UK SPACE AGENCY

National Space Technology Programme


UK SPACE
AGENCY

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PROGRAMME OVERVIEW

Introduction

Space technology is critical in providing UK citizens and businesses with the public infrastructure and security necessary to underpin societal and economic wellbeing.

The National Space Technology Programme (NSTP) launched in 2011 as a result of the Space Innovation and Growth Strategy's recommendation to "increase the UK's returns from Europe by continuing to grow the UK's contributions to European Space Agency (ESA) programmes and securing greater influence in large European-funded programmes."

NSTP exists to develop space technology and capabilities, underpinning growth in the UK economy, as set out in the UK Civil Space Strategy. A central aim of the programme is to sufficiently de-risk technologies to become commercially attractive propositions. We are ensuring that future space technologies are investigated, understood and nurtured.

New partnerships forged through NSTP funding have helped organisations of all shapes and sizes to capture new business and enable companies to position themselves for further funding and investment opportunities. NSTP has also helped established companies to move into the space sector, directly contributing to the national space growth agenda.

There have been two comprehensive evaluations of the NSTP to date. The first was completed and published on our website in November 2014. The second was completed and published in July 2018; a summary of which is published at the back of this booklet which I encourage you to read. The final reports of both evaluations are freely available on www.gov.uk/ukspaceagency.

The activities described in this document provide just a taster of some of the projects that we have funded across the 5 technology areas and 4 NSTP funding streams, of which you can find more detail in the following chapter.

For more information on the National Space Technology Programme, please contact the team at nstp@ukspaceagency.gov.uk.

Dr. Chris Castelli
Director of Programmes - UK Space Agency

Developing Space Technology in the UK

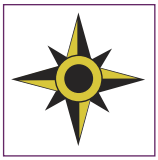
The National Space Technology Programme is a capability programme encouraging the development of the space technology sector in the UK.

The UK Space Agency's aim is to drive growth in the UK economy, supporting the development of space technology and skills as embodied in the UK Space Innovation and Growth Strategy.

NSTP offers support by funding industry, academia and other (not for profit) institutions who are looking to develop technology and build capability in the UK space sector; offering funding for organisations of all sizes, from start-ups to those more established on projects both large and small to contribute to the growth of the UK economy. Collaboration between organisations is strongly encouraged. The programme funds projects across 5 themes through the 4 funding types outlined on the next page.

Access to Space
Typical activities might include but are not limited to: space-plane and reusable launch systems; small satellite launcher and sub-orbital spaceplanes; small and nano platform technologies; inter-orbital transfer capability; fuel and propellant technologies.

Sensing
Typical activities might include but are not limited to: ultra violet,visible, infra-red and x-ray detectors; optical systems and lidar; active and passive microwave sensing systems; in-situ instruments; down-stream technologies and earth observation applications.

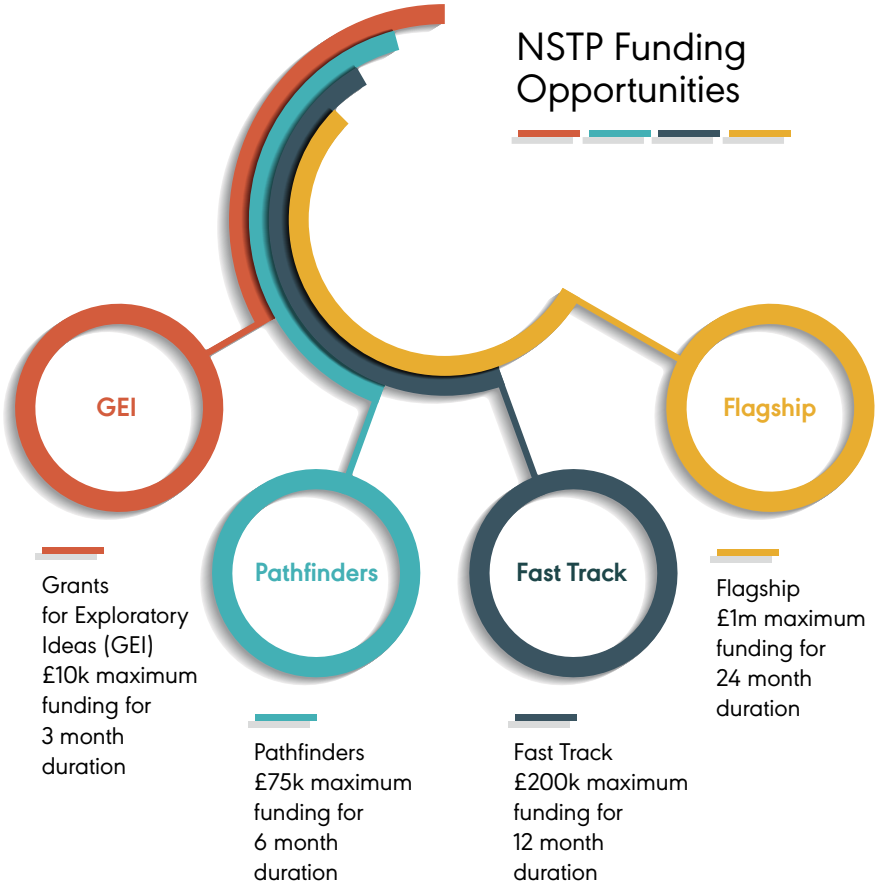


Position, Navigation & Timing
Typical activities might include but are not limited to: quantum precision; clocks and timing mechanisms; securing and exploiting navigation systems for increased security and radio frequency electronic equipment including navigation.

Robotics & Exploration
Typical activities might include but are not limited to: autonomous vehicles; robotic manipulators; novel power technologies; robotic support of manned exploration; robotic control, and rendezvous and docking.

Telecommunications
Typical activities might include but are not limited to: turnkey satellite systems; spacecraft platform, structure and composites; payload systems capability; satellite network operations, business support systems, services and applications; radio frequency electronic equipment including telecoms, communications for science and exploration missions.

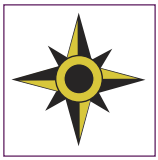
Overview of Funding Types



For more information please refer to the Missions and Programmes on www.gov.uk/government/organisations/ukspace-agency

CASE STUDIES





Compact Fibre-Based Optical Oscillator for Ground and Space Applications

National Physical Laboratory
Fast Track

Next generation Synthetic Aperture Radars (SAR) for Earth observation, ground based stations for deep space satellite tracking, satellite-to-satellite communication and future optical clocks in space, will all require access to improved optical and microwave frequency references. Remarkable progress has been made in the performance of both commercial and research lasers that serves as the optical frequency references. Research-grade lasers stabilized to ultra-low expansion glass (ULE) cavities have already demonstrated linewidths well below 1 Hz and stabilities as low as parts in 10^{17}. This level of stability is several orders of magnitude better than any commercially available laser. However, these exceptionally stable lasers are still largely used only in research labs because of their costs and size.

We developed and tested lasers stabilized to fibre-based optical delay lines instead of ULE optical cavities. Fibre-spool stabilized lasers are intrinsically more robust (no alignment required), easy to construct and assemble (no machining, no optical contacting of mirrors), lower cost and potentially more compact than cavity-based lasers. The delay lines used in our experiments are based on standard single mode telecommunication optical fibre (SMF) and on the emerging hollow core fibre technology (HCF). We used fibre spools of lengths of up to 1 km to generate a large path imbalance in an interferometric setup, acting as a laser frequency discriminator. We achieved a high level of suppression of environmentally-induced thermal fluctuations by placing the spools in a specially designed vacuum environment (SMF) or a temperature controlled sealed enclosures (HCF). With these setups we have demonstrated a laser frequency stability up to 1000 times better than the stability delivered by commercially available lasers.

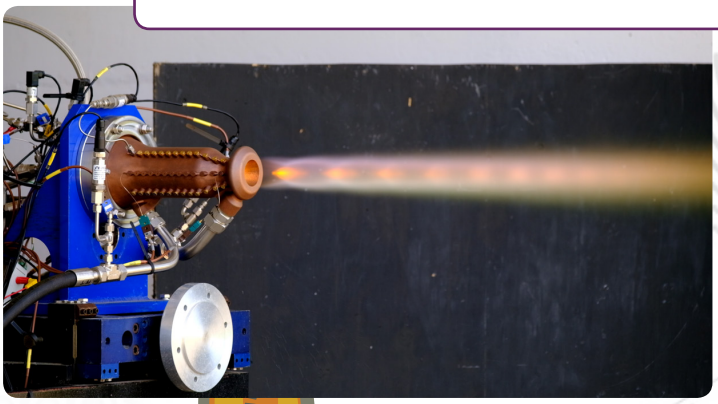
These state-of-the-art results demonstrate that lasers stabilized to optical-delay lines are capable of filling the performance gap between commercial and research-grade cavity-stabilized lasers. Through the know-how gained during this research, we are now able to identify a pathway to further performance improvements as well as to design choices for miniaturization and improved robustness, making this technology a very attractive low-cost solution for ground and space applications.

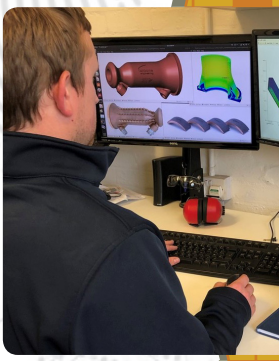
Application of New Alloys to Additively Manufactured Rocket Engines

Airborne Engineering Ltd.
Path Finder

Combustion Chamber Design

AEL used in-house knowledge and software to evaluate the performance of the CuCrZr alloy and design a representative combustion chamber. Small test pieces were printed to evaluate the limits of the printing process and optimise the design.





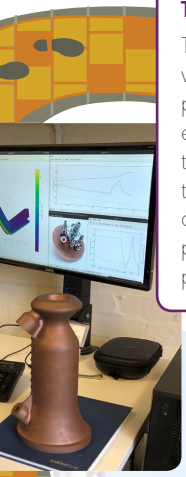
Additive Manufacture

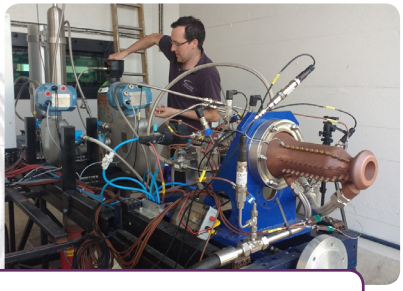
3T AM are a UK market leader in both plastic and metal materials. They developed the CuCrZr printing process having identified the potential opportunity in the space market. This project allowed them to validate their process on a real-life application and showcase the material's potential.

Airborne Engineering (AEL) have designed and tested the first additively manufactured liquid rocket engine combustion chamber to be fired in the UK, using a copper alloy pioneered for additive manufacture (AM) by 3T AM. Copper alloys have high thermal conductivity, which allows the combustion chamber to withstand the extreme temperature environment by transferring heat into a coolant fluid flowing through complex internal pathways. These pathways are difficult to manufacture using traditional methods. This project demonstrated that the new printable CuCrZr alloy could be game-changing for the production of low-cost, high-performance rocket engines for a variety of flight applications.

Testing

The combustion chamber was tested at AEL's Westcott propulsion test facility with excellent performance. This was the first AM copper chamber to be fired in Europe, and demonstrated responsive propulsion design, build and test purely within the UK supply chain.





Downstream Applications

This programme verified AEL's design process and provided confidence to proceed with higher performance engine designs. These could be used to power a multiple-use vehicle for sounding rocket and flying wind-tunnel experiments, suitable for launch from UK spaceports, or to extend the flight time and payload capacity of AEL's vertical take-off, vertical landing (VTVL) vehicle, which is the only flying VTVL vehicle in Europe and could pave the way for reusable rockets or autonomous planetary landing systems.

Thanks to Airborne Engineering Ltd and 3T AM for the use of the photographs.

"Colibri" Launcher – UK Operations Safety Demonstration

B2Space
Grant for Exploratory Ideas

The objective of this project is to demonstrate the safety of B2Space "Colibri" launcher operations. This has been done by studying the most suitable UK launch locations, both in terms of convenience for reaching target orbits, and potential risks for third parties. A set of locations were selected and then a risk analysis performed, to demonstrate that the risks are below the threshold that current Civil Aviation Authority and Federal Aviation Authority regulations set.

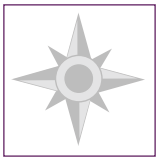
B2Space "Colibri" Programme is born to address the lack of capacity in the global satellite launching market. With that target in mind, the mission of B2Space is to provide an affordable, reliable and flexible launching system for small and micro satellites (<150kg).

This also solves the limitations that current micro satellite companies have to face nowadays, as currently they are launched as secondary payloads, with these disadvantages: design constraints due to main payload, limited decision on the schedule and not affordable for many new technology companies that could benefit from space access.

The system will work as follows:

A stratospheric balloon will lift up to 40km of height a self-operative platform from where to deploy the launcher, which consist of a 3 stage rocket, having a fully re-usable 1st stage. Saving propellant and cost by skipping the densest part of the atmosphere and gaining altitude up to 40 km, a smaller and low cost launcher will deliver the payload into the required orbits. This is done based on existing technology, improved and adapted to maximize performance.





Development of a Miniaturised Multi-Spectral Thermal Infrared Space Imaging System for Improving Volcanic Ash Monitoring

University of Bristol
Path Finder

Volcanic ash causes real harm to jet engines. It melts, and sticks to hot parts of the turbine and, at high enough doses, can cause engines to fail catastrophically. The 2010 Icelandic ash cloud crisis cost the airline industry alone at least £130 million per day, with a total loss estimated at £1.1 billion. As a result, the airline industry needs improved observations and forecasts of volcanic ash in the atmosphere. One way to better manage airspace would be to understand the three-dimensional structure of ash clouds. The University of Bristol, working with the Rutherford Appleton Laboratory (RAL Space, at STFC), is tackling this problem through the development of a miniaturised infrared camera system designed to be flown on a CubeSat (a shoebox sized satellite), that can detect and resolve volcanic ash clouds in three dimensions. The project is driven by undergraduate students, with over 100 students involved in the project so far. A critical part of the development is mission design. The students used the concurrent design facility at RAL, the first time it has ever been used by students, under the guidance of experts to plan the mission. This included trading choice of orbit height, power consumption, and the instruments' ability to detect ash clouds of different sizes and concentrations. We are delighted to announce that the students' hard work is going to come to fruition. This month PROVE was chosen by Lockheed Martin to be launched on their new orbital vehicle as part of the UK's Spaceflight programme.

Roadmapping for Commercial In-Orbit Demonstration

In-space Missions Ltd. Path Finder

In-Space Missions, along with the Knowledge Transfer Network, analysed the National Space Technology roadmaps and the Space Growth Partnership identified space markets. Building on an NSTP-2 GEI grant, 'Smart In-Orbit Demonstration ('IOD')', the team brought together a coherent and well examined set of technologies ready for exploitation on a series of technology enabled, service driven missions.

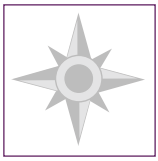
A Smart IOD mission is:

- Aligned – to UK needs
- Responsive – to market needs
- High Value – for investors by addressing the markets where a low-cost IOD/early service mission can deliver significant revenues
- Robust – in orbit by making use of tried and tested core platform technologies
- High Performance and Innovative – by exploiting cutting edge UK technologies to address existing or create new applications and markets

In-Space has consequently developed the commercial Faraday programme as its Smart IOD delivery and innovation platform with the first satellite now complete and awaiting launch later this year.

The credible set of useful 'small' UK Smart IOD missions defined via this study were Quantum Key Distribution IOD; Space Time real-time video from space; and GIoTTO – a relaxed latency 'Internet of Things' mission targeting low cost, low power user terminals. All of these missions are now under development by either In-Space or others in the UK.





Cost-Effective Micro-Vibration Isolation for Spacecraft with High Stability Requirements

The University of Surrey
Fast Track

Micro-vibration is a low-level disturbance produced by on-board mechanisms which can severely affect the performance of payloads with high stability requirements such as cameras and telescopes. With new commercial and scientific missions demanding an even-quieter satellite platform there is a need to come up with new solutions.

This project was aimed at developing the breadboard model of a novel, high-performance strut that has the potential to be a game changer in the perpetual challenge to mitigate micro-vibration on board spacecraft. The proposed technology is highly competitive in terms of isolation performance (complete elimination of the resonance peak and unprecedented reduction of high-frequency micro-vibration disturbances) as well as in terms of system-level benefits (the strut does not require a control algorithm or sensors and uses simple electronics that need little power to function).

The project has been a considerable success, achieving the original goals and taking the understanding of this system to more detail than initially planned. This technology has now reached between TRL 5 & 6, its isolation performance can be reliably predicted and the cost to get to TRL 8 is known.

Looking forward, SSC and SSTL have won a large ESA study to develop a high performance isolations system. SSTL is now in a position to baseline this technology for its ultra-high performance imaging spacecraft.

Smart Tanks for Space

Atout Process Ltd.
Fast Track

Atout is developing the Smart Tank for Space, which knows accurately its own contents – the mass of propellant, the distribution of the contents, how the contents are moving, and the magnitude of the forces exerted on the spacecraft due to the movement. This technology works in any gravity conditions and is well suited to solving real challenges in spacecraft design and operation. The technology is inherently safe and requires low power to operate.

The Smart Tank removes the large margin of error in mass estimation (currently up to 10%) required to ensure safe spacecraft operations at end of life. For a commercial satellite in geostationary orbit the Smart Tank can potentially extend the mission lifetime by up to 6 months or more.

This Fast Track project advanced the technology readiness level of the Smart Tank by integrating Atout's sensor technology into a real spacecraft tank, developing a full system demonstrator, and integrating the support electronics. A Smart Tank prototype was tested in representative operating conditions through a campaign of hexapod testing at DLR, Bremen, Germany

The project was jointly funded by UK Space Agency, Atout Process Ltd, and Catena Space Ltd. Results indicate that the performance of ECT measurements in a real satellite tank can be made to levels of accuracy better than 1% and is ready for engineering into real spacecraft.

Smart Tanks for Space development continues, recent success includes scaling up to to larger tanks and measurement of cryogenic liquids.

NSTP EVALUATION

Scope and Summary of Findings

The UK Space Agency commissioned Technopolis to evaluate the NSTP, focusing on its second round of funding (NSTP2, projects launched between 2014-2016). The objectives of the evaluation were to assess the benefit and impacts of the programme, its value for money (costs vs benefits), and the processes by which it has been delivered and implemented, all of which have been covered extensively in the full report.

It is important to note that most NSTP2 projects had only recently concluded (or were still ongoing) at the time of this evaluation.

Therefore, some of the core intentions of the programme (e.g. supporting entry to /expansion within institutional and commercial space markets) are only expected to be realised in the months and years after project conclusion. As such, findings are only preliminary at this stage. The infographic opposite highlights some of the key findings which came out of the evaluation.

- Most participants believe their NSTP2 project has increased the visibility and reputation of their organisation within the space sector (both to potential partners and funders)
- Most also believe it has improved their prospects within space markets, by increasing their attractiveness to funders and increasing the likelihood of securing contracts
- Most lead organisations report their NSTP2 grant has de-risked their project for further investment, including in most cases a reduction in costs and time to market for their idea/ technology
- Nearly all lead organisations believe their NSTP2 project may generate additional revenue for their organisation (for most the probability is 'high' or 'very high'). This is a strongly positive outcome, given that a certain level of project failure is expected when exploring early stage ideas and technologies

The full document can be accessed via the UK Government web-pages:

https://www.gov.uk/government/ publications/evaluation-of-the-national- spacetechnology-programme-nstp

The UK Space Agency would like to thank: All of the organisations and participants that contributed to this evaluation, Neil Brown, Cristina Rosemberg, Fraser Macleod, Charlotte Glass & Paul Simmonds of Technopolis Group, United Kingdom for their time and effort in compiling their report on behalf of the UK Space Agency.

National Space Technology Programme 2 *Key Impacts*

UK SPACE AGENCY

OBJECTIVES

- Developing UK space technology and capabilities
- De-risking technologies sufficiently to become attractive propositions for further investment
- Increasing the UK's return from European space-related programmes
- Growing the size and value of the UK space sector
- Positioning the UK to benefit from future space technologies

RAISED TRL LEVELS

67% of lead organisations report: TRL **1-2** → TRL **3+**

On application to NSTP2

At end of NSTP2 project

86% of lead organisations report: TRL **3-4** → TRL **5+**

PROJECT PORTFOLIO

120 projects	**£8.4M** in grants	**£69K average** per project
45	Grants for Exploratory Ideas (GEI)	£10K max
27	Pathfinder projects	£50K max
45	Fast Track projects	£150K max
2	Flagship initiatives	£1M

CODIFYING KNOWLEDGE AND KNOWLEDGE TRANSFER

- **16** publications in refereed journals
- **55** other publications
- **7** patent applications

produced by 54 respondents (~1/4 of all participations)

PROJECTS DE-RISKED

lead organisations report

63% reduction in the cost of their project idea or technology

77% reduced the time to market

INCREASED VISIBILITY AND REPUTATION

+90%

of lead organisations report increased attractiveness to institutional funders and likelihood of securing future contracts

95%

of NSTP lead organisations report improvements to internal knowledge, skills and capabilities

ECONOMIC IMPACT

£24.9M in estimated net impact

based on 33 respondents (~1/4 of NSTP2 project leads)

£7:1 return on investment (RoI)

79 jobs created or safeguarded

based on 39 projects (~1/3 of NSTP2 portfolio)

ENCOURAGING STRATEGIC PARTNERSHIPS

between industry and academia

HALF of supported projects include multi-organisation collaboration

93 separate UK-based organisations involved

- **69** Companies
- **21** Universities
- **3** other government-funded bodies

70% of lead organisations reported that their NSTP2 partners included ***new*** **collaborators**

technopolis |group|

UK Space Agency

The UK Space Agency leads the UK efforts to explore and benefit from space. It works to ensure that our investments in science and technology bring about real benefit to the UK and to our everyday lives. The Agency is responsible for all strategic decisions on the UK civil space programme. As part of the Department for Business, Energy & Industrial Strategy, the UK Space Agency helps realise the government's ambition to grow our industry's share of the global space market to 10% by 2030.

The UK Space Agency:

- supports the work of the UK space sector, raising the profile of space activities at home and abroad.
- helps increase understanding of our place in the universe, through science and exploration and its practical benefits.
- inspires the next generation of UK scientists and engineers.
- regulates and licences the launch and operation of UK spacecraft, launch operators and spaceports.
- promotes co-operation and participation in the European Space Agency and with our international partners.

V3 Published September 2019. Designed and printed by UKRI's internal service provider.