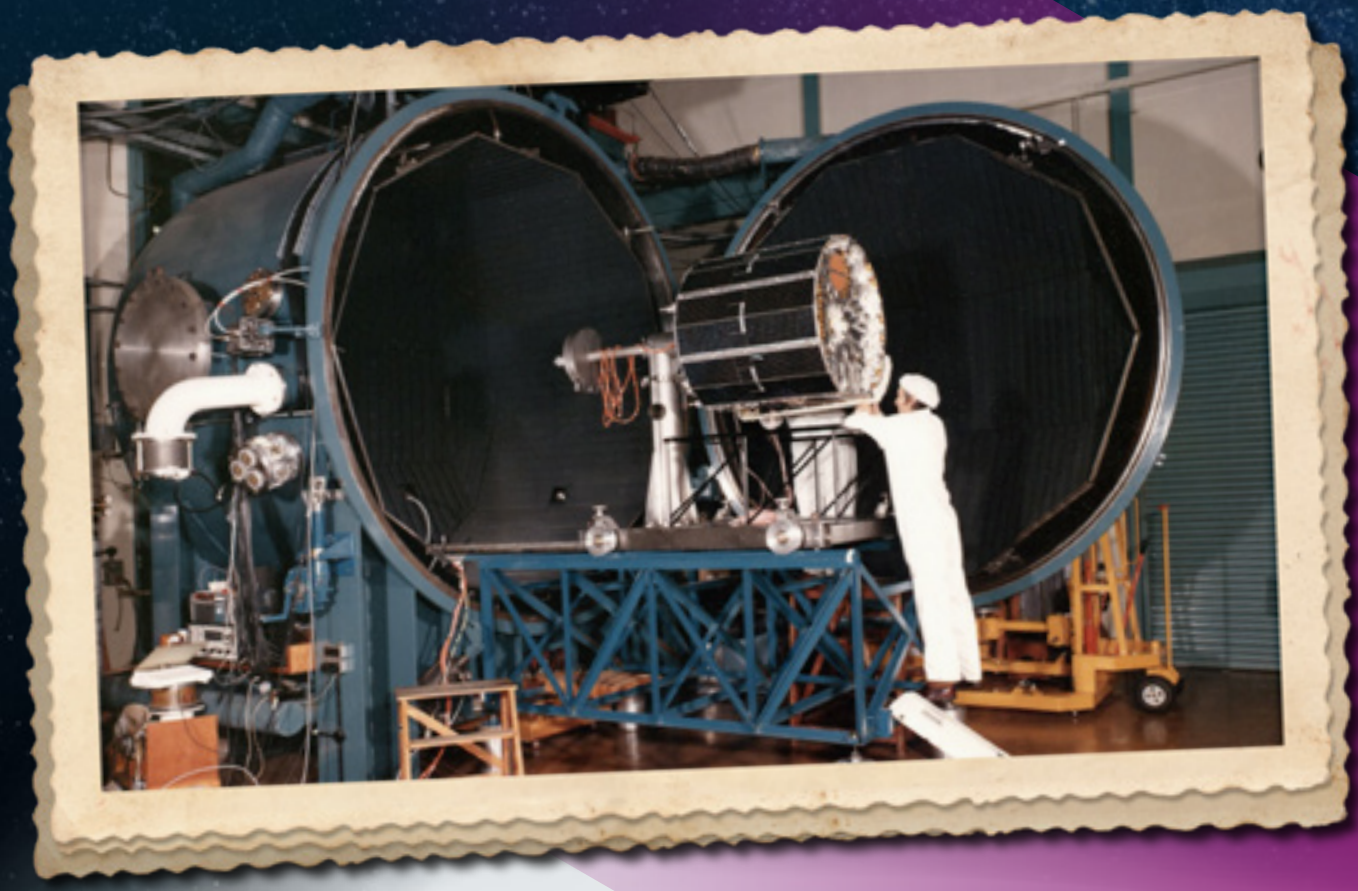
QINETIQ

# Space Heritage

Postcards from the Past




# Contents

# Pushing boundaries in humankind's evolving space odyssey

**QinetiQ's space heritage is an ongoing story of 'firsts'**

The wonders of space have captured the human imagination for centuries. However, it is only little more than sixty years since the first human ventured outside of the Earth's atmosphere, heralding the start of humankind's exciting and increasingly ambitious journey into space exploration and research. We are still only at the start of the journey but the astounding results from this ongoing process of scientific discovery have already proved to be truly transformational in practically every aspect of our 21st century lives.

Any venture into space requires substantial investment. That said, the increasingly significant role of commercial interests in all areas of the space industry is not only helping to reduce the earlier reliance on state funding but also extending the art of the possible. In so many respects, space continues to represent a new, exciting and expansive frontier where imagination and justification are the only constraints.

Our first thoughts when it comes to space exploration will always focus on the spacecraft and space stations that have taken us physically and visually further and further into outer space and, of course, the astronauts who are paving the way for increasingly adventurous missions. It's all too easy to overlook the scientific breakthroughs and giant leaps (!) that have underpinned such adventures.

Here at QinetiQ, our pioneering technologies and expertise have featured prominently in the space success story ever since the 1960s.

Today, the company is at the cutting edge of new satellite technologies, advanced docking systems, the very latest secure communication systems as well as a myriad of instrumentation and experimentation systems for a diverse range of space missions. With much of its heritage founded on the facilities and expertise of scientists at the former Royal Aircraft Establishment (RAE) - which became the Defence Research Agency (DRA) and then the Defence Evaluation and Research Agency (DERA) - at Farnborough, the company's roots in space technologies extend back to the 1950s.

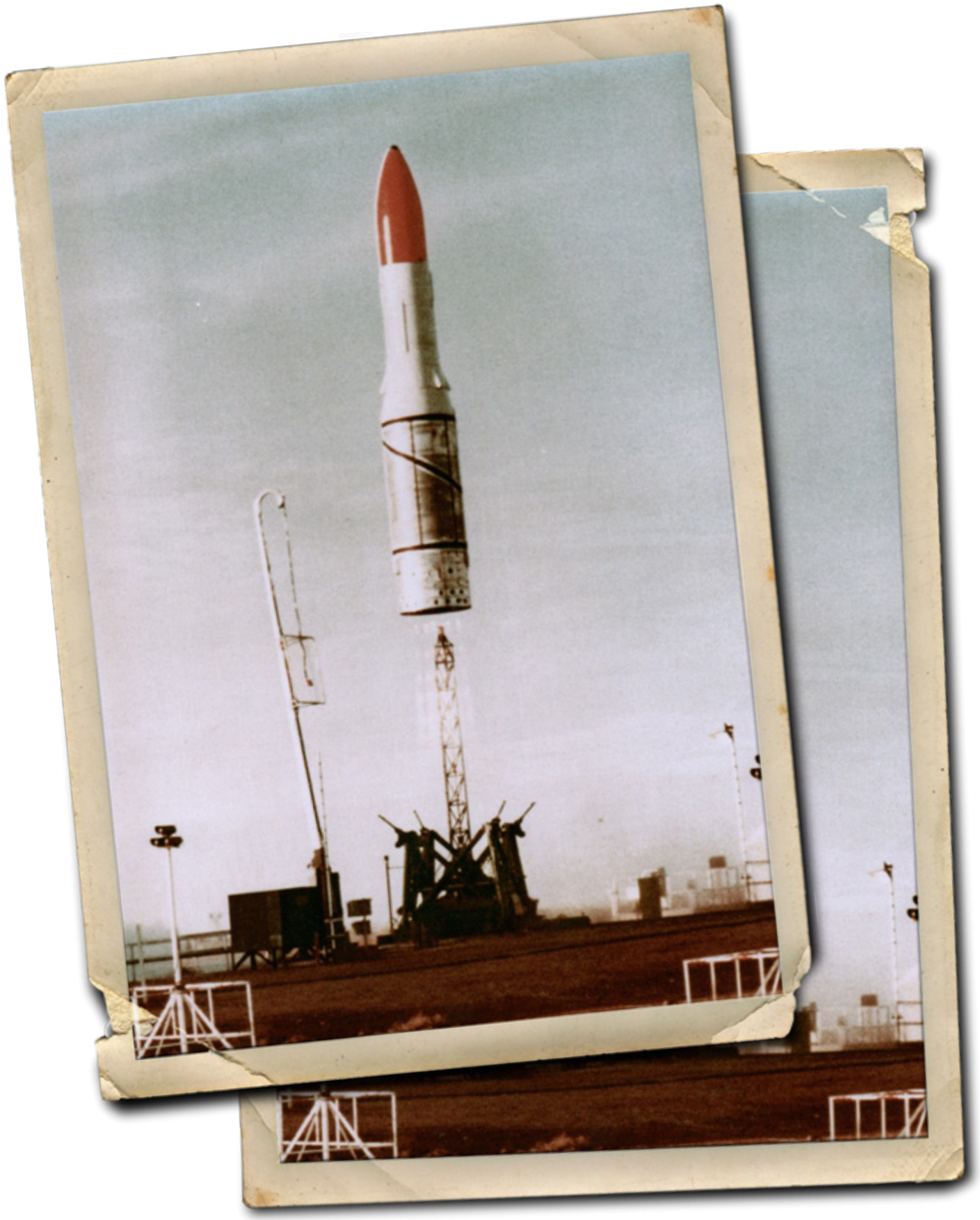
A significant early highlight was the successful launch of the Prospero satellite into a low earth orbit in 1971. This was the first (and, to date, only) all-British mission – with the satellite and Black Arrow carrier rocket both designed and built in the UK. However, this has been followed by work on a huge range of missions from experimental space programmes at the cutting edge of materials science to earth observation satellites for supporting relief efforts in natural disasters as well as pioneering deep space programmes.

In the mid 1960s, RAE invested in a new thermal-vacuum test facility capable of testing complete satellites. This purpose-designed facility comprised a large 3m diameter vacuum chamber and was opened by Her Majesty the Queen during her visit to Farnborough in June 1966. This industry-leading resource has been rebuilt and repurposed many times in its lifetime to meet the evolving demands of the space sector, including a special extension to the facility that was opened by Arthur C. Clarke in the 1990s.

Now, after more than 50 years of invaluable service in such key period for the space industry, it has been decommissioned. Although this move marks the end of an important chapter in QinetiQ's space heritage, the company's ongoing investment in new space resources and capabilities continues unabated and it now has dedicated facilities in six European locations. These include £multi-million state-of-the-art cleanroom facilities in Kruibeke, Belgium, for the integration, testing and production of satellites and docking systems. However, the company's specialist work at its original home in Farnborough has also continued to evolve with an ever-increasing focus on systems integration expertise and consultancy services.

Emerging new space technologies and new digital capabilities are, of course, now very much on centre stage in all areas of the space industry. That said, learning lessons from the past is of vital importance in helping to deliver a progressive, innovative and collaborative ecosystem that is capable of fulfilling the demands and expectations of increasingly diverse and ambitious space programmes. The recent decommissioning of the thermal-vacuum test facility has provided a timely catalyst for us to do just that - to stand back and consider the long list of achievements and QinetiQ's considerable contribution to the space industry.

The company's photographic archive has provided a fascinating insight into the breadth and extent of work completed by its scientists and engineers in helping to advance space technologies and capabilities. As you'll see on the following pages, we have now collated this material to chronicle the remarkable progress achieved in developing effective solutions for missions ranging from communications satellites and pioneering electric propulsion thrusters to experimental spacecraft and X-Ray telescopes. Many of the historic systems and components are now on display in the Science Museum and the Farnborough Air Sciences Trust Museum. Many others, however, are still providing data while not only orbiting around the Earth, but also Mars!

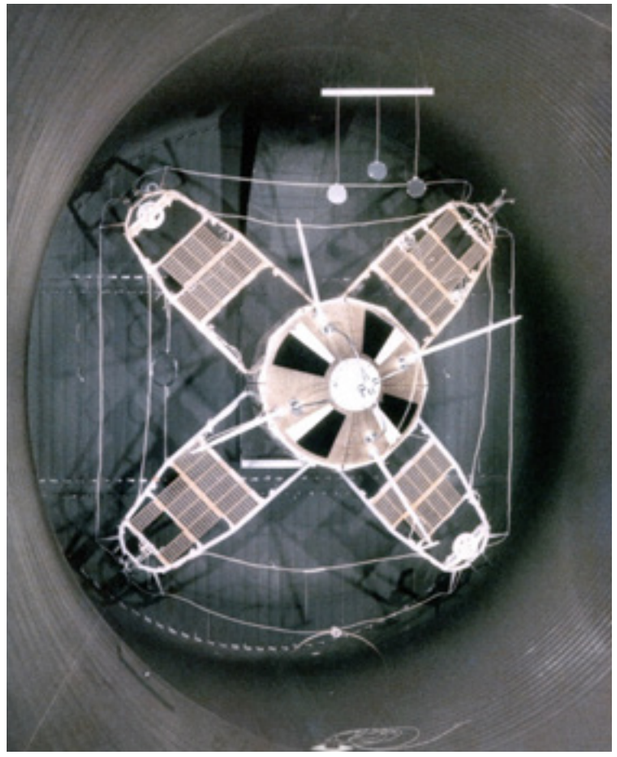


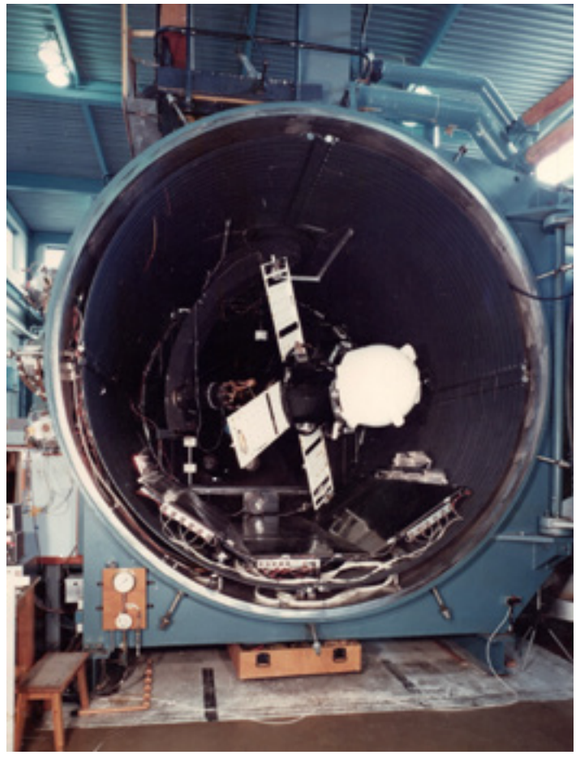
# A fertile ground for scientific advancement

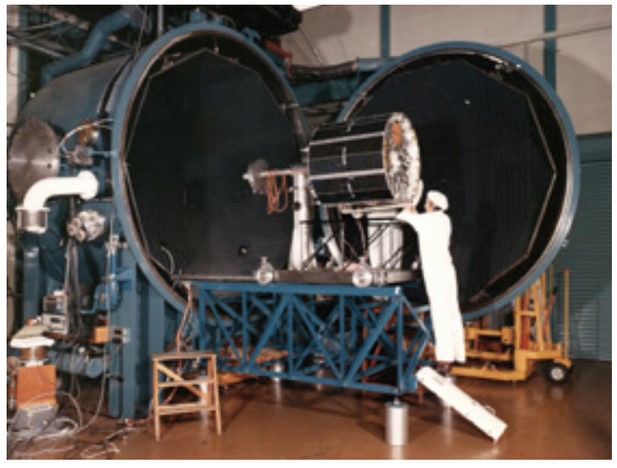
In the 1960s and largely as a consequence of military pressures in the wake of WWII and threats from Cold War tensions, the UK was blessed with some of the most innovative and progressive scientific minds in the world of space, science and technology, with many working at the RAE at Farnborough. RAE scientists directed development of the Blue Streak ballistic missile - intended to be the UK's nuclear deterrent - and Black Knight launcher during the 1950s and 1960s.

Such work led to the highly successful Black Arrow programme, culminating with the launch of the British satellite Prospero in 1971. In parallel, the Skylark sounding rocket programme became one of the most successful space programmes, launching 441 Skylarks over a nearly half a century. These ambitious projects capitalised on specialist knowledge and successes in propulsion, structures, aerodynamics, system testing and integration.

Although still in its relative infancy the focus on space technologies continued to gather momentum and, with full Government backing, eventually led to the formation of a dedicated Space Department in 1961. This resulted in a corresponding and significant shift towards unclassified work. The new Department comprised specialist divisions covering satellite launching vehicles, satellite engineering, ballistics research, instrumentation research and dynamics. From the outset and setting a precedent for what was to follow, there was active participation in the European Space Research Organisation (ESRO), the European Launcher Development Organisation (ELDO) and the International Telecommunications Satellite Organisation (INTELSAT).







# UK firsts

In tandem with the ongoing work on launcher vehicles and ground-breaking moves in the development of ion thruster technologies, the RAE team led the UK's first satellite research programme. A total of six satellites were launched as part of the Ariel programme to study the ionosphere, X-Ray astronomy and cosmic rays. The UK became only the third country to have a satellite orbiting the Earth when Ariel 1 was launched in 1962 and the third satellite in the series was the first to be wholly designed and constructed in the UK. Full testing for the Ariel 5 satellite to study X-Ray sources as well as the low energy X-Ray telescope of Ariel 6 was completed at RAE prior to their respective launches in 1974 and 1979.

In the late 60s, the team led the development of the X Series of small satellites to demonstrate a range of satellite technologies. The third satellite in this series was called Prospero and was launched with the Black Arrow launcher rocket from the rocket-testing facility at Woomera in Australia on October 28th 1971.

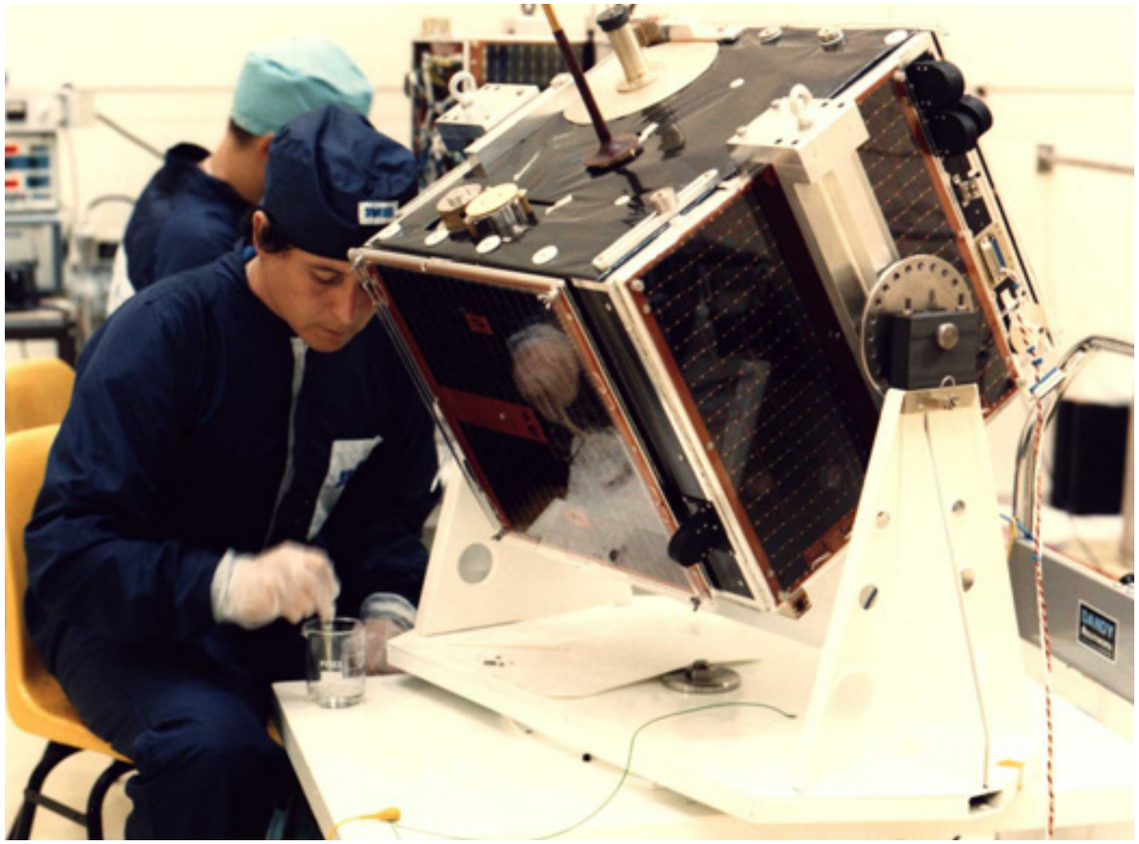
This was the first (and, to date, only) Earth satellite mission where both the satellite and its carrier rocket were designed, built and tested entirely in the UK. The mission was controlled by the RAE's Control Centre at Farnborough and the associated Lasham Ground Station and, significantly, featured innovative early use of automation using EMR 6130 computers. Miranda, the final satellite in the X series, was launched in 1974 and not only included an innovative and highly effective solar array but also used a novel propane cold gas thruster system to provide full attitude control.

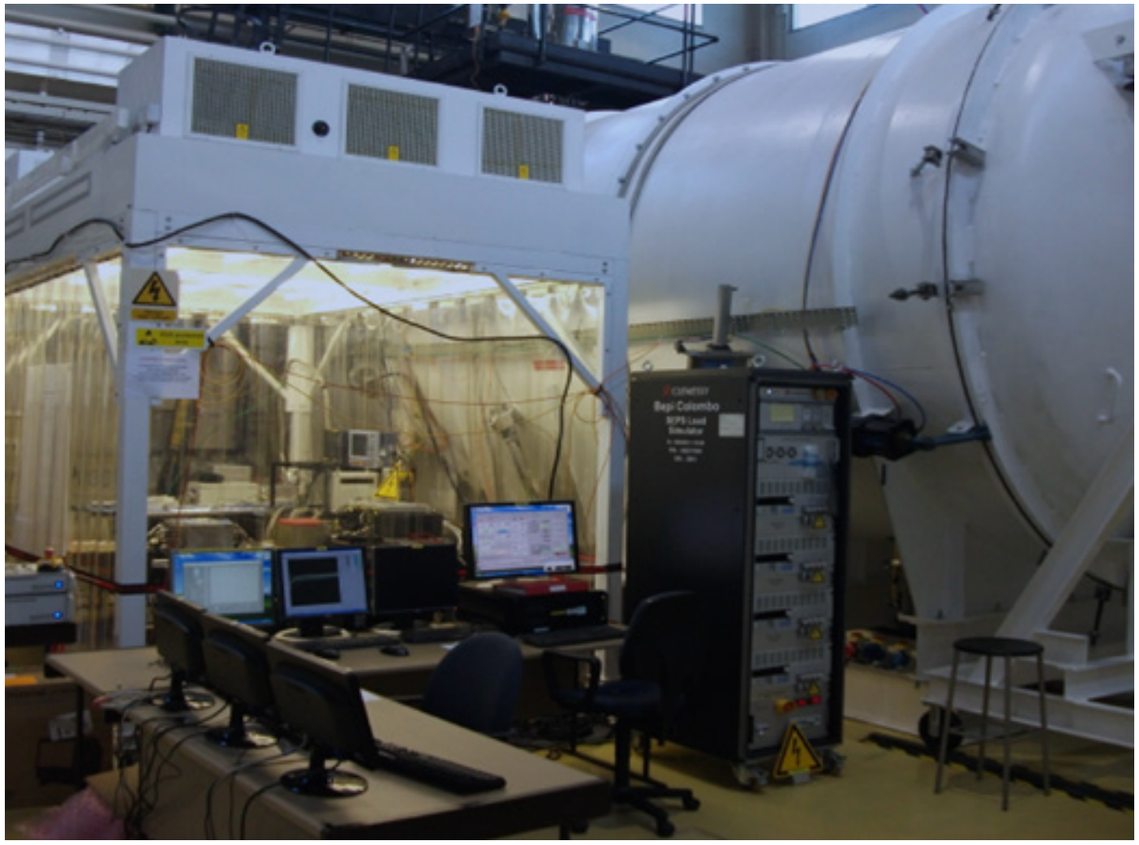
Although the latter half of the 1970s saw something of a hiatus in Government support for new space technologies, RAE continued working on its satellite development programmes and began making inroads into the use of ion thruster technology. It also provided the UK contribution to the US/UK/West Germany AMPTE mission, part of the Explorer programme to study the Earth's magnetosphere and radiation belts. Testing of the satellite was completed by RAE in Farnborough prior to its launch on a Delta 3924 rocket from Cape Canaveral in August 1984.

Despite a cooling of financial support and the move away from the civilian space work, RAE continued to support the development of military space technologies and played a central role in the development of the Skynet series of communications satellites throughout the 1970s. Ongoing evolution of performance and capabilities has built on the success of these highly successful satellites, with QinetiQ currently working in partnership with Airbus to develop the sixth generation of Skynet.

Using technology and experience from its Blue Streak ballistic missile, the team at RAE also worked with their counterparts in France and Germany to develop a civilian satellite launcher, Europa 1. After 10 test launches, the programme was cancelled amid budget cuts. However, the European collaboration paved the way for the European Space Agency and eventually culminated with the successful development of what would become the world's premier commercial launch system – Ariane.

QinetiQ's pioneering work has featured prominently in a huge number of space missions since the early 1960s - from Skylark and Black Arrow launcher rockets to satellites such as Prospero, STRV, TopSat, Skynet and PROBA-1 as well as space radiation monitoring for the Space Shuttle and advanced communications and propulsion systems for deep space missions such as Mars Express and BepiColombo.









# From spacecraft protection and cutting-edge propulsion to microsatellites

Coinciding with a significant resurgence in space activity at RAE – and subsequently DRA and DERA – during the late 1980s, a series of Space Technology Research Vehicle (STRV) microsatellites were developed and built for the UK Ministry of Defence. These used a myriad of sensors and detectors to deliver spectacular results in the testing of new technologies in the harsh radiation environment of a geostationary transfer orbit.

The STRV satellites were launched on Ariane rockets in two pairs. The first two had a mass of 50kg and were launched from French Guiana in June 1994 to test a range of new technologies, including new solar cells, surface static charge measurement and dissipation and space environment monitoring. Six years later, the second pair of 100kg STRV satellites was launched with an array of test technology devices including lithium ion batteries and a GPS receiver.

Another field of research in which RAE played a major role was the study of space radiation - the stream of high energy particles from both the Sun and deep space. In the early 1980s, it was becoming clear that new generations of spacecraft would feature ever more sensitive, high-performance electronics that would be susceptible to radiation damage and a better understanding of the phenomena was required.

Working in collaboration with Harwell laboratory, the Cosmic Radiation Effects and Activation Monitor (CREAM) was conceived to measure several aspects of space radiation. CREAM was flown on a total of 9 Shuttle missions and, in 1998, it was also deployed for six months on the MIR space station.

Other variants flew on various satellites - including STRV - contributing significantly to understanding of the space environment.

Recognising that radiation could also affect high altitude aircraft, CREAM was used on regular BA Concorde flights between 1988 and 1992 and it was the first programme to measure solar-particle events in air flight during the events of September and October 1989. The system provided evidence of potential future problems and subsequently triggered an expansive programme of work on aviation radiation environment and effects.

RAE's pioneering work in the field of electric propulsion originally started in the 1960s with experiments around the first electron bombardment ion engine. The development of the T1 thruster was closely followed by the further thruster developments offering ever-improved performance and efficiency, although it wasn't until there was renewed impetus given to the Electric Propulsion programme in the mid-1980s that major breakthroughs were made.

The original satellite testing chamber was converted into an ion thruster test facility, and was also joined by two more large chambers, creating one of Europe's largest electric propulsion test facilities.

The progress eventually led to the UK-10 gridded ion thruster that was deployed for the first time on the Artemis communications satellite launched in 2001. Subsequent developments led to QinetiQ's T5 thruster operating for an unprecedented 35,000 hours on the GOCE satellite, the first of the Living Planet Programme satellites operated by the European Space Agency (ESA).


# Mission-led innovation

The completion of a brand new state-of-the-art cleanroom facility in Kruibeke, Belgium, for the integration, testing and production of satellites and docking systems has further consolidated QinetiQ's status as a leading player in the sector.

Belgian astronaut, Frank de Winne, opens QinetiQ's new €3m cleanroom facilities in Kruibeke, Belgium, October 2019.

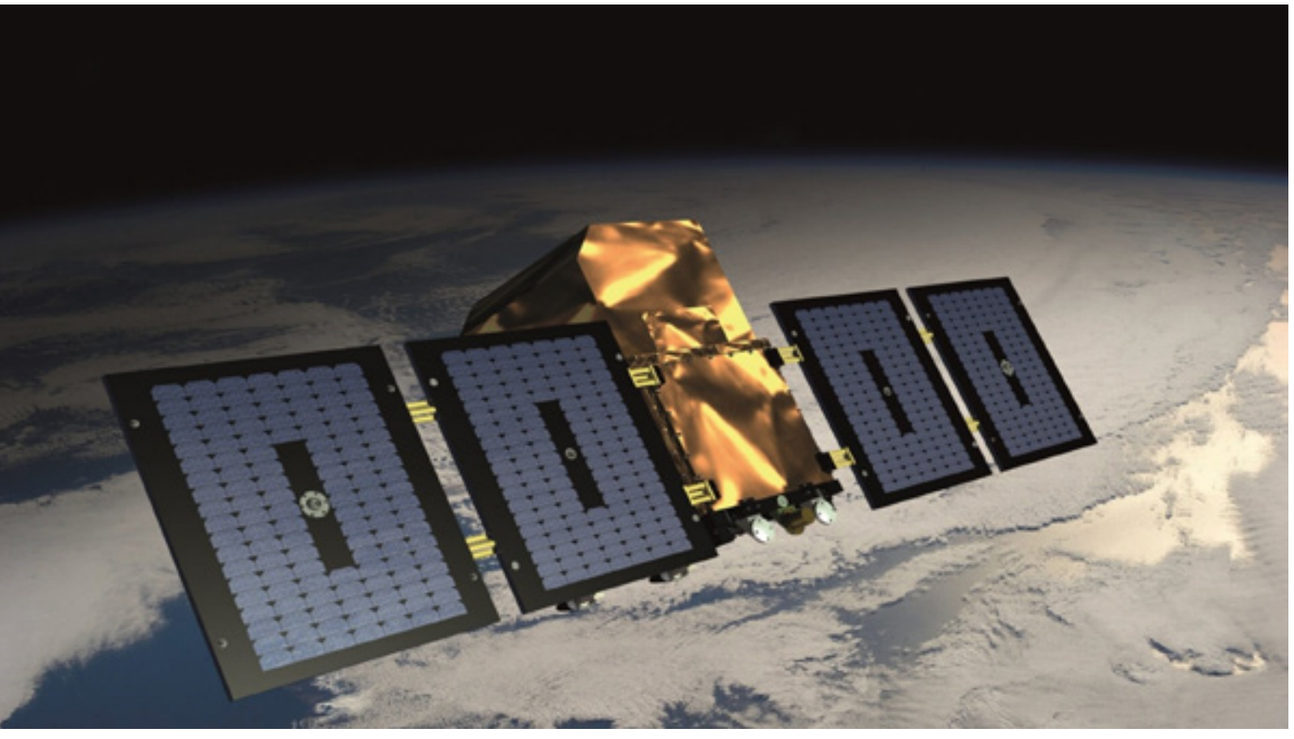
The company is also actively involved in the operational management and maintenance of satellite infrastructure and In-Orbit Testing campaigns. Redu Space Services in the Ardennes region of Belgium is a joint venture between QinetiQ and SES Techcom. An IOT Centre of Excellence, this specialist operation provides full Launch and Early Orbit Phase services, Telemetry, Tracking and Control services, Payload Management and Control and infrastructure hosting as well as integrated applications and downstream services – such as satellite communications, earth observation and navigation.

A wide range of space facilities are still hosted at Farnborough. These include ISO 7 and ISO 8 cleanrooms as well as a range of small vacuum chambers providing thermal/vacuum and electromagnetic compatibility test capabilities for qualification and acceptance tests of space communication systems.

QinetiQ has pioneered many significant developments in new communication technologies, with the company securing some notable successes in this rapidly developing area of technology. For example, the company designed, built and tested the Mars Express Lander Communications system (MELACOM), an instrumental part of the Mars Express spacecraft. Having arrived at Mars in 2003, this transceiver continues to demonstrate its performance and reliability, playing a significant part supporting the data relay from NASA's Mars Exploration Rovers (Spirit and Opportunity). It has also provided support during Entry, Descent and Landing phases for NASA's Phoenix lander, Mars Science Laboratory (Curiosity) rover and ESA's ExoMars Schiaparelli EDM mission. In addition and following a recent software upgrade, the system is now providing new radio science capabilities.

QinetiQ developed the Beagle-2 lander and ExoMars UHF transceiver used as a mission-critical system for the Schiaparalli, Rosalind Franklin and Kazachok missions. It has also completed exhaustive work for the Dual UHF/X-band (DUX) transceiver project, Lunar Communications and Software Defined Radio (SDR) transceiver programmes.

More recently, the company has conducted extensive trials to show that a specially shielded communications system could survive a hard landing on the surface of a moon or planet. Despite being subjected to violent impact speeds up to 300metres per second and peak loads up to 35,000 times the force of gravity, the communications system concealed within QinetiQ's Space Penetrator remained fully operational. Such developments are set to open new doors in space exploration as a hard lander overcomes the huge expense of soft-landing spacecraft. It also facilitates the use of lighter and more compact designs and enables exciting data to be obtained from below the surface.




# Flexibility and new capabilities

In other areas, the company has developed a revolutionary low impact docking solution to overcome the limitations of conventional docking systems and set a new standard for versatility, safety and performance. The International Berthing and Docking Mechanism (IBDM) is a fully computer-controlled solution that offers improved control and faultless alignment to maximise flexibility on both cargo and crewed spacecraft as well as heavy and very lightweight vehicles.

Using innovation to deliver the best operational outcomes for customers also led the company to develop an Advanced Data Power Management System (ADPMS) for small satellites. QinetiQ is now building on this system's success, proven resilience, agility and operational performance and is developing the third generation of the company's redundant on-board computer – the ADPMS3.

The company's involvement on a range of deep space missions is also continuing to gather momentum. The QinetiQ-engineered Solar Electric Propulsion System (SEPS), for example, is on board the BepiColombo spacecraft as it makes its way across the solar system to Mercury following its launch in October 2018.

Building on the success of the T5-powered GOCE spacecraft mentioned earlier, this is the most powerful and high performance electric propulsion system ever flown. The four QinetiQ T6 thrusters emit beams of high-velocity charged particles from xenon gas, using electricity generated by solar panels, to enable the joint ESA/JAXA spacecraft to counteract the enormous gravitational pull of the Sun and achieve the demanding orbital trajectory required to reach Mercury.

This advanced form of propulsion achieves astonishing fuel efficiency allowing the spacecraft to carry a large quantity of scientific equipment.

A total of 23 ion thrust arcs will help to ensure the BepiColombo spacecraft follows the correct interplanetary trajectory to arrive at Mercury in late 2025. This will entail no less than nine flybys of Earth, Venus and Mercury and 18 loops around the Sun before it eventually arrives at the least explored inner planet to gather unprecedented data and insight during a year-long mission.

Recent contracts secured by QinetiQ have included the development, assembly and testing of the ALTIUS satellite for the European Space Agency as well as the delivery and operation of a new In-Orbit Demonstration (IOD) satellite for the European Commission.

Both of these new satellites capitalise on the latest generation of QinetiQ's highly successful PROBA Platform - the P200. This advanced platform provides inherent flexibility and is not only compatible with a wide range of launch rockets but also has simple electrical interfaces, standard protocols and optional specifications for a diverse array of payloads.

Due for launch from French Guiana by the end of 2023, ALTIUS will use advanced spectral imaging technologies to monitor the Earth's atmospheric limb in the Near Ultraviolet, Visible, and Near Infrared spectral regions. The IOD satellite will provide public agencies and commercial enterprises with affordable access to space demonstration and validation to support the increasingly significant market for technological innovation, de-risking and concept testing.

QINETIQ

# TRUSTED TO DESIGN AND DELIVER MISSION SUCCESS

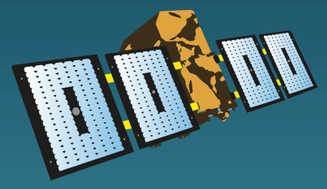
Over 100 mission-years in orbit delivering observation, platforms, science, navigation, propulsion, and secure communications support across military, security and civil space sectors

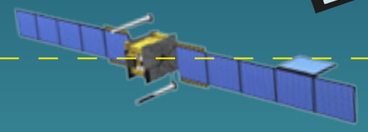
### DEEP SPACE COMMUNICATIONS

Supporting the Lunar Gateway with cutting edge docking mechanism technology and deep space communications to Mars

### SMALL SATELLITE DEVELOPMENT AND MANUFACTURING

Highly manoeuvrable, autonomous and versatile small satellites, such as our hugely successful PROBA series, with advanced subsystems, onboard computers and avionics with the capacity to carry sophisticated payloads





### SECURED NAVIGATION

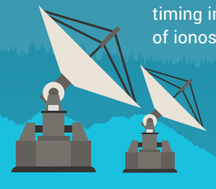
Secured, accurate navigation, positioning and/or timing for mission-critical activity, including the development of multi-constellation satellite receivers under the UK Robust Global Navigation System (R-GNS) programme

### PROGRAMME AND MISSION ASSURANCE

Mission assurance and procurement expertise including the long term support of Skynet MilSatCom programme

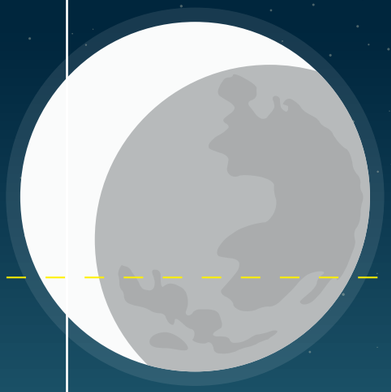
### SPACE SITUATIONAL AWARENESS

Capability to detect, track and identify artificial objects, debris. Highly accurate and resilient position, navigation and timing information. Forecasting impacts of ionospherics on satellite systems



### CYBER ASSURANCE & SECURITY

Ground stations and secure operations centres that host, operate and maintain Comms infrastructure, including protective monitoring, hosting and intrusion detection



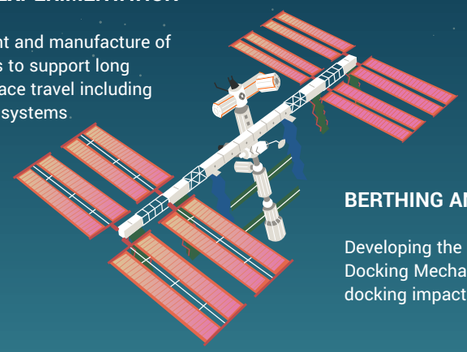
### ION THRUSTERS

Super-efficient, high-powered ion thrusters designed for commercial or scientific missions

DEEP SPACE EXPLORATION

### SCIENCE EXPERIMENTATION

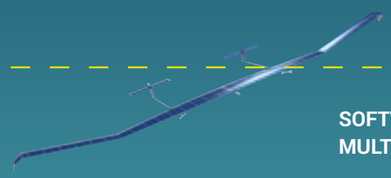
Development and manufacture of experiments to support long distance space travel including life support systems



### BERTHING AND DOCKING MECHANISM

Developing the International Berthing and Docking Mechanism (IBDM) to deliver safe, low docking impact for large and small spacecraft

SPACE



### SOFTWARE DEFINED MULTIFUNCTIONAL LIDAR (SDML)

SDML capability including novel agile LIDAR architecture; Low SWaP sensing flexibility and optical communications mode that overcomes challenge with standard RF

### TEST, EVALUATION AND MANUFACTURING FACILITIES

State-of-the-art cleanroom facilities with manufacturing capability

### SPACE LAUNCH RANGE SERVICE

Assuring the safety, environmental sustainability and security of customer launch operations through provision of range planning, surveillance, command and control and launch monitoring services

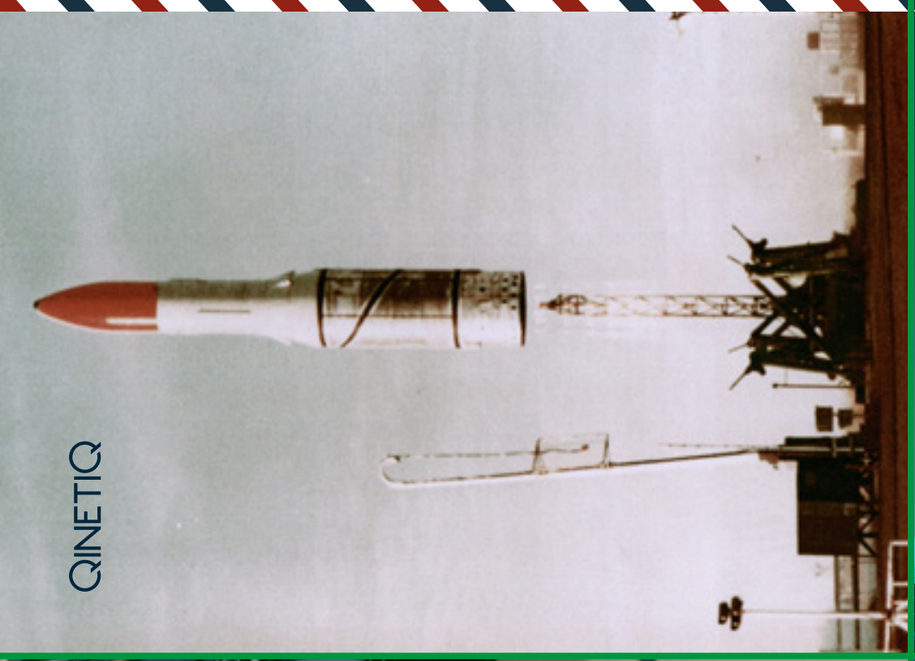
EARTH

QINETIQ

QinetiQ's long and successful history in space has been founded on the insight and specialist expertise of its growing team of scientists, engineers and researchers. Since its formative days, the team has pushed boundaries, opened new doors and harnessed new technologies to extend capabilities and improve performance of evermore complex and sophisticated spacecraft and systems. Significantly, however, the company continues to rise to new commercial challenges and opportunities with a strength and resolve founded on the successful delivery of so many innovative solutions that have not only helped to fulfil mission outcomes and stood the test of space travel … but also the test of time!

We thank our partners and customers for their support.

**www.QinetiQ.com/space**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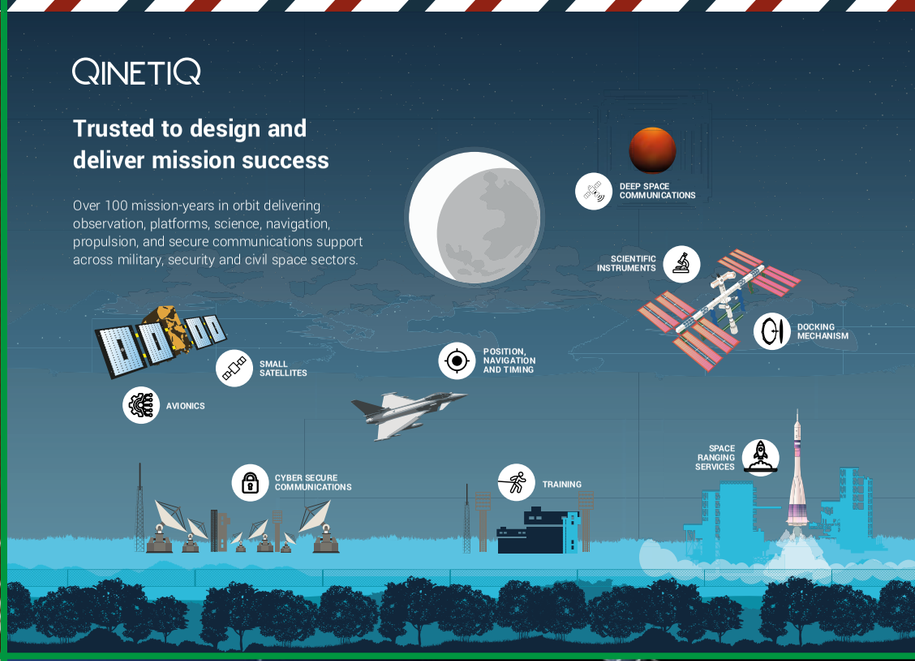
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DEEP SPACE COMMUNICATIONS
SCIENTIFIC INSTRUMENTS
DOCKING MECHANISM
POSITION, NAVIGATION AND TIMING
SMALL SATELLITES
AVIONICS
CYBER SECURE COMMUNICATIONS
TRAINING
SPACE RANGING SERVICES


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