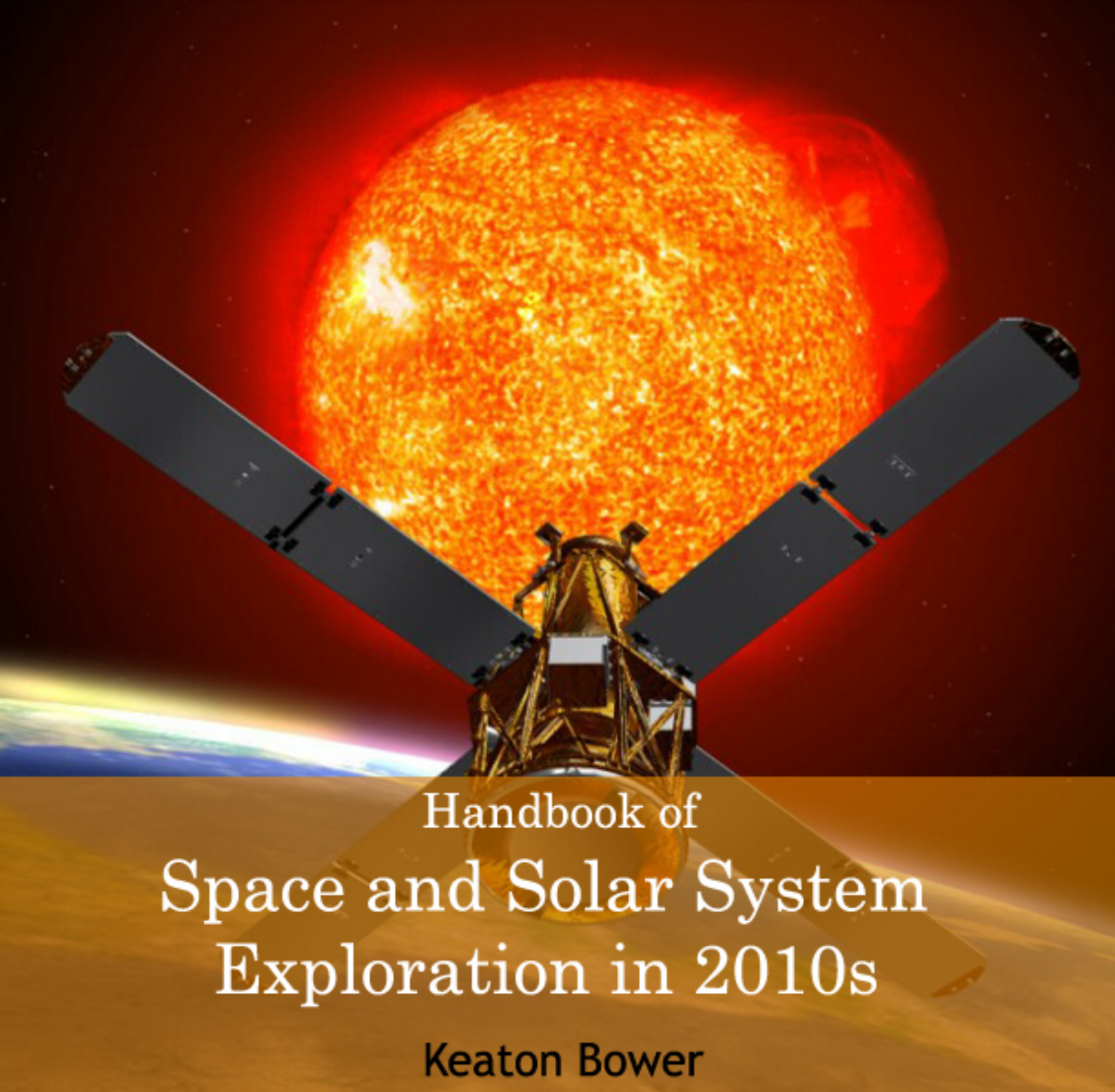

Handbook of Space and Solar System Exploration in 2010s

Keaton Bower

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Chapter- 1

Solar Dynamics Observatory

Solar Dynamics Observatory

Operator	NASA / Goddard Space Flight Center
Mission type	Orbiter
Satellite of	Earth
Launch date	2010-02-11 15:23:00 UTC
Carrier rocket	Atlas V 401
Launch site	Space Launch Complex 41 Cape Canaveral Air Force Station
Mission duration	5 - 10 years elapsed: 11 months, and 3 days
COSPAR ID	2010-005A
Mass	payload: 290 kg (640 lb) fuel: 1,400 kg (3,100 lb) total: 3,100 kg (6,800 lb)

	Orbital elements
Regime	Geosynchronous orbit
Inclination	28°
Longitude	102° W
	Instruments
Spectral band	<.1 nm
Data rate	130 Mbps on the 26 GHz K_a band 150 million bits/second

The **Solar Dynamics Observatory (SDO)** is a NASA mission which will observe the Sun for over five years. Launched on February 11, 2010, the observatory is part of the Living With a Star (LWS) program. The goal of the LWS program is to develop the scientific understanding necessary to effectively address those aspects of the connected Sun–Earth system that directly affect life and society. SDO's goal is to understand the Sun's influence on Earth and near-Earth space by studying the solar atmosphere on small scales of space and time and in many wavelengths simultaneously. SDO will investigate how the Sun's magnetic field is generated and structured, how this stored magnetic energy is converted and released into the heliosphere and geospace in the form of solar wind, energetic particles, and variations in the solar irradiance.

General

The SDO spacecraft was assembled and tested at NASA's Goddard Space Flight Center in Greenbelt, Maryland, and launched on February 11, 2010, from Cape Canaveral Air Force Station. The primary mission is scheduled to last five years and three months, with expendables expected to last for ten years. Some consider SDO to be a follow-on mission to the Solar and Heliospheric Observatory (SOHO).

SDO is a 3-axis stabilized spacecraft, with two solar arrays, and two high-gain antennas. The spacecraft includes three instruments: the Extreme Ultraviolet Variability Experiment (EVE) built in partnership with the University of Colorado at Boulder's Laboratory for Atmospheric and Space Physics (LASP), the Helioseismic and Magnetic Imager (HMI) built in partnership with Stanford University, and the Atmospheric Imaging Assembly (AIA) built in partnership with the Lockheed Martin Solar & Astrophysics Laboratory. Data which is collected by the craft will be made available as soon as possible, after it is received.

Helioseismic and Magnetic Imager

The Helioseismic and Magnetic Imager (HMI), led from Stanford University in Stanford, California, studies solar variability and characterizes the Sun's interior and the various

components of magnetic activity. HMI produces data to determine the interior sources and mechanisms of solar variability and how the physical processes inside the Sun are related to surface magnetic field and activity. It also produces data to enable estimates of the coronal magnetic field for studies of variability in the extended solar atmosphere. HMI observations will enable establishing the relationships between the internal dynamics and magnetic activity in order to understand solar variability and its effects. HMI will take high-resolution measurements of the longitudinal and vector magnetic field over the entire visible disk thus extending the capabilities of the SOHO's MDI instrument.

Extreme Ultraviolet Variability Experiment

Extreme Ultraviolet Variability Experiment logo

The Extreme Ultraviolet Variability Experiment (EVE), will measure the Sun's extreme ultraviolet irradiance with improved spectral resolution, "temporal cadence", accuracy, and precision over preceding measurements made by TIMED SEE, SOHO, and SORCE XPS. The instrument incorporates physics-based models in order to further scientific understanding of the relationship between solar EUV variations and magnetic variation changes in the Sun.

The Sun's output of energetic extreme ultraviolet photons is primarily what heats the Earth's upper atmosphere and creates the ionosphere. Solar EUV radiation output undergoes constant changes, both moment to moment and over the Sun's 11-year solar cycle, and these changes are important to understand because they have a significant impact on atmospheric heating, satellite drag, and communications system degradation, including disruption of the Global Positioning System.

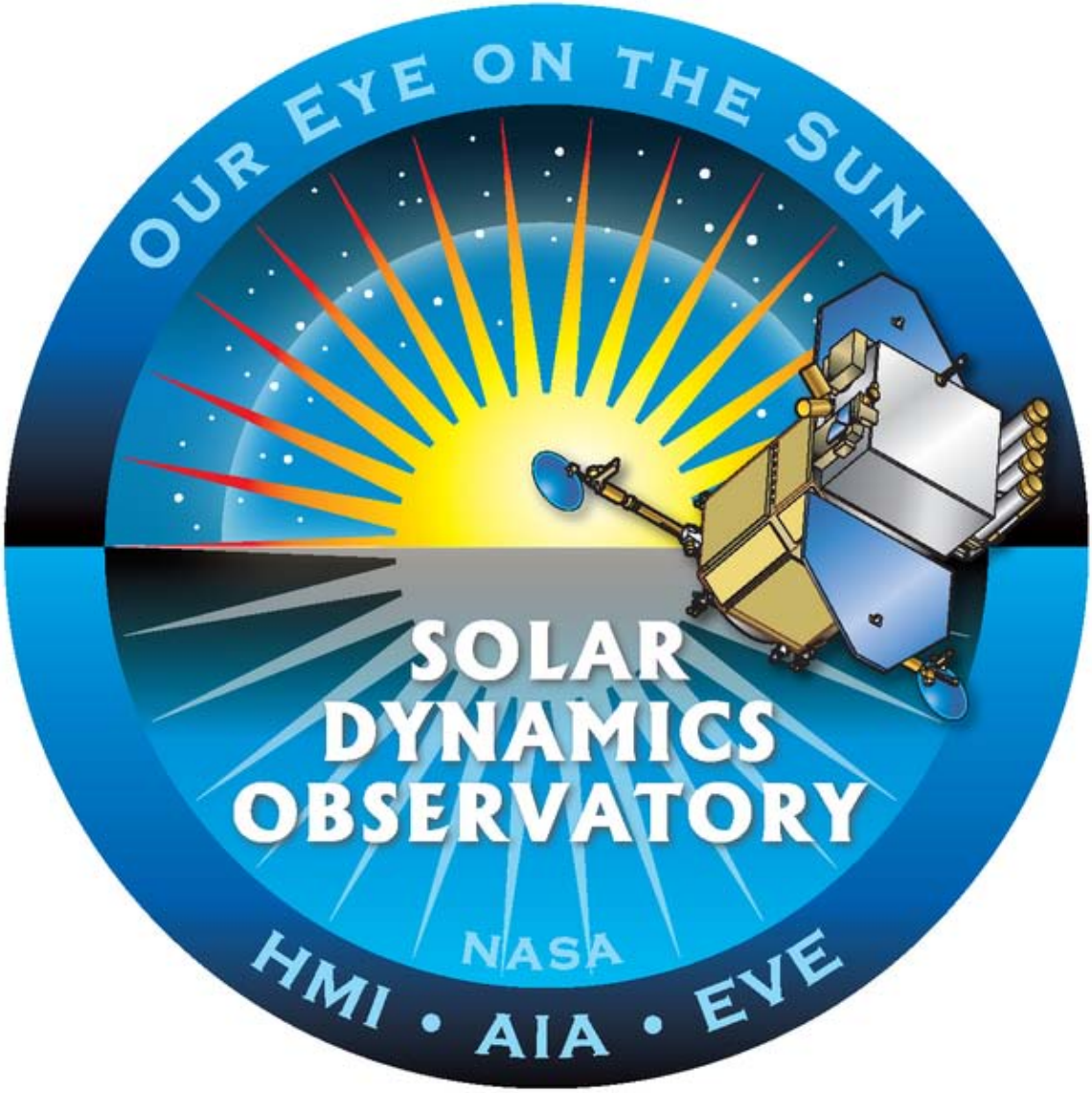
The EVE instrument package was built by the University of Colorado at Boulder's Laboratory for Atmospheric and Space Physics, with Dr. Tom Woods as Principal Investigator, and was delivered to Goddard Space Flight Center on September 7, 2007. The instrument provides improvements of up to 70 percent in spectral resolution measurements in the wavelengths below 30nm, and a 30 percent improvement in "time cadence" by taking measurements every 10 seconds over a 100 percent duty cycle.

Atmospheric Imaging Assembly

The Atmospheric Imaging Assembly (AIA), led from the Lockheed Martin Solar and Astrophysics Laboratory (LMSAL), provides full-disk imaging of the Sun in ten white light, ultraviolet and extreme ultraviolet (EUV) band passes at high spatial and temporal resolution. The four telescopes that provided the individual light feeds for the instrument were designed and built at the Smithsonian Astrophysical Observatory (SAO).

AIA Wavelength Channel	Region of solar atmosphere	Characteristic Temperature
White Light	Photosphere	5000 K
170 nm	Temperature minimum, photosphere	5000 K
160 nm	Transition region & photosphere	10^5 & 5000 K
30.4 nm	Chromosphere & transition region	50,000 K
17.1 nm	Quiet corona, upper transition region	6.3×10^5 K
19.3 nm	Corona & hot flare plasma	1.2×10^6 & $2x10^7$ K
21.1 nm	Active region corona	2×10^6 K
33.5 nm	Active region corona	2.5×10^6 K
9.4 nm	Flaring regions	6.3×10^6 K
13.1 nm	Flaring regions	4×10^5, 10^7 & 1.6×10^7 K

Communications



The insignia of the SDO

SDO will down-link science data (K-band) from its two onboard high-gain antennas, and telemetry (S-band) from its two onboard omnidirectional antennas. The ground station consists of two dedicated (redundant) 18-meter radio antennas in White Sands Missile Range, New Mexico, constructed specifically for SDO. Mission controllers will operate the spacecraft remotely from the Mission Operations Center at NASA's Goddard Space Flight Center. The combined data rate will be about 130 Mbit/s (150 Mbit/s with overhead, or 300 Msymbols/s with rate 1/2 convolutional encoding), and the craft will generate approximately 1.5 terabytes of data per day, beaming back 150 million bits of data every second (The equivalent of about 380 full length movies).

Launch

The launch Thursday, 11 February 2010 15:23:00 UTC (10:23 a.m. EST)

Attempt	Planned	Result	Turnaround	Reason	Decision point	Weather go %	Notes
1	10 Feb 2010, 3:26:00 pm	Scrubbed	---	Weather (high winds)	10 Feb 2010, 11:26 am(T-3:59, immediately after T-4:00 hold)	40%	window 10:26 to 11:26a EST, attempts made at 10:26,

						10:56 and 11:26
2	11 Feb 2010, 3:23:00 pm	Success	0 days, 23 hours, 57 minutes		60%	Window: 10:23 to 11:23a EST

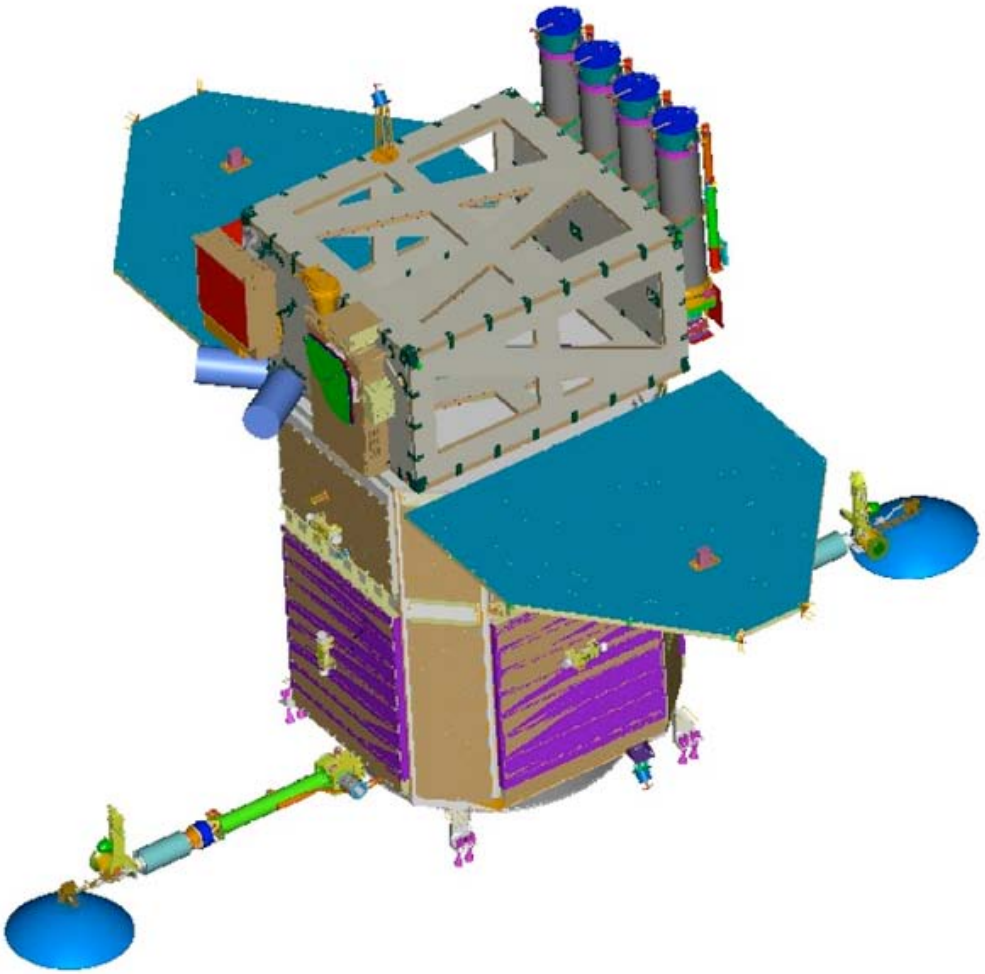
NASA's Launch Services Program at Kennedy Space Center managed the payload integration and launch. The SDO launched from Cape Canaveral Air Force Station Space Launch Complex 41, utilizing an Atlas V-401 rocket with a RD-180 powered Common Core Booster, which has been developed to meet the Evolved Expendable Launch Vehicle (EELV) program requirements.

Orbit

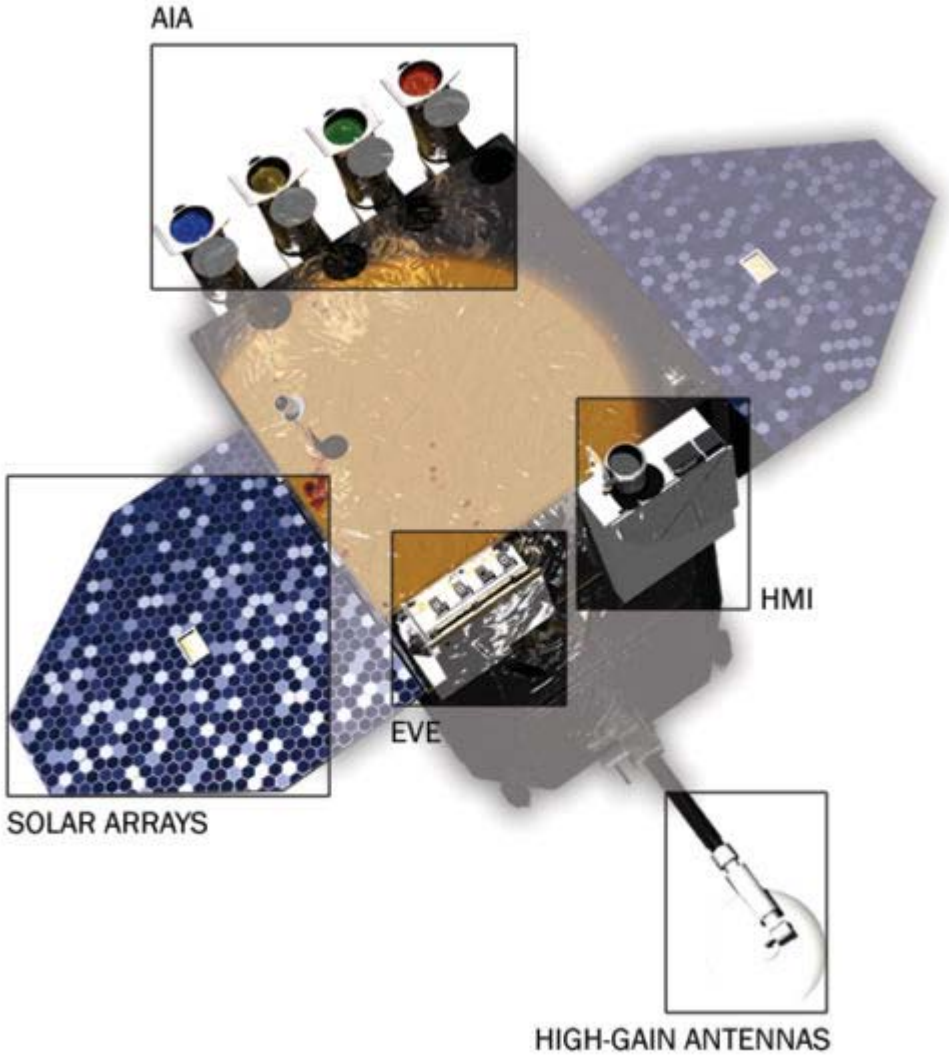
After launch, the spacecraft was placed into an orbit around the earth with an initial perigee of about 2,500 kilometres (1,600 mi). SDO will undergo a series of orbit-raising maneuvers which will adjust its orbit until the spacecraft reaches its planned circular, geosynchronous orbit at an altitude of 36,000 kilometres (22,000 mi), at 102° W longitude, inclined at 28.5°.

Camilla Corona

Camilla Corona SDO is a rubber chicken and mission mascot for NASA's Solar Dynamics Observatory (SDO). She is part of the Education and public outreach team and assists with various functions to help educate the public, mainly children, about the SDO mission, facts about the sun and space weather. Camilla also assists in cross-informing about other NASA missions and space related projects. Camilla Corona SDO uses social media to interact with fans.

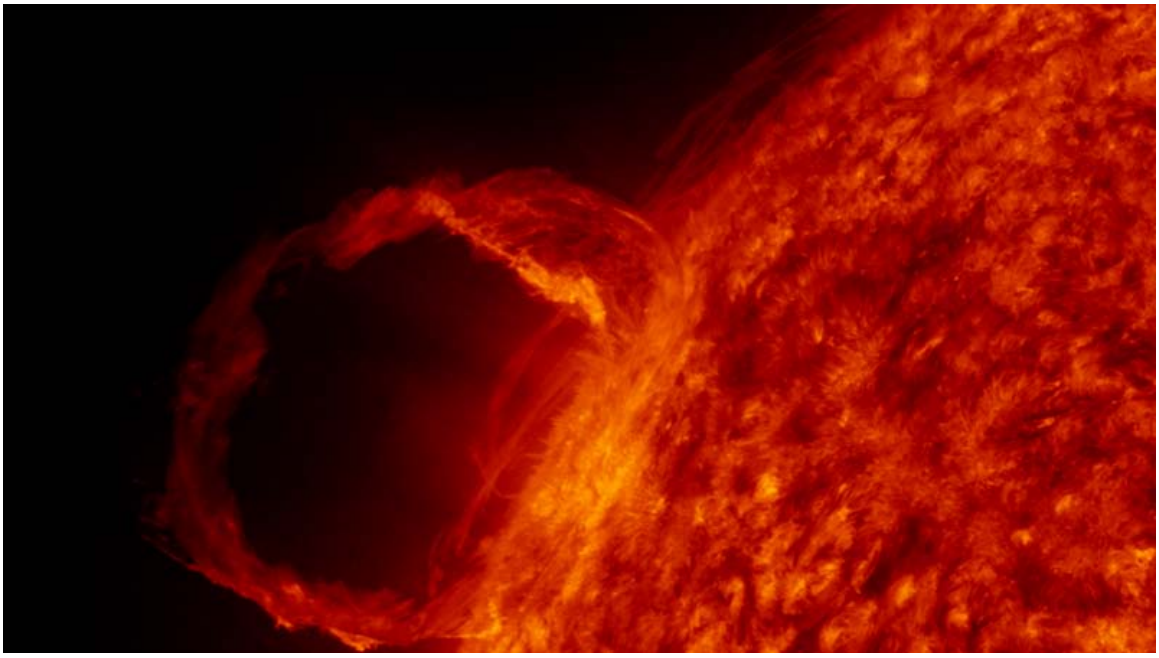


SDO 3-D schematic



SDO Instruments

SDO ready to be placed on Atlas rocket for launch



First light image from the SDO showing a solar flare

Chapter- 2

Akatsuki (spacecraft)

Akatsuki	
Operator	Japan Aerospace Exploration Agency (JAXA)
Mission type	Orbiter
Satellite of	Venus
Orbital insertion date	2010-12-06 23:49:00 UTC (anticipated)
Launch date	2010-05-20 21:58:22 UTC
Carrier rocket	H-IIA 202
Launch site	Tanegashima Space Center Tanegashima, Japan
Mission duration	~2 years elapsed: 7 months, and 28 days
COSPAR ID	2010-020D
Mass	320 kg (710 lb)
Power	1,200 W
Orbital elements	
Eccentricity	0.992
Inclination	172 degrees
Apoapsis	79,000 km (49,000 mi)
Periapsis	300 km (190 mi)

Orbital period 30 hours

Akatsuki (あかつき, 暁?, literally "dawn"), formerly known as the **Venus Climate Orbiter (VCO)** and **Planet-C**, is a Japanese unmanned spacecraft which was intended to explore Venus. It was launched aboard an H-IIA 202 rocket on 20 May 2010, after being delayed because of weather from its initial 18 May scheduled target. The total launch mass of the spacecraft including propellant was 480 kg, 34 kg out of this was scientific instruments. The mission reached Venus on 7 December 2010 (JST) but failed to enter orbit around the planet. It had been intended to conduct scientific research for two or more years from an elliptical orbit ranging from 300 km to 80,000 km from Venus.

Akatsuki is Japan's first planetary exploration mission since the Nozomi probe, which was launched in 1998 but failed to go into a Mars orbit in 2003 as planned.

Design

The mass of the spacecraft is 640 kg (1,400 lb), including 320 kg (710 lb) of propellants and 34 kg (75 lb) of scientific instruments.

The main bus is a 1.6 m x 1.6 m x 1.25 m box with two solar arrays, each with an area of 1.4 m^2 (15 sq ft). The solar array panels provide over 1,200 watts of power in Venus orbit.

Propulsion is provided by a 500 newton (N) bi-propellant, hydrazine / nitrogen tetroxide orbital maneuvering engine and 12 mono-propellant hydrazine reaction control thrusters, eight with 23 N thrust and four with 3 N.

Communications is via a 8 GHZ X-band 20 W transponder using the 1.6 m slot array high gain dish antenna used for most telemetry data. Akatsuki also has a pair of medium gain horn antennas mounted on turntables and two low gain antennas for command uplink. The medium gain horn antennas will be used for housekeeping data downlink when the high gain antenna is not facing Earth.

Instruments

The scientific payload consists of six instruments including a Lightning and airglow camera (LAC), an ultraviolet imager (UVI), a longwave infrared camera (LIR), a 1-μm camera (IR1), a 2-μm camera (IR2), and the radio science (RS) experiment. The five cameras will explore Venus in wavelengths from ultraviolet to the mid-infrared.

The LAC will look for lightning in the visible wavelengths of 552 to 777 nanometers. The LIR will study the structure of high-altitude clouds at a wavelength where they emit heat (10 microns). The UVI will study the distribution of specific atmospheric gases such as sulfur dioxide in ultraviolet wavelengths (293 to 365 nanometers). The IR1 will peer

through semi-transparent windows in Venus' atmosphere to see heat radiation emitted from Venus' surface rocks (0.9 to 1.01 microns) and will help researchers to spot active volcanoes, if they exist. The IR2 will peer through semi-transparent windows in Venus' atmosphere to see heat radiation emitted from the lower reaches of the atmosphere (1.65 to 2.32 microns). The last science instrument - Akatsuki's radio dish, will be used to actively probe the atmosphere.

Mission

Planned investigations include surface imaging with an infrared camera and experiments designed to confirm the presence of lightning and to determine whether volcanism occurs on the surface.

The budget for this mission is ¥13 billion (US$110 million) for the satellite and ¥12 billion (US$100 million) for the launch.

Public relations

There was a public relations campaign held between October 2009 and January 2010 by The Planetary Society and JAXA, to allow individuals to send their name and a message aboard *Akatsuki*. Names and messages were printed in fine letters on an aluminum plate and placed aboard *Akatsuki*. 260,214 people submitted names and messages for the mission. Around 90 aluminum plates were created for the spacecraft, including three aluminum plates in which the images of the Vocaloid Hatsune Miku and her super deformed figure Hachune Miku were printed.

Operation

Launch

The launch of Akatsuki

Akatsuki left the Sagamihara Campus on 17 March 2010, and arrived at the Tanegashima Space Center's Spacecraft Test and Assembly Building 2 on 19 March. On 4 May, *Akatsuki* was encapsulated inside the large payload fairing of the H-IIA rocket that launched the spacecraft, along with the IKAROS solar sail, on a 6-month journey to Venus. On 9 May, the payload fairing was transported to the Tanegashima Space Center's Vehicle Assembly Building, where the fairing was mated to the H-IIA launch vehicle itself. The spacecraft was launched on May 20, 2010 at 21:58:22 (UTC) from the Tanegashima Space Center.

Orbit insertion failure

Akatsuki was planned to initiate orbit insertion operations by igniting the orbital maneuvering engine at 23:49:00 on 6 December UTC. The burn was supposed to continue for 12 minutes, to an initial orbit of 180,000 – 200,000 km apoapsis / 550 km periapsis / 4 days orbital period around Venus.

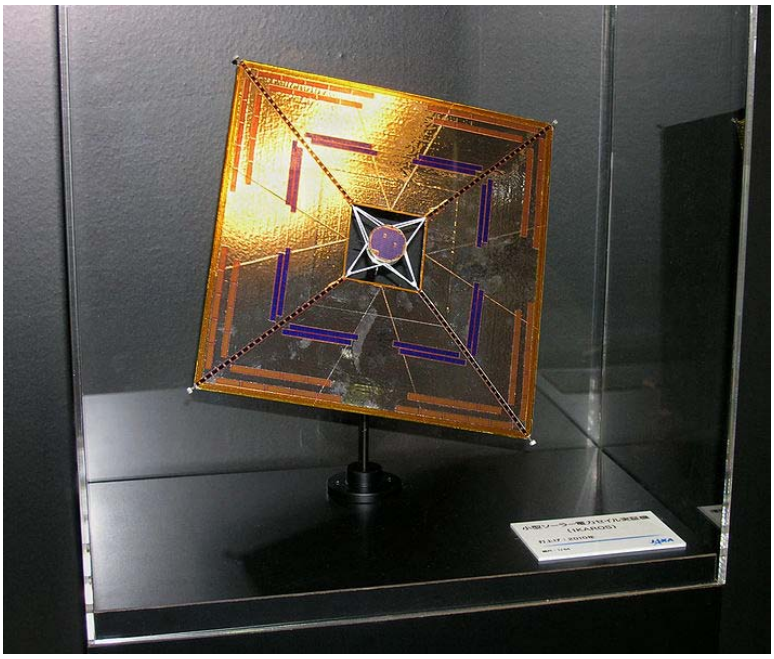
The orbit insertion maneuver was confirmed to have started on time. But after the expected blackout due to occultation by Venus, the communication with the probe did not recover as planned. The probe was found to be in safe-hold mode, spin-stabilized state with 10 minutes per rotation. Due to the low communication speed through low-gain antenna, it took a while to determine the state of probe. JAXA stated on December 8, that the probe's orbital insertion maneuver has failed. At a press conference on 10 December, officials reported that Akatsuki's engines fired for less than 3 minutes far short of what was required to enter into Venus orbit.

JAXA is developing plans to attempt another orbital insertion burn when the probe returns to Venus in 6 years. This requires placing the probe into a hibernation state to prolong its life beyond the original 4.5 year design. JAXA expressed some confidence in keeping the probe operational, pointing to reduced battery wear, since the probe is orbiting the Sun instead of its intended Venusian orbit.

Chapter- 3

IKAROS

IKAROS



Model of the IKAROS spacecraft, not to scale.

Operator	JAXA
Flyby of	Venus
Satellite of	The Sun
Orbital insertion date	2010-05-21
Launch date	2010-05-20 21:58:22 UTC
Carrier rocket	H-IIA 202
Launch site	Tanegashima Space Center

	Tanegashima, Japan
Mission duration	~0.5 years elapsed: 7 months, and 27 days
COSPAR ID	2010-020E
Mass	315 kg

IKAROS (**Interplanetary Kite-craft Accelerated by Radiation Of the Sun**) is a Japan Aerospace Exploration Agency experimental spacecraft. The spacecraft was launched on 21 May 2010 aboard an H-IIA rocket, together with *Akatsuki* (Venus Climate Orbiter) and four other small spacecraft. IKAROS is the first spacecraft to successfully demonstrate solar-sail technology in interplanetary space.

On December 8, 2010, IKAROS passed by Venus at about 80,000 km distance, completing the planned mission successfully, and entered extended operation phase.

Purpose

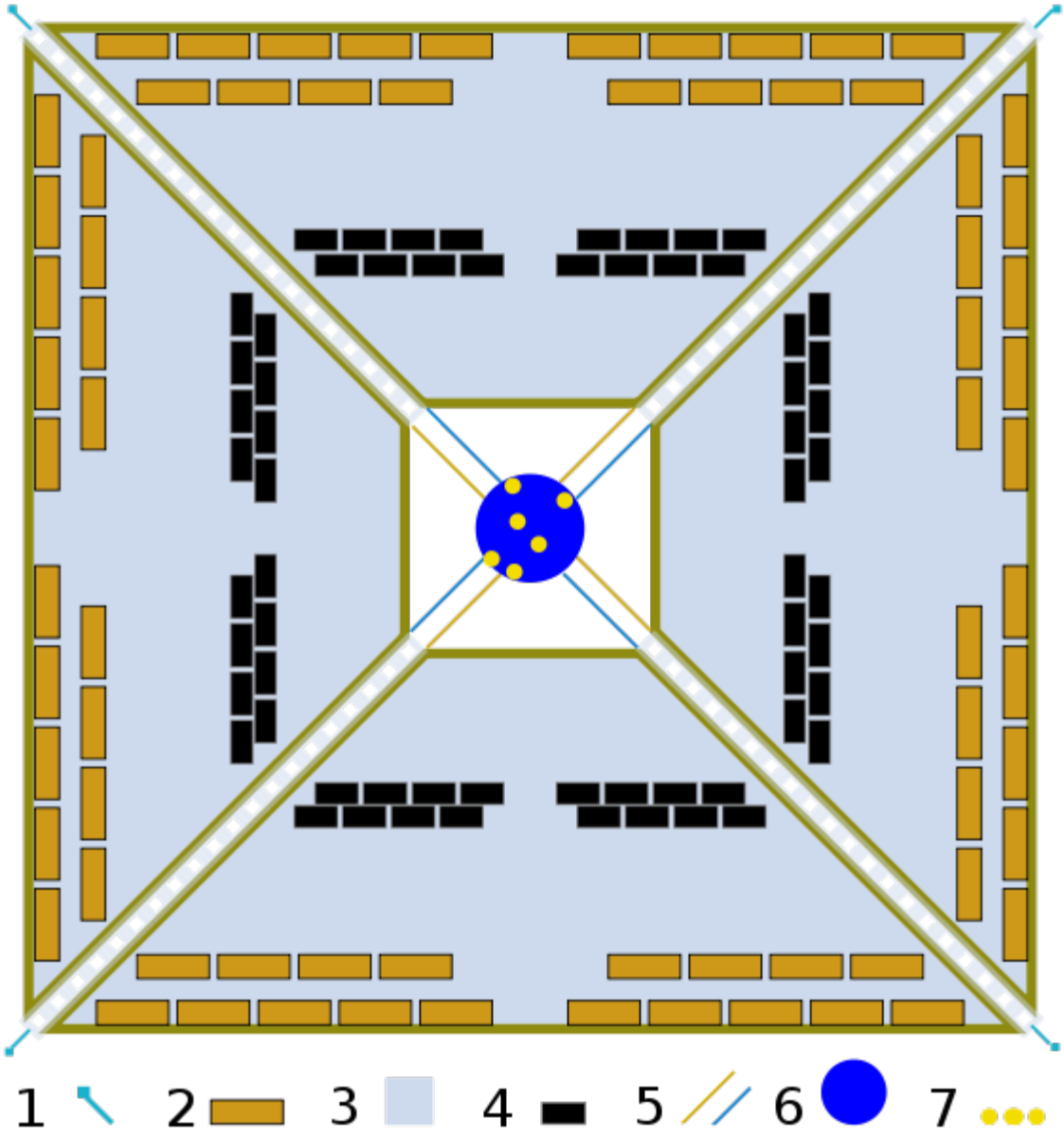
The IKAROS probe is the world's first spacecraft to use solar sailing as the main propulsion. It plans to demonstrate four key technologies (comments in parentheses refer to figure):

1. Deployment and control of a large, thin solar sail membrane (gray areas numbered 3)
2. Thin-film solar cells integrated into the sail to power the payload (black rectangles numbered 4)
3. Measurement of acceleration due to radiation pressure on the solar sail
4. Attitude control via variable reflectance liquid crystal panels (orange rectangles numbered 2)

The sail finished deploying on 10 June 2010, and is currently being tested. The final two items will be tested during the remaining six month voyage to Venus.

The mission also includes investigations of aspects of interplanetary space, such as the gamma-ray burst, solar wind and cosmic dust.

Design



IKAROS sail schematic diagram:
1 (blue square on a line) Tip mass 0.5 kg, 1 of 4
2 (orange rectangle) Liquid crystal device, 1 of 80
3 (blue square) Membrane 7.5 µm thick, 20 metres diameter
4 (black rectangle) Solar cells 25 µm thick
5 (yellow and blue lines) Tethers
6 (blue disc) Main body
7 (yellow dots) Instruments

The square sail, deployed via a spinning motion using 0.5 kg tip masses (1 in key at right), is 20 m (66 ft) on the diagonal and is made of a 7.5-micrometre (0.0075 mm) thick sheet of polyimide (3 in key at right). A thin-film solar array is embedded in the sail (4 in key at right). PowerFilm, Inc. provided the thin-film solar array. Eighty blocks of LCD panels are embedded in the sail, whose reflectance can be adjusted for attitude control (2 in key at right). The sail also contains eight dust counters on the opposite face as part of the science payload.

Mission

IKAROS was successfully launched together with *Akatsuki* (the Venus Climate Orbiter) aboard an H-IIA rocket from the Tanegashima Space Center on 21 May 2010.

IKAROS spun at 20–25 revolutions per minute and finished unfurling its sail on 11 June 2010. The craft contains two tiny ejectable cameras, DCAM1 and DCAM2. DCAM2 was used to visualise the sail after deployment on 14 July 2010.

On 9 July, JAXA confirmed that IKAROS is being accelerated by its solar sail.

If successful, IKAROS is to be followed by a 50 m (160 ft) sail, intended to journey to Jupiter and the Trojan asteroids, later in the decade.

Chapter- 4

STS-131

STS-131

Mission insignia

Mission statistics

Mission name	STS-131
Space shuttle	*Discovery*
Launch pad	39A
Launch date	5 April 2010 06:21:22 EDT (10:21:22 UTC)
Landing	20 April 2010, 09:08:35 EDT (13:08:35 UTC)
Mission duration	15 days 2 hours, 47 min, 11 seconds
Number of orbits	238
Orbital altitude	Insertion: 122 nautical miles (226 km) Rendezvous: 185 nautical miles (343 km)

Orbital inclination	51.6 degrees
Distance traveled	6,232,235 miles (10,029,810 km)

Docking

Docking date	7 April 2010 07:44 UTC
Undocking date	17 April 2010 12:52 UTC
Time docked	10 days, 5 hours, 8 minutes

Crew photo

Seated: James Dutton (left) Alan Poindexter (right), Standing (l-r): Rick Mastracchio, Stephanie Wilson, Dorothy Metcalf-Lindenburger, Naoko Yamazaki (JAXA) and Clayton Anderson

Related missions

Previous mission	Subsequent mission
STS-130	STS-132

STS-131 (ISS assembly flight **19A**) was a Space Shuttle mission to the International Space Station (ISS). Space Shuttle *Discovery* launched on 5 April 2010 at 6:22 AM from Kennedy Space Center's launch pad 39A and landed at 9:08 AM on 20 April 2010 on runway 33 at the Kennedy Space Center's Shuttle Landing Facility. The mission marked the longest flight for space shuttle *Discovery*.

The primary payload was a Multi-Purpose Logistics Module loaded with supplies and equipment for the International Space Station. The mission also removed and replaced an ammonia tank assembly outside the station on the S1 truss. The mission also included several on-board payloads; this mission had the most payloads since STS-107.

Crew

Position	Astronaut
Commander	Alan Poindexter Second spaceflight
Pilot	James Dutton First spaceflight
Mission Specialist 1	Richard Mastracchio Third spaceflight EV1
Mission Specialist Educator 2	Dorothy M. Metcalf-Lindenburger First spaceflight Flight Engineer/Intra-vehicular officer
Mission Specialist 3	Stephanie Wilson Third spaceflight Lead robotics officer
Mission Specialist 4	Naoko Yamazaki, JAXA First spaceflight Load master
Mission Specialist 5	Clayton Anderson Second spaceflight EV2

Notes:

- This was the final Space Shuttle mission with a seven person crew.
- This was the final Space Shuttle mission that contains one or more "rookie" astronauts; the missions after this will have all-veteran crews.
- STS-131 was only the third mission in the Space Shuttle program to carry three female astronauts. Missions STS-40 and STS-96 were the first and the second.
- STS-131 marked the first time that two Japanese astronauts, Naoko Yamazaki from the shuttle crew, and Soichi Noguchi on the ISS, were in space together.
- With three female crew members arriving on-board *Discovery* and Expedition 23 Flight Engineer Tracy Caldwell Dyson on the ISS, the STS-131 mission marked the first time that four women were in space at one time.
- Although Naoko Yamazaki is not the last non-U.S. astronaut, she was the last Japanese astronaut to fly on the space shuttle.

Mission parameters

- **Mass:**
    - Shuttle liftoff weight: 4,521,749 pounds (2,051,031 kg)
    - Orbiter liftoff: 266,864 pounds (121,047 kg)
    - Orbiter landing: 224,957 pounds (102,039 kg)
- **Perigee:** 200 miles (320 km)
- **Apogee:** 215 miles (346 km)
- **Inclination:** 51.6
- **Period:** 90 min

Mission payload

Location	Cargo	Mass
Bays 1-2	Orbiter Docking System EMU 3008 / EMU 3017	1,800 kilograms (4,000 lb) ~260 kilograms (570 lb)
Bay 4P	Shuttle Power Distribution Unit (SPDU)	~18 kilograms (40 lb)
Bay 7S	ROEU 751A umbilical	127 kilograms (280 lb)
Bays 7-12	Leonardo (MPLM FM-1)	12,371 kilograms (27,270 lb)
Bay 13	Lightweight MPESS Carrier (LMC)	1,764 kilograms (3,890 lb)
Starboard Sill	Orbiter Boom Sensor System	382 kilograms (840 lb)
Port Sill	Canadarm	410 kilograms (900 lb)
	Total:	**15,332 kilograms (33,800 lb)**

Multi-Purpose Logistics Module *Leonardo*

The primary payload of STS-131 was the Multi-Purpose Logistics Module (MPLM) *Leonardo*. The MPLM was filled with food and science supplies for the International Space Station (ISS). The MPLM also carried the third and final Minus Eighty Degree Laboratory Freezer for ISS (MELFI), Window Orbital Research Facility (WORF), one Crew Quarters Rack, the Muscle Atrophy Resistive Exercise (MARES) rack, Resupply Stowage Racks (RSRs), as well as Resupply Stowage Platforms (RSPs).

Lightweight Multi-Purpose Equipment Support Structure Carrier

The Lightweight Multi-Purpose Equipment Support Structure Carrier (LMC) carried a refurbished Ammonia Tank Assembly (ATA) to the ISS. The refurbished ATA was removed from the Space Station and returned for use on this mission during STS-128. It was swapped with an empty tank which will ride home on the LMC.

TriDAR

This mission was the second flight of the TriDAR, a 3D dual-sensing laser camera, intended for potential use as an autonomous rendezvous and docking sensor. TriDAR provides guidance information that can be used to guide a vehicle during rendezvous and docking operations in space. TriDAR does not rely on any reference markers, such as reflectors, positioned on the target spacecraft. To achieve this, it relies on a laser based 3D sensor and a thermal imager. Geometric information contained in successive 3D images is matched against the known shape of the target object to calculate its position and orientation in real-time. The TriDAR tracked the ISS position and orientation from the shuttle during docking, undocking, and flyaround operations.

Mission background

The mission marks:

- 162nd American manned space flight
- 131st shuttle mission since STS-1
- 38th flight of *Discovery*
- 33rd shuttle mission to the ISS
- 106th post-*Challenger* mission
- 18th post-*Columbia* mission
- 35th night launch of a shuttle, 22nd night launch from launch pad 39A
- 2nd "descending node" entry since 2003

Shuttle processing

Space Shuttle *Discovery* was moved from its hangar in the Orbiter Processing Facility (OPF) 3 to the nearby Vehicle Assembly Building on 22 February 2010. The rollover was completed around 10:30 EST. According to NASA, the rollover occurred a day earlier than announced to take advantage of favorable weather in advance of poor conditions forecasted on the next day.

An earlier plan to move *Discovery* into the VAB on 12 February 2010 was delayed because of cold weather at the Kennedy Space Center. For the rollover, temperatures in the Vehicle Assembly Building (VAB) had to be above 45 °F (7 °C) for more than twelve hours because *Discovery* was not attached to any heating purges to protect its systems from potential damage from the cold.

Space shuttle *Discovery* began its trip, known as the rollout, to launch pad 39A at 23:58 EST on 2 March 2010. The complete shuttle stack and mobile launch platform were secured to the launch pad 39A structure at 6:49 EST on 3 March 2010. The 3.4 mi (5.5 km) trek took 6 hours 51 minutes to complete. The rollout was delayed 24 hours by the threat of lightning from a passing cold front. That weather moved away, and the stiff wind gusts blowing on Florida's Space Coast on the next day were not a factor for the

rollout. Ahead of the rollout, engineers noticed some damage caused by birds to the External Tank (ET-135), which was repaired inside the VAB. Birds had managed to reach the tank, and pecked away at the Thermal Protection System (TPS) foam.

Space Shuttle *Discovery* rolls toward the Vehicle Assembly Building

Space Shuttle *Discovery* at Launch Pad 39A

International Space Station (bottom right) passes over the Cape 15 minutes prior to launch.

Mission timeline

April 5 (Flight Day 1 - Launch)

Space Shuttle *Discovery* lifted off successfully at 06:21 EDT. After the eight and a half minute ride to space, *Discovery*'s seven person crew began configuring the orbiter from a launch vehicle to an orbital vehicle. Commander Alan Poindexter and pilot Jim Dutton, with help from mission specialist 2 Dorothy Metcalf-Lindenburger, also performed a series of engine firings or burns to adjust their speed and refine their path to the International Space Station. While the engine burns were going on, the rest of the crew opened the payload bay doors, set up the computers and K_u band antenna. The antenna suffered a failure during normal checkout and setup on orbit. Due to the failure, the normal downlink of imagery of the external tank was not completed. The crew onboard will monitor the inspections of the thermal protection system (TPS) in real time and will note any spots of interest and let the ground know while downlinking the imagery after docking. The dish antenna also serves as a radar antenna, measuring the distance to the space station.

The failed K_u band dish antenna

Discovery lifts off Launch Pad 39A

Space Shuttle Discovery launches from Kennedy Space Center, April 5, 2010

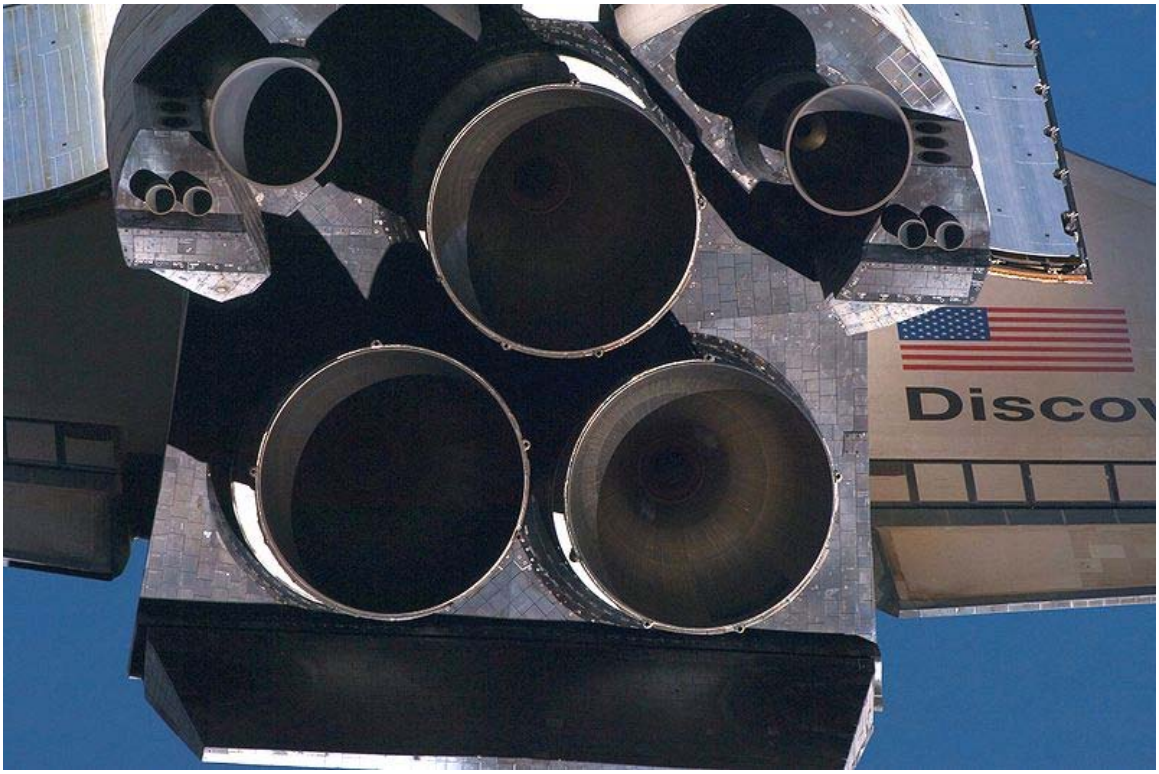
April 6 (Flight Day 2 - Inspections)

The seven person crew of STS-131 was awakened to begin their first full day in space on Flight Day 2. Due to the lack of K_u-band communication, changes to the crews daily plan were read up for them to write out. After their post sleep activities, commander Alan Poindexter and pilot Jim Dutton fired *Discovery*'s Orbital Maneuvering System (OMS) engines to correct and further refine the shuttle's path to the ISS. Astronauts Naoko Yamazaki and Dorothy Metcalf-Lindenburger began activating and checking out the Shuttle Remote Manipulator System (SRMS) also known as the Canadarm. While

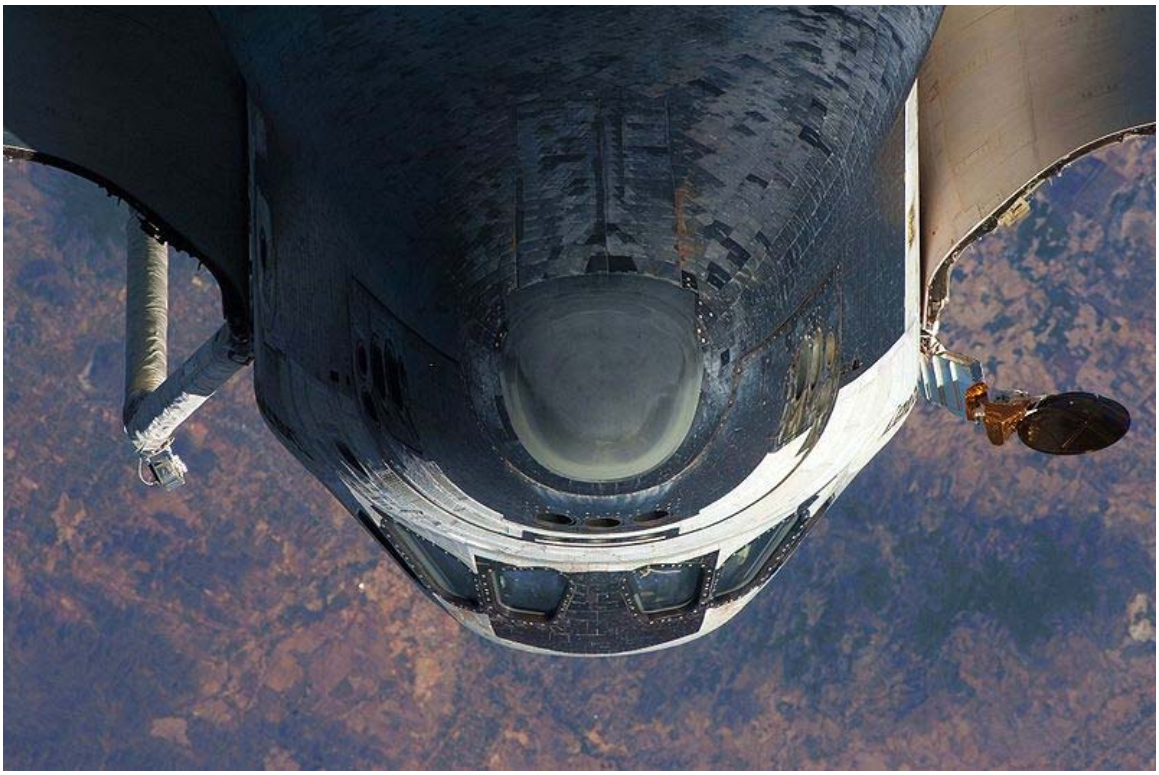
Metcalf-Lindenburger and Yamazaki were working with Canadarm, Stephanie Wilson was getting equipment together and set up to record the inspections of the shuttle's heat shield. The inspections were recorded so they could be downlinked to the ground once docked to the ISS. Once all that work was done, commander Poindexter and pilot Dutton joined Metcalf-Lindenburger, Yamazaki, and Wilson to conduct the inspection of the shuttle's heat shield. While the inspection was going on, Rick Mastracchio and Clayton Anderson were on the mid-deck of *Discovery* checking out the Extravehicular Mobility Units (EMU) and getting them ready for their three spacewalks. The last portion of the crew day was spent preparing and checking out all of the tools used during rendezvous.

April 7 (Flight Day 3 - Docking)

Space shuttle *Discovery* successfully docked with the space station at 07:44 UTC (03:44 EDT) on 7 April 2010 as the two spacecraft sailed 220 miles above the Caribbean. The crew performed six successful engine firings to set up the on-time docking. Prior to docking commander Poindexter guided *Discovery* through the standard Rendezvous Pitch Maneuver (RPM). Station commander Oleg Kotov and flight engineer T.J. Creamer took more than 350 photos of *Discovery'*s heat shield. Once *Discovery* docked to the International Space Station (ISS), a series of leak checks were done on both sides of the hatch by the shuttle and station crews. The hatches between the two vehicles were opened at 09:11 UTC (05:11 EDT), which was 30 minutes earlier than planned. Once the hatches were opened the STS-131 crew got a safety briefing from the station crew, then began to transfer items that would be needed for later in the day and early on flight day 4. Two items that were transferred were the two EMUs that will be used for the three spacewalks. The crew also completed a grapple of the Orbiter Boom Sensor System (OBSS) with the Space Station Remote Manipulator System (SSRMS) also known as Canadarm2. Once the OBSS was grappled it was unberthed from the starboard sill of the space shuttle payload bay, and handed off to the SRMS. Throughout the day, after docking to the station, the shuttle crew began downlinking all of the inspection video from flight day 2, and launch imagery and video.



Aft portion of Discovery, including the three main engines, during the RPM



View of the underside of the crew cabin of Discovery during the RPM

Discovery approaches the Space Station for docking

Kibo, photographed by a crew member while Discovery was docked with the station

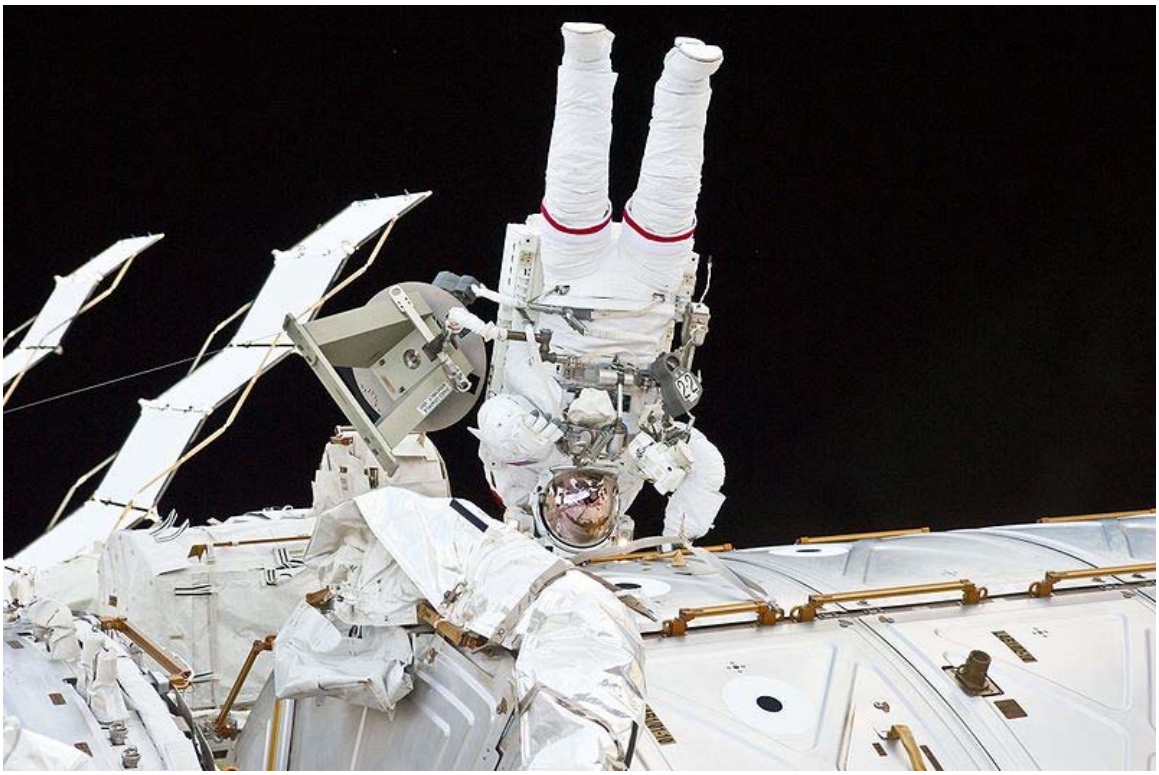
April 8 (Flight Day 4 - MPLM ingress)

On flight day 4 Stephanie Wilson and Naoko Yamazaki grappled and berthed the Multi-purpose Logistics Module (MPLM) *Leonardo*. The MPLM was berthed to the station at 04:24 UTC (00:24 EDT). The hatches were opened by station flight engineer Soichi Noguchi and shuttle mission specialist Clayton Anderson at 11:58 UTC (07:58 EDT). The joint STS-131/Expedition 23 crews began transferring cargo from the MPLM, with the first item being a Rate Gyro Assembly (RGA) which will be replaced on the first spacewalk of the mission. During flight day 4 commander Alan Poindexter did several in-flight interviews. Commander Poindexter was joined by mission specialists Rick Mastracchio and Stephanie Wilson. The interviews were with the Tom Joyner Radio Show, WVIT-TV and Fox News Radio. At the end of the day Mastracchio and Anderson entered the Quest airlock and begin breathing pure oxygen for an hour, while the atmospheric pressure inside the airlock was lowered to 10.2 psi. This procedure is known as the pre-breathe protocol and is done before every spacewalk, to purge nitrogen from the blood stream and prevent the decompression sickness.

April 9 (Flight Day 5 - EVA 1)

Flight day 5 saw the completion of the first spacewalk by Rick Mastracchio and Clayton Anderson. The pair released the new ammonia tank assembly for transfer to station for installation on a later spacewalk. They also removed an experiment from outside on the

Kibo Exposed Facility, replaced a Rate Gyro Assembly (RGA) and performed several get-ahead tasks. The spacewalking pair was assisted by the SSRMS which was operated by pilot Jim Dutton and mission specialist Stephanie Wilson. While the spacewalk was going on, Naoko Yamazaki was assisted by commander Alan Poindexter, and the Expedition 23 crew to move several of the large science racks from the MPLM *Leonardo* to their new location on the ISS.



Mastracchio during EVA 1

April 10 (Flight Day 6 - Transfers)

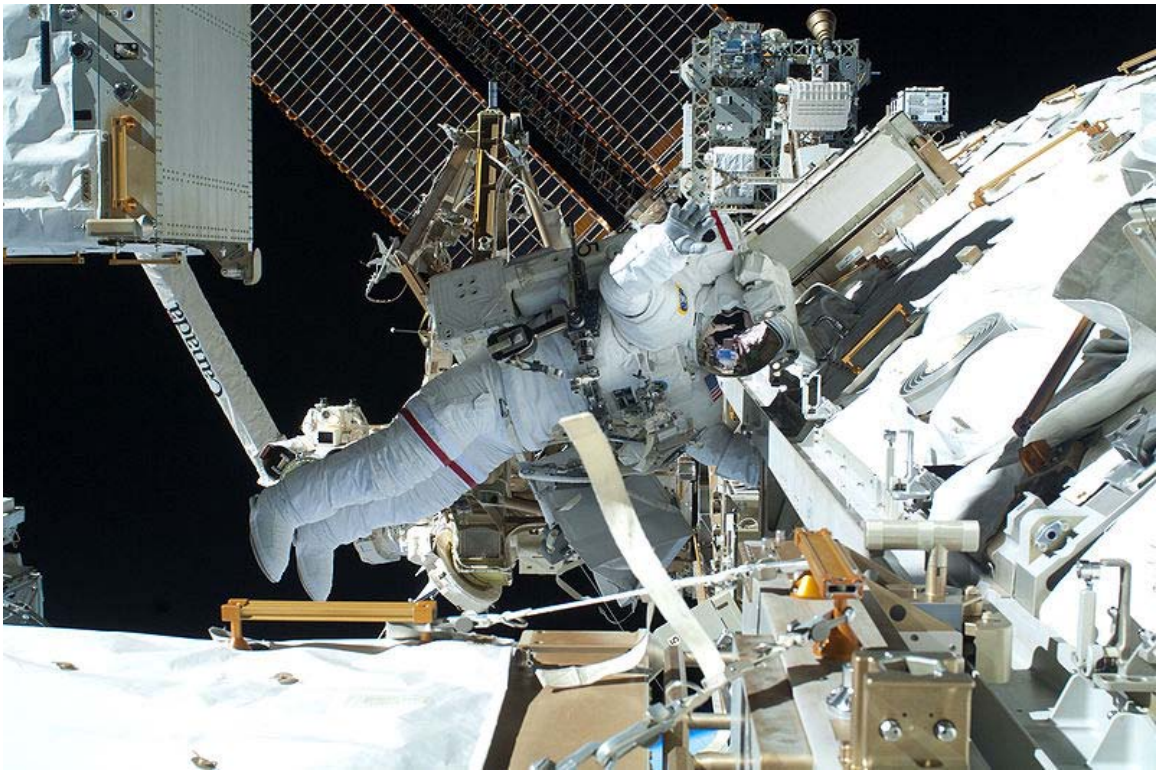
Flight day 6 was dedicated to transferring supplies from the MPLM *Leonardo* and the space shuttle mid-deck. The crews transferred the Windows Observational Research Facility (WORF) to the Destiny lab. Mission specialist Naoko Yamazaki, along with flight engineer Soichi Noguchi also transferred the Express Rack 7 (ER7) to its final location. During the crews morning, a smoke alarm sounded in the Russian segment of the station, which prompted the joint crew to move into emergency procedures. However the alarm was false and was cleared within a couple of minutes and all normal work resumed. Mission specialists Clay Anderson, Rick Mastracchio and Stephanie Wilson conducted in-flight interviews with Nebraska Public Radio, CBS Newspath and Radio Network and KETV-TV in Omaha, Nebraska. Later in the day commander Alan Poindexter, pilot Jim Dutton and mission specialist Dorothy Metcalf-Lindenburger talked with students at the Naval Postgraduate School in Monterey, California. At the end of the crews work day, the joint crew got together and reviewed the procedures for the second

spacewalk. After the procedures review spacewalkers Clay Anderson and Rick Mastracchio entered the Quest airlock, closed the hatch and lowered the inside pressure to 10.2 psi. The pair also breathed pure oxygen for an hour while the pressure was being lowered.

Dorothy Metcalf-Lindenburger inside the MPLM Leonardo

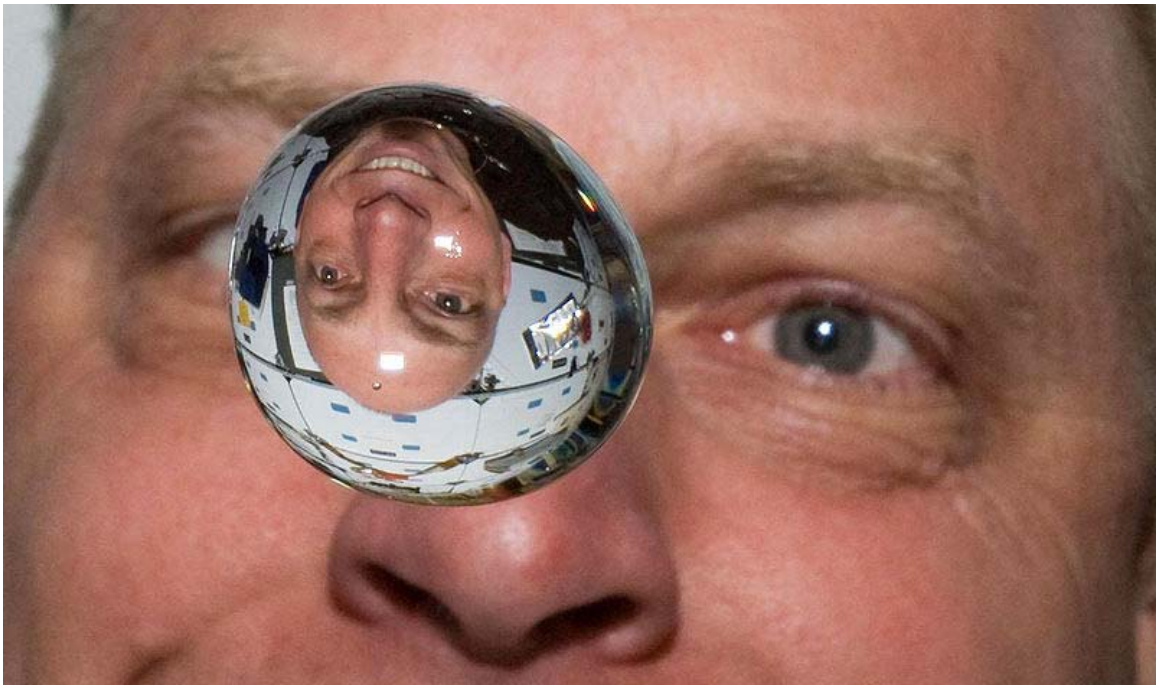
April 11 (Flight Day 7 - EVA 2)

On flight day 7 astronauts Clay Anderson and Rick Mastracchio performed their second spacewalk of the STS-131 mission. Mastracchio and Anderson exited the airlock at 05:30 UTC, a full 45 minutes ahead of the planned time, and spent 7 hours and 26 minutes outside the ISS. The pair removed the old Ammonia Tank Assembly (ATA) from the S1 truss and installed the new ATA. Anderson and Mastracchio ran into a small problem when one of the four bolts that holds the tank in place wouldn't turn. They loosened the other three and tried them all again and the fourth bolt was successfully tightened. The two spacewalkers helped guide the SSRMS to temporarily stow the old ATA on the truss structure. The new ATA had its electrical connections made, but the fluid connections were deferred until the third spacewalk since the EVA was behind the time-line. Mastracchio and Anderson also installed two radiator grapple fixture stowage beams on the P1 truss. While Anderson and Mastracchio were outside, members of the STS-131 crew continued transferring items from space shuttle *Discovery*'s mid-deck and the MPLM *Leonardo*. Overall, the crew had completed about half of the transfer work.



Mastracchio during EVA 2

April 12 (Flight Day 8 - Off duty)



Astronaut Clayton Anderson playing with a water bubble

The joint STS-131/Expedition 23 crews had the morning off on flight day 8. After their morning off the crews continued their transfer activities, which are more than seventy percent complete. The crews also conducted several PAO events, including VIP events with Roscosmos, Russian president Dmitry Medvedev, RSC Energia, the Japanese Aerospace Exploration Agency (JAXA), Japanese students, astronaut Mamoru Mohri, and Japanese dignitaries. Later commander Alan Poindexter, pilot Jim Dutton and mission specialists Dorothy Metcalf-Lindenburger and Stephanie Wilson participated in an in-flight interview with several American media outlets including Fox News, ABC World News and MSNBC. While the PAO events were going on, Rick Mastracchio and Clay Anderson were preparing the spacesuits and tools they will use for the third and final spacewalk. Later in the day the pair will have a procedures review with other members of the ISS and shuttle crews. After the review, they will enter the airlock, close the hatch and lower the pressure to 10.2 psi and breathe pure oxygen for their campout.

April 13 (Flight Day 9 - EVA 3)

On flight day 9, Rick Mastracchio and Clay Anderson completed the third and final spacewalk of the STS-131 mission. Their tasks included hooking up the ammonia and nitrogen lines to the new Ammonia Tank Assembly (ATA), installing the old ATA in the shuttle's payload bay, retrieving some Micro-Meteoroid Orbital Debris (MMOD) shields, bolting a grapple bar (which had been removed from the old ATA) onto the new ATA, and preparation of some cables on the Z1 truss and tools to be used during STS-132. During the installation of the old ATA in *Discovery'*s payload bay, the spacewalkers had some problems securing a bolt on the ATA to the LMC. The spacewalk took 6 hours and 24 minutes, bringing the total EVA time to 20 hours and 19 minutes. While the EVA was going on, commander Alan Poindexter and mission specialist Naoko Yamazaki continued transferring items from the MPLM to the ISS. Transfer is more than seventy-five percent complete.

Mastracchio & Anderson working in Discovery's aft payload bay during EVA 3

Clayton Anderson during EVA 3

April 14 (Flight Day 10 - Final transfers/off duty)

The crew of STS-131 continued with transfer activities on the morning of flight day 10. The morning was devoted largely to transferring items to the MPLM *Leonardo*. There are only a few items awaiting transfer to space shuttle *Discovery*'s mid-deck left. The crew enjoyed an hour long mid-day meal with the Expedition 23 crew. The entire joint crew took part in a crew photo, which was followed by a joint crew news conference with U.S., Russian and Japanese media. Later in the day commander Alan Poindexter, mission specialists Dorothy Metcalf-Lindenburger, Stephanie Wilson and Clayton Anderson took time out to talk with students from Eastern Guilford High School in Gibsonville, North Carolina and with third and fourth graders from that school district. The majority of the crews afternoon was spent off duty.

S131E010080

Naoko Yamazaki eats a snack in the Kibo laboratory

STS-131 and Expedition 23 crew members gather for a group portrait

April 15 (Flight Day 11 - MPLM unberthing)

On flight day 11 the MPLM *Leonardo*s hatches were closed at 07:38 UTC (03:38 EDT) and the MPLM was unberthed from the nadir or earth facing port of the Harmony node at 20:24 UTC (16:24 EDT). It was placed in a low hover, about 3 feet (0.91 m) above shuttle *Discovery'*s payload bay. This was done because the MPLM was unberthed from *Harmony* later than planned. The delay in unberthing was caused by a set of bolts on the Common Berthing Mechanism (CBM) getting stuck due to a broken pin. The crew will finish putting *Leonardo* in the payload bay on flight day 12, prior to the docked late inspection. The crews conducted some transfer operations between the ISS and shuttle mid-deck, which brings the overall transfer operations to ninety-four percent complete for the mission.

April 16 (Flight Day 12 - Late inspection)

The MPLM *Leonardo* secured in Discovery's payload bay.

On flight day 12, the crew of space shuttle *Discovery* secured the MPLM *Leonardo* in the payload bay for return to earth. Mission specialist Dorothy Metcalf-Lindenburger activated the latches to secure *Leonardo* in the payload bay at 07:15 UTC (03:15 EDT). After *Leonardo* was secured, Metcalf-Lindenburger, pilot Jim Dutton began the late inspection of *Discovery*'s heat shield. The pair were joined by commander Alan Poindexter and mission specialist Naoko Yamazaki to complete the inspection of the shuttle's Reinforced Carbon-Carbon (RCC) panels on the wings and nose and the heat-resistant tiles. The scan which takes about 7 hours was completed 3 hours ahead of schedule, and was done while still docked to the International Space Station (ISS) due to the loss of the shuttles K_u-Band antenna.

April 17 (Flight Day 13 - Undocking)

Space Shuttle *Discovery* successfully undocked from the International Space Station (ISS) at 12:52 UTC (08:52 EDT). *Discovery* was docked to the ISS for 10 days, 5 hours and 8 minutes. After *Discovery* departed from the ISS, pilot Jim Dutton took control of the shuttle and performed a fly around of the space station. The undocking was preceded by a farewell ceremony, where shuttle commander Alan Poindexter and station commander Oleg Kotov said farewells on behalf of their crews. After undocking the shuttle crew stowed the Orbiter Boom Sensor System (OBSS) and the Shuttle Remote Manipulator System (SRMS) since they will not be needed for the rest of the flight. The

crew was also informed that *Discovery*'s heat shield was cleared for re-entry in to Earth's atmosphere.

Discovery separates from the Space Station

The underside of *Discovery* soon after post-undocking relative separation

ISS seen from *Discovery* after undocking

April 18 (Flight Day 14 - Landing prep)

On flight day 14, the crew of space shuttle *Discovery* began their final preparations for landing. The crew packed and stowed away items they no longer need for the rest of the flight. Throughout the day commander Alan Poindexter and pilot Jim Dutton completed a series of checkouts of flight systems. These checks include 2 firings of the Reaction Control System (RCS) jets and a test of the Flight Control System (FCS). Once those checkouts were complete the pair began doing communications checkouts with the Merritt Island tracking station and tracking stations at the White Sands Space Harbor in New Mexico and Dryden Flight Research Center at Edwards Air Force Base. The crew also took time out of their day to conduct an in-flight interview with WBZ-AM in Boston, Massachusetts, the Associated Press and KEZI-TV in Eugene, Oregon.

April 19 (Flight day 15 - First landing opportunity)

The crew of STS-131 awoke for flight day 15 and began their deorbit preparations. These preparations include closing the payload bay doors, activating the Flash Evaporator System (FES) and getting into their Advanced Crew Escape Suits (ACES). The crew got as far as "fluid loading", where the crew consumes a set quantity of fluids to counteract the effects of gravity, in their deorbit preps. The crew was informed of the one orbit wave off about one hour prior to the deorbit burn. After the crew was told of the wave off, they held in their procedures to see if they would be given a go for the second landing opportunity. However, they were not given a go for the second chance and the crew began backing out of their deorbit preps. Both landing chances were waved off due to bad weather at the Kennedy Space Center.

April 20 (Flight day 16 - Landing)

Space shuttle Discovery landed at 09:08 EDT (13:08 UTC) on runway 33 at Florida's Kennedy Space Center following a two-week mission in space.

Discovery lands on runnaway 33 at KSC ending the STS-131 mission

Flyover cities during the landing

Crew on the tarmac

Spacewalks

At least three spacewalks were planned for this mission. The main objectives for the three EVAs were as follows:

EVA	Spacewalkers	Start (UTC)	End (UTC)	Duration
EVA 1	Rick Mastracchio Clayton Anderson	9 April 05:31	9 April 11:58	6 hours 27 minutes
	The crew inside used the station's robotic arm to remove a new ammonia tank from shuttle's payload bay and temporarily stow it on the station. The spacewalkers then retrieved a seed experiment from outside the Japanese laboratory, installed a grapple bar to the new ammonia tank on the station's truss and replaced a failed gyroscope that is part of the station's navigation system, along with several get-ahead tasks.			
EVA 2	Mastracchio Anderson	11 April 05:30	11 April 12:56	7 hours 26 minutes
	Crew members, using the station's arm, removed an empty ammonia tank from the station's truss and temporarily stowed it on an equipment cart. The new tank was then installed and electrical connections were made to it. The station's arm then temporarily stowed the old tank on another part of the station's structure until the mission's third spacewalk.			

	Mastracchio Anderson	13 April 06:14	13 April 12:36	6 hours 24 minutes
EVA 3	Using the station's arm, the crew moved the old tank into the shuttle's payload bay for return to Earth. The spacewalkers also removed a grapple bar from the old ammonia tank and attached it to the new one. The pair then relocated a foot restraint and some tools and prepared some cables for the STS-132 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	“Find Us Faithful”	Steve Green	Clay Anderson	WAV, MP3 TRANSCRIPT
Day 3	“I Will Rise”	Chris Tomlin	Jim Dutton	WAV, MP3 TRANSCRIPT
Day 4	“Hato to Shōnen” (The Pigeons and a Boy)	Joe Hisaishi	Naoko Yamazaki	WAV, MP3 TRANSCRIPT
Day 5	"Defying Gravity"	Idina Menzel & Kristen Chenoweth	Dorothy Metcalf-Lindenburger	WAV, MP3 TRANSCRIPT
Day 6	"We Weren't Born to Follow"	Bon Jovi	Rick Mastracchio	WAV, MP3 TRANSCRIPT
Day 7	“Stairway To The Stars”	Ella Fitzgerald	Stephanie Wilson	WAV, MP3 TRANSCRIPT
Day 8	“Because We Believe”	Andrea Bocelli	Alan Poindexter	WAV, MP3 TRANSCRIPT
Day 9	“Galileo”	Indigo Girls	Dorothy Metcalf-Lindenburger	WAV, MP3 TRANSCRIPT
Day 10	“The Miracle of Flight”	Mike Hyden	Clay Anderson	WAV, MP3 TRANSCRIPT
Day 11	“The Earth in the Color of Lapis Lazuli”	Seiko Matsuda	Naoko Yamazaki	WAV, MP3 TRANSCRIPT
Day 12	Opening theme to Stargate SG-1	Joel Goldsmith	Rick Mastracchio	WAV, MP3 TRANSCRIPT
Day 13	"Joy"	Newsboys	Jim Dutton	WAV, MP3 TRANSCRIPT
Day 14	"What A Wonderful World"	Louis Armstrong	Stephanie Wilson	WAV, MP3 TRANSCRIPT

Day 15	"Star Spangled Banner"		Alan Poindexter	WAV, MP3 TRANSCRIPT
Day 16	"On The Road Again"	Willie Nelson	The entire crew	WAV, MP3 TRANSCRIPT

Chapter- 5

STS-132

STS-132

Mission insignia

Mission statistics

Mission name	STS-132
Space shuttle	*Atlantis*
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	Subsequent mission
STS-131	STS-133

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

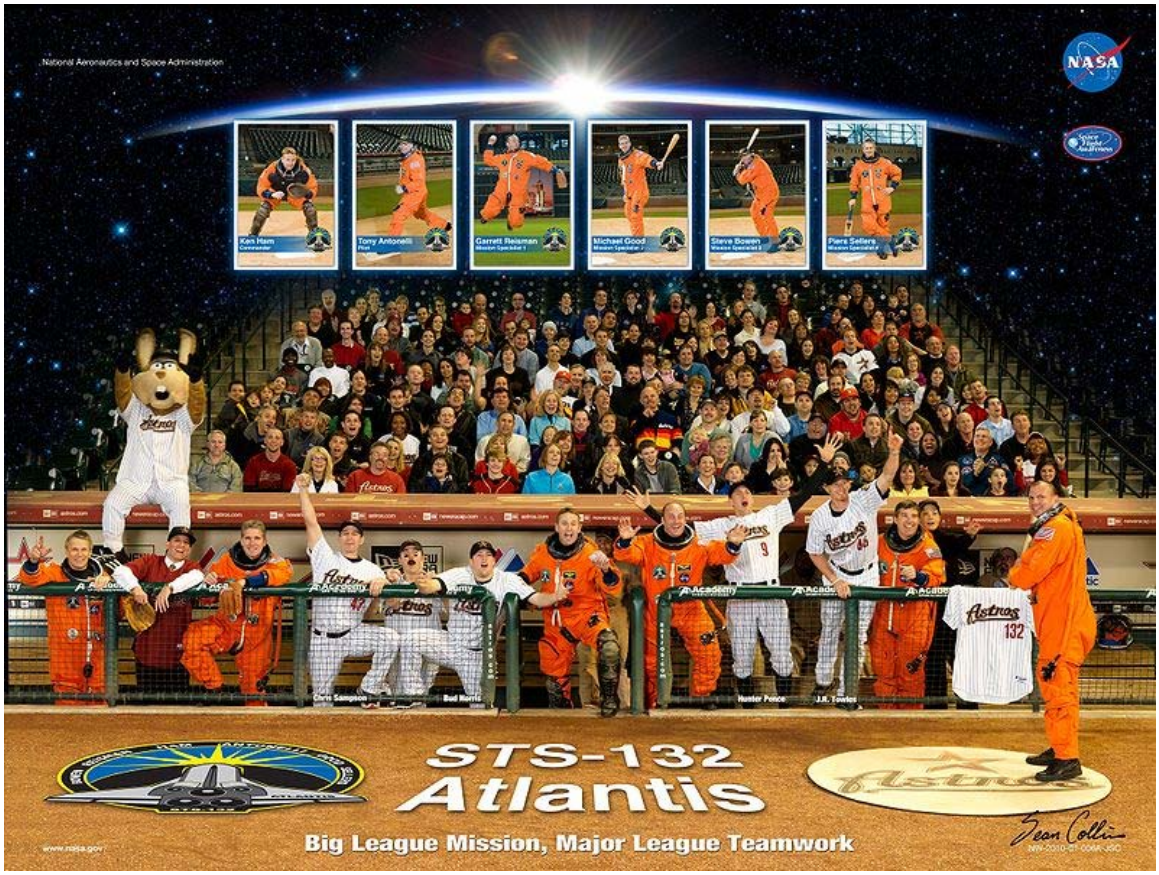
On 11 August 2009, Karen Nyberg was replaced by Michael Good as Mission Specialist 1 due to a temporary medical condition.

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

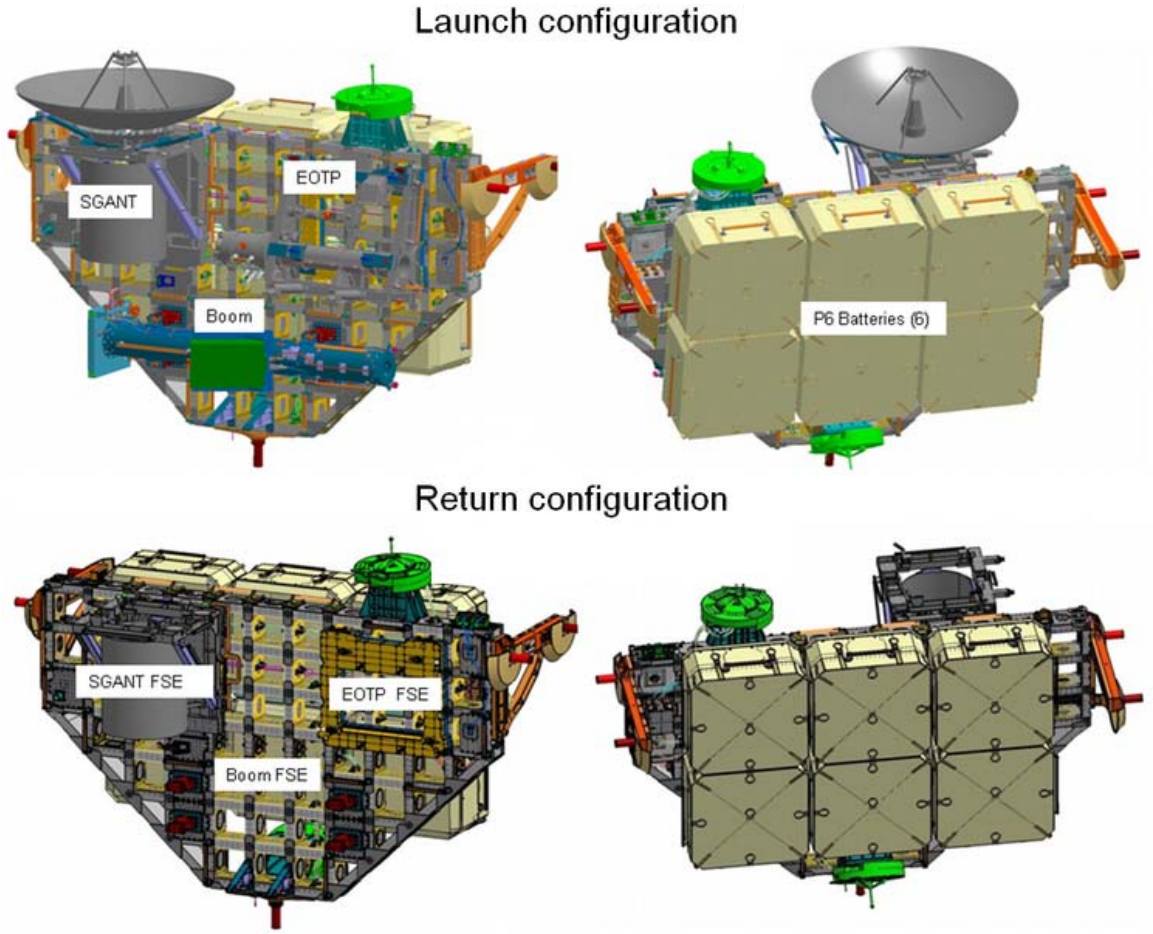
Location	Cargo	Mass
Bays 1-2	Orbiter Docking System EMU 3004 / EMU 3011 / EMU 3018	1,800 kilograms (4,000 lb) ~390 kilograms (860 lb)
Bay 3P	Shuttle Power Distribution Unit (SPDU)	~17 kilograms (37 lb)
Bay 5P	Power & Data Grapple Fixture (PDGF)	~71 kilograms (160 lb)
Bays 6-7	ICC-VLD carrier -6 Battery 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)



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.

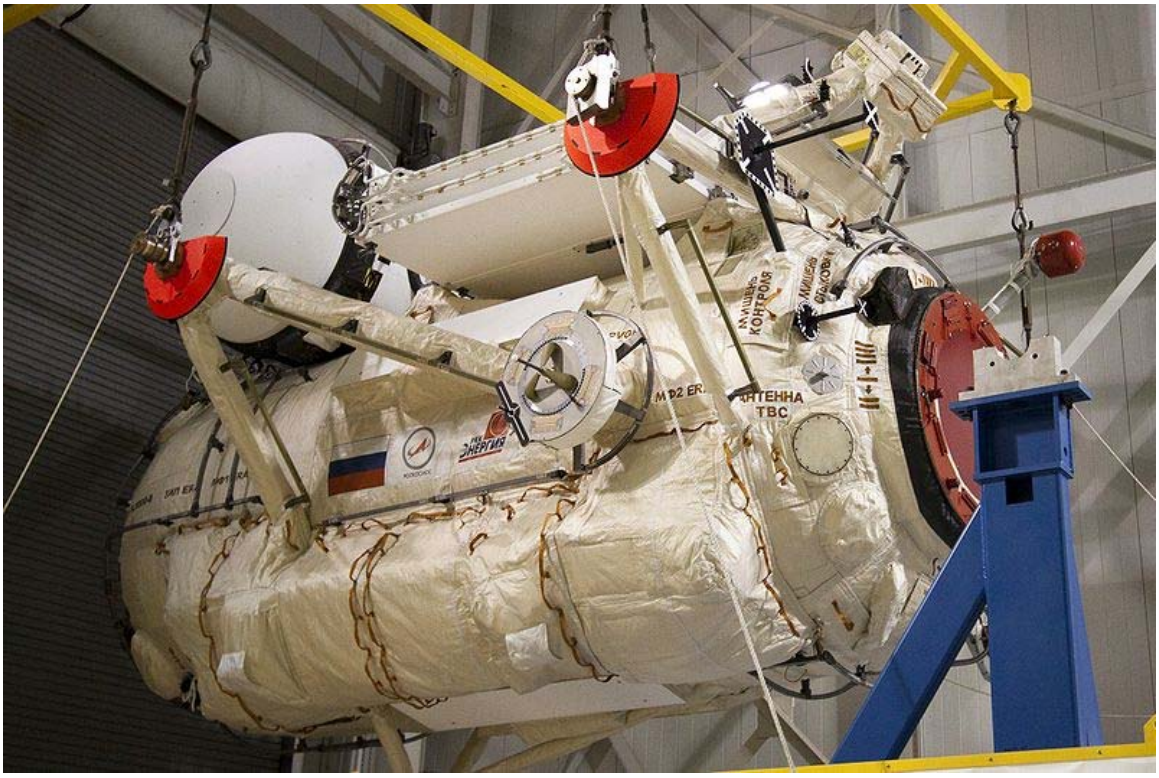
A compact disk (CD) containing the digital copies of all entries submitted to NASA's Space Shuttle Program Commemorative Patch Contest will be flown aboard *Atlantis*. The contest was organized the Space Shuttle Program to mark the end of the shuttle era. The winning patch was designed by Mr. Blake Dumesnil 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.

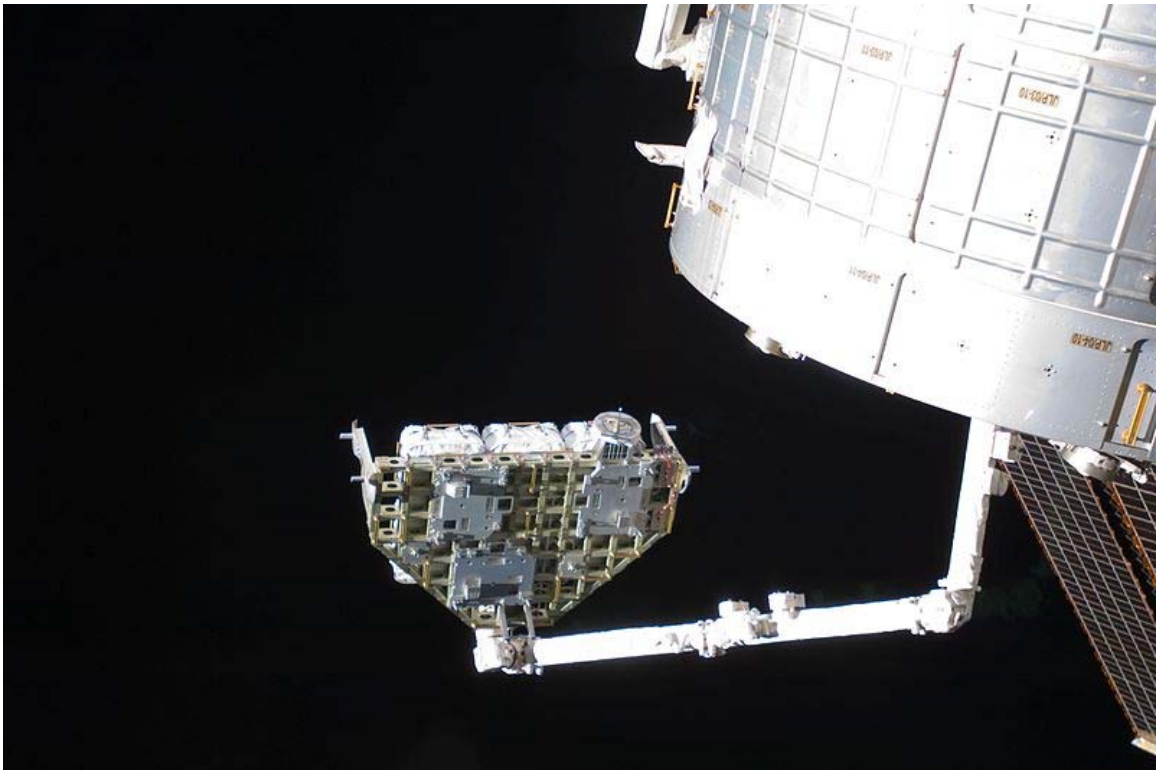
A flag from Clarkson University, Potsdam, New York, will fly on board shuttle *Atlantis*. It will be there in honor of STS-132 lead shuttle flight director, Michael L. Sarafin, who is an alumnus of the Clarkson University.

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*.

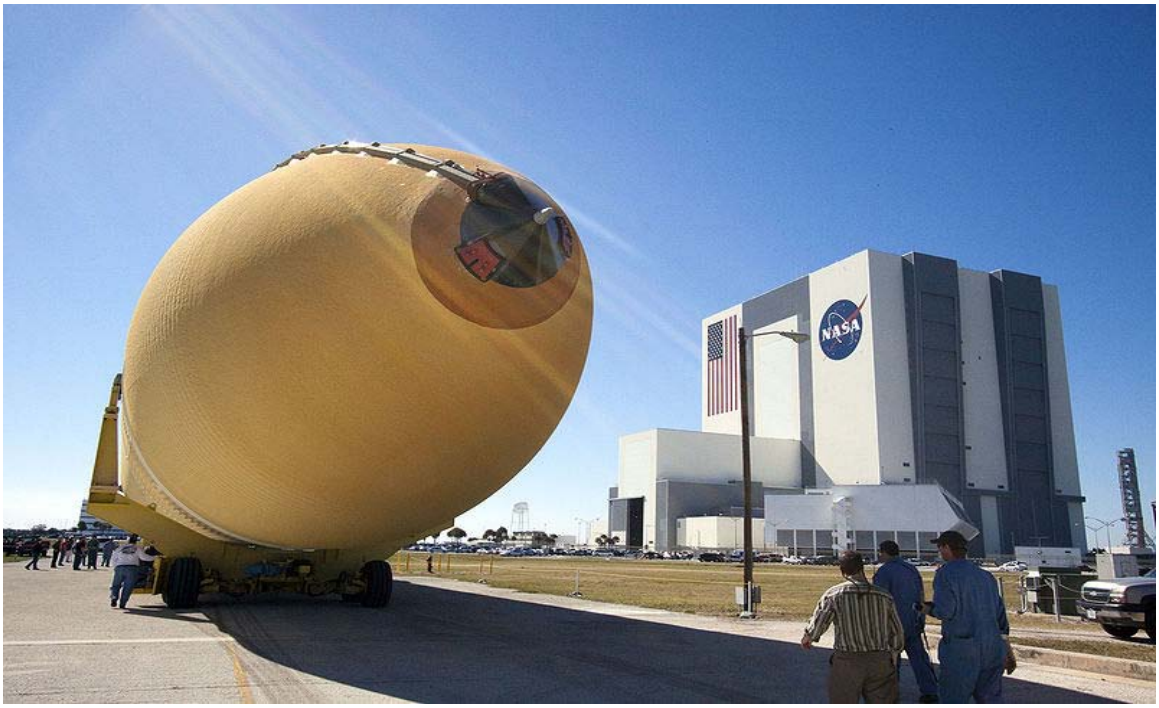
Mission experiments

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)

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

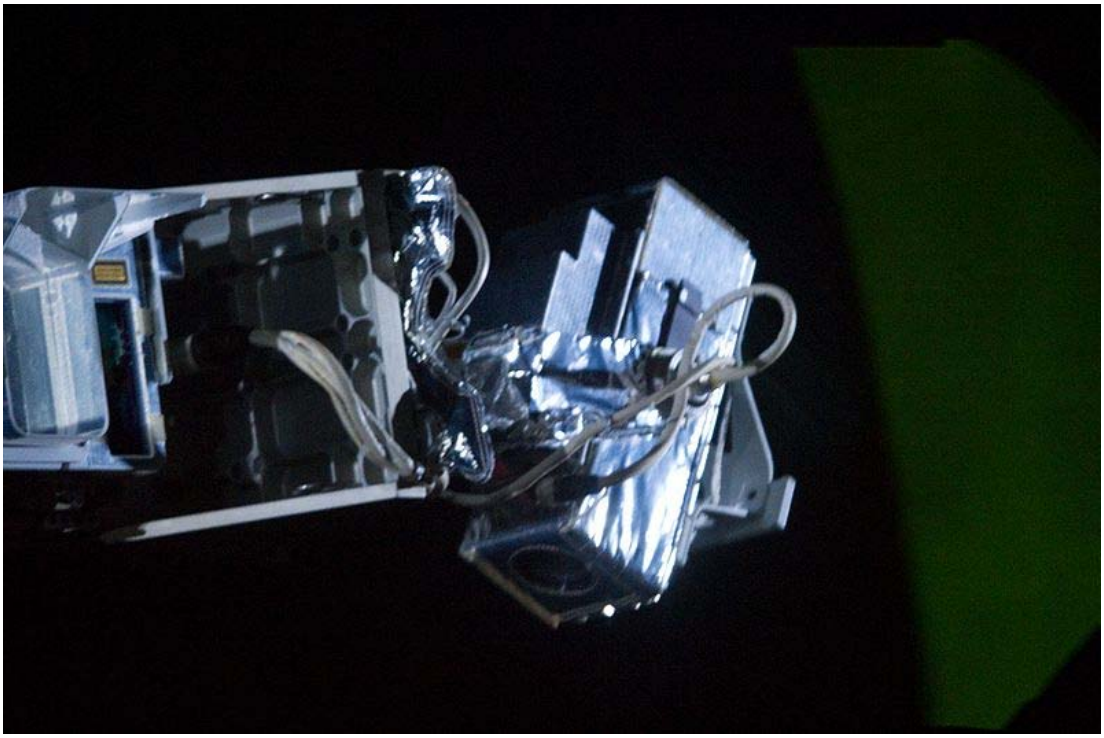
The crew members aboard *Atlantis* began their first full day in space at 08:20 UTC. The day was primarily devoted to inspecting *Atlantis's* thermal protection system using the shuttle's robotic arm and the Orbiter Boom Sensor System (OBSS) to look for any signs of launch damage. Before the thermal 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.

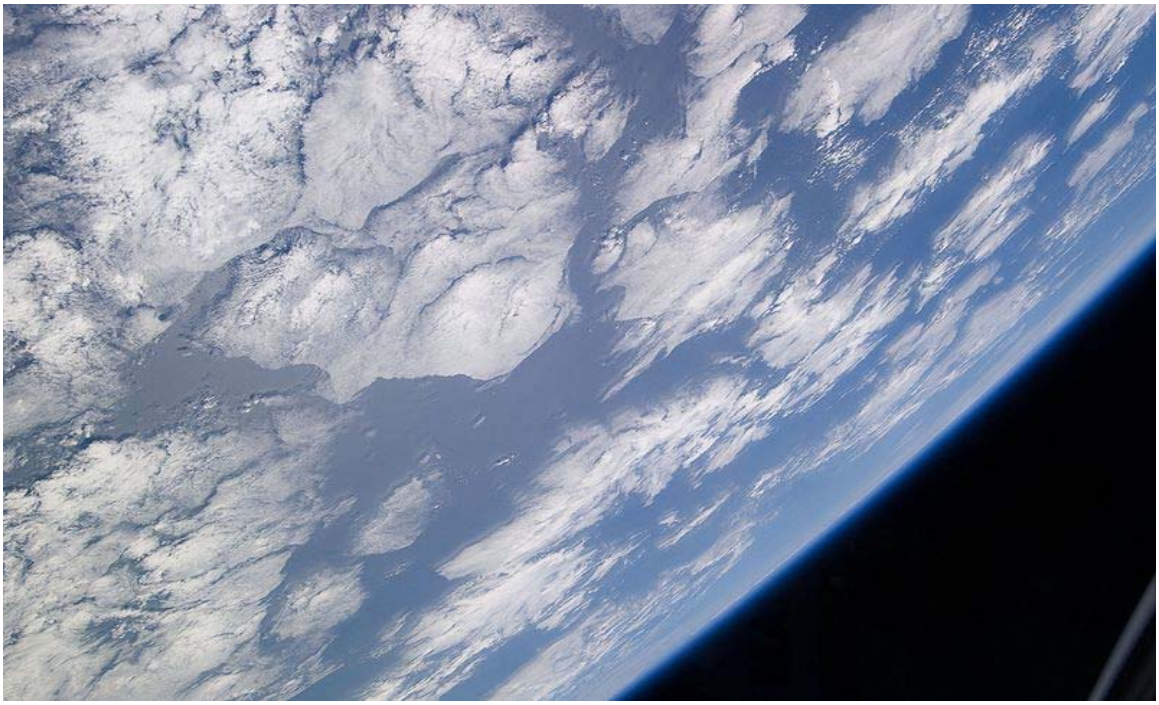
Two course correction burns were also be performed on Flight Day 2. The first 10 second NC-2 burn was performed using the right-hand OMS engine, changing the shuttle's speed by 8 ft/s (2.4 m/s). The burn raised both the apogee and perigee of shuttle's orbit by 1-mile (1.6 km). Atlantis' reaction control 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

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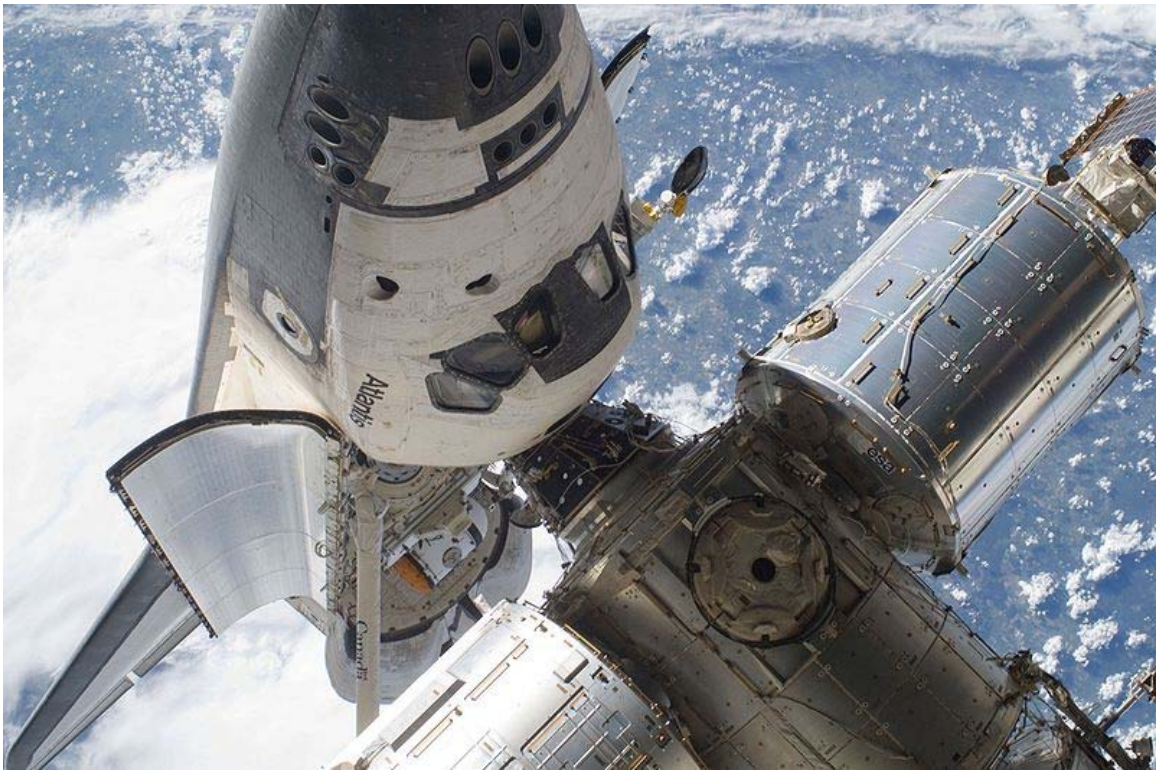
Tony Antonelli

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

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.

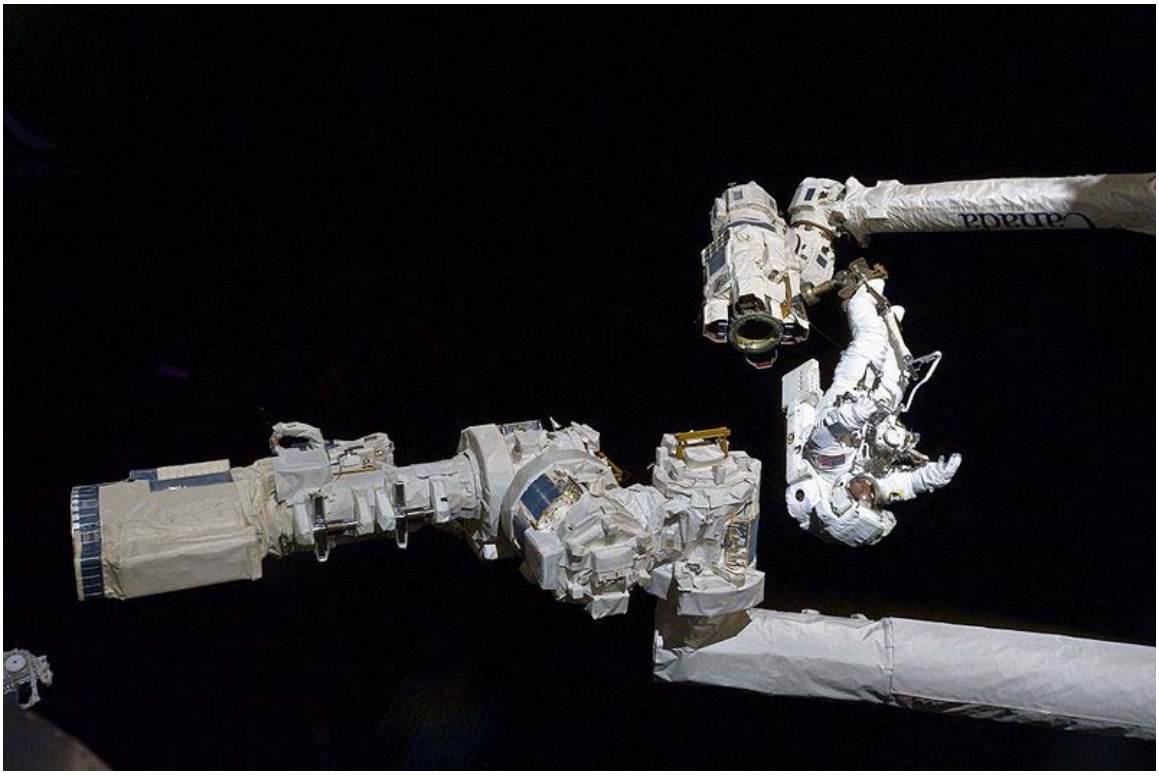
Expedition 23 Flight Engineer Creamer helped the duo with the suit-up preparations. Mike Good joined STS 132 Pilot Antonelli, the intravehicular officer, to assist during the spacewalk. Mission Specialist Sellers and station Flight Engineer Caldwell Dyson operated the robotic arm. Throughout EVA 1, Commander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

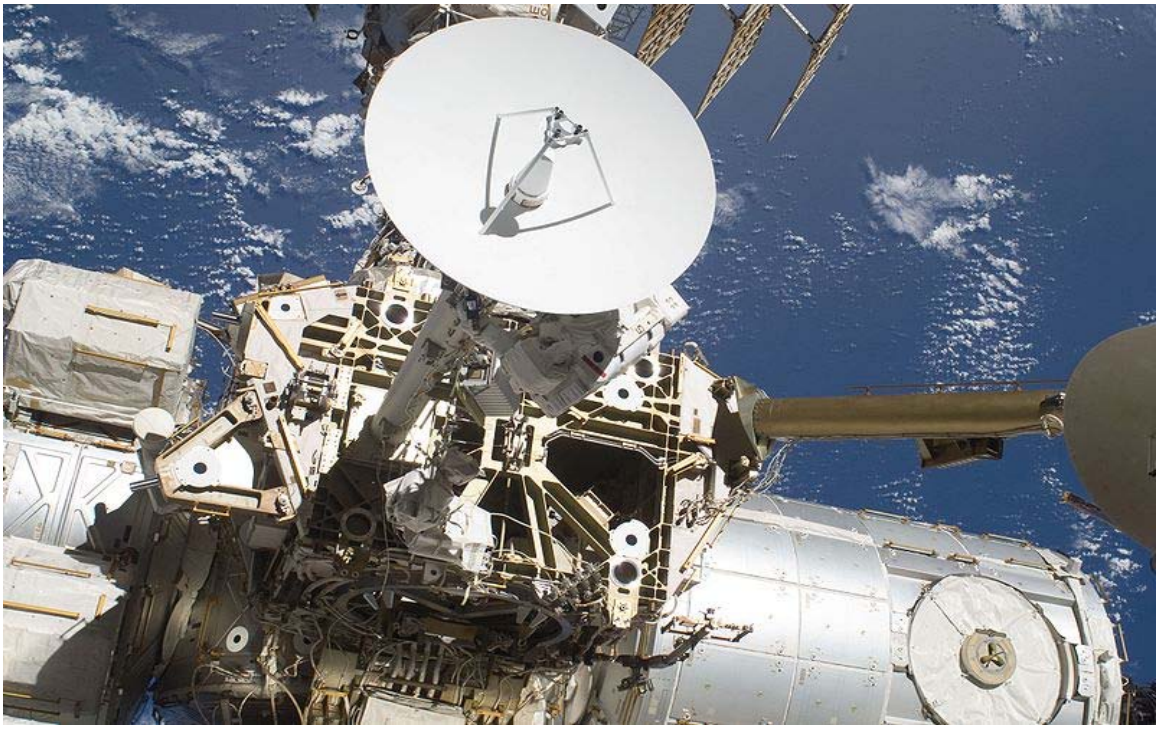
The spacewalk ended at 19:19 UTC after Reisman and Bowen took inventory of the tools they brought with them outside and made their way back into the Quest airlock. EVA 1 was the 237th conducted by U.S. astronauts, the second for Reisman and the fourth for Bowen. It was also the 144th in support of International 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.

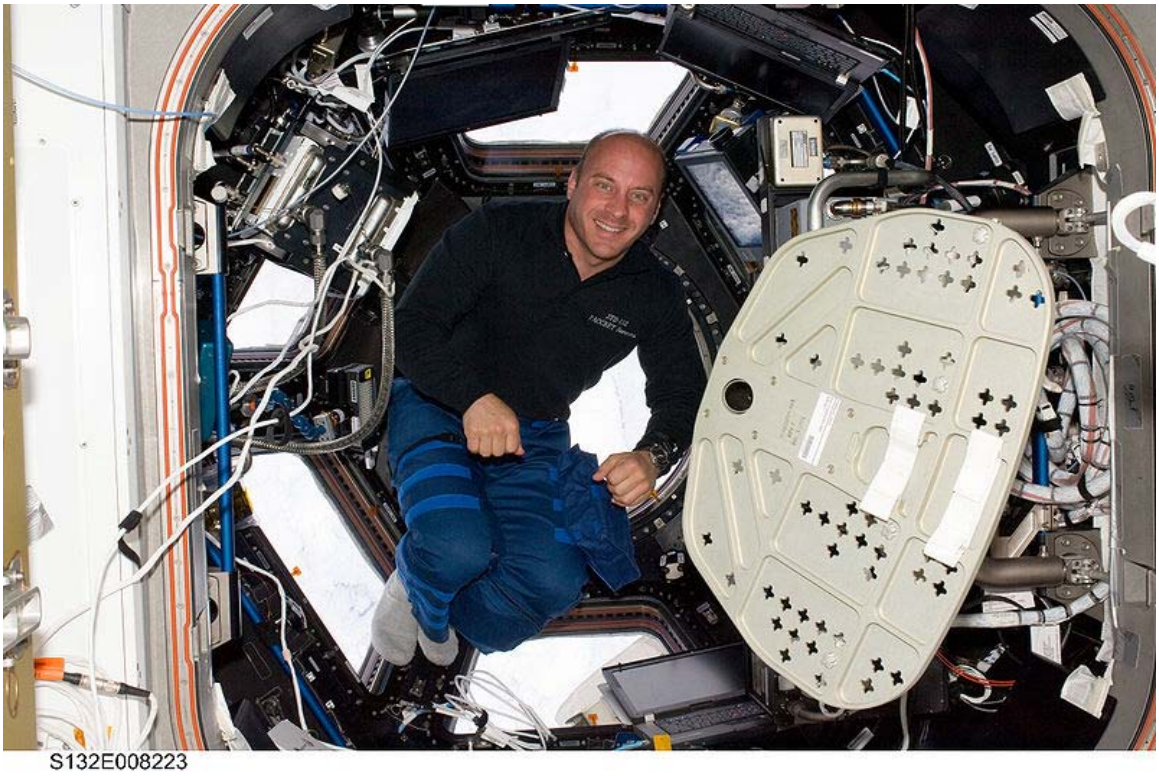
After mid day, Reisman and Sellers used Canadarm2 to unberth OBSS from the sill of Atlantis' cargo bay and handed it off to the shuttle's robotic arm, operated by Ham and Antonelli.

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.

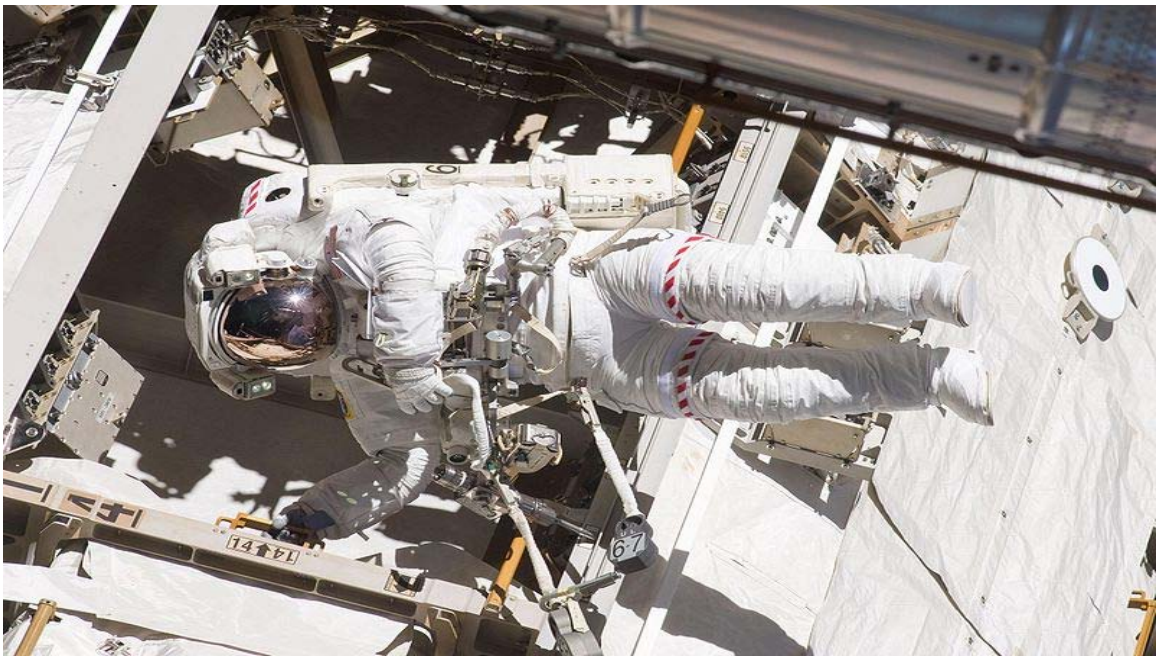
Canadarm2 transfers MRM-1 to the Earth-facing port of the Zarya module

Canadarm2 attaches MRM-1 to the Zarya module



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.

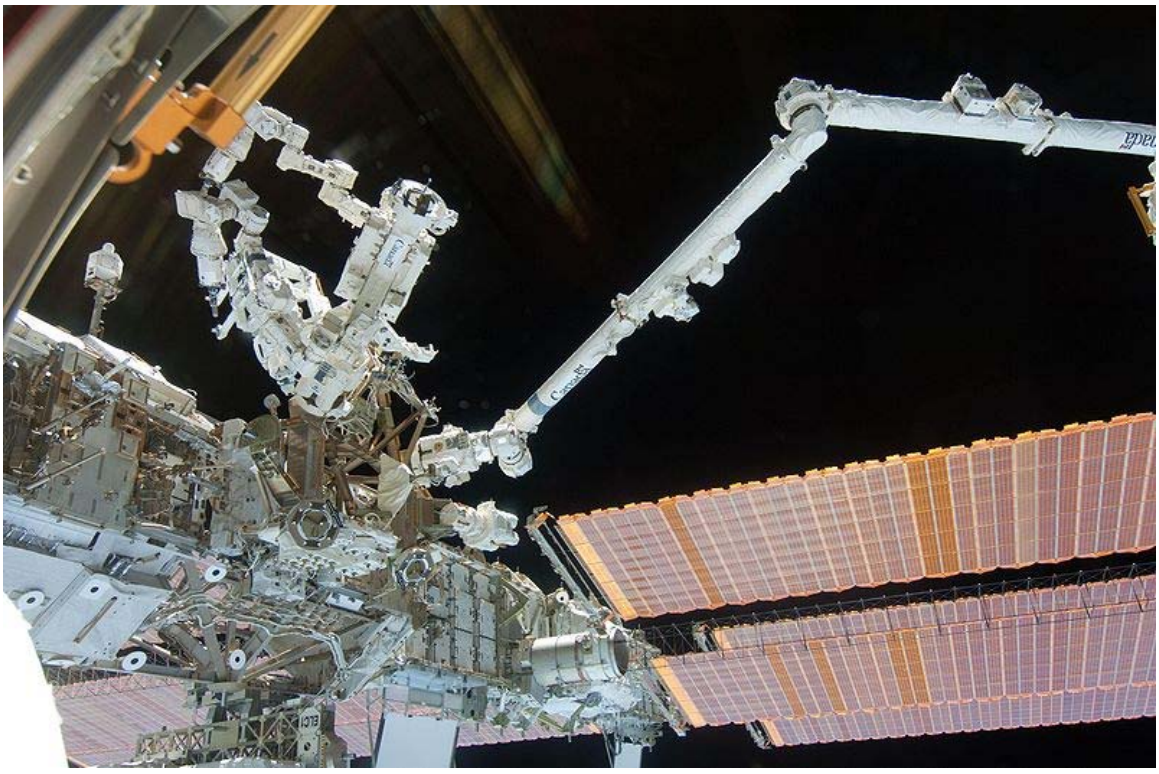
May 20 (Flight Day 7 - MRM-1 initial checks, transfers and off duty)

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

ISS023E047841

Reisman participates in EVA 3

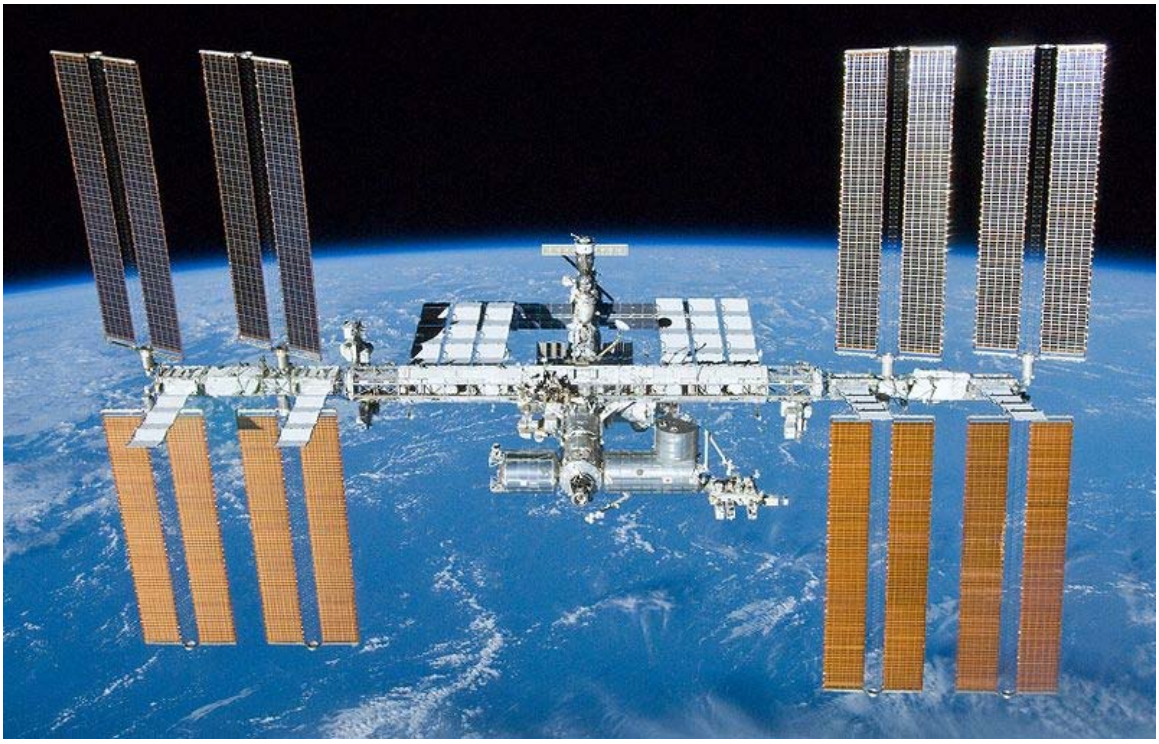
May 22 (Flight day 9 - Off duty)

ISS023E050361

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

ISS023E051233

Departing Atlantis as photographed by a station crew member

Atlantis separates from the ISS after undocking

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, begun 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)

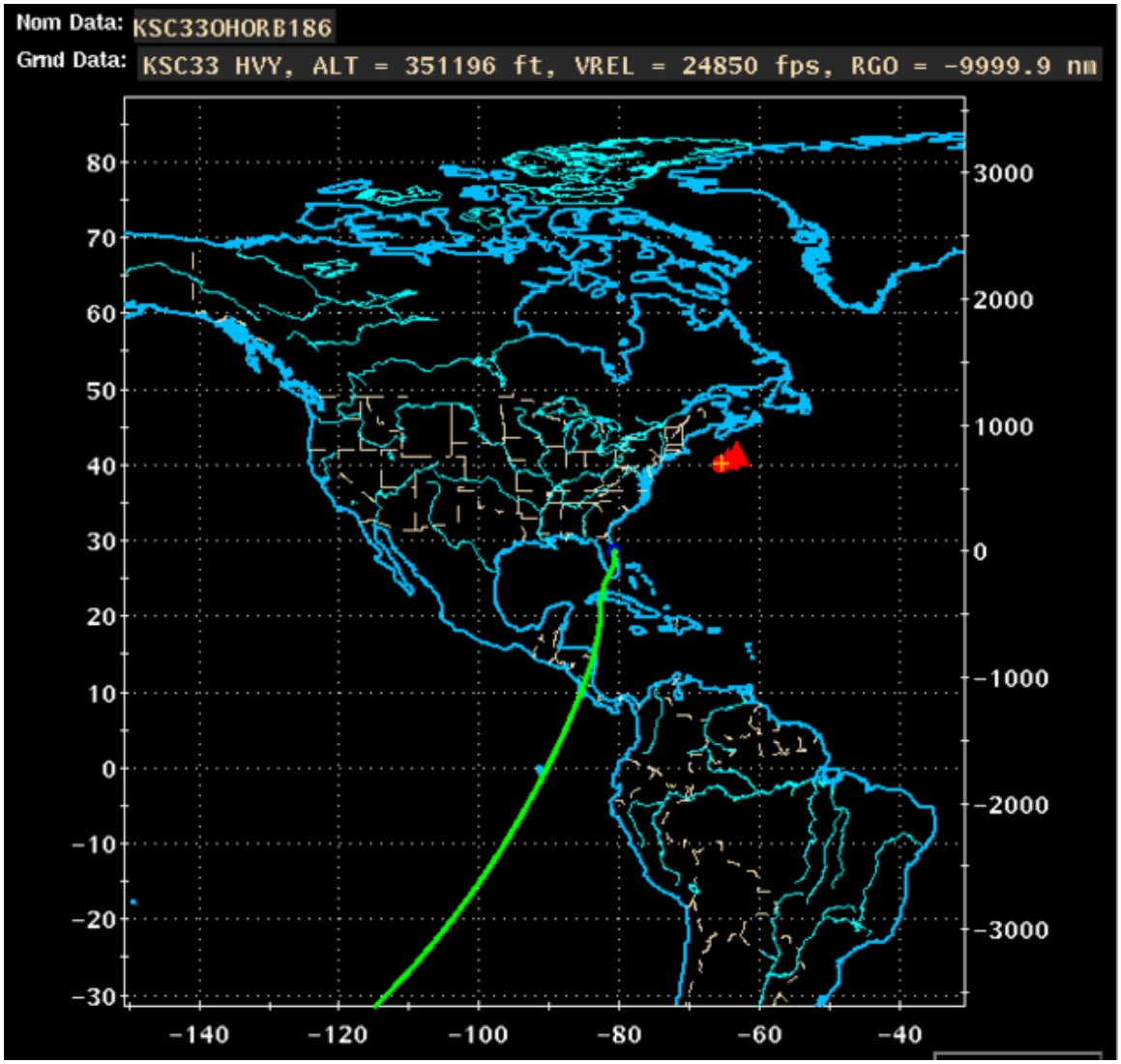
STS-132 ends as Space Shuttle *Atlantis* landed on May 26, 2010, at Kennedy Space Center's Shuttle Landing Facility.

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) and 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.

Atlantis reaches OPF-1 after landing



Long-range ground track

Atlantis approaches Runway 33

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

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 Steve Bowen	17 May 11:54	17 May 19:19	7 hours 25 minutes
	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.			
EVA 2	Steve Bowen Michael Good	19 May 10:38	19 May 17:47	7 hours 9 minutes
	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.			
EVA 3	Michael Good Garrett Reisman	21 May 10:27	21 May 17:13	6 hours 46 minutes
	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 Stones	Piers Sellers	WAV, MP3 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

Chapter- 6

Picard (Satellite) and Chang'e 2

Picard

Picard	
Launch date	June 15, 2010

PICARD is a satellite dedicated to the simultaneous measurement of the absolute total and spectral solar irradiance, the diameter and solar shape, and to the Sun's interior probing by the helioseismology method. These measurements obtained throughout the mission will allow study of their variations as a function of solar activity. It launched, along with the Prisma spacecraft, on June 15, 2010 on a Dnepr-1 launcher from Dombarovskiy Cosmodrome, near Yasny, Russia.

Objectives

The objectives of the PICARD mission are to improve our knowledge of:

- the functioning of our star through new observations,
- the influence of the solar activity on the climate of the Earth.

History

The PICARD mission was named after the French astronomer of the 17th century Jean Picard (1620–1682) who achieved the first accurate measurements of the solar diameter. These measurements are especially important as they were made during a period when the solar activity was minimum characterized by a sun nearly without sunspots between 1645 and 1710. This period was found by Gustav Spörer using sunspots observations gathered in Europe and this period is now named Maunder minimum. By comparing the diameter during the Maunder minimum and the diameter when the sun was active a variation has been found, leading to the still unanswered question "Are diameter and activity linked?". During this period in Europe, there was an unusually cold climate.

Platform

PICARD will use the MYRIADE microsatellite platform, developed by CNES to use as much as possible common equipments. This platform was designed for a total mass of about 120 kg mass at launch. Its attitude in space is maintained by using a star sensor, solar sensors, a magnetometer, gyrometers, several magnetic rods and reaction wheels. If an orbit control and orbit manoeuvres are needed, a hydrazine system may be used. The on-board management is centralised, and uses a 10 MIPS microprocessor T805. A mass memory is available for the data storage. The telemetry and telecommand use CCSDS standard.

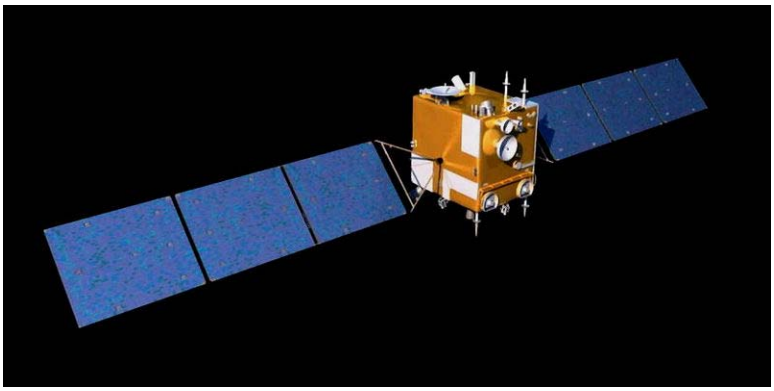
Payload

The PICARD payload is composed of the following instruments:

- **SOVAP** (SOlar VAriability PICARD): composed of a differential radiometer and a bolometric sensor to measure the total solar irradiance (previously called solar constant),
- **PREMOS** (PREcision MOnitor Sensor): a set of 3 photometers to study the ozone formation and destruction, and to perform helioseismologic observations, and a differential radiometer to measure the total solar irradiance.
- **SODISM** (SOlar Diameter Imager and Surface Mapper): an imaging telescope accurately pointed and a CCD which allows to measure the solar diameter and shape with an accuracy of a few milliarc second, and to perform helioseismologic observations to probe the solar interior.

Chang'e 2

Chang'e 2



Operator	CNSA
Mission type	Orbiter / impactor
Satellite of	The Moon
Launch date	2010-10-01, 10:59:57 UTC
Carrier rocket	Long March 3C
Launch site	Xichang Satellite Launch Center Xichang, Sichuan, China
Mission duration	> 6 months elapsed: 3 months, and 16 days
COSPAR ID	2010-050A
Mass	2,500 to 2,600 kg (5,500 to 5,700 lb)
	Orbital elements
Apoapsis	100 km (62 mi)
Periapsis	15 km (9.3 mi)
	Instruments
Main instruments	Charge-Coupled Device (CCD) improved stereo camera Laser altimeter Gamma/X-ray Spectrometers Microwave Detector

Spatial resolution	10 meter at 100 km altitude and 1.5 meter at 15 km altitude

Chang'e 2, is a Chinese un-manned lunar probe that was launched on 1 October 2010. It is a follow-on to the Chang'e 1 lunar probe launched in 2007 and is part of the first phase of the Chinese Lunar Exploration Program. The probe will conduct research at a 100-kilometer-high lunar orbit as a preparation for a soft landing by Chang'e 3. Chang'e 2 is similar to Chang'e 1 with some improvements, including a better camera with a resolution of one meter. It is named after a legendary Chinese goddess of the moon. The total expenditure for the Chang'e 2 mission is approximately CN¥900 million, or US$134 million.

Description

Chang'e 2 is similar to the Chang'e 1 mission, but has important differences. While Chang'e 1 operated in a 200-kilometer orbit, Chang'e 2 is flying at only 100 kilometers, leading to better quality and resolution of the science data. Chang'e 2 also has a higher resolution camera.

Some other key differences between Chang'e 1 and Chang'e 2, as summarized by Qian Huang of the Shanghai Astronomical Observatory and Yong-Chun Zheng of the NAOC:

- Chang'e 2 will have a shorter Earth to Moon cruise of 5 days rather than 12 days. The launch rocket has two more boosters to accomplish this more direct route to the Moon.
- The laser altimeter's footprint will be smaller, and will achieve 5-meter vertical accuracy in estimate of the Moon's radius. It will also pulse more frequently, five times per second rather than just 1 time per second.
- The main camera's spatial resolution will be 10 meters rather than 120 meters.
- Late in the mission, the orbit will be lowered to an elliptical one with the same apolune (100 kilometers) but a perilune of only 15 kilometers
- Tracking will be performed with new X-band radio capability.

Zheng also remarked that "The mission goals of CE-2 will be focused into the high resolution image for the future landing site of CE-3 lunar lander and rover. The key technology about soft landing on the Moon will be tested in the CE-2 mission. The success of CE-2 will provide important technical basis for the successful implementation of China's future lunar exploration."

Launch

Chang'e 2 spacecraft was launched on 1 October 2010 at 10:59:57 UTC, aboard a Long March 3C rocket from Xichang Satellite Launch Center in Xichang, Sichuan. The spacecraft entered an orbit with a perigee of 200 kilometers and apogee of 380,000

kilometers and separated from the carrier rocket as planned. It was the first time that a Chinese lunar probe directly entered the earth-moon transfer orbit without orbiting the earth first. After the launch, Chang'e 2 was expected to arrive at its lunar orbit in about 112 hours (about 4 days and 16 hours), much faster than the 12 days taken by Chang'e 1. Later, the probe was to lower its orbit to 100 km (62 mi) and have a lower point of only 15 km (9.3 mi). Chang'e 2 entered its 100 km working orbit on 9 October 2010 after three successful brakings. On 8 November 2010, China announced the success of all missions of Chang'e 2 and published moon surface images with resolution up to 1.3 metres.

Significance

The launch of the probe coincided with the National Day of the People's Republic of China, on October 1, in a symbolic celebration of the country's 61st anniversary.

Chapter- 7

Soyuz TMA-01M

Soyuz TMA-01M
Союз TMA-01M

Mission insignia

Mission statistics

Mission name	Soyuz TMA-01M Союз TMA-01M
Spacecraft name	Soyuz-TMA-M
Crew size	3
Call sign	Ингул ("Ingul")
Launch pad	Baikonur Cosmodrome Gagarin's Start
Launch date	October 7, 2010 23:10:55 UTC
Landing	March 16, 2011
Apogee	199.85 km
Perigee	258.77 km
Orbital period	88.81 min

Orbital inclination	51.63 degrees (initial orbit)

Crew photo

From left to right: Kelly, Kaleri and Skripochka

Related missions

Previous mission	Subsequent mission
Soyuz TMA-19	Soyuz TMA-20

Soyuz TMA-01M is a Soyuz flight currently docked with the International Space Station.

It transported three members of the Expedition 25 crew to the International Space Station. TMA-01M is the 107th flight of a Soyuz spacecraft, and the first flight of the modernized TMA-M series. The spacecraft will probably remain docked to the space station for the remainder of Expedition 25, to serve as an emergency escape vehicle. The spacecraft's COSPAR ID is 2010-052A.

Crew

The Soyuz TMA-01M prime and backup crews conduct their ceremonial tour on 17 September 2010.

The Soyuz TMA-01M crew was confirmed by NASA on November 21, 2008.

Position	Crew Member
Commander	Aleksandr Kaleri Expedition 25 Fifth spaceflight
Flight Engineer 1	Oleg Skripochka

	Expedition 25 First spaceflight
Flight Engineer 2	Scott J. Kelly, NASA Expedition 25 Third spaceflight

Backup crew

Position	Crew Member
Commander	Sergey Volkov, RSA
Flight Engineer 1	Oleg Kononenko, RSA
Flight Engineer 2	Ronald Garan, NASA

Spacecraft

Soyuz TMA-01M is the first spacecraft of the new modernized Soyuz TMA-M series, developed and built by RKK Energia as an upgrade of the baseline Soyuz-TMA, which has been in use since 2002. 36 obsolete pieces of equipment have been replaced with 19 new-generation devices and the vehicle's total mass has been reduced by 70 kilograms (154 lbs). In particular, the old Argon-16 computer control system, which has been used on Soyuz ships for more than 30 years, has been replaced with a new digital onboard computer, the TsVM-101. Power consumption has been reduced throughout the ship. There are also changes to the spacecraft's structure, such as replacing the magnesium alloy used in the instrument module frame by aluminum alloy, to make the ship easier to manufacture.

The modernized Soyuz ship will also enable engineers to test new equipment which may also be used in Russia's next generation manned space ship that is currently under development.

NASA astronaut Scott Kelly, part of Soyuz TMA-01M's crew, praised the ship's new displays, saying that they make flying easier and less operator intensive.

Two flight development tests are planned: Soyuz TMA-01M and Soyuz TMA-02M. The third ship, Soyuz TMA-03M will be used for qualification tests. In addition to verifying the nominal operation of the spaceship, the testing will include verification of off-nominal modes, such as manual altitude control, issuing of orbital maneuvering pulses using four berthing and attitude thrusters, and flying around the ISS in manual control mode.

The Soyuz TMA-01M launches from the Baikonur Cosmodrome

After the launch of Soyuz TMA-01M, Russian space officials said the new spacecraft performed normally with no problems of any significance. "Soyuz TMA-01M is a digital spacecraft, digital vehicle. As you saw today, it worked extremely well, it was an automatic flight, 100 percent automatic," said Vitaly Lopota, president RSC Energia.

Mission highlights

Launch

The spacecraft lifted off aboard a Soyuz-FG rocket from the Baikonur Cosmodrome at 23:10:55 UTC on Thursday, October 7, 2010 (5:10:55 AM Friday at local time). In 9 minutes, the vehicle reached low earth orbit with the following parameters: min altitude – 199,85 km; max altitude – 258,77 km; revolution – 88,81 min; inclination– 51,63 degrees. Soon after the orbital insertion, the spacecraft unfolded its solar panels and antennas, and flight control gave the ship green light for starting its approach to the International Space Station.

Docking

The Soyuz TMA-01M spacecraft approaches the ISS

The Soyuz TMA-01M spacecraft linked up with the space station at 00:01 UTC on Sunday, October 10, 2010 precisely one minute ahead of schedule. Docking to the Poisk module occurred when both spacecraft were flying more than 220 miles (354 km) above the southern Pacific Ocean, just off the coast from Chile. A few moments later, hooks and latches engaged to pull the spacecraft firmly into place and after extensive leak checks, hatches were opened at 03:09 UTC.

Chapter- 8

Soyuz TMA-18

Soyuz TMA-18
Союз ТМА-18

Mission insignia

Mission statistics

Mission name	Soyuz TMA-18 Союз ТМА-18
Crew size	3
Call sign	утес ("cliff")
Booster	Soyuz-FG
Launch pad	Baikonur Cosmodrome Site 1/5
Launch date	April 2, 2010 04:04 GMT
Landing	September 25, 2010 05:23 GMT

Crew photo

From left to right: Caldwell Dyson, Skvortsov and Korniyenko

Related missions

Previous mission	Subsequent mission
Soyuz TMA-17	Soyuz TMA-19

Soyuz TMA-18 was a 2010 Soyuz flight to the International Space Station. TMA-18 was the 105th manned flight of a Soyuz spacecraft since the first manned flight in 1967.

Crew

Position	Crew Member
Commander	Aleksandr Skvortsov Expedition 23 First spaceflight
Flight Engineer 1	Mikhail Korniyenko Expedition 23 First spaceflight
Flight Engineer 2	Tracy Caldwell Dyson, NASA Expedition 23 Second spaceflight

Backup Crew

Position	Cosmonaut
Commander	Aleksandr Samokutyayev
Flight Engineer 1	Andrei Borisenko
Flight Engineer 2	Scott J. Kelly, NASA

Launch

Soyuz TMA-18 launches from Baikonur Cosmodrome, April 2, 2010

After a successful launch on April 2, 2010 the Soyuz TMA-18 spacecraft transported cosmonauts Alexander Svortsov, Mikhail Kornienko and NASA astronaut Tracy Caldwell-Dyson of the Expedition 23/24 crew to the International Space Station (ISS). Spacecraft commander, Skvortsov occupied the center seat of the Soyuz TMA-18 with Kornienko on his left and Caldwell Dyson on the right. The launch was perfect and the flight only experienced communications difficulties shortly after launch. The communication problem made it impossible for the Russian mission control officials to communicate with the crew until after they reached the preliminary orbit. However, a live

on-board television camera clearly showed the crew was safe. After 9 minutes, the Soyuz spacecraft settled into an preliminary orbit of 143 miles by 118 miles. It also deployed antennas and solar arrays for power generation. The spacecraft spent the following two days orbiting the Earth gradually closing in on the ISS.

Soyuz processing

Prior to the launch systems testing and integration of the rocket and spacecraft had been underway for several months. In February 2010 specialists at the RSC-Energia and Yuzhny Space Center tested the Kurs docking support system and onboard computer of the Soyuz reentry capsule. Autonomous tests of the Soyuz TMA-18 crew vehicle systems were also successfully completed at the Baikonur Cosmodrome and the integrated tests of the rocket commenced at site 254. Filling station (site 31) was prepared for further tanking of the Soyuz propulsion system by propellant components ad pressurized gases. In early March, containment tests on Soyuz TMA-18 were carried out at the vacuum chamber facility. Specialists from the TSKB-Progress in Samara and Yuzhny Space Center started assembling and testing of the Soyuz-FG rocket. Integration of the second stage and pneumatic tests of the first stage's units were performed on March 16.

The Soyuz TMA-18 primary and backup crews arrived at the Baikonur Cosmodrome on March 21. They arrived in two Tu-134 air planes. The Soyuz tanking was completed on March 23 and the spacecraft was returned back to site 254, to proceed with further prelaunch operations.

On March 31 the Soyuz FG rocket carrying the Soyuz TMA-18 spacecraft was rolled out from the integration and test facility and was erected at launch pad 1.

Docking

Soyuz TMA-18 approaches the ISS

On 4 April 2010, three minutes ahead of schedule, Soyuz TMA-18 successfully docked to the *Poisk* module on the ISS at 5:25 UTC. Shortly after the initial contact automatic closing of Soyuz & MRM2 port hooks and latches took place while the space station was in free drift. As part of docking preparations, earlier attitude control authority had been handed over to the Russian Motion Control System at approximately 3:10 UTC. The control was returned back to US CMG control at approximately 6:50 UTC. For the docking, the Russian thrusters were disabled during Soyuz volume pressurization and clamp installation and after wards returned to active attitude control. Before hatch opening, the crew performed leak checks of the Soyuz modules and the Soyuz/MRM2 interface vestibule. They then removed their Sokol suits, and Kornienko set them and their gloves up for drying. Skvortsov deactivated the BOA/Atmosphere Purification Unit in the SA/Descent Module, replaced the Soyuz ECLSS LiOH cartridges, equalized Soyuz/ISS pressures, and put the spacecraft into conservation mode on ISS integrated power.

After about 1 hour 45 minutes spent in Soyuz on pre-transfer activities, hatches were opened at 7:21 UTC and the crew transferred to the ISS. A welcome ceremony for the new arrivals followed hatch opening with family members and dignitaries participating from the Russian mission control center in Korolev. Skvortsov also installed the quick disconnect clamps of the docking & internal transfer mechanism (SSVP) to firm the joint.

The Soyuz spacecraft is intended to remain docked to the space station for the remainder of Expedition 24 to serve as an emergency escape vehicle.

Undocking difficulties

The Soyuz TMA-18 spacecraft departs the ISS

Landing, originally scheduled for 1:34 UTC September 24, was postponed due to difficulties in undocking the Soyuz spacecraft from the ISS. The crew entered the Soyuz TMA-18 on September 23 and closed the main hatch at 6:35 p.m. EDT. Skvortsov, Kornienko and Caldwell-Dyson experienced problems getting a tight seal and were forced to open the Soyuz hatch for a quick inspection. The hatch later was sealed, but Expedition 25 flight engineer Yurchikhin working inside the space station had problems confirming a tight fit with the hatch on the ISS side of the interface. After an extended leak check, flight controllers in Moscow decided the docking interface was tight and leak free. As the countdown neared for undocking, commands were sent to open hooks on the MRM2 module side of the interface. But the mechanism did not respond. It was not clear what caused the hooks not to respond, however, Yurchikhin reported finding a small gear floating from the mechanism when he removed a cover.

A second landing window was missed at 4:35 UTC. But Russian engineers were unable to resolve the problem with the docking mechanism and the undocking attempt was called off. The Soyuz TMA-18 crew removed their pressure suits, opened the Soyuz hatch and returned to the space station.

Landing

The Soyuz TMA-18 with its main parachute deployed for landing

The crew sits in chairs outside the Soyuz capsule minutes after the landing

Marking the end of Expedition 24, Skvortsov, Kornienko and Caldwell-Dyson successfully undocked their Soyuz TMA-18 at 10:02 p.m. EDT on September 24 from the Poisk docking port on the Zvezda module. After undocking and a normal descent, the Soyuz-TMA 18 spacecraft landed at 5:23 a.m. GMT near Arkalyk, Kazakhstan. At that time the space station was orbiting 220 miles above over the Pacific Ocean off the coast of Japan.

Russian recovery teams and helicopters were on hand to help the crew exit the spacecraft and adjust to gravity after 176 days in space.

Mission insignia

The Soyuz TMA-18 mission patch was designed by Nastya Berezutskaya of Kurchatov, Kursk region.

Chapter- 9

Soyuz TMA-19

Soyuz TMA-19
Союз ТМА-19

Mission insignia

Mission statistics

Mission name	Soyuz TMA-19 Союз ТМА-19
Crew size	3
Call sign	Olympus
Booster	Soyuz-FG
Launch pad	Site 1/5, Baikonur Cosmodrome
Launch date	15 June 2010 21:35 UTC
Landing	26 November 2010 04:46 GMT
Orbital period	88.8 minutes

Orbital inclination	51.62 degrees (initial orbit)

Crew photo

From left to right: Wheelock, Walker and Yurchikhin

Related missions

Previous mission	Subsequent mission
Soyuz TMA-18	Soyuz TMA-01M

Soyuz TMA-19 was a manned spaceflight to the International Space Station and is part of the Soyuz programme. It was launched 15 June 2010 carrying three members of the Expedition 24 crew to Space Station, who remained aboard the station for around six months. TMA-19 was the 106th manned flight of a Soyuz spacecraft, since the first mission which was launched in 1967. The spacecraft remained docked to the space station for the remainder of Expedition 24, and for Expedition 25, to serve as an emergency escape vehicle. It undocked from ISS and landed in Kazakhstan on the 26 November 2010. It was the 100th mission to be conducted as part of the International Space Station programme since assembly began in 1998.

Crew

The Soyuz TMA-19 prime and backup crews conduct their ceremonial tour of Red Square on 31 May 2010.

The Soyuz TMA-19 crew was confirmed by NASA on 21 November 2008. The mission Commander is Fyodor Yurchikhin of the Russian Federal Space Agency, who is making his third spaceflight. The other two crew members are Shannon Walker and Douglas H. Wheelock of the United States National Aeronautics and Space Administration and are designated flight engineers. TMA-19 is Wheelock's second spaceflight, and Walker's first.

Position	Crew Member
Commander (Center Seat)	Fyodor Yurchikhin, RSA Expedition 24 Third spaceflight
Flight Engineer 1 (Left Seat)	Shannon Walker, NASA Expedition 24 First spaceflight
Flight Engineer 2 (Right Seat)	Douglas H. Wheelock, NASA

Expedition 24
Second spaceflight

Backup crew

Position	Crew Member
Commander	Dmitri Kondratyev, RSA
Flight Engineer 1	Paolo Nespoli, ESA
Flight Engineer 2	Catherine Coleman, NASA

Launch

A Soyuz-FG launches Soyuz TMA-19 from Baikonur Cosmodrome, 15 June 2010

Soyuz TMA-19 was launched by a Soyuz-FG carrier rocket flying from Site 1/5 at the Baikonur Cosmodrome in Kazakhstan. The launch occurred successfully on 15 June 2010, with the rocket lifting off at 21:35 UTC. After its separation from the last stage of the Soyuz-FG rocket, Moscow Mission Control Center began controlling the Soyuz TMA-19 spacecraft. Nine minutes into the ascent, the spacecraft settled into a preliminary orbit of 200.16 by 259.16 km (124.37 by 161.03 mi) with the inclination 51.62 degrees toward the Equator. The Soyuz spacecraft successfully deployed the solar arrays for power generation and the antennas for navigational and communication systems. Telemetry data received from the Soyuz confirmed that the spacecraft was performing nominally.

Prior to launch, assembly of the rocket and spacecraft had been underway for several months. The Soyuz-FG rocket arrived at Baikonur on 11 March 2010, along with a Soyuz-U which was slated to launch Progress M-06M. The spacecraft itself was shipped from Korolyov on 16 April 2010, arriving at Baikonur by train three days later. Upon delivery, the spacecraft was moved to Site 254.

On 11 June 2010, final inspections of the spacecraft were conducted, and the spacecraft was then encapsulated in its payload fairing to form the upper composite of the rocket. The next day, the upper composite was integrated with the upper stage of the rocket that was to launch it, and subsequently the launch escape system. This assembly work took place at Site 112 of the Baikonur Cosmodrome. Once this was complete, the upper stage was attached to the remainder of the rocket in the MIK. A State Commission met of 12 June to approve rollout, which was authorised.

Rollout to the launch pad began at 01:00 UTC (5 a.m. Moscow Time) on 13 June 2010, with the rocket departing the MIK propelled by a locomotive. Rollout lasted around two hours, with the rocket travelling 2 kilometres (1.2 mi) from the MIK to the launch pad. The winner and runner-up in the patch design competition were present to observe the rollout. Rollout operations were completed by 05:00 UTC (9 a.m. Moscow Time), when the rocket was erected on the launch pad.

Docking

Soyuz TMA-19 spacecraft docked to Rassvet Mini-Research Module 1 (MRM1).

Soyuz TMA-19 docked with the International Space Station on 17 June 2010at 22:25 UTC. It docked with the aft port of the Zvezda module. Ahead of docking, the ISS handed over attitude control to the Russian Orbital Segment at 19:00 UTC, and at 19:17 maneuvered to provide an optimum attitude for docking. At 20:06, the automated rendezvous sequence started. The Kurs docking systems aboard the Soyuz and the Space Station were activated at 20:52 and 20:54 respectively. TMA-19 began station keeping at around 20:08 UTC, before it commenced its final approach at 20:16.

Twenty minutes after docking, hooks were closed securing the Soyuz to the station. Once this was completed, the ISS returned to its normal attitude. Attitude control was returned to the US Orbital Segment at 23:45 UTC.

Relocation

Soyuz TMA-19 relocates from the Zvezda Service Module's aft port to the Rassvet Mini-Research Module 1.

On June 28, cosmonaut Fyodor Yurchikhin along with NASA astronauts Douglas Wheelock and Shannon Walker boarded their Soyuz TMA-19 spacecraft and undocked from Zvezda Service Module's aft port at 3:13 p.m. EDT. They re docked it to its new location on the Rassvet module 25 minutes later as the two spacecraft were flying just off the coast of the Western Sahara on the west coast of Africa. The repositioning of the Soyuz TMA-19 was temporarily delayed due to an electrical breaker problem that delayed proper orientation of the 4B solar array on the space station's P4 truss. The flight went according to plan.

The event marked the first ever docking to the Rassvet module. The change of location released the Zvezda port for the docking of Progress M-06M.

Undocking and landing

The Soyuz TMA-19 spacecraft departs the International Space Station

Soyuz TMA-19 lands in Kazakhstan on 26 November 2010

Soyuz TMA-19 crewmembers after landing

Soyuz TMA-19 undocked from the space station at 01:19 GMT on 26 November, 2010. The descent module landed on the central steppes of Kazakhstan at 04:46 GMT, four days earlier than originally planned. The landing had been set for 30 November, but Kazakh officials decided to restrict air traffic before the start of the Organization for Security and Cooperation in Europe summit in Astana, Kazakhstan, set for 1-2 December. The landing site was located 84 km away from the city of Arkalyk.

On 25 November, 2010, the crew boarded Soyuz TMA-19 to return to Earth. After closing the hatchway between the Soyuz and the station at 22:14 GMT, they donned their Sokol spacesuits and continued with the power up operations. The crew also activated the Soyuz systems and removed the docking clamps. The undock command was issued at 01:20 GMT when the Soyuz and the station was flying above the Russian-Mongolian border.. The physical separation occurred three minutes later at 01:23:13 GMT

After the separation from the station and at a short distance away, Soyuz TMA-19 executed the so called “separation burn” (a 15 seconds burn) to vacate the proximity of the space station. About two and half hours later, at 03:55:12 GMT, the Soyuz spacecraft performed the deorbit maneuver which lasted for 4 minutes and 21 seconds, while it flew backwards over the south-central Atlantic Ocean on a north easterly trajectory towards Asia. With the deorbit burn nominally accomplished, the recovery forces comprising 14 helicopters, 4 airplanes and 7 search and rescue vehicles were dispatched to the landing zone. At an altitude of 140 kilometers, just above the first traces of the Earth's atmosphere, onboard computers commanded the separation of the three Soyuz TMA-19

modules. With the crew inside the Descent Module, the forward Orbital Module and the rear Instrumentation Module were pyrotechnically nominally jettisoned at 04:21 GMT. Three minutes after the separation, with the heat shield of the Descent Module pointing towards the direction of travel, the Soyuz capsule experienced the first traces of the atmosphere ("entry interface") at 04:23 GMT at an altitude of 400,000 feet above the Earth. Around 04:28 GMT, the flight path of the capsule crossed the Mediterranean, Turkey and the Black Sea before flying over southern Russia and into Kazakhstan.

At an altitude of about 10 kilometers, onboard computers started a commanded sequence to unfurl the parachutes. Two "pilot" parachutes deployed first, extracting a 24-square-meter drogue parachute. The parachute deployment reduced the velocity of the Soyuz capsule from 230 m/s to 80 m/s and assisted in the capsule's stability by creating a gentle spin for the Soyuz spacecraft. Once the drogue chute was released, the main parachutes were deployed. They further reduced the descent to 7.2 m/s. Initially, the Descent Module hung underneath the main parachute at a 30-degree angle with respect to the horizon and for the few minutes before the landing, then following the detachment of the bottom-most harness it hung vertically. At this time, flight controllers reported the Soyuz spacecraft was operating as expected on the automatic sequence. During the same time, they were successful in contacting the crew via the fixed-wing aircraft that served as the central command for the search and recovery forces. The recovery forces spotted the Soyuz TMA-19 around 04:36 GMT. At an altitude of five kilometers, the module's heat shield was jettisoned.

At the end of the 163-day voyage, Soyuz TMA-19's landing was confirmed at 04:46 GMT. The recovery team assisted the crew to exit the capsule. First out of the capsule was cosmonaut Fyodor Yurchikhin followed by NASA astronauts Shannon Walker and Douglas Wheelock.

After the successful landing, the Soyuz TMA-19 crew flew to Kustanai in Kazakhstan for the welcoming ceremony. Wheelock and Walker boarded a NASA jet waiting for them in Kustanai for the trip back to the Johnson Space Center in Houston. Yurchikhin headed for Star City - the home of the Gagarin Cosmonaut Training Center in Russia.

Mission insignia

The Soyuz TMA-19 patch design is based on a drawing by Evgeny Emelianov, the winner of the traditional patch contest organized by the Russian Federal Space Agency. His design shows the ISS and the Earth waiting for the crew to come back.