SpaceFlight

A British Interplanetary Society publication

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SLS heading for trouble?

An InSight on Mars

Bremen puts on a show

DAWN calls it a day

Visions of a space station

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COVER: THE SPACE LAUNCH SYSTEM LIFTS OFF FROM LAUNCH COMPLEX 39B / NASA

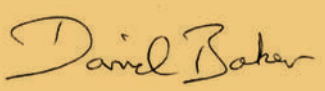
Letter from the Editor

With Mars-watchers around the world gathered to view the arrival of the latest lander on the Red Planet, expectations were high and vindicated – another successful landing and the sixth in a row for NASA. There appears no let-up in the immediate future for Mars explorers. But will it last? Beyond 2020 and the launch of the next probes from NASA and the European Space Agency, uncertainty lurks!

In this issue we reflect upon discoveries in a different part of the Solar System as Chris Starr – no stranger to SpaceFlight readers – tells us about the remarkable but largely unsung triumphs of the little Dawn spacecraft and its electric propulsion system that provided a total expulsion of energy almost equal to that of its Delta launch vehicle!

Future programmes loom large in this issue as well, when we take a look at what was on offer at the IAC conference in Bremen, while former BIS President Bob Parkinson looks back to the BIS's own pioneering work on space station designs 70 years ago!

And for those of you reading this before the big event – a Happy Christmas!



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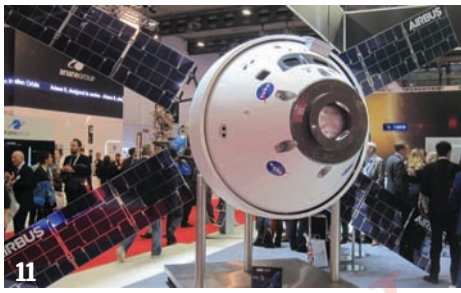
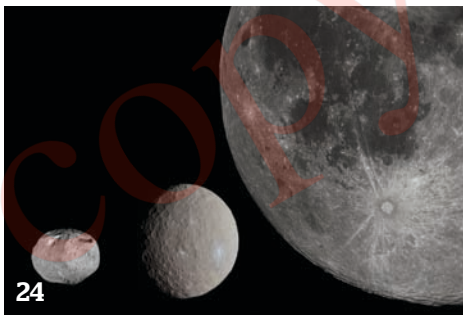
Features





Regulars

OUR MISSION STATEMENT

The British Interplanetary Society promotes the exploration and use of space for the benefit of humanity, connecting people to create, educate and inspire, and advance knowledge in all aspects of astronautics.

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6 IN A ROW!

Mars InSight team members Kris Bruvold, left, and Sandy Krasner react after receiving confirmation inside the Mission Support Area at NASA's Jet Propulsion Laboratory in Pasadena, California that InSight had successfully touched down on the surface of Mars.

Completing a complex landing sequence that saw it pass through six different configurations in almost as many minutes, InSight has hit pay dirt.

AT PRECISELY 19:52:59 UTC on Monday 26 November, mission controllers received the first signal from InSight indicating that NASA had achieved its sixth soft landing in a row on the surface of Mars. This brings to eight the number of spacecraft the agency has put down on the Red Planet in working condition out of nine attempts.

At 19:47 UTC, onboard software commands fired six separation nuts and jettisoned the cruise stage of the spacecraft while it was 125 km above the surface. That started a series of events that took the spacecraft through six different configurations and from a speed of 19,800 km/hr to a gentle touchdown on the surface. It was a sequence of atmospheric deceleration/parachute deployment/propulsive descent that closely followed the entry, descent and landing profile pioneered by previous landers.

After landing, the spacecraft waited roughly seven minutes to use its X-band small deep space transponder to send a tone confirming its health. Then, 25 minutes after that, the lander deployed its two solar arrays, with a width of 6 m, to begin recharging the spacecraft's batteries. InSight began to collect science data within the first week after landing, though the teams focused mainly on preparing to set InSight's instruments on the Martian ground. Some days after touchdown, the engineering team were expected to begin to deploy InSight's 1.8-metre-long robotic arm so that it can take images of the landscape.

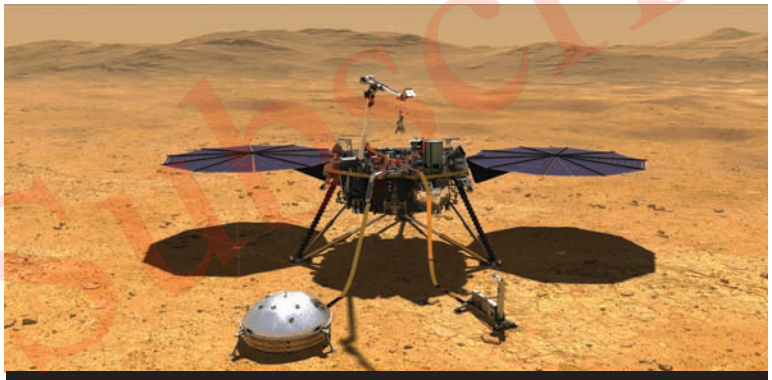
Mars Reconnaissance Orbiter (MRO) and 2001 Mars Odyssey, were also involved in this historic mission. MRO received and recorded InSight data during its journey to the surface, and sent it back to Earth later the following day. Both MRO and Odyssey will provide UHF relay during the entirety of the InSight surface mission – Odyssey in the morning and MRO in the afternoon.

STAGGERED START

This was not the most trouble-free of programmes. The launch originally scheduled for March 2016 was delayed to the next launch window when problems were detected with the seismometer in late 2015. Not known for its trip-off-the-tongue name (Interior Exploration using Seismic Investigations Geodesy and Heat Transport), InSight originated in 2010 when it was known as the Geophysical Monitoring Station (GEMS). Approved in August 2012, it was contracted to Lockheed Martin for a design based on the

IMAGES: NASA-JPL

The first image taken by the Instrument Deployment Camera on NASA's InSight lander on the surface of Mars.



InSight with its seismometer deployed inside a protective bowl-shaped cover (left) with the heat flow drill about to bore into the subsurface.

Phoenix lander which touched down on 25 May 2008.

The prime function of InSight was to obtain a temporal seismic survey utilising a detector placed directly on the surface by a manipulator arm, the first time that had been possible. Two Viking spacecraft each carried a seismometer within the body of the spacecraft but were inconclusive in their results due to interference with the internal working of the lander and the effects of wind pressure on the body of the spacecraft.

Provided by the French national space agency CNES, the Seismic Experiment for Interior Structure (SEIS) was found to have a vacuum leak which caused the delay in launching the spacecraft and placing it in storage at Lockheed Martin at a cost of $150 million. Thermal and vacuum testing of the redesigned instrument was completed on 22 November 2017 in time for delivery to Vandenberg Air Force Base three months later, prior to launch by an Atlas V 401, the first planetary mission launched from this facility.

As well as the SEIS instrument, InSight also »

It was a sequence that followed the entry, descent and landing profile pioneered by previous landers

UK-led instruments for Exomars

WHEN ESA'S EXOMARS LANDER touches down on the clay-rich Oxia Planum region of Mars in March 2021, two key instruments will be on-board to ensure that the rover vehicle achieves its mission. Both of these, the PanCam optical system and the RAMAN Laser Spectrometer, are UK-led.

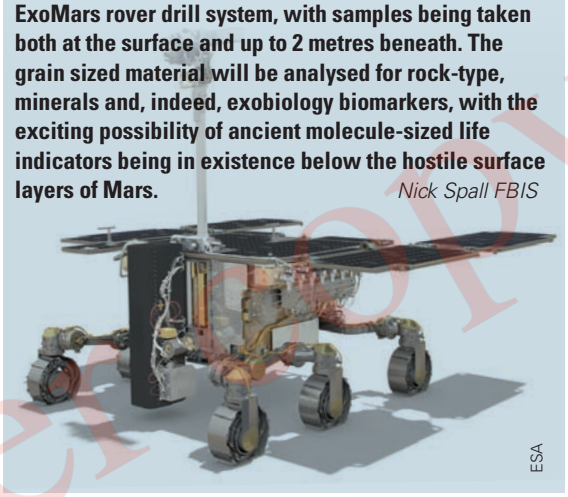
In November 2018, scientists and engineers involved in their construction and operation gathered at the Open University (OU) in Milton Keynes to review progress and plan for the future operations. For the 2 m high PanCam viewing platform on the rover, Prof. Andrew Coates described how the optical camera will allow for wide angle stereo imaging, with a high resolution capability for both traverse and navigation functions, plus detailed geology studies of the surrounding terrain.

The High Resolution Camera (HRC) portion of PanCam does have current folding mirror "astigmatism" issues that are being ironed out but there is high confidence that the instrument will be fully prepared and delivered for the rover and spacecraft assembly and final testing. Well in time for the July 2020 launch window deadline when the UK assembled Exomars rover will sit on its Roscosmos built landing platform atop a Proton launcher at Baikonur. The camera system will be trialled in the Atacama Desert in 2019, following earlier successful trials in Utah in 2016.

PanCam will be turned on for testing three times en-route to Mars. Once on the surface, 10-20 images a day will be provided for detailed analysis at the planned Rover Operations Control Centre (ROCC) at Turin in Italy. UK scientists will be closely involved at Turin, complete with its "Mars yard" rover study facility which is equipped with illuminated and tiltable areas for drill operations planning.

Now well on course in its construction, the RAMAN Laser Spectrometer (RLS) is the second key UK-led instrument, with the Spanish providing its Principal Investigator, Fernando Perez. Dr. Ian Hutchinson describes the RLS as being unique, as it will be the first of its type sent into space.

The size of a shoe-box and weighing only 2 kg, the RLS will analyse crushed material fed into it by the ExoMars rover drill system, with samples being taken both at the surface and up to 2 metres beneath. The grain sized material will be analysed for rock-type, minerals and, indeed, exobiology biomarkers, with the exciting possibility of ancient molecule-sized life indicators being in existence below the hostile surface layers of Mars. *Nick Spall FBIS*



ESA

BOEING

Briefing

NO APPARITION

Boeing has displayed work in progress on its new Phantom reusable launch vehicle (above), under development for the Defense Advanced Research Project Agency. Non-destructive tests of the liquid oxygen composite tanks have gone well, proving that a structure 40% lighter than aluminium is just as resilient. Boeing's Phantom will lift an upper stage (to be defined within the next two months) and payload to Mach 5 and an altitude of up to 45.7 km, before returning to a conventional landing. The winged launcher will be powered by a single oxygen/hydrogen AR-22 engine, derived from the reusable RS-25 motors from the Shuttle programme.

GOODNIGHT KEPLER

On 15 November, NASA's Kepler space telescope received its final set of "goodnight" commands to cease communications with Earth – a process that had begun on 30 October after it ran out of fuel and could no longer function. Coincidentally, its retirement fell on the 388th anniversary of the death of its namesake, German astronomer Johannes Kepler, who discovered the laws of planetary motion.

LITTLE AND LARGE

Virgin Orbit is ready to begin flight trials with its LauncherOne payload delivery system, designed to serve the smallsat market and capable of lifting 500 kg to low Earth orbit. Captive-carry tests with a converted Boeing 747-400 are scheduled for preliminary evaluation prior to flutter and stall tests. Released at Mach 0.67 and a pitch-up attitude of 32°, the rocket weighs 25,855 kg.

VIRGIN ORBIT

« carries the Heat Flow and Physical Properties Package (HP3) which is provided by Germany's DLR and consists of a self-penetrating heat probe, nicknamed "the mole" because it is designed to burrow into the surface to a depth of approximately 5 m, leaving a string of heat sensors as it goes, utilising a Polish boring device at the tip. Mission manager JPL has provided the Rotation and Interior Structure Experiment (RISE) while Spain's Centro de Astrobiologia has produced the Temperature and Winds for InSight (TWINS) instrument designed to measure the weather.

In addition, Italy has put a laser reflector on the body of the spacecraft so that it can be the first « in a net of geodesic reference points for measuring fine scale motion in the rotation and wobble of Mars, with two cameras, one developed from the navcam systems on Spirit, Opportunity and Curiosity rovers and the Instrument Context Camera which is based on the previous hazcam colour cameras from those vehicles.

PURPOSEFUL

InSight fits well within the missions functions of a range of orbiters and landers deployed to Mars over more than two decades, beginning with Mars Pathfinder in 1997. Over that period NASA has placed three rovers on the surface, exploring localised surface areas, while three orbiters have taken a spatial survey and conducted detailed mapping and high-resolution photography to aid future missions. The most recent, MAVEN, is conducting a much needed survey of the atmosphere, notably its upper elements in a search for solutions to issues regarding loss of pressure over millennia and the presence of methane.

Now, InSight is taking the spatial survey down-under, beneath the surface to gain a greater understanding of the structural makeup of the planet by mapping seismic activity and possibly detecting Marsquakes, suspected to exist since tenuous but undercertain measurements from the two Viking landers on the mid-1970s. In total, the investigation of Mars is shaping up in an integrated, international endeavour, supported by ESA's Mars Express, orbiting the planet since December 2003, to be joined by ExoMars in 2020 and NASA's next rover based on the Curiosity rover operating on the surface since 2012. SF

Opinion

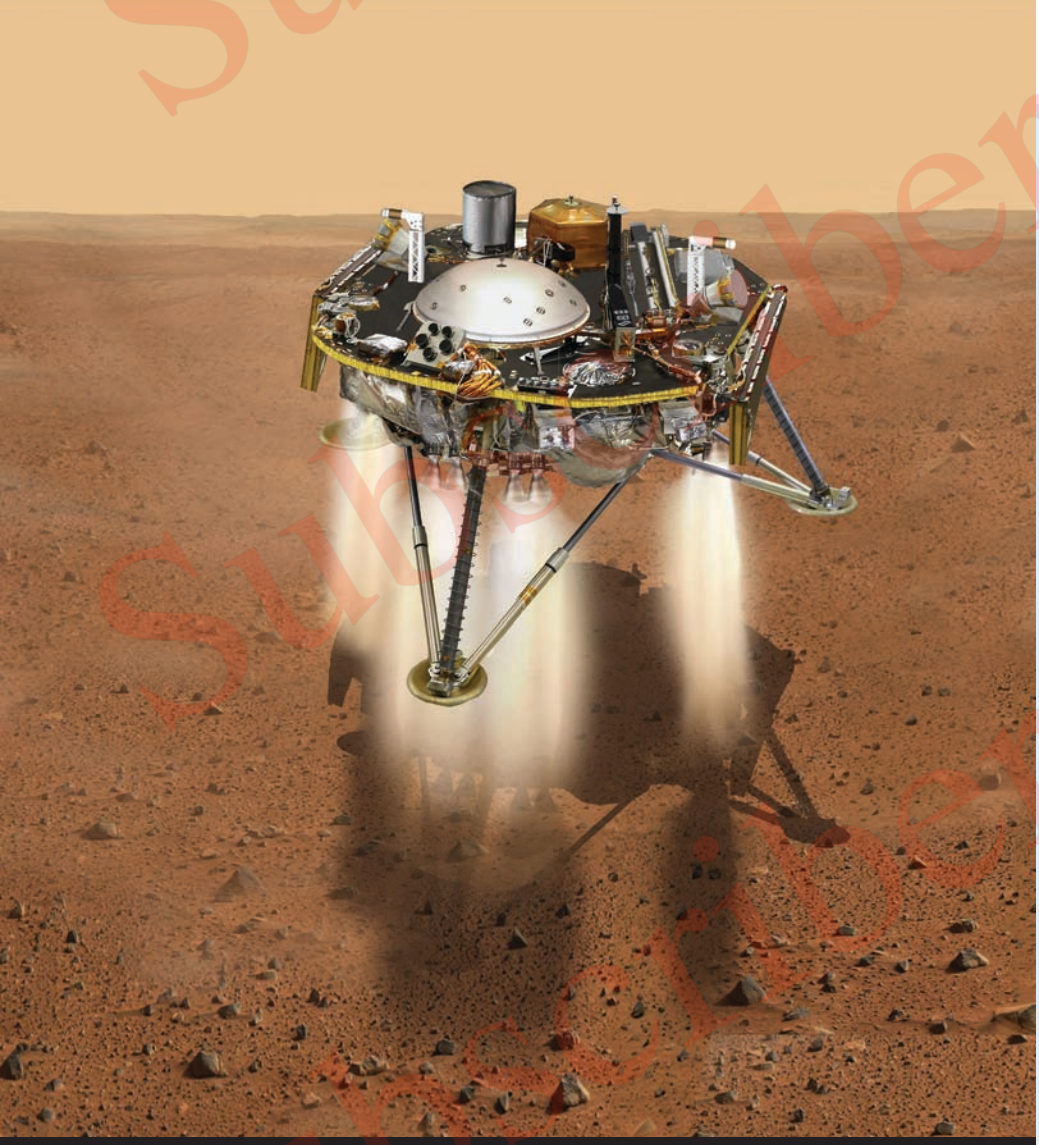
DEMISE OR HIATUS?

WHITHER THE GREAT GAME CHANGER – where are the Russians? As we revel in an embarrassment of planetary exploration, as India, China, Europe and the United States course through the Solar System exploring old worlds, discovering new ones within our Sun's grasp and plan landings on the Moon and Mars, where are the Russians?

It is a question asked by Dwayne Day in a contemporary online publication, The Space Review, both he and they always at the cutting edge of comment and scholarship in all things to do with space. It is a well thought through comment on a space power in decline, prompting a question really worth asking. So thanks to that source for pointing to an enduring reality: where are the Russians? SpaceFlight has its own view.

This Christmas we celebrate 50 years since the first human voices came back from the vicinity of another world, messages from astronauts Borman, Lovell and Anders reading the first verses from the book of Genesis – American voices where once Soviet leaders had jested that they would be there to welcome the first Americans as NASA followed the Soviet Union to the Moon.

It was not to be. The Russians were late: in starting their manned lunar landing programme, in organising a coherent strategy involving competent organisations, in challenging engineers to leap ahead of legacy technology and in liberating innovative thinkers to manage an already stagnating space programme. Their cosmonauts never did make it to the Moon. Only the orbiting space stations were left. And, when it came to resurrecting their country from the ashes of the Soviet



An artist visualises the descent under power of NASA's InSight spacecraft shortly before a successful touchdown.

NASA

Briefing

ESA PLANET HUNTER

ESA's Characterising Exoplanet Satellite, CHEOPS (below), will target 15 October to 14 November 2019 for launch on a Soyuz rocket from Europe's spaceport in Kourou, sharing the ride into space with a satellite that is part of the Italian Cosmo-SkyMed constellation. The two satellites will separate into their own orbits soon after ascent, with Cheops operating in a low-Earth orbit at an altitude of 700 km. The satellite will observe individual bright stars that are known to host exoplanets, in particular those in the Earth-to-Neptune size range. CHEOPS' ability to observe multiple transits of each planet will enable scientists to achieve the high-precision transit signatures that are needed to measure the sizes of small planets.

ESA

COLUMBUS UPGRADE

Named after Columbus' younger brother, the Bartolomeo external payload mount (below) is in the final stages of development in a joint ESA-Airbus deal prior to launch to the ISS in January 2020. Unlike Japan's experiment module, ESA's Columbus has no external structure for the attachment of experiments outside the pressurised environment. But with the clock ticking on the demise of the ISS as a government-funded platform, Bartolomeo's potential as a scientific tool is already being eroded.

ESA

But sadly, in the current political climate, there is little appetite for putting out the hand of cooperation where in fact there should be.

Union that was all they had to offer a world waiting to do business with the new Russia: a partnership, offered by their old ideological adversary.

The last only partially successful Russian planetary explorer, Mars 96 was launched 30 years ago. It failed in its primary objective and there has been nothing sent to Mars since that day in January 1989; even the much hailed Mars 96, launched in November 1996, failed to escape Earth's grip. Since that date there have been more planetary mission proposals than from any other space-faring nation but none have reached fruition and there is little credit to new proposals and boasts about impending flights to the Moon.

But is this a temporary lapse, albeit one measured in decades, or the permanent erosion of a once-proud and successful space-faring nation? It may be just too late for the Russian space programme to recover and we may be witnessing the permanent demise of a once-towering giant in the exploration and exploitation of space and its resources.

Should we care? Yes, of course. But sadly, in the current political climate, there is little appetite for putting out the hand of cooperation where in fact there should be. Apart from which, the reasons for its fall lie very deep inside the institutional geography of the Russian space industry which only Russians themselves can change. SF

David Baker

ISS Report

9 October – 8 November 2018

Following the Soyuz launch abort in mid-October, the station remains under three-person operation with Expedition 57 officially just over one month into its mission. The three crew have been in space for over five months.

Report by **George Spiteri**

On 9 October, the remaining crew – commander Alexander Gerst from Germany and flight engineers American Serena Auñón-Chancellor and Russian Sergey Prokopyev – continued transferring cargo from JAXA's Kounotori-7 (White Stork-7) vehicle to the ISS. Gerst also worked with the Combustion Integrated Rack (CIR) inside Destiny, which he tweeted "helps researchers investigate how fuels burn in space to improve rockets, satellites, and fuel efficiency on Earth".

The following day Gerst and Auñón-Chancellor worked with ESA's Mobile Procedure Review (MOBIPV) experiment, which demonstrates new technologies and operational concepts for both the ISS crew and ground teams. The crew also swapped use of NASA's Actiwatch Spectrum System, which analyses circadian rhythms and sleep-wake patterns.

BELOW ROSCOSMOS / RIGHT: NASA

RIGHT
The H-II Transfer Vehicle-7 (HTV-7) is viewed from one of seven windows inside the cupola about 413 km off the coast of Canada above the Gulf of St. Lawrence.

BELOW
Expedition 57 replacement crew cosmonaut Alexey Ovchinin of Roscosmos, left, and NASA astronaut Nick Hague, right, embrace their families after landing at the Krayniy Airport following their abortive Soyuz launch on 11 October, 2018.

ABORTED LAUNCH

As reported in SpaceFlight Vol 60, No 12, p2, Soyuz MS-10/56S was launched from Baikonur's Site 1 at 08:40 UTC (14:40 local time) atop a Soyuz-FG rocket on 11 October carrying veteran commander, retired Russian Air Force Lieutenant Colonel Alexei Ovchinin (47) on his second space flight and rookie flight engineer, US Air Force Colonel Nick Hague (43). Hague became the first of the astronaut class of 2013 to be assigned a space mission said in a pre-launch interview that "I just want to get up there and get to work". The third seat was taken up with a freight container carrying food stuffs.

After a routine lift-off, TV views of the launch showed the four liquid-fuelled strap-on boosters separating from the central core stage at approximately 2 min into the flight and what

appeared to be multiple objects falling away from the rocket. An interior camera showed the crew inside the Descent Module being shaken violently around. A Russian translator reported "failure of the booster", seconds later Soyuz separated from the rocket's upper stage and Ovchinin radioed "we are in weightlessness according to our sensations" as Soyuz began a ballistic descent back to Earth subjecting the crew to G loads of 6.7 according to Ovchinin.

Moments later he reported "we're feeling rotation; the G load is going down". The ground recommended the crew "tighten the straps" to their seats in anticipation of landing. Communications with Soyuz was sporadic but Soyuz landed 20 km east of Dzhezkazgan, Kazakhstan at 09:00 UTC (15:00 local time) on 11 October, 402.3 km from Baikonur.

Russian search and rescue vehicles had been dispatched at 08:55 UTC and arrived one and a half hours later to find Ovchinin and Hague in good condition. They were flown immediately back to Baikonur for a reunion with space officials, including NASA Administrator Jim Bridenstine and Roscosmos chief Dmitry Rogozin and family and friends, who had all watched the launch earlier.

> "I just want to get up there and get to work"
>
> Astronaut Nick Hague

On 12 October, Ovchinin returned to Star City, Moscow and Hague who flew back to Houston tweeted how outstanding the operational teams were "in ensuring our safety". He told Bridenstine during a NASA TV interview on 17 October that "all things considered being able to walk away from something like that with only a couple of bruises or bumps you know, physically I'm doing awesome".

Former cosmonaut, Executive Director of Roscosmos for manned programmes and head of the Gagarin Cosmonaut Training Centre Sergey Krikalev explained that "there was a deviation from nominal trajectory and damage to the lower part of the second stage". He added that "it is clear there »

« occurred a collision of the first and second stage in the process of separation of the first stage".

On 1 November, Head of the Commission, Oleg Skorobogatov announced at a press conference that Russian investigators had concluded the abort was caused by a contact sensor failure on one of the four Soyuz-FG boosters (block D). The sensor signals the separation of the first and second stages and was "deformed during the rocket's assembly at Baikonur", which was the root cause of the accident.

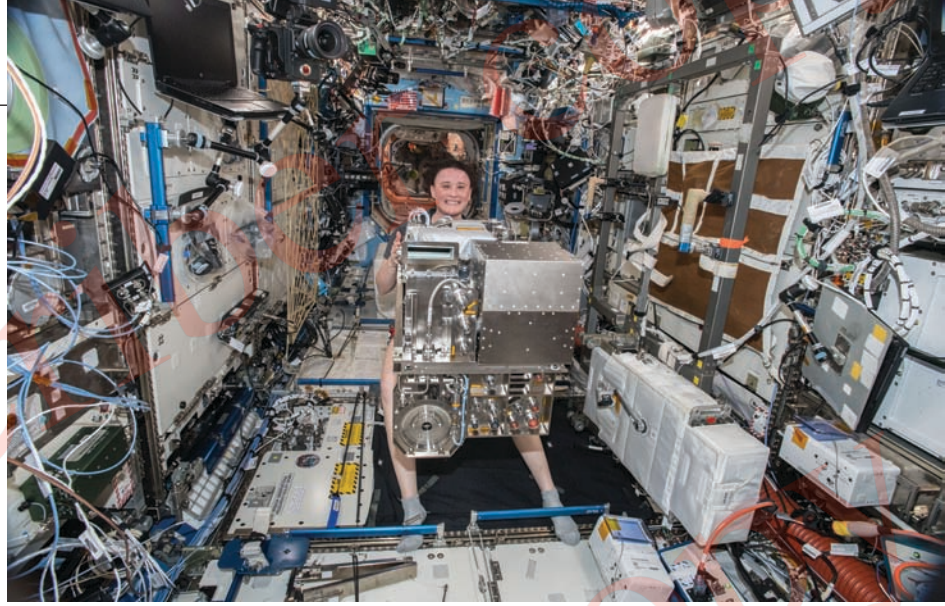
Space analyst Anatoly Zak tweeted that the sensor was accidentally "bended by around six degrees" at the assembly plant. Skorobogatov told TASS "the nozzle lid of the oxidiser tank in the block D did not open", this resulted in the booster sliding down the side of the core and rupturing the tank" causing the abort. This conclusion coincided with dramatic video released by Roscosmos from an external camera mounted on the rocket from lift-off to the moment of the apparent explosion.

During an earlier Moscow news conference, Krikalev announced that Roscosmos would attempt at least three unmanned launches before the end of the year, including a Progress flight to the ISS before another manned Soyuz crew flew again and "only after the inquiry has identified the cause of the emergency and measures have been taken to prevent such situations in the future".

Ovchinin and Hague were due to spend six months aboard the ISS as part of Expeditions 57/58 but there was a possibility they would be re-cycled to fly to the station in the Spring of 2019 either together or separately assigned to future Expedition crews.

The abort also delayed two US spacewalks and a Russian EVA which were due sometime in October or November. There was initial speculation as to when Gerst's crew would return to Earth. NASA said that Soyuz MS-09 currently docked to the ISS had a guaranteed life span until 4 January 2019 and Auñón-Chancellor confirmed on 15 October that "it could be a little longer" before they land; fortunately the crew had substantial food and consumables for an extended stay on the station.

LEFT
At Baikonur in Kazakhstan, Alexey Ovchinin of Roscosmos (left) and Nick Hague of NASA pose in front of the Soyuz MS-10 spacecraft. They launched on 11 October on the Soyuz MS-10 spacecraft, resulting in an abort two minutes later.



ABOVE
Expedition 57 Flight Engineer Serena Auñón-Chancellor holds an Air and Water Management Drawer removed from a Life Support Rack inside the US Destiny laboratory during maintenance work aboard the ISS.

> "It is clear there occurred a collision of the first and second stage in the process of separation of the first stage"
>
> Sergey Krikalev, Executive Director, Roscosmos

TASS quoted Krikalev in late October that the launch of the next crew "may be carried on December 3" and the current crew may return to Earth on 20 December "to avoid shifting the ISS to an unmanned mode". NASA confirmed these dates on 1 November and Auñón-Chancellor told the Houston Chronicle the previous day that the crew were "waiting for Roscosmos to complete its investigation" and they were "already looking forward to the next crew" launching to the ISS.

This was only the second time a Soyuz manned launch had experienced a launch abort, the other occurring in 1975 (*SpaceFlight* Vol 17 No. 6 p 201) and there was a launch pad abort involving a manned Soyuz in 1983 (*SpaceFlight* Vol 26 No. 5 pp 231-234).

THREE TO WATCH OVER

Gerst tweeted his relief that "our friends are fine" together with a spectacular photo he took of the launch from the ISS. On 12 October, Gerst and Auñón-Chancellor worked with the Myotones study, which measures how microgravity has impacted their muscles, whilst Prokopyev updated the station's inventory system and checked on Russian science experiments.

The crew had a light-duty weekend 13/14 October conducting regular housekeeping chores, performing their daily two and a half hours exercises and talking to friends and family.

On 15 October, Auñón-Chancellor tested the performance of battery life in space for the Zero Battery Test experiment, Gerst activated and checked out a life support rack to ensure good carbon dioxide and water management in the device and Prokopyev ran on the Treadmill with Vibration Isolation Stabilisation System (TVIS) inside Zvezda as part of a study to observe how microgravity impacts exercise.

Gerst and Auñón-Chancellor continued with Kounotori cargo transfers on 16 October. Ground specialists estimated that four hours of cargo operations remained to be conducted. The crew also worked with the Cold Atom Lab (CAL) physics experiment, the Lighting Effects study which involved the astronauts performing a numerical and colour discrimination visual test at a designated location and the Canadian RADI-N2 investigation which measures neutron radiation levels in the ISS. Prokopyev continued with the

ongoing Russian Matryoshka-R Bubble radiation experiment and the Uragan (Hurricane) Earth observation study.

Auñón-Chancellor relocated samples on 17 October collected from biology experiments to a science freezer inside Kibo. She also worked with the BioServe Protein Crystalography-1 (BPC-1) experiment, researching how to grow protein crystals aboard the ISS. Gerst performed various plumbing tasks to the station's toilet and worked inside Destiny before updating a warning procedures book. Prokopyev split his time conducting both physics and human research experiments inside the Russian segment and took part in a study which examines the interactions between a space crew and Korolev Mission Control.

On 18 October, Gerst and Auñón-Chancellor set up the Synchronised Position Hold, Engage, Reorient, Experimental Satellites (SPHERES) Tether Slosh experiment inside Kibo for a test to examine what happens when the satellites tow a liquid-filled tank versus a solid mass body with a Kevlar tether. Prokopyev opened up the CIR to replace manifold bottles that contain gases for the flame experiments and also packed items for disposal aboard Kounotori.

The crew worked with JAXA's Atomization experiment on 19 October. The knowledge gained from this study could be applied to improve various engines utilising spray combustion. Gerst and Auñón-Chancellor also used NASA's Meteor study to observe the chemical composition of meteors entering Earth's atmosphere. Gerst ended the working week by thanking ground controllers for their assistance, adding "it's been a challenging time…with lots of re-planning".

During the crew's light-duty weekend 20/21 October, Gerst prepared the Sally Ride EarthKAM hardware inside Unity, which his Russian colleague used the following week for another series of observations. Prokopyev also answered questions from Russian students about life aboard the station and other various aspects of space flight.

On 22 October, Auñón-Chancellor extracted and processed microbial samples from swabbed station surfaces for NASA's Biomolecule Extraction and Sequencing Technology (BEST) experiment and did further research with the BPC-1 study. Gerst photographed how quartz and clay particles form sediment in space and conducted eye scans with an ultrasound device to learn how long duration missions affect vision.

SCARY DAY

Gerst and Auñón-Chancellor worked inside Kibo on 23 October to replace gear inside a Multi-Purpose Small Payload Rack (MSPR), which provides a workspace that supplies power and video enabling research into a variety of smaller experiments. Prokopyev worked out on a treadmill to help Russian scientists understand how the human body is impacted by exercise in microgravity and also devoted time to computer and life support maintenance inside the Russian segment.

The crew conducted further research with the BEST and Sally Ride EarthKAM investigations on 24 October. Prokopyev continued to work with the Uragan hardware and the Profilaktika-2 experiment which examines different methods of preventing disturbances in a cosmonaut's motor activity during long duration missions. Auñón-Chancellor took time out to speak meteorologists and oceanographers attending the annual National Oceanic and Atmospheric Administration (NOAA) Oceans conference in Charleston, South Carolina.

> ...the launch of the next crew "may be carried on December 3"

Gerst worked throughout 25 October photo-documenting the station's port side solar arrays. The photos were downloaded for ground specialists to inspect the arrays for any damage. Auñón-Chancellor conducted botany experiments inside Columbus by setting up the Veggie-03 plant growth facility to grow a variety of edible plants such as kale and lettuce that NASA says have a positive effect on "crew morale" and "to provide a fresh food supply" on future interplanetary space flights. Prokopyev checked on the power systems inside Zarya before conducting a variety of scientific experiments including the Interactions-2 and Matryoshka-R Bubble studies.

The crew ended their working week on 26 October conducting maintenance to Extravehicular Mobility Units (EMUs) suits Nos. 3004 and 3006. Gerst also performed what NASA described as "some needed maintenance" to the CIR, whilst Auñón-Chancellor and Prokopyev worked with the Electrostatic Levitation Furnace (ELF) inside Kibo. ELF enables scientists to observe how microgravity affects the thermophysical properties of a variety of materials at different temperatures.

Mission Control Korolev told the crew to "rest well" at the start of their light-duty weekend 27/28 October which included their weekly Saturday night cinema screening when they get together to view a film of their choice.

On 29 October, Prokopyev set up the SPHERES experiment for a test run of the ongoing Zero Robotics competition due to take place in collaboration with high school students early in 2019. Auñón-Chancellor worked with the NeuroMapping experiment, which explores »

BELOW
Alexander Gerst from ESA looks out from inside the Soyuz MS-09 spacecraft docked to the Rassvet module seemingly dwarfed by cargo bags and the Soyuz hatch.

« an astronaut's neurocognitive abilities before, during and after a space flight and Gerst strapped himself into a specialised seat inside Columbus for ESA's GRIP experiment in an attempt to examine dexterous manipulation in microgravity.

Gerst conducted his second session with the GRIP experiment the following day, whilst his crewmates worked with the Binary Colloidal Alloy Test-Cohesive Sediment (BCAT-CS), Matryoshka-R Bubble and Uragan experiments.

Dressed in appropriate Halloween costumes on 31 October, Gerst tweeted the crew were; "Having a scary day in space" conducting a variety of experiments, including a third session with the GRIP study and another run with the ELF and Actiwatch investigations.

On 1 November, the crew completed their regular Food Acceptability questionnaire, whilst Gerst worked with ESA's Gravitational References for Sensimotor Performance (GRASP) experiment which investigates how the central nervous system integrates information from different sensations such as sight and hearing. The station's commander also spoke to German ZDF TV, whilst Auñón-Chancellor and Prokopyev focused on the joint French/NASA DEvice for the study of Critical LIquids and Crystallisation (DECLIC) physics mini-laboratory.

Gerst continued with the GRASP investigation on 2 November. The crew also harvested plants as part of NASA's Plant Habitat-01 experiment. The growth of the plants was initiated on 18 September but the plants grew slower than expected and only one of the two plant harvests was performed as a result. This experiment is expected to provide key insights on major changes occurring in plants exposed to microgravity.

ABOVE
The International Space Station was orbiting about 412 km above South Australia when a camera on board the orbital complex captured this celestial view of Earth's atmospheric glow and the Milky Way.

> ...one of the three computers on the Russian segment went out of service on 6 November due to "a software glitch"

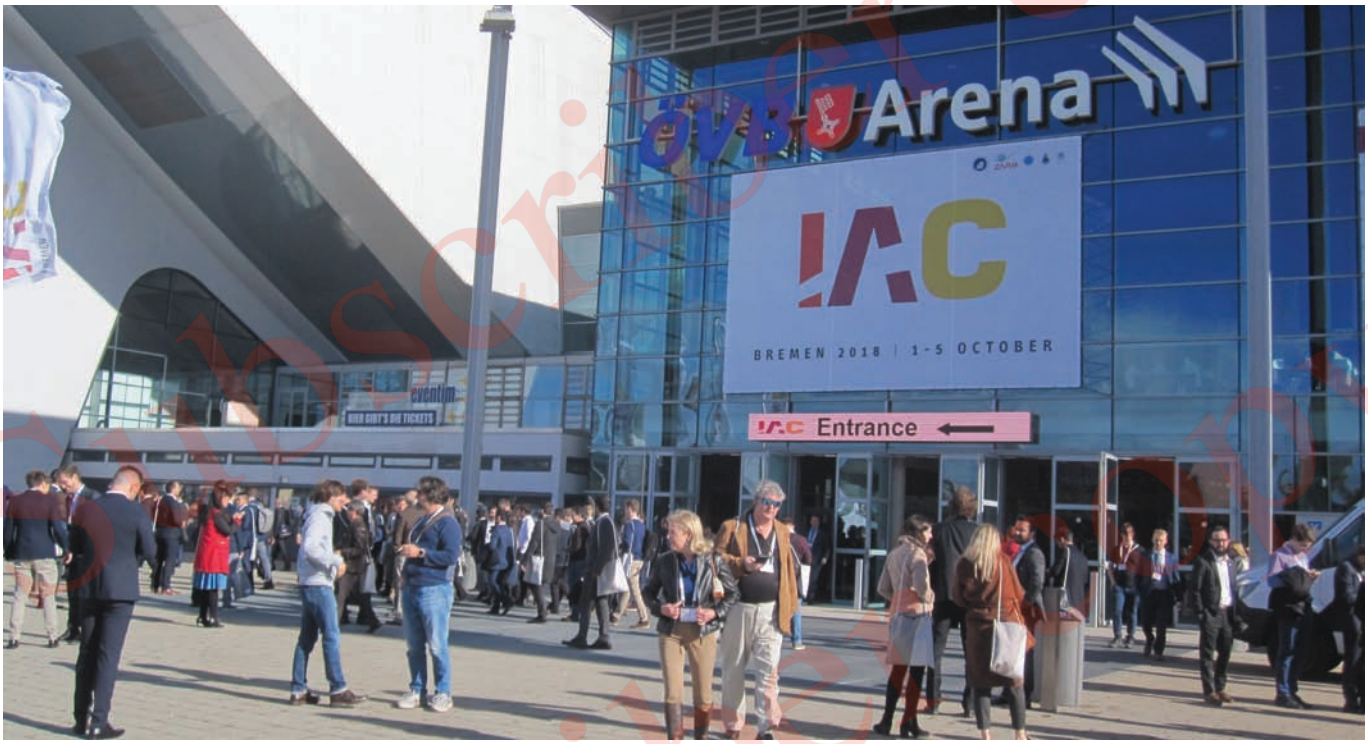
The crew enjoyed another light-duty weekend 3/4 November and on 5 November Gerst and Auñón-Chancellor reviewed procedures for the imminent departure of Kounotori. Prokopyev worked on science and maintenance tasks inside Zvezda. He performed an experiment researching how the space environment and solar radiation affects plasma-dust crystals before disposing of obsolete hardware inside Progress 70.

COMPUTER GLITCH

Roscosmos confirmed that one of the three computers on the Russian segment went out of service on 6 November due to "a software glitch". The space agency added that it "did not affect operations on board the orbital outpost as the standard cyclogram allows us to work with only two computers". There was no need to replace the computer and it was rebooted two days later ahead of the arrival of the next Progress vehicle "to ensure the safety of the November docking with the Progress spacecraft".

At 16:51 UTC on 7 November, Kounotori was released by Canadarm2 as the complex flew 408.7 km above the northern Pacific Ocean. The unmanned cargo vehicle had earlier been unberthed from the Earth facing port of Harmony by robotics officers. Gerst congratulated "all participating engineers" involved with Kounotori as the spacecraft departed the ISS en-route to a destructive re-entry which included the release of a small capsule containing scientific samples to be retrieved in the Pacific Ocean off the southern coast of Japan on 10 November. On 8 November, the crew conducted another Food Acceptability report, and worked with the BEST investigation and ESA's Plasma Kristall-4 experiment. SF

Where next for the IAC?



PHOTOGRAPHS COURTESY OF THE AUTHOR

The International Astronautical Congress may be founded on the twin principles of cooperation and inclusiveness – but is it sustainable?

by **David Todd**, Head of Space Content, Seradata Ltd

The 69th International Astronautical Congress (IAC 2018) was held in the city of Bremen near the coast of Northern Germany. The Congress is both a technical symposium, where engineers, scientists and even lawyers present their papers, and a place where the great space powers meet in an attempt to forge better cooperation. The 2018 Congress was held at Bremen's main exhibition centre located just behind its main railway station.

Previously famous for ship building, and its wartime U-boat submarine production, Bremen has since transitioned itself to become the centre of Germany's space effort. After the President of the International Astronautical Federation (IAF), Jean-Yves Le Gall, had opened proceedings, Thomas Jarzonibek, Minister for space in Germany's federal government, noted that Bremen had been "space-ified" as it worked with the EU and the European Space Agency (ESA) on space programmes. This "Space City" now contains the German Aerospace Centre (DLR) and Airbus Defence and Space establishments.

ABOVE
With reliable German efficiency, movement around the historic city of Bremen and throughout the 39th IAC Conference and exhibition area was effective.

The IAC's opening ceremony was well run with some moments of excellence. There were a few mistakes, however. Rather than having a security bag search, the organisers elected to have bags stored instead – a system that was soon abandoned as the queues grew and many fretted that they would miss the ceremony. Once inside delegates were treated »

« to music from the Bremen Philharmonia orchestra, while acrobatic rope dancers did their bit. The event was compered by comedienne Gayle Tufts to leaven the tedium of the speeches. Meanwhile the orchestra's conductor had the amused audience standing up and doing exercises to the music at the end of the gig.

While the overall theme of the conference was "involving everyone" in space exploration, the need for cooperation was emphasised even more. The ceremony even had a televisual message from ESA astronaut Alexander Gerst, who was on board the International Space Station (ISS). He made reference to the old African saying, "If you want to go fast – go alone", before adding, "If you want to go far go together with others".

FLAGSHIP STATUS

The IAC event remains the pre-eminent space conference for space agencies and companies working with them. Jean-Yves Le Gall noted in his speech that the Congress had a very large 6,300 attendance and that he wanted even more at future events. While the next IAC venues have already been named as Washington DC in 2019 and Dubai in 2020, the venue for 2021 had yet to be chosen. In the end, the French capital Paris beat Venice for the selection by the IAF. This will be very convenient for the IAF President as Le Gall is also President of France's space agency, CNES, which is also located in that fair city.

There were some other nice touches. To save the legs of some, the organisers had laid on a few electrically assisted, pedalled rickshaws between the station and the venue. Likewise, full delegates were even given a free pass for Bremen's excellent tram system – even if it ran out on Friday when needed to get to the airport.

The venue itself was not hard to navigate, even if a few of the major OVB halls were a long walk away from the main conference and exhibition area. The first day ended with a reception held in one of the empty halls. While a little too dark and crowded for this writer, it had a variety of traditional German food on offer as well plenty of drink, sideshow entertainments, and a dance floor.

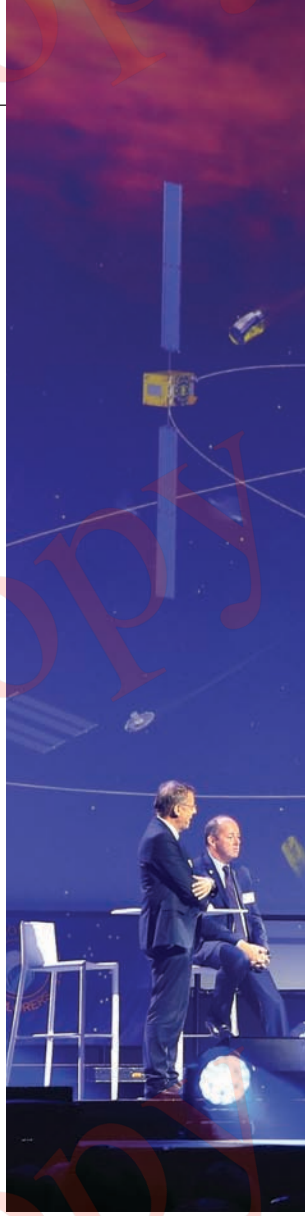
A NOTABLE ABSENTEE

While the major cooperative work is done behind closed doors, the IAC has a head-of-agency "plenary" to air their thinking in public. This was the first IAC for new NASA head Jim Bridenstine. The crowd immediately warmed to him when he publicly announced that, unlike previous reports, he did believe in climate change, and that the human production of carbon dioxide was a cause. (By the way, in a partial change of tune, Bridenstine's boss, President Trump has subsequently said that he also accepts the former although he still resists the latter).

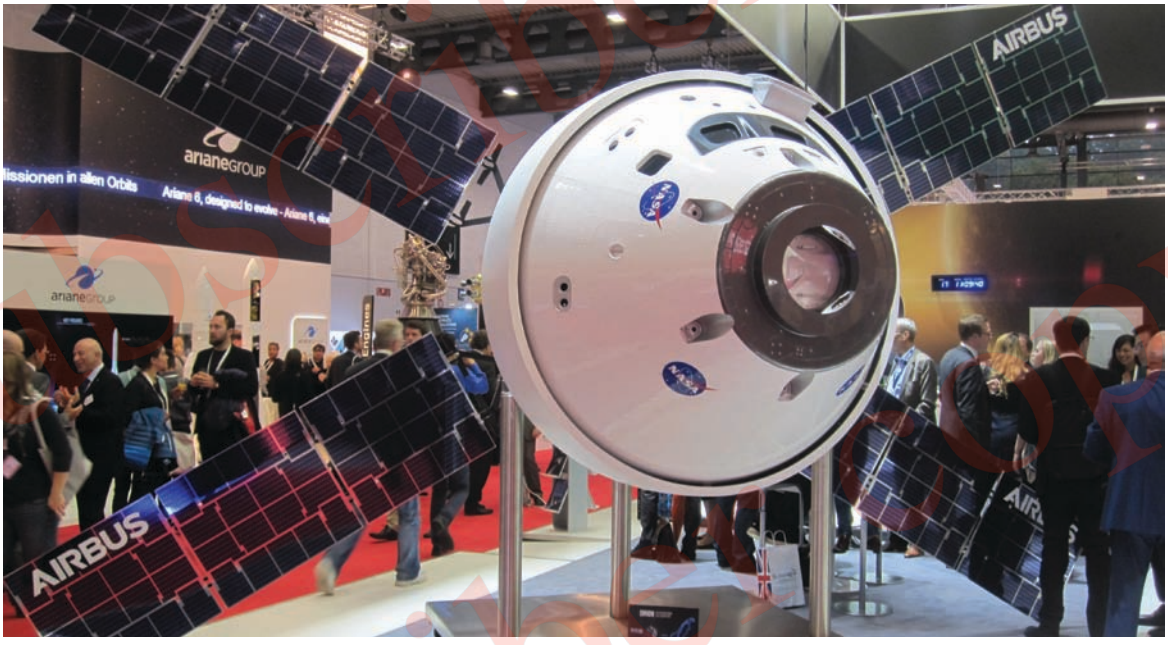
This year, the elephant in the room – or rather not in the room – was the head of the Russian space agency/conglomerate, Dmitry Rogozin. He had been banned from travelling to Germany due to his association with President Vladmir Putin, after Russia's annexation of part of Ukraine. This was a hurdle rather than a barrier to attempts at international cooperation as NASA's administrator, Jim Bridenstine, was due to meet him a week or so later when he went to Kazakhstan to see the (subsequently failed) launch of Soyuz MS-10. In the meantime, Dmitry Loskutov stood in for Rogozin and said that Russia was looking to maintain "sustainable" launch rates.

While Bridenstine said he was looking forward to the development of reusable lunar landers, at the later press conference, chaired by the BBC's Maggie Aderin-Pocock, he responded to a question on whether he had been given a deadline by President Trump to return to the surface of the Moon. NASA's new boss responded: "I do not have a specific time limit…The instruction I have been given is to do it sustainably". He added that NASA's planned lunar return was not just an Apollo-style there-and-back enterprise. In other words, despite the growing clamour for earlier rather than later human landings, this chimes with the Lunar Gateway plan as a base for lunar exploration. Nevertheless, while NASA is happy to explore the Moon, it does not want to get bogged down in building a lunar base.

A time limit Bridenstine does face is the planned ending of NASA's funding of the ISS, and at least some of the off-camera discussions with his fellow space agency



ABOVE
Framed by a stunning light and sound show, the presentations had a dramatic backdrop.



RIGHT
The most outstanding exhibit on display at the 39th Conference was the model of Orion, together with its European Service Module.

heads would have been devoted to coordinating that. With respect to international cooperation on its follow-on, the Lunar Gateway, Bridenstine said that it was too small a space station to include every space agency that wanted to take part, but that lunar exploration would provide opportunities for all. Lunar Gateway is projected to have a 15-year lifespan and would be moveable in orbit via its solar-electric propulsion module, so that it could be placed at Lagrangian points L1 or L2, or into a lunar polar orbit if required.

Jan Woerner, Director General of ESA, agreed with him. He renewed the emphasis on going back to the Moon, ahead of Mars, when he announced his Moon Village concept a few years ago. He reiterated that this did not mean a lunar base with "houses, a town hall and church", but rather a series of surface activities conducted by both institutional and commercial entities. "We don't go back to the Moon, we go forward to the Moon", he said.

Woerner reminded the audience that space agencies had transformed themselves from managing agencies to commissioning agencies. "In the past the agencies were defining everything" he said, whereas the future would see more risk-sharing partnerships with a possible "broker function".

MULTINATIONAL PLANS

The head of India's space programme, Dr K. Sivan, reminded the audience of the threat to both human and unmanned space activities of space debris being left in orbit. With respect to ISRO's plans, including eventual human spaceflight, he said that a lunar flight would be a little too far for India at present.

> "We don't go back to the Moon, we go forward to the Moon"
>
> Jan Woerner, Director General of ESA

China has its own plans for the Moon, including the Chang'e 4 unmanned rover mission to the lunar far side later this year. However, Zhang Kejian, of the China National Space Administration, reminded the audience that in addition to its attention-grabbing missions, China's plans also included the construction of a new recoverable spacecraft able to return 600 kg back to Earth, and the development of Ka-band communications satellites.

Kejian had asked for more cooperation with NASA and said that the initial response had been positive. Cooperation with ESA is likely as some of its astronauts have already begun to learn Chinese with a view to visiting China's planned new space station. A presentation made later in the conference noted that this would have a total mass of 189 metric tons and would consist of an initial core module and two experimental modules.

Sylvain Laporte, President of the Canadian Space Agency, noted that his country was looking forward to the launch of its radarsat constellation, dubbed Radarsat 2.

Hiroshi Yamakawa, head of Japan's JAXA agency, basked in the adulation that followed the recent Hayabusa 2 spacecraft arrival and subsequent »

« Minerva II landings on an asteroid (the DLR would later celebrate the landing of its own MASCOT small hopper lander). Yamakawa looked forward to his agency's lunar mission and a foray to the moons of Mars via its planned MMX mission to Phobos and Deimos (to launch in 2024), which will carry instruments for NASA and the French agency CNES.

When asked if there would ever be an "International Space Agency", Yamakawa responded: "Is one needed now we are working together?" With respect to the threat of space debris, he made the point that JAXA was working on active debris removal technologies.

ABOVE
The BIS stand at the IAC was crewed by a combination of staff and volunteers.

WHERE IS ELON…?

Elon Musk, head of SpaceX, was also a notable absentee given his appearances at the previous two IACs. His technical No. 3 (after Gwynn Shotwell) Dr Hans Koenigsmann stepped up during a special Global Networking Forum (GNF) lecture to explain the advantages of interactive change in the light of the Falcon 9 reusable launches. "We just learned from time to time", said Koenigsmann, who indicated that test flights were used to verify their original analysis. "We trust our tests more than our analyses", he added.

At a subsequent Global Networking Forum (GNF) forum Peter McGrath, of Boeing, reminded the audience that apart from a performance penalty, reusability has its economic limits. NASA eventually gave up trying to reuse the parachute and splashdown recovered Solid Rocket Boosters (SRBs) when it realised that it cost about US40 million extra per year to do so.

Koenigsmann described the demarcation in the regulations relating to launches from the two pads SpaceX uses on the US East Coast. Pad 40, at Cape Canaveral, is under US Air Force rules, while the Kennedy Space Center's Pad 39A is under NASA rules. He went through the history of the firm, describing its growth from 14 employees in 2002 to over 6,500 today.

> Hans Koenigsmann had earlier quipped that having a German accent was an advantage for a rocket scientist applying for jobs in America

The latter figure and a quick analysis of their salary needs made some in the audience wonder just how SpaceX was able to launch its rockets so cheaply.

He defended the planned BFR/BFS launch vehicle/spacecraft combination with a "straight bat" when asked how the BFS spacecraft would survive an Earth atmospheric re-entry at Mach 30+. "I don't think that the Mach number is relevant", he said. He agreed, however, that the heating rate/flux was very much dependent on velocity. According to the entry angle chosen and the vehicle's density (via the ballistic coefficient), he contended that SpaceX's thermal protection system could still handle the heating during a lunar or Mars return. There was no word from him about whether active cooling would be needed, or whether the craft's lift vector would be used to hold it in the atmosphere for long enough to get below super-orbital speed.

On a lighter note, Hans Koenigsmann had earlier quipped that having a German accent was an advantage for a rocket scientist applying for jobs in America. However, his final words to those thinking about a space career was that when it came to rocket engineering, "talent is more important than experience".

TECHNICAL SESSIONS

The lecture sessions covered everything from rocket engine design to space history, so it was often impossible to see everything you wanted to because several strands of lectures coincided. This was aggravated by the growth of the GNF lectures and discussion panels. While these were often more interesting than some of the main plenary sessions, the GNF has now become a "conference within a conference", which risks usurping the main event.

During a GNF panel session covering European launchers, Jan Woerner, of ESA, defended the

expendable Ariane 6. He stressed that it was essential for Europe to have its own launcher system, especially after its experience with the Symphonie communications satellites. After the failure of the Europa rocket programme in the early 1970s, Europe found itself without a launcher. The USA agreed to launch the satellite pair – but only on condition that they would never have a commercial use as the Americans attempted to defend their satellite construction and operator business.

The lesson for Europe was that while it should cooperate with other nations, it should only do so from a position of strength. Woerner was disparaging about SpaceX's sportscar stunt on the Falcon Heavy launch, but he admired the firm's agility in making changes so fast – more or less every flight – although he pointed out the serious risk element. However, he also admitted: "No Risk. No Fun".

If you cannot beat SpaceX, copy it. One stand in the exhibition had a model of the French experimental reusable rocket Callisto – its landing gear make it look remarkably like a Falcon 9.

Luce Fabriguettes, of Arianespace, told the audience there had been a significant slowdown in GEO communications satellite orders, and this would lead to difficult years for the launch industry before the LEO constellations arrived. Others fretted about ordering an Ariane 6 launch when it was not yet flying. Marco Fuchs, of German satellite manufacturer OHB System, said: "I cannot rely on Ariane 6 as it is not confirmed yet".

Of the technical sessions, the ones this writer managed to attend were on the Lunar Gateway and the SLS, and some on space architecture related to lunar exploration.

PAPER TALK

While Europe's "The Space Race", a vague not-for-profit organisation promoting lunar exploration was announced at the Congress, with Blue Origin in support, on sounder ground was.Jason Crusan of NASA, who presented an excellent paper (IAC-18. A5.1.1) showing the main elements of the Lunar Gateway. He explained that several configurations were being considered and noted the role that commercial launch vehicles would play in launching some of the elements. With the use of the solar/electrical thrust module and Earth flyby's, the station would be able to reach lunar polar orbits and well as L1 and L2.

Crusan reiterated the point that Bridenstine had made earlier: at only 125 cubic metres, it was only about 10 per cent of the size of the ISS. Crusan envisaged that the Gateway would be used for human stays of between 30 and 90 days. Increasing use of RFID chips would help monitor logistics on board the vessel.

While Bridenstine had warned that the Lunar Gateway might be too small for large-scale international participation, others were worried about any delays it might cause. "It will take longer to get a partnership agreement than it will to launch hardware", mused NASA's Kirk Shireman as he presented his paper (IAC-19.A5.1.2).

While the lunar village will not be needing a town hall ("rathaus" in German), as Woerner reiterated, some papers at the Congress noted that lunar structures might need a different architectural »

SNAPSHOTS OF BREMEN

ABOVE
Entertainment included a spectacular aerial ballet against a backdrop of traditional fairytale characters.

RIGHT
Hungry delegates were well provided for in the food department.

LEFT
Eco-transport made getting around easy as well as guilt-free.

BELOW
Restored as a visitor attraction, a German U-boat was high on the tour list for the local area.

« approach. These included Sandra Haeuplik-Meusburger's presentation of her Technical University of Vienna students' architectural designs for different elements on the Moon (IAC-18.A5.1.8). Some of the designs looked better than others – even if they were partially underground for radiation reasons.

Christiane Heinicke, of the University of Bremen's Centre for applied Space Technology and Microgravity (ZARM), presented a design for a Moon and Mars Base Analogue (MaMBA) (IAC-18.A5.1.14). She explained that architecture on the Moon was likely to be driven more by utility than aesthetics, but architects would still be needed for the ergonomics, safety, and light and sound requirements. Somewhat disappointing architecturally – even allowing for its protection needs – was the design for the Centauri Lunar Hotel Alpha (IAC-18.A5.1.9). This was no high-end Hilton – more like a single-storey motel.

ON SHOW

The IAC 2018 Bremen exhibition was impressive and reportedly much larger than that at IAC 2017 Adelaide. Most of the major firms involved in space exploration were present. The Airbus stand probably took the prize with an excellent model of Orion and its service module. If there was one criticism it would be that the public day was held too early in the week. Wednesday was effectively a washout for business proper when 10,000 members of the public crowded into the hall on their "German unification" day off.

Megan Clark, head of the newly formed Australian Space Agency, made the point that some Australian visitors to the Congress were thrilled to see that Australia finally had a presence. "We've got a booth! We've got a booth!" they excitedly shouted. And a major one at that, to the point that some other space agencies' stands, e.g. that of Romania, were effectively hidden from view. Australia, by the way, was NASA's only official international partner during the Apollo lunar missions.

The UK pavilion was small but well positioned, right next to NASA's surprisingly modest stand. Like NASA's the UK pavilion lacked a bit of vertical presence – it really needed the Union flag above it. The most visually aesthetic exhibit on show was the "Spaceliner" rocket plane concept design from DLR. While this will probably always be just a paper project, at least we can all dream.

ABOVE
Inspiration was the name of the game with particular emphasis on stimulating junior "space pioneers", never too young to be assailed by "ambassador" teachers.

China had a strong showing with state firms, including CAST, CASIC and CALT, and "private" firms such as LandSpace displaying their rockets and satellite designs.

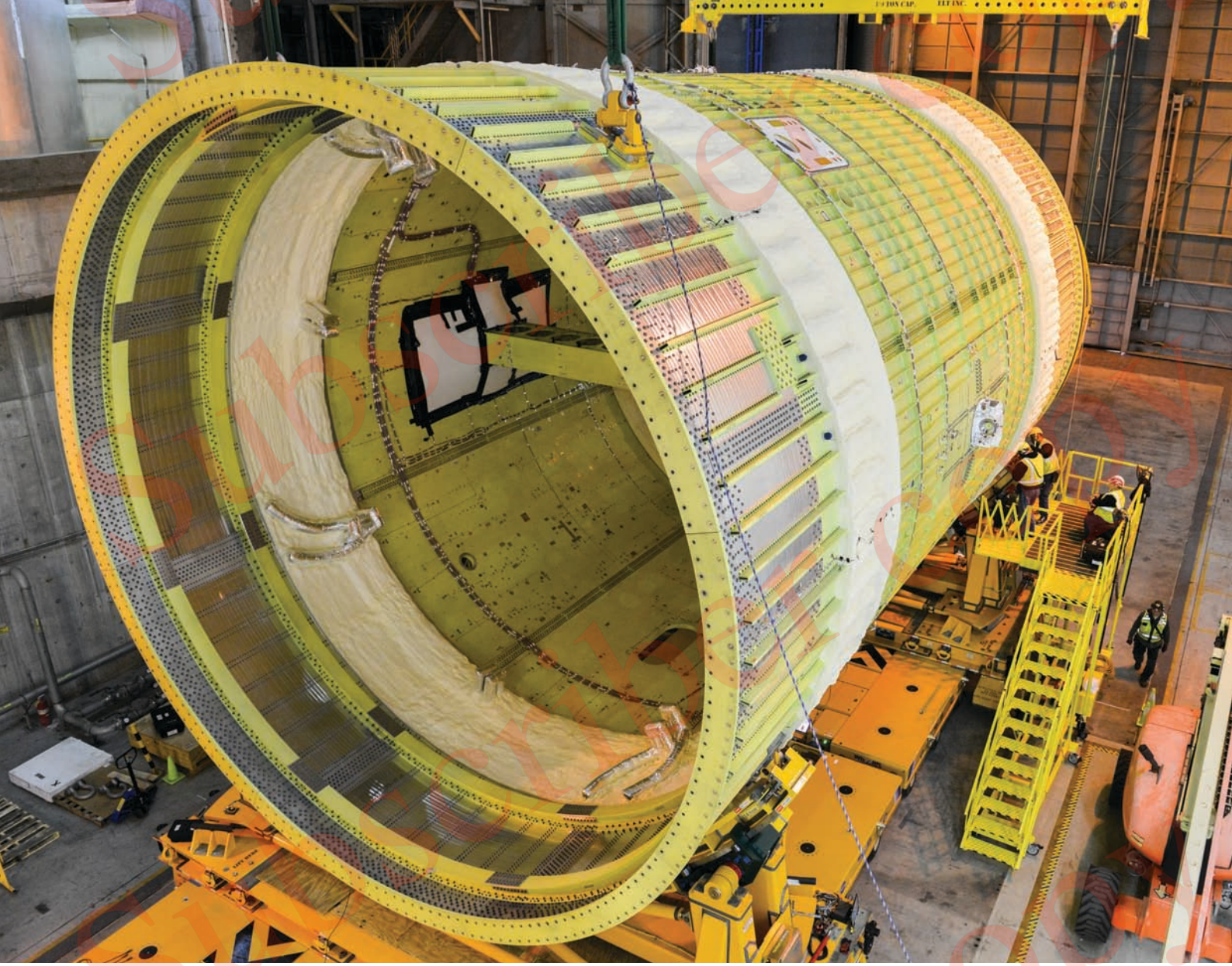
One booth slightly off the beaten track – well actually in the corridor near the main exhibits – was that of Black Engine Aerospace – a company spun off from DLR. It was marketing a type of ceramic rocket engine using a porous wall to transpirationally cool the thrust chamber, using hydrogen tapped off from the fuel. And very interesting it seemed too with claims of 4,000 K temperatures and 60 bar pressures being achieved, and for a 75% lower cost than using regenerative cooling. One wonders, however, whether the core CFRP (Carbon Fibre Reinforced Plastic) matrix could maintain its structural strength at these temperatures – cooled or not – for long.

Apart from the paid-for main Gala in the Rathaus (old town hall), the IAC also laid on various paid-for and free cultural and technical tours, whether to a local bierkeller or to Airbus DS or to DLR. This writer went to DLR – officially known as Deutsches Zentrum für Luft- und Raumfahrt e.V (German Aerospace Centre). It was interesting to see its research on lunar landing gear, and the EU:CROPIS spacecraft in the clean room just before shipment to the Vandenberg launch site ahead of its Falcon 9 launch. That spacecraft will use its spin to mimic both lunar and Martian gravity as tomato plants are grown on board.

The closing ceremony reportedly involved a somewhat confused prize-giving. Holding up the British end was Shaun Andrews, an aerospace engineering student at Bristol University, who took the Gold Medal for best undergraduate paper (IAC-18.E2.2.10), on modelling plasma drag on ion engines in very low orbit. Andrews hopes to work on revolutionary forms of space flight engines in his future career.

Overall, most delegates seemed to enjoy the IAC 2018 Bremen Congress and probably learned something from it. Despite international tensions triggered by the "usual suspect" politicians over the past couple of years, at least the scientists, engineers and even the heads of space agencies still appear to want to cooperate. That is, if their political masters will let them. SF

BELOW
Reusable, winged space freighters were among the concepts on display, despite questionmarks over their commercial feasibility.



SLS: heavyweight

While the SLS Block I variant is nearly certain to achieve flight status, new heavy-lift rockets on the stocks threaten to usurp later variants of this huge US$20 billion Heavy Lift launch vehicle (HLV).

by **David Todd,** Head of Space Content, Seradata Ltd

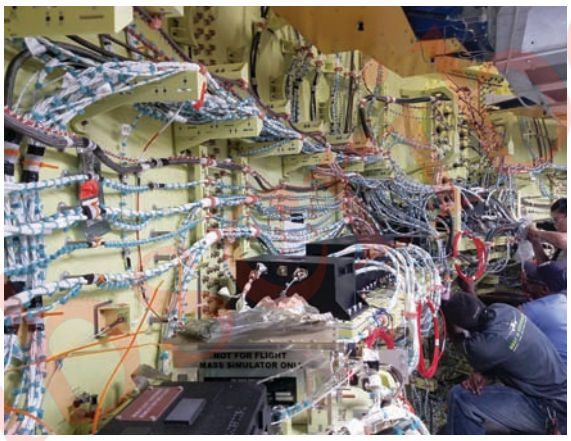
Nevertheless, NASA's new administrator, Jim Bridenstine, is adamant in declaring that SLS and the Orion human-carrying spacecraft would survive the onset of new commercial HLVs and suggested that the SLS would work in cooperation with them. In fact, NASA's Lunar Gateway construction plans specifically include "commercial launches" in its schedule, as shown in a paper presented by NASA's Jason Crusan (IAC-18. A5.1.1) at IAC-2018.

After some setbacks, the SLS programme is back on track. Steve Creech, SLS Strategic Development Manager, revealed that the main LOX (liquid oxygen) tank for the 26 tonne SLS Block I would be ready early next year, while the liquid hydrogen tank would be ready by the autumn.

ABOVE
Connecting the liquid hydrogen and liquid oxygen tanks, the intertank is built differently from the rest of the core stage. It is bolted together, not welded, with ribs on the outside for added strength to support the twin solid rocket boosters.

With respect to other choke points on the critical path in the SLS/Orion schedule, Nico Dettman, head of the exploration group at ESA, said some design changes would be made to the Service Module between the unmanned Orion EM-1 mission, currently planned for 2020-21, and the crewed EM-2 mission in 2022. He noted however that the former flight would be more forgiving in its requirements given its uncrewed status.

Oliver Juckenhofel, head of on-orbit services and exploration at Airbus Defence and Space said it would include mass reduction measures and some new upgraded electronic components. He suggested that



IMAGES: NASA

challenger

the new X-wing solar array configuration had a few advantages over the "Mickey Mouse" designs originally envisaged by Lockheed Martin, mainly in that the stress-reducing flexible joints would allow them to bend backwards during manoeuvres.

With respect to later versions of the SLS, NASA has just reopened negotiations with Boeing to optimise the design of the Exploration Upper Stage (EUS) to further extend the 34-36 tonne TLI (Trans Lunar Injection) capabilities of the now delayed SLS Block IB. This will not now fly until the fourth SLS mission at the earliest. The final and most powerful SLS Block II version, which able to carry 150 tonnes to LEO using the EUS as well as new advanced boosters, will not now be needed until the 2030s.

The late arrival of the EUS resulted in the SLS having to fly in a Block I configuration using its Delta IV rocket derived Interim Cryogenic Propulsion Stage (ICPS) for both the first and second SLS flights, the latter of which is the first human carrying EM-2 mission meaning that the SLS Block I has had to be human-rated after all.

The third SLS Block I flight after EM-1 and EM-2 will be an unmanned "cargo" mission as it is due to launch the scientific probe, the Europa Clipper, in 2022 at the earliest. This science mission to Jupiter's icy moon, very much benefits from the power of the SLS in allowing it a more direct flight trajectory, thus saving years in flight time.

While the ICPS could be stretched further, according to NASA's ICPS specialist Dr Kimberley F. Robinson, NASA is currently planning to make just "performance tweaks" to it. These will add a metric ton or two to its lifting performance which will benefit the Europa Clipper mission's flexibility. Presenting the IAC-18.D2.9-A5.4.1 paper in lieu of Steve Creech, Robinson said that these minor improvements could be done without having to recertify the stage, whereas a full propellant tank stretch would definitely need this.

While the future of the Block I version of the SLS is assured (at least for the three or possibly four flights for which it has already has RS-25D engines), the same cannot be said for the SLS Block 1B. By delaying the EUS upper stage, NASA and its Boeing partners can give the SLS Block 1B slightly more payload via a redesigned EUS, which would be useful for the construction of the Lunar Gateway. However, this move also allows a much easier cancellation of the EUS and SLS Block 1B version (and later SLS Block II) should NASA wish to do so. This might happen if commercial heavy lifters such as the Blue Origin New Armstrong and the SpaceX BFR show that they are likely to work.

One alternative to the SLS Block IB with its EUS would be to further upgrade the SLS Block I. During the early design studies of the SLS, analyses of different engine and configuration options for the upper stage showed that one possibility would be to stretch the tanks of SLS Block I's ICPS. This would get it close to the 34-37 metric ton TLI performance of the EUS equipped SLS Block IB.

The days of the later SLS Block I B and Block II variants could, therefore, be numbered and they may remain as just "paper designs". Nevertheless, for the time being, the SLS Block IB remains integral to the Lunar Gateway plan. SF

TOP
The inside of the core stage is fitted with cables connected to avionics that will guide the flight path and provide communications between Orion and the ground.

ABOVE
NASA Apollo 17 Lunar Module Pilot Jack Schmidt and his wife Teresa inspect SLS elements at NASA's MSFC.

RIGHT
An RS-25 engine test to certify the SLS propulsion system for its first flight in 2020.

Back to the Moon

Back to the future

It is 50 years since NASA sent the first humans into lunar orbit with Apollo 8. They are about to send more.

by **David Baker**

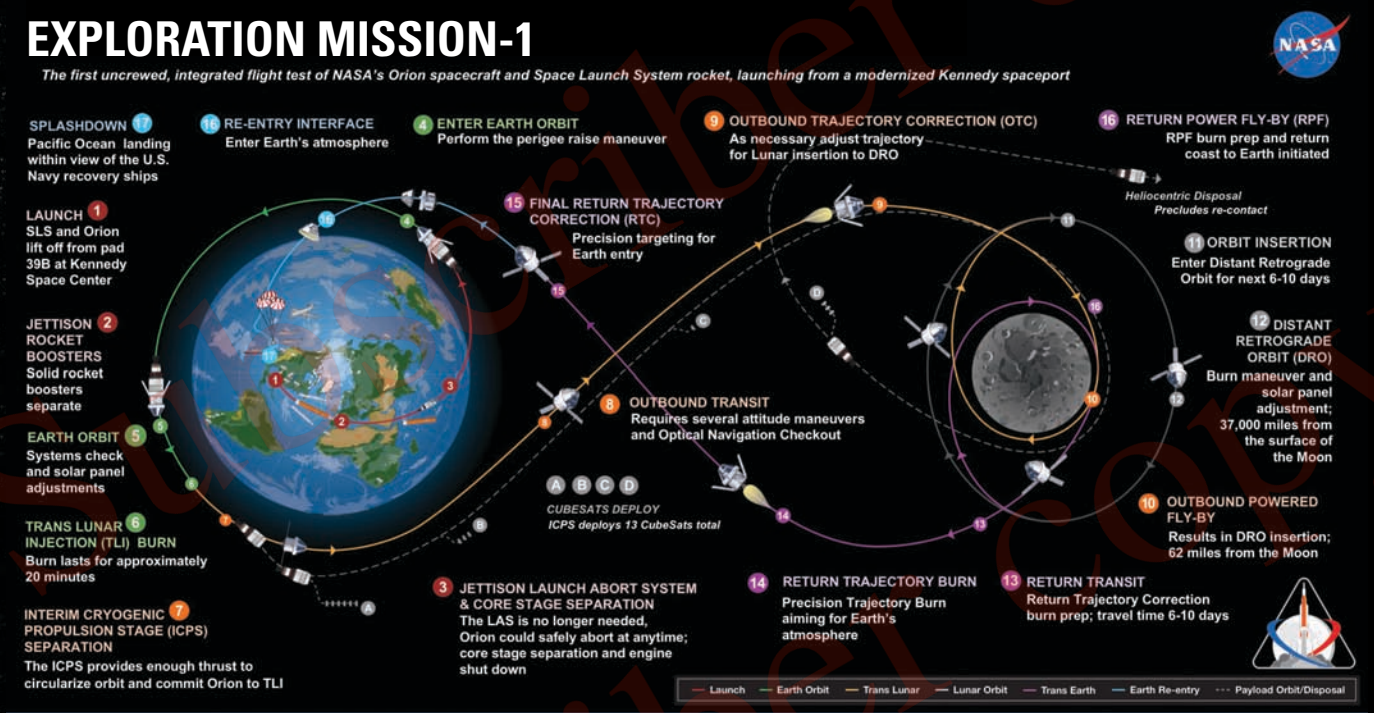
In the long and sometimes turbulent story of NASA's next super-heavy rocket, now getting on for a decade since it was first mooted as the future "big thing", the US space agency is looking to pick up where Apollo left off. But just how different are the prospects for the Lunar Gateway compared with plans for extending Apollo flights in the early 1970s? There are many lessons that can be learned from the Apollo era and advantages to be had from redesigning the next phase for human exploration of the Moon, all of which come down to Earth-Moon geometry and the limitations set by orbital dynamics.

NEVER-NEVER LAND

During the build-up to the Apollo Moon landings, NASA planned extensive use of Apollo hardware to sustain a human presence on the lunar surface and use equipment designed and built to achieve the goal of "first landing" to extend scientific research at the surface. But the very nature of Apollo mission architecture restricted launch opportunities in such a way that launch windows were heavily constrained by the requirement to launch for specific sites at times controlled by flight path angles and lighting conditions during descent and touchdown.

ABOVE RIGHT
Key events for EMS-1, the first flight of the Space Launch System and the unmanned Orion spacecraft to a retrograde lunar orbit which, according to the projected flight plan, will see it achieve an apocynthion of 59,500 km above the far side.

Back in the 1960s it was inconceivable to think that manned landings could be made in anything other than optimum lighting conditions and that constrained the dates when it was possible to launch from Earth. Even a delay of a day or two would begin to shift the landing site further west, retreating from a chasing Sun rising in the east so as to maintain the incident angle to between 7° and 20°; too low a Sun angle and the shadows would hide surface threats, too



high and the light would wash out surface features altogether.

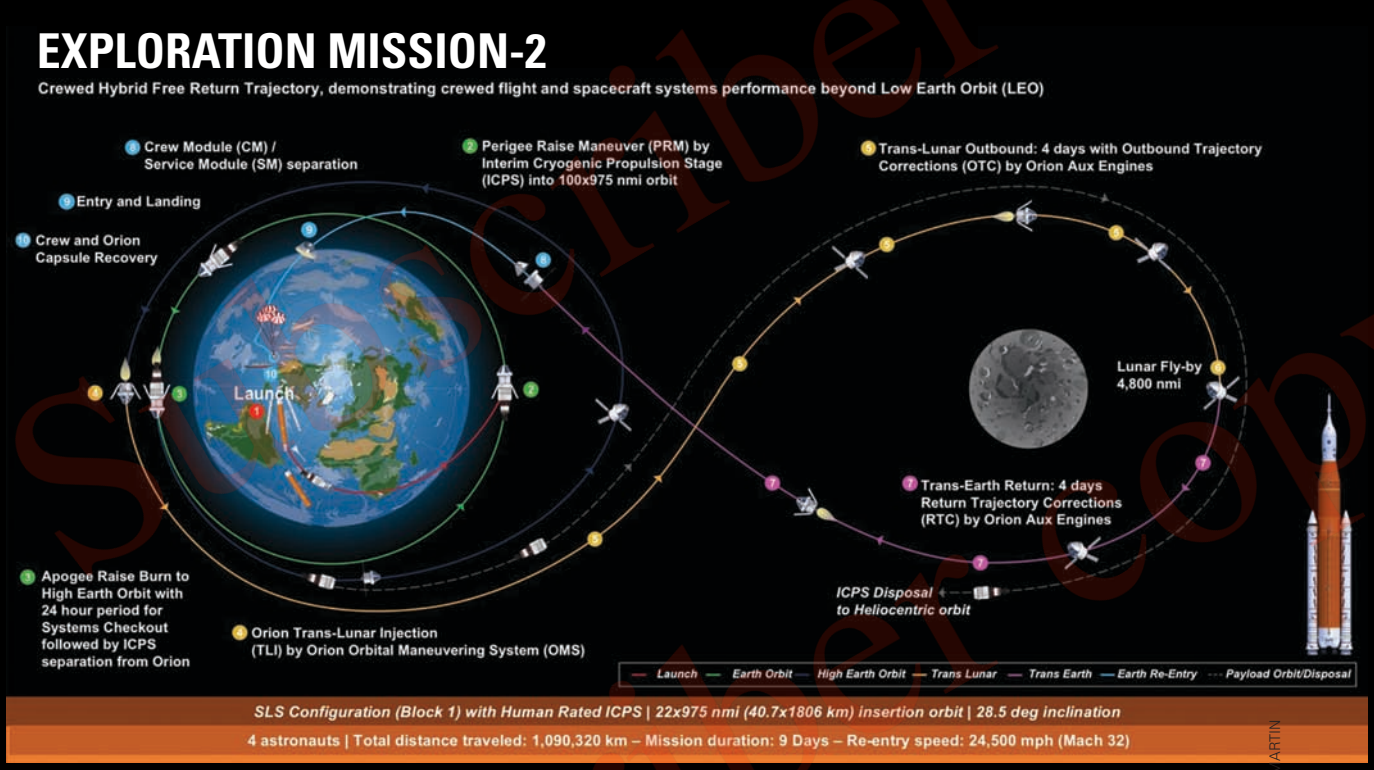
It never would have been possible for NASA to use a single-shot launch to head straight for a specified landing site on any but a few days each year, other constraints being the limitations of azimuthal trajectory alignments and the antipode position relative to the phase angle between the two. Boxed in further by lighting constraints, opportunities would have been few and far between.

This was apparent to Apollo mission planners, which is why the theoretical proposals for a sustained and frequently replenished lunar site for human habitation was not only unrealistic but impossible to support. Two groups were working hard to reconcile the differences but only the engineering plans for »

BELOW
Apollo and Orion compared. The latter is bigger to accommodate a four-person crew but weighs substantially less.

IMAGES: NASA

MOONSHIPS THEN AND NOW



« surface support equipment ever got a popular airing. The constraints imposed by celestial mechanics matched against the inflexible nature of the equipment developed for the Moon landing goal, meant that only after the technology had boxed-out possibilities for frequent re-visits to the same site were sustainable surface bases even considered.

For a more lengthy and evidence-based discussion of these geometric constraints suffered throughout the Moon landing phase of the Apollo programme, members can revisit my lecture at the British interplanetary Society on 21 November through the BIS website where these issues are described at length.

POSSIBILITIES

Fast forward 50 years and things are a lot different. For instance, no longer are there any plans to launch direct from Earth to the Moon based on available opportunities with Earth-Moon geometry. Instead, expectations are focused around not a single launch to achieve a single objective, rather to create a hardware suite that can flexibly adapt to the requirements of the long-term goal, which is to provide a universal capability rather than a specific, one-shot objective. Enter the Lunar Gateway.

By establishing a place in lunar orbit where operations to and from the surface can begin and end, the constraints are removed by embedding the departure point within lunar parameters and not as an interplay between the celestial parameters of two moving bodies in space. It removes entirely the limitations based on matching two very different base lines, separating the Earth-lunar-orbit leg from the lunar-orbit-surface phase which is detached from a separate set of time-constraints.

Because the lesser mass of the Moon allows a higher delta-velocity increment within a given set of orbital parameters, plane-changes and other interesting games of orbital ballet are possible across a broader spectrum of mission requirements. And because the orbital velocities are much lower than those around Earth, a fact entirely the product of the gravitational effect on the mass, it is possible to do more work with less demanding propulsion requirements; which means smaller engines, less thrust, lower propellant levels and higher payload fractions.

ABOVE Planned to conservatively challenge the technology and performance capability of the SLS/Orion system, the first crewed flight will be less ambitious, dwelling a full day in the vicinity of the Earth before embarking on a free-return trajectory and a circumlunar flight path 8,890 km above the Moon.

> Fast forward 50 years and things are a lot different

THAT WAS THEN, THIS IS NOW

Even though this writer spent many months trying to find ways of transforming Apollo hardware into a sustainable lunar exploration programme more than 50 years ago, it was never going to work because the engineering of the hardware was too singly focused around a single-shot flight opportunity with equipment designed for a limited life on site. Now those limitations are reversed, with the only constraints being on the limitations of resources to expand the human presence on the lunar surface.

With the Lunar Gateway the opportunities are virtually endless and the two initial missions on the Space Launch System are designed to demonstrate the capability of both the launch system and the Orion spacecraft itself. Both Exploration Missions 1 and 2 are designed around an Apollo-type retrograde orbit, with the spacecraft approaching first orbit around the western (leading) limb of the Moon as its orbits the Earth – in fact the Moon does not orbit the Earth; both in this bi-planetary system orbit the Sun, with each weaving a path inside and outside each other around a common centre of mass located just inside the Earth's radius.

With this pioneering role, as ESA's Director General Johann-Dietrich Woerner says, we are not going "back to the Moon but forward to the Moon", because the possibilities are infinitely greater than they ever were – or ever could have been – with Apollo. SF

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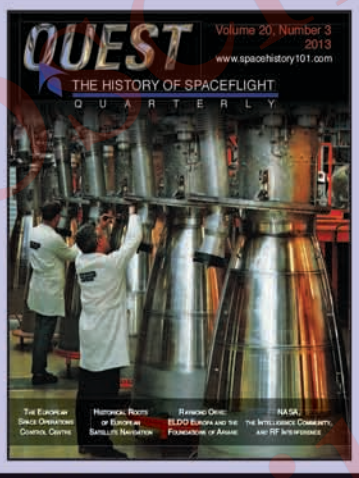

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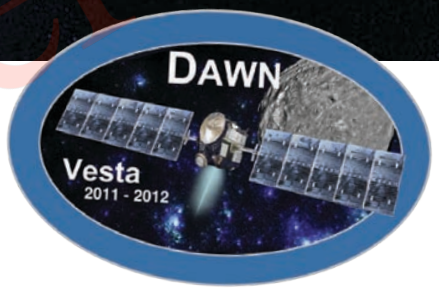
The dark before DAWN

After an epic 11-year mission to the asteroids Vesta and Ceres, NASA's DAWN spacecraft has finally called it a day. What have we learned?



IMAGES: NASA

by **By Chris Starr FRAS FBIS**

On the 31 October NASA's Dawn spacecraft fell silent. After its historic 11-year, 6.9 billion km odyssey to the main asteroid belt, the spacecraft ran out of the hydrazine propellant needed to keep its communication antennas in contact with Earth and mission control at the Jet Propulsion Laboratory (JPL). The loss of attitude control also means that it can no longer maintain the orientation of its solar panels towards the Sun to keep it active.

Having spent 14 months orbiting and studying asteroid 4 Vesta, Dawn has been orbiting dwarf planet Ceres since 6 March 2015, which makes it unique so far in orbiting two separate bodies beyond the Earth-Moon system. Dr. Marc Rayman, the project's Chief Engineer and Mission Director at JPL, says "It's hard to say goodbye to this amazing spaceship", but "we are fortunate that Dawn has lived so long and been so productive in its extraordinary extra-terrestrial expedition".

ABOVE
Dawn in its flight configuration as depicted with its ion engine in operation.

It has certainly exceeded all expectations, continuing to operate well beyond its initial Primary Mission, which ended in June 2016. And our knowledge of the Solar System and its early history have grown

inestimably. As Dr. Rayman says poetically in his engaging and informative "Dawn Journal" *(http://dawn.jpl.nasa.gov/mission/journal.html)*: "Since Galileo pointed his telescope up four centuries ago and beheld astonishing new sights, more and more celestial gems have been discovered, making us ever richer…In a practical sense, Dawn brought two of those jewels down to Earth".

ORIGINS AND DEVELOPMENT

Dawn was targeted specifically at investigating the main asteroid belt between Mars and Jupiter, a region where it is thought that answers to key questions about the early Solar System and its formation might be found.

It is one of NASA's Discovery programme missions, initiated in the 1990s to complement NASA's bigger "flagship" planetary explorations with more frequent, smaller missions at lower cost and with shorter development times. Most completed Discovery missions – from NEAR-Shoemaker to MESSENGER, Pathfinder to GRAIL, Kepler and others - have enjoyed great success. The programme has also aimed to develop and use new technologies, as well as broadening collaboration between NASA and university and industry partners, both in the USA and abroad, including Germany and Italy.

ABOVE
The launch of Dawn by Delta II 7925H, with nine strap-on solids and a PAM third stage, on 27 September 2007.

The latter were important in helping develop and construct elements of Dawn's science payload. This included: two Framing Cameras (FC) with filters for optical imaging and navigation (Germany); a Visible and Infrared (VIR) Mapping Spectrometer Italy), used to determine the mineralogy of Vesta and Ceres; and a Gamma Ray and Neutron Detector (GRaND), developed by Los Alamos National Laboratory in New Mexico, for detecting the elemental composition of the two target worlds.

The spacecraft's radio transmitter was also used in conjunction with sensitive antennas on Earth to study the gravity fields of the two bodies and to provide clues as to their internal structure. Orbital Sciences »

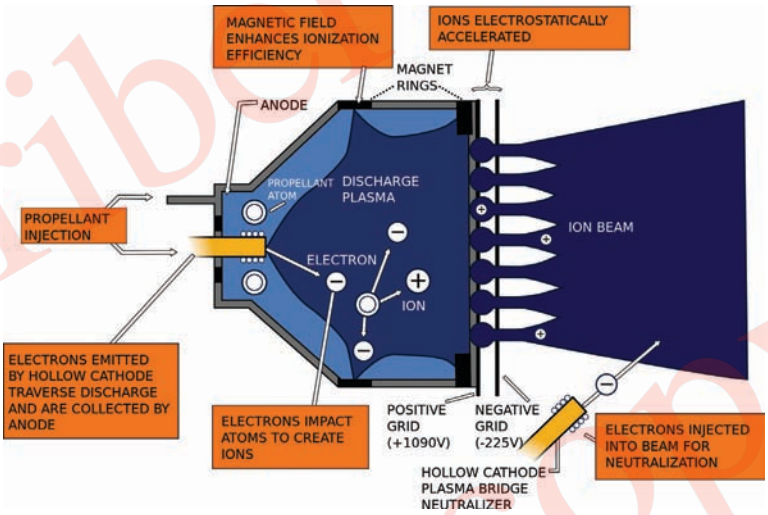
« Corporation provided the spacecraft, their first interplanetary mission.

An important part of the return from the mission has been the proving of new technologies. The radical choice of an advanced ion propulsion system has enabled Dawn to achieve its ambitious goals of visiting and orbiting two different targets beyond the Earth-Moon system. As Marc Rayman explains, "Unlike missions limited to a brief glimpse of their targets during a flyby, Dawn has taken great advantage of being able to conduct comprehensive studies of Ceres and Vesta. And thanks to the manoeuvrability afforded by its ion engines, the spacecraft has frequently changed its orbit to optimize its investigations…We built a very capable spacecraft and developed flexible plans to accommodate the unknowns".

Dawn's engines were based on the system used successfully on the Deep Space 1 trial mission for new technologies between October 1998 and December 2001. A simplified view of how this works is shown here (see diagram). For a more complete description of the propulsion technology used for the mission, visit http://www.nasa.gov/centers/glenn/about/fs21grc.html.

UP, UP AND AWAY

Following its launch on a Delta II from Cape Canaveral on 27 September 2007, Dawn used three xenon ion thrusters (firing only one at a time) to take it on a long outward spiral from Earth into the main asteroid belt, via a gravity assist from Mars. With a specific impulse of 3100 sec and a thrust of 90 millinewtons (mN), the engines were capable of accelerating from 0 to 97 km/h in four days, firing continuously. While a chemical rocket on a spacecraft might have a thrust of up to 500 newtons (N = kg m s-2), Dawn's much smaller engine achieved the same change in trajectory by firing over a much longer period of time, and, above all, using far less fuel. Thus, Dawn was able to conduct rendezvous and orbital insertion manoeuvres with both Vesta and Ceres, as well adjusting to a number of different orbital configurations.



IMAGES: NASA-JPL (LEFT) / NAS (BELOW LEFT)

ABOVE
Dawn's large solar panels power its ion thruster, ionizing its propellant (xenon) and then accelerating it via an electric field created between two grids/electrodes. Electrons are injected into the beam by the neutraliser cathode after acceleration to maintain a neutral plasma.

LEFT
The Dawn spacecraft at the Kennedy Space Center, with folded solar panels.

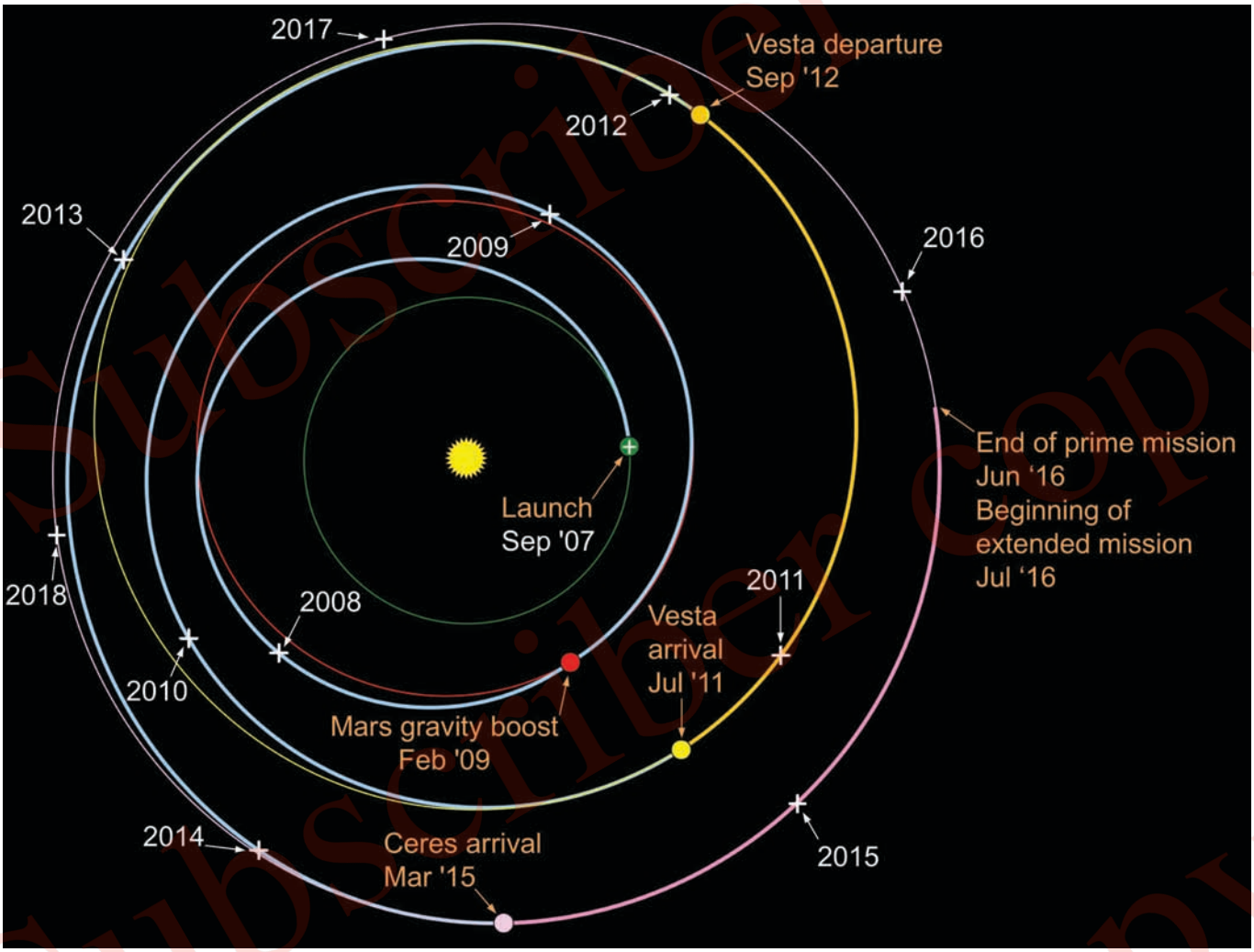
> Dawn's engines were based on the system used successfully on the Deep Space 1 trial mission

The thrusting of Dawn's engines over 5.9 years since launch (53% of the mission time!) has achieved the equivalent of accelerating the probe by 41,400 km/hr. Marc Rayman: "That is about the same as the entire Delta rocket with its nine solid motor strap-ons, first stage, second stage, and third stage, and it is far in excess of what any single-stage craft has accomplished".

Dawn's targets for study are the two most massive objects of the asteroid belt. While small compared to Earth, dwarf planet Ceres (formerly asteroid 1 Ceres) is now estimated (from Dawn's observations) to contain roughly 35% of the total mass in that region of space and protoplanet Vesta (formerly asteroid 4 Vesta) 10%, so Dawn has explored some 45% of the asteroid belt's mass.

Both bodies are regarded as protoplanets, representative of the final, bigger planetary embryos, which came together to form the planets almost 4.6 billion years ago. Only a few of these now remain in the inner solar system. Dawn's observations are helping us to understand the conditions under which these objects formed and the different ways in which they have evolved in this key region close to where the so-called 'frost-line' may have existed. This is the limit beyond which water was able to condense into ice, due to lower temperatures in the solar nebula, whereas in the hotter environments closer to the early Sun water would have combined with other substances to form hydrated minerals.

Ceres and Vesta have been altered much less than other bodies. The Earth is very active and constantly evolving, but Ceres and Vesta are ancient and have preserved a record of the early solar system. Dawn's mission goals included determining their composition and internal structure. Data returned from the spacecraft have enabled us to get an idea of what early conditions of Ceres and Vesta were like and how they have evolved since then. Vesta appears to have been hot



IMAGES: NASA-JPL

and dry, like the terrestrial planets, and experienced at least partial melting and internal differentiation, whereas water seems to have played a role in keeping Ceres much cooler.

VESTA REVEALED

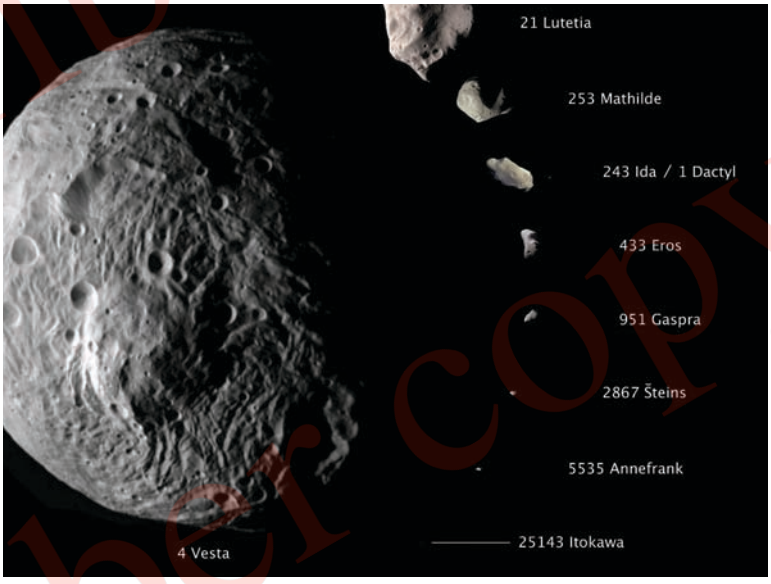
Discovered by Heinrich Wilhelm Olbers on 29 March 1807, Vesta is named after the virgin goddess of home and hearth in Roman mythology. Dawn was the first spacecraft to visit Vesta, entering orbit on 16 July 2011, and successfully completing its fourteen month survey mission of this fascinating body in late 2012. Dawn's instruments revealed a rocky, battered world which reflects the violent early history of the solar system. It accreted from the planetesimals in the region and would perhaps have joined with similar large planetary embryos to form a planet-sized body, were it not for the gravitational influence of massive Jupiter, which disrupted and prevented planet formation in the main asteroid belt, an explanation for the plethora of bodies in this region today. Representative of the type of bodies which eventually collided to form the Earth and other inner planets, it is probably the last of its kind.

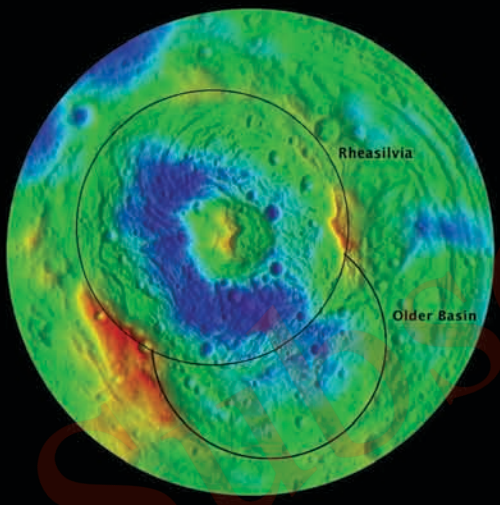
By using radiometric data – that is, detecting tiny variations in the spacecraft's orbit from Doppler shifts in the radio waves of signals transmitted back to Earth – the gravity field and, thus, internal distribution of mass in Vesta's interior was determined. As Marc Rayman explains "If, for example, there is a large region of unusually dense material, even if deep underground, the craft will speed up slightly as it travels toward it. After Dawn passes overhead, the same massive feature will slightly retard its progress, slowing it down just a little".

Dawn showed good evidence for the internal differentiation of Vesta, with a thin crust and rocky (silicate) mantle overlying a metal-rich (iron-nickel) core, estimated to be about 220 km across. This layering, uncommon among asteroids, is borne out by its mean »

ABOVE
Dawn's trajectory, which included a gravity-assisted fly-by of Mars.

BELOW
Vesta compared to other minor solar system bodies.





ABOVE
False colour image showing the relief of Vesta's south polar region and the giant Rheasilvia impact basin with its central peak. Blue areas represent lower elevation, while yellow and red areas show the highest elevations.

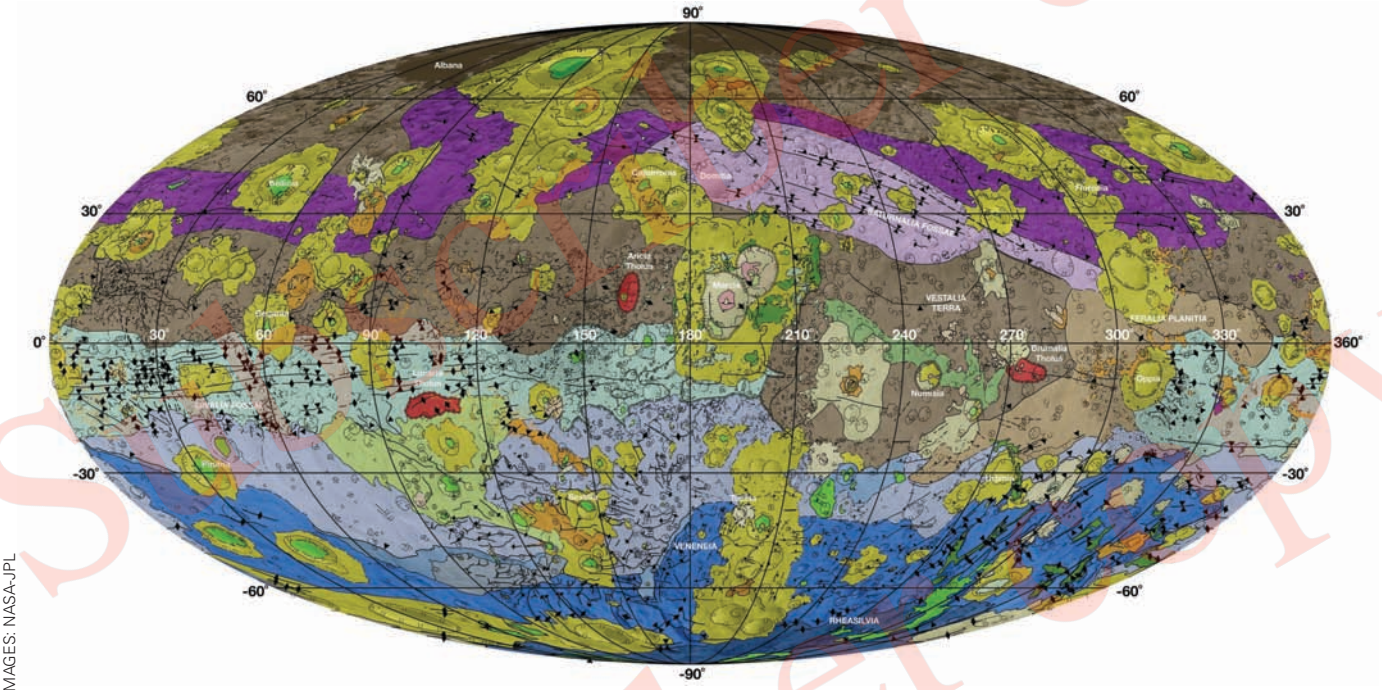
RIGHT
A comparative illustration showing the relative sizes of Ceres, Vesta and the Moon.

IMAGES: NASA-JPL

SIZING UP THE TARGETS

	Mean diameter diameter (km)	Mean distance from Sun (AU)	Mean distance from Sun (million km)	Orbital period (years)	Mass (kg)	Mean density (g/cm^3)
Vesta	528	2.36	353	3.63	2.59×10^{20}	3.456
Ceres	939	2.77	414	4.60	9.43×10^{20}	2.162
Earth	12,742	1.00	150	1.00	5.97×10^{24}	5.510
Moon	3,474	–	–	–	7.35×10^{22}	3.346

LEFT
Building planets through collisions – planetary accretion in the Solar Nebula 4.56 billion years ago.



IMAGES: NASA-JPL

« density (see Table) which is similar to that of our Moon, and not much less than that of Mars (3.93 g/cm^3).

Differentiation would have occurred as heating from radioactive decay, large impacts, and gravitational pressure melted parts of the protoplanet as it grew. In melted zones heavier elements like iron sank to the centre, while lighter materials like silicates rose to the surface. The core is now solid, unlike that of the larger Earth which remains hot, thanks largely to continued radiogenic heating, the heat released by the radioactive decay of certain elements such as uranium, potassium and thorium.

A major source of heating at Vesta will have been impacts, much more frequent during the accretion process when there was a lot more material to be swept up in the inner solar system. There is much evidence of these impacts, both on its heavily cratered and fractured surface, and also in fragments originating from them, many of which end up falling to Earth and other terrestrial bodies as meteorites. An estimated 6% of all meteorites observed on our own planet come from Vesta. Analysis of materials found in them provides supporting evidence for differentiation in the growing proto-planet.

On Vesta itself the scale and violence of impacts early in its history is borne out by at least seven craters of over 150 km in diameter. Most impressive is the scar of an impact which may have come close to smashing Vesta apart, the giant crater named Rheasilvia. The impactor was probably as much as 50 km across, and the resulting basin in Vesta's south-polar region is 500 km across, 12 km deep and is distinguished by a central peak which rises to almost 25 km above the basin floor. This event sent monumental seismic shock waves through Vesta which caused many faults and troughs around its equatorial regions, as well as blanketing the southern half of the protoplanet with a thick layer of debris. This explains the less cratered nature of the south in contrast to the northern regions.

Beyond the rim of Rheasilvia, the rest of Vesta's tormented surface is no less spectacular, and the stories it tells of the distant past will gradually be deciphered by Dawn's science team. The spacecraft broke free from Vesta's sphere of influence in September 2012 to head out towards its next destination, dwarf planet Ceres.

ABOVE
A geologic map of Vesta assembled from multiple Dawn images, illustrating the diversity of such a small world's surface and reflecting its complex early history.

BELOW
Vesta's scarred surface as imaged by Dawn's framing cameras. This mosaic synthesizes some of the best views of the proto-planet.

The scale and violence of impacts early in its history is borne out by at least seven craters of over 150 km in diameter

ODDBALL CERES!

Ceres has been described as an "oddball" in the asteroid belt. Since its discovery on 1 January 1801 by Giuseppe Piazzi, Ceres, named for the Roman goddess of grains, harvests and agriculture, has been considered: firstly as a planet; then an asteroid (or minor planet), when increasing numbers of small bodies were discovered orbiting the Sun between Mars and Jupiter in the 1850s; and, since 2006, as a dwarf planet, being massive enough for its gravity to have pulled it into a roughly spherical shape.

However it is classified today, with a mean diameter of 939 km it is substantially larger than and appears very different from Vesta and other bodies in the main asteroid belt. It has a density closer to that of the big icy moons of the giant planets, like Ganymede or Titan.

The presence of ice was expected to have created differences in the dwarf planet's surface features, when compared to those of Vesta, due to the more flexible nature of ice than that of the latter's rocky surface, »

« even at the relatively low temperatures (130 K-200 K or -73° C to -143° C) found at Ceres. As well as this, Earth or near-Earth observations had hinted at the presence of clay minerals and even traces of water-vapour on or near Ceres, indicating possible past (and even present?) geological activity at its surface.

Given the surprising evidence of activity at Pluto and in some of the icy outer moons of the solar system, there was speculation that liquid water could exist in pockets deep beneath Ceres' surface, even if much of the necessary radiogenic heat in its core has probably long since been lost to space, and there is no large body nearby to produce tidal heating.

After entering into orbit around Ceres on 6 March 2015, thanks to its flexible propulsion system, Dawn's science instruments revealed its nature in detail from a series of ever-closer orbits, including an initial Survey Orbit 4,430 km, from which it made detailed global maps of the dwarf planet with its framing camera and visible and infrared mapping spectrometer (VIR).

Following a problem with a gimbal which moves one of its ion engines, resolved successfully, Dawn descended to reach its High-Altitude Mapping Orbit (HAMO) at 1,480 km, then spiralled in to reach a Low-Altitude Mapping Orbit (LAMO) in December 2015, a mere 375 km above the Cerean surface. From this low altitude the spacecraft's instruments, particularly its gamma-ray and neutron detector (GRaND), were focused on trying to determine the chemical composition at and just below the surface of Ceres.

As at Vesta, from LAMO, Dawn was also able to probe deeper down to try and discover the dwarf planet's internal structure using radiometric data, before moving into a series of Extended Mission orbits from mid-2016. Finally, in June 2018, it descended to its final orbit, Extended Mission Orbit 7 (XMO7), diving down to as close as 35 km above the surface, achieving its highest resolution images.

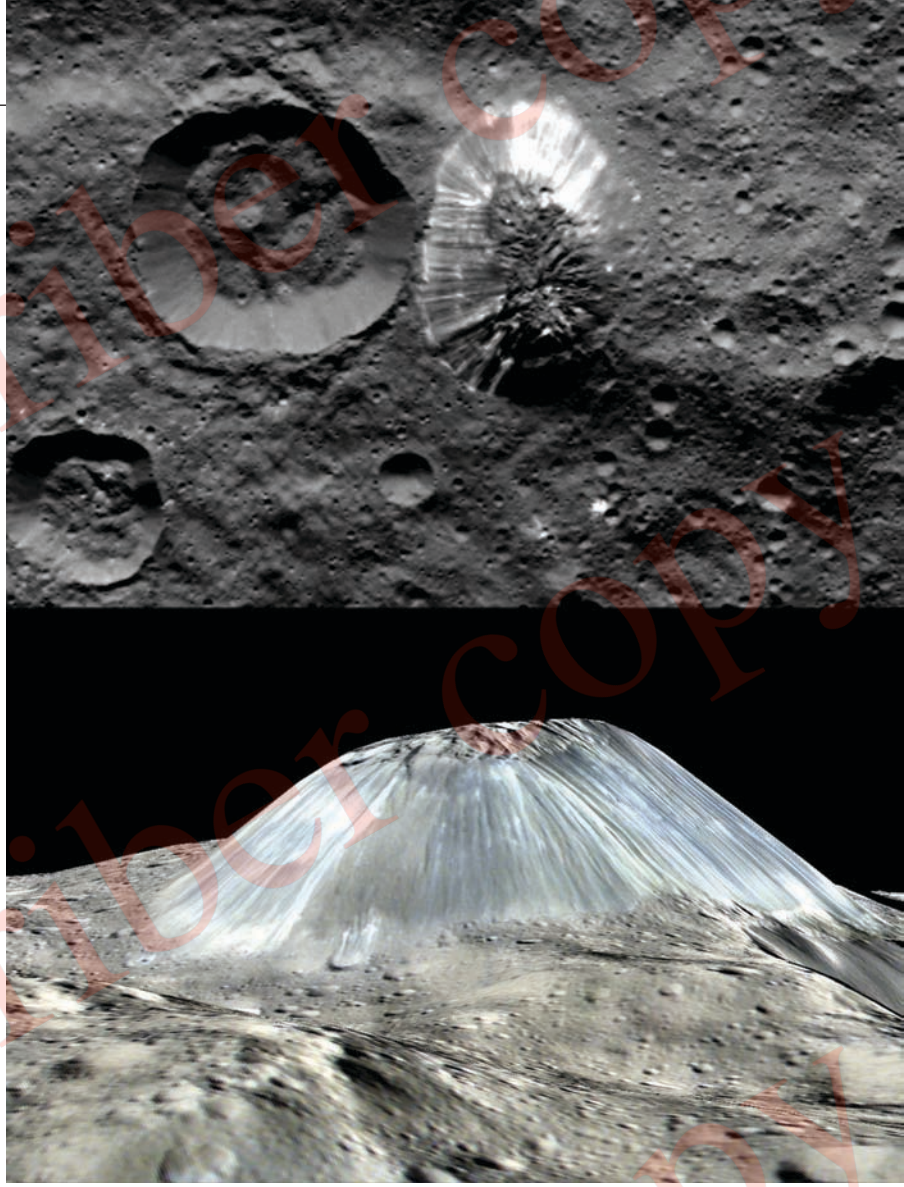
INSIDE A DWARF PLANET

Dawn's measurements now give us an idea of its internal structure, although it isn't yet known if Ceres has a dense core, like the iron-nickel centre of Earth and Vesta, or a rocky one. The mantle is principally hydrated rocks, with minerals incorporating water, such as clay. Above this is a transition zone, 60 km or more thick, consisting not only of hydrated rocks, but perhaps also pockets of briny water, combined in a sort of mud. Surrounding that is the crust, with half the density of the mantle. Crater depth analysis would indicate that this outermost layer, going from the surface down to about 40 km, is made up of about 30-40% ice, mixed with rock and lower-density materials, perhaps hydrated salts and clathrates.

A clathrate is like a molecular cage of water that imprisons a gas molecule. Clathrates are often found on Earth's ocean floors. They are much stronger than ice at the same temperature and make the crust much stronger than it would otherwise be.

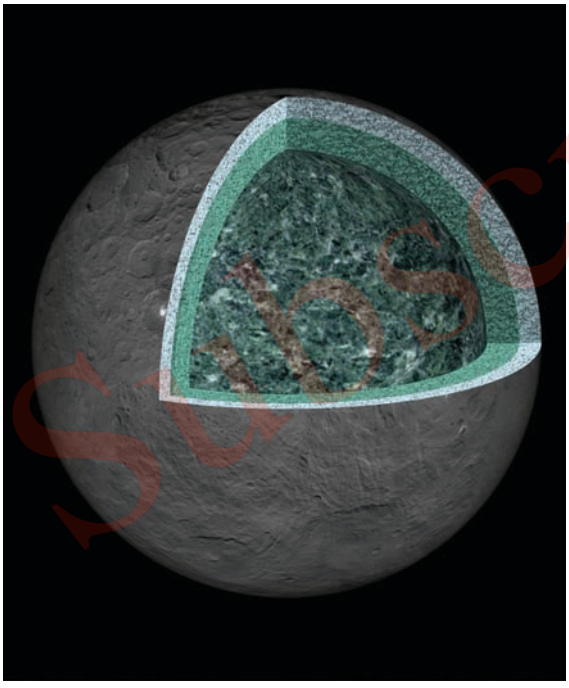
Dawn's instruments have confirmed Ceres' unique status in the main asteroid belt. While its surface is heavily marked by craters of all types and ages, as well as mountains, fractures and faults, like other larger members of this region of the Solar System, its surface indicates a complex geologic evolution. A world with a rich and varied history has been revealed, one which shows evidence of recent and even continuing geological activity.

Ceres' surface composition is broadly similar to that of the C-type (carbonaceous) asteroids common in the outer part of the main asteroid belt. Like them it is dark, with an albedo of just 0.09 - reflecting just 9% of the



ABOVE
Ahuna Mons – a volcanic dome on Ceres imaged by Dawn's High-Altitude Mapping Orbit (top) and a simulated perspective view (below) in which the elevation has been exaggerated by a factor of two. The view was made using enhanced-colour images from Dawn's Low-Altitude Mapping Orbit. The mountain's sharp, unaltered features imply that it is relatively young.

IMAGES: NASA-JPL



LEFT
The Internal structure of Ceres, devised from Dawn data.

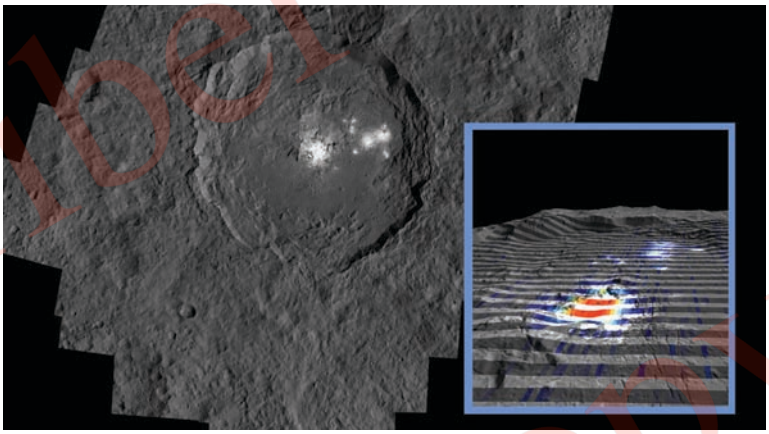
light falling on it - compared to 0.12 for our Moon and 0.30 for Earth. When ice sublimates it leaves behind bright salts which darken from radiation over time. Ceres' surface is relatively warm – up to a maximum of 235K (-38°C) with the Sun overhead at the equator. Water ice is unstable at distances of less than 5 AU from the Sun and sublimates upon direct exposure to solar radiation.

The dark surface is attributed to the presence of organic materials – carbon-containing building blocks of life – some of which have been identified by Dawn's spectral observations. This makes it of considerable interest to astrobiologists looking for clues to the origins and development of life in the solar system and elsewhere. Evidence points to such materials originating within Ceres' interior, possibly in an early interior ocean, much like those thought to exist within icy moons like Europa and Enceladus. Ceres may still preserve some liquid beneath its surface, which increases its interest to astrobiologists.

Despite some similarities, Ceres' surface shows important differences from asteroids, too. The widespread presence of hydrated materials, including phyllosilicates (clays), and localised salt deposits suggests the presence of significant amounts of water in its interior. Some of these clays appear to contain ammonia. This is a significant finding, because such a volatile substance is scarce in the warmer, inner Solar System, but abundant farther out, which has implications when trying to determine the origin of Ceres.

BRIGHT SPOTS AND SALTS

Prior to encounter, Dawn observed intriguing bright spots on Ceres. Closer inspection has found many of these features, or faculae, mainly located near impact craters. The brightest and most striking are found on the floor of the 92 km, 20 million-year old Occator crater. Analysis has shown them to be deposits of salts, particularly sodium carbonate. Described as "the most concentrated known extra-terrestrial occurrence of carbonate on kilometre-wide scales in the Solar System", these bright spots are young, suggesting that "slushy brine" was extruded from buried pockets of liquid water and sublimated (boiled away into space) relatively recently.

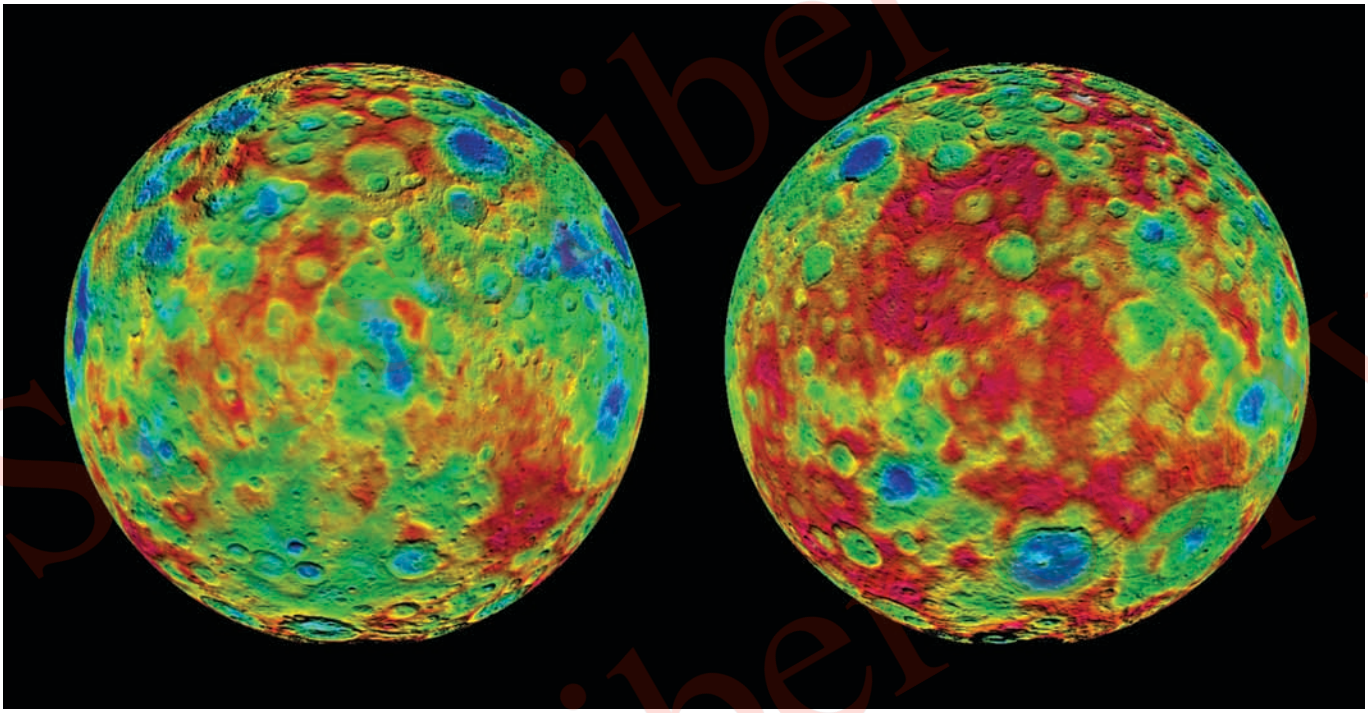


ABOVE
Bright salt deposits in Occator crater on Ceres, imaged from Dawn's Low-Altitude Mapping Orbit (LAMO). Analysis of the data appears to show the highest concentration of carbonate minerals (in red) ever seen outside the Earth.

This is of great significance because they are like salts found in Earth's hydrothermal environments. Some may have been exposed by impacts at Ceres' surface, but most have been formed more recently in processes in its interior involving liquid water, suggesting that it has, or had, a warmer internal temperature than previously supposed.

This raises a number of intriguing questions. Could Ceres still possibly have a remnant internal liquid water ocean beneath its ice layer? The apparent degree of internal activity detected at Pluto was a big surprise, and such activity at Ceres is equally unexpected. More detailed analysis of the composition of salts on the dwarf planet's surface may tell us more about the conditions deep within.

The presence of apparently recent, bright salt deposits at Ceres' surface raises the question of whether hydrothermal activity may still be in progress today. Did it force salts up to the surface? The fractured dome at the heart of Occator's bright central region could be of volcanic origin, forced upwards by material rising from the interior. »



BELOW
Colour-coded maps revealing the topography of Ceres. The map at left is centred on 60° E; the map at right is centred on 240° E. The colour scale extends from about 7.5 km below the surface (in indigo) to 7.5 km above (in red).

« Possible evidence to support the theory of active replenishment of ice or water at Ceres' surface is a haze that appears occasionally above some of Occator's bright spots at local noon-time, when the Sun is high overhead, enhancing sublimation, and creating a thin transient local atmosphere in this particular region of Ceres. This is the first body in the asteroid belt where such a process has been observed directly, and would support observations from Earth, made by ESA's Herschel Space Observatory in January 2014, of water vapour being emitted from mid-latitude sources on Ceres.

Hydrothermal activity is a form of volcanism, and other evidence from Dawn suggests that cryovolcanism – cold volcanism involving volatiles like water ice – has occurred on Ceres at least in recent geological time, not least the spectacular "lonely mountain" of Ahuna Mons, which stands up to 5 km above its surroundings near the dwarf planet's equator. Resembling a volcanic dome, it probably formed as a "salty mud" volcano. It is unique so far in the Solar system, being the first-observed cryovolcano produced by a mixture of brine and clays, as opposed to rock or ices. Although not active now, Ahuna Mons appears surprisingly young geologically-speaking. Bright, sharp, steep-sloped and unmarked by craters, it also has fine features like rock-falls which have not yet been obliterated by long-term processes such as micrometeorite erosion.

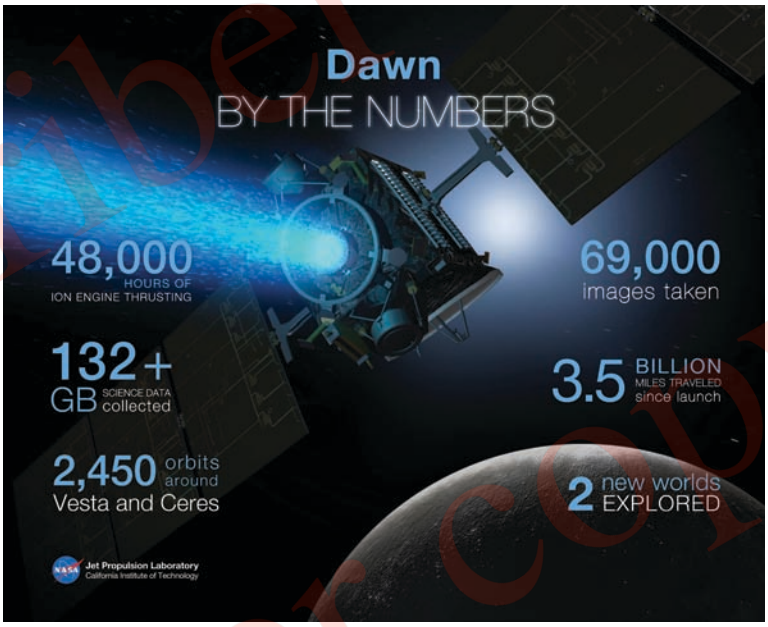
Recent volcanism on an isolated dwarf planet is a surprise, as usually only planets, or natural satellites orbiting around them, have volcanism. Ceres has certainly provided us with many surprises so far and there are no doubt more to come. One of them, the discovery of ammonia-rich materials, may lead to planetary scientists having to rethink our ideas on the dwarf planet's origins and formation.

Ceres is possibly a remnant proto-planet, like Vesta a survivor from the violent planet-building processes of the early Solar System 4.57 billion years ago, if different in composition. However, the presence of ammonia-rich clays on Ceres' surface raises the question as to where and how exactly it originated. Ceres appears to be a transition world, neither totally rocky, nor an ice world. But, while it's close to the so-called "frost-line" in the Solar System, it's not in a cold enough region for such ammonia-bearing materials to form.

So, did it form where it is, and accumulate ammonia-rich material migrating inwards from the early outer Solar System? Or, did Ceres form in the vicinity of Neptune and then move inward when the migration of the giant planets was disrupting these outer regions some four billion years ago, flinging most such objects out to form the Kuiper Belt or even out of the Solar System altogether? Hopefully, further analysis of Dawn's data in the coming years will give us information to help understand this better.

DAWN'S FUTURE?

Dawn may have fallen silent now, but its mission is far from over. Its sensors and cameras have returned sufficient data to keep mission scientists busy for decades in their quest to understand the birth and evolution of planetary bodies, both in our own solar system and around distant stars. It is showing us how important relative location can be in their differing histories, and has added more evidence for the idea that smaller worlds like dwarf planets and large moons could have developed oceans – and may indeed still have substantial subsurface bodies of water.



ABOVE The major achievements of one of NASA's outstanding missions, the Dawn survey of Vesta and Ceres.

"We are lucky to live in a culture in which we have the resources to invest in such projects, just as we do in art"

Dr Mark Rayman
Project leader

As for the spacecraft, Marc Rayman says that "Thanks to curious and creative creatures on Earth, Ceres now has a moon named Dawn". Because of Ceres' chemistry and potential interest to astrobiology, planetary protection protocols have been implemented by NASA. Dawn will remain in a relatively stable orbit around Ceres for at least 20 years, and probably for five decades or more, before crashing onto the dwarf planet's frozen, cratered surface, "an inert, celestial monument to human creativity and ingenuity".

At a time when spending on planetary exploration is being squeezed, and we often hear questions about "why money should be spent on space", Dawn is a great advertisement for the cost-effectiveness and enormous returns of such scientific projects. The total cost of Dawn came in at $492 million. Marc Rayman says that, "at about $1.50 per inhabitant of the USA – just 75¢ per (visited) world, the price of a can of coke – that's a pretty good deal. I think the return truly is fantastic."

And of course there are far greater benefits, as Dr. Rayman explains: "We are lucky to live in a culture in which we have the resources to invest in such projects, just as we do in art. These enrich all of us, help us discover our place in the Universe and open our eyes to new worlds, both literally and figuratively". SF

ACKNOWLEDGEMENTS

- Thanks to Dr. Marc Rayman for comments and interviews, and for permission to use material from his informative and fascinating "Dawn Journal" at: http://dawn.jpl.nasa.gov/mission/journal.html
- For mission overview and news: http://dawn.jpl.nasa.gov/
- Detailed scientific papers on Ceres and Vesta by the mission's science team can be found in Science magazine, 2011-12 and 2016-17.
- For an introduction to early Solar System evolution: An Introduction to the Solar System, Ed. David A. Rothery, Neil McBride & Iain Gilmour, Cambridge University Press, 3rd Edition, Jan 2018.

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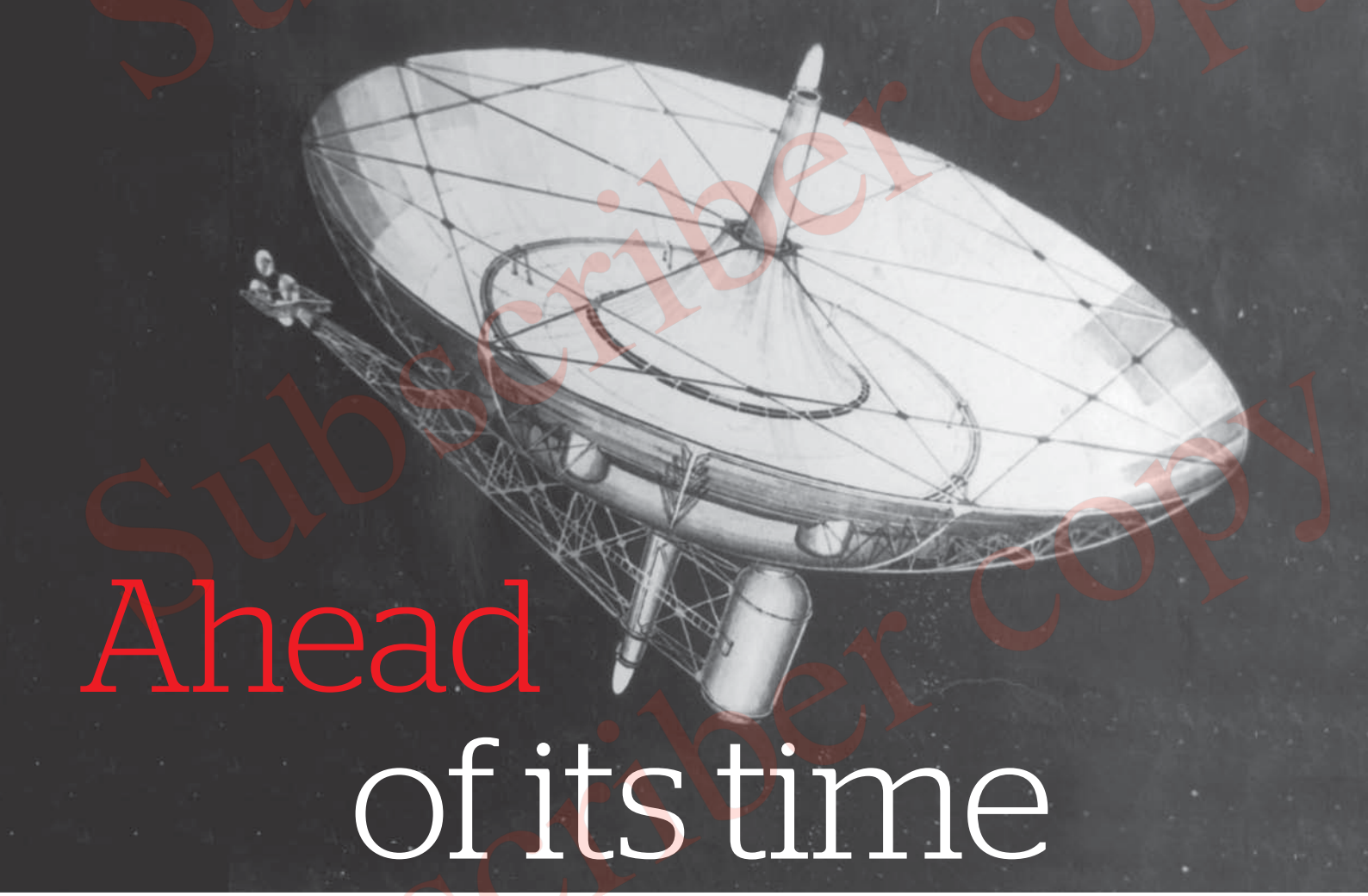


Ahead of its time

In the January 1949 issue of JBIS, a paper appeared with the title "Orbital Bases" under its author H.E.Ross. In fact, it had been presented the previous November and was the work of two people – Ross and the artist R. A. Smith.

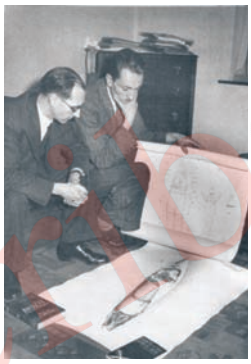
by **Bob Parkinson MBE FBIS**

Harry Ross and Ralph Smith first met one another in the pre-War days of the BIS. They were part of a small, enthusiastic group attempting to design a vehicle capable of landing three men on the Moon and bringing them back. The two men became firm friends, and were active in re-animating the Society after the War.

New calculations in 1948 showed them that getting to the Moon in one go was going to be almost impossible. Now they proposed that the mission should be carried out in stages – first assembling a vehicle in low Earth orbit from multiple launches, and then performing a lunar orbit rendezvous where the Moon Lander could be refuelled. (This idea of orbital rendezvous put forward in Ross' paper later acted as inspiration for NASA in the Gemini and later Apollo programmes.)

The idea of a space station was not original to Smith and Ross. The concept dated back at least as far as 1928 in a book "Das Problem der Befahrung des Weltraums" by the pseudonymous Hermann Noordung (actually a Slovene ex-officer in the Austrian Army), and can probably be traced back to Konstantin Tsiolkowski.

What Smith and Ross had done in their paper was to attempt a detailed design for such an orbital base – or possibly bases, as in the plural! Arthur C. Clarke's ground-breaking 1946 paper on communications satellites had envisaged three large manned bases in geosynchronous orbit handling all the long distance communications for Earth at once, and a diagram of the concept also had a "refuelling zone" in low Earth orbit as well as other orbits for meteorology and astronomy.



ABOVE
R. A. Smith (left) and H. E. Ross muse over the drawings for the 1948 BIS Space Station.

TOP
The Ross Space Station illustrated by Smith which became the first serious post-War concept for a manned orbiting facility.

THE BIG BUILD

As described by Ross, the Space Station had three components which he described as a "bowl," a "bun" and an "arm". The "bowl" was to be a parabolic annular mirror some 60.9 m in diameter which collected sunlight and focused this energy on a system of pipes acting as the "boiler" for the Station's power supply requirements. A mirror of that size would collect some 3900 kW of solar energy, and they thought this might provide nearly 1000 kW of electricity through eight turbo-generators housed in blisters spaced around the circumference of the "bun". (With hindsight their estimate for power conversion efficiency was very optimistic, but the power generated would be far in excess of that needed for any realistic space station.)

The "bun" – a cylindrical disk structure on the

rear of the mirror – provided pressurized living quarters. Because Smith and Ross thought that zero-gravity would not be acceptable as a long-term environment for its crew, both mirror and living quarters were to rotate about a central axis to provide "artificial gravity". They estimated that, rotating once every seven seconds, a 1-g "gravity" could be provided "three feet from the floor" in the lower floor, and 0.43-g on the upper floor.

Current estimates suggests that at this rotation rate Coriolis effects might have proved somewhat uncomfortable – there would have been an 18% difference between "gravity" at head height and foot height. But with a diameter of 26 m across the lower floor, the station provides a total floor space of 683 m2, subdivided into rooms, laboratories, workshops etc and with automatic closing bulkheads to limit damage in the event of accidents or meteor penetration. They estimated a permanent staff of 24 would be required, giving a generous 28 m2 per person.

The large "hub" of the Station would house air and water storage and a reclamation plant and the radio gear, plus six "reaction flywheels" providing attitude and spin control. Smith and Ross proposed that the central axis of the Space Station might house a telescope, looking through a counter-driven system of mirrors to provide a stationary image of the outside as the Station revolved.

The final component of the Station was a long lattice arm, supported on bearings on the central axis of the Station behind the living quarters. Normally this arm would be kept stationary (non-rotating). One end of the arm would carry the radio antennae serving the Station's communications. The other (shorter) end carried a two-deck airtight cylinder with an airlock chamber at each end. This provided a zero-g laboratory, but it also acted as a vestibule for entry to and exit from the Station.

When crew or cargo was to be brought aboard, incoming vessels would first dock with this "vestibule" in a stationary location. When the cargo or crew had been unloaded, the arm would be driven until its speed of rotation matched that of the main Station and the vestibule's inner door matched the airlock location in the outer gallery of the rotating facility. An airtight seal would then be made between the two and entry made into the Station.

LOGISTICS

The paper made an estimate of the life-support supplies that would be required to maintain the crew – each year some 12 tonnes of food, 14 tonnes of oxygen and 44 tonnes of water, assuming that much of the water could be recovered and recycled. Smith and Ross proposed that the oxygen could be brought to the Station as hydrogen peroxide, and then decomposed into oxygen and water – the latter contributing to the water required by the Station. Exhaled carbon dioxide, they proposed, could be removed by circulating the station's air through radiator pipes located on the shadowed side of the Station and freezing out the CO2.

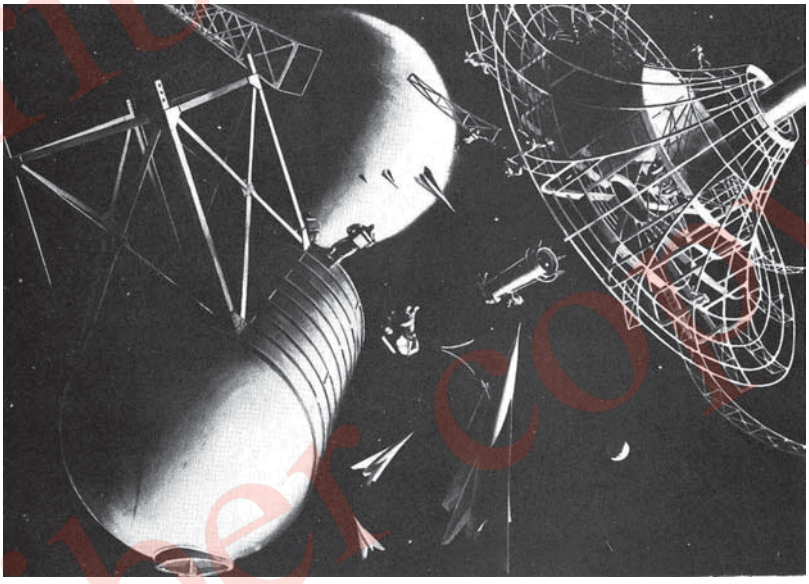
The shadowed side of the Station might not have been as cold as Smith and Ross thought. With the Station capturing 3900 kW of solar energy, then eventually all of this energy will appear as heat to be radiated away again. The authors touch on thermal aspects of the design, but do not attempt any calculations. If they had, they would have found that with the entire rear surface of the Station acting as a radiator it would need to be at 402° K (129° C) to get rid of this much energy.

This idea of orbital rendezvous put forward in Ross' paper later acted as inspiration for NASA in the Gemini and later Apollo programmes

The proposal was that the Station would be constructed in orbit from components ferried up by a succession of launch vehicles. Ralph Smith even produced a painting showing the Station in the process of construction, which won an award for its use of perspective. Although they make comments in their paper about the difficulties of rendezvous in orbit they then make the assumption (common to everybody at the time) that because there is "zero-g" in orbit, parts having been delivered would simply float freely alongside the growing Space Station, benignly awaiting installation. We now aware that each component is in its own, individual orbit and each of the bits will tend to float away from one another. Disturbed by residual forces the components will eventually form a cloud about the Earth. To a modern eye this picture looks like a space debris cascade in the making.

The Smith-Ross Space Station appears, albeit briefly, in two of Arthur C. Clarke's early science fiction novels – "The Sands of Mars" (1951) and "Islands in the Sky" (1952), in the latter case somewhat enlarged since it now has to handle traffic from interplanetary liners shuttling colonists to and from Mars.

A variant of this design formed the cover to Spaceflight for October 1958. By this time solar cells had started to become available for generating power, and the new design had replaced the paraboloid mirror with a 60 m diameter flat mosaic of solar cells. Instead of one lattice boom two were depicted. One carried radio and television arrays and cameras as before, the other a 2.5 m Cassegrain telescope complex fitted with an interferometer beam. Access from the Station was now by a tunnel along the boom. A "space taxi" docking port was also incorporated at the axis of the Station, as the upper part of the variable-g chamber. SF



BELOW
Elements of the Space Station in free-floating proximity to each other, a formation which in reality would have gradually dispersed.

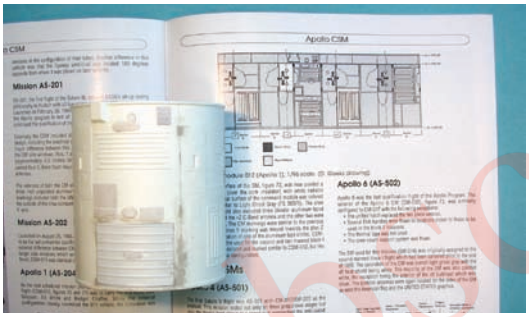
MULTI-MEDIA

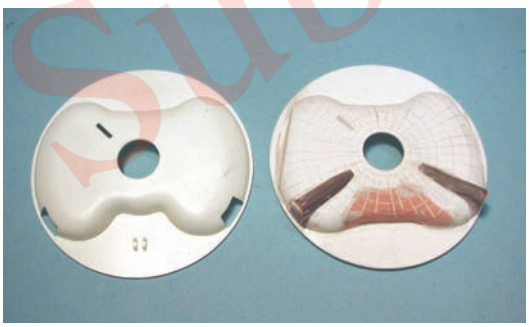
SpaceFlight reviews the latest books, websites, films, TV programmes and games for space enthusiasts of all ages

SPACE MODELS

WHAT'S NOT RIGHT... and what's just wrong

The model kit industry – especially the American one – was obviously very interested in the exciting possibilities opened by the Apollo programme, and it wasn't long before a number of kits hit the market. The problem was that Apollo was constantly changing, but decisions have to be taken when you are making the tooling for a model kit. The most comprehensive Apollo kit made is the 1:48 scale "Apollo Spacecraft" from Revell. But the kit arrived so early that it was based on interim boiler-plate designs. To the purists, the inconsistencies rankled. All crewed Apollo Missions used a Block II Service Module, the unmanned missions used a Block I, and there are visual differences. Even the Service Module in the Revell kit is not an accurate Block I, but a Block 0. Here the project is to convert the 1:48 scale Revell Apollo SM into a more accurate Block I and then to ompare that to a Block II.





ABOVE
One of the many issues of this particular kit from Revell – and you can see this was issued to celebrate the 25th Anniversary!

Author's note
I am indebted to Mike Mackowski's excellent *Space in Miniature* book series, #6' of which covers the Apollo Command and Service Modules. For more details visit **www.spaceinminiature.com.**

LEFT
Converting the radiator pattern to the correct Block I. The reference being used is from Mike Mackowski's Space in Miniature series, #6. Mat Irvine

BELOW LEFT
Converting the SM base pate – the kit original on the left, modified on the right using car filler. Mat Irvine

RIGHT
Removing the two extra 'rings' on the engine bell.

SEEKING PERFECTION

Revell kit is comprehensive, with an interior to the Service Module but this was cemented together. The panel that originally opened was strengthened with plastic strip and any gaps filled with modelling putty. The parachute housing on the tip of the Command Module needs the Launch Escape System tower locator pins removed, and any holes filled. In addition the engine bell has the lower two rings of the three removed. As an example that even "official" drawings are not necessarily correct, there was just one ring on the engine bell for both Block I and II, and although the upper ring of the Revell version is not quite in the correct position, it is acceptable to file off the lower two, leaving the upper one. Next, the plate that holds the engine bell is moulded in a "figure 8" in shape, but

IMAGES BY THE AUTHOR

GAMER'S CORNER with Henry Philp

Apollo 8 in Kerbal Space Program

Since the you will receive this on the 50th anniversary of Apollo 8, the first crewed space flight to the Moon, I decided to pay homage to the mission by recreating it in Kerbal Space Program. It's not a perfect recreation, because the solar system in KSP is 1/10th scale, so velocities and travel times are different.

Our spacecraft is quite realistic, however, with the Saturn V S-IC, S-II and S-IVB stages, Command Module, Service Module and even the launch escape tower with Boost Protective Cover. It is crewed by Frank, Jim and William Kerman (all of the surnames are "Kerman" in KSP, but I created custom first names to match the real Apollo 8 crew).

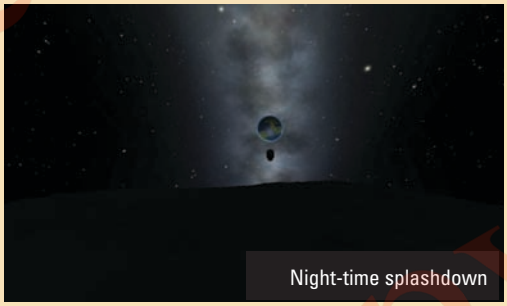
During the launch, I did not model the central F-1 engine shutting down at 126-139 seconds, dependent on mission, to reduce oscillations (this was done on all but the first two Saturn V flights) and the interstage remained attached to the S-IC during staging (the way KSP handles staging prevented me from detaching the interstage after S-II ignition). In the game, Kerbin (the Earth analogue) has two natural satellites, but we will be focusing on the Moon analogue and inner satellite, the Mun, for this mission.

While Apollo 8 took 68 hours to get to the Moon, my Kerbal recreation only took six hours to travel there. (Note, on Kerbin one day is approximately 6 hours, so my mission only took one day to get to its target). The crew took a nice Kerbinrise shot (unfortunately the surface was in darkness at this time) to echo the famous Earthrise shot taken by Bill Anders.

Soon we left Munar (lunar) orbit and performed a direct re-entry. If I had timed it right, I could have done a realistic skip re-entry, but that didn't happen this time. Also, we landed in darkness, which I don't believe any Apollo mission did. Due to the downscaled Kerbal solar system, the total mission elapsed time was two (Kerbin) days, zero hours, twenty-nine minutes, fifty-seven seconds, compared to the real mission elapsed time, which was 6 days, 3 hours, 42 seconds. In July 2019, I will do a homage to Apollo 11, to commemorate that mission's 50th anniversary.

Blast-off!

Arrival at "the Mun"



Night-time splashdown

for a Block I is more like a very fat "B". So it was filled in with an epoxy resin filler and re-scribed.

Although the radiators are mostly Block I type, one quadrant especially needs changing. One of the existing radiator panels needs shortening, by sanding off the lower section, and the lowest area needs a radiator added. Embossed plasticard is available with a suitable pattern and it could be cut and glued straight onto the surface of the SM. However the panel is flush with the surface, so to be slightly more authentic, an area of the existing SM needs cutting out, recessing (to support the embossed plastic), and this glued in place on top. The radiators can them be primed and painted gloss white.

BELOW
The completed 'Block I' showing the original colours and compared to a correct Block II – this is the resin kit from Real Space Models.

Most of the modules for most of the Apollo Missions (Block I and Block II) differed. Here it is built to match the ill-fated Apollo 1, the Command Module of which caught fire during practise in 1967 tragically killing the three astronauts inside – Gus Grissom, the second American into space; Ed White, the first American to walk in space, and Roger Chaffee.

For this craft the SM had all five radiator panels, plus the area under one of the thruster quads, in white. The rest is bright aluminium in colour. The quads themselves were also silver, while the thruster nozzles are a dark metallic grey – almost black.

The Command Module was uniform grey at this time, only broken by the red surrounds to its own thrusters, and three shiny aluminium panels (which were antennae). These are positioned one each either side of the forward facing windows, and the third further round near the rear scimitar antenna. The two scimitar antenna covers were still on the CM for the Block I, for Block II they were moved to the SM. Finally two UNITED STATES and Star and Stripes decals (supplied in the Revell kit) can be applied to the CM. Again with the Block II these moved to the SM.

Mat Irvine FBIS

Satellite Digest 552

Satellite Digest is *SpaceFlight's* regular listing of world space launches using orbital data from the United States Strategic Command space-track.org website.

Compiled by **Geoff Richards**

Spacecraft	International designation	Date	Launch site	Launch vehicle	Mass (kg)	Orbital epoch	Inclin. (deg)	Period (min)	Perigee (km)	Apogee (km)	Notes
SAOCOM 1A	2018-076A	Oct 8.10	WTR	Falcon 9FT	3,000	Oct 8.24	97.90	97.17	616	635	[1]
Yaogan 32-01 01	2018-077A	Oct 9.11	Jiuquan	Chang Zheng 2C/YZ-1S	1,000?	Oct 15.33	99.28	98.65	695	697	[2]
Yaogan 32-01 02	2018-077B				1,000?	Oct 12.73	99.28	98.65	695	697	[2]
Soyuz MS-10		Oct 11.36	Baykonur	Soyuz-FG	7,220	Failed to reach orbit					[3]
Beidou DW39	2018-078A	Oct 15.18	Xichang	Chang Zheng 3B/YZ-1	1,060	Nov 13.02	55.01	773.18	21,510	21,546	[4]
Beidou DW40	2018-078B				1,060	Oct 15.50	54.99	787.26	21,538	22,193	[4]
AEHF 4	2018-079A	Oct 17.18	ETR	Atlas V 551	6,170	Oct 30.27	7.67	1,084.84	21,856	35,338	[5]
BepiColombo	2018-080A	Oct 20.07	CSG	Ariane-5ECA	4,081	Heliocentric orbit					[6]
Haiyang 2B	2018-081A	Oct 24.96	Taiyuan	Chang Zheng 4B	1,575	Oct 29.06	99.35	104.37	965	968	[7]
Tangguo Guan	2018-081B				1,750?	Oct 25.46	99.45	100.63	641	940	[8]
Kosmos 2528	2018-082A	Oct 25.01	Plesetsk	Soyuz-2.1b	6,000	Oct 29.96	67.15	103.04	900	910	[9]
Weilai 1		Oct 27.33	Jiuquan	Zhuque 1	30?	Failed to reach orbit					[10]
Zhongfa Haiyang WX	2018-083A	Oct 29.03	Jiuquan	Chang Zheng 2C	600	Nov 1.62	97.53	94.93	516	518	[11]
Xiaoxiang 1-02	2018-083B				8	Oct 29.75	97.53	94.93	510	523	[12]
Tiange 1	2018-083C				8	Oct 29.69	97.52	94.92	509	524	[13]
Tongchuan 1	2018-083D				8	Oct 29.36	97.52	94.90	507	524	[14]
CubeBel 1	2018-083E				2	Oct 29.36	97.54	94.88	505	524	[15]
Tianqi 1	2018-083G				?	Oct 29.69	97.52	94.92	510	523	[16]
Changsha Gaoxin	2018-083H				8	Oct 29.69	97.53	94.93	510	524	[17]
Ibuki 2	2018-084B	Oct 29.17	Tanegashima	H-IIA 202	1,800	Nov 2.52	97.85	96.81	598	617	[18]
KhalifaSat	2018-084F				330	Oct 29.42	97.83	96.70	592	613	[19]
Ten-Koh	2018-084G				23	Oct 29.98	97.84	96.60	587	608	[20]
Diwata 2B	2018-084H				56	Oct 29.35	97.83	96.51	586	601	[21]
Aoi	2018-084J				1	Oct 29.62	97.84	96.49	586	598	[22]
Gama Kyubu	2018-084K				2	Oct 30.36	97.83	96.50	585	601	[23]

NOTES

1. ***Satélite Argentino de Observación Con Microondas*** **(Argentinian Satellite for Microwave Observation), a radar earth survey satellite built by INVAP for CONAE, carrying a polarimetric L-band synthetic aperture radar for Earth imaging for soil moisture content and other purposes and a thermal infra-red camera for detection of fires. Will be operated in conjunction with COSMO-SkyMed system under the SIASGE agreement with ASI.**

2. **Yaogan 32 Group 01 pair of Earth observation satellites built by DFH Satellite for "electromagnetic measurements and related technical tests", possibly Jianbing type for signals intelligence. First use of Yuanzheng 1S (YZ-1S) upper stage, a simplified version of the YZ-1 for short-duration missions.**

3. **Spacecraft with two-man crew launched to the International Space Station, mission ISS-56S. Crew comprised Aleksei Ovchinin (Soyuz Commander, ISS flight engineer) and Nicklaus Hague (Soyuz/ISS flight engineer, NASA astronaut). Launch vehicle failed due to problem with jettison of one first-stage unit. Emergency escape system activated and crew landed safely 400 km downrange near Zhezkazgan in Kazakhstan. Crew were to be part of ISS Expeditions 57 and 58.**

4. **Pair of third-generation Beidou navigation satellites, also known as Compass 3M15 and 3M16, built by SECM for SASTIND. Launched into plane A of system. Beidou DW39 has manoeuvred to slot 1.**

5. **Advanced Extremely High Frequency SV-4, or USA-288, is a military telecommunications satellite using a Lockheed-Martin A2100M bus, launched for the USAF by ULA. Mass quoted above is at launch. Orbital data is classified, transfer orbit given above is from amateur trackers.**

6. Bepi Colombo, named for the Italian astronautics pioneer, is a Mercury probe built by Airbus and NEC for ESA and JAXA and is an assembly consisting of a Mercury Transfer Module (MTF) and two Mercury orbiters. MTF provides power, propulsion, including four xenon electric thrusters, and attitude control during seven-year journey to Mercury. The 275 kg JAXA orbiter, named Mio (waterway, with a connection to sailing the Solar wind) or MMO (Mercury Magnetospheric Orbiter) built by NEC is a spin-stabilised satellite carrying two magnetometers (MGF) for fields of Sun and Mercury, an array of seven instruments (MPPE) for low-energy particles and plasma around Mercury, a sensor (MDM) for dust particles, an imager (MSASI) for sodium in the atmosphere of Mercury and three receivers (PWI) for plasma waves and solar radio emissions. The 1,838 kg ESA orbiter, MPO (Mercury Planetary Orbiter), built by Airbus is carrying a laser altimeter (BELA) for surface topography, a three-axis accelerometer (ISA) for use in conjunction with a Ka-band transponder (MORE) to measure Mercury's internal structure and conduct relativity checks, two fluxgate magnetometers (MERMAG) for fields of Sun and Mercury, an infra-red radiometer/spectrometer (MERTIS), an imaging X-ray spectrometer (MIXS) and a γ-ray and neutron spectrometer (MGNS) for Mercury surface composition, two ultraviolet spectrometers (PHEBUS) for Mercury exospheric composition, two ion mass spectrometers and two neutral particle analysers (SERENA) for direct measurement of exosphere, a stereo camera system with hyperspectral and high-resolution capability (SYMBIO-SYS) for Mercury surface geology, a solid-state X-ray spectrometer (SIXS) for Solar activity and a jettisonable thermal shield (MOSIF) for Mio. Probe will reach target with combination of electric propulsion and gravitational-assist fly-bys of Earth, Venus and Mercury. First fly-by of Earth is scheduled for April 2020.

7. *Haiyang* ocean survey satellite built by CAST, apparently using an FY-3 bus, for the MNR (Ministry of Natural Resources) with a radar altimeter, microwave radiometer and scatterometer for monitoring sea temperature, sea-surface states and winds, an AIS receiver to track shipping and a store-and-forward transponder to collect data from ocean buoys.

8. *Tangguo Guan* (Candy Jar) was a 29 kg payload for Alibaba attached to the final stage rocket. It included a transponder to communicate with users of AliExpress mobile phone service and the Yuquan 1 (possibly named for the campus of Zhejiang University) set of experiments including Earth and space imaging, communications and computing for Galaxy Aerospace. Stage also carried the SPP (Space Proving Platform) with the Marvel Tech (Shainghai ManWei Technology) DSB-01 payload of DNA samples from eight people in a radiation-proof container, demonstration for a gene-bank for future long-term preservation of human genome.

9. Lotos-S1 (804) electronic intelligence satellite built by KB Arsenal using a TsSKB Progress Yantar bus for MORF. Orbital plane is 120° from that of Kosmos 2523, the previous Lotos.

10. *Weilai* (Future) technology development satellite built using a Micro-NST MN10 bus for China Central Television (CCTV) carrying a camera for Earth imaging and an experiment to investigate decomposition of potatoes. Landspace Zhuque 1 (Vermilion Bird) is a new commercial launch vehicle, possibly a modified DF-26 MRBM with a new third stage. Attitude control failed during third stage burn due to a propellant leak. Planned orbit was Sun-synchronous.

11. *Zhongfa Haiyang Weixing* or CFOSat (China-France Oceanography Satellite) ocean monitoring satellite built by DFH Satellite using a CAST-2000 bus for CNSA and CNES carrying a Ku-band rotating fan-beam scatterometer (SCAT) for surface wind speed and direction and a Ku-band radar with a rotating antenna assembly (SWIM, supplied by France) for ocean wave measurement and surface winds. The launch announcement mentioned a seventh small Chinese payload, but none has been officially named and there is no candidate object. It is currently not clear which payload corresponds to which object.

12. *Xiaoxiang*, also known as Tianyi 1-02, is a technology development 6U Cubesat built by SpaceTy (Changsha Tianyi Space Technology Research Institute) carrying a laser communications system for performance test. Pathfinder for planned 288-satellite constellation for LaserFleet (Shenzhen Hangxing Optical Network Space Technology Co.).

13. *Xinghe* (Galaxy), also known as Tianyi 1-03 and Tianfu Guoxing 1 (Tianfu New Area), is a technology development 6U Cubesat built by SpaceTy carrying a camera for Earth imaging. Also investigating use of Artificial Intelligence. Pathfinder for planned 192-satellite constellation for ADA Space (Chengdu Guoxing Aerospace Technology Co.).

14. *Tongchuan*, also known as Tianyi 4-02 or Zhaojin 1 (Photo), is an astronomy and technology development 6U Cubesat built by SpaceTy for Tsinghua University and Tongchuan city carrying a solid-state crystal scintillator detector (GRID) for γ-ray bursts and a transponder for inter-satellite communications. First satellite for Tiange astrophysics project of Tsinghua University to launch a constellation of satellites to detect γ-ray bursts from merging neutron stars. Also intended to test new commercial ground station at Tongchuan.

15. CubeBel 1 or BSUSat 1 is an educational and scientific 2U Cubesat built by Belarusian State University with a camera for Earth imaging, an infra-red sensor, a spectrometer for γ-radiation and an amateur-band digipeater and transponder.

16. *Tianqi 1* (Revelation) communications technology satellite built by Guodian Hi-Tech (Beijing Guodian Hi-Tech Co.) to demonstrate satellite IoT data acquisition applications. Pathfinder for planned 38-satellite constellation.

17. *Changsha Gaoxin* (Changsha High-Tech Zone), also known as Tianyi 4-01, is a technology development 6U Cubesat built by SpaceTy carrying a transponder for amateur communications and systems from the new 0805 bus for performance test.

18. *Ibuki* or GOSAT 2 is a climate research satellite built by Mitsubishi for JAXA carrying a four-band visual to thermal spectrometer (TANSO-FTS) for atmospheric carbon dioxide and methane and a four-band ultraviolet to infra-red imaging radiometer (TANSO-CAI) for clouds and aerosols.

19. KhalifaSat (named for Sheikh Khalifa Bin Zayed Al Nahyan, President of the UAE) Earth survey satellite built using a SaTReC SI-300 bus by MBRSC (Mohammed Bin Rashid Space Centre, formerly EIAST) carrying a panchromatic and multi-spectral visible/infra-red imaging system (KHCS) for Earth resources imaging.

20. *Ten-Koh* technology development and scientific satellite built by Kyushu Institute of Technology with CFRTP material samples for effects of space, a magnetometer for the Earth's field, a suite of instruments (SHARP-CPD) for radiation, two Langmuir probes for electron density, a UHF transponder for communications and an ultra-capacitor for performance test.

21. *Diwata* is a survey and technology satellite built by PHL-Microsat group for DOST and is carrying a telescope and CCD camera array (HPT) for Earth imaging for disaster monitoring, a multispectral

visible/infra-red imager (SMI/LCTF) for ocean colour and vegetation, a high-resolution camera (ERC) for Earth imaging, a panchromatic wide-angle CCD camera (WFC) for cloud imaging, a colour CCD index camera (MFC) to calibrate attitude control, an amateur-band transponder (ARU) for communications and a deployable drag device for de-orbiting at end of mission.

22. *Aoi* (Blue) or STARS-AO (STARS – Astronomical Observation) is a technology development 1U Cubesat built by Shizuoka University with a high-sensitivity monochrome camera for astronomical observation and a high data rate transmitter. It is not currently clear which Cubesat corresponds to which object.

23. *Gama Kyubu* (Gamagori Cube) or AUTCube 2 is a technology development 1U Cubesat built by Aichi University of Technology with a spectrum analyser for interference to uplink signal, two fish-eye cameras for VR images of Earth, LEDs for optical communications and a low-power transmitter for performance test.

ADDITIONS AND UPDATES

DESIGNATION	COMMENTS
1990-037B	Hubble ST entered safe mode October 5 after failure of rate gyro. Following corrective action to fix another gyro that had been giving faulty readings, operations were restored October 27.
1997-007A	Intelsat 26 was relocated at 62.2°E, co-located with Intelsat 902, October 5.
1998-010A	Iridium 52 was manoeuvred from a reserve orbit to a disposal orbit October 17. Add orbit: Oct 23.86 86.57° 93.02 min 162 km 686 km
1998-014A	NSS 806 was manoeuvred off station at 47.5°W October 1 and is drifting to the west. It has been retired.
1998-021A	Iridium 62 was manoeuvred from a reserve orbit to a disposal orbit October 19. Add orbit: Oct 25.43 86.42° 93.11 min 157 km 700 km
1998-066E	Iridium 83 was manoeuvred out of the Iridium constellation to a disposal orbit October 11. Add orbit: Oct 17.87 86.41° 93.61 min 167 km 738 km
1998-074A	Iridium 20 was manoeuvred from a reserve orbit to a disposal orbit October 5. Add orbit: Oct 12.12 86.62° 92.75 min 149 km 673 km
1998-074B	Iridium 11 was manoeuvred from a reserve orbit to a disposal orbit October 3. Add orbit: Oct 9.47 86.42° 92.92 min 156 km 683 km
1999-034A	QuikSCAT scatterometer was switched off at end of mission October 2.
1999-040B	Chandra X-ray Observatory went into safe mode October 10, but resumed operations October 23 following reconfiguring of gyros.
2000-028A	Eutelsat 36A was relocated back at 70.3°E, co-located with Eutelsat 70B, October 4.
2001-033A	DSP 21 (USA 159) has been manoeuvred off station at 131°E and is drifting to the east, according to amateur trackers.
2002-040A	Eutelsat 36 West A was manoeuvred off station at 59.3°E October 29 and is drifting to the west. It has been retired.
2002-055A	TDRS 10 is drifting eastwards away from its station at 174°W.
2005-015A	Spaceway 1 was relocated at 138.9°W October 15.
2007-043A	Dawn failed to communicate October 31 and has presumably exhausted its attitude control propellant, ending unique dual-asteroid mission.
2009-011A	Kepler transmitted the stored scientific data from its 19th K2 campaign October 11 to 13, but re-entered safe mode October 19 due to exhaustion of attitude control propellant. The exo-planet discovery mission was formally ended on October 30.
2010-008A	GOES 15 was manoeuvred off station at 135°W October 29 and is drifting to the east.
2010-024A	Beidow DW4 (G3) was manoeuvred off station at 110.5°W October 9 and was relocated at 80°E October 23.
2013-004A	TDRS 11 was manoeuvred off station at 171°W October 14 and was relocated at 174°W, replacing TDRS 10, October 30.
2014-054A	Optus 10 was manoeuvred off its station at 164°E October 2 and was relocated at 156°E, co-located with Optus C1 and Optus D3, October 11.
2014-058A	Luch (Olimp-K) was manoeuvred off its station at 50°E October 20 and was relocated at 57°E October 28.
2014-076A	Hayabusa 2 manoeuvred down to 51 m above asteroid Ryugu, where probe released the MASCOT rover before returning to 20 km October 8. MASCOT touched down on Ryugu October 3.09 and successfully used hopping mechanism to move around to gather images and other data at three locations before batteries exhausted October 3.79. Hayabusa 2 repeated the touchdown rehearsal exercise October 14 to 16, successfully reaching a minimum altitude of 22 m on October 15. Third rehearsal October 24 to 26 reached 12 m minimum altitude and released a target marker October 25.11 which landed on Ryugu. Probe then descended to 5 km October 27 to 30.
2015-037A,B	Beidou DW18 (M1-S) and DW19 (M2-S) were declared operational October 1.
2016-025B	Microscope successfully completed its mission October 18 following exhaustion of attitude control propellant. Satellite has deployed IDEAS drag-sail booms to hasten decay.
2016-047A	USA 269 has been relocated at 10°W, according to amateur trackers.
2018-014G-K	These satellites are now identified as S-NET D, S-NET B, S-NET A and S-NET C. The fifth candidate to be one of these objects, D-Star One Phoenix, was announced as lost April 19, although transmissions were reported on the first day. It is possible that it failed to separate from the launch vehicle and was de-orbited.
2018-022A	GOES 17 was manoeuvred off its station at 90°W October 5 and is drifting to the west.
2018-026A	Soyuz MS-08 crewed by Artemyev, Feustel and Arnold undocked from the ISS/Poisk port October 4.33 and landed near Zhezkazgan in Kazakhstan October 4.49.
2018-028A	Kosmos 2525 began manoeuvring October 22, possibly to maintain orbit against decay.
1998-067NT	DebrisSat 2 was ejected from RemoveDebris satellite October 28.26 and served as a target to test the VBN camera/lidar tracking system. Add object with orbit: DebrisSat 2 1998-067PR Oct 30.50 51.64° 93.48 min 400 km 403 km
2018-043A	Gaofen 5 mass is 2,700 kg.
2018-057A	Beidou DW32 (I7) was declared operational October 1.
2018-060A-D	Galileo Sat 25, 26, 23 and 24 (GSAT 0221, 0222, 0219 and 0220) have manoeuvred to slots B2, B7, B4 and B1 in the Galileo constellation. Add orbits: Oct 30.20 56.40° 844.65 min 23,211 km 23,234 km Oct 19.86 56.39° 844.65 min 23,213 km 23,231 km Oct 3.08 56.38° 844.65 min 23,215 km 23,229 km Oct 17.96 56.39° 844.65 min 23,213 km 23,231 km

Teams at BepiColombo Mission Control prior to the launch of ESA's Mercury Orbiter, which lifted off on 20 October.

ESA

DESIGNATION	COMMENTS
2018-065A	Parker Solar Probe carried out its first solar encounter (perihelion science mission) October 31 to November 11.
2018-069A	Telstar 18 Vantage/APStar 5C was manoeuvred off its test station at 136.5°E about October 26, relocated over 138°E, co-located with Telstar 18/APStar 5, about October 29 and declared operational October 31.
2018-070A	ICESat 2 has manoeuvred to its operational orbit. Add orbit: Oct 13.54 92.01° 94.19 min 479 km 483 km
2018-072A	Beidou DW37 (3M13) manoeuvred to slot 1 in plane B by October 10. Add orbit: Oct 10.79 54.98° 773.19 min 21,514 km 21,542 km
2018-073A	Three Cubesats were deployed from ISS via the Kibo airlock October 6.33. STARS-Me has been given the name *Tenryu*, meaning Endurance. It is not yet clear which object corresponds to which payload. Add objects with orbits: SPATIUM-I 1998-067PN Oct 6.97 51.64° 92.54 min 402 km 406 km RSP-00 1998-067PP Oct 6.92 51.64° 92.54 min 401 km 407 km Tenryu 1998-067PQ Oct 6.97 51.64° 92.54 min 400 km 407 km

INTERNATIONAL SPACE STATION ACTIVITY

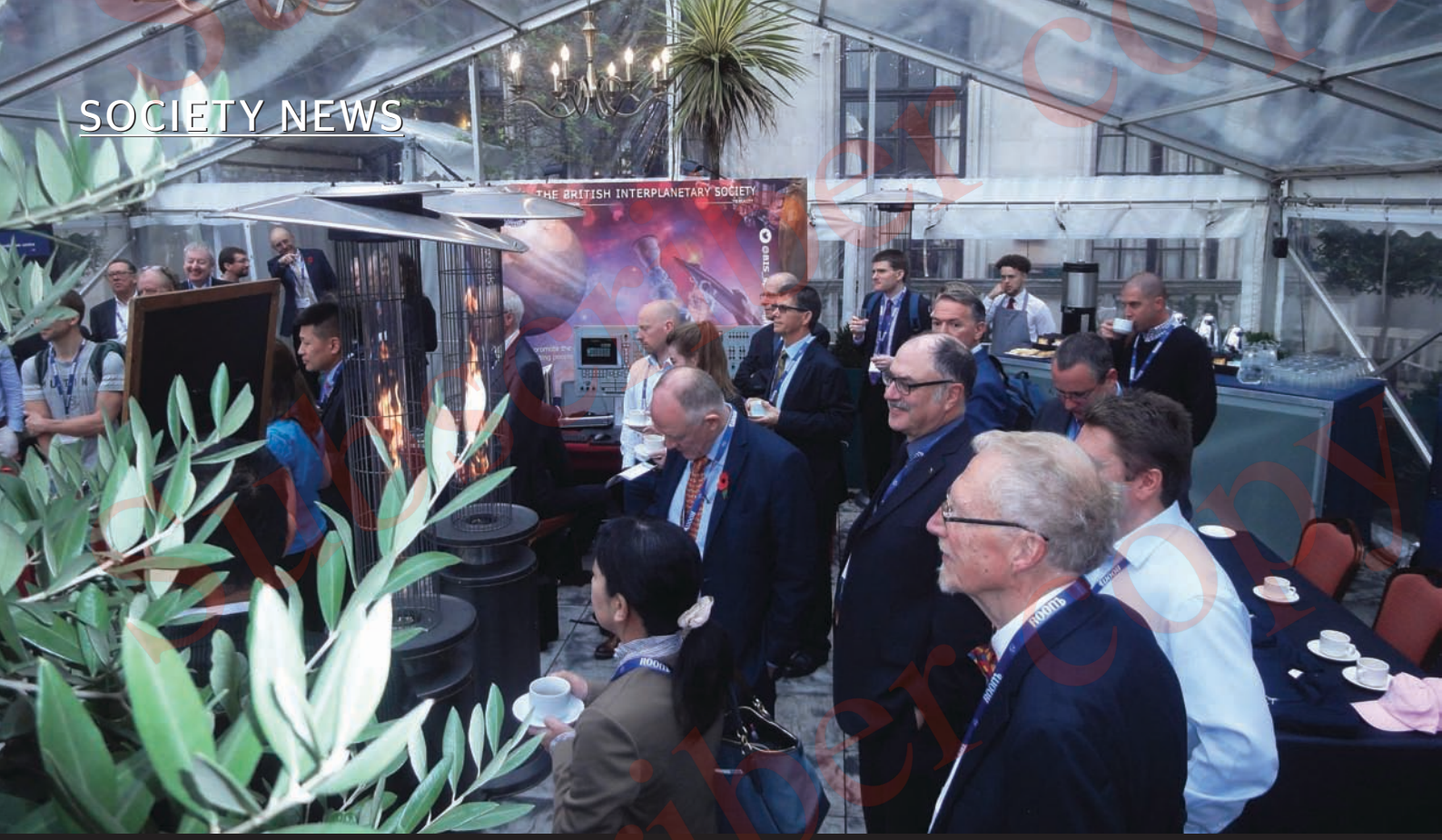
There were no orbital manoeuvres of ISS during October.

End-of-October orbital data:

Oct 31.83 51.64° 92.57 min 403 km 408 km

RECENTLY DETAILED ORBITAL DECAYS

International Designation	Object name	Decay
1997-030D	Iridium 10	Oct 6.13
1997-034A	Iridium 15	Oct 14.43
1998-010B	Iridium 56	Oct 11
1998-032A	Iridium 70	Oct 11.34
1998-066B	Iridium 86	Oct 5.46
1998-074A	Iridium 20	Oct 22.05
1998-074B	Iridium 11	Oct 22.50
1998-067KJ	Flock 2e'-14	Oct 25
1998-067KV	Waseda-SAT 3	Oct 6.2
1998-067LD	Lemur 2 Austinacious	Oct 4.1
1998-067LN	IceCube	Oct 3.2
2018-026A	Soyuz MS-08	Oct 4.49



The BIS host the 16th RiSpace Conference and Exhibition at the Royal Aeronautical Society near Hyde Park Corner in London.

IMAGES: ALISTAIR SCOTT

FROM LITTLE SEEDS...

RiSpace is now a major forum for space industry debate – and it's organised by the BIS.

THE 16TH RE-INVENTING SPACE (RISpace) conference and exhibition, organised by the BIS, was held from 30 October to 1 November at the prestigious Royal Aeronautical Society, which dates from 1866. This annual event targets one of the fastest growing economic sectors – low-cost access to space and its commercial utilisation – by bringing together industry, agency, government, financiers, academia and end users. This year a record 45 papers were delivered.

The global economic trend is to reduce costs, bringing with it new technological challenges and opportunities in the space sector. The current need is to develop dramatically reduced-cost, more responsive systems and launchers capable of delivering to space quickly, cheaply and reliably. The increasing pace of commercialisation is expected to lead to major new applications in Earth orbit over the next decade. These will include mega-constellations for communications, plus active and passive remote sensing in both the optical and RF domains.

The next decade is also expected to see the start of sustainable operations in space. In-situ resource utilisation and in-orbit manufacturing will enable the robotic construction of much larger structures. This will open up new capabilities for space science, and for manned exploration of the Solar System through the increasing availability of cheap launch services.

The top sponsor this year was Raytheon, whose UK operations embrace electronics, mission support systems and sensing, command, communications and intelligence systems. Another key sponsor was Northrop Grumman, the veteran space and defence company that built the Apollo Lunar Module (this year being the 50th anniversary of its first manned flight) and whose Dawn spacecraft ended its phenomenally successful mission during the conference. Other prime sponsors included L3 Space & Sensors, a pioneer in space electronics and infrared detection which now owns BAE Systems, and Airbus. There was also backing from Tri-Sept, Astroscale, Tesat, Umbicord, the Royal Aeronautical Society and Commercial Space Technologies (CST).

ORIENTATION

This year the focus was on the topics and trends that will define space enterprise over the next decade, a period in which rapid development in global space capabilities seems inevitable. Sessions held over the three days covered access to space, enabling technologies, near-Earth operations and missions beyond low-Earth orbit. The fast-emerging fields of

commercialisation in space and space situational awareness also received special attention.

Jacob Geer of the UK Space Agency started the proceedings by outlining the new national space policy objective of securing access to orbit from British territory. The agency has already put funding behind its ambitions, by contributing to the £17.3 million overall budget secured from various sources for The Moine vertical launch site in Sutherland, on Scotland's north coast.

The plans of Skyrora, a potential user of The Moine launch site, were outlined by Lead Engineer Robin Hague. Recalling the legacy of Britain's early rockets, Black Knight and Black Arrow, he explained that Skyrora's sub-orbital and orbital launch vehicles, whose development is well underway, intend to use the same propellant, high-test peroxide.

Mark Hempsell of Hempsell Astronautics drew attention to the fact that the risk of collisions in geostationary orbit is far higher than previously assessed, due to the concentration of objects. In 2017 there were two debris-creation events there, at least one of which was a collision. The economic value of such orbits means special risk mitigation strategies are now required.

After Alex Ellery of Carleton University had made the case that the Moon could offer superior in situ resource utilisation than asteroids, Ido Anteby of SpaceIL explained that even after the demise of the Google Lunar X prize, his non-profit organisation will continue with its plans to launch on a Falcon 9 and send a lander to the Moon in 2019.

Alex Ellery returned to discuss the risk of asteroid impact on Earth, and mitigation methods. The audience was palpably relieved to learn that the improved knowledge has reduced the risk from asteroid impact from equivalent to dying in an air crash, to the risk of death from fireworks. "Exocytosis" is a biological term, but in this context means eroding a dangerous asteroid by mining it and firing its mass off into space piecemeal.

Manny Shar of Bryce Space and Technology reviewed Global Investment Trends in "Start-Up Space". The sector is now attracting and sustaining investor interest in Silicon Valley and worldwide. Space ventures appeals to investors because new, lower-cost systems are envisioned to follow the path to profitability already exhibited by terrestrial tech – fast cost reduction and massively increasing user bases for new products, especially new data. The three years 2015-17 have seen annual private investment in space start-ups of between US$2 billion and $3 billion.

SUSTENANCE

In his Keynote address, Joe Anderson of Northrop Grumman gave a fascinating account of how practical in-orbit servicing of satellites is developing. Their new Mission Extension Vehicle (MEV) is used to extend satellite life to prolong revenues or defer capital expenses, and can re-deploy satellites to new orbital roles. The MEV ingeniously docks with the orifice of the target satellite's disused apogee motor and can fit 80% of current satellites. Once locked there it provides attitude control and propulsion augmentation. MEV 1 is under construction for launch in spring 2019.

"Women in Aerospace" hosted a breakfast at which it came as no surprise to learn that space is hiring more women engineers and scientists than any other industry.

In-situ resource utilisation and in-orbit manufacturing will enable the robotic construction of much larger structures

Jeremy Turner of the University of Nottingham proposed a Gateway Earth GEO space station as part of the solution to space "junk". His mathematical model locates the ideal orbit at slightly beyond GEO, from where servicing, re-purposing or recycling opportunities could generate revenue streams to support the construction and further development of Gateway Earth. Reminding the audience that it was Hallowe'en, he had to mention the out-of-control "Zombie" satellites that broadcast blindly; one eventually re-set itself, while another re-discovered earlier this year had such antiquated software that regaining control was problematic.

Bill Bigge then gave a stimulating overview of his work, under a UKSA grant, on the geometry of 3-D printing that could be used to create massive spherical and tubular structures in orbit. A single machine uses a continual process to enclose a large volume of space in a single, rigid protective shell. Layers of insulation and micro-meteoroid protection could be added later.

Thursday began early with the "Women in Aerospace" breakfast. Gender was not a restriction for attendance at this inspirational event! Alan Webb chaired the Access to Space session, in which Vadim Zakirov of Commercial Space Technologies reviewed the market for a UK launcher. As the production cycles for cheap, small satellites continues to shorten, and launch opportunities cannot keep up with demand, the backlog of satellites waiting for a flight is increasing. Nevertheless, pricing will be critical if a UK's domestic launcher is to succeed in capturing a viable market share.

BIS President Gerry Webb chaired the afternoon session, which covered Cornwall's new spaceport for horizontal launch, a panel discussion on on-orbit servicing, and space situational awareness.

Guests at the conference dinner were entertained and informed by US science educator Bill Nye who explained the Planetary Society's Lightsail 2 project, which will go on the second launch of Space-X's Falcon Heavy. Dallas Campbell, a regular presenter of BBC TV's Horizon programme, hosted the proceedings. SF *Ken McTaggert FBIS*

2018
RiSPACE SPONSORS
- Raytheon
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- L3 Space & Sensors
- Airbus Industrie
- Tri-Sept
- Astroscale
- Tesat
- Umbicord
- Royal Aeronautical Society
- Commercial Space Technologies

Every one a winner!

The great and the good line up to receive their 2018 Sir Arthur C. Clarke Centenary Awards.

IMAGES: ALISTAIR SCOTT

RiSpace holds a gala dinner for the nine worthy recipients of this year's Arthur C. Clarke Awards.

THE ARTHUR C. CLARKE FOUNDATION and its UK partner the British Interplanetary Society have announced the winners of the 2018 Sir Arthur Clarke Centenary Awards. In a relaxed and enjoyable ceremony at the Reinventing Space Conference Gala Dinner at the Royal Aeronautical Society in London on 1 November 2018, nine awards were presented to team and individual winners.

The evening began with a superb pre-dinner reception in the splendid Argyle Room where Sean McCarthy, Head of Market Intelligence at the Satellite Applications Catapult, sponsors of the reception, welcomed some 60 award finalists and their guests and a similar number of conference delegates. Gerry Webb, President of the British Interplanetary Society, then took the opportunity to invite Professor Sir Martin Sweeting to become the Society's fifth Honorary Fellow in recognition of the massive contribution he has made to astronautics both in industry and in education over so many years. He joins the theoretical physicist and mathematician, Professor Freeman Dyson, Apollo astronaut Colonel Al Worden, and UK astronauts Dr Helen Sharman and Major Tim Peake.

The delegates, finalists and guests then made their way down to the lavishly-transformed Boeing Room for dinner. Popular American TV scientist, Bill Nye, the "Science Guy", gave an amusing and energetic talk as the splendid 3-course meal was efficiently served. Dallas Campbell, celebrity TV Presenter and Author of "Ad Astra: An Illustrated Guide to Leaving the Planet", then took to the stage and invited Alistair Scott to say a few words about the Arthur C. Clarke Foundation and its "Sir Arthur Clarke Awards" that recognise and reward teams and individuals for their achievements in the year. Dallas then began the Awards Ceremony, reading out all the finalists for each award and naming their representatives before opening the envelope to reveal the winner.

As each of the Award Winners, listed below, was announced, they came forward to loud applause to collect their Award Monolith, an exact scale replica,

Oxford Space – the deserving Industry award winners.

Vix Southgate collects her award from host Dallas Campbell.

in clear glass, of the monolith in Sir Arthur's "2001: A Space Odyssey". Bill Nye happily participated in the celebrations by joining each winner on stage for their photographs.

The evening culminated in the International Award being presented to the Falcon Heavy Team from SpaceX, represented by their Senior Director Tom Ochinero, who, after a few words of thanks, showed the most amazing short film of the build and launch of the Tesla Roadster and the return to Earth of the first stage boosters. This impressive achievement received tumultuous applause and brought the evening to a fitting close.

It was a memorable evening in which the best of the UK Space Sector, and a number of significant international players, were once again recognised and rewarded for their fantastic achievements. All the Finalists were in effect winners as, against some very stiff competition from 52 nominees for the nine awards, they had been selected by a panel of 38 judges from across the Space Sector as the top three in their award category. SF *Alistair Scott*


Bill Nye crossed the Atlantic to add zest to the awards ceremony.

2018 SIR ARTHUR C. CLARKE AWARDS WINNERS

1 Space Achievement
Industry/Project Team ..... Oxford Space

2 Space Achievement
Industry/Project Individual ..... Magali Vaissière, head of ESA's Directorate of Telecommunications and Integrated Applications.

3 Space Achievement
Academic Study/Research ..... The UK Cassini team

4a Space Achievement
Education & Outreach Team ..... ESERO-UK Space Ambassadors

4b Space Achievement
Education & Outreach Individual ... Vix Southgate

5 Space Achievement
Student ..... Rob Garner

6 Space Achievement
Media, broadcast & written ..... BBC 2's *Astronauts – Do you have what it takes?*

7 **Lifetime Achievement** ..... Richard Peckham

8 **International Achievement** ..... The SpaceX Falcon Team


Left to right: BIS President Gerry Webb, Alistair Scott and Sean McCarthy.

Jerry Stone (left) assists as *SpaceFlight* editor David Baker delivers an insightful talk to a packed house.

IMAGES: GEIR ENGENE

Mission: From the Earth to the Moon

TO A PACKED ATTENDANCE with an overspill in the foyer watching a TV link to the meeting room, *SpaceFlight* Editor David Baker revisited his days with the NASA Mission Planning & Analysis Division to review the many different challenges faced by planners involved in selecting from a menu of possible trajectories the path chosen to fly astronauts to the Moon.

Held on 21 November, the event attracted a wide range of visitors. Not least of them was BIS Chairman Gerry Webb, who brought with him three visitors from Russia including the renowned cosmonaut Anatoly Artsebarsky (who flew with Helen Sharman in 1991). Anatoly spent some time speaking to David after the talk, at which both agreed that there was much to be done to sustain the cordial and respectful camaraderie that already exists between astronauts and cosmonauts around the world.

During his presentation David noted key individuals who inspired him in his early days with the space programme: Ewen Whitaker, Thomas Gold and Bruce Murray; each helped mentor him in his youthful days as a keen and enthusiastic participant in the early days of space exploration. The talk spun out of that work and David explored with his audience the choices and the options facing trajectory planners in the 1960s.

This was the first in a series of three talks examining the rationales behind basic mission capabilities underpinning all Moon missions, this one being about Earth-Moon trajectories and the vagaries of launch windows as determined by the azimuthal and antipodal positions required for a cislunar journey. The talk ran long, seriously abbreviating the time for questions but enthusiasm was high and the interest was great.

The second lecture in this series will be on 20 February when David will explain the intricacies of the Apollo Flight Plan and the methods for achieving rendezvous and docking in space. A third lecture on the mechanics of landing on the Moon will follow shortly before the 50th anniversary of the launch of Apollo 11. SF

Coming up…

For all Apollo-watchers and those who like birthdays, Jerry Stone is giving the next in his series of dedicated Apollo flight overviews on 18 December when he describes and reflects on the pioneering flight of Apollo 8 – seminal in that it was the first to carry humans to the vicinity of our nearest celestial neighbour.

Jerry's next talk in the Apollo@50 series remembers Apollo 9 (first combined flight of Apollo and the Lunar Module), is at the BIS on 6 March, 2019 followed by a talk on Apollo 10 (first flight of both spacecraft around the Moon) on 22 May, 2019. Book early – Jerry's Apollo 8 talk is fast reaching capacity!

Cosmochemist Dr Natalie Starkey tells it like it is.

What to do with the flotsam of space?

DR NATALIE STARKEY, recently returned from three years in California where, as a freelance writer and broadcaster, she was a science host on Neil deGrasse Tyson's StarTalk Radio Show several times, came to BIS Headquarters on 8 November to talk about and promote her latest book "Catching Stardust".

Dr Starkey, now a cosmochemist, not, as she hastened to remind us, an astronomer, was originally a geologist studying ancient volcanoes in the Arctic and active volcanoes in Iceland and the Caribbean. Her first introduction to extraterrestrial geology was when NASA gave her samples collected by the Stardust mission to Comet Wild2 to examine. Then she worked with JAXA on asteroid samples returned by the Hayabusa mission to Itokawa, and was also involved with the "Ptolemy" instrument on ESA's Rosetta Philae comet lander.

Dr Starkey told a fascinated audience that asteroids and comets are among the oldest inhabitants of the Solar System, and within them lie the secrets of its early history, for they are pristine survivors of this epoch she said. Close-range study of these wanderers of space can reveal their story, and, hopefully, gain the answers to a number of basic questions concerning the origin and early evolution of the planets.

Such study, explained Dr Starkey, is also vital to the quest to protect Earth from cosmic impacts, and to the prospects for mining raw materials from these cosmic rocks and snowballs, which could aid in the exploration of deep space as well as providing resources here on Earth.

Dr Starkey's enthusiasm for her subject and her lively presentation style made her talk come alive and helped to enlighten her audience on the current state of knowledge of the flotsam of space. SF

Griffith Ingram

WORLD SPACE WEEK 2018

So how did we do?

UK WORLD SPACE WEEK UK COORDINATOR

Vix Southgate has totted up the numbers and provided the British Interplanetary Society with a report. In 2018 WSW-UK registered 73 events in 39 towns and cities, which were organised by companies, societies, museums, schools and individuals. These included: Schools events, Open Days, Education events, Book Launches, Online events, Astronomy evenings, Talks, Workshops and STEM ambassador visits.

WSW-2108 events were organised and run by schools, members of the public, outreach providers, space companies, science centres, astronomical societies, schools, universities, Twitter account holders, small businesses, space agencies, writers and publishers, and amateur and professional groups and societies.

The UK did not hold a launch event due to lack of human resources, time and funding but WSWUK was pre-launched by TV presenter Dallas Campbell and contestants and experts from BBC Two's "Astronauts: Do you have what it takes?" reality TV show. This was organised by the UK National Coordination Manager, Vix Southgate (Vixen International Events), at New Scientist Live 2018, ExCel London.

Our 2018 events reached across Europe, with the Italian branch of the BIS holding events and raising awareness of World Space Week in Italy, including a presence at the Rome "Maker Fayre".

In 2018, fewer organisers contacted the NC for advice or help and it was noted that several events were branding themselves as WSW but did not register, even when prompted. At least 16 unregistered events were promoting themselves on social media as celebrating WSW in the UK.

The continuing global impact of WSW-UK continues with the WSW "Trackables" (which were placed in geocaches across the UK during WSW-2014) as they travel across the world. However, these are now branded with the old WSW logo.

For the third year in a row, very few results have been recorded as it seems impossible to get organisers to complete their information after the event. Media attention of UK events for WSW-2018 in the UK was limited to local press due to no major events happening around the country. Social media, however saw a surge in activity through twitter coverage, online engagement levels were the best we have had yet.

The 2018 Schools competition failed due to a lack of human resources. The creator failed to follow through with promoting and managing the competition. However, two of the four schools that responded to the competition announcement were converted into registering their own activities. SF

Vix Southgate

BIS LECTURES & MEETINGS

APOLLO 8 – MEN TO THE MOON
18 December 2018, 7pm
VENUE: BIS, 27/29 South Lambeth Road, London SW8 1SZ

Jerry Stone takes us on the next step in his series of 50th anniversary talks covering every Apollo mission up to and including Apollo 17 by looking back at Apollo 8's historic journey into lunar orbit – a triumphant end to an otherwise turbulent and tragic year.

APOLLO MISSIONS: THE MECHANICS OF RENDEZVOUS & DOCKING BY DAVID BAKER
20 February 2019, 7.00pm
VENUE: BIS, 27/29 South Lambeth Road, London SW8 1SZ

Starting with Apollo 9 launched on 3 March 1969, a key feature of the Apollo missions was the ability to rendezvous and dock in orbit – a capability that NASA had evolved over the preceding four years. David Baker describes the process in detail and casts an expert eye over the different options considered by mission planners in the run-up to the lunar landing missions.

APOLLO 9 – RENDEZVOUS IN EARTH ORBIT
6 March 2019, 7.00pm
VENUE: BIS, 27/29 South Lambeth Road, London SW8 1SZ

Jerry Stone continues his series of talks to celebrate the 50th anniversary of the Apollo missions with a uniquely personal take on the story of Apollo 9 – the first test of the full lunar landing package and only the second outing of the Lunar Module.

WEST MIDLANDS BRANCH: A NEW SPACE RACE? & PROJECT CHEVALINE
16 March 2019, 1.45pm
VENUE: Gardeners Arms, Droitwich, Worcestershire WR9 8LU

Gurbir Singh posits the beginning of a new space race between India and China, while John Harlow and Paul Jackman look back to the days of Project Chevaline and the famed Twin Chamber Propulsion Unit.

APOLLO 10 – RENDEZVOUS IN EARTH ORBIT
22 May 2019, 7.00pm
VENUE: BIS, 27/29 South Lambeth Road, London SW8 1SZ

Jerry Stone continues his coverage of Apollo with the first flight to carry both the Apollo spacecraft and the Lunar Module on a full dress rehearsal of a landing.

Call for Papers
RUSSIAN-SINO FORUM
1-2 June 2019, 9.30 am to 5pm (tbc)
VENUE: BIS, 27/29 South Lambeth Road, London SW8 1SZ

The BIS has now scheduled its 39th annual Russian-Sino Forum – one of the most popular and longest running events in the Society's history. Papers are invited. Watch this space for further details.

APOLLO MISSIONS: LANDING ON THE MOON BY DAVID BAKER
12 June 2019, 7.00pm
VENUE: BIS, 27/29 South Lambeth Road, London SW8 1SZ

SpaceFlight's editor looks at the systems evolved by NASA for calculating optimum lunar landing trajectories, and at the descent procedures needed to achieve the maximum chance of success while preserving emergency abort and safety considerations.

MEMBERSHIP NEWS

Here's to a great 2019!

AS THE YEAR ENDS we have arrived at membership renewal time. Your membership runs from January to December each year and we really hope you will continue to support the Society. Our new look SpaceFlight magazine has received much praise this year and we have organised and participated in more events than ever. Our volunteers continue to work incredibly hard and our goal of offering monthly direct debit should be achievable some time in 2019.

If you have not already renewed, and to use our preferred method, please go to bis-space.com/renew and follow the step-by-step process to help you choose the most appropriate membership for you. If you would prefer to send us a sterling cheque, or your credit card details in the mail, please download the form from bis-space.com/renew/form and pop in the post to us at 27/29 South Lambeth Road, London, SW8 1SZ, UK. Call or write to us for a copy of this form if you are unable to print from the internet. Digital publications are available (and are free to those who already take the printed versions) and you can add this to printed editions by specifying this on the checkout part of the purchase.

Of course, for those new members who joined since August 2018 and have a 15 month membership, your membership renewal is not due until the end of 2019. We would really appreciate any feedback that you have regarding your membership, what are you enjoying and what you would like to see as part of your membership.

The BIS has a rich history that deserves to be celebrated and we need to be able to promote our archives so that they are not hidden away. To do this we are always looking for more volunteers to help out in our library and archives on a regular basis, together with our librarian and archivist – please email **volunteers_form@bis-space.com** if you have any time to give.

We particularly need to encourage younger members to get more involved and we must also ensure we continue to look forward, with our technical projects, outreach and events. We continue to strengthen our connections with industry via our Reinventing Space conference and organising the UK Pavilion at the IAC each year.

Happy New Year from us all.

Ralph Timberlake
Membership Committee
(ralph.timberlake@bis-space.com)

NEW MEMBERS

No less than 50 new members signed up for all the BIS has to offer in October: 23 from the UK, an incredible 22 from Italy, 2 from Spain, 2 from the USA and 1 from Turkey.

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