Venus flyby

Humanity to meet the Goddess

Planetary defence
Big decisions for ESA
Venus missions 2024-2031
Artemis update
JUST IN CASE YOU HADN’T NOTICED, there’s a lot happening in space right now. *SpaceFlight* has the inside track, with monthly reports on everything from activities aboard the ISS to the fast-emerging commercialisation of space in which UK companies expect to play an ever more important role.

Meanwhile, the newly revamped quarterly *Space Chronicle* takes a uniquely informed look at where we’ve come from in the last 50 years, and especially at the achievements of the lesser spacefaring nations.

And for the more scientifically inclined among us, there is *JBIS* – academic papers by world-leading authorities at the cutting edge of astronautical thinking as it applies to our own solar system and beyond.

Whatever is going on in space, BIS publications have it covered. Go to [www.bis-space](http://www.bis-space) to find out more.
Features

16 Meeting the Goddess
A human flyby of Venus is gaining momentum

20 Searching hell for life
Venus missions are being planned for later this decade to search for aerial microbes

24 Venus' visitors
From the 1960s to the 1980s, Earth’s harsh twin saw many robotic missions

26 Artemis: the next generation?
What needs to follow Orion and Gateway

30 Bullseye!
NASA’s asteroid deflection mission succeeds

32 Protecting the heavens
ESA’s Hera mission will study NASA’s deflected asteroid

30 Space Launch System troubles
NASA pinned its hopes on 14 November for its first Artemis launch

42 Aim high!
BIS member Brodie Stanhope writes about his Endeavour Scholarship

Regulars

02 Behind The News
ESA Council – UK space Minister? – Habitable exoplanets

08 Space UK
Virgin Orbit arrives in Cornwall

09 New Space
SpaceX Falcon 9 Heavy rides again

10 ISS Report
12 September – 11 October

34 Satellite Digest 599
Sponsored by Seradata September 2022

38 Letters to the Editor

39 Multimedia – book reviews
Interstellar travel and NASA’s history

44 Obituary: Valeri V. Polyakov (1942–2022)
The cosmonaut training for Mars

46 Society news
What’s happened

48 Membership
What’s coming up

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.

Editor: Rob Coppinger  Art Director: Andrée Wilson  Design & Production: andree-wilson.com  Promotion: spaceflight@bis-space.com  Advertising: spaceflight@bis-space.com  Distribution: Warner’s Group Distribution, The Matlings, Manor Lane, Bourne, Lincolnshire PE10 9PH, England  Tel: +44 (0)1778 391 000  Fax: +44 (0)1778 393 668  Printing: Buxton Press Ltd / buxtonpress.com  SpaceFlight: Arthur C. Clarke House, 27-29 South Lambeth Road, London SW8 1SZ, England  Tel: +44 (0)20 7735 3160  Email: spaceflight@bis-space.com  www.bis-space.com

Published monthly by the British Interplanetary Society. SpaceFlight is a publication that promotes the mission of the British Interplanetary Society. Opinions in signed articles are those of the contributors and do not necessarily reflect the views of the Editor or the Council of the British Interplanetary Society. Registered Company No: 402498. Registered charity No: 250556. The British Interplanetary Society is a company limited by guarantee. Printed in England by Buxton Press Ltd.

© 2022 British Interplanetary Society ISSN 0038-6340. All rights reserved. No part of this magazine may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying or recording by any information storage or retrieval system without written permission from the Publishers. Photocopying permitted by license only.
Human spaceflight could be the big winner from the budget setting European Space Agency (ESA) Council at Ministerial level (CMIN), which will meet in Paris on 22 and 23 November to decide what ESA does for the next three years.

While the maiden flight of the ArianeGroup Ariane 6 rocket has been pushed back to late 2023, that launcher has been proposed as the vehicle to orbit an ESA crew capsule. This year has seen a series of meetings in preparation for the CMIN that could see significant projects launched. These could include a crew tended free flyer European space station, which consists of a single module, within a more ambitious exploration programme extending to the 2040s. The CMIN will also see the new ESA class of astronaut candidates announced on 23 November.

The first CMIN related event of the year was the ESA, European Union (EU) Space Summit held in February. Another Space Summit will be held in 2023. The February summit was followed by an ESA, industry conference in June called “Shared Vision for the Future of Space Transportation in Europe”. The conference, held in Palermo, Italy, had more than 100 representatives of Europe’s space sector present to discuss the technical and political challenges. The conference also heard about the agency’s year-long effort to identify a future European space infrastructure to match competition from the United States, China, Russia and India.

In June, ESA published its latest roadmap, Terra Nova 2030+ (SpaceFlight Vol 64 No. 9 September pp 2-3). The roadmap’s top tier objectives are the first European on the Moon by 2030, Europeans going to Mars by 2040 and that free flyer. The roadmap also includes six more ISS missions for ESA astronauts, a European lunar logistics lander, a Mars sample return mission, and the final realisation of the much delayed ExoMars mission. The Terra Nova 2030+ vision also includes the long-term robotic exploration of Mars and European capabilities for a Moon base.

In July, ESA announced it would establish a high-level human and robotic exploration advisory group to advise the November ESA
The recommendation for an exploration advisory group came from the ESA, EU Space Summit held in February. The high-level advisory group consisted of eight men and five women and recommended proposals to ESA’s member state ministers regarding the geopolitical, economic and societal relevance of space exploration.

The 73rd International Astronautical Congress held in Paris from 18-22 September was another opportunity for ESA to promote its Terra Novae 2030+ vision. Just a month later, ESA’s Council met in Paris for its 310th session from 19-20 October. At that meeting it provided the media with an update on its CMIN proposals and at the same time ESA announced the Ariane 6 delay to the fourth quarter of 2023.

Before all of these meetings, ESA had published its Agenda 2025 in April 2021. It set the goal of reinforcing ESA’s position as a “global space leader” by 2035. The Agenda also referred to flagship programmes, expanding security related efforts, space debris reduction, providing support for greener and more digital European societies and reducing ESA’s own environmental footprint.

The next ESA astronaut class will be far larger than previous classes with a core group of astronaut candidates, a wider reserve group and a para-astronaut, someone with a disability. The last class, selected in 2009, consisted of six people, five men and one woman. The agency has committed to all of them going to the International Space Station twice. Some of the 2022 class will have the opportunity to go to the Moon, either to NASA’s Gateway lunar space station or even down to the surface of the satellite.

Current and former European astronauts have also lobbied for increased exploration and space transportation spending. In February this year, the European Astronauts’ Manifesto on the occasion of the European Space Summit was published by the European chapter of the Association of Space Explorers, a professional body for astronauts worldwide. The Manifesto stated: "While Europe is still at the forefront of many space endeavours, such as Earth observation, navigation and space science, it is lagging in the increasingly strategic domains of space transportation and exploration.”

On ESA’s "ESA vision” webpages it pointed to the world’s perilous state as another reason to sustain its funding. “Russia’s invasion of Ukraine has brought fear and instability to the world and will have far-reaching consequences for us all. ESA member states must respond by ensuring Europe will always have access to space." These benefits included climate change monitoring and mitigation, secure communications under European control and rapid and resilient crisis response.

The ESA budget is organised between mandatory and optional programmes. The mandatory activities are the space science programmes and the general budget. They are funded by a financial contribution from all the member states. Each state’s contribution is calculated in accordance with their gross national product. As the name optional programme indicates, each member state can decide whether to participate or not and the amount they wish to contribute. Much of Terra Nova+ falls into the category of optional programmes.

As well as ESA’s member states contribution, the EU works with ESA which manages EU projects and acts as a technical advisor. The EU’s European Union Agency for the Space Programme (EUSPA) oversees Copernicus, Galileo, space situational awareness and other projects. The EU’s Horizon research programme also funds substantial space related research. The EU’s focus on space spending is very much about providing direct and immediate benefits to the citizens. A key difference in industry contract awards between EU and ESA is the former works on the basis of merit alone, while the latter follows the principle of geographic return. For example, if Germany puts most of the money into a European free flyer station, its companies will get the bulk of contracts, and very probably the crew would always have at least one German. As human exploration has been an option, not mandatory, for member states, the first Europeans on the Moon certainly, and possibly for Mars also, will be whomever pays the most.

Above
An artist’s impression of the European Large Logistics Lander, known as EL3, on the Moon.
A UK Parliamentary committee called for a Minister for space, the science Minister announced £15 million for satellite communications and the country’s launch industry advanced, all in October.

The House of Commons’ Defence Committee called for a UK Minister for space in its Defence Space: through adversity to the stars? report. The Committee concluded that the cross-Whitehall governance on space lacks coherence. Its report stated that stronger, more centralised leadership is required and that without it progress on the UK’s own satellite navigation effort had been delayed. In September 2021, the UK government published its national space strategy and being able to implement its recommendations without a responsible Minister is seen as problematic.

The report’s summary stated: “A Minister for space should be appointed within the Cabinet Office to drive forward implementation of the vision set out in the National and Defence Space Strategies.” A Minister within the Cabinet Office is the highest tier of Minister and would place the Minister for space alongside the Prime Minister and Deputy Prime Minister, for example. The Minister made responsible for space strategy last September was Minister of State for Science and Investment Security, Nusrat Ghani, who is the Conservative party member of Parliament (MP) for Wealden. She reports to Jacob Rees Mogg MP, Secretary of State for Business, Energy and Industrial Strategy, which is a Cabinet level position.

Before Ghani’s appointment, earlier in July Morecambe and Lunesdale MP, David Morris, was named the UK’s first national space champion. At the time Morris was chair of the All-Party Parliamentary Group for Space. As national space champion, Morris was replacing the previous Minister responsible for space, George Freeman MP, but Morris had no position in government. Freeman had been the...
Parliamentary Under-Secretary of State for Science, Research and Innovation. His departure was part of an en masse resignation by Ministers to force the then Prime Minister Boris Johnson MP to resign, which he did. As of 19 October, the chair of the All-Party Parliamentary Group for Space was Mark Garnier MP.

The Defence Committee report also identified a low level of UK spending on space. It stated: “Figures from the Organisation for Economic Co-operation and Development place the UK within the bottom half of G20 nations when it comes to spending on space as a percentage of GDP (gross domestic product)”. However, the report also stated that the UK's strengths were in “small satellites and telecommunications, and... emerging technologies such as satellite quantum key distribution”.

The report's recommendation of a Cabinet level space Minister was welcomed by one UK rocket developer, Skyrora. "We are delighted to see that the Defence Committee has called for a Minister for space to be appointed within the Cabinet Office in its latest report," said Skyrora head of government affairs, Alan Thompson. “Tim Peake, one of Skyrora's key advisors, recommended the creation of this new role.”

Peake, the British European Space Agency (ESA) astronaut, gave evidence to the Committee during the third session of its inquiry that led to the report.

Peake is a former Apache helicopter pilot, flight instructor and test pilot, who left the British Army in 2009 to join the ESA astronaut corps. The agency has previously announced that all the 2009 astronauts would go to the International Space Station (ISS) twice and Peake's second mission is expected in 2024. Since 1 October 2019, Peake has been on a leave of absence from the astronaut corps to work with the UK Space Agency (UKSA). The timing for his second ISS mission may be announced during or shortly after ESA's important Council of Ministers' meeting held in Paris from 22-23 November. The agency will also be announcing a new class of trainee astronauts on 23 November which could include a second UK candidate.

**SATELLITE COMMUNICATIONS**

On 17 October, UKSA announced a £15 million fund for UK businesses to revolutionise satellite communications technology. The competition for funding from the £15 million pot runs until the second quarter next year. It is open to organisations developing “ambitious technologies across the satellite communications ecosystem”.

The competition is open to ideas for creating entire new satellite constellations, ground systems, or delivering new services to customers. The funding will come through UKSA's role in ESA's advanced research in telecommunications services programme. Ghani said: “I look forward to seeing the results of the competition.” While her responsibilities include space strategy, they do not include a key satellite communications project, OneWeb, the telecommunications constellation the UK bought a share of for about £400 million.

The satellite communications technology funding competition was announced as Ghani travelled to Rome, Italy, for her first space related visit overseas to meet ESA Director General, Josef Aschbacher. The meeting took place just over a month before ESA's Council of Ministers' meeting (See pages 2-3). At the Council, ESA member states make decisions regarding what programmes to fund for the next few years. The UK committed £374 million per year over five years to ESA in 2019. Some of that funding will be spent during ESA's next budgetary period, beyond November 2022.

The UK rocket developer Orbex announced £40.4 million in private funding on 18 October. The Scottish National Investment Bank was a new investor, among other contributing the £40 million. Orbex is developing its Prime rocket, a 19 m long, two-stage launch vehicle designed to transport small satellites with a mass of up to 180 kg into low Earth orbit. Orbex’s rocket will launch from the Space Hub Sutherland spaceport on Scotland’s northern coast. Orbex »
applied for a space launch licence from the UK’s Civil Aviation Authority (CAA), the UK space regulator, in early 2022.

Orbex has been performing a wide variety of integration tests. These have included testing the main propellant tanks and engines and launch procedures such as rollout, strongback erection and fuelling. The first launch will carry a payload developed by Surrey Satellite Technology. Orbex chief executive officer (CEO), Chris Larmour, said: “Orbex has made significant progress to get to this point, with the invention of ground-breaking, innovative technology, the rapid development and testing of the launch vehicle, the expansion of our manufacturing footprint in the UK and Denmark.”

While UKSA, Virgin Orbit and Spaceport Cornwall make final preparations before a fourth quarter launch, neither Virgin nor Spaceport Cornwall have received their necessary licenses from the CAA. But Virgin Orbit appears to have progressed enough to ensure it will be the first to launch. So, the race now is to see who will be the first to launch a rocket vertically from a UK spaceport. The leading contenders are Lockheed Martin and its partner ABL Systems, Skyrora and Orbex. The two spaceports they will use are Sutherland for Orbex and SaxaVord Spaceport on the Scottish isle of Unst for Skyrora and Lockheed Martin.

Orbex unveiled the first full-scale prototype of its Prime orbital launcher on its dedicated test launch pad, Orbex LPI, in Kinloss, Scotland in May (SpaceFlight Vol 64 No.7 July p 3). Skyrora announced last August it had completed a static fire test of its XL rocket’s second stage in Kintyre and it had applied to the CAA for a launcher licence (SpaceFlight Vol 64 No.10 October pp 2-3). Lockheed Martin calls its vertical rocket project, UK Pathfinder Launch, and its rocket developer is Californian firm ABL Systems which is building its RS1 launcher. Earlier this year, Lockheed revealed that its planned 2022 launch of its RS1 rocket would slip into 2023 (SpaceFlight Vol 64 No.8 September p 8).

The Orbex funding announcement came as Virgin Orbit arrived at Spaceport Cornwall, co-located with Newquay Airport Cornwall. With the completion of a hangar at the Spaceport for preparing the LauncherOne rocket, which is Virgin Orbit’s launch vehicle, both it and the modified Boeing 747 carrier aircraft that air launches it, arrived in October (See page 8). To promote the arrival of Virgin Orbit and the plans for the UK’s first space launch from its soil, a 22 m replica of that LauncherOne rocket went on display outside the Science Museum in London during the weekend of 15-16 October.

The UK Space Agency claimed that thousands of people visited the LauncherOne led exhibition, and that families took part in a range of free space-themed activities. These included a virtual reality experience of being in a “Mission Control,” a real astronaut suit and a meteorite people could handle.

The activities were supported by Virgin Orbit, Spaceport Cornwall, the Science Museum, Imperial College London and the Natural History Museum. Minister Ghani attended the event along with UKSA deputy CEO Ian Annett, Virgin Orbit CEO Dan Hart, Spaceport Cornwall head Melissa Thorpe and UKSA commercial spaceflight director, Matt Archer.
Whether exoworlds are habitable could be determined using a new method to study their atmospheres, researchers at the Hebrew University of Jerusalem announced in October.

The research team examined TRAPPIST-1e, a planet located some 40 light years from the Earth and the fourth planet in its TRAPPIST-1 solar system. TRAPPIST is the acronym for Transiting Planets and Planetesimals Small Telescope, which is in Chile and was used to find the extra-solar system. The researchers examined the sensitivity of the planet’s climate to increases in greenhouse gases and compared it with conditions on Earth. The researchers think that measuring an exoworld atmosphere’s climate sensitivity is central to assessing the planet’s viability for human habitation. TRAPPIST-1e is scheduled to be examined by the James Webb Space Telescope.

“These [greenhouse] variables are crucial for the existence of life on other planets, and they are now being studied in depth for the first time in history,” said Dr Assaf Hochman at the Hebrew University Fredy and Nadine Herrmann Institute of Earth Sciences. “The research framework we developed, along with observational data from the Webb Space Telescope, will enable scientists to efficiently assess the atmospheres of many other planets ... This will help us make informed decisions about which planets are good candidates for human settlement and perhaps even to find life on those planets.”

Hochman and his colleagues used a computer simulation of the climate on TRAPPIST-1e to assess the impact of changes in greenhouse gas concentration. It was found that planet TRAPPIST-1e has a significantly more sensitive atmosphere than Earth. They estimate that an increase in greenhouse gases there could lead to more extreme climate changes than would occur on Earth because one side of TRAPPIST-1e constantly faces its own sun in the same way that our moon always has one side facing Earth.

NASA announced that TRAPPIST-1 had the most Earth-sized planets found in the habitable zone of a low temperature star in 2017 (*SpaceFlight* Vol 64 No.2 February pp26-31). TRAPPIST-1 is believed to be between 5.4 and 9.8 billion years old, twice as old as our own solar system, which formed some 4.5 billion years ago. What is known about TRAPPIST-1 comes from observations made by the Transiting Planets and Planetesimals Small Telescope, NASA’s infra-red observatory the Spitzer Space Telescope, and other ground-based telescopes.

NASA has speculated that the TRAPPIST-1 planets could have thick atmospheres produced by large surface reservoirs of volatile molecules such as water. This is because the planets are believed to have lower densities than the Earth. This combination is expected to ensure that even though TRAPPIST-1’s planets could be twice the age of the Solar System’s planets, they will still have atmospheres. Thick atmospheres would shield the planetary surfaces from harmful radiation. Where a planet is tidally locked to its star, meaning it only ever shows one side, such a thick atmosphere would also see heat redistributed to the permanently dark side.

In March this year, NASA announced that 5,000 exoworlds had been confirmed and its exoplanet exploration website gives the latest result of 5,190. In November 2021, the number of confirmed exoplanets was 4,569. In 2029, ESA plans to launch its Atmospheric Remote sensing Infrared Exoplanet Large Survey (ARIEL) telescope and it will be able to examine thousands of exoplanets at the same time. ARIEL will operate from the second Lagrange point 1.5 million km directly ‘behind’ Earth as viewed from the Sun. The climate sensitivity atmosphere simulation study at Hebrew University was led by Hochman in collaboration with Dr Thaddeus Komacek at the University of Maryland and Dr Paolo De Luca at the Barcelona Supercomputing Center. The study was published in *Astrophysical Journal* in October.
THE VIRGIN ORBIT LauncherOne rocket that will make the first space launch from UK soil landed at Spaceport Cornwall on 14 October after arriving on a United States Air Force Boeing C-17.

The launch was expected for November and LauncherOne would carry seven payloads into low Earth orbit (LEO) for Virgin Orbit’s “Start Me Up” mission. The mission’s name is a play on a Rolling Stones’ song title. Both Virgin Orbit and Spaceport Cornwall need government licences to operate space launch and neither had been awarded them by late October. The Civil Aviation Authority (CAA) is the UK’s regulatory body for space, and it will approve the licenses. As of 25 October, neither Spaceport Cornwall nor Virgin Orbit had received their licences for the planned November launch.

“As we move ever closer to the first satellite launch from UK soil, it’s excellent to see the progress being made by Virgin Orbit, Spaceport Cornwall and those across government in delivering this historic mission, the first of its kind in Europe,” said UK government science Minister, Nusrat Ghani. “I’m looking forward to working with this innovative sector and delivering on our national space strategy. The flight manifest includes payloads from seven customers, based in the UK and internationally, with companies from England, Scotland and Wales involved in their development and manufacture.”

Spaceport Cornwall has stated that key ground support equipment and the integration of the majority of the payloads is complete. LauncherOne was the last piece of the launch infrastructure to arrive on site in October.

LauncherOne is air launched at about 35,000 ft by a modified Virgin Atlantic Boeing 747 named Cosmic Girl. That aircraft also arrived at the Spaceport in October. Virgin Orbit has been working closely with the CAA, the Royal Air Force and Spaceport Cornwall for the necessary preparations. As well as Start Me Up being the first space launch from the UK, it will be the first commercial launch from western Europe and the first international launch for Virgin Orbit. It was on 10 May this year that the then defence procurement Minister, Jeremy Quin, announced a summer launch, but it is now expected in this quarter. The launch has been made possible by UK Space Agency funding and a key customer for the mission is the US government’s National Reconnaissance Office (NRO). There are seven payloads. One is the Coordinated Ionospheric Reconstruction CubeSat Experiment, CIRCE, which is part of a joint mission between the UK Ministry of Defence’s (MoD) Defence Science and Technology Laboratory (DSTL) and the US Naval Research Laboratory. Prometheus-2 has two cubesats that are owned by the DSTL. These satellites are co-funded with Airbus Defence and Space, which is designing them jointly with UK firm In-Space Missions. The cubesats will support MoD science and technology activities both in orbit and on the ground. The in-orbit demonstration (IOD)-3 Amber satellite was developed by UK signals intelligence specialist Horizon Technologies under the UK government’s Satellite Applications Catapult’s in-orbit demonstration programme. IOD-3 Amber was built by AAC Clyde Space and is expected to be the first of more than 20 Amber satellites to provide space-based maritime domain awareness data.

The other four payloads are called Dover Pathfinder, ForgeStar-0, Aman and Stork-6. Developed by RHEA Group in the UK, Dover is for developing resilient navigation satellites. It is co-funded through the European Space Agency’s navigation programme and built by UK rapid mission development specialist Open Cosmos. Developed by Welsh firm Space Forge, ForgeStar is a platform for in-space manufacturing. This launch will be the first for this spacecraft. ForgeStar is designed to return to Earth with what it has made.

Aman is Oman’s first orbital mission and will be an Earth observation satellite. It is meant to demonstrate the feasibility of a future larger constellation. Stork-6 is the next installment of Polish small satellite manufacturer and operator SatRev’s Stork constellation. Virgin Orbit has previously launched two spacecraft for this constellation. The second space launch from UK soil could be from Scotland. The UK companies Orbex and Skyra are both at an advanced stage of their rockets’ development. Lockheed Martin and its partner ABL Space Systems also have their RS1 rocket in test. Orbex intends to launch from the Space Hub Sutherland spaceport on Scotland’s northern coastline and Lockheed and Skyra from the SaxaVord Spaceport on the Scottish isle of Unst. All three firms are planning to launch in 2023.
**SPACEX’S FALCON HEAVY** was set to resume launches after a three-year hiatus with its fourth lift-off scheduled for no earlier than 31 October for United States Space Force (USSF) payloads.

The launch of the 31 October USSF-44 mission was originally scheduled for mid-2021 but significant payload delays pushed this Space Force operation, and the heavy-lift rocket’s return, to late 2022. Falcon Heavy’s third and last launch was June 2019. The USSF-44 mission was to place multiple satellites in orbit. Other future Falcon Heavy payloads, which have suffered delays, include ViaSat-3 for telecommunications provider Viasat, and more USSF payloads including the USSF-67 mission.

“This [USSF-44] will be our first NSSL [National Security Space Launch] Falcon Heavy, and the first Falcon Heavy since STP [Space Test Program]-2 over three years ago,” said USSF Space Systems Command executive officer, Col Douglas Pentecost. “Our launch and mission assurance team and SpaceX, along with the fantastic crew at Space Launch Delta 45, have done an absolutely superb job preparing this rocket.”

Falcon Heavy has a busy launch manifest over the next few years, to make up for the three-year lull. It has four flights scheduled during 2023. Among these is NASA’s Psyche mission, a spacecraft that will investigate the metallic asteroid 16 Psyche. Several more government and commercial customers are set to fly from 2024. These include Astrobotics’ lunar lander and two NASA spacecraft, Europa Clipper and the exoplanet-hunting Roman Space Telescope. Later this decade Falcon Heavy will launch the initial elements of the Gateway lunar station which is integral to NASA’s Artemis Moon architecture.

The Falcon Heavy consists of three Falcon 9-derived cores, topped by an expendable upper stage identical to that used on the Falcon 9. Each core is powered by nine kerosene, oxygen Merlin 1D engines optimised to operate at sea level, making for a total of 27 engines. These cores can be equipped with recovery hardware (landing legs and hypersonic grid fins) and landed, or discarded, depending on mission performance requirements. A single vacuum-optimised variant of the Merlin is used on the upper stage.

While the first three flights attempted to recover all three cores, USSF-44’s trajectory to its final orbit means that there will be no margin to attempt a centre core recovery. The side cores will return to SpaceX’s onshore landing sites, Landing Zones 1 and 2, and will attempt to land simultaneously as has been seen on previous flights. Falcon Heavy remains the world’s most powerful operational rocket. However, SpaceX intends to slowly phase out the Falcon family and Dragon spacecraft and use its Starship Super Heavy instead. This fully reusable launcher has more than twice the thrust of NASA’s Saturn V at lift-off.
Xpedition 68 is in its first month of orbital operations with a temporary crew of eleven. The International Space Station (ISS) is led by its latest commander, European Space Agency (ESA) Italian astronaut Samantha Cristoforetti and her crew of flight engineers, Americans Kjell Lindgren, Robert Hines, Jessica Walker, Nicole Mann, Josh Cassada and Frank Rubio. They are joined by Russians, Sergey Prokopyev, Dmitry Petelin and Anna Kikina and from Japan Koichi Wakata. Prokopyev, Petelin and Rubio arrived aboard the Russian Soyuz MS-22 spacecraft to replace Russians Oleg Artemyev, Denis Matveev and Sergey Korsakov who returned to Earth aboard Soyuz MS-21 in late September. Mann, Cassada, Wakata and Kikina arrived on the SpaceX Crew Dragon Endurance in early October.

On 12 September, the crew of Expedition 67, led by Artemyev, continued research and maintenance tasks for their return to Earth. They took part in a conference with ground and support personnel who would assist them after landing. The cosmonauts also had sessions with the lower body negative pressure (LBNP) suit to adapt to Earth's gravity. The LBNP counteracts microgravity's tendency to pull fluids towards a crew member's upper body.

The United States orbital segment (USOS) crew of Lindgren, Hines, Watkins and Cristoforetti focused on upgrading life support systems. Hines and Watkins later studied how cognition and perception is affected by long duration space flight courtesy of ESA's grip experiment. Cristoforetti, meanwhile, tended to NASA's exposed root on-orbit test system (xROOTS) space botany investigation. During a NASA Public Affairs Office event on 15 September, Lindgren told students from the US state of Georgia, the xROOTS experiment had succeeded in growing "lettuce, carrots, onions and radishes". He added xROOTS "has been really interesting, we've produced great results". Watkins jokingly told reporters on 11 October, xROOTS had taught her how to "experience" her "green thumb" in space.

Lindgren set up hardware inside the microgravity science glovebox (MSG) on 13 September to observe how liquids are held together by surface tension. Cristoforetti looked at foams and emulsions using NASA's keyence research microscope testbed (Kermit) equipment. Results from this experiment could help pharmaceutical, chemical and consumer products industries. Hines and Watkins worked with ESA's gravitational references for the sensimotor performance (grasp) experiment inside the European Columbus module. Grasp examines how a crew member's central nervous system is affected by microgravity. Artemyev ran on one of the Station's two treadmills while attached to sensors and breathing gear to assess how to exercise more effectively in weightlessness.

Matveev assisted Artemyev and later collected microbe samples from inside the Russian Zarya module for analysis. Korsakov put the 11.3 m European robotic arm (ERA) through its paces. He verified ERA's performance, monitored its telemetry and observed the arm's motion while still attached to the Russian Nauka (science in English) multipurpose laboratory module. Hines and Watkins resumed work with the grasp experiment on 14 September. Lindgren collected and analysed water samples for the Japanese Aerospace eXploration Agency's (JAXA) cell biology experiment facility-left (CBEF-L) incubator.

Cristoforetti devoted a second day to research with the Kermit microscope. The ESA astronaut took time out to talk to ESA Director General, Josef Aschbacher and European Parliament President, Roberta Metsola. Cristoforetti described living and working aboard the ISS and provided an insight into Europe's presence in space. Korsakov continued to test the ERA, while Artemyev and Matveev prepared Soyuz for its return to Earth. The engines of the Russian Progress 81 spacecraft were fired for 118.6 secs at 1810hrs universal coordinated time (UTC) on 15 September. This increased the Station's orbit by 410 m to an orbital altitude of 416.25 km. The manoeuvre was
Watkins took her turn with the Kermit microscope on 15 September. Lindgren swapped samples in the MSG for the ringed sheared drop fluid physics experiment to study the formation of destructive protein clusters responsible for diseases such as Alzheimer’s. Hines participated in a cognition test for NASA’s standard measures study and Cristoforetti reconfigured components for NASA’s solid fuel ignition and extinction, growth and extinction limit (SoFIE-GEL) investigation. SoFIE-GEL examines fire growth and fire safety techniques in space. Artemyev, Matveev and Korsakov packed items aboard Soyuz ahead of its departure from the Station. The cosmonauts also studied how to improve the Station’s environment for biotechnology experiments.

**KERMIT**

Lindgren worked with the xROOTS hardware on 16 September, while Hines used the Kermit microscope and Cristoforetti conducted further research with SoFIE-GEL. Watkins set up the surface avatar laptop computer inside Columbus. A NASA blog on 16 September reported this investigation is “studying ways, such as haptic controls, user interfaces, and virtual reality, to command and control surface-bound robots from long distances”. Artemyev, Matveev and Korsakov checked communications systems aboard Soyuz and took part in another session with the LBNP as they continued preparations for returning to Earth.

The crew enjoyed a relatively light-duty schedule over the weekend of 17-18 September. The USOS crew worked with NASA’s ring sheared drop (RSD) experiment. NASA’s on-orbit summary for 15 September reported the ultimate aim of the RSD investigation is to produce “next-generation medicines for treating cancers and other diseases”. On the Russian side of the Station, the cosmonauts packed Progress 80 with unwanted items, performed vision tests and conducted the matryoshka-R study which measures the radiation levels aboard the ISS. On 19 September, Hines began the new working week by examining foam samples inside the Kermit microscope.

Watkins resumed work that day with the surface avatar computer and Lindgren conducted robotics cognition studies with the behavioural core measures experiment. Cristoforetti performed various maintenance tasks including replacing components on the Station’s waste and hygiene compartment. Artemyev, Matveev and Korsakov spent the first of two days packing Soyuz with research materials, checking the Russian Sokol launch and entry suits and reviewing undocking and landing procedures. Watkins scanned her arteries with an ultrasound device and measured her blood pressure on 20 September. This was conducted to understand the risks of space radiation on the cardiovascular system.

Hines planted vegetables as part of the xROOTS experiment and Lindgren worked with the Kermit microscope. Cristoforetti used a smart phone device to guide and control NASA’s Astrobee free-flying robots while assisting her fellow crew members with scientific operations. The Soyuz MS-22/68S spacecraft was launched atop a Soyuz 2.1a rocket from Baikonur’s Site 31 about seven minutes after local sunset at 1354hrs UTC on 21 September (1854hrs local time). Aboard Soyuz was spacecraft commander Russian Air Force Maj (Ret.) Sergey Prokopyev on his second spaceflight and space rookies, flight engineers Dmitry Petelin, an aeronautical engineer, and US Army Lt Col Frank Rubio.

At a pre-launch press conference on 22 August, Rubio told reporters this flight was, “an incredibly important mission”. With reference to the tensions over Russia’s invasion of Ukraine, Rubio justified human spaceflight as “a form of diplomacy” and his
Russian crew mates had "become good friends … at our core we’re all space explorers". The Soyuz docked to the Russian Rassvet module after two orbits and over three hours later at 1706hrs UTC on 21 September as the complex flew over southern Russia. The Soyuz for this flight was named after Russian rocket scientist Konstantin E. Tsiolkovsky in honour of the 165th anniversary of his birth on 17 September.

**KONSTANTIN E. TSIOLKOVSKY**
The hatch to Soyuz Konstantin E. Tsiolkovsky was opened nearly two and a half hours later at 1934hrs UTC to increase the Station’s size to ten crew members. The newcomers then took part in the traditional welcoming ceremony. Immediately afterwards, Artemyev conducted the mandatory safety briefing, pointing out potential hazards and available safety measures as well as equipment required for initial emergency responses. The following day the two Soyuz crews began hand over procedures. On the US side of the Station, Lindgren and Cristoforetti each wore a microphone attached to their shoulder to measure the Station’s acoustic environment and how it affects a crew member’s hearing.

That day, Watkins operated the Kermit microscope and Hines serviced the CBEF-L and spoke to students from the Sam Houston math, science and technology centre in Houston. His brother Michael is an assistant principal there. On 23 September, Prokopyev, Petelin and Rubio began several days of familiarisation activities. The trio reviewed a host of Station systems, lab hardware and safety procedures as they adjusted to their home in space. Cristoforetti checked the Station’s food inventory and moved food packs from the US Unity module to the permanent multipurpose logistics module.

Watkins devoted a second day to the Kermit investigation. Lindgren inspected the ventilation system aboard the US Destiny module, while Hines checked his aerobic capacity with the maximal oxygen consumption (VO2) test experiment. The crew prepared the universal intelligent glass optics (uniglo) experiment during the weekend of 24-25 September. Uniglo could help Earth and space-based industries including communications, aerospace, medicine and astronomy. Rubio set up the microgravity science glovebox (MSG) for the uniglo experiment on 26 September. Watkins donned a specialised vest and headband to begin a two-day session for the bio-monitor biomedical investigation.

Hines checked the xROOTS experiment and Lindgren set up the confocal space microscope to examine how weightlessness affects the nervous system. Artemyev, Matveev and Korsakov resumed preparations for return to Earth, while Prokopyev and Petelin transferred items from Soyuz to the
Station. On 27 September, Rubio continued his research with the uniglo study, while his Soyuz crewmates resumed cargo transfers from Soyuz to the ISS. Both Artemyev, Matveev and Korsakov and Lindgren, Hines, Watkins and Cristoforetti spent the day with undocking, descent and landing preparations respectively.

The traditional change of command ceremony took place on 28 September with Cristoforetti replacing Artemyev as ISS commander. The ESA astronaut became the Station’s first European female commander. During the event Cristoforetti said how much the crew appreciated Artemyev’s leadership. “You really helped us grow together not only as a crew, crewmates, but one big space family”. She also thanked the “gigantic teams on the ground” and “all the people in our respective space agencies”. Cristoforetti added that, “as an Italian astronaut it’s especially an honour to represent Italy”, and concluded by saying a few words in her native Italian.

The hatches between the Soyuz MS-21/67S spacecraft and the Russian Prichal module were closed at 0422hrs UTC on 29 September. With spacecraft commander Artemyev, Matveev and Korsakov aboard, Soyuz undocked from the Station over three hours later at 0734hrs UTC as the complex flew 418.4 km above eastern Mongolia to signal the official start of Expedition 68. Soyuz performed a four minute 41secs de-orbit burn at 1003hrs UTC on 29 September and 29mins later the descent module separated from the orbital and service modules. After Soyuz re-entered the Earth’s atmosphere Artemyev radioed mission control Korolev, “we’re feeling good”.

SAFE LANDING
Soyuz MS-21/67S landed upright at 1057hrs UTC (1647hrs local time) on 29 September about 90 km southeast of Dzhezkazgan, Kazakhstan to complete a mission of 194 days 19hrs 1mins. Artemyev has logged 560 days 18hrs 6mins on his three spaceflights to become the world’s 12th most experienced space traveller. The three cosmonauts were extracted from the spacecraft and later flown from Karaganda, Kazakhstan to Star City, Moscow. On arrival at Star City on 29 September, Korsakov sent a Twitter message from his account @SergKorsakov: “Hello Star City! Greetings to all my friends and colleagues! Thank you all for your support, glad to see everyone! Ahead is a meeting and dinner with the family, as well as the first ‘horizontal’ sleep in six months. You’ll have to get used to the bed and pillow again”.

On 30 September, Rubio conducted further research with the uniglo experiment. Lindgren, Hines, Watkins and Cristoforetti checked launch and entry suits, reviewed undocking and landing procedures ahead of their return to Earth. Prokopyev and Petelin took part in biomedical tests, exploring how microgravity affects the heart and blood vessels. During another light-duty weekend 1-2 October, the crew collected saliva samples as part of the human research programme. Aside from that the crew spoke to family and friends as part of their off-duty schedule.

The new week began on 3 October with Lindgren and Hines focusing on how living in space affects their muscles. They used an ultrasound device and the myotones device to scan and measure the biochemical properties of their legs, neck and back muscles. Watkins checked the xROOTS hardware
and Rubio conducted further research with the MSG and the uniglo experiment. Cristoforetti serviced samples inside the electrostatic levitation furnace (ELF). A NASA blog on 3 October explained that ELF “supports high-temperature thermophysical research in space”.

Prokopyev and Petelin performed routine maintenance tasks, inspected the windows in the Russian Zvezda module and set up Earth observation gear for a series of investigations. Hines and Rubio conducted biomedical research on 4 October. Cristoforetti swapped foam samples inside the fluid science laboratory for the soft matter dynamics experiment. This study provides insights to help researchers improve material production for industries on Earth. Lindgren cleaned the vents inside Unity, Watkins performed cargo transfers and checked various Station hatches and seals. Inside the Station’s Russian segment, Prokopyev and Petelin devoted a second day to maintenance work, checked the ventilation system and participated in Earth observation studies.

NASA and SpaceX launched Crew Dragon Endurance on its second spaceflight (Spaceflight Vol 64 No. 2 p 11) on 5 October (1200hrs local time). Atop a Falcon 9 rocket, Endurance ascended from Kennedy Space Center launch complex 39A at 1600hrs UTC. Aboard the spacecraft was Crew-5 commander, United States Marine Corps Col Nicole Mann, together with pilot, United States Navy CAPT Josh Cassada and mission specialists, aeronautical engineer Koichi Wakata and engineer and Russian cosmonaut Anna Kikina. Wakata was on his fifth spaceflight and is Japan’s most experienced astronaut, while the rest of the crew were all space rookies.

ENDURANCE
Mann became the first female commander of a Dragon space mission and the first Native American female in space being of Waialaki heritage. Kikina was the first Russian cosmonaut to fly aboard a Dragon spacecraft. At a pre-flight press conference on 4 August, associate administrator of NASA’s human exploration and operations mission directorate, Kathy Luders, told reporters: “We’re very proud to have” Kikina as part of the crew, Wakata added that during training the four of them had “been working together as a family”.

The Falcon 9 first stage was on its first flight and made a successful landing on the drone ship Just Read The Instructions in the Atlantic ocean about 9mins 3secs after launch. Once in orbit, Mann radioed SpaceX mission control at Hawthorne, California and said: “That was a smooth ride up the hill” and Luders described the lift-off as “beautiful” at a post-launch briefing. Commercial crew programme manager, Steve Stich, told reporters at the post-launch briefing. “it was good to see Anna fly”.

Endurance docked to the International Docking Adaptor-2 on the forward port of the US Harmony module at 2101hrs UTC on 6 October as the complex flew 415.2 km above the west coast of Africa. The hatches between Endurance and the Station were opened nearly two hours later at 2249hrs UTC to increase the Station’s population to eleven crew members. During a brief welcoming ceremony, a euphoric Mann told her mother, “look I’m finally in space!” Wakata said it was, “good to be back in zero g” and Kikina added: “It’s so wonderful to have international friends”.

The new arrivals began to familiarise themselves to their new orbital home on 7 October. Watkins returned to the xROOTS experiment and Rubio studied how weightlessness can improve the production and quality of fibre optic cables. Cristoforetti and Lindgren collected blood samples for a biomedical investigation, while Prokopyev and Petelin performed routine maintenance work in the Russian segment. The crew devoted part of the weekend of 8-9 October with handover activities as Crew-5 continued to adapt to weightlessness and the Station’s environment. The USOS crew also conducted Dragon transfers, while Lindgren’s Crew-4 of Hines, Watkins and Cristoforetti made preparations for their imminent return to Earth.

The USOS crew collected saliva samples for NAAs food physiology experiment on 10 October. They also worked with the standard measures study, resumed crew familiarisation and adaptation activities and Dragon cargo transfers. On 11 October, Crew-4 took part in a final press conference from orbit ahead of undocking and splashdown aboard SpaceX Crew Dragon Freedom. Lindgren told reporters, “[they] had an extraordinary experience…..we’re excited to get home to our families”. Each crew member was asked what they had missed aside from family and friends? Hines said “certainly some ice cream, some pizza”.

Cristoforetti looked forward to “a good shower”. Watkins added “some good food” and Lindgren wished for “a cold drink with ice in it” and went on to say he would miss “being able to float, it’s such a bizarre thing”. The cosmonauts spent 11 October studying the patterns of crew behaviour courtesy of the Russian interactions-2 investigation. They also used the Ekon-M hardware to photograph and study Earth’s environment. Mann and Cassada conducted research inside Destiny, while Rubio and Wakata worked with the xROOTS experiment and Astrobees, respectively.
Meeting the Goddess

A human flyby Venus mission was studied as part of the Apollo programme in 1967 and now experts believe that such an attempt would be an important crew test mission for Mars.
the scope for long distance human health research and mitigations testing, presented a robust argument. The report stated that: "Any mission outside of the Earth–Moon system, including to Venus, will test our readiness for long-duration deep space human spaceflight, in particular long-duration spacecraft operations, as well as crew psychology and health.” While a Venus mission could be as little as 365 days, or thereabouts, the symposium discussed a 566-day flight with a free-return trajectory called a Venus backflip.

The appeal of the backflip is that it provides more time in the vicinity of Venus to enable teleoperated Venus science. The backflip means two flybys with 176 days within a light-minute of Venus. During the 111-day interval between the two Venus flybys the spacecraft would remain over a Venusian pole, enabling continuous teleoperation. The backflip’s benefits are a new flight duration record, science teleoperation, and valuable human performance knowledge all while on a free-return trajectory. This mission’s trajectory would see the spacecraft go below, or above the plane of the ecliptic, by about 0.1 AU, or 15 million km, presenting a new view of the Solar System.

MISSION 2034

The report sets out a mission with a launch date of 7 August 2034. After the Earth departure, the crew will be on a free-return trajectory, only needing to carry out some small trajectory corrections. The first Venus flyby would occur on 18 November 2034 and the second would be on 9 March 2035, both at 500 km altitude. The crew would have roughly 177 days for scientific studies and of those 177 days, 111 are between the flybys, but still with a view of the southern hemisphere. After the second flyby, the crew would return to Earth on 24 February 2036. An Earth-Venus opportunity occurs every 19 months compared to 26 months for Earth to Mars.

Each Earth-Venus opportunity can differ significantly in terms of departure and arrival velocities. A high return velocity cannot be higher than the design constraints of the Orion spacecraft’s heat shield and parachute system. Another difference between each opportunity is which hemisphere is available. For a backflip this varies depending on where Venus is in its orbit at the first encounter. The symposium report found that the simplest possible back-of-the-envelope analysis suggests that a vehicle conducting a Venus backflip mission would have about 80% of the total galactic cosmic ray environment exposure of the very best-case Mars conjunction class mission. This Mars conjunction mission was analysed by NASA’s strategic analysis cycle 2021 and it assumed nuclear electric propulsion.

The report spells out that human missions have additional opportunities compared to robotic ones, increasing the science return. They are significantly increased communications capabilities and the opportunity to carry multiple ride-along payloads. These can be sent down to explore the Venusian atmosphere and surface and can be teleoperated. High data and communications bandwidths are often required for crewed missions, including for mission
operations, personal communications home, and for public engagement purposes. These communications capabilities are significantly more than what robotic missions have. As such, more science data can be returned to Earth.

As set out in a previous edition of SpaceFlight (SpaceFlight Vol 64 No. 8 August p42), the symposium report agrees that the high mass of human mission spacecraft means substantial science payloads can accompany the mission at small additional cost. Multiple robotic probes can accompany a human-class mission to Venus, where it can be a challenge to obtain funding for a single robotic mission. Another advantage human missions have over robotic ones is that the mission’s goals do not have to be prescriptive with a predefined set of targets. The crew has the ability to make spontaneous decisions in real time.

An example of this real time decision making would be reaching Venus and being able to determine that a location previously deemed important is not as high a priority as another location. This would ensure the highest possible scientific return. A crew can use infra-red (IR) telescope data, targeted radar emissivity images, or even flyover drone footage for real-time analysis of a volcano, for example. The substantial communications capabilities of a crew mission also mean significant amounts of data can be sent back to Earth for analysis by experts there.

There is also a psychological benefit for the crew in having this role. The crew are onsite, and they are, arguably, bar the Earth based scientists, in the best position to make immediate decisions. This decision-making capability also increases crew autonomy, which generally enhances the sense of agency and improves the team’s psychological outlook. A priority for a Venus mission would be to seek evidence of active tectonics. Tectonic activity has played a major role in life on Earth and could do also on Venus. In the search for evidence of active tectonics, a human crew can identify areas of interest after cursory observations of potentially active faults.

TELEOPERATIONS
The very first human Mars mission has been touted as an opportunity for teleoperations using robots on the surface controlled by the crew in Martian orbit. A human Venus mission would also offer this opportunity and teleoperations is only going to be possible with this planet anyway because of its extremely harsh surface conditions. The Keck Institute report outlines how remotely operated rovers and aircraft could be used. A solar-powered semi-autonomous aircraft could have astronauts monitoring its flight and able to identify in real time compelling science objectives.

The aircraft could recharge its batteries using solar power above the clouds at more than 70 km altitude. The aircraft could then fly into the clouds and use its instrumentation to study the cloud composition looking for habitability and biosignatures. A human teleoperator, even with up to a few seconds time delay could actively guide such an aircraft, or powered balloon, through the hazes and clouds. The astronaut operator would be able to guide these instrumented vehicles down to the lower cloud layers where particles from geological, volcanological or even biological processes can be found. Finding the source of the phosphene in the atmosphere would be a priority.

An aircraft with a fully charged battery could also fly into the planet’s night side, both within and below the cloud deck. Within the clouds, answers could be found to their temperature variations and the possible effects on potential cloud habitability and haze photochemistry. Below the clouds, using far-optical to near-IR sensors, the aircraft could locate silicate mineralogy and map volcanic hotspots. For the harsh surface environment, the Keck Institute report expects advances in high temperature power sources and electronics to enable weeklong surface missions for rovers.

But it also suggests landing a rover on a mountain top. To escape the Venus’ harsh mean surface temperature of about 464 degrees Celsius, a rover could be landed on the Maxwell Montes. Its top is 11 km above the planetary mean surface level and is the highest point on the planet. At this elevation, the temperature is more than 100 degrees cooler, about 377 Celsius, and has an easier pressure level of 45 bar, half that of the mean surface level. On Maxwell Montes a rover could last for longer than a week. As the rover is teleoperated it could travel far faster than the autonomous Mars rovers.

With astronauts a light minute away, the humans can direct the speed and direction of travel, coupled with near-real-time audio, image and video uplink. The rover would only need to stop for geochemical analysis, such as from laser-induced breakdown spectroscopy, Raman spectroscopy, or x-ray diffraction; multispectral stereo imaging would occur during the fast-paced drive, allowing for geomorphometric, topographic, and compositional mapping from the resulting dataset. Astronauts
would respond almost immediately to serendipitous discoveries and adjust the rover’s actions accordingly. The rover could even take samples, its robot arm teleoperated by the crew.

**VENUSIAN SAMPLE RETURN**

With the backflip mission configuration with two flybys, samples could be launched on both occasions from the surface or mountain top. The sample return vehicle would rendezvous with the crewed ship and the material transferred to a secure onboard laboratory. The crew could perform sophisticated laboratory experiments to determine the presence of or amenability to life. The results from the analysis of the first flyby’s sample return could lead to better target collection for the second flyby’s sample batch. The samples could be a mixture of atmospheric gases and particles and regolith. A mix of samples from two sample returns would allow for more detailed analyses once the samples are returned to Earth.

More than 50 years ago, NASA’s Manned Space Flight office proposed a Venus flyby mission to the Apollo Applications programme. Using a single standard Saturn V, a three-man crew would be sent to the planet in November 1973. The Saturn V would be able to loft 48,432.32 kg, enough for the Command and Service modules to be attached to an environmental support module and a spent S-IVB stage. The S-IVB stage would be used for habitable volume and structural support for a solar array power system. Today, NASA’s Mars mission reference architecture, for its ongoing analysis, foresees a crew of four with two going down to the surface. The Mars ship uses nuclear propulsion, and the crewed part of the spacecraft is one large habitat module attached to an Orion spacecraft. The Space Launch System (SLS) rocket would presumably launch the ship and crew separately. An SLS Block 2 Crew, with a 43 t payload capacity, would launch the Orion and perhaps the habitat, which could be expandable. An SLS Block 2 Cargo with a 46 t payload capacity would launch the nuclear electric propulsion part of the ship with additional orbiters, landers, rovers, balloons and fixed wing robot aircraft attached. While Mars is attractive because humans can walk on its surface, the journey will be a long one with many potential hazards. Flying by Venus could reduce substantially the risk of a future multi-year Mars mission. The planet of the Greek goddess is a solution to many possible problems, almost as beautiful as Aphrodite herself.
SEARCHING HELL FOR LIFE

After years of Mars rovers and orbiters, last year saw three new Venus missions proposed between NASA and ESA and a stated goal is to look for life on Earth’s harsh twin sister.

The number of planned robotic missions to Venus is now five, two from NASA, one by the European Space Agency (ESA), one by India, and a delayed Russian mission which had been a joint effort with the United States. The NASA and ESA missions were announced in June last year. They are Venus Emissivity, Radio Science, InSAR [synthetic aperture radar], Topography, and Spectroscopy, (VERITAS), Deep Atmosphere Venus Investigation of Noble gases, Chemistry, and Imaging (DAVINCI) and ESA’s EnVision. VERITAS is an orbiter, DAVINCI has an orbiter that will drop a probe into the atmosphere and EnVision is an orbiter with a US radar. The formerly joint, US, Russian mission is Venera-Dolgozvivshchaya, named after the Venus missions of the Soviet era (see pages 24-25). It was to have an orbiter and a lander with a launch window of 2026 or 2027, but that is now proposed for 2029 by the Russian Federal Space Agency, Roscosmos. India’s mission, Shukrayaan-1, could be the first to launch in late 2024 and the primary science objectives are to map Venus’ surface and subsurface, while studying the planet’s atmosphere. Its chemistry and interaction with the solar wind will also be a focus for the work. The mission had been announced in 2017 with the plan to launch in 2020, but the pandemic caused some delays. While Shukrayaan is India’s first Venus mission, Veritas will be NASA’s first dedicated Venus mission in almost 40 years. NASA’s last mission to study the planet’s surface, Magellan, arrived at Venus in 1990 and ended its work in 1994. NASA’s VERITAS orbiter could provide data to help reveal how the paths of Venus and Earth diverged, and how Venus lost its potential to be a habitable world. VERITAS will seek to provide answers about the internal geodynamics of Venus. The project’s partners include Lockheed Martin, the Italian Space Agency, the German Space Agency, and the French Space Agency. VERITAS will orbit the planet and with its radar system collect data to create 3D global maps. Its near-infrared spectrometer will help scientists figure out what the surface is made of. VERITAS will also measure the planet’s gravitational field to determine the structure of Venus’ interior. Together, its instruments could offer clues about the planet’s past and present geologic processes from its core to its surface. Producing high-resolution 3D topographic maps VERITAS will bring into focus structures that have previously been too small to resolve with cameras. VERITAS would also look for active surface faulting using something called interferometric deformation maps. Using its spectrometer, VERITAS would determine which rocks recently formed from erupting magma, before interactions with the atmosphere have had time to change their chemical composition.

In addition, the spectrometer would search for hotspots from active eruptions, while the radar
instrument would search for active faulting, an indication of tectonic activity. VERITAS will also study vast deformation structures called tessera. These plateau-like features may be analogous to Earth’s continents. A leading theory is that Earth’s continents formed when iron-rich oceanic crust subducted and melted in the presence of water, producing huge volumes of new, less iron-rich continental crust that rose above the ocean. To determine if Venus’ tessera plateaus formed in a similar way to Earth’s continents, VERITAS could construct the first global multispectral maps of Venus’ surface composition. If their composition resembles that of continental crust, then that would help inform science’s understanding of Venus’ wet past.

DAVINCI
NASAs DAVINCI mission is expected to launch in June 2029 and start its observations in 2031. The mission’s carrier, relay and imaging spacecraft (CRIS) has two onboard instruments that will study the planet’s clouds and map its highland areas during flybys of Venus and drop the 1m diameter titanium descent probe with its five instruments. DAVINCI will make use of three Venus gravity assists, which save fuel by using the planet’s gravity to change the speed or direction of the CRIS flight system. The first two gravity assists will set CRIS up for a Venus flyby to perform remote sensing in the ultraviolet (UV) and the near infrared. The first flyby of Venus will be six and half months after launch.

After exploring the top of Venus’ atmosphere, a third Venus gravity assist will set up the spacecraft to release the probe in about June 2031 for its entry, descent and touchdown. The probe will fall for an hour and take thousands of measurements and snap up-close images of the surface. It may not survive the landing, which is more of a crash at 12 m/s, but if it does, it could continue to operate collecting data for up to 18mins. It will descend over the mountainous highlands of Venus’ Alpha Regio and map rock composition and surface relief at scales of less than 1 m.

The probe will commence science observations after jettisoning its heat shield about 67 km above the surface. With the heat shield jettisoned, the probe’s inlets will ingest atmospheric gas samples for detailed chemistry measurements of the sort that have been made on Mars with the Curiosity rover. The DAVINCI orbiter will measure gases present in very small amounts and the deepest atmosphere, including the key ratio of hydrogen isotopes. These isotopes are components of water that help reveal the history of water, either as liquid water oceans or steam within the planet’s interior at the topographic trench.

DAVINCI uses observations from both above and within the planetary atmosphere to answer major questions about how Venus was formed, has evolved, and possibly lost its habitability and past surface oceans. This artist’s concept shows the proposed VERITAS spacecraft using its radar to produce high-resolution maps of Venus’ topographic and geologic features.

CLOCKWISE FROM LEFT
An artist’s concept of active volcanos on Venus, depicting a subduction zone where the foreground crust plunges into the planet’s interior at the topographic trench.

DAVINCI uses observations from both above and within the planetary atmosphere to answer major questions about how Venus was formed, has evolved, and possibly lost its habitability and past surface oceans.

This artist’s concept shows the proposed VERITAS spacecraft using its radar to produce high-resolution maps of Venus’ topographic and geologic features.

EnVision is ESAs mission to make detailed observations of Venus. As a key partner in the mission, NASA is providing the Synthetic Aperture Radar, called VenSAR, to make high-resolution measurements of the planet’s surface features. Once EnVision completes its definition phase when the design of the satellite and instruments is finalised, a European industrial contractor will be selected to build and test EnVision. The spacecraft is to be launched on an ArianeGroup Ariane 6 rocket. The earliest launch opportunity for EnVision is 2031, with other possible options in 2032 and 2033.

The spacecraft will take about 15 months to reach the planet, with a further 16 months to achieve orbit circularisation through aerobraking. Its final 92-minute orbit will be quasi-polar with an altitude of between 220 km and 540 km. EnVision’s innovative instruments include a sounder to reveal underground layering, and spectrometers to study the atmosphere and surface. The spectrometers will monitor trace gases in the atmosphere and analyse surface composition, looking for any changes that might be linked to signs of active volcanism.

A NASA-provided radar will image and map the surface. In addition, a radio science experiment will probe the planet’s internal structure and gravity field as well as investigate the structure and composition of the atmosphere. The instruments will work together to best characterise the interaction between the planet’s different boundaries – from the interior to surface to atmosphere – providing an all-encompassing global view of the planet and its processes.

SOVIET REBIRTH
Venera-Dolgozvivuschaya began with representatives from the US and Russian Venus research communities working together to identify and prioritise the scientific objectives for a joint mission concept. The science definition team, consisting of NASA and Russian Academy of Sciences’ Space Research Institute (IKI) personnel, recommended both an orbiter and a lander to address the high priority science goals of studying the atmospheric dynamics and the surface geology and chemistry. Called Venera-D, the mission concept aimed for a launch window in 2026 or 2027.

The IKI Venera-D mission concept, when NASA
and Russia were still cooperating, included a Venus orbiter that would operate for up to three years, and a lander designed to survive on the surface for a few hours. The science definition team also assessed the potential of flying a solar-powered airship in Venus’ upper atmosphere (see below). The independent flying vehicle could be released from the Venera-D lander, enter the atmosphere, and independently explore Venus’ atmosphere for up to three months.

The orbiter was to be designed to study the dynamics and properties of super-rotation, radiative balance and the nature of Venus’ greenhouse effect. It would also characterize the thermal structure of the atmosphere and winds. It would measure the composition of the clouds, their structure, composition, microphysics, UV absorption and chemistry. Finally, it would investigate the upper atmosphere, ionosphere, electrical activity and magnetosphere.

Japan’s Akatsuki Venus probe has already been doing some of this work. It has been able to take detailed readings of the atmosphere since its arrival at Venus in 2015. Akatsuki has an elliptical orbit that is as far out as 80,000 km from Venus and a periclytherion as close as 300 km. At this short distance Akatsuki can take close-up photos of Venus and observe the storm winds that blow on the Venusian surface, at speeds that reach 100 m a second, 60 times the speed at which Venus rotates. This phenomenon is known as super-rotation and remains the biggest mystery of Venus, as it cannot be explained meteorologically. Akatsuki has employed infrared imaging to observe the atmosphere under the clouds and the conditions on the planet’s surface.

The lander, that would only last a few hours, was to be designed to perform chemical analysis of the surface material and study its elemental composition. It would study the interaction between the surface and atmosphere, presumably during its descent. The lander would also study the structure and chemical composition of the atmosphere down to the surface, including isotopic ratios of the trace and noble gases. Direct chemical analysis of the cloud aerosols was another goal, as was characterising the geology of local landforms at different scales.

Missions which have not been approved but proposed have included high altitude balloons, like Venera-D, and they would also fly for long periods and study the planet. A crewed version of these high-altitude balloon platforms has also been proposed along with a human flyby mission (see pages 16-19). In May 2015, Northrop Grumman announced its Venus Atmospheric Manoeuvrable Platform (VAMP) concept, a long-lived, manoeuvrable, semi-buoyant platform that would coast through Venus’ clouds gathering atmospheric data. VAMP is the first application for the lifting entry atmospheric flight family of vehicles that could serve as atmospheric “rovers,” going to any Solar System body.
Although the surface of Venus is hot and hostile, its atmosphere at 50 km altitude is Earth-like and its clouds hold the key to the difference. VAMP is a large and light, inflatable and deployable vehicle that would cruise through Venus' clouds at altitudes ranging from 52 km to 68 km using solar-powered propellers to manoeuvre on Venus while gathering science data. It was being designed to be inflated and deployed on orbit and "float" like a leaf into Venus's atmosphere, where it could operate for more than year.

Another strong reason for sending a floating platform to fly through the atmosphere at high altitudes is because super rotation was discovered in the 1960s by astronomers who were tracking the motion of dark streaks in the atmosphere. The dark streaks seen in the atmosphere at 50-60 km altitude are known to absorb UV light and have been hypothesised as microbial life. The detection of phosphine, a gas emitted by organic processes, but sometimes from volcanic sources, has raised questions again about the possibility of microbial life in Venus' atmosphere.

Mars has been the focus of much of humanity's space exploration, its surface conditions making it a lot easier to send landers and rovers, and more recently helicopters. Flying probes that can fly through Venus' dark streaks could potentially be a far more successful approach to finding life elsewhere. Venus may be described as Earth's evil twin because of its horrendous environment, but it may also have one other very powerful characteristic in common, the independent evolution of life within the Solar System.
VENUS

Venus' visitors

The brightest star in the sky, Venus attracted a lot of attention from the beginning of the space age when this sister planet was deemed hospitable to life.

NASA's Mariner 2 probe in 1962 was the first spacecraft to flyby Venus and it quickly ended the dreams that there might be another biosphere in the Solar System, Venus' surface temperature was too high. Mariner 2 was followed by the Soviet Union's Venera 4 in 1967 and NASA's Mariner 5 in the same year. The Soviet Union sent Venera 7 in 1970, Venera 8 in 1972 and NASA's Mariner 10 went to Venus in 1973. Venera 4 was the first probe to transmit data from a planet, within Venus' atmosphere. However, the transmission stopped before it reached the surface, but the Venera 7 lander successfully landed. It was the first touch down on another planet. Venera 8 established that the rapid rotation of Venus' deep atmosphere, from 62 km to the surface, was in the same direction as the planet's backward spin. Mariner 10 returned the first images of Venus from its fly-by trajectory in 1974. This added to the knowledge of the atmosphere, its circulation and how it is organised into two hemispheric vortices.

By the mid-1970s it was clear that Venus was very different to its inner planet sisters, Earth and Mars. Venus was a barren hell planet of extremely hot temperatures and destructive winds in its atmosphere. Venus' average orbital distance from the Sun is 108.20 million km, its equatorial radius is 6,051.8 km, only 320 km less than Earth's and Venus' surface gravity is 8.87 m/s². But its surface temperature is a scorching 462 degrees Celsius. Its atmosphere is carbon dioxide and nitrogen, and its surface level pressure is more than 75 bar, equivalent to being at 750 m depth in Earth's oceans.

In 1975, the Soviet Venera 9 and Venera 10 landers returned the first images of Venus' surface, the very first taken from the surface of any other planet. The view that society has today of Venus were largely formed by then. The next Soviet Venus mission was in 1978, the landers Venera 11 and 12. The same year, NASA sent its Pioneer Venus probe, and it was the first to carry a radar to observe another planet. Three years later, the Soviet Union sent two more landers, Veneras 13 and 14 in 1981. The Soviet approach was to send two spacecraft at a time to try to ensure mission success.

In 1983, the Soviets sent two more spacecraft, Venera 15 and 16 but they were orbiters. In what could one day be seen as forerunners to future Venus missions (See pages 20-23), 1985's Soviet Vega 1 and Vega 2 missions were the first to successfully deploy balloons in another planet's atmosphere. The two...
probes, after deploying their Venus payloads, carried on to study Halley's Comet. The latter half of the 1980s saw Venus exploration fall out of favour and NASA's next mission to the goddess of love was not until 1989, Magellan. Launched from the bay of the Space Shuttle Atlantis May 1989, Magellan reached Venus in October 1990. It provided the first high resolution mapping by radar of another planet.

The 1990s were completely barren of dedicated Venus missions and the beginning of the 21st Century did not look much better, but the European Space Agency sent its Venus Express in 2005. The Galileo and Cassini spacecraft did flyby Venus on their way to their respective destinations. In February 1990, on its way to Jupiter, Galileo took infra-red imagery of the planet. In 1998, Cassini searched for lightning in Venus’ atmosphere as it flew by and used its radar to look at the surface, on its way to Saturn.

It was on 9 November 2005 that the first Venus dedicated mission in 15 years was launched by a Russian rocket and that was ESA’s Venus Express mission. It arrived in orbit around Venus on 11 April 2006. The mission provided data on the Venus atmosphere and the mission continuously collected observations of the planet until December 2014 when its signal was lost. Venus Express had two solar cell panels per wing comprising alternating rows of standard triple junction solar cells as well as highly reflective mirrors to reduce the operating temperatures.

This temperature reduction is needed because there is twice as much sunlight at Venus. There is also heat from the Venusian surface and atmosphere because 75% of the sunlight is reflected up from it. In certain situations, this resulted in Venus Express receiving an equivalent of the thermal input from 3.5 Suns. Two missions that went much nearer to the Sun and flew by Venus were ESA’s BepiColombo and the joint ESA-NASA Solar Orbiter. BepiColombo flew by Venus in August 2021 on its way to Mercury. BepiColombo made two gravity assist manoeuvres around Venus to reach the innermost planet of the Solar System.

Launched from Cape Canaveral in February 2020, Solar Orbiter made numerous gravity assist flybys of Venus over the course of its mission to adjust its orbit, bringing it closer to the Sun. Its many gravity assists were also necessary to send the spacecraft out of the plane of the Solar System, so it could observe the Sun from progressively higher inclinations. This was so Solar Orbiter could take the first ever images of the Sun's polar regions. The images of the uncharted polar regions of the Sun are expected to help scientists understand how the stellar object works.

Venus, along with Mars, was one of the places humanity had hoped would also contain life, but it was not to be. Venus is now viewed as a planet that can help scientists understand Earth’s own changing climate and the worst effects of global warming. With a renewed interest in Venus (see pages 20-23) and missions planned for later this decade, recent observations of phosphine in the atmosphere will see a search for microbial life on Venus.
The long-term goal of lunar exploration set out by NASA and its partner space agencies for the Artemis moon programme is a lunar economy, the outward edge of a cislunar economic system that starts with Earth continues into orbit and then expands out to the Moon’s far side. If this lunar economy is to be realised, the transportation infrastructure, the rockets, spacecraft, space stations, landers, habitats and vehicles that enable the initial phase of human exploration must transition to a second generation. That next generation infrastructure must facilitate the permanent occupation and economic exploitation of the Moon.

The International Space Exploration Coordination Group and its most recent report, the August 2022 published Lunar Surface Exploration Scenario update, has nothing beyond the first-generation lunar surface base. Neither does NASA in its plans, its Artemis architecture and infrastructure has been fixed. It is too late to implement any major changes for the Space Launch System (SLS), Orion spacecraft and Gateway lunar space station, but there are several downstream elements that are still undefined.

Put concisely, the Artemis architecture uses the fully expendable SLS heavy lift rocket to send crew and cargo to the Moon. Its human rated payload, the Orion spacecraft, is planned to have some reusability of its subsystems and eventually its crew modules. Orion’s European Space Agency (ESA) provided service module is only expendable. Orion will take crews to and from the Gateway lunar space station which is expected to operate for 15 years. Gateway will be resupplied by SpaceX Dragon XL cargo spacecraft. The undefined elements of the Artemis first generation architecture are the lunar landers and...
the surface systems, habitats and in-situ production facilities.

Those undefined elements can still benefit from second generation studies that will then have a substantive input during these first-generation elements’ development. The studies can establish the framework for technology projects that would be conducted during first generation development. Those technology projects would lead to first generation systems and components that can have a second-generation role. A key criterion for the studies would be that the first-generation systems would lead to reusability. Reusability will make a significant permanent lunar presence economically viable. The reusability means that even a very small infrastructure can support significant permanent surface activity with hundreds of people and thousands of metric tonnes of Earth-Moon traffic.

One example of the problem of architectures that do not include second-generation systems is the adoption of the definition of the international docking system standard. It has many short comings in large scale operations and would not be viable in a second-generation infrastructure. A genuine obstacle between first and second generations is the fact that in the earliest phases of lunar exploration there is no existing lunar infrastructure. However, in scoping the first-generation capability requirements, an understanding of what is important for the second generation would allow key technologies to be identified.

This demonstrates the need for second generation studies. The key second generation technologies can be developed to a technology readiness level of seven or eight during the first generation’s development in the knowledge they will achieve full readiness with the second generation. One early conclusion that can be drawn about second-generation human and cargo landing systems is that they should use chemical engines and utilise in-situ lunar oxygen. Oxygen is expected to be a key cislunar market. As such, technologies related to oxygen generation, storage, transportation and utilisation should be prioritised.

The second-generation infrastructure will retain the science objectives of the first, but the big difference is that there will be economic return objectives. These economic returns justify the expansion in costs. This would include in-situ resources, manufacturing, public access, and baseload power generation. To compare the two generations, a first-generation infrastructure is characterised by minimised acquisition and absolute costs, low and fixed capability and intermittent service. The Gateway will only be crewed one month in 12, for example. The second generation has minimised lifecycles and specific costs, expandable capability and continuous service.

**TRANSITIONS**

Transitions need to be seamless and so moving from a first-generation architecture to a second generation one is not feasible in a single step for budgetary and technical reasons. This transition could involve a 1.5 generation. This 1.5 generation will need to have small spacecraft, landers, habitats, and vehicles because the main constraint will still be the capacity and cost limitations of the Earth to LEO launch systems. However, while 1.5 generation vehicles will be small, they will have to have the key criterion of reusability.

Hempsell Astronautics has designed the Anzu reusable multirole crew capsule, able to land on the Moon when combined with a drop tank. The Anzu would replace Orion and NASA’s human landing system (HLS). An Anzu would be able to make six landings. Each landing would require about 20 t of propellant and other supplies. Operationally, three Anzus would be used for 18 landings, along with about 20 t for support equipment that stays in lunar orbit. With 18 landings, one mission a week for six months, it is possible to scout different parts of the Moon for resources and begin to establish production.
The limitations of the 1.5 generation Anzu would mean that a first-generation human-rated crew and cargo lander, NASA’s HLS, would be needed. This could land an unpressurised rover or other equipment to aid the Anzu crews. Anzu uses drop tanks because it is multirole. It was originally designed in a 2005 *Journal of the British Interplanetary Society* paper and was called Excalibur. Here, Anzu is being employed within the framework of a second-generation lunar architecture. It should be noted that NASA’s reference design for its HLS has a three-stage lander with transfer, descent and ascent modules. The transfer module would take the lander from Gateway, where the lander is permanently berthed, to a lunar orbit where it will make a powered descent.

The Gateway will have a near-rectilinear halo orbit that will take it as close as 3,000 km to the Moon and as far out as 70,000 km. This is important as the L1 Lagrange point is about 53,000 km from the Moon and this is a key location for a second-generation architecture. Gateway, if it could be moved using its electric propulsion system to the L1 Lagrange point, could be developed into a second-generation architecture spaceport. Lagrange Points are positions in space where the gravitational forces of the Sun and the Earth produce areas of mutual attraction and repulsion and spacecraft can remain in position with little propulsion necessary. Lagrange points are named in honour of European mathematician Joseph Louis Lagrange.

For the lunar surface systems, a key technical issue is the need for liquid oxygen (LOX) production and for the second generation this will need to be on a large scale. The Anzu and its first-generation HLS can deliver the equipment and the astronauts to start putting in place this infrastructure. For this second-generation architecture, the surface cargo delivery capacity needs to increase to about 100 t per mission. This is deemed suitable for the longer-term construction of a large enough base, or bases, at an economic scale, to support in-situ oxygen production. SpaceX’s Starship is to have a 100 t cargo capacity but it will need to be refuelled in low Earth orbit (LEO) to continue to the Moon.

**NUCLEAR PROPULSION**

For scales of economy, large in-space only craft using nuclear propulsion are important for the second generation. The US military announced at the beginning of this year (*SpaceFlight* Vol 64 No. 3 March pp 34-35) that it would develop nuclear propelled spacecraft to travel in cis-lunar space. For a 1.5 generation solution, SpaceX’s Starship could deliver 100 t to the Moon but come the second generation it would simply go to a LEO space station. From there, the cargo is transferred to a nuclear propelled cis-lunar spacecraft. Later on, the second generation architecture envisages a spaceplane, Reaction Engines’ Skylon, to take cargo to the LEO spaceport instead of Starship.

The second-generation lunar architecture uses a nuclear propelled cis-lunar spacecraft design called Scorpion (*SpaceFlight* Vol 62 No. 4 April 2020 pp 30-36). Scorpion is not only a cis-lunar spacecraft but is also designed to land on the Moon. It has habitation facilities comparable to the International Space Station and can act as a lunar surface base. Scorpion was designed to explore the potential of technologies that were achievable in the past half century for the next half century. Scorpion uses a hybrid nuclear engine which combines direct thermodynamic heating of the hydrogen propellant with electric arc heating.

The propulsion system is the Serpent engine,
designed by Reaction Engines' founder, Alan Bond. Serpent is capable of effective exhaust velocities in excess of 12 km per second. That is 50% more than can be achieved with simple direct thermodynamic heating alone such as the NASA's NERVA project. Scorpion can deliver 339 t into a 100 km lunar orbit and can stay in orbit for six months, or even longer if the payload includes additional crew supplies. The long stay time is possible because the Scorpion's electrical power comes from the nuclear engine's reactor and is for practical purposes indefinite. The stay time is limited by the supplies the mission carries.

For the Moon landings and ascents, Scorpion uses four throttleable chemical engines. They ensure the Serpent nuclear engine is not used within 50 km of the surface to ensure any community is not exposed to unacceptable radiation. For a lunar surface mission, Scorpion carries a crew of six with their supplies and a usable payload of about 21 t. As useful as the Scorpion is, it is not the cargo carrier that second-generation level activities need, thousands of metric tonnes for hundreds of people. But its design is the basis for other freighter cislunar spacecraft.

Mark Hempsell has designed a tug for large payloads called Taurus which uses Serpent and a larger version of Taurus called Aquarius. Taurus and Aquarius are modular carriers with 96 attachments. Aquarius transports hydrogen with an additional eight propellant tanks. There is also the Zibanna passenger craft which can carry up to 100 people to and from any Earth or Lunar orbit. The three craft were designed to maximise their commonality with the Scorpion to reduce technical risks and development and other acquisition costs.

Mark Hempsell's Khonsu lunar lander could be the replacement for Anzu and HLS. The crewed Khonsu can carry twelve passengers and two crew. Khonsu was an Egyptian Moon god whose name means traveller. Khonsu's design is based on Scorpion's chemical engines, using LOX. It is optimised for operating from a spaceport in a high lunar orbit, like Gateway, or from the Earth Moon L1 Lagrange point. Khonsu has maximum LOX and hydrogen loads of 85 t and 14 t, respectively. The hydrogen is loaded at the lunar spaceport and the LOX at the surface base.

Considering the many elements of Artemis and the long-term requirements for creating the foundations for a cislunar economy, a path forward can be seen using Hempsell's designs. Today's SLS can be replaced first by Starship and then Skylon. NASA's planned commercial LEO space stations can become the Earth spaceport. Orion and HLS are replaced first by an SLS launched Anzu and that in turn is replaced by Scorpion for the cislunar journey and Khonsu for Moon landing and ascents. An evolution of Gateway becomes the lunar spaceport. The last 60 years of space exploration saw a brief period of great ambition from the 1960s to 1975, but from 1981, humanity was stuck in LEO. The next 50 years could see hundreds of people working on the Moon and a level of Earth-Moon traffic measured in thousands of metric tonnes.

This article is based on a presentation given by Mark Hempsell at the 73rd International Astronautical Congress in Paris.
Humanity has succeeded in changing the orbit of an asteroid with the Double Asteroid Redirection Test mission, potentially giving the species the ability to avoid a dinosaur-like extinction event.

Setting a spacecraft for the sole purpose of deliberately colliding with an asteroid has the novelty of never having been tried before but in this case, it had a deadly serious intent with the Double Asteroid Redirection Test (DART) Impactor spacecraft aiming to shift the orbit of the hunk of Solar System rubble known as Dimorphos. It orbits a larger asteroid called Didymos and the Impactor collided at the speed of about 22,530 km per hour. This NASA mission had a goal of successfully changing the orbit period of Dimorphos by 73 seconds or more. The early data the agency analysed in September and October showed that DART surpassed this by more than 25 times, by 32mins.

Prior to the Impactor spacecraft’s collision, it took Dimorphos 11hrs and 55mins to orbit its larger parent asteroid, Didymos. After DART’s intentional collision with Dimorphos on 26 September, astronomers used ground based telescopes to measure how much that time may have changed. The investigation team confirmed on 11 October the spacecraft’s impact altered Dimorphos’ orbit around Didymos by 32 minutes, shortening the 11hrs 55min orbit to 11hrs and 23mins. This measurement has a margin of uncertainty of about plus or minus 2mins.

Decades of missile guidance algorithms developed at APL were used for this

Described as a binary asteroid system, Didymos, which means twin in Greek, has a diameter of 780 m and its smaller moonlet asteroid, which orbits it, Dimorphos, has a 160 m diameter. The distance between the centres of the two asteroids is 1.18 km.

Neither Dimorphos nor Didymos pose any hazard to Earth before or after DART’s controlled collision with Dimorphos. The telescopes that contributed to the DART team’s observations included Goldstone, Green Bank Observatory, Swope Telescope at the Las Campanas Observatory in Chile, the Danish Telescope at the La Silla Observatory in Chile, and the Las Cumbres Observatory global telescope network facilities in Chile and in South Africa.

With the orbit time change detected, researchers focused on analysing the ejecta from the DART collision. The spacecraft’s impact saw many tonnes of asteroid rock launched into space. The recoil from this blast of debris substantially enhanced DART’s effect on Dimorphos. Analysing the ejecta will help scientists understand the asteroid’s physical properties, the characteristics of its surface, and how strong or weak it is. Asteroids have been thought to be like mountains in space but many of them could just be coalesced Solar System rubble whose uniformity can easily be disrupted. DART is a mission of NASA’s Planetary Defense Coordination Office, and the spacecraft was built by Johns Hopkins Applied Physics Laboratory.

Designed for destruction

The DART Impactor spacecraft’s main structure is a box with dimensions of roughly 1.2 × 1.3 × 1.3 m from which other structures extend. This results in a total size of about 1.8 m wide, 1.9 m long and a height of 2.6 m. The Impactor also has two very large solar
arrays which are 8.5 m long each when deployed. The total mass of the spacecraft was about 610 kg at launch and about 570 kg on impact. The Impactor carried 50 kg of hydrazine propellant for spacecraft manoeuvres and attitude control, and 60 kg of xenon to operate the ion propulsion technology demonstration engine.

The spacecraft’s engine was NASA’s Evolutionary Xenon Thruster – Commercial (NEXT-C), an ion propulsion system developed by the agency’s Glenn Research Center and Aerojet Rocketdyne. The NEXT-C is a solar-powered electric propulsion system using a gridded ion engine producing thrust by electrostatic acceleration of ions formed from the xenon propellant. According to NASA, NEXT-C offers improved performance with higher specific impulse, better fuel efficiency, and operational flexibility compared to ion propulsion systems flown before, such as NASA’s Dawn and Deep Space 1 missions.

DART’s Impactor spacecraft was also the first spacecraft to use flexible and rollable solar arrays which were installed at the International Space Station (ISS) in June 2021 for full-time use. These arrays are lighter and more compact than traditional ones, despite their length. This technology was first tested successfully in 2017 on ISS. NASA intends to use this type of solar array on future missions. The Impact spacecraft only had one instrument, the Didymos Reconnaissance and Asteroid Camera for Optical navigation (DRACO). DRACO is a high-resolution imager derived from a New Horizons programme camera to support navigation and targeting.

The DRACO camera can also help measure the size and shape of the asteroid target, and to determine the impact site and geological context. The camera is a narrow-angle telescope with a 208 mm aperture and field of view of 0.29 degrees. It has a complementary metal-oxide semiconductor detector and onboard image processor to determine the relative location of Dimorphos. The images acquired by DRACO before the kinetic impact were streamed back to Earth in real time. In its final moments, DRACO helped characterize the impact site by providing high-resolution, scientific images of the surface of Dimorphos.

The DRACO telescope also supported the Impactor’s “SMART Nav” system. The spacecraft’s primary challenge was to reliably target and squarely impact Dimorphos, a 160 m diameter target, when it is 11 million km away from Earth. For the necessary guidance, navigation and control (GNC), the DART team developed algorithms called small body manoeuvring autonomous real time navigation, or SMART Nav. Decades of missile guidance algorithms developed at APL were used for this. This autonomous optical navigation system identified and distinguished between the two bodies at Didymos and then, working in concert with the other GNC elements, directed the spacecraft toward Dimorphos, all within roughly an hour of impact. As well as the ground based observatories, astronomers will continue to study imagery of Dimorphos from DART’s Italian Space Agency provided Light Italian CubeSat. This will help the DART team to approximate the asteroid’s mass and shape. In 2024, the European Space Agency’s Hera project is planned to conduct detailed surveys of both Dimorphos and Didymos (see pages 32-33).

FROM ABOVE
Asteroid moonlet Dimorphos as seen by the DART spacecraft 11 seconds before impact. DART’s onboard DRACO imager captured this image from a distance of 42 miles (68 kilometers). This image was the last to contain all of Dimorphos in the field of view. Dimorphos is roughly 525 feet (160 meters) in length. This image is shown as it appears on the DRACO detector and is mirror flipped across the x-axis from reality.

Asteroid Didymos (bottom left) and its moonlet, Dimorphos, about 2.5 minutes before the impact of NASA’s DART spacecraft. The image was taken by the on board DRACO imager from a distance of 570 miles (920 km). This image was the last to contain a complete view of both asteroids. Didymos is roughly 2,500 feet (780 meters) in diameter; Dimorphos is about 525 feet (160 meters) in length. Ecliptic north is toward the bottom of the image. This image is shown as it appears on the DRACO detector and is mirror flipped across the x-axis from reality.

PHOTOS: NASA/JOHNS HOPKINS APL
Protecting the heavens

Hera is the European Space Agency’s contribution to the asteroid redirection effort with NASA, whose Impactor spacecraft has altered the orbit of an asteroid.

The European Space Agency’s spacecraft Hera, named after the queen of the Greek gods, will perform a detailed post-impact survey of the target asteroid, Dimorphos. It is the 160 m wide Moonlet orbiting the larger 780 m diameter asteroid known as Didymos, in this binary asteroid system. NASA’s Double Asteroid Redirection Test (DART) Impactor spacecraft (see pages 30-31) collided with Dimorphos on 26 September and already measurements have determined that its orbit was changed more significantly than expected by the impact. Hera will be demonstrating new technologies from autonomous navigation around an asteroid to low gravity proximity operations. Didymos was first spotted in 1996 by Joe Montani of the Spacewatch Project at the University of Arizona.

Originally assumed to be a single body, the asteroid system did not meet the criteria for an official name at the time. Observers have to consistently trace an asteroid’s orbit and confirm that it will not fade away and become lost again before they can file for a formal designation. In 2003, Petr Pravec, a planetary astronomer at the Ondřejov Observatory in the Czech Republic, was tracking the brightness of this then-nameless asteroid when he recognized a pattern consistent with a satellite orbiting the main body. Hera will be the first probe to rendezvous with a binary asteroid system, unlike DART’s Impactor which simply hit it.

In September 2020, ESA awarded a €129.4 million contract covering the detailed design, manufacturing and testing of Hera.

Hera will be launched in October 2024 and reach Didymos in December 2026. The Hera spacecraft, which is the size of an office desk, will perform a close-up survey of the aftermath of impact, gathering key information such as the size of DART’s crater, the mass of Dimorphos and its make-up and internal structure. The Hera team has been carrying out the critical design review (CDR), which if approved will lead to the full construction of the spacecraft. Hera will carry two cubesats, Milani and Juventas. Milani is named after mathematician and astronomer Andrea Milani. He led the creation of the first automated system to compute the probabilities that an asteroid could impact the Earth in the future.

The two cubesats have their own roles in the mission. Milani will carry out spectral measurements of asteroid dust while Juventas will perform the first radar probe of an asteroid. Juventas is a ‘6-unit’ cubesat, measuring 10 x 20 x 30 cm, while its quartet of radar antennas measure 1.5 m long each. Juventas’s main antennas will radiate at 60 MHz. The radar aboard Juventas is developed from the Rosetta spacecraft’s CONSERT radar system, which peered into the interior of Comet 67P/Churyumov–Gerasimenko. It is a synthetic aperture radar, meaning it will take advantage of Juventas’s orbit 3 km above the
surface of Dimorphos to integrate together multiple signal reflections and resolve them into images. The cubesats have already passed their CDRs.

The main purpose of a CDR is to confirm the design readiness of a spacecraft, its instruments and interfaces with other mission segments, such as its launcher and ground infrastructure. The CDR is undertaken by an expert review board and involves hundreds of documents and data packages covering all aspects of the mission’s readiness. In September 2020, ESA awarded a €129.4 million contract covering the detailed design, manufacturing and testing of Hera. The contract was signed by ESA director of technology, engineering and quality, Franco Ongaro, and Marco Fuchs, OHB chief executive officer.

German space firm OHB is the prime contractor of the Hera consortium. The contract signing took place at ESA’s European Space Operations centre in Germany which will serve as mission control for the 2024 launched Hera. Hera’s flight model is being built at the OHB company in Bremen, Germany, and at Avio in Colleferro, Italy. At Avio, Hera’s propellant tanks, thrusters and associated pipes and valves will be integrated. While at OHB, its avionics test bench at Bremen is testing the mission systems.

At OHB, Hera’s core module is being built. This will carry all the mission’s scientific instruments as well as on-board computer and other subsystems. The spacecraft will be completed when these two halves are eventually joined together. The engineering model of Hera’s precision guidance, navigation and control system was put together by GMV in Spain. The Japan Aerospace Exploration Agency has also supplied an instrument for Hera, the TIRI thermal infrared instrument and it has passed its CDR. DART and Hera were originally conceived as coordinated double-spacecraft missions, with one mission to perform the deflection and the other to perform precision measurements of the result.

Over the years, the implementation of the two missions was separated but international collaboration was maintained through the asteroid impact and deflection assessment scientific consortium. While the pair are designed to function separately, their data will complement each other. Hera will be launched by ESA’s new rocket the ArianeGroup Ariane 6. The Ariane 6 upper stage will have a new kick-stage called Astris that will send Hera on its way. The very first sensor to be used by Hera was made in Ireland. A gyroscope unit manufactured by Dublin-based Innalabs will track the spacecraft’s spin rate as it tumbles away from its Ariane 6 launcher following its 2024 lift off. This will allow it to safely orient its solar panels to the Sun and come to life.

ESA provided ground station support to DART, helping relay signals from the mission following launch. The agency’s deep space ground station at New Norcia in Western Australia supported NASA’s Deep Space Network. The ESA station’s 4.5 m antenna captured the first signal from DART after it separated from its Falcon 9 launcher. The station also helped maintain contact as the spacecraft headed towards Didymos. And it will do the same when the time comes for Hera’s mission.
Satellite Digest is SpaceFlight's regular listing of world space launches using orbital data from the United States Space Command space-track.org website

Compiled by Geoff Richards | Sponsored by Seradata

| Satellite Digest 599 |

Due to the number of individual Starlink and OneWeb satellites, the entries for these launches have been compressed.
1 Yaogan 33 Earth observation satellite built by SAST for “scientific experiments, land survey, crop yield assessment, and disaster monitoring”, with an imaging radar payload possibly for military purposes.

2 Set of 51 communication satellites built by SpaceX, each carrying transponders for communications, an inter-satellite optical communication system and an autonomous collision avoidance system. Satellites in catalogue order are Starlink 4725, 4711, 4724, 4731, 4714, 4717, 4716, 4667, 4694, 4685, 4696, 4627, 4683, 4698, 4688, 4686, 4699, 4702, 4695, 4644, 4642, 4707, 4700, 4705, 4663, 4704, 4697, 4701, 4640, 4651, 4641, 4636, 4661, 4574, 4616, 4618, 4652, 4646, 4662, 4613, 4607, 4614, 4637, 4645, 4670, 4656, 4589, 4657, 4669, 4680 and 4612. Launch Group 4-20 in Starlink broadband system. All satellites have manoeuvred up to a 350 km holding orbit to allow drift to correct planes, apart from Starlink 4613, 4657, 4696, 4702 and 4704 which failed and Starlink 4644 which initially failed to manoeuvre, but recovered 30 September. First batch (Starlink 4589, 4607, 4642, 4604, 4618, 4637, 4645, 4646, 4656, 4662, 4669, 4670 and 4680) began moving up 25 September, but Starlink 4614 halted at 376 km 28 September. First stage, that previously flown on Danuri launch, landed on the Just Read the Instructions barge 624 km downrange.

3 Sherpa-LTC is a manoeuvrable payload platform built by Spaceflight Inc carrying Varuna-TDE built by Astro Digital for Boeing, an attached communications technology payload with V-band transponders for broadband communications and atmospheric effects on propagation, a transmitter using the Globalstar system and a Benchmark IPA/HTP liquid propellant propulsion system.

4 CentiSpace-1, or Weili Kongjian, are a pair of navigation technology development satellites each built using a WN100 bus by IAMCAS for Beijing Future Navigation and carrying a test payload for a planned constellation of low-orbit navigation and positioning satellites including a GNSS receiver and a laser inter-satellite communications system.

5 Yaogan 35 Group 05 was announced as a trio of remote sensing satellites, two (A and B) built by DFH Satellite and the third (C) built by SAST carrying instruments for “scientific experiments, land and resources census, agricultural product assessment and disaster prevention and mitigation”. A and B rumoured to have optical sensors and C a radar for Earth observation.

6 Eutelsat Konnect Very High Throughput Satellite is a communications satellite built using the new Spacebus NEO 200 bus by Thales Alenia Space and launched by ArianeSpace for Eutelsat. Mass quoted above is at launch. The satellite will manoeuvre using electric propulsion to station at 13°E for high-throughput communications and Internet service to Sub-Saharan Africa and Europe.

7 Set of 34 communication satellites built by SpaceX, each carrying transponders for communications, an inter-satellite optical communication system and an autonomous collision avoidance system. Satellites in catalogue order are Starlink 4718, 4719, 4722, 4708, 4664, 4709, 4706, 4678, 4662, 4679, 4536, 4687, 4638, 4631, 4743, 4744, 4666, 4734, “A”, 4739, 4728, 4730, 4742, “B”, 4723, 4712, 4710, 4720, 4715, 4726, 4727, 4729, 4763 and 4768. Starlink A and B are Starlink 4721 and 4791 which are apparently not transmitting and thus cannot be identified. Launch Group 4-2 in Starlink broadband system. All satellites have manoeuvred up to a 350 km holding orbit to allow drift to correct planes, apart from Starlink 4638, 4721, 4744 and 4791 which failed. First stage, that previously flown on Starlink 4-21 launch, landed on the A Shortfall of Gravitas barge 645 km downrange.

8 BlueWalker is a communications satellite built by AST & Science (Avellan Space Technology & Science) for AST SpaceMobile with a large deployable antenna array carrying transponders for mobile phone communications. Pathfinder for proposed 168-satellite constellation.

9 Telecommunications satellite built using a CAST DFH-4 bus, officially for China Satcom but apparently a Fenghuo 2 military communications payload. Mass quoted above is estimated at launch. The satellite is located over 81.4°E, replacing Zhongxing 1C, to provide a service to China.

10 Radar Earth survey satellite built by Synspective and launched by Rocket Lab carrying an X-band radar for all-weather Earth imaging. First of planned constellation of 25 satellites.

11 Set of 54 communication satellites built by SpaceX, each carrying transponders for communications, an inter-satellite optical communication system and an autonomous collision avoidance system. Satellites in catalogue order are Starlink 4749, 4738, 4758, 4752, 4713, 4748, 4757, 4751, 4756, 4764, 4760, 4759, 4761, 4649, 4747, 4711, 4733, 4738, 4778, 4776, 4773, 4784, 4766, 4750, 4754, 4769, 4745, 4753, 4746, 4777, 4780, 4770, 4767, 4755, 4797, 4794, 4800, 4703, 4795, 4809, 4798, 4799, 4781, 4792, 4788, 4779, 4785, 4762, 4793, 4789, 4810, 4732 and 4740. Launch Group 4-3 in Starlink broadband system. All satellites have manoeuvred up to a 350 km holding orbit to allow drift to correct planes, apart from Starlink 4713 which appears to have failed and straggler Starlink 4748. First stage, that previously flown on Dragon CRS 25 launch, landed on the Just Read the Instructions barge 666 km downrange.

12 Multipurpose satellite built by SAST for GAD measuring atmospheric, marine and space environment and for disaster prevention and mitigation and scientific experiments. Payload includes a dual-band microwave radiometer, a scanning infra-red radiometer and receivers to measure cloud data from GPS occultation and sea state from GPS reflection.

13 Spacecraft with three-man crew launched to the International Space Station, mission ISS-68S, also named K. E. Tsiolkovsky to mark the 165th anniversary of the astronautics pioneer. Crew comprises Sergei Prokopyev (Soyuz Commander, ISS flight engineer) and Flight Engineers Dmitri Petelin and Francisco Rubio (NASA). Crew are to be part of ISS Expeditions 67 and 68, with Prokopyev to become the ISS Commander for later part of Expedition 68. Spacecraft docked with ISS/Rassvet port September 21.71.

14 Classified satellite, also known as NROL-91, is probably a reconnaissance satellite launched for NRO by ULA to replace USA 290. Orbit is classified, that given is from amateur trackers. Final Delta launch.
INTERNATIONAL SPACE STATION ACTIVITY

There was the following orbital manoeuvre of ISS during September boosted by Progress MS-20.

Pre-manoeuvre orbit: Sep 15.84 51.64° 92.79 min 415 km 418 km
Post-manoeuvre orbit: Sep 16.11 51.64° 92.80 min 415 km 418 km

End-of-September orbital data:
Sep 30.87 51.64° 92.78 min 414 km 417 km

CHINA SPACE STATION ACTIVITY

There was the following orbital manoeuvre of CSS during September.

Pre-manoeuvre orbit: Sep 27.41 41.47° 92.02 min 377 km 383 km
Post-manoeuvre orbit: Sep 27.60 41.47° 92.10 min 381 km 386 km

End-of-September orbital data:
Sep 30.61 41.47° 92.09 min 382 km 385 km

RECENTLY DETAILED ORBITAL DECAYS

<table>
<thead>
<tr>
<th>International Designation</th>
<th>Object name</th>
<th>Decay</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017-042BB</td>
<td>Flock 2k-43</td>
<td>Sep 19</td>
</tr>
<tr>
<td>2017-042BT</td>
<td>Flock 2k-15</td>
<td>Sep 5</td>
</tr>
<tr>
<td>2017-071N</td>
<td>Asgardia 1</td>
<td>Sep 12</td>
</tr>
<tr>
<td>2018-004AG</td>
<td>SpaceBEAM 2</td>
<td>Sep 6</td>
</tr>
<tr>
<td>2018-070D</td>
<td>ELFIn*</td>
<td>Sep 30</td>
</tr>
<tr>
<td>2018-070E</td>
<td>ELFIn</td>
<td>Sep 17</td>
</tr>
<tr>
<td>2019-071K</td>
<td>VPM</td>
<td>Sep 29</td>
</tr>
<tr>
<td>1998-067RH</td>
<td>SORTIE</td>
<td>Sep 18</td>
</tr>
<tr>
<td>2020-022A</td>
<td>TDO 2</td>
<td>Sep 28</td>
</tr>
<tr>
<td>2020-025C</td>
<td>Starlink 1339</td>
<td>Sep 11.81</td>
</tr>
<tr>
<td>2021-005A</td>
<td>Starlink 1952</td>
<td>Sep 16.94</td>
</tr>
<tr>
<td>2021-042B</td>
<td>TDO 3</td>
<td>Sep 27</td>
</tr>
<tr>
<td>2021-042C</td>
<td>TDO 4</td>
<td>Sep 18</td>
</tr>
<tr>
<td>1998-067SN</td>
<td>G-Satellite 2</td>
<td>Sep 15</td>
</tr>
<tr>
<td>1998-067SR</td>
<td>Binar 1</td>
<td>Sep 30</td>
</tr>
<tr>
<td>1998-067SU</td>
<td>CUAVA 1</td>
<td>Sep 2</td>
</tr>
<tr>
<td>1998-067SV</td>
<td>CAPSat</td>
<td>Sep 18</td>
</tr>
<tr>
<td>2021-110A</td>
<td>DART</td>
<td>Sep 26.97 (on Dimorphos)</td>
</tr>
<tr>
<td>2022-026A</td>
<td>Soyuz MS-21</td>
<td>Sep 29.46</td>
</tr>
<tr>
<td>2022-104AC</td>
<td>Starlink 4654</td>
<td>Sep 15.2</td>
</tr>
<tr>
<td>2022-104AD</td>
<td>Starlink 4653</td>
<td>Sep 14.0</td>
</tr>
</tbody>
</table>
### ADDITIONS AND UPDATES

<table>
<thead>
<tr>
<th>DESIGNATION</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007-063B</td>
<td>Horizons 2 was relocated back at 73.8°W 28 September.</td>
</tr>
<tr>
<td>2009-047A</td>
<td>PAN (USA 207) has manoeuvred to a westward drift, according to amateur trackers.</td>
</tr>
<tr>
<td>2010-064A</td>
<td>Zhongxing 20A was manoeuvred off station at 112.8°E 23 September and is drifting to the west.</td>
</tr>
<tr>
<td>2011-040A</td>
<td>Juno passed 354 km from Europa September 29.40 and obtained images and other data.</td>
</tr>
<tr>
<td>2013-060A</td>
<td>MOM mission has ended, with insufficient propellant remaining to restore control after an eclipse period in April.</td>
</tr>
<tr>
<td>2015-073A</td>
<td>Zhongxing 1C was manoeuvred off station at 89°E 10 September and relocated at 70.2°E 24 September.</td>
</tr>
<tr>
<td>2016-055A</td>
<td>Shijian 17 was relocated back at 94.2°E 6 September.</td>
</tr>
<tr>
<td>2016-055A</td>
<td>Parker Solar Probe carried out its thirteenth perihelion pass 6 September.</td>
</tr>
<tr>
<td>2018-110A</td>
<td>Tongxin Jisshu SW3 was relocated at 88.3°E 13 September.</td>
</tr>
<tr>
<td>2020-019F</td>
<td>Solar Orbiter performed a 6,447 km gravity-assist fly-by of Venus September 4.06 to reduce perihelion to 0.293 AU.</td>
</tr>
<tr>
<td>2020-010A</td>
<td>Starlink 1317 has lost attitude control.</td>
</tr>
<tr>
<td>2022-086</td>
<td>First Starlink batch reached 540 km operational orbit 8 September, followed by second batch 20 September. Fourth batch (Starlink 4050, 4051, 4057, 4069, 4107, 4122, 4149, 4159, 4162, 4164, 4165, 4169, 4172 to 4174, 4175, 4178 to 4180 and 4182) began moving up 23 September, though Starlink 4169 halted at 360 km 25 September.</td>
</tr>
<tr>
<td>2022-096</td>
<td>First Starlink batch reached 540 km operational orbit 8 September, followed by second batch 20 September. Starlink 4050, 4051, 4057, 4069, 4107, 4122, 4149, 4159, 4162, 4164, 4165, 4169, 4172 to 4174, 4175, 4178 to 4180 and 4182) began moving up 23 September, though Starlink 4169 halted at 360 km 25 September.</td>
</tr>
<tr>
<td>2022-097</td>
<td>First Starlink batch reached 540 km operational orbit 8 September, followed by second batch 20 September. Second batch (Starlink 4304, 4476, 4479, 4480, 4484, 4491, 4492, 4496, 4497, 4500, 4501, 4502, 4503 to 4506, 4520, 4521 to 4525, 4539, 4541, 4545 and 4552) began moving up 14 September, followed by Starlink 4544 on 18 September.</td>
</tr>
<tr>
<td>2022-099</td>
<td>All Starlink satellites reached 563 km operational orbit 25 to 30 September, with Starlink 4400 continuing to 566 km 2 October.</td>
</tr>
<tr>
<td>2022-101</td>
<td>Starlink 4477 reached 350 km 5 September. First batch (Starlink 4120, 4123, 4128, 4129, 4134, 4139, 4144, 4159, 4169, 4175, 4178 to 4180 and 4182) began moving up 23 September, followed by second batch (Starlink 4053, 4108, 4127, 4133, 4139, 4143, 4148, 4149, 4150, 4151 to 4154, 4156, 4158 and 4163) 24 September.</td>
</tr>
<tr>
<td>2022-102A</td>
<td>Chuangxin 16 separated into two component satellites about 19 September, with Chuangxin 16A retaining the 2022-102A identity. They are keeping within a few km of each other. Add object and orbit:</td>
</tr>
<tr>
<td>2022-102B</td>
<td>Starlink 4477 reached 350 km 5 September. First batch (Starlink 4120, 4123, 4128, 4129, 4134, 4139, 4144, 4159, 4169, 4175, 4178 to 4180 and 4182) began moving up 23 September, followed by second batch (Starlink 4053, 4108, 4127, 4133, 4139, 4143, 4148, 4149, 4150, 4151 to 4154, 4156, 4158 and 4163) 24 September.</td>
</tr>
<tr>
<td>2022-103</td>
<td>Second batch (Starlink 4304, 4476, 4479, 4480, 4484, 4491, 4492, 4496, 4497, 4500, 4501, 4502, 4503 to 4506, 4508, 4510, 4513, 4514, 4516, 4518 and 4563) 24 September.</td>
</tr>
<tr>
<td>2022-104</td>
<td>Starlink 4654 also failed to manoeuvre and Starlink 4665 halted at 323 km 12 September. Remaining satellites reached 350 km by 8 September, apart from straggler Starlink 4605 which recovered and reached 350 km 12 September. First batch (Starlink 4668, 4671 to 4677, 4682, 4684, 4689, 4691 and 4693) began moving up 14 September, followed by second batch (Starlink 4591, 4648, 4660, 4690 and 4692) 23 September.</td>
</tr>
</tbody>
</table>
LETTERS TO THE EDITOR

PLANETARY PROTECTION

Sir,
I read with interest your article on proposed Mars sample return missions. I think the phrase “crash land” describing the sample capsule’s return to Earth is not a good one as that is the last thing you would want it to do. All it takes is one broken seal and possible Martian microbes could get into the Earth’s biosphere. And after the frigid environment of Mars, they will think Earth is Bora Bora. As I have said in my previous correspondence on this, the NASA Gateway station is the best place to examine Mars samples. The Earth return vehicle (ERV) could be modified by having the heavy Earth entry capsule and its heat shield replaced by a lighter sample canister. The lighter canister would allow more fuel to match up the orbits of the ERV and Gateway. The Canadarm 3 would grapple the ERV and bring it in for a hard berthing with a special Mars sample reception module (MSRM) which would be attached to the Gateway core. For added security the vestibule between the hatches of the MSRM and Gateway would be kept in vacuum. The station crew would cooperate with Earth based controllers, watching closely the examination of the samples. If they are safe the crew can enter and take them back on the next Orion or Starship. If something alive is detected, a special unmanned Orion or Starship with special protection would dock with the MSRM and the canister would be transferred over and returned under careful supervision to Earth.

Yours
Edward Philpott (by email)

WEIGHTS AND MEASURES

Sir,
When quoting measurements of temperature, thrust etc the problem arises as whether to quote the original author’s values first, followed in brackets with the converted values. Or vice-versa. Examples of this appeared recently in the article “Future Moon rocket booster tested” in the October 2022 SpaceFlight. A temperature of 3,093.33 degrees C (5,600 degrees F) was quoted. Obviously, the original source would have used Fahrenheit and been quoted to an accuracy of 10 or 100 degrees F. Would it not be better to quote the degrees C value to an equivalent accuracy, say 3,100 degrees C and/or quote them the other way round. Similarly with thrust where the quoted values 16,013.59 kN (3.6 million pounds) are listed. In this case 16,000 kN would have sufficed. I remember raising this many years ago and I quoted a case of extreme conversion accuracy which for new readers I have repeated below. The values were given in the book Astronomy for Amateurs. This was an authorised translation, by Frances A. Welby, of a book by Camille Flammarion published in 1903. On page 110 the weight of the Sun is given as eighteen hundred and seventy octillions of kilogrammes. This was written out in full as 1,870,000,000,000,000,000,000 kilograms and the equivalent weight as 1,842,364,532,019,704,433,497,536,945 tons. A quick calculation indicates that a conversion factor of 1015 kg to 1 ton had been used. Three points arise. First the mass quoted is now more than 6% less than accepted values. The conversion factor is low by 0.1%. And thirdly why were the extra 16 cwt 28 lb and 11 oz ignored!

Yours,
Dr Alan Welch FBIS (by email)

Back-up Planet

Sir,
The current international situation, depressing though it is, does offer support for advocates of space exploration. On one hand, the prospect of escalating energy shortages has helped publicise the idea of solar power satellites, intercepting much more of the Sun’s energy than ever makes its way through the Earth’s atmosphere, and then either (or both) using the energy for space-based manufacturing or sending it down to Earth, in a more concentrated form, to support existing sources of energy. On a less positive note, President Putin’s various utterances concerning the possible use of nuclear weapons should help remind people of the disadvantages of being entirely dependent on a single planet for humanity’s survival (and that of all the assorted flora and fauna). As the late Robert A. Heinlein once famously wrote: “The Earth is simply too small and fragile a basket for the human race to continue to keep all its eggs in. Where there is no vision the people perish – perhaps literally.”

Yours,
Peter Davey (by email)
BOOKS

A Traveler’s Guide to the Stars

A Traveler’s Guide to the Stars is a popular introduction to interstellar travel written for an educated general audience, and in this regard, it works very well. Readers who have already been following the subject are unlikely to learn anything new, nor is it a textbook that can take the reader into practitioner level. However, for people whose interest has been piqued by new interstellar discoveries like exoplanets and objects like ‘Oumuamua, or have a fascination for space fiction, this is an easy to understand and comprehensive guide to the real science and engineering behind interstellar flight.

The book is comprehensive covering everything from serious studies that could use our current capabilities to dip into the edge of interstellar space to the wildest speculations of science fiction traversing the whole galaxy. It even explains the different physics that distinguishes warp drive from hyper space. The science explanations are admirably clear, and the author also gives a realistic assessment of the viability of each proposal and the problems they may encounter. However, in one respect this book is far from comprehensive as it suffers from the classic American affliction of “World Series syndrome” where the winners of a national league are declared world champions, forgetting the rest of the world exists.

While the British Interplanetary Society is given credit as a centre of WorldShip thinking, almost everything else in the book is American. Amongst many other omissions, this means that Project Daedalus is not mentioned, and pulsed fusion is the only potential interstellar propulsion system that is ignored. Which is a shame because Daedalus covered so many of the issues the book raises and ways to resolve them. Despite that shortfall, A Traveler’s Guide to the Stars remains an accessible and authoritative tour of the current thinking on interstellar flight which is exciting and fascinating without any oversell or sensationalism.

Mark Hempsell

Out of This World

As the name of Out of this world suggests this book is about pictures that look, literally, out of this world, with an impact on their first viewing. A book for the person with a casual interest in space the pictures are accompanied with short descriptions of the scene or the missions or programmes. It also has quotes from various astronauts including James Lovell and John Glenn, as well as other prominent and politically significant figures, such as John Fitzgerald Kennedy. The author, Bill Schwartz, writes about how the Apollo programme and science fiction inspired him as a child, a story many BIS members will know.

Schwarz works in entertainment, and he produced a documentary called Journey to Mars, about NASA’s Viking Pathfinder. Viking has its place in Out of this world, as the book is divided into seven sections covering, among them, Apollo, Space Shuttle, Skylab, Mars and robotic missions of various sorts. As the book’s title indicates, this is very America centric, and the pictures seem largely from NASA’s archives.

The Russians, for example, are only mentioned in relation to Mir, as part of the Space Shuttle section, and the International Space Station. The book only has one reference to Apollo-Soyuz despite that mission’s historic significance. This NASA history stretches from the very beginnings of space flight in 1958 through to this year’s James Webb Space Telescope mission. Between those two dates, the many images cover the 12 men who have walked on the surface of the Moon, the launch of Voyager 1 on 5 September 1988 (now the furthest humanmade object from Earth as it travels beyond the reaches of the Solar System), the formation of the International Space Station, NASA’s losses from Apollo I in 1967, Space Shuttle Challenger in 1986 and Space Shuttle Columbia in 2003.

The book’s publicity refers to rare photos but to anyone who has perused the NASA website or bought other books on the various space programmes, almost all the pictures will be familiar. The book could be a nice, but pricey, gift for a friend or family member with a casual interest in space, but it is not one for the enthusiast who already has a bookshelf full of NASA books.

Rob Coppinger
NASA was aiming for 14 November with a 69mins launch window that opened at 1207hrs local time (1607hrs universal coordinated time) for its Artemis I mission following a 4 November roll out from Kennedy Space Center’s (KSC) Vehicle Assembly Building (VAB) to pad 39B, 39 days after the Space Launch System (SLS) rocket arrived back at the VAB for the third time on 27 September. Artemis I is an uncrewed flight test to launch SLS and send Orion around the Moon and back to Earth to test its system before astronauts’ flights. The recurrent problem stopping the mission has been hydrogen leaks with the dress rehearsals and the previous launch attempts. The space agency announced on 12 October the 14 November launch would have a mission duration of about 25.5 days, which is about 40% shorter than previous launch dates’ flight times. With 25.5 days, the Artemis I Orion spacecraft’s splashdown in the Pacific Ocean would be 9 December. The Apollo 17 mission launched on 7 December 1972. NASA also announced backup dates and times on the 12 October. They are 16 November at 1304hrs local time and 19 November at 1345hrs. Both have 2hr launch windows.

In its 12 October Artemis blog entry, NASA stated that inspections and analyses of SLS and Orion in the past week had convinced its engineers that minimal work was required to prepare the rocket and spacecraft for the next roll out. NASA had been targeting a 27 September launch attempt but due to Hurricane Ian’s proximity to the launch site, the agency announced on 24 September that SLS would be rolled back. It was at about 0915hrs local time on 27 September that SLS and its Orion were secured inside the VAB after the 6.43 km journey from pad 39B. That journey began, 41 days after SLS’s arrival at 39B in August, on 26 September at 2321hrs, to avoid the arrival of Hurricane Ian.

Upon its arrival, the initial inspections carried out once the work platforms around SLS and Orion were extended found no damage to SLS and Orion. There was only minor rainwater intrusion identified in a few locations. Exterior inspections were also carried out to note any foam or cork damage on the rocket or spacecraft’s thermal protection systems that might need repair. The batteries on the rocket’s interim cryogenic propulsion stage, the SLS solid rocket boosters, core stage, several secondary cubesat payloads, and the SLS flight termination system (FTS) would be replaced or recharged.

Months ago, NASA had said the FTS was a major constraining factor for the launch with a maximum of 20-days utility after a VAB roll out. At 20-days the FTS would have to be retested and that would require a roll back to the VAB. But the agency initially...
increased that limit to 25 days as it tried for an early September launch. It then said the FTS retest requirement was up to the launch range authorities, which is the United States Space Force. Its Delta 45 unit would be the people to activate the FTS if the SLS ascent failed.

Inside Orion’s capsule, the work has included replenishing the specimens and batteries for the biology investigations and recharging the batteries for the crew seat accelerometers and space radiation experiments. The November launch period was decided upon partly to allow KSC workers and their families to address the needs of their families and homes after the storm. Although the KSC area received minimal impacts from Hurricane Ian, many team members who live farther west experienced larger effects from the storm and were still recovering.

TRY, TRY AGAIN

Previous attempts had been 29 August, 3 September and 23 September was briefly a possible date before 27 September was chosen and then abandoned. After the 3 September launch scrub due to another hydrogen leak, NASA planned for propellant tanking tests that month and set the 23rd as a possible launch date. But by 12 September, NASA said the tanking test would not start until 21 September and the launch attempt would now be the 27th. There was also a potential backup opportunity of 2 October but that was also abandoned with the threat of Hurricane Ian.

Prior to the 29 August launch attempt, SLS and Orion arrived at pad 39B on 17 August at about 0730hrs local time. The journey from VAB to pad 39B took about 10 hours. At the time NASA's officials referred to a new 25-day limit for the FTS, an increase on the original 20 days. This gave the agency up to the 11 September to launch SLS, and the agency would announce launch opportunities in August, the 29th, and four in September, the 2nd, 5th, 16th and 27th. After the August and 3 September launch scrubs, NASA tried to solve its hydrogen leak problems while SLS was at 39B. During the 23 September media teleconference about the propellant tanking test, NASA officials were positive about a 27 September launch. The tests followed the replacement of seals on an interface for the liquid hydrogen quick disconnect fuel line between the SLS rocket and its mobile launcher (SpaceFlight Vol 64 No. 9 September pp. 26-29). The officials said both primary and secondary objectives of the tanking test had been achieved. NASA engineers believed that the leak was caused by a sudden rapid change in pressure. A solution was to change the cryogenic loading procedures to better control the temperatures and pressures during tanking.

The hydrogen problems had persisted despite NASA conducting wet dress rehearsals (WDR) in April and June and carrying out work on SLS in the VAB to stop the leaks in July. The first WDR lasted from 1-14 April (SpaceFlight Vol. 64 No.6 June p.45) and the second from 18-20 June (SpaceFlight Vol. 64 No.8 August pp. 16-17). The second launch rehearsal was ended by the same problem as the first; a leak from the tail service mast umbilical. After the second rehearsal, the SLS was rolled back to the VAB on 2 July.

By 8 July, the space agency’s technicians were working to inspect, fix, and check out equipment associated with a seal on the quick disconnect hardware of the tail service mast umbilical. This is located at the base of the rocket’s mobile launcher and connects to the rocket’s core stage feeding it with cryogenic propellants. Once that work had been completed NASA started planning for the August and September launch date. All the necessary SLS and Orion testing had to be completed by mid-August for the roll out to 39B. While in October NASA planned for a 14 November launch attempt, it set 27 November as the end of the launch period.
In October 2019, I met an astronaut for the first time when visiting the BIS stand at the New Scientist convention. After docking the Soyuz to the International Space Station with the BIS simulator on that stand, and learning more about spaceflight, I felt a sense of excitement about the future.

Despite an overwhelming sense of bewilderment, I purchased a signed copy of the astronaut’s autobiography *Falling to Earth*, signed “Aim High! – Al Worden, Apollo 15.” This experience was somewhat formative. At the time my interest in space was growing, but I had no awareness of the BIS’ existence or UK space activities. Discovering that the UK did indeed have a future in space filled me with optimism and motivation to pursue a science, technology, engineering, and mathematics (STEM) career. In the next two years, as I was moving into sixth form, the late Al Worden joined forces with the Kallman Foundation as the face of the Endeavour Scholarship, enabling teams of secondary-age students to participate in Space Camp, Huntsville, Alabama.

Worden reasoned: “When you consider the decades of rigor and discipline it’s going to take to successfully put people from Earth on Mars… we need to pick up the pace. The pipeline for STEM talent can handle a lot more volume, and Space Camp is a proven connection.” The Kallman Foundation, which supports the Endeavour Scholarship, partnered with several organisations in four different countries, Chile, Singapore, the United Arab Emirates, and the United Kingdom. In the UK, Worden partnered with the Royal Air Force Air Cadets (RAFAC), a youth organisation promoting aerospace, providing useful training, and helping young people to develop leadership and teamwork skills.

Once all the teams had arrived, we had the privilege of touring the US Space and Rocket Centre with Apollo 16 Lunar Module pilot Charles Duke. Duke told us of his experiences riding the Saturn V, walking on the Moon, and acting as a CAPCOM on Apollo 11, while standing in front of his Command Module Casper.

Throughout the next week, we completed practical STEM activities, built model rockets and heat shields, and attempted to protect an apple from some of the conditions experienced in space. The Space Camp programme included space history, aviation, interplanetary missions, propulsion, and astronaut selection, covering a broad base of topics to prepare us for practical experiences. We also took part in an adventure training element, climbing and ziplining, all while coping with the 40 degrees Celsius heat, which built up our teamwork skills. Astronaut training simulators included a multi-axis trainer and a one sixth gravity chair.

The favourite activities were the mission simulations, comprising two Space Shuttle missions and a Mars mission based on the President George Bush era Constellation Moon, Mars programme. Filling the role of pilot on the Space Shuttle was incredibly exciting, especially with another air cadet in the commander’s seat and touching down on the runway without any significant calamities. The
highlight of the overall experience was the sense of community that these space enthusiasts, from across the globe, built during the camp. Having like-minded people in the same place, all dedicated to STEM, led to a profound sense of belonging and friendship. Our cooperation and synergy throughout Space Camp were recognised and we were given the best teamwork award at graduation. Before returning to our home countries, we had a final visit. Taking a domestic flight to Washington DC, we visited Worden’s resting place at Arlington Cemetery and were joined by his granddaughter, Katherine Christians. The Endeavour Scholarship is part of his legacy, helping to build the next generation of STEM professionals.

Back in the UK, we were presented with certificates at the Royal International Air Tattoo (RIAT) by Duke, Timothy Peake, and Air Cdre Anthony Keeling, Air Cadets commandant. We then began our tasks as space ambassadors, supporting the UK Space Agency’s stall at RIAT. In a strange parallel, I was in the opposite position to visiting the BIS stand in 2019. Now I was behind the stall, sharing my experiences and talking to people of all ages. I feel strongly that the Endeavour Scholarship captures the international spirit of cooperation in space exploration.

As the UK looks towards advancing its space capabilities further, we will need more STEM professionals from all backgrounds, embracing this same spirit of cooperation. Just as I was inspired three years ago, outreach activities and space advocacy do indeed have an impact, especially on young people. I have been fortunate enough to have a personal connection with spacelift from the Endeavour Scholarship, and it all began by walking up to the BIS stall at a convention. ■
A pioneer in the quest for Mars

Remembering Valeri V. Polyakov (1942–2022)

Prior to embarking on extended missions to Mars, a wealth of ground simulations and preparations in near-Earth space are being conducted. One man’s early contribution to exploring the parameters of extended human space endurance remains a milestone in attaining that goal. Dr Valeri V. Polyakov, who passed away aged 80 on 19 September 2022, once claimed that his 280 million kilometres logged during 437 consecutive days in space was “enough to reach Mars and come back.” Born Valeri Vladimirovich Korshunov on 27 April 1942 in Tula, Russia, the industrial heartland of the former Soviet Union, his surname was legally changed to Polyakov in 1957 after adoption by his step-father. By the time he graduated from Tula High School No.4 two years later, Polyakov had developed a keen interest in aviation medicine, which had evolved from an early desire to become a pilot.

Polyakov then embarked on his distinguished medical career by first attending the 1st Moscow Medical Institute named for I.M. Sechenov, receiving his medical degree in June 1965. His initial clinical residency was taken at the Institute of Medical Parasitology and Tropical Medicine named for E.I. Martinovsky, but his studies lasted only the first year. After that he worked at the All-Union Research Institute for Social Hygiene and (Public) Health Organization. From 1967 until 1971, Polyakov worked as a senior inspector of the 3rd Main Directorate (space medicine) for the Ministry of Health and took additional duties as an emergency ambulance driver.

In October 1971, he joined the Institute of Biomedical Problems (IBMP), where he would remain for the next 24 years. Initially employed as a laboratory junior, in 1978 he was promoted to senior researcher of a laboratory. Polyakov attended graduate school at IBMP between 1971 and 1974, defending his thesis for his Candidate of Medical Sciences, awarded in 1976. Polyakov decided to devote himself to space medicine following the Voskhod flight of Dr Boris Yegorov in October 1964 but had to wait some years before fulfilling that ambition full time. He seems to have completed some work with cosmonaut candidates and applied to join the cosmonaut team himself in 1969. He passed the medical requirements in 1970 and was selected for enrolment in the first IBMP cosmonaut group on 22 March 1972.

A LOST OPPORTUNITY

The initial IBMP cosmonaut group of three candidates was formed with the goal of providing medical assistance to crews on orbit. As a student cosmonaut, Polyakov’s preparation for space flight lasted between 1972 and 1980, encompassing a basic cosmonaut training course at the Cosmonaut Training Centre named for Yuri Gagarin between October 1978 and December 1979. He also had parachute and survival training and worked at Mission Control near Moscow. Polyakov specialised in the health and safety of Soyuz and Salyut crews and completed an assignment to the Soviet medical support team in the mid-1970s for the Soyuz-Apollo Test Programme. From 1980 to 1988, he headed the IBMP cosmonaut cadre.

His initial crew assignment was to the original prime crew of Soyuz T-3, responsible for a range of medical research and experiment objectives onboard Salyut 6 in 1980. However, when the mission evolved into a more repair-oriented flight due to the status of the aging station, Polyakov was reassigned to the back-up Soyuz T-3 cosmonaut researcher position. He was next assigned to long-duration training as a cosmonaut researcher in the second back up crew for what became the third Salyut 7 expedition, serving as alternate to Dr Oleg Atkov on Soyuz T-10 in February 1984. In 1987, he qualified from the extravehicular activity training course and was the original cosmonaut researcher assigned to the Soyuz TM-4 mission to Mir. But he was replaced by test pilot...
Anatoli Levchenko due to Buran shuttle programme requirements. Reassigned yet again, this time his preparations would finally see him reach orbit.

Assigned as a physician cosmonaut to a new Mir training group in early 1988, Polyakov’s preparations included undergoing surgery to remove bone marrow samples for post-flight comparison. On 29 August 1988, Valeri Polyakov finally made it to orbit, as cosmonaut researcher for Soyuz TM-6 and the 66th Soviet cosmonaut. Once onboard Mir, he joined the third resident crew for an eight-month evaluation of medical support procedures and equipment for long-duration expeditions.

By the time he returned to Earth on 27 April 1989, Polyakov had logged over 240 days and 23 hours in space. Having rigorously followed a daily two-hour exercise regime, he suffered no long-term effects from the mission and was able to resume running only three days after landing. By October 1989 he had been appointed a deputy director of science at IBMP and the following year was assigned as a deputy flight director at the IBMP medical flight support station for Mir expeditions.

TO MARS AND BACK

Training for his second mission began in 1993, where he submitted himself to a planned and gruelling 540-day mission despite objections from his wife. Launched on 8 January 1994 on Soyuz TM-18, Polyakov worked with Mir Expeditions 14, 15, 16 and 17, cooperating with fellow cosmonauts and astronauts from Russia, European Space Agency and NASA. During his flight, Polyakov performed over 1,000 medical tests in a programme of 50 experiments. He returned on Soyuz TM-20 on 22 March 1995 after setting a new world record of over 437 days 17 hours for a single space flight. His mission was curtailed by difficulties in funding the original return mission’s launch vehicle.

Polyakov had demonstrated that a properly prepared human could medically survive a long flight to Mars and back, as long as they maintained their condition during the trip. In fact, his wife noted that after 14 months in space Polyakov had returned in better shape than when he left. Following this flight, with over 679 days 16 hours of space flight experience from two long missions, Polyakov stepped down from active flight status and retired from the IBMP cosmonaut team effective 1 June 1995. He subsequently became deputy chairman of the Ministry of Public Health in Moscow, overseeing medicals for long-duration crews.

As a member of the Russian Chief Medical Commission, he was also involved in the selection of new cosmonauts. In 1999 Polyakov became a Doctor of medical sciences and Professor of medicine. In February 2000, Polyakov served as the crew commander on the second seven-day ‘visiting crew’ for the Simulation of Flight of International Crew on Space Station, a ground-based isolation experiment. In a statement of condolence about the passing of Polyakov, Roscosmos remarked that "his research has helped prove that the human body is ready to travel not only to Earth orbit, but also into deep space."

David J. Shayler FBIS
After the long hiatus due to the pandemic, European Space Agency opened once more the gates of its ESRIN centre, near Rome, for the European Research Night on 30 September.

The BIS was invited to help in the effort to provide the public with dedicated outreach activities and BIS-Italia members participated. The collaboration between the Agency and our Society has been in place since 2015 and as part of the agreements the BIS can also introduce the Society, show our publications and projects, and in general attract new members.

For ERN-2022, BIS-Italia produced a brand-new outreach activity to highlight the physics principle behind ESA’s FLEX (Fluorescence Explorer), a soon to be launched experimental Earth Observation mission that will globally map chlorophyll. The entire activity has been managed by Mario Benincasa, who professionally works on FLEX in this very centre, his daughter Sara (a new BIS Member) and Giorgio Basile, another space professional.

Another activity was the recreation of an amateur rocketry laboratory to explain the techniques of this hobby while at the same time make a comparison with real solid rocket motors rocket, like the the Vega-C. Alessandro Tozzi, Alessandro Menchinelli and our new member Francesco Di Matteo, who actually works on the Italian launcher, ran this laboratory. Davide Coco managed during the event, the many rocket launches, fighting the winds and the night, once the Sun set. He was helped by Ginevra Bernardini and Domenico Geraci.

The BIS table was crewed by Glenda Acerbi, while Davide Palombi and Giuseppe Mattia showed the Q-Cube satellite, as a side attraction. Steve Salmon introduced young engineers to the art of making your own version of ESA’s Lunar Village, using materials commonly found at home. The presence of the BIS was recognised by Dr Simonetta Cheli, ESRIN centre director, renewing her support for the collaboration between ESA and the BIS while visiting our area.

The event, which included activities from other organisations, was visited by 800 people. Being part of an ESA event is a privileged opportunity that is seldom offered in this environment. The BIS is grateful of the opportunity and looks forward to being able to offer new unique outreach experiences. In addition to the people mentioned (some of whom took long trips to be there), other unnamed members helped make this participation possible. Thanks to all of them!

Fabrizio F. Bernardini FBIS
Beyond The Moon 2022 – A Reminder

It is not long now before the 2022 ‘Beyond The Moon’ Symposium being held on 14 December and it is looking to be an interesting meeting which I hope will produce some more ideas to enable human occupation of the Solar System.

I first listed my view of the problems that have to be addressed before this can happen in the January SpaceFlight and further discussed them in my introduction to Beyond The Moon (BTM) 2022 in the April issue of this year. It is hoped that the presentations will either show how these problems can be alleviated directly or discuss technologies being developed that will generally assist in this great enterprise.

Two of the presentations address, in different ways the timescales needed to reach anywhere outside the Earth-Moon system. The first, by Michel Lamontagne, examines the direct approach of taking propulsion systems to their most logical energetic limit – fusion. This work refines the modelling of the Firefly open core Z-pinch fusion engine to reflect the physics of its operation more accurately and propose its use for interplanetary transportation. The use of deuterium (D)-He3 as a fuel is proposed as an alternative to the original D-D fuelled engine. It also describes a method for injecting the inert propellant into the engine and studies suitable construction materials and engineering requirements.

Even after advanced fusion drives are in regular use the times necessary for an Earth orbit to Saturn system transit are still daunting. The other presentation on timescales by Vanessa Farsadaki, on ‘Hibernation for Deep Space Travel’ shows how humans may be able to survive onerous interplanetary flights by using various clinical methods, now being investigated to enable humans to hibernate for weeks or even months. In this review, the author attempts to assemble all known research to date of how hibernation affects the human body. The ultimate goal is for this to be a reference guide for all those working to make deep space hibernation a reality for humanity’s future exploration.

For all forms of propulsion the importance of access to extra-terrestrial sources of fuel cannot be over estimated. A presentation by Richard Soilleux identifies the various extra-terrestrial sources for nitrogen, liquid hydrogen and fusion fuel. It then investigates the feasibility and logistics of recovery from further out in the Solar System to an Lagrange point 5 located materials processing and manufacturing complex.

Two other presentations deal with enabling technologies. The first is on delivering cargoes, particularly materials and fuel to various orbits from bodies such as the Earth, Moon and Mars using electromagnetic launchers. This is not a new idea, see for example, ‘Exploration of the Moon,’ 1954, by our own R.A. Smith and A.C. Clarke, pages 102 and 103, but has not yet been needed. With an increasing space infra-structure, starting with a permanent lunar base, it becomes increasingly attractive. It is hoped that Artemy Muslov will be able to expand on the paper he gave at BTM 2021.

With a Moon base established, the use of the lunar resources becomes increasingly interesting. Martin Braddock will discuss how humankind’s aspirations to colonise other worlds will use the Moon as a case study and stepping stone to Mars and beyond. In order to determine the feasibility of off-Earth colonisation, lunar settlements will manage their lunar regolith to support agriculture and with the exception of reactive nitrogen, lunar regolith appears to contain all essential minerals to support plant and crop growth. He will present an overview of progress made in understanding both the opportunities and challenges of working with lunar regolith for agriculture and the maintenance of human health.

Helen Schell, an artist and space-science educator, poses the question: ‘Can extensive space exploration and settlement plans rely entirely on scientific thinking and methodology?’ I totally agree they cannot. Colonies will not be able to survive long-term without properly considered biological, social, political and ideological structures, let alone psychological considerations and the arts. She will present a series of art work images, collaborative art and science research looking at a range of space living designs and materials to enable long-term human survival.

This interesting and rewarding event will start at 1pm. Please note that at 1230hrs, our proceedings will be introduced by Jerry Stone who will give a short Apollo 17 talk. (After the meeting he will give a more detailed presentation.) As you know, December 14 is a significant date for our symposium: the 50th anniversary of the last time human beings set foot on the Moon. I do hope you can join us in celebrating this significant date with some hope for the future.

Gerry Webb FBIS
MEMBERSHIP NEWS

Marketing Committee: We Need Your Help!

The Marketing Committee was formed in 2012 out of the former BIS Future Group with the goal of formulating ideas to grow the Society’s membership, influence and ensure its continuation.

Committee member Robin Tucker, a marketing professional, formulated the idea of the support for the BIS being divided into three audiences, the ‘three Es’, of Enthusiasts, Experts and those in Education. Robin worked on a strategy based on making the Society as attractive to these groups as possible. This was refined with help from our other marketing professional, Vix Southgate, who with Robin worked on ideas on how the audiences could help each other and enhance their experience. The strategy has to two priorities, a, website and social media, and, b, industry engagement.

Given the importance of our digital presence, the website has been a high priority and was redesigned by Vix to have a cleaner feel. It is a work in progress and refinements are added periodically. Another update is planned, and volunteer help will be needed to make the user experience as smooth and enjoyable as possible. BIS social media has been successful, with a profile built to a level rivalling much bigger organisations, extending across Twitter, Facebook, Instagram and LinkedIn. Our YouTube channel, where members can watch recordings of our lectures and symposia, is well received, helping to make the BIS the home for all things Space.

The other priority is to make the Society as attractive as possible to industry, and to bring in sponsorship, both to the BIS as a whole, and to our events, the most important of which is Reinventing Space. The plan is to look for opportunities to increase sponsorship as awareness of the Society widens.

As with all the BIS’s committees, the work is done by volunteers who give their time and effort. The Marketing Committee has been fortunate in having a group of committed and enthusiastic members, but we need more help with social media and the website, so if you are a Member and have skills and experience in these areas you will be very welcome to join us. Please do get in touch. I can be contacted at colin.philp@bis-space.com

Colin Philp Chair, BIS Marketing Committee

CHARITABLE DONATIONS

Members can donate to the Society through Amazon Smile, every penny goes towards the Society’s advocacy for space exploration. Amazon donates 0.5% of the price of eligible purchases to the charity of your choice. Amazon Smile can be reach via the URL https://smile.amazon.co.uk/

NEW MEMBERS FOR SEPTEMBER

The Society gained ten new members in September, nine from the UK and one from Peru.
19th Reinventing Space 2022 Conference
Strategic Foundations For New Space

**Dates:** Monday 28 – Tuesday 29 November 2022  
**Location:** Aerospace Bristol, Hayes Way, Patchway, Bristol, BS34 5BZ, UK

**Reinventing Space** will take place on 28th to 29th November 2022 at Aerospace Bristol Museum and Conference Centre, in Bristol, with the **Gala Dinner** and **Sir Arthur Clarke Awards** taking place on 29th November 2022.

Organised by the British Interplanetary Society, the Reinventing Space Conference is a conference and exhibition dedicated to advancing humanity’s future capabilities in space and highlights the trends that will define space enterprise a decade from now. Each year, the conference brings together a network of innovators from industry, agency, government, financiers, academia and end users to present and discuss the key challenges and opportunities for future space leadership and growth.

**Programme Outline**
The theme for the 19th Reinventing Space conference is Strategic Foundations for New Space, and will focus on the ‘building blocks’ and the critical pathways that will take us from where we are today, towards future improved utilisation of space. The conference will include presentations and panel sessions across key topics on ground and space-based infrastructure and operations, linking humanity’s longer-term aspirations for space and how they can be used for the benefit of life on Earth. This year’s conference runs across two consecutive days, with the option to attend either or both days. Each day will consist of a combination of talks from selected presenters as well as dedicated panel sessions and Keynote talks from invited speakers on key topics to each day’s theme.

**Day 1: Strategic Foundations**  
Key enablers, emerging capabilities, technologies/systems, services and infrastructure that form the ‘building blocks’ for New Space.

**Day 2: Space Energy Applications**  
Opportunities and challenges for providing and harnessing energy in space for in-space or terrestrial power applications.

For more information and to register, see [www.bis-space.com/reinventing-space](http://www.bis-space.com/reinventing-space)

---

Beyond The Moon Symposium 2022

**Date:** 14 December 2022  
**Time:** 12:30 – 18:00 GMT

The British Interplanetary Society’s **Beyond the Moon Symposium** is a focus for future space activity and anticipating the steps that the human race will have to take to ensure its long-term survival. To invite and encourage international participation, the event will also be open to virtual attendance. The date of the symposium coincides with our Apollo 17 celebrations to celebrate the Lunar Module Ascent from the Moon’s surface on 14 December 1972, marking the 50th anniversary of the last manned Moon landing.

See the events section of the BIS website for the latest information
SPACE EXPLORATION
Signature® Auction | December 15-16

Final Offering of Selections Directly from Michael Collins’ Personal Collection

Don’t miss our December 15-16 auction for the last opportunity to bid on great items such as these, directly from the personal collection of Apollo 11 astronaut Michael Collins!

For information on our easy consignment process, please call 877-HERITAGE (437-4824)
Brad Palmer | Director, Space Exploration | ext. 1185 | BradP@HA.com

Apollo 11 Flown and Crew-Signed Beta Cloth Mission Insignia Directly from the Personal Collection of Michael Collins, Signed and Certified, CAG Certified and Encapsulated

Apollo 11 Flown MS66 NGC Silver Robbins Medallion, Serial Number 32, Directly from the Personal Collection of Michael Collins, with Handwritten and Signed Letter of Certification, CAG Certified

Apollo 11 Flown Crew-Signed “Type One” Quarantine Cover, Hand-numbered C-41 and Certified by Michael Collins, Directly from His Personal Collection, CAG Certified and Encapsulated

Apollo 11 and Gemini 10 Flown Largest Size American Flag, Signed and Certified by Michael Collins, Directly from His Personal Collection, CAG Certified and Encapsulated

Apollo 11 Flown Command Module Pilot Solo Book Page, Signed and Certified by Michael Collins, Directly from His Personal Collection, with Handwritten and Signed Letter of Certification, CAG Certified and Encapsulated

Apollo 11 Flown Crew-Signed “Type One” Quarantine Cover, Hand-numbered C-41 and Certified by Michael Collins, Directly from His Personal Collection, CAG Certified and Encapsulated

Apollo 11 Flown MS66 NGC Silver Robbins Medallion, Serial Number 32, Directly from the Personal Collection of Michael Collins, with Handwritten and Signed Letter of Certification, CAG Certified

Apollo 11 Flown Crew-Signed “Type One” Quarantine Cover, Hand-numbered C-41 and Certified by Michael Collins, Directly from His Personal Collection, CAG Certified and Encapsulated

Apollo 11 and Gemini 10 Flown Largest Size American Flag, Signed and Certified by Michael Collins, Directly from His Personal Collection, CAG Certified and Encapsulated