

Successful mission clears way for ISS completion

Back to back for Discovery

by Gerard van de Haar, Rudolf van Beest and Clive Simpson

The Space Shuttle Discovery and its crew completed a very successful 13 day, five million mile journey in space in July, testing Shuttle safety improvements, repairing a rail car on the International Space Station (ISS) and producing never-before-seen high-resolution images of the Shuttle during and after its 4 July launch.

STS-121 commander Steve Lindsey, pilot Mark Kelly and mission specialists Mike Fossum, Piers Sellers, Lisa Nowak and Stephanie Wilson landed on 17 July at NASA's Kennedy Space Centre, Florida, at 1314 GMT (9:14 am local time).

Shuttle programme managers were pleased with Discovery's performance. The flight verified the safety of the biggest aerodynamic change (removal of the protuberance air load ramps) to the external

fuel tank in Shuttle history after a piece of foam came off this area during Discovery's flight last year.

STS-121 was the most photographed Shuttle mission ever, with more than 100 high definition, digital, video and film cameras documenting the launch and climb to orbit. Data from these images helped assess whether the orbiter sustained any damage and whether that damage posed any risk to Discovery's return to Earth.

Media representatives awaiting tower roll-back at pad 39B.



Rudolf van Beest



Roel Dekens



Rudolf van Beest





The launch of Discovery and its seven member crew on 4 July 2006.
NASA



The STS-121 crew seen here during their second walk-out.

Rudolf van Beest

The STS-121 mission also bolstered the ISS with Fossum and Sellers completing three spacewalks, the third confirmed after mission managers determined there was enough electrical power to add an extra day to the flight.

The astronauts tested the Shuttle's 50 foot robotic arm boom extension as a work platform, and removed and replaced a cable that provides power, command and data and video connections to the Station's mobile transporter rail car. During the third spacewalk, the astronauts tested techniques for inspecting and repairing the reinforced carbon-carbon segments that protect the Shuttle's nose cone and leading edge of the wings.

Discovery delivered more than 28,000 pounds of equipment and supplies to the Station, as well as a third crew member, European Space Agency astronaut Thomas Reiter who joined Russian Pavel Vinogradov and American Jeff Williams. This marks the first time since May 2003 that the Station crew has three members.

Everything appeared to go smoothly with the first launch countdown – even the service tower was retracted almost on time on the evening of 30 June (delays in this process are frequent) and when the floodlights came on an hour later Discovery could be seen standing magnificently against the dark Florida sky.

On the initial launch day, 1 July, the weather did not seem so bad as the crew headed for the pad and was strapped in. Reiter's personal physician commented that ESA's first long-stay ISS crew member was in high spirits to go fly.

A small problem with a heater on a vernier OMS thruster was quickly considered to be "negligible" but the weather for launch kept changing between "go" and "no go" and at the T-9 minute hold it was decided that the weather was unacceptable for launch. Vice-president Dick Cheney and many other onlookers, including other astronauts like Reiter's backup Leopold Eyharts, had come for nothing.

Even though weather predictions were worse for 2 July, NASA decided to try again 24 hours later. That day rain was falling all morning and during walkout of Discovery's crew four hours before launch. It came as no surprise when this attempt was scrubbed early, at some two hours before the scheduled lift-off.

As NASA wanted to repair the vernier thruster and reload Discovery's fuel cells in order to keep the option open for a one day mission extension and adding a third spacewalk, the third launch attempt was set for 4 July. There was much speculation if this date had been deliberately chosen as it was US Independence Day and never before a Shuttle launched on this national day of celebration.

After the second attempt, engineers inspecting the pad found a small piece of foam that had fallen off the External Tank, again causing concern for the next launch opportunity. After hours of debating, however, the Shuttle team decided the incident would not prevent a third try.

The morning of 4 July saw some rain in the Kennedy Space Centre area but, as the crew headed again for their waiting Shuttle, the weather gradually improved until it was

considered not to be a problem for launch. At walkout all US astronauts were on this special day waving small US flags, Reiter carrying a German flag and waving it, instead of giving thumbs-up signals as he did on previous walkouts.

The only concern now was the oxygen temperature in the inlet from the tank to the Shuttle, which seemed a bit too warm, but this potential problem went away as the clock reached the final minutes and seconds before ignition and lift-off.

Launch came on time at 18.37.55 GMT (1438 local time) and, with a thundering roar combined with a brilliant light, STS-121 was on its way! In the press centre soon everyone was looking and listening anxiously to NASA TV for any news on foam dropping off and hitting the orbiter.

Spectacular images poured out of the various screens and everything seemed to be going well; only tiny fragments were seen, all considered harmless. After many years, once again people could simply watch a Shuttle launch in amazement and enjoy the moment! And an estimated crowd of 200,000

onlookers did just that.

Some eight minutes later Discovery was safely in orbit, chasing the Space Station on a two day catch up.

Over the next few days NASA engineers and managers examined all the data and images from the launch, including those taken from the tank and the solid boosters. The foam problem appeared to be solved; but future external tanks will continue to be improved as the foam issue is now thought to be better understood.

"The Space Shuttle certainly is back in business again," commented Discovery's vehicle manager Stephanie Stilson.

During their first day in orbit (5 July), the astronauts spent several hours examining Discovery with the Orbiter Boom Sensor System (OBSS) but found no evidence of any damage from debris during the launch on the reinforced carbon-carbon panels along the leading edge of the orbiters starboard wing.

A day later ESA astronaut Thomas Reiter of Germany became the newest member of the ISS Expedition 13 crew just hours after

Discovery docked at the Station's Pressurized Mating Adapter 2, as the two ships flew above the Pacific Ocean south of Pitcairn Island. For the first time in more than three years there was a permanent crew of three aboard the ISS and, for the first time ever it included an American, a Russian and a European.

Commander Steve Lindsey had piloted Discovery's approach to the ISS, halting 600 feet directly below the Station to perform the rendezvous pitch manoeuvre where the orbiter carries out a nose-over-tail somersault so Pavel Vinogradov and Jeff Williams could photograph the thermal protection system tiles on the Orbiters underside.

Lindsey and his crew – pilot Mark Kelly and mission specialists Mike Fossum, Lisa Nowak, Stephanie Wilson, Piers Sellers and Reiter – greeted the Station crew members when the hatches between the vehicles were opened.

After Vinogradov's safety briefing, he helped Reiter install his customised Soyuz seat liner into the Russian return vehicle and check his pressurised Sokol suit, finalising Reiter's transfer from Discovery to the ISS. Other first-day transfers from Discovery included the spacesuits that Sellers and Fossum would wear on their spacewalks out of the Quest airlock on Flight Days five and seven.

After the successful docking, the focus of the STS-121 shuttle mission turned to unloading more than 7000 lbs of cargo, continued Shuttle inspections and preparations for the mission's first spacewalk.

On 8 July, after several hours of final preparations, Piers Sellers and Mike Fossum turned their spacesuits to battery power to officially start the mission's first spacewalk at 13:17 GMT.

After they configured their tools and safety tethers, they moved to the S0 Truss and installed a blade blocker in the zenith Interface Umbilical Assembly to protect the undamaged power, data and video cable. Then they rerouted that cable through the

New firing room used for first time

The launch of STS-121 on 4 July marked the first use of a new Firing Room in the Launch Control Centre at Kennedy Space Centre, writes Joel Powell. Newly operational Firing Room Number 4 will now serve as the primary launch control facility for the remainder of the Space Shuttle programme. The existing Firing Rooms have been retired from operational service.

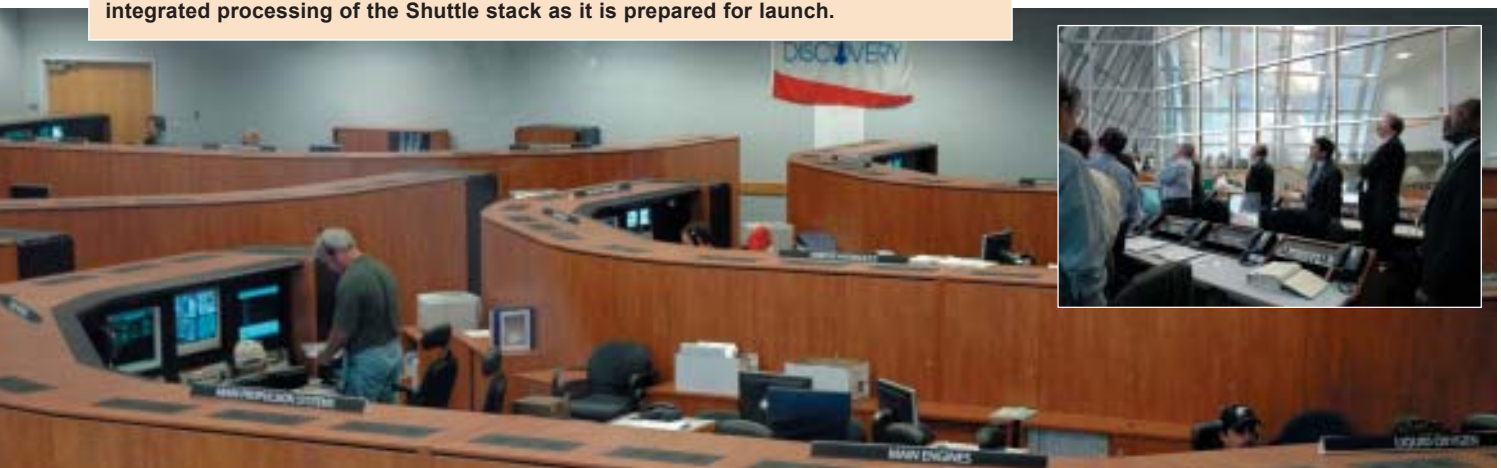
NASA activated Firing Room 4 for STS-121 after two years of extensive renovations – designated the Launch Processing System Extended Survivability Project. The former conference and office space (with a small backup firing room) was converted into the primary Shuttle firing room with the help of a Canadian firm hired by United Space Alliance (USA), NASA's Space Shuttle support contractor.

Evans Consoles of Calgary, Alberta, designed and built ergonomic computer work stations for the new Firing Room that were produced with direct input from the engineers who would actually be using the facilities.

The spacious décor is a distinct improvement over the original Firing Rooms, with beige walls concealing sound-proofing materials to reduce the noise levels that plagued the original rooms.

Launch controllers also appreciate the less frigid temperature maintained in the new facility, and the engineers no longer have to bring a jacket with them to work, according to NASA test conductor Ted Mosteller.

The new Firing Room, with updated computers and checkout equipment, will also be used to manage daily operations in the Orbiter Processing Facilities and to direct integrated processing of the Shuttle stack as it is prepared for launch.



IUA so the Mobile Transporter rail car could be moved into position on the truss for replacement of the Trailing Umbilical System containing the severed power and data cable during a further spacewalk.

The remainder of the first spacewalk was devoted to testing the combination of Space Shuttle robotic arm and Orbiter Boom Sensor System as a platform for spacewalking astronauts to make repairs to a damaged orbiter.

Sellers got into a foot restraint on the OBSS, almost 100 feet from where the Shuttle arm is attached to the payload bay sill, and performed a set of motions designed to see how the arm/OBSS handled the forces generated by those movements. Fossum stood nearby and reported his observations of the arm/OBSS movements.

Then Fossum joined Sellers on the end of the OBSS for another round of demonstrations, with measurements again taken by a load cell mounted under the foot restraint. For the last measurement the arm manoeuvred Fossum into position so he could push against the end of the P1 Truss. It had been the fourth spacewalk of Sellers' career and the first for Fossum.

During the EVA, Vinogradov and Reiter unloaded cargo from the MPLM, including a new oxygen generator, to be installed in the Destiny laboratory in the coming months, and a European Minus Eighty Degree Laboratory Freezer, which will provide low temperature storage for lab supplies and for experiment samples awaiting return to Earth.

On 10 July a six hour 47 minute spacewalk by the same two men restored the ISS's Mobile Transporter rail car to full operation and delivered a spare pump module for the station's cooling system.

Sellers and Fossum exited the Quest module's airlock and climbed down into the Shuttle payload bay where they lifted the Pump Module from its stowage platform so Lisa Nowak and Stephanie Wilson could grapple it with the Station's robotic arm.

While the arm moved the module to its destination, Sellers and Fossum moved to the S0 Truss segment to begin work on the primary task of the EVA, replacement of the nadir-side Trailing Umbilical System (TUS).

A TUS contains a power, data and video cable that serves the Mobile Transporter as it moves along the Station's truss; the nadir TUS cable was inadvertently severed late last year and required replacement. As the first step in that process Sellers replaced the Interface Umbilical Assembly – the component containing the cutter – with a new IUA, one without a blade.



Sellers moves along a Space Station truss during the mission's third and final spacewalk. NASA

By that time, Canadarm2 had reached External Stowage Platform 2 on the forward side of Quest with the Pump Module and so Sellers and Fossum moved to the platform to receive the module from the arm, secured it to the storage platform, and returned to the TUS work site.

They removed the damaged TUS from within the S0 Truss, and Fossum carried it to the payload bay while riding the Station arm. When he arrived, Sellers removed the new TUS from the payload bay platform, and the two swapped cable reels. Sellers stowed the old TUS on the cross-bay carrier while the arm moved Fossum back to the truss work site, where Sellers rejoined his crew mate to complete installation of the TUS and properly route its power, data and video cable through the IUA.

At two points during the spacewalk Fossum paused to take care of a loose connection of the emergency jet thruster backpack on Sellers' spacesuit, securing it the first time with a safety tether.

The spacewalkers closed the hatch and began to re-pressurise Quest to end the spacewalk and conclude the mission's second excursion.

In between the second and third spacewalks, the joint crews turned their attention to packing the Leonardo logistics module in preparation for its return to Earth.

Vinogradov, Williams and Reiter spent most of 11 July loading items no longer needed on the Station into the MPLM which was still docked to the Unity module and would be returned to Discovery's payload bay three days later. For its return to Earth,

A close-up view of Discovery's tail section. Visible are the Shuttle's main engines, vertical stabilizer, orbital manoeuvring system (OMS) pods and a portion of the aft cargo bay and wings. NASA





The STS-121 (green shirts) and Expedition 13 crew members gather for a group photo in the Destiny laboratory. They are (front row from left): Thomas Reiter, Pavel Vinogradov and Jeffrey Williams. Middle (from left): Stephanie Wilson, Steven Lindsey, and Lisa M. Nowak. Back (from left): Piers Sellers, Michael Fossum, and Mark Kelly. NASA

the Italian-built Leonardo was filled with almost 4,400 pounds of experiment samples, unneeded hardware and rubbish.

Included in the supplies delivered to the

Station was a new window and window seals for the Microgravity Science Glovebox (MSG), an ESA-developed enclosed workspace for science experiments involving fluids, flames, particles or fumes.

With the Shuttle mission now well into its final days, astronauts Sellers and Fossum performed a third and final spacewalk on 12 July to gather valuable new data as part of an ongoing evaluation of repairing a damaged orbiter.

They began the spacewalk by preparing a

foot restraint on the end of the Space Station's Canadarm2. Sellers rode the arm, commanded by Nowak and Wilson, to the starboard wing of Discovery where he used an infrared camera to shoot 20 seconds of video of selected reinforced carbon panels on the wing's leading edge. Such imagery is useful in identifying damage on the inside of those panels.

Fossum moved to the aft of Discovery's payload bay to join Sellers and help prepare a box containing 12 sample panels for the EVA's primary task of testing a repair material known as NOAX. Non-oxide adhesive experimental is a pre-ceramic polymer sealant containing carbon-silicon carbide powder, and is being evaluated for repairing damage to the panels.

Data gathered from tests on mission STS-114 last year indicated NOAX is most effective when applied while the temperature of a panel is falling between 120 F and 30 F. Over the course of almost two and a half hours, Sellers and Fossum completed three gouge repairs and two crack repairs with NOAX, and provided mission control a running dialogue describing the repair activity and how the NOAX responded. They also imaged four of the samples with the

NASA's schedule for remaining Shuttle missions

28 August 2006

Atlantis STS-115. Second portside truss segment; second set of US solar arrays and batteries.

14 December 2006

Discovery STS-116. Third portside truss segment. Single Spacehab cargo module. Integrated Cargo Carrier.

22 February 2007

Atlantis STS-117. Second starboard truss segment with Photovoltaic Radiator. Third set of US solar arrays and batteries.

11 June 2007

Endeavour STS-118. Third starboard truss segment. Single Spacehab cargo module. External Stowage Platform 3.

9 August 2007

Atlantis STS-120. Node 2 (a connecting module with several hatches that ultimately will lead to European and Japanese science laboratories).

27 September 2007

Discovery. STS-122. ESA's Columbus science laboratory and the Multi-Purpose Experiment Support Structure.

29 November 2007

Endeavour STS-123. Will deliver the first of three parts that eventually make up the Japanese Kibo science facility at the Station and the Canadian robotic arm extension.

7 February 2008

Atlantis STS-124. The Japanese Kibo Experiment Module and the Kibo Remote Manipulator System.

19 June 2008

Endeavour. STS-119. Fourth starboard Station truss

segment; fourth set of US solar arrays and batteries.

21 August 2008

Atlantis STS-126. Multi-Purpose Logistics Module Leonardo (last flight of Atlantis), ULF-2 flight.

30 October 2008

Discovery STS-127. Kibo Japanese Experiment Module Exposed Facility; the Kibo Exposed Section and a Spacelab pallet.

22 January 2009

Endeavour STS-128. Multi-Purpose Logistics Module Donatello; lightweight Multi-Purpose Experiment Support Structure (three crew quarters will be added on this flight; crew size will be expanded to six).

30 April 2009

Discovery STS-129, ULF-3. Two EXPRESS Logistics carriers loaded with station equipment and spare parts (last scheduled flight of Discovery).

16 July 2009

Endeavour STS-130. Multi-Purpose Logistics Module Raffaello; lightweight multi-purpose experiment support equipment.

22 October 2009

Discovery STS-131, ULF-4 (if needed).

21 January 2010

Endeavour STS-132. Node 3 with the Cupola.

15 July 2010

Endeavour STS-133, ULF-5 (if needed). Two EXPRESS Logistics carriers.



infrared camera, which Fossum also used to gather video of an area of Discovery's port wing while riding Canadarm2 back to the airlock.

Near the end of the EVA, mission control added a final task. Since the spacewalkers were on schedule and had plenty of supplies, Sellers carried a Pistol Grip Tool to the Integrated Cargo Carrier in Discovery's payload bay and removed the fixed grapple bar used during delivery of the Pump Module during the second spacewalk. He carried it to the S1 Truss where Fossum helped him install it on an ammonia tank inside that truss so that the tank can be moved on a later Shuttle assembly mission.

The spacewalk was seven hours and 11 minutes, the 68th in support of ISS assembly and maintenance. The cumulative duration of the three spacewalks on this mission was 21 hours and 29 minutes, and. Sellers' total spacewalking time of 41 hours and 10 minutes on six EVAs ranks him fourth among US spacewalkers and ninth in the world all-time list.

Thursday 13 July was a good one for the astronauts on board Discovery as they got a much deserved day off before beginning in earnest the preparations for returning back to Earth.

The Shuttle astronauts said goodbye to Reiter and his crew mates Vinogradov and Williams, before Lindsey and Kelly reported the hatches between the two ships closed at 32015 GMT on 15 July.

With Kelly at the controls, Discovery released its grip on the station at 5:08 am and springs pushed the two ships apart. Kelly guided the Shuttle away to a distance of 400 feet and fired thrusters to separate the orbiter from the vicinity of the ISS complex.

A second engine firing, 50 minutes after undocking while above and behind the Station, set Discovery on course for a landing two days later. No other engine firings were necessary before the final de-orbit burn.

After Discovery left the Station, the

After a successful mission Discovery landed at first attempt on 17 July and was towed back to the hangar the same day. NASA

Shuttle crew used the robotic arm and boom sensors to thoroughly inspect the starboard wing and nose cap heat shield, looking for damage from orbital debris. A similar survey of the port wing was conducted the previous day. Afterwards the boom was berthed along the starboard sill of the payload bay and the robot arm was powered down.

After a very successful mission, Discovery was ready to come home again. Inspections on orbit had proven the orbiter vehicle to be very "clean" indeed, with hardly any holes and cracks in the heat resistant tiles both on the underside or on the nose and wings.

As always, the weather in Florida is hard to predict, and in the week before landing expectations for a KSC landing (the first after STS-113 in 2002) were not high because of thick clouds.

However, slowly the forecasts improved as the landing day approached, until just two hours before the first scheduled landing attempt, the Florida rain radar saw only one small wet area 50 miles north of KSC. After making sure this was not a threat for landing, the 'go' was given for de-orbit burn, just 10 minutes before time ran out to prepare for the first attempt.

The de-orbit burn was initiated at 1207 GMT (8.07 am local time) and lasted three minutes. However the persistent rain area was still a cause for slight concern and so some 15 minutes before touchdown the landing direction was switched from north to south. Discovery's re-entry path took the returning Orbiter over Guatemala, the Gulf of Mexico and south Florida.

The astronauts later described the re-entry as "beautiful...during a left bank manoeuvre the Earth was visible below with



an orange glow above and the Moon shining through the plasma". Curiously enough Discovery flew over Sarasota where the only flown Russian Shuttle in the US (a Bor-5) is presently on display (*Spaceflight*, January 2003, p26).

Lindsey brought the orbiter to a picture perfect landing at 9.14 am local time and just over a minute later the Shuttle stopped rolling; STS-121 was over after a mission lasting 202 orbits and 12 days, 18 hours, 37 minutes and 54 seconds. About 90 minutes later a jubilant crew stepped from their vehicle and inspected it immediately, finding nothing but satisfying proof of its excellent condition.

When Discovery was towed back to its hangar five hours after landing, a handful of selected media was allowed to see the vehicle close by and inspect it themselves. As Lindsey commented at the press conference later: "This is the cleanest vehicle I've ever seen. We're ready to start flying shuttles on a more regular basis!"

The stage is set now for the resumption of Space Station assembly and preparations continue for Space Shuttle Atlantis' launch, targeted for late August/early September, on the STS-115 mission to deliver additional truss segments to the Station. Atlantis was expected to be moved to the launch pad early in August, with NASA managers planning to meet shortly thereafter to clear the Orbiter for its first mission since October 2002.