



# Current Notes

## Space Shuttle Special

July 2011



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# Introduction

Welcome to the special edition of Current Notes. This Edition has been compiled to celebrate 30years of Space Shuttle missions and to coincide with the last mission.

NASA's greatest achievement was the creation of a reusable spacecraft. The Apollo spacecraft cost an astronomical sum to produce and were single-use only. The heat from Earth's atmosphere essentially disintegrated the shielding used to protect the spacecraft. The spacecraft also landed in the ocean, and the impact and sea water damaged the equipment. To remedy this, NASA built a spacecraft that had two rocket launchers attached to an external fuel tank and an orbiter module. They coated the spacecraft with protective heat-resistant ceramic tiles and changed the landing design to a glider-style. It took nine years of preparation, from 1972 to 1981, before the first mission.

I would like to thank NASA/JPL and ESA for the information that has been compiled in this special edition.

I dedicate this edition to my new soon to be born child.

**“As you are being born the last mission of the space shuttles are coming to an end.”**

**Anthony Jennings**

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# History

The Space Shuttle is a reusable launch system and orbital spacecraft operated by the U.S. National Aeronautics and Space Administration (NASA) for human spaceflight missions. The system merges rocket launch, orbital spacecraft, and re-entry space plane with modular add-ons. The first of four orbital test flights occurred in 1981 leading to operational flights beginning in 1982, all launched from the Kennedy Space Centre, Florida. The system is scheduled to be retired from service in 2011 after 135 launches. Major missions have included launching numerous satellites and interplanetary probes, conducting space science experiments, and servicing and construction of space stations. Five space-worthy orbiter's were built.

It has been used for orbital space missions by NASA, the U.S. Department of Defence, the European Space Agency, Japan, and Germany. The United States funded STS development and shuttle operations except for Spacelab D1 and D2 — sponsored by West Germany and reunified Germany respectively. In addition, SL-J was partially funded by Japan.

At launch, the Space Shuttle consists of the shuttle stack, which includes a dark orange-colour external tank (ET); two white, slender Solid Rocket Boosters (SRBs); and the Orbiter Vehicle (OV), which contains the crew and payload. Payloads can be launched into higher orbits with either of two different booster stages developed for the STS (single-stage Payload Assist Module or two-stage Inertial Upper Stage). The Space Shuttle is stacked in the Vehicle Assembly Building and the stack mounted on a mobile launch platform held down by four explosive bolts on each SRB which are detonated at launch.

The shuttle stack launches vertically like a conventional rocket. It lifts off under the power of its two SRBs and three main engines, which are fuelled by liquid hydrogen and liquid oxygen from the external tank. The Space Shuttle has a two-stage ascent. The SRBs provide additional thrust during lift-off and first-stage flight. About two minutes after lift-off, explosive bolts are fired, releasing the SRBs, which then parachute into the ocean, to be retrieved by ships for refurbishment and reuse. The shuttle orbiter and external tank continue to ascend on an increasingly horizontal flight path under power from its main engines. Upon reaching 17,500 mph (7.8 km/s), necessary for low Earth orbit, the main engines are shut down. The external tank is then jettisoned to burn up in the atmosphere. It is, however, possible for the external tank to be re-used in orbit. After jettisoning the external tank, the orbital manoeuvring system (OMS) engines may be used to adjust the orbit.

The orbiter carries astronauts and payload such as satellites or space station parts into low Earth orbit, into the Earth's upper atmosphere or thermosphere. Usually, five to seven crew members ride in the orbiter. Two crew members, the commander and pilot, are sufficient for a minimal flight, as in the first four "test" flights, STS-1 through STS-4. A typical payload capacity is about 22,700 kilograms (50,000 lb), but can be raised depending on the choice of launch

configuration. The orbiter carries the payload in a large cargo bay with doors that open along the length of its top, a feature which makes the Space Shuttle unique among present spacecraft. This feature made possible the deployment of large satellites such as the Hubble Space Telescope, and also the capture and return of large payloads back to Earth.

When the orbiter's space mission is complete, it fires its OMS thrusters to drop out of orbit and re-enter the lower atmosphere. During descent, the orbiter passes through different layers of the atmosphere and decelerates from hypersonic speed primarily by aero braking. In the lower atmosphere and landing phase, it is more like a glider but with reaction control system (RCS) thrusters and fly-by wire-controlled hydraulically-actuated flight surfaces controlling its descent. It then makes a landing on a long runway as a space plane. The aerodynamic shape is a compromise between the demands of radically different speeds and air pressures during re-entry, hypersonic flight, and subsonic atmospheric flight. As a result, the orbiter has a relatively high sink rate at low altitudes, and it transitions during re-entry from using RCS thrusters at very high altitudes to flight surfaces in the lower atmosphere.

## Early history

President Nixon with NASA Administrator Fletcher in January 1972, three months before Congress approved funding for the shuttle program. Though design and construction of the Space Shuttle began in the early 1970s, conceptualization began two decades earlier, before the Apollo program of the 1960s. The concept of a spacecraft returning from space to a horizontal landing began within NACA, in 1954, in the form of an aeronautics research experiment later named the X-15. The NACA proposal was submitted by Walter Dornberger.



The X-15 launches away from the B-52 mother ship with its rocket engine ignited. The white patches near the middle of the ship are frost from the liquid oxygen used in the propulsion system, although very cold liquid nitrogen was also used to cool the payload bay, cockpit, windshields, and nose.

In 1958, the X-15 concept further developed into another X-series space plane proposal, called the X-20, which was not constructed. Neil Armstrong was selected to pilot both the X-15 and the X-20. Though the X-20 was not built, another space plane similar to the X-20 was built several years later and delivered to NASA in January 1966 called the HL-10. "HL" indicated "horizontal landing".

In the mid-1960s, the US Air Force conducted a series of classified studies on next-generation space transportation systems and concluded that semi-reusable designs were the cheapest choice. It proposed a development program with an immediate start on a "Class I" vehicle with expendable boosters, followed by slower development of a "Class II" semi-reusable design and perhaps a "Class III" fully reusable design later. In 1967, George Mueller held a one-day symposium at NASA headquarters to study the options. Eighty people attended and presented a wide variety of designs, including earlier Air Force designs as the Dyna-Soar (X-20).

In 1968, NASA officially began work on what was then known as the Integrated Launch and Re-entry Vehicle (ILRV). At the same time, NASA held a separate Space Shuttle Main Engine (SSME) competition. NASA offices in Houston and Huntsville jointly issued a Request for Proposal (RFP) for ILRV studies to design a spacecraft that could deliver a payload to orbit but also re-enter the atmosphere and fly back to Earth. One of the responses was for a two-stage design, featuring a large booster and a small orbiter, called the DC-3.

In 1969, President Richard Nixon decided to proceed with Space Shuttle development. In August 1973, the X-24B proved that an unpowered space plane could re-enter Earth's atmosphere for a horizontal landing.

Across the Atlantic, European ministers met in Belgium in 1973 to authorize Western Europe's manned orbital project and its main contribution to Space Shuttle — the Spacelab program. Spacelab would provide a multi-disciplinary orbital space laboratory and additional space equipment for the Shuttle.

Roger A. Pielke, Jr. has estimated that the Space Shuttle program has cost about US\$170 billion (2008 dollars) through early 2008. This works out to an average cost per flight of about US\$1.5 billion. However, two missions were paid for by Germany, Spacelab D1 and D2 (D for Deutschland) with a payload control centre in Oberpfaffenhofen, Germany. D1 was the first time that control of a manned STS mission payload was not in U.S. hands.

At times, the orbiter itself is referred to as the Space Shuttle. Technically, this is a slight misnomer, as the actual "Space Transportation System" (STS) is the combination of the orbiter, the external tank, and the two solid rocket boosters. Combined, these are referred to as the stack; the components are assembled in the Vehicle Assembly Building, originally built to assemble the Apollo-Saturn V rocket stacks.



President Richard M. Nixon and Dr. James C. Fletcher, NASA Administrator, discussed the proposed Space Shuttle vehicle in San Clemente, California, on January 5, 1972. The President announced that day that the United States should proceed at once with the development of an entirely new type of space transportation system designed to help transform the space frontier into familiar territory.





The Space Shuttle Atlantis atop the Shuttle Carrier Aircraft (SCA) returns to the Kennedy Space Centre after a ten month refurbishment.

# Space Shuttle Orbiter

The Space Shuttle orbiter is the orbital spacecraft of the Space Shuttle program operated by NASA, the space agency of the United States. The orbiter is a reusable winged "space-plane", a mixture of rockets, spacecraft, and aircraft. This space-plane can carry crews and payloads into low Earth orbit, perform on-orbit operations, then re-enter the atmosphere and land as a glider, returning her crew and any on-board payload to the Earth.

A total of six Orbiters were built for flight: Atlantis, Challenger, Columbia, Discovery, Endeavour and Enterprise. All were built by the southern California based Rockwell International company.



The first Orbiter to fly, Enterprise, took her maiden flight in 1977. Built solely for unpowered atmospheric test flights and landings, her take-off was from the back of a modified Boeing-747 cargo plane, the Shuttle Carrier Aircraft, while the remaining Orbiters were built for orbital space flights, launched vertically as part of the full Space Shuttle package. Enterprise was partially disassembled and retired after completion of critical testing.

Columbia was the first Orbiter to launch into space as a Space Shuttle, in 1981. The first launches of Challenger, Discovery, and finally Atlantis, followed in 1983, 1984 and 1985 respectively. In 1986, Challenger was destroyed in an accident after launch. Endeavour was built as Challenger's replacement, and was first launched in 1992. In 2003, Columbia was destroyed during re-entry, leaving just three remaining Orbiters. Atlantis was used last in May 2010, and is scheduled to fly again for the last shuttle flight STS-135 in June 2011. Discovery made its final flight, landing on March 9th 2011, and Endeavour is going to be retired in May 2011.

In addition to their crews and payloads, the reusable Space Shuttle Orbiter carries most of the Space Shuttle System's liquid-fuelled rocket propulsion system, but both the liquid hydrogen fuel and the liquid oxygen oxidizer for her three main rocket engines is fed from an external cryogenic propellant tank, and there are also two reusable large solid-fuelled rocket boosters that help to lift both the Orbiter and her external propellant tanks during approximately the first two minutes of her ascent into outer space.

Attitude control system The Space Shuttle Orbiter resembles an aircraft in its design, with a standard-looking fuselage and two double-delta wings, both swept at an angle of 81 degrees at their inner leading

edges and 45 degrees at their outer leading edges. The vertical stabilizer of the Orbiter has a leading edge that is swept back at a 45-degree angle. There are four elevons mounted at the trailing edges of the delta wings, and the combination rudder and speed brake is attached at the trailing edge of the vertical stabilizer. These, along with a movable body flap, control the Orbiter during her later stages of descent through the atmosphere and her landing.

Overall, the Space Shuttle Orbiter is roughly the same size as a McDonnell Douglas DC-9 airliner.

The Reaction Control System (RCS) is composed of 44 small liquid-fuelled rocket thrusters and their very sophisticated computerized (fly-by-wire) flight control system, which utilizes computationally intensive digital Kalman Filtering. This control system carries out the usual attitude control along the pitch, roll, and yaw axes during all of the flight phases of launching, orbiting, and re-entry. This system also executes any needed orbital manoeuvres, including all changes in the orbit's altitude, orbital plane, and eccentricity. These are all operations that require a lot more power and energy than mere attitude control.

The forward rockets of the Reaction Control System, located near the nose of the Space Shuttle Orbiter, include 12 primary and two vernier RCS rockets. The aft RCS engines are located in the two Orbital Manoeuvring System (OMS) pods at the rear of the Orbiter, and these include 12 primary and two vernier RCS engines in each pod. The RCS system provides the fine-pointing control of the Orbiter, and the RCS is used for the manoeuvring during the rendezvous, docking, and undocking manoeuvring with the International Space Station, or formerly with the Russian Mir space station. The RCS also controls the attitude of the Orbiter during most of its re-entry into the Earth's atmosphere - until the air becomes dense enough that the elevons and the rudder become effective.

## Pressurized cabin

The Orbiter astronaut's crew cabin consists of three levels: the flight deck, the mid-deck, and the utility area. The uppermost of these is the flight deck, in which sit the Space Shuttle's commander and co-pilot, with up to two mission specialists seated behind them. The mid-deck, which is below the flight deck, has three more seats for the rest of the crew members.

The galley, toilet, sleep locations, storage lockers, and the side hatch for entering and exiting the Orbiter are also located on the mid-deck, as well as the airlock. The airlock has an additional hatch into the Payload Bay. This airlock allows two astronauts, wearing their Extravehicular Mobility Unit (EMU) space suits, to depressurize before a walk in space (EVA), and also to re-pressurize and re-enter the Orbiter at the conclusion of the EVA.

## Propulsion

Three Space Shuttle Main Engines (SSMEs) are mounted on the Orbiter's aft fuselage in the pattern of an equilateral triangle. These three liquid-fuelled engines can be swivelled 10.5 degrees vertically and 8.5 degrees horizontally during the rocket-powered ascent of the Orbiter in order to change the direction of their thrust. Hence, they steer the entire Space Shuttle, as well as providing her rocket thrust towards orbit. The aft of the fuselage also houses three auxiliary power units (APU). The APUs burn hydrazine to provide hydraulic pressure for all of the hydraulic system, including the ones that point the three main liquid-fuelled rocket engines, under computerized flight control. The hydraulic pressure generated is also used to control all of the Orbiter's "aero surfaces" (the elevons, rudder, air brake, etc.), to deploy the landing gear of the Orbiter, and to open and close the cargo bay's large main doors.

Two Orbital Manoeuvring System (OMS) thrusters are mounted in two separate pods in the Orbiter's aft fuselage, located between the SSMEs and the vertical stabilizer of the Orbiter. The OMS engines provide significant thrust for coarse orbital manoeuvres, including insertion, circularization, transfer, rendezvous, de-orbit, abort to orbit, and to abort once around.

## Thermal protection

The Thermal Protection System (TPS) covers the outside of the Orbiter, protecting it from the cold soak of  $-121\text{ }^{\circ}\text{C}$  ( $-250\text{ }^{\circ}\text{F}$ ) in space to the  $1649\text{ }^{\circ}\text{C}$  ( $3000\text{ }^{\circ}\text{F}$ ) heat of re-entry.

## Structure

The orbiter structure is made primarily from aluminium alloy, although the engine thrust structure is made from titanium alloy. The windows are made of aluminium silicate glass and fused silica glass, and comprise an internal pressure pane, a 1.3-inch-thick (33 mm) optical pane, and an external thermal pane. The windows are tinted with the same ink used to make American banknotes.

## Landing gear

The Space Shuttle Orbiter has three sets of landing gear (wheels, brakes, and steering motors) which emerge downwards through doors in the heat shield. As a weight-saving measure, the gear cannot be retracted once deployed. Since any premature extension of the landing gear would very likely be catastrophic (as it opens through the heat shield layers), the landing gear can only be lowered by manual controls, and not by any automatic system. Similarly, since the Shuttle lands at high speed and cannot abort its landing attempt, the gear must deploy reliably on the first try every time.

The gear is unlocked and deployed by triple redundant hydraulics, with the gear doors actuated by mechanical linkages to the gear strut. If all three hydraulic systems fail to release the landing gear uplocks within one second of the release command, pyrotechnic charges automatically cut the lock hooks and a set of springs deploy the gear.

## Lack of navigational lights

The Space Shuttle Orbiter does not carry anti-collision lights, navigational lights, or landing lights, as the Orbiter always lands in areas that have been specially cleared by both the Federal Aviation Administration and the Air Force. The Orbiter nearly always lands at either Edwards Air Force Base (California) or near to the Patrick Air Force Base (Florida), although one mission - STS-3 - landed at the White Sands Space Harbour in New Mexico. Similar special clearances (no-fly zones) are also in effect at potential emergency landing sites, such as in Spain and in West Africa during all launches.

When an Orbiter landing is carried out at night, the runway is always strongly illuminated with light from floodlights and spotlights on the ground, making landing lights on the Orbiter unnecessary and also an unneeded spaceflight weight load. Thus far 24 landings have taken place at night, the first being STS-8 in September 1983.

## Retirement

The three remaining shuttle orbiter's will go on permanent display at the end of the shuttle program. NASA Administrator Charles Bolden announced on Tuesday April 12, 2011, the anniversary of the first manned space flight and the first flight of Columbia, the disposition location of the orbiter's. Discovery will go to the Smithsonian's Steven F. Udvar-Hazy Centre, Atlantis will go to the Kennedy Space Centre, and Endeavour will go to the California Science Centre in Los Angeles. Enterprise, which is currently at the Udvar-Hazy Centre, will be relocated to the Intrepid Sea, Air & Space Museum in New York City. Hundreds of other shuttle artefacts will be put on display at various other museums and educational institutions around the US.



# Shuttle Orbiter Specifications

(For the Endeavour, OV-105)

Length: 122.17 ft (37.24 m)

Wingspan: 78.06 ft (23.79 m)

Height: 58.58 ft (17.25 m)

Empty Weight: 151,205 lb (68,585 kg); 172,000 lb (78018 kg) with SSME installed

Gross Liftoff Weight: 240,000 lb (109,000 kg)

Maximum Landing Weight: 230,000 lb (104,000 kg)

Main Engines: Three Rocketdyne Block two-A SSMEs, each with a sea-level thrust of 393,800 pounds-force (1.75 meganewtons)

Maximum Payload: 55,250 pounds (25,060 kg)

Payload Bay dimensions: 15 ft by 60 ft (4.6 m by 18.3 m)

Operational Altitude: 100 to 520 nautical miles (190 to 960 km)

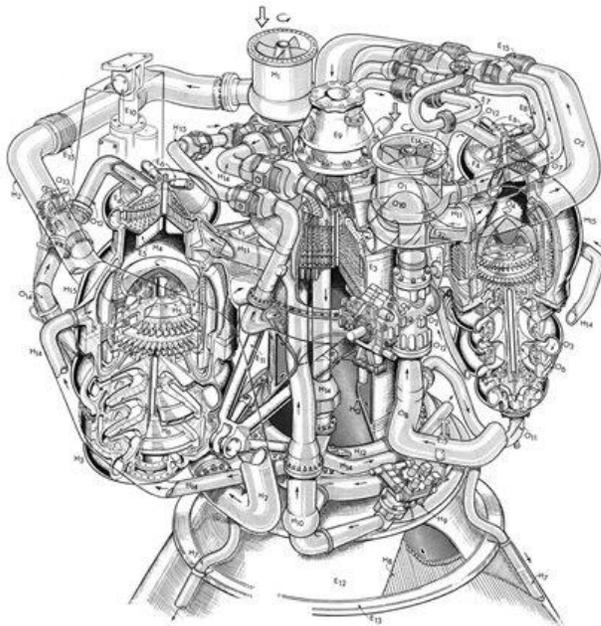
Speed: 25,404 feet/sec (7,743 meters/sec, 27,875 km/hour, 17,321 mph.)

Cross-range capability: 1,085 nautical miles (2,010 km)

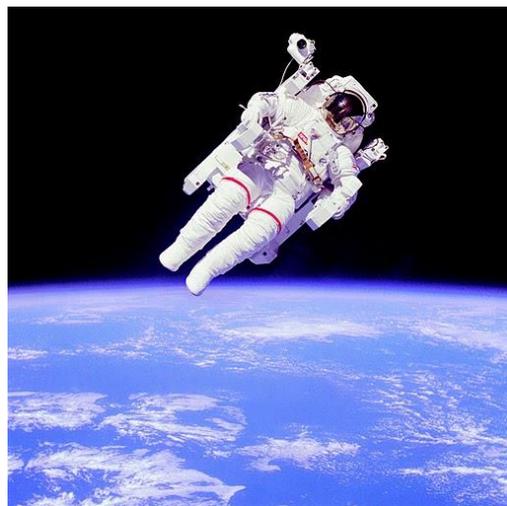
Crew: six to eight (Commander, Pilot, four to six Mission Specialists, Payload Specialists, or passengers to/from space stations). Two astronauts (the Flight Commander and the Pilot) is the minimum number of crewmen.



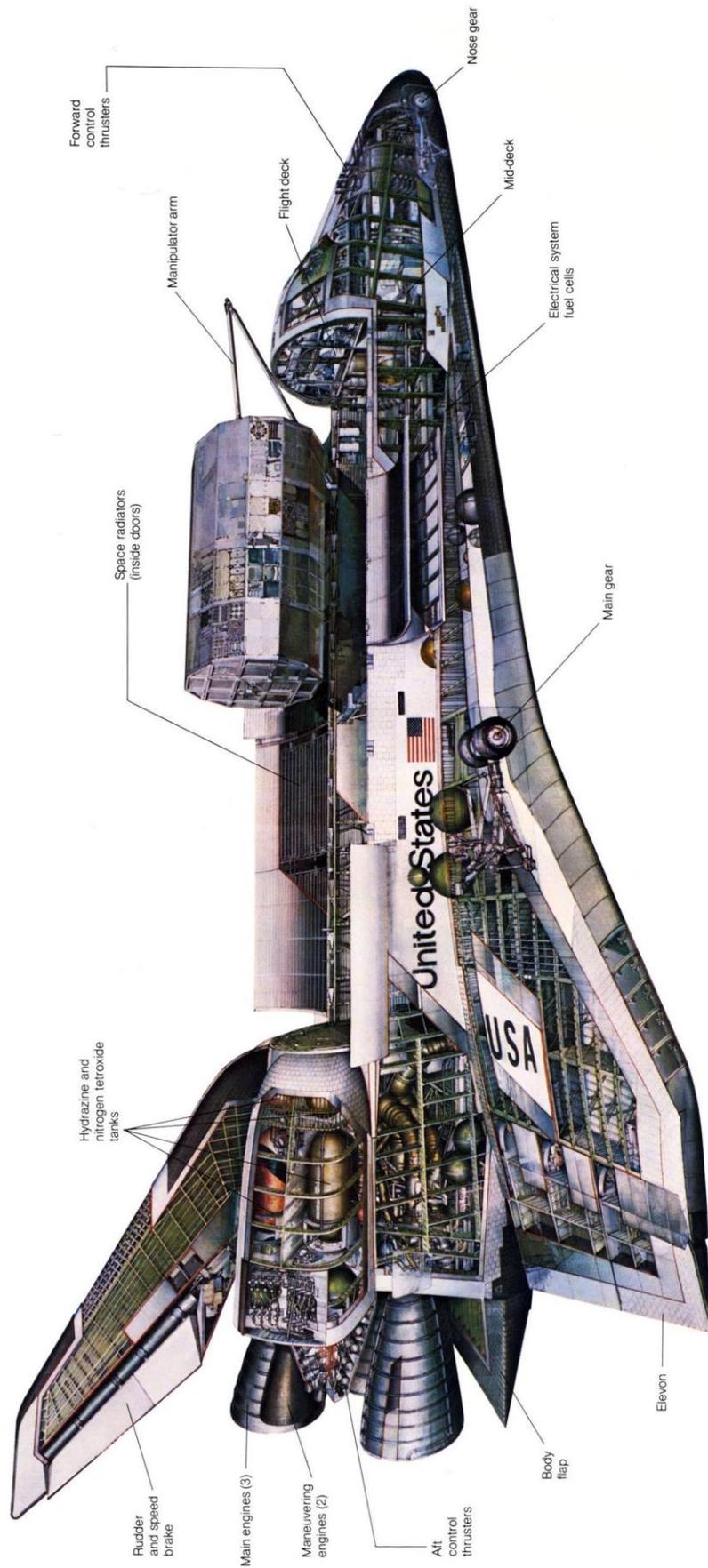
Crew Compartment Space: 2,325 cu ft (65.8 m<sup>3</sup>) (With internal airlock) or 2,625 cu ft (74.3 m<sup>3</sup>) (With external airlock inside the payload bay)



Space Shuttle Engine Cutaway



The first untethered spacewalk was made by American Bruce McCandless II on February 7, 1984, during Challenger mission STS-41-B, utilizing the Manned Manoeuvring Unit



# Shuttle-Mir Program

The Shuttle-Mir Program was a collaborative space program between Russia and the United States, which involved American Space Shuttles visiting the Russian space station *Mir*, Russian cosmonauts flying on the shuttle and an American astronaut flying aboard a Soyuz spacecraft to engage in long-duration expeditions aboard *Mir*.

The project, sometimes called "Phase One", was intended to allow the United States to learn from Russian experience with long-duration spaceflight and to foster a spirit of cooperation between the two nations and their space agencies, the US National Aeronautics and Space Administration (NASA) and the Russian Federal Space Agency (Roskosmos). The project helped to prepare the way for further cooperative space ventures; specifically, "Phase Two" of the joint project, the construction of the International Space Station (ISS). The program was announced in 1993, the first mission started in 1994 and the project continued until its scheduled completion in 1998. Eleven Space Shuttle missions, a joint Soyuz flight and almost 1000 cumulative days in space for American astronauts occurred over the course of seven long-duration expeditions.



During the four-year program, many firsts in spaceflight were achieved by the two nations, including the first American astronaut to launch aboard a Soyuz spacecraft, the largest spacecraft ever to have been assembled at that time in history, and the first American spacewalk using a Russian Orlan spacesuit.

The program was marred by various concerns, notably the safety of *Mir* following a fire and a collision, financial issues with the cash-strapped Russian Space Program and worries from astronauts about the attitudes of the program administrators. Nevertheless, a large amount of

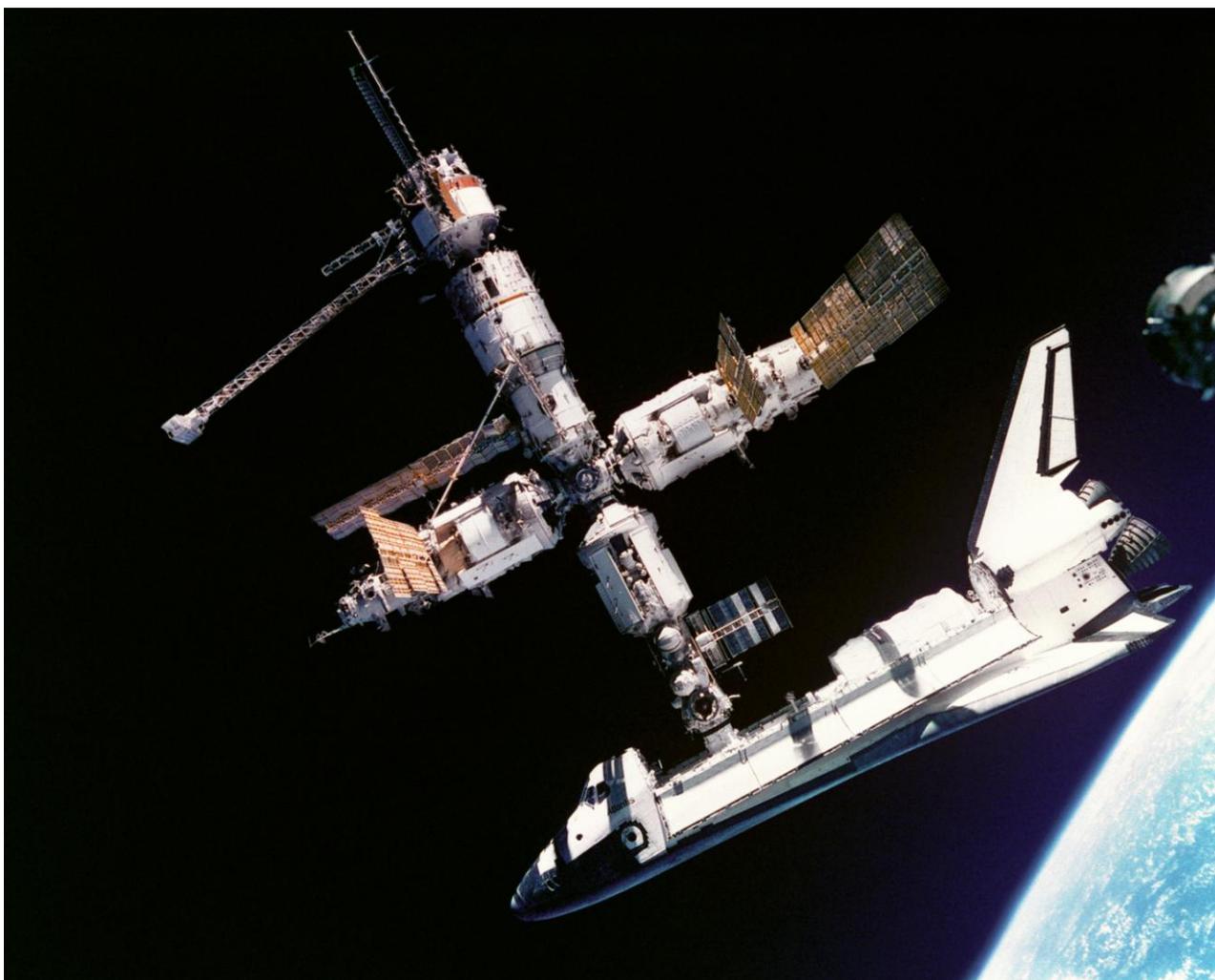
venture was gained from the combined operations, allowing the construction of the ISS to proceed much more smoothly than would have otherwise been the case.

Mir was constructed between 1986 and 1996 and was the world's first modular space station. It was the first consistently inhabited long-term research station in space, and previously held the record for longest continuous human presence in space, at eight days short of ten years. Mir's purpose was to provide a large and habitable scientific laboratory in space, and, through a number of collaborations, including Intercosmos and Shuttle-Mir, was made internationally accessible to cosmonauts and astronauts of many different countries. The station existed until March 23, 2001, at which point she was deliberately deorbited, and broke apart during atmospheric re-entry.



Mir was based upon the Salyut series of space stations previously launched by the Soviet Union (seven Salyut space stations had been launched since 1971), and was mainly serviced by Russian-manned Soyuz spacecraft and Progress cargo ships. The Buran space shuttle was anticipated to visit Mir, but its program was canceled after its first unmanned spaceflight. Visiting US Space Shuttles used a Androgynous Peripheral Attach System docking collar originally designed for Buran, mounted on a bracket originally designed for use with the American Space Station Freedom.

With the Space Shuttle docked to Mir, the temporary enlargements of living and working areas amounted to a complex that was the world's largest spacecraft at that time, with a combined mass of 250 metric tons.



A view of the US Space Shuttle Atlantis and the Russian Space Station Mir during STS-71 as seen by the crew of Mir EO-19 in Soyuz TM-21. Cosmonauts Anatoliy Y. Soloviyev and Nikolai M. Budarin, Mir-19 Commander and Flight Engineer, respectively, temporarily undocked the Soyuz spacecraft from the cluster of Mir elements to perform a brief fly-around. They took pictures while the STS-71 crew, with Mir EO-18's three crew members aboard, undocked Atlantis for the completion of this leg of the joint activities. Soloviyev and Budarin had been taxied to Mir by Atlantis.



#### Hubble - Servicing Mission 4

Hubble floats free from Atlantis after SM4. Servicing Mission 4 (SM4), which took place in May 2009, was the last scheduled shuttle mission (STS-125) for the Hubble Space Telescope. The mission was first planned for October 14, 2008. However on September 27, 2008, the Science Instrument Command and Data Handling (SI C&DH) unit on HST failed. All science data pass through this unit before they can be transmitted to Earth. Although it had a backup unit, if the backup were to fail, the HST's useful life would be over. Therefore on September 29, 2008, NASA announced that the launch of SM4 would be postponed until 2009 so the SI C&DH unit could be replaced as well. SM4, with a replacement SI C&DH unit, was launched aboard Space Shuttle Atlantis on May 11, 2009.



On SM4, astronauts, over the course of five spacewalks, installed two new instruments, Wide Field Camera 3 (WFC3), and the Cosmic Origins Spectrograph (COS). WFC3 will increase Hubble's observational capabilities in the ultraviolet and visible spectral ranges by up to 35 times due to its higher sensitivity and wider field of view. The telephone-booth sized COS assembly replaced the Corrective Optics Space Telescope Axial Replacement (COSTAR) that was installed in 1993 to correct Hubble's spherical aberration problems. (COSTAR was no longer needed after the replacement of the FOC in 2002, the last original instrument without the necessary correction built in.) The COS will do observations in the ultraviolet parts of the spectrum, complementing the measurements done by the repaired STIS system.

The mission repaired two instruments that had failed, the Advanced Camera for Surveys (ACS) and the Space Telescope Imaging Spectrograph (STIS). The astronauts also performed other component replacements, including all three Rate Sensor Units (each containing two gas-bearing gyroscopes); one of three Fine Guidance Sensor (FGS) units used to help keep pointing accuracy and increase platform stability;

the SI C&DH unit; all six of the 125-pound (57 kg) nickel-hydrogen batteries used to provide all Hubble's electrical power to support operations during the night portion of its orbit; and three New Outer Blanket Layer (NOBL) thermal insulation protective blankets. The batteries had never been replaced and were more than 13 years over their original design life.



Atlantis released the Hubble Space Telescope on May 19, 2009 back into space after all repairs were successfully made. After testing and calibration, Hubble resumed routine operation in September 2009. These efforts are expected to keep the telescope fully functioning at least into 2014, and perhaps longer.

Hubble was originally designed to be returned to earth on board a shuttle. With the retirement of the shuttle fleet, in July 2011, this is no longer possible. NASA engineers developed the Soft Capture and Rendezvous System (SCRS), a ring-like device that was attached to

Hubble's aft bulkhead during SM4, which will enable the future rendezvous, capture, and safe disposal of Hubble by either a crewed or robotic mission. The next mission will be to deorbit Hubble at the end of its service life.



To consummate Hubble Telescope's 20th Birthday, NASA, along with ESA and M. Livio and the Hubble 20th Anniversary Team (STScI), featured a finding from the Carina Nebula



The "glass cockpit" installed on the Space Shuttle: JSC2000-E-10522 (March 2000) – Eleven new full-color, flat-panel display screens in the Shuttle cockpit replace 32 gauges and electromechanical displays and four cathode-ray tube displays. The new "glass cockpit" is 75 pounds (34 kg) lighter and uses less power than before, and its color displays provide easier pilot recognition of key functions.



	<b>Launch Date</b>	<b>Mission</b>	<b>Shuttle</b>	<b>Crew</b>	<b>Duration</b>	<b>Landing Site</b>	<b>Notes</b>
1	12 August 1977	ALT-12	Enterprise	2	00d 00h 05m	Edwards	First free flight of Space Shuttle; first non-captive flight of Enterprise
2	13 September 1977	ALT-13	Enterprise	2	00d 00h 05m	Edwards	Second free flight
3	23 September 1977	ALT-14	Enterprise	2	00d 00h 05m	Edwards	Third free flight
4	12 October 1977	ALT-15	Enterprise	2	00d 00h 02m	Edwards	Fourth free flight; first flight without tail cone (operational configuration)
5	26 October 1977	ALT-16	Enterprise	2	00d 00h 02m	Edwards	Final free flight; final non-captive flight of Enterprise

	<b>Launch Date</b>	<b>Mission</b>	<b>Shuttle</b>	<b>Crew</b>	<b>Duration</b>	<b>Landing Site</b>	
1	April 12, 1981	STS-1	Columbia	2	02d 06h	Edwards	First reusable orbital spacecraft flight; first flight of Columbia
2	November 12, 1981	STS-2	Columbia	2	02d 06h	Edwards	First reuse of a manned orbital space vehicle; first test of Canadarm robot arm
3	March 22, 1982	STS-3	Columbia	2	08d 00h	White Sands	Shuttle R&D flight, first and only landing at White Sands, New Mexico
4	June 27, 1982	STS-4	Columbia	2	07d 01h	Edwards	Last shuttle R&D flight, first DoD payload
5	November 11, 1982	STS-5	Columbia	4	05d 02h	Edwards	Multiple comsat deployments. First EVA of program cancelled due to suit problems
6	April 4, 1983	STS-6	Challenger	4	05d 00h	Edwards	TDRS deployment; first flight of Challenger; first space shuttle extra-vehicular activity
7	June 18, 1983	STS-7	Challenger	5	06d 02h	Edwards	First US woman in space Sally Ride; Multiple comsat deployments
8	August 30, 1983	STS-8	Challenger	5	06d 01h	Edwards	Comsat deployment; test of robot arm on heavy payloads
9	November 28, 1983	STS-9	Columbia	6	10d 07h	Edwards	First Spacelab mission
10	February 3, 1984	STS-41-B	Challenger	5	07d 23h	Kennedy	Comsat deployments, first untethered spacewalk by Bruce McCandless
11	April 6, 1984	STS-41-C	Challenger	5	06d 23h	Edwards	Solar Max servicing (first satellite rescue by astronauts), LDEF deployment
12	August 30, 1984	STS-41-D	Discovery	6	06d 00h	Edwards	Multiple comsat deployments; first flight of Discovery, test of OAST-1 Solar Array
13	October 5, 1984	STS-41-G	Challenger	7	08d 05h	Kennedy	Earth Radiation Budget Satellite deployment
14	November 8, 1984	STS-51-A	Discovery	5	07d 23h	Kennedy	Multiple comsat deployments, retrieval of two other comsats
15	January 24, 1985	STS-51-C	Discovery	5	03d 01h	Kennedy	First classified Department of Defence (DoD) mission; Magnum satellite deployment
16	April 12, 1985	STS-51-D	Discovery	7	06d 23h	Kennedy	Multiple comsat deployments,
17	April 29, 1985	STS-51-B	Challenger	7	07d 00h	Edwards	Spacelab mission
18	June 17, 1985	STS-51-G	Discovery	7	07d 01h	Edwards	Multiple comsat deployments
19	July 29, 1985	STS-51-F	Challenger	7	07d 22h	Edwards	Spacelab mission
20	August 27, 1985	STS-51-I	Discovery	5	07d 02h	Edwards	Multiple comsat deployments, rescue of Syncom F3 (Leasat-3) by Astronauts
21	October 3, 1985	STS-51-J	Atlantis	5	04d 01h	Edwards	Second classified DoD mission; DSCS satellite deployment; first flight of Atlantis
22	October 30, 1985	STS-61-A	Challenger	8	07d 00h	Edwards	Spacelab-D1, Germany funded mission, last successful mission of Challenger
23	November 26, 1985	STS-61-B	Atlantis	7	06d 21h	Edwards	Multiple comsat deployment, EASE/ACCESS experiment
24	January 12, 1986	STS-61-C	Columbia	7	06d 02h	Edwards	Comsat deployment, flight of US Representative Bill Nelson
25	January 28, 1986	STS-51-L	Challenger	7	01m 13s	N/A	Planned TDRS deployment, Loss of vehicle and crew, Teacher in Space Flight

	<b>Launch Date</b>	<b>Mission</b>	<b>Shuttle</b>	<b>Crew</b>	<b>Duration</b>	<b>Landing Site</b>	
26	September 29, 1988	STS-26	Discovery	5	04d 01h	Edwards	TDRS deployment; first post Challenger flight
27	December 2, 1988	STS-27	Atlantis	5	04d 09h	Edwards	Third classified DoD mission; Lacrosse 1 deployment
28	March 13, 1989	STS-29	Discovery	5	04d 23h	Edwards	TDRS-D/IUS, IMAX, SHARE I space station radiator experiment.
29	May 4, 1989	STS-30	Atlantis	5	04d 00h	Edwards	Magellan Venus probe deployment
30	August 8, 1989	STS-28	Columbia	5	05d 01h	Edwards	Fourth classified DoD mission; Satellite Data System deployment
31	October 18, 1989	STS-34	Atlantis	5	04d 23h	Edwards	Galileo Jupiter probe deployment, IMAX
32	November 22, 1989	STS-33	Discovery	5	05d 00h	Edwards	Fifth classified DoD mission; Magnum/IUS
33	January 9, 1990	STS-32	Columbia	5	10d 21h	Edwards	SYNCOM IV-F5 satellite deployment, LDEF retrieval, IMAX
34	February 28, 1990	STS-36	Atlantis	5	04d 10h	Edwards	Sixth classified DoD mission; Misty reconnaissance satellite deployment
35	April 24, 1990	STS-31	Discovery	5	05d 01h	Edwards	Hubble Space Telescope deployment
36	October 6, 1990	STS-41	Discovery	5	04d 02h	Edwards	Ulysses/IUS solar probe deployment
37	November 15, 1990	STS-38	Atlantis	5	04d 21h	Kennedy	Seventh classified DoD mission. Likely SDS2-2 deployed.
38	December 2, 1990	STS-35	Columbia	7	08d 23h	Edwards	Use of ASTRO-1 observatory
39	April 5, 1991	STS-37	Atlantis	5	05d 23h	Edwards	Compton Gamma Ray Observatory deployment
40	April 28, 1991	STS-39	Discovery	7	08d 07h	Kennedy	First unclassified DoD mission; military science experiments
41	June 5, 1991	STS-40	Columbia	7	09d 02h	Edwards	Spacelab mission
42	August 2, 1991	STS-43	Atlantis	5	08d 21h	Kennedy	TDRS deployment
43	September 12, 1991	STS-48	Discovery	5	05d 08h	Edwards	Upper Atmosphere Research Satellite deployment
44	November 24, 1991	STS-44	Atlantis	6	06d 22h	Edwards	DSP satellite deployment
45	January 22, 1992	STS-42	Discovery	7	08d 01h	Edwards	Spacelab mission
46	March 24, 1992	STS-45	Atlantis	7	08d 22h	Kennedy	ATLAS-1 science platform
47	May 7, 1992	STS-49	Endeavour	7	08d 21h	Edwards	Intelsat VI repair; first flight of Endeavour. First 3 person EVA. ASEM space station truss experiment
48	June 25, 1992	STS-50	Columbia	7	13d 19h	Kennedy	Spacelab mission
49	July 31, 1992	STS-46	Atlantis	7	07d 23h	Kennedy	EURECA and the joint NASA/Italian Space Agency Tethered Satellite System (TSS)
50	September 12, 1992	STS-47	Endeavour	7	07d 22h	Kennedy	Spacelab-J, Japan funded mission
51	October 22, 1992	STS-52	Columbia	6	09d 20h	Kennedy	LAGEOS II, microgravity experiments
52	December 2, 1992	STS-53	Discovery	5	07d 07h	Edwards	Partially classified 10th and final DoD mission. Likely deployment of SDS2 satellite.
53	January 13, 1993	STS-54	Endeavour	5	05d 23h	Kennedy	TDRS-F/IUS deployment
54	April 8, 1993	STS-56	Discovery	5	09d 06h	Kennedy	ATLAS-2 science platform
55	April 26, 1993	STS-55	Columbia	7	09d 23h	Edwards	Spacelab-D2, Germany funded mission
56	June 21, 1993	STS-57	Endeavour	6	09d 23h	Kennedy	SPACEHAB, EURECA
57	September 12, 1993	STS-51	Discovery	5	09d 20h	Kennedy	ACTS satellite deployed, SPAS-Orfeus with IMAX camera.
58	October 18, 1993	STS-58	Columbia	7	14d 00h	Edwards	Spacelab mission
59	December 2, 1993	STS-61	Endeavour	7	10d 19h	Kennedy	Hubble Space Telescope servicing
60	February 3, 1994	STS-60	Discovery	6	07d 06h	Kennedy	SPACEHAB, Wake Shield Facility

	<b>Launch Date</b>	<b>Mission</b>	<b>Shuttle</b>	<b>Crew</b>	<b>Duration</b>	<b>Landing Site</b>	
61	March 4, 1994	STS-62	Columbia	5	13d 23h	Kennedy	Microgravity experiments
62	April 9, 1994	STS-59	Endeavour	6	11d 05h	Edwards	Shuttle Radar Laboratory-1
63	July 8, 1994	STS-65	Columbia	7	14d 17h	Kennedy	Spacelab mission
64	September 9, 1994	STS-64	Discovery	6	10d 22h	Edwards	Multiple science experiments; SPARTAN
65	September 30, 1994	STS-68	Endeavour	6	11d 05h	Edwards	Space Radar Laboratory-2
66	November 3, 1994	STS-66	Atlantis	6	10d 22h	Edwards	ATLAS-3 science platform
67	February 3, 1995	STS-63	Discovery	6	08d 06h	Kennedy	Mir rendezvous, Spacehab, IMAX
68	March 2, 1995	STS-67	Endeavour	7	16d 15h	Edwards	ASTRO-2
69	June 27, 1995	STS-71	Atlantis	7	09d 19h	Kennedy	First Shuttle-Mir docking
70	July 13, 1995	STS-70	Discovery	5	08d 22h	Kennedy	TDRS-G/IUS deployed
71	September 7, 1995	STS-69	Endeavour	5	10d 20h	Kennedy	Wake Shield Facility, SPARTAN
72	October 20, 1995	STS-73	Columbia	7	15d 21h	Kennedy	Spacelab mission
73	November 12, 1995	STS-74	Atlantis	5	08d 04h	Kennedy	2nd Shuttle-Mir docking. Delivered docking module. IMAX cargo bay camera.
74	January 11, 1996	STS-72	Endeavour	6	08d 22h	Kennedy	Retrieved Japan's Space Flyer Unit, 2 EVAs.
75	February 22, 1996	STS-75	Columbia	7	15d 17h	Kennedy	Tethered satellite reflight, lost due to broken tether.
76	March 22, 1996	STS-76	Atlantis	6	09d 05h	Edwards	Shuttle-Mir docking
77	May 19, 1996	STS-77	Endeavour	6	10d 00h	Kennedy	SPACEHAB; SPARTAN
78	June 20, 1996	STS-78	Columbia	7	16d 21h	Kennedy	Spacelab mission
79	September 16, 1996	STS-79	Atlantis	6	10d 03h	Kennedy	Shuttle-Mir docking
80	November 19, 1996	STS-80	Columbia	5	17d 15h	Kennedy	Wake Shield Facility; ASTRO-SPAS
81	January 12, 1997	STS-81	Atlantis	6	10d 04h	Kennedy	Shuttle-Mir docking
82	February 11, 1997	STS-82	Discovery	7	09d 23h	Kennedy	Hubble Space Telescope servicing
83	April 4, 1997	STS-83	Columbia	7	03d 23h	Kennedy	Truncated due to fuel cell problem
84	May 15, 1997	STS-84	Atlantis	7	09d 05h	Kennedy	Shuttle-Mir docking
85	July 1, 1997	STS-94	Columbia	7	15d 16h	Kennedy	Spacelab mission
86	August 7, 1997	STS-85	Discovery	6	11d 20h	Kennedy	CRISTA-SPAS
87	September 25, 1997	STS-86	Atlantis	7	10d 19h	Kennedy	Shuttle-Mir docking
88	November 19, 1997	STS-87	Columbia	6	15d 16h	Kennedy	Microgravity experiments, 2 EVAs, SPARTAN
89	January 22, 1998	STS-89	Endeavour	7	08d 19h	Kennedy	Shuttle-Mir docking
90	April 17, 1998	STS-90	Columbia	7	15d 21h	Kennedy	Spacelab mission
91	June 2, 1998	STS-91	Discovery	6	09d 19h	Kennedy	Last Shuttle-Mir docking
92	October 29, 1998	STS-95	Discovery	7	08d 21h	Kennedy	SPACEHAB; John Glenn flies again
93	December 4, 1998	STS-88	Endeavour	6	11d 19h	Kennedy	ISS assembly flight 2A: Node 1. First Shuttle ISS assembly flight
94	May 27, 1999	STS-96	Discovery	7	09d 19h	Kennedy	ISS supply
95	July 23, 1999	STS-93	Columbia	5	04d 22h	Kennedy	Chandra X-ray Observatory deployed
96	December 19, 1999	STS-103	Discovery	7	07d 23h	Kennedy	Hubble Space Telescope servicing
97	February 11, 2000	STS-99	Endeavour	6	11d 05h	Kennedy	Shuttle Radar Topography Mission
98	May 19, 2000	STS-101	Atlantis	7	09d 21h	Kennedy	ISS supply
99	September 8, 2000	STS-106	Atlantis	7	11d 19h	Kennedy	ISS supply

	<b>Launch Date</b>	<b>Mission</b>	<b>Shuttle</b>	<b>Crew</b>	<b>Duration</b>	<b>Landing Site</b>	
101	November 30, 2000	STS-97	Endeavour	5	10d 19h	Kennedy	ISS assembly flight 4A: P6 solar arrays, radiators
102	February 7, 2001	STS-98	Atlantis	5	12d 21h	Edwards	ISS assembly flight 5A: Destiny lab
103	March 8, 2001	STS-102	Discovery	7	12d 19h	Kennedy	ISS supply, crew rotation
104	April 19, 2001	STS-100	Endeavour	7	11d 21h	Edwards	ISS assembly flight 6A: robotic arm; First spacewalk by a Canadian Chris Hadfield
105	July 12, 2001	STS-104	Atlantis	5	12d 18h	Kennedy	ISS assembly flight 7A: Quest Joint Airlock
106	August 10, 2001	STS-105	Discovery	7	11d 21h	Kennedy	ISS supply, crew rotation
107	December 5, 2001	STS-108	Endeavour	7	11d 19h	Kennedy	ISS supply, crew rotation
108	March 1, 2002	STS-109	Columbia	7	10d 22h	Kennedy	Hubble Space Telescope servicing, last successful mission for Columbia before STS-107
109	April 8, 2002	STS-110	Atlantis	7	10d 19h	Kennedy	ISS assembly flight 8A: S0 truss
110	June 5, 2002	STS-111	Endeavour	7	13d 20h	Edwards	ISS supply, crew rotation, Mobile Base System
111	October 7, 2002	STS-112	Atlantis	6	10d 19h	Kennedy	ISS assembly flight 9A: S1 truss
112	November 23, 2002	STS-113	Endeavour	7	13d 18h	Kennedy	ISS assembly flight 11A: P1 truss, crew rotation
113	January 16, 2003	STS-107	Columbia	7	15d 22h	N/A (Ken.)	SPACEHAB; Loss of vehicle and crew before landing at KSC
114	July 26, 2005	STS-114	Discovery	7	13d 21h	Edwards	First post Columbia flight. Flight safety evaluation/testing, ISS supply/repair
115	July 4, 2006	STS-121	Discovery	7	12d 18h	Kennedy	ISS Flight ULF1.1: Supply, crew rotation, MPLM Leonardo
116	September 9, 2006	STS-115	Atlantis	6	11d 19h	Kennedy	ISS assembly flight 12A: P3/P4 Truss, Solar Arrays
117	December 9, 2006	STS-116	Discovery	7	12d 21h	Kennedy	ISS assembly flight 12A.1: P5 Truss & Spacehab-SM, crew rotation
118	June 8, 2007	STS-117	Atlantis	7	13d 20h	Edwards	ISS assembly flight 13A: S3/S4 Truss, Solar Arrays, crew rotation
119	August 8, 2007	STS-118	Endeavour	7	12d 18h	Kennedy	ISS assembly flight 13A.1: S5 Truss & Spacehab-SM & ESP3. First use of SSPTS
120	October 23, 2007	STS-120	Discovery	7	15d 02h	Kennedy	ISS assembly flight 10A: US Harmony module, crew rotation
121	February 7, 2008	STS-122	Atlantis	7	12d 18h	Kennedy	ISS assembly flight 1E: European Laboratory Columbus, crew rotation
122	March 11, 2008	STS-123	Endeavour	7	15d 18h	Kennedy	ISS assembly flight 1J/A: JEM ELM PS & SPDM, crew rotation
123	May 31, 2008	STS-124	Discovery	7	13d 18h	Kennedy	ISS assembly flight 1J: JEM - Japanese module Kibo & JEM RMS
124	November 14, 2008	STS-126	Endeavour	7	15d 20h	Edwards	ISS assembly flight ULF2: MPLM Leonardo, crew rotation
125	March 15, 2009	STS-119	Discovery	7	12d 19h	Kennedy	ISS assembly flight 15A: S6 Truss, Solar Arrays
126	May 11, 2009	STS-125	Atlantis	7	12d 21h	Edwards	Last Hubble Space Telescope servicing mission (HST SM-04). Final Non-ISS flight.
127	July 15, 2009	STS-127	Endeavour	7	15d 16h	Kennedy	ISS assembly flight 2J/A: JEM Exposed Facility (EF) & JEM ELM ES.
128	August 28, 2009	STS-128	Discovery	7	13d 21h	Edwards	ISS assembly flight 17A: MPLM Leonardo & 6 person ISS crew.
129	November 16, 2009	STS-129	Atlantis	6	10d 19h	Kennedy	ISS assembly flight ULF3: ExPRESS Logistics Carriers (ELCs) 1 & 2.
130	February 8, 2010	STS-130	Endeavour	6	13d 18h	Kennedy	ISS assembly flight 20A: Node 3 and Cupola
131	April 5, 2010	STS-131	Discovery	7	15d 03h	Kennedy	ISS assembly flight 19A: Utility and Logistics Flight 4: Multi-Purpose Logistics Module
132	May 14, 2010	STS-132	Atlantis	6	11d 18h	Kennedy	ISS assembly flight ULF4: Mini-Research Module 1.
133	February 24, 2011	STS-133	Discovery	6	12d 19h	Kennedy	ISS assembly flight ULF5, PMM Leonardo (to be left permanently attached),
134	May 16, 2011	STS-134	Endeavour	6	15d 18h	Kennedy	ISS assembly flight ULF6, ELC 3, ROEU, Alpha Magnetic Spectrometer.
135	July 8, 2011	STS-135	Atlantis	4	12d 18h	Kennedy	Payload Multi-Purpose Logistics Module (MPLM) Raffaello.



This image of the International Space Station and the docked space shuttle Endeavour (STS-134), flying at an altitude of approximately 220 miles, was taken by Expedition 27 crew member Paolo Nespoli from the Soyuz TMA-20 following its undocking

# STS-135 Daily Mission Reports

## MCC Reports (Mission Control Centre)

### STS-135 MCC Status Report #01

With a cargo carrier packed with supplies and equipment, Atlantis launched Friday morning to the International Space Station on the final space shuttle mission.

The shuttle with its crew of four lifted off from the Kennedy Space Centre on its 12-day flight at 10:29 a.m. CDT. Aboard are the Raffaello multi-purpose logistics module and the Robotic Refuelling Mission experiment, which could help develop ways to refuel satellites in orbit.

Nearly a million people came to the Kennedy area to see Atlantis lift off on a mission marking the end of the space shuttle era. The mission's focus was to leave the station as well supplied as possible to begin its post-shuttle existence. Atlantis also is scheduled to return a failed ammonia pump to Earth for examination – a task no other spacecraft can do.

Commander Chris Ferguson, Pilot Doug Hurley and Mission Specialists Sandra Magnus and Rex Walheim, are scheduled to rendezvous and dock with the station on Sunday.

Raffaello is making its fourth trip to the station. On flight day 4 it will be lifted from the cargo bay and attached to the Harmony node. It will be unloaded there and subsequently loaded with station discards before it is returned to the cargo bay on flight day 10 for return to Earth.

The Robotic Refuelling Mission experiment will be installed during the only spacewalk, by station crew members, while Atlantis is docked there. The experiment will test concepts, techniques and tools for robotically refuelling satellites in orbit. The test will use the station's robotic capabilities, the first test in space of ways to refuel satellites, including those not designed for such servicing.

Aboard the station waiting to welcome Atlantis and its crew are Expedition 28 Commander Andrey Borisenko and Flight Engineers Alexander Samokutyaev, Ron Garan, Sergei Volkov, Mike Fossum and Satoshi Furukawa.

STS-135 is the 135th shuttle flight, the 33rd flight for Atlantis and the 37th shuttle mission dedicated to station assembly and maintenance.

The next shuttle status report will be issued after crew wakeup or earlier if warranted. The crew is scheduled to awaken just before 3 a.m. Saturday.

### STS-135 MCC Status Report #02

The final shuttle crew began their first full day in space with a chorus of well wishes from some of the many people who helped put them there.

“Good morning, Atlantis!” NASA employees said in a message recorded before launch. “The Marshall Space Flight Centre hopes you enjoyed your ride to orbit. We wish you a successful mission and a safe return home.”

Marshall Space Flight Centre, located in Huntsville, Ala., is responsible for the space shuttle's propulsion system – the shuttle's three main engines, the twin solid rocket boosters and the external tank.

The message was preceded by the mission's first wake up song, Coldplay's “Viva la Vida,” which was played for Pilot Doug Hurley. The wakeup call came at 2:59 a.m.

With that encouragement, space shuttle Atlantis' crew – Hurley, Commander Chris Ferguson and Mission Specialists Sandy Magnus and Rex Walheim – got to work on their flight day two activities. The main objective of the day will be to get a closer look at the shuttle's heat shield to verify that it didn't sustain any damage during Atlantis' climb into orbit.

To do so, Ferguson, Hurley and Magnus will use the space shuttle's robotic arm and 50-foot long boom to get a close up look at the shuttle's wing leading edges and nose cap. A suite of cameras on the end of the boom will capture images of the reinforced carbon that protects the shuttle from the hottest temperatures it experiences. Imagery experts on the ground will comb through the data to make sure that the heat shield is still in good shape.

The survey is scheduled to start at 7:19 a.m., and wrap up about six hours later.

Later in the day, Walheim will work with Hurley to check out the tools that will be used during Atlantis' rendezvous and docking with the International Space Station on Sunday. Meanwhile, Ferguson and Magnus will install a camera in the window of the shuttle's hatch for a view that will help them align Atlantis with the space station.

The next shuttle status report will be issued at the end of the crew's day or earlier if warranted. The crew is scheduled to go to sleep just before 6:30 p.m.

### STS-135 MCC Status Report #03

Atlantis astronauts inspected the orbiter's thermal protection system with its robotic arm and attached 50-foot boom Saturday. They also prepared rendezvous tools for arrival at the International Space Station.

Docking with the orbiting laboratory is scheduled for a little after 10 a.m. CDT Sunday.

Commander Chris Ferguson, Pilot Doug Hurley and Mission Specialist Sandra Magnus spent much of their day gathering visual and electronic data on the reinforced carbon of the wings' leading edges and the nose cap. Experts on the ground will review the data to ensure they have not been damaged.

No obvious issues were reported. If analysis reveals any indication of damage the crew could be asked to conduct a focused inspection of any suspect area.

While the inspection was under way, the fourth crew member, Mission Specialist Rex Walheim, spent much of his afternoon on Atlantis' middeck. He worked to prepare items carried into orbit there for transfer to the space station.

In addition to the middeck cargo, Atlantis is bringing to the station the Raffaello multi-purpose logistics module, packed with supplies and equipment for the station. Raffaello is to be unberthed from the cargo bay and installed on the station's Harmony node early Monday. After unloading, it will be packed with station discards and other items, and put back in the cargo bay for return to Earth.

After the heat shield survey and the work with the middeck cargo, all four crew members worked to prepare for rendezvous and docking with the station. Hurley and Walheim checked out rendezvous tools while Ferguson and Magnus installed the centreline camera and extended the orbiter docking system ring.

The next status report will be issued after crew wakeup or earlier if warranted.

### STS-135 MCC Status Report #04

Space shuttle Atlantis' crew began their third day in space at 2:29 a.m., just hours away from the scheduled final docking of a space shuttle with the International Space Station.

The wakeup call for Commander Chris Ferguson, Pilot Doug Hurley and Mission Specialists Sandy Magnus and Rex Walheim came in the form of "Mr. Blue Sky" by Electric Light Orchestra. That song was played for Ferguson.

The shuttle has been closing the distance between it and the space station since it reached orbit on Friday and with the help of a final firing of the shuttle's jets, scheduled for 7:29 a.m., it will finish closing that distance by 9:06 a.m. At that point, the shuttle will be directly below the International Space Station, and in place for the rendezvous pitch manoeuvre, a back flip that will expose the tiles on the shuttle's underbelly to the space station, where station crew members will be standing by with cameras to document its condition.

At the windows in the Russian segment of the space station, Flight Engineer Ron Garan will use a 800 mm camera to gather photos of Atlantis' heat shield, while Flight Engineer Satoshi Furukawa will have a 400 mm camera, and Flight Engineer Sergei Volkov will use a 1,000 mm.

The back flip will last about eight minutes. Once it's complete, Ferguson will move Atlantis to a point 310 feet directly in front of the space station and begin slowing down so that the station can catch up with the shuttle, for a 10:07 a.m. docking. After a series of leak checks, hatches between the two vehicles are scheduled to open at 12:19 p.m.

The next status report will be issued at the end of the crew's day or earlier if warranted. Atlantis' crew is scheduled to go to sleep just before 6 p.m.



### STS-135 MCC Status Report #05

Atlantis docked with the International Space Station at 10:07 a.m. CDT Sunday with a cargo-carrying module in its payload bay filled with equipment and supplies for the orbiting laboratory.

“Atlantis arriving,” said Flight Engineer Ron Garan after the ceremonial ringing of the station’s bell. “Welcome to the station for the last time.”

After a pause to let the relative motion between the two spacecraft dampen out and do leak checks, hatches separating crews were opened at 11:47 a.m. Shuttle crew members, Commander Chris Ferguson, Pilot Doug Hurley and Mission Specialists Sandra Magnus and Rex Walheim, entered the station moments later to begin their week-plus stay.

First came the standard safety briefing for the new arrivals. Then work began.

Ferguson and Hurley used the shuttle arm to take its 50-foot extension boom from the station’s Canadarm2 operated by station Flight Engineers Garan and Satoshi Furukawa. The station arm had plucked the boom from its stowage position on the shuttle cargo bay sill. The handoff was to prepare to use the boom for any needed shuttle heat shield inspection later this week. Magnus worked with TV setup and Walheim transferred spacewalk gear.

Docking had gone just as planned. Ferguson and the crew of space shuttle Atlantis began their final approach to the station from about eight miles distance with the terminal initiation burn at 7:29 a.m.

About 600 feet below the station, Atlantis did a back flip to enable station crew members to photograph the shuttle’s heat shield. Flight Engineers Mike Fossum, Satoshi Furukawa and Sergei Volkov used cameras with 1,000 mm, 800 mm and 400 mm lenses, respectively, to take high resolution digital photos of the shuttle’s upper and lower surfaces. The photos were being sent to mission control to be evaluated by experts on the ground to look for any damage.

Flight controllers began monitoring reports from the Department of Defence’s U.S. Strategic Command that a piece of orbital debris may come near the station and shuttle complex about noon on Tuesday. The debris, part of satellite COSMOS 375, is one of more than 500,000 pieces of debris tracked in Earth’s orbit. The team expected updated tracking information following today’s docking to help determine if a manoeuvre using the shuttle’s thrusters is necessary to avoid the debris.

The next status report will be issued after crew wakeup or earlier if warranted. The crew is scheduled to awaken just before 2 a.m. Monday.

### STS-135 MCC Status Report #06

Space shuttle Atlantis’ crew will be getting down to the main objective of their mission today, as they temporarily install the Raffaello multipurpose logistics module on the International Space and begin unloading its contents.

The crew started their fourth day in space at 2:02 a.m., after being awakened by the Chumbawamba song “Tubthumping.” It was played for Mission Specialist Sandy Magnus.

Magnus, along with Pilot Doug Hurley, will be at the controls of the space station’s robotic arm beginning at 4:09 a.m. to remove the Raffaello module from the shuttle’s cargo bay. They’ll install it on the station’s Harmony node 30 minutes later.

Once that is complete, Magnus will work with Commander Chris Ferguson to prepare the module’s hatch for opening at 12:39 p.m., after which the crew will begin unloading the 9,402 pounds of supplies it carried into space.

In addition, Ferguson and Mission Specialist Rex Walheim will begin moving another 2,281 pounds of cargo brought up on Atlantis’ middeck over to the space station. And later in the day, the entire shuttle crew will come together with station Flight Engineers Ron Garan, Satoshi Furukawa and Mike Fossum to review the procedures for the mission’s spacewalk. Fossum and Garan will perform that spacewalk on Tuesday.

Meanwhile, here on the ground, flight controllers were able to verify that the track of a piece of orbital debris they began watching on Saturday will not be a threat to the shuttle and station. No adjustments to the shuttle and station’s orbit will be necessary to avoid the debris, which is part of satellite COSMOS 375 and one of more than 500,000 pieces of debris tracked in Earth’s orbit.

The next status report will be issued at the end of the crew’s day or earlier if warranted. The crew is scheduled to go to sleep just before 6 p.m.



### STS-135 MCC Status Report #07

Atlantis astronauts moved the Raffaello cargo carrier from the shuttle's cargo bay to the Earth-facing port of the International Space Station's Harmony node early Monday.

Pilot Doug Hurley and Mission Specialist Sandra Magnus moved the multi-purpose logistics module using the station's Canadarm2. The installation of Raffaello was completed a little after 5:45 a.m. CDT.



After leak checks, hatches between Raffaello and the station were opened before noon. Unloading of the more than 9,400 pounds of supplies and equipment aboard Raffaello was scheduled to begin early Tuesday.

The module is to be unloaded, then filled with 5,666 pounds of equipment and discards no longer needed on the station. It is scheduled to be taken from the Harmony node port and reinstalled in Atlantis' cargo bay on Monday, July 18, several hours before crews of the two spacecraft say goodbye and close hatches. Atlantis is now scheduled to undock from the station that evening at 11:56 p.m.

Mission managers said Monday afternoon Atlantis' stay at the station would be extended for one day. The first Kennedy Space Centre landing opportunity for Atlantis would be at 4:56 a.m. July 21. Landing had been scheduled for July 20, but conservation of power-generating consumables made the extension possible.

Managers also determined that after Saturday's inspection, further detailed inspections of Atlantis' heat shield are not required. A customary, final inspection will be completed after Atlantis undocks from the station.

Other activities on the crews' schedules today included continuing transfer of items between the shuttle's middeck and the station. Atlantis brought almost 2,300 pounds of experiments, equipment and supplies for the station in the shuttle's middeck lockers.

Shortly before the end of their workday, the four shuttle crew members and station Flight Engineers Ron Garan, Mike Fossum and Satoshi Furuakawa met

for about an hour to review procedures for Tuesday's spacewalk. Beginning about 7:45 a.m., Garan and Fossum, who did three spacewalks together during STS-124 in June 2008, will leave the Quest airlock for the 6.5-hour outing.

Major spacewalk activities include retrieving a failed 1,400-pound pump module and installing it in the shuttle cargo bay for return to Earth, installing a robotic satellite refuelling experiment and setting up a materials experiment.

The next status report will be issued after crew wakeup or earlier if warranted. The crew is scheduled to awaken just before 2 a.m. Tuesday.

### STS-135 MCC Status Report #08

Transfer work will be going on inside and outside of the International Space Station today, as the crew performs the first and only spacewalk of the STS-135 mission.

Space shuttle Atlantis' crew was awakened at 1:59 a.m. by the song "More" by Matthew West. It was played for Mission Specialist Rex Walheim.

Walheim today will be choreographing from inside the space station the spacewalk being done outside by Expedition 28 Flight Engineers Mike Fossum and Ron Garan. Fossum and Garan will be packing a pump module that failed in 2010 into the shuttle's cargo bay. It was moved into a temporary storage location on external stowage platform-2 during the STS-133 mission earlier this year. Returning it to Earth will allow engineers to look into what caused its failure and then refurbish it for use as a spare.

Fossum and Garan will also be installing the Robotic Refuelling Mission experiment on a platform used by the Special Purpose Dexterous Manipulator, or Dextre, to hold spare parts. The Robotic Refuelling Mission will demonstrate and test the tools, technologies and techniques needed to robotically refuel and repair satellites in space.

The spacewalk is scheduled to begin at 7:44 a.m., and last six and a half hours.

Meanwhile, inside the space station, every member of the shuttle crew and many of the station crew will be working to unload the newly installed Raffaello multipurpose logistics module. It brought up 9,400 pounds of cargo to the space station, all of which must be unloaded and replaced with 5,700 pounds of trash and used equipment to return home.

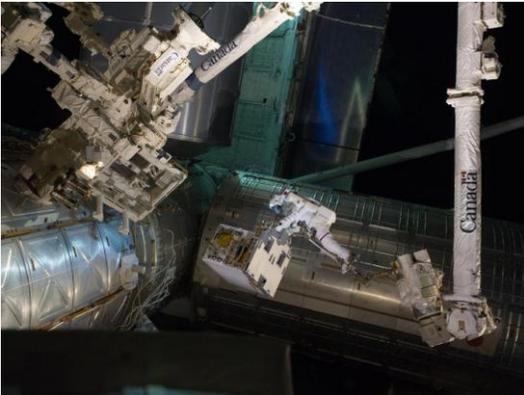
The next status report will be issued at the end of the crew's day or earlier if warranted. The crew is scheduled to go to sleep just before 6 p.m.

### STS-135 MCC Status Report #09

Two International Space Station astronauts completed a six-hour, 31-minute spacewalk at 2:53 p.m. CDT Tuesday, retrieving a failed pump module for return to Earth, installing two experiments and repairing a new base for the station's robotic arm.



Flight Engineers Mike Fossum and Ron Garan used that arm, Canadarm2, in their first and most lengthy task; retrieval of the failed 1,400-pound pump module from the station's cooling system that failed last year. Garan rode the arm to the pump module's stowage rack where he and Fossum removed it.



Still on the arm, operated by Atlantis Pilot Doug Hurley and Mission Specialist Sandra Magnus in the station's cupola, Garan took the pump module to a carrier in Atlantis' cargo bay. There Fossum bolted it into place for the ride home.

Coached by intravehicular officer and Atlantis Mission Specialist Rex Walheim, with help from spacewalk capcom and astronaut Steve Bowen in the station flight control room, the spacewalkers moved on to their next task, installation of the Robotic Refuelling Mission experiment. The experiment is designed to help in development of ways to robotically refuel satellites in space.



Fossum was making his seventh spacewalk and Garan his fourth (all with Fossum). They removed the refuelling experiment from the cargo bay. Fossum, now on the arm, carried the experiment to a platform on Dextre, the Special Purpose Dexterous Manipulator.

Fossum removed the foot restraint he and Garan had used at the end of the Canadarm2, then moved

to the front of the Zarya module. There he freed a wire stuck in one latch door at a data grapple fixture installed during the STS-134 mission in May. The fixture can serve as a base for Canadarm2, considerably extending its range of operation.

Meanwhile, Garan deployed a materials experiment also installed during STS-134, on a carrier on the station's starboard truss. The eighth in a series of station materials experiments, it focuses on optical reflector materials. It was not deployed during the previous flight because of concerns about outgassing from insulation on the nearby Alpha Magnetic Spectrometer experiment, also installed during the earlier mission.

Back together again, the two spacewalkers moved on to Pressurized Mating Adaptor 3 on the Tranquillity node. They installed an insulating cover on the end of the PMA, an area exposed to considerable sunshine.

Inside the shuttle-station complex, transfer of material from the Raffaello multipurpose logistics module began. The work to unload the more than 9,400 pounds of supplies and equipment brought up by Raffaello and then repack it with 5,700 pounds of equipment, supplies and trash to return home will continue for much of Atlantis stay at the station.

The next status report will be issued after crew wakeup or earlier if warranted. The crew is scheduled to awaken just before 1:30 a.m. Wednesday.

### STS-135 MCC Status Report #10

The space shuttle Atlantis crew received a special wakeup call today to kick off flight day 6 of the STS-135 mission.

"Good morning, Atlantis, this is Elton John," the British singer said in a pre-recorded message. "We wish you much success on your mission. A huge thank you to all the men and women at NASA who worked on the shuttle for the last three decades."

The message followed the day's wakeup song, John's "Rocket Man," which was played at 1:29 a.m. It was not the first time the song has been played in space – "Rocket Man" has awakened four shuttle crew's in the shuttle program's 30-year history, and it was one of NASA's top 40 wakeup call songs listed for voter selection during a contest to commemorate space shuttles Discovery and Endeavour's last missions. In that contest, it earned nearly 5,000 votes from the public.

With the mission's one spacewalk successfully behind them, Atlantis' crew will return its focus today to

unpacking the Raffaello multipurpose logistics module. The crew started the day 26 percent through the combined 15,069 pounds of cargo to transfer in or out of Raffaello – 9,403 pounds that launched on Atlantis and 5,666 pounds that it will bring home when it lands.

In addition, the crew will be taking some time out of its work at 11:54 a.m. to talk with reporters from WBNG-TV and WICZ-TV in Binghamton, New York, and KGO-TV of San Francisco.

The next status report will be issued at the end of the crew's day or earlier if warranted. The crew is scheduled to go to bed just before 4:30 p.m.

#### STS-135 MCC Status Report #11

Atlantis crew members spent much of Wednesday moving equipment and supplies from the multipurpose logistics module Raffaello to the International Space Station.

They had some help from station Commander Andrey Borisenko and Flight Engineers Sergei Volkov and Satoshi Furukawa in the transfer operations. The bottom line was that the more than 9,400 pounds of material in Raffaello was considerably reduced.

Station lead flight director Chris Edelen said at an afternoon briefing that about half of the cargo had been moved from Raffaello and the shuttle's middeck to the space station. Almost 5,700 pounds of unneeded equipment and supplies from the station will be packed aboard the module for return the transfer activity can be strenuous. While the cargo bags are weightless, they do have mass. They require effort to be put in motion, effort to change their direction and effort to stop their motion.

Crew members opened Pressurized Mating Adaptor 3, attached to the Tranquillity node, and stored some of the material from Raffaello there. On Tuesday spacewalkers had put an insulating cover on the outside of PMA-3 to protect it from temperature extremes.

A little before noon CDT, all four shuttle crew members talked with representatives of WBNG-TV and WICZ-TV in Binghamton, N.Y., near Pilot Doug Hurley's home town of Apalachin, and KGO-TV of San Francisco. Mission Specialist Rex Walheim is from nearby San Carlos.

The next status report will be issued after crew wakeup or earlier if warranted.

#### STS-135 MCC Status Report #12

Flight day 7 of the STS-135 mission started out with a serenade for the crew of space shuttle Atlantis.

In a special message recorded before launch from Venice, Italy, Michael Stipe, lead singer of R.E.M., sang an A capella version of the band's song "Man on the Moon," then followed it with a greeting to the astronauts.

"Good morning, Atlantis," he said. "This is Michael Stipe from R.E.M. We wish you much success on your mission, and thank all the women and men at NASA who have worked on shuttle for three decades. From Earth, a very good morning to you."



More unpacking of the Raffaello multipurpose logistics module is on tap today for Commander Chris Ferguson, Pilot Doug Hurley and Mission Specialists Sandy Magnus and Rex Walheim. But they'll also take some time out for a few special events.

At 5:59 a.m., Ferguson and Magnus will be speaking with reporters from Fox News Radio and KTVI-TV and KSDK-TV in St. Louis. Then, at 8:19 a.m., the entire crew will be interviewed by WBBM-TV in Chicago, KTVU-TV in Oakland, Calif., and WTXF-TV in Philadelphia.



In addition, both the shuttle and station crews will have the opportunity to enjoy an "All-American Meal" of barbecue brisket or grilled chicken and baked beans, south-western corn and apple pie, and the public is invited to share in it, virtually. The shuttle and station crews' midday meals are scheduled to begin at 7:19 a.m.

The next status report will be issued at the end of the crew's day or earlier if warranted. The crew is scheduled to go to sleep just before 3:30 p.m.

### STS-135 MCC Status Report #13

Continuing cargo transfer, news media interviews and exercise sessions kept Atlantis crew members busy Thursday morning. They enjoyed some welcome off-day time during their afternoon.

Unloading of the multi-purpose logistics module Raffaello's 9,400 pounds of cargo was well over half complete. Transfer of its remaining cargo to the International Space Station was expected to be finished Friday or Saturday.

Raffaello is to be reloaded with almost 5,700 pounds of gear from the station, mostly unneeded equipment and trash. It is to be replaced in Atlantis' cargo bay Monday morning for return to Earth.



A little before their midday meal, about 6 a.m. CDT, shuttle commander Chris Ferguson and Mission Specialist Sandra Magnus talked with representatives of FOX News Radio and KTVI-TV and KSDK-TV, both in St. Louis. All four shuttle crew members chatted with WBBM-TV of Chicago, KTVU-TV of Oakland, Calif., and WTXF-TV of Philadelphia at about 8:20 a.m.

Afterward the shuttle crew had most of the afternoon off. Station crew members also had some free time early in their afternoon.

The crew's supper was special. That All-American Meal was initially scheduled for July 4 but wound up being enjoyed today because of Atlantis' launch delay. Grilled chicken, corn, baked beans, cheese and more, topped off with apple pie, were on the menu. The next status report will be issued after crew wakeup or earlier if warranted. The crew is scheduled to awaken at 11:29 p.m.

### STS-135 MCC Status Report #14

Sir Paul McCartney awakened the crew of Atlantis today with a special message and the song "Good Day Sunshine," starting a day for the final shuttle crew that will be highlighted by a call from President Barack H. Obama.

"Good morning guys!" McCartney said in a message recorded pre-launch for the final space shuttle crew. "Wake up! And good luck on this, your last mission. Well done!"

McCartney's wakeup call came at 11:59 p.m. Thursday, 30 minutes later than Atlantis' crew had been scheduled to wake up. It was delayed to give the crew time to make up sleep they lost over the course of the night due to a failure of one of the shuttle's five general purpose computers.



At 5:07 p.m. on Thursday, a failure alarm rang on board Atlantis, tripped by a problem with general purpose computer 4. Only two of the shuttle's computer are needed when the shuttle is orbiting the Earth, so the functions that computer had been responsible for were simply transferred to another computer. But the crew spent 40 minutes of their sleep time working through the procedures to do so, and elected to make that time up by sleeping in for 30 minutes.

Commander Chris Ferguson and Pilot Doug Hurley have an hour set aside this morning to work with the computer and get it back up and running.

Much of the rest of the crew's day will be again be spent transferring cargo to and from the Raffaello multipurpose logistics module. But the crew will take several breaks – at 5:44 a.m., 7:04 a.m. and 8:24 a.m. – to talk with reporters back on Earth.

And before they turn in for the night they'll take one more break to answer a call from the White House – President Obama is scheduled to call e 1:30 p.m.



### STS-135 MCC Status Report #15

News media interviews, a news conference with reporters at NASA centres and in Japan and a call from President Obama highlighted Atlantis crew activities Friday.

Between those events, it was back to the demanding work of cargo transfer between the shuttle and station. The unloading of the Raffaello multi-purpose logistics module's 9,400 pounds of cargo was about 70 percent complete and packing its 5,700 pounds of homeward-bound material had begun.

At about 11:30 a.m. CDT Obama radioed the combined International Space Station and shuttle crews that he was proud of all the crew members.

"We're all watching as the 10 of you work together as a team," Obama said. "Your example means so much not just to your fellow Americans but also your fellow citizens on Earth. The space program has always embodied our sense of adventure and explorations and courage."

He thanked those who had supported the shuttle program during the past 30 years, and all the men and women of NASA who helped the country lead the space age.

Atlantis Commander Chris Ferguson said that all the partners on the station were honoured to represent their home countries in this multinational effort.

Station Flight Engineer Sergei Volkov described the station and shuttle crews, from three nations, as "one big family."

The media interviews began about 5:45 a.m. Ferguson and Pilot Doug Hurley talked with representatives of CBS Radio, KYW-TV in Philadelphia and Associated Press. Next up was a 7:04 a.m. chat by all Atlantis crew members with WPVI-TV and KYW Radio, both of Philadelphia, and Reuters.

At the 45-minute crew news conference, Atlantis crew members and their six station colleagues gathered in the Japanese Kibo Laboratory to take questions from news media. Reporters at four NASA centres, NASA headquarters and in Japan participated.

This morning Ferguson and Hurley brought General Purpose Computer 4 back on line in a backup role. GPC-4 had unexpectedly shut down a little after 5 p.m. Thursday, about an hour and a half after the crew had gone to bed. Crew members transferred its functions to another computer, and this morning reloaded its software and got it running again.

Atlantis Mission Specialist Rex Walheim and station Flight Engineer Mike Fossum worked to resize U.S. spacesuits to be left on the station.

### STS-135 MCC Status Report #16

The crew of the final space shuttle mission woke up today to well wishes from a former neighbour of sorts.

"Good morning, Atlantis!" Houston native Beyonce Knowles said in a pre-recorded message for the STS-135 astronauts. "This is Beyonce. Sandy, Chris, Doug and Rex, you inspire all of us to dare to live our dreams, to know that we're smart enough and strong enough to achieve them."

The message was preceded by Knowles' song "Run the World (Girls)," and before the singer wrapped up her greeting, she had a special shout out for the crew's female member, Mission Specialist Sandy Magnus.

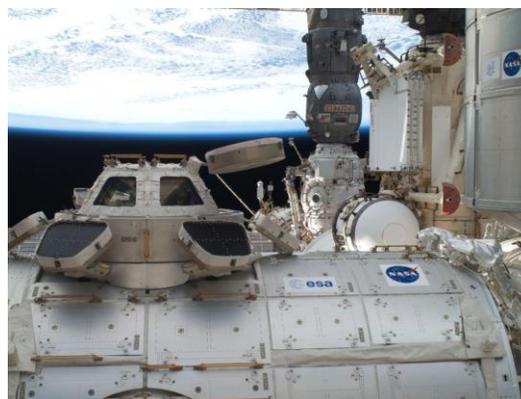
"This song is especially for my girl, Sandy," she said, "and all the women who've taken us to space with them, and the girls who are our future explorers."

Magnus, along with Commander Chris Ferguson, Pilot Doug Hurley and Mission Specialist Rex Walheim are scheduled to spend more time today filling the Raffaello multipurpose logistics module up for return to Earth.

But as the list of items left to be packed grows shorter, they'll be branching out to other activities, picking up some station work and performing spacesuit maintenance and even unpacking some of the cargo they've delivered.

Ferguson and Hurley will also spend some time working to repair the door that gives the crew access to the shuttle's air revitalization system. The latch on the door was reported by the crew to have broken on Friday. The door is located in the floor of the shuttle's middeck and opened by the crew when they change out the lithium hydroxide canisters that remove carbon dioxide from the shuttle's atmosphere.

The next status report will be issued at the end of the crew's day or earlier if warranted. The crew is scheduled to go to sleep just before 2 p.m. on Saturday.



### STS-135 MCC Status Report #17

All four Atlantis crew members worked Saturday to move equipment and supplies between the International Space Station and the multi-purpose logistics module Raffaello.

Commander Chris Ferguson, Pilot Doug Hurley and Mission Specialists Sandra Magnus and Rex Walheim, with help from their station colleagues, were nearing the home stretch in transfer activities. Most of the 9,400 pounds of equipment brought up in Raffaello is aboard the station, and the loading of 5,700 pounds of return items is well under way. Raffaello is scheduled to be unberthed from the station's Harmony node and returned to the shuttle's cargo bay early Monday.

Early Saturday Ferguson and Hurley fixed a latch on a door in the floor of Atlantis' middeck. The air revitalization system compartment beneath the door houses lithium hydroxide canisters, used to scrub carbon dioxide from the shuttle's cabin atmosphere. The system will be needed once hatches between Atlantis and the station are closed about 8:30 a.m. CDT Monday. Atlantis is scheduled to undock from the station about 1:30 a.m. Tuesday, and land at Kennedy Space Centre just before 5 a.m. on Thursday.



Magnus spent about an hour and a half Saturday morning taking microbial air samples in the station. They will be returned in Atlantis for study and analysis.

Walheim continued his work with spacewalking tools and equipment. Some will be left on the station, and be available for use in upcoming Russian spacewalks from the Pirs docking compartment. It will be about a year before the next scheduled U.S. spacewalk from the station's Quest airlock takes place.

The astronauts also provided a recorded message as a tribute to Atlantis, the entire Space Shuttle Program and team. In the message, Ferguson spoke about the U.S. flag displayed behind them that was flown on the first space shuttle mission, STS-1. It was flown on this mission to be presented to the space station crew and it will remain displayed onboard the station until the next crew launched from the U.S. retrieves it for return to Earth. It will fly from Earth again, with the next crew that launches from the U.S. on a journey of exploration beyond Earth orbit.

### STS-135 MCC Status Report #18

After several days of wakeup calls from celebrities, the STS-135 crew kicked off their 10th day in space with a message from some of the stars of the Space Shuttle Program.

"Good morning Atlantis, from your friends at Stennis Space Centre," Stennis employees said in a message recorded before launch. "It's time to fire up your engines – laissez les bons temps rouler!"

"Laissez les bons temps rouler," is a Cajun French phrase that translates "Let the good times roll." Stennis Space Centre, located in southern Mississippi, 50 miles from New Orleans, is home to the test stands that verified each of the main engines that helped propel space shuttles into low Earth orbit – including the three used in the STS-135 launch – was in good working order before it was installed.

The message was fittingly preceded by the wakeup song, "Celebration" by Kool and the Gang, which was played for Mission Specialist Sandy Magnus. The wakeup call came at 9:59 p.m.

Flight day 10 will see the wrap up of transfer work inside the Raffaello multipurpose logistics module, before the crew closes its hatch and returns it to the shuttle's cargo bay on Monday. They started the day with 96 percent of the work inside Raffaello done.

In addition, Commander Chris Ferguson and Pilot Doug Hurley are scheduled at 5:09 a.m. to answer videotaped questions from students at NASA Explorer Schools across the country, in the last interactive educational event with a space shuttle crew.

Following that, the crew will have two hours of off duty time.

The next status report will be issued at the end of the crew's day or earlier if warranted. The crew is scheduled to go to sleep just before 1:30 p.m.



STS-135 MCC Status Report #19

Moving days aboard the International Space Station are nearing completion for the station and shuttle crews.

The 9,400 pounds of equipment and supplies brought up by the multi-purpose logistics module have been moved to the International Space Station. The loading of Raffaello with almost 5,700 pounds of unneeded station equipment and trash also is almost finished.

The Raffaello module is scheduled to be unberthed early Monday from the station's Harmony node and secured in Atlantis' cargo bay for the ride home. At the controls of the station's Canadarm2 will be Atlantis Mission Specialist Sandra Magnus, who served as load master for the complex and demanding cargo transfer, and Pilot Doug Hurley.

After their midday meal today, Magnus and Commander Chris Ferguson worked a little over an hour continuing to move experiments and equipment to and from Atlantis' middeck. That done, the shuttle crew had most of the afternoon off.

Mission control data processing experts declared Atlantis' General Purpose Computer 4 to be healthy after its Thursday shutdown. It is back in operation in its normal role of shuttle systems management. GPC 1 remains the guidance, navigation and control computer while GPCs 2 and 3 are in standby.

Beginning about 5:10 a.m. CDT, Hurley and Mission Specialist Rex Walheim answered questions from NASA Explorer Schools students. It was the last opportunity for shuttle crew members to respond to students' questions.

STS-135 MCC Status Report #20

The STS-135 flight day 11 wakeup call came from Houston, as always, but in a broader sense of the word than usual.

"Good morning, Atlantis, from all of us at the Johnson Space Centre!" chorused an auditorium-full of Johnson employees in a message recorded before Atlantis' launch. "Have a great mission!" Johnson Space Centre is home not only to the astronaut corps, but also Mission Control and the Space Shuttle Program, itself. The message was preceded in the 9:29 p.m. wakeup call by Keith Urban's "Days Go By," which was chosen by Mission Specialist Rex Walheim.

Walheim and his fellow crew members – Commander Chris Ferguson, Pilot Doug Hurley and Mission Specialist Sandy Magnus – are scheduled to close the hatches between the International Space Station and a space shuttle for the last time today, at 8:19 a.m. But before they do that, they'll pack up the last of the cargo to come home from the station on the shuttle's middeck and move the Raffaello multipurpose logistics module back into place inside the shuttle's cargo bay. The crew finished packing Raffaello on flight day 10, and now it's just a matter of getting it – with its 5,666 pounds of returning cargo – back in place for the trip home. When it's unpacked back on Earth, multipurpose logistic modules will have returned 20 tons of supplies and equipment to Earth, and carried another 50 tons into space since their first mission, STS-102 in 2002.

After returning to the space shuttle for the remainder of the mission, the crew will prepare for Tuesday's undocking from the space station, checking out the tools they'll use for that activity and setting up a camera inside the shuttle hatch.



### STS-135 MCC Status Report #21

Atlantis and International Space Station crew members said their goodbyes and closed hatches between the two spacecraft at 9:28 a.m. CDT, ending seven days, 21 hours, 41 minutes of docked operations.

Shuttle Commander Chris Ferguson, Pilot Doug Hurley and Mission Specialists Sandra Magnus and Rex Walheim are spending their night with Atlantis still docked to the station. They will begin their journey home with undocking, scheduled for about 1:30 a.m. Tuesday.

Aboard the station, Commander Andrey Borisenko and Flight Engineers Alexander Samokutyaev, Ron Garan, Sergei Volkov, Satoshi Furukawa and Mike Fossum will work during the coming days stowing equipment and supplies left by Atlantis. About 9,400 pounds of it came up on Raffaello, the multi-purpose logistics module. Almost 2,300 pounds of additional cargo, including scientific equipment and experiments, was brought up on Atlantis' middeck.

Hatches were closed separating Raffaello and the station, beginning at 12:03 a.m. Monday when the hatch on the cargo carrier was closed. It was undocked from the station's Harmony node and returned to Atlantis' cargo bay by Magnus and Hurley using the station's Canadarm2. Raffaello and its return cargo of almost 5,700 pounds of unneeded equipment and trash from the station, was secured in the cargo bay shortly before 7 a.m.

At the farewell ceremony before the shuttle crew returned to Atlantis, Ferguson presented to the station a small U.S. flag that had flown on STS-1. It will remain on the station's Harmony node until the arrival of an astronaut launched in a U.S. spacecraft returns it to Earth. Ferguson said that later it will fly again, on a spaceflight beyond low Earth orbit.

He also presented a shuttle model signed by program officials and the mission's lead shuttle and station flight directors. "What you don't see is the signatures of the tens of thousands who rose to orbit with us over the past 30 years, if only in spirit," Ferguson said.

Ferguson thanked station commander Andrey Borisenko for the hospitality and his crew's help in making the mission a success. Borisenko replied by wishing the shuttle crew a safe trip home and happy landings. Station Flight Engineer Ron Garan said the best thing Atlantis did was bring up Magnus. "Sandy, we can't thank you enough for all that you did." Magnus was a previous station resident and Atlantis' load master, responsible for the major mission activity of moving cargo between the two spacecraft.

Shortly after hatches between the two spacecraft were closed, Atlantis crew members began preparations for undocking. Ferguson and Hurley installed the centreline camera while hatch leak checks were still under way. Subsequently Hurley and Walheim checked out rendezvous tools. The camera and the tools will provide information as shuttle crew

members move Atlantis away from the station. Undocking is scheduled for 1:28 a.m. Tuesday.

The next status report will be issued after crew wakeup at 8:59 p.m. Monday or earlier if warranted.

### STS-135 MCC Status Report #22

The final space shuttle crew is now just hours away from undocking from the International Space Station, one more time. Commander Chris Ferguson, Pilot Doug Hurley and Mission Specialists Sandy Magnus and Rex Walheim began their day at 8:59 p.m. Their wakeup call came in the form of Coldplay's "Don't Panic," which was played for Hurley.

After 37 space shuttle visits, in which 10 modules, four sets of solar arrays, 354 feet of truss and countless science experiments – not to mention the necessities of day-to-day living in space – have been delivered, space shuttle Atlantis will pull away from the space station for the last time at 1:28 a.m.

Before the crew gets too far away, however, they'll have one more service to perform for the orbiting laboratory. Hurley will move the shuttle out to a distance of 600 feet away, and then fly half a loop around the station, so that Atlantis' astronauts can document once more the product of the space shuttle fleet's efforts.

Although a fly-around has been performed following undocking for most of the shuttle missions to the station, this last half lap should provide some new views. The space station will rotate 90 degrees to give the shuttle crew a view down its long axis, an angle not normally visible.

The fly-around should be complete by 2:50 a.m., at which point Atlantis' engines will fire in a series of burns to begin moving it further away from the space station. The crew on board will spend the second half of its day inspecting the shuttle's heat shield for any damage it may have received while in space.

The next status report will be issued at the end of the crew's day or earlier if warranted. The crew is scheduled to go to sleep just before 1 p.m. on Tuesday.



Space shuttle Atlantis is seen from the International Space Station shortly after undocking

### STS-135 MCC Status Report #23

Atlantis undocked from the International Space Station early Tuesday, marking the end of shuttle visits to the orbiting laboratory that owes much of its existence to the 37 flights they made to help build and maintain it.

The 1:28 a.m. undocking ended an Atlantis stay at the station of eight days, 15 hours and 21 minutes. All in all, Atlantis and its sister shuttles spent a total of 276 days, 11 hours and 23 minutes docked at the station.

After undocking, Atlantis moved slowly away, to a point about 600 feet ahead of the station, Pilot Doug Hurley paused Atlantis before beginning a final fly around that was in some ways a first. Before Atlantis began the half loop around the station, the orbiting laboratory changed its orientation by rotating 90 degrees to the right.

That gave Atlantis video and still cameras a chance to photograph areas of the station not normally documented in previous fly-arounds. The images will be evaluated by experts on the ground to get additional information on the station's conditions.

Teams in both flight control rooms were working their last shuttle shift. Atlantis Commander Chris Ferguson thanked the orbit 1 team of shuttle flight controllers. He urged them to pause a moment on their way out and "make a memory."

From the station flight control room, astronaut and Capcom Dan Tani, himself a former station crew member, told Ferguson that it had been "a pleasure and an honour" to support the mission. "We are proud to be the last of a countless line of mission control teams" who have watched while shuttles visited the ISS. "The ISS wouldn't be here without the shuttle."

"It's been an incredible ride", replied Ferguson. "On behalf of the four of us, we're really appreciative we had the opportunity to work with you on this pivotal mission."

After completing the half loop, Atlantis did two separation burns, the second at 3:18 a.m. to move away from the station.

After their midday meal, Ferguson, Hurley and Mission Specialist Sandra Magnus did the late survey of Atlantis' heat shield, focused on the reinforced carbon of the wing leading edges and the nose cap. They used the shuttle robotic arm and its 50-foot orbiter boom sensor system to look first at the starboard wing, then the nose cap and finally the port wing.

Data from the survey will be transmitted to the ground for evaluation by experts. Atlantis is scheduled to land at Kennedy Space centre just before 5 a.m. on Thursday.

The next status report will be issued after crew wakeup, scheduled for 8:59 p.m. Tuesday.

### STS-135 MCC Status Report #24

The final shuttle crew's final full day in space began with a fanfare – literally – and fond greetings from Florida.

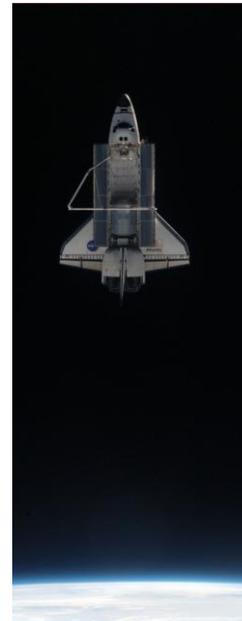
Commander Chris Ferguson, Pilot Doug Hurley and Mission Specialists Sandy Magnus and Rex Walheim woke up at 8:32 p.m. to Aaron Copland's "Fanfare for the Common Man." It was followed by a pre-recorded message from Kennedy Space Centre employees.

"Three ... two ... one ... Good morning, Atlantis!" the group said. "Kennedy salutes you. See you back at wheels stop!"

Kennedy is, of course, home to the space shuttle fleet, along with its launch pads and the people who prepared the shuttles for each trip into space. Atlantis is scheduled to land at the Shuttle Landing Facility in Kennedy on Thursday.

Before it does so, however, the STS-135 crew will spend the day checking out the shuttle's flight control surfaces and hot firing its reaction control system jets, making sure everything is ready for deorbit. They'll also pause in their work for one last round of interviews with reporters back home – at 3:44 a.m., the crew will be talking with ABC News, CBS News, CNN, Fox News and NBC News.

Meanwhile, here on the ground, another United States icon will pay its own tribute to Atlantis' mission. The Empire State Building in New York City – instantly recognizable, just as the NASA space shuttle is – will celebrate the Space Shuttle Program Wednesday night by lighting the way home for Atlantis and its crew.



To honour 30 years of space shuttle flights on 135 missions, the Empire State Building will glow Red, White and Blue throughout the night Wednesday as Atlantis prepares to return home ending the last ever shuttle flight.

### STS-135 MCC Status Report #25

Deployment of a small satellite, checkout of Atlantis' flight flaps and rudder, and packing up for their return home kept shuttle crew members busy Wednesday.

Commander Chris Ferguson, Pilot Doug Hurley and Mission Specialists Sandra Magnus and Rex Walheim are scheduled to land Atlantis a little before 5 a.m. CDT Thursday at Kennedy Space Centre. Forecasters are calling for good weather. That last landing of the shuttle program will bring Atlantis to its final home. It is to be displayed at the Kennedy Space Centre Visitor's Complex.



The crew began cabin stowage – packing up in preparation for Thursday's landing – early in its workday. Ferguson, Hurley and Walheim spent a little over an hour beginning around 1:15 a.m. with a checkout of the flight control surfaces, the rudder and flaps with which they will guide the shuttle through the atmosphere. Subsequently they hot fired reaction control system jets, the thrusters that control Atlantis' orientation before the flight control surfaces become effective as the shuttle descends into the atmosphere.

Springs pushed the PicoSat from Atlantis' cargo bay at 2:49 a.m. It is designed to evaluate the performance of a variety of solar cells mounted on it. The eight-pound, 5- by 5- by 10-inch satellite could lead to development of improved solar cells for use in space.

It was the 180th payload deployed by a space shuttle.



Shuttle crew members got one last chance to talk from space with news media representatives on the ground. A little before 4 a.m., crew answered questions from ABC News, CBS News, CNN, Fox News and NBC News.

The next status report will be issued after crew wakeup, scheduled for 8:29 p.m. Wednesday or earlier if warranted.

### STS-135 MCC Status Report #26

The final day of the final space shuttle mission began at 8:29 p.m. with an iconic final wakeup song.

Kate Smith's rendition of Irving Berlin's "God Bless America" woke Commander Chris Ferguson, Pilot Doug Hurley and Mission Specialists Sandy Magnus and Rex Walheim. But unlike most wakeup songs, which are played in honour of a particular crew member, this one was dedicated to not only the entire crew, but also all "the men and women who put their heart and soul into the shuttle program for all these years," as Capcom Shannon Lucid told the crew.

Ferguson said it was an appropriate song for their last day in space.

"Thank you, America, for supporting this program," he said. "We'll see you on the ground here in a few short hours, hopefully."



Preparations are now underway for Atlantis' 33rd and final landing, scheduled for 4:56 a.m., just before dawn in Florida. The teams here on the ground will spend the intervening time taking a close look at weather conditions at Kennedy Space Centre in Florida, which are forecast to be favourable, before giving the crew a go or no-go to perform a deorbit burn at 3:49 a.m. to put Atlantis on the path home.

If, for any reason, the first opportunity can't be taken, a second opportunity would allow Atlantis to land in Florida at 6:32 a.m. To make that touchdown time, the crew would perform a deorbit burn at 5:25 a.m. Additional opportunities are also available on Friday morning.

Assuming Atlantis does land on its first opportunity today, it will be the 19th night landing at Kennedy Space Centre, and the 78th landing there at any time of the day. There have been 54 landings at Edwards Air Force Base in California over the course of the program, and one at White Sands Space Harbour in New Mexico, for a total – including today's scheduled landing – of 133 space shuttle landings in 30 years.

The next status report will be issued after landing or at the end of the crew's day if landing is waved off.

### STS-135 MCC Status Report #27

Atlantis landed at 4:57 a.m. CDT Thursday, wrapping up a successful 13-day mission, ending its own 33-flight career and closing out the 30-year, 135-flight Space Shuttle Program.

Kennedy Space Centre weather was near perfect with light winds and clear skies. Atlantis glided to a smooth predawn landing under a waning half-moon. “Mission complete, Houston,” said Commander Chris Ferguson just after wheels stop. “After serving the world for over 30 years, the shuttle has earned its place in history, and it has come to a final stop.”

Entry Capcom Barry Wilmore responded: “We congratulate you, Atlantis, as well as the thousands of passionate individuals across this great space faring nation who truly empowered this incredible spacecraft ... which has inspired millions around the globe.” Atlantis crew members, Ferguson, Pilot Doug Hurley and Mission Specialists Sandra Magnus and Rex Walheim, wound up the successful mission to the International Space Station. It left the station with about 9,400 pounds of equipment and supplies carried aloft in the Raffaello multi-purpose logistics module, and almost 2,300 pounds of experiments, equipment and supplies brought up in its middeck lockers.

Atlantis returned almost 5,700 pounds of unneeded equipment and trash in Raffaello. The shuttle also brought back material, including experiments, in its middeck lockers and a 1,400-pound pump module. Part of the station cooling system, it had failed last year. It will be examined to determine what caused the failure. During Atlantis’ eight-day, 15-hour stay at the orbiting laboratory, station Flight Engineers Mike Fossum and Ron Garan did a 6.5-hour spacewalk that included placing the pump module in the shuttle cargo bay and installing on the station a satellite refuelling experiment called the Robotic Refuelling Mission.

On Atlantis’ way home the small PicoSat, designed to evaluate performance of a variety of solar cells, was deployed from the cargo bay. During STS-135, Atlantis orbited the Earth 200 times, travelling 5,284,862 statute miles. Over its 33 missions, it spent 307 days in space, completing 4,848 orbits and travelling 125,935,769 miles. STS-135 was the 37th visit of a space shuttle to the station.

Shuttles on all 135 missions travelled more than 542 million miles in space.

This was the 78th shuttle landing at Kennedy Space Centre. Shuttles landed 54 times at Edwards Air Force Base in California and once, on Columbia’s STS-3 flight in March 1982, at White Sands Space Harbour in New Mexico.

A celebration of Atlantis crew members’ homecoming will be held in Houston at 4 p.m. Friday. Open to the public, the ceremony will be held at Ellington’s Hangar 990. Ellington gates will open at 3:30 pm



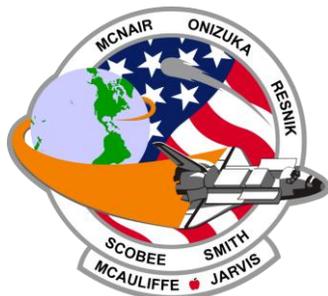
## Space Shuttle Challenger disaster

The Space Shuttle Challenger disaster occurred on Tuesday, January 28, 1986, when Space Shuttle Challenger broke apart 73 seconds into its flight, leading to the deaths of its seven crew members. The spacecraft disintegrated over the Atlantic Ocean, off the coast of central Florida, United States, at 11:38 am EST (16:38 UTC). Disintegration of the entire vehicle began after an O-ring seal in its right solid rocket booster (SRB) failed at lift-off. The O-ring failure caused a breach in the SRB joint it sealed, allowing pressurized hot gas from within the solid rocket motor to reach the outside and impinge upon the adjacent SRB attachment hardware and external fuel tank. This led to the separation of the right-hand SRB's aft attachment and the structural failure of the external tank. Aerodynamic forces promptly broke up the orbiter.

The crew compartment and many other vehicle fragments were eventually recovered from the ocean floor after a lengthy search and recovery operation. Although the exact timing of the death of the crew is unknown, several crew members are known to have survived the initial break-up of the spacecraft. However, the shuttle had no escape system and the astronauts did not survive the impact of the crew compartment with the ocean surface.

The disaster resulted in a 32-month hiatus in the shuttle program and the formation of the Rogers Commission, a special commission appointed by United States President Ronald Reagan to investigate the accident. The Rogers Commission found that NASA's organizational culture and decision-making processes had been a key contributing factor to the accident. NASA managers had known that contractor Morton Thiokol's design of the SRBs contained a potentially catastrophic flaw in the O-rings since 1977, but they failed to address it properly. They also disregarded warnings from engineers about the dangers of launching posed by the low temperatures of that morning and had failed to adequately report these technical concerns to their superiors. The Rogers Commission offered NASA nine recommendations that were to be implemented before shuttle flights resumed.

Many viewed the launch live because of the presence on the crew of Christa McAuliffe, the first member of the Teacher in Space Project. Media coverage of the accident was extensive: one study reported that 85 percent of Americans surveyed had heard the news within an hour of the accident. The Challenger disaster has been used as a case study in many discussions of engineering safety and workplace ethics.



## Space Shuttle Columbia disaster

The Space Shuttle Columbia disaster occurred on February 1, 2003, when shortly before it was scheduled to conclude its 28th mission, STS-107, the Space Shuttle Columbia disintegrated over Texas during re-entry into the Earth's atmosphere, resulting in the death of all seven crew members. Debris from Columbia fell to Earth in Texas along a path stretching from Trophy Club to Tyler, as well as into parts of Louisiana.

The loss of Columbia was a result of damage sustained during launch when a piece of foam insulation the size of a small briefcase broke off from the Space Shuttle external tank (the main propellant tank) under the aerodynamic forces of launch. The debris struck the leading edge of the left wing, damaging the Shuttle's thermal protection system (TPS), which shields it from heat generated with the atmosphere during re-entry. While Columbia was still in orbit, some engineers suspected damage, but NASA managers limited the investigation, on the grounds that little could be done even if problems were found.

NASA's original Shuttle design specifications stated that the external tank was not to shed foam or other debris; as such, strikes upon the Shuttle itself were safety issues that needed to be resolved before a launch was cleared. Launches were often given the go-ahead as engineers came to see the foam shedding and debris strikes as inevitable and irresolvable, with the rationale that they were either not a threat to safety, or an acceptable risk. The majority of Shuttle launches recorded such foam strikes and thermal tile scarring. During re-entry of STS-107, the damaged area allowed the hot gases to penetrate and destroy the internal wing structure, rapidly causing the in-flight break-up of the vehicle. An extensive ground search in parts of Texas, Louisiana, and Arkansas recovered crew remains and many vehicle fragments.



Mission STS-107 was the 113th Space Shuttle launch. It was delayed 18 times over the two years from its original launch date of January 11, 2001, to its actual launch date of January 16, 2003. (It was preceded by STS-113.) A launch delay due to cracks in the shuttle's propellant distribution system occurred one month before a July 19, 2002, launch date. The Columbia Accident Investigation Board (CAIB) determined that this delay had nothing to do with the catastrophic failure six months later.

The Columbia Accident Investigation Board's recommendations addressed both technical and organizational issues. Space Shuttle flight operations were delayed for two years by the disaster, similar to the Challenger disaster. Construction of the International Space Station was put on hold, and for 29 months the station relied entirely on the Russian Federal Space Agency for resupply until Shuttle flights resumed with STS-114 and 41 months for crew rotation until STS-121.

## Remembrance for the Shuttle astronauts who have died in the line of duty



Crew of the final ill-fated flight of the Space Shuttle Challenger, mission STS-10. In the back row from left to right: Ellison S. Onizuka, Sharon Christa McAuliffe, Greg Jarvis, and Judy Resnik. In the front row from left to right: Michael J. Smith, Dick Scobee, and Ron McNair.



Crew of the final ill-fated flight of the Space Shuttle Columbia, mission STS-107. This is the official crew photo from Mission STS-107 on the Space Shuttle Columbia. From left to right are Mission Specialist David Brown, Commander Rick Husband, Mission Specialist Laurel Clark, Mission Specialist Kalpana Chawla, Mission Specialist Michael Anderson, Pilot William McCool, and Israeli Payload Specialist Ilan Ramon





STS - 1



STS - 135

# The Future ?

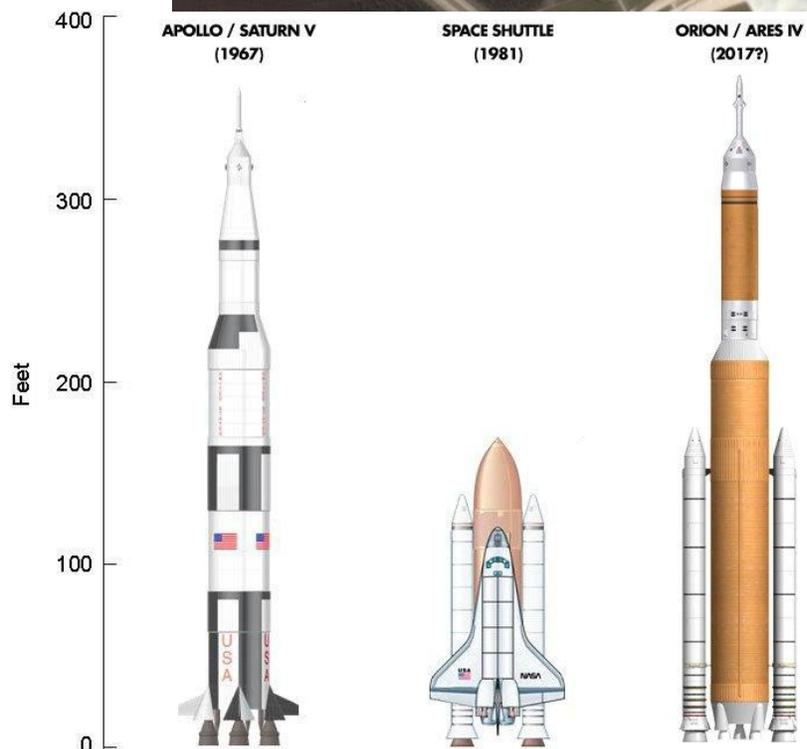
The space policy of the Barack Obama administration was announced by U.S. President Barack Obama on April 15, 2010, at a major space policy speech at Kennedy Space Centre. He committed to increasing NASA funding by \$6 billion over five years and completing the design of a new heavy-lift launch vehicle by 2015 and to begin construction thereafter. He also predicted a U.S. crewed orbital Mars mission by the mid-2030s, preceded by an asteroid mission by 2025. In response to concerns over job losses, Obama promised a \$40 million effort to help Space Coast workers affected by the cancellation of the Space Shuttle program and Constellation program.

The Obama administration's space policy was made subsequent to the final report of the Review of United States Human Space Flight Plans Committee, which it had instituted to review the of 2010, passed on October 11, 2010, enacted many of the Obama administration's space policy goals.

In the speech, Obama announced the development of the Shuttle-Derived Heavy Lift Launch Vehicle (HLV) to replace the planned Ares V, with the design planned for completion by 2015, two years prior to the Constellation plan, and construction commencing thereafter.

Shuttle-Derived Launch Vehicle, or simply Shuttle-Derived Vehicle (SDV), is a term describing one of a wide array of concepts that have been developed for creating space launch vehicles from the components, technology and/or infrastructure of the Space Shuttle program. SDVs have also been part of NASA's plans several times in the past. In the late 1980s and early 1990s, NASA formally studied a cargo-only vehicle, Shuttle-C, that would have supplemented the crewed Space Shuttle in orbiting payloads.

In 2005, NASA decided to develop the Ares I and Ares V launch vehicles, based in part on highly modified Shuttle components to replace the Space Shuttle, and enable exploration of the Moon and Mars. The agency also studied a third such vehicle, the Ares IV. As of April 2011, NASA's replacement vehicle for the Space Shuttle, to be retired in 2011, is a SDV, the Space Launch System.



# Manchester Astronomical Society

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Contributions are welcomed from all members of the Society, and can cover any area of astronomy, from beginners' initial experiences, to more advanced and specialized aspects. Remember, this is your forum for letting other members know who you are and what are your interests.

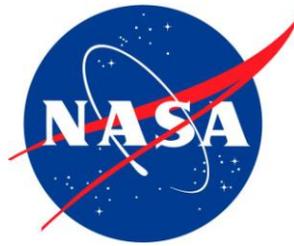
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### Guidelines for Submissions

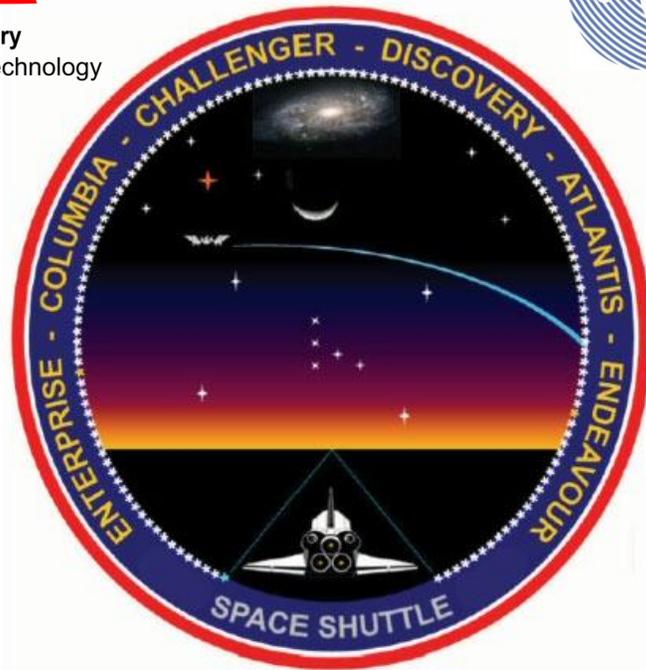
**In the absence of an editor for Current Notes please submit a copy of any contribution on floppy disk or as e-mail attachment to [maspresident@btinternet.com](mailto:maspresident@btinternet.com) in either MS Word format, PDF or as plain text file. If possible, please also submit a hard (printed) copy.**

Hand-written or typed contributions are also welcome, although to limit the editorial workload, these should ideally be kept short in length. Finally, any data submissions (e.g. statistics, observations, measurements) should be submitted either in a suitable digitized format (e.g. Excel spreadsheet, completed graphs) or with clear instructions as to how the data should be presented in Current Notes. If in doubt, please contact the editor.



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