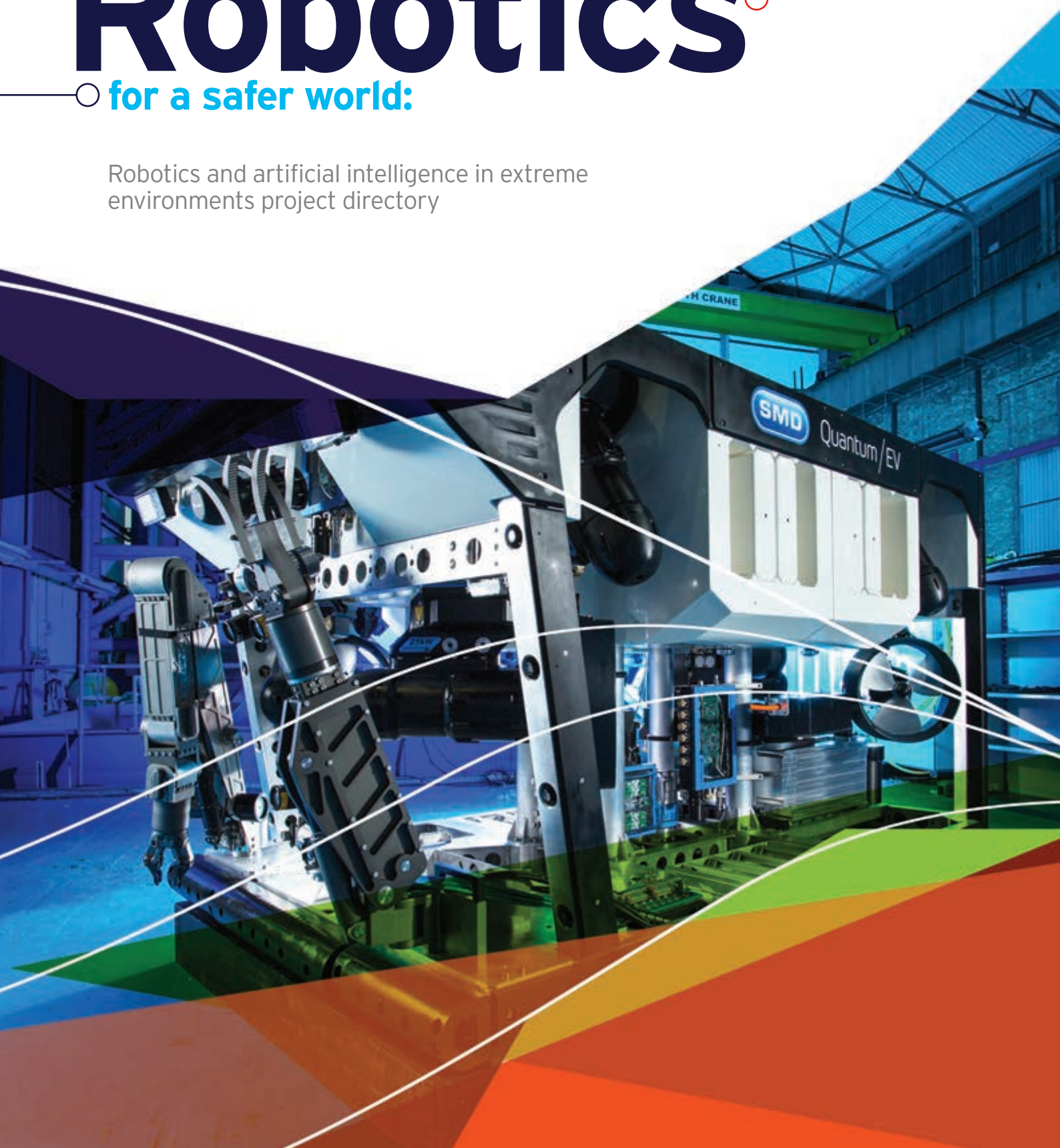
INDUSTRIAL STRATEGY

UK Research and Innovation

Robotics

for a safer world:

Robotics and artificial intelligence in extreme environments project directory



INDUSTRIAL STRATEGY

UK Research and Innovation

Contents

Challenge

When the case for Industrial Strategy Challenge Fund (ISCF) in Robotics and Artificial Intelligence (RAI) was written back in 2016, one of the key standout areas was extreme and hazardous environments. We were delighted when the £93m investment was confirmed; the task was then to rapidly take a business plan from paper to reality in a matter of months. In the last 3 years we have so far supported 149 unique organisations (106 businesses and 43 RTO's and Universities), funded 83 different projects across the offshore, nuclear, space and mining sectors and beyond and invested over £93m with another £80m+ invested in matched funding. We have also built a cohort of organisations all pulling in the same direction, bringing innovative products and services to market. We have compared ourselves on the international stage, with a Mission to the USA, visiting NASA at JPL, energy-based organisations in Houston, and nearer to home robotics clusters in Amsterdam and Rotterdam.

It is great to see we can compete on the international stage, both technically and commercially. The challenge is to turn that promise into reality and increase productivity in the workplace, while keeping people safe in these extreme environments. In this document, we highlight the projects and organisations we are supporting to deliver on that challenge and are proud to be associated with these leading world leading organisations.

Andrew Tyrer
ISCF Challenge Director
Robotics for Extreme and Challenging Environments

We have characterised extreme environments as places that are difficult or dangerous for humans to access. Robotics can take on the priority areas of 'The 6 Ds' – tasks that are dull, dirty, dangerous, demanding, distant, and distributed, carrying risks or demanding different skills to those available from humans.

The investment made by the ISCF will develop robotics and artificial intelligence systems that can carry out tasks in extreme environments such as the freezing depths of the North Sea, dealing with the process of nuclear energy production and decommissioning, the hostile vacuum of space and the heat of deep mining.

The current RAI market landscape

The market opportunities in this area are vast. For example, the global nuclear decommissioning market is currently estimated to be worth £50 billion per year by 2020. The total cost of nuclear decommissioning in the UK alone, mostly at Sellafield, is currently estimated at £60 billion.

Analysis by the National Nuclear Laboratory shows that 20% of the cost of complex decommissioning will be spent on Robotics and Autonomous Systems (RAS) technology. In the broadest terms, there is much to be gained from exploiting and extending our current strengths in robotics and artificial intelligence.

A recent report estimated that these technologies will have an impact on global markets of between $1.7 and $4.5 trillion per year by 2025[1] and the creation and expansion of innovative RAI related businesses would help boost growth, generating and protecting jobs in the UK.

The use of industrial robots is increasing significantly worldwide with a record 294,000 installed in 2016.[2] In the UK, Accenture estimates that automation and robotics could provide significant economic benefits over the next 10 years.[3]

- £183.6 billion of value to UK industry
- £15 billion of cost savings passed on to consumers
- 127,000 workplace injuries avoided

There's a significant opportunity for the use of robotics in extreme and challenging environments, driven by market pull from end users in key UK industries, such as energy and space, which deliver critical infrastructures in the UK and globally.

The robotics challenge offers more than £93 million in a 4-year programme that will develop robots and AI to take people out of dangerous work environments and go into areas beyond human limits. Currently the ISCF RAI in Extreme Environments programme has 3 delivery streams to provide funding to various projects around the UK. These fall under:

- collaborative research and development
- demonstrator competitions
- hubs

As of February 2020, £95.1 million has been committed through these delivery streams, complemented by around £80 million of industry matched funding. The breakdown of the committed spend to date from these delivery streams is shown in figure 1 below, with figure 2 highlighting the geographic spread of funding.

The details below illustrate the projects receiving this funding and demonstrate the cross-cutting nature of RAI with a broad range of activities that ISCF is funding to ensure that the UK remains at the forefront of this growing industry.

This document breaks down the funded activities into five environments:

- offshore (wind, underwater, ice)
- nuclear
- space
- mining
- cross-cutting – projects that cover different technological developments or could be applied across many industries

The following tables show the kinds of technology involved within the projects. You can use the links to help you navigate through the document.

1 McKinsey and Company "Disruptive technologies: Advances that will transform life, business, and the global economy", 2013

2 IFR - https://ifr.org/downloads/press/Executive_Summary_WR_2017_Industrial_Robots.pdf

3 Made Smarter Review 2017 - https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/655570/20171027_MadeSmarter_FINAL_DIGITAL.pdf

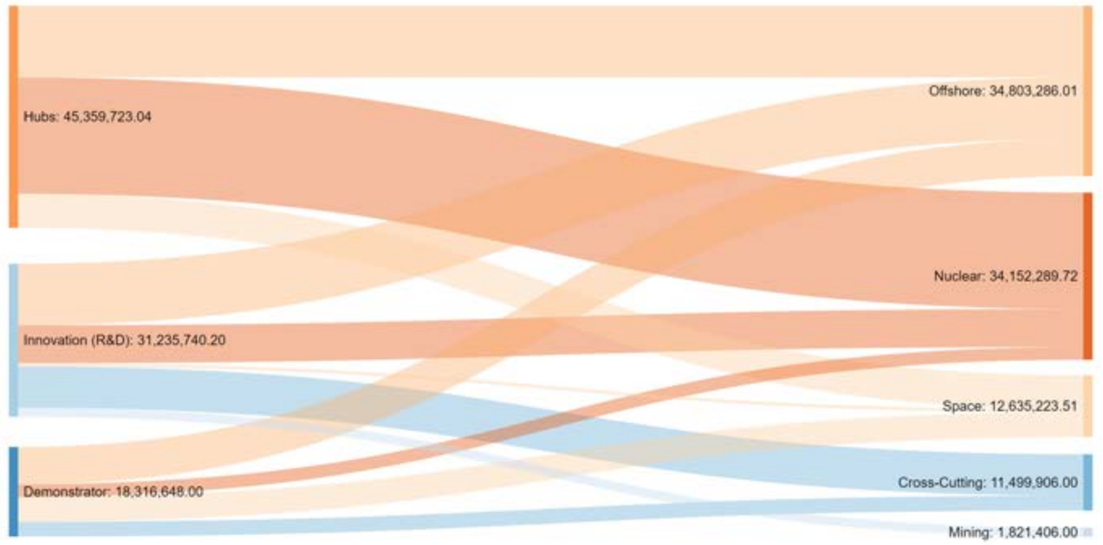


Figure 1 Sankey diagram showing commitment from the 3 delivery streams to extreme environments.

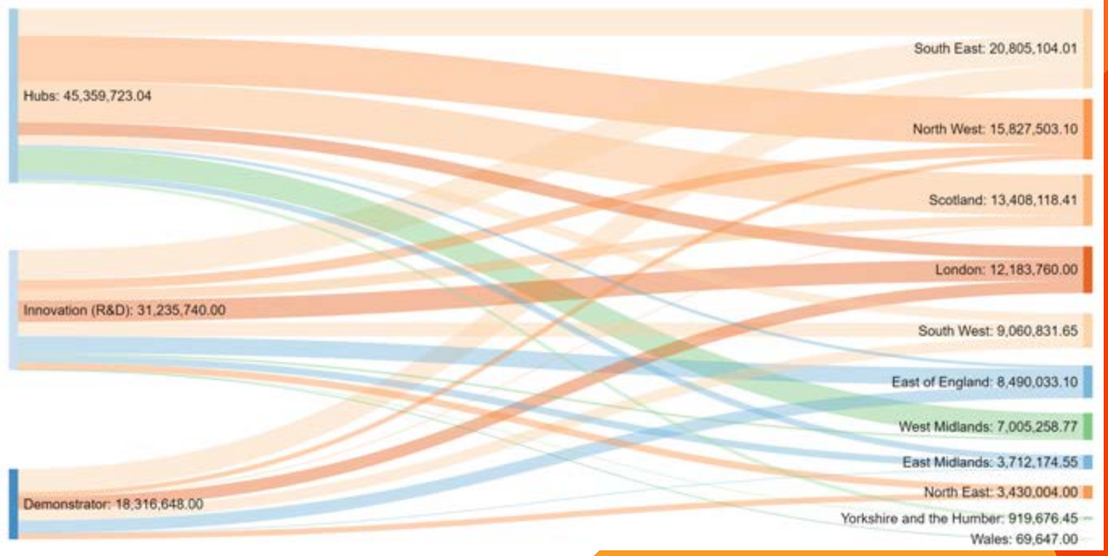


Figure 2 Sankey diagram showing funding to regional areas.

Completed Phase 1 Demonstrators with Phase 2 projects

In 2017, the ISCF Robotics for a Safer World programme ran the first stage of its demonstrator competition where it funded seventeen smaller projects. Of these, nine progressed to be funded as part of a second round in 2019. The first stage projects of those nine demonstrators are now closed and the second stage projects are underway. Listed below are the nine completed stage 1 projects with the title of their phase two project – please go to the page of the phase two project to get the latest information on these demonstrators.

Please note that this programme has funded additional demonstrators as a part of other activity so not all demonstrators are multi-stage – only those listed here.

Application title	Lead organisationname	Robot type	Phase 2 Project
Offshore			
Advancing underwater vision for 3D (AUV3D)	ROVCO Limited	AUV	Advancing underwater vision for 3D Phase 2 (AUV3D-P2)
Autonomous robotic intervention system for extreme maritime environments (ARISE)	L3Harris	USV/ASV and ROV	Autonomous Robotic Intervention System For Extreme Maritime Environments (ARISE) Stage 2
Autonomous, robotic and AI-enabled biofouling monitoring, cleaning and management system for offshore wind turbine monopile foundations – RoBFMS (Phase 1)	Innovative Technology and Science Limited	Service Robotics	Autonomous, robotic and AI-enabled biofouling monitoring, cleaning and management system for offshore wind turbine monopile foundations – RoBFMS (Phase 2)
Enabling technology for robotic inspection and maintenance of offshore wind turbine blades	Bladebug Limited	Service Robotics	Demonstrator for robotic inspection and maintenance of offshore wind turbine blades
In-service X-ray radiography of offshore wind blades (RADBLAD) (Phase 1)	Innvotek Limited	Service Robotics	In-service X-ray radiography of offshore wind blades (RADBLAD) (Phase 2)
Micro autonomous surface vessel (Micro-ASV) for inland waterway surveying	HydroSurv Limited	ASV	Unmanned Surface Vessels for Rapid Environmental Assessment in challenging inland waterways and tidal environments
Offshore infrastructure robotic inspection System (OSIRIS)	Autonomous Devices Limited	Service Robotics	Offshore infrastructure robotic inspection System (OSIRIS) Demonstrator
Space			
AI object detection hardware for space and polar region exploration	Myrtle Software Limited	Service Robotics	LEO Satellite Based AI Demonstrator
Cross-Cutting			
Watch chain for pipeline and border monitoring	Archangel Imaging Limited	Service Robotics	WatchChainR

Contents of this brochure

This brochure is an overview of the following projects that are funded either wholly or partially by the ISCF Robotics for a Safer World challenge. They are arranged by sector, in the order that starts on this page until page 17

Offshore

Application title	Lead organisation name	Robot type	Subsystem focus	AI/ Machine learning	Main activity/ operation
Advancing Underwater Vision for 3D Phase-2 (AUV3D-P2)	Rovco Limited	ROV	Stereo Camera System, Low-Bandwidth Comms, Mapping & Localisation	Yes	Inspection/ Maintenance
Amphibious robot for inspection and predictive maintenance of offshore wind assets-IFROG	Innovative Technology and Science Limited	AWCR - Amphibious Wall Climbing Robot	Platforms, Localisation and Sensing systems	No	Inspection/ Maintenance
AutoNaut for extreme environments	Autonaut Limited	USV	High latitude seas endurance, energy harvesting, ice detection and avoidance	No	Data collection at high latitude in all seasons
Autonomous Offshore Wind Farm Inspection	Perceptual Robotics Limited	USV/ASV and UAS	Sensing, localisation and mapping	Yes	Inspection
Autonomous Robotic Intervention System For Extreme Maritime Environments (ARISE) Stage 2	L3Harris	USV/ASV and ROV	Systems integration	Yes	Inspection
Autonomous, robotic and AI enabled biofouling monitoring, cleaning and management system for offshore wind turbine monopile foundations (RobFMS)	Innovative Technology and Science Limited	Service Robotics	Sensing, Autonomy and Cleaning systems	Yes	Inspection / Maintenance
Compact and cost effective; submersible subsystems for inspection	Deep6 UK Limited	ROV/ASV	Sensing for navigation and mapping	Yes	Inspection
Demonstrator for robotic inspection and maintenance of offshore wind turbine blades	Bladebug Limited	Multi-legged walking robot	Multiple articulated legs and sensors	No	Inspection/ Maintenance / Repair

Offshore

Application title	Lead organisation name	Robot type	Subsystem focus	AI/ Machine learning	Main activity/ operation
Enabling low cost AUV technology: Development of smart networks & AI based navigation for dynamic underwater environments	Planet Ocean Limited	AUV	Sensing and control	Yes	Navigation
Friction Stir Welding Crawler for Internal Repair and Refurbishment of Pipelines - FSWBot	Forth Engineering (Cumbria) Limited	AUV / PIG (scraper)	Sensing and control	Yes	Inspection/ Repair
In-service X-ray radiography of offshore wind blades (RADBLAD)	Innvotek Limited	Service Robotics	Mechanical design, radiography and machine vision	Yes	Inspection
Intelligent on-board processing of visual data for real-time situational awareness by Unmanned Surface Vessels (USVs)	Seiche Limited	USV	Smart remote sensing and monitoring	Yes	Inspection/ Monitoring/ Operation
Multi-Platform Inspection Maintenance & Repair In Extreme Environment (MIMRee)	Plant Integrity Limited	UAV/USV	Various	Yes	Inspection/ Maintenance / Repair
Offshore Infrastructure Robotic Inspection System (OSIRIS) Demonstrator	Autonomous Devices Limited	Hybrid (flying and crawling) mobile robot	Platform and sensing systems	No	Inspection/ Maintenance / Repair
Palantir - Real time inspection and assessment of wind turbine blade health	Braendler Engineering Limited	Drone, Crawler, ROV	Sensing and control	Yes	Inspection
Piglet – a new robotic solution to lower maintenance costs and improve safety in high pressure gas systems	Process Vision Limited	Service Robotics	Monitoring	No	Dehydration monitoring
Precise Positioning for Persistent AUVs	Sonardyne International Limited	ASV/AUV	Sensing and navigation	No	Operation

Offshore

Application title	Lead organisation name	Robot type	Subsystem focus	AI/ Machine learning	Main activity/ operation
Project Anemoi	Soil Machine Dynamics Limited	Subsea robotics and sensors	High power electric ROV, Cable Detection	No	Inspection/ Maintenance / Repair / Operation
SeaWynd: Autonomous Inspection of Seabed and Splash Zone Structures for Offshore Wind Arrays	MarynSol Limited	USV	Sensing, data fusion	Yes	Inspection
Shared Waterspace Autonomous Navigation by Satellites (SWANS)	BMT Ship & Coastal Dynamics Limited	USV	Sensing and control	No	Inspection
Team Tao XPRIZE	Soil Machine Dynamics Limited	AUV	Sensing	No	Operation
Offshore Robotics for Certification of Assets (ORCA) Hub	Heriot-Watt University (Edinburgh Centre for Robotics)	Hub	Various	Yes	All
Unmanned Surface Vessels for Rapid Environmental Assessment in challenging inland waterways and tidal environments	Hydrosurv Unmanned Survey Limited	USV	Platform, Command and Control, RF Mesh Comms	Yes	Inspection
Windfarm Autonomous Ships Project (WASP)	L3Harris	Service Robotics	Various	Yes	Operation
Dynamic Vessel Design Feasibility Study for subsea WITT Energy Harvester	Witt Limited	Stationary USV/ASV	Energy harvesting/ conversion sub-system	No	Operation
Environmentally Powered Integrated Thermoelectric Harsh Environment Robotic Magnetic Anomaly Locator (EPITHERMAL)	Nemein Limited	Experiment	Experimentation in interaction of electrothermal effects with magnetic effects	No	Feasibility study
HyRIZON for Maritime Protection	Archangel Imaging Limited	Service Robotics	Machine vision	No	Inspection
Robotic digital X-ray scanning system for deep water flexible riser inspection (RobotX)	Innovative Technology and Science Limited	AUV/Robot Crawler	Sensing and X-ray	Yes	Inspection

Nuclear

Application title	Lead organisation name	Robot type	Subsystem focus	AI/ Machine learning	Main activity/ operation
Alpha Glovebox Decommissioning Feasibility Study	National Nuclear Laboratory Limited	Modular Grasper	N/A	No	Operation/ Hazard Reduction / Safety and Efficiency
Automated Nuclear Decontamination Cell (AND-C)	Create Technologies Limited	Robotic Arm	automated scanning sensor payload to determine the localisation of radiological contamination	No	Inspection
Barrnon Integrated Decommissioning System	Barrnon Limited	Hazardous environments sensor platform	Various	Yes	Inspection/ Operation
Collaborative Technology Hardened for Underwater and Littoral Hazardous Environments	QinetiQ Limited	USV/ASV/UUGV	Sensing, SLAM and manipulation	No	Operation
Connect-R - Providing Structure in Unstructured Hazardous Environments	Barrnon Limited	Modular robotic ecosystem	Modularity, control, fluid power transfer, mechanical structure, reconfigurable structure	Yes	Inspection/ Operation
Elephants to Ants: Innovation in Integration	Create Technologies Limited	Mobile Robotics, Cobots, Manipulators	N/A	No	Decommissioning
National Centre for Nuclear Robotics (NCNR)	University of Birmingham	Manipulators, vehicles, drones, pipe crawlers, soft robotics	Various	Yes	All aspects of robotics for: new-build power stations; in-service maintenance and monitoring; decommissioning and waste handling
Nu-Decom	Nuvia Limited	Manipulators, 6DOF robotics	Various	No	Inspection/ Operation

Nuclear

Application title	Lead organisation name	Robot type	Subsystem focus	AI/ Machine learning	Main activity/ operation
Optical Stimulated Luminescence Detection of Beryllium within Nuclear Fusion Facilities (OSLB)	IS-Instruments Limited	COTS industrial robots	Remote sensing	Yes	Inspection/ Maintenance
Robotics and Artificial Intelligence for Nuclear (RAIN)	University of Manchester	Mobile (UAV, UGV, ROV), Fixed (tele-operated remote handling, continuum)	Various	Yes	Inspection/ Maintenance/ Repair/ Operation/ Decommissioning
Sellafield In-Cell Decommissioning System (SIDS)	Cavendish Nuclear Ltd	Service Robotics	System level	No	Decommissioning
Smart Radiation Sensor for Intelligent Nuclear Robots	Create Technologies Limited	Mobile Robotics	Smart radiation sensing	No	Inspection
Closed Loop Variable Buoyancy Lifting System for In-Pond Nuclear Retrievals	National Nuclear Laboratory Limited	Service robotics	Buoyancy and control	No	Operation
Integrated Innovation for Nuclear Decommissioning	Amec Foster Wheeler	Service robotics	Various	No	Decommissioning
Smart IMAging for Nuclear "SIMAN"	I3D Robotics Limited	N/A	Smart imaging	Yes	Decommissioning

Space

Application title	Lead organisation name	Robot type	Subsystem focus	AI/ Machine learning	Main activity/ operation
Assessing the feasibility of photonic transceivers for satellites and planetary robotics	Spacechips Limited	Planetary Robotics	Sensing	Yes	Operation/ Hazard Reduction / Safety and Efficiency
Feasibility study of active radiation shielding for electronics, sensors and photonics applications	Space Talos Limited	Planetary Robotics	Sensing space radiation	No	Inspection
Future AI and Robotics for SPACE (FAIR-SPACE)	University of Surrey	Various	Various	Yes	Inspection/ Operation
In orbit Servicing Control Centre National Facility	Astroscale	N/A	Robotic Capture system	Yes	Operation
LEO Satellite Based AI Demonstrator	Myrtle Software Limited	Remote satellite sensing	Machine learning object detection systems	Yes	Operation
Robotic In-Space Manufacturing Demo	Airbus Defence and Space Limited	Robotic assembly	Manipulator	No	Decommissioning
SMARTER - Space Manufacturing, Assembly and Repair Technology Exploration and Realisation	BAE Systems (Operations) Limited	Service Robotics	Autonomy, AI, ML and health monitoring	Yes	Decommissioning
Orbital Situational Awareness using Infrared Cameras	Neptec UK Limited	Service robotics	6DOF capability, sensor and actuator	No	Inspection/ Operation

Mining

Application title	Lead organisation name	Robot type	Subsystem focus	AI/ Machine learning	Main activity/ operation
Autonomous Robotic InSpEction (ARISE)	GMV	Mining Robots	Human safety	Yes	Inspection/ Operation
Prometheus - A reconfigurable robotic platform(s) with advanced sensing for confined spaces	Headlight AI Limited	Reconfigurable robot	Sensing and mapping	Yes	Inspection/ Operation/ Mapping

Cross-cutting

Application title	Lead organisation name	Robot type	Subsystem focus	AI/ Machine learning	Main activity/ operation
A UAV based logistice capability for use in military and civilian missions	Barnard Microsystems Limited	VTOL capable Panchito unmanned aircraft	Autonomous cargo transportation using unmanned aircraft	Yes	Feasibility study
AutoMINDER – Autonomous MarIne Navigation in Denied Environments	Sonardyne International Limited	ASV/ROV	Sensing and navigation	No	Inspection/ Repair
Autonomous Aquatic Inspection and Intervention (A2I2)	Rovco Limited	AUV	Autonomous inspection and intervention of underwater assets in both the offshore and nuclear industries using advanced 3D perception systems	Yes	Inspection
Autonomous Confined Space Inspection using Drones	Hybird Limited	UAV	SLAM	Yes	Inspection
Bathyscaphic Robotic Floor Thickness Monitoring of Hazardous Liquid Storage Tanks (NautilUS)	Monition Limited	Inspection robot	Internal floor inspection of storage tanks	No	Inspection/ Monitoring/ Operation
CHIMERA - Robotic Inspection of Pressure Vessels	Forth Engineering (Cumbria) Limited	Service Robotics	Various	Yes	Inspection/ Maintenance / Repair
COBRA: Continuum roBot for Remote Applications	Rolls-Royce PLC	Continuum Robot	Various	No	Inspection/ Maintenance / Repair
Developing a miniature robot to install a nervous system within non-man entry sewers	Nuron Limited	Sub-surface	Remote inspection, cleaning and installation, confined spaces	No	Inspection/ Operation/ Installation

Cross-cutting

Application title	Lead organisation name	Robot type	Subsystem focus	AI/ Machine learning	Main activity/ operation
INSPECT (In-situ optical inspection of engine components)	Rolls-Royce plc	Service Robotics	Various	Yes	Inspection
METIS Advanced - end-to-end solution for autonomous resupply	QuintiQ Limited	UGV/UAS	Planning, logistics, autonomous navigation	No	Operation/ Logistics Support
Nesta-FIying High Phase 1&2	Nesta	UAS/Drone	CONOPS/System Requirements	No	Operation
SIMVEE - Synthetic Imagery training for Machine Vision in Extreme Environments	L3Harris	USV/ASV	Sensing and navigation	Yes	Operation
The development of an ATEX zone 0 encoder for explosive environments (ATEX Encoder)	Innovative Technology and Science Limited	N/A	A contactless low-torque incremental/absolute encoder to ATEX Zone 0 specification	No	Operation/ Other – wherever an encoder for extreme explosive environments is required
WatchChainR	Archangel Imaging Limited	UGV, UAV and unattended sensors	Systems Integration	Yes	Inspection/ Maintenance / Operation
WormBot	Q-Bot Limited	Service Robotics	Sensing, actuators and control	Yes	Inspection/ Operation
Enhanced Performance of Robotic Drilling Tools using High Frequency Vibration	Magna Parva Limited	Service robotics	Actuator and end-effector	No	Dehydration monitoring
Infrastructure for Drone Operations	Herotech8 Limited	UAS/drone	Landing	No	Operation

Offshore

The projects in offshore energy include one Innovation Hub, nine Phase 1 Demonstrator projects, seven of which proceeded to a second phase Demonstrator, and 17 CR&D projects. There is also a specially funded demonstrator project that was entered into Shell's XPRIZE competition in 2018, TeamTao. Three of the CR&D projects are from the programme's most recent competition focussed on Electronics, Sensors and Photonics in Extreme Environments.

These projects address sensing, control, actuators, mapping and navigation, and vehicle design, with many of them addressing UAVs, USVs and UUVs; cases with crawler and climbing robots also exist.

Advancing Underwater Vision for 3D Phase-2 (AUV3D-P2)

Summary of the project aim

AUV3D-P2 will develop a next-generation Intelligent Data Collection System, capable of building metric models of subsea assets, whilst live streaming the data back to shore over low bandwidth links. The project will augment the 3D and video data with integrated Machine Learning to generate key metrics for subsea inspection and automatic reporting.

Project information

Project lead: Rovco Limited
Collaborators: Offshore Renewable Energy Catapult
Project type: Demonstrator
Total project cost: £1,287,366
Grant award: £1,003,109
Start date: December 2018
End date: May 2020

Executive Summary

Inspection of subsea infrastructure is currently expensive, time-consuming, dangerous and imprecise. The AUV3D Phase-1 Project developed a now commercialised Intelligent Data Collection System – SubSLAM X2- that solves each of these problems for the industry. Now, Phase-2 of the project (AUV3D-P2) is enhancing the capabilities of this same technology, applying Machine Learning and Artificial Intelligence to generate key metrics of subsea inspection and automatic reporting, eradicating human error.

The SubSLAM X2 Intelligent Data Collection System allows precise monitoring of asset condition and in-the-field measurements by producing centimetre accurate metric models in real-time. The project pushes the boundaries of underwater SLAM performance to allow the use of robots, where previously divers were necessary, removing people from harm's way and reducing costs.

The SubSLAM X2 system is small enough to mount on an observation class ROV, and therefore launch from a smaller vessels. The visual SLAM system allows mapping of a subsea environment without additional infrastructure or prior knowledge of the area. When removing the need for large vessels or complex positioning infrastructures, the technology reduces total survey by tens of thousands.

Machine Learning techniques for the underwater domain will be instrumental in bridging the big data-information gap, drastically cutting the lag between data collection and decision making. A typical subsea survey produces huge volumes of data, which then needs subsequent analysis by a human expert. Handing this task to computers, during the data collection phase, eliminates common human error, and produces accurate, reliable and repeatable results that guide business decisions.

By combining the technology's capabilities with a web-based Intelligent Data Delivery Platform, AUV3D-P2 will provide secure, real-time access to information of subsea asset integrity to any device, anywhere in the world, without the need to send people into hazardous offshore environments.

What is the value or size of the addressable market?

The European offshore wind O&M market is worth circa £1.6bn/year with subsea work accounting for 25% to 40% of this figure. Research suggests annualized growth of 17% year-on-year between now and 2028, giving a figure of £5.8bn/year in Europe, and an additional £3.7bn worldwide.

Besides Offshore Wind, Oil and Gas inspection provides another market. Operators forecast total decommissioning spend on the UK Continental Shelf will be £17 billion between 2017 and 2025, with an additional £2-4bn on the Norwegian Continental Shelf and £650-800m on the Dutch Continental Shelf.

Project Plan / Progress

As of January 2020, AUV3D-P2 has achieved many of the technical goals set out by the project. Phase-1 of the project, SubSLAM X2, has been integrated and tested at the Offshore Renewable Energy Catapult's facility in Blyth and is now commercialised in the industry, worldwide. Testing for Phase-2 of the Systems' capabilities is planned for April in a TRL-7 environment off the coast of Northumberland.

Unique 3D data streaming capability has been demonstrated over low bandwidth links, providing subsea data, live, to any device, anywhere in the world, via Rovco's Intelligent Data Platform. Machine learning algorithms have also been applied to a live data stream with results delivered through the same web interface, proving the system design and paving the way for Autonomous Offshore activities, improving safety, efficiency, and reducing the carbon footprint across the sector.

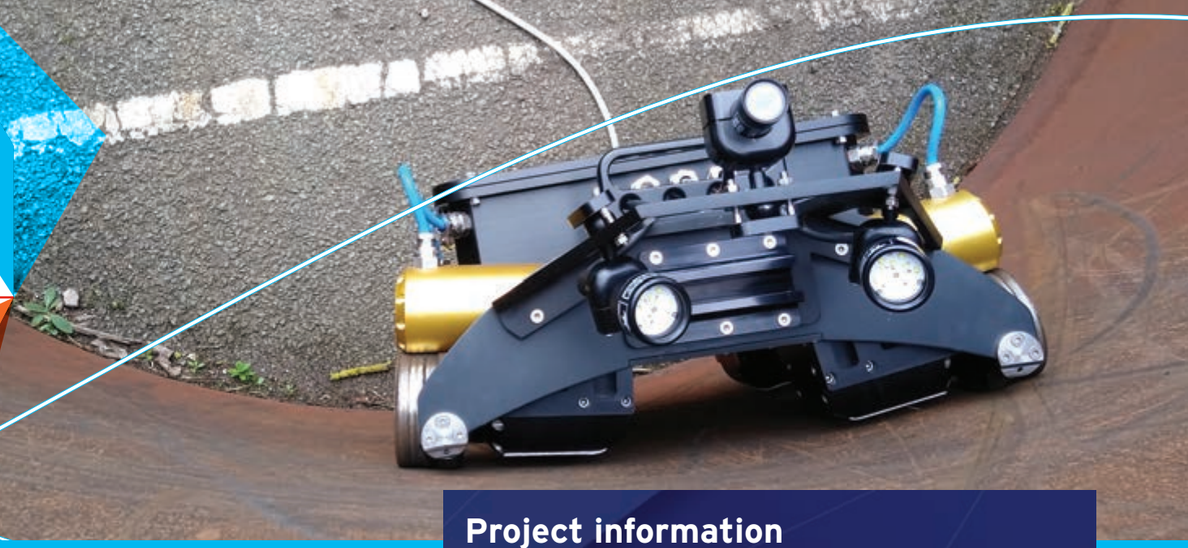
At the Offshore Renewable Energy Catapult centre in Blyth, a bespoke monopile test rig has been manufactured and delivered for representative system testing in a controlled environment. Machine learning models developed during the project have already proven themselves capable of a variety of tasks.

Rovco's Series A investment during Q4 2019 has allowed the commercialisation of the SubSLAM X2 Intelligent Data Collection System, and will enable Phase-2 of the technology to be brought to market, rapidly.

ROVCO OCEAN INSIGHT

CATAPULT Offshore Renewable Energy

Amphibious robot for inspection and predictive maintenance of offshore wind assets - IFROG



Summary of the project aim

IFROG will deliver an innovative multi-robot maintenance solution for offshore wind assets. The technology aims perform NDT inspections of monopile foundations and transform maintenance from reactive, hazardous, and expensive to preventative, safe and cost-effective.

Project information

Project lead: Innovative Technology and Science Limited
Collaborators: Offshore Renewable Energy Catapult, TWI Limited, Brunel Innovation Centre
Project type: Collaborative Research and Development
Total project cost: £1,348,543
Grant award: £1,028,211
Start date: March 2018
End date: November 2020

Executive Summary

Present maintenance in the offshore industry is reactive rather than preventative. This means that the damage to the base monopile of a turbine, such as cracks, holes, or bending, is assessed after it has already occurred.

Inspection of monopile foundations is currently performed by divers or remotely operated underwater vehicles (ROVs) that require a boat transfer to deliver the specialists and equipment to the wind turbines. For offshore farm owners, this represents a massive hiring cost, since these transport companies operate as taxis. Moreover, the inspection which the divers and ROVs provide is not a structural assessment, but only a visual check.

Offshore wind foundation inspection and maintenance account for approximately 65% of total operation and maintenance costs. More than 50% of those costs are due to scheduled hazardous diver-based visual inspections or corrective inspection and maintenance.

In collaboration with partners, InnoTecUK is developing a new methodology for preventative maintenance of offshore wind assets – a multi-robot solution named iFrog.

IFROG is a team of two mobile robotic crawlers. The first robot performs water jet cleaning of the monopile foundation in air and sub-sea. It is also able to deploy ultrasonic NDT techniques for corrosion mapping. The second robot is targeting the weld line inspection of the steel foundation to assess the integrity and characterise the potential defects in the air and seawater. Both crawlers can operate at a depth of up to 60 metres.

By using the inspection data, the technology aims to extend the Mean Time to Failure (MTTF) of a wind turbine foundation by providing information regarding the type, size and location of damage that can lead to structural failures. With iFROG, operators could increase the quality and frequency of their sub-sea structural inspections by getting early warning of those failures. **It is estimated that iFROG can save up to £150,000 per foundation annually equalling £4 million per turbine over the course of its lifecycle.**

Besides cleaning and NDT operations, the robots have the potential of being adapted for use in the Oil & Gas, ship hull manufacturing and maintenance, Military, and other large structure related industries, where they would perform inspection and cleaning under extreme conditions and on also on curved surfaces due to its robustness.

What is the value or size of the addressable market?

Approximately 90% of offshore wind turbines installed in UK waters are built upon monopile foundations, with the remaining 10 per cent consisting of jacket, gravity base and floating foundations. Across Western Europe alone the market for monopile inspection technologies is expanding at a rapid pace, from £38 million in 2017 to £81 million per year by 2022.

Project Plan / Progress

At the present stage, InnoTecUK as a lead partner in the project is finalising development of the two marinised robotic platforms within the NDT integration phase. TWI have delivered the NDT techniques, encompassing UT, ToFD and Eddie Current. BIC are assisting in the software development and acquisition of the NDT data. OREC oversee the development of the test piece monopile and will install it at their facilities for the final demonstration of the project in November 2020 (due to the extension granted).

https://innotecuk.wixsite.com/ifrog

AutoNaut for extreme environments

Summary of the project aim

An unmanned surface vessel (USV) high latitude sensor platform. Little data is available from the Southern Ocean surface, particularly in winter, because few ships work there. Conditions in the Arctic are similar. The data needed to understand climate change includes the CO2 flux at the surface, and ocean warming changes.

Project information

Project lead: AutoNaut Limited
Collaborators: University of East Anglia, University of Exeter
Project type: Collaborative Research and Development
Total project cost: £500,003
Grant award: £395,001
Start date: January 2018
End date: December 2020

Executive Summary

This three-year project will complete in January 2021.

Solutions were needed for anti-icing, detection and avoidance of small ice in the sea, robust materials able to cope with extremes of temperature and changes, as well as energy harvesting in the dark of winter when PV panels will not operate.

University of Exeter has researched energy harvesting and is producing a simple pendulum generator to be trialled at sea in summer 2020. University of East Anglia used their Roland von Glasow sea ice chamber to research icing and cold temperature issues.

Some 25 hydrophobic and wax coatings, as well as topside finished and antifouling were tested in the sea ice chamber for fresh water accumulation, sea water ice accumulation, and ice abrasion in sea water. Long-term environmental testing indicates 1 year effective life. Build materials including connectors, hatches and gaskets were tested in extreme cold, and with temperature changes.

Autonomously avoiding collision with small ice in big waves is important for a USV. To test if small ice could be detected a 1 cubic metre block was deployed at sea. Three forward looking sonars and a thermal camera were used. One sonar and the IR camera gave usable detections at 80m and 200m.

Robustness of the USV hull and parts was tested during a series of crane drops at various angles and heights up to 5m, and impact tests. These findings are now being incorporated into a new 5m AutoNaut for Extreme Environments to be launched and trialled summer 2020.

What is the value or size of the addressable market?

The value of data from high latitude seas, in all seasons, is increasingly driven by the need to understand climate change, and also by commercial, fishing and military interests endeavouring to exploit resources and new routes.

An AutoNaut that can gather data using a wide range of sensors year-round in such hostile regions can operate in any seas in the world. This represents significant market potential.

The global market for USVs quoted by MarketsandMarkets was £361 million in 2017 growing to £721 million by 2022. High latitude operation is a small but important part of this market.

Project Plan / Progress

The research and development conducted with our University partners is now being incorporated into a new 5m 'AutoNaut for Extreme Environments' USV. This will be ready for sea trials in summer 2020.

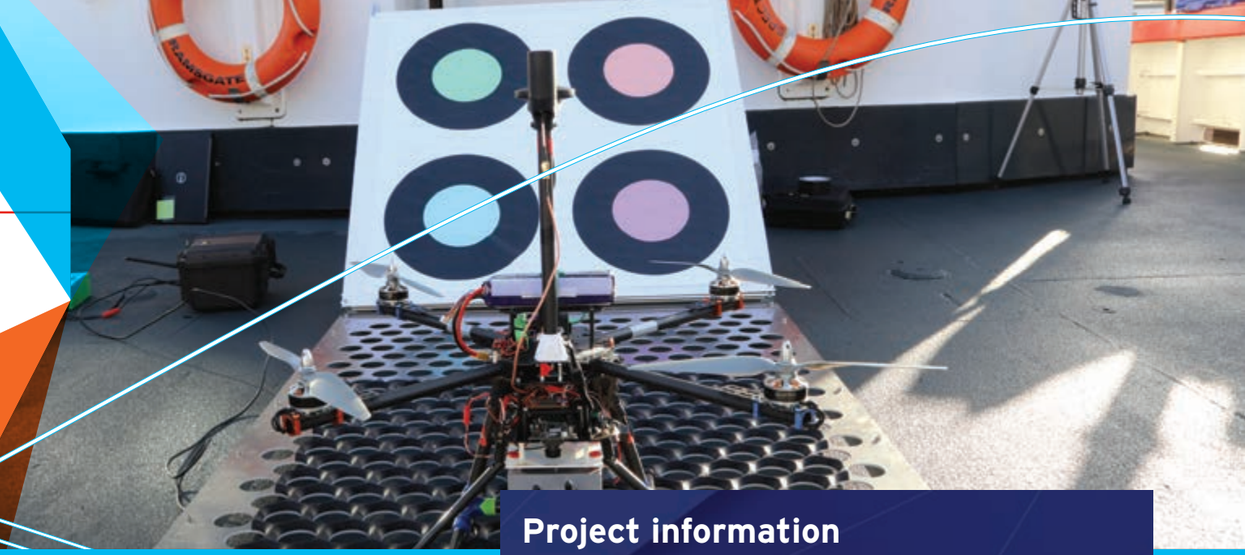
Some aspects of our research are marked for continued development. Ice detection and avoidance is one of these. Now that we know it is possible to detect small ice in waves from a small USV it is necessary to train a machine learning programme to feed detections into our collision avoidance system.

Similarly, the provision of hotel power for bigger sensors, onboard analysis and summarisation, and other energy hungry uses, means the need to provide more power is ongoing. In addition to UoE's pendulum energy harvester we are actively developing a marinised fuel cell able to cope with the temperatures and violent motion.

Concurrent with this project AutoNaut has recently delivered to UEA a new vessel designed to carry and launch an underwater glider (robot launches robot). Named 'Caravela' this USV combination is now on her first deployment in the Atlantic. The new technologies developed in this project will transfer to Caravela for use in the Southern Ocean.

mike.poole@autonautusv.com

Autonomous offshore wind farm inspection



Project information

Project lead: Perceptual Robotics Limited
Collaborators: L3Harris, University of Bristol and VulcanUAV Limited
Project type: Collaborative research and development
Total project cost: £1,271,354
Grant award: £989,926
Start date: April 2018
End date: March 2020

Executive Summary

Offshore wind is a key energy source for the UK. It will play an increasingly significant role in future years as part of an energy mix that's moving towards cleaner and more renewable sources. Offshore wind turbines (OWTs) have significant environmental challenges in terms of both the marine environment and the weather.

This project, led by Perceptual Robotics in partnership with L3Harris, the University of Bristol and VulcanUAV – will be developing and testing key technologies to address the autonomous inspection of offshore turbines. Building on an existing capability for the inspection of onshore wind turbines, the team will work on integrating this with an autonomous surface boat provided by L3Harris, creating a system that will automatically deploy and recover the inspection drone without the need for human interaction.

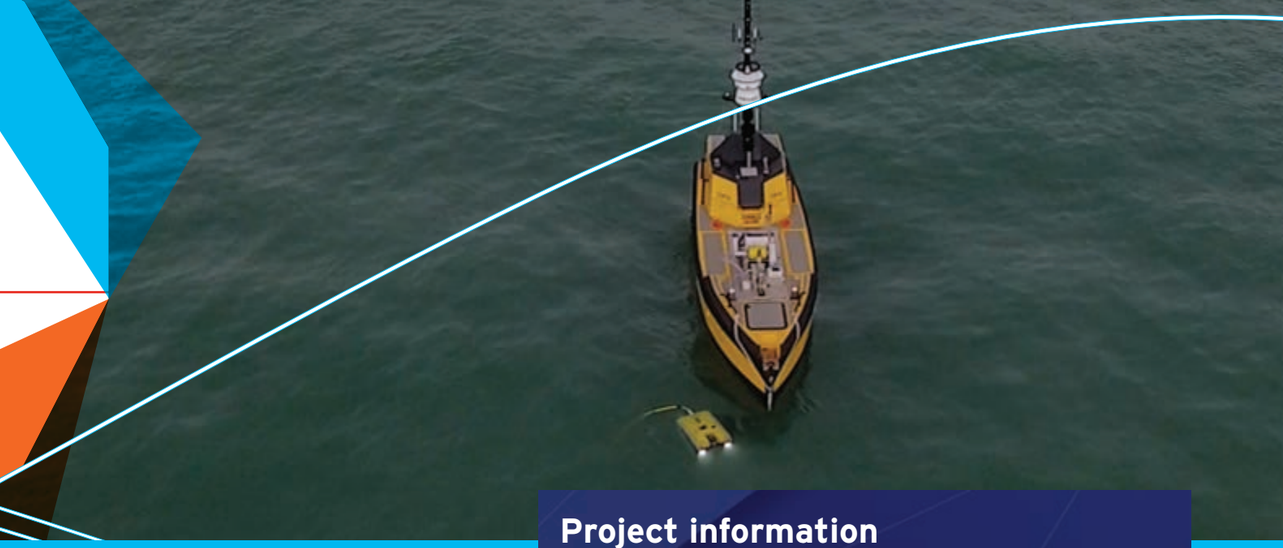
The long-term vision of this project is to enable fully autonomous inspection for OWT – working from an autonomous boat monitored remotely from land. Key challenges include mechanical deployment, robust operations, multi-vehicle cooperation, communications and the handling and processing of large datasets.

The team consists of:
- specialists in drone design, construction and operation in Perceptual Robotics and VulcanUAV
- specialists in autonomous marine vehicles through L3Harris
- experts in computer vision with Bristol University
- the ideal facilities to develop and test the system at the ORE Catapult platform

Working together to solve the problems associated with operating an autonomous system in the extreme environment found offshore, the team will need to use modern control theory, sensors, materials, computer technology and artificial intelligence algorithms to create a platform that can carry out rapid, robust inspections. A fully autonomous system for offshore turbine inspection will significantly reduce the costs associated with ongoing inspection and improve the quality and quantity of the inspection data.

Modern sensing, including the vision processing offered by the University of Bristol, will allow perceptual robotics to fly closer and more accurately with respect to the blades, improving the images and maximising the flight envelope. This will offer the potential for accurate condition monitoring and possible lifetime extensions. The UK is currently a world leader in offshore wind energy and this project will provide further advances in the efficiency and quality of inspections.

Autonomous Robotic Intervention System For Extreme Maritime Environments (ARISE) Stage 2



Project information

Project lead: L3Harris
Collaborators: University of Exeter
Project type: Demonstrator
Total project cost: £962,071
Grant award: £586,160
Start date: March 2019
End date: May 2021

Executive Summary

The key innovation of this project is to design and test a truly unmanned inspection system for operations in harsh offshore marine environments to conduct subsea asset inspection. The proposed intervention technology builds on existing individual capabilities in USVs and ROVs which we will combine and enhance with AI capabilities. The ARISE system would significantly challenge the existing methodologies to increase safety and reduce costs. The project builds on a Phase 1 project which integrated an existing ROV system and completed real world trials demonstrating the feasibility of this system. The project phase 2 project will deliver a pre-commercial system capable of completing inspection work to 100m water depth. This system will be a stepping stone to realising a wider adoption of unmanned systems for inspection tasks.

With industry partner BP bringing real world challenges to the project and providing clear insight into end user requirements. The University of Exeter will provide analytical project support through modelling of the system and environment. Project lead L3Harris will bring these together with world leading autonomy solution and in house design and build capability. This will produce a system capable of completing a range of demonstrations and early commercial operations to accelerate the adoption of unmanned systems in this environment.

The project will complete a number of trials and interested parties are encouraged to contact L3Harris to find out more.

L3HARRIS™ UNIVERSITY OF EXETER

Autonomous, robotic and AI enabled biofouling monitoring, cleaning and management system for offshore wind turbine monopile foundations - RobFMS (Phase 2)

Summary of the project aim

ROBFMS2 is a portable robotic system for offshore wind turbine foundations maintenance. The technology aims to reduce the cost of offshore wind energy by providing an efficient and smart solution for bio fouling cleaning.

Project information

Project lead: Innovative Technology and Science Limited
Collaborators: Brunel University London
Project type: Demonstrator
Total project cost: 993,014
Grant award: £761,996
Start Date: March 2019
End Date: February 2021

Executive Summary

Offshore wind energy is an attractive exploitable resource. In the UK, its volume is estimated at 6200TWhpa (terawatt-hours per annum), which is 18 times present UK electricity consumption. This could easily provide the annual UK's electricity requirement with minimal emission and visual impacts.

However, the levelized cost of electricity (LCOE) from offshore wind is 2-3 times higher than from other sources such as onshore wind, solar, and nuclear – £140 per megawatt-hour. This is due to the expensive maintenance of seabed turbine foundations (largely monopile structures), operated in the severe environment. Operational, reliability and maintenance costs account for at least 25% of turbine lifecycle O&M expenses.

The high cost is caused by growing marine biofouling which deposits on foundations and leads to stress-induced corrosion and crack defects. Fouling-related cleaning and repair works presently take up to 10% of the LCOE.

Current fouling remediation treatment includes deploying divers with cleaning tools or remotely operated underwater vehicles (ROVs) to the turbines. It is a hazardous and complex procedure costing the operators around £30,000 per megawatt yearly.

Meeting this challenge, InnoTecUK and Brunel University are developing a fouling management system, ROBFMS2. It will consist of a mobile survey robot that will eliminate the need for divers and ROVs for deep-sea monopile cleaning operations.

The robot will be placed on the turbine structure at sea level and will journey down below sea level to where the work is required. It will travel autonomously over the entire subsea monopile surface, imaging the fouling and monitoring its thickness in real time wherever it occurs. Simultaneously, the robot will travel to every over fouled location and remove the biofouling with an innovative guided power ultrasound technique. On returning to the surface, the robot would simply be transported to the next turbine scheduled for treatment, and the cycle repeated, or the system might even be reside in each turbine if provisions are made from wind farm owners.

Overall O&M costs will be reduced by at least 50% compared to present diver/ROV techniques. This would mean a £7 per megawatt (5%) reduction in LCOE. This is a significant contribution to the overall LCOE reduction required to make offshore wind competitive with other energy sources and reap the full environmental advantages of offshore wind.

What is the value or size of the addressable market?

For the current installed capacity of 5.06 GW in UK markets, the O&M markets has been estimated at £0.6 bn for 2018 which is £118.5 kpa/MW. This UK O&M market is expected to reach £1.2 bnpa by 2020 and £2.6 bnpa by 2025 assuming ~5500 turbines are installed by 2025 with an average capacity of 4MW. The UK foundation O&M market is £30 k/MW, reaching £0.65 bnpa by 2025.

Project Plan / Progress

As a lead project partner, InnoTecUK have finalised the robotic platform's marinised mechanical design and are currently in the manufacture/assembly phase. Brunel University London (BUL) are progressing with the ultrasound cleaning hardware, along with the development of AI system for bio-fouling monitoring. European Marine Energy Centre (EMEC) are making the preparations for trials.Concurrent with this project AutoNaut has recently delivered to UEA a new vessel designed to carry and launch an underwater glider (robot launches robot). Named 'Caravela' this USV combination is now on her first deployment in the Atlantic. The new technologies developed in this project will transfer to Caravela for use in the Southern Ocean.

Compact and cost effective; submersible subsystems for inspection

Summary of the project aim

Subsea inspections are a highly resource-intensive activity. This can lead to reduced inspection rates for invested parties. We aim to lower the barrier to entry of submerged inspections, significantly reducing costs whilst also improving the success rate and quality of data captured by unmanned submersibles.

Project information

Project lead: Deep6 UK Limited
Project type: Research and Development
Total project cost: £71,751
Grant award: £50,226
Start date: November 2019
End date: October 2020

Executive Summary

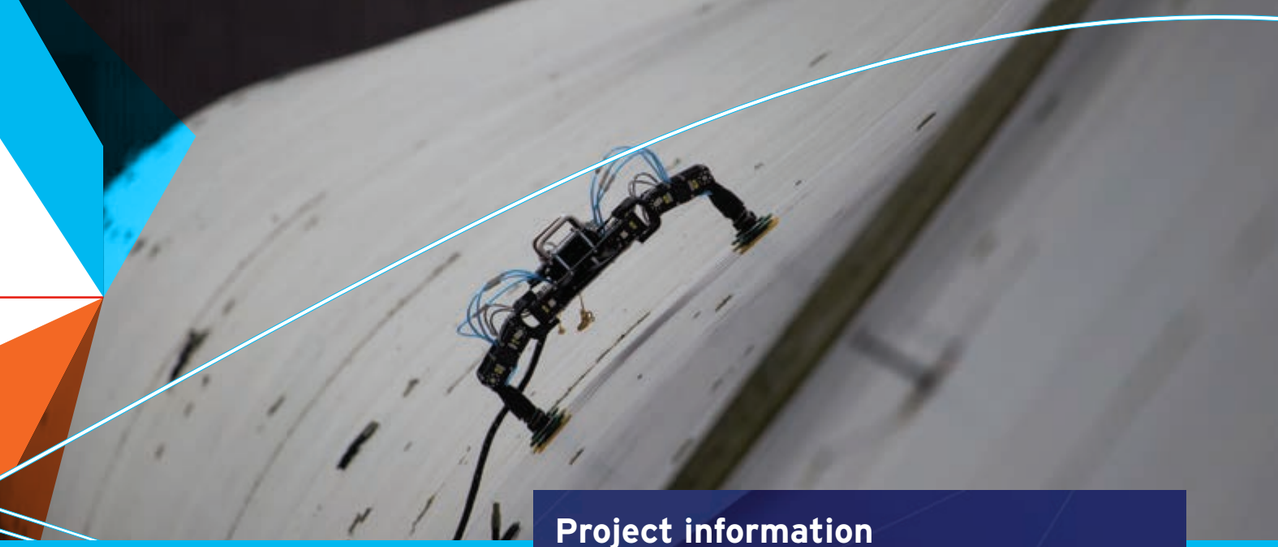
With the increasing pressure our oceans are under, be it biodiversity loss from overfishing or ocean acidification, or loss of sea ice; it is more important than ever before that we maintain an accurate understanding of the state of our ocean ecosystems. Additionally, more money than ever is being invested in expanding renewable offshore energy infrastructure. This requires careful management to ensure that the systems operate efficiently and that their local ecosystems are not negatively impacted.

Subsea inspections are a highly resource-intensive activity. This can lead to reduced inspection rates for invested parties. At Deep6 we aim to lower the barrier to entry of submerged inspections; significantly reducing costs whilst also improving the success rate and quality of data captured by unmanned submersibles.

To date, we have developed a unique, cost-effective unmanned submersible design to be launched from an autonomous surface vessel. Now our objective is to develop two new subsystems; to enable it to realise its goals as a compact and low cost, yet powerful inspection tool.

Typical industry standard ROV inspection systems have an open chassis design. This means that many subsystems on the market simply aren't ideally matched for deployment from our new subsea inspection platform. To solve this problem we are completely rethinking the way we integrate typical inspection subsystems. This will ensure that we can deliver a compact and cost-effective inspection solution to our customers.

Demonstrator for robotic inspection and maintenance of offshore wind turbine blades



Summary of the project aim

BladeBUG Limited is developing a unique walking robotic device designed to remotely perform detailed inspection, maintenance and repair of wind turbine blades, offering significant health and safety benefits over rope access technicians. The robot utilises multiple legs with vacuum cups, and can be rapidly deployed and retrieved, minimising turbine losses.

Project information

Project lead: Bladebug Limited
Collaborators: Offshore Renewable Energy Catapult
Project type: Demonstrator
Total project cost: £950,099
Grant award: £747,824
Start date: March 2019
End date: November 2020

Executive Summary

Offshore wind is a rapidly growing industry, with double digit growth forecast globally for at least the next ten years. The UK is the current world leader in installed offshore wind capacity, making it the perfect breeding ground for UK companies to develop innovative solutions for offshore related issues and disrupt the market within the UK sector and beyond.

BladeBUG Limited is developing a unique walking robotic platform designed to remotely carry out detailed inspections, maintenance and repairs, initially focusing on wind turbine blades and the offshore wind sector. Its BladeBUG robot enables semi-autonomous navigation over the varying blade geometry of wind turbine blades, with high degrees of dexterity that allows operation in any orientation on all surfaces and areas of wind turbine blades. The robot will be capable of performing repairs on both the critical leading edges of blades and their internal structures in order to maintain power output and reliability of turbines.

The BladeBUG platform will offer cost savings through faster inspection and maintenance of blades when compared with traditional rope access methods, in addition to a significant reduction in risks to health and safety. The BladeBUG platform will also enable servicing of turbines where otherwise prevented by current weather limitations and scarcity of skilled technicians: an increasing likelihood as wind turbines increase in number and size.

What is the value or size of the addressable market?

Offshore wind is a rapidly growing industry, with steady 16% compound annual growth expected globally for at least the next ten years. The UK is the leader in installed offshore wind capacity, with 45% of Europe's total in operation. The size of the UK offshore blade maintenance market is currently £60 million annually and this is expected to grow to £195 million/year by 2030. Globally, the market size is currently £132 million/year and is expected to grow to £710 million/year by 2030. BladeBUG Limited will manufacture the robotic system for use by wind turbine owners, operators and blade maintenance companies.

Project Plan / Progress

BladeBUG Limited and the Offshore Renewable Energy (ORE) Catapult are collaborating on a 21 month project, with the objective of delivering a fully working demonstrator of a robotic system for wind turbine inspection, maintenance and repairs, tested on ORE Catapult's 7MW offshore wind turbine in Levenmouth.

The project is currently on track to achieve all the project goals of developing the demonstrator BladeBUG robot and the necessary ancillary equipment, along with a thorough commercialisation strategy and route to market. Within the first 9 months of the project going live, BladeBUG Limited has grown from a single full-time employee to five, and now has the in-house capabilities to concurrently develop the hardware and software required for the development of the BladeBUG robot to achieve all the project objectives.

The most significant achievements during this project to date have been the growth of BladeBUG Limited through the successful hiring of this highly skilled team, and the progress made in the development of the prototype robot that is now capable of walking over and adapting to curved surfaces whilst using vacuum to adhere to them. By the end of the project we hope to have achieved successful tests of the complete robotic system walking over an offshore wind turbine blade and performed some non-destructive testing of the blade lightning protection system and blade surface defects. BladeBUG Limited are also expectant of securing additional investment and a pre-commercial contract with at least one customer.

Enabling low cost AUV technology: Development of smart networks & AI based navigation for dynamic underwater environments

Project information

Project lead: Planet Ocean Limited
Collaborators: National Oceanography Centre, University of Newcastle
Project type: Collaborative research and development
Total project cost: £773,280
Grant award: £602,590
Start date: February 2018
End date: July 2019

Summary of the project aim

Small, low-cost autonomous underwater vehicles (AUVs) are providing a step-change in the accessibility, adoption and use of autonomous systems in the harsh and challenging marine environment. This project successfully tackled the challenge of affordable underwater navigation, enabling a low cost, intelligent solution using nano-modem technology and network localisation.

Executive Summary

ecoSUB AUVs have been developed in collaboration between Planet Ocean and the National Oceanography Centre (NOC) providing low-cost, small, easy to operate, launch and recover, AUV platforms with up to 2,500m depth rating and long range/endurance capability.

Applications for these vehicles are extensive, however, they have limitations due to their size and design. They are currently unable to rely on incumbent technologies for navigation, such as expensive Inertial Navigation Systems (INS), large Doppler Velocity Logs (DVLs) and traditional Long Baseline positioning (LBL). Due to their small size, low power/long range capability, they also have limited resistance to tides and currents and the navigational challenge they present.

This project sought to develop an innovative solution enabling accurate underwater positioning and smart AI for navigating in dynamic environments. It translated fundamental research in underwater positioning and delivered a network localisation system for AUVs and enhanced AI navigation. Nano-modem technology developed within Newcastle University is an integral component in delivering success in this project.

The project outputs have been proven in multiple open water trials environments, including extensive missions in UK and Croatian waters. The project team came together with a successful history of collaboration; Planet Ocean and the National Oceanography Centre (NOC) have previously completed a successful Innovate UK/Dstl project and developed the ecoSUB AUV technology in partnership. Newcastle University has been well engaged with both Planet Ocean and NOC in the development of their nano-underwater modem technology and other systems previously commercialised under IP licencing arrangements.

What is the value or size of the addressable market?

The AUV (including navigation and payload) market is forecasted to grow from USD 362.5m in 2017 to USD 1.2b in 2023 as technology matures and adoption rate increases. The market is presently occupied by incumbent technology focused on large and expensive systems. ecoSUB AUVs are a disruptive technology designed to markedly increase accessibility and overall market size, rather than displace traditional AUV technology, creating many more new users who will benefit from the limited infrastructure required to operate and reduction budgetary barriers.

Project Plan / Progress

Since project completion the network localisation capability has been integrated into vehicles and will be available to all users of ecoSUB AUV technology when production systems launch in Summer 2020. Network localisation has been successfully demonstrated during the Breaking the Surface conference in Croatia during October 2019 with multiple ecoSUB AUVs operating accurate navigation whilst completing overlapping missions. Data from the Croatian missions has been presented at various events, including the Marine Autonomous Technology Showcase (MATS), Southampton in November 2019.

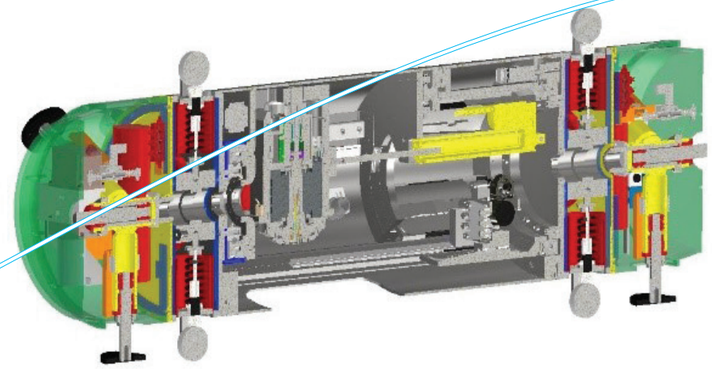
Planning for a joint demonstration with ecoSUB AUVs and an Autonaut ASV is underway, where Autonaut will become a node in the network, providing position information and also high bandwidth communications for the network. This mission is intended to be operated in Plymouth during the Marine Tech Expo 2020.

Planet Ocean is currently supporting a customer led research grant proposal for utilising ecoSUB AUVs operating with network localisation to collect data in a high-risk mission in the presence of glacial ice calving. The advancements in nano-modem technology developed during the course of the project by Newcastle University are currently being adopted by commercial partners under licence and will be available to the market during 2020.

Exploitation of the project success and deliverables has been, and continues to be, a key priority for all project partners, enabling the engagement in many other opportunities as a direct result. The project outcomes are actively supporting global interest in ecoSUB and contributing significantly to the ongoing technical and commercial efforts.

Iain Vincent • iain@planet-ocean.co.uk

Friction Stir Welding Crawler for Internal Repair and Refurbishment of Pipelines - FSWBot



Project information

Project lead: Forth Engineering (Cumbria) Limited
Collaborators: Innvotek Limited, Lancaster University, London South Bank University, TWI Limited
Project type: Collaborative research and development
Total project cost: £1,999,916
Grant award: £1,427,223
Start date: April 2018
End date: January 2021

Executive Summary

Steel pipelines corrode because of the liquids they contain. Cracks can also form over time leading to failure and leakage of the contents, resulting in severe economic losses and environmental pollution. To avoid this, inspection, evaluation and repair activities are performed periodically. Internal cracks and areas of corrosion and metal loss are monitored by the use of intelligent inspection devices (PIGs), which carry special sensors. Sections of pipeline that are found to be likely to fail are reinforced using an externally applied bolt-on clamp, which is costly as well as difficult and dangerous to install. As this requires full mobilisation of top side vessels as well as a fully manned diving team.

The FSWBot project will see the development of a radical new solution to internal corrosion that form inside pipelines. Meeting the objective will result in a much cheaper, safer repair process that will enable pipeline asset owners and their service providers to produce very high-quality welds in steel pipelines without shutting down and purging petroleum pipelines and without the use of divers and surface vessels. This is of enormous importance especially for inaccessible pipelines and those installed in parallel groups where space around pipes is restricted.

The objective is to develop a robotic platform consisting of unique sparkless hydraulic friction stir welding system, Milling and Patch Deployment system to repair internal corrosion. The corrosion will be identified by UT scanning probe, all contained within a fully autonomous system. Data obtained by prior high- resolution mapping of anomalies that are produced by erosion and corrosion will be used to provide information for mission planning. Repairs will be carried out in-situ using no external power and no welding consumables. The robot will generate electricity from the liquid flow in the pipeline using a variable pitch turbine driving a generator, which will supply power to the system and a battery that drives hydraulic clamping and crawling systems. FSWBot will bring about a step change in the competitiveness and growth for 2 UK business, Forth Engineering and Innvotek.

Project Plan / Progress

- Significant technical achievement, the performance of a friction stir weld in steel, under oil this is a world first achievement
- Miniaturisation of the Sub system with complete design
- Hydraulic clamping and Crawl modules built
- Simulations and methodology developed for on-board power generation.
- Website Developed www.fswbot.co.uk

info@forth.uk.com

In-service X-ray radiography of offshore wind blades (RADBLAD) (Phase 2)

Summary of the project aim

RADBLAD addresses the structural inspection of composite wind turbine blades. Such inspections are complex, dangerous, expensive and time consuming as they take place onshore. RADBLAD will solve this problem by developing a first-of-its kind climbing robot able to deploy a radiographic inspection system in-situ.

Project information

Project lead: Innvotek Limited
Collaborators: Forth Engineering (Cumbria) Limited, Offshore Renewable Energy Catapult, London South Bank University, TWI Limited, Renewable Advice Limited
Project type: Demonstrator
Total project cost: £943,337
Grant award: £772,335
Start date: April 2019
End date: March 2021

Executive Summary

RADBLAD follows on from "In-service X-ray radiography of offshore wind blades (RADBLAD) (Phase 1)". UK targets to cut carbon emission by 57% by 2030 led to a significant growth in installed wind power capacity during the last decade from 3GW to 22GW. Massive offshore farms' developments are driving this growth. As of January 2020, the UK offshore wind power installed capacity is 10,490 MW, the largest in the world.

Turbine blades are subjected to extreme wind loads. The accumulation of fatigue damages in the blade structures, leads to blade failures. 3,800 blade failures occur annually due to poor maintenance.

Blade inspection is a risky task that take place in remote and hazardous environments. Globally, accidents and fatalities are not uncommon, with 2,265 incidents reported to date including 136 fatalities and 158 injuries.

Typically, Inspections and maintenance cost up to £700,000 per turbine over the course of turbine's life. The operation is dangerous, time consuming, logistically and technically complex. For major repairs, the blades must be dismantled transported onshore, inspected, returned and reassembled. Weather permitting, the turnaround time is 10-days, compounding downtime costs to the cost of the operation itself.

RADBLAD is a phase 2 project further developing a first-of-its-kind magnetically-adhering tower-climbing robot, with a manipulator arm that deploys a complete X-ray inspection system around a blade. A crucial and novel extension of RADBLAD is the use of an integrated radiographic system for inspection.

RADBLAD will offers a safe, cost effective, high-quality in-situ blade inspection to improve wind farm capacity factor.

What is the value or size of the addressable market?

The target market is the O&M companies working within the wind energy sector. This can be subdivided into: Park owners/operators with own maintenance teams/divisions, such as EDF; Manufactures, who also provide O&M, such as Vestas, Simens Gamesa, GE, Enercom, etc. or other third party independent companies such as Intertek Group Plc, SGS SA, Cenergy International Services, UL International Gmbh, etc.

According to Coherent Market Insights, the global wind turbine blade inspection services market will surpass $38.7bn by 2025. Today, the UK market for operation and maintenance of offshore wind turbine is estimated at £860m with blade inspection alone representing £287m.

Project Plan / Progress

The RABLAD phase 2 project completed its third quarter and all the elements necessary to develop the prototype are in place. The consortium has completed a survey, with input from numerous end users, gained the insights to the market needs and system specifications are fully determined and understood.

A suitable X-ray equipment has been identified and sourced and it will be with the team by the end of January. The specific details of the X-ray machine have been integrated into the robot mechanical design and a way forward to scale-up the assembly is now being finalised. This will allow the team to build the full-scale prototype.

The Team showcased RADBLAD capabilities at the KTN Innovation Exchange (iX) Challenge. RADBLAD received interest from General Electric (GE). GE is one of the world's leading wind turbine suppliers generating wind electricity across the globe. GE is also a leading wind turbine blade design and technology who are the record holder for the largest wind turbine blade (107m). When RADBLAD is fully validated, we expect to be able to access GE wind farm to test RADBLAD in-situ. There has been strong interest from other several large-scale owner-operators of wind turbines in the UK.

In parallel to RADBLAD swift mechanical development, the team is improving on its machine learning software to detect defects within the composite structure. We aim to surpass the detection limit set during RADBLAD Phase 1. We are improving on data processing time and accuracy of detection.

Intelligent on-board processing of visual data for real-time situational awareness by Unmanned Surface Vessels (USVs)

Summary of the project aim

We are developing an intelligent visual imaging system that is integrated into an unmanned surface vehicle (USV). The system will process data using computational algorithms and artificial intelligence to detect and track objects of interest at sea. This will be a low-power, low bandwidth system capable of long-duration missions and integration into all autonomous platforms, including AutoNaut.

Project information

Project lead: Seiche Limited
Collaborators: AutoNaut Limited and National Oceanography Centre
Project type: Collaborative research and development
Total project cost: £306,551
Grant award: £226,620
Start date: November 2017
End date: October 2019

Executive Summary

We are developing a new low power, low bandwidth and lightweight intelligent visual imaging system for Unmanned Surface Vehicle (USV) that is capable of 24-hour coverage during long duration missions and can send processed images to a remote display on land. It processes data onboard using computational algorithms and artificial intelligence to visually detect and track objects of interest at sea. Detection data is then transferred to a remote display for assessment via a robust communication link.

The system does not require bulky and expensive gimbals commonly used in industry and can cope with significant vessel motion and a wide variety of environmental conditions at sea. It is platform agnostic and therefore versatile for use in many different applications. The system combines state-of-the-art computer vision and artificial intelligence technology with a new portable and robust thermal camera solution to ensure that only important information is transferred offshore, thus saving hugely on bandwidth.

The primary application of the system is for marine mammal monitoring which is a key concern for the offshore energy industry. However, this innovative method will also have potential in other marine domain awareness applications, such as; asset integrity monitoring, surveillance of marine protected areas, security, border patrol and defence.

What is the value or size of the addressable market?

The target market is offshore energy. The specific application is based on extensive regulations world-wide that require monitoring for marine mammals pre-, during and post- industrial operations.

Project Plan / Progress

We have recently completed the 2-year project and we have developed a new low power thermal camera solution for 24-hour coverage. The system is self-reliant with in-built GPS, compass and inertial sensor and does not require a bulky and expensive stabilising gimbal. We have proven the viability of the system for monitoring marine mammals and other targets of interests from small vessels such as the AutoNaut.

We have also developed and tested a new low bandwidth communication system for sending detected targets over Inmarsat. We have improved our existing image stabilisation algorithm to cope with increased movement on these small platforms like the AutoNaut. Finally, we have developed two new automated algorithms; 1) a simple algorithm for detecting boats on the horizon and 2) a new AI algorithm for detecting marine mammal whale blows. We have shown that these algorithms can run in real-time on low power systems such as this one, although this will require careful software optimisations and new hardware solutions; this is the next step.

l.baruwa@seiche.com

Multi-Platform Inspection Maintenance & Repair in Extreme Environment (MIMRee)

Summary of the project aim

The Multi-Platform Inspection, Maintenance & Repair in extreme environments (MIMRee) project will use autonomous robots to introduce a step change in the Operations and Maintenance (O&M) of offshore wind farms by removing humans from the loop during the inspection, maintenance and repair (IMR) of offshore wind turbine blades.

Project information

Project lead: Plant Integrity Limited
Collaborators: Offshore Renewable Energy Catapult, Royal College of Art, Thales UK Limited, University of Bristol, Royal Holloway University of London, University of Manchester, Wootzano Limited
Project type: Collaborative research and development
Total project cost: £4,180,784
Grant award: £2,988,335
Start date: March 2019
End date: February 2021

Executive Summary

The aim is to significantly reduce the costs and turbine downtime associated with IMR tasks and reduce the H&S risks of using rope access technicians. In this project, the multi autonomous platform approach will be demonstrated for a use case in offshore renewables. However, the developed autonomous surface vessel hub, Human-Machine Interface (HMI), robotic teaming and communications, and automated mission planning will also have applications in the offshore Oil & Gas, Search and Rescue and Defence sectors.

Key objectives

- Remove the need to send humans offshore to perform wind turbine blade IMR tasks;
- Remove the need to shut wind turbines down to carry out blade inspections;
- Reduce the risk of using autonomous vehicles offshore to carry out asset IMR tasks;
- Safely demonstrate a fully autonomous approach to blade IMR tasks;
- Establish the business case for using autonomous vehicles for blade IMR;
- Develop a roadmap for transferring the MIMRee system to other relevant industries.

Main areas of focus

The developed MIMRee system will comprise of an Autonomous Surface Vessel (ASV) with capabilities to autonomously transport and deploy UAVs and blade crawling IMR robots at offshore wind farms. The robotic crawlers will be developed to conduct both autonomous NDT inspections and maintenance and repairs of wind turbine blades. A HMI will enable an onshore operator to issue automatically generated IMR mission plans. A novel sensor will record images of moving wind turbine blades, which could be integrated with the UAVs and/or ASV. All technologies will be tested, validated and demonstrated.

What is the value or size of the addressable market?

Target customers include wind farm Owner/Operators, turbine OEMs and Independent Service Providers. ORE Catapult estimates that the MIMRee system could reduce the lifetime operational costs of an average wind farm by £26 million. By reducing turbine stoppage time, it could increase revenue generation by £1.1 million.

By April 2021, the system will be tailored for use in offshore renewables, addressing a potential global market size of £213 million per year by 2030. Beyond this project, the MIMRee consortium foresee similar operational benefits to other types of offshore operations too, such as onshore wind, defence, and oil and gas facilities.

Project Plan / Progress

MIMree is an ambitious two-year project bringing in expertise from the fields of robotics, non-destructive testing, artificial intelligence, space mission planning, marine and aerial engineering and nanobiotechnology. It aims to prove that offshore wind operations and maintenance missions can be conducted by autonomous vessels, aerial vehicles and crawling robots. Eight industry and academic partners are working together to build on their own existing innovations. Plant Integrity is leading the consortium and the Offshore Renewable Energy (ORE) Catapult is providing offshore wind industry insight, engineering expertise and access to facilities to test and demonstrate the MIMRee system. Thales' Halcyon autonomous vessel will play a key role, as will a drone system under development by the University of Bristol. On-board drones will take off from the mothership and deploy blade crawling robots carrying Plant Integrity's autonomous inspection system and the Royal College of Art's innovative robotic arm for repairing WTBs. The University of Manchester is developing a system for transporting, deploying and retrieving the blade crawler from a stationary wind turbine blade. The Royal Holloway University of London is creating a human-machine interface that will allow personnel located onshore to plan autonomous missions and analyse the data transmitted by MIMRee and intervene, as necessary. An electronic skin, developed by high-tech start-up Wootzano, will 'feel' the surface and collect a deeper level of data on the blade surface structure. The core innovation challenge will be to bring these modules into a single system capable of planning, communicating, sharing data and working together on a complex chain of M&R tasks.

Team Contact: Martin Bourton martin.bourton@plantintegrity.co.uk Press Contact: Amy Needham amy.needham@ore.catapult.org.uk

Offshore Infrastructure Robotic Inspection System (OSIRIS) Demonstrator

Summary of the project aim

OSIRIS improves decision making in offshore wind O&M by obtaining blade condition intelligence in a faster, safer and cheaper manner than existing methods. The project will demonstrate a novel robotic inspection system for turbine blades, combining the access advantages of a drone with the NDI capability of a crawler.

Project information

Project lead: Autonomous Devices Limited
Collaborators: Offshore Renewable Energy Catapult, TWI Limited, Wood Group UK Limited
Project type: Demonstrator
Total project cost: £582,555
Grant award: £454,829
Start date: March 2019
End date: November 2020

Executive Summary

OSIRIS combines the best features of drones and climbing robots in challenging tasks such as wind turbine blade inspection. Drones offer flexible stand-off inspection, but their inability to achieve secure contact with structures limits their potential for contact-based Non-Destructive Inspection techniques such as active thermography and ultrasound. Climbing robots offer constant contact with the target structure, but access requires placement and retrieval by a human, obviating the risk alleviation and time-saving benefits. OSIRIS operates as both a drone and a climbing robot, with an ability to transition between the two modes, and therefore offers the benefits of each without its inherent limitations.

What is the value or size of the addressable market?

The offshore wind industry is in a period of massive growth. Installed power capacity is predicted to grow from 16.4 GW in 2017, to 94.0 GW in 2026. Operational expenses are expected to be £61bn in the same period. Inspection of offshore turbines is currently limited relative to onshore turbines, but the demand for optimisation of power output, and the realisation that even superficial damage can have a large impact on power efficiency throughout the life of a turbine, will increase that demand, particularly as assets age. This is a massive market that is currently barely accessed.

Project Plan / Progress

The project is working towards a TRL 5-6 demonstration on an offshore wind turbine owned by the Offshore Renewable Energy Catapult, towards the end of this year. The demonstration will show the OSIRIS vehicle conducting both stand-off and contact based inspection of a turbine blade, validating the concept. The goal is to secure further demonstrations, trials and pilot programmes with owner operators as the technology continues to be matured.

Palantir - Real time inspection and assessment of wind turbine blade health

Summary of the project aim

Palantir takes people out of dangerous environments replacing them with roboticized inspection systems. It achieves this by enabling the remote capture of precise 3D data from harsh industrial spaces (eg offshore turbines) utilizing drones, ROVs and crawlers. It then uses enhanced AI analysis to produce fast and accurate inspection results.

Project information

Project Lead: Braendler Engineering Limited
Collaborators: Offshore Renewable Energy Catapult, University of Bristol
Project type: Collaborative research and development
Total project cost: £869,764
Grant award: £535,389
Start date: April 2018
End date: September 2020

Executive Summary

The Palantir inspection technology consists of several components:

- Data Capture: 2D, 3D and acoustic data capture.
- Data Processing: Cloud based software for organizing, stitching, and 2D/3D reconstruction of images.
- Machine Learning: Proven machine learning models that analyze and classify image data
- Data Visualization: Intuitive web interface that enables our clients to schedule follow up actions.
- Simulations: Realistic simulations that accelerate the development of autonomous control systems.

Palantir has been tested in confined spaces, on drones and on ROVs, and provides cutting edge results accessible through an intuitive interface.

What is the value or size of the addressable market?

The target markets for the Palantir product is Wind Energy (£5B), Shipping (£6B), Power Generation and Distribution (£11B). The direct users of the inspection technology are asset owners and site operations, and the data interface is accessed by asset managers and investors to understand the status of their assets.

Project Plan / Progress

Commercially our approach has been to focus on asset owners and investors - an approach that has proven very successful.

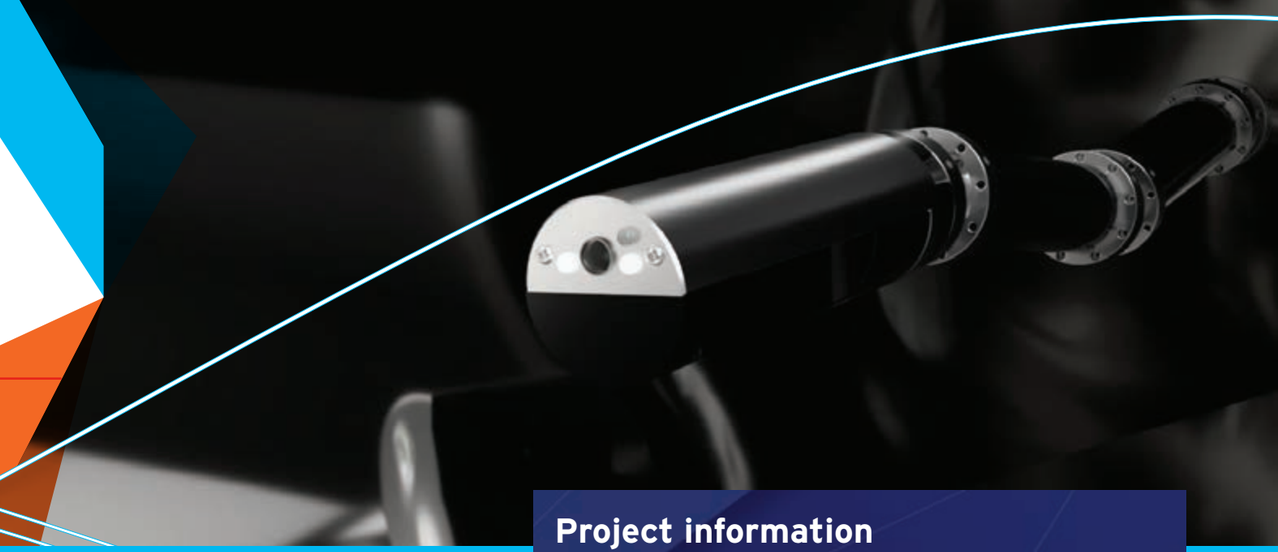
Shipping: a number of banks and vessel owners are adopting one of our data portals - Triton - which provides an understanding of the environmental state of their vessels. We are on track to achieve a 20% market share of the global fleet of 60,000 vessels. This platform will enable us to introduce Palantir's advanced digital inspections to our existing clients within the shipping industry, to further enhance understanding of their asset's carbon footprint.

Renewable Energy: a number of owners/operators of offshore and onshore wind turbines have expressed interest in another of our portals which provides an understanding of financial performance of power generation assets. BE are planning to integrate Palantir to this platform by late 2020, to enable complete asset health by integrating inspection data with performance.

Technical progress has been rapid, with all components of Palantir now operational (data capture, data processing, machine learning, visualization and simulations). Technical work at this stage is focused on accelerating the flow of data through our systems and tailoring the output to suit the needs of particular clients.

David Braendler • david.braendler@braendler.com • +44 7957-228-676

Piglet – a new robotic solution to lower maintenance costs and improve safety in high pressure gas systems



Project information

Project lead: Process Vision Limited
Collaborators: University of Reading
Project type: Collaborative research and development
Total project cost: £850,873
Grant award: £642,379
Start date: February 2018
End date: January 2020

Executive Summary

Within oil and gas processing, the challenges of high pressure and/or temperature, safety and certification have meant that until now, the benefits of robotic viewing of online infrastructure have not been available. This results in many processes across the world under-performing, running under optimum flow rates and below optimum revenues for the operator. Internal inspection of pressure vessels is required to maintain the integrity and safety of many processes. With the cost of shutdown in a gas treatment plants often exceeding $1M/day, a device capable of performing inspection and some maintenance tasks will provide significant improvements in both safety and maintenance costs.

At a time when oil and gas profits are under pressure, key players are looking for innovative ways to improve performance and revenues from existing plants. Glycol dehydration is the most common and economical means of removing water from natural gas. Interiors present an extreme and challenging environment, operating with natural gas at a pressure of around 50-200bar. There is currently no robotic system capable of inspecting the columns during operation. Any blockages should be identified and quickly removed to maintain performance.

Blocked ports and other problems can occur that degrade performance, reduce process throughput and plant profitability. Our concept is Piglet, pigging for un-piggable lines, which will provide a live video feed to an operator, to give a true picture of the internal condition of the facility. This will provide early warning of plugging, scale, wax or corrosion, which may result in dangerous failures and/or costly downtime involving potentially hazardous human intervention.

What is the value or size of the addressable market?

With over 10,000 gas treatment plants globally, the market for robotic inspection pressure vessel is estimated to be worth between £80M to £100M/year. Besides gas treatment other markets include refineries and petro-chemical plants that have similar processes. With 80% of downtime currently spent in preparing the vessels for human entry, the aim is to reduce the total cost of inspections by 25% and improve process efficiency by more frequent maintenance while on line.

Project Plan / Progress

As of February 2020, Piglet has achieved many of the technical, IP and commercialisation goals set out in the project.

Control modelling has been completed and implemented for multiple joints for a follow the leader control systems. Initial engagement with industry has provided the project with excellent feedback and confirmation of the need for such a product. Discussions are ongoing with three oil & gas majors to commercialise the product and move towards the first deployment.

Process Vision

University of Reading

Precise Positioning for Persistent AUVs

Summary of the project aim

This project will improve the navigational accuracy of autonomous underwater vehicles (AUVs) helping to further reduce the dependency on offshore infrastructure for wide area surveys of challenging marine environments.

Project information

Project lead: Sonardyne International Limited
Collaborators: L3Harris and National Oceanography Centre
Project type: Collaborative research and development
Total project cost: £1,427,924
Grant award: £822,985
Start date: December 2017
End date: November 2019

Executive Summary

This will be achieved through a combination of 3 novel techniques:
- using enhanced autonomy to increase the accuracy of Long BaseLine (LBL) calibration to achieve 1m, deep sea positional accuracy
- reducing the power requirements of the navigation systems
- reducing AUV dive errors through novel techniques for deep-sea errors for current profiling

What is the value or size of the addressable market?

'Autonomous Underwater Vehicles Market by Type, Technology, Application - Global Forecast to 2022' forecast the AUV market to grow from US$ 211.8M in 2016 to US$ 497.9M in 2022, at a CAGR of 15.31%. Assuming that navigation and positioning systems account for ca. 10% of each AUV, this translates into an accessible market growth of $21.2M to US$ 49.8M for these systems.

Project Plan / Progress

The Project Demonstrator at Loch Ness has been completed with the following achievements;
Sonardyne: By developing and integrating each organisations' technologies, including Sonardyne's own SPRINT-Nav navigation instrument, the trials have proven the viability of maintaining navigational accuracy over long distances without external aiding and at lower power than existing systems.

L3Harris: The trials have proved that USV using autonomous calibration techniques can replace manned vessels currently required for this task. This removes people from harm's way, as well driving down fuel emissions and improving efficiency.

NOC: The trials have realised a step-change in AUV operations by combining all of these capabilities. This will reduce the costs and improve the navigation precision of autonomous ocean science in remote areas. This disruptive capability will be applicable to a wide variety of applications in the marine autonomy space.

Sonardyne SOUND IN DEPTH | L3HARRIS™ | National Oceanography Centre

Project Anemoi

Summary of the project aim

High Power Work Class ROV electrification. Development of core technologies to enable this – High voltage direct current transmission and conversion system, control backbone, high power electric thruster motors. Disruptive cable detection system – novel magnetic cable inductive and detection system (Artemis) – full scale dock test of the technology to map behaviour.

Project information

Project lead: Soil Machine Dynamics Limited
Collaborators: Magnomatics Limited and Offshore Renewable Energy Catapult
Project type: Collaborative research and development
Total project cost: £1,996,662
Grant award: £1,122,355
Start date: January 2018
End date: June 2019

Executive Summary

SMD - underwater vehicle manufacture and systems integrator, specified high power ROV technology requirements, developed Quantum EV design and develop control backbone and integrated the DC transmission power technologies into 6,000m pressure compensated modular components. Magnomatics – magnetic gearbox and electric motor developer, developed 25kW ROV thruster motor to meet SMD's thrust curve for Quantum EV ROV. Offshore Renewable Energy Catapult - provided full scale testing facilities with specific seabed set up to test cable detection system. Researched and provided independent cable failure market analysis for SMD's technology and future product development.

The partnership achieved the development of a 200kW Quantum EV electric work class ROV design and key power and control technologies to enable this. Artemis cable detection is the first development for SMD's ambition to disrupt the cable survey and cable repair market.

What is the value or size of the addressable market?

This project is looking to exploit its technologies in the offshore operations in Offshore Wind, Oil and Gas for survey, inspection, repair, maintenance and construction and drilling support.

Project Plan / Progress

Achievements: Full scale dock trials of cable tracking system, 25kW electric thruster fully tested, HVDC transmission system, ROV control backbone, feasibility studies for new trenching and ROV tool all completed. ROV technology announced at Offshore Europe 3/9/19. Artemis cable detection system announced at Global Offshore Wind 25/6/19.

To Do: Subsea DC converter is still under development, Artemis is undergoing further testing offshore with end users on live projects to complete the development. First commercial ROV ready by Q3 2020. Most powerful Electric ROV, with DC transmission, being shown at Oceanology 17/3/20, Artemis launched at Global Offshore Wind 16/6/20.

SeaWynd: Autonomous Inspection of Seabed and Splash Zone Structures for Offshore Wind Arrays

Summary of the project aim

On offshore wind turbines, the monitoring of seabed scour and erosion around foundations, and inspecting the condition of the supporting structure up through the splash-zone is very challenging. SeaWynd is an integrated multi-sensor suite designed to collect and collate 3D structural and visual data of these areas from an Unmanned Surface Vehicle (USV) platform.

Project information

Project lead: MarynSol Limited
Collaborators: HydroSurv Unmanned Survey (UK) Limited and Offshore Renewable Energy Catapult
Project type: Collaborative research and development
Total project cost: £249,884
Grant award: £182,077
Start date: November 2019
End date: March 2021

Executive Summary

The project will deliver a sea-tested prototype, multi-sensor payload with a unique, non-invasive, seabed-to-splash-zone inspection capability targeting a recognised problem area in offshore wind structures. This payload will be suitable for deployment on autonomous/unmanned marine robotic vessels to remotely and non-invasively collect essential inspection data and feed into innovative automated structural fault and biological anomaly detection algorithms.

Data will be collected using a combination of LIDAR and SONAR to generate point clouds above and below the water surface. These will be fused with data from High-Definition (HD) video feeds, to produce a measurement-based, geo-referenced, 3D-model of the surveyed area. As the sensor suite will be mounted on a highly dynamic sea-surface mobile robotic platform, the location and orientation of each reading will be anchored through survey-grade, sub-centimetre, attitude and GNSS/GPS sensors.

The innovation challenge is to manufacture the proposed device with the required sensors having been marine hardened to operate in the harsh marine environment. The complex, dynamic motion of the vehicle will need to be compensated to achieve necessary the accuracy. Furthermore, precise, simultaneous calibration of all the sensors is required to generate the output 3D structures in an efficient, automated manner.

The project team has extensive experience with the integration of novel sensors onto unmanned marine vehicles and is skilled in complex post-processing of data. The final prototype will have undertaken at-sea validation trials on an offshore wind turbine array.

What is the value or size of the addressable market?

The offshore wind energy market is large and growing strongly. In UK waters there are already >2300 offshore wind structures and this grew by 250 (in the first-half of 2019 alone). The annual UK O&M (Operations and Maintenance) market is projected to be £2billion/yr by 2025. The European and global market are similarly growing.

The target end-user would offshore wind operators, or their contractors undertaking regular inspections of their marine structures. There are also other potential markets in other marine sectors, including port/harbour infrastructure, coastal assets, and offshore oil-&-gas.

Project Plan / Progress

The project is running until March-2021, and will undertake a series of real-world on-water trials during summer/autumn 2020, including a demanding system validation trial on an operational offshore wind array. Initial tasks underway concern selection of sensors, modification and integration to the host USV, software data processing tasks and development of simulation tools for testing.

Jonathan Evans • jonathan.evans@marynsol.com

Shared Waterspace Autonomous Navigation by Satellites (SWANS)

Summary of the project aim

This project develops and implements new solutions enabling the improved utilisation of shared waterspace by traditionally manned, partially automated and fully autonomous surface vessels. The focus is the interaction in potentially hazardous situations between mariners in conventional manned craft as they perceive and respond to COLREGS- compliant autonomous surface vessels.

Project information

Project lead: BMT Ship and Coastal Dynamics Limited
Collaborators: L3Harris and Deimos Space UK Limited
Project type: Collaborative research and development
Total project cost: £550,000
Grant award: £275,000
Start date: November 2017
End date: October 2019

Executive Summary

This project develops and implements new solutions enabling the improved utilisation of shared waterspace by traditionally manned, partially automated and fully autonomous surface vessels. Our focus is the interaction in potentially hazardous situations between mariners in conventional manned craft as they perceive and respond to ASVs operating both over the horizon (beyond line of sight) and in proximity to other vessels using newly fused visual and satellite data. There is a pressing need to guide and train pilots and other mariners and marine insurers in how to react to this evolving ASV technology as it enters a rapidly growing marketplace. Our main objectives are fourfold; to exploit satellite sensing technology to enable a higher fidelity world model to be provided to vessel operators and /or supervisors; to simulate new scenarios for ASV operations; to combine, for the first time, ASV control simulators and ship hydrodynamic simulators into a single suite capable of visualising different datasets in 3-D; and to evaluate new multi-vessel conflict scenarios in the real-world.)

What is the value or size of the addressable market?

Our four target markets are global in nature and have high cross-leveraging potential because customers in each segment (shipping companies, port authorities and developers, port state control and other regulatory and statutory bodies, pilots) already interact significantly within day to day maritime operations. The accessible market for ASV designs, system assurance and training for key stakeholders is valued at £650 million annually within 10 years.

Project Plan / Progress

SWANS has delivered a demonstration of a suite of integrated simulators combining operational awareness, over the horizon optimised unmanned navigation and operation in congested waters in the presence of manned vessels.

Demonstrations have been given of the use of both manned vessel in unmanned mode and an unmanned vessel in autonomous mode operating over the horizon at sea and also in congested waters such as ports, navigation channels and inland waterways. A digital forensics module has been developed within the integrated simulators, which allows rapid visualisation and lessons learned after scenarios have been simulated that identify a very high risk of collision or contacts.

Successful completion of work packages covering Training & Environment Simulation and the development and testing of a manned and unmanned conflict prediction tool will now feed into recommendations for regulations for safe operation and updates to the International Maritime Organisation (IMO) working group on autonomous vessels.

Commercial exploitation has been rapid, with BMT simulators being adopted by numerous manned and autonomous ship operators as well as the leading statutory marine accident investigation bodies worldwide. These include the US National Transportation Safety Board and the UK Marine Accident Investigation Branch and counterparts in the Netherlands, Australia and Singapore.

Dr. Phil Thompson • Director Phil.Thompson@bmtglobal.com

TeamTao XPRIZE

Summary of the project aim

TEAMTAO are developing a cost effective platform which enables access to the depths of our oceans, using a cubesat-like philosophy to change the way we approach ocean data collection. A growing team with expertise in subsea engineering, acoustics, robotics and material science, we are testing and validating a step-change in technology to make deep sea data rapidly attainable and affordable.

Project information

Project Lead: Soil Machine Dynamics Limited
Collaborators: Newcastle University
Project type: Demonstrator
Total project costs: £1,171,234
Grant award: £738,486
Start date: June 2018
End date: March 2019

Executive Summary

With 95% of our oceans unexplored, we know more about the surface of Mars than what exists thousands of meters below the waves. From climate change, to over-fishing, diminishing resources, algal blooms and ocean-plastics, there's an exponentially growing need for better understanding of our oceans.

Our dynamic constellation of deep sea drones will enable rapid and repetitive access to our oceans' vital signs, forming a cost-effective platform to change the way we collect and understand ocean data.

Due to the support of the ISCF, we were the only UK team to reach the final of the prestigious $7m Shell Ocean Discovery XPRIZE competition and proceeded to win the 'Moonshot' prize for innovation.

What is the value or size of the addressable market?

The global ocean economy output is predicted to double to $3 trillion by 2030. This increase of ocean opportunities will require a commensurate level of traditional survey and new data types to support them; something that our highly innovative autonomous survey system would facilitate. Our system will allow a cost reduction of ocean data, enabling new entrants to access the ocean economy.

Project Plan / Progress

Due to the support of the ISCF, we achieved the goals set in not only our project but also our business.

We were the only UK team to reach the final of the prestigious $7m Shell Ocean Discovery XPRIZE competition and were honored to be awarded the 'Moonshot' prize in recognition of the outstanding innovation of our system and its potential to change the survey industry. The judges unanimously agreed to bestow this award and it is represents first time this has been done in the 23 year history of XPRIZE competitions.

In the past year since concluding the UKRI project, we have continued the development of our pioneering autonomous system and are pursuing numerous potential commercialisation routes.

Offshore Robotics for Certification of Assets (ORCA) Hub

Summary of the project aim

The multimillion-pound ORCA Hub addresses the offshore energy industries' vision for completely autonomous inspection repair and maintenance of remotely deployed surface and submerged assets. The Hub brings together internationally leading experts with over 30 industry partners to create a multi-disciplinary consortium.

Project information

Project lead: Heriot-Watt University (Edinburgh Centre for Robotics)
Collaborators: University of Edinburgh, University of Oxford, University of Liverpool and Imperial College London and over 30 industry partners. From January 2020: 8 additional UK universities joined the Hub as Partnership institutes (University of Glasgow, University of York, University of Lancaster, National Oceanography Centre, Edinburgh Napier University, Glasgow Caledonian University, University of Newcastle, and University College London)
Project type: Use-inspired hub
Grant award: £14,635,590
Start date: October 2017
End date: April 2021

Executive Summary

The ORCA Hub's primary goal is to use Advanced Robotics and Artificial Intelligence to revolutionise Asset Integrity Management for the offshore energy sector through the provision of game-changing, remote inspection, repair and maintenance solutions. These should be readily used with existing and future assets and sensors, operating and interacting safely in autonomous or semi-autonomous modes in complex and cluttered environments.

The key research objective is to develop technologies that enable reliable, robust and certifiable robot assisted asset inspection, autonomous decision making and intervention capabilities for the offshore domain, with specific focus on challenges inherent to this extreme and unpredictable environment using aerial, topside and marine robot platforms.

The ORCA Hub uses a spiral innovation model where groups of desirable but unavailable advanced autonomous and semi-autonomous robot and interaction capabilities are derived from operational use cases defined by industrial partners. Applied research rigorously pursues these capabilities and demonstrates progress towards them in regular realistic field trials, shared with partners. Future research plans are then modified with industry feedback for sprints to the next demonstration trials. In parallel, industry requirements are modified so as to converge on a set of robot and interaction capabilities that are both feasible and of practical use, ready for translation in collaboration with and supported by industrial partners.

Applied Research Themes:
- Subsea, ground and aerial robotic platforms
- Human-machine Interaction, including human-robot collaborative planning and monitoring of cognitive load
- Innovative sensor development for Non Destructive Evaluation, low-cost sensor networks and autonomous robot deployment
- Advanced environment mapping from multiple sensors
- Advanced robot motion planning and control for autonomous and shared-autonomy missions
- Shared autonomy robot task planning
- Approaches to robot verification, validation, fault detection, diagnosis and plan repair including self-certification.

ORCA HUB
Offshore Robotics for Certification of Assets
Remote Safety and Integrity

What is the value or size of the addressable market?

The end users are the offshore energy asset owners, operators, service companies and technology developers.

The size of the addressable market for offshore Robotics and Autonomous Systems (RAS) carrying out Inspection, Maintenance and Repair (IMR) tasks is significant, for example, global offshore IMR currently sits at approximately $7.19billion per year, expecting to increase to $17.33 billion by 2026. Offshore wind farm operation and maintenance spend in the UK alone is due to increase from approximately £600million per year today to approximately £2 billion per year by 2030. RAS has the potential to help reduce this through increased efficiency, smarter planning and reduced manpower requirements.

Project Plan / Progress

The hub has made technical advances in critical capabilities identified in conjunction with industrial partners as essential to envisaged use cases, specifically

a) mapping and surveying of complex structures using multiple robots equipped with distributed, mobile optical and acoustic spatial sensors and industry accepted non- destructive evaluation (NDE) sensors in the dynamic and challenging off-shore environment,

b) planning and execution of efficient, localisable and repeatable motion, and contact of heterogeneous robotic deployment platforms (wheeled and legged for topside, aerial and marine) for sensor placement and manipulation in extreme and dynamic conditions - with specific emphasis on failure prediction, re-planning and recovery strategies,

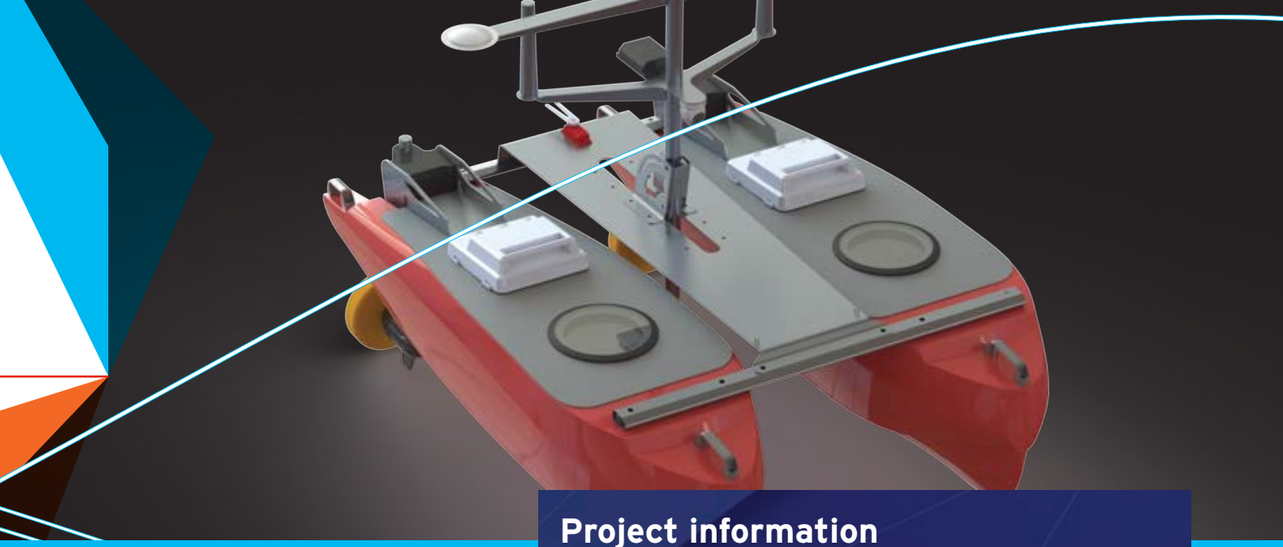
c) effective communication of world view, system actions and plan failures between remote robot and operator to develop trust and avoid unnecessary aborts,

d) designing robotic systems that can self-certify and guarantee their safe operation, including when learning systems are involved, alongside methodologies for verification and validation.

As part of the spiral innovation model, 3 cycles of whole-Hub technology demonstration and requirements refinement have taken place in the first 2 years of operation. At each, all-hands from the Hub deployed, tested and demonstrated their robot capabilities at the Underwater Centre Fort William, the Fire Services College Moreton-in-Marsh, and the ORE Catapult, Blyth.

After 24 months, 6 spin out products, 4 IP licence opportunities and 2 knowledge transfer activities are in evaluation. £2m of a £10m industrial translation forward opportunity pipeline has been converted. 8 new research organisations have now joined the hub from flexible funds. Impact includes over 120 publications, more than 1,000 followers on social media, 16.7m people reached through conventional media, 28 events with 6 exhibition stands including 1800 school children and 10,000 members of the public through the 2019 Royal Society Summer Science Exhibition. This impact will continue to grow as the translation to commercial impact from the Hub continues to grow in the third year of operation.

Unmanned Surface Vessels for Rapid Environmental Assessment in challenging inland waterways and tidal environments



Summary of the project aim

HydroSurv™ is developing two Unmanned Surface Vehicles (USVs) known as Rapid Environmental Assessment Vessels (REAVs) for hydrographic, geophysical and environmental data collection in extreme and challenging environments. This R&D project is developing and integrating new command, control and communication systems in collaboration with partner technologists Reygar and Core Blue.

Project information

Project lead: HydroSurv Unmanned Survey (UK) Limited
Collaborators: Reygar Limited, Core Blue Limited, Offshore Renewable Energy Catapult
Project type: Demonstrator
Total project cost: £918,679
Grant award: £663,629
Start date: February 2019
End date: January 2021

Executive Summary

There is proliferating need for waterborne data acquisition across several sectors driven by increasing demand for resources and the need to ensure exploitation is safe and sustainable.

HydroSurv™, an innovative designer, builder and operator of USV platforms is developing a range of lightweight and portable platforms capable of economic and rapid data acquisition at low capital cost, without compromise on data yield, positioning accuracy, levels of integrity or maneuverability.

In collaboration with technologist partner Reygar, a new command and control system capable of mission planning, execution and live-streaming of survey data to a shore-based operative is being developed and tested on the REAV USVs, building upon a proof of concept developed during Phase 1 of the project.

Joining the consortium, technologist partner Core Blue are developing and integrating a mesh network radio communication system, capable of relay / range extension on inshore and coastal survey campaigns using collaborative manned and unmanned teaming.

The project will deliver prolonged testing in a range of operational environments and use scenarios with design optimization and improvement work packages running in parallel to the test programme. Approaches to robot verification, validation, fault detection, diagnosis and plan repair including self-certification.

What is the value or size of the addressable market?

The project is addressing the growth in the ocean economy, which the OECD expects to become a $3 trillion dollar market by 2030. Global surveying and seabed mapping was a market worth $38.1B in 2018, and the global USV market is expected to grow from $534M to >$1B from 2018 to 2023. HydroSurv™ is mainly targeting its services at inland, inshore and coastal segments where there are a vast range of applications.

Project Plan / Progress

Following detailed requirements planning, the project team has designed and developed working command and control, and communication sub-systems which have been bench-tested and / or verified in a representative environment.

Reygar has developed a command and control system for USVs using its own data bus control architecture and featuring a mission planning and execution front end informed by close consultation with HydroSurv™ operators.

Core Blue has developed a Multiple Input Multiple Output (MIMO) RF mesh network communications system, incorporating failover features and graphical visualization. A working system is currently undergoing testing, prior to integration into the vehicle. In parallel to sub-system development, HydroSurv™ has designed and constructed two new USV platforms aimed at different use applications. REAV-16 is a lightweight and portable modular USV system primarily intended for use in challenging inland environments, such as rivers, tidal estuaries or beaches. The larger REAV-40 is a trailer portable, seagoing USV aimed at applications within inshore and coastal areas, or as a force-multiplier for offshore survey operations.

Windfarm Autonomous Ships Project (WASP)

Project information

Project lead: L3Harris
Collaborators: Houlder Limited, Offshore Renewable Energy Catapult, Seaplanner Limited And University of Portsmouth
Project type: Collaborative research and development
Total project cost: £965,252
Grant award: £667,489
Start date: January 2019
End date: December 2019

Executive Summary

The UK economic opportunity in offshore wind energy is robust and growing, but further cost reduction is essential to compete with fossil fuel and nuclear energy systems. The application of robotics and artificial intelligence (RAI) is being assessed in all other major sectors. For offshore wind, RAI offers the opportunities to minimise the need to send personnel offshore, reduce health and safety risks, improve offshore wind turbine availability and potentially significantly reduce operating costs by around 2.8% while reducing turbine downtime by around 13%.

A consortium led by L3Harris with SeaPlanner Limited, Houlder, University of Portsmouth and Offshore Renewable Energy Catapult will carry out industrial research to establish the baseline for autonomous vessel operations in offshore wind and verify the timeframe for their introduction. Windfarm autonomous support vessels project (WASP) will undertake an 18-month industrial research project to benchmark the technological challenges facing the sector transition to autonomous support operations and chart a roadmap for the phased introduction of RAI systems for spares supply, asset surveillance, security patrol and crew transfer.

The project will also create design specifications for new offshore command and control infrastructure and an innovative autonomous vessel with integrated robotic cargo capability. WASP will pull through existing enabling technology from project partners L3Harris (autonomous vessel AI technology), Houlder (gyro stabilised robotic arm) and SeaPlanner (offshore wind marine coordinator systems) demonstrating their application to offshore wind cargo supply.

University of Portsmouth will develop decision support algorithms to enhance SeaPlanner marine coordination software enabling integrated manned and autonomous vessel offshore operations. ORE Catapult's cost and performance analysis will pinpoint how this new capability increases uptime of offshore wind turbines.

These products will also apply to adjacent maritime sectors such as oil and gas, wave and tidal energy, border patrol, fishery protection, search and rescue and merchant cargo handling, where there is a need to reduce costs, enhance efficiency and minimise the need for manned offshore operations conducting dull and dangerous missions. Insights from the project will be made available by ORE Catapult to raise awareness in the offshore wind sector of the huge benefits that RAI can bring and to drive investment in RAI technology and infrastructure. This project will help stimulate the UK supply chain to become a major player in the offshore wind autonomous support vessel market.

L3HARRIS™ HOULDER CATAPULT Offshore Renewable Energy SeaPlanner UNIVERSITY OF PORTSMOUTH

Dynamic vessel design feasibility study for subsea WITT energy harvester

Project information

Project lead: Witt Limited
Project type: Collaborative research and development
Total project cost: £97,266
Grant award: £68,086
Start date: November 2017
End date: July 2018

Executive Summary

This feasibility project looks to determine whether the WITT energy harvester, which converts chaotic motional energy from all 6 degrees of freedom into electrical energy, could be tethered to the sea floor in remote locations and housed within a protective casing, to convert sub-sea currents into electrical energy to power sensor instrumentation.

Witt Limited will be working with The Offshore Renewable Energy Catapult (OREC), the UK's flagship technology, innovation and research centre for offshore wind, wave and tidal energy. As a subcontractor they'll draw on their expertise and knowledge to devise an efficient way to convert such subsea currents into electricity with the WITT housed inside.

Witt Limited has been approached by oil and gas entities interested in the capability for the WITT to power sensors subsea, defence entities for sensors, and others for environmental and other applications. The benefit of the WITT is that it would be able to provide continuous power where otherwise battery solutions would be required, which are expensive to replace in remote sea locations.

Environmentally Powered Integrated Thermoelectric Harsh Environment Robotic Magnetic Anomaly Locator (EPITHERMAL)

Project information

Project lead: Nemein Limited
Project type: Research and development
Total project cost: £99,496
Grant award: £69,647
Start date: December 2019
End date: November 2020

Executive Summary

Nemein is an award-winning small business based in South Wales, manufacturing downhole tools for the oil and gas industry. The proposed project targets the development of a magnetic anomaly sensing capability purpose-built for the extreme environment found at the bottom of kilometres-deep wells.

HyRIZON
for maritime protection

Project information

Project lead: Archangel Imaging Limited
Project type: Demonstrator
Total project cost: £99,898
Grant award: £69,928
Start date: January 2018
End date: December 2018

Executive Summary

We're developing hyperspectral machine vision payloads for unmanned systems. Not only will we be able to see the invisible, we'll be able to tell what it's made from and detect interesting objects automatically in remote areas.

Robotic digital X-ray scanning system for deep water flexible riser inspection (RobotX)

Project information

Project lead: Innovative Technology and Science Limited
Project type: Demonstrator
Collaborators: Brunel University London, Computerised Information Technology Limited and London South Bank University
Total project cost: £498,841
Grant award: £393,956
Start date: April 2018
End date: March 2019

Executive Summary

Offshore oil and gas operators have new challenges in providing adequate integrity assurance of their assets as production facilities reach for the deep-water areas. Challenging conditions arise from more corrosive environments, higher pressures and temperatures.

In deep water and hostile environments, where loading is high and complex and design methods are often pushed to the limit of current industry capability and experience, the riser systems have received an increased focus, more than ever in the light of several operational incidents (like Deepwater Horizon accident in the Gulf of Mexico). These accidents have caused operators and regulators to question and update codes of practice.

Flexible riser pipes are by nature complicated in design with many material types, corresponding to challenges in the inspection and integrity evaluation. The inspection techniques currently available in the market consist of only irregular diver or remotely operated underwater vehicle (ROV) inspections and can only inspect the near side layers for wire disruptions, with the far side layers remaining uninspected. The RobotX project will investigate the feasibility of a robotic digital x-ray scanning system that will address the needs and challenges of deep water flexible risers inspection.

The robot and digital radiography equipment would have to withstand harsh environmental conditions of high pressure (100bar). The system will perform a see-through quick scan as it crawls and will process the data using innovative image processing methods, then categorise them using machine learning. If defects are detected the robotic system will be able to turn around the riser and perform a more thorough scan. The defect will be correctly identified, using images taken at several angles.

These innovations will allow for not only the detection and location of defects, but also classification according to an existing historical database before automatically deciding on bespoke scans to assess the severity and need for future intervention.

Nuclear

For operations in the nuclear energy environment sixteen projects addressing RAI capabilities and systems have been funded; these include two Innovation Hubs, six Demonstrator and seven CR&D projects. The demonstrator projects include those from the SBRI on Nuclear Decommissioning, while the CR&D ones are from specific Electronics Sensor & Photonics (ESP) competitions as well as the Innovation Lab/sandpit competition.

Most of the projects project are addressing overall system and system integration related issues, with two them working on Unmanned Under-water Vehicles (UUVs).

Alpha Glovebox Decommissioning Feasibility Study

Summary of the project aim

The Alpha Glovebox Decommissioning Challenge is a highly skilled project exploring how to use lasers and autonomous grasping to cut up – and dispose of – decommissioned gloveboxes that have become contaminated with alpha emitters. This would achieve safer, faster and cheaper nuclear decommissioning.

Project information

Project lead: National Nuclear Laboratory Limited
Collaborators: The Shadow Robot Company Limited, I3D Robotics Limited, TWI Limited, University of Strathclyde
Project type: Collaborative research and development
Total project cost: £204,311
Grant award: £155,727
Start date: February 2018
End date: January 2019

Executive Summary

Current cutting and disposing of contaminated alpha boxes are very much a manual process with significant risks to the operator involving radiation. It is also an inefficient way of getting rid of secondary waste taking up more storage containers leading to soaring costs related to equipment decontamination.

The project solved this problem by using laser cutting via remote technologies instead of manual size reduction methods. Not only do we provide a layer of safety between the operator and the task, we also help keep costs down and create more environmentally friendly operations.

Success was achieved through the systematic project management ensuring:
- engineering design
- technology integration
- date fusion and data analytics
- software development
- laser and fume management developments
- the output of the project will be a full feasibility study of the system

Prior to this, the industry had significant uncertainty over the capability, integration and use of this technology however the alpha glovebox decommissioning challenge project has successfully demonstrated the feasibility of developing an automatic robotic control system.

What is the value or size of the addressable market?

The project is aimed at the nuclear decommissioning sector particularly around the disposing of contaminated gloveboxes. Since then, The Shadow Robot Company has taken its hardware and key learnings to create the Tactile Telerobot (a remote teleoperation system with haptic feedback) which can also help with the earlier stages of nuclear decommissioning (not just waste reduction).

The Tactile Telerobot allows operators to remotely sift through radioactive material in alpha gloves boxes from a safe and comfortable distance, significantly improving safety without drastically changing existing procedures. It can also be used in other extreme environments where remote manipulation is needed.

Project Plan / Progress

The Alpha Glovebox project enabled the Shadow Robot Company to take its hardware and explore it further within realistic decommissioning scenarios. NNL's 'Enhanced Glovebox Operations Overview' stated that the tech has: "a number of advantages to robotic teleoperation, both from a control and an operator's point of view."

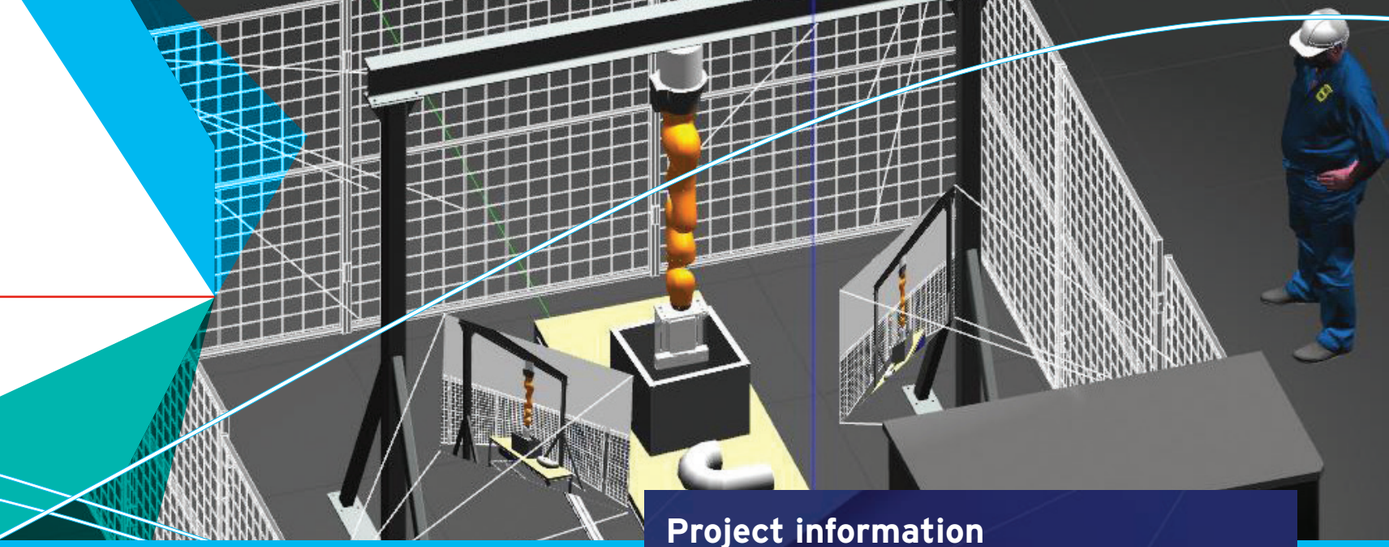
Shadow also explored the effect of radiation on their tech, the use of vision and improved dexterity within automatic grasping. The company then applied the learnings to the Tactile Telerobot (a collaboration between SynTouch and HaptX, funded and facilitated by ANA) which is the world's first haptic telerobot hand and the forerunner of today's most advanced remote systems. The Tactile Telerobot can be set-up at a glove box and the Shadow Hand component is inserted into existing glove ports. The operator wears a haptic glove allowing them to control the Shadow Hand at a safe distance, e.g. another vicinity. The robot mimics the operator's hand and arm movements, handling hazardous materials so the operator doesn't need to. "Touch sensations" allows the operator to feel what they're handling for better accuracy.

Jeff Bezos, CEO & Founder of Amazon tried the tech and stated: "Weirdly natural... the tactile feedback is really tremendous!"

The benefits to the sector include:
1. 0% risk to the worker
2. No dose exposure
3. More operational hours
4. Eliminate restrictive personal protective equipment (PPE)
5. Vision and touch feedback to enable more precision and accuracy
6. Reduce cost of significant secondary waste
7. New technology to encourage millennial recruits

contact@shadowrobot.com

Automated Nuclear Decontamination Cell (AND-C)



Project information

Project lead: Create Technologies Limited
Project type: Collaborative research and development
Total project cost: £99,395
Grant award: £69,576
Start date: November 2019
End date: October 2020

Summary of the project aim

AND-C will respond to the challenge of removing workers from nuclear hazardous environments by providing a system that can remotely scan items for radioactive contamination and then automatically remove the contamination from the item.

Executive Summary

AND-C will respond to the challenge of removing workers from nuclear hazardous environments by providing a system that can remotely scan items for radioactive contamination and then automatically remove the contamination from the item.

The nearest state-of-the-art is manual decontamination or possibly manual decontamination combined with some robotic remote handling. AND-C will improve manual decontamination by removing the requirement to have a worker in a hazardous environment. AND-C improves any remote handling decontamination system by combining radiation source mapping with the robotic system used for decontamination.

The AND-C sensor pack on the robotic arm scans the contaminated item and the 3D radiation contamination map will be transferred directly to the robotic system to guide the arm to the precise location and remove the contamination.

There are two main foci of innovation, firstly navigation of the sensor pack over the item to build up a point cloud model and collect the radiometric data. Secondly, using N-Visage to estimate the source distribution of the contamination on the item surface and translate that information into a 3D location map that can be transferred to the robotic arm control system.

A prototype cell with a robotic arm is to be developed that can demonstrate the Createc sensor pack producing the 3D contamination model that can be then be used by the robotic arm to move to the right location to build the best contamination map.

What is the value or size of the addressable market?

It is difficult to extrapolate the value of the market for decontamination cells in the main target markets of UK, Germany, France and Belgium. However, it is a reasonable assumption that each reactor in permanent shut down could have an AND-C system. According to the International Atomic Energy Agency's (IAEA) Power Reactor Information System (PRIS) these countries would give a potential market of 72 systems.

In the UK alone there are 29 redundant, defueled reactors awaiting decommissioning and 15 operable reactors.

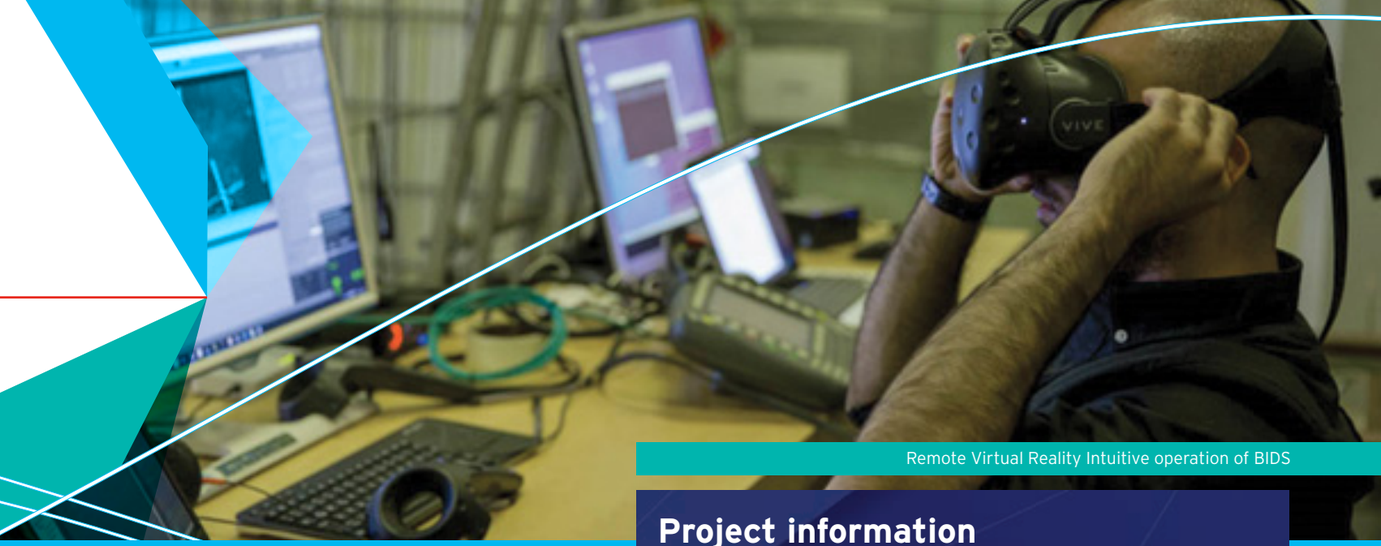
Project Plan / Progress

The AND-C project started in November 2019 and builds on the decommissioning experience Createc has gained since 2010. Createc started in the nuclear industry with the N-Visage 3D radiation analysis software and has gone on to develop a range of N-Visage instruments for collecting data in many different decommissioning applications. Createc was awarded the Queens Award for Enterprise in 2018 for exporting R&D work to help the clean-up work at Fukushima Daiichi in Japan and the Queens Award for Enterprise in 2019 for innovative work in nuclear decommissioning. The developments during the project to create an automated nuclear decommissioning cell system will be demonstrated towards the end of the 2020.

createc

pete.rodgers@createc.co.uk

Barrnon Integrated Decommissioning System



Remote Virtual Reality Intuitive operation of BIDS

Summary of the project aim

The BIDS System is a platform designed to deploy tools used in the decommissioning process for nuclear environments. It captures the environment by measuring it with a laser and presenting images to an operator in Virtual Reality. An algorithm generates a work plan allowing the robots to segregate waste.

Project information

Project lead: Barrnon Limited
Collaborators: Create Technologies Limited, Cambrian Intelligence Limited
Project type: SBRI
Total project cost: £1,499,950
Grant award: £1,499,950
Start date: January 2018
End date: September 2019

Executive Summary

A specialist hydraulic-mechanical platform hosts multiple robotic manipulators with quick change tool capability. The platform is combined with on-board scanning and radiation detection technologies to characterise the physical and radiation profile of the redundant work environment.

Using data, a 3-D map is generated. This allows an algorithm produced plan for size reduction, resulting in categorised waste and more efficient storage.

Once this plan is obtained, a range of tools are deployed. The tools range from laser cutting, to proven nuclear decommissioning tools such as Barrnon's patented Bladecutter and traditional hand tools. Once the fabric of the cell is cut up, the waste can be picked up by a gripper and disposed of.

The system seamlessly integrates Virtual Reality, visualising both a point cloud model, radiation scan, CAD representation of the manipulators and an array of mono and stereo camera views providing an intuitive user environment for the operator. It delivers an easy to use system reducing risk and cost whilst saving time.

A successful Phase 1 (Concept and Prototype development) led to a Phase 2 – non-active demonstration, of which Barrnon were one of the two winners.

Barrnon is delighted with the outcome of the Phase 2 developments. The resulting system has been demonstrated as an extremely versatile and modular platform, capable of transporting and deploying an array of tools into the decommissioning environment in an effective and intuitive manner.

createc BARRNON /> Cambrian Intelligence

What is the value or size of the addressable market?

Globally a large portion of the legacy nuclear infrastructure will undergo a major shift in focus. As generation and reprocessing ceases, decommissioning, waste management and site remediation assume increased priority. There are many opportunities to do things more safely, faster and at reduced cost.

There are numerous nuclear facilities in the UK, and Barrnon are reaching out to the USA, Japanese and Canadian markets. They each have their own challenges, but a significant proportion are associated with processing operations, both historic and recent. The BIDS provides a unique turn-key solution to the decommissioning of these hazardous facilities.

Project Plan / Progress

Our unique platform is a real game changer within the industry. "A highly radioactive area that has very limited human access either cannot be dismantled or requires many teams of technicians to carry out simple tasks. A conservative estimate would be a relative cost reduction of 300% based on a BIDS system with two operators," an industry expert told Nuclear Energy Insider (Dec 4th 2019).

The project received significant investment to bring it to market – at speed. Further enhancements to the system are now needed, hopefully funded as part of a Phase 3 active trial.

One of the key parts of the system is its VR component, which allows an operator to perform scans, review data, command robots, calculate cut plans, and fully deploy a range of tools -- safely. However, to make the system more usable, it needs:

- Improved reach of the BIDS arms
- Improved control of the hydraulic arms
- Enhanced control of Laser cutting
- Research into new VR 'controllers'
- Enhanced Collision avoidance

The next step is the deployment in an active environment in collaboration with the project sponsors and the end users. A commercial model is being built and the system has had considerable interest from the domestic – and international - nuclear decommissioning community. (The unit is going to be dispatched to trade exhibitions in the USA in March).

Collaborative Technology Hardened for Underwater and Littoral Hazardous Environments

Project information

Project lead: QinetiQ Limited
Collaborators: Bristol Maritime Robotics Limited, Fortis Mechanical Design Limited, Lancaster University and Nuvia Limited
Project type: Collaborative research and development
Total project cost: £1,370,363
Grant award: £948,776
Start date: January 2018
End date: December 2019

Executive Summary

QinetiQ, a UK multinational defence technology company based in Farnborough, Hampshire, has teamed up with a number of the UK's top innovative technology providers in response to Innovate UK's competition for robotics and artificial intelligence in extreme and challenging environments.

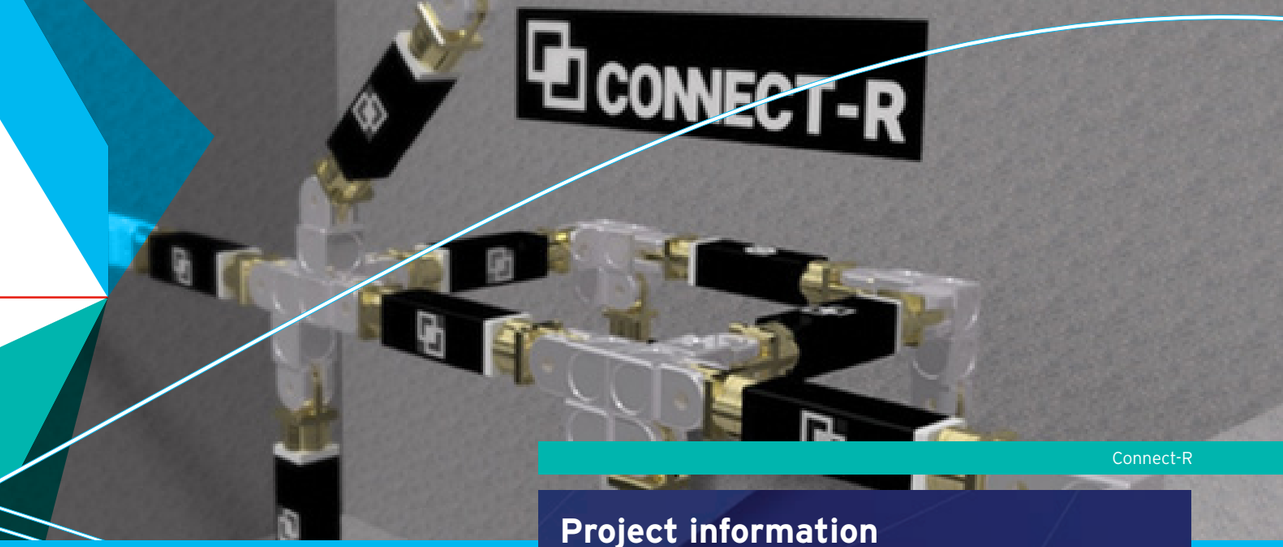
The title of the project is 'Cthulhu' named after the cosmic entity created by writer H. P. Lovecraft. Cthulhu is described as looking like an octopus, a dragon and a caricature of human form. QinetiQ has assembled a comprehensive team suited to the complex and wide ranging challenges associated with the decommissioning of the active process plants on the Sellafield site. The team includes experts from both industry and academia including QinetiQ (lead), Nuvia UK Limited, University of Lancaster, Bristol Maritime Robotics and FORTIS Remote Technology.

All the partners have worked in the past or are currently already working with Sellafield Limited and also across the Nuclear Decommissioning Authority (NDA) estate on a number of diverse decommissioning related projects. These projects bring together complimentary technologies, systems, understanding and skills to deliver solutions for extreme environments that have applications and some cross-cutting, nationally and internationally.

This project undertakes research and the development of autonomous systems that exploit state-of-the-art machine learning technologies for autonomous inspection and maintenance of hazardous (nuclear) spaces. The proposed solution will deliver the following innovative components:

- a robust robotic platform that is amphibious, with higher levels of autonomy for extreme environment operations and 24/7 availability
- simultaneous localisation and mapping (SLAM) based on sonar, tactile and passive electro-optical (EO) sensors enabling underwater operations – able to recognise objects of interest using new fast transparent deep learning image classifiers and make decisions in the context of the task (inspect and move) including collision detection and avoidance
- tactile sensing for visually obscure environments to enable detailed local situational awareness to be achieved in support of the sonar sensing
- the platform will be compatible with a range of intelligent tooling modules and adaptable for a range of operational scenarios

Connect-R - Providing Structure in Unstructured Hazardous Environments



Connect-R

Summary of the project aim

Connect-R is a modular robotic ecosystem that encompasses industrial-scale manipulation through to fine scale flexible task capabilities. This is delivered using a modular configurable and self-building component set supported by innovative AI to infer condition and plan deployment missions.

Project information

Project lead: Barrnon Limited
Collaborators: University of Edinburgh, Royal Holloway University of London, Ross Robotics Limited, RACE (part of UK Atomic Energy Authority), Tharsus Vision Limited, Jigsaw Structures Limited
Project type: Collaborative research and development
Total project cost: £5,997,917
Grant award: £4,669,475
Start date: January 2019
End date: February 2021

Executive Summary

There are many hostile working environments that require sophisticated tasks to be performed, such as the building of structures and deployment of tools where there is significant risk to the health and safety of any manual workers involved, high cost of deployment and significant timescales for completion.

Examples are Nuclear Decommissioning, Oil and Gas, Mining and Space systems. Common to many of these environments is the extreme difficulty of effective deployment of the sophisticated kind of equipment that replaces human beings. These environments present the following challenges:

Hazardous working environments requiring protective equipment and limited time windows for operation

Limited access through which to deploy the systems

Unstable structures present that prevent occupation

Lifting of heavy objects (~50kg) that require mechanical assistance

Processing of large volumes of liquids (1000s litres)

The Connect-R team propose to develop an industrial-scale self-building modular robotic solution to provide robotic access to work-sites in these hazardous environments.

The Connect-R project aims to develop a robotic and artificial intelligence (RAI) system that removes humans from infrastructure inspection, maintenance and repair in extreme environments such as nuclear decommissioning, oil-and-gas offshore, and mining. Our innovative self-building robotic system provides structure in unstructured environments and represents a significant step towards making unmanned operation the standard approach in hazardous environments. The modular scaffold system enables heavy-engineering operations to be performed in work-sites that were previously inaccessible to robotic systems. By providing both structure, and infrastructure (internal services carrying power, hydraulics, vacuum extract etc.) the Connect-R system will be capable of working safely, and efficiently, over long periods of time, and without human-maintenance---the builder-bot system will be capable of maintenance tasks on the modular structure.

What is the value or size of the addressable market?

Globally a large portion of the legacy nuclear infrastructure will undergo a major shift in focus. As generation and reprocessing ceases, decommissioning, waste management and site remediation assume increased priority. There are many opportunities to do things more safely, faster and at reduced cost.

There are numerous nuclear facilities in the UK, and Barrnon are currently reaching out to the USA, Japanese and Canadian markets. They each have their own challenges, but a significant proportion are associated with processing operations, both historic and recent. The Connect-R provides a unique solution to assist the decommissioning of these hazardous facilities.

Project Plan / Progress

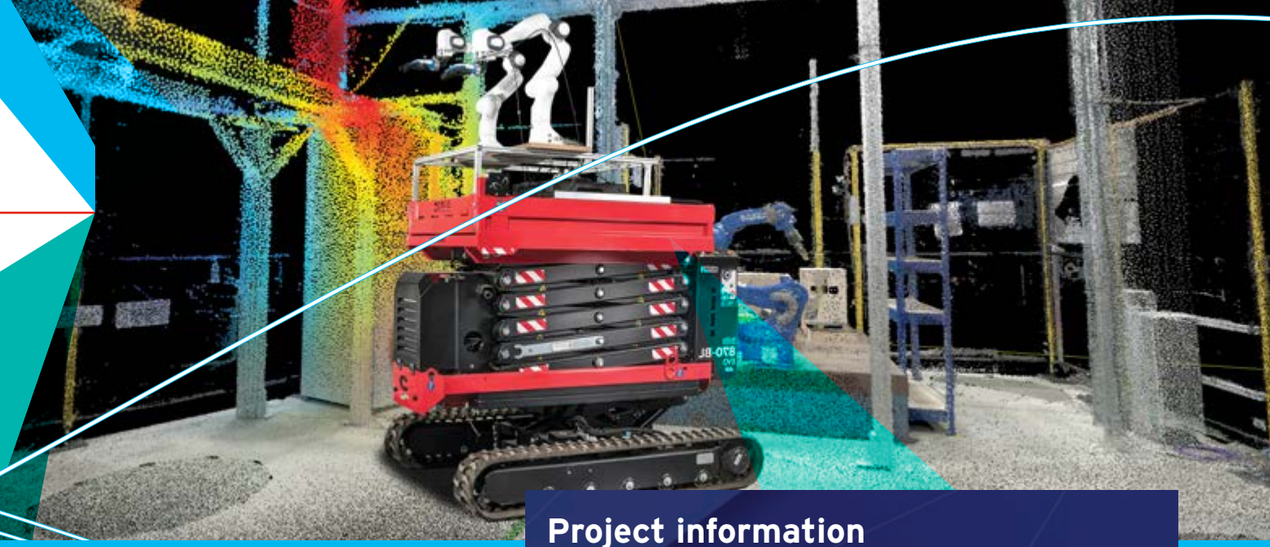
During the early stages of the project in-depth analysis of the operational requirements identified significant packaging constraints. A cross-consortium design review was completed to assess the risks and benefits of each potential solution. Beyond this fundamental design optioneering, great progress has been made with the overall 'Super Strut' (SS) design concept and configuration. 1:1 scale models have been created of the SS and the connector to allow visualisation and initial functional validation.

The fundamental building blocks of the mission planning process have now been developed for full 3D visualisation of an optimised mission against a representative goal. This planning process will now be exposed to the physical and performance constraints as defined by the Super Strut and connector design together with the associated verification and validation process.

Fluidic logic remains the stretch target for control and good progress has been made in core building blocks, conceptual DEMUX design and selection of representative COTS components to allow a bench test to be planned. These systems when used in the full SS design will require 100's of active elements so miniaturisation of each of these remains the major challenge that keeps full hydraulic control as a stretch target / moon-shot of the project.

There remains continued enthusiasm and active collaboration between all members of the consortium and the project remains on track in terms of Scope, Cost and Time.

Elephants to Ants: Innovation in Integration



Summary of the project aim

The aim for Elephants to Ants (E2A) is to develop an end to end inactive decommissioning demonstration. The underlying principle of E2A is the integration of multiple, relatively small robots or devices ('ants') working together to achieve goals beyond their individual capabilities, eliminating the need for a large, complex, 'one size fits all' machine ('elephant').

Project information

Project lead: Create Technologies Limited
Collaborators: RACE (Remote Applications in Challenging Environments), RED Engineering, Structure Vision, REACT Engineering, OC Robotics, Shepley Engineers, Italian Institute of Technology (IIT)
Project type: SBRI
Total project cost: £1,500,000
Grant award: £1,500,000
Start date: January 2018
End date: September 2019

Executive Summary

The prevailing vision of a nuclear decommissioning robot is of a large, single purpose, bespoke machine that achieves its functional specification largely through mechanical design, coupled with a very simple (often naïve) control system. However, as the physical capabilities of robots more closely approximate those of humans (e.g., through soft robotics), then relatively small (and therefore intrinsically safe) 'ant' robots remotely operated by humans should be able to deliver the dexterity required to carry out the majority of decommissioning tasks.

The vision behind Elephants to Ants is of a modular robotics decommissioning system in which a toolkit of relatively small robotics modules ('ants') could be controlled through a single interface and reconfigured to solve many decommissioning challenges. The project emphasises adapting pre-existing or off-the-shelf modules over design of new machines and tries to exploit the potential of software to make robot control easier wherever possible.

Some significant advantages of the proposed approach include: to eliminate the hazard of the large robot; to remove humans from exposure to radiation; to make a leap in safety beyond the current state of the art in either manual or robotic decommissioning; to introduce a dramatic reduction in costs by removing the need for the huge investment in bespoke robot; to remove the high risk that a bespoken robot does not achieve its intended functionalities.

What is the value or size of the addressable market?

The target is teleoperated robotics in fields such as nuclear, where the off-the-shelf mechanical components exist, but systems development is time consuming and technically risky, particularly where the field does not traditionally employ skills required to implement such systems from scratch.

A conservative market value for the global nuclear mobile robotics market today, pricing in short term opportunity, would be in excess of $100M. Given that global decommissioning spend is expected to increase dramatically over the next 10 years, it is not unreasonable to expect up to tenfold growth to around $1Bn for the global market over the same period.

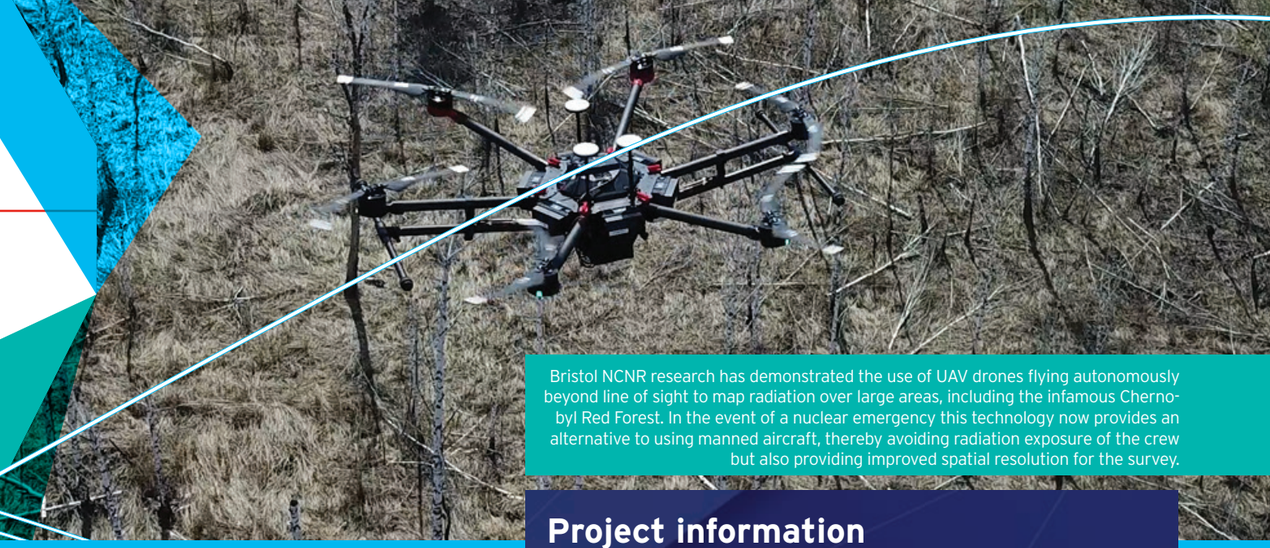
Project Plan / Progress

In order to build small robotics reconfigurable modules that could be controlled through a single interface, Createc Iris was developed. Iris is a scalable 'tool-kit' of off-the-shelf robotic software modules that can be easily reconfigured to solve the many hazardous work-face challenges currently tackled by human workers. Users with no robotics or programming knowledge are able to safely and effectively reconfigure a robotic system without needing to write any code. Iris enables users to focus on tasks to accomplish, not on understanding the tools to do them.

Iris VR was also developed as a single interface for remote scene perception and robot control. It replaces an entire control room with a VR headset. It gives operators virtual presence in a remote environment by combining VR visualisation of real time sensor data with a gesture-based user-interface that simplifies the remote control of robots and tools.

Finally, using Iris, a toolbox of robots and devices was integrated and an end to end inactive decommissioning demonstration was executed.

National Centre for Nuclear Robotics (NCNR)



Bristol NCNR research has demonstrated the use of UAV drones flying autonomously beyond line of sight to map radiation over large areas, including the infamous Chernobyl Red Forest. In the event of a nuclear emergency this technology now provides an alternative to using manned aircraft, thereby avoiding radiation exposure of the crew but also providing improved spatial resolution for the survey.

Summary of the project aim

The UK National Centre for Nuclear Robotics, is a world-leading consortium of 12 UK universities, along with industry and other stakeholders. The consortium works on a very diverse range of robotics, sensing, and AI applications for all aspects of the nuclear power industry: including robotics for new-build power stations; in-service maintenance and monitoring; decommissioning and waste handling.

Project information

Project lead: University of Birmingham
Collaborators: University of Essex, Queen Mary University of London, University of the West of England, University of Edinburgh, Lancaster University, University of Lincoln, University of Bristol
Project type: Use-inspired hub
Grant award: £11,588,431
Start date: October 2017
End date: April 2021

Executive Summary

Nuclear facilities require a wide variety of robotics capabilities for a variety of extreme robotics and artificial intelligence challenges. NCNR brings together a diverse consortium of experts in robotics, artificial intelligence, sensors, radiation and resilient embedded systems to address these complex problems. In high gamma environments, human entries are not possible at all. In alpha-contaminated environments, air-fed suited human entries are possible, but create significant secondary waste (contaminated suits) and reduced worker capability. We have a duty to eliminate the need for humans to enter such hazardous environments wherever technologically possible.

Hence, nuclear robots will typically be remote from human controllers, creating significant opportunities for advanced telepresence. However, limited bandwidth and situational awareness demand increased intelligence and autonomous control capabilities on the robot, especially for performing complex manipulations. Shared control, where both human and AI collaboratively control the robot, will be critical because safety-critical environments demand a human in the loop, but complex remote actions are too difficult for a human to perform reliably and efficiently.

Before decommissioning can begin (and while it's progressing) characterisation is needed. This can include 3D modelling of scenes, detection and recognition of objects and materials, as well as detection of contaminants, measurement of types and levels of radiation, and other sensing modalities such as thermal imaging. This will necessitate novel sensor design, advanced algorithms for robotic perception, and new kinds of robots to deploy sensors into hard-to-reach locations.

To carry out remote interventions, both situational awareness for the remote human operator, and also guidance of autonomous/semi-autonomous robotic actions, will need to be informed by real-time multi-modal vision and sensing. This will include real-time 3D modelling and semantic understanding of objects and scenes, active vision in dynamic scenes and visionguided navigation and manipulation.

The nuclear industry is high consequence, safety critical and conservative. It is critically important to rigorously evaluate how well human operators can control remote technology to safely and efficiently perform the tasks that industry requires. We have rich international involvement, including NASA Jet Propulsion Lab and Carnegie Melon National Robotics Engineering Center as collaborators in USA, and collaboration from Japan Atomic Energy Agency to help us carry out test deployments of NCNR robots in the unique Fukushima mock-up testing facilities at the Naraha Remote Technology Development Center.

What is the value or size of the addressable market?

Clean-up of the UK's 4.9million tonnes of legacy nuclear waste is expected to take 120 years at estimated costs of up to £230billion. Over the past decade, these forecast costs have steadily risen. Worldwide decommissioning needs are of the order of £1trillion or more. Robotics for new-build reactors is an emerging field, but we expect this market to grow rapidly.

Project Plan / Progress

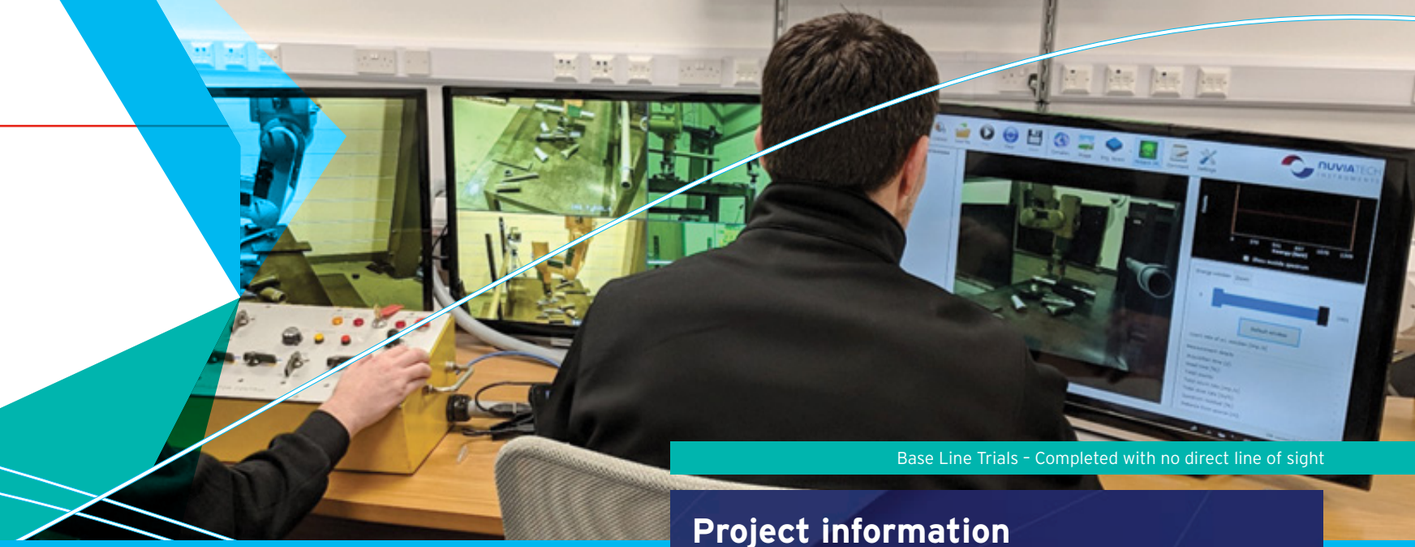
The National Centre for Nuclear Robotics has been highly successful at achieving both world-leading robotics research, and also industrial impact and innovation, together in parallel.

Within its first 18 months, the National Centre consortium published 100 peer reviewed research papers. In parallel we carried out a large amount of technology transfer, including multiple commercial contracts, via our several spinouts, from Nuclear Decommissioning Authority, Sellafield Ltd, National Nuclear Laboratory Ltd, and other stakeholders.

The National Centre also delivered landmark deployments of autonomous drone radiation surveys at Chernobyl disaster site, and other high radiation legacy sites of the former Soviet union.

The National Centre is regarded as world-leading by the international community. We have collaborated with the euRobotics community to create the Topic Group on Robotics for Harsh Environments. We have also worked with the OECDs global Nuclear Energy Agency, representing 33 nations, to create the international Expert Group on Robotics and Remote Systems, chaired by the National Centre's Director, Prof. Rustam Stolkin.

Nu-Decom



Base Line Trials - Completed with no direct line of sight

Summary of the project aim

This project addresses the challenges associated with the end to end decommissioning of highly active process cells typically found on the Sellafield Site. This project integrates legacy systems with state-of-the-art decommissioning technologies, new processes, and innovative engineering workflows to achieve the "safer, quicker and cheaper" aim.

Project information

Project lead: Nuvia Limited
Collaborators: RACE (part of UK Atomic Energy Authority), PaR Systems, Pixel Mill Limited, ImiTec, Hu-Tech, University of Manchester, University of Bristol
Project type: SBRI
Total project cost: £1,499,224
Grant award: £1,499,224
Start date: January 2018
End date: September 2019

Executive Summary

The project has developed a toolbox of innovative technologies that deliver value to the decommissioning workflow by improving safety and reducing costs timescales.

The project demonstrated that a legacy design of gantry manipulator can be upgraded for use in decommission scenarios and is capable of deploying a range of MOTS and bespoke tools systems for the decommissioning of typical process cells, including the dismantling of vessels, pipework and support structures. This combines tried and tested mechanical handling systems with the latest control system technology. The upgrade included the use of inverse kinematics and joysticks to replace the legacy joint by joint control switches. This has improved the operators experience and reduced cognitive load.

The project has demonstrated that a range of COTS characterisation tools can be adapted for remote deployment for the acquisition of geometric and radiometric data.

The project has demonstrated an efficient workflow for the development of as-built 3D models for use throughout the design process, for the training of operators and for improved situational awareness of operators during remote dismantling.

The project's innovations can be routinely applied to the decommissioning process to deliver increases in productivity. Nuvia has already applied some of these innovations, methodologies, and workflows on other projects in parallel with delivering Nu-Decom.

The project has shown that with the aid of the modern control systems it is possible to carry out remote operations without the need for co-location in the same building or even on the same site.

What is the value or size of the addressable market?

This project initially focussed on providing a specific solution targeted at process cell decommissioning and thereby limiting the UK market mainly to Sellafield, Dounreay and AWE Aldermaston, However, as the project evolved, it was evident that the components of the toolbox can be applied individually, or as integrated systems and this expands the scope to other high-hazard environments where cost-effective remote dismantling is preferable over the utilisation of human resources in personal protective equipment. There is therefore global export potential for these technologies including: La Hague in France, Ozersk in Russia, India, Rokkasho and Tokai MOX in Japan.

Project Plan / Progress

Nuvia UK and the members of the Nu-Decom project Team are ideally placed to provide technology exploitation and commercialisation on a global scale, due to a combination of experience working with SME's (Small to Medium Size Enterprises) and an established system for the integration of technology from all tiers of organisation. Nuvia have current access to a growing market, worth of £48 B, worldwide decommissioning frameworks and are currently a top 20 Tier 2 supplier to the NDA in the UK. Nuvia are one of the largest nuclear operations companies in France and the world leader in radiation protection. The diversity of the Nu-Decom project team and Nuvia's cross sector approach facilitates widespread cross-fertilisation of technology and potential to commercially exploit not just in the Nuclear Decommissioning Sector.

The project team have developed strong links as part of the delivery of Nu-Decom and there is a degree of enthusiasm to continue these collaborations. Nuvia have been exploiting elements of the toolbox via Nuvia Canada and has also recently secured a place on the Dounreay Site Restoration Decommissioning Services Framework and this may provide additional opportunities for exploitation of the Nu-Decom Toolbox of technologies.

As a result of the learning from the project PaR Systems are developing a cost-effective decommissioning manipulator based on their M3000 manipulator used in the Nu-Decom demonstrations.

UKAEA RACE are continuing to provide CorteX solutions as part of the EPSRC's NNUF project and Nuvia are supporting NNUF at RACE with the provision of a ModuCon containment system.

Adrian DAVIS-JOHNSTON • +44 (0)1946 593971 • adrian.davis-johnston@nuvia.com

Optical Stimulated Luminescence Detection of Beryllium within Nuclear Fusion Facilities

Summary of the project aim

This project aims to develop a new robotic sensing system to identify BeO deposits within a fusion reactor using optical stimulated luminescence. Currently, within the UK JET facility, this issue is addressed by personnel cleaning all the surfaces of the site. This is time consuming and potentially hazardous.

Project information

Project lead: IS-Instruments Limited
Collaborators: UK Atomic Energy Authority
Project type: Collaborative research and development
Total project cost: £241,702
Grant award: £190,887
Start date: October 2019
End date: March 2021

Executive Summary

Nuclear fusion is a long-term solution to the future energy supply of the planet. It is carbon free and highly efficient. However, the inside of a fusion reactor is an unforgiving environment. Experiments at the Joint European Torus (JET) in Culham have shown that beryllium (Be) is an essential material in a fusion reactor. However, human exposure to Be and its compounds can cause berylliosis, a chronic allergic-type lung response and chronic lung disease.

During a reactor's operational lifetime, sections will need to be periodically removed for refurbishment or replacement. These components will become radioactive and covered in Be/BeO deposits due to particle induced sputtering and re-deposition. Therefore, the ability to handle Be dust and components contaminated with this dust is essential to safe and efficient operation of a fusion plant. Currently within the UK JET facility this issue is addressed by personnel cleaning all the surfaces of the site. This is time consuming and potentially hazardous. Currently no sensing solution exist to quickly and accurately identify the Be/ BeO deposits within a given facility.

This proposal by IS-Instruments Ltd and UKAEA seeks to develop a new sensing system target BeO deposits. The focus of the development will the production of a new prototype sensor and a robotic platform that will be used to scan the instrument at the target within the environment. The system will take in account the challenges for working in this high radiation regime.

What is the value or size of the addressable market?

There are three main value drivers within the Fusion industry to which this innovation will be targeted:
1. Regulatory approval to operate.
2. Reduction in waste volume and costs.
3. Improved efficiency

The operating overheads of complex scientific experiments such as ITER are estimated to be in €1ms/ day. For commercial fusion reactors the loss of generation costs is even greater, so savings in the turnaround time of critical components will present massive operating savings. The proposed instrument offers a clear value proposition in reducing the required downtime to decontaminate parts of the facility, potentially providing massive cost savings.

Project Plan / Progress

The project started in October 2019 and is currently reviewing the requirements for a system in the field. This includes understanding the measurement limits that must be achieved both in terms of speed and sensitivity. Once the requirement are defined the team will seek to design and build a Robotic mounted and controlled sensor platform targeting Be and BeO.

jstorey@is-instruments.com

Robotics and Artificial Intelligence for Nuclear (RAIN)

Attendees and exhibitors at the "Delivering change through robotics' event in Cumbria, late 2019

Summary of the project aim

The RAIN Hub exists as a vehicle to enact ISCF strategy aims, primarily;
1 - To increase the volume of research in the RAI in Nuclear field
2 - To enhance the connectivity between research and industry, and
3 - To transfer people, skills and technology from academia into industry.

Project information

Project lead: University of Manchester
Collaborators: RACE (UKAEA), University of Bristol, Lancaster University, University of Liverpool, University of Sheffield, University of Nottingham, University of Oxford, University of Leeds, University of Reading, Newcastle University
Project type: Use-inspired hub
Grant award: £12,203,190
Start date: October 2017
End date: April 2021

Executive Summary

RAIN (Robotics and Artificial Intelligence in Nuclear) is a collaborative research project, which forms a community hub to accelerate the development of UK robotics for the nuclear industry with a focus on demonstrating quantitative benefits against demanding use cases. RAIN brings together UK robotics experts working across new build, life extension and decommissioning, bridging fission and fusion, to address common challenges. The RAIN team is intricately linked with key nuclear partners across the industry to ensure that the research remains end-use focused with major demonstrators through the initial 3.5 years.

The RAIN Hub works across the academic, nuclear supply chain and operator communities.

RAIN has developed working relationships and deployment plans with UK end-users including Sellafield Ltd, Rolls Royce, Atomic Weapons Establishment, EDF Energy, United Kingdom Atomic Energy Authority, Dounreay Site Restoration Ltd and Magnox.

RAIN has developed a reputation for enthusiastic and use-case-driven research and deployments with an approachable and collaborative team.

What is the value or size of the addressable market?

The primary focus for RAIN is the nuclear sector; opportunities are being explored for wider technology transfer.

In terms of nuclear decommissioning, the UK market is estimated at £90bn - £220bn with a global value of $1tn; estimates suggest that 10-20% of this could be robotic-specific. TEPCO Fuel Debris Retrieval is £12bn over next 12 years and ~£60bn total.

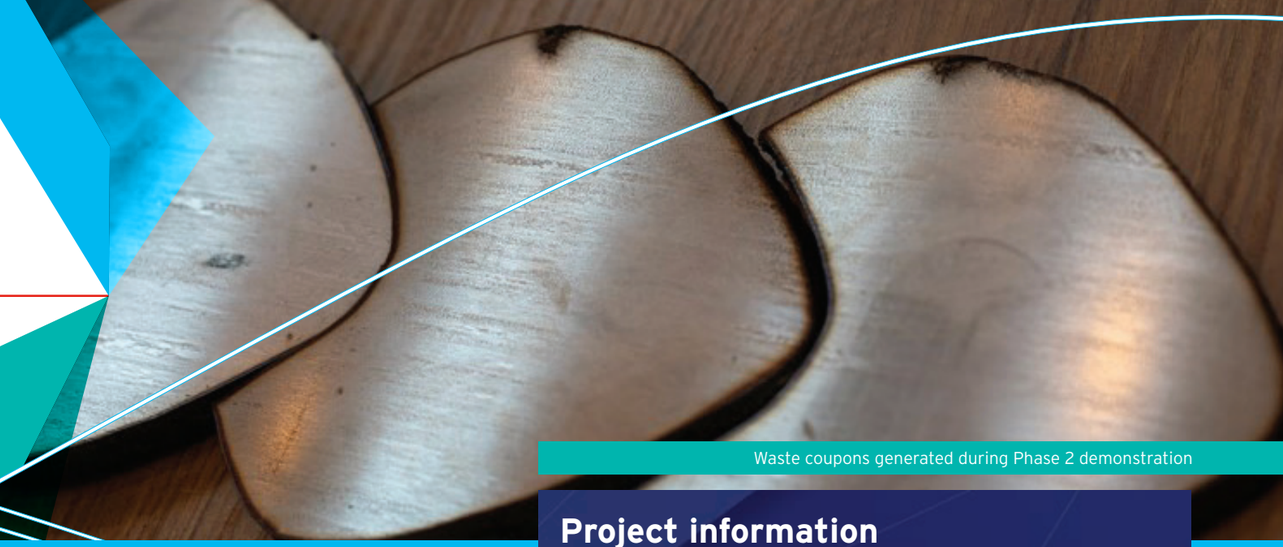
Nuclear new build is estimated at £60bn, GDF (£14bn), ITER hot cell (£1bn of procurement and £1.6bn of R&D robotic).

Project Plan / Progress

As of Jan 2020; RAIN has supported over 35 industrial projects (including over 15 SME projects), 16 secondments into industry and academia, and published over 100 journal articles. RAIN has supported the nuclear research community via three Working Groups (Remote Handling, Remote Inspection and Safety Case). From the RH and RI groups we have undertaken deployments in over 30 simulated environments and active deployments in 5 environments. 4 products are being commercialised. Via the SC group we have fostered connections with the ONR on the topic of RAI adoption in the nuclear industry.

RAIN hosted an open day technology showcase in early 2019; featuring RAIN tech, and the 'Delivering change through robotics' event in Cumbria, late 2019; featuring robotics technology from RAIN (inc. NCNR and ORCA ISCF Hubs), nuclear suppliers and SL. Through events such as these RAIN has built a network of over 350 industrial representatives and circa 100 businesses.

Sellafield In-Cell Decommissioning System (SIDS)



Waste coupons generated during Phase 2 demonstration

Summary of the project aim

Redundant reprocessing cells contain contaminated vessels and pipework that must be safely decommissioned. This hazardous work is technically challenging and time consuming. Cavendish Nuclear and partners have combined technologies in spatial and radiometric scanning, remote deployment and virtual reality control to create an integrated system for safe and efficient decommissioning.

Project information

Project lead: Cavendish Nuclear Limited
Collaborators: OC Robotics Limited, Babcock Digital Solutions, TWI Limited
Project type: SBRI
Total project costs: £1,398,328
Grant award: £1,398,328
Start date: January 2018
End date: September 2019

Executive Summary

The Sellafield In-cell Decommissioning System (SIDS) developed by Cavendish Nuclear and partners increases the capability and speed with which redundant pipework and vessels are decommissioned by adopting a 'point and teach' approach to remote control by operators working within a safe Virtual Reality (VR) environment. SIDS creates safer, quicker and more cost-effective operations by offering:

- Fully remote decommissioning
- Less people and equipment
- Reduced man-machine interface
- Improved understanding of continually changing operating environments
- Quick and easy programming of multiple tasks using novel VR operator interface
- Low risk pre-job planning, checking and refinement using VR animated simulations
- Automated operations to ensure accuracy, repeatability and waste form consistency
- Progressive hazard reduction methodology
- Improved waste consistency, tracking and packing

The deployment device is initially used to conduct surface image and radiological scans. The data is then used to create an intelligent and accurate 3D VR model. The operator works within the VR cell environment to programme, check and refine automated cutting operations. Once satisfied, the programme is downloaded to the deployment system and tools which size reduce pipework and vessels into small coupons. Waste coupons are bulk collected and placed into containers using a Remotely Operated Vehicle (ROV) with clamshell bucket attachment, or pick and placed using grabs.

This innovation in integrating proven technologies transforms the way active cells and other redundant nuclear facilities are decommissioned. Its modular form means it can be customised to work with a range of deployment devices and tools, changing functions or capabilities to effectively address each unique decommissioning challenge.

What is the value or size of the addressable market?

4 reprocessing facilities in the UK that SIDS could be deployed:

- Sellafield First Generation Reprocessing Plant
- Dounreay Fuel Cycle Area
- Sellafield Thermal Oxide Reprocessing Plant
- Sellafield Magnox Reprocessing Plant

NDA's UK decommissioning provision is £109-250Bn. £3Bn p.a. is spent by NDA and 76% is at Sellafield which represents the biggest immediate market (~£20M based on 10 known UK opportunities).

However, the full market for SIDS products type services hasn't yet been explored and constantly changes according to feedback from customers. SIDS products type services could also be beneficial to other industries where it isn't possible or undesirable to use people.

Project Plan / Progress

The IIND competition was split into 3 phases:

1. Concept Development 2017
2. Inactive Demonstration 2018
3. Active Demonstration 2020 onwards

Work began on a concept in the autumn of 2017. Cavendish Nuclear partnered with OC Robotics (OCR) and The Welding Institute (TWI) during phases 1 and 2. OCR supplied a Snake Arm manipulator to deploy a range of tools. TWI supplied the laser equipment and technical support. SIDS was designed, built and tested within 12 months, before conducting a full demonstration in a purpose built test cell at Cavendish Nuclear's Whetstone Facility in December 2018.

SIDS Phase 3 Active Demonstration proposals were submitted in October 2019. In consideration of SIDS modularity and difficult to reach pipework and vessels in the chosen cell, an alternative deployment system was proposed for demonstration on site. A Brokk 170 Remotely Operated Vehicle (ROV) with Fanuc CR-14iA/L robot arm attachment was chosen to deploy the tools to decommission Sellafield Solvent Treatment Bulge (STB) in much the same way as the Snake Arm had demonstrated in Phase 2.

Inactive demonstrations and promotions generated considerable interest from key clients, with feedback that SIDS represents a step change from the norm that could deliver significant benefits compared to typical man entry methods. Encouraged by this, further development work commenced in 2019 to effectively integrate and control the Fanuc robot. On completion later in 2020, Cavendish Nuclear aim to have a fully tested demonstrator to help further promote the system and prove its ability to control alternative deployment devices.

cavendish nuclear

Toby Carrigan • +441946 551712 • Tony.Carrigan@cavendishnuclear.com

Smart Radiation Sensor for Intelligent Nuclear Robots

Summary of the project aim

We propose to develop a smart radiation sensor for robots that embodies not only the ability to measure radiation at a known location, but also to automatically interpret that data in the light of a survey objective to demonstrate a proposed next action for the robot to implement.

Project information

Project lead: Create Technologies Limited
Collaborators: University of Oxford
Project type: Collaborative research and development
Total project costs: £250,000
Grant award: £197,500
Start date: November 2019
End date: December 2020

Executive Summary

Measuring radiation is often not an objective in itself, but a stepping stone towards another objective such as locating and quantifying radioactive sources or managing radiation exposure. To achieve these objectives it is important not only to measure radiation, but to record where it was measured and, crucially, make good judgements about where to measure in order to achieve the overall objective efficiently. The aim of the project is to develop a Smart Sensor that not only has the ability to sense radiation, but also comprises all of the physics knowledge, algorithms and computing power to understand the meaning for the data and advise other system components on how to react to the data.

The smart sensor will therefore make it easy for anyone to make their robot respond intelligently in radioactive environments, avoiding hazards and actively managing its own exposure to radiation. Using this Smart Sensor will enable any compatible robot to act as a radiation expert, efficiently gathering optimum measurements and autonomously mapping its own radiation exposure. This capability will be invaluable both in decommissioning, where better data leads to cheaper, quicker projects, and in accident response, where rapidly gathering good information is crucial to effective accident management.

What is the value or size of the addressable market?

The nuclear robots market has grown significantly in the last few years and is still rapidly developing. Growth is being aided by technological developments, increased customer awareness, and increased demand driven by the growing number of higher-radiation decommissioning challenges.

A conservative market value for the global nuclear mobile robotics market today, pricing in short term opportunity, would be in excess of $100M. Given that global decommissioning spend is expected to increase dramatically over the next 10 years, it is not unreasonable to expect up to tenfold growth to around $1Bn for the global market over the same period.

Project Plan / Progress

A series of modular packages have been developed, including: radiation detector packages, a sensor package for 6D SLAM, and a package to deliver on-board processing to other packages.

Createc's N-Visage 3D gamma mapping software has been modularised to be deployed alongside existing end-user software (e.g., a external 3D SLAM module).

The completed sensor packages have been mounted on two robot platforms from Oxford Robotics Institute and were interfaced. The 3D gamma imaging functionality was tested and validated to work with the existing robot platforms' software.

Closed Loop Variable Buoyancy Lifting System for In-Pond Nuclear Retrievals

Project information

Project lead: National Nuclear Laboratory Limited
Collaborators: Rovtech Solutions Limited
Project type: Demonstrator
Total project cost: £156,935
Grant award: £103,618
Start date: October 2017
End date: August 2018

Executive Summary

The in-pond harsh environment closed loop variable buoyancy lifting device relies on the Archimedes principle. The Archimedes principle states that a body partially or completely immersed in a fluid is buoyed up by a force equal to the weight of the fluid displaced by the body. By changing the volume of displaced fluid, the device creates a variable lifting force.

The novel application is to use a closed loop in which the inflation air is stored under pressure in a receiver. This compressed air inflates the variable displacement to provide lift. To submerge, the air is transferred back into the receiver through a compressor and a series of control valves. The small observation class ROV systems currently being operated on the Sellafield site will be able to manoeuvre the suspended load.

The principle can be demonstrated with a historical example, when during the era of canal transportation a horse could easily pull a fully laden 100-ton barge along a canal.

Integrated Innovation for Nuclear Decommissioning

Project information

Project lead: AMEC Foster Wheeler Nuclear UK Limited
Project type: SBRI
Total project cost: £1,497,239
Grant award: £1,497,239
Start date: January 2018
End date: September 2019

Executive Summary

Our aim is to develop a modular integrated platform that will combine state-of-the-art technology with tried and tested decommissioning knowhow. We will use experience from the conventional decommissioning sectors, combined with cutting-edge space, defence, medical and industrial technologies, to produce a streamlined, safety orientated solution.

The project will be developed using our experience of the pragmatic integration of complex technology to generate a step-change in decommissioning performance that will be cheaper, faster and safer as follows:

- an innovative modular control and automation strategy that can be proven and validated within the nuclear environment
- draw on cross-sector innovations and a pioneering approach to reliability and fault recovery: our approach removes the need for manned entry to cells
- a philosophy of minimal in-situ characterisation
- a planning approach that enables simulation within a virtual environment, optimising sequence, process and waste management
- a remote de-planting process that reduces operations at height and removes the need for temporary platforms, scaffolds and man entry
- a suite of innovative modular waste handling and processing tools that characterise, size-reduce, sort and decontaminate waste, using a repeatable and scalable process

Our team builds on existing relationships, creates new ones, and comprises nuclear and out-of-sector expertise, innovative SMEs and applied academic innovation. We will collaborate to bring true innovation in thought and technology to this decommissioning challenge. Amec Foster Wheeler's world-class track record in delivering and integrating complex, multi-partner projects gives us confidence that we can deliver the project successfully within tight constraints. Our strong position in the nuclear decommissioning market provides a platform to commercialise any technology developed both in the UK and overseas.

Smart IMAging for Nuclear "SIMAN"

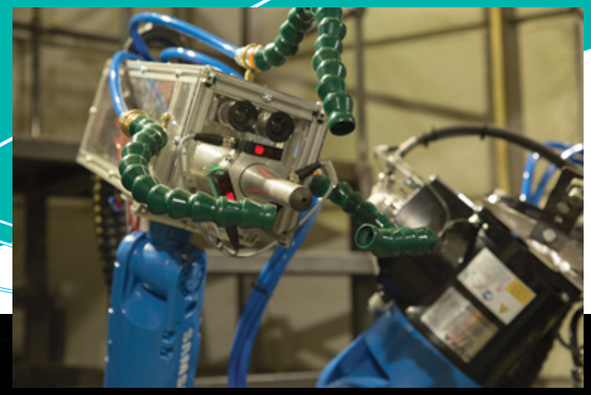
Project information

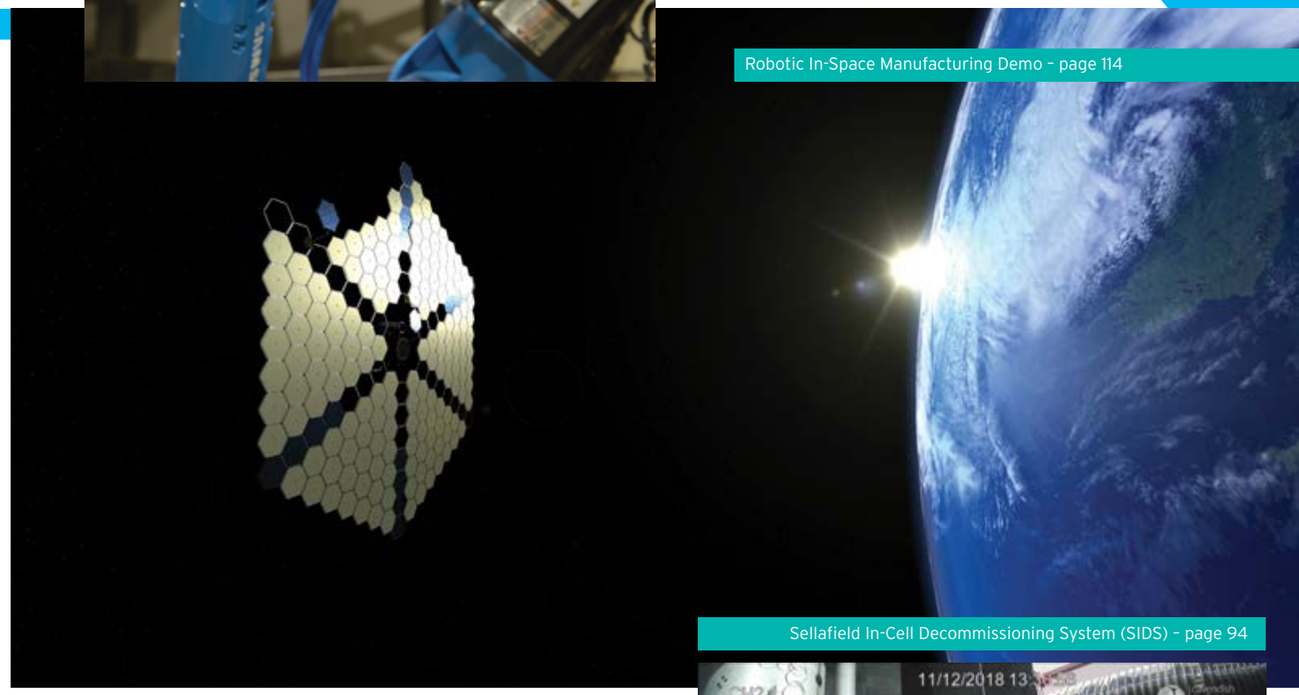
Project lead: I3D Robotics Limited
Collaborators: National Nuclear Laboratory Limited
Project type: Collaborative research and development
Total project costs: £162,793
Grant award: £107,917
Start date: October 2019
End date: March 2021

Executive Summary

This project will develop the use of 3D vision in alpha glovebox operations. It is led by SME i3D robotics with the National Nuclear Laboratory as a project partner. The team will develop a 3D stereo vision system that is capable of operation in alpha glovebox environments. This will allow glovebox operators to view the contents of a scene using 2D images or 3D models. Algorithms will also be produced to highlight objects which are deemed sharp or hazardous. A further aim of the project is to interface the systems with robotic and AI (RAI) technologies currently used in nuclear decommissioning. This will allow for autonomous cutting of gloveboxes as well as sorting and segregating nuclear waste. Through a combination of these aspects, the system will also be aimed at advancing the "no-arms-in-gloveboxes" where the contents of a glovebox will be displayed and controlled through robotic systems or teleoperations.

Barrnon Integrated Decommissioning System - page 78





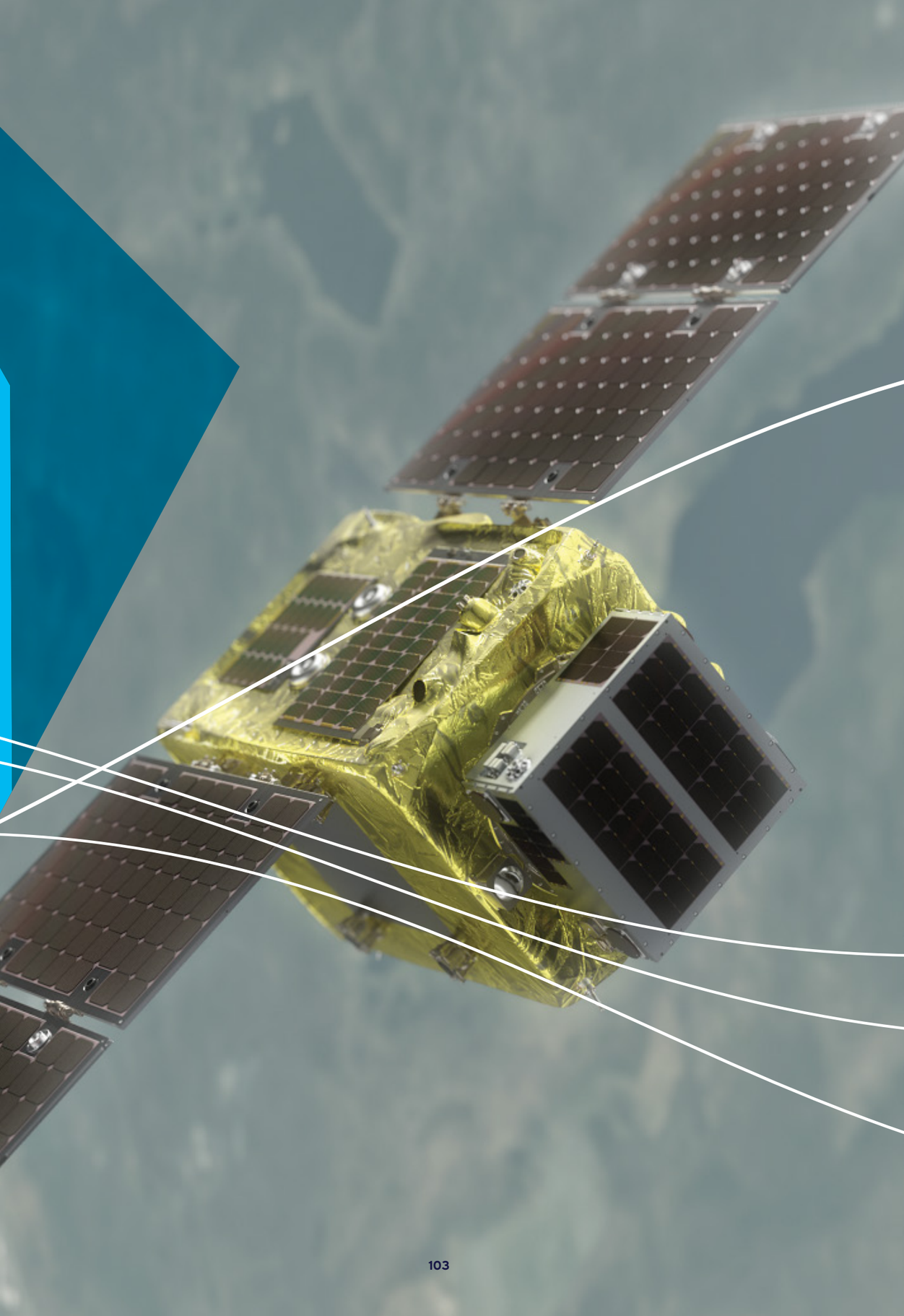
Robotic In-Space Manufacturing Demo - page 114

Sellafield In-Cell Decommissioning System (SIDS) - page 94

Space

The projects for robotics operating in space include one Innovation Hub, one phase 1 Demonstrator that continued into a second phase, two further Demonstrators and three CR&D projects.

The demonstrator projects include one special project, while CR&D include two from the recent ESP competition. The projects address mostly operational aspects, covering system level issues to go along with components and subsystems (e.g. FPGA and photonics).



Assessing the feasibility of photonic transceivers for satellites and planetary robotics

Project information

Project lead: Spacechips Limited
Project type: Collaborative research and development
Total project: £98,442
Grant award: £68,909
Start date: November 2019
End date: September 2020

Summary of the project aim

The project investigates the applicability of optical transceivers and related on-board processing electronics to enable ultra high-resolution streaming video for use by Earth-Observation satellites and planetary robotics.

Executive Summary

To deliver added value over competitors, owners of Earth-Observation satellites want to be able to offer customers real-time 4K UHD and 8K SUHD streaming video to enable new remote-sensing applications. Traditional and commercial operators are targeting the lucrative data-analytics market and wish to offer customers enabling services such as high-resolution, streaming video SAR and LIDAR, together with the use of AI on-board to autonomously detect and identify moving targets in real-time, the calculation of their velocities and advanced tracking, intelligence, surveillance and reconnaissance.

Agencies operating robotic landers and rovers for space exploration want to deliver a new public experience and level of engagement, and deliver real 'live science'. Current, spacecraft-imaging payloads require high levels of on-board storage and computation, however, to deliver ultra high-resolution streaming video necessitates a step-change improvement in in-orbit processing throughput and capability.

To deliver the required performance, the project proposes a novel approach to space-based imaging payloads, an optical transponder architecture. Compared to traditional copper, optical technology offers larger bandwidths (throughput) and faster speeds per unit time, has lower loss, is lighter in mass, has better signal integrity and is immune to electromagnetic interference. Current optical transceivers are specified at 12.5 Gbps, capable of supporting high-resolution, real-time, streaming video SAR and LIDAR.

The project has two key objectives:

1. To research the applicability of 12.5 Gbps optical transceivers and related on-board processing electronics for use in the harsh environment of space.
2. To develop a prototype sub-system to de-risk the concept.

What is the value or size of the addressable market?

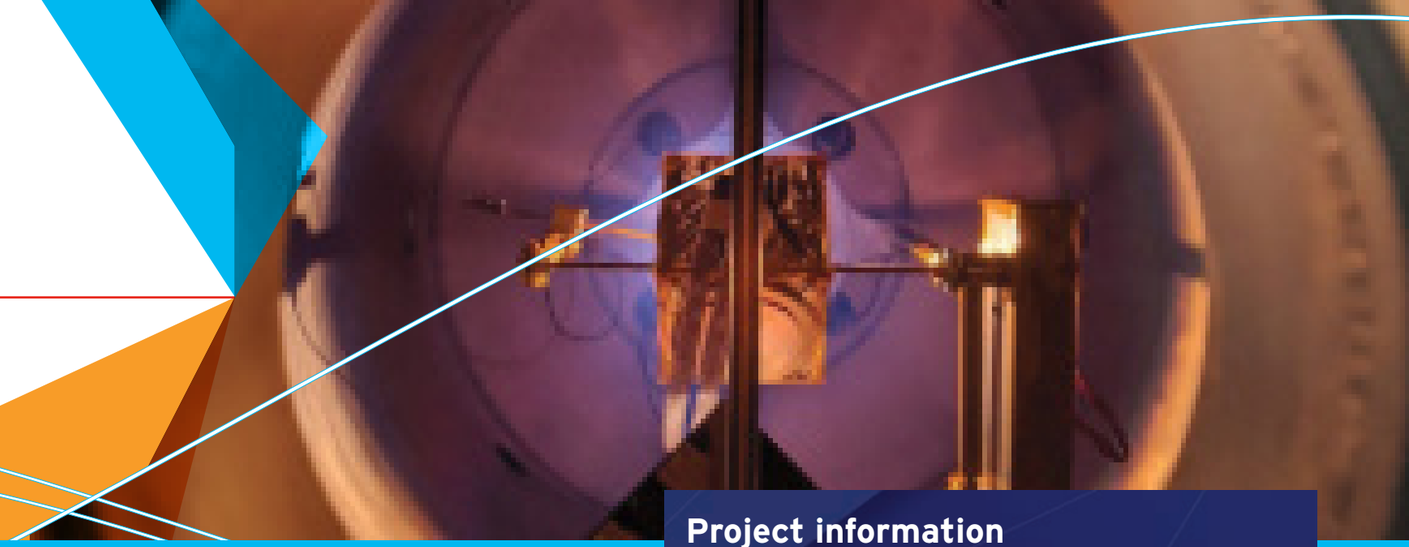
The target market is manufacturers of Earth-observation satellites comprising traditional OEMs as well as commercial, NewSpace operators. These customers were engaged in initial market research, validating the concept, the grant application, the project plan, route to market, risk assessment and our commercialisation aspirations. The target market is also agencies and OEMs developing planetary robotics.

Project Plan / Progress

The project has been running for two months and we are on-schedule having almost completed WP1. Spacechips has made a number of key observations and discoveries regarding the applicability of optical transceivers for Earth-Observation satellites and planetary robotics.

rajan@spacechips.co.uk

Feasibility study of active radiation shielding for electronics, sensors and photonics applications



Project information

Project lead: Space Talos Limited
Project type: Collaborative research and development
Total project cost: £84,798
Grant award: £59,359
Start date: January 2020
End date: July 2020

Summary of the project aim

This project investigates the use of active shielding with sensitive robotic sensors that are normally susceptible to the radiation-heavy environments of space. The company uses an active shielding method to protect those sensitive electronics from radiation.

Executive Summary

Satellites provide us with many benefits from telecommunication, predicting the weather to protecting the environment. However, space is a harsh environment, and satellites are constantly bombarded by strong ionising radiation. The cosmic and solar radiation in space 'fry' electronics which means only very special and 'hardened' electronics can be used, that are heavy, require a lot of power and as a result, are quite simplistic compared to some electronics we enjoy on earth.

We propose to analyse and evaluate the potential and compatibility of Space Talos Ltd. active radiation shielding solution with commercial off-the-shelf electronics, sensors, and photonics commonly used for robotics. Active radiation shielding traps plasma in an electromagnetic field, protecting the satellite. In particular, active radiation shielding will give easier access to orbits beyond low Earth orbits for small satellites where robotic applications such as satellites maintenance and mining are more significant.

What is the value or size of the addressable market?

The end user for our product would be service providers in radiation harsh environments for satellites (repair, refuelling, deorbiting etc.)

Project Plan / Progress

This project will evaluate the benefits and limitations of this technology for space robotic applications. This will help inform Space Talos Limited to work either individually or collaboratively with other industrial or research organisations to conduct a subsequent larger project which would lead to immediate adoption by the market.

Space Talos

Future AI and Robotics for SPACE (FAIR-SPACE)

Autonomous capture of a moving large inertia object with two arms.

Summary of the project aim

The aim is to establish a national asset strengthening the UK's capability and growing its community; to position the UK as a recognised leading nation in robotics and autonomous systems for space. FAIR-SPACE goes beyond the state-of-the-art solving the technical barriers faced by the global space sector.

Project information

Project lead: University of Surrey
Collaborators: Imperial College London, University of Edinburgh, University of Liverpool, University of Salford, University of Warwick
Project type: Use-inspired hub
Grant award: £6,932,511
Start date: November 2017
End date: March 2021

Executive Summary

The FAIR-SPACE Hub is a UK national centre of research excellence in space robotics and artificial intelligence. The hub was launched in November 2017 as part of the government's £84 million research and development funding on 'robotics and AI for extreme environments' through the Industry Strategic Challenge Fund (ISCF).

In its initial 3-year programme, the Hub secured a £6.9 million research grant from the Engineering and Physical Sciences Research Council (EPSRC) and the UK Space Agency (UKSA), boosted by a further £7.5 million match fund from the industrial sector and a £15 million business development fund.

FAIR-SPACE consists of 5 world leading Universities in Robotics and Autonomous Systems (including Surrey as the lead, Imperial College London & Universities of Edinburgh, Liverpool, Salford & Warwick) with over 30 international partners (including Industry). The FAIR-SPACE Hub consortium offers a unique combination of expertise and capabilities to address key challenges in space robotics and autonomous systems, as well as influencing and engaging with the wider community of academia, industry, government and the public. Surrey draws on 4 decades of research and development heritage in spacecraft engineering to lead the FAIR-SPACE Hub.

While primarily aimed at solving the technical barriers faced by the global space sector, the technologies developed by FAIRSPACE also have applications in other industries with a need to navigate hazardous or challenging environments, such as nuclear, underwater, mining and agriculture. Indeed the novel gripper being developed with FAIR-SPACE has been demonstrated in the SBRI project Integrated Innovation for Nuclear Decommissioning and the gripper's control system is also being applied to connected autonomous vehicles through the Innovate UK funded Project Synergy.

What is the value or size of the addressable market?

FAIR-SPACE establishes a national asset in space intelligent systems and robotics helping to realise the target of creating a £40Bn UK space industry by 2030, providing research and innovation to a sector that generates £13.7bn of income, supports 38,500 jobs with worker productivity 2.7x greater than the national average (UK Space Agency, December 2016). The research confers significant benefits additionally to a number of other sectors, including telecommunication, broadcasting, navigation/location-based services, meteorological/geospatial services, defence and security, and healthcare. The Hub contributes to safety-critical autonomy for extreme environments, e.g. deep mining and nuclear decommissioning, and the wider industrial robotics sector.

Project Plan / Progress

FAIR-SPACE has developed visual GNC algorithms for orbital rendezvous, manipulation and grasping with TRL of 4-5 validated in digital simulators and physical testbeds representing space environment. Techniques are applicable to on-orbit operations/ servicing/assembly and debris removal. A photorealistic orbit simulator is under development. Algorithmic development is in collaboration with a UK company for on-orbit operations.

Robotic surface and subsurface locomotion techniques have been developed including three prototypes of Wasp Drill, MARCEL Rover, Soil Sampler. The Wasp Drill and Soil Sampler work builds on research arising from the ESA lunar mission study on lunar simulants/L-GRASP, with research contributing to the ESA Sample Analogue Curation Facility. The Wasp Drill is currently under development with British Telecom (BT) for a national programme. The MARCEL Rover chassis provides active suspension enabling crawling and climbing, offering expertise/capabilities for UK space industry partners.

In orbit Servicing Control Centre National Facility

End-of-Life Services by Astroscale-demonstration (ELSA-d) launching in 2020

Project information

Project lead: Astroscale Limited
Collaborators: Satellite Applications Catapult
Project type: Demonstrator
Total project cost: £4,823,956
Grant award: £4,179,308
Start date: January 2018
End date: November 2020

Summary of the project aim

Astroscale's mission is to secure long-term spaceflight safety and orbital sustainability for the benefit of future generations through the provision of End-of-Life Services and Active Debris Removal. To facilitate this, Astroscale, in partnership with Satellite Applications Catapult, is establishing a National In-Orbit Servicing Control Centre, which will be used first to support Astroscale's demonstration mission in 2020, but this innovative centre will be fully available for companies around the UK to access.

Executive Summary

Space debris is a major global issue that for too long has been treated as a scientific research topic and not practically addressed. As of 2019, there are 34,000 objects larger than 10 cm, which can disable an active satellite and cause major commercial risks. This impacts the public as space-derived services are affected. As an example, loss of satellite positioning would cost the UK £1 billion per day.

This industry-led project was conceived by Astroscale (a global company with headquarters in Tokyo). In 2020, Astroscale will launch two satellites for the world's first commercial debris removal mission, End-of-Life Services by Astroscale-demonstration (ELSA-d), and will demonstrate the technology which will be operated from this facility, including identify track, rendezvous, dock and de-orbit. The consortium is expanding the current Satellite Applications Catapult Control Centre to establish a facility for in-orbit services operations.

The new centre will provide a national capability, enabling UK companies to unlock opportunities in space debris removal, in-orbit satellite servicing and other autonomous robotic applications. The Astroscale and Catapult partnership is the beginning of an exciting opportunity to deliver a scalable, tailored and re-usable centre to meet the complex demands of advanced satellite constellations, as part of a national network of operations facilities.

What is the value or size of the addressable market?

Astroscale, as the first users of the In-Orbit Servicing Facility, will provide commercial end-of-life services to satellite operators, as well as active debris removal services for governments and institutions.

By ensuring the centre has the backbone services it needs to be usable by the widest possible range of organisations, the facility will support many UK companies in the future, enabling them to grow more quickly by overcoming the high barriers to entry in the space industry.

Project Plan / Progress

The design of the National In Orbit Servicing Control Centre is complete and most of the components are finished.

The Satellite Applications Catapult is performing network and infrastructure upgrades including those to the display systems and voice loop system.

The initial testing of all the components has been completed and now the next step is to perform the integration and validation of the whole control centre.

As soon as the facility is validated, Astroscale will start testing the operational procedures of the ELSA-d mission. This will be the first mission to use this facility and will take place in the second half of 2020.

Alberto Fernandez • Project Manager of National Facility • a.fernandez@astroscale.com • 07438 031994

LEO Satellite Based AI Demonstrator

FPGA testing at Thales Alenia Space

Project information

Project lead: Myrtle Software Limited
Project type: Demonstrator
Total project cost: £802,225
Grant award: £561,557
Start date: April 2019
End date: March 2021

Summary of the project aim

The project aims to develop a 'close-to-sensor' object detection system for use on a satellite or in space using SoTA machine learning algorithms compressed to run on space-grade FPGA silicon. This would provide in orbit scene analysis and decision autonomy as well as minimising substantial data transfer via the downlink.

Executive Summary

This is an ambitious project demonstrating close to sensor, deep learning object detection running on a satellite-ready platform. Satellites must deal with extreme temperatures, have limited power and can only use space-grade computing devices. The diverse Sentinel satellites used for low earth observation (LEO), for instance, provide both image and radar data of the earth's surface, which we can use for on-board AI object detection.

With access to accurate, labelled satellite training data we can train an object detection algorithm with a high degree of accuracy to recognize one or more known objects in the sensor field of view and to label it and assign a recognition confidence score. Once the algorithm is trained with sufficient accuracy using GPU platforms, then we can use Myrtle know how to compress and quantize the algorithm and translate it into low level VHDL to make it fit on the smaller, space-grade silicon FPGA devices, with no loss of accuracy.

This will remove the need to transmit dense, raw data to the surface whenever the orbit-dependent downlink window is available, thus saving data bandwidth and reaction time. If certain image signatures are identified, then the satellite system can take immediate action to alert other satellites or relevant partners to take further action. This could be used in adverse weather situations, earthquakes, crop failures, volcanic activity, oil spills etc to ensure that aid and other services are able to respond efficiently.

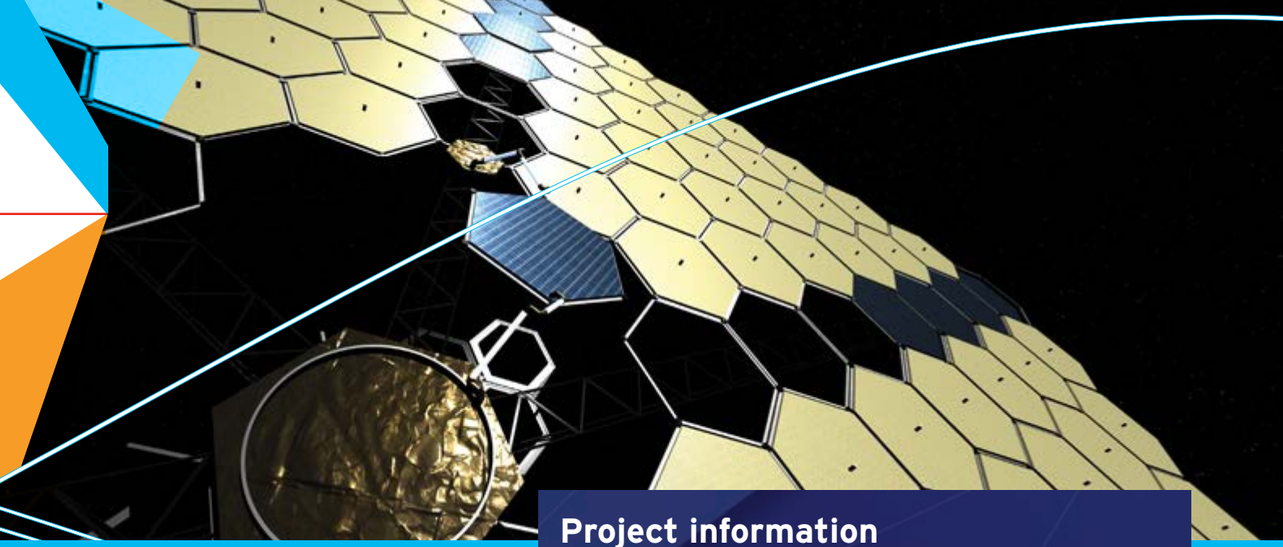
What is the value or size of the addressable market?

The result of this project will be an FPGA based AI processor, qualified for space and of great interest to satellite and space vehicle manufacturers worldwide. This is a growing and very specialised business sector, shifting from human-based, deep-space exploration and embracing tourism and lower cost solutions as well as an established Earth observation satellite industry. Space-grade AI functionality will be an important feature of future space vehicle and satellite deployment. The global satellite manufacturing market was worth US$15.5B in 2017 and the UK produces around 40% of small satellites, with launches increasing by 60% in the next 5 years.

Project Plan / Progress

This project today is only 3 quarters into an 8 quarter project, so still much to do. We have identified a likely training data set called SpaceNet and started working with the manufacturer of the FPGA space grade cards, Xilinx. We have started to extend our tool set and automated test processes to handle these new devices. We have initially introduced their larger datacentre FPGA cards into our servers, so we can test out all our new tools and Xilinx new libraries etc. before we start to compress and quantize the algorithm for the smaller space-grade devices and we have looked at a number of candidate AI object detection algorithms we could use in the project. We are in discussion with potential, commercial users in the EU, such as Thales Alenia Space and will identify others in the next quarters, where an AI processor would be an advantage.

Robotic In-Space Manufacturing Demo



Summary of the project aim

With the space industry rapidly evolving we have reached a limit on what can be launched into orbit on a single launch vehicle. This project has developed some of the key building blocks to enable in-space manufacturing, assembly and servicing; allowing much larger and novel spacecraft to be launched.

Project information

Project lead: Airbus Defence and Space Limited
Collaborators: Tisics Limited
Project type: Demonstrator
Total project cost: £237,577
Grant award: £128,311
Start date: December 2017
End date: December 2018

Executive Summary

In the next decade, both government and commercial entities will increasingly rely on robotic in-space assembly, manufacturing and servicing for the setup and maintenance of future space assets for civil and commercial missions. Intelsat published an analysis (AIAA Sep 2014) that calculated that in-orbit servicing could save commercial telecommunications companies alone $28 million per year per spacecraft.

While fields of autonomy, robotics, and space engineering are all making progress, true representative in-space manufacturing and assembly as an end-to-end process has not been widely demonstrated, despite the UK having a strong knowledge base in these 3 areas. The project aimed at developing mission concepts for in-space manufacturing and assembly, choosing a viable candidate and prototyping the key building blocks. These were designed, implemented and tested successfully as part of the activity, raising the confidence in the underlying mission concept. This project paved the way to envisage future larger scale developments and identify in-orbit demonstration opportunities to further validate manufacture/assembly technologies with a path to bringing them into service within the next decade.

What is the value or size of the addressable market?

Space agencies such as the UK Space Agency and European Space Agency will be anchor customers to this technology, their commitment enables novel telecom services such as high bandwidth telecom platforms assembled in space, payload swapping or tugging to different orbits to be offered to the space industry. Spin-off areas such as active debris removal will also use similar technology.

Project Plan / Progress

This project developed and assessed mission scenarios using in-space manufacturing and assembly technologies, concluding that a large phased array antenna would be the most viable product to bring to market in the next 5-10 years. This mission concept was developed and the assembly process was demonstrated in the lab using a scaled prototype.

During development of the mission concept, the need for a durable robotic manipulator was identified with the ability to perform a large number of actuations. An extremely light-weight manipulator with the ability to swap joints was designed and built during the project, enabling large numbers of movement cycles thanks to the ability of swapping to a new motor/gear. The project partners TISICS produced innovative aluminium silicon-carbide composite limbs that provided high levels of stiffness with a low mass and coefficient of thermal expansion, a necessity for the harsh thermal environment of space. This manipulator has now been expanded into a family of products that can be adapted for various missions, both in-space and extra-terrestrially.

The work completed in this study has enabled Airbus to bid for further work in the UK from both the UKSA and ESA, growing the robotics industry within the UK and developing the technology for reducing the cost of space assets through in-space assembly. TISICS have been able to leverage the aluminium silicon-carbide technology for other applications such as the nuclear industry. The project is seen as a great success by both parties and a step towards robotically assembled structures in space.

AIRBUS

TISICS
Titanium Composites

alexander.hall@airbus.com

SMARTER - Space Manufacturing, Assembly and Repair Technology Exploration and Realisation

Project information

Project lead: BAE Systems (Operations) Limited
Collaborators: Lena Space Limited, Magna Parva Limited, Manufacturing Technology Centre (MTC), Printed Electronics Limited, Reaction Engines Limited, Satellite Applications Catapult, University of Nottingham
Project type: Collaborative research and development
Total project cost: £724,075
Grant award: £516,025
Start date: January 2018
End date: March 2020

Summary of the project aim

Demand for ongoing growth of space-based communications and exploration drives the need for more capabilities to build a better infrastructure. The ability to build, maintain and manage this in situ is key to sustainable growth. SMARTER aims to understand and demonstrate the key challenges of deploying an intelligent, state-of-the-art manufacturing solution whilst considering the complexities of a space environment.

Executive Summary

The need for reconfigurable, autonomous manufacturing capabilities in space stem from recent paradigm changes in space operations and the development of enabling new capabilities that will put mankind's ambient to the test. These include cost reduction of payload launch, sustainable space exploration, low-cost satellite constellations, deep space exploration and preventative maintenance on existing space assets. NASA's On-orbit Satellite Servicing Study from 2010 advises such a capability to be within a 10-20 year timeframe. Based on this, the UK has a prime opportunity to position and invest now.

SMARTER aims to collaborate with multiple partners, each with either in-depth manufacturing or space based knowledge, in order to explore and understand how an already complex Industry 4.0 based manufacturing capability on earth may be reimagined within a space environment.

In order to apply direction and value-add to the programme's output on what is a very wide and complex problem, SMARTER focussed on how reconfigurable autonomous robotic technologies could be used to automatically manufacture components, large structures and potentially undertake repairs.

Specifically, well-known industry use case- large scale modular satellite and deep space telescope construction- was chosen as the basis of a robotic demonstrator platform at the end of the programme. This physical demonstration is built as a test bed to develop and demonstrate aspects of Machine Learning and Artificial Intelligence in the form of facility health monitoring of a collaborative assembly system, and the recovery and completion of any ongoing manufacturing tasks where no human intervention to repair will be possible.

Orbital Situational Awareness using Infrared Cameras

Project information

Project lead: Neptec UK Limited
Collaborators: University of Oxford
Project type: Demonstrator
Total project cost: £244,949
Grant award: £189,244
Start date: December 2017
End date: November 2018

Executive Summary

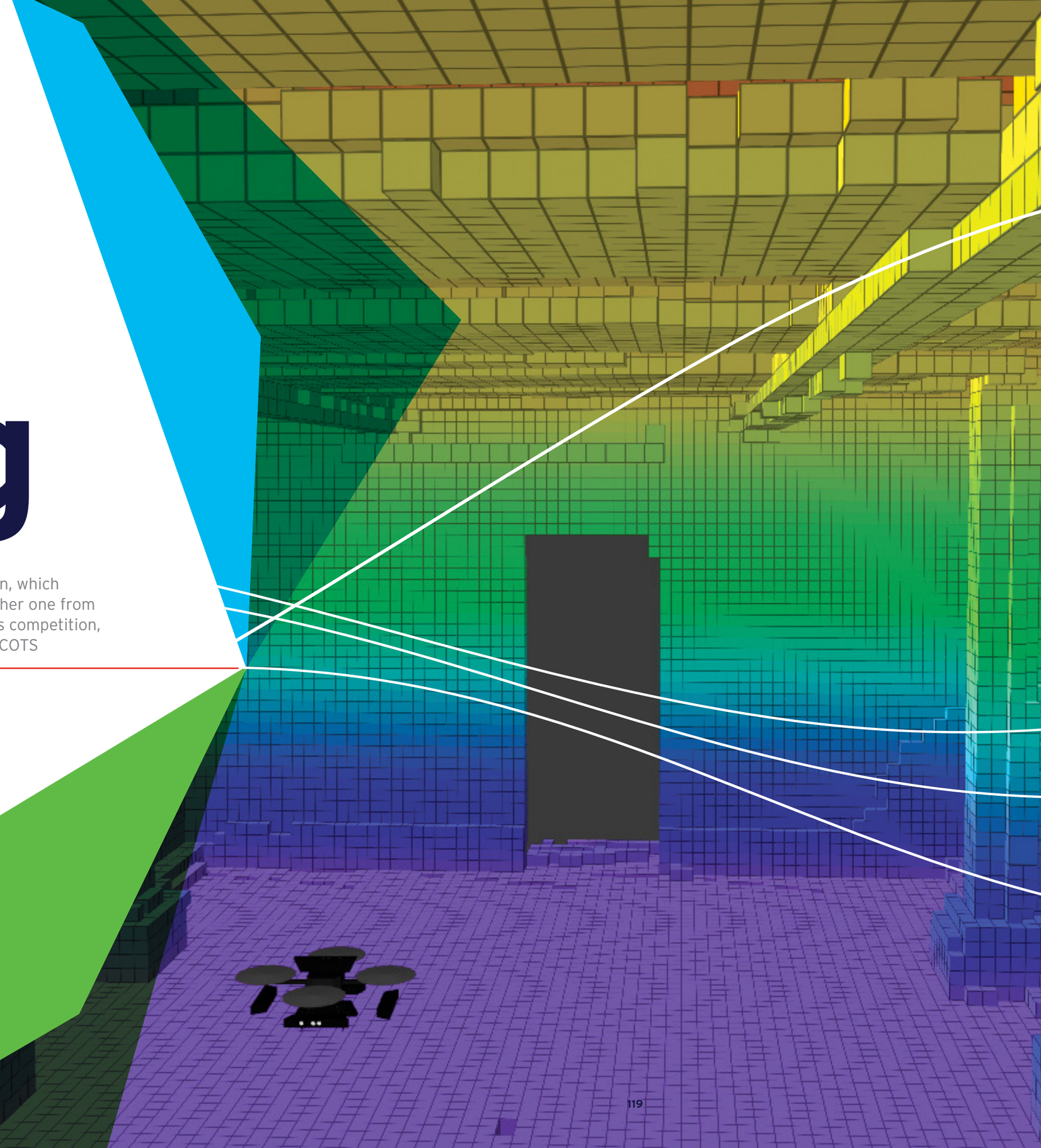
The key objective of this project will be to conduct a feasibility study into the development of algorithms to generate positional information in all 6 degrees of freedom from data generated by the Neptec UK (NUK) space qualified IR Camera. NUK will use its Space IR Camera and simulator to demonstrate the technology being developed by NUK and Oxford University Active Vision Group.

We also plan a basic hardware demonstration to test the feasibility of the technology. The innovation in this study resides in the identification and tracking of non-cooperative targets by a cost-effective, low mass, volume and power solution. The main markets for this technology will be orbital debris removal and satellite servicing. These are 2 key activities that will play a major role in making the skies safe by removing orbiting debris from space and the future maintenance of satellites.

Both of these activities require a high degree of robotics artificial intelligence (RAI) to autonomously control the movement of a chase vehicle up to a target satellite or debris then guide a grappling device to accurately capture it.

Mining

There is one project coming from the Innovation Lab competition, which includes the use of UAV enhanced sensing capabilities, and another one from the Electronics, Sensors and Photonics in Extreme Environments competition, addressing on-board electronics and integration of existing and COTS components for autonomous surveying.



Autonomous Robotic InSpEction (ARISE)

Summary of the project aim

ARISE aims to implement autonomous surveys of geotechnical conditions during the normally unproductive period immediately after the blast when workers vacate the mine due to post-blasting fumes and seismic risk. ARISE will make blast mining process faster, cheaper and safer.

Project information

Project lead: GMV
Collaborators: Sundance Multiprocessor Technology Limited, University of Exeter, MDA Space and Robotics Limited
Project type: Collaborative research and development
Total project cost: £247,343
Grant award: £174,653
Start date: November 2019
End date: January 2021

Executive Summary

The mining industry is committed to operating safely and reducing accident numbers, and it is increasingly migrating underground as surface deposits are exhausted. The underground environment is challenging due to: high rock stress, high temperatures, poor communications with surface, restricted access and lack of access to satellite positioning systems.

The robotic platform will be used to:
- Survey roof conditions in newly-blasted areas;
- Monitor material flow in orepasses and extraction points, particularly mapping 'hangups' that can block orepasses. Mapping hangups from below is extremely dangerous for people;
- Accurately map areas in 3D for reconciliation and design verification.

ARISE will provide safety and financial benefits while not affecting the production cycle (operating in the shift change periods) and is therefore attractive for industrial roll-out.

What is the value or size of the addressable market?

ARISE will solve real mining problems without needing a significant system change on the mines. Improving re-entry safety by establishing a methodology that could be incorporated into autonomous machinery.

The route-to-market for ARISE is through comprehensively solving two immediate real problems for the industry, re-entry safety and rock-pass hangups, and using the credibility gained through those products to build up business in more generally introducing robotics into mining. Given the size of the global mining industry ($600-billion revenue in 2017) there is a substantial market. If robotics is 1% of the equipment market = $1-billion.

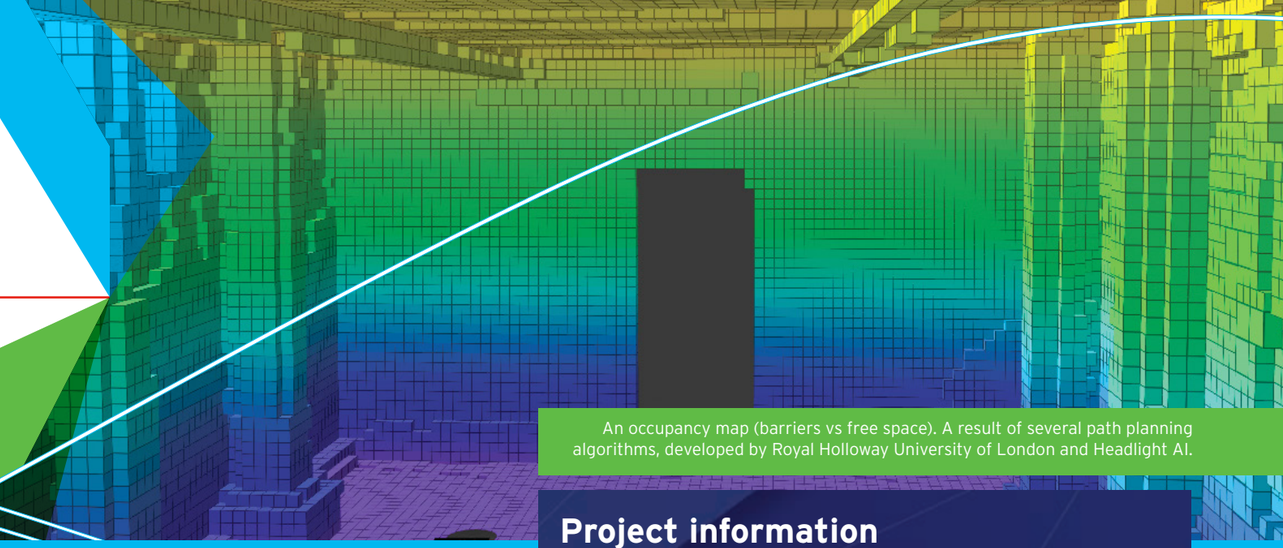
Project Plan / Progress

The project objective is to (1) create new electronics for mining environment, (2) select new sensor suit and (3) integrate all components including a LIDAR in the ARISE system. The ARISE system is an autonomous robot for mine inspection.

From the start the project consortium is in touch with the end users to gather and refine requirements for the system.

ARISE started in Q4 of 2019 and throughout the project will include iterative testing with final demonstration of the full system in Q4 2020.

Prometheus - A reconfigurable robotic platform(s) with advanced sensing for confined spaces



An occupancy map (barriers vs free space). A result of several path planning algorithms, developed by Royal Holloway University of London and Headlight AI.

Summary of the project aim

This project is concerned with the inspection and exploration of unknown environments which can only be accessed through boreholes of operating range of 140-150mm. The primary use-case is the inspection of subterranean mines, which are dark, lack GPS, can be partially flooded and underlay the rail network and other infrastructure.

Project information

Project lead: Headlight AI Limited
Collaborators: Royal Holloway University of London, Network Rail Infrastructure Limited, Callen-Lenz Associates Limited, University of Bristol, Thales UK Limited, University of Manchester
Project type: Collaborative research and development
Total project cost: £2,187,718
Grant award: £1,632,753
Start date: April 2019
End date: March 2021

Executive Summary

The Prometheus project will develop a fully autonomous robot capable of geo-technical surveys in unknown voids for use in the mining, water infrastructure monitoring, disaster relief, building construction and offshore industries.

This robot will be able to be automatically deployed and recovered through a standard restricted access bore of an operating range of 140-150mm diameter. Key demonstrations will be carried out during the project in conjunction with Network Rail - to explore and map mine workings that extend under existing rail infrastructure.

Further, applications are also within the water industry with aging water infrastructure. This is presenting major issues to societies, in terms of leakages, burst water mains, flooding, contamination, etc. This is resulting in significant costs to infrastructure providers in terms of fines, legal fees, and complex repairs. The system itself will be designed, built and tested by a consortium led by Headlight AI - an SME working with leading edge sensor and data processing technologies. Partners include Callen-Lenz, an SME with expertise in airborne robotic systems development and deployment. They will work closely with the Universities of Manchester, Royal Holloway and Bristol to integrate the latest sensors, control and manufacturing techniques into a truly novel and highly capable platform. This will include sensors and adaptive sensing software provided by both Thales and Headlight AI.

The joint requirements of fully autonomous operation beyond visual line of sight (BVLOS), combined with deployment through a limited access borehole will be demonstrated at key milestone demonstrations in conjunction with Network Rail.

What is the value or size of the addressable market?

End users of Prometheus technology include:
- Linear Infrastructure operators, e.g., Network Rail (consortium member) affected by underground abandoned mines (assessment for the UK network would cost in excess of £1B)
- Water Utilities companies that own and operate water networks (global addressable market for inspection is £125M per annum)
- Emergency Services and building construction

A PwC report, "Clarity form Above" (2016), values drone powered solutions to £65B with key sectors, e.g., infrastructure £22.6B and mining £2.15B. The Prometheus platform will become an emerging and critical tool in the overall infrastructure inspection solution.

Project Plan / Progress

Prometheus is a 24-month programme with six key work packages (WPs):
Project Lead – Headlight AI Ltd.
- WP1 - Compliance, Site Access and Testing – Led by Network Rail.
- WP2 - Situational Awareness and Sensing – Led by Headlight AI.
- WP3 - Platform Design, Regulatory Compliance - Lead is Bristol University.
- WP4 - Planning, Navigation and Exploration - Lead is Royal Holloway University.
- WP5 - Systems Integration & Demonstration - Lead is University of Manchester
- WP6 - Route to market, Subsystem Manufacturing - Lead is Callen-Lenz

Each WP has cross dependencies and the partners have been working closely together. Significant effort has also been assigned to key industry exploitation areas such as the route to market, access to industry sites and sensor development to ensure that there is real industry pull through of the technologies developed.

The consortium has successfully completed confined spaces and mines familiarisation. This was facilitated by Network Rail giving a realistic perspective and challenges in confined spaces.

Outcome (Technical and Commercial)
1. Design and assemble of the Prometheus drone prototype (image attached)
2. A lower power, lightweight see in the dark 3D vision system, Dragonfly by Headlight AI (image attached)
3. Advanced path planning algorithms that allow robots to adapt to the environment and make smarter decisions
4. 2 Conference papers prepared and submitted for peer-review
5. Set of systems requirements (agreed in principle by the consortium)
6. Successful sub-systems test 1 – sensor integration and flight tests
7. Sara Bernardini and Puneet Chhabra visit JPL, NASA as part of a UK delegation, representing Innovate UK funded projects.

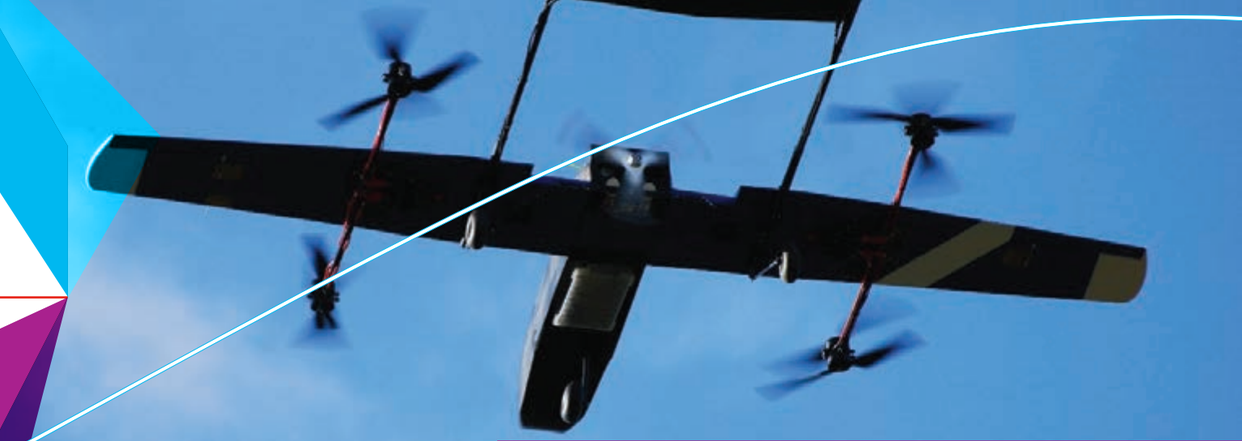
Puneet Chhabra, Co-founder and CTO, Headlight AI. Lead Project Manager **puneet@headlight.ai**

Cross-Cutting

The cross-cutting projects group comprises two Phase 1 Demonstrators, one of which progressed to a second Phase, 6 further Demonstrator projects and 11 CR&D projects. The demonstrator projects include those from the DSTL last mile re-supply, as well as the special projects for use of drones in beyond visual line of sight (BVLOS) operations; the CR&D include two projects funded following a weeklong Innovation Lab/sandpit event and one from our recent competition on Electronics, Sensors and Photonics in Extreme Environments.

The projects cover a broad spectrum of robotics aspects & capabilities, including sensing, navigation, SLAM, control, sub-system and system integration related issues, the majority of them working with UxVs (i.e. UAV, UGV, USV, UUV) as the core platform for inspection & operation.

A UAV based logistic capability for use in military and civilian missions



BML VTOL capable Panchito UAV, as seen from the ground

Summary of the project aim

We proposed to develop and demonstrate an integrated logistics system, based on the use of State-of-the-Art unmanned aircraft with a Vertical Take Off and Landing capability, to deliver cargo Beyond Radio Line Of Sight in complex military environments and in humanitarian / development missions.

Project information

Project lead: Barnard Microsystems Limited
Collaborators: Plextek Services Limited
Project type: Demonstrator
Grant award: £687,500
Start date: July 2018
End date: October 2019

Executive Summary

BML have demonstrated the Panchito UAV carrying a 5 kg cargo. BML have tested the Panchito UAV transporting 7.5 kg in fully automatic (autonomous) flight mode, and 10 kg in manual UAV flight control mode, where the Panchito UAV was fitted with 8 OFF P80 electric lift motors and a 170 cc internal combustion pusher engine. For safety reasons, we need to perform around at least 10 test flights with the Panchito UAV in automatic flight mode, carrying a 10 kg payload, before we demonstrate this capability.

We participated in the Coalition Assured Autonomous Resupply 2019 event at Camp Grayling in Michigan, USA in August 2019.

- As we progressed through tests and demonstrations, we not only added important capability to the system, but we have also improved the usability and reliability of the Panchito UAV. Although everyone realises that we are in a prototype development and demonstration phase, expectations of uneventful demonstrations are high.

- Our robust communication system between the GCS and the UAV functioned flawlessly during the demonstrations.

- We inadvertently demonstrated a safety feature of the VTOL capable Panchito UAV when the UAV was safely and controllably landed without any drama, after losing the pusher propeller, using its vertical take off and landing capability. The ability of the VTOL capable Panchito UAV to land anywhere in an emergency is an important feature of this hybrid type of UAV.

We are very thankful for the huge amount of support we received from the UK MOD, from InnovateUK and from DFID.

What is the value or size of the addressable market?

The addressable market size is several tens of millions of pounds right at this time. End users include:
- The UK MOD
- Development activities in Africa, such as in Malawi where we have set up Barnard Limited.
- Export opportunities throughout the world.

Project Plan / Progress

Our project has completed successfully. We spent 6 months after the completion of this project commercialising our technology – this work continues:
- Setting up a scalable, ISO 9001:2015 compliant, supply chain
- Create 3D CAD files for each component to be manufactured
- Creating wiring loom schematics, with detailed information
- Working on closing the technology gaps identified during tests and exercises
- Creating sales brochures and marketing materials
- Attending DIT / DSO Trade Missions overseas, primarily in Africa
- Setting up local representatives and engaging with potential customers

We have received a multi-million dollar purchase order as a result of our sales and marketing activities in Africa, and needed to create and submit a DIT / DSO Standard Individual Export Licence (SIEL) application – and then answer a series of questions arising from our submission. Our SIEL Application was approved, and we started the manufacture of the Panchito UAVs, since a partial payment had been received from the customer.

Air-freight of the parts was an ordeal in itself, as the Panchito UAV has a 4m wingspan.

The shipment of the first UAV was intercepted at Heathrow Airport by the Border Force people, and we had to reply to a series of questions before the first shipment was allowed to proceed.

All the parts have now arrived at the customer site, where we are working on the assembly of the parts we shipped – so the export adventure for us continues...

Exploitation of the work performed has enabled us to employ an additional 6 people in the U.K.

AutoMINDER – Autonomous Marine Navigation in Denied Environments

Summary of the project aim

Vessels navigating in complex marine environment such as shipping channels, harbours or close to offshore energy installations need to behave in a safe and predictable manner when external positioning services such as global navigation satellite system (GNSS) are denied. The main aim of AutoMINDER was to mitigate such situations by demonstrating the integration of environmental referencing technologies, such as laser and radar scanning, with a hybrid inertial navigation system (INS) and Doppler velocity log (DVL).

Project information

Project lead: Sonardyne International Limited
Collaborators: Guidance Marine Limited
Project type: Demonstrator
Total project cost: £422,836
Grant award: £233,338
Start date: December 2017
End date: November 2018

Executive Summary

Recent Global Navigation Satellite System (GNSS) jamming and spoofing events emphasise the current dependence of shipping on GNSS and highlight the challenges, particularly of autonomous/unmanned vessels, in establishing their position reliably in extreme and complex marine environments such as shipping channels, harbours and offshore energy installations. In response to these challenges, AutoMINDER sought to integrate available positioning technologies with new sensor types and new integration methods, while establishment of a standardised integration architecture that supports easy adoption was proposed. This added redundancy, diversity and support for graceful degradation to fail-safe navigation is applicable to a number of manned and unmanned/autonomous ship operations.

What is the value or size of the addressable market?

There are several addressable markets for this technology, including:
- Marine support, survey and lightweight intervention / ROV vessels in offshore energy;
- Autonomous vessels, operating in areas where GNSS reception is at risk (e.g. close to structures), and
- Defence platforms that may need to operate in GNSS denied environments

Combined total global population for the above categories is ca. 13,000 vessels with ca. 250 – 500 vessels per year being accessible as new builds or retro-fit.

Project Plan / Progress

The project completed in November 2018 following a field trial/demonstrator at Sonardyne's facility in Plymouth during April 2018. This trial included a number of runs up to 2km, conducted at 4kts with comparison to real-time kinematic (RTK) GPS. Generally the trial generated encouraging results, especially on a straight course or when turning slowly.

The project was presented at the RINA Smart Ship Technology conference in London and the Autonomous Ship Technology Symposium in Amsterdam; both in 2018.

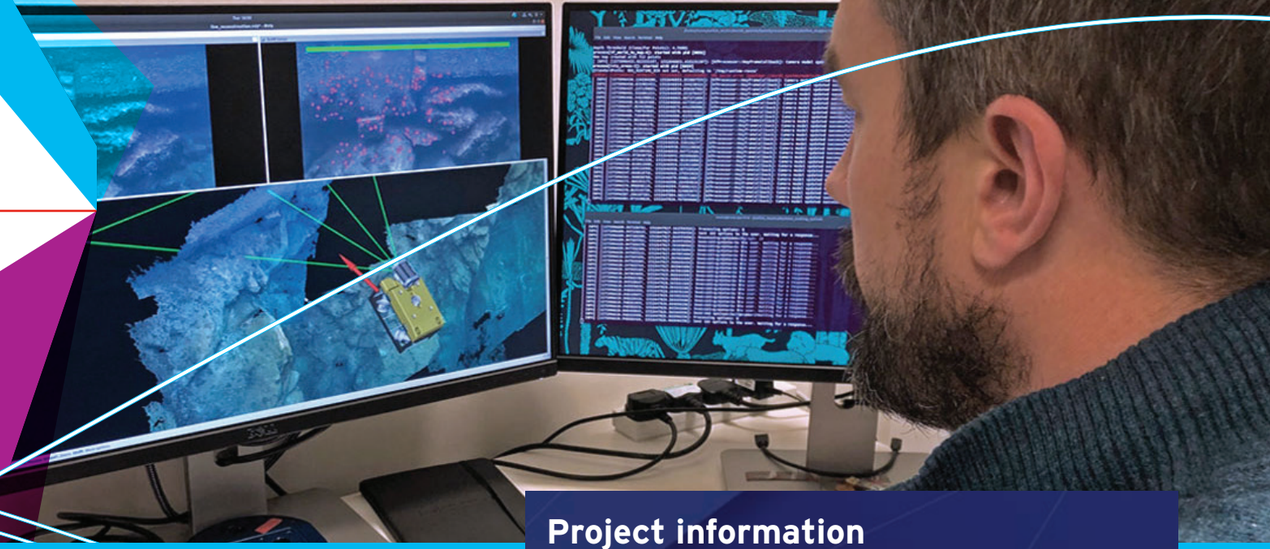
More recently (2020), Sonardyne has deployed similar technology (although environmental aiding was not used) on a UK-manufactured Unmanned Surface Vehicle (USV) to trial navigation in GNSS-denied environments to the UK MOD as part of their Autonomy in a Dynamic World competition.

Sonardyne SOUND IN DEPTH

GUIDANCE MARINE A WARTSILA COMPANY

www.sonardyne.com/sonardyne-tests-navigation-systems-for-autonomous-surface-vehicles-for-uk-mod/

Autonomous Aquatic Inspection and Intervention (A2I2)



Summary of the project aim

A2I2 is developing autonomous underwater systems to perform inspection and intervention activities in hazardous environments in the offshore and nuclear industries. Through the development of advanced 3D perception systems and autonomous capabilities, the A2I2 systems will deliver better safety and efficiency.

Project information

Project lead: ROVCO Limited
Collaborators: D-RisQ Limited, Forth Engineering (Cumbria) Limited, National Oceanography Centre, University of Manchester, Thales UK Limited
Project type: Collaborative research and development
Total project costs: £2,387,540
Grant award: £1,824,645
Start date: January 2019
End date: March 2021

Executive Summary

Underwater robots are increasingly utilised for commercial and scientific applications to make measurements and interact with the underwater environment. The Autonomous Aquatic Inspection and Intervention (A2I2) project will develop systems to operate in hazardous conditions, for offshore renewables, oil and gas, and nuclear decommissioning.

Two specific intervention use-cases will be addressed through demonstrators: offshore survey, inspection and intervention; and wet nuclear storage pond inspections and interactions.

The ambition to develop autonomous underwater systems is driven by the need to increase the quality of customer service by reducing operational risks, whilst improving safety and lowering operating costs. Autonomous and artificially intelligent systems provide the opportunity to deploy innovative technologies in pursuit of this ambition. This includes increasing the robustness, reliability and efficiency of underwater vehicles and perception systems.

Autonomy is an enabling technology which not only improves existing services but also brings new services to clients. This can be delivered through pilot or tether free operation, autonomous decision making, enhanced situational awareness, and improved localisation and mapping.

The A2I2 offshore and nuclear use cases are significantly different, enabling the project to address multiple market opportunities. This project will tackle the need for new approaches that are required to permit operation in proximity to critical infrastructure. These will include increased intelligence on the underwater robots to enable them to position themselves and navigate, avoiding collision with the surrounding environment.

This project was funded following the Innovation Lab sandpit event held by this programme.

What is the value or size of the addressable market?

The offshore industry is expanding, where high growth areas include oil and gas decommissioning, wind farm renewables, and ecological studies. Windfarm renewables are particularly notable as there is a UK commitment to increase the national energy production from 8GW to 30GW by 2030, where inspection, maintenance, and repair costs of offshore wind are predicted to be £36k/MW. Nuclear decommissioning worldwide is a £250 billion market, estimated £70 billion+ in the UK alone. The 2018 forecast is that future nuclear clean-up across the UK will cost £121 billion spread across the next 120 years.

Project Plan / Progress

Offshore underwater structures are frequently inspected for the purpose of monitoring their long-term health as part of a maintenance and repair schedule. Currently, in the windfarm domain, there is a requirement to inspect only 15% of the assets year on year, which can lead to poor data informing the long-term maintenance routine. This can lead to higher operating costs through unscheduled downtime due to faults, and a requirement for increased performance monitoring. This is particularly notable with newer, larger turbines, where the loss of revenue per hour is more significant when compared to older and smaller models. A2I2 partners are on track to address these issues through the demonstration of novel autonomous subsea capabilities that will provide detailed inspections to enable the full understanding of the structures' long-term integrity.

The nuclear industry is tasked with the decommissioning of ageing storage ponds which have accumulated large quantities of waste, sludge and biological matter over decades of service. ROV's have been used in support of nuclear decommissioning, where the vehicles are equipped with appropriate tooling to complete several tasks. This may include visual inspection, environmental mapping, asset removal and size reduction. The development of new and novel technologies in the nuclear case is progressing as planned. A2I2 will provide the next-generation autonomous systems with the capability to operate in these very challenging nuclear environments. robustness, reliability and efficiency of underwater inspections.

ROVCO OCEAN INSIGHT · THALES · MANCHESTER 1824 The University of Manchester · FORTH · National Oceanography Centre · D-RisQ

Programme Lead wallace@rovco.com • Technical Lead gary.cross@rovco.com

Autonomous Confined Space Inspection using Drones

Summary of the project aim

HyBird was focused on solving the problems of inaccessibility in extreme environments (specifically confined spaces) as well as the major time and cost inefficiencies that result from poorly managed robotic inspection data.

Project information

Project lead: Hybird Limited
Collaborators: Costain Limited
Project type: Collaborative research and development
Total project costs: £2,387,540
Grant award: £1,824,645
Start date: March 2018
End date: August 2019

Executive Summary

Confined spaces currently account for around 15 deaths per year in the UK alone, a loss rate that can and should be diminished to zero through the use of technology in large infrastructure projects. HyBird is developing technology to meet this target through autonomous confined space UAV solutions comprising a small, lightweight, collision-tolerant smart drone, an autonomous deployment docking station and an AI-based in-situ material characterisation and threat detection and inspection software.

These capabilities will minimise the need to send personnel into potentially hazardous environments and will analyse and assess the environment for threats/dangers. In addition to the human safety cost, extreme environments cost infrastructure projects billions of pounds each year due to defects, site down-time, and labour costs. Deployment of such a system can reduce the cost of inspection by more than 80%, while drastically improving productivity through early defect detection, and reduced down-time.

HyBird's autonomous UAV solution will directly benefit asset owners, as well as service providers in the infrastructure/ construction space. For a relatively small investment, the return on investment is realised through reduced project costs, lower health and safety risk, greater quality analytics, service transparency, and ultimately more business opportunities.

What is the value or size of the addressable market?

The digital inspection market, including hardware and software, is currently worth over £18Bn so far, and is set to exceed £25Bn within the next 5 years. This is spread across several key verticals, but our focus at HyBird is on asset-intensive industries.

Project Plan / Progress

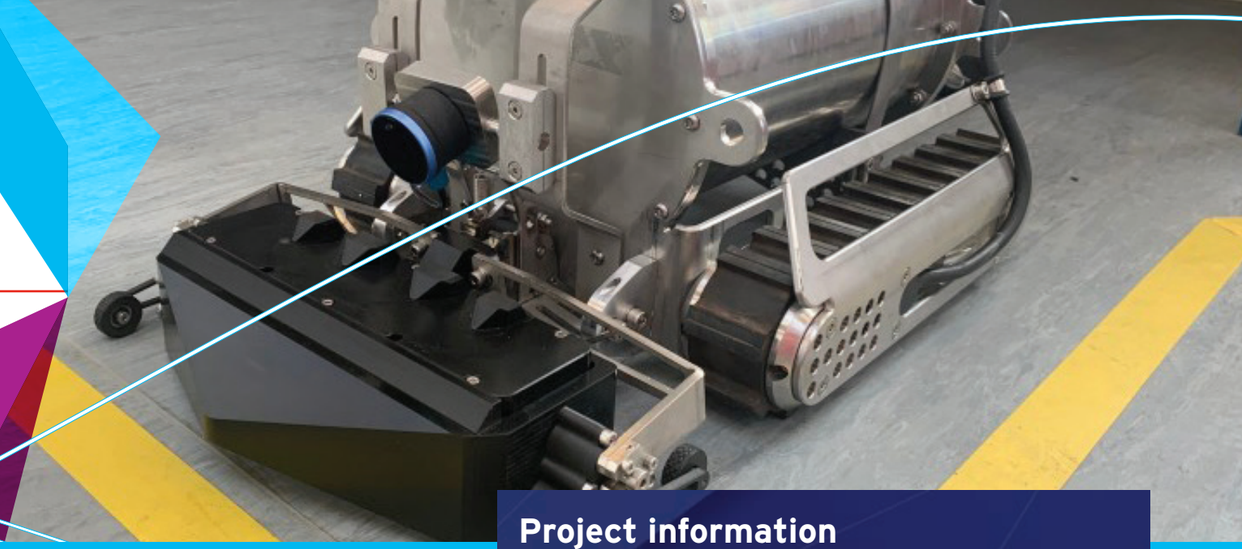
We have now completed our InnovateUK project titled Autonomous Confined Space Inspection using Drones, and we have been receptive to the market in identifying where our unique value proposition is: data management and analytics.

Towards the end of our project, we were selected as delegates for the US Global Expert Mission with the Knowledge Transfer Network and partners, where we were then successfully admitted to the inaugural Techstars Starburst Space Accelerator Program in LA, with partners that included Lockheed Martin, NASA JPL, Maxar, SAIC, US Air Force, IAI, and more.

Following the completion of this project, we intend to continue innovating and working with InnovateUK to fund further growth opportunities.

Ahmed Hadid • ahmed@hybirdtech.com •+447872173201

Bathyscaphic Robotic Floor Thickness Monitoring of Hazardous Liquid Storage Tanks (NautilUS)



Summary of the project aim

Aboveground storage tanks corrode over time leading to possible leakage of contents, resulting in severe economic losses and pollution. To avoid these consequences, manual inspection activities are performed periodically although these require tanks to be off line. This project is developing a small intrinsically safe robot to perform in-service inspection.

Project information

Project lead: RS Monition
Collaborators: London South Bank University, Innovative Technology and Science Limited, Sonomatic Limited, TWI Limited
Project type: Collaborative research and development
Total project costs: £1,516,018
Grant award: £1,192,233
Start date: February 2018
End date: July 2020

Executive Summary

The nautilUS robot will reduce the costs, danger and environmental and health and safety risks involved in inspections required by the American Petroleum Institute (API) industry standard for petrochemical storage tank periodic inspections and in particular for corrosion thinning of the tank floor. At the same time, the shortcomings of existing robotic solutions will be overcome due to unique physical characteristics of the nautilUS robotic platform.

The output of the project will lead to a product that will increase the turnover and profitability of 2 UK SMEs - InnotecUK Ltd. and Sonomatic Ltd. , and one UK Large Enterprise - RS Components Limited through creation of an opportunity worth £17M in turnover over the five years following commercialisation.

The overall objective of negating the current need for removing the tank to be inspected from service will be achieved through developments in low power explosion-proof robot design, the development of in-tank robot localisation and ultrasonic hardware and software developments, which will be integrated into a product to provide a cost-effective, continuously deployed statistical inspection solution.

What is the value or size of the addressable market?

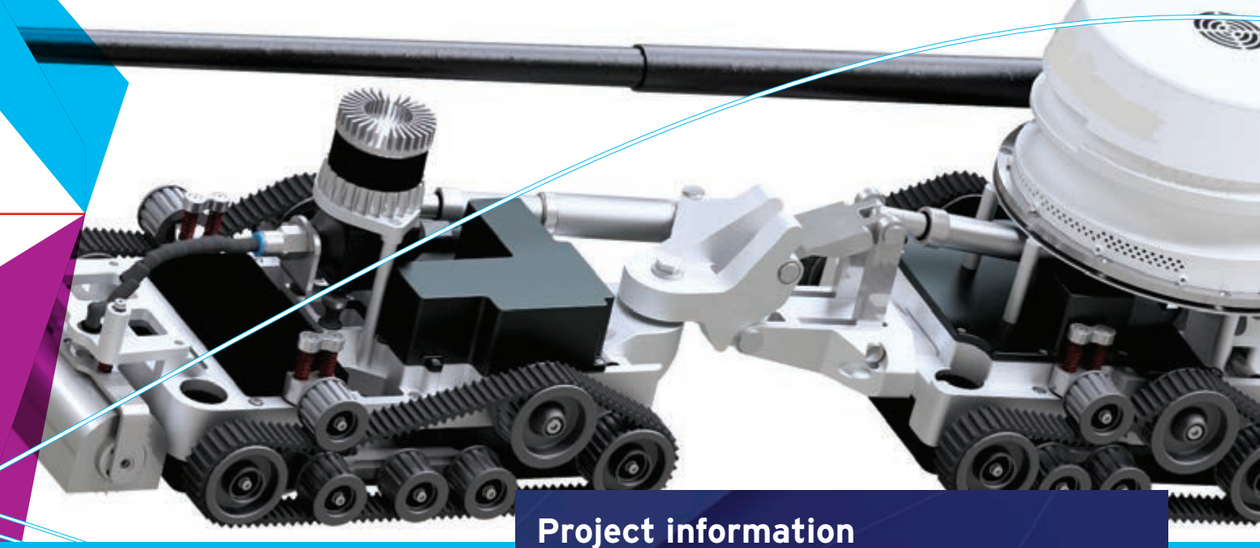
Main end users of this project will be a wide range of businesses involved in storage and/or transportation of fuels, oil and petrochemicals in industrial scale. In addition, this project gives a great opportunity to all tank maintenance and inspection service providers to access and use a state of the art robotic technology for enhanced inspection.

Project Plan / Progress

Strong collaboration between the project partners have made this project to be ahead of its original schedule. The integrated robot is to be initially demonstrated in February 2020. This will be then followed by a series of tests for further improvements and demonstrations within the last two quarters of the project. This project is to end in July 2020 , when the full robot is to be delivered.

In addition, the project consortium is currently discussing the potential opportunity to apply for a safety (ATEX) certificate which this in turn will put the nautilUS technology in an exceptional position when it comes to the post-project deployment/commercialisation.

CHIMERA - Robotic Inspection of Pressure Vessels



Summary of the project aim

CHIMERA consortium is developing a ground-breaking semi-autonomous robotic platform for internal inspection, repair and maintenance of pressure vessels and gas turbines. Novel features include augmented intelligence (AI) for the evaluation of fitness for service and modular continuum arms with miniaturised end effectors.

Project information

Project lead: Forth Engineering (Cumbria) Limited
Collaborators: Rolls-Royce PLC, Metallisation Limited, Headlight AI Limited, Sound Mathematics Limited, TWI Limited, RACE (Part of the UK Atomic Energy Authority), University of Nottingham
Project type: Collaborative research and development
Total project costs: £3,490,791
Grant award: £2,413,640
Start date: January 2019
End date: March 2021

Executive Summary

Taking assets like pressure vessels and gas turbines offline for mandatory inspection is an extremely costly and time-consuming undertaking. Recent advances in AI and improvements in sensors and data interpretation offer the vision of robotic inspection with positive impact on processes by limiting down time and therefore increasing profitability. To deliver this Innovate UK project successfully, a consortium of experts has been formed with capabilities in robotics, inspection, navigation, in-situ repair, AI, civil nuclear, civil aviation and oil & gas. The magnetic tracked vehicle in development will operate in any orientation, carry a significant payload in a modular design and be equipped with a continuum arm and miniaturised inspection and repair end effectors.

The CHIMERA system will integrate SLAM and ultrasonic survey data into a corrosion map, assess vessel fitness for service using accepted industry standards, and automatically generate an inspection report. It will drive across an outside and inside arris and negotiate obstacles. Navigating by using a suite of sensors and capable of operating underwater, the CHIMERA crawler will have a wide variety of uses across a range of industrial sectors, nuclear, aerospace, energy, marine but is aimed at the global oil & gas industry. The continuum robotic platform with thermal barrier coating repair system will be demonstrated within an installed gas turbine combustor to contain in-service damage.

What is the value or size of the addressable market?

The target market for the CHIMERA system is the billion-dollar installed asset management industry. It will add value by reducing asset down time and increase safety by reducing the need for confined space man entry.

While developed in the UK by a consortium including end users and local supply chains it is aimed at the global oil & gas industry and civil aviation. Further applications for CHIMERA can be found in the civil nuclear, energy generation and maritime industries.

Project Plan / Progress

The project is on track to achieve all the project milestones and deliverables on time and within budget.
The project is aiming to deliver key demonstrations of

- A novel cleaning, inspection and repair crawler in a pressurised environment,
- A continuum robot with repair tools in gas turbine combustor,
- An innovative pressure balancing headworks and umbilical management system,
- An integrated crawler and snake system in a range of environments,
- Miniaturisation of inspection and repair end effectors,
- The use of self-adjusting combinations of sensors to increase the quality of data captured for SLAM functions,
- AI for automatic generation of ultrasonic inspection reports.

To deliver on the system in the last year the consortium has developed its concepts and undertaken subsystem testing and is currently in detailed design with the expectation of patent applications in 2020.

Good progress has been achieved on implementing the exploitation plan, with additional interest in individual aspects of the project. Individual members are optimistic in achieving commercial success post project. The year one exploitation plan review includes these opportunities and the commercial partners are actively seeking investment for the commercialisation of the CHIMERA system.

COBRA: Continuum roBot for Remote Applications

Project information

Project lead: Rolls-Royce PLC
Collaborators: University of Nottingham, OpTek Limited , RACE (part of UK Atomic Energy Authority)
Project type: Collaborative research and development
Total project costs: £1,953,386
Grant award: £1,354,739
Start date: January 2018
End date: December 2020

Summary of the project aim

COBRA seeks development, manufacture and testing of a sub-9mm diameter prototype snake robot capable of entering highly restricted industrial environments. The device includes haptic interface (with remote teleoperation), augmented reality, digital twin of deployment scenario, 3D image reconstruction with stereo camera and a laser milling capable end effector.

Executive Summary

COBRA aims to develop a pair of snake robots that will improve restricted or hazardous inspection, maintenance and repair capabilities in the aerospace and nuclear sectors. The end goal is to prevent unplanned engine removals and to improve inspection capability in both fission and fusion nuclear environments. Both robots will be up to 5m in length, and 8.5mm outer diameter. The design is scalable, both in terms of length and diameter.

The base station will include a haptic interface between the robot and the operator, and communication protocols will be developed to demonstrate teleoperation.

Augmented reality will provide the operator with quick and simple guidance and instructions for task simplification and will be provided via a snake point of view in 3D.

The operator will also be able to view a 'digital twin' of the snake in the deployed scenario, which will be continually updated with a fusion of data from pose sensing fibre, visual odometry & forward kinematics. One of the snakes will also include a miniature laser milling end effector, for repair of currently impossible to reach areas. This comprises a highly compact (Ø8mm) laser scanner, delivering a high power laser machining capability at the distal end of the snake.

What is the value or size of the addressable market?

Rolls-Royce plc are leading the project from an end user perspective, both in the Aerospace & Nuclear fields. In terms of ensuring installed power plant equipment remains safely operational, significant value is attached to preventing down time (e.g. £M saving for preventing unplanned engine removal). Significant tier II value is associated in manufacture, supply and support for COBRA hardware and software, with end users from industries currently outside the consortium already expressing interest in a finished product.

Project Plan / Progress

The project is entering the sub-system integration phase of the project and on schedule, with the full system demonstrations expected to be completed on time in Q4 2020. All the major sub-systems exist and have been tested in isolation, such as:

- Miniature laser scanner
- 3D image reconstruction from stereo camera
- 2 COBRA insertion tubes a.k.a. snake bodies
- Inverse kinematics and snake modelling
- Integrated low level control system and actuator pack
- Twist and feed mechanism
- Human Robot Interaction device
- Digital twin of demonstration scenario
- Shape sensing fibre

2 project specific demonstration mock-up scenarios have been built, one from a nuclear fission perspective, and one with an aerospace end use for jet engine maintenance. The COBRA project team plans to demonstrate the prototype at the National Nuclear User Facility – Hot Robotics once complete.

James Kell, Rolls-Royce plc •James.kell@rolls-royce.com

https://twitter.com/RollsRoyce/status/1143581432264237056

Developing a miniature robot to install a nervous system within non-man entry sewers

OSCAR, the nuron installation is lowered into a sewer chamber during successful pilot operations

Project information

Project lead: Nuron Limited
Project type: Collaborative research and development
Total project cost: £95,437
Grant award: £42,947
Start date: March 2018
End date: December 2018

Summary of the project aim

Sewers provide a vital service and their failure has severe consequences such as sewer flooding. nuron has developed a unique fibre-optic monitoring system using a bespoke containment bonded to the pipe wall. This project is to develop a miniature robot to perform the installation remotely in non-man-entry sewers.

Executive Summary

Sewer flooding in your home is one of the worst things to experience, costing owners and UK wastewater companies tens of millions of pounds each year. Blockages, which are one cause of sewer flooding, mainly occur in small non-man entry sewers with an internal diameter of less than 600mm.

nuron has developed a unique fibre sensing technology that will provide a step-change for home-owners and wastewater network operators alike. Our unique containment system is designed to be installed along the wall of a sewer network creating a nervous system for sewers so blockages, flooding and other environmental incidents can be predicted and prevented.

The sewer environment itself represents a challenge to the installation of a monitoring system. Sewers are confined spaces coated with organic material including fats, oils and greases. They also contain decomposition gases which are often corrosive, toxic and/or explosive.

This project is focused on the design and development of a miniature robot for the installation of the nuron fibre sensing containment system in non-man-entry sewers. There was previously no existing robot or other technique available on the market with the capability of installing our sensing technology within such a confined and inhospitable space.

The project includes development of the installation robot itself, plus the surface support equipment and umbilical system. It also includes incremental validation from bench-top component testing, through full-scale above-ground tests, to below ground installation in a sewer.

make fibre make sense

Paul Dickenson, Technical Director, paul.dickenson@nuron.tech

What is the value or size of the addressable market?

nuron's end users are the UK wastewater companies. nuron plans to expand globally once established within the UK market. Based on industry information we forecast the UK wastewater market to grow to at least £75M p.a. by 2021, which we expect to take a 40% share forecasted from on-going discussions with UK WaSCs.

nuron expect competition from sewer monitoring providers and acknowledge that 40% market share is not sustainable. However, our solution includes duct capacity for broadband rollout.

nuron's robotic installation technique supports the broadband market by accessing smaller diameter pipes traditionally not previously accessible by fibre companies.

Project Plan / Progress

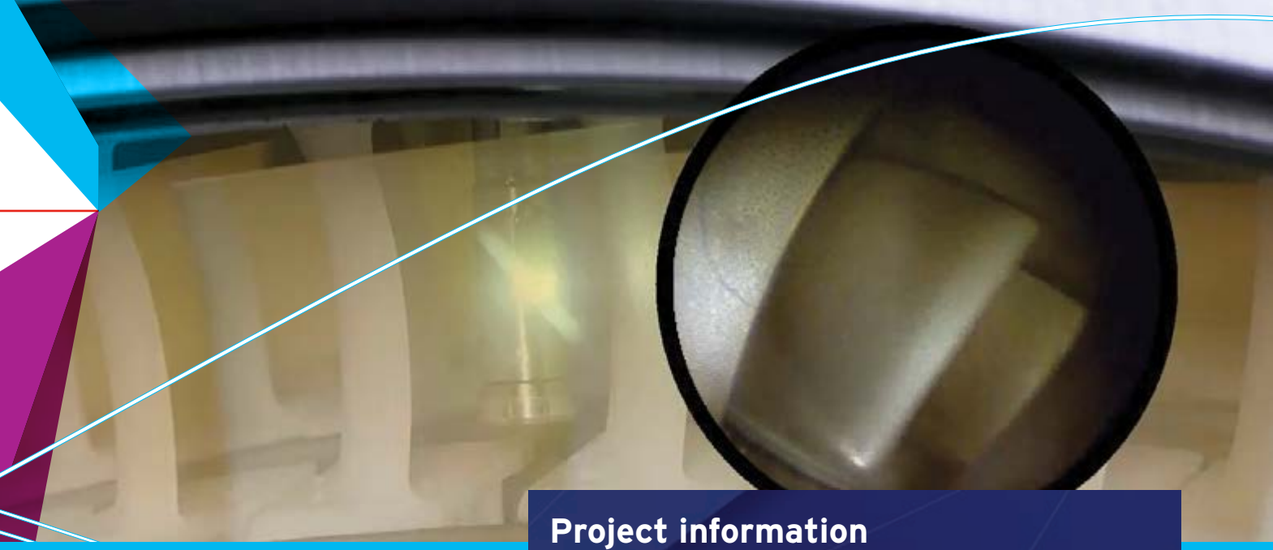
This project delivered a unique miniature robot installation system for deployment of the nuron fibre-optic sewer monitoring system. We began with detailed design of the robot itself, combining some off-the-shelf components with significant bespoke elements. Key sub-systems were assembled and tested at small scale leading to minor modifications. The main chassis was fabricated in parallel so that overall operation could be tested in a single pipe-length above ground.

The surface support system was designed and built in two phases to allow for early testing followed by field validation. In the first phase, the robot was connected to a short umbilical with prototype surface equipment. This pre-release system was tested in a 15m above-ground test bed, delivering useful learning about both the technical configuration and the processes needed for effective operation. The full release surface system was designed and sourced in parallel, incorporating early learnings while accommodating long lead times.

The original project scope assumed operation from a basic vehicle with manual handling of the umbilical which provides power, control and materials. During the project we took the opportunity to fit out an installation vehicle including mechanised umbilical handling for more efficient operations.

Following completion of the project, the robotic installation system was used for a pilot installation in an operational sewer, partly supported by a separate Innovate Loan. The pilot was successful, proving the technology in the field and delivering world-first results. We are now planning larger roll-out projects while implementing lessons learned from the pilot.

INSPECT (In-situ optical inspection of engine components)



Project information

Project lead: Rolls-Royce PLC
Collaborators: University of Nottingham, BJR Systems Limited, Roke Manor Research Limited, Oxsensis
Project type: Collaborative research and development
Total project costs: £1,973,680
Grant award: £1,223,866
Start date: January 2018
End date: December 2020

Summary of the project aim

INSPECT is a state-of-the-art inspection technology capable of being retrofitted to existing aerospace gas turbine borescope ports, and used to output component health information of compressor or turbine blades. Novel actuation and optical features, coupled with advanced inspection algorithms, allow for game-changing inspection regimes and create big data analytics opportunities.

Executive Summary

With the civil aviation sector continuing to grow year-on-year, an ever-increasing number of routine in-situ gas turbine inspections are undertaken by both propulsion providers and their customers. While these are critical for ensuring a high-level of aeroengine safety, they are time intensive, vary between inspectors, and offer limited data capture and assessment possibilities.

Through the INSPECT consortium, an optical inspection system will be developed that can be retrofitted and permanently embedded into the gas turbine borescope ports. The probes are retracted during engine running, and the tip acts like a conventional borescope port plug to restrict gas path air from escaping.

During slow engine rotation at start-up or shutdown, the inspection probes are automatically inserted into the engine gas path. These illuminate the region, and autonomously insert to different position to see root-to-tip of the rotating blades. In addition, the probe is rotated to both see the leading and trailing edges of the neighbouring blades and to optimise the inspection regime. The images are passed from the camera to a processing system where quality checks are performed, and a series of algorithms detect and measure features of interest. The data is transferred to a remote location for further analysis and sentencing.

INSPECT can provide a fast, frequent, and standardised compressor inspection after every operation. The state-of-the-art inspection technology enables future big data analytics, data mining, and trending. It will ultimately make Rolls-Royce and its customers data rich and able to optimise flight paths, maintenance schedules, and possibly even OEM design.

What is the value or size of the addressable market?

Rolls-Royce will be the primary end user of the INSPECT technology and, when the system is fully matured and validated, will look to deploy it in a range of aerospace scenarios. It shall be able to vastly increase the data collection opportunities on its existing gas turbines. Through using this in conjunction with other data sources, and empowering it through advanced data analytics techniques, Rolls-Royce can deliver upon its IntelligentEngine vision of self-aware propulsion systems. The technology could be readily deployed in other sectors where access is restricted but data collection is vital for asset integrity (e.g. offshore energy, nuclear).

Project Plan / Progress

INSPECT aims to deliver a prototype inspection device which can be installed into an existing aeroengine borescope port hole to inspect the leading and trailing edges of neighbouring compressor blades. Due to the geometrical constraints that the borescope port imposes on the inspection device, coupled with size and stand-off distance to the rotating components, a significant amount of work has been required to design the optical architecture and actuation methodology. The solution involves a camera located in a colder zone away from the borescope hole, with the images relayed to it through a series of high-temperature capable lenses. Robust and novel algorithms are being developed which can locate and size a range of commonly found damage features (e.g. dents, nicks).

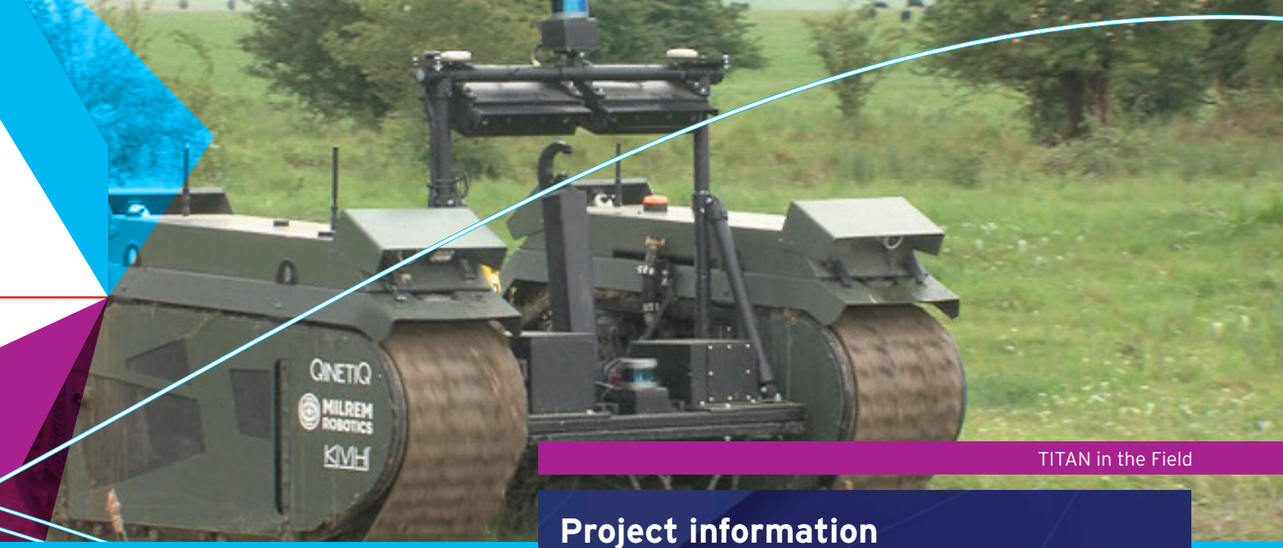
At the end of 2019 the INSPECT team tested the first fully-integrated inspection system on a compressor rig. The probe could be robustly and accurately deployed and rotated within the engine, and high-quality images and videos taken. The algorithms developed by Roke were able to locate a range of representative sub-millimetre features, many of which could not be repeatedly found by eye.

Further work is planned in 2020 to optimise the hardware and software, prior to delivering an integrated Technology Readiness Level 4 prototype in Quarter 4 2020. This will include demonstrating the complete system on a real (but not live) engine and testing the environmental capability of the sub-systems in the laboratory. In conjunction, investigations of read-across opportunities to hotter regions such as the turbine will be explored.

Andy Norton andy.norton@rolls-royce.com

https://vimeo.com/280333978

METIS Advanced - end-to-end solution for autonomous resupply



TITAN in the Field

Project information

Project lead: QinetiQ
Project type: Demonstrator
Total project costs: £1,270,000
Grant award: £562,000
Start date: July 2018
End date: October 2019

Summary of the project aim

QinetiQ's proof of concept solution to the challenge of autonomous resupply in military and humanitarian aid scenarios. Making use of mobile phone technology, autonomous UXVs, a backbone logistics engine and ground/ airspace management systems.

Executive Summary

QinetiQ developed an integrated network of autonomous systems to provide a proof of concept demonstration of end-to-end tactical-level logistic delivery in a representative environment.

The system is designed for use in dynamic, unstructured and uncertain environments to reduce risk, increase tempo and ease the cognitive burden associated with current resupply operations, for both defence and humanitarian missions.

Human machine interface is by means of a mobile phone application to order prioritised supplies to chosen locations. This passes data through a stores management system that monitors usage and real time scenario information to make predictive resupply suggestions and accurate travel time predictions for improved scheduling.

Resupply requests are processed through an operations centre that schedules and route plans the delivery tasking, taking air and ground space management and no-go areas into account. Loading and delivery tasking's are then sent to a respective location and UXVs are tasked depending on load type and priority. The link to the UXV is by means of a software bridge and reconfigurable wireless network that enables rapid integration of almost any UXV using common command protocols.

The TITAN UGV has on board autonomous navigation capability that enables it to follow a high level delivery tasking without human intervention. It's fast, highly mobile and can carry large consignments with a NATO pallet loader that can take up to 450KGS. QinetiQ is developing the Reason vehicle autonomy system to provide SAE level 4/5 autonomy for dynamic, unstructured, off-road conditions in contested RF and cyber environments

The Malloy UAS air vehicle can take off and land autonomously from dynamically designated locations. It is robust and can cope with winds and adverse weather. There are a range of Malloy UAS, the largest of which can carry over 100KGS.

The concept was demonstrated on Salisbury Plain Training Area using one TITAN UGV and three Malloy T-80 UAS to illustrate several military and humanitarian aid scenarios.

This project was co-funded by DSTL and DFID as a part of the Autonomous Last Mile programme.

Flying High (Phase 1 & 2)

Summary of the project aim

Nesta's Flying High is the first programme of its kind to convene city leaders, regulators, public services, the public, central government and industry around the future of drones in cities. Flying High seeks to position the UK to become a global leader in shaping drone systems that place people's needs first.

Project information

Project lead: Nesta
Project type: Demonstrator
Total project costs: £987,044
Grant award: £987,044

Phase 1
Start date: October 2017
End date: March 2018

Phase 2
Start date: December 2018
End date: November 2019

Executive Summary

In the first phase of Flying High, Nesta engaged five UK cities over six months in 2018 to explore the potential uses of drones/aerial robotics in urban environments, capture public sentiment, propose guidelines on drone use in the public realm and analyse the technical and economic feasibility of five socially beneficial use cases in real-world scenarios - transporting medical supplies among hospitals, responding to emergencies and supporting infrastructure development.

In the second phase, Nesta carried out detailed service design for urban drone use scenarios based on unique place-based circumstances and regulatory conditions relevant to UK cities; and explored the development and testing requirements for integrated drone services in a complex city environment, based on city demand and CAA requirements. Nesta focused on socially beneficial, city-based use cases in the categories of medical transport, emergency response and infrastructure maintenance.

What is the value or size of the addressable market?

Research carried out by Nesta as part of Flying High found a thriving ecosystem of 700+ UK civic and commercial drone industry players.

Project Plan / Progress

Building on the in-depth research, engagement and design carried out in Phase 1 and Phase 2, Nesta have designed a multi-stage accelerator focused on publicly beneficial urban drone services. Nesta is currently exploring funding opportunities for this. Urban drone technologies represent a significant economic opportunity for the UK, but cities and the public they represent will be critical in enabling their development. The Flying High accelerator will open up urban drone opportunities by placing the public at the forefront of shaping this disruptive technology.

The accelerator will invite drone technology companies to collaborate with prospective clients and city partners in the rapid development of publicly beneficial urban drone services. It will provide support in public and city engagement, regulation, service design, business case and investor mentoring to help participants secure regulatory approvals, refine technology and build sustainable service models.

Public engagement is not a standalone challenge but a key enabler for all drone technology. Flying High will help industry to explore the appropriate development and regulation of products that are truly responsive to public demand. It will aim to capture public imagination, and strengthen understanding across industry of what cities and citizens need and want, setting a new standard for how emerging technology systems should be developed in the public realm.

SIMVEE - Synthetic Imagery training for Machine Vision in Extreme Environments

Project information

Project lead: L3Harris
Collaborators: BMT Ship and Coastal Dynamics Limited
Project type: Collaborative research and development
Total project cost: £1,206,547
Grant award: £689,071
Start date: January 2018
End date: June 2020

Executive Summary

Autonomous cars are frequently in the headlines due to their potential to revolutionise the industry and transform road safety. Similar technologies can be used in the maritime environment but due to the extreme and dynamic conditions more research is needed to address and achieve similar capabilities. This project will focus on innovation research using a combination of simulated and real world imagery to train deep learning neural networks to undertake object detection classification in extreme maritime environments.

We will develop a sensor system for autonomous boats using artificial intelligence (deep learning) techniques to detect objects in extreme environmental conditions. The performance of such techniques is dominated by the volume and quality of training data, but collecting such a set in extreme conditions is prohibitive. We will explore novel ways of combining simulated and recorded data together to develop a system that will detect, track and classify objects in extreme maritime environments.

Currently there are no sensor systems able to detect small objects (such as humans or buoys) in extreme environmental conditions at sea. We will use ground-breaking research in mixed synthetic and real data training to address this sensing gap. Specifically we will integrate the BMT Rembrandt simulator and ASView control software together to research and develop artificial intelligence classifier training performance (as well as in verification and validation) in extreme environments. We will also integrate the SARIS search and rescue mission planning tool to demonstrate this capability in a fully autonomous real world search and rescue scenario.

This project will be led by L3Harris in collaboration with BMT. L3Harris is the world leading developer of autonomous surface vehicle systems and has been developing advanced autonomy for these systems for over 3 years. This research has resulted in an advanced autonomy system capable of using radar and automatic identification system (AIS) technology to complete collision avoidance across a wide range of scenarios at speeds of up to 30 knots. BMT is a leading engineering, science and technology consultancy operating mainly in the maritime industries. With around 1,500 professionals located in 60 offices in Europe, Asia and the Americas we draw upon a wide range of experience and expertise to provide high-quality, high-value products and services.

As USVs are fundamentally limited by sensing ability, fully autonomous operation in extreme environments is currently not possible. This project seeks to address this and expand market opportunities.

The development of an ATEX zone 0 encoder for explosive environments (ATEX Encoder)

Summary of the project aim

To develop a contactless low-torque incremental encoder to ATEX Zone 0 specification suitable for NDT, used in oil tank inspection (submersible into hydrocarbons).

Project information

Project lead: Innovative Technology and Science Limited
Collaborators: Granta Design Limited, TWI Limited
Project type: Collaborative research and development
Total project costs: £242,422
Grant award: £177,952
Start date: January 2020
End date: December 2020

Executive Summary

- To develop a contactless low-torque incremental encoder to ATEX Zone 0 specification suitable for NDT, used in oil tank inspection (submersible into hydrocarbons).
- Investigate the different options for magnet/sensor geometries and effect of casing material and filling options on the encoder performances.
- Develop a design blueprint for future ATEX-encoder development with various specifications, including electronic and mechanical design, details of filling procedures, and study of the impact of the new assembly on the encoder performances.

What is the value or size of the addressable market?

Manufacturers requiring an encoder in explosive environments, specifically with ATEX certification requirements.

Project Plan / Progress

The project is currently at the encoder design stage, with detailed investigation of appropriate materials for the intended application being done in parallel. The consortium will progress to manufacturing the first prototypes in the following month. Technical decisions are being continuously communicated with the certification agency to ensure the successful development of an ATEX zone 0 certified encoder.

WatchChainR

Summary of the project aim

This project seeks to develop and prove the feasibility of advanced machine vision algorithms, including the ability to provide automatic monitoring of secure areas and critical infrastructure. Primary operational scenarios include pipeline protection in remote areas and border protection over extended borders. Secondary applications include deep mining, nuclear safety and disaster relief.

Project information

Project lead: Archangel Imaging Limited
Collaborators: GMV
Project type: Demonstrator
Total project costs: £683,303
Grant award: £370,711
Start date: January 2019
End date: June 2020

Executive Summary

Machine vision technology has been applied widely for automatic inspection, and industrial robot guidance, reducing labour, recognising and patterning human activity for personal and industrial advantages. However, techniques developed and adopted so far face technical challenges in that they have not been applied successfully to wide areas or automatic surveillance. Traditional CCTV systems currently require data to be constantly reviewed by a human operator and transferred via a very high bandwidth link.

Oil rigs and pipelines are susceptible to deliberate attack and accidents causing pollution and losses to the economy. Public services require large areas of ground to be manned and monitored for suspicious activity. Smart grids require constant monitoring, not only to operate at an optimum efficiency, but to protect critical infrastructure from accident or malicious damage.

Revenue for just pipeline inspection by drone in oil & gas was $500M in 2015, est. $3B by 2020 (Pipeline and Gas Journal). That cannot prevent deliberate tapping of pipes and theft of oil as the data arrives too late for analysis.

Wider challenges: unmanned surface, air and ground vehicles (generically termed UXV), smart buoys and static autonomous and remote monitoring systems have struggled to achieve their potential, needing to maintain reliable high rate data links to operate effectively. The ability of WatchChainR to survey vast areas, and report any changes to them in real time will help to tackle these problems, and hence will aid in preventing many of the issues outlined above.

What is the value or size of the addressable market?

The primary target market is the energy industry and the private security companies who already service that industry. The secondary market is for government border control.

We conducted an independent assessment of the market size with Said Business School at Oxford University who assessed our SAM to be worth $1.6 billion for related or derivative products.

We are also targeting export markets, such as the Philippines, Malaysia, Singapore, UAE and Oman. Customers in the energy export markets are well unified by best practice and common supply chains but the security and safety patrol customers are deeply segmented by geography.

Project Plan / Progress

The project currently in progress: WatchChainR.
In part, the WatchChainR system aims to demonstrate the capability of humans and machines to operate as a team with the technology built by the project partners:

- Archangel Imaging are currently developing edge-AI and smart camera technology, and a centralised management platform for human and AI teaming
- GMV are currently developing a UGV (unmanned ground vehicle) capable of infrastructure monitoring (e.g., oil and gas pipelines)

Together the teams aim to demonstrate the ability for the systems to work together and provide infrastructure monitoring in complex environments (e.g., factories, construction sites, decommissioned buildings) and remote environments (e.g., rail lines, oil and gas pipelines).

WormBot

The WormBot with multiple bends in 2D, similar to the potential underfloor use case.

Project information

Project lead: Q-Bot Limited
Collaborators: Queen Mary University of London
Project type: Collaborative research and development
Total project costs: £704,423
Grant award: £538,091
Start date: April 2018
End date: March 2020

Summary of the project aim

Q-Bot, in collaboration with QMUL is researching, evaluating, prototyping and validating a soft worm-like robot, named 'WormBot', for the inspection and thermal insulation of suspended floors and cavity walls. Further applications within extreme and challenging environments are being identified and will be explored using the created WormBot prototype.

Executive Summary

Q-Bot specialises in robotic services in the built environment that allow easier, cheaper, safer and more effective repair, maintenance and upgrade of buildings and infrastructure. Q-Bot will be the end user of the WormBot system providing robot enabled services, initially in the application of underfloor insulation to buildings (at a fraction of the current cost, and with none of the disadvantages of traditional methods). It will use a robot to apply insulation in an environment that's currently inaccessible for human operatives without prohibitive disruption and expense.

The service is already being commercialised (with the help of a much more cumbersome system) with a number of clients including local authorities and housing associations with over 500 sites successfully insulated and over 1500 committed to by clients.

This project builds on ground-breaking robotics innovation in the area of soft and flexible robotic manipulators by the Centre for Advanced Robotics @ Queen Mary (ARQ), Queen Mary University of London (QMUL) initially developed for surgical applications. It will develop the technology further with a view to using it in extreme and challenging environments of inaccessible areas of buildings (initially), infrastructure networks (including sewers) as well as nuclear site inspection.

The project will deliver a proof of concept prototype that will be validated in demanding environments as well as developing further the service robotics business model and validating it in various industrial segments using the lean start-up principles.

What is the value or size of the addressable market?

In the UK over 10M homes have uninsulated suspended timber floors and over 4M have 'hard to treat' cavities. Within this market Registered Social Landlords (RSLs) manage \>0.8M hard to treat homes.

Q-Bot is a market leader in insulation to suspended timber floors and will initially be the end user of the WormBot technology. The underfloor insulation market exceeds £15Bn in the UK alone, with addressable market \>£2Bn (appropriate properties owned by Social Landlords). Overseas markets (e.g. Denmark, Holland, France & Germany) increase this much further.

Project Plan / Progress

The project is entering the final quarter, where the prototype systems will be tested and validated. Whilst some extra time was spent on developing the prototype systems, the overall project is expected to complete as planned.

The work packages completed so far are:

WP1 - Research and Specification. This initial work package included engaging with stakeholders and identifying customer needs, surveying the market and technical needs, developing the system architecture plan and creating a detailed requirements specification.
WP2 - Concept Design and Development. This package included surveying the current state of the art, design and development of overall robotic system, selection of key hardware such as actuators and materials.
WP3 - Structure Design and Fabrication. This work focussed on the design and fabrication of the prototype soft robot mechanism.
WP4 - Testing, Control and Actuation Development. Development of the firmware and control systems for actuation of the WormBot.
WP5 - Detailed Design and Manufacture. This involved the development of initial working prototype and systems into a minimal viable product to be used as a test bed for lab and site experiments.

The remaining work packages are:

WP6 - Operational Prototype Testing, Validation and Demonstration. This work package has already commenced and involves testing to validate performance of the prototypes and control systems.
WP7 – Exploitation. This package considers the commercial and business issues that will need resolving in order to fully exploit the technology.

Enhanced Performance of Robotic Drilling Tools using High Frequency Vibration

Project information

Project lead: Magna Parva Limited
Collaborators: Schlumberger
Project type: Collaborative research and development
Total project cost: £94,230
Grant award: £65,961
Start date: December 2017
End date: November 2018

Executive Summary

Drilling for oil and gas is a costly activity (around £1 million per day). The drills are complex robotic machines, capable of autonomously controlling their steering using attitude sensors while working in some of the most extreme and challenging environments (up to 3000psi, 200 atmospheres and 120 degrees centigrade, in drilling mud, heavy liquid designed to prevent well blowouts).

Any enhancement to the performance of the drill has potentially large economic benefits, and that is the objective of this project. Magna Parva will investigate the feasibility of enhancing the performance of these drills (especially in hard rock such as granite or marble) by applying high-frequency vibrations ahead of the cutting teeth. Such vibrations have 2 potential effects, generating micro-cracks in the rock and reducing friction.

The latter is particularly interesting, because it may assist the autonomous steering of the robotic drill, so we will make 'wet' tribometer measurements under drilling mud.

Infrastructure for Drone Operations

Project information

Project lead: Herotech8 Limited
Project type: Collaborative research and development
Total project cost: £76,967
Grant award: £53,876
Start date: November 2017
End date: July 2018

Executive Summary

Herotech8 is a UK-based robotics company and CWEIC Commonwealth First Export Champion, with a vision to create wide-scale, clean and sustainable infrastructure hardware for drones. The recipient of the InFocus Women In Innovation Prize in 2016, the team seeks to complete an industrial research project in robotics and autonomous systems.

This will allow development of the core technology and demonstrate the core functionality of the Herotech8 Skystation and its potential value, in a highly controlled environment. With our integrated technology, the Skystation will enable rapid growth in drone adoption, and provide the necessary safety assurances without the need for a human operator.

INDUSTRIAL STRATEGY

UK Research and Innovation

UK Research and Innovation is a new organisation that brings together the UK Research Councils, Innovate UK and Research England into a single organisation to create the best environment for research and innovation to flourish. The vision is to ensure the UK maintains its world-leading position in research and innovation.

For more information visit www.ukri.org

Published by Innovate UK, part of UK Research and Innovation
For more information visit innovateuk.ukri.org

Telephone: 01793 361000

Follow us

September 2018 18.1136.057