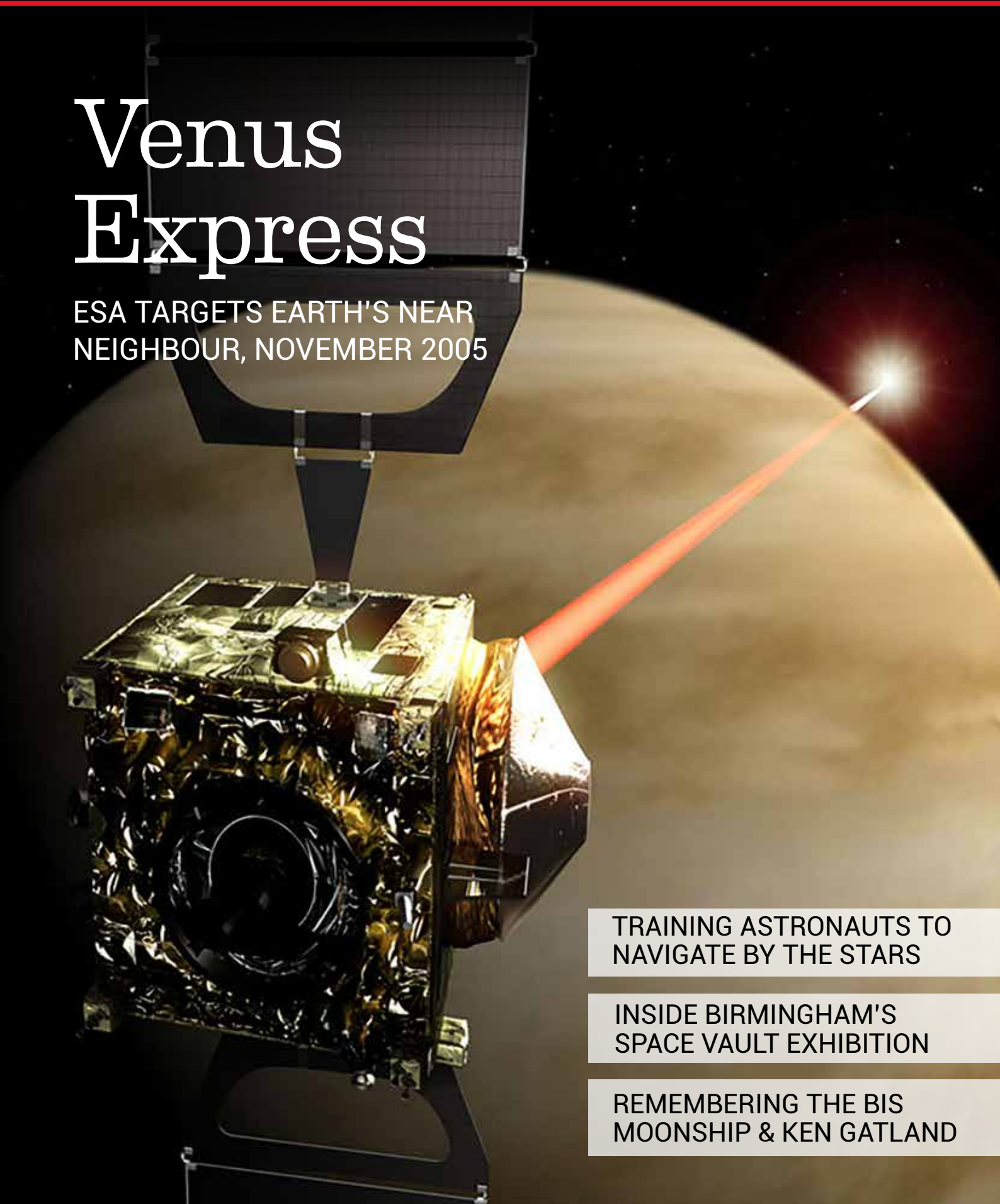
SPACE CHRONICLE
THE BRITISH INTERPLANETARY SOCIETY SPACE HISTORY MAGAZINE
VOLUME 5-4 OCTOBER 2025

Venus Express

ESA TARGETS EARTH'S NEAR NEIGHBOUR, NOVEMBER 2005



TRAINING ASTRONAUTS TO NAVIGATE BY THE STARS

INSIDE BIRMINGHAM'S SPACE VAULT EXHIBITION

REMEMBERING THE BIS MOONSHIP & KEN GATLAND

SPACE CHRONICLE

THE BRITISH INTERPLANETARY SOCIETY SPACE HISTORY MAGAZINE

Letter from the Editor

Presenting stories behind historical events, hardware and key figures across a century of astronautics is the primary remit for *Space Chronicle*. In this issue, we certainly meet that aim. From milestones in the 1920s and 1930s recounted in TIMELINES to reporting on a current exhibition of space artefacts, we offer a broad spectrum of content in just 36 pages.

Events leading up to the 2005 launch of ESA's pioneering mission to the shrouded planet Venus are recalled by Paolo Ferri, the Director of Flight Operations for Venus Express. Understanding celestial navigation is not just for planning automated space probes but also remains an integral part of astronaut training as it has since the 1960s, as explained by Philip Corneille. We next turn to the display of significant items, mostly flown, from one of the largest private collections of space artefacts in the UK. I was fortunate to preview the installation of the items at Birmingham's Think Tank Science Museum and to interview their owner, Dr Michael Warner, to learn how these items were gathered, prepared and displayed, together with their unique stories. As fascinating as they are, this feature is not primarily about those objects and their stories, but about the story behind their stories and the efforts required to create an engaging exhibition.

We round off this issue with a new section, SocietySPACE, where matters relating to the rich heritage of the Society are covered. Mark Stewart begins by reflecting on the BIS Moonship, the Society's treasure-trove Library, former President Ken Gatland's popular books and the Arthur C. Clarke Archives. Next, Ken MacTaggart recalls how engineer Robert Smylie led a team to work out, literally, how to 'fit a square peg into a round hole' to help save the crew of Apollo 13. Mat Irvine's latest ModelSPACE feature references the need for a more powerful vehicle to launch America's early deep space probes and satellites and examines the miniature replica the configuration generated. Then, Rick Mulhern reports on his recent interview with two-time Shuttle veteran and author Susan Kilrain. Finally, Brian Harvey recalls how, 50 years ago, China became the third country to return a satellite from orbit successfully. An issue certainly packed with a varied payload.

David J. Shayler FBIS

YOUR MAGAZINE NEEDS YOU!

As we move forward in these challenging times, SPACE CHRONICLE will continue to explore space history through a selection of regular features, for which contributions are especially welcome.

MuseumSPACE is an opportunity for readers to share their visits to established and new space-related museums, exhibitions and locations around the world.

ShelfSPACE reviews both new and vintage / secondhand space-related books that deserve a place in your own space library.

TalkSPACE provides an opportunity for readers to comment on items featured in the magazine and on general matters of space history.

MemorabiliaSPACE focuses on the growing space collectibles market, with tips on what to buy and where to find it.

MySPACE gives readers a chance to share their personal space-related recollections and associations.

BackSPACE focuses on a single image, preferably rare or previously unpublished, that recalls a milestone in space history.

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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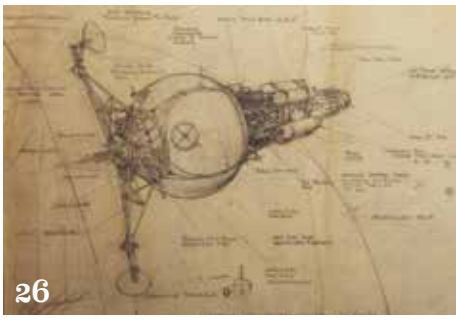
Contents

VOLUME 5-4 OCTOBER 2025



On the cover: An artist's impression of Venus Express perfoming a stellar occultation experiment, October 2011 (ESA).

Contributors to this issue

Paolo Ferri spent his entire 36+ year career in space mission operations, working for the European Space Agency at ESOC, in Germany. He led many scientific missions, in particular interplanetary missions like Rosetta, Mars Express and Venus Express. From 2013 to 2020 he was responsible for the ground segment and operations of all ESA's robotic missions.

Philip Corneille is a retired NATO officer who has been collecting and archiving spaceflight photos since 1971. He writes frequently on space-flown wristwatches and maintains the acclaimed *MoonwatchUniverse* photoblog. Philip took early retirement to pursue his primary interests in astronomy, aviation and spaceflight.

Ken MacTaggart is a journalist and economics consultant who has followed the Soviet/Russian space programme closely since 1968. He is the author of the *Haynes Astronaut Manual,* and more recently has written the obituaries of several cosmonauts for the *Daily Telegraph*, *SpaceFlight* and other publications. His first item published in *SpaceFlight* was in 1971, a letter about the Soyuz 11 tragedy.

Rick Mulheirn is a retired retailer of 43 years standing who has harboured a passion for the US space programme as an enthusiast and collector for more than 59 years. He joined the BIS in 1977. Now a Fellow of the Society, Rick is still happily married and divides his time between that of full-time grandad and armchair sportsman.

Mat Irvine has specialised in spacecraft modelling for most of his life, including work at the BBC Visual Effects Department on programmes such as Horizon, Tomorrow's World and Spaceships of the Mind, and live appearances on both Swap Shop and Superstore. He has also supplied models for The Sky at Night and Stargazing Live. A Fellow of the Society, Mat has written over 16 books.
www.matirvine.com

TRANSIT OF VENUS

The inside story behind ESA's mission to the Earth's inhospitable neighbour, now celebrating its 20th anniversary, from the former Director of Flight Operations.

by **Paolo Ferri**

ALL IMAGES: ESA

ABOVE RIGHT
Artist's impression of Venus Express as it goes into orbit around Venus.

Around the turn of the millennium, the European Space Agency (ESA) finally decided to enter the world of interplanetary space missions. There had been two missions before that had left Earth's orbit: Giotto, the legendary probe that had achieved a close fly-by of the nucleus of comet Halley in March 1986; and Ulysses, launched in 1990 as the first space probe to leave the ecliptic plane, which flew over the Sun's polar regions. But neither mission really required Europe to cover all aspects of interplanetary flight. Giotto had flown at relatively short distances from Earth, whilst Ulysses had made use of technology from the US (such as the radioisotope thermoelectric generator) and its entire ground support infrastructure had been provided by NASA.

INTO THE SOLAR SYSTEM

In November 1993, ESA's Space Programme Committee (SPC) approved Rosetta, the first mission to rendezvous and land on a comet. Rosetta was a fully European mission, with only minor contributions from international partners. To realise this mission, the European space industry had to develop an entire, true interplanetary probe. For ground support, ESA's mission control at the European Space Operations Centre (ESOC) in Darmstadt, Germany, had to build the entire infrastructure to control a deep space mission, such as large ground antennas, specialised flight dynamics tools and operating systems capable of coping with the challenges of interplanetary navigation and mission control.

Rosetta was approved as a flagship of ESA's scientific programme, funded with the budget for what is today termed a "Large" class mission. But the Agency also took advantage of the technology, infrastructure and know-how developed for Rosetta to design and launch its first planetary orbiter, Mars Express, a smaller probe that would maximise the use of that experience. Mars Express (MEX) was launched first, in June 2003, followed by Rosetta in March 2004. In the meantime, ESOC had also built its first deep space antenna, a 35m-wide dish, in New Norcia, Western Australia. With these two missions, ESA had finally properly entered the world of solar system exploration.

On the back of the success of the low-cost approach to Mars Express, in 2001 ESA launched a call for ideas to reuse the Mars Express platform

for future scientific missions. Ten ideas were proposed in response to the call and, in an unprecedentedly fast process, ESA short-listed three of them for a brief industrial feasibility study between July and October 2001. In November 2001, ESA's SPC approved the start of pre-phase B for the selected candidate: Venus Express (VEX). This was a mission to orbit planet Venus based on a maximum reuse of the existing platform and would be built by an industrial consortium under the lead of Astrium-France. The SPC provided final approval for the mission one year later, on 4 November 2002. The only modification to the initial proposal was the exclusion of VENSIS (VENus radar for Subsurface and Ionosphere Sounding), an instrument proposed for radar investigation, which lacked the necessary financial support. Apart from the reuse of the Mars Express platform, the payload complement was based on a significant reuse of instruments developed either for Rosetta or Mars Express.

ABOVE RIGHT
ESAs newly commissioned tracking station at Cebreros in southern Spain (top) and an artist's impression of the agency's first planetary orbiter – Mars Express.

RECYCLING THE PROBE

Venus Express was approved with a relatively small budget (ca. 220 million Euro covering spacecraft development, launch and operations cost) and a very tight development schedule (three years). The understanding was that everything possible would be reused from Mars Express and Rosetta, in order to reduce the development cost and schedule significantly. The platform was a carbon-copy of Mars Express, save for the necessary modifications to cope with the different environmental conditions at Venus compared to Mars, dictated by their different distances from Earth and the Sun.

Using an existing platform like Mars Express, which was already proven in operation, was a good basis for VEX. However, it is one thing to build a spacecraft to reach and orbit Mars, but a very different proposition to do so for Venus. The thermal environment at Venus is very different from that of Mars, with a solar flux that is about four times greater. Clearly, this would require major changes to the thermal protection and regulation of the spacecraft. The passive thermal control approach of Mars Express was retained, but with heavy modifications to the external coatings and the Kapton multi-layer insulation covering the spacecraft, as well as the inclusion of optical solar reflectors on the radiators and the solar array. The solar generator of Mars Express »

« had to be fully replaced, because the silicon cells would have been incapable of handling the wide range of temperatures the array would be exposed to at Venus's distance from the Sun. The probe was thus fitted with two panels with two sections each, based on gallium-arsenide cells. Because Venus orbits closer to the Sun than does Earth, the Earth-spacecraft-Sun angle can vary up to 360 degrees, impacting the geometry of the communications with ground control on Earth. Therefore, a second high gain antenna had to be added, to be used around the inferior conjunction phases, to maintain communications while coping with the pointing constraints governed by the thermal requirement of keeping the radiators away from solar illumination.

RECYCLING THE PAYLOAD

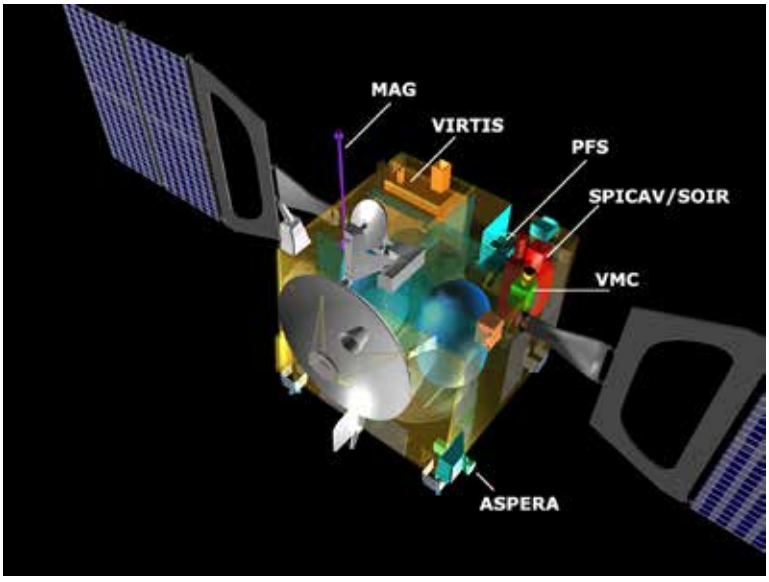
Right from the start of the mission definition, the strict requirements on schedule and cost containment for Venus Express dictated the substantial reuse of existing instruments. This oriented the scientific objectives of the mission towards studying the Venusian atmosphere, for which the existing modern instruments developed for Rosetta and Mars Express would provide a major step forward compared to investigations conducted by previous Venus missions.

The six scientific instruments aboard Venus Express were all either re-built or derived from existing ones carried by either Mars Express or Rosetta. They were: Aspera, a plasma analyser, derived from the Mars Express instrument and adapted to the Venus environment; MAG, a magnetometer derived from the Rosetta lander's Romap instrument; VMC, a wide-angle camera evolved from Mars Express; PFS, an infrared spectrometer modified from its twin on Mars Express; SPICAV, an IR and UV imaging spectrometer also derived from Mars Express; and finally VIRTIS, a visible and infrared imaging spectrometer copied from Rosetta.

REUSING THE GROUND SUPPORT

The basic assumption for ground support was

ABOVE
The author at his post. These were stressful times for Paolo Ferri.



BELOW
A cutaway of the Venus Express spacecraft showing the location of the science instruments.

that all the tools developed for Rosetta and Mars Express would be reused without modifications (apart from the necessary configuration changes). Given that the onboard software for the probe was intended to be almost fully reused from Mars Express, the ground databases and flight operations procedures could also largely be reused with minimal or no changes. At least, this was the assumption we had to make when I started working on Venus Express at the beginning of 2003. At that time I was the Spacecraft Operations Manager (SOM) for Rosetta, but the launch of the comet probe had just been postponed to early 2004 due to a problem with the Ariane 5 launcher. Thus, I found myself also temporarily having to cover the role of SOM for Venus Express for just over a year, until after the launch of Rosetta, when we could assign this role more permanently to another member of my team, to work full-time on the preparation of the mission to Venus. The initial months of 2003 were quite tough for me. On the one hand I had to work with my Rosetta team on the redefinition of the mission for a new target comet and a new trajectory, which was eventually only identified and confirmed in April. Then Mars Express, the "sister" probe to Venus Express, was launched in June and we rapidly had to incorporate the experience of the new probe's first few months of flight into the plans and procedures we were developing for Rosetta and Venus Express. We also always had to work under the strict assumption of full reuse of whatever we had developed for the other two missions. Whenever this was not possible, every small change in the Venus Express spacecraft or ground systems had to be analysed for its impact on our tools and procedures. Finally, the operational approach to the very aggressive thermal and radiation environment at Venus would be completely different from the one we had prepared for in the case of Rosetta and Mars Express, which would be flying far away from the Sun. Overall, therefore, it was a very difficult year, but the prospect of soon having three probes flying in interplanetary space was also very exciting for all of us. Our teams were highly

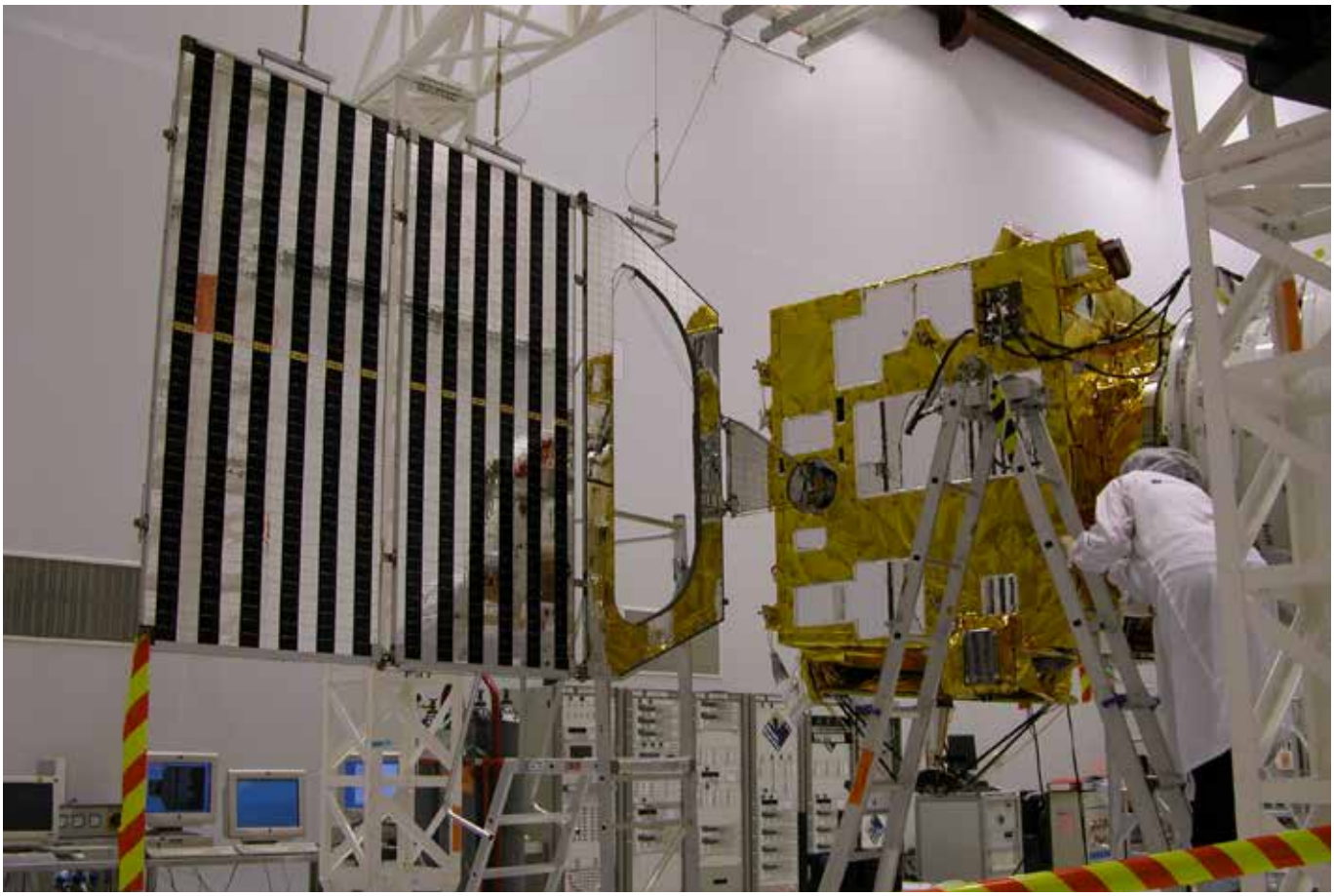
ABOVE
The Venus Express spacecraft undergoes vibration testing at EADS Astrium's Intespace facility in Toulouse.

engaged and motivated by these new challenges.

Although the ground segment, with its computer software, flight dynamics tools, communications lines and ground stations, would be fully reused from Rosetta and Mars Express, an important new element was introduced: a second, brand new, deep space antenna. The first ESA deep space antenna at New Norcia, inaugurated in spring of 2003, had been built mainly to support Rosetta. With that mission having opened the doors to ESA's exploration of the Solar System and with new interplanetary missions being proposed and developed (starting with Mars and Venus Express), it soon became clear that ESA needed more capability to communicate in deep space without having to rely too much on external support such as NASA's Deep Space Network (DSN). Using this argument, Manfred Warhaut, ESA's ground segment manager for both Rosetta and Venus Express and project manager for the New Norcia ground station, managed to convince ESA's management to propose the construction of a second deep space antenna to the Member states. Once approved, the construction of the antenna proceeded very rapidly: from the start of the site selection process in April 2002, to the initiation of procurement activities in February 2003, to the start of construction in early 2004. The selected site was Cebreros, in Spain, an ideal complement to the existing station in Western Australia. Separated by almost exactly 120 degrees, the two stations together would provide coverage of two thirds of the celestial sphere while the Earth rotated. The location also had a special advantage for Venus Express because it is at a very similar longitude to that of our control centre in Germany. Given that planet Venus, as seen from Earth, is always relatively close to the Sun, it meant that the ground contacts with the probe at Venus would more or less always occur during daytime, a special luxury for our spacecraft controllers. The new Cebreros antenna was completed and ready for operational use in August 2005, just in time to support the launch of Venus Express which was planned for the end of October.

Mars Express was launched on 2 June 2003 and arrived at the Red Planet on 25 December that year. This gave us our first in-flight experience of the new platform and the ground support infrastructure. As an example, Mars Express soon started to experience problems with its star trackers, which were apparently suffering more stray light disturbances than the designer had anticipated. As a result, new operational constraints and attitude ranges were established in flight for MEX and Rosetta. Venus Express had the advantage that its launch date was still some way off, so modifications could be implemented with its star trackers on ground to reduce the effects of stray light disturbance. Mars Express also experienced a problem related to the reuse of Rosetta's solar array power regulators. The probe had smaller solar arrays compared to Rosetta, with the number of power regulators reduced accordingly. However, a design mistake in the connection between the solar cell sections and the regulators limited the power extractable from the solar arrays to about 70% of the theoretical maximum. This was a very hard lesson learned on the re-usability of hardware between Rosetta and Mars Express. As a consequence, a new full analysis of all the items reused but modified from Mars Express was performed on the Venus Express spacecraft, to avoid encountering similar problems.

Flight software modifications were kept to the bare minimum as planned, which helped our ground support team because it allowed us to use the operational database and flight procedures as planned. Nevertheless, Venus Express would also gain from the experience of the two "sister" probes. Rosetta's software had been specified to include a novel software tool called "On-Board Control Procedures (OBCP)". This function allowed the operators to load and modify simple application programs without affecting the basic onboard software; a very powerful tool that Rosetta efficiently and extensively used from the beginning. Although Mars Express had inherited this tool from the Rosetta onboard software, »



ABOVE
A key part of the Venus Express spacecraft's testing programme – deployment of the solar arrays.

« the Project team had forbidden its use for the mission, fearing that it could cause instabilities in the onboard software itself. Since the Venus Express Project team was largely the same as the one for Mars Express, the same veto over the use of OBCP was imposed for Venus Express before launch. However, the experience of the first years of flight with Rosetta's OBCP was so positive that the Venus Express Project team eventually softened their negative attitude towards them. While still preventing Astrium from making use of the tool during the development of the spacecraft, they allowed the ESOC operations team to design and develop ad hoc OBCP, under the condition that they would only be uplinked to the spacecraft after launch. Several OBCP were prepared and validated and the related operational procedures written accordingly. Once in flight, the OBCP were uplinked and activated, allowing ESOC to make use of this powerful and flexible tool from the beginning of the mission. (Mars Express was only allowed to use it from a few years after launch, and it was saved thanks to the use of OBCP on various occasions.) The use of this novel function increased the robustness of the Venus Express mission and streamlined the overall operational set-up.

Rosetta was finally launched on 2 March 2004. One month later my deputy team leader, Andrea Accomazzo, was nominated as SOM of Venus Express and started to build up the team that would bring the mission to launch just one and a half years later. Some other members of the Rosetta team, which was being reduced for the start of the long (and supposedly quiet) cruise to the comet, were also moved to the Venus Express team. Meanwhile I continued working full time on Rosetta, which was about to face its first Earth swing-by in March 2005. After that milestone, the operations became a bit quieter and I was assigned in parallel to the role of deputy Flight Director (FOD) for the launch of Venus Express.

For the first few days after launch, the so-called Launch and Early Orbit Phase (LEOP), ESOC traditionally establishes an extended Mission Control Team, divided into two shifts in order to fully cover 24-hour operations per day. The lead position for each of the two shifts is the Flight Director (FOD). Traditionally, one of the two FODs is the ground segment manager of the mission, while the other is an experienced operations manager from another mission. On this mission, I would be the Flight Director for the B-team. Although the role only lasts for about three days into the flight, the preparation activities for the Mission Control Team begin many months before launch. There are typically two simulation sessions per week, in which all the mission operations team members gather in their control rooms and exercise flight operations scenarios, training for the execution of normal operations as well as for recovery from unexpected anomalies and failures. It is a tough activity, but also very interesting and exciting. I was extremely happy to have been given this opportunity, even if it had come on top of my normal job of Rosetta SOM which still occupied most of my time.

TESTING AT RECORD SPEED

The spacecraft structure was delivered to the integration facilities in April 2004. By the spring of 2005, less than a year later, the spacecraft was ready for its thermal balance / thermal vacuum tests. After this milestone was completed, a rapid series of electromagnetic compatibility, system validation and integrated system tests were conducted. As with Mars Express, the launch would occur aboard a Russian Soyuz rocket from the Baikonur cosmodrome in Kazakhstan. On 3 August 2005, the spacecraft was ready for transport to the launch site, to which it was delivered on 7 August to begin launch preparations and integration with its Soyuz launcher. The spacecraft was fuelled in September and then finally integrated on top of the Fregat upper stage on 12 October.

APPROACHING LAUNCH

The launch window would open on 26 October and would remain open for about a month, until 23 November. For a direct trajectory towards Venus, missing this window would have meant having to wait for about 18 months until the next low energy launch opportunity.

The launch time was planned to be 04:43 UTC. My B-team would spend the night before launch on console in ESOC's Main Control Room (MCR), covering the so-called "network countdown" activities. This period starts about six hours before launch, during which the readiness of all ground segment elements and the related communication lines would be verified. In parallel, the engineers at Baikonur would prepare and fuel the rocket, as well as activate and configure the spacecraft mounted at its top for the initial flight activities. At around 03:45 UTC, I would be replaced on console by Manfred's A-team, who would then follow the final launch countdown and take over control of the spacecraft once released from the rocket's upper stage.

ABOVE
The Venus Express spacecraft's Soyuz-Frégat launcher glints in the evening sunlight at Baikonur Cosmodrome, Kazakhstan.

A few days before launch, on 21 October, I was in my office when bad news from the launch site reached us: an accident had occurred a few hours earlier. No more details were provided for the time being, but everyone in our team was very alarmed. We knew that on that day, the rocket – fully integrated and with our spacecraft already mounted on the top and enclosed in the fairings – was going to be transported horizontally to the launch pad and then erected vertically next to the launch tower. We assumed that something had gone wrong during this activity. We were informed that the dress rehearsal, the final joint simulation planned for the following Monday, would be postponed, but we still did not know the reason, nor until when. In my mind the nightmare scenario for anyone working on an interplanetary mission took on all its dramatic forms: a last- »

BELOW
Venus Express is rolled out aboard its launcher's Transport & Erector Wagon.

« minute problem that prevents the launch; the short launch window missed; the launch delayed to the next opportunity, many months or years later. I had gone through this very bad experience less than three years earlier, when Rosetta's launch was cancelled just one week before the planned date. This had forced us to redefine the entire mission, look for another comet, find another feasible trajectory and launch more than one year later.

After a very depressing weekend, with scant news coming from Baikonur, on Monday morning we finally received detailed information about what had happened. As the Soyuz was being transported to the launch pad, some debris was seen coming out of the fairings. By looking through the inspection openings in the fairings, the technicians discovered that the multi-layer insulation of the Fregat, the upper stage to which Venus Express was attached, was damaged, probably by excessive flux from the air conditioning inlet. With small insulation debris flying everywhere inside the fairings, a detailed inspection was absolutely necessary to find and remove all of it, to avoid potential damage to the rocket and the probe once in flight.

It took days to recover the situation, repairing the Fregat insulation first, then illuminating all parts of the probe and the upper stage which were exposed to the potential debris contamination with visible and UV light, finding all debris and removing it. Finally, nitrogen flow was used to blow away any remaining small debris that might have escaped the detailed search. We had to wait until 31 October to receive a new launch date, which was set for 9 November at 03:33 UTC, almost right in the middle of the four-week launch window. It was very good news and we could finally restart our preparation work in a positive spirit.

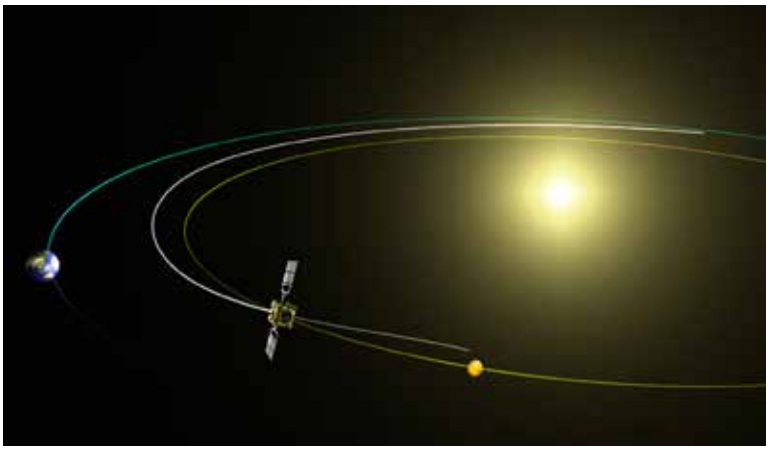
ABOVE
Venus Express finally lifts off from Baikonur Cosmodrome aboard its Soyuz-Frégat launcher, 9 November 2005.

LAUNCH

Around 22:00 local time on 8 October, my team took position on console in the Main Control Room. The ground station network we planned to use for the LEOP was quite wide, including our two deep space stations in Australia and Spain, our 15m antennae in Perth and in Kourou, plus two NASA DSN ground stations in Canberra, Australia and Goldstone, California. The readiness of all these stations and of our communications lines, prime and redundant, had to be verified sequentially during the night. The network countdown job is usually quite boring, but contrarily on that night it became the most stressful network countdown of my career. First, at about L-6 hours, while we were observing telemetry of the gradual activation and configuration of the spacecraft performed in Baikonur by our colleagues, we suddenly lost the contact. It turned out that the launch site had suffered a sudden power interruption, which had reset all computers and of course caused the complete switch-off on the spacecraft as well. The preparation work had to restart from the beginning. Fortunately, it was early enough in the pre-launch sequence for the work to be completed in time for the intended launch time. Then, while we were continuing our network verification activities, I saw Vicente Companys, our Flight Dynamics Team Coordinator, rushing into the control room. He told me that, during a final check of the launch geometry, his team had discovered that the Earth might appear in the field of view of the star trackers, blinding them and preventing them from working, at least temporarily. This meant we had to change the initial activation timeline to make sure we would not switch on the star trackers while they were blinded. In addition, some of our computer systems had problems throughout the night and had to be reset and re-tested. When Manfred Warhaut and his team came to replace us on console, at around 3:30 local time, my handover report to him contained a long list of issues, most of which were resolved but others were still being worked. Manfred took over the Flight Director position and I rushed to the canteen, to have some breakfast before coming back to witness the launch. It is a tradition in ESOC that the B-team stays around beyond the end of its shift and waits for the launch activities to be completed – up to the moment the first signal from the spacecraft is acquired – before going home and taking some

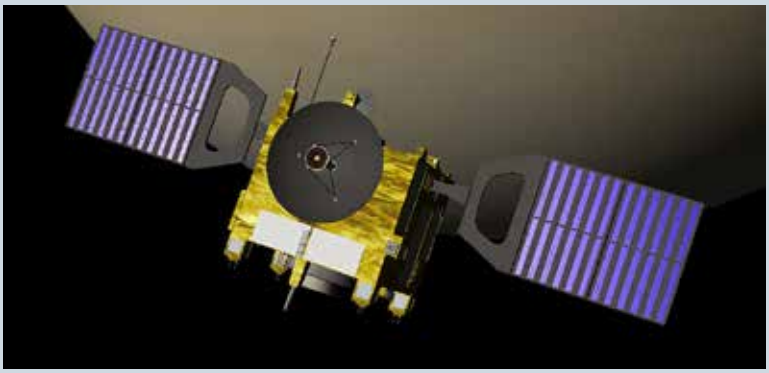
rest in preparation of the next day's shift.

At 03:33 UTC on 9 November 2005, the Soyuz lifted off as planned, taking our spacecraft into space. The flight of Soyuz included two burns of the upper stage Fregat, the first to enter a parking orbit and the second, about 90 minutes later, to inject Venus Express into an Earth escape trajectory towards Venus. Following these manoeuvres, the separation of the spacecraft from the rocket occurred automatically as planned at 05:30 UTC. The spacecraft activated its transmitter and our station in New Norcia immediately picked up the radio signal, confirming that the spacecraft was in good shape and in the expected orbit – at least roughly. At that moment I left the MCR and went home, to take a short rest and get some sleep before coming back on shift the next evening. The Venus Express LEOP, which had started with a long series of troubles in the last hours before launch, passed exceptionally quietly for the rest of the three days. The spacecraft was rapidly configured into its cruise operations mode, with all its required systems and units activated and verified (including a test of the propulsion system on 11 November). On 12 November, we officially declared the successful completion of the LEOP phase. The support teams and the additional stations were released and mission control was transferred to the interplanetary control room on the second floor of ESOC's D building, the same room from which we were operating the "sister' probes Mars Express and Rosetta. The journey of Venus Express towards Venus had begun in the best possible way. The flight control team immediately started the so-called commissioning phase, in which all on-board systems and payload instruments would be activated and verified in flight. This activity would keep them busy over the next few weeks. After that, preparations for the arrival at Venus would start while the spacecraft was quietly travelling in deep space. There was still a lot to do to get ready for Venus and our target was only 153 days away. SC



ABOVE
Artist's impression of the mission's flight trajectory.

BELOW
The author (right) in the ESOC Main Control Room during one of the Venus Express mission simulations.

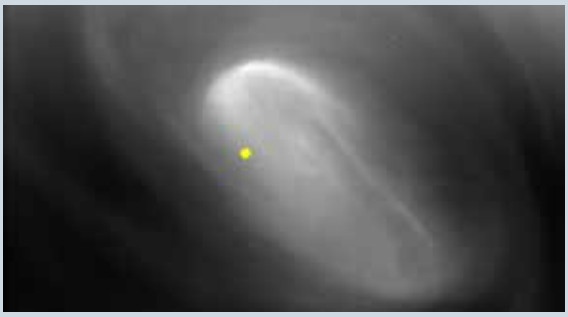


Venus Express Milestones

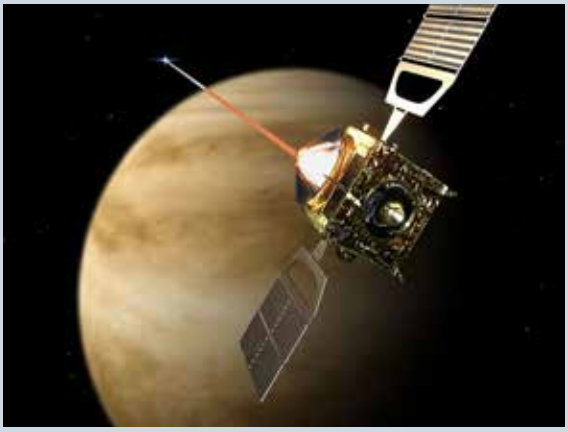
ORIGINALLY PLANNED FOR A 500 (EARTH) DAY NOMINAL MISSION (TWO YEARS), VENUS EXPRESS WAS EXTENDED FIVE TIMES TO OVER NINE YEARS.

9 November 2005	Launch.
11 November 2005	First trajectory correction manoeuvre using thrusters.
17 February 2006	The main engine is fired successfully in a dress rehearsal for the arrival manoeuvre.
24 February 2006	Second trajectory correction manoeuvre successful.
29 March 2006	Third trajectory correction manoeuvre successful – on target for orbit insertion on 11 April.
7 April 2006:	Command stack for orbit insertion manoeuvre is loaded on the spacecraft.
11 April 2006	Venus polar orbit insertion, after a 153-day journey, into a nine-day orbit of 400 by 330,000 km.
7 May 2006	Following seven further orbit control manoeuvres, Venus Express enters its target operational orbit of 250 × 66,000 km.
27 February 2007	First mission extension, until early May 2009.
19 September 2007	The 500-(Earth) day nominal mission concludes and the first mission extension period begins.
4 February 2009	Second mission extension, until 31 December 2009.
7 October 2009	Third mission extension, until 31 December 2012.
23 November 2010	Fourth mission extension, to 31 December 2014.
20 June 2013	Fifth and final mission extension, until 2015.
15 May 2014	Routine science operations concluded due to low propellants.
18 June 2014	Aerobraking experiment begins.
28 November 2014	Contact lost, possibly due to low propellant after nine years, though intermittent telemetry and telecommand links continue.
3 December 2014	Intermittent contact is re-established.
16 December 2014	After 9 years, 2 months and 9 days, ESA officially announces the end of the mission, although the X-band carrier signal is still being received.
18 January 2015	Last X-band carrier signal detected.
Late January/early February 2015	Estimated decay date.

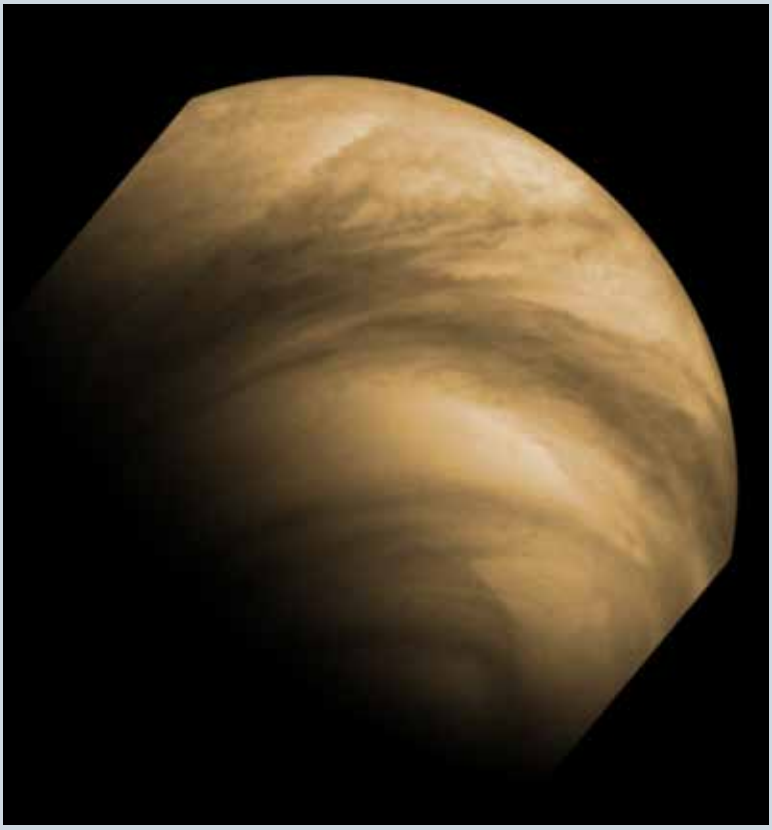
NOVEMBER 2007: LIGHTNING ON VENUS
The magnetometer (MAG) on board ESA's Venus Express detects wave signals that show evidence of lightning in the atmosphere.



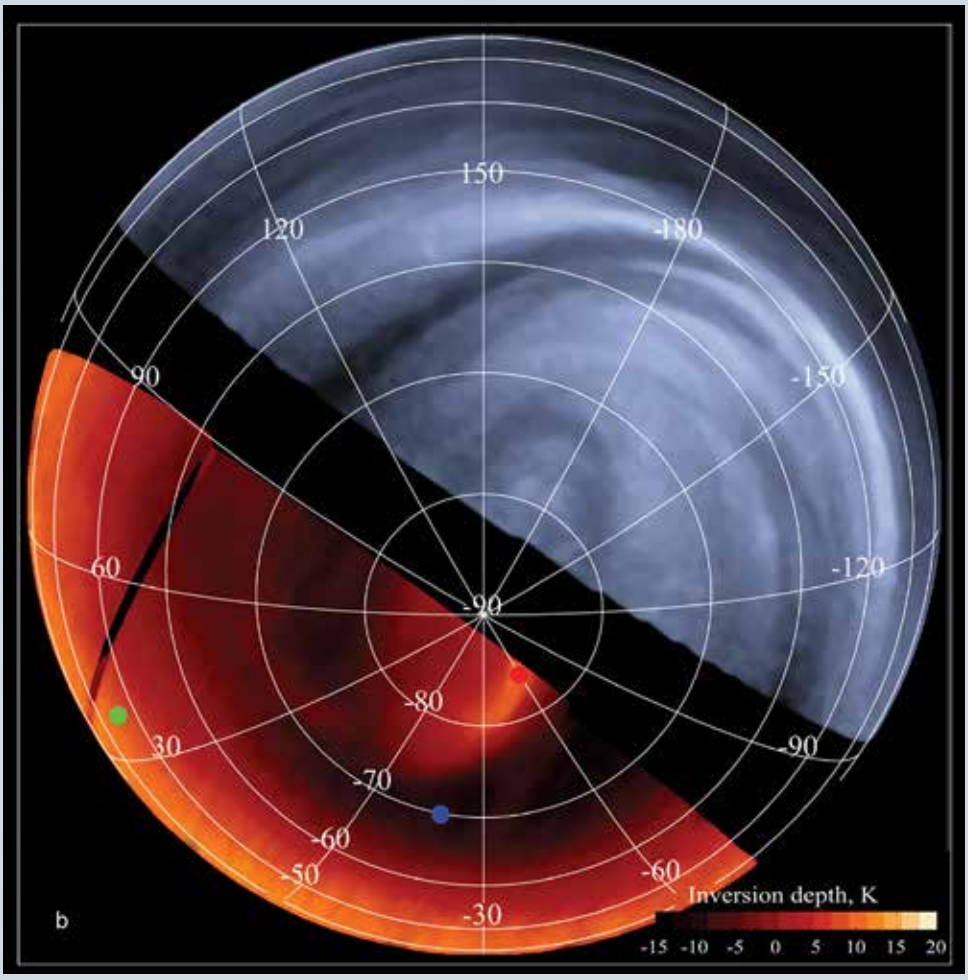
MARCH 2008: SOUTH POLAR VORTEX
This 'eye of the hurricane' on Venus was taken by the Visible and Infrared Thermal Imaging Spectrometer (VIRTIS) aboard Venus Express. The image shows a region in the Venusian atmosphere about 60 km from the surface, at a wavelength of about 5 µm. The yellow dot is the south pole.



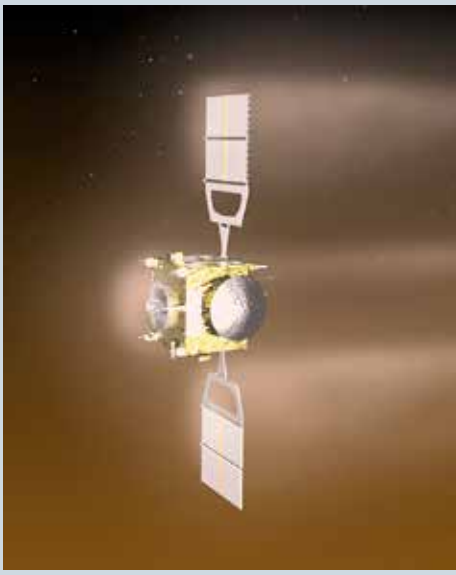
OCTOBER 2011: STELLAR OCCULTATION AT VENUS
Venus Express was the first mission to apply the technique of stellar occultation, which consists of looking at a star through Venus's atmospheric limb. By analysing the way the star's light is absorbed by the atmosphere, it is possible to deduce the characteristics of the atmosphere itself.



DECEMBER 2011: VENUS CLOUD TOPS
A false-colour image of the Venusian clouds taken by the Venus Monitoring Camera (VMC) on Venus Express at a distance of 30,000 km.



DECEMBER 2008: VENUS IN THE ULTRAVIOLET AND THE INFRARED
Venus pictured at night in the infrared (lower left) and during the day in the ultraviolet (upper right). Ultraviolet imaging reveals the structure of the planet's clouds and conditions in the atmosphere, while the infrared imaging provides information on the temperature and altitude of the cloud tops.



JUNE 2014: AEROBRAKING EXPERIMENT
A visualisation of Venus Express during aerobraking, which reduced its orbital altitude from around 200 km to 130 km. The spacecraft survived the test and its orbit was later raised back to 450 km for a final round of experiments before it was left to plunge into the Venusian atmosphere.

EYES ON THE STARS

Looking back on 65 years of NASA astronaut celestial navigation training.

by **Philip Corneille**

From 1960 onwards, all NASA astronauts were trained in astronomical observations, in recognition that it provided the basis for celestial navigation. Training started with a six-hour basic course followed by eight hours of star recognition, practicing celestial navigation. Celestial navigation using a sextant is the fine art of navigation by using the stars of well-known constellations, the naked-eye planets and the Moon.

While not a replacement for primary navigation systems, the hand-held sextant offered the crew an emergency back-up option to orientate their spacecraft and for navigational purposes, in the event of inertial platform or radio communications failure. While geo-positioning on Earth (e.g. by using the sextant in Marcq St. Hilaire azimuth intercept method) has been part of naval officers' training, space flight navigation using a hand-held sextant was more complicated, as spacecraft used high accuracy star trackers to measure the positions of stars in the reference frame of the spacecraft.

In practice, the automated star tracking navigation system needed a periodic update by human intervention as a little bit of drift would creep into the automatic system over a period of time, which could progressively accumulate into inaccuracies.

ABOVE
1960: Mercury astronaut John Glenn confronts a transparent celestial sphere as part of his space navigation training.

PLANETARIUM TRAINING

From 1960 until 1967, NASA astronauts trained at the Morehead Planetarium in Chapel Hill, North Carolina. From 1967 onwards they used the Griffith Observatory Planetarium in Los Angeles, California. The full-dome theatre at Morehead Planetarium became the hub where 62 astronauts assigned to the Mercury, Gemini, Apollo and Skylab programmes were taught to navigate through the stars, in case the spacecraft technology failed.

University of North Carolina astronomers and planetarium educators designed a general navigation training programme to teach the astronauts the positions of constellations and 57 guide stars that could key them into different areas of the sky. For the Apollo programme, the number of guide stars was trimmed down to 37. The aim was to provide the astronauts with a rock-solid mental picture of the star field, which was quintessential to applying procedures for celestial navigation correctly. This was an essential part of astronaut training, with this back-up celestial navigation proving important to their survival on a number of occasions.

Since the astronauts had only a limited view of the sky through a spacecraft's window, the planetarium staff turned to creative solutions in order to give the crew the most realistic view of the sky. For the Mercury astronauts, an old fighter pilot Link Aviation trainer with bespoke canopy was put into the planetarium to simulate star field movement.

AD-HOC SOLUTIONS

For the two-man Gemini missions, the Morehead staff created a two-man spacecraft trainer using a pair of swivelling barber chairs covered by a specially designed plywood box, with Gemini windows above their heads. Between the two axes of motion provided by the Zeiss planetarium projector, the modified barber chair could slowly turn to simulate the yaw motion of the Gemini spacecraft, providing the effect astronauts would encounter in Low Earth Orbit. During Gemini programme training, the planetarium could adapt the brightness of the stars to exactly how these would be seen outside Earth's atmosphere. The astronauts practiced using a hand-held sextant in the cramped Gemini spacecraft and during a Gemini stand-up EVA (spacewalk).

APOLLO'S PINGS AND AGS

In the Apollo programme, the Command & Service Module (CSM) spacecraft built by North American Aviation and the Lunar Module (LM) built by Grumman Aviation both had a built-in primary guidance, navigation, and control system (PGNCS). This was developed at the Massachusetts Institute of Technology (MIT) laboratory under the direction of aeronautical engineer Charles »

ABOVE
March 1960: Mercury astronauts Walter Schirra, Scott Carpenter and Morehead Planetarium staff pose besides a Link Aviation trainer with bespoke canopy.
BELOW
May 1965: Gemini IV astronauts Ed White and James McDivitt use the swivelling barber chair combo to practice celestial navigation at Morehead Planetarium, North Carolina.

RIGHT: NASA / ABOVE RIGHT: UNIVERSITY OF NORTH-CAROLINA/NASA

NASA

« Stark Drape (1901-1987), who became known as "the father of inertial navigation".

The PGNCS of both the CSM and LM had the same Inertial Measurement Unit (IMU) and Apollo Guidance Computer (AGC) but used a different optical unit, consisting of a sextant and scanning telescope with different eye pieces. The IMU, consisting of three gyroscopes and three accelerometers, was linked to the AGC using onboard guidance software. The spacecraft platform, with its three gyroscopes isolated from spacecraft motions, provided a fixed reference frame which could be aligned in relation to the stars.

However, due to the gyroscopes' precession, the Apollo inertial guiding system drifted by 1 milliradian per hour and needed to be realigned by sighting of guidance stars. Essentially, NASA's worldwide Deep Space Network provided accurate telemetry and tracking data to Mission Control, which periodically updated the astronauts with given state vector updates to be entered into the AGC.

The LM had a third means of navigation in the form of the Abort Guidance System (AGS), built by TRW aerospace. This could be used in case of PGNCS failure. The AGS was designed to provide navigation during take-off from the Moon and to rendezvous with the CSM, but not for lunar landing.

When the Apollo astronauts began training at Griffith Observatory from 1967, a simple recliner chair with a head cover simulating the CSM sextant view was used.

ABOVE
May 1965: Gemini IV astronaut Ed White demonstrates the use of a hand-held sextant.

BELOW
May 1965: Gemini XII astronaut Buzz Aldrin is briefed by Dr Nancy Grace Roman, NASA's first chief of Astronomy, as she points out celestial objects on a star chart at NASA HQ, Washington, D.C..

MERCURY AND GEMINI

The Mercury project astronaut was primarily occupied with systems management and sequence monitoring, but navigation was an important task as the astronaut constantly had to know his correct position. The Mercury spacecraft travelled at 8 km per second in Low Earth Orbit, so nominal trajectory keeping was crucial because contact over the monitor ground stations of the Manned Spacecraft Network (MSN) only lasted between two and five minutes. The Mercury capsule was monitored by radar sites around the Earth, which transmitted telemetry and tracking to

NASA

the central computer at the Mercury Control Center. This information was used to set the exact retro time into the onboard mechanical clock, which would not be affected by any loss of electrical power in the vehicle. If visibility allowed, the Mercury astronaut could update nominal trajectory data by looking at ground references through the periscope, or make corrections via celestial reference by looking at the constellations through the capsule window.

During the May 1963 Mercury-Atlas 9 "Faith-7" mission, astronaut Gordon Cooper was on his way back to Earth when all his primary and secondary navigation equipment failed. Looking out of the spacecraft's window, Cooper searched for and found three guide stars to navigate the capsule manually to splashdown in the Pacific Ocean. Despite the lack of automatic systems, it proved to be the most accurate landing of any during the Mercury missions. Cooper later mentioned that he had drawn lines on the capsule window to stay aligned with the constellations and had used his Omega Speedmaster chronograph wristwatch to time the burn and his eyes to maintain attitude.

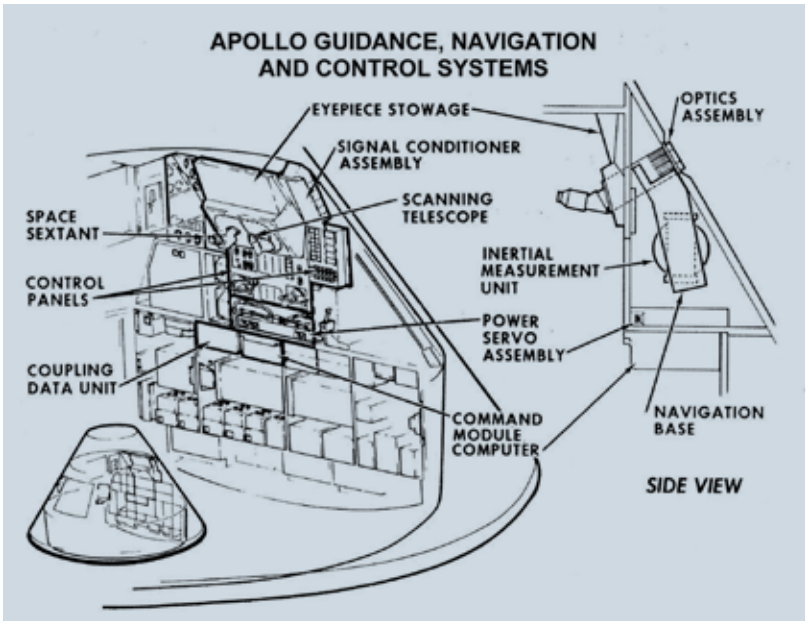
During the Gemini IV mission in June 1965, it became clear that it was very difficult to use a sextant in the spacecraft and Edward White found out he could only do so after removing his spacesuit helmet. As David Scott held a master's degree in interplanetary navigation before joining NASA, he was given responsibility for guidance and navigation issues as a technical assignment in the astronaut office. However, it was Michael Collins who earned the nickname "Magellan" due to his dedication in training aboard NASA's zero-G aircraft practicing the use of a hand-held sextant. Collins performed two EVAs during the Gemini X mission in July 1966, the first of which was a Stand-Up EVA in the hatch doing celestial navigation and taking ultra-violet signatures of selected stars. During Gemini XII in November 1966, Buzz Aldrin used a two-line-of-sight sextant which was stowed between the two astronauts. In practice, a long eye relief telescope eyepiece facilitated sextant usage while wearing a helmet, demonstrating the potential of a hand-held sextant for future Apollo programme midcourse navigation.

THE APOLLO YEARS

Records show that Neil Armstrong completed 11 sessions of celestial navigation training totalling 116 hours at the Morehead Planetarium. This was supplemented by endless familiarization training of PGNCS equipment at the MIT laboratory in Massachusetts. During the Apollo 11 mission, two PGNCS alarms (1201 "No VAC areas available" and 1202 "Executive alarm, no core sets") were relayed to Mission Control as the first lunar landing was being attempted »

RIGHT & ABOVE RIGHT: NASA

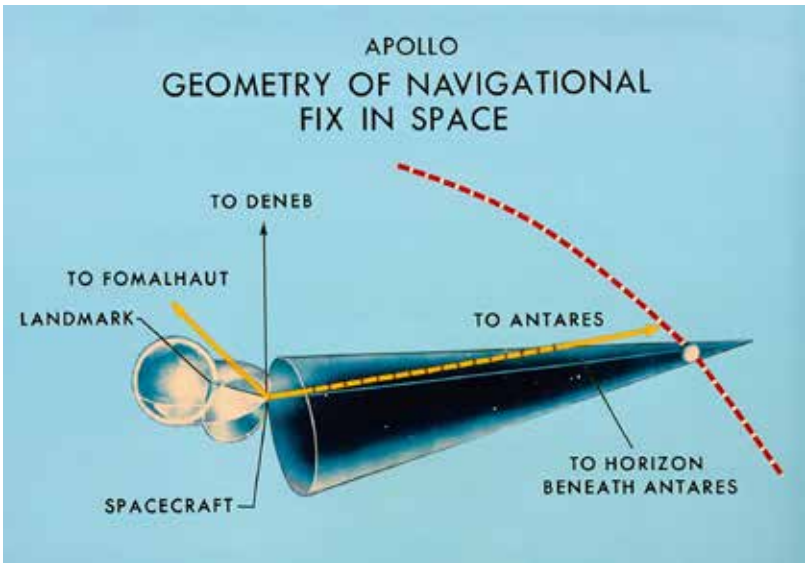
ABOVE
December 1967: Astronauts assigned to the first LM test flight mission in Earth orbit pose with Griffith Observatory director Dr. Clarence Cleminshaw near the Zeiss Mk IV projector. David Scott (CMP) lies in the recliner chair with the bespoke head cover used for Apollo training. From left: Dr. Gleminshaw, Rusty Schweikart (LMP), Jim McDivitt (Commander), Al Worden (Support), Dick Gordon (backup CMP) and Al Bean (backup LMP).
BELOW
The celestial naviagtion equipment carried aboard the Apollo CSM.



« on 20 July 1969. The computer system overload was caused by the simultaneous capture of landing radar data and rendezvous radar data. Support staff at Mission Control concluded that the alarms could be safely ignored and the landing succeeded.

On 14 November 1969, lightning struck the Apollo 12 spacecraft atop the Saturn V launch vehicle immediately after lift-off, temporarily disabling the spacecraft's navigation system. Protective circuits on the fuel cells in the Service Module falsely detected overloads and took all three fuel cells offline, along with much of the CSM instrumentation. A second lightning strike at 52 seconds after launch knocked out the "8-ball" attitude indicator. The telemetry stream at Mission Control was garbled, but the Saturn V continued to fly correctly as the strikes had not affected the rocket's Instrument Unit, whose separate navigation system remained operational to achieve Low Earth Orbit. Following this, the Apollo 12 astronauts used their Morehead star training to realign their spacecraft's system and then went on to carry out the translunar injection burn successfully to put them on course for the Moon.

During Apollo 13, after the most critical burn near the Moon, the Abort Guidance System aboard LM "Aquarius" was used instead of the PGNCS because it required far less electrical power and cooling water. On 15 April 1970, the crew worked together to perform a 14-second LM Descent Propulsion System burn to align both spacecraft, leading ultimately to a safe re-entry and splashdown in the Pacific Ocean near Samoa on 17 April 1970.



NASA

ABOVE
Diagram showing how the Apollo spacecraft could fix its position in space by reference to a designated landmark on Earth and the positions of the three bright stars Antares (Scorpius), Deneb (Cygnus) and Fomalhaut (Piscis Austrinus).

BELOW
2018: ISS-56 astronaut Alexander Gerst operates a Sextant Navigation device to test emergency navigation methods for future Orion missions.

ANNO 2025

Fast-forward over 65 years and hand-held sextant celestial training remains part of international spacefarers' mission preparations. It provides a back-up navigational tool in case of emergencies onboard the International Space Station, such as loss of radio contact or failure of the solar arrays. Moreover, the centuries old Mariners' modus operandi – using a sextant as a means of autonomous navigational back-up in critical situations – will continue to be important during future space flight missions to the Moon, Mars and beyond. SC

The author thanks Ed Hengeveld for confirming the dates of NASA photographs.

ESA

UNLOCKING THE SPACE VAULT

In June 2025, one of the largest private collections of flown space artefacts landed in the UK at the Thinktank: Birmingham Science Museum. A wide programme of events over the next year supports this exciting collection and offers the opportunity to see rare and historic objects returned from the Moon, low Earth orbit and from deeper in space.

by **David J. Shayler FBIS**

As Editor of *Space Chronicle*, I had the opportunity to interview the collection's owner and curator, Dr Michael Warner, to ask how this collection came about and was prepared for display. I also took a behind-the-scenes look at the challenges of setting up such a unique private collection as a public exhibition, as well as the exhibits themselves.

UK space journalist Tim Furniss once told me that the challenge of telling the story of space exploration is that once an object is launched into space, it generally does not return to Earth. The items that do are usually large re-entry capsules, complex experiment hardware, or lumps of charred metal that survive re-entry. Getting the public interested in these inert objects is difficult and trying to tell the story behind them is even more challenging. With just a few words or associated pictures in a display case, selection and presentation is key. It is unlike walking around a castle or ancient monument, seeing jewels and pottery in shiny display cases or on life-like mannikins, or following in the footsteps of countless visitors that have wandered historical sites over the centuries. Space is for everyone, or so it is said, but not everyone can access 'space'.

ABOVE
The pristine Space Vault Exhibition awaits its first visitors, who would be unaware of the passion, cost and commitment in creating and preparing this unique collection for public display.

BRINGING SPACE DOWN TO EARTH

There have been collections of 'space hardware' on display across the globe since the dawn of the Space Age, usually »

in galleries at leading space agencies or national museums, or sometimes in travelling or special exhibitions. These can feature officially donated 'flown items', together with training mock-ups, back-up hardware or un-flown spares. So what makes this collection different?

Private collectors of unique space memorabilia or certified flown items do not normally display them to the public. Even rarer is the desire and commitment to tell the story behind the objects displayed. This is where Space Vault stands out from other collections. As one of the UK's largest private collections of space artefacts, in public view for a limited time, it contains rare and historic objects presented in 12 chronological displays, brought to life using immersive visuals and targeted story-telling.

During the 12 months the exhibition will be at Thinktank[1], visitors are not only able to view the objects up close, but also enjoy a programme of space-related events (including expert talks and space-themed cinema screenings) and special opportunities to explore in depth and learn more about selected artefacts and the intriguing stories behind them.

The box feature on pp. 23-24 lists the primary exhibits, but the story behind each object and why it was selected is reserved for the exhibition itself. Here is the genesis of that exhibition, revealing how, for a young Michael Warner, the summer of 1969, and a few decades later surfing the news in 2010 to pass time in a South African airport lounge and an Act of Congress all ignited a spark of interest to buy a star chart that had flown on Apollo 15. From there, the collection grew to what is now on display in Birmingham, primarily because of the story behind each object and a passionate desire to share those stories with a wider audience.

NOT REALLY A SPACE FAN

On Monday 21 July 1969, a six-year-old Michael Warner was sitting on the floor in a primary school assembly, watching a TV set on a stage that was showing a black-and-white transmission from the Apollo 11 Moon landing. He clearly remembered the wooden floor of the stage and that "the casing that the TV was in was [also] lightly coloured wood… It had four legs and looked a lot like the lunar lander and that sort of stuck in my head". But for years afterwards Michael was not a 'space fan', as such: "No, not really. My education [and career] was in civil engineering and environmental management. I had a general [rather than] particular wonder in space, until recent years when the environmental

[1] General entry to the Space Vault exhibition is included in the admission price for Thinktank via their website (see p.24).

ABOVE
Owner and curator of the Space Vault collection, Dr Michael Warner, enthusiastically introduces the exhibition to invited guests on 13 June 2025 – the day before it opened to the public.

world, especially climate change, bumped up against satellite imagery. It just sort of [crept up] gradually." Michael recalled that his dad was "quite into astronomy" and sometimes he would stop the car and get out while driving back from the countryside. Then aged around eight or nine years old, Michael and his brothers would lie on the bonnet of the car while their father explained the stars and how to navigate around the night sky. "I think from him there was a little bit of fascination [with the stars], but no I wasn't some sort of space geek," Michael recalled. Many years later, legislation passed through US Congress re-ignited the spark of interest for Michael, who began to secure space-flown items for what would become the Space Vault collection.

AN ACT OF CONGRESS

Around 2010, during a business trip in South Africa, Michael was in an airport lounge killing time surfing the news online when he became aware of Jim Lovell's attempt to sell the Lunar Module Activation list from Apollo 13. The news item told how NASA had stopped the sale, claiming that these

ALL IMAGES COURTESY OF DAVID J. SHAYLER/AIS ARCHIVE UNLESS OTHERWISE STATED.

and similar items were owned by the space agency and not the astronaut. "I though that was interesting", Michael explained, "[I was] unaware that anyone could even attempt to purchase something like that."

The background to this event was a two-year process to define US legislation on such items, resulting in Act of Congress H.R. 4158 in September 2012 "to confirm full ownership rights for certain United States astronauts to artefacts from the astronauts' space missions". Proposed as a particular reward for the huge risks taken in these pioneering programmes, the legislation was bipartisan and flew through both the House of Representatives (19 September) and the House of Congress (20 September). The legislation was specific only to "astronauts who participated in, or received any artefact during his participation in, any of the Mercury, Gemini or Apollo programs through the completion of the Apollo-Soyuz Test Project in July 1975". These specific items included personal logs, checklists, flight manuals, prototype and proof test articles used in training and disposable flight hardware salvaged from jettisoned Lunar Modules but did NOT include lunar rocks and other lunar material.

In my discussions with Michael we wondered together why the legislation cites only the Apollo program lunar modules and not the Mercury or Gemini capsules or Apollo Command Module. We came up with two possible explanations, firstly that the lunar modules were never intended to come back to Earth and return to NASA, so the crews had an incentive to extract an item or two before jettisoning the craft in lunar orbit. The second explanation Michael's wonders is "a nod to the Apollo 13 mission, in which the crew were able to scramble together items from the lunar module, which had acted as their lifeboat and was only jettisoned when near Earth. Of note, storage netting from *Aquarius* – the Apollo 13 lunar module – is on display in the Space Vault Exhibition, supported by a letter from Fred Haise describing "the frantic time-pressured salvage operation".

According to the wording of the act, these astronauts "shall have full ownership of and clear title to such artefacts… and [for] a United States astronaut who participated in said program, the [US] Federal Government has no claim or right to ownership, control or use of any artefact in possession of an astronaut or that is subsequently transferred, sold or assigned to a third party by an astronaut".

In other words, the Act confirmed full ownership rights by certain astronauts to certain artefacts. "If you met the criteria," Michael explained "the government had no claim over the ownership of items subsequently transferred or sold." At the time, around 30 astronauts who qualified were still alive. Of course, as time moved on that number reduced and the objects became rarer, but as Michael pointed out, "so was born a market in these astronaut-owned artefacts." This inevitably led to a wave of flown or personal artefacts appearing on the open market at auctions and this is where Michael got caught up – surfing this wave.

"I WENT TO THE GARDEN LOOKING AT THE CHART AND LOOKING UP AT THE MOON AND REALISED WOW! – THAT THING WENT AROUND IT"

AN OBJECT FROM THE HEAVENS

The first artefact obtained by Michael was a star chart flown on Apollo 15, with appropriate provenance from the man who used it on the mission, CM Pilot Al Worden. "It was just crazy for me in my head to receive that [artefact]," recalled Michael. "I went to the garden looking at the chart and looking up at the Moon and realised Wow! – that thing went around it."

That "Wow" factor is the story behind that star chart and the other flown items that Michael wanted to tell in his collection. He noted that there were two types of audience for exhibitions and artefacts such as those displayed in Space Vault. There are those, like Michael, who realise that such objects can reach the heavens and return to Earth and that there is a story to tell around it which brings the object to life through its interaction with the astronauts at a particular moment in history. Then there are those visitors who walk through the exhibition, "…waiting for something to excite them, like a video clip or something, who are not enamoured by the story behind the object". It is exactly the former group - those enthralled by the stories

BELOW
The power and the glory: recreating the 'Wow!' factor for the audience with a film of a Saturn 5 launch as they enter the exhibition and begin their journey around the displays.

behind each artefact - that Michael aimed his exhibition towards to engage and hopefully inspire visitors to learn more.

RESEARCHING THE BACKGROUND

This type of commitment does not happen overnight and does not come cheaply. Initially, Michael knew he could not afford such "out-of-this-world" luxuries as space-flown artefacts, but over time and unexpected developments in his career, it did indeed become possible to own an object that had been flown in space. "That's a hell of a thing to have in your house," Michael admitted and it certainly becomes an intriguing talking point over dinner.

Michael has always been interested in what could be discovered in the detail behind each object: "I've never bought anything that I haven't researched beforehand and found a particular interesting story to tell," he told *Space Chronicle*.

SOUND BITES

"It's an absolute joy to have an artefact that is mentioned directly or used in some way in the air-to-ground transcripts. We have all the transcripts from all those Apollo missions and then you've got to find the audio [linked to the object]. So I used to be busy working and I'd have the audio running [in the background], waiting to hear certain words. It might take two hours, but over the years I've speeded this up because all you have to do is pick out a word that you think relates to the artefact. It could be 'checklist'. That's easy. Finding it in the transcript is easy. However, the audio archive is not, in my experience, as nicely laid out in the audio as per the ground elapsed time, so it doesn't match the timing of the transcripts and it's in about 100 chunks. But you can play a piece of the audio archive, find the words that are unique, look them up in the transcript, then work out how far into the audio it is and you can get quite close. [It takes] about half an hour now to find both the audio and the transcript. Then I'd put together a display presentation that's got the audio aligned with the transcript and the artefact - all laid out together."

LINKING HISTORY

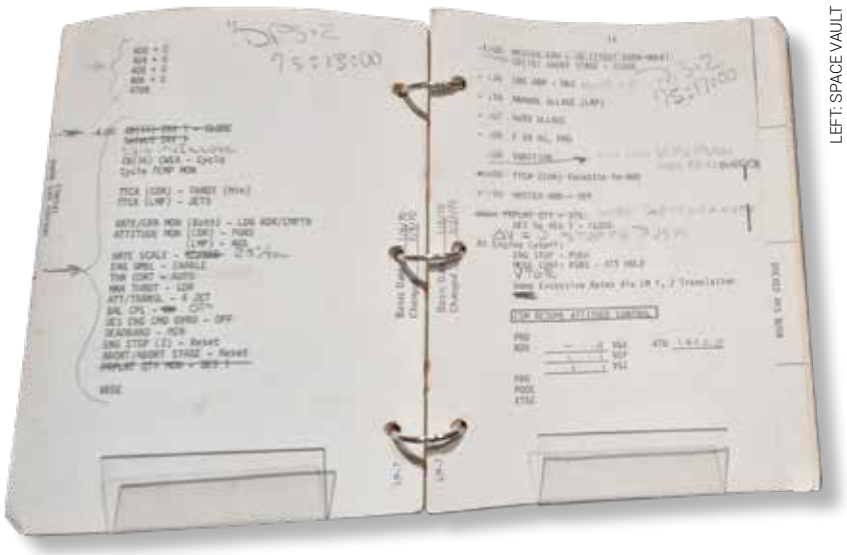
Describing one particular period of research, Michael cited the link between Apollo 13 and Apollo 9 and the documentation in the exhibition that told the story of the manuals that saved Apollo 13 (a story published by BIS in *SpaceFlight* Vol 62 April 2020). On Apollo 13, the aborted lunar landing mission of April 1970, there was the scheduled flight plan document for the mission as it should have been flown. "It's fascinating hearing these things [on the air to ground commentary] changed along the way, together with reading the hand-amended notes and transcription, which in effect becomes the artefact and seeing history in front of you to tell the story," Michael observed enthusiastically.

ABOVE
A page from the flown Apollo 9 Lunar Module #3 documentation with LMP Rusty Schweickart's comment on seeing it again 46 years later.

Two important documents highlighting the story of Apollo 13 are on display in the Space Vault exhibition. The first is from Apollo 9 flown in March 1969, over a year before Apollo 13. That mission was the very first full (all-up stack) crewed test of the complete Apollo Saturn V hardware in Earth orbit: All three stages of the Saturn, the Command Service Module, the Lunar Module and the EVA spacesuit. On display is the flown Apollo 9 Lunar Module Systems Evaluation checklist, with real-time annotations by the astronauts. During the mission, the crew practised a contingency burn of the descent engine of the LM with the CSM still attached, recording the data as they experienced it. Fortuitously – and unknown at the time – this would be the exact burn needed to bring Apollo 13 back home a year later.

The second important document on display was not flown in space but was as critical, if not more so, for Apollo 13. On console in April 1970 was Capcom Charles Duke, the back-up LM pilot. He had the LM contingency checklist manual on hand, heavily annotated from all the simulations of a docked CSM/LM burn and the lessons learnt on Apollo 9, which he read up to the crew. As the audio played, Michael explained: "You can see the handwritten annotations by Duke on the document and you can hear the exact air-to-ground commentary as Fred Haise and Jim Lovell read them back to Duke to ensure they

BELOW
The Apollo 13 display (right) gives pride of place to Charlie Duke's annotated LM Contingency Docked DPS (Descent Propulsion System) Burn checklist (below), which he referred to while on capcom duty during the Apollo 13 mission.



LEFT: SPACE VAULT

had the procedures and figures noted down correctly. Key moments from space history."

CREATING AN EXHIBITION

Walking around this and similar exhibitions and displays, you will view pristine objects in protective glass cases, all neatly annotated with labels and explanations. But this is not a permanent exhibition and will leave Birmingham after a year, so ensuring that the artefacts are handled with care and attention for the next exhibition venue is taken very seriously. A lot of time has been invested in getting it right.

You would imagine that such an exhibition of space-flown hardware and fragile objects would need a huge team and long lead time, as with curating and displaying Egyptian relics of antiquity or priceless Royal jewels. In such cases, a huge team of professional curators spends months or years gathering, displaying and caring for the objects in situ. For the Space Vault Exhibition, Michael and his team are equally diligent, but clearly not so large. This is only the third display of these objects, as Michael explained: "Six months with the European Space Agency in Oxford, then a year at the public museum in Henley on Thames and now it's at the second largest science museum site in the UK." Being a touring exhibition adds to the complexity of maintaining and displaying artefacts in good order. How can the artefacts be packed, transported, then unpacked and displayed again without damaging their fragile condition? Michael observed that such operations can be challenging and worrying but also personally satisfying:

"[For] the initial setup going to the Thinktank museum, I've moved the artefacts. I bring them out from their displays myself, protect them in their packaging and then take them in my vehicles [to the venue]. That protects [them] because I really don't want anyone touching those artefacts. You can insure it, but they are really uninsurable. What's the point in being given the money back to buy something you can't ever buy again? So I see myself as a custodian of these things. One day they will all go back to auction, probably back to the US. [For now] I'm here as the custodian, the guardian and I've decided to put them on public display. Then the other set of objects are the display cases, the pedestals and the display text boards. All that stuff is less worrying. You can replace that. That's all sent up in advance.

"We've had an adventure acquiring a quite chunky one-metre-diameter globe. It's an LED spherical screen actually, which is just fantastic. NASA has open-source software images for spherical screens, so that's going to be pretty cool. That's a piece of immersive equipment. In addition, humidity, temperature, and sunlight are the three things you've got to watch, particularly sunlight.

ABOVE
Exhibition views the public will not see. Amid packing cases, ladders and bubble wrap, the displays slowly take shape (top), while (above) Michael Warner (left) and helper carefully lower a protective cover over the Apollo 9 artefacts.

BELOW
Michael Warner gives former LLRV test pilot Jack Klueveron's pilot helmet one final check.

The Henley Museum was brilliant. We could control all three of those. We had humidifiers in there, we had air conditioning, temperature control and we had no external light coming in. We could control which spotlights we wanted on or off and where they pointed, so that was all absolutely brilliant.

"Lighting, temperature, humidity. [that's] down to a specialist [in the venue]. The museum in Birmingham is one of nine establishments – art galleries, museums – where the trustees are the Birmingham Museums Trust. It's a civil service machine. They've got people for everything and they've got someone dedicated to this who did an excellent job identifying and then setting the optimum levels of light and other parameters".

"Also, [its important] not to have certain [document] pages open all the time, especially for a year-long [exhibition], even though they are the critical pages. So you turn the pages and lights go off at night".

"So I am conscious of it. I'd like it all to go back to auction, so I'm being pretty careful. It's all under protected hoods. No one can touch anything, [as everything is under] thick Perspex hoods. Its [fixings are] drilled in and you can't get at it. So it's all pretty protected."

A final word of advice from Michael regarding moving and setting up such fragile displays was "Never underestimate bubble wrap and plastic disposable gloves."

»

BEYOND APOLLO

In 2022, Michael began to target objects specifically to fill gaps in the story of the six displays that focused on Apollo and six on developments after the lunar programme, creating the 12 chronicles found in the Thinktank displays. There are objects from the Soviet space era and recent US commercial programmes, but not everything is a flown object. Michael explained: "The exhibition is about human space flight. It's not 'space exploration' it's not satellites, it's the human factor; the way that astronauts interacted with these objects in space and on the Moon. That is just fascinating. [For example] Apollo 13 does seem to be the enduring, exciting story beyond Apollo 11, [and recently] I invested in a [Soviet] Strizh pressure suit, which was quite expensive. I was thinking here about the exhibition and how it's quite story-heavy and text-heavy. As I've moved into the exhibition world, I've realised you need items that have a sort of 'Wow' factor for everyone, even if they don't bother reading the text, so a couple of spacesuits looks cool and they are just amazing pieces of kit."

On the subject of artifacts that Michael had bid for at auction but was unsuccessful, he explained: "Very early ones are much harder to get. I tried but failed to get some from the early Soviet era. Alexei Leonov was commander of the Soyuz in the Apollo joint mission and his logbook was up for auction. On the back leaf of the front cover was a sketch, debatably the first piece of art in space, which I really thought would be fantastic and a major part of the display. But I didn't bid high enough." (The display does include gloves used by Nikolai Budarin on missions to the Mir space station.)

PROVENANCE, PROVENANCE

Ensuring the items obtained are genuine and having the evidence to support that is also crucial: "Provenance, provenance, provenance. There's no point, no validity, in the item without provenance. And obviously if I want to resell them I need the provenance. The best is where it's signed by the astronaut." Michael says he has yet to be challenged on the authenticity of stating an object had been flown based on a Letter of Authenticity (LOA) as this type of provenance is known in the space auction market. "We haven't yet seen such a challenge in the space artefacts market. It's different, not where the art market is. The space market is much smaller and a long way behind. There isn't much money to be made from forging this stuff, especially the Apollo mission artifacts, because with just a handful of individuals covered by the legislation it's fairly easy to verify. I haven't come across anything which I am strongly suspicious of in 15 years." But just a few weeks before the Birmingham exhibition, Michael experienced a surprise with his collection.

LEFT: BIRMINGHAM MUSEUMS TRUST

ABOVE
The Soviet Strizh (Buran) pressure suit awaits its display case (top) and (above) Michael, wearing protective gloves, gives the visor a final polish.

BELOW
The 'NASA's Finest Hour' Apollo 13 display includes a 2017 note from LMP Fred Haise recalling the "salvage" of items from LM *Aquarius* towards the end of the mission and a ground-test Command Module LiOH filter.

NOT WHAT IT SEEMED

"I was sat on a Zoom call with a fellow British collector and I'm opening a Union Carbide package, the manufacturer of Apollo's contingency sample bag. When the Commander first stepped off the ladder, within the first minute, they had to scoop up a little [lunar] sample in a Teflon bag, on a concertina sort of tube that became a rod, like a golf club." This ensured that at least a small, undocumented lunar sample had been gathered from the landing site, in case of an early return to orbit. Michael continued: "[Before use] It was a quite small, 1 kg [package], but this unflown one had never been opened. It was wrapped in a metal mesh, like medieval armour and [still had the original] tape on it. You know when tape is very old, it flakes away. I thought I knew what we were getting and the idea was to video the exciting experience of opening it. That would cause obviously irreversible damage to the packaging, but with the objective of displaying the sample bag and creating a story around it [and the packaging] for the exhibition. We debated it for a long time. I've got a video of me and my friend talking whether or not to do it.

They decided to go ahead with opening that package, but all was not as advertised.

"Inside was a light, Bakelite material, which they used to put around radios, but that's all. In other words, the sample wasn't there. For me [that meant] I've lost a considerable amount of investment in the process.

"But to be fair to the auctioneers they reimbursed the purchase, which is exactly what an auction house should do. I pointed out that this item I bought was not correctly advertised and when opened – it had never been open in 55 years – did not contain the said contingency soil sampler. Instead, there was a mock-up of the weight and size of the piece of equipment that should have been there." Michael explained that he found out that NASA sometimes did this to test out the storage space during the design of the Lunar Module. "So, although that's an interesting story, there was no actual soil sampler container contained within.

"If [the auction house had] played hardball, they could have said 'We didn't say it was in there', but I would have argued that they had because the title of it was 'A Contingency Soil Sampler' and [they] described the sampler in an unopened package. I think if ever it had gone to court, I probably would have won that. But they didn't. They agreed 'it wasn't in there [and] we said it was, so here's your money back.'

PUTTING IT ALL TOGETHER

Shortly after the interview, I was able to visit the Thinktank museum display a couple of days before its formal opening. Here, I was able to see Michael and his colleagues put the finishing touches to the display. During the exhibition, the public will see the items on display – with explanation cards or audio – in pristine condition and correctly lit. Many do not realise the effort, time and worry that goes into setting up something like this. These were not museum owned objects but items personally loaned by Michael, adding pressure regarding their security as these were his objects, collected over several years and at significant cost. Great care has to be taken in siting and installing each item safely, while the lighting, graphics and audio/video has to be coordinated. All this within the few days prior to the official launch.

With the exhibition advertised weeks in advance, it has to open at the appointed time, so it can become stressful working against the clock to ensure everything is in place and working as it should. Lunch breaks were forgotten and the days flew by as Michael and his team ensured that all last minute items were checked off the list. Right on time (Friday 13 June, of all dates), Michael enthusiastically introduced the exhibition to the 80 or so invited guests.

WE HAVE LIFT OFF!

It is one thing to see a picture of an object to be used in space, or an image of it during an actual mission. It is quite another experience to see it for real on display and learn of the story behind it. This feature was not intended as an explanation of each and every object or the stories behind them. This is the story behind those stories and objects you will see if you visit the exhibition at Thinktank.

On that preview night, there was genuine interest in the contents of the exhibition. From 14 June, it opened to the public for the next year. So why not take the opportunity, when in Birmingham, to take a look inside the Space Vault yourselves. You will not be disappointed. SC

The author wishes to extend his thanks to Michael Warner, owner and curator of the fascinating Space Vault collection, for an interview and for allowing unique behind-the-scenes viewing of the display before the official opening. Thanks also to the staff of Birmingham Museums, especially PR & Comms Officer Sue Smith, Exhibitions Manager Katie Morton and Digital Coordinators Ria Frate and Nadine Lees.

BELOW
Two views of the exhibition – one in the still of night, shortly before the opening; the other on Opening Day, Friday 13 June 2025, before an invited audience. Public viewing commenced the following day.

LOWER RIGHT: SPACE VAULT

The Exhibition Display Stations

There are 12 chronological displays, which take the visitor through this collection of space artefacts from the 1960s to the present day surrounded by a lunar landscape backdrop made up of photographs taken by the Apollo astronauts. There are more than 100 artefacts to view and learn about. Your journey starts with an impressive video of a Saturn V launch – Earth to orbit in just a few minutes. Then you are then invited on a journey through the key moments and objects from space history portrayed in the dozen displays, with supplementary audio guides. The museum's website explains other activities and events across the year.
https://www.birminghammuseums.org.uk/exhibitions/the-space-vault

DISPLAY STATION 1 ENGINEERING THE MOON
The flight suit used by Emil 'Jack' Klueveron, who piloted the Lunar Landing Research Vehicle, the forerunner of the training vehicle used by astronauts to simulate lunar landing procedures on Earth. Also included are flight helmets, manuals, reports and photographs.

DISPLAY STATION 3 APOLLO 9. A TEST PILOT'S DREAM
A systems evaluation manual from the third crewed Apollo mission reveals one of the most heavily annotated flown checklists in the history of human spaceflight. The pages on view show the critical test of the contingency burn of the Lunar Module descent engine, while the LM was still docked to the Command Module. This operation would be called upon during Apollo 13 one year later.

DISPLAY STATION 2 SATURN V
On view is the Saturn V engine gimbal console from Mission Control, used by flight controllers to monitor the outboard engines on the first two stages of the lunar rocket. Cathode ray tubes display the appropriate pitch and yaw deflections which kept the vehicle on its correct trajectory as it streaked to orbit.

DISPLAY STATION 4 APOLLO 11 – "I'M GOING TO STEP OFF THE LEM NOW"
The words spoken by Neil Armstrong as he prepared to place his booted left foot on the lunar surface on 20 July 1969. There are three artefacts to view: a piece of thermal protection material from the Command Module *Columbia* as it orbited the Moon; pages from the Apollo lead launch test conductor Norm Carlson; and an X-ray of Armstrong's hand-sewn gloves (below), which was taken prior to launch to ensure there were no sharp objects left inside the gloves that might have caused a puncture and a dangerous depressurization in space.

DISPLAY STATION 5 APOLLO 13 – NASA'S FINEST HOUR
This display features a rare, salvaged piece of storage netting from the Apollo 13 Lunar Module, *Aquarius* and the LM Contingency Checklist with procedures for critical burns that was used by Capcom Charlie Duke during the Apollo 13 mission.

DISPLAY STATION 6 APOLLO 15 – LIFE, THE UNIVERSE AND EVERYTHING

Apollo 15 was one of the final three 'J' series of extended science missions. This display includes Dave Scott's lunar surface communications umbilical, which he wore during his surface excursions on the Moon, as well as a sample of lunar dust from the Hadley Apennine region of the Moon where Apollo 15 landed in July 1971. The dust had impregnated Scott's personal preference bag from the lunar suit he took off back inside the LM.

DISPLAY STATION 7 A GEOLOGIST IN SPACE

From Apollo 17, the display features pages of a manual that spent three days inside the Lunar Module *Challenger* as it sat serenely on the lunar surface at Taurus Littrow, plus a map of the location of 'Shorty Crater' where the famous 'orange soil' was discovered, and drill bits manufactured by Martin Marietta used to extract core samples from the lunar regolith.

DISPLAY STATION 8 THE SOVIET ERA

Included here is a fragment of the Kosmos 1686 heavily modified former military TKS supply module that was docked to the Salyut 7 space station from October 1985 until February 1991. One of the largest pieces of debris ever to have fallen to Earth, it survived re-entry and was later auctioned. There are also a pair of Orlan EVA gloves and a pair of Soyuz Sokol "IVA" gloves used on Mir missions, together with a Strizh pressure suit designed for use on the Buran space shuttle.

DISPLAY STATION 9 US SPACE SHUTTLE – MOTHER OF ALL RFPS

The Request for Proposal, or RFP, is a request for a contractor to bid for the contract to design and build an element of hardware, in this case a spacecraft. In the exhibition is a copy of the RFP from NASA including the design specifications and requirements to built a fleet of Shuttle orbiters. There are also samples of the O-rings which were cited as a critical element in the loss of *Challenger* in 1986 and a sample of the flown thermal layer found behind the reinforced carbon-carbon on the leading edge of the orbiter's wing. This is similar to the thermal protection that bore the brunt of the heat behind the failed RCC on *Columbia's* ill-fated final mission in 2003.

DISPLAY STATION 10 INTERNATIONAL SPACE STATION

Artefacts from the more recent era of the ISS are on display, including Gennady Padalka's wristwatch worn during his 185 days aboard the space station in 2004 and a US flag flown as part of the payload of an uncrewed SpaceX Dragon flight in August 2021.

DISPLAY STATION 11 COMMERCIALISATION OF SPACE

On display is a flown aluminium fragment from the wreckage of a developmental test flight of the Falcon 9 rocket, as well as a recovered nose cone thermal tile from the second integrated Starship Plus Super Heavy Booster, Starship 25, launched in November 2023.

DISPLAY STATION 12 THE RIGHT STUFF

Completing the collection are two performance records of Buzz Aldrin, one from 1965 and a second after he had flown on Gemini 12 in 1966. The display also includes a handwritten memo from Chief Astronaut John Young, who expresses serious concerns about the Space Shuttle pressure suit.

SocietySPACE

From imagination to reality?

"Goonhilly: this is Tranquillity Base here: the Newton has landed."
"Copy that, Newton. The team are about to turn blue here; we're breathing again now."

Despite what the conspiracy theorists think, it is a well-documented fact, a matter of historical record, that America was the first nation to land astronauts on the Moon back in July 1969 (unless of course you believe the account recorded in 1901 by a certain Herbert George Wells documenting his encounter with Selenites). But a case can be made for saying that the BIS got there first decades earlier, if only by means of the technical specifications it outlined for its own Moonship.

The Moon has long been a source of fascination for the BIS. Helping to reach the Moon through the advocacy of human space flight was one of the Society's earliest goals, an ambition which attracted the submission of numerous papers to *JBIS* and frequent articles and letters to *SpaceFlight*. Treading the lunar regolith remains an abiding dream. Our satellite is a siren world, luring explorers to its surface regardless of the dangers and challenges of getting there. Since the advent of speculative fiction the Moon has become a crowded place, both above and below ground. The various spacecraft (real and imaginary) which rest upon its unchanging surface include a polyhedral "sphere," a two-man diving bell designed to fly through space powered by a strange substance – an anti-gravity metal known as "Cavorite." The footprints made by twelve astronauts on the lunar surface prove that this goal can be reached in fact as well as fiction. But there are other footprints "up there" too, such as those left behind by the sturdy walking boots of Professor Cavor in H.G. Wells's classic tale, *The First Men in the Moon*. There can be little doubt that this eccentric but visionary physicist would have joined the BIS had it existed in turn-of-the-century Britain.

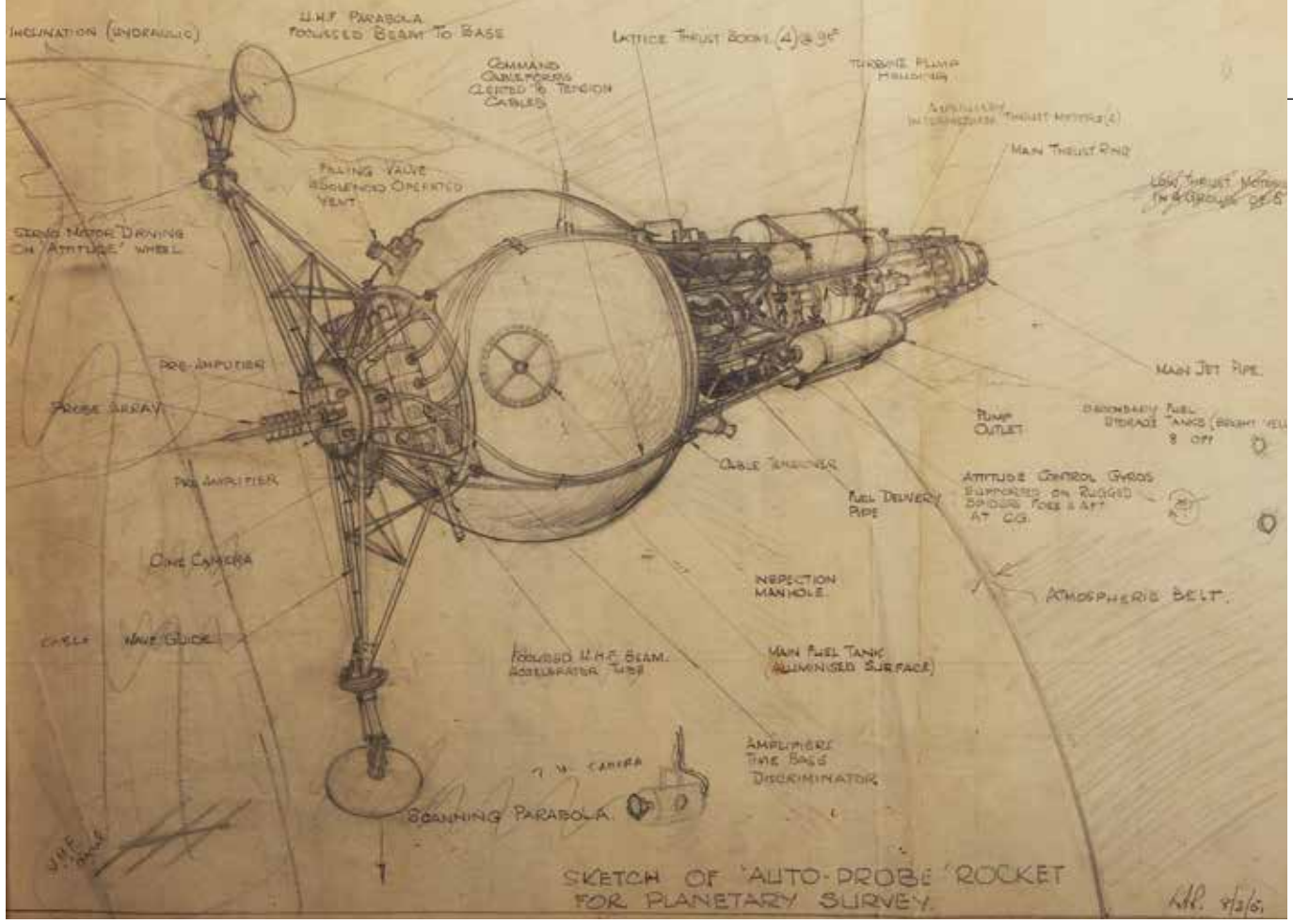
BELOW Astronauts dressed in BIS-designed Moonsuits film the landing of a BIS Moonship in this painting by the celebrated Ralph Smith, date unknown.

One of the main reasons for writing this article is to unlock some of the secrets contained in the BIS archive, especially for those members of the Society who cannot easily visit South Lambeth Road. There are no "Selenites" in the archive, but there are plenty of rare and fascinating items of major historical interest. This, then, is a route into those archives, a chance to explore the Society's rich heritage.

The late, great, and much missed Angela Carter (1940-1992) wrote many fine novels, amongst them *The Magic Toyshop*. Few writers have produced better novels so early in their writing careers and *The Magic Toyshop* has one of the finest last lines in any novel: "At night, in the garden, they faced each other in a wild surmise." I have always thought of the BIS archive as an enchanted place in its own right, a collection of rare treats. Amongst its many treasures are the paintings of R. A. Smith and the BIS Moonship – originally designed by the hugely talented Smith between 1937 and 1939 – represents "a wild surmise" unique to the BIS; a "What If?" that still challenges the imagination today, over eighty years since Smith penned his wonderful designs:

- What if the Blue Streak and Black Arrow rocket programmes had not been abandoned, along with the test range at Woomera in the wilds of the antipodean outback, a site which hosted the launch of many Anglo-Australian experimental rockets?
- What if the British government had ploughed the money that went into Polaris and Trident into ramping up the Blue Streak engines designed by Val Cleaver, resulting in a more muscular design capable of putting a British Saturn V into orbit, along with a Moon-bound crew?
- And what if at least one person in that crew had been a member of the BIS, determined to

ALL IMAGES: BIS



discover a fragment of Isaac Newton's "great ocean of truth" which lies beyond the Earth's thin atmosphere?

There is something distinctly "Wellsian" about the design of Ralph Smith's Moonship. Indeed, it is the sort of device that the hero of H.G. Wells's most famous story might have constructed, had he not been so preoccupied in building a time machine. Perhaps Smith drew on the rich heritage of contemporary – or near contemporary – writers who shared a common dream: a desire to leave footprints on the surface of our nearest celestial neighbour. Given that John Beynon, better known as John Wyndham (author of *The Midwich Cuckoos*, *The Day of the Triffids* and *The Kraken Wakes*, amongst others), was a member of the early BIS, it is perhaps not such a stretch to extend that lineage just a little further back to the days of Wells himself. Had the ever-dapper H.G. been a member of an Edwardian era BIS, the rocket ship that carried Bedford and Cavor to the lunar surface in *The First Men in the Moon* might well have displayed the BIS logo.

The hesitant Cavor was – is – the archetypal English space explorer: an eccentric but gifted dreamer, equipped for a journey off world with little more than a stout pair of walking boots and a tweed jacket. Imagine a BIS evening lecture with Professor Cavor as the speaker: "Amongst the Selenites – My Time on the Moon". The BIS HQ would not hold the crowd such a lecture would draw. If the multiverse theory is true, then perhaps in some other universe Ralph Smith's design did in fact beat the Americans to the Moon. And maybe, in that other universe, BIS astronauts are even now descending the side of their lander, while the people of Earth look on, waiting and listening for confirmation of the landing: "That's one small step for a man; one giant leap for the BIS." Who knows? It might still happen. If we can set about designing starships – and Daedalus shows that we can indeed do just that – building a Moonship should be easy. I think Arthur C. Clarke would have loved the idea. And the challenge.

Mark Stewart

ABOVE
Annotated pencil drawing of a potential Mars probe by R. A. Smith dated 1951.

LEFT
Don Dixon's 1981 representation of the BIS's Project Daedalus starship design.

Haunted Libraries and Rocket Summers: Remembering Ken Gatland (1924–1997)

ABOVE
Looking decidely James Bond-like, Ken Gatland meets Vostok 6 cosmonaut Valentina Tereshkova at a drinks reception in London, 1964.

If you grew up in the 1970s or thereabouts with an early interest in space exploration, you would almost certainly have come across some of Ken's books. The very same ones that are now on display in the BIS library. Often in the form of easily accessible pocket guides, they were an ideal primer to the subject and, I suspect, remain on many a bookshelf to this day.

Ken worked in the aeronautical industry in the Surbiton and Kingston area and was a life-long member of the BIS, serving as its President for three years (1973–76). He was part of a true "Golden Generation" of BIS members that included contemporaries such as Val Cleaver, Arthur C. Clarke and Patrick Moore. In addition, Ken was editor of *SpaceFlight* magazine for 20 years.

As a boy growing up in New Malden, I had no idea that Ken lived literally right around the corner from me, not until many years later when I, too, was a member of the BIS. I never met Ken but you can still feel his presence at the BIS, as if he is standing in the library – which he must have visited – quietly studying the shelves for a tome that sparked his interest. Libraries are haunted terrain after all, with all those ghosts longing to escape the confines of the books that hold them fast, to tell the stories that run through their spectral veins.

Ray Bradbury wrote about "rocket summers" but so did Ken, about destinations you could reach in real-life "silver locusts". I like to think that is where he is now, at the end of an interplanetary excursion, stepping down onto the surface of a "fossil sea" to keep Ray company in a "house of crystal pillars" on the edge of a Martian bone town. A long way from New Malden.

You can read more about Ken in *Interplanetary*, the updated history of the BIS. The next time you are in London, come and see our Ken Gatland corner in the BIS Library, which also houses our Arthur C. Clarke display.

Ken is pictured above with cosmonaut Valentina Tereshkova, the first woman in space. For more on that picture see the May 2012 issue of *Odyssey*, the BIS arts and culture magazine, available by contacting the editor, Mark Stewart, here: **odyssey@bis-space.com**. To learn more about *Interplanetary* visit our bookstore: **https://tinyurl.com/3awuf923**

Mark Stewart

The BIS Library and Arthur C. Clarke display

Some of our members may have noticed from our social media feeds and in the pages of our digital arts and culture magazine *Odyssey* that the BIS library has been undergoing something of an upgrade and transformation to bring into the light some of the treasures it contains. The library now includes a Space Shuttle corner, a display of rare Arthur C. Clarke first editions and a mini-exhibition on early German rocketry and the legacy of Wernher von Braun.

We are always looking to expand our stock of books, magazines and journals, so if you are interested in donating to the library, please contact Mark Stewart at **odyssey@bis-space.com**. We are particularly interested in expanding our range of speculative fiction (e.g. works by, but not limited to, Kim Stanley Robinson, H.G. Wells, Jules Verne, Isaac Asimov, Arthur C. Clarke and J.G. Ballard) and books by Patrick Moore, Carl Sagan, Ken Gatland and Reg Turnhill, along with Tom Wolfe (*The Right Stuff*) and Andrew Chaikin (*A Man on the Moon*). Donations of space posters, leaflets and flyers would also be welcome, together with science fiction magazines.

We would also very much like to obtain a hard copy of the November 1948 issue of JBIS, which features Olaf Stapledon's lecture "Interplanetary Man" so this can also be put on display.

Please help if you can! Many thanks.

Mark Stewart

Obituary

Robert Smylie

Robert 'Ed' Smylie, an engineer who led the team at NASA which solved the perilous cabin atmosphere problems of the damaged Apollo 13 spacecraft in April 1970, died peacefully on 21 April 2025 in Crossville, Tennessee. He was aged 95 years.

On the evening of 13 April 1970, as Apollo 13 was approaching the Moon, the crew were closing a live TV broadcast. Suddenly, a faulty oxygen tank exploded with a loud bang and streams of gas were seen venting into space. The Command Module (CM) was seriously damaged and their electricity supply fell steadily to zero.

Apollo 13's original mission, to make the third US Moon landing in rolling highlands north of Fra Mauro crater, was abandoned. The crew of Jim Lovell, Jack Swigert and Fred Haise were suddenly in a desperate struggle for survival. Their primary spacecraft, the CM *Odyssey*, was no longer functioning but the Lunar Module (LM) *Aquarius* was available to provide power and propulsion. Had it not still been attached, the crew would have become America's first fatal casualties in space.

Smylie and dozens of other experts were summoned to Mission Control to assist with the rescue plans. As the crew manually navigated around the Moon onto a course back to Earth, Smylie's team analysed their special responsibility; the environmental control system.

Although remaining oxygen supplies were adequate, Smylie and his team realised that another issue, carbon dioxide, would soon become critical for survival. Exhaled in the crew's breath, this is filtered from the cabin atmosphere by lithium hydroxide canisters. High concentrations cause confusion, loss of consciousness and eventually death by asphyxiation.

There were adequate square canisters in the now powered-down CM, built by North American Aviation, but they were not compatible with the cylindrical ones in the LM, built by Grumman. The need to substitute them had never been considered.

Smylie and his colleagues worked through the night to devise a method to make the CM's canister fit the LM's receptacle. First, he asked for a list of items stowed aboard Apollo 13, the only things the astronauts had available to cobble something together.

Upon seeing duct tape on the list, Smylie

BELOW
NASA Crew Systems Chief Robert "Ed" Smylie simulates the work he and a team of engineers at NASA's Mission Control carried out during the Apollo 13 mission in April 1970 to solve the problem of rising carbon dioxide levels in the Lunar Module.

LEFT & ABOVE RIGHT: IMAGES COURTESY OF MISSISSIPPI STATE UNIVERSITY / RIGHT: NASA

breathed a sigh of relief: "I felt like we were home free. One thing a southern boy will never say is 'I don't think duct tape will fix it'."

Smylie was an improvisational genius. The contraption they invented involved a sock, a cover off the Flight Plan, tubes from their backpacks and a plastic bag. After testing at Mission Control, assembly instructions were radioed up to the bemused crew. They built it in an hour and switched it on. Carbon dioxide levels immediately began to drop. The magazine *Time* later described it as the ultimate solution for fitting a square peg into a round hole.

In a memorable scene from the 1995 cinema blockbuster *Apollo 13*, a character based on Smylie empties a box of duct tape, plastic bags, hoses and other items onto a table, then holds up the CM's square canister and the LM's round one. "We've got to make this fit into the hole made for this," he says, then gestures toward the odd assortment of miscellaneous items: "…using nothing but this."

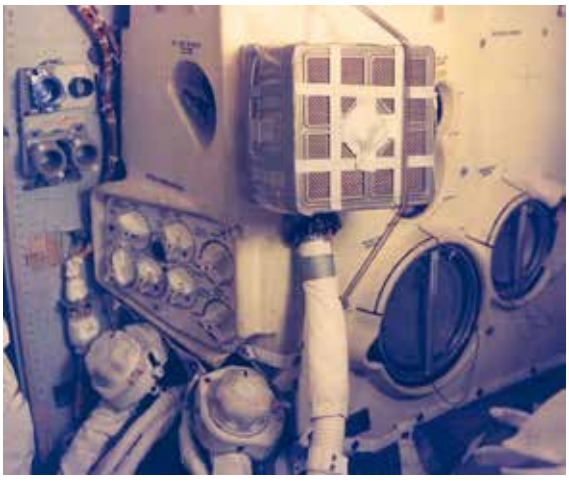
Robert Edwin Smylie was born on Christmas Day, 1929 to Robert and Leona Smylie at his grandparents' farm in Mississippi.

After service in the US Navy, he undertook bachelor's and master's degrees in Mechanical Engineering at Mississippi State University in the 1950s. He later earned a master's in Management from MIT.

After a period with Douglas Aircraft, he joined NASA in 1962 as head of life systems, then became head of the environmental control systems branch at the Manned Spacecraft Center (MSC) in Houston, Texas. He rose to chief of the crew systems division, which was his role during the Apollo 13 emergency. He later assumed more senior posts at NASA headquarters in Washington, D.C.

For his service to the space programme, especially his role in saving the Apollo 13 crew, Smylie and his team received the Presidential Medal of Freedom from President Richard Nixon.

Ken MacTaggart



ABOVE
Smylie next to a recovered CM, whose LiOH canisters were subsequently modified to work in the Apollo 13 LM *Aquarius*.

LEFT
Jack Swigert with some of the temporary hose connections and other apparatus needed when the Apollo 13 crew moved from the Command Module to their Lunar Module "lifeboat" and (below) the jerry-rigged "mailbox" built by the crew to adapt the CM's lithium hydroxide canisters for use in the LM.

ModelSPACE

Thor, Able and the Pioneer 1 probe

RIGHT
The recently formed NASA's Thor-Able rocket on the launch pad with Pioneer 1, November 1958.

Once the United States of America had finally launched an artificial satellite with Explorer 1 on 31 January 1958 (EST), attention turned to a reasonably regular programme of satellite launches. One enduring series was Pioneer, covering two periods: the first from 1958-1960 and the second 1965-1992. They encompassed a very wide range of scientific missions, including probes to the Moon, probes to study interplanetary space weather, then probes to the planets. The latter included Venus and the first of the very long-distance probes to Jupiter and Saturn: Pioneers 10 and 11.

These needed a new launcher, other than the initial US Jupiter C and Vanguard. Vanguard was a purpose-built satellite launcher, but the Jupiter C was developed from the Redstone SRBM (Short Range Ballistic Missile) and not – as the name might suggest – the Jupiter missile. It is more correctly called Juno 1, but is invariably referred to as 'Jupiter C'.

Neither of these rockets was powerful enough for a launch away from Earth orbit, so attention turned to another US missile, the Thor, which was an IRBM (or Intermediate Range Ballistic Missile). Subsequently developing into the Delta, it became one of the longest running satellite launchers, with the last launch of a Thor-derived stage coming as recently as 2018.

BELOW
Box art for the two Aurora 1:72 kits – the Thor-Able -Pioneer 1 combo (left) and the Thor Intermediate Range Ballistic Missile.

Initially, the engineers took the standard Thor and turned it into the Thor-Able by adding a second stage; essentially the second stage of the Vanguard. For satellite launches, a third, solid-fuel Altair rocket stage was also added. It was this combination that launched the first Pioneer space probes, starting with Pioneer 0, (yes 'zero'), followed by Pioneers 1 and 2. In all there were 16 Thor-Able launches, from 17 August 1958 to 1 April 1960, of which ten were successful.

As with the Jupiter C – and, to a certain extent, Vanguard – which had garnered significant interest from the model kit companies, Thor-Able did likewise, with kits from Revell, Adams (now Glencoe), ITC and, in recent years, the French company Mach-2. However, the most famous example is probably that from Aurora.

Aurora was one of the oldest American names in the model business. It actually stopped trading in 1977, with the tooling being purchased by Monogram, but the name lives on in most model-makers' minds – even those who were not born when the company ceased to exist.

Aurora made kits across the subject spectrum, though it is likely most famous

ALL PHOTOS AND BUILDS COURTESY OF THE AUTHOR EXCEPT ABOVE: NASA

for its 'Monsters of the Movies' figure series, featuring the likes of Dracula, the Mummy, the Wolfman and Frankenstein's Monster. As with most Aurora figure kits, these were excellently done and have continued to be re-issued under various names, half a century on.

Aurora also made aerospace subjects, though with the best will in the world many were not exactly up to standards then being turned out by other famous names, such as Airfix, Monogram and Revell. However, alongside the aircraft were other aerospace subjects such as missiles, including two kits based on the Thor IRBM. What was slightly unusual was that these two kits were to the established scale of 1:72, the main aircraft scale. Many kits of the period were not built to a 'conventional scale', but to an arbitrary 'box scale'. Basically, the parts were scaled to fit the box. In addition, these two kits were actually very detailed. The basis for both was the same, with one being the Thor in its original IRBM form and the other as the 'Lunar Probe' (i.e. a Pioneer satellite launcher), which is subject of this piece.

The kit not only supplied the launch vehicle and the tiny Pioneer probe under the nose cone, but also included the launch pad, service tower and a base. It came moulded in two colours of plastic, white and mid-grey, along with comprehensive plans and an equally comprehensive decal sheet. Plastic-coated coloured wire was also included, to be used for the various flexible piping that connected the tower to the rocket.

The rocket itself was moulded in white plastic and just needed a topcoat of white and the decals applied. The tower needed painting two-tone white and red (as were most service towers of the day). The parts started on the grey runner, but a good coat of white primer provided a base for gloss white. Once thoroughly dry, the white sections would be carefully masked so the red could be applied. Some bleed through of paint is inevitable with these fiddly structures and red seems to be the worst. A judicial supply of cleaning buds and some thinner were standing by as the masking was removed.

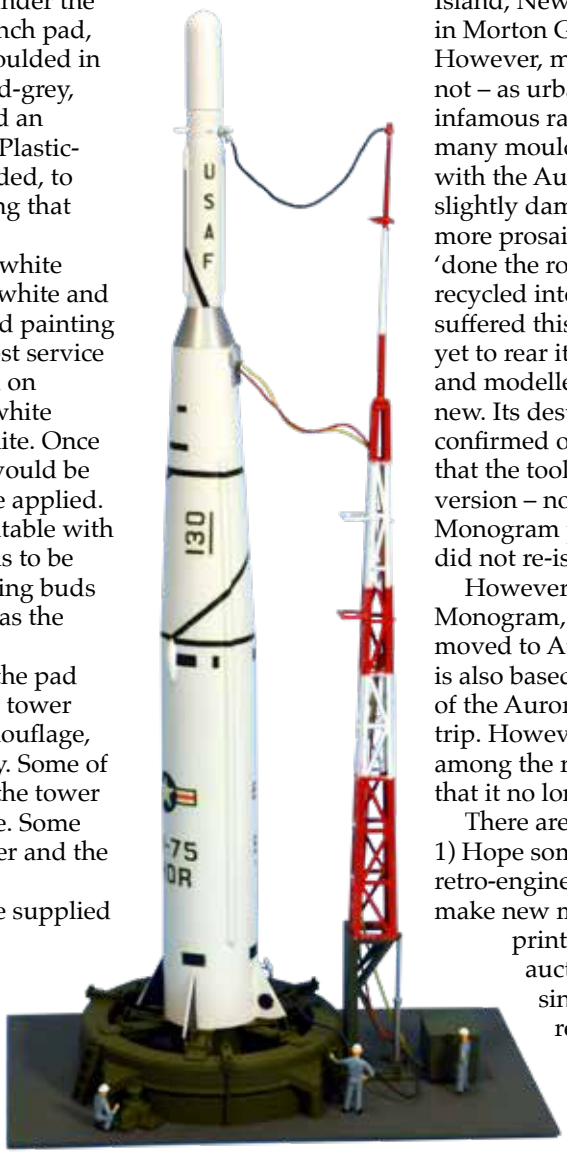
Checking contemporary photos, the pad itself and the support for the service tower seem to be a dark green, almost camouflage, with the rectangular base a mid-grey. Some of the coloured wire was threaded up the tower to emerge at connector on each stage. Some was also used at the base of the tower and the base of the first stage.

Finally, three in-scale figures were supplied to place around the launch pad.

One inevitable question is 'Is the kit still available?' to which the answer is unfortunately 'no'. The tooling that survived at the end of Aurora was bought by Monogram and the moulds transported from

ABOVE
The Lunar Probe kit includes a tiny Pioneer 1 probe (right, in real life) under the upper stage pod.

BELOW
The completed model with launch pad, ground crew and service tower.



Aurora's base in West Hempstead, Long Island, New York, to Monogram's facilities in Morton Grove near Chicago, Illinois. However, many never got there. This was not – as urban myth has it – because of the infamous railroad crash that destroyed many moulds. Yes, there was a rail crash with the Aurora tooling on board, but it only slightly damaged a few moulds. The far more prosaic answer is that once a kit had 'done the rounds', the mould materials were recycled into new kits. Many Aurora models suffered this fate because 'collectability' had yet to rear its – dubious – head at that time and modellers constantly wanted something new. Its destruction has not really been confirmed one way or the other, but it seems that the tooling for this kit – and the IRBM version – no longer existed by the time of the Monogram purchase. Monogram certainly did not re-issue it.

However, much of Aurora (along with Monogram, Revell and Renwal tools) has now moved to Atlantis Models. This, ironically, is also based in Long Island, NY, so much of the Aurora tooling has done the return trip. However, this kit does not appear to be among the returnees, more or less confirming that it no longer exists.

There are only really two ways around this. 1) Hope someone, somewhere decides to retro-engineer the kit, using an original to make new moulds (maybe with the help of 3D printing), or 2) find one on the on-line auction sites – assuming you can, since a recent search bought up zero results. Even if one did come up for auction, you can expect a very high price.

Mat Irvine FBIS

ShelfSPACE

Still flying high

RIGHT
Susan Still (as she was before her marriage to Vice Admiral Colin J. Kilrain USN) in the front cockpit of a NASA T-38 jet. She is wearing the STS-94 mission emblem on her flight suit.

Rowland Lindill – aka "The Armchair Astronaut" – once again provided an opportunity (Cranfield University, Bedford on 10 May 2025) for friends old and new to hang out… with an astronaut and a book illustrator thrown in for good measure. Shuttle Pilot Susan Kilrain (the youngest of the three female Shuttle pilots) found her way to the latest "Spring Space Social" and spent the day sharing her story with eager space fans, also posing for photos, signing items and promoting her new children's book, *An Unlikely Astronaut*.

Tailored to the inquisitive bystander, the casual enthusiast and hard-core space nerd alike, the afternoon lecture was light, yet candid and funny in equal measure. Who knew we had an absence of the Disney Channel, MTV and Netflix to thank for bringing Susan to the space programme? By way of entertainment when she was young, Susan's Dad, Joe Still, would take his children to the local airfield to watch planes. Almost inevitably, the flying bug bit one of the Still family – and it just happened to be Susan.

While in school, Susan flew solo with just four and a half hours tuition and acquired her pilot's licence soon after. By her own admission, it was more the consequence of a bet between instructors than any particular skill. An aeronautical degree steered her to Lockheed but she found aeronautical engineering boring, instead harbouring ambitions to fly in space. It was at this point that her boss reached out to a buddy, astronaut Dick Scobee. Dick advised that she should join the military as a pilot if she wanted to increase her chances of being accepted into the astronaut programme. With her dad's support, Susan joined the US Navy in 1985.

I had an opportunity to speak with Susan and asked how she fitted in at the Navy.

"It was a time when women were not readily accepted and typically there was a male fraternity environment that played out in jokes and that kind of stuff: I just ignored all of it."

I understand that the Navy quickly began to take you seriously?

"Yes, at Aviation Officer Candidate School. I was the only woman in a class of 60! When we finished, they voted me #1 in the class. So, I was the Regimental Commander for our parade and commissioning. In test pilot school I was also classed the highest academically, but I don't think they do those evaluations anymore."

Scott Altman once told me his favourite aircraft was the F-14 Tomcat. He said "It was like flying a Cadillac!" During a 20-year naval career you logged over 3,000 hours in 30 different aircraft. Did you have a favourite?

"Well, Scott Altman is a much larger person than I am. He was probably super uncomfortable in the A-4 [Sky Hawk] for instance, which I loved flying. The Tomcat was physically harder for me to fly so I preferred the smaller cockpits like the A-4, F-16 [Fighting Falcon] and the F-18 [Hornet]. They were my favourites because they fitted me like a glove and were more fun"

You joined NASA in March 1995 and by July 1997 you had two Shuttle missions under your belt: STS-83 and 94. But you never flew the Shuttle again. Why was that?

"It was my request, after my baby was born and my husband was deployed. I asked not to be put on the flight schedule… which was the opposite of Eileen [Collins]. She had hers (baby) then walked in and said, "I'm ready to fly again". Then in late 2000, my husband was transferred to Washington, D.C. and I was expecting my second child, so I was posted to NASA HQ, so that essentially took me off the flight schedule for a longer period of time. Then, when he was transferred to Puerto Rico, I opted to leave NASA and go back to the

BELOW
Susan pictured aboard Space Shuttle flight STS-94 *Columbia* in July 1997.

Navy. I considered being a mission Commander but I wasn't going to give up the opportunity to have kids and I wasn't getting any younger so it just wasn't on the cards. My kids would have had to sacrifice had I chosen to go to Houston without my husband to train as a Commander. For me, it wasn't the right thing to do."

Susan insists to this day that bringing up four kids is much, much harder than flying a Space Shuttle. She left NASA in December 2002 and retired from the Navy in June 2005.

Looking back over your two Shuttle missions, what was your most memorable moment?

"Probably the radio call we got up [on orbit] saying that our flight [STS-83] was being terminated and that we were coming home. That really stands out. From my perspective as a pilot, it was not that big of a deal. While everybody was disappointed… I was probably the least disappointed because I didn't have anything on the schedule anyway… except housekeeping! As a pilot you launch, you fly around the world a few times and you come home to land. But we had two scientists onboard for whom this was their one chance to do this science and to fly in space and all of their science was being cut short. We got maybe a day and a half of science instead of 16. But they ended up going twice. Interestingly enough the Commander received an email on orbit from the Chief Astronaut saying they were going to fly us again… and nobody believed it. We all thought it was just to keep our morale up for the return home. But after we landed and got out of the Shuttle the administration told us that we were going to fly again. We thought this was like two carnival rides for the price of one."

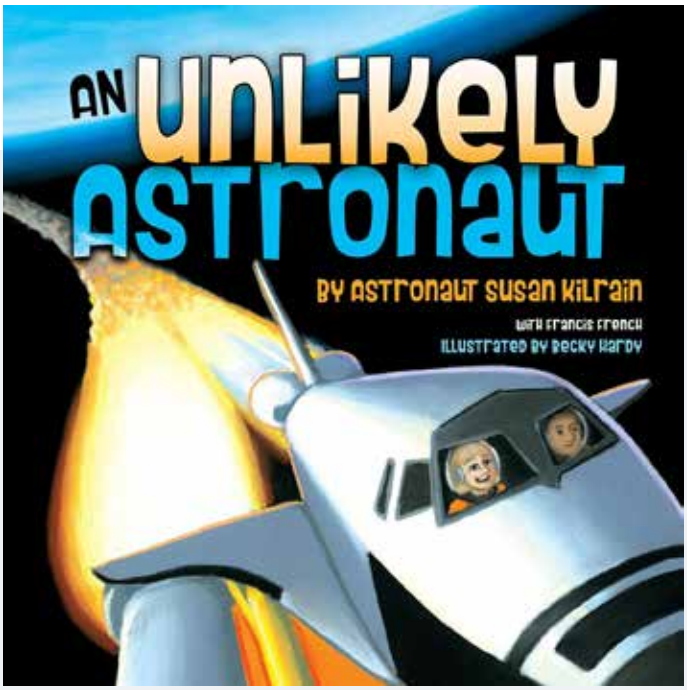
With hindsight, do you have any regrets from your time at NASA? Is there one thing you really wish you had done?

"I do know that when I went to Pam Melroy's launch on STS-120, I took my two oldest kids when they were still pretty young: 3rd or 4th grade maybe. I took photos and video of the launch… but not a single photo of them watching the launch and I really regret that. Who needs another picture of a Shuttle launching? But to have a photo of your kids watching the launch would have been so much more spectacular."

Your recent book *An Unlikely Astronaut* is a children's book. Do you have plans to write something for the grown-ups?

"I am the process of writing a book. It's not a straight-up memoir. It is similar to what you heard today. Stories throughout my life that I think are interesting and made me who I am today… but also with a takeaway for the reader. The book will obviously be attractive to the space enthusiast: space enthusiasts are great about buying books, right? That part is an easy sell, but I want it to be attractive to young people who are trying to succeed in their dreams, whatever they may be. How I learned to harness and overcome my own fears, coupled with what I've learned about leadership. I'd call it a prescriptive memoir [rather] than just a memoir… and it's not going to tell my whole story."

That evening's VIP dinner afforded illustrator Becky Hardy an opportunity to discuss her involvement in *An Unlikely Astronaut*, a collaborative book co-authored by Susan and Francis French. Arguably one of the UK's finest exports, Francis is certainly worthy of a ten percent trade tariff in anybody's book! By profession, Becky admitted to being a tax advisor. While there may have been a sharp intake of breath from some in the audience, clearly nobody held that against Becky as all the books on her trade stand sold out in minutes.



An Unlikely Astronaut

Susan Kilrain with Francis French, illustrated by Becky Hardy

Laun 39 Books, 2023
ISBN: 978-1-9473-0573-1
softback, 32 pages, illustrated in colour, age range 5-8, £17.50

An auction of four choice framed pieces (two signed by Susan and two by Charlie Duke) raised much needed funds for a project close to Rowland's heart. At least once a year, he takes a coach load of under privileged children to the National Space Centre in Leicester and acts as their tour guide on a STEM- [Science, Technology, Engineering, Maths] and space-themed day out. If spending time with an astronaut is not sufficient to entice folks to support Rowland's next Armchair Astronaut event, his support for these children most certainly is.

A very convivial event was rounded off nicely by the presentation of freshly minted, silver "Armchair Astronaut" pins, each containing metals flown on a Shuttle mission. Fittingly, Susan was awarded the very first, but five others who have supported Rowland's events over many years were surprised with pins of their own. Going forward, VIP ticket holders for any three "Armchair Astronaut" event, past… or in the future, will find themselves in exclusive company. Expect an announcement for Rowland's next event in the not-too-distant future. SC

Rick Mulheirn FBIS

FSW@50

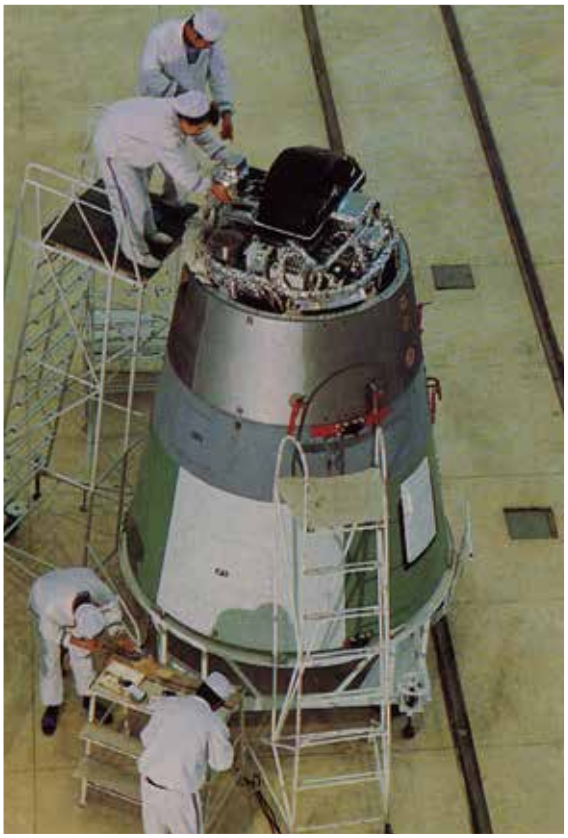
ABOVE
Crowds gather at the landing site of an unidentified FSW capsule.

RIGHT
Technicians prepare an FSW satellite for launch.

Nobody actually saw it land. Fifty years ago, on 30 November 1975, the browned, burned but otherwise intact Fanhui Shi Weixing (FSW) parachuted down into the tree-covered mountains of Sichuan after 47 orbits. China thus became the third country to overcome the technical challenges of recovering a satellite from orbit after the US and the USSR (both August 1960). It was an early indicator of China's long-term ambitions in space.

FSW cabins (literally, 'recoverable experimental satellite') are still flying, but in the Shijian programme. The project was approved in 1964 as the next big leap in China's space programme, designed to pave the way for Shuguang human space flight missions. The FSW weighed 1,900kg: size-wise, it fell between the American Mercury and Gemini cabins. With Shuguang cancelled (1972), FSW was used for survey and close-look military missions (the Jianbing programme) and civilian Earth observations and also, from the 1980s, for scientific experiments (e.g. materials processing, semi-conductors), some with international participation (e.g. Germany, France, Japan). Mission durations grew from three days to 27, weight to 3,800kg, orbital height up to 560km.

There have been 26 FSW missions. They may be divided into the FSW 0 series (1975–87); FSW 1 (1987–93); FSW 2 (1992–6); FSW 3 (2003–5); and



IMAGES COURTESY OF THE AUTHOR

then the Shijian programme: Shijian 8 (2006), 10 (2016) and 19 (2024). Shijian 8 was called the 'seeds' mission; Shijian 10 focussed on microgravity and life sciences; while Shijian 19 carried more seeds, germplasms, three rabbits and a catalyst testbed. FSW's comparators in the Soviet/Russian space programme were Bion and companion Foton. They remain the world's only automated recoverable space science programmes. Compared to space station-based research, they have advantages of simplicity, cost and purer microgravity unaffected by a human presence.

Brian Harvey

TIMELINES

SELECTED MILESTONES FROM ANNALS OF SPACEFLIGHT

[October-November-December 2025]

Years ago	Year	Date	Event
100	1925	23 December	Birth of future USAF X-20 Dyna-Soar pilot-astronaut Henry Gordon (d. 24 September 1996, aged 70).
95	1930	30 December	A 3.35-metre liquid-fuelled (Robert Goddard) rocket launched from Roswell, New Mexico, reaches 609 metres and a velocity of 804+ km/hr.
90	1935	11 November	Albert Stevens and Orvil Anderson ascend to a record 22.065 km over Rapid City, South Dakota in the Explorer II stratospheric balloon, in a flight lasting 8 hours 13 minutes.
85	1940	6 October	1972 (unflown) test cosmonaut Boris Andreyev is born (d. 9 July 2021, aged 80).
80	1945	3 October	The US Navy Committee for Evaluation of the Feasibility of Space Rocketry (CEFSR) is established by BuAer. In November, CEFSR recommends a high priority for satellite development.
75	1950	During December	Construction for the first Florida Missile Test Range (later Atlantic Missile Range) tracking station starts at Grand Bahama Island.
70	1955	7 October	Martin Company is awarded the prime contract for the Project Vanguard satellite project.
65	1960	6 November	Japan's Space Development Council recommends starting basic studies for launching a national Earth satellite.
60	1965	15 December	Gemini 6 accomplishes the first space rendezvous between crewed spacecraft, approaching to within 30 cm of Gemini 7 and remaining in close formation for 270 minutes.
55	1970	17 November	Luna 17 lands the first self-propelled (uncrewed) vehicle on the Moon. The Lunokhod rover would operate for 11 months.
50	1975	22 and 25 October	The descent modules of two Soviet probes, Venera 9 and 10, land on Venus and return the first pictures from the surface.
45	1980	29 December	The crawler-transporter delivers the Space Shuttle *Columbia* to Pad 39A at KSC for a series of tests prior to its planned maiden launch in the spring of 1981.
40	1985	24 October	ESA announces approval to full membership status for Austria and Norway, effective from 1 January 1987.
35	1990	7 November	NASA begins a five-year, $6 billion budget reduction overhaul of Space Station objectives by removing equipment to study the Earth, astronomical observations and servicing outbound lunar and Mars spacecraft.
30	1995	23 October	Wendy ("too short") Lawrence and Scott ("too tall") Parazynski are rejected as long-duration Mir candidates to fly on Soyuz or conduct Orlan-suited EVAs, due to height restrictions.
25	2000	2 November	The first ISS resident crew (EO-1, ISS Cdr William Shepherd, Soyuz Cdr Yuri Gidzenko and FE Sergei Krikalev) arrive at the station on Soyuz TM-31 for a planned 4.5 month stay.
20	2005	17 October	The descent module of China's second crewed mission, Shenzhou 6 (Fei Junlong and Nie Haisheng), safely returns to Earth after a five-day, 3.25 million km mission.
15	2010	13 December	Travelling towards interstellar space, Voyager 1 (launched September 1977) reaches 17.38 billion km from the Sun – where the outward velocity of the solar wind is zero.
10	2015	23 November	The second test flight of Blue Origin's New Shepard sub-orbital rocket becomes the first to cross the Kármán line (reaching 100.5 km) and achieves the first powered soft landing of its propulsion stage, near the launch site.
5	2020	3 December	Chang'e 5 becomes the first robotic sample-return mission to launch from the lunar surface since the Soviet Union's Luna 24 in 1976. It returns to Earth on 16 December.

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