Results of Competition: Commercialising Quantum Technology: Large Collaborative Projects Round 1

Competition Code: 1908_CRD_CO_ISCF_QUANTUM

Total available funding is £23 million

Note: These proposals have succeeded in the assessment stage of this competition. All are subject to grant offer and conditions being met.

Participant organisation names	Project title	Proposed project costs	Proposed project grant
MICROCHIP TECHNOLOGY CALDICOT LIMITED	MAG-V : Enabling Volume Quantum Magnetometer Applications through Component Optimisation & System Miniaturisation	£547,330	£273,665
Cardiff University		£137,910	£137,910
COMPOUND SEMICONDUCTOR CENTRE LIMITED		£466,528	£279,917
COMPOUND SEMICONDUCTOR TECHNOLOGIES GLOBAL LIMITED		£461,567	£276,940
INEX MICROTECHNOLOGY LIMITED		£407,221	£285,055
NPL MANAGEMENT LIMITED		£449,648	£449,648
TATA STEEL UK LIMITED		£41,741	£16,696
University of Nottingham		£149,738	£149,738

Note: you can see all Innovate UK-funded projects here: https://www.gov.uk/government/publications/innovate-uk-funded-projects
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Project description - provided by applicants
Quantum magnetometers optically monitor the interaction between alkali-metal-atoms and an external magnetic field and detect the change in electron spin due to the magnetic field being applied. This allows the detection of micro-defects in materials and objects that are not visible or hidden from view. The MagV project will deliver the World's first commercial miniaturised rf atomic magnetometer that can operate in unshielded environments allowing general use and wide deployment. Primary applications have been identified in consultation with an extensive Industry Advisory Board, who have defined industry challenges driving the need for miniaturised-RF-quantum-magnetometers as novel sensors within non-destructive testing. The project brings together substantial research on quantum magnetometers with route to commercialisation through established VCSEL supply chain partners and an end-user to maintain UK leadership in quantum technologies.

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Arqit Ltd	Next Generation Satellite QKD - Creating a UK Sovereign Capability for Manufacturing Satellite QKD Payloads	£1,778,766	£1,245,136
AegiQ Ltd.		£542,411	£379,688
BRITISH TELECOMMUNICATIONS PUBLIC LIMITED COMPANY		£64,310	£32,155
FRAUNHOFER UK RESEARCH LIMITED		£411,243	£411,243
Heriot-Watt University		£443,387	£443,387
NU QUANTUM LTD		£350,000	£245,000
ORCA Computing Ltd.		£795,922	£557,145
STFC - Laboratories		£111,902	£111,902

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TOSHIBA RESEARCH EUROPE LIMITED		£2,186,094	£1,093,047

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Project description - provided by applicants
Quantum Key Distribution (QKD) facilitates the secure sharing of encryption keys using quantum technology. These keys can encrypt data for transmission over conventional fibre links across any distance, but QKD itself is limited over fibre to around 150km. Beyond this, 'trusted nodes' are required, but at major risk of creating security vulnerabilities. A number of fibre QKD networks are being built, including in the UK, but all are subject to this constraint. QKD through free space is less sensitive to distance. Thus, satellites provide the means for distributing keys across very large distances between end users spread across countries or continents - they are a facilitator of global QKD networks. Satellite components in QKD networks are being planned or researched in a number of countries. A consortium led by Arqit aims to establish the world's first commercial QKD satellite constellation. The first satellite is being build under contract with the European Space Agency, with a quantum payload being manufactured by European partners. There is an opportunity for the UK quantum technology industry to leapfrog other countries by creating a capability to manufacture the next generation of space QKD payloads here in the UK. The "Quantum Payload Factory" project will work with organisations across the UK to progress the state of the art of promising quantum communications technologies, understand their potential to enhance the performance of Arqit's global QKD system, validate their capabilities and technology readiness, engineer them to become "space ready" and develop an enhanced performance payload design that brings these new UK technologies into the second generation of Arqit satellites.

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QLM TECHNOLOGY LTD	Single Photon Lidar Imaging of Carbon Emissions (SPLICE)	£1,545,771	£1,082,040
Aston University		£24,550	£24,550
BAY PHOTONICS LTD		£209,999	£146,999
BP P.L.C.		£0	£0
COMPOUND SEMICONDUCTOR APPLICATIONS CATAPULT LIMITED		£179,824	£179,824
ID QUANTIQUE LTD		£954,690	£477,345
LAND INSTRUMENTS INTERNATIONAL LIMITED		£0	£0
NATIONAL GRID GAS PLC		£0	£0

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NPL MANAGEMENT LIMITED		£91,334	£91,334
University of Bristol		£195,830	£195,830
University of Sheffield		£264,000	£264,000

Note: you can see all Innovate UK-funded projects here: https://www.gov.uk/government/publications/innovate-uk-funded-projects
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Project description - provided by applicants
As natural gas becomes the leading fossil fuel, industrial gas leaks are becoming a major source of climate changing carbon emissions. The SPLICE project assembles a world-leading scientific and industrial consortium to develop and industrialise gas (methane) imagers based on time-correlated single photon counting, one of the early applications of quantum technology. This revolutionary UK technology will make accurate leak measurements at a fraction of existing costs, allowing the global gas industry to control fugitive gas emissions, help save many billions of £, and building a sustainable world leading business that reduces climate change. Shortwave infrared (SWIR) wavelength single photon avalanche detectors (SPADs) are emerging from initial applications to quantum telecommunication networks into new sensing applications, including vehicle lidar. QLM, a start-up out of the University of Bristol and QuantIC, the Quantum Enhanced Imaging Hub, and ID Quantique, the world leader in near IR single photon detection, have used non-cryogenic SWIR SPADs to demonstrate innovative, low-cost, highly sensitive, long range, single-photon lidar gas imagers that see and measure invisible toxic gases. These quantum gas imager prototypes have demonstrated outstanding performance, but the technology remains at prototype level, using individually packaged commercial-off-the-shelf (COTS) photonic and optical components and only addressing a single gas, methane, so is not yet ready for industrial use. The SPLICE project will be a major expansion of engineering talent and effort aiming to build the first scalable industrial product to come from the UK's £billion investment in quantum technology. The SPLICE team will innovate this technology into a flexible sensor platform that addresses key customer demands for robust, low cost and industrially qualified products that can simultaneously image multiple greenhouse gases. Commercial photonics experts QLM, IDQ, Compound Semiconductor Application Catapult and Bay Photonics will collaborate to expand the range of critical components, develop new multiple gas designs, start UK development of enabling SPAD detectors with the University of Sheffield, and expand work on new mid-IR quantum sensing architectures that can measure all possible gases with the University of Bristol. Together we will integrate the best of these new designs into compact state-of-the-art packages and develop and qualify complete networked IoT imager products to industry requirements. And then with gas emissions experts at the National Physical Laboratory and natural gas and industrial sensor leaders National Grid, Ametek, and BP we will validate our imagers' capabilities for commercial applications and start to address the multi £100m business opportunity.

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Participant organisation names	Project title	Proposed project costs	Proposed project grant
ADAPTIX LIMITED	Transforming Tissue Differentiation via Quantum Digital Tomosynthesis	£685,434	£479,804
KROMEK LIMITED		£777,389	£466,433
The University of Manchester		£538,040	£430,432

Note: you can see all Innovate UK-funded projects here: https://www.gov.uk/government/publications/innovate-uk-funded-projects
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Project description - provided by applicants
This application is about improving an existing medical imaging technique which is used during cancer surgery to distinguish between healthy and non-healthy tissue. The improvements will rely on the application of 'quantum technology'. Pathology is the study and diagnosis of disease through examination of surgically removed organs, tissues (biopsy samples) and fluids. When a cancerous tumour is excised (taken out) the surgeon needs to be certain that all the diseased tissue has been removed, and therefore they also remove some surrounding tissue around the edge of the tumour (the 'margins'). The surgeon needs to be sure these margins are free of cancer and can be described as 'clear or negative'. Clear margins suggest all the cancer has been removed and is not able to spread, giving the best outcome for the patient. So, a highly sensitive method of differentiating between healthy and unhealthy soft tissue is vital, and also between soft and hard tissues (bones). The establishment of these 'clear tissue margins' is best done whilst surgery is ongoing -- so the technique also needs to give accurate 3D images quickly and not take up much room in a busy operating theatre. Currently this is done via 'pathology cabinets' which give 2D or 3D images - but are often are slow (several minutes) and bulky (similar to a filing cabinet). The need is for more accurate differentiation of the boundaries between the tumour and healthy tissue, enabling surgeons to make confident real-time decisions during operations. The equipment also needs to be cost-effective, have a small footprint in the operating theatre and give accurate, easily understandable images. This grant would be used to build a prototype of a new type of pathology cabinet -- using quantum technology applied to both key parts of the system (the X-ray source & detector), plus new software to produce high-resolution material discriminating images (which are also better suited for the training of machine learning and application of Artificial Intelligence). The resulting images would give better differentiation between cancerous and healthy tissue, enabling surgeons to confidently remove the minimum amount of healthy tissue whilst being sure of clear margins. This will benefit healthcare providers in terms of better patient care, reduced workflow and costs, and most importantly, improve outcomes for patients in terms of reduced risk of more than one operation and a reduced chance of cancer spreading from positive margins left after initial surgery.

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TOSHIBA RESEARCH EUROPE LIMITED	Single Photon Infrared Imaging, Detection and Ranging (SPIDAR)	£2,305,892	£1,152,946
BAY PHOTONICS LTD		£392,970	£275,079
COMPOUND SEMICONDUCTOR TECHNOLOGIES GLOBAL LIMITED		£541,345	£324,807
Heriot-Watt University		£298,136	£298,136
HORIBA MIRA LIMITED		£82,346	£41,173
IQE PLC		£885,681	£442,840
JAGUAR LAND ROVER LIMITED		£141,213	£70,606
NETWORK RAIL INFRASTRUCTURE LTD		£11,457	£0

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THALES UK LIMITED		£103,505	£51,752
University of Cambridge		£243,522	£243,522
University of Edinburgh		£321,807	£321,807
University of Glasgow		£396,314	£396,314

Note: you can see all Innovate UK-funded projects here: https://www.gov.uk/government/publications/innovate-uk-funded-projects
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Project description - provided by applicants
This project will develop novel range finding and 3D imaging systems which will be used for driver assistance and the autonomous vehicles of the future. The cameras are based on detecting single photons (light particles) in the infra-red region of the electromagnetic spectrum. Depth information is gained by measuring the time of flight of the photons from the illuminating laser, to the object and back to the photon detector in the camera with sub-nanosecond precision. By detecting single photons, the faintest possible light signals, we will realise cameras that can 'see' further than the 3D cameras available today.

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COLDQUANTA UK LIMITED	High-BIAS2: High-Bandwidth Inertial Atom Source & Sensor	£1,287,978	£901,585
ALTER TECHNOLOGY TUV NORD UK LIMITED		£900,858	£450,429
BAE SYSTEMS PLC		£199,802	£99,901
CALEDONIAN PHOTONICS LIMITED		£286,719	£200,703
FRAUNHOFER UK RESEARCH LIMITED		£837,871	£837,871
PA CONSULTING SERVICES LIMITED		£68,103	£0
REDWAVE LABS LTD		£522,420	£365,694

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Project description - provided by applicants
Navigation using space-based satellite signals underlies many critical technologies across the UK. Most advanced navigation technologies rely on the signals from networks known as the Global Navigation Satellite System (GNSS) to remain accurate over long distances. Loss of these signals result in an unstable navigation systems and increasingly less accurate location and direction estimation during operation. GNSS signals may be lost accidentally from criminal activity or due to military action. For example, in 2018 several passenger flights off the Norwegian coast lost GNSS signals due to signal 'jamming' from military exercises. In addition, 'Spoofing' or deliberately transmitting false guidance signals has been demonstrated as an insidious cyberweapon that can deliberately mislead and fool cargo or passenger vessels. As systems are increasingly automated, the consequences of the loss of GNSS signals dramatically increase and may include loss of property, or in the extreme case, loss of life. Local on-board instruments can provide measurements to stabilise current navigation system technology without GNSS signals. Quantum technology-based sensors have the potential to provide stability to navigation systems over long periods of time due to the unique combination of high sensitivity to motion with superb isolation from changes in the surrounding environment. High-BIAS2 will demonstrate the ability of a quantum rotation sensor's ability to stabilise the orientation of aircraft guidance system in the absence of GNSS signals. Local stabilisation using quantum technology will decrease the reliance of navigation systems on GNSS and provides a measure of protection against signal loss, jamming, and spoofing to increase safety and security.

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BRITISH TELECOMMUNICATIONS PUBLIC LIMITED COMPANY	AIRQKD	£499,999	£250,000
ANGOKA LIMITED		£787,378	£551,165
Arqit Ltd		£401,676	£281,173
BAY PHOTONICS LTD		£305,640	£213,948
COMPOUND SEMICONDUCTOR APPLICATIONS CATAPULT LIMITED		£107,070	£107,070
Duality Quantum Photonics		£463,014	£324,110
FRAUNHOFER UK RESEARCH LIMITED		£421,117	£421,117
Heriot-Watt University		£309,495	£309,495

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NPL MANAGEMENT LIMITED		£299,467	£299,467
NU QUANTUM LTD		£2,498,000	£1,748,600
OPENLIGHTCOMM LTD		£405,901	£284,131
University of Bristol		£209,088	£209,088
University of Edinburgh		£261,085	£261,085
University of Strathclyde		£200,659	£200,659
University of Warwick		£336,770	£336,770

Note: you can see all Innovate UK-funded projects here: https://www.gov.uk/government/publications/innovate-uk-funded-projects
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Project description - provided by applicants
AirQKD establishes a UK ecosystem, from single-photon components to networked quantum systems, to protect short to mid-range communication in free space. In particular we carry out pilot demonstrations of the enabling infrastructure for quantum-secure 5G and autonomous and connected vehicles.

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AGM BATTERIES LIMITED	Quantum sensors for end-of-line battery testing	£617,526	£432,268
ALTER TECHNOLOGY TUV NORD UK LIMITED		£600,413	£300,206
CDO2 LIMITED		£631,091	£441,764
CENTRE FOR PROCESS INNOVATION LIMITED		£352,311	£352,311
COMPOUND SEMICONDUCTOR CENTRE LIMITED		£300,469	£180,281
COMPOUND SEMICONDUCTOR TECHNOLOGIES GLOBAL LIMITED		£215,176	£129,106
COSWORTH LIMITED		£198,800	£99,400
KELVIN NANOTECHNOLOGY LIMITED		£404,551	£202,276

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MAGNETIC SHIELDS LIMITED		£1,168,558	£701,135
University of Strathclyde		£525,215	£525,215
University of Sussex		£511,592	£511,592

Note: you can see all Innovate UK-funded projects here: https://www.gov.uk/government/publications/innovate-uk-funded-projects
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Project description - provided by applicants
It is anticipated that 50% of vehicle production will be wholly or partially electric by 2030\. This project aims to commercialise known quantum technology to address identified challenges in the manufacture of batteries and lithium cells. Quantum technology enables highly sensitive measurements of magnetic fields. This project will use these magnetic measurements to diagnose current flows in lithium cells and the consortium will develop a complete environmentally controlled ageing test production system deployed at the largest commercial powder to power lithium-ion and sodium-ion manufacturing plant in the UK (project lead: AGM). The system will be integrated into AGM's pouch cell assembly and test processes trialled on the range of High, Ultra High power, High Energy and Sodium-ion cells currently being scaled-up and commercialised for UK niche automotive market in particular. _Having gained global acclaim for best-in-class ICE's, Cosworth are perfect examples of what's best about the UK's high-performance automotive developers. Now they are seeking to build equally successful electric drive trains and only power cells of the very highest quality will suffice. The project is fortunate to have Cosworth as an active partner taking advantage of the Quantum Sensor technology ability to select A-Grade cells for the best hybrid battery performance and good lifetime state-of-health. The technology adds strength to 2nd life use of cells viability due to better SoH confidence through 1st life._ _In the next few years, the UK-BIC (Battery Industrialisation Centre) will be opened. This will be closely followed by AGM's parent company's AMTE GigaFactory which will be capable of manufacturing millions of cells in the UK every year. Like all cell manufacturers, AGM will be burdened with the bottleneck of cell formation and ageing processes. This project aims to significantly reduce this impact and also improve quality yields providing the ability to grade cells effectively. This could prove massively beneficial to the fledgling industry providing a competitive edge enabling AGM to take market share earlier._

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RIGETTI UK LIMITED	Quantum Computing Platform for NISQ Era Commercial Applications	£6,411,413	£3,846,848
OXFORD INSTRUMENTS NANOTECHNOLOGY TOOLS LIMITED		£1,483,166	£741,583
PHASECRAFT LIMITED		£972,488	£680,742
STANDARD CHARTERED BANK		£92,400	£46,200
University of Edinburgh		£1,035,979	£1,035,979

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Project description - provided by applicants
Rigetti Computing, Oxford Instruments, Standard Chartered, Phasecraft, and the University of Edinburgh will collaborate to advance quantum computing in the UK. The team will address several key aspects of quantum computing including: 1) hardware, infrastructure, and supply chain; 2) accelerating industrial applications; and 3) developing the quantum ecosystem to help solve important but currently intractable problems. This work positions the UK as a global leader in the emerging quantum industry, expected to be £4B by 2024, growing to £350B/year by 2050\. The project's main focus area are: _**1\. Infrastructure deployment**_ Rigetti will leverage its London-based team to assemble and operate a quantum computer in the UK, accessible via the cloud. This new investment into the UK's growing technology sector is an important milestone---no commercially available quantum computing platform currently exists in the UK. To support the infrastructure, Oxford Instruments will mature cryogenic technology reliability and provide initial hosting. To maximise long-term value, the team will migrate the infrastructure to align with national strategic initiatives such as the UK National Quantum Computing Centre. _**2\. Core applications development**_ Building on the infrastructure, the applications development team will validate the value of quantum computing to end users in the UK's economy. The approach builds on academic research and industry-led quantum software capability in the UK to transition knowledge to economic value. Phasecraft, a UK quantum software start-up, will build a quantum simulation work package that brings quantum computing to end users in the most promising near-term application area---quantum chemistry. Phasecraft is a UK quantum software start-up, founded by quantum computing researchers Toby Cubitt, Ashley Montanaro, and John Morton. From the University of Edinburgh, Professor Elham Kashefi's group will deliver quantum hardware verification and testing, with a focus on machine learning applications. They will also collaborate with Standard Chartered, complementing their work on financial synthetic data generation (Kondratyev & Schwarz, "The Market Generator"). _**3\. Broad initiatives to grow the UK's quantum computing sector**_ To demonstrate value beyond this project, the consortium will develop the UK's nascent quantum ecosystem to extend industry capabilities in finance, energy, pharmaceuticals, aerospace, and automotive. Through existing relationships and forums, the consortium will expand the community by delivering workshops, computing credits, and technical support, helping end users to validate their research and business concepts.

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