in NASA's launch rules, beginning over two hours before the scheduled launch. The second launch attempt scheduled for August 26, 2009 at 01:10:22 EDT was called off the previous evening due to an anomaly in a fuel valve of the orbiter. The launch took place on August 28, 2009 at 23:59 EDT.

Crew

Position	Launching astronaut	Landing astronaut
Commander	Frederick W. Sturckow Fourth spaceflight	
Pilot	Kevin A. Ford First spaceflight	
Mission Specialist 1	Patrick G. Forrester Third spaceflight Intra-vehicular Officer (IV)	
Mission Specialist 2	José M. Hernández First spaceflight Flight engineer	
Mission Specialist 3	Christer Fuglesang, ESA Second spaceflight EV3	
Mission Specialist 4	John D. Olivas Second spaceflight Lead spacewalker EV1	
Mission Specialist 5	Nicole Stott Expedition 20 First spaceflight EV2	Timothy Kopra Expedition 20 First spaceflight

Crew notes

Nicole Stott was originally scheduled to return aboard Soyuz TMA-15, but a change in the flight plan was made due to the possible flight delays in future shuttle missions, which may extend Canadian astronaut Robert Thirsk's mission beyond the six-month duration preferred for station crew members.

STS-128 is planned to be the final Space Shuttle flight used for ISS crew rotation, with Nicole Stott replacing Tim Kopra. Stott returned on STS-129, but that flight did not bring her replacement.

The mission of Christer Fuglesang is named *Alissé* by the European Space Agency. The name was proposed by Jürgen Modlich from Baierbrunn, Germany. The name refers to the 15th-century explorers who used the trade winds to follow Christopher Columbus across the oceans to the New World.

STS-128 also marked the first time two Hispanic Americans were on the same crew. John "Danny" Olivas of El Paso, Texas, made his second trip up into space, and José Hernández of Stockton, California, made his first. Both are of Mexican heritage.

Mission payload

Location	Cargo	Mass
Bays 1-2	Orbiter Docking System EMU 3009 / EMU 3015	1,800 kilograms (4,000 lb) ~260 kilograms (570 lb)
Bay 3P	Shuttle Power Distribution Unit (SPDU)	~17 kilograms (37 lb)
Bay 4P	APC/MISSE Carrier	57 kilograms (130 lb)
Bay 5P	APC/MISSE Carrier	57 kilograms (130 lb)
Bay 7S	ROEU umbilical	~79 kilograms (170 lb)
Bays 7-12	Leonardo (MPLM FM-1)	12,131 kilograms (26,740 lb)
Bay 13	Lightweight MPESS Carrier (LMC)	1,780 kilograms (3,900 lb)
Starboard Sill	Orbiter Boom Sensor System	~382 kilograms (840 lb)
Port Sill	Canadarm	410 kilograms (900 lb)
	Total:	16,973 kilograms (37,420 lb)

Multi-Purpose Logistics Module (MPLM) *Leonardo*



Leonardo, as flown on STS-102.

The primary payload of STS-128 is the Multi-Purpose Logistics Module. *Leonardo's* purpose is to assist with establishing a six-man crew capacity by bringing extra supplies and equipment to the station. The Multi-Purpose Logistics Module will contain three racks for life support, a Crew quarter to be installed in Kibo, a new treadmill (COLBERT) that will temporarily be placed in Node 2 and later in Node 3, and an Air Revitalization System (ARS) that will temporarily be placed in Kibo and later in Node 3.

Leonardo Specifications

- Length: 21 feet (6.4 m)
- Diameter: 15 feet (4.6 m)
- Payload Mass (launch): 27,510 pounds (12,480 kg)
- Payload Mass (return): 16,268 pounds (7,379 kg)
- Empty Weight: 9,810 pounds (4,450 kg)

Lightweight Multi-Purpose Carrier (LMC)

The shuttle carried a Lightweight Multi-Purpose Experiment Support Structure Carrier (LMC) with Ammonia Tank Assembly (ATA). The new ammonia tank will replace an empty tank during an EVA.

TriDAR

The shuttle flew the first test flight of the TriDAR, a 3D dual-sensing laser camera, intended for potential use as an autonomous rendezvous and docking sensor. The TriDAR successfully tracked the ISS position and orientation from the shuttle during docking operations.

Other science packages

It will also contain three racks dedicated to science, FIR (Fluids Integrated Rack) and the first Materials Science Research Rack (MSRR-1) to be placed in Destiny and MELFI-2 (Minus Eighty Laboratory Freezer for ISS) to be placed in Kibo. The FIR will enable detailed study of how liquids behave in microgravity, a crucial detail for many chemical reactions. One experiment, for instance, will examine how mixtures known as colloids behave without being stirred by sedimentation and convection. Another using the Light Microscopy Module (LMM) will examine how an ideal heat pipe works without the distortions of gravity.

Mission experiments

The STS-128 mission (as did STS-125 and STS-127) took part in crew seat vibration tests that will help engineers on the ground understand how astronauts experience launch. They will then use the information to help design the crew seats that will be used in future NASA spacecraft.

STS-128 repeated the Boundary Layer Transition (BLT) Detailed Test Objective (DTO) experiment that was done by the same shuttle during STS-119. In this experiment, one of the thermal protection systems was raised to create a boundary layer transition in which the air flow becomes turbulent beyond a certain speed. During STS-119 the tile was raised 0.25 inches (6.4 mm) above the others, tripping the flow at Mach 15 during reentry. In the modification being done, the tile has been raised 0.35 inches (8.9 mm) to trip at Mach 18 producing more heat.



Launch from 180 miles away (long exposure)



STS-128 as seen from Bartram Springs in Jacksonville, FL

Discovery undertook the testing of a catalytic coating which is meant to be used by the Orion (spacecraft). Two TPS tiles located in the protuberance downstream from the BLT tile had been fully coated with the catalytic material in order to understand the entry heating performance. The tiles were instrumented to collect a wide variety of data.

Mission background

The mission marks:

- 159th American manned space flight
- 128th shuttle mission since STS-1
- 37th flight of *Discovery*
- 30th shuttle mission to the ISS
- 103rd post-*Challenger* mission
- 15th post-*Columbia* mission
- 32nd shuttle night launch
- NASA's first space shuttle launch to take place during two calendar days
- 25th anniversary of *Discovery's* first flight, STS-41-D (30 August 1984)

Shuttle processing

Discovery rolled from the Orbiter Processing Facility to the Vehicle Assembly Building after the external tank was cleared for use and was mated with it. The foam insulation on the tank underwent stringent pull tests after the foam liberated and hit the orbiter during STS-127. The STS-128's tank initially exhibited no concerns while the STS-127 case was determined to be a one off case due to surface contamination prior to foam application.

The main change from previous missions is the change of the Ground Umbilical Carrier Plate (GUCP) vent housing. The quick release vents exhibited leaks during STS-119 and STS-127, which were determined to be due to a misalignment in the vent. This led to the one part rigid seal in the external tank being replaced with a two part flexible seal.

Discovery later rolled out from the VAB to Launch Complex 39A on 4 August 2009, in a slow drive on the top of the Crawler-transporter. The 3.4-mile (5.5 km) rollout began at 02:07 EDT, and ended with the launch platform secured in place at about 13:50 EDT. The move took longer than expected due to adverse weather conditions, which included lightning warnings. The crawler also had to pause occasionally so mud could be removed from its treads and bearings. Technicians then quickly prepared the shuttle to host the crew's countdown dress rehearsal known as the Terminal Countdown Demonstration Test (TCDDT). *Discovery's* seven astronauts flew to Kennedy on 5 August 2009 for the training activity which concludes later in the week with a complete practice countdown, minus liftoff, involving the crew and the launch team. Meanwhile, in an unprecedented operation, modifications were made to the left Solid rocket booster on the pad. The modifications involved replacement of a check valve filter assembly in the booster which was found to have broken. In a potentially delaying factor, in depth testing of the external tank with X-ray revealed voids in the foam which might have formed during the injection molding of the foam. This has also been decided as a suspect factor in the foam shedding during STS-127. The air in the voids could have expanded due to the high temperatures generated during ascent thus breaking the foam. The reviews considered a rollback as an option since the defect could not be set right in the pad. Later, the tank was cleared for launch as is without any additional inspections.



Long exposure picture of STS-128 launching





Olivas(left) and Stott (right) during EVA 1.



Leonardo is placed back in Discovery's payload bay.

Launch attempts

The first launch attempt was delayed by 24 hours due to weather concerns including multiple weather violations in NASA's launch rules beginning over 2 hours before the scheduled launch. During the second attempt on Wednesday morning, a problem with a LH2 fill-and-drain fuel valve inside space shuttle Discovery's aft compartment led to another scrubbing. The problem arose when sensors did not detect the closure of the valve when commanded to do so. The issue was thought to be with the sensors rather than the valve itself. After inerting the orbiter's tank, which involved draining it, tests were conducted on the valves. Despite the valves working normally, another delay was called for to have more confidence in the system, and to give the console operators who performed the test some rest. The launch team evaluated the issue, passing on a possible launch window 27 August 2009 at 00:22 EDT. The launch was delayed till 23:59 EDT 28 August 2009 to allow the engineers to be fully satisfied with the vehicle. Later the mission was cleared for launch which involved a flight rule waiver for cycling the valve and a discussion to analyze the test failure of an Ares-1 booster that was similar to the SRBs used for the mission. NASA feared another delay when storms formed near the Kennedy Space Center on 28 August 2009 but the weather cleared in time for a successful launch of Discovery at 23:59 EDT.

Attempt	Planned	Result	Turnaround	Reason	Decision point	Weather go %	Notes
1	25 Aug 2009, 1:36:05 am	Scrubbed	---	Weather	25 Aug 2009, 1:25 am(T-9:00 hold)	80%	Precipitation and lightning in launch and landing area
2	26 Aug 2009, 12:22:07 am	Scrubbed	0 days, 22 hours, 46 minutes	Technical	25 Aug 2009, 5:52 pm	70%	Failure indicator on LH2 inboard fill and drain valve
3	28 Aug 2009, 11:59:37 pm	Successful	2 days, 23 hours, 38 minutes			60%; later 80%	

Mission timeline

Aug. 28 (Flight Day 1 – Launch)



Space Shuttle *Discovery* launches from Kennedy Space Center, August 28, 2009

After launch at 23:59 EDT, *Discovery* opened her payload bay doors. Once the doors were opened the crew deployed the Ku-band antenna and activated the Shuttle Remote Manipulator System (SRMS). Once the Ku-band antenna was deployed and activated the crew then down-linked photos from the External Tank Umbilical Well Camera system, so controllers on the ground could see how the tank performed and how much if any foam was shed during ascent.

Aug. 29 (Flight Day 2 – TPS Survey)

During *Discovery's* first full day on orbit, the crew used the SRMS to grapple the Orbiter Boom Sensor System (OBSS) and survey the wing leading edges, nose and other parts of the Thermal Protection System (TPS), as well as the Orbital Maneuvering System (OMS) Pods. During this time some of the crew were preparing the space suits that will be used during the 3 Extra-vehicular activities (EVA) and setting up the tools that will be used during the docking. This includes installing the Centerline Camera and extending the Orbiter Docking system Ring Extension.

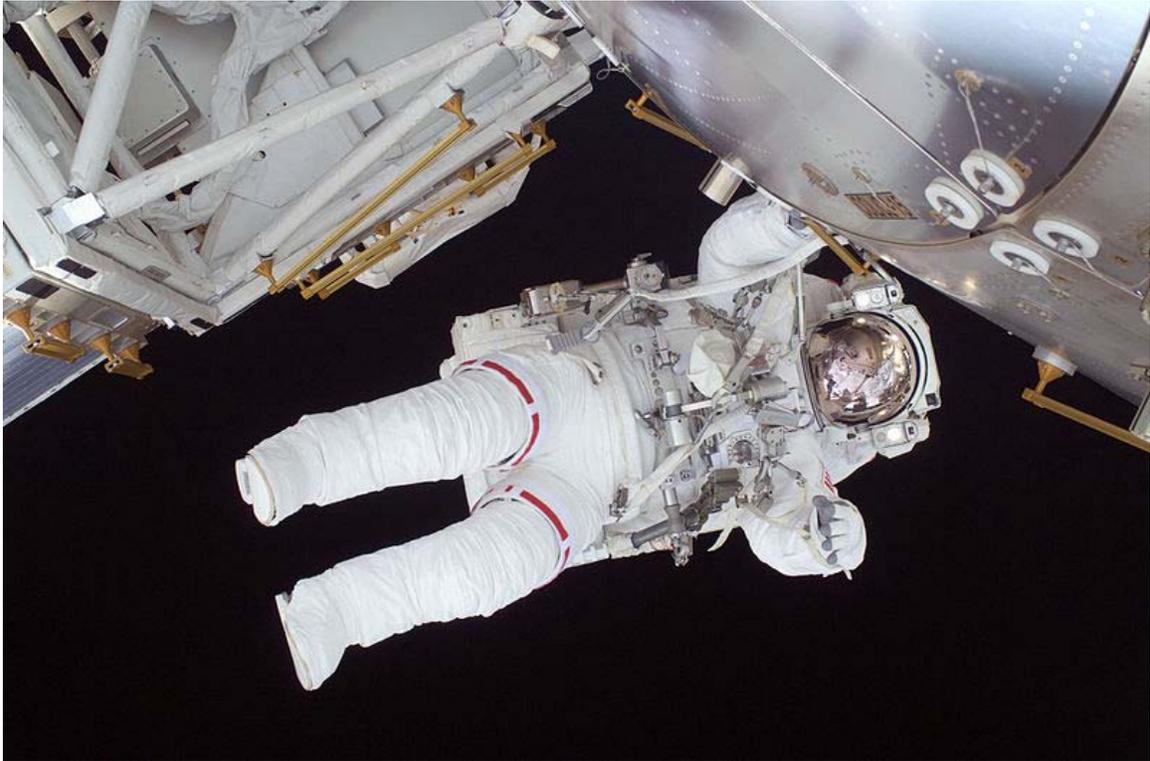
Aug. 30 (Flight Day 3 – Docking)

Discovery docked with the Pressurized Mating Adapter (PMA) 2 on the front of the Harmony connecting module. Before the shuttle docked Commander Rick Sturckow performed what is known as the Rendezvous Pitch Maneuver (RPM), while Expedition 20 Commander Gennady Padalka and Flight Engineer Michael Barret took photos of the shuttles belly. The photos were down-linked to mission control for review. After docking, Nicole Stott and Tim Kopra switched Soyuz seat liners, making Stott an Expedition 20 Flight Engineer and Tim Kopra an STS-128 Mission Specialist. The joint crews also performed some transfers from the shuttle mid-deck and checked on the pressure in the MPLM Leonardo.

Aug. 31 (Flight Day 4 – MPLM Berthing)

During flight day 4 the MPLM Leonardo was berthed to the Nadir or earth facing port on Harmony using the Space Station Remote Manipulator System (SSRMS). Once it was berthed, the crews activated it and opened the hatch for ingress. Some more items were transferred from the shuttle mid-deck including the MDS experiment and the space suits Danny Olivas and Nicole Stott will use during EVA 1. The pair also prepared all the tools that will be used during the EVA with some help from Tim Kopra. Later on during the night when the crews were asleep, the team of ground controllers vented the Port 1 (P1) Ammonia Tank Assembly (ATA) Nitrogen Vent lines, in preparation for the ATA to be removed during EVA 1.

Sept. 1 (Flight Day 5 – EVA 1)



Nicole Stott during the STS-128 mission's first space-walk.

EVA 1 was performed, and saw the removal of the empty Ammonia Tank Assembly, and the removal and stowage of the EuTef and MISSE 6 experiments. While the spacewalk was going on crew members inside were transferring the Crew Quarters, C.O.L.B.E.R.T treadmill and the Node 3 Air Revitalization System rack (ARS). The treadmill and ARS were temporarily stowed, while the crew Quarters was installed in the Kibo Module where setup and activation was begun.

Sept. 2 (Flight Day 6)

During flight day 6 the joint crews continued the activation of the new crew quarters. The last of the major transfer items, the Fluids Integrated Rack (FIR), Materials Science Research Rack and the Minus Eighty Laboratory Freezer ISS 2 (MELFI-2) were transferred from the Multi-Purpose Logistics Module (MPLM) Leonardo. Astronauts Danny Olivas and José Hernández answered some questions submitted on Youtube and Twitter. Olivas along with Christer Fuglesang also prepared for the second EVA and "camped out" in the air lock at a lower pressure to help get ready for EVA 2 on flight day 7.

Sept. 3 (Flight Day 7 – EVA 2)

On flight day 7, Danny Olivas and Christer Fuglesang performed the second spacewalk of the STS-128 mission. Olivas and Fuglesang installed and connected the new Ammonia Tank Assembly (ATA), and also performed two get aheads. The get ahead tasks included installing protective lens covers on the Space Station Remote Manipulator System (SSRMS) End B cameras . Once the ATA was installed, the tank was integrated into the cooling loop. While Olivas and Fuglesang were outside, the rest of the crew continued on transferring items to and from both the shuttle mid-deck and MPLM.

Sept. 4 (Flight Day 8)

The first part of the crew day was spent off duty. The crews enjoyed a meal, took a crew photo and took part in a PAO event. More transfer was completed by both crews. The space station crew calibrated the Oxygen Generation System (OGS) H2 sensor. Timothy Kopra and Nicole Stott continued their hand over activities, helping Stott who is taking over from Kopra. Danny Olivas and Christer Fuglesang got their space suits ready for the third and final space walk. The pair spent the night in the Quest Joint Airlock, at a lower pressure of 10.2 psi instead of 14.7 psi.

Sept. 5 (Flight Day 9 - EVA 3)



Danny Olivas during EVA 3.



Highlights from the third spacewalk (2 min 21 secs)

During flight day 9 Danny Olivas and Christer Fuglesang performed EVA 3. The pair completed all tasks that were to be done, including installing two GPS antennas and deploying the Starboard 3 (S3) Payload Attach System (PAS), a new Rate Gyro Assembly (RGA) 2 and routing of Node 3 Avionics cables. The joint crew also completed more transfer, mostly transfer for return to earth in the MPLM and space shuttle mid-deck. The ISS crew also replaced a bolt on the Common Berthing Mechanism (CBM) so that the MPLM won't get stuck, and also to ensure correct capture of the HTV.

Sept. 6 (Flight Day 10 - Off duty)

Flight day 10 saw the joint crews transfer samples from the space station to the shuttle freezer known as Glacier. The samples will be returned to earth for examination by scientists who will develop ways to prevent bone and muscle loss in space as well as cures for other illnesses on earth. The crews also completed some close outs of the Multi-Purpose Logistics Module Leonardo. The last portion of the crew day was spent off duty.

Sept. 7 (Flight Day 11 - Hatch closure)

On flight day 11 the joint ISS/shuttle crews completed transfers and closed the hatches with the MPLM. Once the hatches were closed, the MPLM was deactivated, demated and berthed back in the payload bay of the space shuttle. During this process José Hernández and Nicole Stott took part in a PAO event. The end of the crews work days saw the two crews say goodbye in a farewell ceremony and close the hatches between the shuttle and ISS. Once the hatches were closed, the Pressurized Mating Adapter 2 was depressurized, in advance of undocking. The shuttle crew setup and checked out the rendezvous tools before going to bed.

Sept. 8 (Flight Day 12 - Undocking)

On flight day 12, space shuttle *Discovery* successfully undocked from the International Space Station at 19:26 UTC. After undocking, the shuttle backed out and performed a fly around of the ISS. The space shuttle then performed 2 separation burns using its thrusters. After the separation burns, astronauts Kevin Ford, José Hernández and Christer Fuglesang used the Orbiter Boom Sensor System (OBSS) to inspect the shuttle's Thermal Protection System (TPS). When they completed that task the OBSS was berthed on the starboard sill of the payload bay and the Shuttle Remote Manipulator System (SRMS) was powered down.

Sept. 9 (Flight Day 13 - End Of Mission Prep)

On flight day 13 the space shuttle crew began stowing items for landing. During the course of the day commander Frederick W. Sturckow and pilot Kevin A. Ford performed standard checks of the Flight Control Systems (FCS), Reaction Control System (RCS) jets and communications with the ground. The crew also deactivated the Wing Leading Edge System (WLES), stowed the Ku-band antenna, and reviewed landing procedures.

Sept. 10 (Flight Day 14 - Landing Postponed)

On flight day 14, *Discovery* was scheduled to land at Kennedy Space Center at 19:04 EDT (23:04 UTC) which was postponed due to weather conditions, the second opportunity at 20:40 EDT (00:40 UTC) was also postponed due to weather conditions.

Sept. 11 (Flight Day 15 - Landing)



After weather delayed two landing opportunities at Kennedy Space Center, *Discovery* lands at Edwards Air Force Base, California.

On flight day 15 at 19:47 EDT (23:47 UTC), *Discovery* started the de-orbit burn for landing at Edwards Air Force Base after two landing attempts at Kennedy Space Center were waved off. *Discovery* touched down at 20:53 EDT (00:53 UTC).

Spacewalks

Each spacewalk was planned to last approximately 6.5 hours.

EVA #	Spacewalkers	Start (UTC)	End (UTC)	Duration
	John D. Olivas Nicole Stott	1 September 21:49 UTC	2 September 04:24 UTC	6 hours, 35 minutes
EVA 1	Prepared for the replacement of an empty ammonia tank on the station's port truss by releasing its bolts. Retrieved the Materials International Space Station Experiment and European Technology Exposure Facility mounted outside the Columbus laboratory, and stowed them in <i>Discovery</i> 's cargo bay for their return to Earth. :Robotic Arm Operators: Ford and Thirsk			

John D. Olivas	3 September	4 September	6 hours, 39
Christer Fuglesang	22:13 UTC	04:51UTC	minutes

EVA 2

Removed the new ammonia tank from the shuttle's payload bay and replaced it with the used tank from the station. The new tank, weighing about 1,800 pounds (820 kg), was the most mass ever moved by spacewalking astronauts.

With this spacewalk, ESA astronaut Fuglesang became the first person, who is not from either an American or Russian space program, to have participated in four or more spacewalks.

:Robotic Arm Operators: Ford and Stott

John D. Olivas	5 September	6 September	7 hours, 01
Christer Fuglesang	20:39 UTC	03:40 UTC	minutes

EVA 3

Preparations for the arrival of the Tranquility node by attaching cables between the starboard truss and the Unity node, the area where Tranquility will be installed. Tranquility is targeted to arrive on STS-130 in February 2010. The spacewalkers also replaced a communications sensor device, installed two new GPS antennas, and replaced a circuit breaker.

Wake-up calls

NASA began a tradition of playing music to astronauts during the Gemini program, which was first used to wake up a flight crew during Apollo 15. Each track is specially chosen, often by their families, and usually has a special meaning to an individual member of the crew, or is applicable to their daily activities.

Flight Day	Song	Artist	Played for	Links
Day 2	"Back In The Saddle Again"	Gene Autry	Frederick W. Sturckow	WAV MP3 TRANSCRIPT
Day 3	"Made to Love"	TobyMac	Nicole Stott	WAV MP3 TRANSCRIPT
Day 4	"Mi Tierra"	Gloria Estefan	José Hernández	WAV MP3 TRANSCRIPT
Day 5	"Indiana, Our Indiana"	Indiana University Band	Kevin A. Ford	WAV MP3 TRANSCRIPT
Day 6	"What a Wonderful World"	Louis Armstrong	Christer Fuglesang	WAV MP3 TRANSCRIPT
Day 7	"There is a God"	33Miles	Patrick G. Forrester	WAV MP3 TRANSCRIPT

Day 8	“What a Wonderful World”	Louis Armstrong	Danny Olivas	WAV MP3 TRANSCRIPT
Day 9	“El Hijo del Pueblo”	José Alfredo Jiménez	José Hernández	WAV MP3 TRANSCRIPT
Day 10	“Rocket”	Andrew Peterson	Patrick G. Forrester	WAV MP3 TRANSCRIPT
Day 11	“Only One”	Jeremy Kay	John D. Olivas	WAV MP3 TRANSCRIPT
Day 12	"Beautiful Day"	U2	Timothy Kopra	WAV MP3 TRANSCRIPT
Day 13	"Sailing"	Rod Stewart	Christer Fuglesang	WAV MP3 TRANSCRIPT
Day 14	"Good Day Sunshine"	The Beatles	Kevin A. Ford	WAV MP3 TRANSCRIPT
Day 15	"Big Boy Toys"	Aaron Tippin	Frederick W. Sturckow	WAV MP3 TRANSCRIPT

Chapter- 5

STS-132

STS-132

Mission insignia



Mission statistics

Mission name	STS-132
Space shuttle	<i>Atlantis</i>
Launch pad	39A
Launch date	14 May 2010, 14:20 EDT (18:20 UTC)
Landing	26 May 2010, 08:49:18 EDT (12:49 UTC)
Mission duration	11days 18hours 29minutes 09seconds
Number of orbits	186
Orbital altitude	Insertion: 122 nautical miles (226 km) Rendezvous: 190 nautical miles (350 km)
Orbital inclination	51.6 degrees
Distance traveled	4,879,978 miles (7,853,563 km)
Docking	
Docking date	16 May 2010, 14:28 UTC

Undocking date 23 May 2010, 15:22 UTC

Time docked 7 days 1 hour 1 minute

Crew photo



Sitting: Ken Ham (center), Garrett Reisman (left), Stephen Bowen (Right),

Standing: Michael Good, Tony Antonelli, Piers Sellers

Related missions

Previous mission

STS-131



STS-133

Subsequent mission

STS-132 (ISS assembly flight **ULF4**) was the most recent Space Shuttle mission, which docked with the International Space Station on 16 May 2010. It was launched from the Kennedy Space Center on 14 May 2010. The primary payload was the Russian *Rassvet* Mini-Research Module along with an Integrated Cargo Carrier-Vertical Light Deployable (ICC-VLD). Space Shuttle *Atlantis* landed at the Kennedy Space Center on 26 May 2010.

STS-132 is scheduled to be the final flight of *Atlantis* provided that the STS-335/STS-135 Launch On Need rescue mission is not flown.

Crew

Position	Crewmember
Commander	Kenneth Ham Second spaceflight
Pilot	Dominic A. "Tony" Antonelli Second spaceflight
Mission Specialist 1	Garrett Reisman Second spaceflight EV1

Mission Specialist 2

Michael T. Good
Second spaceflight
Flight Engineer/EV3

Mission Specialist 3

Stephen G. Bowen
Second spaceflight
EV2

Mission Specialist 4

Piers Sellers
Third spaceflight
Loadmaster/Lead robotics officer

On 11 August 2009, Karen Nyberg was replaced by Michael Good as Mission Specialist 1 due to a temporary medical condition.

Crew seat assignments



Seats 1–4 are on the Flight Deck.
Seats 5–7 are on the Middeck.

Seat	Launch	Landing
S1	Kenneth Ham	Kenneth Ham
S2	Dominic Antonelli	Dominic Antonelli
S3	Garrett Reisman	Piers Sellers
S4	Michael Good	Michael Good
S5	Stephen Bowen	Stephen Bowen
S6	Piers Sellers	Garrett Reisman

Mission parameters



Mission poster

- **Mass:**
 - *Shuttle liftoff weight:* 4,519,769 pounds (2,050,133 kg)
 - *Orbiter/payload liftoff weight:* 263,100 pounds (119,300 kg)
 - *Orbiter/payload landing weight:* 209,491 pounds (95,024 kg)
 - *Payload weight:* 26,615 pounds (12,072 kg)
- **Perigee:** 208 miles (335 km)
- **Apogee:** 223 miles (359 km)
- **Inclination:** 51.6°
- **Period:** 91 min

Mission payload

Location	Cargo	Mass
Bays 1-2	Orbiter Docking System	1,800 kilograms (4,000 lb)

	EMU 3004 / EMU 3011 / EMU 3018	~390 kilograms (860 lb)
Bay 3P	Shuttle Power Distribution Unit (SPDU)	~17 kilograms (37 lb)
Bay 5P	Power & Data Grapple Fixture (PDGF)	~71 kilograms (160 lb)
Bays 6-7	ICC-VLD carrier -6 Battery ORUs -SGANT antenna -EOTP platform	1,913 kilograms (4,220 lb) 1,020 kilograms (2,200 lb) 293 kilograms (650 lb) 191 kilograms (420 lb)
Bay 10P	ROEU 755 umbilical	90 kilograms (200 lb)
Bays 9-13	Rassvet Mini-Research Module 1 -Nauka Airlock -Nauka Radiator -ERA Elbow Joint -ERA Work Platform	6,295 kilograms (13,880 lb) 900 kilograms (2,000 lb) 570 kilograms (1,300 lb) 150 kilograms (330 lb) 100 kilograms (220 lb)
Starboard Sill	Orbiter Boom Sensor System	382 kilograms (840 lb)
Port Sill	Canadarm	410 kilograms (900 lb)
	Total:	14,592 kilograms (32,170 lb)

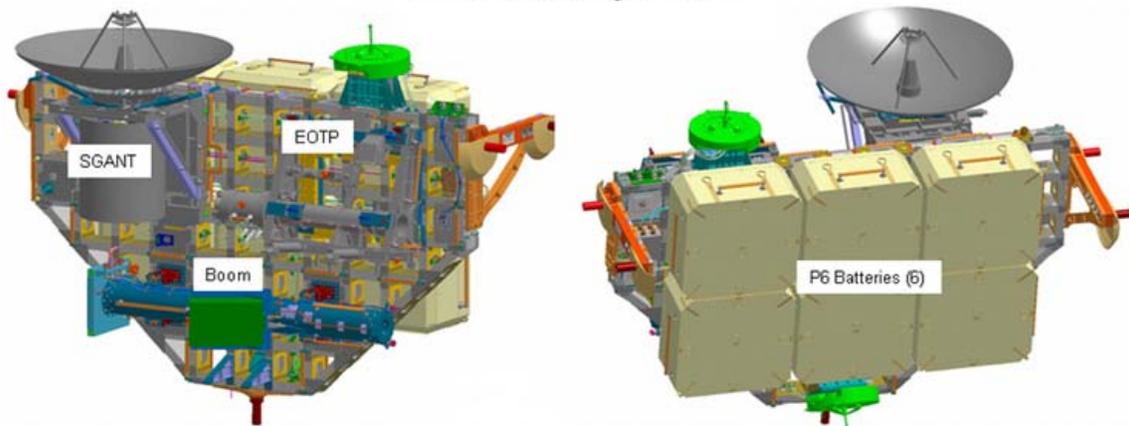
Mini-Research Module 1 (MRM 1)

STS-132 carried the Russian Rassvet Mini-Research Module 1 to the International Space Station. *Rassvet* means "dawn" in Russian. The module was built by Russian aerospace company Energia. Rassvet arrived at the Kennedy Space Center (KSC) aboard an Antonov 124 cargo plane on 17 December 2009 at about 13:00 EST. After it was unloaded from the Antonov, the module was transported to an Astrotech processing bay in Cape Canaveral to undergo preparations for launch.

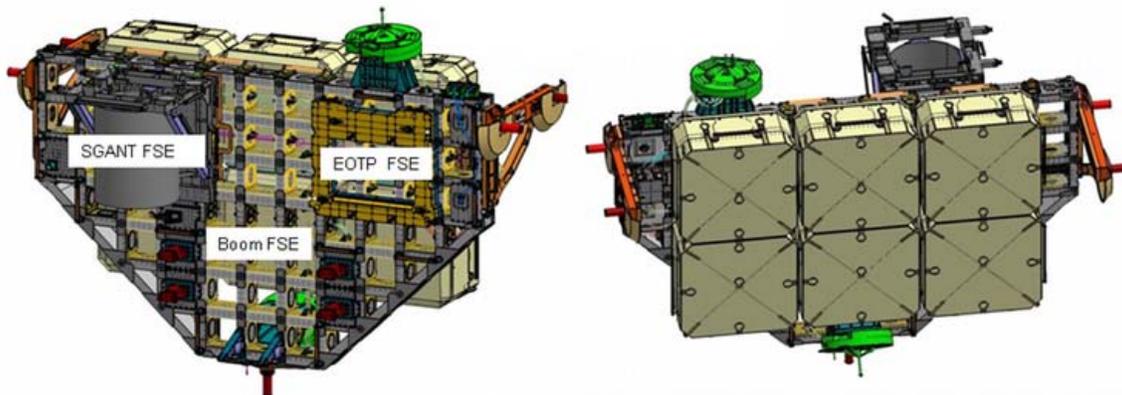
An airlock and radiation heat exchanger to be used for outfitting the Russian *Nauka* Module (to be launched in 2012), a spare elbow part of the European Robotic Arm (ERA) and a portable work platform for science hardware for performing experiments in outer space were externally mounted on Rassvet in its launch configuration. Russian and US cargo to be delivered will also be accommodated inside the module. The volume for cargo and science inside MRM1 is 5 cubic meters. Rassvet was outfitted with ISS standard grapple fixtures that allowed the module to be unloaded from the payload bay of *Atlantis* using the station's robotic arm.

Integrated Cargo Carrier-Vertical Light Deployable (ICC-VLD)

Launch configuration



Return configuration



ICC-VLD launch and return configurations

Also on board *Atlantis* will be the Integrated Cargo Carrier-Vertical Light Deployable (ICC-VLD) pallet holding a Ku-band Space to Ground Antenna (SGANT), SGANT boom assembly, Enhanced Orbital replacement Unit (ORU) Temporary Platform (EOTP) for the Canadian Dextre robotic arm extension, Video and Power Grapple fixtures (PVGf) and six new battery ORUs. The six new batteries will replace older ones on the P6 truss of the ISS. The old batteries will be placed on the ICC-VLD pallet for return to Earth. The EOTP was built by MacDonalD, Dettwiler and Associates Ltd. (MDA) of Brampton, Ontario, Canada, for NASA.

The ICC pallet is constructed of aluminum. It is approximately 8 feet (2.4 m) long, 13 feet (4.0 m) wide and 10 inches thick. The empty weight of the pallet is 2,645 pounds. The total weight of ICC-VLD and the ORUs is approximately 8,330 pounds. ICC-VLD return mass is 2,933 kilograms (6,470 lb).

The ICC-VLD will be berthed in the center of the payload bay for both launch and reentry.

Other items

In addition to the standard Official Flight Kit (OFK) flown inside a locker on the mid-deck, two Light Weight Tool Stowage Assemblies were modified to fly memorabilia and then were stowed to the left and right of Atlantis' airlock in the shuttle's payload bay.

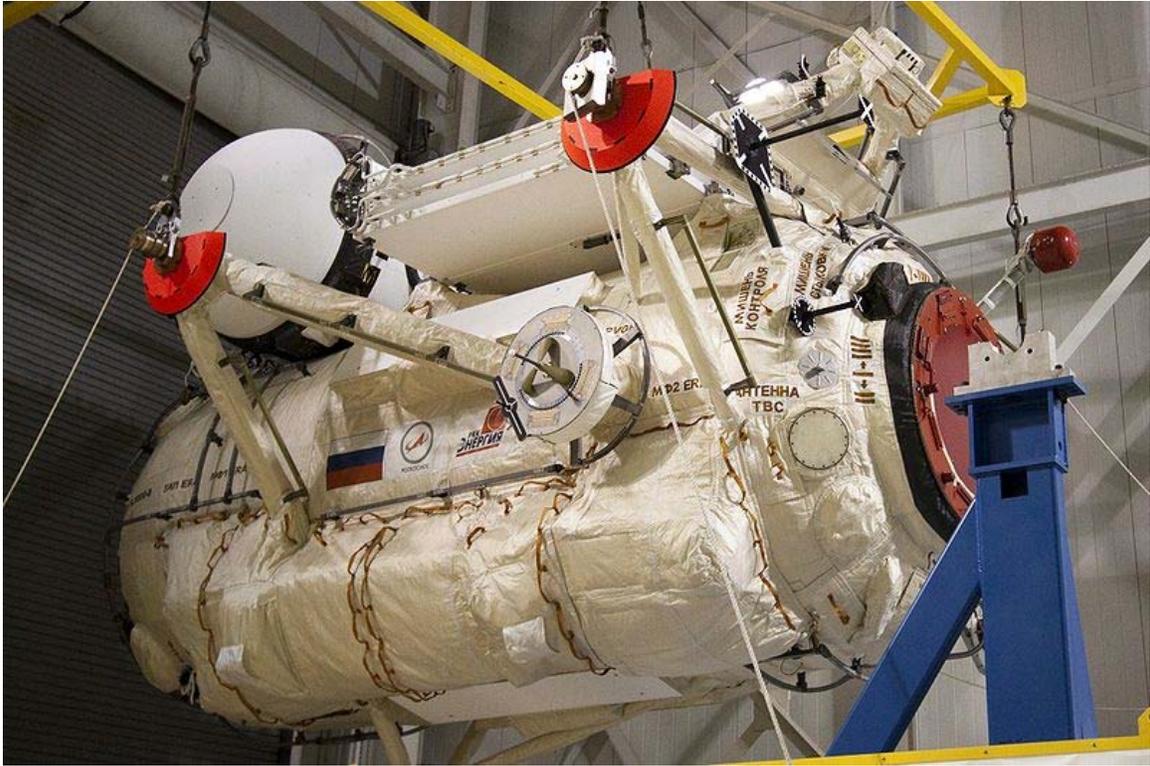
A compact disk (CD) containing the digital copies of all entries submitted to NASA's Space Shuttle Program Commemorative Patch Contest will be flown aboard *Atlantis*. The contest was organized the Space Shuttle Program to mark the end of the shuttle era. The winning patch was designed by Mr. Blake Dumesnil of Hamilton Sundstrand, Johnson Space Center. A panel of NASA judges who included shuttle program manager John Shannon, Leroy Cain and three other shuttle program managers including former astronaut John Casper, selected the winning patch from a pool of 85 entries by NASA employees and contractors.

Seventeen handcrafted beads made by nine different artists across North America will be on board Atlantis' STS-132 mission. NASA teamed up with Beads of Courage, Inc. an approved public charity to bring hope and inspiration to children coping with serious illnesses through the Beads in Space project. The Beads in Space project is the idea of Jamie Newton, an employee at the Marshall Space Flight Center in Huntsville, Alabama. The 17 beads weigh eight ounces and were selected after a contest organized by Beads of Courage that attracted 54 beads.

On board *Atlantis* will be a 4-inch long wood sample of Sir Isaac Newton's apple tree. The piece from the original tree that supposedly inspired Newton's theory of gravity, along with a picture of Newton, will be taken into orbit by astronaut Piers Sellers. The wood is part of the collection of the Royal Society archives in London, and will be returned there following the flight.

A flag from Clarkson University, Potsdam, New York, will fly on board shuttle *Atlantis*. It will be there in honor of STS-132 lead shuttle flight director, Michael L. Sarafin, who is an alumnus of the Clarkson University.

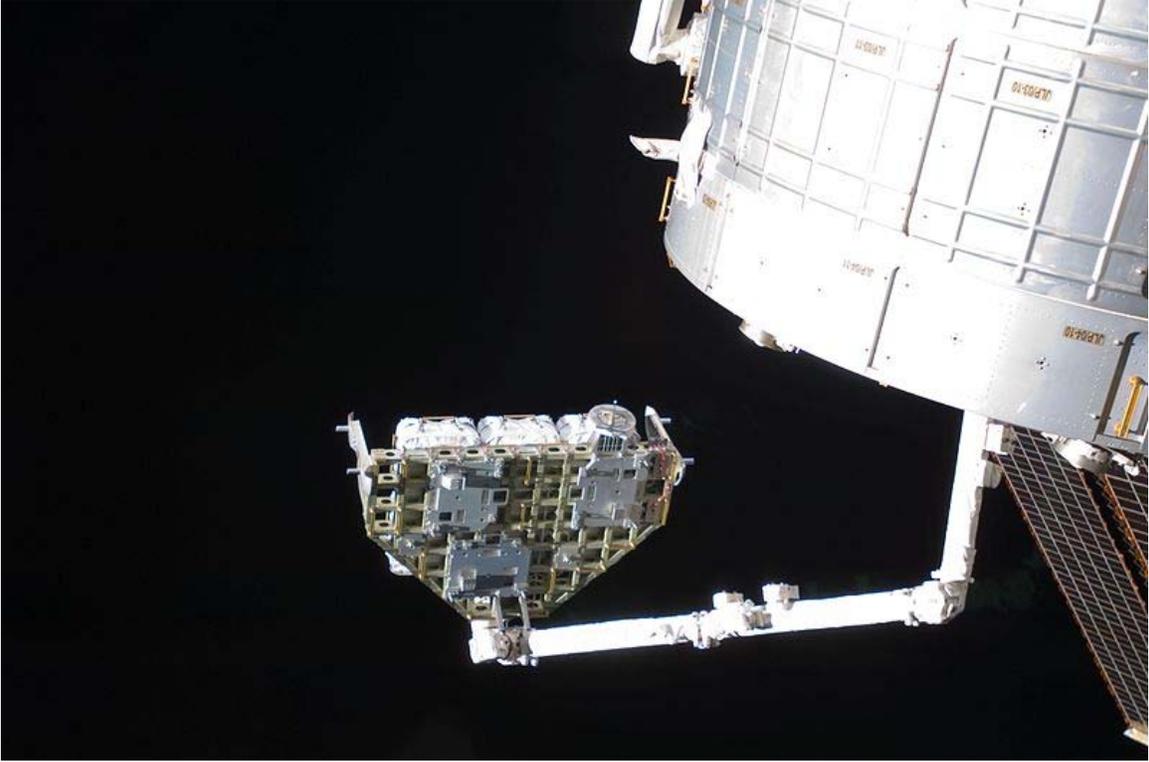
A comprehensive list of STS-132 items that will be carried aboard Atlantis and their descriptions can be found in the Official Flight Kit.



MRM 1 in the Space Station Processing Facility (SSPF) at Kennedy Space Center.



MRM 1 in the Astrotech payload processing facility.



ICC-VLD was first carried on STS-127 in July 2009.



Winner of the Space Shuttle Program Commemorative Patch Contest

Mission background



Atlantis heads into space while a pair of F-15E Strike Eagle jets patrolled the skies over Kennedy Space Center.

The mission marked:

- 163rd American manned space flight
- 132nd shuttle mission since STS-1
- 32nd flight of *Atlantis*
- 34th shuttle mission to the ISS
- 11th flight of *Atlantis* to the ISS

- 3rd shuttle flight in 2010
- 107th post-*Challenger* mission
- 19th post-*Columbia* mission

NASA arranged a Tweetup to cover the launch of the STS-132 mission. 150 people attended the event from more than 30 US states, the District of Columbia, Puerto Rico, Belgium, the Netherlands, New Zealand and the United Kingdom. The Tweetup participants met with shuttle technicians, managers, engineers and astronauts, took a tour of the Kennedy Space Center and viewed the launch of *Atlantis*.

Mission experiments

Atlantis crew worked with several short-term experiments during their mission. The shuttle transported new long-term experiments to the ISS. At the end of the mission, *Atlantis* returned some of the completed experiments from the ISS.

Short-term experiments include:

- *Micro-2*: Researchers from Rensselaer Polytechnic Institute sent microorganisms to investigate new ways of preventing the formation and spread of clusters of bacteria (biofilms), that could pose a threat to the health of astronauts. After the shuttle landed, the resulting biofilms were examined to see how their growth and development were impacted by microgravity.
- *Hypersole*: Hypersole is a Canadian research project that plans to investigate sudden changes in skin sensitivity experienced by some astronauts in space. The researchers hope to understand more about how the skin sensitivity of the soles of the feet affect the human balance. Three STS-132 crew members participated in identical trials before the launch and immediately upon landing. The trials will also be repeated on five astronauts scheduled to fly on STS-133 and STS-134 missions. Project findings are expected to add significant knowledge to existing studies of aging and to be beneficial for the elderly and people who suffer from balance problems.
- *Shuttle Ionospheric Modification with Pulsed Localized Exhaust Experiments (SIMPLEX)* - STS-132 crew performed the SIMPLEX burn on Flight Day 12. The experiment investigates plasma turbulence driven by shuttle exhaust in the ionosphere using ground-based radars. The processes by which chemical releases can produce plasma turbulence are quantified with the SIMPLEX measurements. Plasma turbulence can affect military navigation and communications using radio systems. They can also be used to promote communications by opening radio channels at abnormally high frequencies.

Shuttle processing



ET 136 arrives at the Vehicle Assembly Building.



Atlantis leaves behind OPF-1 on its move to the Vehicle Assembly Building.



Space Shuttle *Atlantis* at Launch Pad 39A

The external tank (ET 136) built to help launch *Atlantis* began its 900-mile (1,400 km), six-day journey across the Gulf of Mexico from NASA's Michoud Assembly Facility in New Orleans, Louisiana, on 24 February 2010. ET 136 measures 154 feet (47 m) long and 28 feet (8.5 m) in diameter. The solid rocket booster retrieval ship *Liberty Star*, towed the ET in the enclosed barge *Pegasus*. After docking in the turn basin at the Kennedy Space Center, the tank was offloaded and driven to the Vehicle Assembly Building (VAB) on 1 March 2010.

On 29 March 2010, workers attached ET 136 to its solid rocket boosters. A crane lifted the ET into high bay No. 1 inside the VAB. The day-long process was completed around 18:00 EDT as the tank was bolted to the *Atlantis*'s twin solid rocket boosters.

Atlantis rolled out of its processing bay (OPF-1) around 07:00 EDT on 13 April 2010. The shuttle entered the VAB around 11:00 EDT for attachment to its external tank and solid rocket boosters. Given that this is potentially *Atlantis*' final rollover for a mission, the shuttle stopped for several hours en route to the VAB allowing engineers and technicians to pose for photographs with the orbiter. The rollover occurred exactly 25 years after *Atlantis* first arrived at the Kennedy Space Center after a cross-country trip from the shuttle factory in Palmdale, California. The path to rollover was without any incidents of major concern, with only 22 Interim Problem Reports (IPRs) noted during *Atlantis*' flow since returning from the STS-129 mission in November 2009.

The transport canister containing the STS-132 payload arrived at Pad 39A on 15 April 2010 ahead of *Atlantis'* rollover to the launch pad. The canister is shaped like the shuttle's 60-foot (18 m)-long payload bay. Packed inside it was MRM1 and the cargo-carrying pallet ICC-VLD.

Space shuttle *Atlantis* began its trip, known as the rollout, to launch pad 39A at 23:31 EDT on 21 April 2010. The complete shuttle stack and mobile launch platform were secured to the launch pad 39A structure at 6:03 EDT on 22 April 2010. The 3.4 mi (5.5 kilometres (3.4 mi)) trek took 6 hours and 32 minutes to complete. The rollout was originally planned for 19 April 2010 evening, but wet weather and thunder storms on the Space Coast caused several delays.

STS-132's payload was installed in the shuttle's cargo bay on 25 April 2010.

Pad engineers preparing *Atlantis* had noticed paint peeling from shuttle's main payload, the MRM-1 module. Although the problem was declared to have no impact on the operation of MRM-1, it holds a potential threat of releasing debris on orbit. Engineers also noted MRM-1 cycled its Fire and Smoke detector self test several times. Similar events occurred during *Atlantis'* STS-129 mission in November 2009 when Shuttle and Station crew were awakened consecutive nights by false depressurization and fire alarms that originated from the MRM-2 (Poisk) module.

The agency wide Flight Readiness Review (FRR) was held at KSC in Florida on 5 May 2010 to discuss *Atlantis'* launch preparations. At the end of the review, top NASA managers made the decision to officially set the launch for 14 May 2010 at 14:20 EDT. NASA held a post news conference to brief about the results of the FRR. The briefing was broadcasted on NASA TV and was attended by NASA's Associate Administrator for Space Operations, William Gerstenmaier, Space Shuttle Program Manager John Shannon and Space Shuttle Launch Director, Michael Leinbach. Mr. Shannon mentioned that (1) ceramic inserts around *Atlantis'* windows and forward rocket pod were tested after an insert loosened during *Discovery's* re-entry on STS-131, posing a potential impact threat. The inserts had been re-installed on to *Atlantis* using a thicker braided cord to reduce the chances of a backing out. (2) Engineers had reviewed work to confirm that all systems on *Atlantis'* Ku-band antenna were in place. The testing had been provoked after the failure of that communication system during STS-131. Mr. Leinbach also acknowledged the skills and experience of the engineering teams and thanked the engineers who had successfully resolved hypergolic loading issues. Hypergolics are chemicals that ignite when they come in contact with each other. The propellants are used in the reaction control system that steers the shuttle in space.

A booster rocket segment that first flew 25 years ago on *Atlantis'* maiden flight STS-51-J will also help to fly STS-132. The aft dome on the left solid rocket booster will lift off to support *Atlantis'* STS-132 mission first launched STS-51-J on 3 October 1985. Including STS-132, 18 of *Atlantis'* 32 flights are represented by the boosters' segments.

Launch preparations



Technicians prepare to close Atlantis' payload bay doors for launch.

Atlantis' astronauts traveled from Johnson Space Center, Houston to the KSC launch site on 10 May 2010 to prepare for the launch. The crew arriving in four T-38 jets landed on the Shuttle Landing Facility around 18:49 EDT.

The official countdown to liftoff started on 11 May 2010 after the countdown clocks at KSC were activated at 16:00 EDT, ticking backward from the T-43 hour mark.

Program managers completed the L-2 Mission Management Team (MMT) meeting on 12 May 2010. At the end of the 18 minute long meeting management team officially cleared

Atlantis for launch. NASA held a pre-launch news conference to reveal the outcomes of the MMT and to brief the press on the upcoming launch. The news conference was attended by Chair, pre-launch mission management team, Mike Moses, Mike Leinbach and STS-132 weather officer, Todd McNamara. The weather officer spoke of a favorable launch weather forecast due to a high pressure weather pattern and despite a low cloud ceiling, calling a 70 percent chance of favorable conditions at launch time. He further elaborated on the predicted weather conditions at the Transoceanic Abort Landing (TAL) sites: Zaragoza and Moron in Spain, and Istres, France, in case of an emergency.

The Space Shuttle Program MMT met at 04:15 EDT on 14 May 2010 and gave a go to begin loading shuttle *Atlantis*' ET with liquid oxygen and liquid hydrogen. The fuel tanking operation began on time at 04:55 EDT and was completed within three hours at 07:56 EDT with replenishment fuel being added throughout the countdown.

Crew preparations for the launch day began at 05:00 EDT following an eight hour overnight sleep. An hour later they completed their final medical check ups. Crew suiting began around 10:00 EDT and the astronauts departed for the launch pad at 10:30 EDT. At around 11:00 EDT, first Commander Ham ingressed the shuttle first and strapped into his seat followed by pilot Antonelli, mission specialists Bowen, Sellers, Reisman and Good in order. Inside the orbiter, all six astronauts performed checks with ground controllers to verify that communications links work properly. With all astronauts onboard, *Atlantis*' hatch was closed and latched for the flight. Inside the White Room, the closeout crew finished their job by pressurizing the crew cabin and checking for leaks before leaving the pad.

Launch day countdown procedures went without any major problems however *Atlantis* encountered two minor issues. The Final Inspection Team looking for ice & frost buildup on the ET had spotted a small stress fracture on an umbilical strut. Later during the post-launch news conference, chair of NASA's pre-launch mission management team, Mike Moses said that it was not unusual. Engineers also resolved any concerns about a ball bearing found near the shuttle's payload bay days earlier. The bearing was determined to likely be from a camera system, and was ultimately ruled out as a concern.

Mission timeline

May 14 (Flight Day 1 – Launch)



The Space Shuttle external tank falls away (1 min 16 secs)





Space Shuttle *Atlantis* launches from Kennedy Space Center, 14 May 2010.

Launch of the Space Shuttle *Atlantis* occurred on time at 18:20 UTC with launch commentator George Diller's words upon launch being "liftoff of space shuttle *Atlantis*, reaching the crest of its historic achievements in space". Powered flight conformed to the standard timeline, with main engine cutoff (MECO) occurring at eight minutes and 32 seconds Mission Elapsed Time (MET). The ET-136 separated from the shuttle another 15 seconds later at 8:47 MET. A further boost from the Orbital Maneuvering System (OMS) engines was not required due to the nominal MECO and *Atlantis* settled into its planned preliminary orbit. A subsequent NC-1 engine firing of about 26 seconds adjusted the orbital path of the shuttle to the International Space Station (ISS), by altering the shuttle's velocity by about 41 ft/s (12 m/s).

NASA held a post launch news conference with Bill Gerstenmaier, Alexey Krasnov, chief of Piloted Programs Directorate, Russian Federal Space Agency, Mike Moses and Mike Leinbach. During the conference Gerstenmaier made mention of a piece of space junk that may add a bit more complexity to *Atlantis*' planned arrival at the ISS.

More than 39,000 guests that included Television host David Letterman, astronaut Buzz Aldrin, and former NASA administrator Mike Griffin witnessed the launch. Russian deputy prime minister, Sergei Ivanov and the head of the Russian Space Federal Agency Anatoly Perminov were also present at KSC.

Once in orbit the crew opened the payload bay doors, activated the radiators and deployed the Ku band antenna successfully. They also completed checkout of orbiter's

Shuttle Remote Manipulator System (SRMS). The crew was also successful in down-linking all imagery from Atlantis' umbilical well cameras and crew video of the ET for review by imagery experts in the ground. Preliminary inspections showed that ET 136 was very clean and had performed well during the ascent with only a few foam liberation incidents visible.

May 15 (Flight Day 2 – TPS survey)



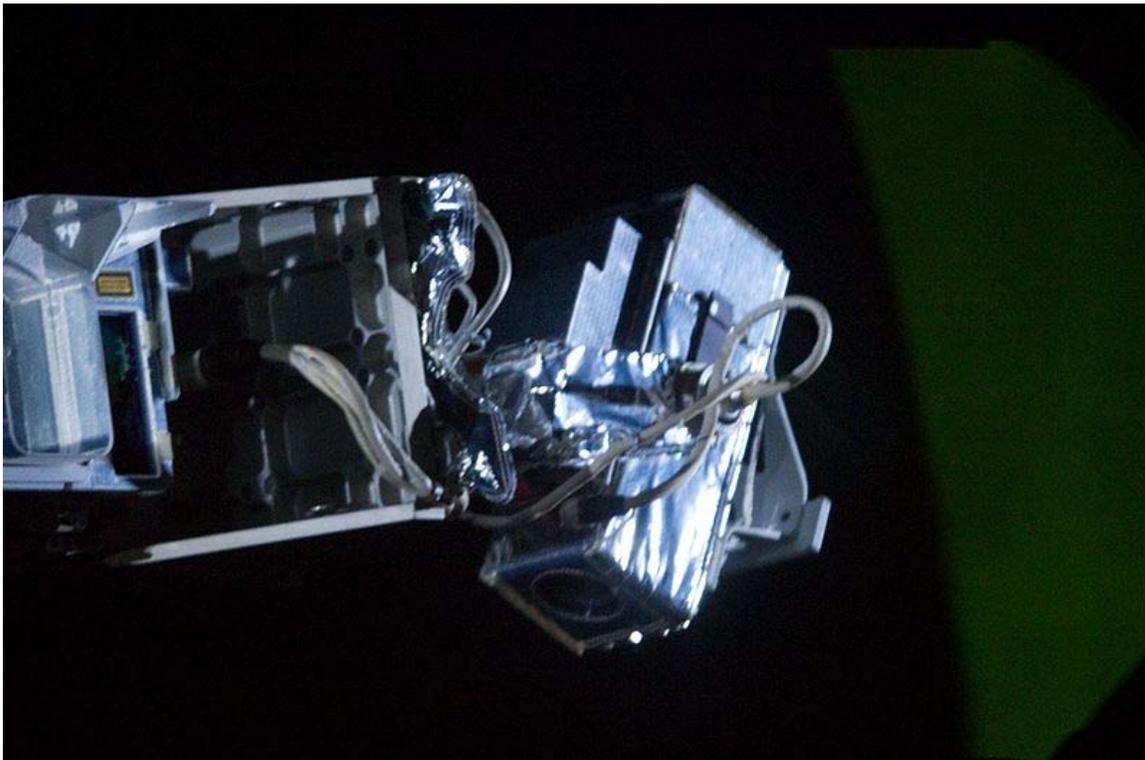
Atlantis' cargo bay and its vertical stabilizer.

The crew members aboard *Atlantis* began their first full day in space at 08:20 UTC. The day was primarily devoted to inspecting *Atlantis*'s thermal protection system using the shuttle's robotic arm and the Orbiter Boom Sensor System (OBSS) to look for any signs of launch damage. Before the thermal protection checkout began, the crew encountered a problem with the Laser Dynamic Range Imager (LDRI) and the Intensified TV Camera (ITVC) because of a snagged cable in that system's pan and tilt unit. As a result, mission control decided to switch to the less-capable backup sensor system: sensor package 2, a laser camera and a digital camera mounted near the end of the OBSS. Sensor package 2 requires an additional light source such as daylight, has a resolution of a few millimeters and can scan at about 2.5 inches per second. The crew followed "late inspection" procedures for surveying and images of the right wing, the nose cap and much of the left wing were sent to the ground for detailed analysis.

Commander Kenneth Ham installed the centerline camera in the Orbiter Docking System (ODS) to help him during Atlantis' approach to the ISS. Down on the shuttle's middeck, Good and Bowen spent several hours checking out spacesuits and preparing them for transfer to the station. Reisman spent much of his day working with Antonelli and Ham on the TPS survey. He also managed to spend some time helping with the suit and spacewalk equipment checkouts. The crew also performed the ODS ring extension that will connect the shuttle's docking port to the station's Harmony module. The last portion of the crew day was spent preparing and checking out all of the tools used during rendezvous.

Two course correction burns were also performed on Flight Day 2. The first 10 second NC-2 burn was performed using the right-hand OMS engine, changing the shuttle's speed by 8 ft/s (2.4 m/s). The burn raised both the apogee and perigee of shuttle's orbit by 1-mile (1.6 km). Atlantis' reaction control jets were again fired for a second time to execute the eight second NC-3 burn which changed the shuttle's velocity by about 2 ft/s (0.61 m/s).

Mission Control managers determined that the ISS will not need an avoidance maneuver to avoid a piece of orbital debris. Updated tracking information showed that the ISS and debris won't pass close enough the next day to require any action.



Snagged cable in the sensor package pan and tilt unit.



Garrett "Big G" Reisman in the middeck of *Atlantis*.



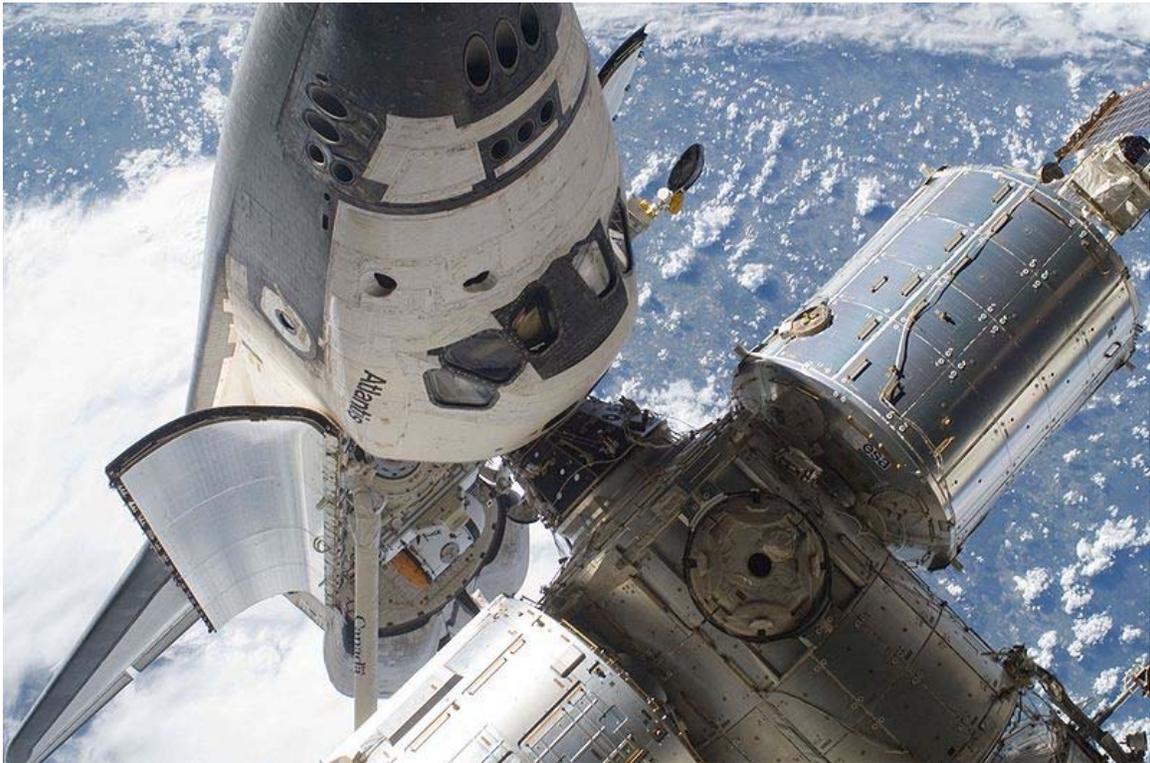
Blue and White part of Earth as photographed by a crew member.



S132E007675

Tony Antonelli.

May 16 (Flight Day 3 – Docking)



Atlantis docked to the ISS.

The STS-132 crew began their day at 07:20 UTC and prepared to dock with the ISS. Commander Ken Ham performed a series of rendezvous burns (NH, NC4 and TI) to boost the orbit of *Atlantis* to match with that of the ISS. The major one minute 24 seconds long orbit raising maneuver, NH burn changed *Atlantis*' velocity by 132 feet per second and placed the shuttle into a new 212 by 145 miles (233 km) orbit. A 63 second circularization burn, known as NC4, next boosted *Atlantis* into a 214 by 210-mile (340 km) orbit. At 11:40 UTC with about 9 miles (14 km) separating the shuttle and the ISS, commander Ken Ham performed the final 12-second terminal initiation (TI) burn firing the left OMS engine of *Atlantis*.

By 13:26 UTC with Ken Ham at the controls Ham was flying the shuttle from the aft flight deck, *Atlantis* positioned beneath the ISS and began the 360-degree flip rendezvous pitch maneuver (RPM). As the shuttle's underside rotated into view, three ISS crew members, Oleg Kotov using a camera with 400mm lens, Timothy Creamer and Soichi Noguchi having two 800mm lens cameras took 398 photographs of *Atlantis*' belly as part of post-launch inspections of the thermal protection system.

Atlantis docked with the ISS Pressurized Mating Adapter-2 at 14:28 UTC as the two orbited 220 miles (350 km) over the South Pacific Ocean. After docking, the ISS was reoriented by the small vernier thrusters on *Atlantis* to minimize the risk of Micro-

Meteoroid Orbital Debris (MMOD) impacts upon the Shuttle. A series of leak checks were done on both sides of the hatch by the shuttle and station crews were done before the hatches were opened at 16:18 UTC. After a brief welcoming ceremony by the station crew, Atlantis' astronauts got the standard station safety briefing. Then the crew got to work with initial transfers of equipment and supplies. Spacesuits were among the first items to go to the ISS. Station crew member Noguchi also transferred high-priority JAXA experiments to the Kibo Module.

Sellers and Expedition 23/24 astronaut Tracy Caldwell Dyson got to work on their joint task to relocate the ICC-VLD cargo pallet. The duo used the station's robotic arm to transfer the pallet from *Atlantis* to the station's mobile base system to prepare for the spacewalks.

In preparation for next day's spacewalk, all Atlantis' crew members gathered for an hour-long spacewalk procedure review. Mission Specialists Reisman and Bowen spent the night in the Quest airlock as part of the overnight "campout" procedure to help them get prepared for the spacewalk. The crewlock was depressurized from 14.7 to 10.2 psi. The depressurization is required to avoid formation of nitrogen bubbles in astronaut's blood in the vacuum of space.



Flying above the Atlantic coast of Spain and the Gulf of Cadiz *Atlantis* approaches the ISS for docking.



Underside of *Atlantis* is revealed during the RPM.



Atlantis docks with the space station (4 mins 30 secs).



Flight Day 3 highlights (26 mins 1 sec).

May 17 (Flight Day 4 – EVA 1)



Reisman takes a self portrait during EVA 1.

After the wakeup call went to awaken the crew, mission control CAPCOM Shannon Lucid informed them that no detailed flight inspection would be required on the next day. However, the crew were requested to utilize that time to do inspections on various sections of *Atlantis* that were not done on Flight Day 2.

Flight day 4 saw mission specialists Garret Reisman and Steve Bowen perform the first of three planned spacewalks. The pair installed a spare Space To Ground Antenna (SGANT), a new enhanced tool platform for the Special Purpose Dexterous Manipulator (SPDM) also known as Dextre and released torque on the six new batteries for the Port 6 (P6) truss segment.

Expedition 23 Flight Engineer Creamer helped the duo with the suit-up preparations. Mike Good joined STS 132 Pilot Antonelli, the intravehicular officer, to assist during the spacewalk. Mission Specialist Sellers and station Flight Engineer Caldwell Dyson operated the robotic arm. Throughout EVA 1, Commander Ken Ham oversaw the extravehicular activities.

During the spacewalk, several problems were encountered, the first of which was during installation of the SGANT. A slight gap was observed between the antenna dish and its mounting pole. The spacewalkers were given a go to loosen the bolts and use a higher torque setting, which managed to get the gap to a smaller amount. The launch locks were

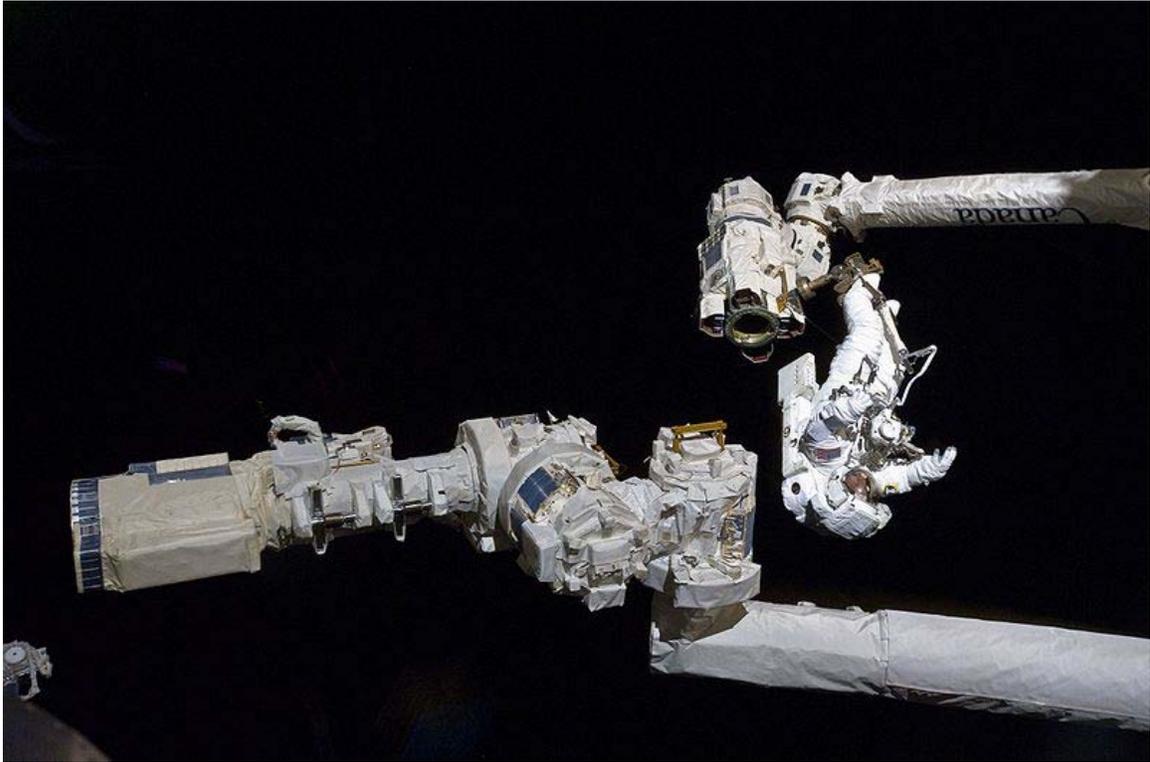
left on the SGANT to allow engineers on the ground to determine if the gap is acceptable or if more troubleshooting will be needed. The second problem occurred during the installation of the SGANT, and was related to the Command and Control (CNC) computers. During installation, when Steve Bowen removed a cover from a connector the prime CNC computer detected an error and shut down. The cap is a special cap which allows the circuit for that connector to be closed, when it was opened sensor detected the error. The shut down of the CNC, cause a brief 2 minute loss of communications. The safeing of the computer also stopped the Canadarm2 and for a reconfiguration of the cameras being used during the spacewalk by both the robotic arm operators and the ground.

The spacewalk ended at 19:19 UTC after Reisman and Bowen took inventory of the tools they brought with them outside and made their way back into the Quest airlock. EVA 1 was the 237th conducted by U.S. astronauts, the second for Reisman and the fourth for Bowen. It was also the 144th in support of International ISS assembly and maintenance. For EVA 1, lead spacewalker Reisman had a spacesuit with no stripes. Bowen' spacesuit was marked with a red stripe.

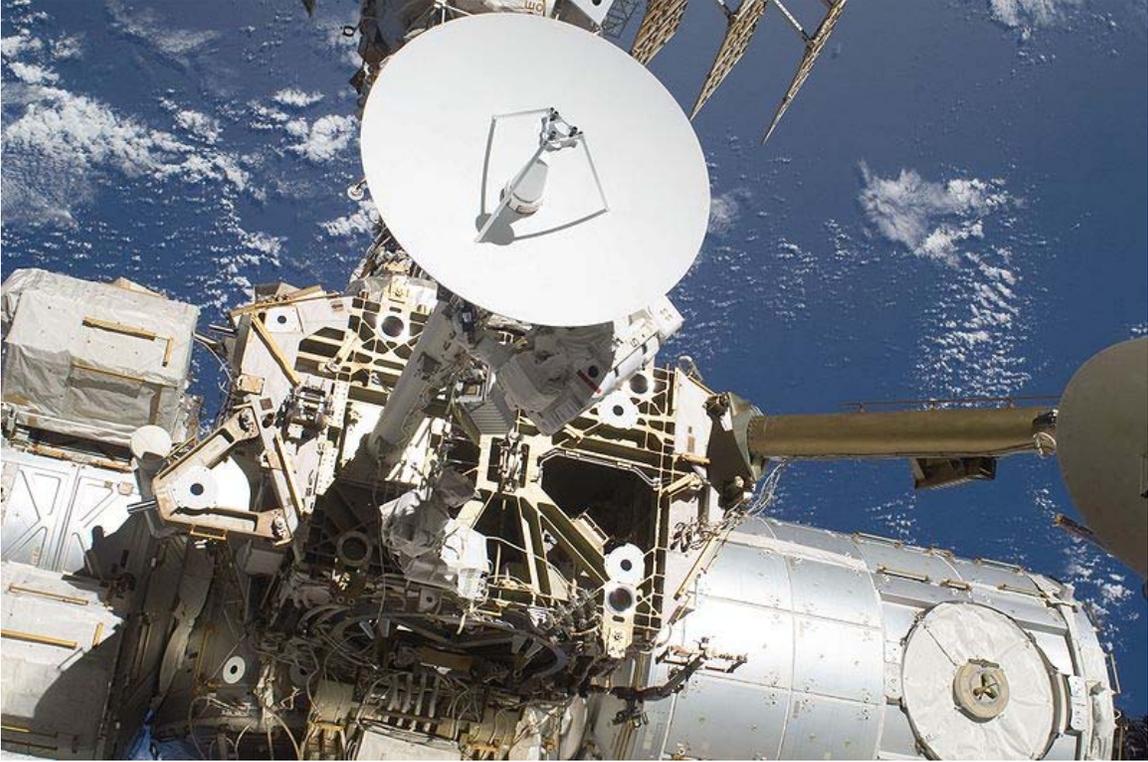
Shuttle's arm also successfully grappled the MRM-1 module in Atlantis' cargo bay in preparation of its next day berthing to the Zarya service module.



Reisman during EVA 1.



Garrett Reisman anchored to a Canadarm2 mobile foot restraint during EVA 1.



Stephen Bowen works on the installation of the Ku band antenna system.

May 18 (Flight Day 5 - MRM1 installation)



Atlantis docked with the ISS moving southeast across the skies of Tampa, FL

On Flight Day 5 crew focused on the addition of the MRM-1 module to the space station. Commander Ken Ham and pilot Tony Antonelli maneuvered *Atlantis*' robotic arm to unberth MRM-1 from the shuttle's payload bay at 09:49 UTC and handed it off to the station Canadarm2 at 10:14 UTC. Mission specialists Garrett Reisman and Piers Sellers, working from inside station's Cupola, then maneuvered the Canadarm2 arm to deliver MRM-1 to its new position, the Earth-facing port of the Zarya service module. The docking occurred at 12:20 UTC when the shuttle-station stack was flying above Argentina. Following the successful docking, Sellers reported to the mission control that during the docking, he did not see the expected "capture 1" confirmation signal popping up in his laptop to which CAPCOM Steve Swanson replied "And station, that error's expected. The reason you didn't get 'contact 1' is because Garrett did too good of a job flying. He went right down the middle and got a hole in one"

Expedition 23 Commander Oleg Kotov also monitored the activities from the Russian segment as the MRM-1 engaged into its automated docking sequence for the final attachment to the Zarya module. The berthing marked the first time that the Russian automated docking system has been used along with the station's robotic arm.

At 17:20 UTC, shuttle crew Ham, Reisman, Sellers, and station crew Kotov, Skvortsov and Caldwell Dyson gathered in space station's Harmony module to talk with reporters from MSNBC, Fox News and CNN. The two crews answered questions related to their stay in orbit, medical experiments being conducted at ISS, spacewalking experience and the Gulf of Mexico oil spill.

After mid day, Reisman and Sellers used Canadarm2 to unberth OBSS from the sill of *Atlantis*' cargo bay and handed it off to the shuttle's robotic arm, operated by Ham and Antonelli.

Mission specialists Bowen and Good prepared for next day's EVA 2. Earlier on the day, they configured the tools and prepared their spacesuits. At the end of the workday, *Atlantis*' crew along with three station crew members met for an hour-long spacewalk procedures review.

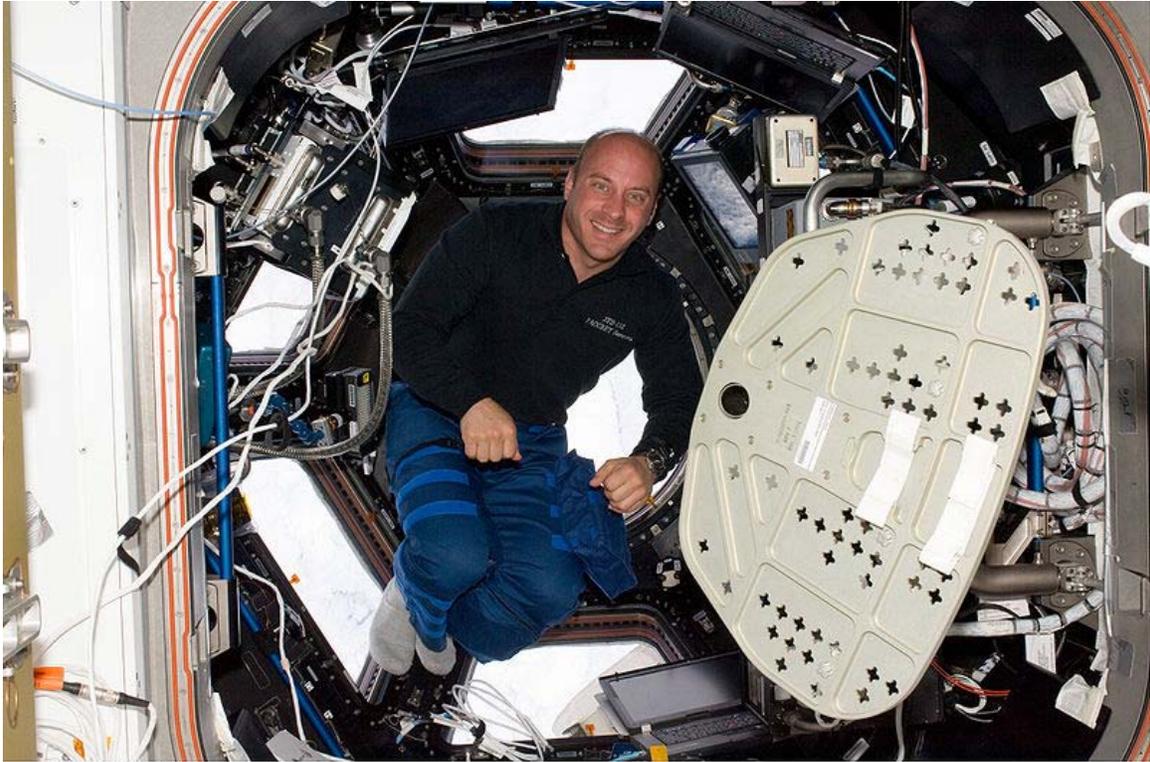
At 21:45 UTC, Good and Bowen began their "camp out" inside the Quest airlock with pressure reduced to 10.2 psi.



Canadarm2 transfers MRM-1 to the Earth-facing port of the Zarya module.



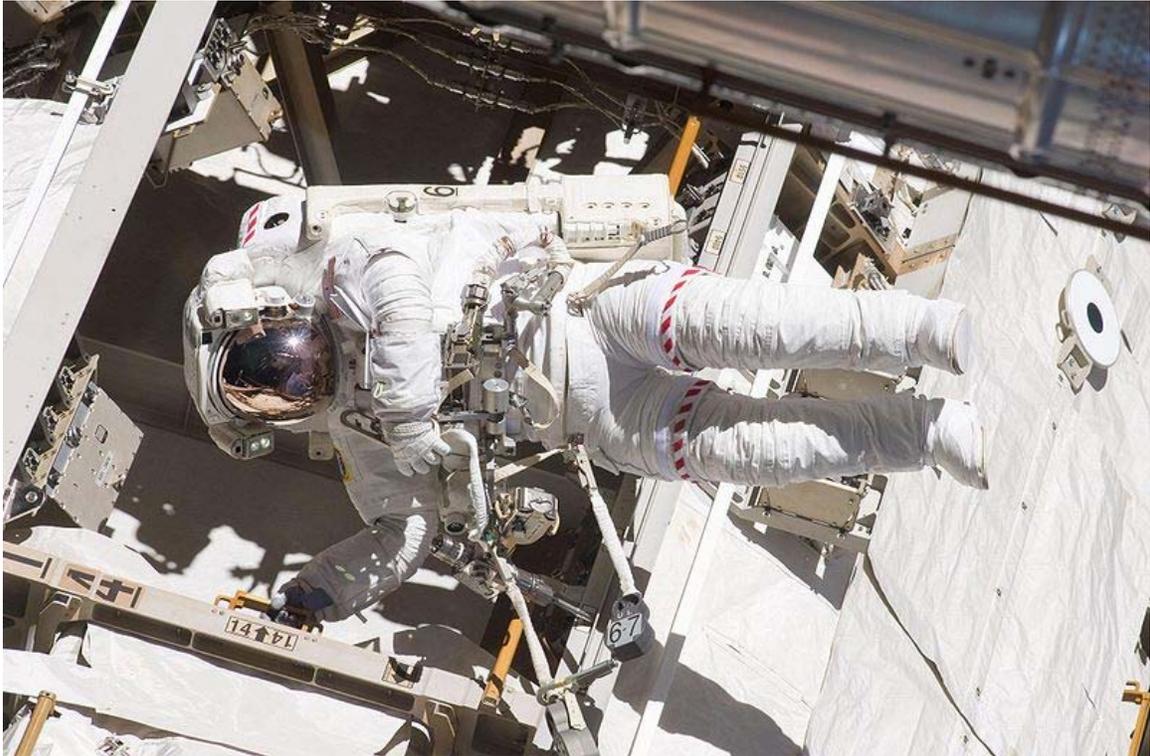
Canadarm2 attaches MRM-1 to the Zarya module.



S132E008223

Garrett Reisman inside the Cupola.

May 19 (Flight Day 6 - EVA 2)



Mike Good during EVA 2.

The primary task on the mission's second spacewalk, EVA 2 was to remove and replace batteries on the station's port 6 truss. The spacewalk, got under way at 10:38 UTC, more than 25 minutes ahead of the scheduled start that already had been moved up 30 minutes.

Lead spacewalker Bowen's first task was to remove a cable snag in the OBSS's pan and tilt mechanism. Bowen looped a tie wrap on two cables to relieve the snag and completed that task in less than 30 minutes, while Good began work with the batteries. Although the initial plan call was to replace three batteries, the two astronauts managed to replace an additional fourth battery during EVA 2. The batteries Bowen and Good replaced were launched in November 2000. After the battery work and cleanup of the area, Bowen and Good moved on to the new backup Ku band antenna on the Z1 truss. They tightened bolts holding its dish to its boom, closing a gap left there after EVA 1. Good performed a wiggle test and confirmed that two spacewalkers did not see any signs of motion in the antenna-mast interface. They then removed the antenna's launch locks, leaving the antenna ready to operate.

During EVA 2, commander Ken Ham provided photo and television support, and pilot Tony Antonelli served as the spacewalk choreographer. ISS crew member Tracy Caldwell Dyson also assisted with spacewalk preparations. EVA 2 marked the 238th conducted by U.S. astronauts, the fifth for Bowen and the third for Good. It was also the 145th in support of International Space Station assembly and maintenance.

May 20 (Flight Day 7 - MRM-1 initial checks, transfers and off duty)



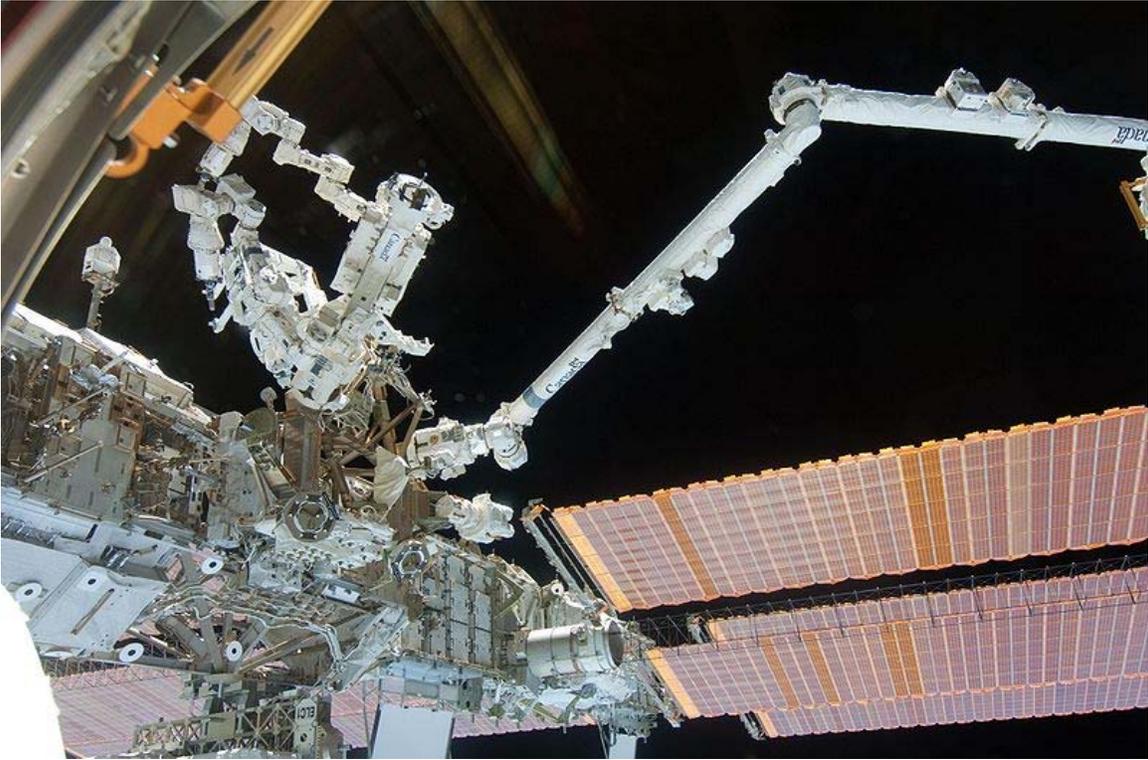
Good, Bowen and Reisman pose for a photo with an Extravehicular Mobility Unit (EMU).

On Flight Day 7 the crew spent a few hours of off duty time in the afternoon, but otherwise, they largely focused on preparations for EVA 3. Earlier on the day, at 10:52 UTC, following leak checks, ISS Expedition 23 commander Oleg Kotov and flight engineer Alexander Skvortsov opened the hatch to the MRM-1 module. They wore eye and breathing protection as a standard precaution when entering a new module. Kotov reported that some metal filings were drifting inside the new module as unpacking activities gathered pace although initially he reported the interior of MRM-1 looked clean. Flight controllers both in Houston and in Moscow were working with the crew to develop a technique for safely removing the floating debris.

At 12:25 UTC, shuttle crew members, Ken Ham, Tony Antonelli, Piers Sellers and ISS flight engineer Tracy Caldwell Dyson talked with the Associated Press, Fox News Radio, and CBS News. Ham also joined in with past and present members of Mission Control to recognize Lonnie J. Schmitt as the first flight controller to reach his 100th shuttle mission.

During the day, Ham, Antonelli and Sellers transferred equipment, supplies and experiments between *Atlantis* and the ISS. Mission specialists Mike Good and Garrett Reisman prepared for their spacewalk (EVA 3), configuring tools and preparing suits and the airlock. Ham, Antonelli and Sellers also joined them to review the procedures. As

part of the "campout" procedure, the two spacewalkers spent the night in the Quest airlock with its pressure reduced to 10.2 psi.



View of a section of ISS as photographed by a STS-132 crew member.



Garrett Reisman inside the Quest airlock.



The aft section of Atlantis while docked with the Station.

May 21 (Flight Day 8 - EVA 3)

On flight day 8, Mike Good and Garret Reisman completed the third and final spacewalk of the STS-132 mission. The pair connected a pair of ammonia jumpers on the P4/P5 truss segment before continuing on out to the end of the P6 truss. Once at the P6 truss, Good and Reisman completed the battery swap by removing and replacing the final 2 batteries and retrieving the temporarily stowed old battery on the truss. Once that task was complete, Good and Reisman moved to *Atlantis's* payload bay where they removed a grapple fixture and took it to the Quest airlock. The pair then moved on to fix some insulation on the Dextre robot and stowed some tools in an external toolbox on the Z1 truss. Pilot Tony Antonelli choreographed the spacewalk from inside the shuttle.

While the spacewalk was going on, commander Ken Ham and mission specialist Steve Bowen completed some more of the transfer work for the mission.



Good (left) and Reisman look through the aft flight deck windows of Atlantis during EVA 3.



Good during EVA 3.



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Reisman participates in EVA 3.

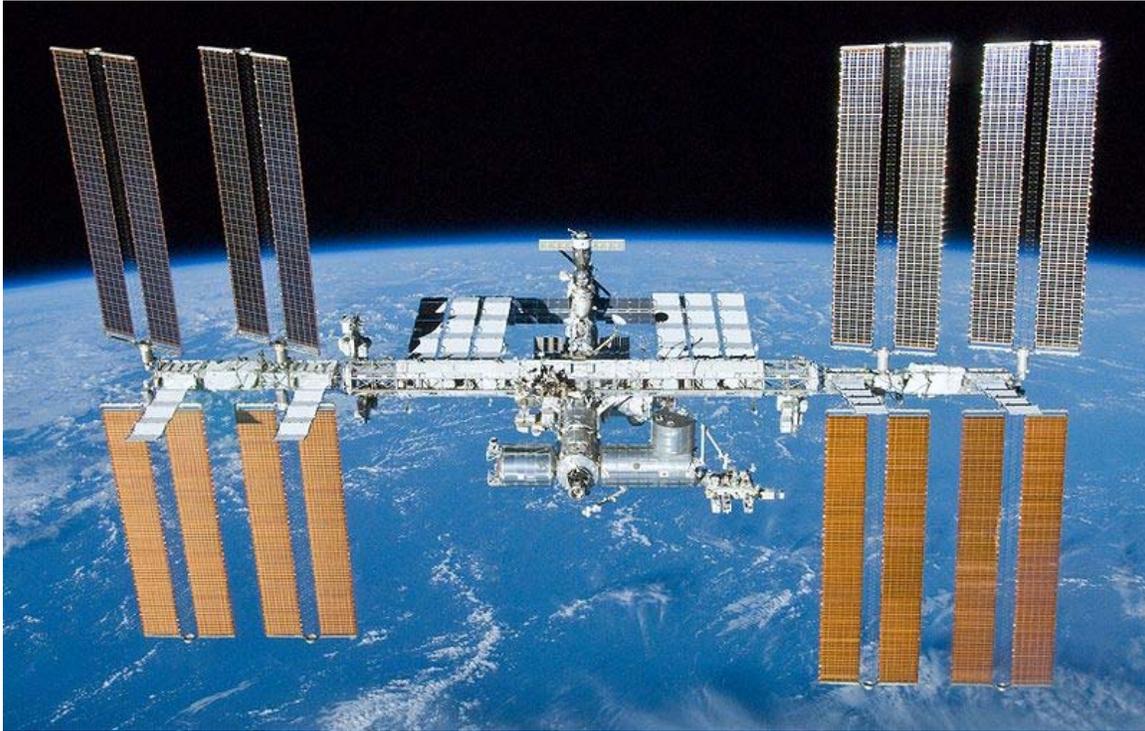
May 22 (Flight day 9 - Off duty)



STS-132 Crew and Tracy Caldwell-Dyson during the educational event.

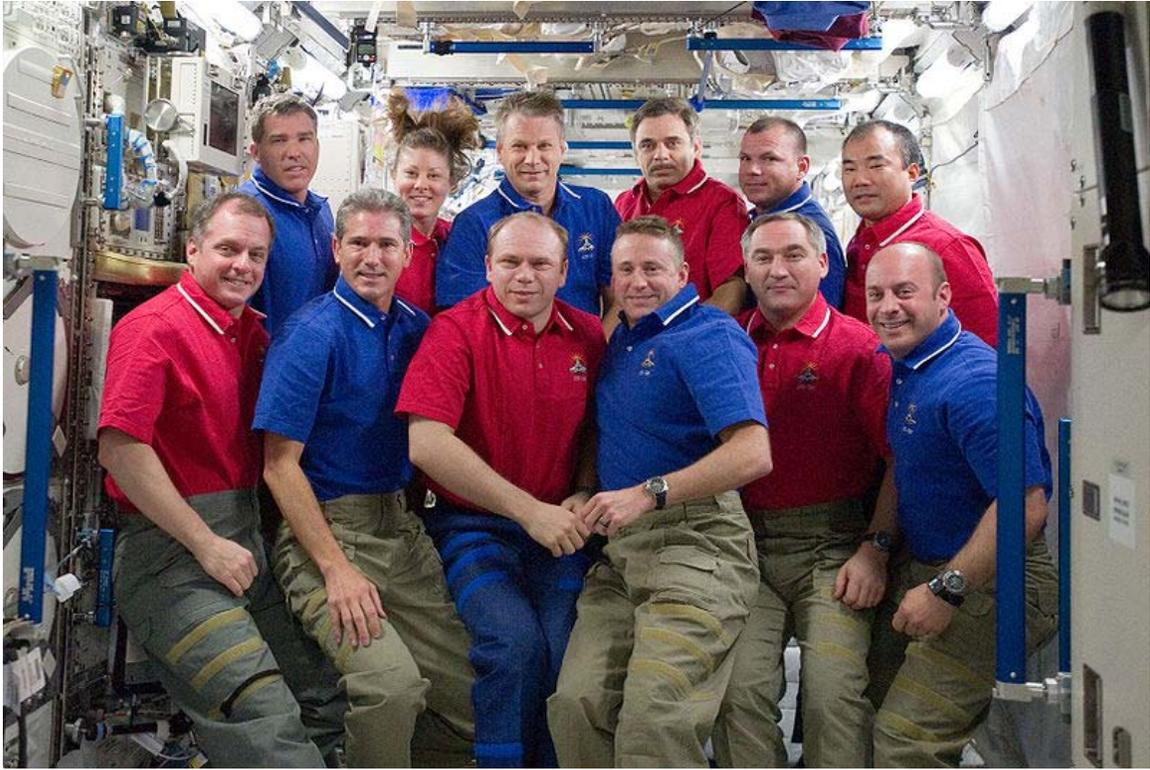
Flight day 9 saw the shuttle crew enjoying some off duty time during the crews afternoon. In the morning, the entire crew participated in some transfer activities and orbiter maintenance. The ICC-VLD was also berthed back in space shuttle *Atlantis* payload bay, having completed its tasks for this mission. The SSRMS or Canadarm2 was used to install it back in the payload bay and was operated by mission specialists Piers Sellers, Garrett Reisman and space station flight engineer Tracy Caldwell Dyson. The ICC-VLD moving operations began just after 4:30 a.m. EDT, and was completed at 5:50 a.m. EDT. The shuttle crew and Caldwell Dyson also answered some questions from elementary and middle school students around the U.S. Students from 12 NASA Explorer Schools had submitted their questions earlier by video. The combined shuttle-station crew also shared a joint meal before the shuttle crew enjoyed two and a half hours of off-duty time starting at 11:05 a.m. EDT.

May 23 (Flight day 10 - Undocking)



Newly upgraded ISS seen from the shuttle after undocking.

On flight day 10, the joint STS-132/Expedition 23 crews awoke to begin the final hours of the joint docked mission. The crews completed the final time sensitive transfers of the mission, which included scientific research samples that need to be kept cold. Once those transfers were completed, the two crews held a joint crew news conference and took a crew photo and later prior to hatch closure the crews held a farewell ceremony to say goodbye to one another. After the ceremony the hatches between the space shuttle *Atlantis* and the International Space Station (ISS) were closed and a leak check was performed to ensure all the hatches were sealed properly. The space shuttle undocked from the ISS at 15:22 UTC, a little more than 2 hours after the hatches were closed. At the time of undocking the two spacecrafts were sailing 220 miles (350 km) above the Southern Ocean southwest of Perth, Australia. The shuttle guided by pilot Tony Antonelli backed away from ISS to a distance of about 400 feet (120 m), at which time Antonelli began conducting a fly around of the space station, so that crew members on both the ISS and shuttle could get photos of both vehicles. Once the fly around was complete the shuttle crew conducted two separation burns to move away and in front of the space station.

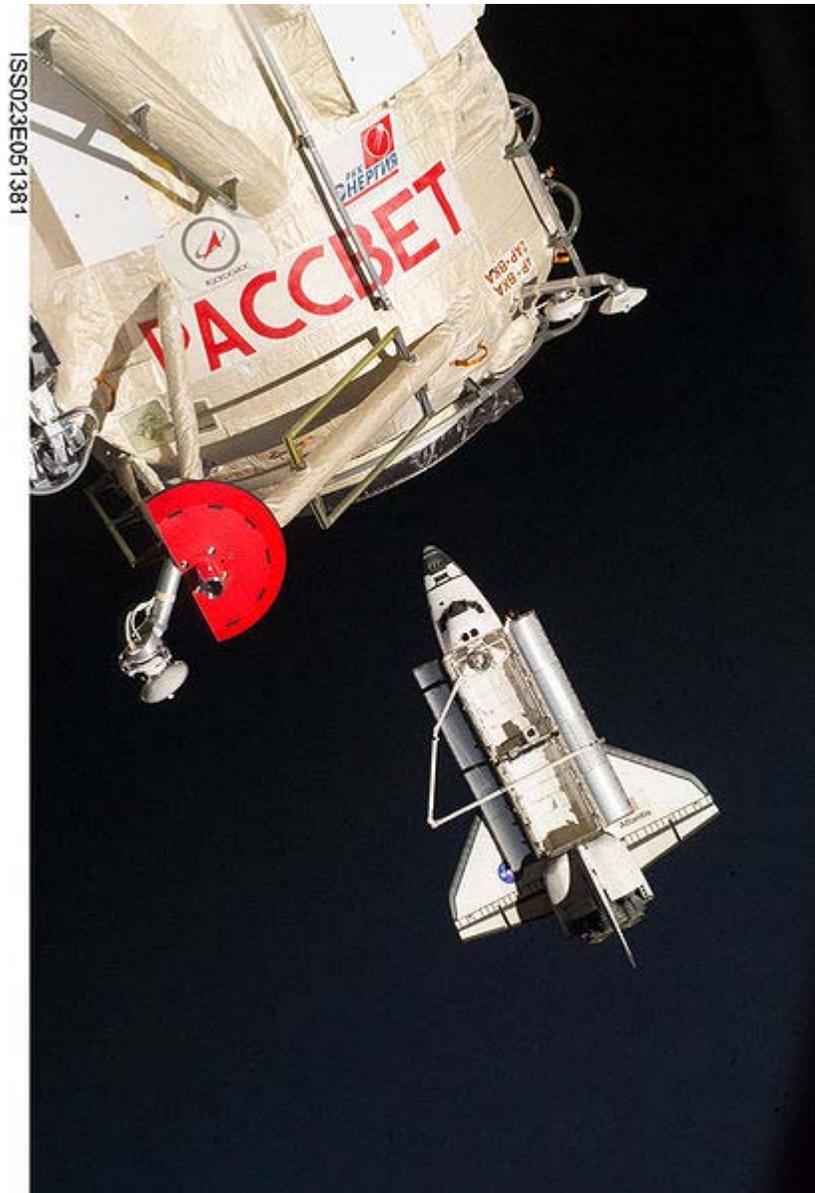


STS-132 (blue shirts) and Expedition 23 crew members pose for a group portrait on the ISS.



ISS023E051137

Ham and Kotov shake hands at the farewell ceremony.



Atlantis separates from the ISS after undocking.



ISS023E051233

Departing Atlantis as photographed by a station crew member.

May 24 (Flight day 11 - Late inspection)

The crew of space shuttle *Atlantis* awoke on flight day 11 and after a couple of hours of personal time, began the late inspection of the shuttles wing leading edges and nose cap. The crew worked through the time line and finished the scans about two and a half hours ahead of schedule. By 09:50 UTC they had finished their look at the right wing, by 10:52 UTC the nose cap survey was complete and the left wing survey was finished at 11:17 UTC. The TPS survey was done using the shuttle arm and its OBSS extension. While the scans were going on, some of the crew was stowing items that were no longer needed or were transferred right before undocking. Spacewalkers Mike Good and Steve Bowen cleaned up and stowed their spacesuits for landing. The latter part of the crews day was spent with some off duty time.

May 25 (Flight day 12 - Landing prep)

Atlantis astronauts devoted flight day 12 to get ready to return home. The crew executed standard day-before-landing activities. Commander Ham, Pilot Antonelli and Mission Specialist Good began the flight control system (FCS) hot-fire checkout at about 1:40 a.m. EDT, operating the rudder and flaps that will control Atlantis' flight through the atmosphere to the KSC runway. That complete, Ham and Antonelli fired each of the shuttle's 44 attitude control thrusters that orient Atlantis in space as it descends from orbit and through the upper atmosphere. Both those tests were completed successfully.

All STS-132 crew members worked at various times throughout the day to stow items in the cabin to prepare for landing. They also gathered for a 30-minute deorbit briefing at 5:40 a.m. EDT. Immediately afterward the crew talked with representatives of The Colbert Report, ABC Radio Network and WEWS-TV of Cleveland, Ohio.

Late in their day, mission specialists Reisman and Sellers stowed the Ku-band antenna in Atlantis' cargo bay.

May 26 (Flight day 13 - Re-entry and Landing)



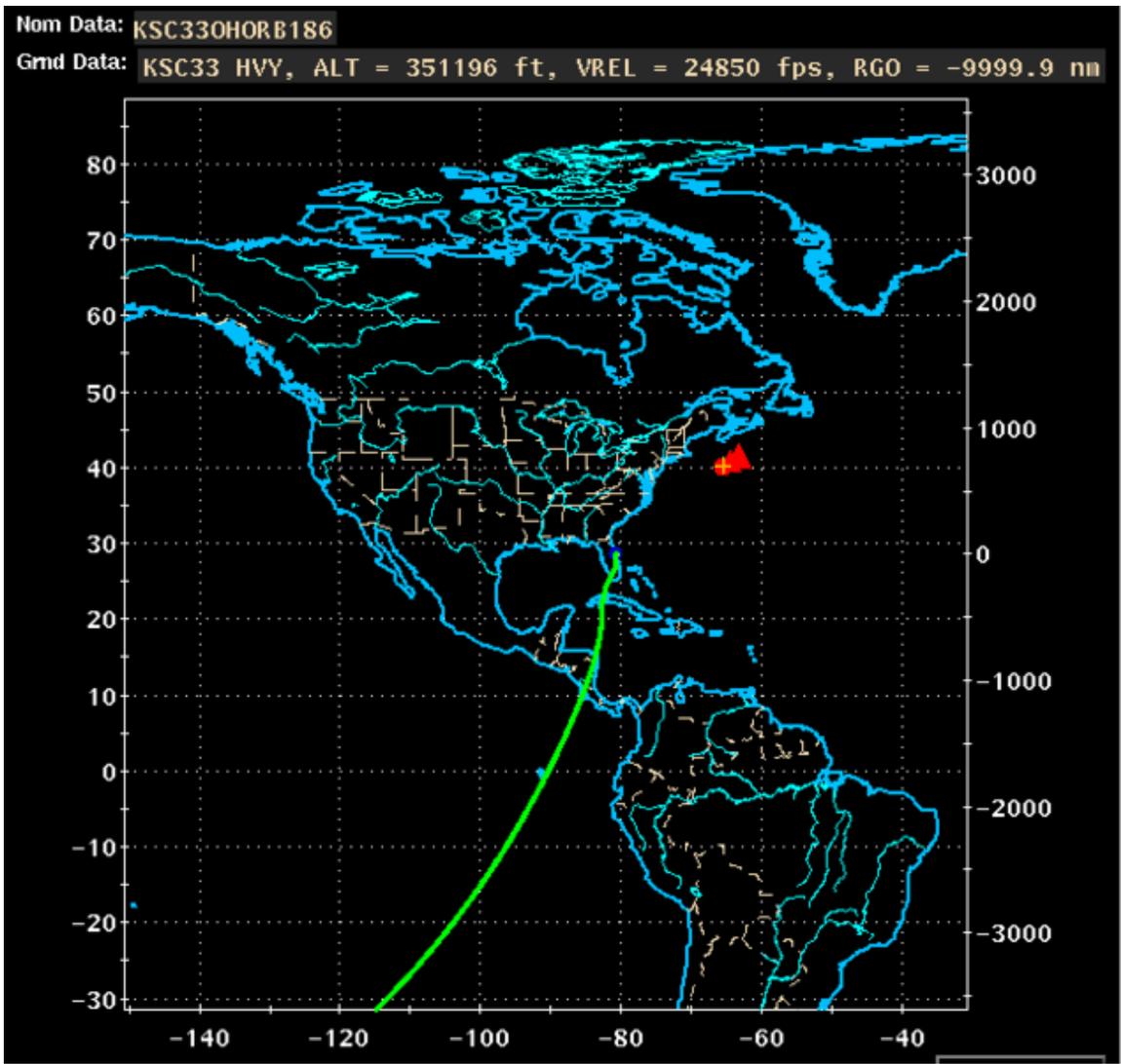
STS-132 ends as Space Shuttle *Atlantis* landed on May 26, 2010, at Kennedy Space Center's Shuttle Landing Facility.



The STS-132 crew awoke at 12:20 EDT (4:20 UTC). At about 7:40 UTC, the astronauts began deorbit preparations and closed the payload bay doors at 9:01 UTC. The deorbit burn initiated at 11:42 UTC 220 miles (350 km) above Indonesia for a landing at KSC and terminated at 11:45. At an altitude of 400,000 feet (120,000 m) and a speed of Mach 25, Atlantis began re-entry at 12:16. At about 12:23 UTC, Atlantis began its s-rolls to bleed off speed and energy during re-entry. At about 12:29, the shuttle was more than 40 miles (64 km) above Earth and 2,000 miles (3,200 km) from KSC traveling at Mach 22. At 12:34, Atlantis was about 180,000 feet (55,000 m) altitude traveling at about 9,200 mph and was 600 miles (970 km) from the runway. At about the same time, the shuttle was experiencing maximum re-entry heating conditions peaking at about 2,900 degrees Fahrenheit, lasting about two minutes. At 12:39, long-range cameras at KSC spotted the shuttle gliding towards the runway at an altitude of 16 miles (26 km) and a distance of 77 miles (124 km) from KSC. At 12:44, commander Ken Ham took manual control of the orbiter for landing as it glided through the 50,000-foot (15,000 m) mark.

Atlantis landed on runway 33, on its main wheels at 08:48:11 EDT (12:48:11 UTC) at KSC. The nose wheel touched down 10 seconds later, at 08:48:21 EDT (12:48:11 UTC), with the vehicle coming to a stop at 08:49:18 EDT (12:49:18 UTC). The entire mission lasted 11 days, 18 hours, 29 minutes, and 9 seconds, during which time the space shuttle traveled 7,724,851 kilometres (4,800,000 mi).

The six astronauts headed to Houston on May 27. A welcome ceremony for the crew was held on the same day at 5 p.m. EDT at Ellington Field's NASA Hangar 276.



Long-range ground track.



Atlantis approaches Runway 33.



Crew pause for a post-landing photo opportunity on the tarmac.



Atlantis reaches OPF-1 after landing.

Spacewalks

Three spacewalks were conducted to replace six aging batteries and to stage spare components outside the station, including a secondary Ku-band antenna and spares for the Canadian Dextre robotic arm extension.

EVA	Spacewalkers	Start (UTC)	End (UTC)	Duration
EVA 1	Garrett Reisman	17 May	17 May	7 hours 25 minutes
	Steve Bowen	11:54	19:19	
EVA 2	Steve Bowen	19 May	19 May	7 hours 9 minutes
	Michael Good	10:38	17:47	

Reisman and Bowen installed a spare space-to-ground Ku-band antenna on the station's truss, or backbone. They then installed a new tool platform on Dextre. The spacewalkers also broke the torque on bolts holding batteries in place on the truss, in preparation for their removal and replacement on the second and third spacewalks.

Bowen and Good removed and replaced four of the six batteries on the port truss to store electricity from the solar arrays on that truss. The used batteries will be installed on the cargo carrier for return to Earth on Atlantis. They also fixed a snagged cable on the Orbiter Boom Sensor System. The final task was to re-torque the bolts on the SGANT and

then remove the launch locks and tether that were helping hold it in place.

Michael Good	21 May	21 May	6 hours 46
Garrett Reisman	10:27	17:13	minutes

EVA 3

Good and Reisman first connected a liquid ammonia jumper hose. They then installed the final two new batteries on the truss and put the old batteries on the carrier. Next, they retrieved a grapple fixture from Atlantis' payload bay and brought it inside the station to be modified for future installation on the Zarya module. The pair also stowed some tools in an external toolbox outside the airlock for future spacewalks.

Mission insignia

The STS-132 mission patch was designed by NASA artist Sean Collins working with astronaut Garrett Reisman. The patch shows *Atlantis* flying towards a sunset landing, with the names of the STS-132 astronauts around the border.

STS-132 mission decal

During the standard post-flight inspection of Atlantis, a United Space Alliance inspector found a STS-132 mission decal accompanied by an inscription, "*The first, last flight of Atlantis left Earth on 14 May 2010 from Pad 39A*" together with the crew's signatures. The worker had found it tucked away on the upper side of Locker A-16 while scanning the area with a mirror. Moreover, he said the note must have been written on orbit since otherwise, the crew would have had to stand on their heads.

Wake-up calls

NASA began a tradition of playing music to astronauts during the Gemini program, which was first used to wake up a flight crew during Apollo 15. Each track is specially chosen, often by their families, and usually has a special meaning to an individual member of the crew, or is applicable to their daily activities.

Flight Day	Song	Artist	Played for	Links
Day 2	"You're My Home"	Billy Joel	Kenneth Ham	WAV, MP3 TRANSCRIPT
Day 3	"Sweet Home Alabama"	Lynyrd Skynyrd	Dominic A. "Tony" Antonelli	WAV, MP3 TRANSCRIPT
Day 4	"Alive Again"	Matt Maher	Michael T. Good	WAV, MP3 TRANSCRIPT
Day 5	"Macho Man"	Village People	Garrett Reisman	WAV, MP3 TRANSCRIPT
Day 6	"Start Me Up"	The Rolling	Piers Sellers	WAV, MP3

		Stones		TRANSCRIPT
Day 7	“Welcome to the Working Week”	Elvis Costello	Steve Bowen	WAV, MP3 TRANSCRIPT
Day 8	“Travelin' Light”	JJ Cale	Piers Sellers	WAV, MP3 TRANSCRIPT
Day 9	“Shine”	Matt Redman	Michael T. Good	WAV, MP3 TRANSCRIPT
Day 10	“These Are Days”	10,000 Maniacs	Dominic A. "Tony" Antonelli	WAV, MP3 TRANSCRIPT
Day 11	“Theme from Wallace and Gromit”	Julian Nott	Steve Bowen	WAV, MP3 TRANSCRIPT
Day 12	“Empire State of Mind”	Jay-Z	Garrett Reisman	WAV, MP3 TRANSCRIPT
Day 13	“Supermassive Black Hole”	Muse	Kenneth Ham	WAV, MP3 TRANSCRIPT