



your window to space

CAPCOM

Volume 30 Number 04 March—April 2020

NASA, SpaceX Complete Final Major Flight Test of Crew Dragon Spacecraft

Jessica Meir and
Christina Koch
Complete Third
Spacewalk to Replace
ISS Batteries

Christina Koch returns
to Earth after a record-
breaking 328 days in
space

NASA/ESA Solar
Orbiter Successfully
Launched



Apollo 13 50th
Hubble 30th



CAPCOM is Produced by Go Space Watch for Midlands Spaceflight Society

www.gospacewatch.co.uk | www.midspace.org.uk

Editor: Mike Bryce | President: David J Shayler | Secretary: Dave Evetts | Honorary Member: Helen Sharman OBE



Global Space News

NASA, SpaceX Complete Final Major Flight Test of Crew Spacecraft

NASA and SpaceX completed a launch escape demonstration of the company's Crew Dragon spacecraft and Falcon 9 rocket Sunday. This was the final major flight test of the spacecraft before it begins carrying astronauts to the International Space Station under NASA's Commercial Crew Program.

The launch escape test began at 10:30 a.m. EST with liftoff from historic Launch Complex 39A at NASA's Kennedy Space Center in Florida on a mission to show the spacecraft's capability to safely separate from the rocket in the unlikely event of an in-flight emergency.

"This critical flight test puts us on the cusp of returning the capability to launch astronauts in American spacecraft on American rockets from American soil," said NASA Administrator Jim Bridenstine. "We are thrilled with the progress NASA's Commercial Crew Program is making and look forward to the next milestone for Crew Dragon."

As part of the test, SpaceX configured Crew Dragon to trigger a launch escape about 1.5 minutes after liftoff. All major functions were executed, including separation, engine firings, parachute deployment and landing. Crew Dragon splashed down at 10:38 a.m. just off the Florida coast in the Atlantic Ocean.

"As far as we can tell thus far, it's a picture perfect mission. It went as well as one can possibly expect," said Elon Musk, Chief Engineer at SpaceX. "This is a reflection of the dedication and hard work of the SpaceX and NASA teams to achieve this goal. Obviously, I'm super fired up. This is great."

Teams of personnel from SpaceX and the U.S. Air Force 45th Operations Group's Detachment-3 out of Patrick Air Force Base will recover the spacecraft for return to SpaceX facilities in Florida and begin the recovery effort of the Falcon 9, which broke apart as planned.

"The past few days have been an incredible experience for us," said astronaut Doug Hurley. "We started with a full dress rehearsal of what Bob and I will do for our mission. Today, we watched the demonstration of a system that we hope to never use, but can save lives if we ever do. It took a lot of work between NASA and SpaceX to get to this point, and we can't wait to take a ride to the space station soon."

Prior to the flight test, teams completed launch day procedures for the first crewed flight test, from suit-up to launch pad operations. The joint teams now will begin the full data reviews that need to be completed prior to NASA astronauts flying the system during SpaceX's Demo-2 mission.

NASA's Commercial Crew Program is working with the American aerospace industry as companies develop and operate a new generation of spacecraft and launch systems capable of carrying crews to low-Earth orbit and the International Space Station.

Commercial human space transportation to and from the station will provide expanded utility, additional research time and broader opportunities for discovery on the orbiting laboratory. The program also has the benefit of facilitating and promoting for America a vibrant economy in low-Earth orbit.

NASA
www.nasa.gov

Third Spacewalk for Meir and Koch

At 1:33 p.m. EST, on the 20 January 2020, Expedition 61 Flight Engineers Jessica Meir and Christina Koch of NASA concluded their third spacewalk together. During the six hour and 58-minute spacewalk, the two NASA astronauts successfully completed the battery upgrade for one channel on one pair of the station's solar arrays.

Today's work included removing the last two nickel-hydrogen batteries from this area of the station's backbone near the port solar array and moving them to an external platform. The batteries will be stored there until they can be disposed of in the next Japanese HTV cargo spacecraft after it delivers tons of supplies to the space station later this year. Meir and Koch also installed the sixth and final new lithium-ion battery, and ground controllers verified the new batteries powered up successfully to provide an improved and more efficient power capacity for station operations.

The spacewalkers concluded their work by paying tribute to Dr. Martin Luther King, Jr. Meir said he was a personal hero and looking down on planet Earth reminded her of his words: "We may have all come on different ships, but we're in the same boat now." Koch noted how much is owed to those who worked for civil rights and inclusion and "paved the way for not only us, but so many who have a dream."

This was the second spacewalk outside the station in 2020. Space station crew members have now conducted 226 spacewalks in support of assembly and maintenance of the orbiting laboratory. Spacewalkers have spent a total of 59 days, 6 hours, and 10 minutes working outside the station. It is the third time all spacewalkers have been women and the 45th spacewalk to include women.

This spacewalk was the third for Meir, who now has spent a total of 21 hours and 44 minutes spacewalking, and the sixth for Koch for a total of 42 hours and 15 minutes. Koch is third place behind Peggy Whitson and Suni Williams for cumulative time by a female spacewalker and 21st on the all-time spacewalk list for aggregate time.

NASA
www.nasa.gov

UK-built Solar Orbiter successfully launched

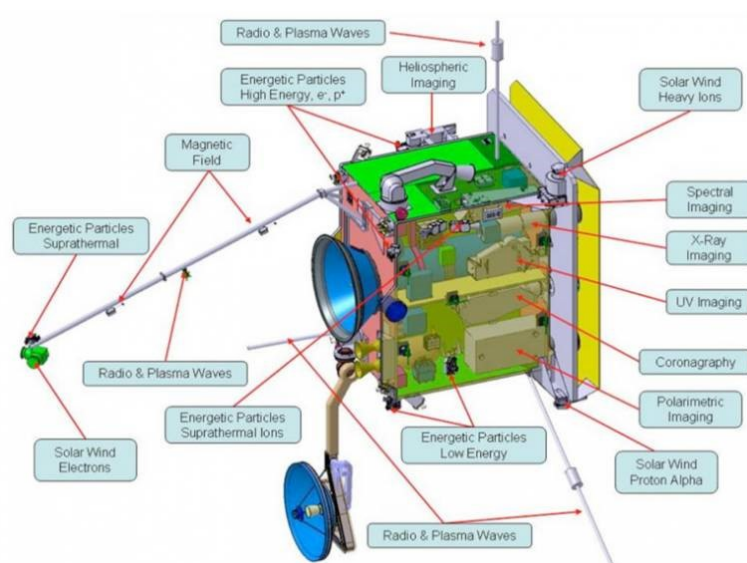


Image courtesy University College London
<https://www.ucl.ac.uk/mssl/research-projects/2020/feb/solar-orbiter>

The mission will take the most detailed images ever of the Sun and provide crucial information about how our star's volatile activity affects its atmosphere. This knowledge will help improve predictions of space weather events, which can disrupt and damage satellites and infrastructure on Earth.

This has never been more important as the UK economy is increasingly reliant on space, with satellite services such as communications, navigation and Earth observation supporting wider industrial activities worth £300 billion.

Solar Orbiter will allow scientists to study our star in much more detail than previously possible and to observe specific features for longer periods than can be achieved by any spacecraft circling the Earth. The spacecraft's orbit will also give unprecedented views towards the Sun's poles.

The UK is at the heart of this European Space Agency (ESA) mission with UK industry winning £200 million worth of contracts and the UK Space Agency investing £20 million in the development and build of the instruments. Business Secretary Andrea Leadsom said: "Solar storms could cause major disruptions to technologies including our energy grid, mobile phone signal and navigation systems".

This new mission demonstrates the UK's leading role in the global space industry, while supporting our economy, creating jobs and helping establish the UK as a global science superpower.

Solar Orbiter carries 10 state-of-the-art instruments. Remote sensing payloads will perform high-resolution imaging of the Sun's atmosphere – the corona – as well as the solar disk. Other instruments will measure the solar wind and the solar magnetic fields in the vicinity of the spacecraft.

This will give us unprecedented insight into how the Sun works, and how we can better predict periods of stormy space weather, which are related to coronal mass ejections (CMEs) that the Sun throws towards Earth from time to time.

UK scientists were instrumental in proposing the Solar Orbiter mission to ESA. The UK Space Agency provided funding for four of the 10 scientific instruments on board. Imperial College London, UCL Mullard Space Science Laboratory and the Science and Technology

Facilities Council's RAL Space led international teams to design and build three instruments while UCL are major contributors to a fourth.

Chris Lee, Chief Scientist at the UK Space Agency, said: "I am incredibly excited by Solar Orbiter. It is the most important UK space science mission for a generation, both in terms of our leading industrial role on the satellite itself and our key academic roles on the science payload. It also contributes massively to the development of operational space weather forecasting as championed by the UK Met Office and so will have real impact for the UK public at large. Solar Orbiter truly is a "big beast" for our UK space community".

Solar Orbiter, which will take just under two years to reach its initial operational orbit, will follow in the footsteps of NASA's Solar Parker Probe, which launched in 2018. The two missions will offer complementary perspectives of the Sun – with Parker Solar Probe travelling through the Sun's atmosphere, while Solar Orbiter observes the surface and near environment.

Engineers at Airbus in Stevenage designed and built the spacecraft to withstand the scorching heat from the Sun that will hit one side, while the other is frozen as the orbit keeps it in shadow. It will face intense solar radiation that is 13 times more powerful than that in Earth's orbit. The design is based on ESA's BepiColombo mission to Mercury, the closest planet to the Sun, which launched in 2018 with significant involvement from UK engineers and scientists.

The UK's space sector is going from strength to strength, employing around 42,000 people and carrying out world-class science while growing the economy. The UK continues to be a leading member of ESA, which is independent of the European Union, having committed a record investment of £374 million per year in November 2019. This included £80 million on space safety and security for a mission in partnership with the US to protect infrastructure in space and on Earth from space weather and to help remove space debris.



Honouring the Past... Prospects for the Future

Four lectures, four prominent Speakers, 4th April 2020

**We honour the 50th Anniversary of Apollo 13 and the 30th
Anniversary of the Hubble Space Telescope**

A Public Lecture Event by Go Space Watch

Saving Apollo 13 by Dave Eagle FRAS

The Legacy of the Hubble Space Telescope by Dr Steve Barrett (University of Liverpool)

Return to the Moon—A New Era by Dr James Carpenter (European Space Agency)

Science with the James Webb Space Telescope by Naomi Rowe-Gurney (University of Leicester)

Saturday 4th April 2020 from 10:00 am until 5:00 pm

at Sutton Arts Theatre, South Parade, Sutton Coldfield. B72 1QY

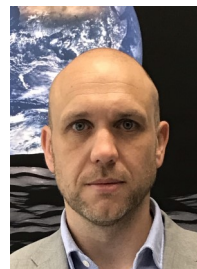
Tickets £10.00 per person for the Day. Open to all.

There will also be an Exhibition Area featuring local space related businesses and Astronomical Societies. The venue is Accessible.

Tickets available online at: <https://gsw4april.eventbrite.co.uk>

www.gospacewatch.co.uk

michael@gospacewatch.co.uk | 07821 896 304





CAPCOM and MSS: The Future

Midlands Spaceflight Society — Go Space Watch

Midlands Spaceflight Society (MSS) will close in August 2020 after 30 years of continued operation.

How times have changed. It is time for a new chapter to begin.

Since its creation in the early 1990's MSS's Newsletter CAPCOM has communicated to its subscribers the latest news and information, including original articles and other contributions, about Space Exploration.

Beginning in the days long before the wonderful Internet came to be the valuable resource it is today, CAPCOM has been continually Edited and Produced by Michael Bryce, with Proof-Reading by Dave Evetts. This will continue with new plans to further develop the magazine content and appeal. Michael Bryce has set up a new Company "Go Space Watch" in order to carry on this venture and bring CAPCOM into the 21st Century. Current subscribers through MSS will continue to receive CAPCOM Magazine until their subscription completes.

From 1st September 2020 the MSS Facebook group will become a Go Space Watch group.

New CAPCOM subscribers can sign up now through the Go Space Watch web site below.

CAPCOM will then be available as a printed document as it is currently or securely downloadable from the Internet after purchasing a subscription online.

Contribution Opportunity

Go Space Watch is looking for contributors for CAPCOM Magazine. Original Articles on all aspects of Space Exploration and Astronomy will be considered. Content ideas are also welcome. At present this would be on a voluntary basis but as CAPCOM is being made available world wide and could nurture future possibilities.

Public Speaking

Go Space Watch hold public lecture meetings around the West Midlands to further engage the general public of all ages in Space Exploration and Astronomy. Interested participants, either as Speakers or Attendees, should contact Go Space Watch at the email address or telephone number below. Go Space Watch is looking for low cost, good value meeting venues for these events.

Go Space Watch can be contacted at:

michael@gospacewatch.co.uk or 07821 896 304

CAPCOM Magazine may be purchased for £14.00 per Annum for six issues through the Go Space Watch web site below. This includes six printed issues plus digital download versions.

www.gospacewatch.co.uk

MSS Facebook Group: <https://www.facebook.com/groups/midspace/>

Go Space Watch Facebook Page: <https://www.facebook.com/gospacewatch/>

Space Adventures Announces Agreement with SpaceX to Launch Private Citizens on the Crew Dragon Spacecraft

Building on the success of Crew Dragon's first demonstration mission to the International Space Station in March 2019 and the recent successful test of the spacecraft's launch escape system, Space Adventures, Inc. has entered into an agreement with SpaceX to fly private citizens on the first Crew Dragon free-flyer mission. This will provide up to four individuals with the opportunity to break the world altitude record for private citizen spaceflight and see planet Earth the way no one has since the Gemini program.

If interested parties are secured, this mission will be the first orbital space tourism experience provided entirely with American technology. Private citizens will fly aboard SpaceX's fully autonomous Crew Dragon spacecraft launched by the company's Falcon 9 rocket, the same spacecraft and launch vehicle that SpaceX will use to transport NASA astronauts to the International Space Station.

"This historic mission will forge a path to making spaceflight possible for all people who dream of it, and we are pleased to work with the Space Adventures' team on the mission," said Gwynne Shotwell, President and Chief Operating Officer, SpaceX.

"Creating unique and previously impossible opportunities for private citizens to experience space is why Space Adventures exists. From 2001-2009 our clients made history by flying over 36 million miles in space on eight separate missions to the ISS. Since its maiden mission in 2010, no engineering achievement has consistently impressed the industry more than the Dragon/Falcon 9 reusable system. Honoring our combined histories, this Dragon mission will be a special experience and a once in a lifetime opportunity – capable of reaching twice the altitude of any prior civilian astronaut mission or space station visitor," said Eric Anderson, Chairman, Space Adventures.

Space Adventures
www.spaceadventures.com

Heather Couper: Broadcaster and Astronomer dies at 70

Broadcaster and astronomer Heather Couper has died at the age of 70. Dr Couper appeared on the BBC's Blue Peter and The Sky At Night programmes, as well as presenting and producing acclaimed science documentaries.

She also hosted radio series including the BBC World Service's long-running Seeing Stars and BBC Radio 4's Cosmic Quest and Starwatch.

Her best friend and business partner, Nigel Henbest, said she had died on Wednesday after a short illness. She had been a "charismatic... and passionate communicator of science", he said. "She got people really excited about the Universe and about space - that was her love, her passion in life."

Born in 1949, she fell in love with astronomy as a child and recalled a day, in 1968, when she had realised astronomy was not just "for shambolic old men in tweed jackets any more". She went home and wrote in her diary: "I want to help knowledge. I want to make known and publicise science."

So she left her management trainee job at Top Shop to become a research assistant at the Institute of Astronomy in Cambridge.



Heather Couper 1949—2019

Image credit: BBC News
www.bbc.co.uk/news

Her big break came when she was asked to appear as a guest on Sir Patrick Moore's The Sky At Night.

Sir Patrick later recalled: "Of course, she wrote to me when she was a little girl and said, 'Is there any future for me in astronomy?' And I said, 'Of course there is.' And I tried to give her a hand."

Astronaut application

She also presented the 1981 ITV children's series Heavens Above and, in 1984, became the first female president of the British Astronomical Association.

Four years later, she co-founded a film and TV production company, then, in 1993, took up the chair of astronomy at Gresham College, a post previously held by Sir Isaac Newton and Sir Christopher Wren.

She and Dr Henbest co-wrote dozens of books as well as monthly astronomy columns for the Independent, the last of which was published on 6 February.

The pair even applied to be the first British astronauts, Dr Couper told the Guardian in 1993, but were quickly rejected.

"They wanted someone technologically on the ball, someone who would know what buttons to press in an emergency," she said.

"If something blew up, I would think, 'Oh Christ! What wire goes where?'"

BBC News
www.bbc.co.uk/news

400 Marsquakes detected by UK sensors in one year

The NASA InSight lander, which is supported by the UK Space Agency, has recorded 400 likely 'Marsquakes' in the first year of its mission.

The seismic vibrations on Mars were detected by a set of silicon sensors developed in the UK for InSight's Seismic Experiment for Interior Structure (SEIS).

Imperial College London, Oxford University, University of Bristol and STFC RAL Space worked in partnership, with £4 million in funding from the UK Space Agency, to develop three sensors which are sensitive enough to detect motion at sub-atomic scales.

Full story at UK Space Agency
<https://www.gov.uk/government/organisations/uk-space-agency>

Shetland Space Centre receives initial £2 million investment boost

Shetland Space Centre's (SSC) plan to build and operate a satellite launch site has been given a major boost by a £2,050,000 investment from Leonne International, the international private equity firm.

The cash injection, which gives Leonne a 20 per cent stake in the business, will be used for future growth of the company, such as the development of the launch site and ground station in Unst.

This was identified in the Sceptre Report, an independent report commissioned for the UK Space Agency, as the optimal location in the UK for launching small satellites into space, a rapidly growing sector of the international economy.

SSC's integrated business model creates revenues from launch, ground and tourism. Shetland's space economy should be seen as a unique and very valuable asset to the UK where it can support the work done by the other sector initiatives and clusters in the rapidly growing "New Space" economy.

SSC also has support from within the Unst and broader Shetland communities, as well as a proactive and supportive relationship with the local authority, Shetland Islands Council. Critically, the landowner and crofting community have recognised the benefits both locally and to Scotland and the UK and have agreed to lease the required land to the project and SSC does not anticipate any major environmental issues.

SSC intends to create an international exemplar by developing a green space centre and showcasing that space and its numerous applications are a "force for good" as well as creating employment and attracting new business opportunities to Shetland in particular.

For the last two-and-a-half years SSC has been developing its plans and collaborating with space industry giants such as Lockheed Martin, Aecom and ArianeGroup and also working closely with legitimate industry newcomers such as Rocket Factory Augsburg and Skyrora, the Edinburgh-domiciled Scottish Launch Provider, Raptor Aerospace, B2Space and C6 as well as Scottish Enterprise, Strathclyde and Edinburgh universities and the Technical University of Munich.

SSC has also partnered with Goonhilly and the Cornwall Space Centre, ensuring the UK makes the most of its geography by having a space footprint at both its northern and southern tips. SSC is also working very closely with Faroese Telecom as it seeks to build relationships around the Arctic economy.

Frank Strang, CEO of Shetland Space Centre, said: "We are delighted to have Leonne International as a partner in realising the benefits of space exploration for the UK, and for Shetland's economy: bringing jobs, revitalising the economy, attracting visitors and establishing Shetland as a northern hub supporting vertical launch and ground station activity. Mike Haston and his team at Leonne International bring tremendous enthusiasm, drive and belief to the business which will turbo charge an already dynamic and fast moving project. Just as his grandfather Dougal, a thoughtful visionary and one of Scotland's legendary rock climbers, pioneered Scottish winter climbing and conquered the world's biggest and most dangerous mountains, I have no doubt that Mike will lead the way into this next frontier and

help us conquer the new space economy for Britain.

"Importantly, the investment enables us to proceed with the first stages of gaining the necessary permissions and licences required to operate the facility and get on with building our launch site and ground station.

"Furthermore, the funding validates what we and, crucially, the wider space industry has been saying for several years now – that Shetland is absolutely the right location for kick-starting the UK's entry into this rapidly growing market."

Michael Haston, CEO, Leonne International, said: "We are always excited to partner with firms which exhibit ambition, innovation and excitement, and Shetland Space Centre exceeds this criteria with the plans they have in place for their satellite launch programme.

"With the help of the SSC, Shetland's space economy is unique and will inevitably become a very valuable asset to the UK."

Shetlands Space Centre
www.shetlandspacecentre.com

UK Welcomes Canadian Space Sector

A large space sector delegation from Canada visited the UK in early March to explore new partnerships and seek valuable opportunities to use space data, supported by the UK Space Agency.

More than 20 representatives from the Canadian space industry and government visited the Harwell Space Cluster in Oxfordshire as well as organisations in London, Surrey Research Park and Glasgow's thriving space sector.

The visit, led by the High Commission of Canada, the Canadian Space Agency, the National Research Council of Canada's Industrial Research Assistance Programme and Satellite Canada Innovation Network, builds on the close ties between Canada and the UK and will look at collaborative research and commercial opportunities in the exploitation of space data.

Along with the UK Space Agency, the visit is also supported by the Satellite Applications Catapult in Harwell, the Knowledge Transfer Network, Scottish Development International, Scottish Centre of Excellence in Satellite Applications and Enterprise Europe Network.

The UK space sector employs 42,000 people and generates an income of £14.8 billion each year, with the value of exports standing at £5.5 billion.

The UK continues to be a leading member of ESA, which is independent of the EU, having committed a record investment of £374 million per year in November 2019.

Full story at UK Space Agency
<https://www.gov.uk/government/organisations/uk-space-agency>

“A Successful Failure”: Remembering Apollo 13, 50 Years On

By Ben Evans

For centuries, thirteen has been an unlucky number, but when astronaut Jim Lovell told his wife that he would command Apollo 13—the third landing of humans on the Moon—she experienced an unmistakable pang of dread. Lovell’s reply, immortalised in the 1995 Hollywood retelling of the story, was pragmatically simple: “It comes after twelve!” And yet back luck did indeed stalk Apollo 13. If the plan to launch the mission at 13:13 Houston time or the intent for it to enter the lunar sphere of gravitational influence on 13 April 1970 was not enough to tempt fate, then German measles and an undetected design flaw in the spacecraft certainly was.

As Lovell, his command module pilot Ken Mattingly and lunar module pilot Fred Haise trained for their ten-day flight, backup crewmen John Young, Jack Swigert and Charlie Duke shadowed them. Two weeks before the 11 April 1970 launch, Duke was exposed to measles through the young son of a family friend. Although Duke was not contagious, and Lovell and Haise were both immune, the case for Mattingly was uncertain and the disease’s two-week incubation period meant he might get sick during the mission.

Switching Lovell’s entire crew for that of Young was considered but dropped in favour of replacing Mattingly with Swigert. NASA Administrator Tom Paine feared a media and political frenzy if Mattingly fell ill in space and Lovell’s entreaties were rebuffed by the flight surgeons, who felt that blurred vision or swollen joints from a case of German measles could threaten mission success. Nor could Apollo 13 be straightforwardly delayed until the next lunar ‘launch window’ in May 1970, for that risked causing components of its Saturn V rocket to degrade and would cost \$800,000. Besides, command module pilots worked alone for long periods and this made it simpler to swap Mattingly for Swigert.

Apollo 13 would alight in a hilly region of the lunar surface for the first time. The lunar highlands were thought to be virtually unchanged, morphologically and geochemically, since the Moon’s youth and exploring them might reveal rocks dating back billions of years. Lovell and Haise would land their lunar module, which they had named ‘Aquarius’, at a rugged place called Fra Mauro, about 300 miles south of the southern rim of the vast Mare Imbrium impact basin. Carved by a cataclysmic collision in the Moon’s infancy, ejected subsurface material from Imbrium was believed to be widespread at Fra Mauro, particularly on the flanks of the thousand-foot-wide Cone Crater. And sampling that material could shed new light on the nature of the original lunar crust, establish a date for when the impact happened and advance human knowledge of the Moon’s history.

Almost as soon as it began, Apollo 13 was touched by the breath of



Apollo 13 Mission Insignia: Apollo, the sun god of Greek mythology, was represented as the Sun, with three horses driving his chariot across the surface of the Moon, symbolizing how the Apollo flights have extended the light of knowledge to all mankind. The Latin phrase “Ex Luna, Scientia” means “From the Moon, Knowledge.”

**Image Credit: NASA
www.nasa.gov**

misfortune, mixed with the breath of its own Saturn V exhaust. Five minutes after liftoff, unexpected oscillations in the rocket’s second stage caused the centre J-2 engine to shut down too soon. Its four siblings automatically compensated by firing a little longer, but even their input was not enough and it took an added push by the third stage to put the 101,000-pound spacecraft—command and service module ‘Odyssey’ and lunar module Aquarius—into a safe orbit around the Earth. At length, with all checks completed, the third stage fired a second time later that afternoon to propel them to the Moon.

For the next two days, mission controllers in Houston, Texas, were bored to tears, so well-behaved was the spacecraft as it traversed the 240,000 miles between the Earth and the Moon. Swigert’s biggest concern was forgetting to file his tax returns; an admission that left flight controllers in fits of laughter. Then, 55 hours after launch, disaster struck as the astronauts bedded down for their third night’s sleep in space. Lovell had just given

a televised tour of his ship, although he could not have known that landing men on the Moon had lost its lustre for an increasingly fickle American public, most of whom had instead tuned in to watch *The Doris Day Show* or *Rowan & Martin’s Laugh-In*.

The chain of events which unfolded that night would almost claim the astronauts’ lives. Deep inside the service module, two cryogenic tanks housed liquid oxygen and hydrogen to feed three fuel cells, which provided the crew with electricity, water and heat. But before Apollo 13 even launched, the No. 2 tank had exhibited problems. Tubing to fill and empty the tank had been accidentally damaged two years earlier and in March 1970 it was loaded with cryogenics for a test run. At the end of the test the damage prevented the super-cold fluids from draining as they should. Engineers eventually boiled them off using the tank’s electric heater, aided by ground equipment at 65 volts of power.

But another fatal gremlin lurked in the system. Several years earlier, the Apollo spacecraft was upgraded from 28 volts to 65 volts. Its systems were modified to accept the change...apart from for a small



thermostat in the oxygen tank, which remained rated to 28 volts and should have turned off the electric heater when temperatures hit 26 degrees Celsius. No one caught the mistake and as the tank's contents were boiled off in March 1970 excessive voltages triggered an arc that welded its electrical contacts shut. The test conductor's gauge went no higher than 30 degrees; he could not possibly have known that temperatures inside the tank had risen to over 500 degrees. This enormous heat cracked Teflon insulation on wires to an electric fan that would periodically stir the tank's contents in space. Any spark or short-circuit could now set off an explosion. And when the tank came to be loaded with highly flammable cryogenics before launch, bits of Teflon debris and stripped-bare wiring created the perfect conditions for a ticking bomb.

That bomb detonated late on 13 April 1970, two hundred thousand miles from the Earth, when mission control asked Swigert to stir the service module's tanks. In weightlessness, the cryogenics tended to become stratified and periodic stirs provided engineers with more accurate quantity readings. Swigert duly flipped the H2 FANS and O2 FANS switches. Seconds later, Apollo 13 shuddered with a dull bang.

Lovell was floating through the connecting tunnel from Aquarius to Odyssey at the time. Instinctively, he guessed the culprit was Haise, who had a mischievous habit of setting off the spacecraft's noisy cabin repress valve to scare them. But the wide eyes of his crewmates quickly assured him that this was no light-hearted tomfoolery. The two steely test pilots were truly, wholly and profoundly frightened.

Their attention was soon arrested by the blaring master alarm and the red glow of the 'Main Bus B Undervolt' light on Odyssey's instrument panel. It told them that one of the command module's twin electrical buses had lost power.

"Hey," Swigert radioed to Houston. "We've got a problem here!"

"This is Houston, say again, please," replied fellow astronaut Jack Lousma, the duty capcom in mission control.

"Houston, we've had a problem," said Lovell, keen and unwavering urgency in his voice. "We've had a main B bus undervolt."

"Roger, main B undervolt," replied Lousma. "Okay, stand by, 13, we're looking at it."

Mission control's first thought that it was an instrumentation hiccup was quickly nixed by recognition that the astronauts had heard and felt the bang, which sounded like a reverberating thunderclap and manifested itself as a visible flexing of the tunnel walls between

Odyssey and Aquarius. But as data streamed back to Earth, horrified flight controllers could only watch as quantity and pressure readings for the No. 2 tank crept down to zero. Aboard the spacecraft, more warning lights glowed, revealing two of the three fuel cells to be dead and oxygen to be slowly leaching out of the No. 1 tank.

The likelihood of so many simultaneous catastrophic failures—an oxygen tank gone, two fuel cells down and one power bus dead—seemed impossibly remote. And for engineers whose years of experience had taught them that fluid lines might leak, electrical wires might short, but physical structure should not break, it was a rude awakening.

Odyssey's behaviour, too, was disconcertingly out of the ordinary. The command module's computer shut down, then restarted, whilst its high-gain antenna lost functionality. Aware that Bus B was gone, Haise reconnected its systems over to Bus A, only to discover that it too was starving of current. With only one healthy fuel cell left, landing on the Moon was now out of the question and getting home alive was Apollo 13's new mission.

Thirteen minutes after the bang—yet another reminder of the unlucky number, if one were needed—Lovell craned his neck to the window and was startled to see a white vapour gushing from the side of the service module. As it emerged into the frigid cold of space, it crystallised and expanded into a broad, halo-like cloud.

"Houston, we are venting something into space," he reported. "It's a gas of some sort."

"Roger," replied Lousma, "we copy you're venting."

At that point, remembered Apollo 13 lead flight director Gene Kranz, the pieces of this inscrutable puzzle snapped into place. A short-circuit and explosion in the troubled No. 2 tank had ruptured the service module, venting its oxygen overboard and triggering a torrent of apparently unrelated failures. The blast had snapped shut the fuel cells' reactant valves and starved the ship's electrical system, whilst fuel valves to the thrusters had closed, making it difficult for the astronauts to regain control. And the escaping oxygen was now acting like a thruster, making the vibrations even worse.

Ninety minutes after the bang, it was obvious that Odyssey's third fuel cell was close to death. The only way to isolate the leak and save whatever was left in the surviving cell was to close off the reactant valves of the two dead cells. After that, the next headache would be getting home. Firing the large engine at the base of the service module would enable Apollo 13 to do an about-turn in space (a

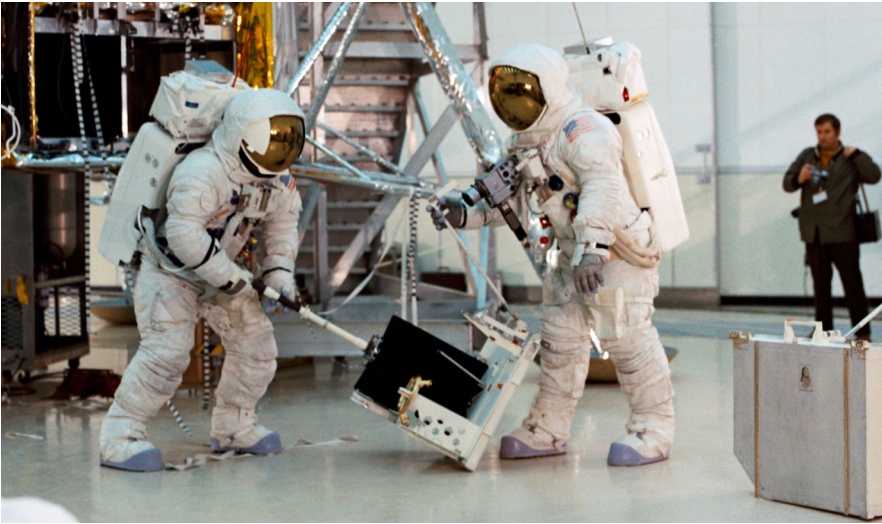


Image Left: Jim Lovell and Fred Haise train for their ill-fated Moonwalks.

‘direct abort’) and bring the astronauts back in a couple of days. But with the service module crippled, so too might the engine be, and besides there now remained insufficient power to open the valves to its combustion chamber, much less swivel its nozzle or steer its five-minute ‘burn’.

Yet hope was kindled in the form of using the undamaged lunar module Aquarius as a lifeboat. It did not have the power to direct-abort them back home, but it could put them onto a ‘free-return’ trajectory’, pushing them around the Moon and allowing its natural gravity to fling them back to the Earth. Several earlier lunar missions included this safety feature in their flight design, but the free-return also restricted the range of landing sites that could be reached. From Apollo 12 onwards, a ‘hybrid trajectory’ was implemented to broaden the scope of lunar landing options—including Fra Mauro—but required the spacecraft’s own propulsion to power them back home.

As Lovell and Haise brought Aquarius to life, Swigert shut down most of Odyssey’s systems to conserve them for re-entry. One of his final tasks was transferring guidance and control over to the lunar module. But with a huge cloud of shimmering debris around the spacecraft, it was virtually impossible to acquire accurate star sightings for the navigation platform. The only option was to hand-write the data from Odyssey’s computer, mentally calculate the differing frames of reference between the two ships, then input it into Aquarius’ computer...all the while, acutely aware that time was of the essence as the command module was slowly but surely dying.

As they battled tiredness, the astronauts were reliant upon mission control to cross-check their arithmetic.

Finally, Swigert shut Odyssey down and joined his crewmates in Aquarius. Controlling the 60-foot-long ‘stack’ from the lunar module carried its own idiosyncrasies, which Lovell compared to steering a wheelbarrow with a long broom handle, but he had little time to adapt to this oddly new flying regime. Six hours after the explosion, he fired Aquarius’ descent engine to put Apollo 13 onto a free-return trajectory around the Moon. This committed them to getting back home and splashing down somewhere in the Indian Ocean.

But it was not enough. ‘Somewhere’ in the Indian Ocean was a long way from recovery forces and Lovell, Swigert and Haise still needed four days to get home, far longer than Aquarius could sustain them. Discarding the huge service module might bring them back in under 40 hours, but its presence protected the command module’s heat shield against solar radiation and huge temperature extremes of deep space.

By now, the media had picked up the story, their fervour intensified by the assessment of senior NASA manager Chris Kraft that Apollo 13 was “about as serious a situation as we’ve ever had in manned spaceflight”. Prayers were offered by Pope Paul VI in Rome, by pilgrims in India and at Jerusalem’s Wailing Wall and several nations, including the Soviet Union, offered assistance in the form of recovery forces if necessary.

Image Right: Apollo 13 astronauts (from left) Jim Lovell, Jack Swigert and Fred Haise, pictured after the mission.



Image Right: Astronauts confer in mission control at the height of the crisis. Standing are Ken Mattingly (left) and Vance Brand. Seated from left to right are astronauts Deke Slayton, Jack Lousma and pipe-smoking John Young.



With plenty of oxygen aboard Aquarius for two now-forgotten Moonwalks, breathing during the journey home was not a problem, but carbon dioxide from the astronauts' exhaled breath certainly was. Canisters of lithium hydroxide ordinarily 'scrubbed' this toxin from the spacecraft's air, but Aquarius only carried enough for 45 hours, far short of the return-home travel time of 90 hours. More canisters were aboard Odyssey, but with the two spacecraft having been built by different companies their shapes and fittings were different. NASA's crew systems division quickly rigged up a device to literally fit a square peg into a round hole. Using only bits and pieces that the astronauts had with them—socks, duct tape, plastic bags, a spare oxygen hose, the cover of a flight plan—they improvised an effective fix. Instructions were radioed to the crew, who built and fitted it. Shortly afterwards, to everyone's intense relief, carbon dioxide levels began to fall.

The next challenge was power, for unlike Odyssey the lunar module relied on batteries to support two men for 33 hours on the Moon's surface; stretching those capabilities to three men and several days

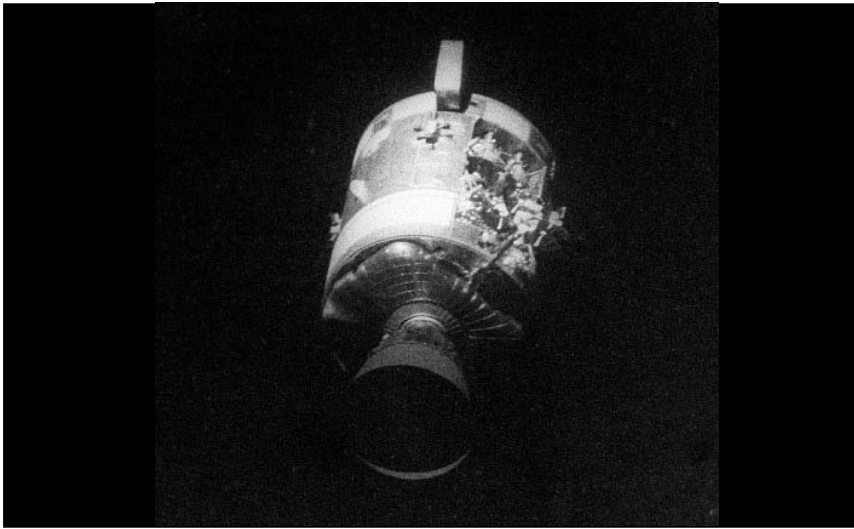
required switching off most of its systems, including lights, gauges and even its computer. Apollo 13's homeward-bound route was further shortened by the PC+2 'burn' of Aquarius' descent engine, executed shortly after their closest approach to the Moon. It cut the return journey from four days to only two-and-a-half.

All three men gaped at the windows as they saw the forbidding lunar terrain, their lost goal, pass serenely beneath them. Lovell had been here before on Apollo 8, but for Swigert who never expected to fly Apollo 13 and for Haise who spent months practicing for a pair of four-hour walks on its surface, it was an intensely bittersweet moment.

After the PC+2 burn, most of Aquarius' remaining systems were shut down. Temperatures inside its broom-cupboard-sized cabin plummeted, moisture formed on its windows, living conditions resembled a dank cellar and the astronauts managed a couple of hours' sleep at best. Food stocks were frozen solid and water was seldom drunk for fear that 'urine dumps' could knock Apollo 13 off-



Image left: Jack Swigert works to assemble the box-like device to allow command module lithium hydroxide canisters to fit the lunar module.



Apollo 13's damaged service module, seen shortly after it was discarded, late in the mission.

course. Lovell's crew returned to Earth severely dehydrated and Haise suffered a kidney infection.

By 16 April 1970, the home planet began to loom large in Aquarius' triangular windows as the astronauts and mission control prepared to reactivate Odyssey after several days in frozen darkness. Writing re-entry checklists for the command module usually took three months, but the experts in mission control put one together in only two days.

One question on the astronauts' lips was the health of Ken Mattingly. Lovell asked capcom Vance Brand if the 'blooms' of rubella had finally hit his former crewmate.

"Are the flowers blooming in Houston yet?"

"Nope," replied Brand. "Still must be winter."

"Suspensions confirmed," retorted Lovell, grimly.

Late on the 16th, a fighting-fit Mattingly strode into mission control with a 39-page sheaf of 400 procedures to bring Odyssey back to life. For two hours, he talked Swigert through every switch throw and keystroke. Shortly thereafter, the crippled service module was

discarded, revealing the true extent of the damage: an entire side panel, 13 feet long, was gone, leaving a jumble of shredded wiring and torn plumbing. Capcom Joe Kerwin joked that Swigert ought to take better care of his ship. The joke fell on deaf ears.

Next came the jettison of Aquarius, "a good ship", said Haise, which had served them fittingly in the darkest moments of their mission. Alone now, the command module plunged into the Earth's atmosphere at 24,000 miles per hour, whereupon super-heated plasma blocked communications with the ground. This 'blackout' was expected to last for three minutes and the unspoken fear in mission control that Odyssey's heat shield or parachutes had been fatally damaged was pervasive.

"Odyssey, Houston," radioed Kerwin after three minutes. "Standing by."

His voice echoed in the silent Houston control room.

Five thousand miles away in the Pacific, the amphibious assault ship *Iwo Jima* and its detachment of Marine Corps helicopters had been scrambled as part of a massive search-and-rescue operation. They saw no sign of the command module or its parachutes descending

The scene in mission control on 17 April 1970 as Odyssey descends to a smooth splashdown in the Pacific Ocean.



Image Right: Apollo 13 flight directors celebrate the successful splashdown and recovery of the Apollo 13 crew. From the left are Gerry Griffin, giving thumbs up, Gene Kranz and Glynn Lunney.



through the crisp blue morning sky.

Four minutes of radio silence passed. A feeling of dread crept into mission control.

At length, it was the Apollo Range Instrumentation Aircraft which reported it had acquired a signal from the spacecraft. Hearts leapt into throats.

"Odyssey, Houston," repeated Kerwin. "Standing by."

Then came Swigert's voice. "Okay, Joe."

Seconds later, television pictures from *Iwo Jima* revealed the command module, descending beneath three red-and-white main parachutes.

"Odyssey, Houston, we show you on the mains," yelled Kerwin. "It really looks great!"

Six days after leaving the Earth to limited public interest, Apollo 13 was home safely, against a multitude of odds, its ill-fated journey watched by a billion people. And the "successful failure" of the mission became NASA's finest hour. Everyone associated with Apollo had stayed at work until the mission was over. Many had not seen

their families since the night of the explosion, surviving on coffee and cigarettes and a few hours' sleep on their office floors. Gene Kranz would later reflect on their steely resolve. "I remember their eyes," he said, "dull with fatigue and shadowed by anxiety. But their confidence and focus never wavered."

Footnote from NASA

After an intensive investigation, the Apollo 13 Accident Review Board identified the cause of the explosion. In 1965, the CM had undergone many improvements that included raising the permissible voltage to the heaters in the oxygen tanks from 28 to 65 volts DC. Unfortunately, the thermostatic switches on these heaters weren't modified to suit the change. During one final test on the launch pad, the heaters were on for a long period of time. This subjected the wiring in the vicinity of the heaters to very high temperatures (1000 F), which have been subsequently shown to severely degrade teflon insulation. The thermostatic switches started to open while powered by 65 volts DC and were probably welded shut. Furthermore, other warning signs during testing went unheeded and the tank, damaged from eight hours of overheating, was a potential bomb the next time it was filled with oxygen. That bomb exploded on April 13, 1970 - 200,000 miles from Earth.

NASA
www.nasa.gov

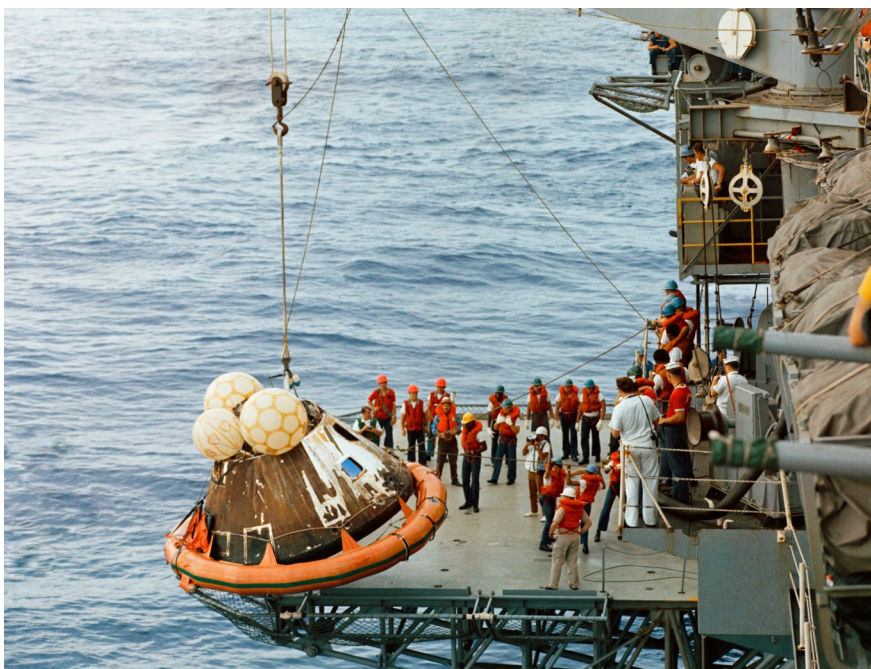


Image left: The Apollo 13 command module, Odyssey, is winched aboard the recovery ship Iwo Jima on 17 April 1970.

Hubble Space Telescope 30th Anniversary

First conceived in the 1940s and initially called the Large Space Telescope, the Hubble Space Telescope took decades of planning and research before it launched on 24 April 1990. Since launch, Hubble has overcome its troubled beginnings to perform innumerable science observations that have revolutionized humanity's understanding of the universe. From determining the age of the universe to observing dramatic changes on celestial bodies in our own solar system, Hubble has become one of humanity's greatest scientific instruments.

Here we present a number of Interesting Facts about the Hubble Space Telescope

- The HST was developed alongside the Space Shuttle. HST was of a modular design that enabled future upgrades and repairs to be carried out by Astronauts on visiting Space Shuttles.
- HST was originally planned to be launched in 1986 by Space Shuttle Atlantis but this date was put on hold after the Challenger Accident in January 1986.
- HST was deployed by Astronauts on Space Shuttle Mission STS-31 Discovery.
- The flawed HST mirror, 2.4 metres in diameter and built by optics company Perkin Elmer had a twin backup mirror built at the same time by photography giant Eastman Kodak. The Kodak version did not suffer the same fate as the installed Perkin Elmer version. The Kodak version is on display in Washington DC's National Air and Space Museum.
- The nominal mission time for HST was fifteen years. HST is now has 30 years on orbit and continuing operations.
- Four HST Servicing missions were planned to keep the telescope updated and repaired. But this turned into 5 when SM3 was split into two due to the increasing number of tasks required to keep HST afloat.
- The final HST Servicing Mission (SM4) was cancelled by NASA Administrator Sean O'Keefe following the investigation into the Columbia disaster in 2003 that Shuttle flights should be restricted to ISS missions, whereupon the ISS would be utilised as a "safe haven" for Shuttle crews if the Orbiter was damaged in such a way that it could not return the crew home safely.
- O'Keefe's replacement, Michael D. Griffin, took just two months after his appointment to announce that he disagreed with O'Keefe's decision, and would consider sending a Shuttle to repair Hubble. The Final Hubble Servicing Mission took place on STS-125 in May 2009.

Hubble Servicing Mission Emblems



Servicing Mission 1
(SM1): 2—13
December 1993



Servicing Mission 2
(SM2): 11 - 21
February 1997



Servicing Mission
3A (SM3A): 19—27
December 1999



Servicing Mission
3B (SM3B): 1—12
March 2002



Servicing Mission 4
(SM4): 11—24 May
2009

One Giant Leap: Exploring the Moon and Space

**NOW AVAILABLE TO PRE-ORDER:
A SIGNED COVER BY ASTRONAUT AND
MOONWALKER CHARLES M DUKE -
EXCLUSIVE TO ISLE OF MAN POST OFFICE.**



The Isle of Man Post Office is pleased to present a set of eight stamps titled “One Giant Leap, Exploring the Moon and Space.” The issue continues the story of NASA human spaceflight, which commenced with [“One Small Step”](#) issued in April 2019.

It has been our great honour and privilege to work with George Abbey and NASA to create this second set of stamps marking over 50 Years of Lunar Exploration and mankind’s further exploration of space, symbolically themed around that ‘One Small Step’ Neil Armstrong took on the surface of the Moon in 1969 and the ‘Giant Leap’ forward for humanity. We have studied the Moon for millennia; it governs our tides, our planting seasons, even the rhythm of our bodies, it is an ever-changing constant in our lives, but it is that ‘one small step, but giant leap’ that marked the beginning of human exploration beyond the confines of our planet. Our continued fascination with space has led to satellites and space stations, rockets and now visionary plans for a return to the Moon.



Exclusive to Isle of Man Post Office we are honoured to present this very special, limited edition of only 750, signed cover by astronaut and Moonwalker Charles M Duke.

For details and prices of all products please visit Isle of Man Post Office at www.iompost.com



CAPCOM is produced and published by Go Space Watch for Midlands Spaceflight Society. For information on how to subscribe to CAPCOM please visit www.gospacewatch.co.uk and follow the link to CAPCOM.

50 years since Black Arrow launched the UK into space

The 4 March 2020 marks 50 years since the UK built Black Arrow rocket conducted its first successful flight, launching the UK into the space age.

In the years since Black Arrow, the UK has become one of the world's leading satellite manufacturers, providing technology that helps the world communicate, keeps people safe and monitors the environment.

The government wants to establish a new UK launch capability on a commercial footing, with a number of potential spaceports across the country and new launch operators developing the capability to take small satellites into orbit from UK soil.

Emma Floyd, Director of Commercial Spaceflight at the UK Space Agency, said:

"Our aim is to establish commercial vertical and horizontal satellite launch from UK spaceports - providing world-leading capability, bringing new markets to the UK and inspiring the next generation of British space scientists, engineers and entrepreneurs.

"Black Arrow is an important part of the UK's space heritage, and it is great to be able to recognise the achievements of the past, as we look to the future."

The UK Space Agency is partnering with Farnborough Air Sciences Trust (FAST) and British rocket launch provider Skyrora to celebrate the 50th anniversary of the Black Arrow launch and the current success of the UK space sector. Skyrora brought the first stage of Black Arrow R3 back to the UK from Australia two years ago and has lent it to the FAST Museum where it will be on display from today for the next three years.

About Black Arrow

Black Arrow is of great historical and technical importance playing a pioneering role during the late 1960s and early 1970s in placing the first British designed and built space satellite into Earth orbit. The programme grew from earlier UK space research and development programmes undertaken by the Royal Aircraft Establishment (RAE) at Farnborough, which included designing and building in conjunction with industry, a series of launch vehicles and their rocket engines, along with all the associated ground-based infrastructure, including assembly and test facilities in the UK and a launch complex with control and range facilities at Woomera, Australia.

The intention was to see if a rocket, capable of launching satellites into space, could be developed from existing technologies, for example HTP/kerosene powered engines developed in experimental British submarines and torpedoes.

The Black Arrow programme developed four rockets between 1969 and 1971. Black Arrow was a three-stage rocket, thirteen metres tall, with a single eight-chambered engine in its first stage. The third stage for Black Arrow was a solid rocket motor manufactured by RPE Westcott. The first stage of Black Arrow R3, the surviving launcher that was used to place the Prospero satellite into orbit in 1971, has been brought back to the UK by Skyrora and is now on public display at the Farnborough Air Sciences Trust Museum, close to the original programme birthplace, the RAE Space Department.

UK Space Agency
www.gov.uk/government/organisations/uk-space-agency



Midlands Spaceflight Society

Contact

Dave Evetts, Secretary,
Midlands Spaceflight Society
124 Stanhope Rd, Smethwick
B67 6HP
Tel. 0121 429 8606
(evenings & weekends only) or
e-mail mss.shop@midspace.org.uk

Web Site:

www.midspace.org.uk

Contributions to CapCom

The Editor welcomes contributions for CapCom. Articles on any aspect of space exploration are considered. Articles in Word format or text files should be sent by email to

capcom.editor@midspace.org.uk

The Society is not responsible for individual opinions expressed in articles, reviews or reports of any kind. Such opinions are solely those of the author. Material published in CapCom does not necessarily reflect the views of the Society. Any comments directly concerning the magazine should be addressed to the Editor via the email address above.

Copy Deadline

All contributions intended for the May — June 2020 issue should be emailed to the editor by
Friday 10 April 2020