



Return of the Space Shuttle

by Clive Simpson

Discovery's seven returning astronauts were undoubtedly uneasy during the first fiery atmospheric re-entry since the 2003 Columbia disaster, even after the Space Shuttle's \$1.5 billion refit and unprecedented heat-shield inspection in orbit.

In the end it was a perfect, early August Californian dawn that provided the finale to this breath-taking mission, a long-awaited test flight that had shown up both the strengths and weaknesses of NASA's approach.

The new arrays of cameras and sensors certainly provided a plethora of data to make the Shuttle safer. But they also gave everyone back home much more information to worry about – from damage caused by relatively small foam chunks hitting Discovery to bits of filler sticking out from the Shuttle's underbelly.

Pilot Jim Kelly admitted going through “a moment of trepidation” before the Orbiter's manoeuvring engines fired on 9 August, kicking off an hour long free-fall back to Earth that exposed the hull of Discovery to temperatures of up to 3,000 degrees.

Then, he said, came “a moment of reflection”. “We thought about the Columbia crew, obviously hoping we'd make it further than they did, and wishing that they had

made it all the way home.”

Discovery's seven astronauts landed 3,000 miles away from the Shuttle's home port in Florida after bad weather forced NASA to give up on a Kennedy Space Center landing on two successive mornings.

After circling the Earth 219 times during a 5.8 million mile mission, Shuttle commander Eileen Collins pulled off a challenging landing in the dark, deftly guiding the 100 ton glider to a safe touchdown at Edwards Air Force Base.

“Eileen made it look like a cakewalk. She did a spectacular job,” said NASA space operations chief and former astronaut Bill Readdy. The relief for NASA staff and families was palpable.

Discovery spent two weeks in space where the crew demonstrated new methods to inspect and repair the Shuttle in orbit. They also delivered supplies, and outfitted and performed various items of maintenance on the International Space Station (ISS). A number of these tasks were conducted during three space walks.

In an unprecedented event, astronauts were called upon to remove protruding gap fillers from the heat shield on Discovery's underbelly, whilst in other space walk activities, the astronauts installed an external platform onto the Station's Quest Airlock and replaced one of the orbital outpost's Control

Moment Gyroscopes.

Inside the ISS, the STS-114 crew conducted joint operations with the Expedition 11 crew, also unloading fresh supplies from the Shuttle and the European-built Raffaello Multi-Purpose Logistics Module (MPLM). Before Discovery undocked, the crews filled Raffaello with unneeded items and returned it to the Shuttle payload bay.

Discovery, which launched on July 26 (*Spaceflight*, September 2005, p324) and spent almost 14 days in orbit, glided to a pre-dawn landing at Edwards Air Force Base in California on 9 August – two days later than originally planned – concluding a journey of 5.8 million miles, when it touched down at 7:11 am CDT (1211 GMT). The landing marked the sixth night landing at Edwards Air Force Base, and the 50th time overall that a Shuttle has concluded its mission in the Californian desert.

Discovery had undocked from the Space Station on 6 August and, with pilot James Kelly at the controls, pulled away directly in front of the ISS complex and then flew a loop around the Station for a spectacular photo survey.

In what may be some of the most stunning video ever shot to date, Discovery's cameras captured the Space Station flying serenely against the backdrop of central

Asia like some great bird, its huge solar arrays stretching across the scene like wings as the snow-capped Himalayas came into view below the limb of the Earth.

Earlier, in a brief farewell ceremony inside the Destiny laboratory, Collins thanked the Station's two man crew "for being such great hosts".

Back on the ground, a 'tiger team' of NASA and contractor engineers had already started reviewing the manufacturing history of Discovery's external fuel tank to find clues about what might have caused a chunk of foam insulation to cut loose during the launch.

NASA officials admitted that foam in the area that pulled away was slightly damaged during the tank's processing, requiring a standard repair for relatively routine cracks and gouges.



James Kelly at the controls of Canadarm2.
NASA

The extent of the void, however, was very small and it may have had nothing to do with the foam loss that marred Discovery's launch. If the launch debris incident can be traced to this or any other one-time flaw that only affected Discovery's tank, NASA might be able to return the Shuttle programme to flight in relatively short order without having to implement generic, fleet-wide modifications.

Time, however, is short. The next available launch window, which originally opened on 9 September 2005, shrank to four days (22-25 September) because of the delays in the launch of Discovery (the Space Shuttle Atlantis will not be cleared for the second post-Columbia mission until Discovery is ready for launch on a rescue mission as a cover for any problems that might develop in orbit).

Whilst the time to resolve the foam issue was already tight there was also the time-consuming and expensive complication of having to fly Discovery piggyback on a 747 jet back to its processing home and launch base in Florida.



Hi guys! Eileen Collins floats in Zvezda watched by John Phillips (bottom right). NASA

But even as Discovery was preparing to land NASA administrator Michael Griffin said he had not given up hope. "Until we run out of lead time to make the September window, we'll preserve it because that's what taxpayers pay us to do. When we no longer can make it, we'll tell you and we'll recycle for November." In the immediate post-landing analysis, however, the prospects of either launch diminished rather quickly.

The question of prior damage to the foam on Discovery's tank first came up during a post-launch review following the insulation shedding observed during the Shuttle's climb to space. A few seconds after the ship's solid-fuel boosters separated, a larger chunk of foam ripped away from an aerodynamic ramp used to smooth the supersonic flow of air over external pressurisation lines and electrical cables.

The 'protuberance air load' (PAL) ramp is sprayed on by hand and, as such, is subject to more inconsistencies than machine-sprayed foam. As it turns out, the PAL ramp was not part of NASA's post-Columbia re-design effort since engineers believed its design was sound and because the last known incident of foam shedding from the ramp was in 1983.

So when Collins guided Discovery to a perfect docking with the Space Station on 28 July the mission was already overshadowed – in the eyes of the world's media at least – by a crisis of confidence in NASA after the 'grounding' of the Shuttle fleet due to the foam problem.

Docking occurred at 1118 GMT as the two spacecraft sailed 220 miles above the south Pacific Ocean. It followed one of the most spectacular manoeuvres so far carried out in orbit by a Space Shuttle, a planned 'back flip' so Station crew members could photograph its thermal protection system.

Collins and Kelly flew Discovery through the rendezvous pitch manoeuvre about 600 feet below the Station about an hour before

docking and the photos taken by Sergei Krikalev and John Phillips were transmitted straight to the ground.

Together with many other images taken from the ground, aircraft and the Space Shuttle itself, the photos were subject to immediate scrutiny by a team of about 200 people to ensure Discovery's thermal protection system was in good order for re-entry.

"We have contact and capture," Kelly radioed as the Shuttle's docking port gently contacted its counterpart on the front of the US laboratory module, Destiny. After damping out post-docking oscillations, powerful latches locked the two spacecraft together.

Discovery was the first Shuttle to visit the Station since late 2002 and after the initial hugs and handshakes Krikalev gave a safety briefing to the new arrivals – Collins, Kelly and mission specialists Soichi Noguchi (of the Japanese Aerospace Exploration Agency), Steve Robinson, Andy Thomas, Wendy Lawrence and Charlie Camarda.

Among early work for the joint crews was preparation for additional robotic arm surveys of the orbiter. Tasks on the three planned space walks included testing thermal protection system repair techniques, replacement of one of four Station control gyros (which control the orbiting laboratory's orientation in space) and restoration of power to another. The spacewalkers also installed an external spare parts carrier on the outside of the Quest airlock.

During the mission's first live press conference from orbit, Discovery's crew revealed they had been disappointed to learn about foam insulation falling off their ship's external tank during launch.

Collins agreed the Shuttle programme should remain grounded until the problem is fixed. "I don't think we should fly again unless we do something to prevent it from happening again. But I'd also like to point out, we're in the Space Shuttle Discovery

Soichi Noguchi during the mission's first EVA on 30 July.
NASA



right now, which is operating fantastically," she said.

"I was expecting a lot more malfunctions or incidents with the equipment on Discovery because it's been so long since we've last flown. But it has done well. So I'm very confident. The Shuttle should be retired eventually, but we've got more years in them and I think we need to get this problem licked with the external tank and keep working on it. I'm not ready to give up yet."

It was never NASA's intention to eliminate entirely the shedding of foam – nor, indeed, is it thought possible. Instead, the agency's two year refit focused on reducing the size of the bits that fell off to the point of insignificance. It also took steps to prevent debris from hitting the Shuttle.

To this end, NASA managed to slash the number of times the Shuttle was struck by falling foam from an average of 150 on previous launches to just two dozen this time and so Discovery's launch was relatively clean.

As the flight rolled into its seventh day the NASA mission management team agreed they would ask astronaut Steve Robinson to remove two pieces of protruding gap filler from the underbelly of the Orbiter during an already planned third spacewalk.

It was nothing short of a coup de grace for news hungry journalists – a piece of high space theatre that was just what the 24 hour news networks needed to propel the mission back to the top of the bulletins in the hiatus between the more dramatic and potentially dangerous parts of the mission – launch, docking and landing.

NASA had decided to order the repair work after a long meeting in which aerodynamicists said they could not guarantee a problem-free re-entry with the gap fillers sticking out as they were.

The stumbling block was uncertainty about high-altitude, high-speed aerodynamics and how any turbulence caused by the extended gap fillers might affect heat loads on the orbiter.

Wayne Hale, chairman of the management team, said that estimates of possible consequences ranged from no problems of any significance right through to exceeding the Shuttle's design limits and safety margins.

"At today's meeting I went in with a very simple question – did we have the engineering knowledge and analysis that would, without a shadow of a doubt, allow us to be 100 percent confident the vehicle could fly safely during entry?"

"We investigated that at length," he



An unusual photograph showing both a Soyuz and Space Shuttle docked to the Space Station. Both the Shuttle's and Station's robotic arms are also visible. NASA

explained. "The team has been working for three days and they came in with a very long report. The management team asked them a lot of detailed questions and at the end of the day, the bottom line is there is large uncertainty.

"As a result the EVA (spacewalk) team has put together a very simple plan, with good safety precautions that will allow a crew member to go out and remove the two gap fillers."

Despite the anticipation and intense planning, in the final analysis Robinson made it look rather easy on 3 August as he gently pulled two protruding gap fillers from between thermal protection tiles on Discovery's underside. "It looks like this big patient is cured," he told delighted flight controllers.

Fellow spacewalker Soichi Noguchi helped Robinson with preparations and, from a perch near the end of a Space Station truss, acted as observer and communication relay station between Robinson and Andy Thomas aboard Discovery.

Gap fillers like those Robinson removed are thin, coated Nextel fabric, and the protruding fillers had been identified in photos taken by Station crew members as Discovery approached.

During the same spacewalk Noguchi and Robinson, helped by the Station's robotic arm, installed an external stowage platform outside the Station that will be used to house spare parts. Noguchi also installed another Materials International Space Station Experiment (MISSE). Like its predecessors,

MISSE 5 exposes samples of various materials to the harsh space environment for several months.

In other activities, Kelly worked with mission specialist Charlie Camarda on an inspection of the repair demonstration tiles in Discovery's cargo bay. Using the Orbiter Boom Sensor System, they looked at tiles brought up for an experimental repair carried out by Robinson and Noguchi on the mission's first spacewalk.

The following day, 4 August, NASA ruled out another repair spacewalk – this time to fix a damaged insulation blanket near a cockpit window – saying a detailed analysis showed Discovery's crew could return safely.

"We have good news," astronaut Julie Payette radioed from mission control. "The MMT just got to the conclusion that the blanket underneath (the commander's) window is safe for return. There is no issue."

Concern about the damaged insulation blanket (measuring 20 by four inches) just below Collins' left cockpit window was the only remaining question mark about the Shuttle's condition prior to re-entry and landing.

The blanket forms an interface of sorts between heat-shield tiles surrounding the cockpit windows and thermal insulation blankets that protect much of the Shuttle's upper fuselage. Rather than being a threat during the high-speed, high-heating parts of re-entry, engineers had been concerned that the blanket's top layer could rip away at lower velocities, fly back and impact the back end of the Space Shuttle.

Deliberately damaged blankets similar to the one aboard Discovery were tested in a wind tunnel at NASA's Ames Research Center in California to help engineers and aerodynamicists calculate when during entry debris might rip away, what sort of trajectory it might follow and whether an impact could cause serious damage to the Shuttle's rear wing elevons, rudder/speed brake or aft rocket pods. But they showed the blanket posed no significant threat.

Earlier in the day, the Discovery astronauts and their colleagues on the ISS paid tribute today to the 21 astronauts and cosmonauts who lost their lives in spacecraft mishaps, saying the benefits of space travel outweigh the risks.

Taking turns at reading prepared scripts while down-linking video of a long pass across the Indian Ocean, they remembered the crews of Columbia, Challenger, Soyuz 1 and 11 and the Apollo 1 victims of the launch pad fire.

At every media opportunity during the mission, NASA administrator Michael Griffin mounted a spirited defence of the Shuttle programme and the beleaguered external tank project.

Referring to the overall number of dents, dings and chips seen in the Shuttle's heat-shield tiles, Griffin said: "Discovery is the cleanest bird we've seen – six times cleaner than the average across 113 (previous) missions. We have three or four things that we still need to clean up from our first test flight in two-and-a-half years – but in the world of engineering, we did pretty well."

Asked by journalists how NASA could get another launch off this year with all the testing that now must be done, Griffin replied "by being smart and working hard".

"If we can do those and are successful, then we'll capture one of those flight opportunities – if not, it will move. But we don't start out by assuming that we can't succeed."

Griffin was also asked if the media had over-reacted to the foam problems experienced during Discovery's launch.

"Essentially this was a test flight," he said. "It has now provided data that we can use going forward. The bad news is there were three or four things we didn't get. The good news is we hugely reduced any damage to the orbiter through the engineering measures we took to improve the tank.

"We specifically said the return to flight test sequence was two test flights. We plan for the worst and we hope for the best and that's how we conduct business."

Coming into land

by Curtis Peebles



The original plan for the landing of Discovery at the end of the STS-114 mission was a return to the Kennedy Space Center. This had the advantages of both reducing the turnaround time and lessened the risk to populated areas should a re-entry breakup occur. The re-entry path into Florida was over the Pacific and Gulf of Mexico.

The only land areas it crossed were a narrow section of Central America and then Florida just before touchdown. Edwards and White Sands had not been alerted for the first landing opportunities on 8 August 2005 but when the first two landing attempts at Kennedy were waved off due to weather outside acceptable limits, both sites were alerted to support a possible landing the following day. The Florida weather continued to be unacceptable and Edwards was selected as the landing site. Touchdown was scheduled for 5:11 am Pacific Daylight Time (PDT) on 9 August.

With an Edwards landing confirmed, I headed to the base. The desert was pitch black on the drive out, with the only illumination the stars. Once at Edwards, I could see the billion candlepower lights set up at the far end of Runway 22. These shined down the length of the runway. Overhead, a Shuttle Training Aircraft made a practice approach, and then climbed out for another pass. As I reached the NASA Dryden Flight Research Center, I could see the convoy of Shuttle support vehicles lined up on the taxiway.

The first Shuttle flight since the loss of Columbia more than two and a half years

before resulted in a great deal of press attention. A large contingent of reporters had been accredited to be at Edwards for a possible landing, even though the planned site was at Kennedy. This was much larger number than the handful of reporters who attended previously diverted landings at Edwards.

When I arrived at 3:30 am, a line of television station satellite trucks were set up in the Dryden visitor parking lot. They had been set up the evening before, in the event of a change in landing site. The trucks – lit up with their power generators running – carried news crews not only from the Los Angeles area, but also from Bakersfield, Las Vegas, and San Diego. There was a major contingent of reporters from Japanese media outlets and a number of other foreign reporters on site.

The press centre was crowded with NASA employees and contractor personnel. Many had been on hand since the previous evening, fielding numerous phone calls, signing in reporters, and dealing with the last minute switch. Television sets in the press centre were tuned to NASA TV, and were showing animation of Discovery's position over the Earth, and shots of mission control.

Media trucks at Edwards Air Force Base.

Curtis Peebles



The mood in the building was quiet as the time for retrofire drew closer. There was nothing much to say.

After the deorbit burn was confirmed, NASA TV began reporting Discovery's speed and altitude as it descended toward landing. The employees and reporters in the press centre waited. The re-entry path into Edwards was over the Pacific. It then crossed the California coast near Vandenberg AFB, avoiding the Los Angeles basin. The Shuttle continued west until it was over the Antelope Valley, when Discovery would make a right hand turn to line up on Runway 22. The 16 minute mark until touchdown was passed and Discovery continued on track to a landing.

At about the eight minute point, most of the people in the press centre went outside. The night was clear and a cool breeze from the west was blowing. This was a change from the humidity and threat of afternoon thunderstorms which had troubled the area for several weeks. High overhead, Mars was a bright reddish orange point of light. To the east, the constellation Orion could be seen above the first glow of dawn.

During daytime landings, it was possible to see the Shuttle at altitudes of some 15,000 metres. However, local sunrise was not until 6:09 am, and the Shuttle did not have running lights.

This was the first night Shuttle landing I had attended and, did not know what to expect. Given its altitude, there was speculation that the Shuttle might be illuminated by the Sun below the horizon. Right on time, a bright point of light appeared high to the northwest sky. It was travelling to the east, with what seemed to be the right angular speed. As it moved past our position, the group waited for the distinctive double sonic boom, which trails behind the vehicle.

When the light was in what seemed to be the proper point we heard the loud double boom, reverberating off the buildings. This was followed by the sound of car alarms going off, which had been triggered by the shock waves. The light continued east, dropping lower in the eastern sky. I finally lost sight of it.

Then, within what seemed to be a matter of moments, the public address system began playing the 'Star Spangled Banner',

The STS-114 crew members pose for a crew photo shortly after landing at Edwards Air Force Base in California. They are (from left): Stephen Robinson, Eileen Collins, Andrew Thomas, Wendy Lawrence, Soichi Noguchi, Charles Camarda, and James Kelly.



Close-up of Discovery after landing showing the loose flap of insulation material midway between the 'D' and side cockpit window.
Curtis Peebles

the traditional signal that the Shuttle had touched down. I could not understand how the Orbiter could have gotten from where I saw it to a landing in so short a time. We went back inside the press centre and on NASA TV were infrared images of Discovery stopped on Runway 22. The body flap was still glowing with the heat of re-entry, and the pulsing exhaust from an Auxiliary Power Unit was visible to the infrared camera.

There was similar confusion at the press site near the runway. I learned later that a group of reporters and media escorts had also seen the object. Some thought it was Discovery, while others insisted it was the International Space Station (ISS). As they watched the object, however, they noticed it was continuing to head east, and was not turning right toward the Heading Alignment Circle. They could also hear the Shuttle approaching. Suddenly, Discovery materialised out of the darkness, touched down on the runway, deployed its parachute

and slowed to a stop.

The object that the two groups had seen was indeed the ISS. After Discovery had undocked it made a separation manoeuvre and pulled ahead of the Station by some two minutes. As a result, both arrived over Edwards at nearly the same time. The assembled spectators were trying to see the Shuttle as it approached, and spotted a bright object, heading in the right direction. Or at least, so it seemed. In retrospect, Discovery was too low when it reached Edwards to have been illuminated by the Sun.

On NASA TV, the recovery crew was shown preparing the Discovery to be towed off the runway. The astronauts were shutting down the systems and getting ready to leave Discovery and make the walk around inspection. In the visitor's parking lot, reporters and camera crews prepared to update their news shows. To the east, the horizon was lit by a golden desert sunrise. It had been a great morning.

