Liftoff

New Zealand's space exploration magazine

Issue 264
July-August 2011

Wheels stop

- An era ends

Also inside:

- **Dawn reaches Vesta**
- **Apollo 15 – 40th anniversary**

Liftoff

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NZSA News and Notices

Auckland meetings

The next Auckland meetings are on **5 September** and **3 October** at 7:45 pm at MOTAT, Great North Road, Western Springs (entry via Stadium Rd).

The Auckland Branch meets at MOTAT on the first Monday of each month (except January).

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Subscriptions 2011-2012

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Note, too, that for each new member you introduce to the NZSA, providing they join for a full year and nominate you on their membership form, you will receive a credit of $5 against your next subscription. There is no limit to the number of credits you can qualify for.

Cover Photo: An American flag waves in the wind in front of space shuttle Atlantis on the Shuttle Landing Facility's Runway 15 at NASA's Kennedy Space Center in Florida. Atlantis' final return from space at 5:57 a.m. (EDT) on 21 July 2011. (NASA)

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Editor's Corner

And so the Space Shuttle passes into the pages of history, joining other pioneering human spaceflight programmes such as Mercury, Gemini, Apollo, Vostok, Salyut, and Mir. With the ending of Shuttle flights many commentators (and a few politicians) have bemoaned the "end" of the US human spaceflight.

When *Atlantis* rolled to a stop on 21 July, it marked the last gasp of the momentum that had carried US human spaceflight through triumph and tragedy since its beginnings 50 years ago, and which peaked in July 1969 with the first lunar landing. (Ironically, perhaps, Atlantis' landing came just one day after the 42nd anniversary of that historic moment.) Like Apollo, the Shuttle was a product of the Cold War rivalry with the then-Soviet Union for space supremacy. But the Shuttle, and the International Space Station that its crews helped build, also saw the former rivals become partners.

The end of the Shuttle programme is not the end of US human spaceflight, but it's fair to say that things are in a state of transition, and the future course is far from clear. Vague goals of visiting an asteroid or eventually going to Mars, but lacking a firm commitment and timetable, will only result in endless deferments as cost-cutting politicians look for easy targets. Similarly, private-sector companies such as SpaceX are probably going to find that building a human-rated spacecraft is a lot harder than they think, and it would be surprising if any of their vehicles fly for at least five years, making the US totally reliant on Russia for space access in the meantime.

However, the good news is that robotic solar system exploration has never been busier. In July, NASA's Dawn spacecraft – a project that was nearly cancelled a few years ago – has become the first spacecraft ever to orbit an asteroid (see page 16). More recently, the Juno spacecraft has successfully been launched towards Jupiter (more on that in the next issue), and the Curiosity Mars rover is at Cape Canaveral being readied for a November launch. Not to mention ongoing missions such as Cassini, MESSENGER, and the Mars rover and orbiters. Plenty to get excited about, then!

-- David Maclennan

LRO declared fully successful

On 10 June 2011, the Lunar Reconnaissance Orbiter spacecraft angled its orbit 65° to the west, allowing the LRO Camera NACs to capture a dramatic sunrise view of Tycho crater. The summit of the central peak is 2 km above the crater floor. Tycho crater's central peak complex, shown here, is about 15 km wide, left to right (southeast to northwest in this view). (NASA Goddard/Arizona State University)

NASA has declared full mission success for the Lunar Reconnaissance Orbiter (LRO). LRO changed our view of the entire Moon and brought it into sharper focus with unprecedented detail.

NASA's Exploration Systems Mission Directorate (ESMD) operated the LRO spacecraft and its instruments during the one-year mission phase. Now that the final data from the instruments have been added to the agency's Planetary Data System, the mission has completed the full success requirements. The data system, which is publicly available, archives data from past and present planetary missions as well as astronomical observations and laboratory data. The rich new portrait rendered by LRO's seven instruments is the result of more than 192 terabytes of data, images and maps, the equivalent of nearly 41,000 typical DVDs.

"LRO is now in the very capable hands of NASA's Science Mission Directorate, with ongoing, near continuous acquisition of science data," said Douglas Cooke, associate administrator of ESMD at NASA Headquarters in Washington. "Exploration will be well served by the LRO science mission, just as the LRO exploration mission has benefited lunar science."

The primary objective of the mission was to enable safe and effective exploration of the Moon. "We needed to leverage the very best the science community had to offer," said Michael Wargo, chief lunar scientist of ESMD. "And by doing that, we've fundamentally changed our scientific understanding of the Moon."

The most precise and complete topographic maps to date of the Moon's complex, heavily cratered landscape have been created from more than four billion measurements, which are still coming in, taken by LRO's Lunar Orbiter Laser Altimeter (LOLA). LOLA has taken more than 100 times more measurements than all previous lunar instruments of its kind combined, opening up a world of possibilities for future exploration and for science.

The Lunar Reconnaissance Orbiter Camera (LROC) revealed stunning details after imaging nearly 5.7 million square kilometers of the Moon's surface during the mission's exploration phase. That is roughly the same amount of land as all contiguous states west of the Mississippi River. Though earlier missions also imaged the Moon, what sets LROC apart is its ability to image with surface pixels that are only 1.5 feet in size, small enough to distinguish details never before possible. "With this resolution, LRO could easily spot a picnic table on the Moon," said LRO's Project Scientist Richard Vondrak of NASA's Goddard Space Flight Center in Greenbelt, Md.

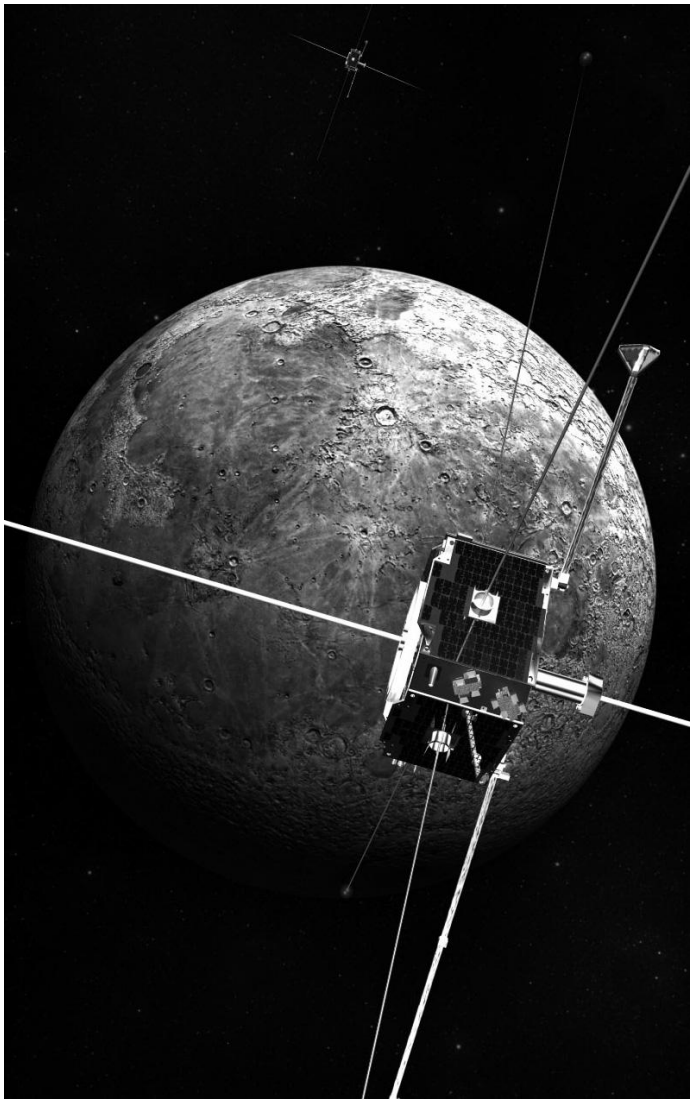
While studying the Hermite crater near the Moon's north pole, LRO's Diviner Lunar Radiometer Experiment found the coldest spot in the solar system, with a temperature of minus 248 degrees Celsius. To further explore these regions, LRO's Lyman Alpha Mapping Project, which can "see" in the dark, is imaging the shaded areas, while LOLA's precise measurements map solar illumination. This work has provided new insight into the shadowed regions and also revealed areas that receive nearly continuous Sun. Because sunlight itself is a resource on the Moon, knowing there are areas that get Sun for approximately 243 days a year and never have a period of total darkness for more than 24 hours is extremely valuable.

Complementing those efforts are both the Lunar Exploration Neutron Detector (LEND) and the Miniature Radio Frequency advanced radar, which are searching for deposits of water ice. LEND also seeks hydrogen, which could be used potentially as fuel. LRO's Cosmic Ray Telescope for the Effects of Radiation is studying the lunar radiation environment, which is important to keep astronauts healthy and safe.

LRO launched aboard an Atlas V rocket from Cape Canaveral, Fla., on 18 June 2009.

Two probes tackle new mission: studying the Moon

Two small NASA probes that had been used to study space weather now are orbiting the Moon to study its interior and surface composition. The spacecraft, called Acceleration, Reconnection, Turbulence and Electrodynamics of the Moon's Interaction with the Sun (ARTEMIS), began their journey away from Earth's orbit in July 2009. The first spacecraft entered lunar orbit on 27 June 2011, and the second on 17 July.



An artist's concept of the THEMIS spacecraft in orbit around the Moon. (NASA/Conceptual Image Lab)

Engineers used complex orbit maneuvers to relocate the spacecraft to their new locations. The journey required many gravity assists from the Moon and Earth and used minimal amounts of fuel. The probes will now approach the Moon's surface to within 96.5 kilometres once per orbit. The data will provide scientists with new information about the Moon's internal structure for the next seven to 10 years.

Both spacecraft were previously in areas called the Lagrangian points, areas on either side of the Moon, where the Moon and Earth's gravity balance perfectly. These locations were ideal spots to study Earth's distant magnetic field and how the solar wind, made up of ionized gas known as plasma, flows past the Moon and tries to fill in the vacuum on the other side.

The ARTEMIS mission was made possible by repurposing two spacecraft that would otherwise have ceased operations in 2010. The spacecraft were part of NASA's Time History of Events and Macroscale Interactions during Substorms (THEMIS) mission launched in 2007.

"From their new orbits about the Moon, ARTEMIS will collect important data about the Moon's core, its surface composition, and whether it contains pockets of magnetism," said Dave Sibeck, ARTEMIS and THEMIS project scientist at NASA's Goddard Space Flight Center in Greenbelt, Md. "ARTEMIS also will provide information needed to understand the Moon's magnetic environment in space and its relationship to events near Earth."

The THEMIS mission consisted of five identical spacecraft that studied the magnetic environment around Earth, the aurora, and how these are affected by the Sun. The other three THEMIS probes continue their original science mission. Substorms are atmospheric events visible near the poles as sudden increases in the brightness of the aurora. The findings from the mission may help protect commercial satellites and humans in space from the adverse effects of particle radiation.

MESSENGER confirms theories, sees surprises at Mercury

Data from MESSENGER, the first spacecraft to orbit Mercury, is giving scientists important new clues to the origin of the planet and its geological history and helping them better understand its dynamic interior and exterior processes. NASA's MErcury Surface, Space ENvironment, GEochemistry, and Ranging spacecraft, or MESSENGER, has been orbiting Mercury since 18 March. To date the spacecraft has provided tens of thousands of images showing detailed planetary features. The planet's surface previously had been seen only at comparatively low resolution but is now in sharper focus.

The spacecraft also has collected extensive measurements of the chemical composition of Mercury's surface and topography and gathered global observations of the planet's magnetic field. Data now confirm that bursts of energetic particles in Mercury's magnetosphere are a continuing product of the interaction of Mercury's magnetic field with the solar wind.

"We are assembling a global overview of the nature and workings of Mercury for the first time," said MESSENGER principal investigator Sean Solomon of the Carnegie Institution of Washington. "Many of our earlier ideas are being cast aside as new observations lead to new insights. Our primary mission has another three Mercury years to run, and we can expect more surprises as our solar system's innermost planet reveals its long-held secrets."

Flyby images of Mercury had detected bright, patchy deposits on some crater floors. Without high-resolution images to obtain a closer look, these features remained only a curiosity. Now new detailed images have revealed these patchy deposits to be clusters of rimless, irregular pits varying in size from several hundred feet to a few miles wide. These pits are often surrounded by diffuse halos of more reflective material and are found on central peaks, peak rings, and rims of craters.

"The etched appearance of these landforms is unlike anything we've seen before on Mercury or the moon," said Brett Denevi, a staff scientist at the Johns Hopkins University Applied Physics Laboratory (APL) in Laurel, Md., and a member of the MESSENGER imaging team. "We are still debating their origin, but they appear to be relatively young and may suggest a more abundant than expected volatile component in Mercury's crust."

One of two instruments on the spacecraft designed to measure the quantity of key chemical elements on Mercury has made several important discoveries since the orbital mission began. Elemental ratios averaged over large areas of the planet's surface show that Mercury's surface differs markedly in composition from that of the Moon.

Observations have revealed substantial amounts of sulphur at Mercury's surface, lending support to prior suggestions from ground-based telescopic observations that sulfide minerals are present. This discovery suggests that the original building blocks from which Mercury formed may have been less oxidized than those that formed the other terrestrial planets. The result also hints that sulphur-containing gases may have contributed to past explosive volcanic activity on Mercury.

Topography data of Mercury's northern hemisphere reveal the planet's large-scale shape and profiles of geological features in high detail. The north polar region is a broad area of low elevations, whereas the overall range in topographic heights seen to date exceeds 9 kilometres.

Two decades ago, Earth-based radar images showed deposits thought to consist of water ice and perhaps other ices near Mercury's north and south poles. These deposits are preserved on the cold, permanently shadowed floors of high-latitude impact craters. MESSENGER is testing this idea by measuring the floor depths of craters near Mercury's north pole. The craters hosting polar deposits appear to be deep enough to be consistent with the idea that those deposits are in permanently shadowed areas.

During the first of three Mercury flybys in1974, Mariner 10 discovered bursts of energetic particles in the planet's Earth-like magnetosphere. Four bursts of particles were observed on that flyby. Scientists were puzzled that no such strong events were detected by MESSENGER during any of its three flybys of the planet in 2008 and 2009. But now that the spacecraft is in near-polar orbit around Mercury, energetic events are being seen regularly. For more information about the mission, visit: **http://www.nasa.gov/messenger**

New study suggests Sun and planets constructed differently

Researchers analyzing samples returned by NASA’s 2004 Genesis mission have discovered that our Sun and its inner planets may have formed differently than previously thought. Data revealed differences between the Sun and planets in oxygen and nitrogen, which are two of the most abundant elements in our solar system. Although the difference is slight, the implications could help determine how our solar system evolved.

"We found that Earth, the Moon, as well as Martian and other meteorites which are samples of asteroids, have a lower concentration of the O-16 than does the Sun," said Kevin McKeegan, a Genesis co-investigator from UCLA, and the lead author of one of two papers published in June. "The implication is that we did not form out of the same solar nebula materials that created the Sun – just how and why remains to be discovered."

The air on Earth contains three different kinds of oxygen atoms which are differentiated by the number of neutrons they contain. Nearly 100% of oxygen atoms in the solar system are composed of O-16, but there are also tiny amounts of more exotic oxygen isotopes called O-17 and O-18. Researchers studying the oxygen of Genesis samples found that the percentage of O-16 in the Sun is slightly higher than on Earth or on other terrestrial planets. The other isotopes’ percentages were slightly lower.

Another paper detailed differences between the Sun and planets in the element nitrogen. Like oxygen, nitrogen has one isotope, N-14, that makes up nearly 100% of the atoms in the solar system, but there is also a tiny amount of N-15. Researchers studying the same samples saw that when compared to Earth's atmosphere, nitrogen in the Sun and Jupiter has slightly more N-14, but 40% less N-15. Both the Sun and Jupiter appear to have the same nitrogen composition. As is the case for oxygen, Earth and the rest of the inner solar system are very different in nitrogen.

"These findings show that all solar system objects including the terrestrial planets, meteorites and comets are anomalous compared to the initial composition of the nebula from which the solar system formed," said Bernard Marty, a Genesis co-investigator from Centre de Recherches Pétrographiques et Géochimiques and the lead author of the other new paper. "Understanding the cause of such a heterogeneity will impact our view on the formation of the solar system."

Data were obtained from analysis of samples Genesis collected from the solar wind, or material ejected from the outer portion of the Sun. This material can be thought of as a fossil of our nebula because the preponderance of scientific evidence suggests that the outer layer of our Sun has not changed measurably for billions of years.

"The Sun houses more than 99% of the material currently in our solar system, so it's a good idea to get to know it better," said Genesis Principal Investigator Don Burnett of the California Institute of Technology, Pasadena, Calif. "While it was more challenging than expected, we have answered some important questions, and like all successful missions, generated plenty more."

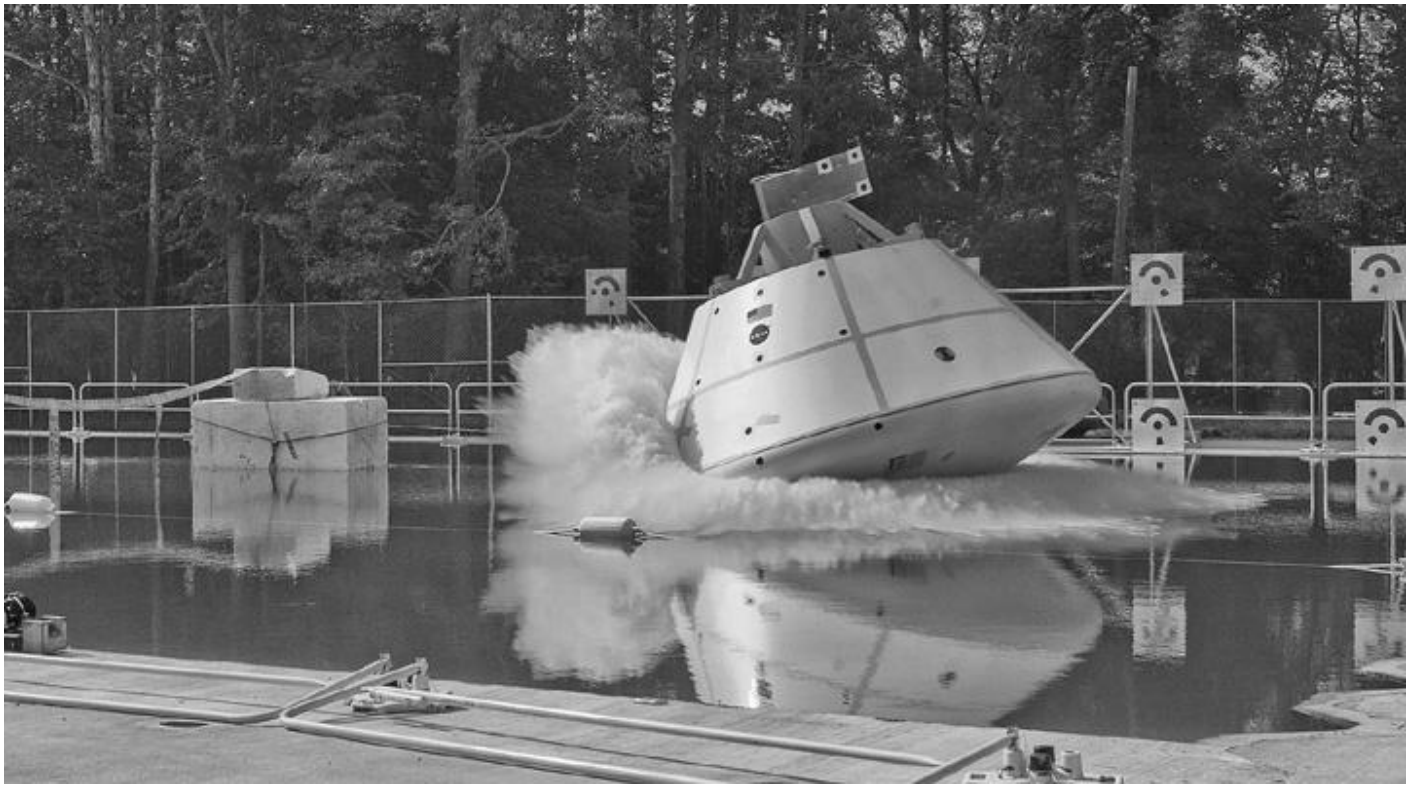
Genesis launched in August 2000. The spacecraft traveled to Earth’s L1 Lagrange Point about 1.6 million kilometres from Earth, where it remained for 886 days between 2001 and 2004, passively collecting solar-wind samples. On 8 September 2004, the spacecraft released a sample return capsule, which entered Earth's atmosphere. Although the capsule made a hard landing as a result of a failed parachute in the Utah Test and Training Range in Dugway, Utah, it marked NASA’s first sample return since the final Apollo lunar mission in 1972, and the first material collected beyond the Moon. NASA’s Johnson Space Center in Houston curates the samples and supports analysis and sample allocation.

NASA tests future deep space vehicle for water landings

Testing began in July at NASA's Langley Research Center in Hampton, Va., in the new Hydro Impact Basin to certify the Orion Multi-Purpose Crew Vehicle (MPCV) for water landings. The Orion MPCV will carry astronauts into space, provide emergency abort capability, sustain the crew during space travel and ensure safe re-entry and landing.

Engineers have dropped a 9,977-kilogram MPCV mockup into the basin. The test item is similar in size and shape to MPCV, but is more rigid so it can withstand multiple drops. Each test has a different drop velocity to represent the MPCV's possible entry conditions during water landings.

The last of three drop tests to verify the new facility was scheduled for the end of July, with testing resuming in September with a slightly modified test article that is more representative of the actual MPCV.



Hydro Impact Basin (HIB) Orion Multi-Purpose Crew Vehicle (MPCV) Boilerplate Test Article (BTA) drop test from 21 July 2011. (NASA/Sean Smith)

The new Hydro Impact Basin is 35 metres long, 27.4 metres wide and 6 metres deep. It is located at the west end of Langley's historic Landing and Impact Research Facility, or Gantry, where Apollo astronauts trained for Moon walks.

Research offers new prospect of water on Mars

NASA scientists are seeing new evidence that suggests traces of water on Mars are under a thin varnish of iron oxide, or rust, similar to conditions found on desert rocks in California's Mojave Desert.

Mars could be spotted with many more patches of carbonates than originally suspected. Carbonates are minerals that form readily in large bodies of water and can point to a planet's wet history. Although only a few small outcrops of carbonates have been detected on Mars, scientists believe many more examples are blocked from view by the rust.

"The plausibility of life on Mars depends on whether liquid water dotted its landscape for thousands or millions of years," said Janice Bishop, a planetary scientist at NASA's Ames Research Center at the SETI Institute at Moffett Field, Calif., and the paper's lead author. "It's possible that an important clue, the presence of carbonates, has largely escaped the notice of investigators trying to learn if liquid water once pooled on the Red Planet."

Scientists conduct field experiments in desert regions because the extremely dry conditions are similar to Mars. Researchers realized the importance of the varnish earlier this year when Bishop and Chris McKay, a planetary scientist at Ames investigated carbonate rocks coated with iron oxides collected in a location called Little Red Hill in the Mojave Desert.

"When we examined the carbonate rocks in the lab, it became evident that an iron oxide skin may be hindering the search for clues to the Red Planet's hydrological history," McKay said. "We found that the varnish both altered and partially masked the spectral signature of the carbonates." McKay also found dehydration-resistant blue-green algae under the rock varnish. Scientists believe the varnish may have extended temporarily the time that Mars was habitable, as the planet's surface slowly dried up.

"The organisms in the Mojave Desert are protected from deadly ultraviolet light by the iron oxide coating," McKay said. "This survival mechanism might have played a role if Mars once had life on the surface."

In addition to being used to help characterize Mars' water history, carbonate rocks also could be a good place to look for the signatures of early life on the Red Planet. Every mineral is made up of atoms that vibrate at specific frequencies to produce a unique fingerprint that allows scientists to accurately identify its composition.

Research data were similar to observations provided by NASA's Mars Reconnaissance Orbiter (MRO) spacecraft, as it orbited an ancient region of Mars called Nili Fossae. The area revealed the strongest carbonate signature ever found. Although MRO recently detected small patches of carbonates, approximately 61-152 metres wide, on the Martian surface, the Mojave study suggests more patches may have been overlooked because their spectral signature could have been changed by the pervasive varnish.

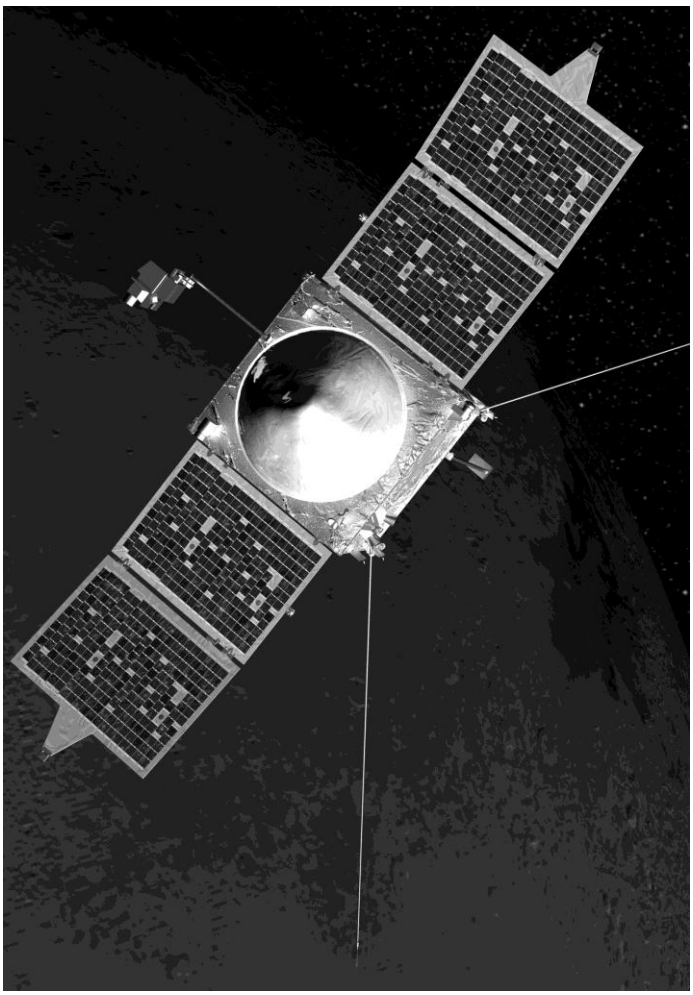
"To better determine the extent of carbonate deposits on Mars, and by inference the ancient abundance of liquid water, we need to investigate the spectral properties of carbonates mixed with other minerals," Bishop said.

The varnish is so widespread that NASA's Mars Exploration Rovers, Spirit and Opportunity, used a motorized grinding tool to remove the rust-like overcoat on rocks before other instruments could inspect them. In 2010, scientists using data collected by Spirit also identified a small carbonate outcrop at a crater called Gusev. NASA's newest and most capable rover, the Mars

Science Laboratory Curiosity is schedule to launch in November. It will use tools to study whether the Mars had environmental conditions favorable for supporting microbial life and favorable for preserving clues about whether life existed.

MAVEN mission completes major milestone

The Mars Atmosphere and Volatile EvolutioN (MAVEN) mission reached a major milestone in late July when it successfully completed its Mission Critical Design Review (CDR). MAVEN, scheduled for launch in late 2013, will be the first mission devoted to understanding the Martian upper atmosphere. The goal of MAVEN is to determine the history of the loss of atmospheric gases to space through time, providing answers about Mars climate evolution. It will accomplish this by measuring the current rate of escape to space and gathering enough information about the relevant processes to allow extrapolation backward in time.



The MAVEN spacecraft (NASA)

Noting this milestone, Michael Meyer, Lead Scientist for NASA's Mars Exploration Program at NASA Headquarters said. "It is a real pleasure to see the MAVEN team is doing an exemplary job on this important mission, which was identified as a top priority mission in the 2002 National Research Council Decadal Survey and addresses high-priority goals of two Divisions – Planetary Sciences and Heliophysics."

"Understanding how and why the atmosphere changed through time is an important scientific objective for Mars," said Bruce Jakosky, MAVEN Principal Investigator from the Laboratory for Atmospheric and Space Physics at the University of Colorado (CU/LASP) at Boulder. "MAVEN will make the right measurements to allow us to answer this question. We're in the middle of the hard work right now – building the instruments and spacecraft – and we're incredibly excited about the science results we're going to get from the mission."

From 11-15 July the MAVEN Critical Design Review was held at NASA Goddard Space Flight Center in Greenbelt, Md. An independent review board, comprised of reviewers from NASA and several external organizations, met to validate the system design. Critical Design Reviews are one-time programmatic events that bridge the design and manufacturing stages of a project. A successful review means that the design is validated and will meet its requirements, is backed up with solid analysis and documentation, and has been proven to be safe. MAVEN's CDR completion grants permission to the mission team to begin manufacturing hardware.

"This team continues to nail every major milestone like clockwork, as laid out three years ago when the mission was proposed," said Dave Mitchell, MAVEN Project Manager at NASA Goddard Space Flight Center in Greenbelt, Md. "CDR success is very important because it validates that the team is ready for fabrication, assembly, and test of all mission elements. It also enables us to stay on plan for launch in November 2013."

MAVEN will carry three instrument suites. The Particles and Fields Package, built by the University of California at Berkeley with support from CU/LASP and NASA Goddard, contains six instruments that will characterize the solar wind and the ionosphere of the planet. The Remote Sensing Package, built by CU/LASP, will determine global characteristics of the upper atmosphere and ionosphere. The Neutral Gas and Ion Mass Spectrometer, provided by NASA Goddard, will measure the composition and isotopes of neutral ions.

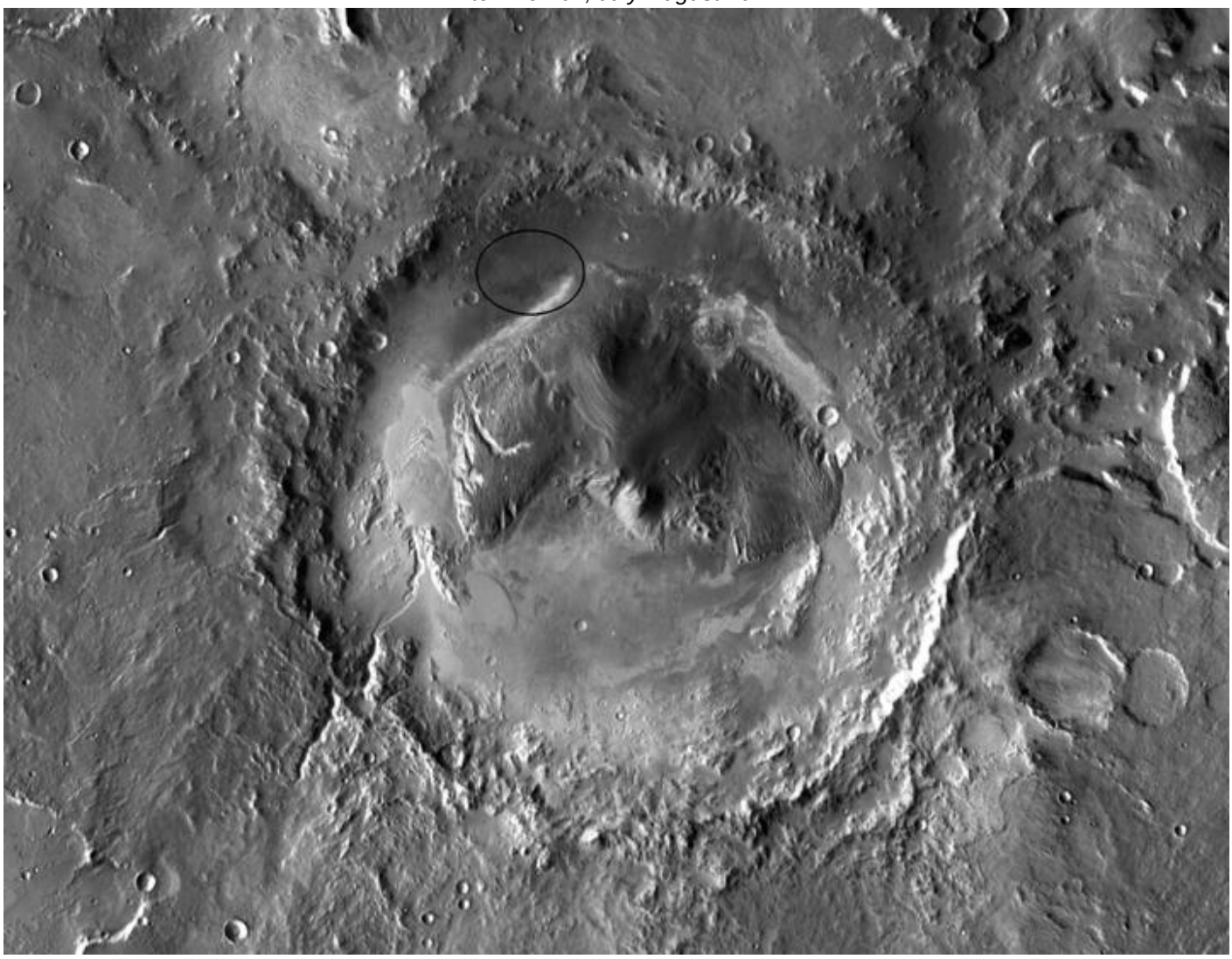
Next Mars rover to land at Gale Crater

NASA's next Mars rover will land at the foot of a layered mountain inside the planet's Gale Crater. The car-sized Mars Science Laboratory, or Curiosity, is scheduled to launch late this year and land in August 2012. The target crater spans 154 kilometres in diameter and holds a mountain rising higher from the crater floor than Mount Rainier rises above Seattle. Gale is about the combined area of Connecticut and Rhode Island. Layering in the mound suggests it is the surviving remnant of an extensive sequence of deposits. The crater is named for Australian astronomer Walter F. Gale.

During a prime mission lasting one Martian year – nearly two Earth years – researchers will use the rover's tools to study whether the landing region had favorable environmental conditions for supporting microbial life and for preserving clues about whether life ever existed.

"Scientists identified Gale as their top choice to pursue the ambitious goals of this new rover mission," said Jim Green, director for the Planetary Science Division at NASA Headquarters in Washington. "The site offers a visually dramatic landscape and also great potential for significant science findings."

In 2006, more than 100 scientists began to consider about 30 potential landing sites during worldwide workshops. Four candidates were selected in 2008. An abundance of targeted images enabled thorough analysis of the safety concerns and scientific attractions of each site. A team of senior NASA



Gale crater, the landing site selected for the Curiosity Mars rover (circled above), is 154 km in diameter and holds a layered mountain rising about 5 km above the crater floor. The ellipse superimposed on this image indicates the intended landing area, 20 km by 25 km. The portion of the crater within the landing area has an alluvial fan likely formed by water-carried sediments. The lower layers of the nearby mountain -- within driving distance for Curiosity -- contain minerals indicating a wet history. The intended landing site is at 4.5 degrees south latitude, 137.4 degrees east longitude. (NASA/JPL)

science officials then conducted a detailed review and unanimously agreed to move forward with the MSL Science Team's recommendation. The team is comprised of a host of principal and co-investigators on the project.

Curiosity is about twice as long and more than five times as heavy as any previous Mars rover. Its 10 science instruments include two for ingesting and analyzing samples of powdered rock that the rover's robotic arm collects. A radioisotope power source will provide heat and electric power to the rover. A rocket-powered sky crane suspending Curiosity on tethers will lower the rover directly to the Martian surface.

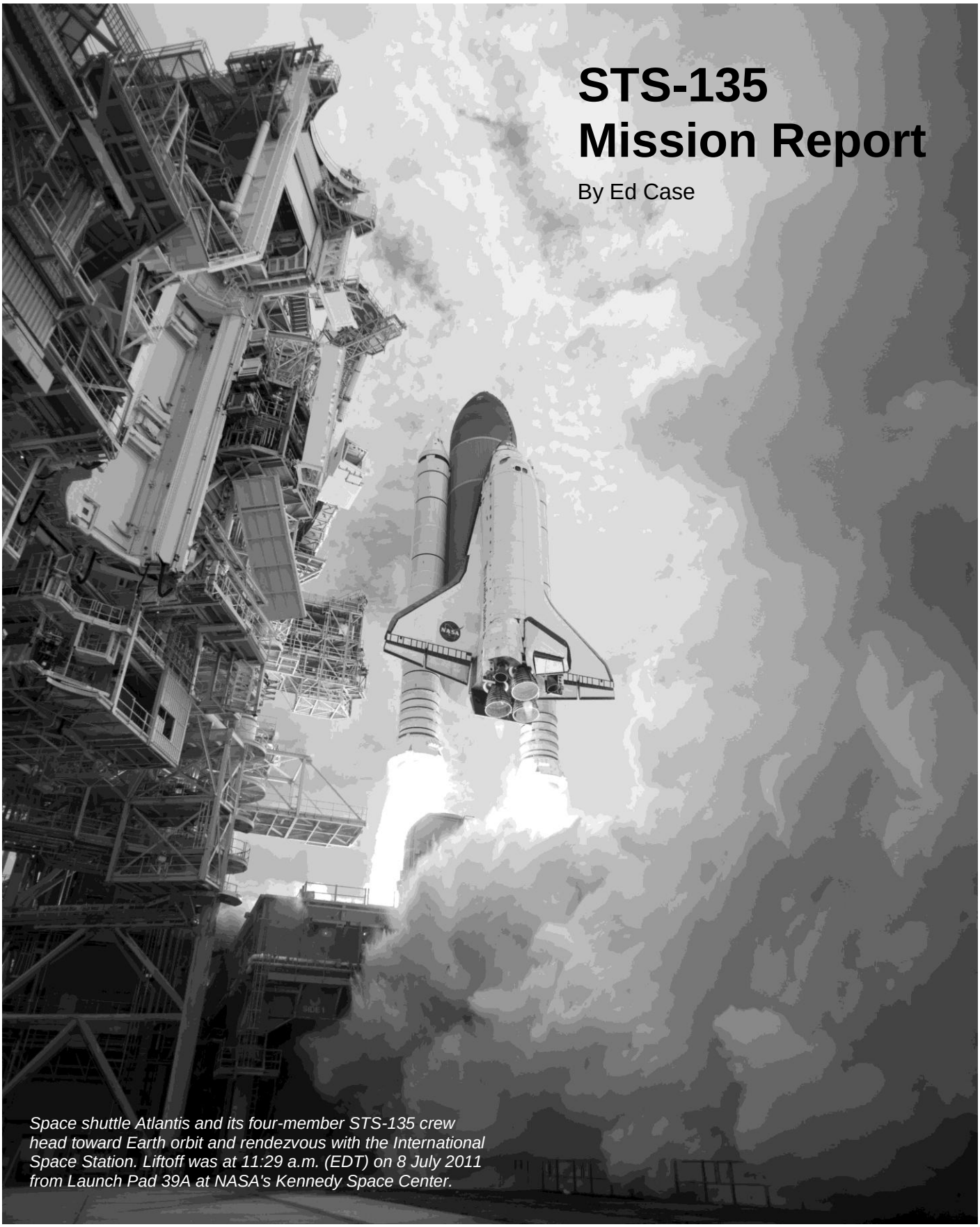
The portion of the crater where Curiosity will land has an alluvial fan likely formed by water-carried sediments. The layers at the base of the mountain contain clays and sulfates, both known to form in water. "One fascination with Gale is that it's a huge crater sitting in a very low-elevation position on Mars, and we all know that water runs downhill," said John Grotzinger, the mission's project scientist at the California Institute of Technology in Pasadena, Calif. "In terms of the total vertical profile exposed and the low elevation, Gale offers attractions similar to Mars' famous Valles Marineris, the largest canyon in the solar system."

Curiosity will go beyond the "follow-the-water" strategy of recent Mars exploration. The rover's science payload can identify other ingredients of life, such as the carbon-based building blocks of biology called organic compounds. Long-term preservation of organic compounds requires special conditions. Certain minerals, including some Curiosity may find in the clay and sulfate-rich layers near the bottom of Gale's mountain, are good at latching onto organic compounds and protecting them from oxidation.

"Gale gives us attractive possibilities for finding organics, but that is still a long shot," said Michael Meyer, lead scientist for NASA's Mars Exploration Program at agency headquarters. "What adds to Gale's appeal is that, organics or not, the site holds a diversity of features and layers for investigating changing environmental conditions, some of which could inform a broader understanding of habitability on ancient Mars."

STS-135 Mission Report

By Ed Case



Space shuttle Atlantis and its four-member STS-135 crew head toward Earth orbit and rendezvous with the International Space Station. Liftoff was at 11:29 a.m. (EDT) on 8 July 2011 from Launch Pad 39A at NASA's Kennedy Space Center.

Atlantis crew:

Christopher Ferguson (Commander; 3rd flight)
Douglas Hurley (Pilot; 2nd flight)
Sandra Magnus (Mission Specialist; 4th flight)
Rex Walheim (Mission Specialist; 3rd flight)

Notes: 135th shuttle flight, 33rd flight for Atlantis, 37th flight to the ISS. Endeavour was scheduled for the last flight in the shuttle program but Congress funded one more flight so this will be the last flight for Atlantis and the last flight scheduled for the Space Shuttle Program. Only time a crew of 4 will fly to the ISS. First iPhone to fly on a shuttle.

On Friday 8 July 2011, Shuttle *Atlantis* with four crewmembers aboard lifted off for the International Space Station for the last time at 10:29 a.m. CDT from Kennedy Space Center, Florida. Aboard were the Raffaello multi-purpose logistics module and the Robotic Refueling 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* was to return a failed ammonia pump to Earth for examination – a task no other spacecraft can do. Raffaello is making its fourth trip to the station.

On Saturday 9 July 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 Center hopes you enjoyed your ride to orbit. We wish you a successful mission and a safe return home." Marshall, located in Huntsville, Ala., was responsible for the space shuttle's propulsion system – the shuttle's three main engines, the twin solid rocket boosters and the external tank.

With that encouragement, the shuttle crew got to work on their flight day two activities. The astronauts inspected the orbiter's thermal protection system with its robotic arm and attached the 50-foot boom. They also prepared rendezvous tools for arrival at the International Space Station. 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 carbon of the wings' leading edges and the nose cap. Experts on the ground reviewed the data to ensure they have not been damaged.

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

After the heat shield survey and the work with the middeck cargo, all four crewmembers 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.

Docking with ISS

Sunday 10 July was docking day. The shuttle had been closing the distance between and it and the space station since it reached orbit on two days earlier, and with the help of a final firing of the shuttle's jets at 9:06 a.m. At that point, the shuttle was directly below the ISS and in place to expose the tiles on the shuttle's underbelly to the space station, where station crew members used their cameras to document its condition.

At the windows in the Russian segment of the space station, flight Engineer Ron Garan used a 800mm camera to gather photos of *Atlantis*' heat shield, while flight Engineer Satoshi Furukawa used a 400mm camera and Flight Engineer Sergei Volkov used a 1,000mm lens. The back flip lasted about eight minutes. Once that was completed, Ferguson moved *Atlantis* to a point 94.4 metres directly in front of the space station and began slowing down so that the station could catch up with the shuttle.

Atlantis docked with the ISS at 10:07 a.m. CDT. "Atlantis arriving," said Flight Engineer Ron Garan after the ceremonial ringing of the station's bell. "Welcome to the International Space 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. The shuttle crew entered the station moments later to begin their week-plus. First came the standard safety briefing and then the work began.

Flight controllers began monitoring reports from the Department of Defense'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 maneuver using the
Shuttle's thrusters are necessary to avoid the debris.

On Monday 11 July 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. Mission managers said Monday afternoon *Atlantis*' stay at the station would be extended for one day. Also, managers determined that after Saturday's inspection, further detailed inspections of *Atlantis*' heat shield are not required.

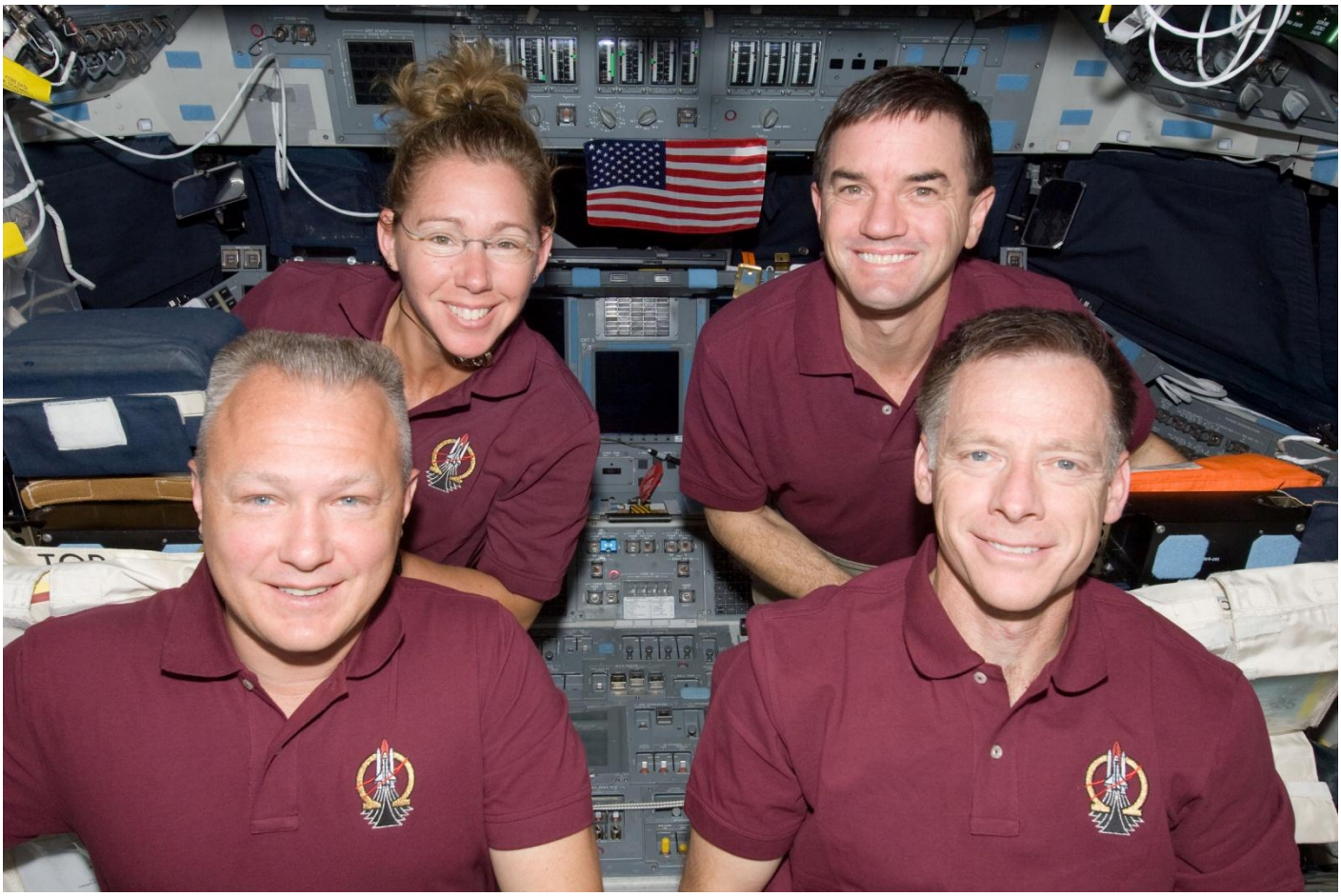
The crew continued to transfer items between the shuttle's middeck and the station. *Atlantis* brought almost 1,043 kilograms of experiments, equipment and supplies for the station in the shuttle's middeck lockers. Shortly before the end of their workday, the four astronauts met for about an hour to review procedures for the spacewalk. Spacewalkers Fossum and Garan then spent the night in the Quest airlock.

Last Shuttle-era spacewalk

On Tuesday 12 July the spacewalk begin at 7:44 a.m. Fossum was making his seventh spacewalk and Garan his fourth (all with Fossum). During this spacewalk, every member of the shuttle crew and many of the station crew were working to unload the newly installed Raffaello Multipurpose logistics module.

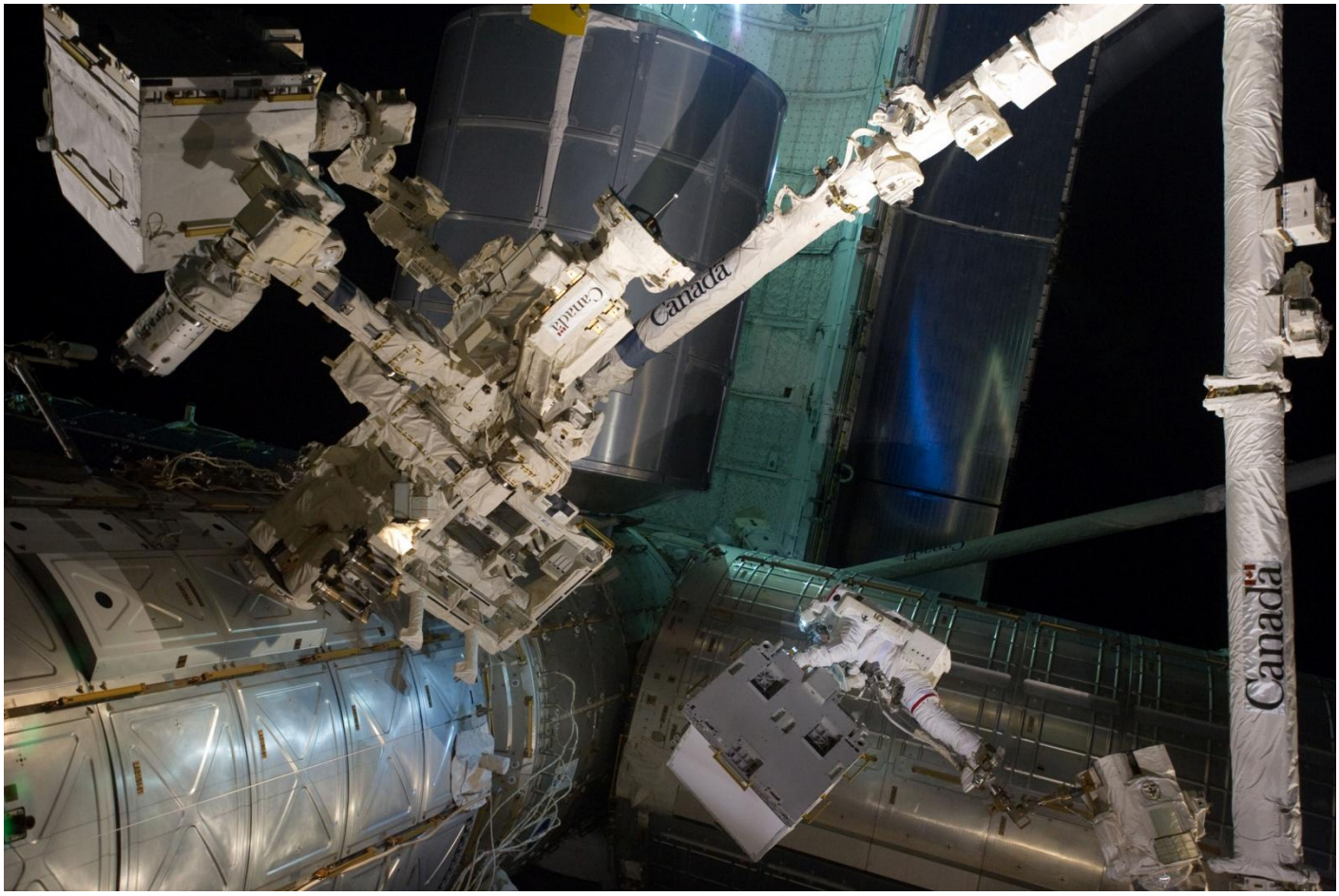
Fossum and Garan used the Canadarm2 in their first and most lengthy task, retrieval of the failed 635-kilogram pump module from the station's cooling system that failed last year. Garan rode the arm to the pump module's stowage rack where he and Fossum removed it. Still on the arm, operated by *Atlantis* 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.

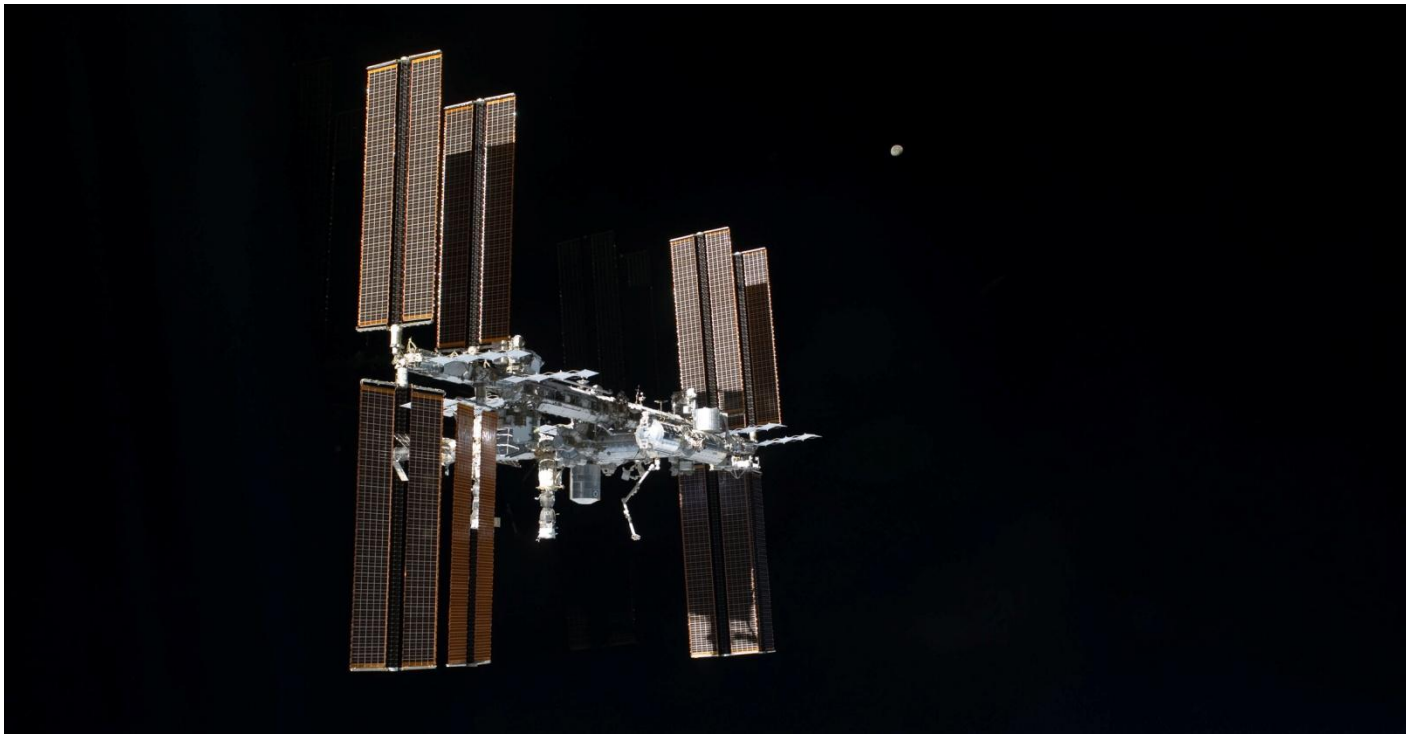
Coached by intravehicular officer and *Atlantis* Mission Specialist Rex Walheim, with help from spacewalk Capcom and astronaut Steve Bowen in the station flight control room, the spacewalkers moved on to their next task, installation of the robotic refueling Mission experiment. The experiment is designed to help in development to ways to robotically refuel satellites in space. They removed the refueling experiment from the cargo bay. Fossum, now on the arm, carried the experiment to a platform on Dextre, the Special Purpose Dexterous Manipulator.



(Top) The four crew members of the Atlantis STS-135 mission pose for a picture on the spacecraft's flight deck. On the front row are NASA astronauts Doug Hurley (left) and Chris Ferguson, pilot and commander respectively. In the rear are NASA astronauts Sandy Magnus and Rex Walheim, both mission specialists. The U.S. flag pictured was flown on the first space shuttle mission, STS-1, and flew on this mission to be presented to the space station crew.

(Bottom) One of the STS-135 Atlantis crewmembers took this photo of the Southern Lights or Aurora Australis while visiting the International Space Station on July 14, 2011. Part of the orbiter boom sensor system (OBSS) is seen, as it was attached on the end of the shuttle's robotic arm (out of frame). A part of the port side wing of the shuttle is at right. (NASA)





(Top) With his feet secured on a restraint on the space station remote manipulator system's robotic arm or Canadarm2, NASA astronaut Mike Fossum (lower right side of frame) holds the Robotics Refueling Mission payload, which was the focus of one of the primary chores accomplished on a six and a half hour spacewalk on 12 July.

(Bottom) This picture of the International Space Station was photographed from the space shuttle Atlantis as the orbiting complex and the shuttle performed their relative separation in the early hours of 19 July 2011. The Moon is visible in the background. (NASA)

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 stations 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. Fossum and Garan completed a six-hour, 31-minute spacewalk at 2:53 p.m. CDT

Rocket men

On Wednesday 12 July the *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 you 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. It was not the first time the song has been played in space: Rocket Man has awakened four shuttle crew's in the shuttle programme'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 mission. In that contest, it earned nearly 5,000 votes from the public.

With the mission's one space walk successfully behind them, *Atlantis*' crew continued unpacking the Raffaello multipurpose logistics module. The crew started the day 26% through the combined 6,833.7 kilograms of cargo to transfer in or out of Raffaello – 4,264.2 kilograms that launched on *Atlantis* and 2,569.5 kligrams that it was to bring home when it lands.

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.

Thursday 14 July, flight day 7, 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 acapella version of the bands 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 you 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."

Continuing cargo transfer, news media interviews and exercise sessions kept *Atlantis* crewmembers busy this morning. They enjoyed some welcome off-duty time during their afternoon.

The crew's supper was special. That All-American Meal was initially scheduled for 4 July but would up being enjoyed today because of *Atlantis*' launch delay. Grilled chicken, corn, backed beans, cheese and more, topped off with apple pie, were on the menu.

On Friday 15 July, Sir Paul McCartney awakened the crew of Atlantis today with a special message and the song Good Day Sunshine. "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.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.

A call from the boss

At about 11:30 a.m. CDT President 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. "You 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 exploration 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 honored 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."

At a 45-minute crew news conference, *Atlantis* crewmembers and their six station colleagues gathered in the Japanese Kibo Laboratory to take questions from the media. Reporters at four NASA centers, NASA headquarters and in Japan participated. Later, Mission Specialist Rex Walheim and station flight Engineer Mike Fossum worked to resize US spacesuits to be left on the station.

On Saturday 16 July, 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 programme. "Good morning *Atlantis* from your friends at Stennis Space Center," Stennis employees said in a message recorded before launch. "It's time to fire up your engines - laissez les bons temps rouler!" – a Cajun French phrase that translates "Let the good times roll." Stennis Space Center, located in southern Mississippi, 80.4 kilometres 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 into eh STS-135 launch-was in good working order before it was installed.

Commander Chris Ferguson, Pilot Doug Hurley and Mission Specialist Sandra Magnus and Rex Walheim, with the help form their station colleagues, were nearing the home stretch in transfer activities. Most of the equipment brought up in Raffaello was aboard the station, and the loading of return items was well under way.

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. Magnus spent about an hour and a half 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 US spacewalk from the station's Quest airlock takes place.

The astronauts also provided a recorded message as a tribute to *Atlantis*, the entire Apace Shuttle programme and team. In the message, Ferguson spoke about the US flag displayed behind them that was flown on the first space shuttle mission, STS-1.

On Sunday 17 July 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 Center!” chorused an auditorium-full of Johnson employees in a message recorded before *Atlantis*’ launch. “Have a great mission!”

Now that the crew had finished packing Raffaello, it was just a matter of getting it, with its 2,569.5 kilograms of returning cargo, back in place for the trip home. When unpacked back on Earth, multipurpose logistic modules will have returned 20.3 tonnes of supplies and equipment to Earth, and carried another 50.8 tonnes into space since their first mission, STS-102 in 2002.

Final departure

On Monday 18 July, at the farewell ceremony before the shuttle crew returned to *Atlantis*, Ferguson presented to the station crew the small US 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 US spacecraft returns it to Earth. Ferguson said that later it would 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 in 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 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. Both crews 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.

Tuesday 19 July was the final crew’s final full day in space, and began with fanfare – literally – and fond greetings from Florida. The shuttle crew woke up at 8:32 p.m. to Aaron Copland’s “Fanfare for the Common Man.” It was follow by a prerecorded message for Kennedy Space Center employees. “Three…two…one…Good morning, *Atlantis*!” the group said. “Kennedy salutes you. See you back at wheels stop!”

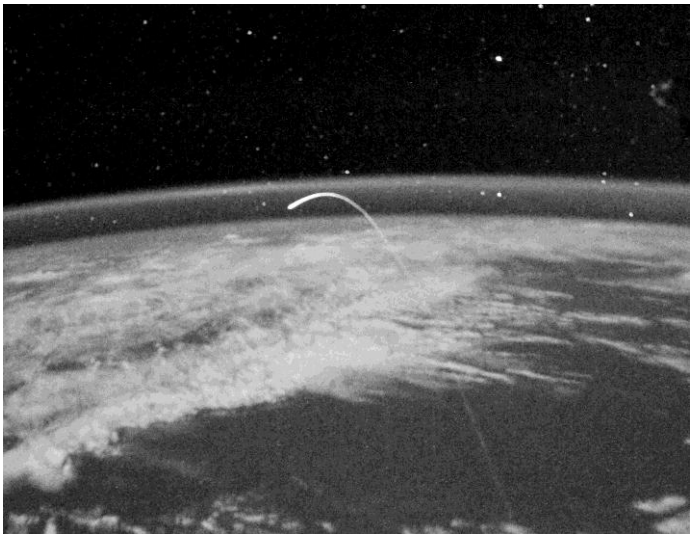
Atlantis undocked for the ISS early, marking the end of shuttle visits to the orbiting laboratory that owes much of its existence to the 37 flights they make to help build and maintain it. The 37 visits included 10 modules, four sets of solar arrays, 107.8 metres of truss and countless science experiments. 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 183 metres 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. After completing the half loop, *Atlantis* did two separation burns; the second at 3:18 a.m. moved the shuttle away from the station.

Homecoming

Wednesday 20 July, the final day of the final space shuttle mission, began at 8:29 p.m. with an iconic final wakeup song. Kate Smith rendition of Irving Berlin’s “God Bless America” woke the shuttle crew. But unlike most wakeup songs, which are played in honor 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 programme,” he said. “We’ll see you on the ground here in a few short hours, hopefully.”

Deployment of a small satellite, checkout of *Atlantis*’ flight flaps and rudder, and packing up for their return home kept the crew busy. Springs pushed the PicoSat from the cargo bay at 2:49 a.m. It is designed to evaluate the performance of a variety of solar cells mounted on it. The 3.6-kilogram satellite could lead to development of improved solar cells for use in space. It was the 180th payload deployed by a space shuttle.



This unprecedented view of the space shuttle Atlantis, appearing like a bean sprout against clouds and city lights, on its way home, was photographed by the Expedition 28 crew of the International Space Station. Airglow over Earth can be seen in the background. (NASA)

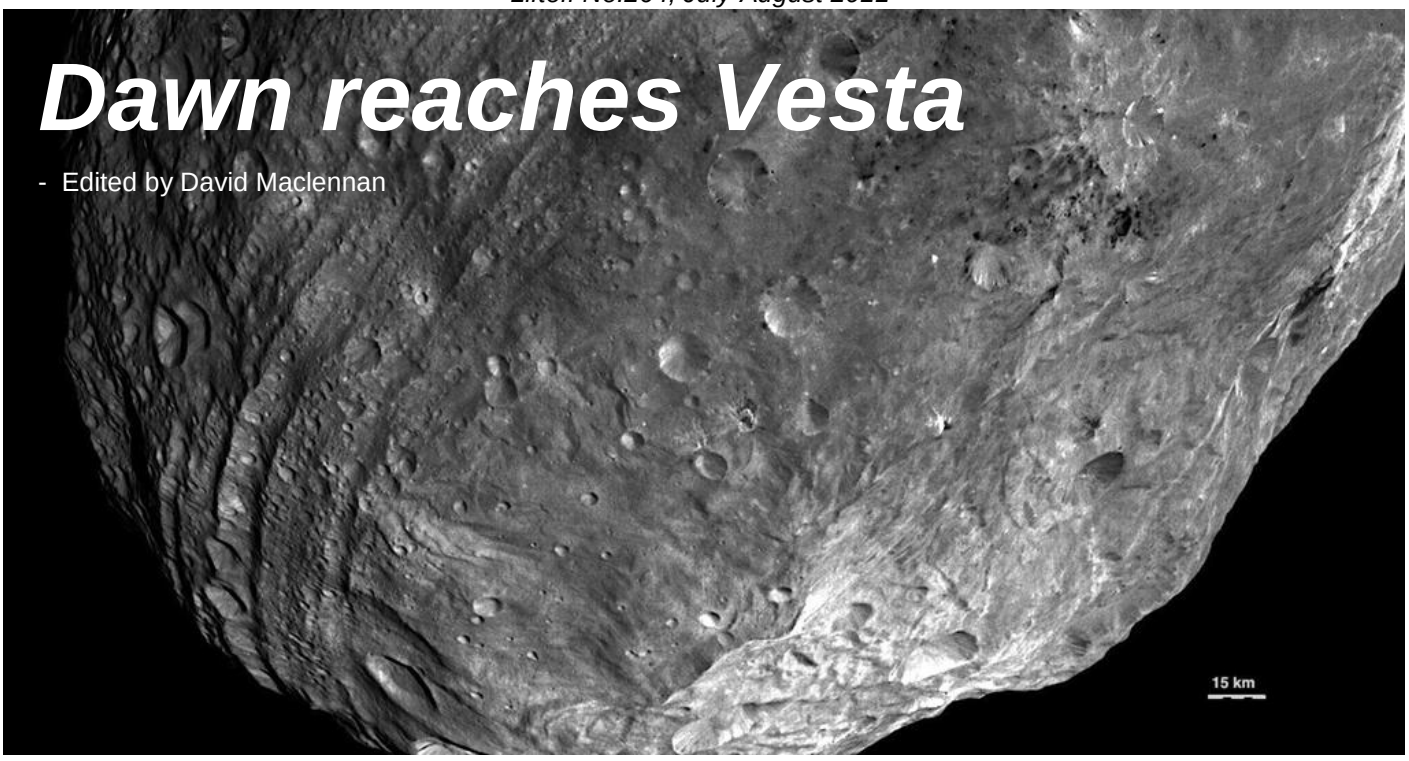
On Thursday morning, 21 July, after a 12 day, 18 hour, 28 minutes and 50 seconds, Atlantis landed the Kennedy Space Center at 4:57 a.m., ending its own 33-flight career and closing out the 30-year flight space shuttle program. “Mission complete, Houston,” said Commander Chris Ferguson just after wheels 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 spacefaring nation who truly empowered this incredible spacecraft…which has inspired millions around the globe.”

During the mission, Atlantis orbited the Earth 200 times, traveling 8,503,342.9 kilomtres. Over 33 missions, it spent 307 days in space, completing 4,848 orbits and this was the 37th visit of a space shuttle to the station. Shuttles on all 135 missions traveled more than 872 million kilometres in space.

Panama-based NZSA member Ed Case is our regular correspondent on Shuttle and ISS news.

Dawn reaches Vesta

- Edited by David Maclennan



This image, taken by the framing camera instrument aboard NASA's Dawn spacecraft, shows the south polar region of this object, which has a diameter of 530 km. This region is characterized by rough topography, a large mountain, impact craters, grooves and steep scarps. (NASA/JPL-Caltech/UCLA/MPS/DLR/IDA)

On Friday 15 July 2001, NASA's Dawn spacecraft reached asteroid Vesta and became the first probe to enter orbit around an object in the main asteroid belt between Mars and Jupiter. It's first image after entering orbit, taken for navigation purposes, showed Vesta in greater detail than ever before. When Vesta captured Dawn into its orbit, there were approximately 16,000 kilometres between the spacecraft and asteroid.

Vesta is 530 kilometres in diameter and the second most massive object in the asteroid belt. Ground- and space-based telescopes have obtained images of Vesta for about two centuries, but they have not been able to see much detail on its surface.

"We are beginning the study of arguably the oldest extant primordial surface in the solar system," said Dawn principal investigator Christopher Russell from the University of California, Los Angeles. "This region of space has been ignored for far too long. So far, the images received to date reveal a complex surface that seems to have preserved some of the earliest events in Vesta's history, as well as logging the onslaught that Vesta has suffered in the intervening eons."

Vesta is thought to be the source of a large number of meteorites that fall to Earth. Vesta and its new NASA neighbor, Dawn, are currently approximately 188 million kilometres away from Earth. The Dawn team will begin gathering science data in August. Observations will provide unprecedented data to help scientists understand the earliest chapter of our solar system. The data also will help pave the way for future human space missions.

After traveling nearly four years and 2.8 billion kilometres, Dawn also accomplished the largest propulsive acceleration of any spacecraft, with a change in velocity of more than 6.7 kilometres per second, due to its ion engines. The engines expel ions to create thrust and provide higher spacecraft speeds than any other technology currently available. "Dawn slipped gently into orbit with the same grace it has displayed during its years of ion thrusting through interplanetary space," said Marc Rayman, Dawn chief engineer and mission manager at NASA's Jet Propulsion Laboratory in Pasadena, Calif. "It is fantastically exciting that we will begin providing humankind its first detailed views of one of the last unexplored worlds in the inner solar system."

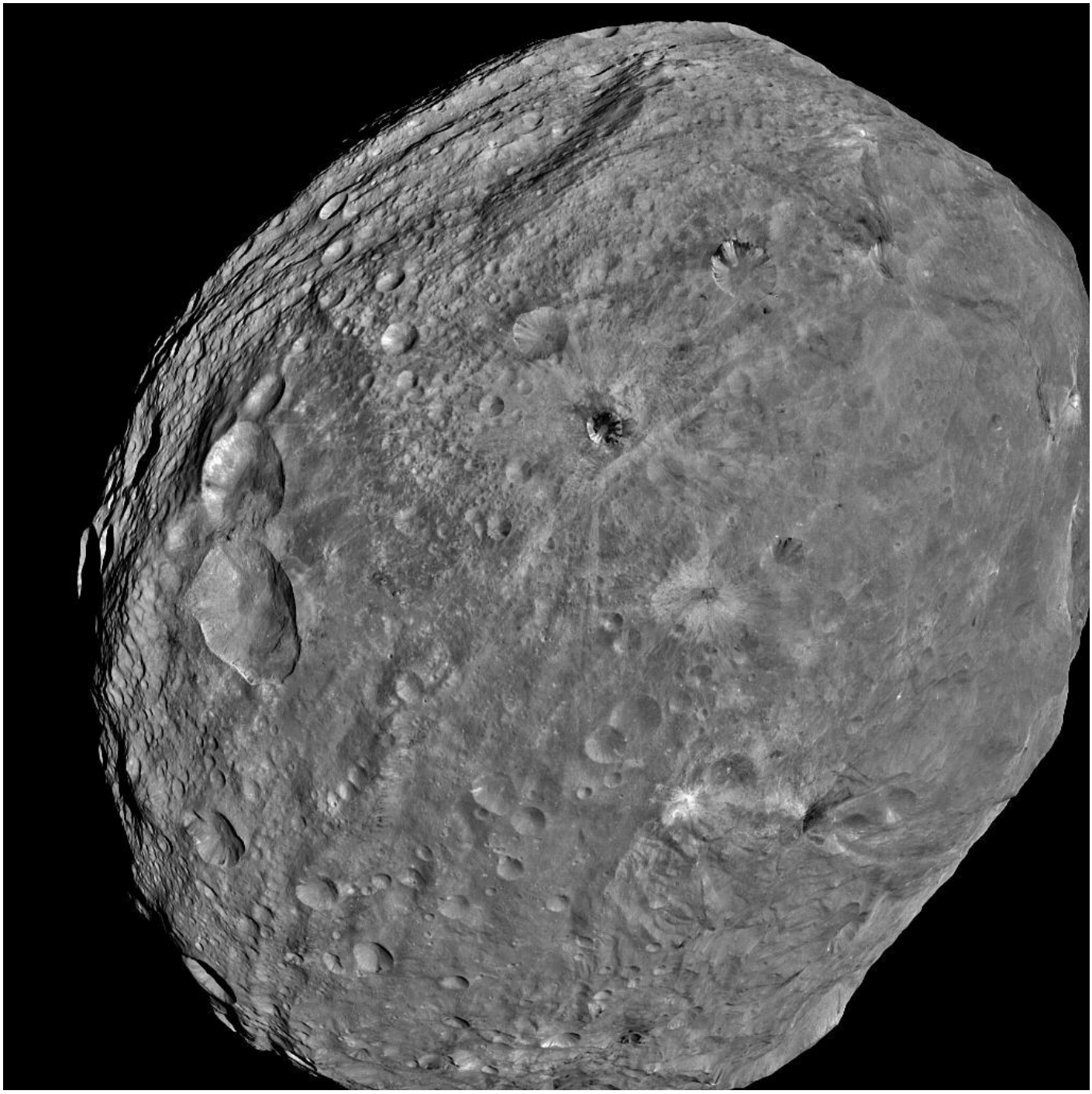
Although orbit capture is complete, the approach phase was to continue for about three weeks. During approach, the Dawn team will continue a search for possible moons around the asteroid; obtain more images for navigation; observe Vesta's physical properties; and obtain calibration data. In addition, navigators will measure the strength of Vesta's gravitational tug on the spacecraft to compute the asteroid's mass with much greater accuracy than has been previously available. That will allow them to refine the time of orbit insertion.

The Dawn mission

Since launching from Cape Canaveral Air Force Station, Fla., on 27 September 2007, the Dawn spacecraft has used hyper-efficient ion propulsion to glide toward its first destination, the protoplanet Vesta. After a planned year in orbit there, Dawn will depart for a nearly three-year cruise to the dwarf planet Ceres, where it will arrive in 2015. Dawn will spend five months in orbit at Ceres. The spacecraft will be the first ever to orbit one extraterrestrial body, depart, and then orbit a second body. Dawn's odyssey will cover 4.8 billion kilometres in all.

Dawn has already completed four phases of its mission: launch and initial acquisition, initial checkout, interplanetary cruise and Mars gravity assist. It is currently in Vesta orbit, with Ceres approach and Ceres orbit to come.

Studying Vesta and Ceres – the two most massive objects in the asteroid belt – allows scientists to do historical research in space, opening a window into the earliest chapter in the history of our solar system. At each target, Dawn will acquire colour photographs, compile a topographic map, map the elemental composition, map the mineralogical composition, measure the



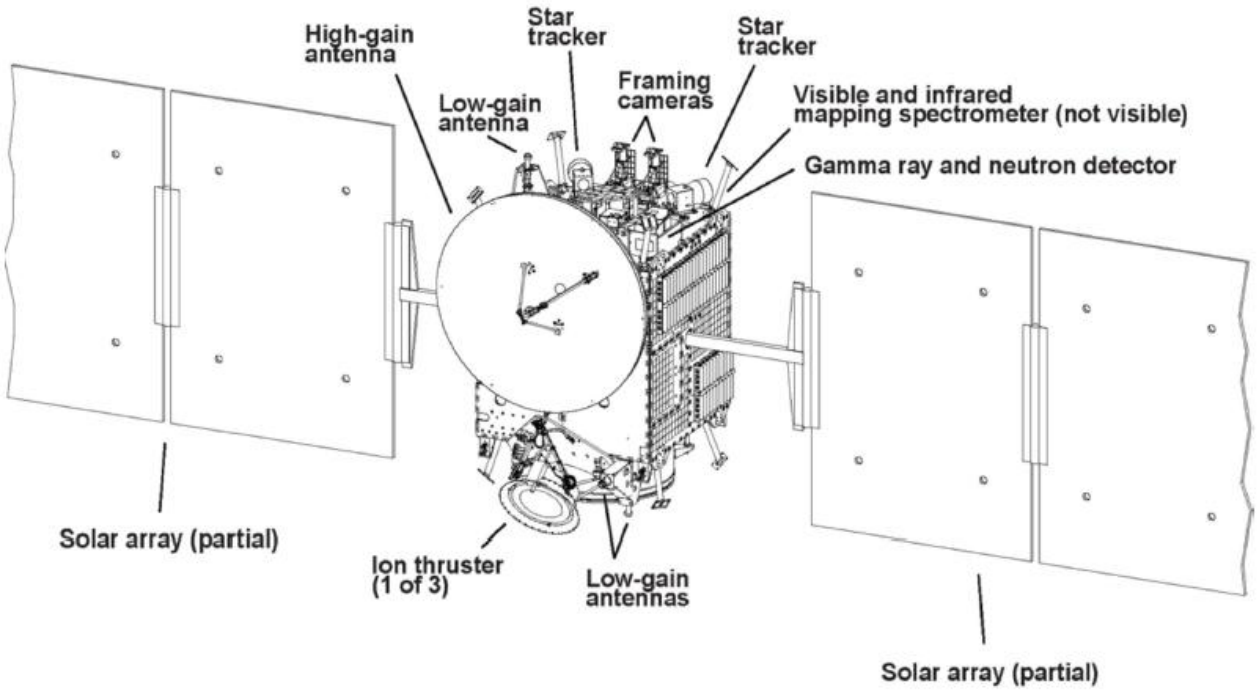
NASA's Dawn spacecraft obtained this image of the giant asteroid Vesta with its framing camera on 24 July 2011. It was taken from a distance of about 5,200 km. (NASA/JPL-Caltech/UCLA/MPS/DLR/IDA)

gravity field and search for moons. The data gathered by Dawn will enable scientists to understand the conditions under which these objects formed, determine the nature of the building blocks from which the terrestrial planets formed and contrast the formation and evolution of Vesta and Ceres. Dawn's quest to understand the conditions that existed when our solar system formed provides context for the understanding of the observation of planetary systems around other stars.

To carry out its scientific mission, the Dawn spacecraft will conduct four science experiments whose data will be used in combination to characterize these bodies. Dawn carries a pair of visible-light cameras known as the framing cameras, a visible and infrared mapping spectrometer, and a gamma ray and neutron spectrometer. Radio and optical navigation data will provide data relating to the gravity field and thus bulk properties and internal structure of the two bodies.

Vesta orbit

This phase extends from the beginning of the first science-collecting orbit at Vesta – known as survey orbit – to the end of the last. It is expected to start in early August. The spacecraft will follow a series of near-circular polar orbits, allowing it to study nearly the entire surface of the asteroid. Because Vesta is an unknown environment, mission managers have scheduled more than enough observations during each orbit to fulfill the basic science objectives. This will enable Dawn to achieve its



scientific goals even if delays occur or some data are not acquired.

Survey Orbit

At Vesta, the initial and highest orbit will be roughly 2,750 kilometres in altitude, providing a nice vantage point to obtain a global view of the rocky world. The orbit will take Dawn over the equator, the south pole and back to Vesta's night side, in orbits that take almost three Earth-days to complete. The primary objective of the survey orbit is to get a broad overview of Vesta with colour pictures and spectra – data in different wavelengths of reflected light. In this case, Dawn is collecting data in ultraviolet, visible and infrared wavelengths. The camera will obtain views with a resolution of 250 metres per pixel, about 150 times sharper than the best images from the Hubble Space Telescope. The mapping spectrometer will reveal much of the surface at better than 700 metres per pixel. The survey phase is planned to last for seven orbits, or about 20 days.

High Altitude Mapping Orbit

After it has completed its survey of Vesta, Dawn will resume thrusting, taking about a month to spiral down gently to its next science orbit for an even closer view. The orbit known as High Altitude Mapping Orbit (HAMO) begins in late September, at an altitude of around 680 kilometres. (A second High Altitude Mapping Orbit – known as HAMO2 – will occur near the end of Dawn's time at Vesta.)

HAMO, which will be the most complex and intensive science campaign at Vesta, has three primary goals: to map Vesta's illuminated surface in colour, provide stereo data, and acquire visible and infrared mapping spectrometer data. For about 10 days, Dawn will peer straight down at the exotic landscape below it. For about 20 days, the spacecraft will view the surface at multiple angles. Scientists will combine the pictures to create topographic maps, revealing the heights of mountains, the depths of craters and the slopes of plains. This will help scientists understand the geological processes that shaped this protoplanet.

Low Altitude Mapping Orbit

Dawn will take six weeks to spiral down to its lowest orbit, known as Low Altitude Mapping Orbit (LAMO), which will bring Dawn to an altitude of less than 180 kilometres) above Vesta's surface. Dawn will spend at least 10 weeks in LAMO, the longest part of its Vesta orbit, revolving around the rocky body once every four hours. The framing camera and visible and infrared mapping spectrometer will image the surface at higher resolution than obtained at higher altitudes. But the primary goal of LAMO is to collect data for the gamma ray and neutron detector and the gravity experiment.

The gamma ray and neutron detector is designed to detect the by-products of cosmic rays hitting Vesta. Cosmic rays are energetic, subatomic particles – such as protons – that originate from outer space. LAMO will be the most effective time for the gamma ray and neutron detector, when it will sense enough of the emitted particles to reveal the identities of many kinds of atoms in the surface. It also will record some radioactive decays of atoms there.

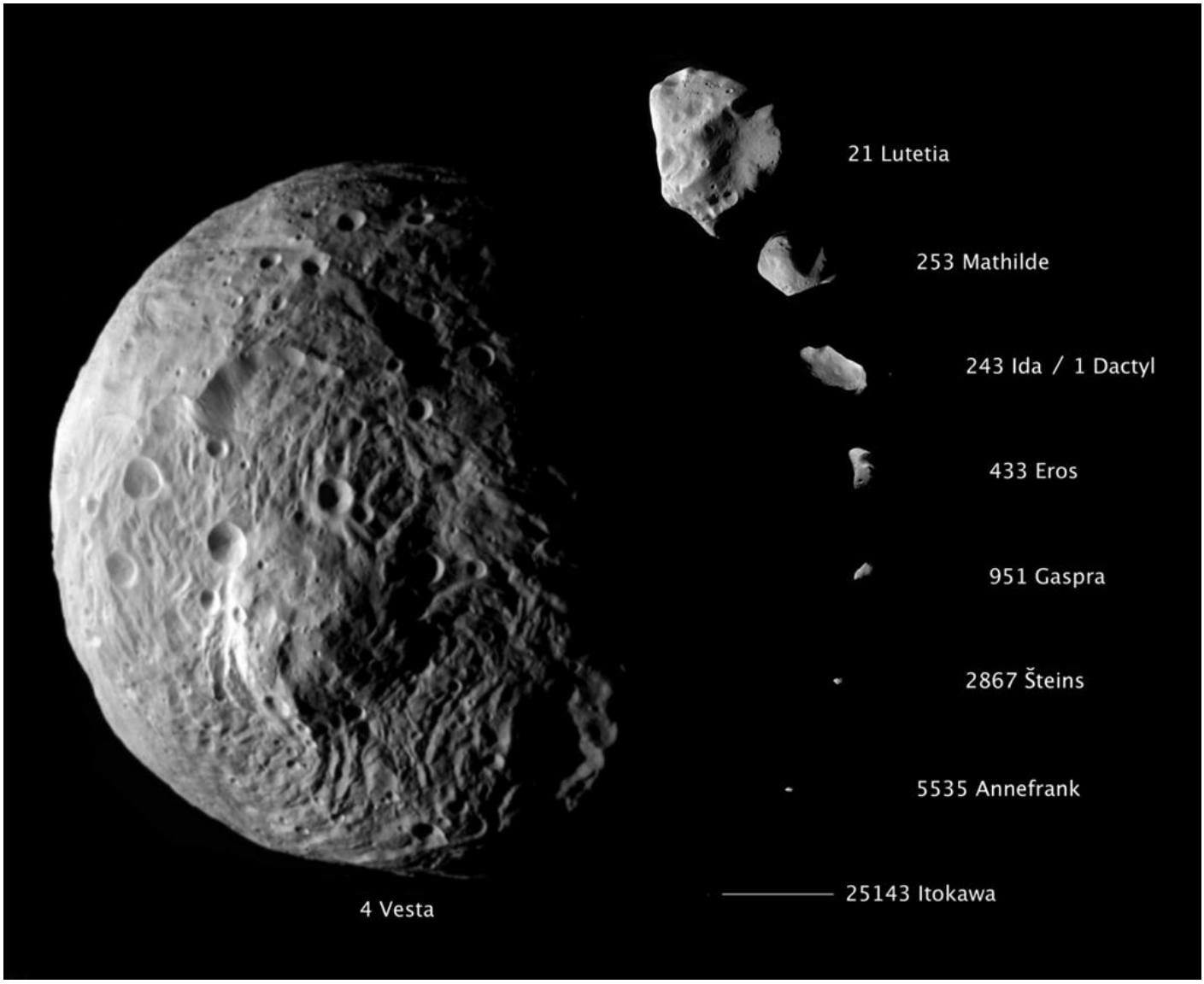
LAMO also focuses on ultrasensitive measurements of Vesta's gravitational field and internal structure. As Dawn travels in its orbits, its motion is dictated by the combined gravitational attraction of all of the matter within the protoplanet. By measuring the probe's orbit, scientists can calculate the arrangement of Vesta's constituent masses.

High Altitude Mapping Orbit 2

After LAMO, Dawn will spiral out during a six-week climb away from Vesta. It will pause its ascent for a second stop at the High Altitude Mapping Orbit (HAMO2) at the same height as HAMO – about 680 kilometres above Vesta's surface. HAMO2 is scheduled to last three weeks.

Vesta departure

Dawn is planning on beginning its departure from Vesta in June 2012, spending about five weeks getting out of Vesta's orbit.



This composite image shows the comparative sizes of nine asteroids. Up until now, Lutetia, with a diameter of 130 km, was the largest asteroid visited by a spacecraft, which occurred during a flyby. Vesta, which is also considered a protoplanet because it's a large body that almost became a planet, dwarfs all other small bodies in this image, with its diameter sizing up at approximately 530 km. (NASA/JPL-Caltech/JAXA/ESA)

Dawn firsts

Dawn's mission to Vesta is unique for the following reasons:

- Dawn is the first mission to Vesta and the first mission to Ceres.
- Dawn is the first spacecraft to orbit two bodies in the solar system.
- Dawn is the first mission to visit a protoplanet.
- Dawn's stay at Vesta is the first prolonged visit to a main belt asteroid.
- When Dawn arrives at Ceres in February 2015, it will be the first spacecraft to visit a dwarf planet. (New Horizons arrives at Pluto on July 2015.)
- Dawn has accomplished the largest propulsive acceleration of any spacecraft, thanks to its ion engines. It increased its velocity by 6.4 kilometres per second by 3 May 2011, the start of its approach to Vesta.
- When its solar panels are extended, Dawn has the longest wingspan of any NASA interplanetary mission launched so far. (When Juno launches later this year and deploys its solar panels, Juno's wingspan will be wider by about 0.3 meter.) Dawn's wingspan is 19.7 metres.

Apollo 15: To the mountains of the Moon

By David Maclennan

A spectacular northward-looking panorama from Station 2 during EVA-1 shows Irwin at the rover overlooking Hadley Rille, with a large boulder at left (NASA/D Harland)

Apollo 15 was significant for us here in New Zealand because it provided the first-ever "live via satellite" telecast in this country (the NZ Post Office's Warkworth satellite receiving station having only recently opened): the first hour of the first Moonwalk by Apollo 15 astronauts David Scott and Jim Irwin, followed a week later by an hour-long telecast of the splashdown and recovery at the end of the mission (all in black & white – no colour TV here until 1973!) The fact that we only got the first hour of the Moonwalks was a bit frustrating as it meant that once again I had to rely on the spotty Voice of America radio coverage.

Apollo 15 was a big mission for me, too, as I had prepared a large display on it for the Taita College library, where I was a 6th former that year. I had recently scored a copy of a neat little booklet from NASA, On the Moon with Apollo 15, which was a guide to what they were going to do on the lunar surface. It was my Bible for the mission, and many of the illustrations were photocopied and used in the display. I was more clued-up for this mission than any of the previous landings. – David Maclennan

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With the flight of Apollo 15, manned lunar exploration took a quantum leap. The earlier Apollo landings (Apollos 11, 12 and 14) were limited in their scientific scope, and the astronauts could only venture a kilometre or two from the lander. Apollo 15, however, was the first of the more advanced J-series Apollos. Improvements to the spacecraft and equipment allowed for longer, more extensive explorations. In particular, the addition of the Lunar Roving Vehicle (LRV), a lightweight four-wheel drive Moon buggy, meant that the landing crews could cover much more ground than on earlier landings. They also had much more extensive geological training, almost the equivalent of an undergraduate degree's worth.

Orbital operations were also enhanced by the addition of a suite of high-resolution cameras and other scientific experiments housed in a compartment in the Service Module, including a small subsatellite that was launched into lunar orbit to make particles and fields measurements.

Apollo 15 was commanded by David Scott, who had flown earlier on Gemini 8 and Apollo 9. Joining him on the surface was Jim Irwin, while Al Worden piloted the Command/Service Module. Worden and Irwin were making their first (and as it turned out, only) space flight on Apollo 15.

Launch occurred on 26 July 1971, and three days later Apollo 15 braked into lunar orbit. Apollo 15 was targeted to what was probably the most spectacular landing site of the whole Apollo programme. Apollo 15's lunar module *Falcon* would set down on a flat plain, bounded on two sides by the Apennine mountains, towering some 4,572 metres in height, and on a third by Hadley Rille, a meandering 1.6-kilometre wide canyon whose depth varied from 182 to 365 metres.

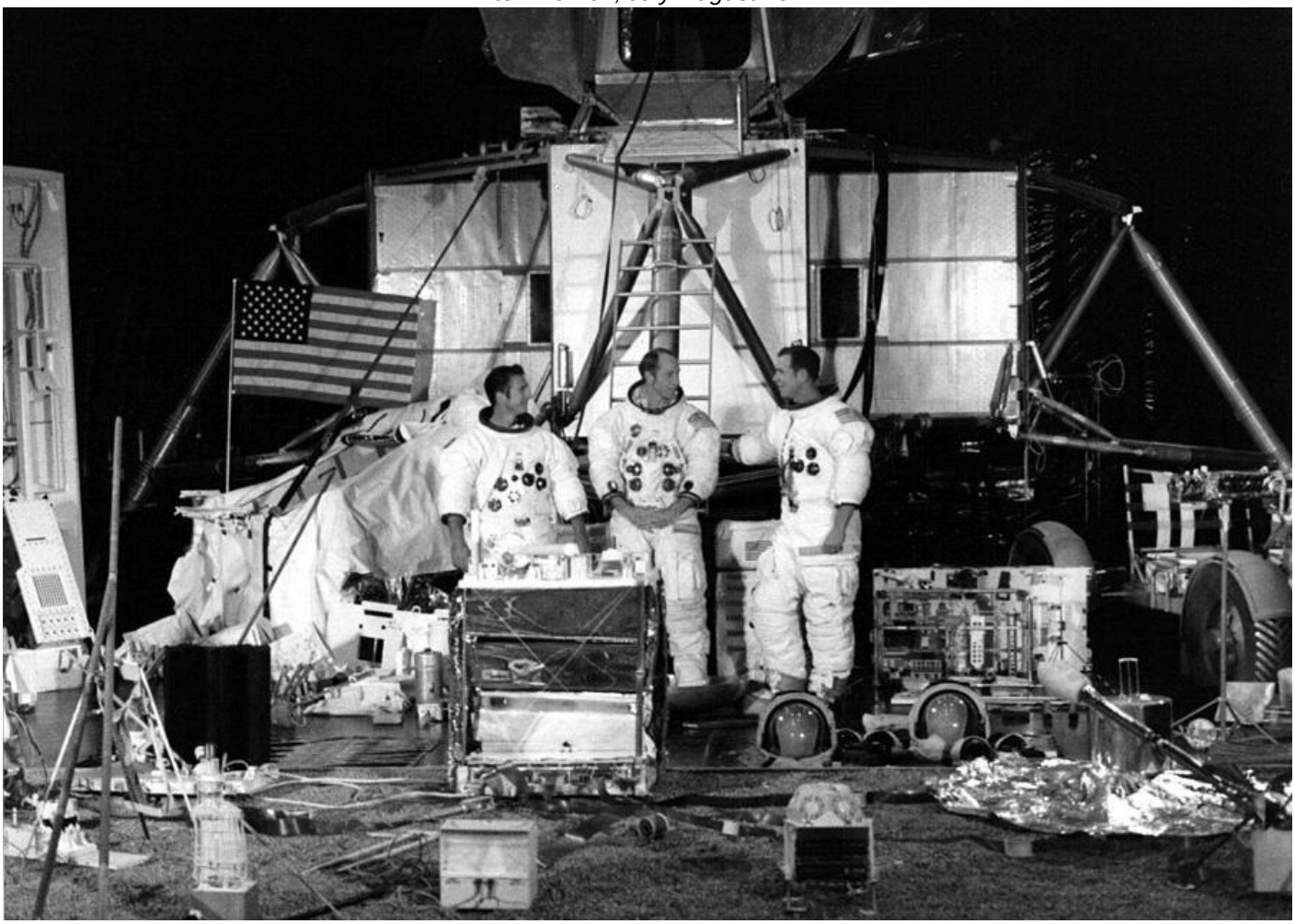
Previous Apollo landings had come in on a relatively shallow 15-degree trajectory, but in order for Apollo 15 to reach its Hadley-Apennine site it had to skim the top of the Apennine front and then descend on a 26-degree slope.

With Scott at the controls and Irwin reading off the numbers, *Falcon* headed down. Scott was impressed by the sight of Mount Hadley Delta, off to his left, towering half a kilometer *above* him, and Irwin later characterized the landing approach as akin to flying a high-performance jet through a mountain pass. Noting that he was a little south of the planned track, Scott tweaked the trajectory to bring *Falcon* down within a few hundred metres of the target area.

"*Falcon* is on the plain at Hadley!" Scott announced after touchdown. About two hours after landing the crew depressurized the LM and opened the top hatch. Scott then climbed onto the ascent engine cover and, with his head and shoulders outside, carried out a site survey. Officially called the stand-up extravehicular activity (SEVA), it was the only time this was done on an Apollo landing. Scott put his geological training to work, describing the surrounding area and taking photographs. This lasted for 33 minutes, after which Scott and Irwin repressurised *Falcon* and settled down for a sleep period. It had been a long day.

Driving on the Moon

Scott and Irwin slept soundly for five hours then began preparations for the first EVA. Whereas on earlier missions setting up the Apollo Lunar Surface Experiments Package



Packing for the Moon: The Apollo 15 crew (L-R, Jim Irwin, Al Worden and David Scott) pose with the equipment and experiments they took to the Moon (NASA)

(ALSEP) was the first priority for EVA-1, on Apollo 15 Scott and Irwin were to begin with a four-hour geology traverse out to where Hadley Rille met the foot on Mt. Hadley Delta.
The first job was to deploy the rover, which was neatly folded up inside one of the descent stage quadrants.

As Scott stepped onto the surface for the first time, he exclaimed; “As I stand out here in the wonders of the unknown at Hadley, I sort of realize there’s a fundamental truth to our nature: Man must explore, and this is exploration at its greatest.” Not quiteas memorable a quote as Neil Armstrong’s two years earlier, but the point was well made!

The LRV was deployed with the aid of lanyards and spring-loaded actuators, and after a few hitches Scott and Irwin had it on the surface, ready for a test drive. Scott quickly discovered that the front steering wasn’t working, but pressed on anyway: the rover could be steered adequately using the rear steering alone.

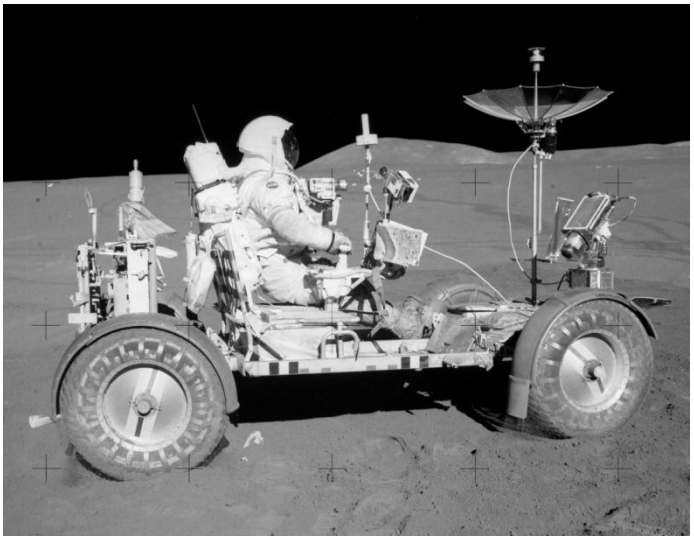
Here in New Zealand we got to see all this activity on live TV – the first ever via-satellite telecast. Personally, I felt this was the least interesting hour they could have picked – much better, I thought, to have done it later in the EVA when there was actually some spectacular scenery to see. - DM

Setting out on their first drive, Scott and Irwin headed for a crater dubbed Elbow, on the edge of Hadley Rille below a much larger crater called St. George on the lower slope of Mt. Hadley Delta. En route, Scott commented on the handling characteristics of the rover, which, he reported, handled quite well.

The rover was something of an engineering marvel. Developed to a very short timeframe, the vehicle weighed only 209 kg unloaded (700 kg after all the astronauts’ equipment had been loaded). It had wire mesh wheels, and measured three metres long by 1.5 metres wide. All four wheels had independent electric motors, and steering could be accomplished with the front or back wheels, or both together (steering was done using a T-shaped hand controller rather than a steering wheel). At low speed the rover could turn in its own length. Top speed was 12 km/hr. A colour TV camera was mounted at the front, operated remotely from Mission Control in Houston.

After a sampling stop at Elbow, Scott and Irwin drove further upslope towards St. George Crater, in search of samples of different material than that found on the plains. In particular, they were looking for a type of coarse-grained crystalline rock known as anorthosite, which had cooled slowly at depth not long after the Moon had formed. They spied a metre-sized boulder that looked like what they were looking for, but it turned out to be breccias. Perhaps samples of anorthosite would be more elusive than they thought.

Scott and Irwin were back at Falcon about four hours and 20 minutes into the EVA, and set about deploying the ALSEP. One experiment, the Heat Flow Experiment, required Scott to use a special drill to drill three 2.5 metre-deep holes. Two of these holes were to have thermocouples lowered into them to



David Scott aboard the Lunar Roving Vehicle (NASA)

measure heat flow from the lunar interior, while the third was to be a core sample. However, the drill proved troublesome and Scott was not able to drill the holes to the full length. Finally, after a record 6.5 hour EVA, Scott and Irwin called it a day.

A long drive south

The next day Scott and Irwin were to return to Mt. Hadley Delta, this time by a different route that took them first to a cluster of craters called South Complex. When they started up the rover, the astronauts were pleasantly surprised to find that the front steering was now working! “I bet you let some of those Marshall [Space Flight Center] guys come up and fix it,’ joked Scott.

As they headed south, Scott concentrated on the driving while Irwin described the view. Two kilometers into the drive, Irwin reported he could see South Cluster ahead. The crew eventually made a sampling stop half-way between two craters, Spur and Window, which they designated Station 6. At this point they were 100 metres above the plain on a steep slope, and the view was spectacular. Once again, the search for anorthosite proved fruitless.

Scott and Irwin then moved on to Station 6A a short distance away, near the rim of Spur. As they proceeded around the rim, Scott noticed a rock with a white corner to it. When they sampled it, it proved to be crystalline rock – the very thing they had been looking for.

"I think we found what we came for," Irwin told Houston. "I think we might have [found] ourselves something close to anorthosite," Scott said with some satisfaction, "because its crystalline, and... it's just almost all plag(ioclase). What a beaut."

This sample, which weighed 0.27 kg, indeed proved to be 98% plagioclase, so was truly anorthositic. Dubbed the “Genesis rock” by the media, the sample was extremely old and almost certainly part of the original lunar crust.

On the way back to the LM the crew made a sampling stop a Dune crater, but could only stay a short time. Back at the LM, Scott once again tried to use the drill for a deep core, but it again proved troublesome (the problem turned out to be a design flaw that prevented the drill stem flutes from carrying the cuttings to the surface, resulting in them getting clogged).

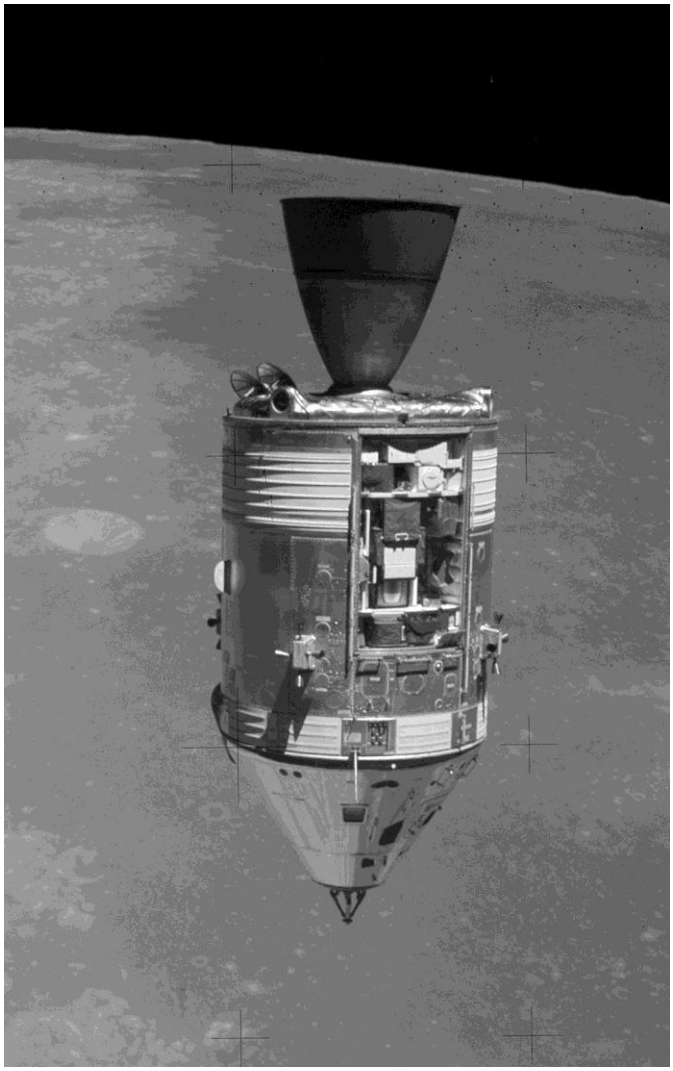
One final task before closing out the EVA was to deploy the US flag. After the obligatory flag-salute photos, the crew called it a day: the second EVA had set a new record of seven hours 12 minutes.

Shortened final EVA

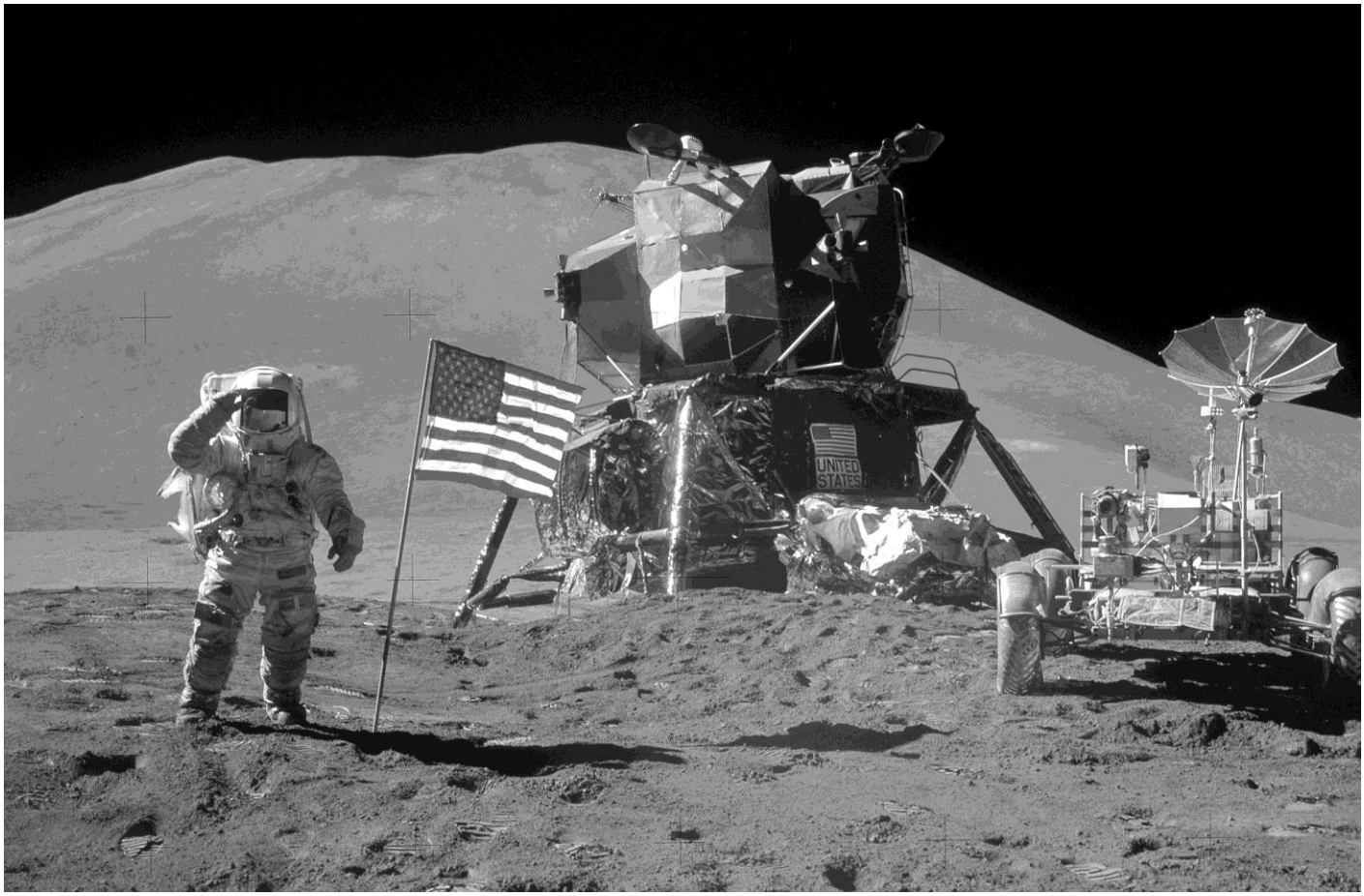
The third and final EVA began an hour and 45 minutes later than planned, and the planned trip to a crater field called North Complex was cancelled. Instead Scott and Irwin drove west to the rim of Hadley Rille, making several sample stops in its vicinity and taking high-resolution photos of the far wall of the rille. The crew then returned to the LM via the ALSEP site to retrieve the ramining sections of the deep core sample.

Before closing out the EVA, Scott performed a little experiment for the TV audience on Earth. In his left hand he held a feather (appropriately, a falcon feather), and in his right had a geological hammer. “One of the reasons we got here today was because of a gentleman named Galileo, a long time ago, who made a rather significant discovery about falling objects in gravity fields,” Scott explained. “And we thought, where would be a better place to confirm his findings than on the Moon?” He let go of both simultaneously, and sure enough, the feather and the hammer both hit the surface at the same time. “How about that!” exclaimed capcom Joe Allen. “Mr Galileo was correct” said Scott.

The third EVA had lasted four hours and 49 minutes, making a total of 18 hours 34 minutes of EVA time.



The Apollo 15 Command/Service Module Endeavour showing the Scientific Instrument Bay (NASA)



An iconic image: Irwin salutes the US flag, backdropped by the LM Falcon, the rover, and Mount Hadley Delta (NASA)

Farewell to Hadley

After 67 hours on the Moon, Scott and Irwin lifted off on 2 August 1971 to rejoin Worden in the command ship *Endeavour*. Thanks to the TV camera on the rover, Earthbound viewers could see the ascent stage blast off.

While his colleagues were exploring the surface, Worden had been extremely busy with a science programme of his own, using the cameras and other instruments contained in the Scientific Instrument Module (SIM). An X-ray spectrometer found high concentrations of aluminium and sparse amounts of magnesium in the lunar highlands, and a magnetometer detected a very weak lunar magnetic field. A gamma ray spectrometer detected radioactive hotspots on the Moon indicating deposits of radioactive elements such as potassium, thorium and uranium. Worden also observed cinder cones on the southeastern border of Mare Serenitatis, evidence of volcanism.

Before leaving lunar orbit the crew ejected a small subsatellite from the SIM bay. Weighing just 35.5 kg, the subsatellite was designed to make particles and fields measurements from lunar orbit.

Endeavour departed lunar orbit on 4 August 1971. The following day Al Worden had his starring moment when he performed the first-ever deep-space EVA to retrieve exposed film from the SIM bay cameras. Worden made three trips to and from the bay with the film canisters in a spacewalk lasting 20 minutes. At approximately 316,973 kilometres from Earth, Worden still holds the record for the furthest spacewalk ever made.

Heart-stopping splashdown

Just over 12 days after they left Earth, the Apollo 15 crew splashed down north of Hawaii on 7 August 1971. As the craft descended, watchers were alarmed to note that one of its three parachutes had not opened fully. While this resulted in a slightly harder-than-usual splashdown, the crew were in no danger as the craft could safely splash down on two chutes.

Once again, NZ viewers were treated to an hour-long live coverage of the event. It was a Sunday morning here, and reportedly, church attendances were down that day! – DM

This image of the International Space Station and the docked space shuttle Endeavour, flying at an altitude of approximately 354 km, was taken by Expedition 27 crew member Paolo Nespoli from the Soyuz TMA-20 following its undocking on 23 May 2011. The pictures taken by Nespoli are the first taken of a shuttle docked to the International Space Station from the perspective of a Russian Soyuz spacecraft. Onboard the Soyuz were Russian cosmonaut and Expedition 27 commander Dmitry Kondratyev; Nespoli, a European Space Agency astronaut; and NASA astronaut Cady Coleman. Coleman and Nespoli were both flight engineers. The three landed in Kazakhstan later that day, completing 159 days in space. (NASA)