UK Research and Innovation

Robots
for a Safer World

Challenge overview and project directory

2017–2022

UK Research and Innovation

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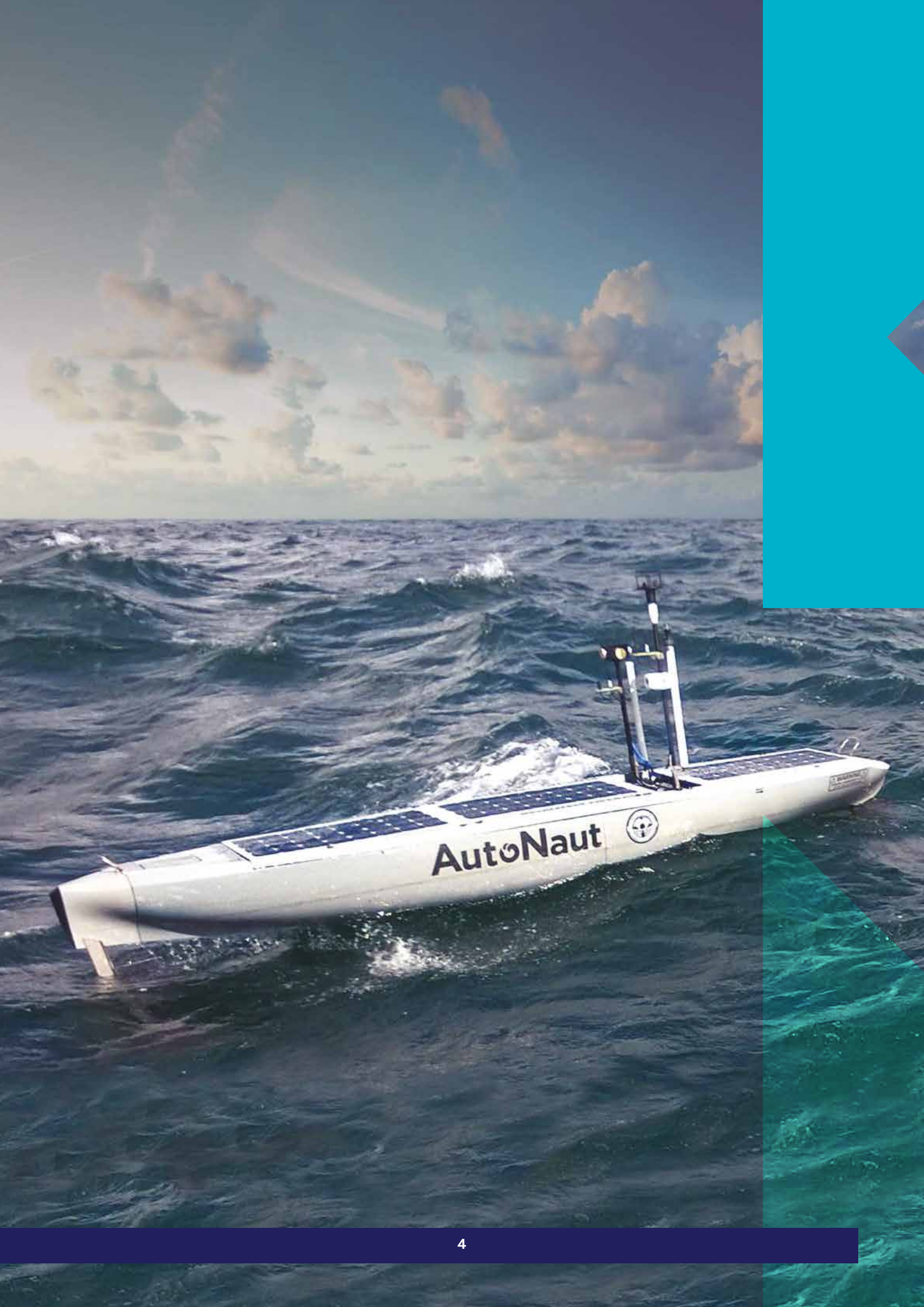

AutoNaut

Challenge

The Robots for a Safer World challenge was set up in 2017, at the same time as the formation of UK Research and Innovation (UKRI), which brought together the delivery of the Government's UK research and innovation strategy into one place. The Robots for a Safer World Challenge was the first time a coordinated programme had been initiated to improve the capability of robots and artificial intelligence (AI) to keep people working in extreme and hazardous environments safe and more productive.

Over the past five years the Challenge has invested £112 million and supported over 153 projects and 212 organisations in areas such as nuclear decommissioning, space, and marine and offshore environments. It's not surprising then that the possibilities for using robots and drones to take humans out of these dangerous areas has gained traction over that time.

Thanks to investments in projects focussed on areas such as: inspection, maintenance, and repair of wind turbines; taking humans away from directly sorting radioactive materials; and autonomously decommissioning defunct satellites in space, the Challenge has achieved many world firsts as it acted as a catalyst to the rapid deployment of these new technologies. Operating in these environments is complex and using robotics in these areas, especially for the first time, is technically difficult and requires the integration of many different technologies. During the last year of the Challenge, we funded projects that extended the scope into the wider service robotics markets, such as agri-tech, logistics, construction and healthcare, transferring the knowledge gained over the first four years into new and exciting areas.

Funding these projects has allowed the companies involved to take a high-risk technology development strategy and start to build world-leading capabilities. By demonstrating capability early on, and following up with rapid commercialisation, UK organisations have been able to take their first steps to addressing a global need for robotics across many sectors to make operations safer, smarter, and more efficient.

Andrew Tyrer
Challenge Director
Robots for a Safer World Challenge

The current Robotics and Autonomous Systems (RAS) market landscape

RAS adoption has been increasing both in the UK and worldwide. COVID-19 has forced many sectors to re-evaluate everyday operations from healthcare to food preparation. Recent macro events have accelerated development and deployment, and many industries now have the mindset to be radically transformed.

The market opportunities are vast, the recent RAS report (2021) from the Department for Business, Energy and Industrial Strategy (BEIS) estimated that these technologies will have an impact on global markets of between $1.7 and $4.5 trillion per year by 2025 and the creation and expansion of innovative RAS related businesses would help boost growth.

Robots, and more specifically co-bots, allow repetitive tasks in different business environments to more efficient. Mobile robots are acquiring data and enabling this rapid flow of information to increase productivity, and delivery robots are demonstrating that each link in the supply chain can be optimized. Novel approaches to deploying RAS have become mainstream with RaaS (Robotics as a Service), the expensive capital Robot can now be bought as a subscription transforming the economics of adoption.

The UK has the opportunity to benefit from these significant changes not only in the domestic development of RAS technology but deploying RAS rapidly into new areas.

The Robots for a Safer World Challenge

The robotics challenge commenced in 2017, offering more than £93 million as part of a four-year programme that would develop robots and AI to take people out of dangerous work environments and go into areas beyond human limits. In 2020, in response to the disruption caused by COVID-19 and the clear demand for robotics in sectors such as agriculture, health, logistics and construction, the programme was granted a £15 million one-year extension from which it funded "Robots for a More Resilient Future". This competition focused on funding research and development projects in service robotics. From this extension, the programme was also able to provide financial support to some existing projects who had been impacted by the pandemic.

Currently the Robots for a Safer World programme has three delivery streams to provide funding to various projects around the UK. These fall under:

- Research and development (including collaborative R&D and feasibility studies)
- Demonstrator competitions
- Hubs

At the programme's completion in March 2022, it will have committed £112 million through these delivery streams, complemented by over £500 million of industry matched funding. The breakdown of the committed spend to date from these delivery streams is shown in figure 1 and 2 on the next page, with figure 3 highlighting the geographic spread of funding. The details below illustrate the projects receiving this funding and demonstrate the cross-cutting nature of robotics in the UK with a broad range of activities that UKRI is funding to ensure that the UK remains at the forefront of this crucial industry.

This document breaks down the funded activities into the five environments addressed by the original programme scope of extreme environments:

- Offshore (wind, underwater)
- Nuclear
- Space
- Mining
- Cross-Cutting – projects that cover different technological developments or could be applied across many industries

It also features sections focused on the projects funded through the one-year extension:

- Resilient future – this includes projects in the agriculture, health, logistics, construction and infrastructure sectors amongst others
- COVID-19 fast start – the programme funded 16 projects from the Innovate UK organised "Business-led innovation in response to global disruption" competition

Across the next few pages are the contents tables that show the projects funded and the kinds of technology involved within them. You can use the links to help you navigate through the document.

All content in this brochure was kindly provided by the project teams either at application stage, during their project, or following their projects completion. As a result, there may be slight variances in the style of writing throughout this brochure based on the styles of the individual projects.

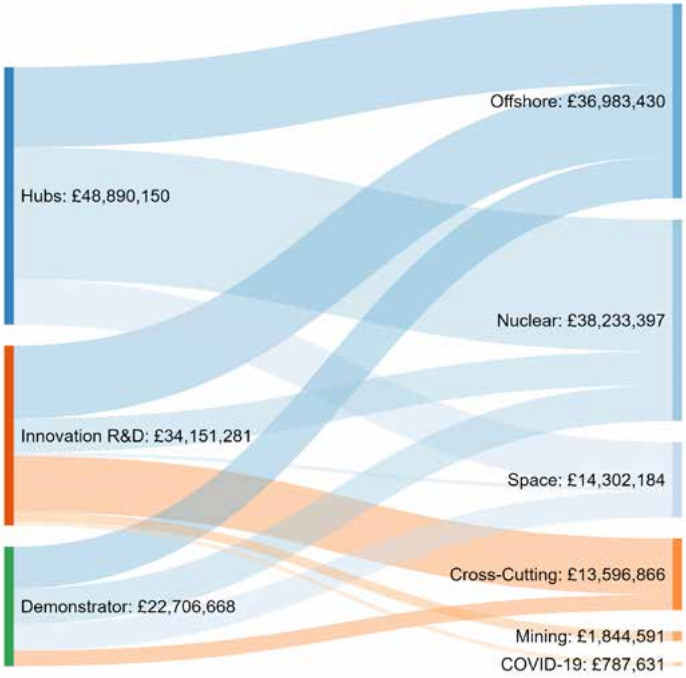


Figure 1: Sankey diagram showing commitment from the delivery streams to the extreme environments part of the challenge

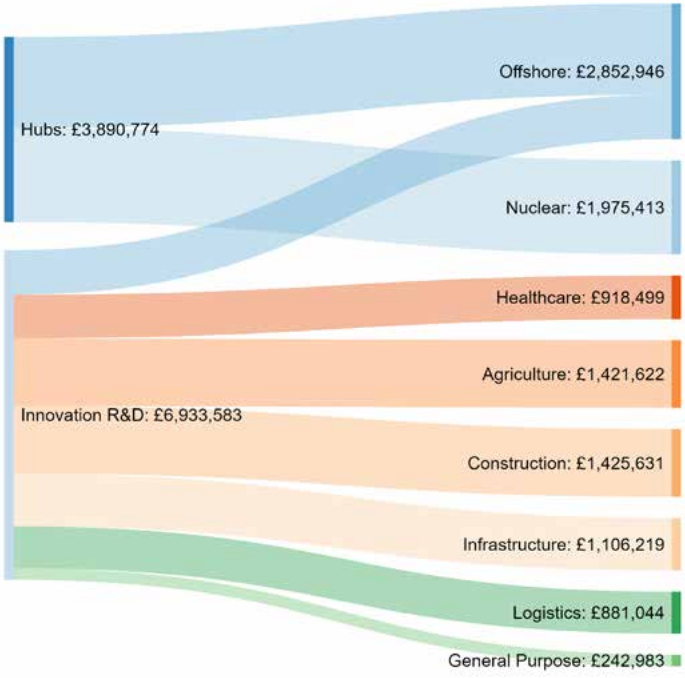


Figure 2: Sankey diagram showing commitment from the delivery streams to the sectors supported by our 'resilient future' activity

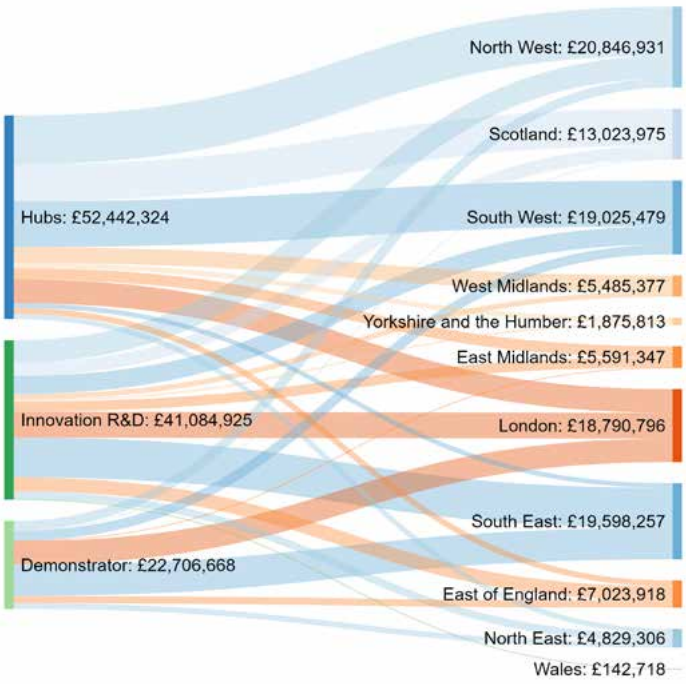


Figure 3: Sankey diagram showing the funding to regional areas

Completed Phase 1 Demonstrators with Phase 2 projects

In 2017, the UKRI's Robots for a Safer World challenge ran the first stage of its demonstrator competition where it funded 17 smaller projects. Of these, nine progressed to be funded as part of a second round in 2019.

Listed below are the nine completed first phase 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 organisation name	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 UKRI's Robots for a Safer World. 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	Innvotek 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)	Innvotek 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
Demeter	Autonomous Devices Limited	USV, UUV	Energy-harvesting; Systems Integration, subsea sensor data retrieval and analysis Control, Automated decision-making, and planning	Yes	Inspection / Survey / Mapping / Collaboration
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
Project Anemoi	Soil Machine Dynamics Limited	Subsea robotics and sensors	High power electric ROV, Cable Detection	No	Inspection / Maintenance / Repair / Operation

Offshore

Application title	Lead organisation name	Robot type	Subsystem focus	AI / machine learning	Main activity / 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
Squads of Adaptive Robots (SoAR)	Planet Ocean Limited	AUV, USV	Systems Integration, Sensing and Control, Automated decision-making and planning	Yes	Inspection / Survey / Mapping / Collaboration
Subsea Enhanced Autonomous Mapping (SEAMless)	Rovco Limited	AUV	Navigation / Control / Autonomy / Mapping	Yes	Inspection / Survey
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

There are more Offshore projects below under the 'Resilient Future' section.

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	Decommis-sioning
LONG-OPS: A UK-Japan R&D programme to develop long reach manipulators for use in long term remote operations for nuclear decommissioning	Remote Applications in Challenging Environments (RACE)	Focus is on digital tools for operations in challenging nuclear environments, including haptic telemanipulators and long-reach articulated booms	Digital Twins, Machine learning datasets, Operations planning tools	Yes	Inspection / Maintenance / Debris retrieval

Nuclear

Application title	Lead organisation name	Robot type	Subsystem focus	AI / machine learning	Main activity / operation
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; Decommis-sioning and waste handling
Nu-Decom	Nuvia Limited	Manipulators, 6DOF robotics	Various	No	Inspection / 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 / Decommis-sioning
Sellafield In-Cell Decommissioning System (SIDS)	Cavendish Nuclear Ltd	Service Robotics	System level	No	Decommis-sioning
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	Decommis-sioning
Smart IMAging for Nuclear "SIMAN"	I3D Robotics Limited	N/A	Smart imaging	Yes	Decommis-sioning

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	Decommis-sioning
SMARTER – Space Manufacturing, Assembly and Repair Technology Exploration and Realisation	BAE Systems (Operations) Limited	Service Robotics	Autonomy, AI, ML and health monitoring	Yes	Decommis-sioning
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	QinetiQ	UGV / UAS	Planning, logistics, autonomous navigation	No	Operation / Logistics Support
Nesta-Flying 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)	Innvotek 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

Resilient Future

Application title	Lead organisation name	Sector focus	Robot type	Subsystem focus	AI / machine learning	Main activity / operation
A Pet-like Socially-Assistive Robot to Support Health and Well-Being	Consequential Robotics Limited	Healthcare	Pet robot	Linguistic interaction, behaviour interaction	Object recog-nition	Verbal interaction and biomimetic behaviour for therapeutic / Calming interaction with kids
APLAUSE – Automated Precision Loading And Unloading System Environment	Digital and Future Technologies Limited	Logistics	Drone	Mechatronics, automation, integration	NA	Drone cargo loading / unloading
ARC – Autonomous Research Continuity – A national resource to protect UK life sciences R&D against disruption	Arctoris Limited	Healthcare	Industrial, laboratory automation	Informatics, automation Control	NA	Automation of laboratory research
AutoInspect	Create Technologies Limited	Infrastructure	Quadrupeds	Metrology, control, integration	Yes	Inspection / Autonomy
Automated Human Inoculation – Covid	Aqualife Services Limited	Healthcare	Collaborative robot arm	Human innoculation	Yes	Operation / Safety and Efficiency
Automation harvesting of whole-head iceberg lettuce	Grimme (U.K.) Limited	Agri-tech	Robotic arm, end-effector	Machine vision, mechatronics	Object detection	Robotic harvesting
BladeBUG Leading Edge Repair Tool	BladeBUG Limited	Offshore	Mobile robot	Mechatronics, end-effector	No	Inspection, Maintenance and Repair
Blended dexterous autonomy and remote robotics for resilient economic service delivery	Plexus Systems	Teleoperation/ General Purpose	Remote manipulator	Haptics, vision	Yes	Other
Building Resilient Robotic Harvesters for High Value Field Vegetables	Muddy Machines Limited	Agri-tech	Field / agricultural robot	Selective green asparagus harvest	Yes	Vegetable harvest
Calculating the precise geolocation of commercial unmanned aerial vehicles	Drone Defence Services Limited	Logistics	Drone	Comms, localisation	NA	GPS localisation system for drones

Resilient Future

Application title	Lead organisation name	Sector focus	Robot type	Subsystem focus	AI / machine learning	Main activity / operation
Deep Crop Growbotics (DCG)	Capture Automation Limited	Agri-tech	Mobile robot	3D vision, mechatronics, end-effector	Object recog-nition, CNN	Robotic harvesting
Detection of fungal plant pathogen spores using Advanced AI and Imaging (AAII)	Platform Kintetics Limited	Agri-tech	Autonomous (stationary) monitoring robot used to sample and analyse air particulates	Automated microscopy and particle capture mechanisms	Yes	Monitoring
Distributed Middleware and Semantic Hardware Description for Heterogeneous Mobile Robotic Fleets in Logistics Warehousing	Seyo Limited	Logistics	Mobile robots	Simulation, collision avoidance, control	NA	Path planning collision avoidance and control of layer for warehouse robotics
EchoBoltBUG	Energy Integrity Services Limited	Offshore	Crawler robotic platform	Robot gait, Ultrasonic inspection service module	No	Inspection
FASTPICK: Novel active vision and picking head to robotically harvest soft fruit	Saga Robotics Limited	Agri-tech	Mobile robot	Object classification, end-effector	Vision, object class-ification	Robotic harvesting
Feasibility of a standardised, optimised Soft Robotics CPU as the core Industry 4.0 architecture to advance the rapidly growing soft robotics industry	BiologiC Technologies Limited	General purpose	Soft robotics	Fluidics, sensing, electronics	No	Inspection / Maintenance / Repair / Operation
Feasibility of Causal Learning System for Robotic Transportation and Materials Handling	Inner Machines Limited	Logistics	Autonomous vessels	Maritime vessel collision avoidance	Yes	Operation
Feasibility Study for the Application of CellRail as an Automated Weight-Bearing Scaffolding Solution	Resolve Robotics Limited	Infrastructure	Scaffolding robot	Structural, stress test	NA	Automated scaffolding

Resilient Future

Application title	Lead organisation name	Sector focus	Robot type	Subsystem focus	AI / machine learning	Main activity / operation
FollowPV - Developing autonomous unmanned aerial vehicles with spatial awareness for improved image quality from solar farm inspections	Resolve Robotics Limited	Infrastructure	Drone	Control, path planning, sensor fusion	NA	PV farm survey
HausBots – Wall Climbing, Damp Proofing and Paint Applicator Robot	Hausbot Limited	Construction	Wall-climbing robot	Autonomous path planning	Yes	Maintenance
Holistic Principal Tunnel-Sewer Survey System (HS3) using Unmanned Aerial vehicle and Artificial Intelligence+Big Data	Clogworks Technologies Limited	Infrastructure	UAVs	Platform, sensing	Yes	Inspection
LianaBot	Q-Bot Limited	Construction	Service robotics	Sensing, actuators and control	Yes	Inspection
Nano-Agro: a novel, multi-purpose RAI system for sports turf	E-Nano Limited	Agri-tech	Autonomous rover	Automated intrusive and non-intrusive sensors (incl. computer vision) for soil and turf inspection and maintenance	Yes	Inspection / Maintenance
OSPREH: Optimising Speed, Productivity, Resilience and Efficiency in Healthcare	Motion Robotics Limited	Logistics	Unmanned Drone, Rover Ground Robots	Machine Vision Navigation, Deep Reinforce-ment based multi robot collaboration automation and optimisation	Yes	Transport of Urgent Medical Supplies
OTFT based e-skin for robots in picking and packaging of agriculture produce (ESIPP)	NeuDrive Limited	Agri-tech	Robotic hands / grippers	Haptics, electronics	No	Operation

Resilient Future

Application title	Lead organisation name	Sector focus	Robot type	Subsystem focus	AI / machine learning	Main activity / operation
RICHE – Robots In Controlled Healthcare Environments	Westfield Sports Cars Limited	Healthcare	Mobile robot/ POD	Integration, mechatronics	NA	Logistics in healthcare using POD and hot swappable payload
RoboCapture. Automated and agile robotic platform for image and 3D scanning data capture in construction	Motion Impossible Limited	Construction	Mobile wheeled robot	Path planning,	NA	Inspection of brownfield land
Robotics for Resilient Environmental Gravimetric Surveying	M-Squared Lasers Limited	Construction	Mobile robot	Sensor integration, gravimeter	NA	Deployment of a gravimeter in a robotic platform
Robust Automated Discovery (RAD)	Gearu Limited	Construction	Mobile robot	Teleoperation, validation and verification	NA	Tele-operation of robot in a scientific laboratory
SAR Box: Developing AI to enable unmanned search and rescue	Zelim Limited	Offshore	Unmanned rescue vessel and search and rescue drone	Casualty detection system to enable identification and tracking of people in the water	Yes	Search & Rescue
SeaLens: Autonomous marine robot for seaweed and shellfish aquaculture	Plant Ecology Beyond Land (PEBL) CIC	Agri-tech	Marine robot	Mechatronics, sensing (visual, chemical), comms	NA	Monitoring aquacultures
SUPERIOR – SUPer-immErsive remote working via Virtual Reallty cOntrolled Robotics	Ecom Scotland Limited	Teleoperation/ General Purpose	Franke Emika robotic arm	Workflow based user experience	No	Operation/ Other
Swimming through the Grains: Robotic Device for the Autonomous Monitoring of Cereal Grains in Long-Term Storage	Crover Limited	Agri-tech	Robot capable of movement in bulk solids and powders (i.e. a CROVER)	Mechanical design, motion control, autonomous navigation, sensing and monitoring	Yes	Inspection

Resilient Future

Application title	Lead organisation name	Sector focus	Robot type	Subsystem focus	AI / machine learning	Main activity / operation
TEK7 RBT	B.E. Design Consultancy Limited	General purpose / Sport	NA	RFID electronics, digial, wearable, mobile robot	NA	Robotic and digital football training
The application of robotics for the automated installation of tunnel mechanical, electrical and communication systems.	Tunnel Engineering Services (U.K.) Limited	Infrastructure	Industrial robot	Positional sensing, robotic part fixing	NA	Visual inspection of tunnel and robotic positioning and fixing of electrical and communica-tion cables
The Distributed Automated Cutting System project (DACS)	Eurovia Infrastructure Limited	Construction	Industrial robot	Metrology, machining	Yes	Operation
Unmanned Coastal Air Bridge	UAVAID Limited	Logistics	UAV / UAS	Command & Control	No	BVLOS Operation

COVID-19 Fast Start

In 2020, following the onset of the global COVID-19 pandemic, UKRI were involved in a number of interventions targeted at supporting academic research into the virus and mitigating the impact on innovative businesses.

As part of this, Innovate UK ran the "Business-led innovation in response to global disruption" competition for short, high-impact projects that dealt with the impacts of the pandemic. The response to the competition attracted a record 20,000 applications, with over 800 businesses awarded funding, totalling £134m.

The Robots for a Safer World programme extended this funding even further, by providing funding for another 16 projects.

The public descriptions for these projects can be found in this brochure.

Read about the other different ways that UKRI has supported the response to the COVID-19 pandemic here: https://www.ukri.org/our-work/tackling-the-impact-of-covid-19/

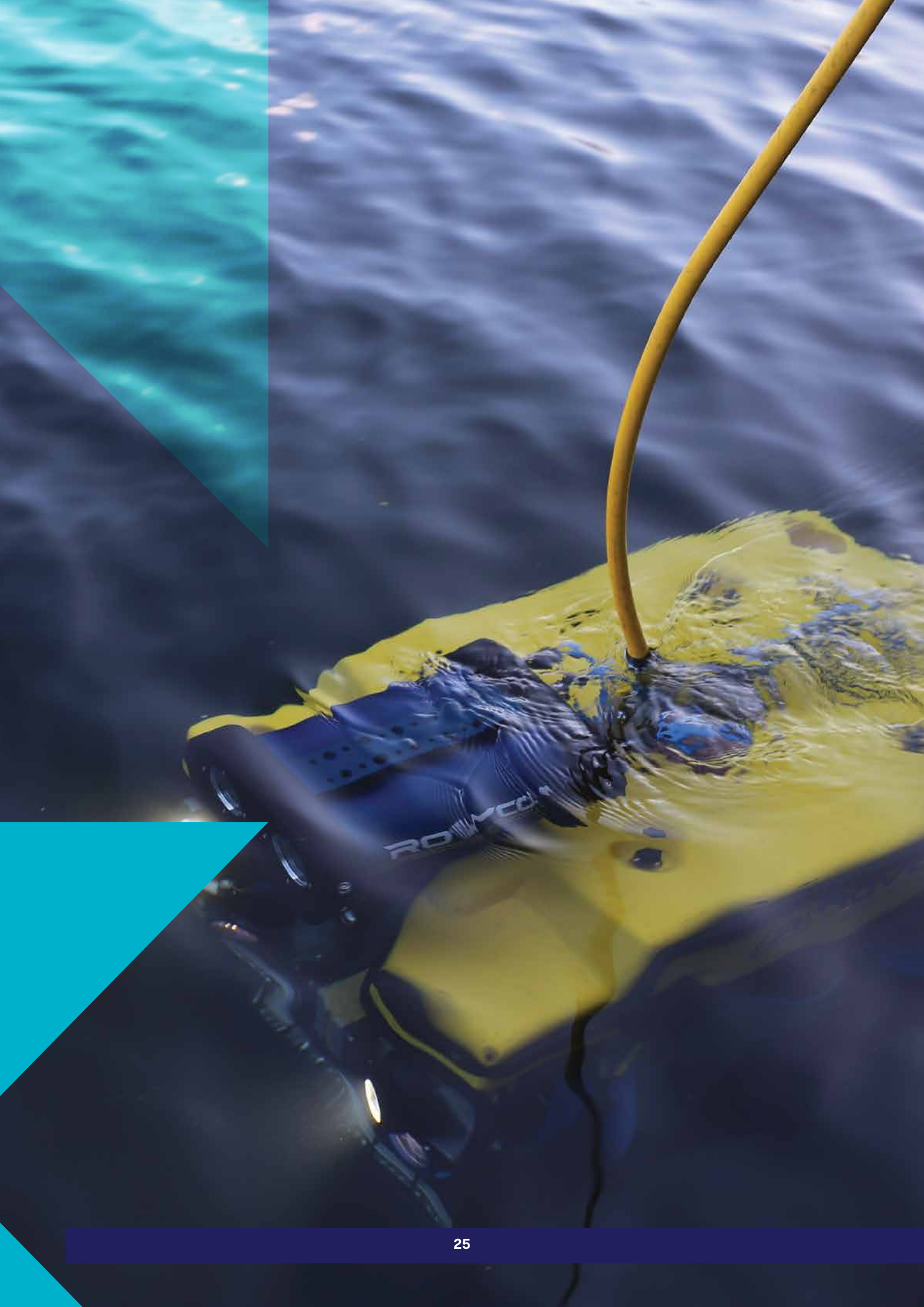
Application title	Lead organisation name
ADR – Autonomous Disinfection Robots	Q-Bot Limited
An autonomous, modular robotic platform, enabling disinfection and telepresence in a care setting	Ice Nine Limited
Autonomous Cargo Aerial Last Mile Resupply (A CALM-R)	Hybrid Drones Limited
Autonomous Mobile Irradiation Robot (AMIR)	Peacock Technology Limited
Developing a novel web platform for remote control and communication with industrial robots	E-Nano Limited
Fugro Marine Remote Operations Centre	Fugro GB (North) Marine Limited
General Purpose, Form Agnostic, Robot oversight and Tele-operation	Reach Industries Limited
Low cost and fully integrated Robotic fruit & vegetable handling & packing line for distributors	Wootzano Limited
Minimal Infrastructure Robotic Delivery System for Non-Contact Logistics	Toshiba Research Europe Limited
Multi-purpose dexterity tele-operation robot for remote working and healthcare	Extend Robotics Limited
No Human Contact Deliveries Via Semi-Autonomous Vehicles	Academy of Robotics Limited
Robotic sanitising Care Homes and Health Care Facilities	The Perfect Little Company Limited
Skyfarer – Autonomous medical logistics by drones	Skyfarer LTD
Smart Robotics for Crisis Resilient Food Fulfilment Centre Operations	Smartia LTD
UAV Crowd monitoring	Level Five Supplies Limited
VR collaborative robotics, enabling remote physical work	Titan Reality LTD

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 20 collaborative research and development (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 competition focussed specifically on Electronics, Sensors and Photonics in Extreme Environments.

These projects collectively 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.

This section also includes three projects funded following an Innovation Lab focussed on developing subsea autonomous systems. This was a virtual sandpit event run in 2021 jointly by UK Research and Innovation, UK Defence Solutions Centre, the Royal Navy, and the Net Zero Technology Centre. These projects, involving AI to make gathering data, maintaining windfarms, and mapping the sea floor more efficient and cost-effective, have started in 2021 and are to be completed by September 2023.



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.

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.

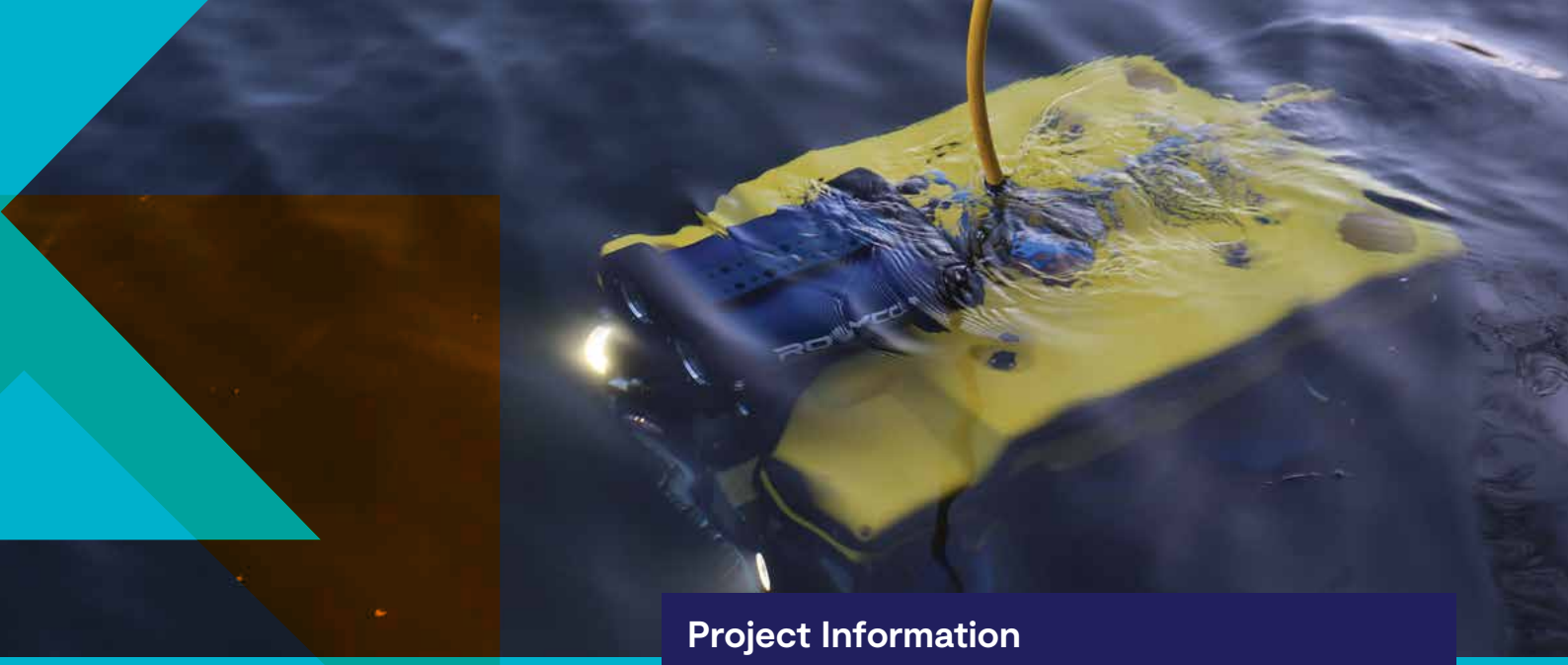
Machine Learning techniques for the underwater domain will be instrumental in bridging the big data-information gap, drastically cutting the lag between data collection and decision making. A typical subsea survey produces huge volumes of data, which then needs subsequent analysis by a human expert. 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.

Contact:
www.rovco.com

ROVCO OCEAN INSIGHT

CATAPULT Offshore Renewable Energy



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: November 2020

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.

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

Summary of the project aim

The iFrog project has delivered an innovative multi-robot maintenance solution for offshore wind assets. The technology performs NDT inspections of monopile foundations and transform maintenance from reactive, hazardous, and expensive to preventative, safe and cost-effective.

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.

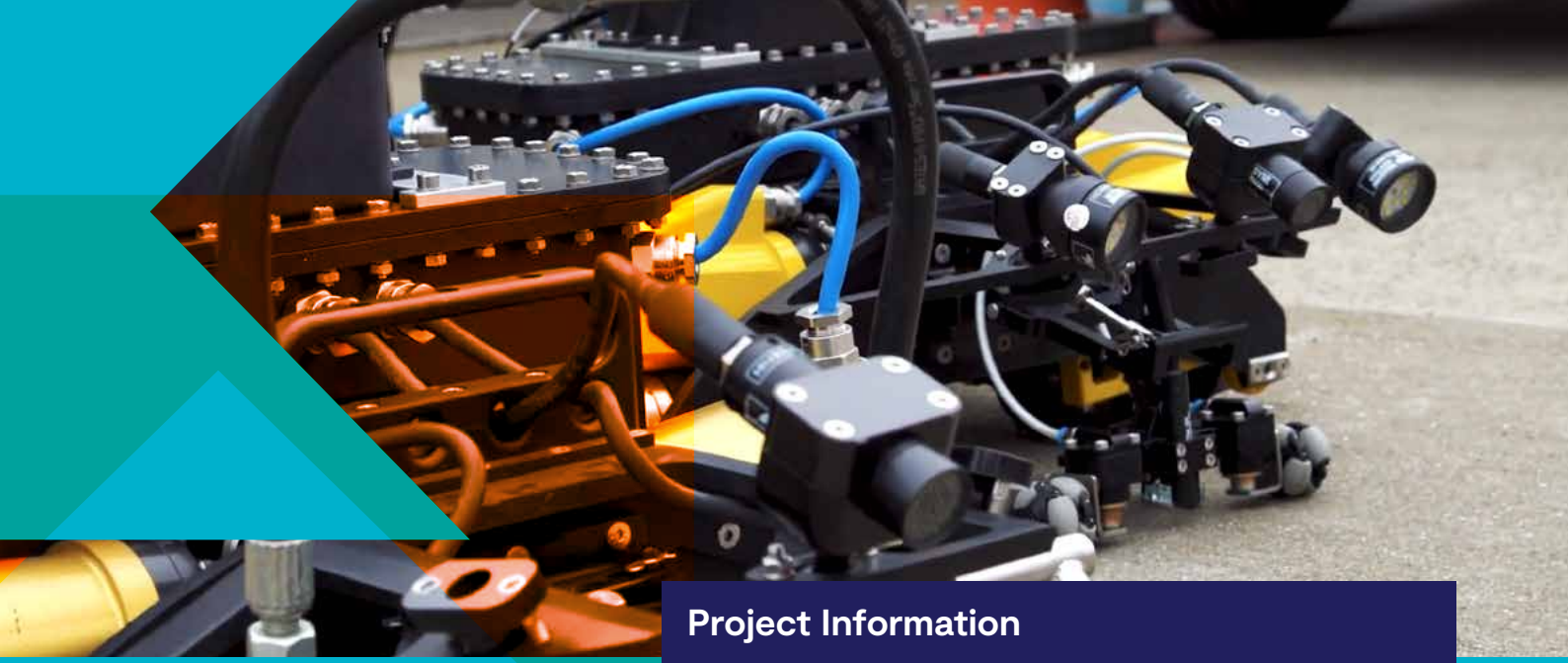
In collaboration with partners, Innvotek has developed a new methodology for preventative maintenance of offshore wind assets – a multi-robot solution. In 2021, the robotic platform got a market name Amphibian.

The project has delivered 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 the smart platform, operators could increase the quality and frequency of their sub-sea structural inspections by getting early warning of those failures. It is estimated that the technology can save up to 20% of annual maintenance costs for wind turbine foundations.

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.

Contact:
https://innvotek.com/robotics-and-automation/amphibian/



Project Information

Project lead: Innvotek Ltd
Collaborators: Offshore Renewable Energy Catapult, TWI Limited, Brunel Innovation Centre (BIC)
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

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

As a lead partner in the project, Innvotek developed the two marinised robotic platforms within the NDT integration phase. TWI delivered the NDT techniques, encompassing UT, ToFD and Eddie Current. BIC assisted with the software development and acquisition of the NDT data. OREC oversaw the development of the test piece monopile and supported the final demonstration of the project. In 2020, the project was completed after two sets of successful trials, with the technology having proved its designed capabilities. In 2021, the platform's features were advanced within another Innovate UK-funded project, RobFMS. At the end of 2021, the enhanced platform caught attention of key offshore industry players, such as General Electric (GE).

AutoNaut for extreme environments

Summary of the project aim

The aim is to develop the AutoNaut wave-propelled uncrewed surface vessel (USV) for long endurance high latitude missions. Little data is available from the Southern Ocean and Arctic surface waters, particularly in winter, because few ships work there. The data needed to understand climate change includes the CO_2 flux at the surface, and ocean warming changes.

Executive Summary

The initial three-year 'AutoNaut for Extreme Environments' project 2018–20 was affected by COVID-19. An Extension was granted 2021 to allow a long endurance sea trial of the new USV aimed at validating the technologies developed in phase 1. Also to demonstrate the USV to external stakeholders its operation in unsheltered open ocean without an escort or mothership.

For high latitude operations, 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, fuel cell or batteries to provide hotel power in the dark of winter when PV panels will not recharge batteries.

University of Exeter developed a pendulum energy harvester. Fuel cells or batteries may also be used. University of East Anglia used their '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 for fresh-water and sea-water ice accumulation, and ice abrasion. Long-term environmental testing indicates 1-year effective life. Build materials including connectors, hatches and gaskets were pressure tested in extreme cold, and with temperature changes.

Autonomously avoiding collision with small ice in big waves is important for a USV. A method to do this was established in phase 1. The Extension is enabling machine learning to be trained to identify the target ice and avoid it.

Robustness of the USV hull and parts were tested during a series of crane drops at various angles and heights up to 5m, and ice impact tests. These findings were incorporated into the new 5m AutoNaut. In the Extension mission they proved robust over 115 days and some 4,000 nautical miles in the open Atlantic.

For the Extension mission AutoNaut was partnered with SAMS and a science plan developed to gather contemporary surface data with a programme of glider deployments and moored sensor arrays in the Atlantic. USV sensors were Nortek ADCP, Seiche PAM, Xylem Aanderaa Motus Wave sensor, Seabird CTD, and a weather station. Other parties interested in the research data include the Irish Marine Institute, CEFAS, Met Office, NOC, OSNAP, iFADO, University of Exeter, GMIT, and Maynooth University.

Contact:
mike.poole@autonautusv.com
www.autonautusv.com

University of East Anglia
University of Exeter
AutoNaut

AutoNaut 'Oban' arrives in Penzance after 115 days at sea and 4,000 nautical miles – November 2021

Project Information

Project lead: AutoNaut Limited
Collaborators: University of East Anglia, University of Exeter, Scottish Association for Marine Science
Project type: Collaborative Research and Development
Total project cost: £500,003 (Extension project cost: £274,556)
Grant award: £395,001 (Extension grant award: £192,191)
Start date: January 2018
End date: December 2020
Extension: April 2021–March 2022

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 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.

Project Plan / Progress

The research and development conducted with our university partners was incorporated into a new 5m boat. This proved robust in the 115-day Extension operation.

Work on ice detection and avoidance continues. New technologies to provide high energy density hotel power are being continuously developed globally. AutoNaut continues to seek compatible solutions.

Data gathered during the Extension has been distributed freely to partners for analysis. This is proving of value. The 16-week Extension operation has aroused significant commercial interest from external stakeholders. Technologies developed and proven in this Extreme Environments project are being incorporated into further new AutoNaut sales.

This project received a further grant through the 'Robots for a Safer World: extension competition' as a part of the challenge's 1–year extension into the 2021/22 financial year. The length and value are detailed in 'Project information' above.

Autonomous offshore wind farm inspection

Executive Summary

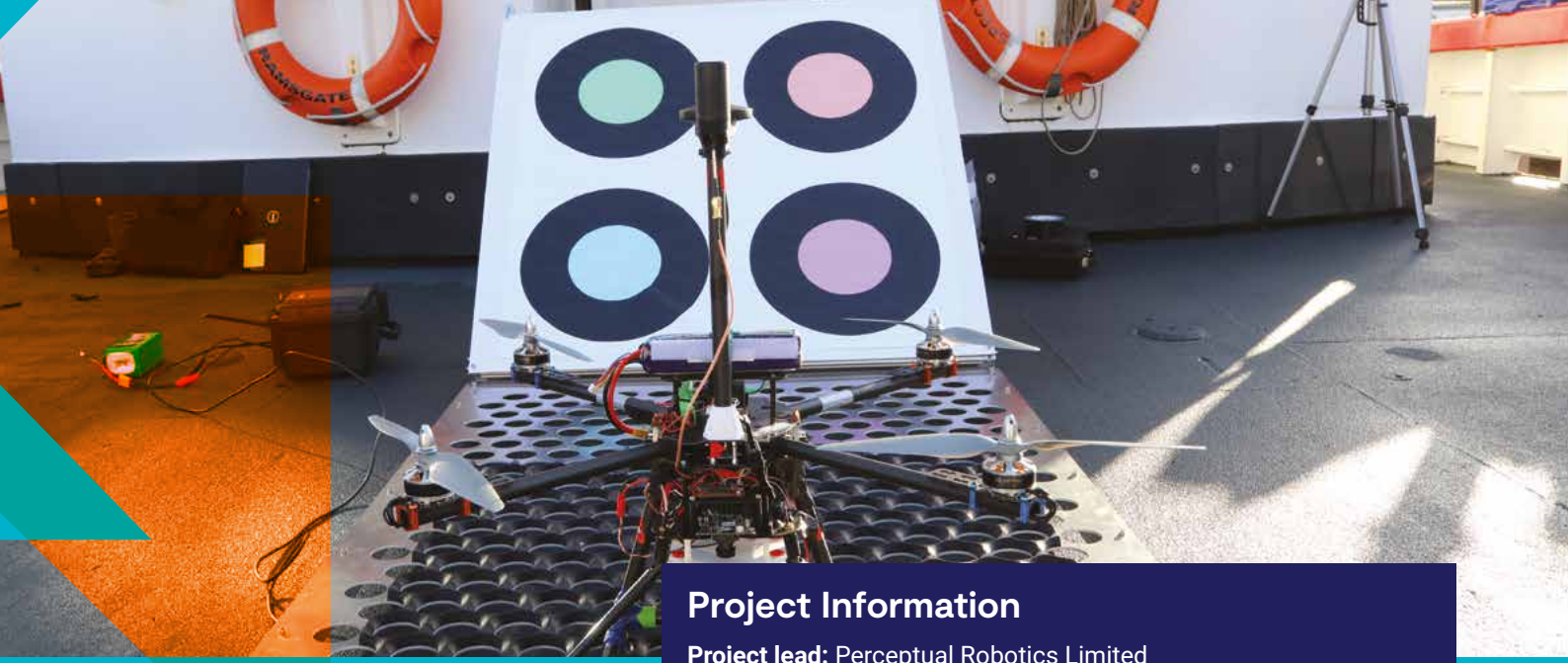
Offshore wind is a key energy source for the UK. It will play an increasingly significant role in future years as part of an energy mix that's moving towards cleaner and more renewable sources. Offshore wind turbines (OWTs) have significant environmental challenges in terms of both the marine environment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



Project Information

Project lead: Perceptual Robotics Limited
Collaborators: L3Harris, University of Bristol, VulcanUAV Limited, Garrad Hassan & Partners Limited
Project type: Collaborative research and development
Total project cost: £1,262,981 (Extension project cost: £249,832)
Grant award: £989,479 (Extension grant award: £190,148)
Start date: December 2018
End date: September 2020
Extension: April 2021–March 2022

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.

This project received a further grant through the 'Robots for a Safer World: extension competition' as a part of the challenge's 1–year extension into the 2021/22 financial year. The length and value are detailed in 'Project information' above.

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

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.

L3HARRIS™ UNIVERSITY OF EXETER

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

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.

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 has developed a portable robotic system for offshore wind turbine foundations maintenance. The technology reduces the cost of offshore wind energy by providing an efficient and smart solution for bio fouling cleaning. The project was able to improve the designed characteristics of the robotic platform created in course of iFrog, another Innovate UK-funded project completed in 2020 with many successes.

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, Innvotek and Brunel University have developed a fouling management system – a mobile survey robot that eliminates the need for divers and ROVs for deep-sea monopile cleaning operations.

The robot can be placed on the turbine structure at sea level and journey down below sea level to where the work is required. It travels autonomously over the entire subsea monopile surface, imaging the fouling and monitoring its thickness in real time wherever it occurs. Simultaneously, the robot travels to every over fouled location and removes the biofouling with a guided power ultrasound technique.

Overall maintenance costs can be reduced by at least 20% compared to present diver/ROV techniques. 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.

Contact:
https://innvotek.com

Project Information

Project lead: Innvotek Ltd
Collaborators: Brunel University London (BUL)
Project type: Demonstrator
Total project cost: £993,014
Grant award: £761,996
Start Date: March 2019
End Date: February 2021

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, Innvotek finalised the robotic platform's marinized mechanical design and assembled the platform. Brunel University London (BUL) addressed the development of the ultrasound cleaning hardware, along with the AI system for bio-fouling monitoring. European Marine Energy Centre (EMEC) supported technology's testing. In 2021, the platform went through the successful set of trials in Scotland and got a market name Amphibian. It drew commercial interest from key offshore industry players, including General Electric (GE).

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.

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.

Contact:
www.deep6.io

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: May 2021

Demeter

Executive Summary

Demeter uses energy-harvesting, intelligent, uncrewed vehicles to provide a persistent, infrastructure-independent subsea sensor data retrieval and analysis service. It is a compelling alternative to CAPEX-heavy fixed power and communication networks that would otherwise be required to support the widespread use of subsea sensors and systems for long-term monitoring of asset health, thus accelerating subsea digitalisation. Demeter will enable more cost-effective predictive maintenance of subsea assets, greatly reduce OPEX and downtime, and ultimately lower the cost and environmental impact of exploiting renewable and non-renewable offshore resources alike. Downstream, Demeter has further application in maritime security operations, including maritime surveillance.

Key innovations include: long-endurance, energy-harvesting, hybrid underwater and surface autonomous vehicles; an onboard edge-processing module based on a novel computer architecture, capable of performing intensive statistical analysis of harvested sensor data at a fraction of the power of current technologies; a technology stack for high-integrity long-term autonomous navigation and decision making; and embedded subsea sensors adapted for data retrieval by the autonomous vehicles.

As an integrated solution, Demeter aims to shift the subsea monitoring paradigm from one of manual, expensive, and low-frequency _data_ retrieval to that of automated, inexpensive, high frequency and on-demand _intelligence_ retrieval. Suitably evolved, Demeter will open up entirely new concepts of operation for maritime security that are not currently feasible.

The project brings together a diverse set of partners to deliver a game-changing capability: Autonomous Devices, a specialist developer of robotic solutions for extreme and challenging environments; Signaloid, developers of a paradigm-shifting computer architecture for edge computing; D-RisQ, developers of a unique technology stack for the implementation of high integrity autonomous behaviours; CRP Subsea, developers of advanced subsea infrastructure monitoring and engineering products; autonomous mission planning experts from Royal Holloway University of London; autonomous navigation experts from the University of Manchester; and novel marine vehicle design, analysis and testing experts from the University of Strathclyde.

Project Information

Project lead: Autonomous Devices Limited
Collaborators: CRP Subsea Limited, D-Risq Limited, Royal Holloway University of London, Signaloid Limited, The University of Manchester, University of Strathclyde
Project type: Collaborative research and development
Total project cost: £1,997,065
Grant award: £1,549,805
Start date: October 2021
End date: September 2023

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.

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.

Contact:
https://bladebug.co.uk

This project received a further grant through the 'Robots for a Safer World: extension competition' as a part of the challenge's 1–year extension into the 2021/22 financial year. The length and value are detailed in 'Project information' above.

Project Information

Project lead: Bladebug Limited
Collaborators: Offshore Renewable Energy Catapult
Project type: Demonstrator
Total project cost: £965,858 (Extension project cost: £215,476)
Grant award: £747,824 (Extension grant award: £168,301)
Start date: December 2018
End date: February 2021
Extension: April 2021–September 2021

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

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

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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

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.

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

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.

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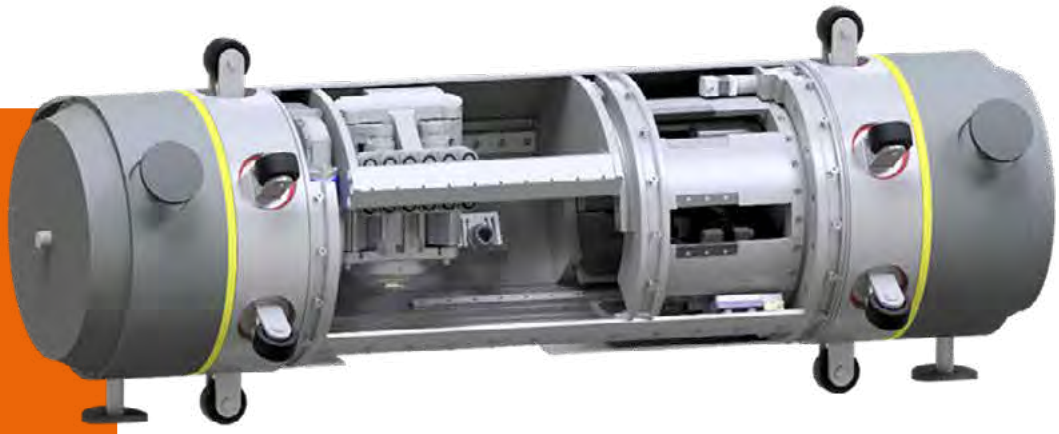
FORTH® INNVOTEK Lancaster University London South Bank University TWI



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: £1,856,616
Grant award: £1,468,669
Start date: April 2018
End date: June 2021

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

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 solves this problem by offering a first-of-its kind climbing robot able to deploy a radiographic inspection system in-situ.

Executive Summary

RADBLAD followed 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, a phase 2 project, developed **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 was the use of an integrated radiographic system for inspection.

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

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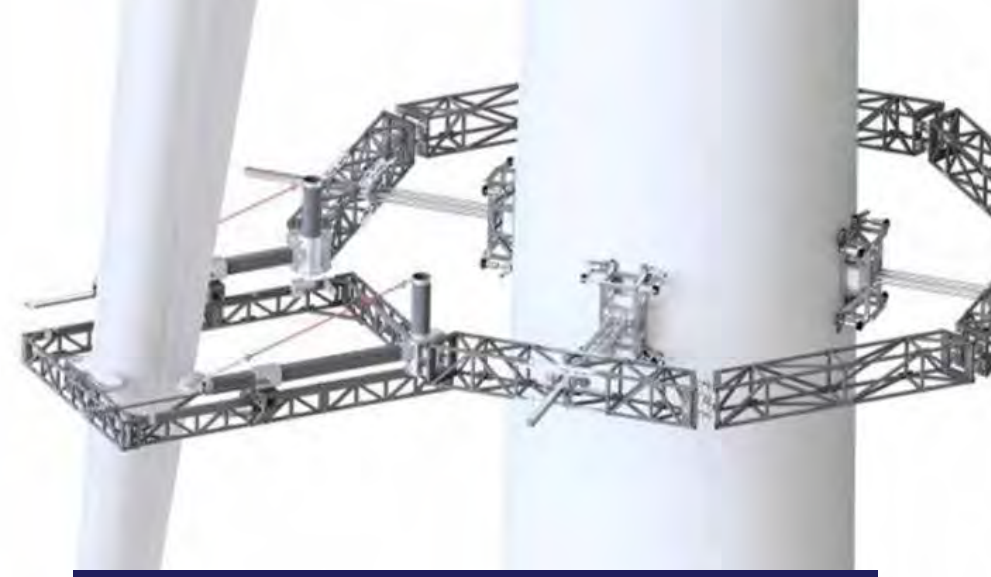

Project Information

Project lead: Innvotek Limited
Collaborators: Forth Engineering (Cumbria) Limited, Offshore Renewable Energy Catapult, London South Bank University (LSBU), 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

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

LSBU and Forth Engineering developed the robotic system. TWI have successfully completed live trials of the X-ray system that is in a fully working position to be integrated with the robotic climber. The images captured by the radiographic system can be autonomously analysed for detection of blade defects. Innvotek have delivered a time-saving and user-friendly automated defect detection software to identify blade defect in X-ray images.

The consortium completed a survey, with input from numerous end users, gained the insights to the market needs and system specifications are fully determined and understood. The team showcased RADBLAD capabilities at the KTN Innovation Exchange (iX) Challenge. The solution received interest from several large-scale owner-operators of wind turbines in the UK.

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.

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.

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Seiche AutoNaut National Oceanography Centre

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

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 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
2. A new 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.

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.

Executive Summary

The aim is to significantly reduce the costs and turbine downtime associated with IMR tasks and reduce the health and safety (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.

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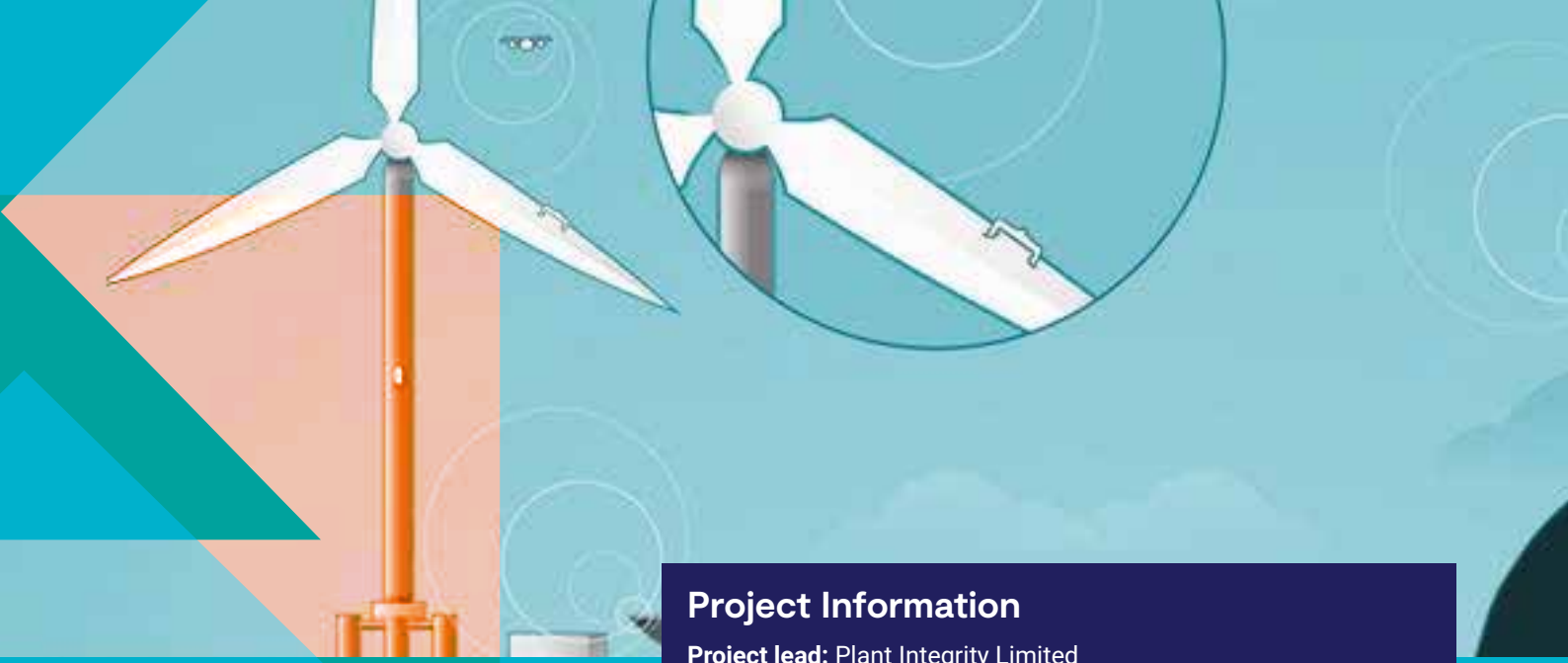

Project Information

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

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, robotics company 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.

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.

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.

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AUTONOMOUS DEVICES TWI CATAPULT Offshore Renewable Energy wood.

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: February 2022

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.

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.

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Braendler Engineering

CATAPULT Offshore Renewable Energy

University of BRISTOL

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: December 2020

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.

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

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.

Process Vision

University of Reading

Project Information

Project lead: Process Vision Limited
Collaborators: University of Reading
Project type: Collaborative research and development
Total project cost: £850,873
Grant award: £659,319
Start date: February 2018
End date: February 2021

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.

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.

Executive Summary

This will be achieved through a combination of three 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

Sonardyne SOUND IN DEPTH L3HARRIS™ National Oceanography Centre

Project Information

Project lead: Sonardyne International Limited
Collaborators: L3Harris and National Oceanography Centre
Project type: Collaborative research and development
Total project cost: £1,235,706
Grant award: £734,070
Start date: December 2017
End date: February 2020

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.

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.

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.

Stephen Wilson
www.smd.co.uk

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: £1,994,840
Grant award: £1,122,353
Start date: January 2018
End date: December 2019

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.

Executive Summary

The project has delivered 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 is suitable for deployment on autonomous/uncrewed marine robotic vessels to remotely and non-invasively collect essential inspection data and feed into innovative automated structural fault and biological anomaly detection algorithms.

Inspection data is collected using a combination of LIDAR and SONAR to generate point clouds above and below the water surface. These are then 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 is mounted on a highly dynamic sea-surface mobile robotic platform, the location and orientation of each reading is anchored through survey-grade, sub-centimetre, attitude and GNSS/GPS sensors.

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www.hydro-surv.com
https://ore.catapult.org.uk

Jonathan Evans
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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: £253,259
Grant award: £182,077
Start date: November 2019
End date: June 2021

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 successfully completed in June 2021. It undertook a series of demanding real-world system validation tests at the Levenmouth Demonstration Turbine. The promising results are now feeding into further testing and future commercial productisation tasks.

This project received support from a continuity grant through UKRI's COVID-19 response fund.

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.

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.)

Dr. Phil Thompson (Director)
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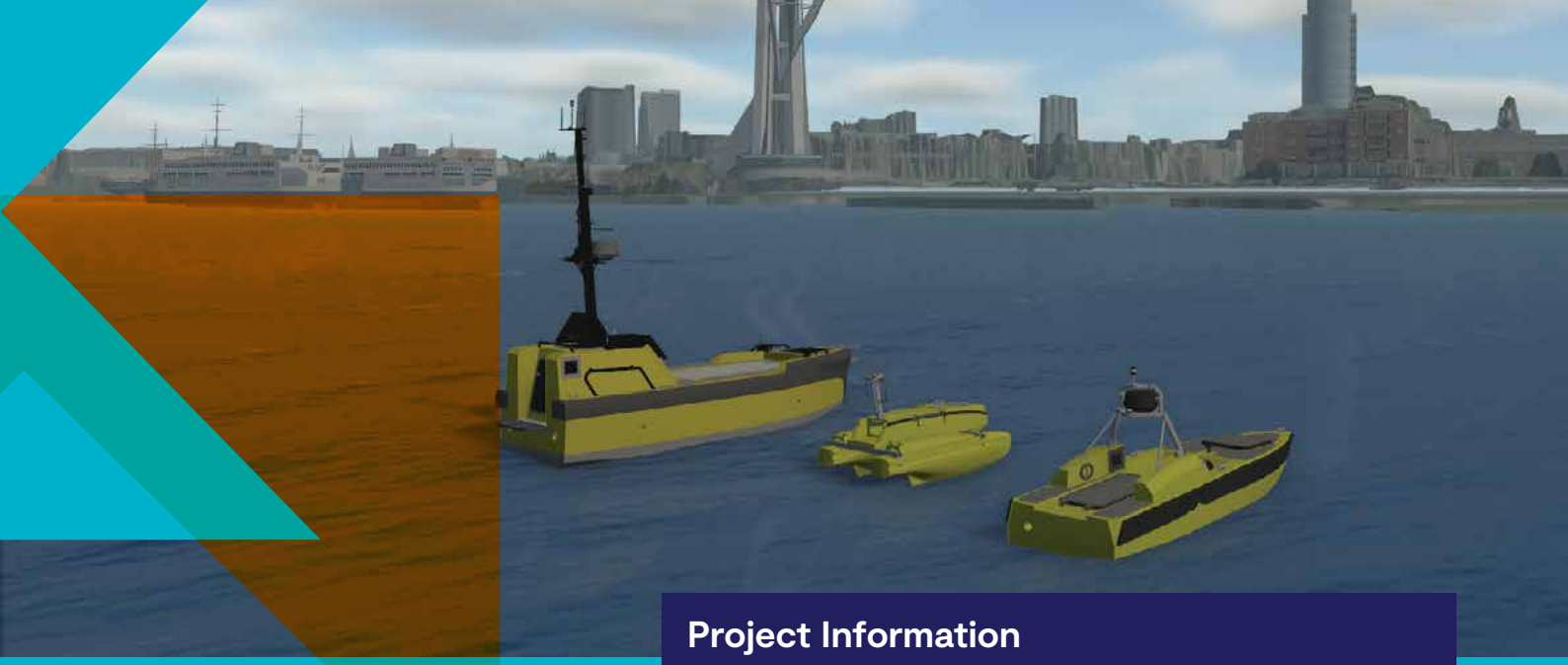

Project Information

Project lead: BMT Ship and Coastal Dynamics Limited
Collaborators: L3Harris and Deimos Space UK Limited
Project type: Collaborative research and development
Total project cost: £1,230,177
Grant award: £685,886
Start date: November 2017
End date: February 2020

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.

Squads of Adaptive Robots (SoAR)

Summary of the project aim

The SoAR project is reducing the costs and timescales for sensing, detection, navigation and data processing in the offshore domain. We are building an open network infrastructure including a fleet-level autonomy engine to provide mission planning, decision making and adaption to automate the deployment of a single-operator heterogeneous robotic survey.

Executive Summary

The existing paradigm of a single high-power vehicle with expensive support vessel and large numbers of people is currently the preserve of a limited number of operators and does not scale easily to meet the emerging needs of the offshore wind sector. In particular end-users are looking for the most cost-effective means to observe the environment, respond to incidents, and monitor underwater features and structures. This dependence on large vehicles is driven by the payload and power requirements to support high quality sensors and navigation instruments.

The SoAR project is developing a sophisticated network protocol and fleet level autonomy engine to provide integrated communication and navigation support for a dynamic mixed fleet of uncrewed surface and underwater vehicles. This will provide swarm mission planning, continuous monitoring of networked vehicles, and a decision-making capability for responsive re-tasking of the fleet to ensure mission objectives are completed efficiently. The fleet level autonomy engine will receive information from vehicles regarding features or targets, enabling it to deploy vehicles with appropriate payload to complete an emergent task, such as close inspection of an identified potential hazard. Development of a low-cost common communications and navigation module with open standards for integration into compact underwater vehicles is one of the key enabling technologies for this project. The network protocols and framework will provide generic interface to allow any platform to be integrated into the fleet to suit a specific mission.

Project Information

Project lead: Planet Ocean Limited
Collaborators: National Oceanography Centre, Sonardyne International Limited, Royal Holloway University of London, HydroSurv Unmanned Survey (UK) Ltd, Offshore Renewable Energy Catapult
Project type: Collaborative research and development
Total project cost: £1,959,351
Grant award: £1,438,832
Start date: October 2021
End date: September 2023

What is the value or size of the addressable market?

Survey services are delivered using sensors deployed from sub-contracted crewed vessels. Environmental surveys for windfarm sites currently cost £4m / 1GW and geological / hydrographic surveys cost £8m/1GW. Offshore wind deployment in UK waters will grow to 40GW by 2030, and by 2040 will reach 65GW in the rest of Europe and 195GW globally.

The current generation of autonomous systems are large and expensive to provide the power and payload capacity to support instrumentation for accurate navigation. SoAR promises a disruptive low-cost alternative by using small specialist robotic assets with dramatically increased automation and a reduction in deployed manpower.

Project Plan / Progress

The SoAR project launched in October 2021. A concept of operations has been defined along with a system architecture combining the mission management system, autonomy engine and communications network. The project's fleet includes a REAV-60 USV to supervise and coordinate AUV squad, hosting the link to Fleet Autonomy Engine and providing navigation and positional reference data. Below the surface we will deploy five x ecoSUBm5-Scout AUVs to provide rapid survey of area using side scan sonar, and an AutoSub Hover AH-1 AUV to provide close inspection of identified targets. The fleet will be tasked and monitored from a deployable shore-based mission management system. The fleet's autonomy engine will be designed to formulate and distribute missions to all assets, continuously monitor the fleet and re-task as required to maximise the efficient delivery of the mission goals.

Communications protocols will be defined and extended to meet the needs of a diverse fleet tackling issues such as network capacity and the provision of generic interfaces for the integration of other future platforms. The communications and navigation technology is being optimised and miniaturised to make the most of our small form-factor robots.

Subsea Enhanced Autonomous Mapping (SEAMless)

Summary of the project aim

This project will solve the problem of large-scale 3D mapping underwater. This will be achieved by enhancing the accuracy and fidelity of underwater localisation and perception, by fusing data between multiple systems and generating a single 3D composite map.

Executive Summary

The proposed solution will develop a suite of software systems and a novel bio-inspired whiskers sensor, alongside existing and mature complimentary technologies, to demonstrate an exemplar and novel autonomous system. A hybrid AUV will be utilised to provide a unique and capable platform for offshore operations.

The system will be scalable, with on-board 'edge' functionality, enhancing perception and autonomy through a modular software architecture. Sensor data will be fused through an innovative set of software interfaces to create a detailed 3D model of the environment, in this case, the seabed. This will be uploaded and shared between adjacent sub systems, feeding directly into the autonomy stack. This enables assured intelligent decision making, with the ability to operate efficiently in open waters and in proximity to structures.

This technical output will deliver a game-changing capability, where systems can measure their surroundings and position accurately with integrity. This is essential for persistent safe navigation along collision free paths within complex and challenging subsea environments. All supervised by a safety system that ensures the optimal operation even under faulty circumstances.

An innovative 3D immerse visualisation tool is developed utilising games engines. The use of games engine technology for enabled maps from complex multiple data sources will not only have applied benefits for this subsea use case, but equally will build the overall market and understanding for developing Digital Twins more broadly.

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Project Information

Project lead: Rovco Limited
Collaborators: National Oceanography Centre, Sonardyne International Limited, D-Risq Limited, Soil Machine Dynamics Limited, Digital Catapult, Stellar Advanced Concepts Limited
Project type: Collaborative research and development
Total project cost: £1,998,973
Grant award: £1,545,588
Start date: October 2021
End date: September 2023

What is the value or size of the addressable market?

The UK offshore wind market is undergoing rapid growth. Operators forecasting growth from 10GW installed in 2020 to 20GW in 2030. In this period the estimated market size for pre-site consenting and environmental surveying is expected to grow from £70M to £292M.

Highly detailed, accurate maps provide key information for decision-makers, reducing the number of offshore operations required. This is critical in enabling an efficient and environmentally friendly offshore wind industry.

Project Plan / Progress

As the project is in its early stages, WP2000 is being executed at this time. This work package contemplates the definition of all the necessary requirements to successfully complete the project. This involves AUV system requirements, sensor suit requirements and software package requirements. The next work packages on the timeline will define the whole design of the system and will start developing the bases pieces for the completion of the project.

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.

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.

Contact:
www.team-tao.org

TEAMTAO SMD Newcastle University

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

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 honoured 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's aim is to advance robotics and Artificial Intelligence technologies for the inspection, repair, maintenance and certification of offshore energy assets. In the last year it has explored the potential cross sector use of this technology (including in construction, decommissioning and urban infrastructure). The Hub has built a community of roboticists, bringing together internationally leading experts with industry partners to create a multi-disciplinary consortium.

Executive Summary

Started in 2017, the ORCA Hub has become synonymous with UK offshore robotics. Its original aims were to lead advancement of key robotics and AI technologies and create a step change in current practice of inspection, repair and maintenance offshore. In the first 3 years the Hub made significant advances in research along its four initial research strands: Mapping and Navigation, Planning, execution and physical interactions, Effective Human-machine teaming and methods and architectures for self-certification of robots and assets.

Over the last year, efforts have focussed on accelerating the translation and expansion of the work into our industry network and new sectors, adapting the current output to tackle novel issues through four user-driven challenges:

- Offshore Renewable Energy Subsea Inspection
- Aerial Inspection of Large Infrastructures in Challenging Conditions
- Robust Inspection and Manipulation in Hazardous Environments
- Symbiotic Systems for Resilient Autonomous Missions

The ORCA Hub has continued to use a spiral innovation model where groups of desirable but yet unavailable advanced autonomous and semi-autonomous robot solutions are derived from operational use cases defined by industrial partners. Applied research rigorously pursues the capabilities and demonstrates progress in regular realistic field trials, shared with partners. Future research plans are then modified with industry feedback for sprints to the next demonstration trials, with three cycles of whole-Hub technology demonstration and requirements refinement to date. In parallel, industry requirements are matured 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.

We have made significant advances to bring robots closer to widespread adoption in the offshore domain, developing close ties with industrial actors across the sector. The recent pandemic has highlighted a widespread need for remote operations in many other industrial sectors.

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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: £16,800,000
Start date: October 2017
End date: March 2022

What is the value or size of the addressable market?

The international offshore energy industry is undergoing a revolution, adopting aggressive net-zero objectives and shifting rapidly towards large scale offshore wind energy production, with a market predicted to reach $58b by 2026 and trillions forecast for investment to achieve 2050 climate change targets. Whilst Offshore wind is one of the most promising green technologies, Offshore wind turbines are susceptible to accelerated decay, as they operate in harsh marine environments. Moreover, as they continue to increase in size, challenges related to construction, transportation, installation, and operation also increase. Using 'business as usual' approaches in a competitive market with low margins is unachievable, particularly as new generations of suitable offshore graduates prefer not to work in hazardous places. Operators therefore require safer, more cost effective methods to manage their topside and marine offshore infrastructure. Robotics and artificial intelligence are seen as key enablers to achieving the long-term vision for a digitised offshore energy field, operated, inspected and maintained from the shore using robots, digital architectures and cloud-based processes.

Project Plan / Progress

The hub has made significant technical advances in key capabilities identified with our industrial partners to tackle important use cases, specifically a) mapping and surveying of complex structures using multiple robots equipped with multi modal (optical and acoustic) and non- destructive evaluation (NDE) sensors, b) planning and execution of efficient and safe 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 improve performance and robustness, d) designing robotic and learning systems that can self-certify and guarantee their safe operation, verification and validation.

The last 6 months have seen successful offshore trials including an offshore wind farm foundation inspection using ORCA's autonomous underwater inspection payload, the deployment of the Limpet multi-sensing industrial IoT device at an offshore wind farm and a quadruped inspection trial.

Moreover, £6m of industrial translation forward opportunity pipeline has been converted and Sonobotics, an ORCA Hub and Imperial College (non-destructive evaluation (NDE) group) spin-out were runners-up in the Sprint Robotics innovation category.

The Hub has produced over 260 publications, reached over 16.7m people via conventional media, gained 2000+ social media followers, participated in 37 industry events and 2 Royal Society Summer Science Exhibitions - which attracted over 1800 school children and 15,000 members of the public – webinars, school visits and 3 live virtual RAS demonstrations. Cross-hub interaction has continued throughout, culminating in a cross-hub digital twin workshop at ICRA 2021.

The network and impact of the ORCA Hub will continue beyond its current funding through industry led programmes and the continued translation of the technology into commercial impact. Supported by the National Robotarium, we will work with companies, academia, and the public to ensure that everyone who can benefit from the outcomes of ORCA is able to do so.

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.

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 manoeuvrability.

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.

Contact:
www.hydro-surv.com

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 (Extension project cost: £249,234)
Grant award: £663,629 (Extension grant award: £151,034)
Start date: February 2019
End date: April 2021
Extension: April 2021–March 2022

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.

This project received a further grant through the 'Robots for a Safer World: extension competition' as a part of the challenge's 1–year extension into the 2021/22 financial year. The length and value are detailed in 'Project information' above.

Windfarm Autonomous Ships Project (WASP)

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.

L3HARRIS™ HOULDER CATAPULT Offshore Renewable Energy SeaPlanner UNIVERSITY OF PORTSMOUTH

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: £895,596
Grant award: £636,758
Start date: January 2019
End date: December 2019

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.

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: January 2019

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: Innvotek 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

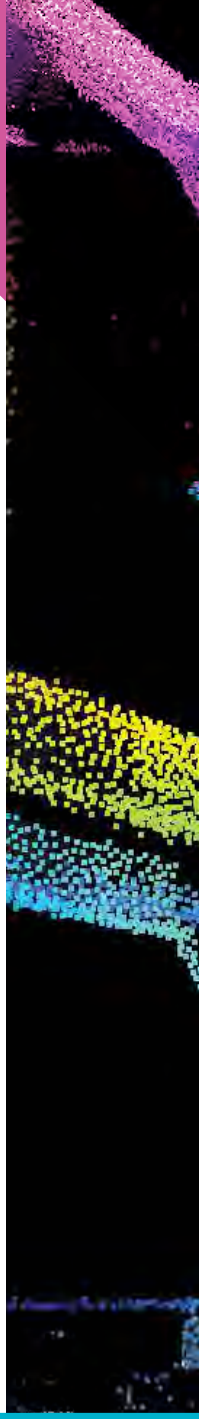
Offshore oil and gas operators have new challenges in providing adequate integrity assurance of their assets as production facilities reach for the deep-water areas. Challenging conditions arise from more corrosive environments, higher pressures and temperatures.

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 the 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.

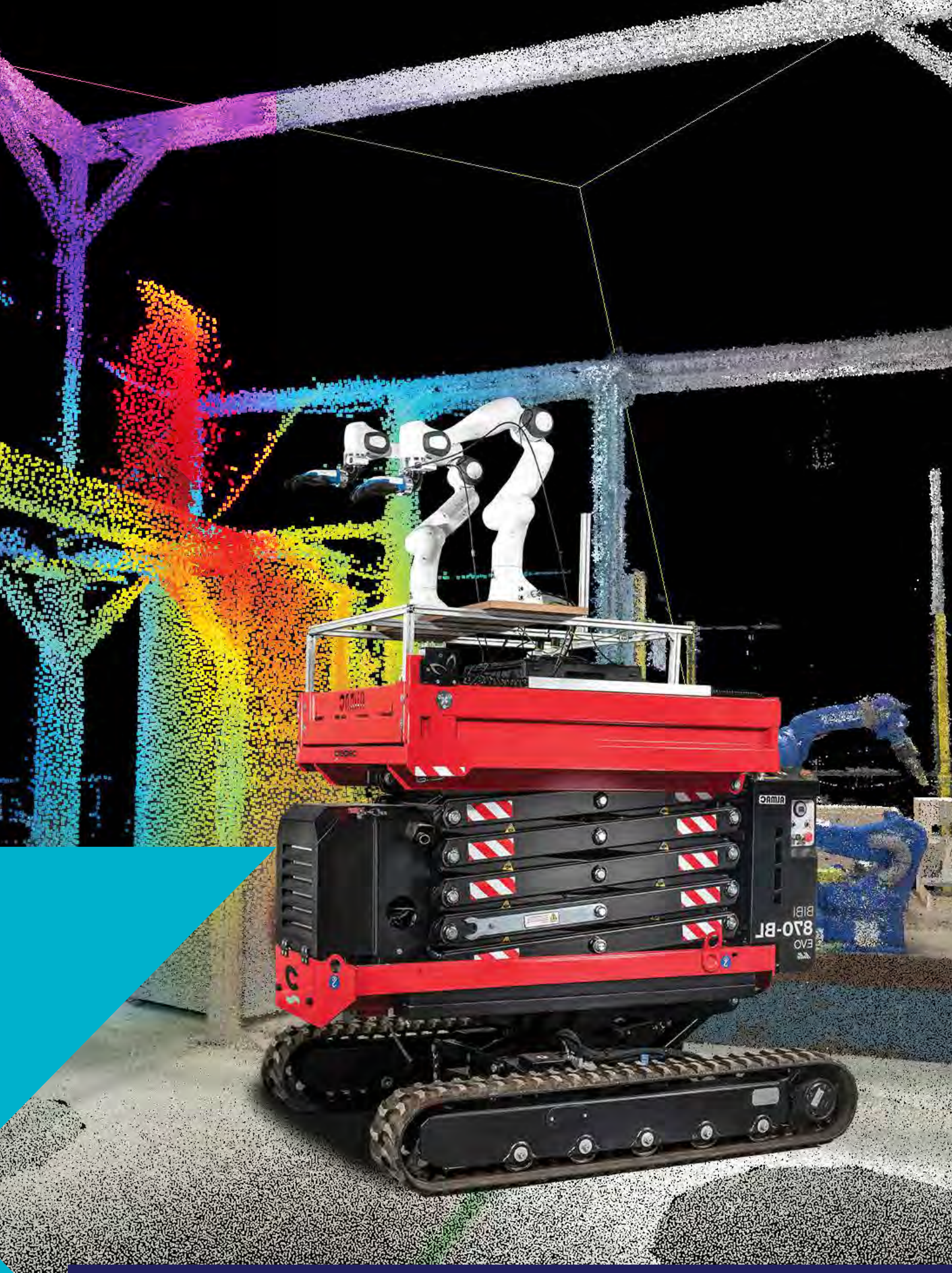
These innovations will allow for not only the detection and location of defects, but also classification according to an existing historical database before automatically deciding on bespoke scans to assess the severity and need for future intervention.



Nuclear

For operations in the nuclear energy environment sixteen projects addressing robotics and AI 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. The programme is also supporting the £12m LongOps project, led by RACE and jointly funded with the Nuclear Decommissioning Authority and Japanese energy company TEPCO.

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

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.

Contact:
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www.shadowrobot.com/alpha-glovebox-project/

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

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

Automated Nuclear Decontamination Cell (AND-C)

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.

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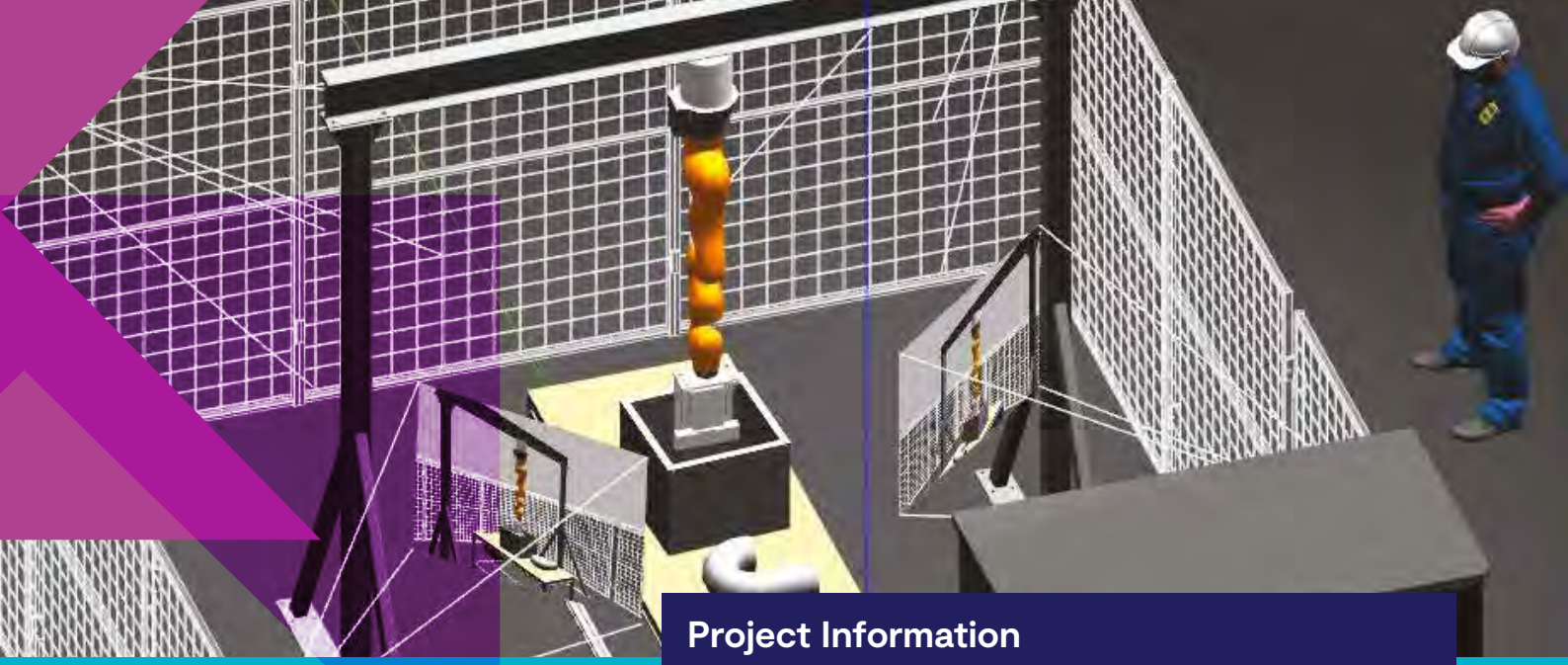
createc



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: January 2021

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.

Barrnon Integrated Decommissioning System

Summary of the project aim

How do you get waste out of a nuclear cell in a safe, efficient, and effective way? The BIDS System is a Mantis-like platform, with a variety of end effectors, that's designed to capture the unknown environment by scanning it and presenting images to an operator in Virtual Reality. An algorithm then generates a cut plan allowing the robots to size reduce and segregate the waste.

Executive Summary

This project started off as a global prototype competition (Innovative Integrated Nuclear Decommissioning) to decommission active cells at Sellafield, which Barrnon won. It beat off competitors from global conglomerates.

BIDS is now a product; a system controlled through Virtual Reality, in a 3D immersive environment, to make the process more efficient. It gives:

- A complete solution. It goes into a cell and decommissions it without the need for other products
- Full immersive control – in VR you feel like you are inside the environment
- Super-human powers so you can identify the radiation hotspots and then segregate them – using an algorithm

A specialist hydraulic-mechanical platform hosts multiple robotic manipulators with quick-change tool capability. The platform is combined with on-board scanning and radiation mapping technologies to analyse and characterise the physical and radiation profile of the redundant work environment using Lidar scanning. A 3-D map is then generated. This map enables an algorithm produced cut plan for size reduction, resulting in categorised waste and more efficient storage.

Once this plan is obtained, a range of tools can be deployed. These range from laser cutting, to 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 a 3D 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.

Contact:
www.barrnon.com

createc BARRNON /> Cambrian Intelligence

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

What is the value or size of the addressable market?

This product gives global vertical and horizontal opportunities.

Vertically: A large portion of the legacy nuclear infrastructure will undergo a major shift in focus. There are numerous nuclear facilities in the UK, and Barrnon has a strong network of contacts in the American, Japanese and Canadian markets. For example, BIDS was demonstrated at the World's biggest waste expo in Arizona. And as reprocessing ceases in some countries, decommissioning, waste management and site remediation assume increased priority. There are many opportunities to do things more safely, faster and at reduced cost.

Horizontally: It also provides a unique turn-key solution in the likes of oil and gas markets.

Project Plan / Progress

The project received significant investment to bring it to market – at speed.

A successful Phase 1 (concept and prototype development) led to Phase 2; BIDS MkII has been built to be deployed into an active cell in Sellafield. Both Barrnon and its customers (Sellafield and the NDA) are delighted with the outcome. As are others…

It's been labelled as a 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 (December 4th 2019).

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.

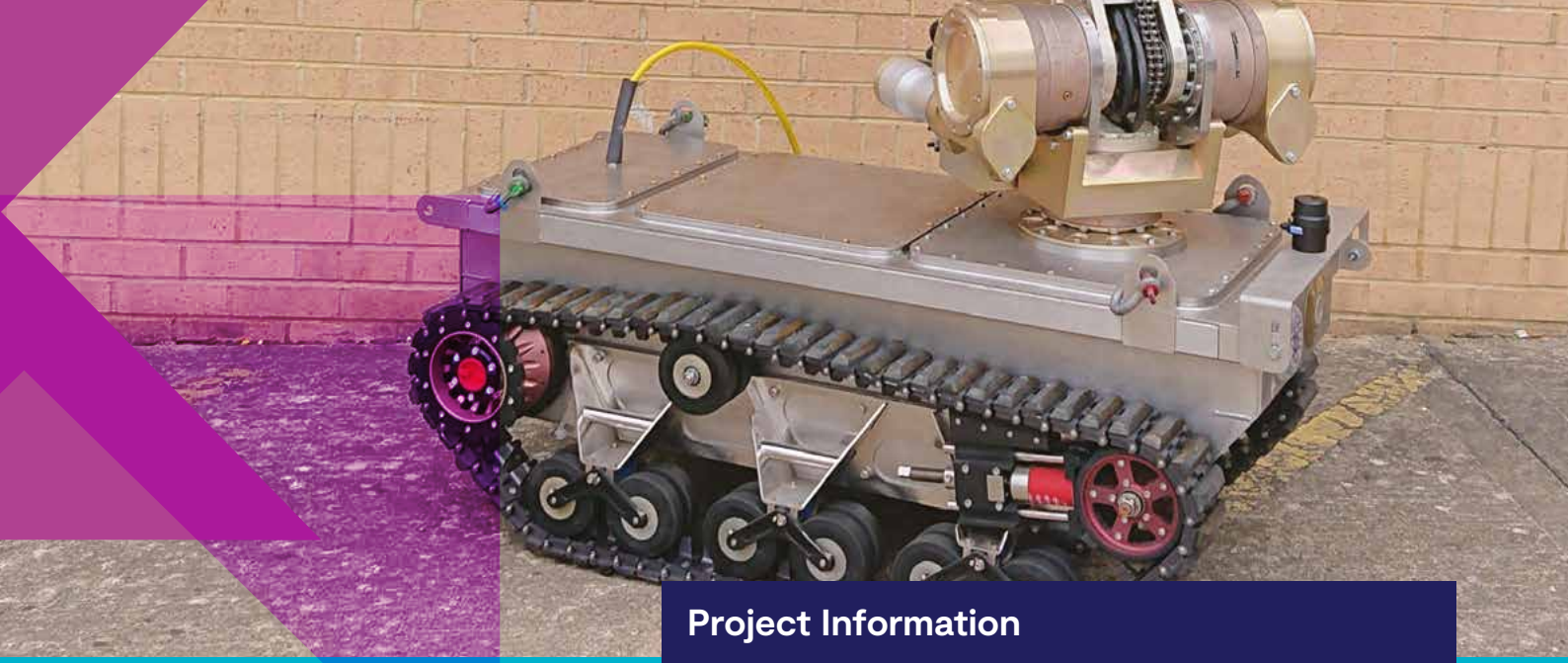
Collaborative Technology Hardened for Underwater and Littoral Hazardous Environments

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.



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: £1,335,278
Grant award: £947,656
Start date: January 2018
End date: December 2019

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

Summary of the project aim

Connect-R is a robotic ecosystem that provides industrial-scale manipulation.
Connect-R is a modular, configurable, self-building structure controlled by innovative AI.

Executive Summary

The problem: Hostile working environments present significant risk to the health and safety of any manual workers, high cost of deployment and significant timescales for completion. Sectors: Nuclear Decommissioning, Oil and Gas, Mining and Space systems. Common to these environments is the extreme difficulty of effective deployment of the sophisticated kinds of equipment that replace human beings. Challenges:

- Hazardous working environments requiring protective equipment and limited time windows for operation
- Radioactive environments
- Limited access through which to deploy the systems
- Unstable legacy structures that prevent occupation
- Lifting of heavy objects (~50kg) that require mechanical assistance The Connect-R team developed an industrial-scale self-building modular robotic solution to provide robotic access to work-sites in these hazardous environments.

The Connect-R project developed a robotic and artificial intelligence (RAI) system that removes humans from infrastructure inspection, maintenance and repair in extreme environments. Our innovative 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 situations that were previously inaccessible to robotic systems. By providing both structure, and infrastructure (power, hydraulics, vacuum extract etc.) the Connect-R system is capable of working safely, and efficiently, over long periods of time, and without human-maintenance – the system is capable of maintenance tasks on the modular structure.

Contact:
www.barrnon.com

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 (Extension project cost: £233,134)
Grant award: £4,669,475 (Extension grant award: £163,194)
Start date: January 2019
End date: February 2021
Extension: April 2021–March 2022

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, the priority becomes decommissioning, waste management and site remediation. 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 gaining traction in the USA, Japanese and Canadian markets. Each has their own challenges, but the cost of extreme environment operations is significant. Connect-R provides a unique solution to assist the decommissioning of these hazardous facilities.

Project Plan / Progress

The project culminated in a demonstration of the Connect-R building a structure. The Multitask Robot was able to climb on that structure, navigating the space in three dimensions. The connect R demonstration was able to showcase the various novel technologies that had been developed to enable the function of the Connect-R system. These technologies included micro hydraulic valves and architectures, genderless mechanical, data and hydraulic connections as well as demonstrations of the AI planning software allows control of the system.

The Connect-R project has led to more funding looking in more detail at the genderless connector technology. Barrnon and Jigsaw Structures aim to develop the connector to a higher TRL level and gain an understanding of the design rules around how the genderless fluid connection works in more detail.

This project received a further grant through the 'Robots for a Safer World: extension competition' as a part of the challenge's 1–year extension into the 2021/22 financial year. The length and value are detailed in 'Project information' above.

This project also received support from a continuity grant through UKRI's COVID-19 response fund.

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').

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.

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createc

Project Information

Project lead: 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

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.

LONG-OPS: A UK-Japan R&D programme to develop long reach manipulators for use in long term remote operations for nuclear decommissioning

Summary of the project aim

LongOps is a new £12 million UK-Japanese research and development programme to explore and extend the functions of digital robotic technologies for use in nuclear and fusion energy decommissioning. The project will focus particularly on the digital tools used by operators to control long-reach robotics in long-term operations — hence it is known as 'LongOps'.

Executive Summary

The key theme of LongOps is the development of digital twins or digital mock-ups (DMUs) — a set of technologies including virtual reality (VR) and simulations of robotics that pair the virtual and physical worlds. In nuclear decommissioning, these can enable strategy planning, training, remote operations, storage and analysis of data, including forecasting of maintenance events and potential operational issues.

In the UK and Japan, nuclear decommissioning and fusion end-of-life all face common challenges to conduct work remotely over many decades in large, shielded spaces containing hazardous materials using long-reach robotics. The consensus is that a DMU is essential to conduct certain high hazard nuclear operations by showing decision-makers how the work will be conducted and to develop end user capability to conduct remote operations safely and efficiently.

LongOps builds on RACE's unique heritage of effective use of virtual reality and operations management tools at JET to produce a DMU appropriate for the coming decades. In addition, the LongOps team at RACE is engaging with teams at Sellafield and TEPCO to understand the specific challenges, provide training for teams performing remote operations, and demonstrate state-of-the-art technologies. RACE is also procuring a pair of industry-leading teleoperated manipulators and will be the first organisation to perform side-by-side assessment of these.

LongOps technologies will open more routes to safer, faster and cheaper decommissioning. It will also promote cost-effective reactor design for fusion and fission.

Prof. Rob Buckingham
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www.race.ukaea.uk/longops

RACE UK Research and Innovation NDA Sellafield Ltd TEPCO

Project Information

Project lead: Remote Applications in Challenging Environments (RACE) – part of the UK Atomic Energy Authority
Funded by: UK Research and Innovation (UKRI), Nuclear Decommissioning Agency (NDA), TEPCO
Partner: Sellafield
Project type: Demonstrator
Grant award: £12,000,000
Start date: November 2020
End date: March 2024

What is the value or size of the addressable market?

LongOps research and development is currently targeted at end-users of digital technologies for high hazard nuclear operations. This currently includes decommissioning use cases in decommissioning of legacy UK nuclear reactors at Sellafield in Cumbria, the Fukushima Daiichi decommissioning project led by TEPCO in Japan, and the end-of-life of the JET fusion device in Culham, Oxfordshire.

The Next Generation of Digital Mock-Up (NG-DMU) will allow these end-users to develop strategy, decrease risk, deliver training, and manage long term remote operations in hazardous environments.

NG-DMU technologies are likely to be of value in other adjacent industries involving remote operations, including Space, Offshore, Autonomous Vehicles and others.

Project Plan / Progress

Since project initiation in late 2020, LongOps' primary focus has been on engaging with the programme's end-users to understand the challenges by each one. This knowledge has allowed RACE to develop a set of requirements for each of the LongOps R&D areas which include automation, haptics, modular software, manipulators and software to control long-reach equipment.

LongOps was established with a target to flow 50 per cent or more of its funding to the supply chain, to procure specialist equipment that supports the R&D programme, and to fund industry- and academia-led R&D. Specialist haptic teleoperated manipulators have been specified and procured, and will be delivered in early 2022.

R&D contracts have been placed, and the remaining Invitations To Tender (ITTs) are due to be published by Feb 2022. These subcontracts will allow industry to collaborate with RACE, and develop IP against LongOps challenges whilst retaining favourable IP rights which will allow continued industrial exploitation of enhanced capability.

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)

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.

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.

Contact:
www.ncnr.org.uk

NCNR
NATIONAL CENTRE FOR NUCLEAR ROBOTICS

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.

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: £12,256,862
Start date: October 2017
End date: March 2022

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

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.

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.

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Base Line Trials –
Completed with no direct line of sight

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

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.

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.

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.

Contact:
jstorey@is-instruments.com
www.is-instruments.com

is-instruments

UK Atomic Energy Authority

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: June 2021

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.

Robotics and Artificial Intelligence for Nuclear (RAIN)

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.

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. Major demonstrations, including first-of-a-kind trials have been undertaken through Phase One and Phase Two of RAIN.

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.

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

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" to "RACE (UKAEA), University of Bristol, Lancaster University, University of Nottingham, University of Warwick, University of Oxford, University of Leeds, University of Reading, Newcastle University
Project type: Use-inspired hub
Grant award: £14,783,322
Start date: October 2017
End date: March 2022

What is the value or size of the addressable market?

The primary focus for RAIN is the nuclear sector; opportunities have been explored for wider technology transfer including renewable energy, utilities, and emergency services.

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 2022; RAIN has supported over 35 industrial projects (including over 15 SME projects), 16 secondments into industry and academia, and published over 250 journal articles.

RAIN has supported the nuclear research community via five Working Groups (Remote Handling, Remote Inspection, Autonomy & Verification, Human Robot Interaction and Standardisation).

From the RH+HRI and RI groups we have undertaken deployments in over 40 simulated (physical and digital) environments and active deployments in 5 environments. 4 products are being commercialised. Via the A&V group we have fostered connections with the ONR on the topic of RAI adoption in the nuclear industry. Our work in Standardisation has begun to set the foundations for improved interoperability from human and machine perspectives.

RAIN has hosted a regular webinar event series showcasing progress during the pandemic. Events such as these have helped to foster enthusiasm and support from the network of over 350 industrial representatives and over 100 businesses that RAIN is proud to call its fanbase.

Sellafield In-Cell Decommissioning System (SIDS)

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.

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.

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cavendish nuclear

Waste coupons generated during Phase 2 demonstration

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

What is the value or size of the addressable market?

Four 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.

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.

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

Contact:
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www.createc.co.uk

createc

Radiation module on the ANYmal

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: March 2021

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.

This project received support from a continuity grant through UKRI's COVID-19 response fund.

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

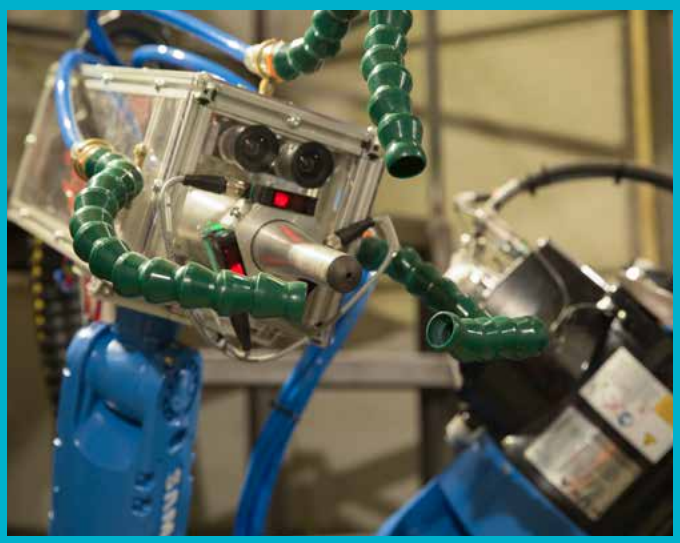
Project lead: I3D Robotics Limited
Collaborators: National Nuclear Laboratory Limited
Project type: Collaborative research and development
Total project costs: £162,793 (Extension project cost: £90,144)
Grant award: £107,917 (Extension grant award: £63,101)
Start date: October 2019
End date: March 2021
Extension: April 2021–March 2022

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.

This project received a further grant through the 'Robots for a Safer World: extension competition' as a part of the challenge's 1–year extension into the 2021/22 financial year. The length and value are detailed in 'Project information' above.

Robotic In-Space Manufacturing Demo –
page 128–129



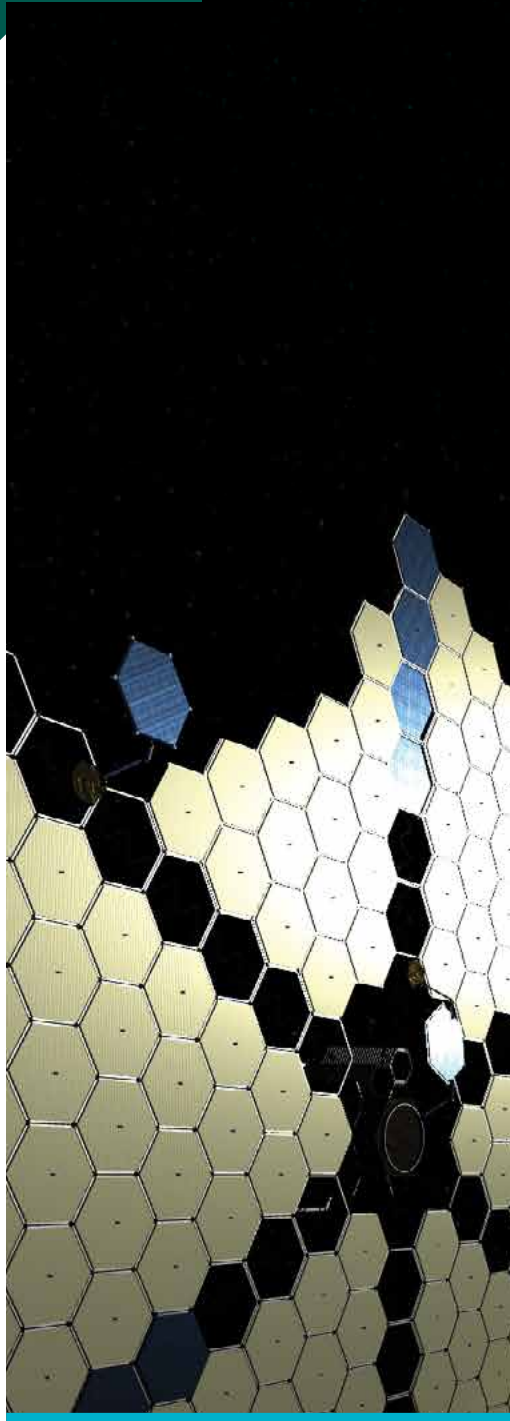
Barrnon Integrated Decommissioning System –
page 90–91

Sellafield In-Cell Decommissioning System (SIDS) –
page 108–109

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

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.

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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

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.

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

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.

Contact:
https://spacetalos.com

Space Talos

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: October 2020

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.

Future AI and Robotics for SPACE (FAIR-SPACE)

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.

Executive Summary

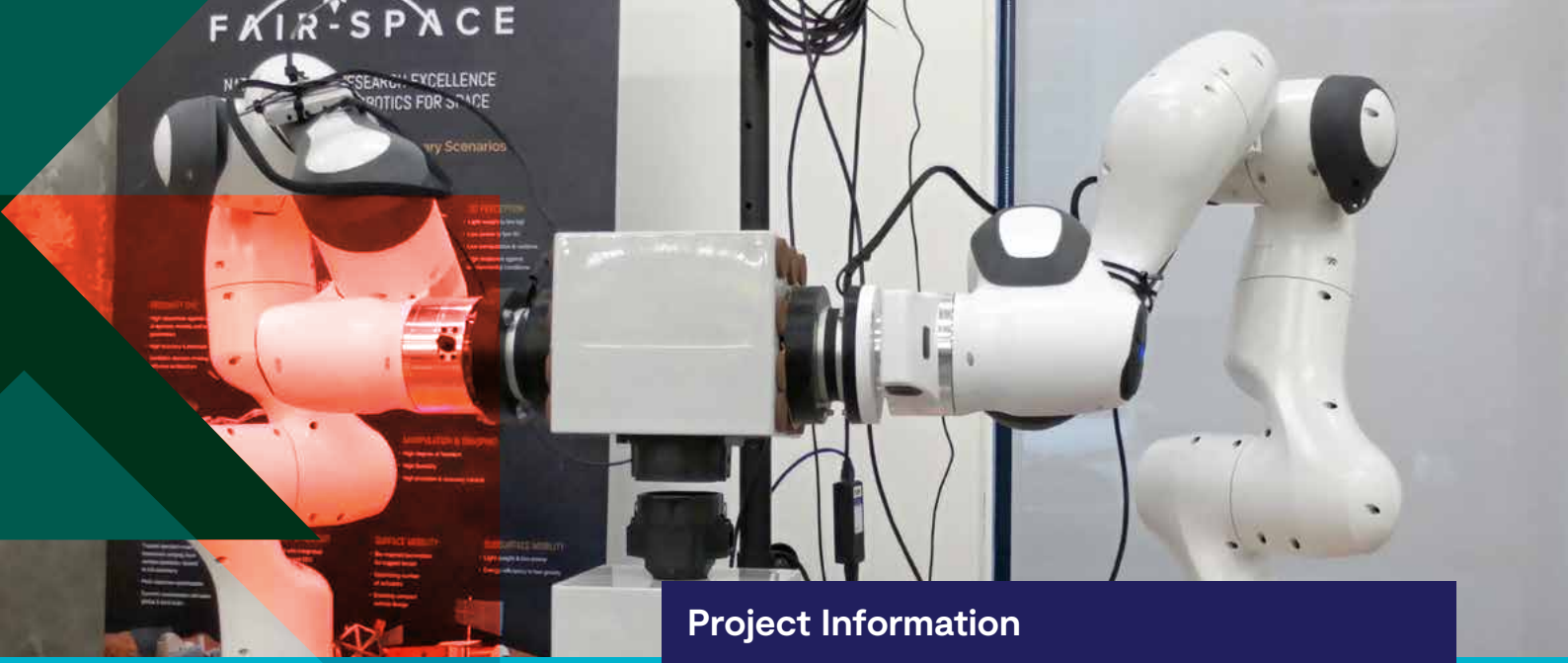
The FAIR-SPACE Hub is a UK national centre of research excellence in space robotics and artificial intelligence.

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 FAIR-SPACE 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.

Contact:
www.fairspacehub.org



Project Information

Project lead: Project lead: University of Surrey
Collaborators: Imperial College London, University of Edinburgh, University of Liverpool, University of Manchester, University of Salford, University of Warwick
Project type: Use-inspired hub
Grant award: £8,602,141
Start date: November 2017
End date: March 2021

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

Summary of the project aim

Astroscale is the first private company with a vision for the safe and sustainable development of space for the benefit of future generations, and the only company solely dedicated to in-orbit servicing across all orbits. To facilitate this, Astroscale, in partnership with Satellite Applications Catapult, upgraded their Control Centre to become the National In-Orbit Servicing Control Centre (IOSCC), which is being used to support Astroscale's debris removal demonstration mission ELSA-d in 2021–2022. This innovative centre will be fully available for companies around the UK to access thereafter.

Executive Summary

Space debris is a major global issue that needs to be addressed to prevent orbits from becoming unusable. As of 2021, there are 36,500 objects larger than 10 cm*, which can destroy an active satellite and cause major commercial damage. We rely on space-based services more and more each year, including to provide our environmental monitoring, banking systems, navigation and location-based services, and to support our security and defence capabilities.

This industry-led project was conceived by Astroscale, a global company headquartered in Tokyo, which has rapidly expanded to the UK, USA and Israel. In 2021, Astroscale launched The End-of-Life Services by Astroscale-demonstration (ELSA-d), a mission comprised of two satellites that will validate the technology required to remove debris from low Earth orbit. ELSA-d is using innovative Mission Operations, Ground Station and Flight Dynamics capability from the IOSCC. The facility provides tracking, rendezvous, docking and de-orbit capabilities that are being utilised for complex satellite captures using a magnetic docking plate mechanism.

After the ELSA-d mission, the IOSCC will be available as a national facility for in-orbit services operations for businesses across the UK. Companies will be able to seize opportunities in space debris removal, in-orbit satellite servicing and other autonomous robotic applications. The Astroscale and Satellite Applications Catapult partnership is the beginning of an exciting opportunity to deliver a scalable, tailored and re-usable Centre to meet the complex demands of new space missions and new markets, as part of a national network of operations facilities.

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Astroscale CATAPULT Satellite Applications

* Source: European Space Agency: https://www.esa.int/Safety_Security/Space_Debris/Space_debris_by_the_numbers

End-of-Life Services by Astroscale-demonstration (ELSA-d) launched in March 2021 from Baikonur Cosmodrome, Kazakhstan

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: March 2021

What is the value or size of the addressable market?

Astroscale, as the first users of the In-Orbit Servicing Control Centre, will provide commercial end-of-life and active debris removal services to satellite operators, 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 costs of delivering operations in the space industry.

Project Plan / Progress

The design of the National In-Orbit Servicing Control Centre is complete and has been tested before the beginning of ELSA-d Mission Operations. Astroscale and Satellite Applications Catapult teams integrated and validated the whole control centre.

The Satellite Applications Catapult has performed security audits and extensive tests, network and infrastructure upgrades including the display systems and voice loop system.

ELSA-d is the first mission to use this facility and it is expected operations will complete during 2022.

LEO Satellite Based AI Demonstrator

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.

Contact:
https://myrtle.ai

Myrtle.ai

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: September 2021

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

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.

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.

Contact:
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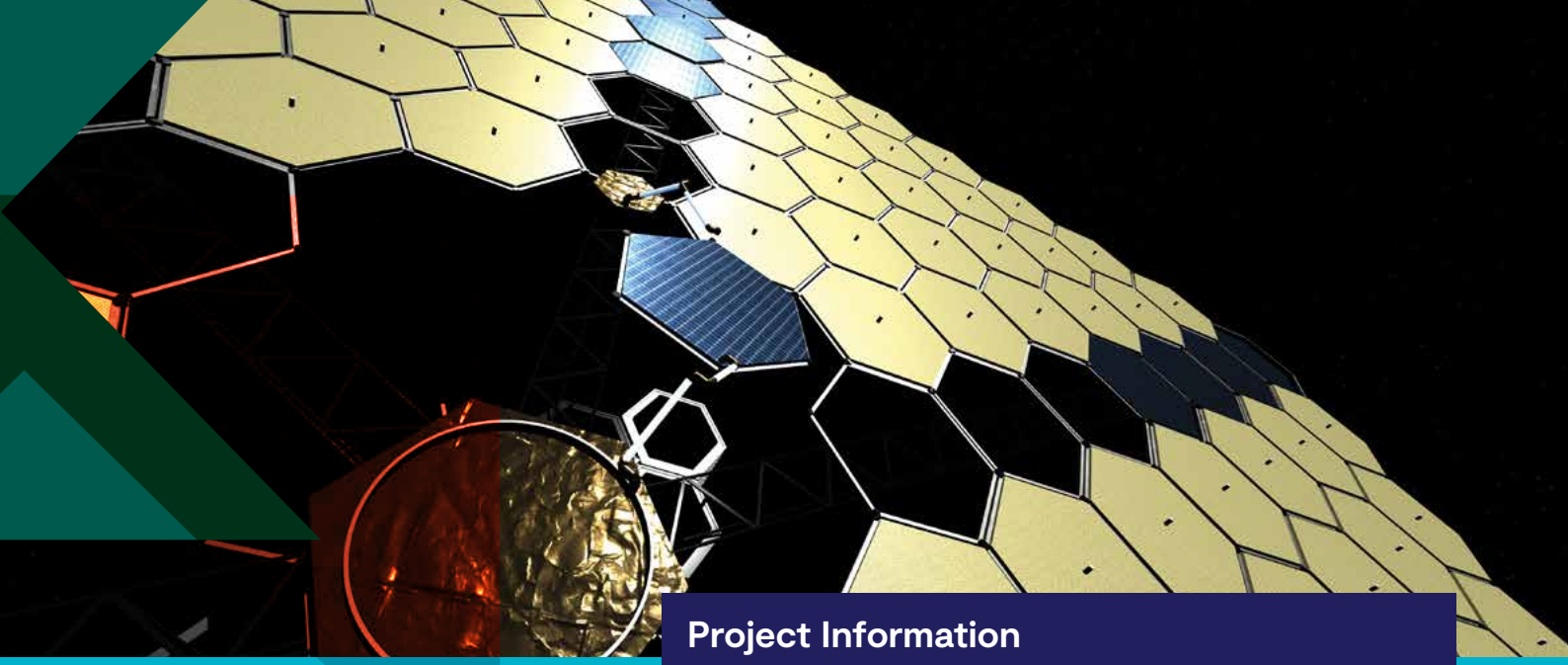
AIRBUS TISICS Titanium Composites



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

What is the value or size of the addressable market?

Space agencies such as the UK Space Agency (UKSA) and European Space Agency (ESA) 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.

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: £718,150
Grant award: £513,346
Start date: January 2018
End date: June 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: February 2019

Executive Summary

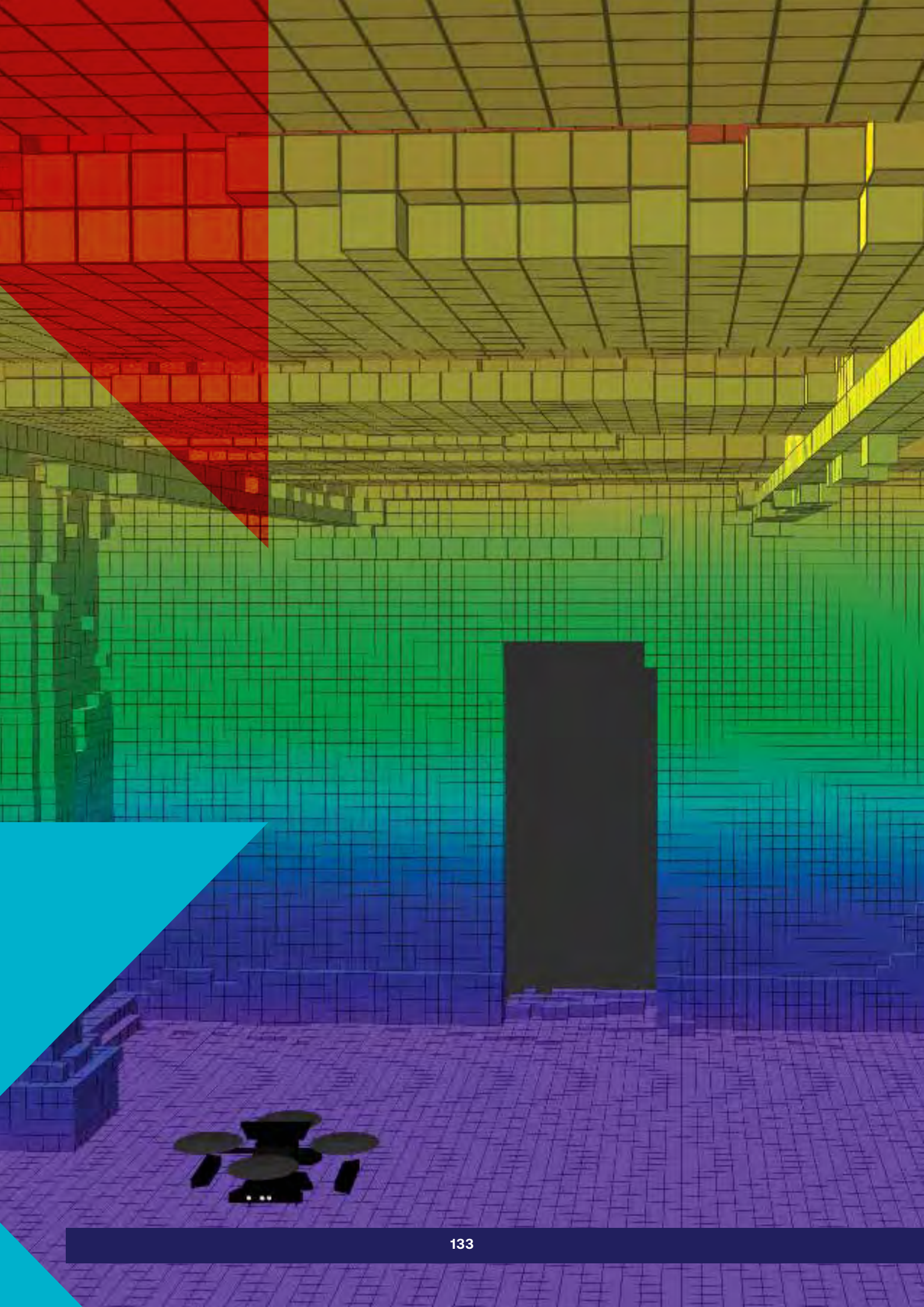
The key objective of this project will be to conduct a feasibility study into the development of algorithms to generate positional information in all 6 degrees of freedom from data generated by the Neptec UK (NUK) space qualified IR Camera. NUK will use its Space IR Camera and simulator to demonstrate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

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.

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: £195,287 (Extension project cost: £184,253)
Grant award: £148,626 (Extension grant award: £63,303)
Start date: November 2019
End date: April 2021
Extension: July 2021–March 2022

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
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.

This project received a further grant through the 'Robots for a Safer World: extension competition' as a part of the challenge's 1–year extension into the 2021/22 financial year. The length and value are detailed in 'Project information' above.

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

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.

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.

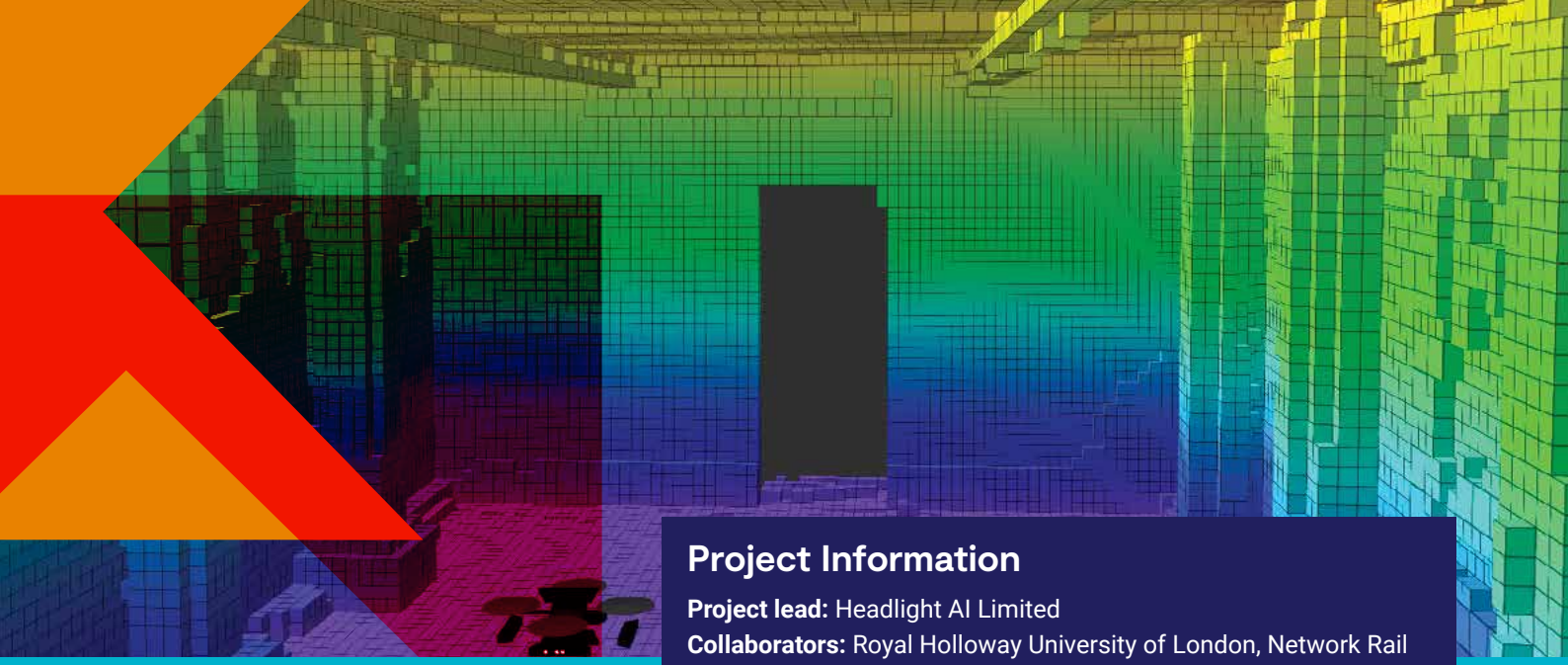
Puneet Chhabra
Co-founder and CTO, Headlight AI. Lead Project Manager
puneet@headlight.ai | www.headlight.ai

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.



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

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: £2,162,421
Grant award: £1,632,662
Start date: April 2019
End date: July 2021

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. Two 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

Cross-Cutting

The cross-cutting projects group comprises two Phase 1 Demonstrators, one of which progressed to a second Phase, six 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 week-long 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.


4114 PRO

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

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.

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 Ministry of Defence (MOD), from Innovate UK and from Department for International Development (DFID).

Contact:
https://barnardmicrosystems.com

BML VTOL capable Panchito UAV, as seen from the ground

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

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 six 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 six 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).

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.

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

Sonardyne SOUND IN DEPTH

GUIDANCE MARINE A WÄRTSILÄ COMPANY

Project Information

Project lead: Sonardyne International Limited
Collaborators: Guidance Marine Limited
Project type: Demonstrator
Total project cost: £391,256
Grant award: £217,547
Start date: December 2017
End date: November 2018

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.

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.

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.

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Programme Lead: wallace@rovco.com
Technical Lead: gary.cross@rovco.com
www.rovco.com

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

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 (Extension project cost: £351,225)
Grant award: £1,824,645 (Extension grant award: £269,869)
Start date: January 2019
End date: June 2021
Extension: April 2021–December 2021

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.

This project received a further grant through the 'Robots for a Safer World: extension competition' as a part of the challenge's 1–year extension into the 2021/22 financial year. The length and value are detailed in 'Project information' above.

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.

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.

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HYBIRD

COSTAIN

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

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 Innovate UK 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.

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.

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.

Contact:
https://maintenance.rs-online.com

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: £1,515,590 (Extension project cost: £249,830)
Grant award: £1,192,233 (Extension grant award: £151,507)
Start date: February 2018
End date: October 2020
Extension: April 2021–March 2022

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

This project received a further grant through the 'Robots for a Safer World: extension competition' as a part of the challenge's 1–year extension into the 2021/22 financial year. The length and value are detailed in 'Project information' above.

CHIMERA – Robotic Inspection of Pressure Vessels

Summary of the project aim

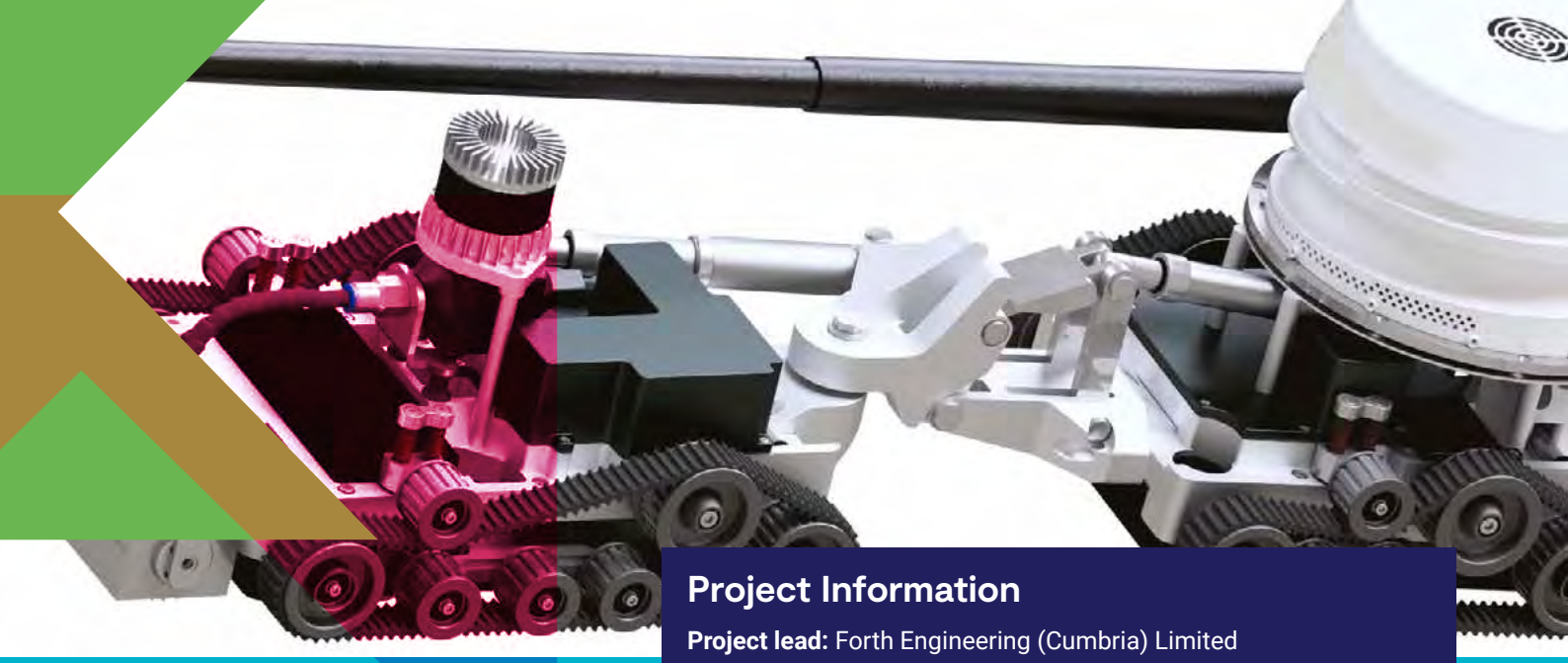
CHIMERA consortium is developing a ground-breaking semi-autonomous robotic platform for internal inspection, repair and maintenance of pressure vessels and gas turbines. Novel features include augmented intelligence (AI) for the evaluation of fitness for service and modular continuum arms with miniaturised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

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.

Martyn Beardsell
www.chimeraiuk.co.uk



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 (Extension project cost: £249,614)
Grant award: £2,413,640 (Extension grant award: £197,156)
Start date: January 2019
End date: March 2022
Extension: April 2021–March 2022

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.

This project received a further grant through the 'Robots for a Safer World: extension competition' as a part of the challenge's 1–year extension into the 2021/22 financial year. The length and value are detailed in 'Project information' above.

COBRA: Continuum roBot for Remote Applications

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.

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

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: March 2021

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
- Two 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

Two 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.

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

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.

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nuron
make fibre make sense

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: February 2019

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 Water and Sewage Companies (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)

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.

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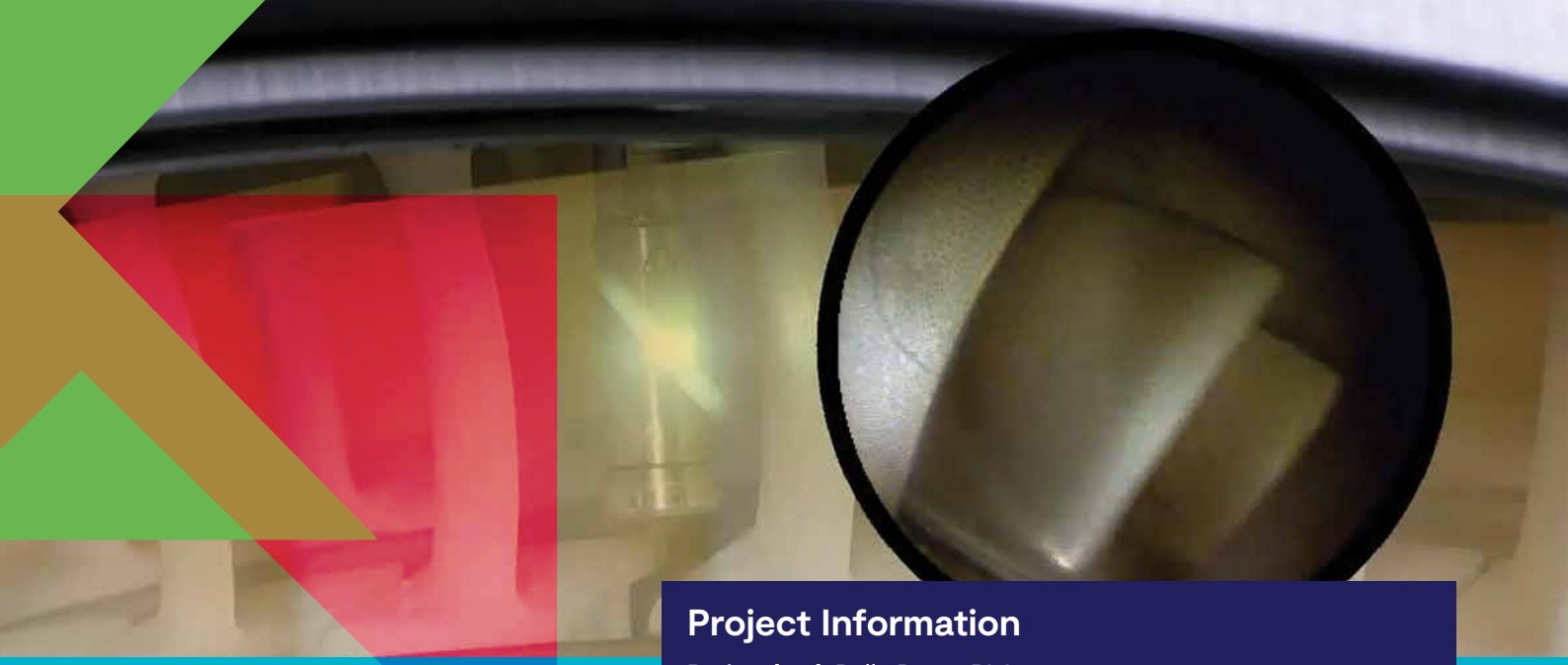

Project Information

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: £1,951,721
Grant award: £1,223,866
Start date: January 2018
End date: March 2021

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.

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

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.

Contact:
https://qinetiq.com

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

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.

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

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www.challenges.org

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

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

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.

L3HARRIS™ BMT

Project Information

Project lead: L3Harris
Collaborators: BMT Ship and Coastal Dynamics Limited
Project type: Collaborative research and development
Total project cost: £1,222,431
Grant award: £689,071
Start date: January 2018
End date: June 2020

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

The project has developed a contactless low-torque incremental encoder to ATEX Zone 0 specification suitable for NDT, commonly used in oil tank inspection (submersible into hydrocarbons).

Executive Summary

The encoder is a novel and compact high-speed rotary magnetic equipment. By being intrinsically safe, it ensures conversion of angular position or motion to digital output signals for a wide range of hazardous applications in manufacturing, even in harsh, explosive environments associated with oil and gas, coal mining, pharmaceutical, food industries, etc.

The encoder module offers a non-contact two-part design consisting of a magnetic actuator and a custom encoder chip mounted on a sensor board, both enclosed in a bespoke brass casing. Rotation of the magnetic actuator is sensed by the encoder chip and processed to give the required output format. Output signals are provided in industry standard, incremental, analogue, commutation, and linear formats.

The encoder was designed so that it is affordable, compact and ready for direct integration into high volume OEM equipment.

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Project Information

Project lead: Innvotek Ltd
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

What is the value or size of the addressable market?

Manufacturers requiring an encoder in explosive environments, specifically with ATEX certification requirements, including flammable gases, mists, combustible dusts, and vapours.

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.

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.

Project Information

Project lead: Archangel Imaging Limited
Collaborators: GMV
Project type: Demonstrator
Total project costs: £683,303
Grant award: £370,690
Start date: January 2019
End date: September 2020

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).

This project received support from a continuity grant through UKRI's COVID-19 response fund.

WormBot

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.

q-bot

Advanced Robotics @ Queen Mary ARQ | Queen Mary University of London

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 (Extension project cost: £498,696)
Grant award: £538,091 (Extension grant award: £393,952)
Start date: April 2018
End date: March 2020
Extension: April 2021–March 2022

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 over 800,000 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 and 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.

This project received a further grant through the 'Robots for a Safer World: extension competition' as a part of the challenge's 1–year extension into the 2021/22 financial year. The length and value are detailed in 'Project information' above.

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 two 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.

Resilient Future

The projects funded under “Robotics for a more Resilient Future” include 19 feasibility study and 19 collaborative R&D projects, developing solutions in application areas such as agri-robotics, logistics, offshore wind, healthcare and cross-cutting.

These projects address opportunities that arise from the need to build solutions with global reach that make the UK economy more resilient to external or unforeseen shocks. The projects develop and utilize different core technologies including machine learning and AI for visual processing, sensor development, robot manipulator development and systems integration.

A Pet-like Socially-Assistive Robot to Support Health and Well-Being

Project Information

Project lead: Consequential Robotics Limited
Project type: Research and development
Total project cost: £99,828
Grant award: £69,880
Start date: April 2021
End date: March 2022

Executive Summary

There is growing evidence that social robots able to interact with people through sound and touch, can help individuals cope with stress and anxiety. As robots are improved, they may also be able to provide other forms of social support for people in need of care, such as reducing the experience of depression and social isolation. This project builds on evidence that interacting with a suitably-designed pet-like robot can have some of the calming and supportive effects of interacting with a companion animal. We will work with multiple stakeholders in the healthcare and education sectors to understand how social robots could be used to support well-being in their settings, and how the robot's behaviour can be best adapted to assist people in specific scenarios. For example, we will explore how children could interact with a robot while they are waiting for a procedure such as a blood test or an operation, and how a social robot could operate as part of pastoral care in schools as a form of "classroom pet". Longer-term applications such as use of robots with older adults in residential care will also be explored. Outcomes of the project will include (i) an improved understanding of the use of social robots to promote health and well-being, (ii) a prototype pet-like robot for therapy and healthcare applications, and (iii) plans for efficacy studies and the production and marketing of a new UK-designed social robot.

APLAUSE – Automated Precision Loading And Unloading System Environment

Project Information

Project lead: Digital & Future Technologies Limited
Collaborators: Miralis Data Limited
Project type: Collaborative research and development
Total project cost: £378,401
Grant award: £264,881
Start date: April 2021
End date: December 2021

Executive Summary

The APLAUSE project focuses on the emerging UAV drone delivery market. The project looks to build on our engineering works to support Unmanned Air Vehicles during the COVID-19 pandemic for the NHS.

We have been working with the NHS, flying UAV's carrying COVID-19 samples, PPE and other biological agents between pathology labs and hospitals.

APLAUSE takes these works and looks to build automated loading and unloading systems for UAV's, providing a new man to machine interface.

UAV's are inherently dangerous. At the moment they are manually flown by pilots at each end of the flight. Landing is a manual operation and the loading/unloading phase only happens when pilot calls out that all is clear. This is a commitment the pilot has to do as detailed in their operations manual as approved by the CAA.

Our vision for the project it to take the learnings from our previous endeavours working with our partners within the NHS and create and automated loading and unloading system for UAV's that will stand the test of time and allow us to work with the CAA as they move from manual control of UAV's through to automatic, where one pilot flies the UAV remotely all the way and then on to autonomous mode where one pilot is overseeing 15 UAV's in flight at any one time.

Our key objectives are to build a working demonstrator system, funded with help from the public purse, that enables us to demonstrate how a UAV may unload and load new cargo, whilst operating within a closed aviation environment. By doing this we will be propelling the UK forward as a country with innovative solutions for the UAV industry with a focus on parcel delivery solutions.

Our main area of focus is on the loading and unloading of goods and power sources on to UAV's to enable remote operated parcel delivery flights to be fully automated. We need to create a safe environment to automate the loading and unloading of UAV's that complies to aviation and commercial needs and regulations.

APLAUSE is innovative as it builds on our initial UAV flights, made under COVID-19, utilises the opportunity that the CAA has afforded us,with regards flying in a pandemic, and takes a significant step forward for the UK UAV and robotics industries alike, building a solution that can be adapted to changes in UAV airframe and commercial context alike.

ARC – Autonomous Research Continuity – A national resource to protect UK life sciences R&D against disruption

Executive Summary

2020 has witnessed business disruption like no-other in living memory. In the life sciences sector, laboratories were abruptly closed, immediately bringing R&D to a standstill. Pharmaceutical companies in the UK, with tens of thousands of staff each; over 40 top tier universities each with active research programmes; numerous biotechnology companies across the country; even Public Health England and its national biobank resource – all were shut down from March 23rd to May 10th with far-reaching repercussions. Life sciences laboratories operate complex, multi-stage processes such as the growth of human cells and tissues in vitro for research purposes. Termination of these processes is destructive, irretrievable and costly. Not to mention the delays to life-saving new treatments.

Until now, life science laboratories were operated by, and dependent on, humans. The laboratories of tomorrow, however, will be autonomous, robotically operated, and therefore resilient to disruption, and compatible with the evolving nature of work.

ARC will exploit existing proprietary robotic laboratory infrastructure within Arctoris, the leading outsourced autonomous laboratory, and innovate to establish new competencies that will underpin a national laboratory continuity resource, the 'Arc'. The Arc will operate fully autonomously to salvage disrupted processes and provide continuity to research activity for life science laboratories in pharmaceutical, academic and biotech research centres nation-wide. The Arc will become the UK's trusted and resilient resource for the provision of cellular, biochemical and biophysical experimental processes along the entire pre-clinical drug discovery and development pipeline – from target and hit identification all the way until in vivo studies.

Project Information

Project lead: Arctoris Limited
Collaborators: Peak Analysis and Automation Limited
Project type: Collaborative research and development
Total project cost: £458,440
Grant award: £320,908
Start date: April 2021
End date: March 2022

Arctoris, with its robotic facilities in Oxford, UK, is the global leader in fully automated experimentation but does not yet have the technology required to fully support sufficient scale and diversity of automated processes to secure national R&D efforts. ARC will expand on proprietary robotic and computational technologies that are currently used for delivering fully automated drug discovery experiments and enable the Arc to support nation-wide life sciences research activities. Through ARC Arctoris will complete a plan of experimental development to expand the breadth of robotic cell handling competency and the computational orchestration of processes to sustain hundreds of activities in parallel.

ARC, and its experimental development plans, represent the greatest chance for UK life sciences R&D to step forward into a stable and resilient future and to maintain our position of global competitiveness in the face of a rapidly evolving and demanding work environment.

AutoInspect

Summary of the project aim

Autonomous inspection for hazardous environments has become a proven application of robotics. However, rapid scaling of this technology is blocked by the need to embark on the scratch development of a new robotics system to meet the specific requirements of each use case.

Executive Summary

The AutoInspect Project developed a complete, automated pipeline for autonomous quadruped robotic inspection. This inspection system included data management to respond to changes to the robotic platform, sensor suite, mission parameters and data management platform without fundamental re-engineering.

The system enables autonomous inspection of hazardous environments where the correct robot and inspection payload, can help minimize the need for people to access unsafe areas, such as those containing radiological or chemical contamination.

The system is based around the Boston Dynamics Spot quadruped robot; equipped with a custom payload combining inspection cameras, gas and radiation sensors, and 3D autonomous navigation from Oxford Robotics Institute.

AutoInspect developed integration with existing BIM models and systems for the plant owners to plan inspection tasks, and to allow inspection results to update BIM backends.

The system was demonstrated at a nuclear licenced site in the UK and an operational lubricant processing plant in Belgium in Q1 2022 and enable the Arc to support nation-wide life sciences research activities. Through ARC Arctoris will complete a plan of experimental development to expand the breadth of robotic cell handling competency and the computational orchestration of processes to sustain hundreds of activities in parallel.

ARC, and its experimental development plans, represent the greatest chance for UK life sciences R&D to step forward into a stable and resilient future and to maintain our position of global competitiveness in the face of a rapidly evolving and demanding work environment.

Contact:
www.createc.co.uk

createc

ORI OXFORD ROBOTICS INSTITUTE

Project Information

Project lead: Create Technologies Limited
Collaborators: University of Oxford
Project type: Collaborative research and development
Total project cost: £452,373
Grant award: £356,704
Start date: March 2021
End date: March 2022

What is the value or size of the addressable market?

The end user of AutoInspect are the owners of complex plant, where staff currently undertake hazardous inspection tasks.

It is reported the global inspection market is worth $16B in 2022, robotics and machine vision can increase this market by making better auditable inspections.

Project Plan / Progress

AutoInspect ran from Q1 2021 until Q1 2022, during the project we have developed and demonstrated all the components need for an end-to-end autonomous inspection system.

The partial system was tested at the Fire Service College in Gloucestershire in November 2021 with the Spot robot autonomously exploring the 4-floor facility. The system is now ready for end-to-end testing with key industry stakeholders in Q1 2022.

The demonstrations in representative environments on operational plants will allow us to convince the stakeholders that AutoInspect should be business as usual on their hazardous plants in their wider business.

Automated Human Inoculation – Covid

Project Information

Project lead: Aqualife Services Limited
Project type: Research and development
Total project cost: £98,840
Grant award: £69,188
Start date: April 2021
End date: March 2022

Summary of the project aim

Humanity is faced with a novel virus which now has a vaccine to prevent serious disease. Untreated, the virus causes illness and, in some cases, death. There have been over five million deaths recorded worldwide. Our project plans to determine whether we can adapt our expertise in the mass vaccination of fish for the mass vaccination of humans.

Executive Summary

The project is to determine if we can build a bench test consisting of a robotic arm, a bespoke end-of-arm tool, vision system and algorithms to deliver a vaccine or vaccine substitute into a dummies arm in the correct place, correct depth and consistently.

What is the value or size of the addressable market?

Every human being on planet Earth is a potential end user for this project.

Project Plan / Progress

We have developed and built a bench test consisting of a collaborative robotic arm combined with a computer vision system and novel end of arm tool. This bench test is almost capable of safely delivering vaccine into a human arm in an autonomous manner. Post project we aim to build a full-scale prototype demonstrating how a product such as this could integrate into healthcare environments all around the world.

Aqualife
FISH CARE PROFESSIONALS

Automation harvesting of whole-head iceberg lettuce

Project Information

Project lead: Grimme (U.K.) Limited
Collaborators: University of the West of England, AGRI-EPI Centre Limited, Salads Harvesting Services Limited, P D M Produce (U.K.) Limited, IDS Imaging Development Systems Limited
Project type: Collaborative research and development
Total project cost: £354,751
Grant award: £248,217
Start date: April 2021
End date: March 2022

Executive Summary

The horticulture sector is heavily reliant on access to seasonal labour for many field operations, including harvest. Movement restrictions because of Covid-19, post-Brexit uncertainty, competition from other sectors, and the lack of suitable UK-based labour have driven growers to seek investments in labour-replacing technologies.

99,000 tonnes of lettuce were harvested by seasonal workers in the UK in 2019 with a farm gate value of £178 million (Defra BHS, 2020), UK's highest value field vegetable crop.

This project has identified an opportunity to automate the process, and reduce the reliance on seasonal labour, by developing an innovative robotic solution.

We intend to adapt existing mechanical capability and lift the lettuce clear of the ground by discs and then gripping the stem with pinch belts.

The lettuce will then be presented to camera sensors that will direct an air blast which will blow the outer wrapper leaves of the lettuce head clear to expose the stem.

Machine vision via deep segmentation will then be deployed using a second camera sensor to train a deep learning model to identify the precise location to be cut.

The three separate developments will be combined to form a prototype for field trials towards the end of the 2021 UK season.

Engagement with end-users has confirmed their need and willingness to be part of the development of such a machine. Early indications are that harvesting costs could be reduced by around £5,000 per hectare per annum.

123,000ha of lettuce and chicory was grown in the EU in 2018 (FaoStat, 2020) with similar areas in the USA. These areas have similar issues to the UK with access to seasonal labour, therefore the potential market for such an innovative machine is extensive.

This project was featured in Farmer's Weekly in October 2021 sharing their progress from their work: https://www.fwi.co.uk/machinery/technology/prototype-lettuce-harvester-could-cut-manual-labour-by-50

BladeBUG Leading Edge Repair Tool

Summary of the project aim

Wind turbine blade leading edge erosion is a major ongoing issue affecting all wind turbines. This erosion reduces the aerodynamic efficiency, resulting in reduced annual energy production and potential blade failures. BladeBUG is developing a robotic system to repair and reinstate the leading edges to maintain optimised performance.

Executive Summary

Blades are a key element of a wind turbine with leading edge erosion of these blades a significant issue resulting in reduced energy generation and serious structural failures. Repairing this damage is essential and is currently carried out by technicians sanding the blade edge before applying filler and a protective coating.

BladeBUG is responding to this need with a universal robotic system designed to remove the complexity and risk of offshore inspection maintenance and repair. The system consists of a walking robotic platform and interchangeable tool payloads.

Having developed two inspection tool payloads, this project focuses on adapting concepts and mechanisms from pre-existing sanding and cleaning tools and ORE Catapult research to create a novel LEE repair tool for use via the BladeBUG robot.

The BladeBUG robot can remotely position tools at any point outside or inside offshore blades and requires single operator.

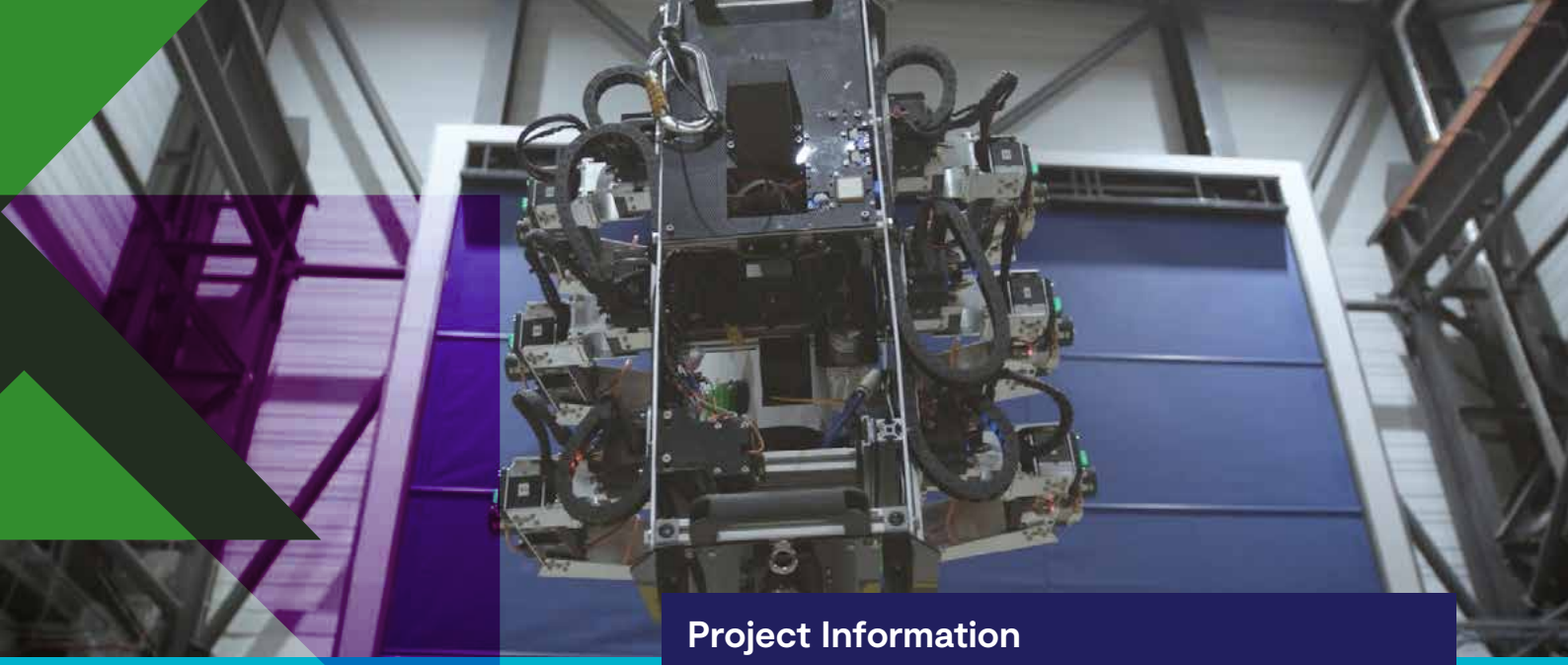
The semi-autonomous approach aims to improve on hand tools by leveraging the precision and repeatability of robotics to perform tasks on blades while reducing cost.

Three main objectives of this project:

- Development and demonstration of an automated leading edge repair tool
  - Sanding tool development
  - Cleaning tool development
- Demonstrations
- Experimental deployment and recovery of the robot (onshore and offshore)

BLADEBUG

CATAPULT Offshore Renewable Energy



Project Information

Project lead: Bladebug Limited
Collaborators: Offshore Renewable Energy Catapult
Project type: Collaborative research and development
Total project cost: £391,935
Grant award: £283,229
Start date: April 2021
End date: March 2022

What is the value or size of the addressable market?

BladeBUG is initially targeting the European offshore blade IMR market before expanding worldwide. Offshore wind O&M will grow globally by 17% annually to €12billion by 2028.

BladeBUG will initially conduct services alongside independent service providers to establish value, before transitioning to supplying the robot as a service to OEMs, owners and operators and independent service providers.

Project Plan / Progress

There have been a number of significant achievements so far during this BladeBUG Leading Edge Repair Tool project, they include:

- Unassisted offshore wind turbine blade deployment
- Sub 35min onshore deployment trials on a test turbine
- Implementation of a constant velocity walking gait to facilitate the control of repair tools
- Design and manufacture of a leading edge sanding/ cleaning tool
- Integration of sanding / cleaning tool into robot
- Prototype dust shroud

In the final stages of the project, all of the work on the individual elements will be consolidated and tested by sanding and cleaning the leading edge of a section of a vertical supported wind turbine blade tip. This will be further validated by performing an offshore deployment and leading edge walk at the Offshore Renewable Energy Catapult's 7MW offshore turbine in Levenmouth, Scotland.

BladeBUG Limited will continue to develop the leading edge repair capabilities, developing the technology to a commercially ready technology readiness level and will continue to explore collaborations and opportunities with end users to trial and validate the systems and processes.

Blended dexterous autonomy and remote robotics for resilient economic service delivery

Summary of the project aim

Despite ever increasing automation capability, human dexterity, perception, skill and perhaps most importantly judgement is still necessary for a vast range of services and processes in society and the economy.

Executive Summary

Having people carry out tasks in-person has a range of disadvantages.

They have to be a in a particular place to deliver the service – incurring economic and environmental costs in travelling to that location.

Humans are susceptible to fatigue, injury and mistakes, particularly when carrying out repetitive manual tasks.

Whether in a pandemic or not, humans are a vector for disease – this is relevant in any situation where humans come into contact with one another, directly or indirectly through products or the environment.

It would be great if we could have robots to carry out every task humans can, but the current state of the art in robotics is a long way short of this level of capability.

We propose an economical remote robotics system way to remove the human from these situations by projecting a human's motor skills and perception into a robotic proxy, augmented by AI for simple tasks. From a societal point of view this carries health benefits to the worker (reduced injury, convenience). From a business point of view it allows the delivery of services, with associated economic activity, in a wider range of situations that might otherwise disrupt either the service itself or the demand for the service.

We will demonstrate the system in two everyday scenarios:

- Healthcare
- Service delivery

Project Information

Project lead: Plexus Systems
Project type: Research and development
Total project cost: £97,592
Grant award: £68,314
Start date: April 2021
End date: March 2022

What is the value or size of the addressable market?

The end user for the project is healthcare trusts and service providers in industries not typically catered to by robotic solutions.

Project Plan / Progress

In this project we have delivered a new control system, control algorithms, and end effector system. A number of challenges were overcome in the fabrication of the new end effector system in particular – this was completely reengineered using new materials to ensure sufficient robustness. We have delivered and integrated the main subsystems and are now focused on the applications, in order to show practical benefits for commercial applications. Based on stakeholder / end user engagement we have focused on the healthcare applications as a key market of interest.

Building Resilient Robotic Harvesters for High Value Field Vegetables

Summary of the project aim

Vegetable growers are facing existential labour shortage problems. Brexit and Covid-19 have created a 'perfect storm. Robots that can carry out the most labour intensive task in the production process (harvesting) will ensure the survival of domestic vegetable production and reduce the need for people to do hard field work.

Executive Summary

This project aims to field the world's first commercially viable (fast, reliable, accurate) green asparagus harvest robot. The machine is lightweight to avoid soil compaction, battery-powered to reduce carbon footprint and low-cost so that it can operate in a swarm where any single points of failure have a low impact. Project partner JGHC provides expert asparagus grower knowledge and access to fields for testing. WMG delivers a cyber security work package that Muddy Machines will use to ensure that its machines are safe from any attacks.

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MUDDYMACHINES WMG THE UNIVERSITY OF WARWICK COBREY

Project Information

Project lead: Muddy Machines Limited
Collaborators: WMG (University of Warwick), JGHC Limited
Project type: Collaborative research and development
Total project cost: £497,479
Grant award: £363,374
Start date: March 2021
End date: March 2022

What is the value or size of the addressable market?

Asparagus growers in Europe and North America spend £350m per year on harvest work. Asparagus is merely the first crop of many for this robotic platform. The market increases to £7bn when expanding to other selectively harvested vegetables.

There are further opportunities in grading, hand-weeding and data services to be exploited.

The machines will be made available as a service, at a cost comparable to human labour, so that growers have 'peace of mind' in terms of operating and maintaining these novel machines.

Project Plan / Progress

After successful field trials in 2021 where the accuracy of the software and end-effector was proven, Muddy Machines is on track to deliver a commercially viable robot for (paid) operation in the fields of the largest UK asparagus grower in the 2022 season starting in March. Muddy Machines is then planning to raise funds to ramp up production to operate several machines in a swarm in 2023.

Calculating the precise geolocation of commercial unmanned aerial vehicles

Project Information

Project lead: Drone Defence Services Limited
Project type: Research and development
Total project cost: £88,614
Grant award: £62,030
Start date: March 2021
End date: November 2021

Executive Summary

Drones are set to transform industries of all types by optimising processes and reducing the cost of e.g. logistics and surveillance to near £zero. However, methods capable of tracking and increasing drone visibility need to be developed before commercial drones gain mainstream and legislative acceptance safely around our towns and cities.

Drone Defence herein aim to prove the feasibility of re-engineering the hardware/software of our existing RF sensor network. This innovation will allow our network sensors to act as differential GPS reference antennas; drone positioning accuracies down <50cm could be attainable.

For companies like e.g. Amazon, UPS and DHL knowing a drone's precise geolocation is critical to ensure: (1) more drones can fly closer together; (2) pin-point parcel drop-offs e.g. on a sheet of A4 paper rather than in someone's garden; (3) avoid critical infrastructure e.g. buildings and people; and (4) take the shortest route to each preplanned point coordinate, saving battery life, time and money. Finally, with the benefit of knowing their operational airspace is going to be protected and not at risk from unwanted threats.

Our proposed capability will allow the above vision to become a commercial reality and allow the creation of "sky ways", for the free movement of legal drones for logistical operations. Without our solution the e.g. Civil Aviation Authority (CAA) could restrict drone usage, possibly damaging if nor destroying this fledgling industry. We propose a viable alternative to support the industry and inhibit restrictive measures.

Our approach will use the latest telemetry methodology and in the near future will be augment with artificial intelligence and machine-learning capabilities; enabling autonomous drone tracking.

Our technology will offer end-users e.g. major cities, airports, prisons and the infrastructure sector to geofence "guard" their airspace, allowing robust vigilance to the growing network threat posed by commercial drones.

Deep Crop Growbotics (DCG)

Project Information

Project lead: Capture Automation Limited
Project type: Research and development
Total project cost: £95,224
Grant award: £66,657
Start date: March 2021
End date: January 2022

Executive Summary

DCG is a feasibility study testing equipment to be used in a modular, selective ground vegetable harvesting unit. with the use of a robotic platform, AI and robotics. Growers will be able to selectively harvest based on pre entered crop parameters, each module covers one row of crop. The unit is self-propelled and scans the field bed. The system identifies the crop positions and if they meet the selection parameters it actuates the cutting robot to extract the crop and release it onto a conveyor for transfer into the trailer module automating the harvesting process. This project focuses on testing a concept that allows gradual adoption of automation and fits within current farming practices.

Detection of fungal plant pathogen spores using Advanced AI and Imaging (AAII)

Summary of the project aim

Air-borne fungal spores cause crop disease and significant yield loss. These microscopic particles remain undetected until symptoms of infection show. A field deployable robotic instrument that captures and detects these spores using real-time AI and imaging can reduce these losses and the environmental burden of unnecessary fungicide spraying.

Executive Summary

This project aims to create a highly affordable and deployable air sampling instrument allowing large areas to be monitored. The system captures spores and uses AI and automated imaging techniques to provide detection and identification, providing data on inoculum levels for multiple pathogens of concern initially in the UK. Remote communications provide early warning and real-time threat detection to growers and land management organisations.

Platform Kinetics Ltd will use its expertise in creating deployable scientific instrumentation, combining embedded electronics, optical design, image processing, automation and AI. Rothamsted Research will provide test samples during the project and a proving ground at that end of the project.

The goal is to create a low cost, highly deployable instrument to monitor vast open spaces for different threat pathogens and report the species and levels of each to growers, land managers and policy makers.

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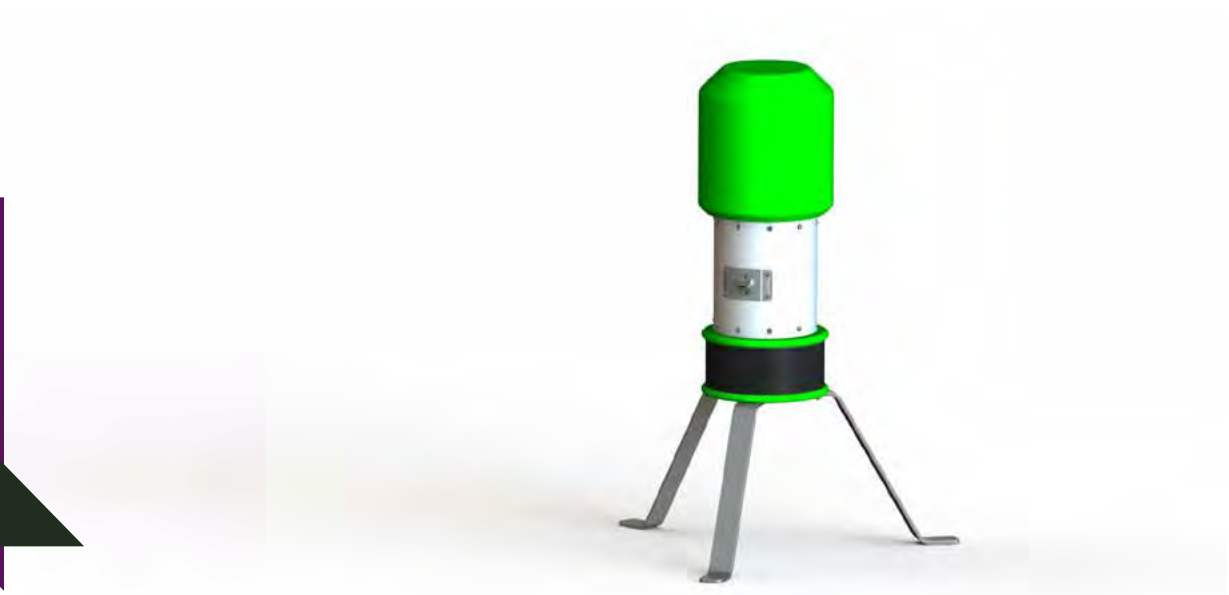
Platform Kinetics

ROTHAMSTED RESEARCH



Project Information

Project lead: Platform Kinetics Limited
Collaborators: Rothamsted Research
Project type: Collaborative research and development
Total project cost: £139,322
Grant award: £109,974
Start date: March 2021
End date: March 2022

What is the value or size of the addressable market?

Our primary target market is in the agricultural space, specifically monitoring high value crops such as vines and soft fruits and those grown in glasshouses. As an example, vines were grown in the EU on 3.2 million hectares with the EU representing 45 % of the world's total area under vines. Changes in environmental and climate policies mean that current spraying practices need to be disrupted and become data driven, rather that purely schedule based. This monitoring technology is applicable to many other sectors outside of agriculture.

NG-DMU technologies are likely to be of value in other adjacent industries involving remote operations, including Space, Offshore, Autonomous Vehicles and others.

Project Plan / Progress

The project has culminated in the successful develop and build of a prototype monitoring instrument. Testing of the Platform Kinetics demonstrator instrument was performed at Rothamsted Research in November 2021 and March 2022.

A new company called Perception Devices Ltd was incorporated in December 2021 to commercially exploit the technology and field trials for the 2022 season are in preparation, with paid subscribers/end-users planned for 2023. A patent has been filed as part of the project and another patent is being prepared, to provide more novel features arising post project. We are already in talks with different industries/sectors where this technology could be applied with some reconfiguration.

Distributed Middleware and Semantic Hardware Description for Heterogeneous Mobile Robotic Fleets in Logistics Warehousing

Project Information

Project lead: Seyo Limited
Collaborators: Tu Pack Limited
Project type: Collaborative research and development
Total project cost: £448,176
Grant award: £313,723
Start date: April 2021
End date: March 2022

Executive Summary

E-commerce growth has supported the proliferation of third party logistics warehouses (3PL), however, it is difficult for these companies to stay competitive without embracing robotic automation. This problem has been exacerbated by the ongoing pandemic and the related social distancing measures, which necessarily reduce the ability to process parcels quickly and efficiently. Nonetheless, 3PL are struggling to migrate to robotic automation: this is not due to hardware availability or costs, given that solutions are available and can be affordably leased; the issue lies in fragmentation (i.e. robots from different manufacturers that do not talk to each other), which imposes expensive integrations (three to five times the cost of hardware) to those brave 3PL that take the leap. Ultimately, these solutions only address functional interoperability and do not provide warehouse-wide process optimisations, which makes them unsuitable for most 3PL scenarios.

Seyo Ltd and Tu Pack Ltd aim to build and trial innovative technology for the creation of a platform enabling interoperability across different types of robots in a 3PL environment. The main vision consists of enabling gradual and risk free transition of small/medium 3PL to robotic automation, which allows them to:

- Grow their profits by increasing the amount of processed orders within the time unit
- Improve the quality of life for their employees, by allowing them to focus on value added tasks, whilst letting robots take care of the menial ones
- Become more resilient to market fluctuations

To achieve this, Seyo will build a software layer that hides the hardware details of a robotic device and represents such a device in terms of what tasks it can perform. This software can run on a designated board or on the robot itself and it allows each robot to safely communicate and move together with other robots as part of a well defined choreography. Moreover, the project aims to build a system that keeps track of the available robots, along with their capabilities, and optimises the aforementioned choreographies by analysing the warehouse processes in a holistic fashion. Finally, a warehouse simulation system will be prototyped with the aim to analyse several warehouse configurations, and select the best one in terms of throughput, ahead of the live trial, which will take place at one of the Tu Pack warehouses.

EchoBoltBUG

Summary of the project aim

Bolt re-tightening is the single biggest scheduled maintenance task for wind turbines, performed repeatedly over the turbine lifetime using heavy, manual high-pressure hydraulic equipment. This project will address the challenge of excessive manual re-tightening by developing and demonstrating the world's first wind turbine bolt inspection robot.

Executive Summary

Wind turbines are constructed with a series of large bolted connections. To prevent catastrophic failure these bolts are pre-emptively re-tightened at regular intervals throughout the turbine lifetime. This process requires the manual placement and operation of heavy high-pressure hydraulic equipment.

Turbine operators and manufacturers recognise significant volumes of bolt re-tightening work as a major health and safety concern and a time-consuming, costly activity, accounting for 0.5% Levelised Cost of Energy (LCOE) from offshore wind.

By integrating two previous innovations, this project will automate the inspection of existing wind turbine bolts using ultrasonics, verifying bolt condition and eliminating unnecessary manual hydraulic re-tightening.

Key Project Objectives:

- Developing the technology integration concept to create a full-scale prototype remote bolt inspection solution.
- Demonstrating the prototype on operational offshore wind assets.
- Creating unique IP to reside within the project consortium in the UK.
- Establishing a clear route to commercialisation through GE Renewable Energy and wider industrial support.

This project will combine two highly innovative solutions, both successfully developed through IUK projects: BladeBUG's market leading robotic platform, a hexapod robot designed to access multiple areas of a turbine to undertake inspection and repair; and EIS's proven ultrasonic bolt inspection device, EchoBolt.

The technology will undergo laboratory testing and validation prior to full demonstration on the ORE Catapult offshore demonstration turbine.

EchoBoltBUG will deliver a world-first remote bolt inspection solution for wind turbines: a truly disruptive technology to address a clear need within the wind industry.

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EchoBolt BLADEBUG GE Renewable Energy CATAPULT Offshore Renewable Energy

Project Information

Project lead: Energy Integrity Services Limited
Collaborators: Bladebug Limited, Offshore Renewable Energy Catapult, GE Energy (UK) Limited
Project type: Collaborative research and development
Total project cost: £405,725
Grant award: £291,089
Start date: April 2021
End date: March 2022

What is the value or size of the addressable market?

Commercial opportunities for EchoBoltBUG exist with wind farm operators, dominated by major utilities and turbine OEMs.

By the end of 2020, Europe's installed offshore wind capacity of 25GW corresponded to 5,402 grid-connected turbines, forecast to achieve 111GW by 2030.

Detailed O&M cost modelling by ORE Catapult has confirmed that for current state-of-the-art offshore wind farm installations, the annual cost of bolt re-tightening is in the range £3,800–4,100 per turbine.

Based on the above, the European Offshore Wind Total Addressable Market (TAM) exceeds £20.5m/year, growing to over £90m/yr by 2030.

Project Plan / Progress

The EchoBoltBUG project is nearing completion and thus far has achieved the following major milestones:

- Walking gait developed on test rig and tested on turbine tower;
- Integration of ultrasonic device into robot;
- Creation of sprung ultrasonic probe mount;
- Remote-control functionality developed;
- Ultrasonic probe software and data transfer functionality proven;
- Developed tether-less assembly;
- Engineering dosing of couplant;
- Developed probe positioning system;
- Benefit Analysis and End User Requirement assessment.

The final phase of the project is seeing work focussed on optimising the walking gait, successfully moving between bolt measurement locations, optimising the couplant dosage and improving the probe positioning. This work will culminate in a two-day trial and demonstration of the robotic solution capabilities at the Levenmouth demonstration turbine.

In addition, it has been identified that digital photogrammetry (DPA) 3D scanning technology has the potential to automate the physical measurement required as a reference measurement on each bolt. Work will be undertaken to construct a scale test rig and demonstrate the viability of this technology for this application.

Energy Integrity Services and BladeBUG are engaged in further developing the EchoBoltBUG to a commercially deployable stage and working to identify the most achievable routes to this end. Work will continue on the exploitation strategy, exploring additional opportunities to partner with operators and manufacturers to exploit the greatest operational benefits that the EchoBoltBUG can deliver.

FASTPICK – Novel active vision and picking head to robotically harvest soft fruit

Project Information

Project lead: Saga Robotics Limited
Collaborators: University of Lincoln
Project type: Collaborative research and development
Total project cost: £499,894
Grant award: £394,894
Start date: April 2021
End date: March 2022

Executive Summary

Uncertainty over access to seasonal migrant labour is placing the otherwise vibrant UK fresh produce and soft fruit sector under unprecedented pressure. The immediate impacts of Brexit and COVID-19 have and are restricting availability to the 69,000 seasonal migrant workers who travel to the UK each year to harvest over £1bn of fresh fruit and vegetables. Robotics and automation technology offers a permanent solution that can disconnect the sector from it's labour dependency, whilst also creating high skilled jobs and growth for the UK robotics sector. However, critical challenges remain to develop robotic technology that can pick fruit within dense, occluded and biologically variable clusters. Leading robotic fruit picking technology can pick 80% of strawberries at 4 seconds per berry. FASTPICK will develop active vision systems integrated to a novel robotic picking head and private 5G network that aims to pick 95% of fruit at c. 2 seconds per berry, the same performance of human harvesters. This performance removes the final technical barrier to large scale adoption of agri-robotic systems for the soft fruit sector.

FASTPICK will develop a state of the art active and dynamic vision system that uses multiple cameras, including visual serving in the picking head to create a 3D scene of complex clusters and identify critical picking points for the gripper. FASTPICK will be implemented in a Gazebo digital twin environment that can be used to optimise picking control and as a key tool for future robotic development. High speed image processing will be optimised by integrating the system into cloud and mobile edge compute via a private 5G network. An optimised picking head and active vision system will be integrated onto the fully autonomous Thorvald robotic platform developed by Saga in collaboration with the University of Lincoln. It will be tested and demonstrated on semi-commercial crops of strawberries.

The collaboration is led by Saga Robotics Ltd in collaboration with the University of Lincoln (UoL) and leading robotic system developers Cambridge Consultants. The picking solution will be co-created with Berry Garden Growers whose cooperative members produce over 45% of the UK's soft fruit. Co-creation enables effective and responsible innovation whilst also underpinning significant, rapid and scaled routes to market for Saga. The technology will be marketed to the UK and global fresh produce sectors but secondary markets exist across multiple robotic application domains.

Feasibility of a standardised, optimised Soft Robotics CPU as the core Industry 4.0 architecture to advance the rapidly growing soft robotics industry

Summary of the project aim

In the same way the integrated circuit revolutionised information processing, new highly-integrated architectures have the potential to revolutionise major industries including soft robotics. The project undertook a feasibility study into a soft robotics CPU ("srCPU") that will provide the core cyber-physical architecture central to new soft robotic development.

Executive Summary

Our motivation is to integrate Industry 4.0 technologies to solve enormous challenges faced by humanity (feeding 9.8 billion people by 2050, improving health/quality of life, addressing climate change) contributing to a $5bn market opportunity in an industrially resilient, environmentally sustainable, economically accessible way.

This programme addressed grand challenge 1 "Artificial intelligence and data" and aligns to 2 "Ageing society".

In the same way the integrated circuit revolutionised information processing, new highly-integrated architectures have the potential to revolutionise major industries including soft robotics. This pioneering project deploys BiologIC's industry 4.0 UK technologies, establishing critical UK capability in this growth industry.

The project undertook a feasibility study into a soft robotics CPU ("srCPU") that will provide the core cyber-physical architecture central to new soft robotic development. The srCPU integrates hardware components together with embedded software as a central operating system to control the information processing and actuation of soft robots. The srCPU will be able to interconnect to soft robot prototypes either as standalone systems or to interface with hard robots and remote devices such as Unmanned Autonomous Vehicles.

The project aimed to advance the total technology readiness level of the soft robotics market segment. New generations of soft robots will operate in dynamic-task/unstructured environments in increasing collaboration with humans. Advantages of soft robots are easy-fabrication/low-cost/lightweight/high-flexibility/safety. However, there are critical operational needs to advance core central processing architectures that reduce the significant control infrastructure burden (pumps/valves/electronics/optics), improve remote operability, broaden application areas and accelerate customer speed-to-market.

The objective was to demonstrate feasibility of a prototype standardised srCPU from BiologIC capable of being interconnected to a soft robots (soft end-effectors e.g. grippers/hands/arms/worms) to show portability of the open-innovation platform.

Inspired by integrated circuits, BiologIC's full-stack "digital hardware" srCPU architectures are software-configurable with horizontal applications across many markets, increasing industrial resilience in warehousing/logistics (handling complex inventory), healthcare (surgical devices/infectious material), nuclear decommissioning and agriculture.

BiologIC Technologies

Project Information

Project lead: BiologiC Technologies Limited
Project type: Research and development
Total project cost: £50,000
Grant award: £35,000
Start date: April 2021
End date: September 2021

What is the value or size of the addressable market?

Soft robotics can grow globally from circa $645m (2019) to circa $5bn (2025) at CAGR>40% [Research and Markets] provided central processing constraints are addressed. We estimate the srCPU can address up to 20% of this market through this game-changing, user-focused programme.

The open-innovation platform developed allows Original Equipment Manufacturers/developers to leverage standardised srCPUs, in the same way that the electronics ecosystem uses ARM development boards. This allows OEMs to accelerate application-specific development.

The srCPU will substantially reduce soft robotic costs by standardising core architectures used by OEM developers. Cost of goods to developers across the ecosystem could be reduced by 25–50% and this margin improvement can be passed on to end-users. Additionally, development time would be similarly reduced, with more time focused on application-specific development, accelerating speed-to-market for thousands of new soft robots. Developers will benefit from improvements in each generation of srCPU architecture, with a tick-tock of power in a smaller 3D-footprint enabling greater soft robotic sophistication.

Project Plan / Progress

The key initial objective under this project was development of a soft robotics CPU Proof-of-Concept that may be deployed with a range of end effectors. The plan, objectives and deliverables remained consistent with the original application and have been successfully achieved.

During the project we redeployed capability in multi-material 3D printing leveraged from BiologIC's applications in the life science industry into the field of soft robotics.

We designed and fabricated novel components for the srCPU including valves and hydraulic rams. We also developed the associated electronics and software capability. We initially demonstrated a logical control unit for precision hydraulics.

We then studied effector components and assemblies in order to advance the logical fluidic system and integrate it with an end effector. The demonstration included flexing the end effector under the logical control of the srCPU.

We progressed our TRL from 2 to 3 and delivered a successful result. Having successfully demonstrated the feasibility of the concept, further work will be required after the project to further develop the sophistication of the capability.

Feasibility of Causal Learning System for Robotic Transportation and Materials Handling

Summary of the project aim

This project applies cutting edge nonalgorithmic transducing and generative AI techniques to the problem of autonomous maritime vessel collision avoidance. The project tackles the adaptiveness of robotics AI, reducing the need for human involvement in machine learning across development and training.

Executive Summary

The core robotics AI being applied and tested in this project has been developed internally by InnerMachines. The technology concerns generative nonalgorithmic computability with symbolic representation that is 'grounded' in the physical environment by way of transduction. This new causal approach to AI is projected to reduce personnel workload by >60% in developing and training machine learning tasks.

The AI technology is applicable to machine learning sectors generally, and in this project it is being tested in a maritime context for autonomous vessel collision avoidance. The project intends, in comparison with existing machine learning strategies, acquisition of sophisticated robotic competencies during real-time application with minimal human input and without application-specific programming.

Vessel path following and collision avoidance are interrelated maritime problems, and the application of AI in this project is embracing a reactive format for dealing with environmental dynamics as wind and oceanic currents, while retaining safe and cohesive vessel trajectory. Autonomous vessels are also required to adhere to international maritime navigation regulations, which as operating factors along with environmental dynamics, can be learned during application in relation to reinforced goals.

innermachines

Project Information

Project lead: InnerMachines Limited
Project type: Research and development
Total project cost: £63,372
Grant award: £44,360
Start date: April 2021
End date: March 2022

What is the value or size of the addressable market?

90% of all goods in international supply chains are transported by sea, and artificial intelligence is making its way into the oceans. This project addresses the technology sector of a growing maritime economy, which is on course to expand from $1.5 trillion to a $3 trillion market by 2030 (OECD), along with a projected doubling of global trade during the period.

Feasibility Study for the Application of CellRail as an Automated Weight-Bearing Scaffolding Solution

Project Information

Project lead: Resolve Robotics Limited
Project type: Research and development
Total project cost: £98,514
Grant award: £68,960
Start date: April 2021
End date: March 2022

Executive Summary

Resolve Robotics delivers start-to-end full system design, development, testing and calibration of complex integrated electro-mechanical and software systems. Our active projects include a world-leading computer vision algorithm, robotics system integration, a distributed modular manufacturing ecosystem, and multiple novel robotic deployment systems for nuclear sites.

CellRail is a modular deployment and retrieval mechanism for robotic payloads which deploy sensors and tools through a 150mm access port. It delivers a payload to any position and orientation in inaccessible locations, at height, and in confined spaces, something which cannot currently be achieved by other robotic systems. It improves safety, increases productivity, and reduces costs.

We are seeking funding to analyse and explore the scaffolding structure's maximum weight bearing capabilities. If the structure can support the intended weight, including the total weight of persons using the scaffolding, tools, equipment and transmitted loads, it can replace manually built scaffolding to aid the fast, safe and cost-effective construction, inspection, maintenance, and repair of structures at height across multiple global heavy industries.

FollowPV – Developing autonomous unmanned aerial vehicles with spatial awareness for improved image quality from solar farm inspections

Project Information

Project lead: Resolve Robotics Limited
Collaborators: Loughborough University, University of Essex
Project type: Collaborative research and development
Total project cost: £354,810
Grant award: £280,254
Start date: April 2021
End date: March 2022

Executive Summary

The FollowPV project plans to develop a 'self-driving' (semi-automated) drone system for inspecting solar farms. Our device will allow a drone to follow rows of solar panels in the same way that a 'self-driving' car is able to keep in lane. However, unlike a car, a drone is not connected to the road by wheels. Therefore, our device must also enable the drone to follow the rise and fall of solar panels over uneven terrain.

Solar farms are critical to the UK's energy supply and to reducing emissions, so they need to be inspected regularly for defective components. We use drones with specialist cameras to inspect entire solar farms in a single visit, which is more efficient than inspecting panels on-foot. This reduces maintenance costs of solar farms allowing operation at optimum condition, which helps keep down the cost of electricity to the consumer.

However, some defects are only visible very close-up, yet reveal early systemic degenerative problems for the future. Current drones are not accurate enough to fly very close to solar panels, and therefore manual inspections are sometimes still needed. These are very time-consuming, expensive, and involve health and safety risk.

To use a drone to capture this ultra-high detail imagery, we want to fly much closer to the panels (within 5m). However, in the same way that 'sat nav' is not accurate enough to control the steering wheel of a self-driving car, then GPS is not accurate enough to control a drone so near to the solar panels. To do this accurately, the drone (like the car) needs to be able to 'see' its environment, and to understand and use this information to make tiny control adjustments. This requires special sensors on the drone, and onboard artificial intelligence (AI), which can rapidly process and make in-flight corrections.

Loughborough University (LU) and the University of Essex (UoE) already have expertise in utilising drone technology with this capability for use in 'smart agriculture' (e.g. crop disease monitoring), but similar technology can be applied to solar farms.

In our proposed partnership, the expertise of LU and UoE in drone automation will be combined with Above's expertise in solar farm inspection and worldwide network of international customers and commercial partners. Ultimately, our desire with this project is to ensure that the UK and the world's solar plants are working as efficiently as possible, thus reducing our reliance on fossil fuels.

HausBots – Wall Climbing, Damp Proofing and Paint Applicator Robot

Summary of the project aim

HausBots will revolutionise the painting and damp proofing application tools market through the development of The Haus Bot (THB), a wall-climbing, painting, robotic solution, exceeding existing machinery and manual application performance. Traditional methods are dangerous, expensive and time consuming, often requiring scaffolding.

Executive Summary

HausBots Limited, a Birmingham based SME is focused on developing transformative wall-climbing, paint applicator technology, that disrupts project delivery within the painting, decorating and damp proofing industries.

Painting is the 5th most dangerous job in the UK, with Painters at risk of falling from height and experiencing health conditions, including repetitive strain injury and contact dermatitis as well as long term exposure to hazardous materials.

With application methods barely changed since paint was invented, painting is time consuming, labour intensive and dependant on height access equipment. HausBots will change this, with their robots significantly de-risking paint and damp proofing application, disrupting the industry through safer, cost effective methods.

This project accelerates the development of their world-first solution, exploring hardware and software enhancements covering precision painting to deliver safety, productivity and financial advantages to Painters, Contractors and Clients.

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Project Information

Project lead: Hausbots Limited
Collaborators: Safeguard Europe Limited
Project type: Collaborative research and development
Total project cost: £312,961
Grant award: £219,073
Start date: April 2021
End date: March 2022

What is the value or size of the addressable market?

HausBots is targeting a sub-segment of the Global Decorative Coatings market (£40.6Bn, £4bn UK), with increased construction contributing to future growth (Transparency Market Research, 2019). The sub-segment – global painting tools market reached £8.1bn 2018 and is expected to grow at CAGR 6% to £12bn by 2025 (Global Market Insights, 2019).
The painting tools market is dominated by brushes, rollers and sprayers (GMI, 2019).

HausBots will initially target application of damp-proofing products, where transparent coatings reduce project complexity. Manual application typically costs £5–8k per house in labour, materials and scaffolding costs, creating an addressable market of ~£1.6bn (Available,~£0.5bn).

The end user of the product is painting contractors, with the end beneficiary being the owner of the housing stock (councils, housing associations or homeowners).

Project Plan / Progress

Robot side: At the beginning of this project, the HausBots robot was teleoperated and fully manually controlled.

We have so far integrated and tested a series of stereo cameras to allow the robot to be spatially aware. As a next step we have taken that data and are able to undertake SLAM on a wall surface during climbing

Painting side: During the project we have specified and tested a 6DOF robot arm weighing 3kg to be coupled with our climbing platform. This arm is able to carry an airless spray head payload and accurately position this end effector for highly accurate paint application.

Holistic Principal Tunnel-Sewer Survey System (HS3) using Unmanned Aerial vehicle and Artificial Intelligence+Big Data

Summary of the project aim

This project is developing a holistic tunnel-sewer survey system (HS3) to ease the very tedious survey process of deep principal tunnel-sewers, comprising a tunnel survey-specific unmanned aerial vehicle (T-suv) and artificial intelligence classification models (AI-CM) that will analyse T-suv's videos for fault-classification and survey reports production quicker and safer.

Executive Summary

The survey process of deep principal tunnel-sewers is very tedious, needing sewerage regulation entity be disconnected for 2-months for crucial airing and intercommunication network setup, and survey done by 3-squads for 0.5months (assuming a 4-mile long tunnel), expending 2.5 months in total and over half a million pounds in costs. The environment is also particularly unsafe, with rodents and other disease-carrying animals, and carries harmful solids and chemicals even after airing. All these make it difficult to conduct the required annual multiple surveys, causing intermittent collapse, blockages, and particularly incessant leaks and associated pollution episodes.

Pollution episodes from leaks are big and frequent because there are over 3,500 deep principal tunnel-sewers, to which over 400,000 miles of sewers are connected to, and from which sewage is transported to treatment stations. The leaks have led to pollution of more than 50% of UK rivers (Environment Agency, 2018). The penalty fee for such leaks are usually huge, causing tunnel owners to be desperate for alternative survey methods.

An unmet market need exists for a highly productive (quicker, cheaper and safer) survey system that will engender frequent tunnel-sewers surveys.

This project develops a holistic tunnel-sewer survey system (HS3) that includes a tunnel survey-specific UAV (T-suv) and artificial intelligence classification models (AI-CM) that will analyse T-suv's videos for fault-classification and survey reports production.

T-suv will produce survey videos of a typical tunnel-sewer system in hours and the AI-CM model will subsequently analyse the generated survey videos and product fault reports in circa 30 minutes.

Project Information

Project lead: Clogworks Technologies Limited
Collaborators: Intenttech Limited, University of Hertfordshire, AA Sewercare Limited
Project type: Collaborative research and development
Total project cost: £424,921
Grant award: £333,444
Start date: April 2021
End date: March 2022

What is the value or size of the addressable market?

Companies performing sewer surveys as well as water companies themselves are the first customers who can benefit from the technology. Sewers and culverts can be inspected by this method, which makes T-suv and the subsequent AI-CM fault classification models of interest to different culverts owners to allow for quicker, cheaper and safer inspections, such as Highways England, Network Rail or their foreign equivalent, for example.

Project Plan / Progress

T-suv has been constructed from carbon fibre and aircraft grade aluminium in a modular chassis resistant to wet environment that allows for assembly within inspection chambers. Onboard cameras and lightning are being tailored to the sewer environment to allow for good quality videos to be recorded, while maintaining a long flight endurance to allow for maximum flight time and distance cover during aerial survey.

A collision tolerant system has been designed through propeller guards and a sense-and-avoid Lidar solution is being developed to allow for safe flying in GPS-denied environment.

The artificial intelligence classification models (AI-CM) are being developed by Big Data Technologies and Innovation Lab led by Professor Hafiz Alaka at University of Hertfordshire in conjunction with Intenttech.

The AI-CM model has been produced and is being fine-tuned with more data being fed to the system to analyse T-Suv's videos for fault-classification and survey reports production.

The first model automatically detects defects in a sewer and has been developed using Convolutional Neural Network and Big Data Analytics with over a million images with and without sewer defects. The second used support vector machine to predict potential defects.

Exploitation
Discussion about the project with several water companies showed interest from their part. Two stakeholders workshop were organised towards the start of the project and one is due soon to engage further with external stakeholders.

Two literature papers were written about the AI/ML models.

The exploitation plan is to be updated to reflect the best ways to capitalise on solutions developed.

LianaBot

Summary of the project aim

Q-Bot's goal, in collaboration with QMUL, is to develop, build and test a prototype eversion robot that can navigate and inspect severely confined voids in a building structure i.e. such as between the leaves of a cavity wall, behind plasterboard and between floors.

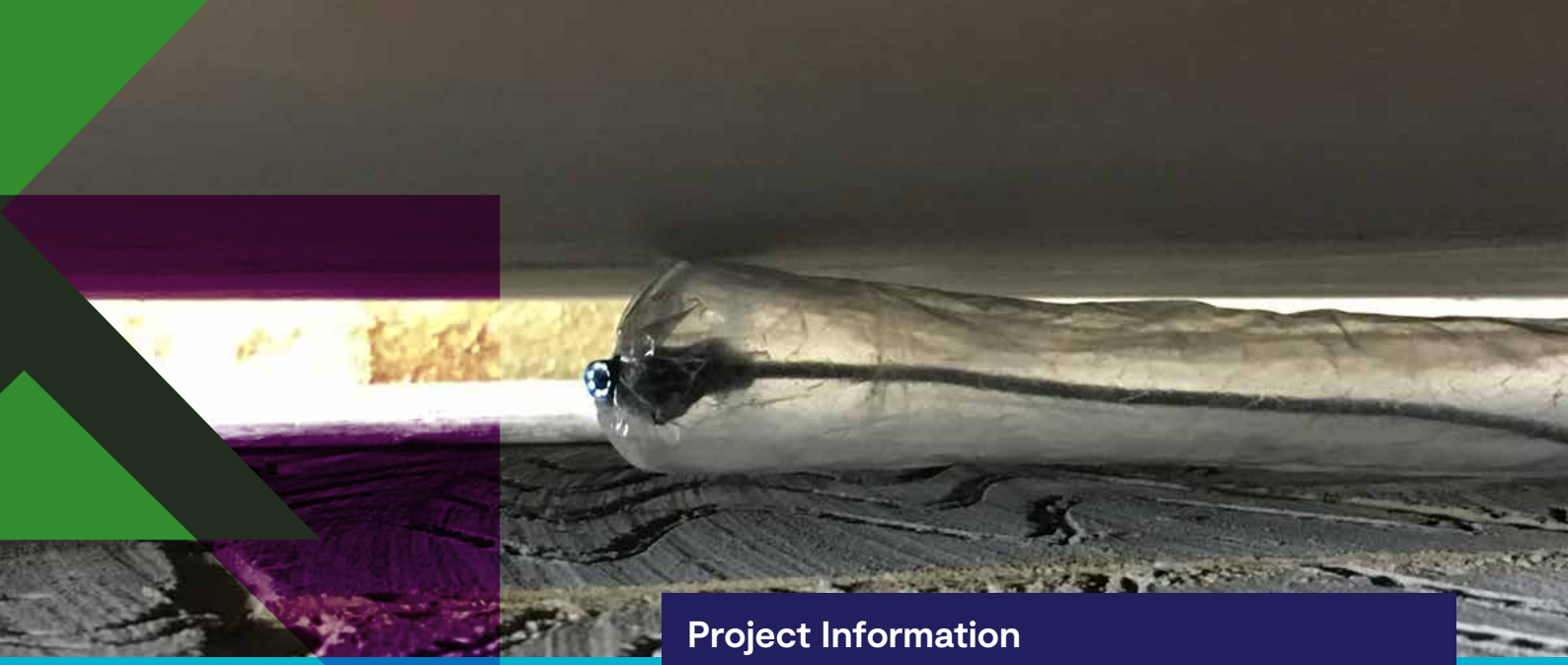
Executive Summary

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's Installation Partners will be the end user of the system providing robot enabled services, initially in the application of inspection and treatment of small voids within buildings using a soft robot to apply insulation in an environment which is currently inaccessible for human operatives without prohibitive disruption and expense. The current retrofit insulation service by Q-Bot is already British Board of Agrément (BBA) accredited and commercialised (with the help of a more cumbersome robot and heavy hardware) with clients from enthusiast homeowners to Local Authorities and Housing Associations. Q-Bot's robots have insulated over 2000 sites successfully so far.

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, and a previous project funded by InnovateUK (104059).

The development of LianaBot is intended to address the limitations of the currently available tools to inspect and apply treatments to inaccessible, severely constricted void spaces within buildings. The use of a soft, flexible, inexpensive robot that can squeeze through small gaps, navigate around obstacles and operate in tight spaces will enable access to areas that currently are accessible only through highly destructive and costly processes.

Contact:
https://q-bot.co



Project Information

Project lead: Q-Bot Limited
Collaborators: Queen Mary University of London
Project type: Collaborative research and development
Total project cost: £249,761
Grant award: £197,127
Start date: April 2021
End date: March 2022

What is the value or size of the addressable market?

In the UK around 4.6m homes have 'hard-to-treat' cavity walls and 900,000 have failed cavity wall insulation that requires removal. These properties suffer from draughts, uneven temperatures and cold surfaces, significantly impacting occupants' comfort, health and energy use. If the UK targets for reducing CO2 emissions and fuel poverty are to be met, this market will require an economical and rapidly deployable solution that is reliable, effective and correctly suited for each property.

Project Plan / Progress

The project has entered the final quarter, where the prototypes are being tested in realistic environments. Whilst the start of the project has experienced some delays, the key deliverables of this project are expected to be completed as planned.

The work packages completed so far are:

WP1 – Requirements and state of the art review. This work package included engaging with stakeholders and identifying customer needs as well as reviewing the state of the art and the market.

WP5 – Localisation and Mapping. This covered the development of a system enabling the prototype to map the surroundings and identify where it is positioned within the map.

The following work packages have started but are not yet completed:

WP2 – Prototype design, development & production. This covers the development of a prototype soft robot capable of navigating narrow vertical cavities in buildings.

WP3 – Development of control mechanisms. This covers the development of mechanisms to control a prototype soft robot capable of navigating narrow vertical cavities in buildings.

WP4 – Payload Delivery & Manipulation System Design. This work package involves testing previous payload and deployment designs in vertical cavities to identify weak points. It also includes developing a mechanism to maintain the sensors at the tip of the prototype and developing a mechanism to deploy and manipulate the prototype within vertical cavities.

WP6 – Testing. This is to test the prototype in realistic environments and create case studies to disseminate results and share with existing partners and potential clients.

WP7 – Exploitation, business plan and IP.

Nano-Agro – a novel, multi-purpose RAI system for sports turf

Summary of the project aim

E-Nano is a robotics and AI startup working on optimising maintenance and improving the playability of sports surfaces to enhance athletes' performance. This project has enabled further development and technical validation of the robot and embedded measurement tools.

Executive Summary

E-Nano has developed O.S.C.A.R., a novel programmable controller module and online platform that can easily interconnect most robotic solutions in the market to allow live communication and control with remote operators, automated control, and enables real-time analysis of collected data.

Sprout is a low-cost and multi-purpose small robot that can navigate autonomously within sports surfaces and comprises instruments to perform various operations such as soil and turf assessment. Sprout integrates O.S.C.A.R.'s communication and control module for online monitoring and automated control.

This project has enabled further development and technical validation of the robot and embedded measurement tools. The project team has finalised robot design and built two iterations of a demonstrator that will be tested and validated in a real-environment configuration early in 2022.

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E-NANO

Project Information

Project lead: E-Nano Limited
Project type: Research and development
Total project cost: £99,753
Grant award: £69,827
Start date: April 2021
End date: December 2021

What is the value or size of the addressable market?

E-Nano focuses on providing a Robot as a Service consultancy for sports turf maintenance, delivering an intuitive, adaptable, and scalable combination of hardware, and software tools to its end-user for an affordable price.

The primary addressable market consists of Elite Football in the UK and globally. Secondary markets include Golf courses, Non-Elite Football, and Other Sports (including American football, baseball, Tennis, and Horse Racing).

The global sports turf market is significant $11.8B and projected to show continuing growth in the future (CAGR:5.5%,2021–2026).

Project Plan / Progress

E-Nano has proposed this project in order to bring its innovation from TRL4 to TRL6 by Q4–2021, with additional developments and iterations undertaken before producing a TRL9/market ready robot of Sprout by Q4–2022.

During this project, E-Nano has successfully developed, tested, and validated two iterations of a demonstrator of the solution in a controlled environment. Following promising demonstrations to end-users, pilots are now planned for Q1 2022 before the solution can be commercialised to Elite football clubs later that same year, generating first revenues for the company.

OSPREH – Optimising Speed, Productivity, Resilience and Efficiency in Healthcare

Summary of the project aim

For drone fast, efficient and low cost delivery in healthcare, parcel handling must be done autonomously. Moreover, a “Droneport” is required to garage drones when stationed or being re-charged and to locker parcels that have been delivered or awaiting delivery. Multi robot collaboration in dense Droneport networks will require further intelligent automation.

Executive Summary

The OSPREH project has been successful in achieving all of its goals.

The architecture for a compact multipurpose two storey Drone port was designed and the building structure fabricated and is to be commissioned in March 2022.

Rover robots have been developed to perform a multitude of autonomous intelligent tasks such as picking up parcels off the landing pad, receiving parcels from drones, loading parcels onto drones, lockering parcels and collecting the drones off the landing pad and garaging them.

AI based Droneport security systems have been developed to ensure humans and animals can be detected if they trespass.

A decision tree random forest based AI system has been developed and the hospital scenarios simulated, so that automated 24/7 decisions can be made for whether blood pathology samples are best sent by van or drone.

In order to deal with the high complexity of multi robot collaboration between multiple busy drone ports, we have used deep reinforcement learning to train multiple robot types and drone ports to interact efficiently, and we have shown that it outperforms human management.

Follow on exploitation is planned with multiple Drone ports based around the Solent region.

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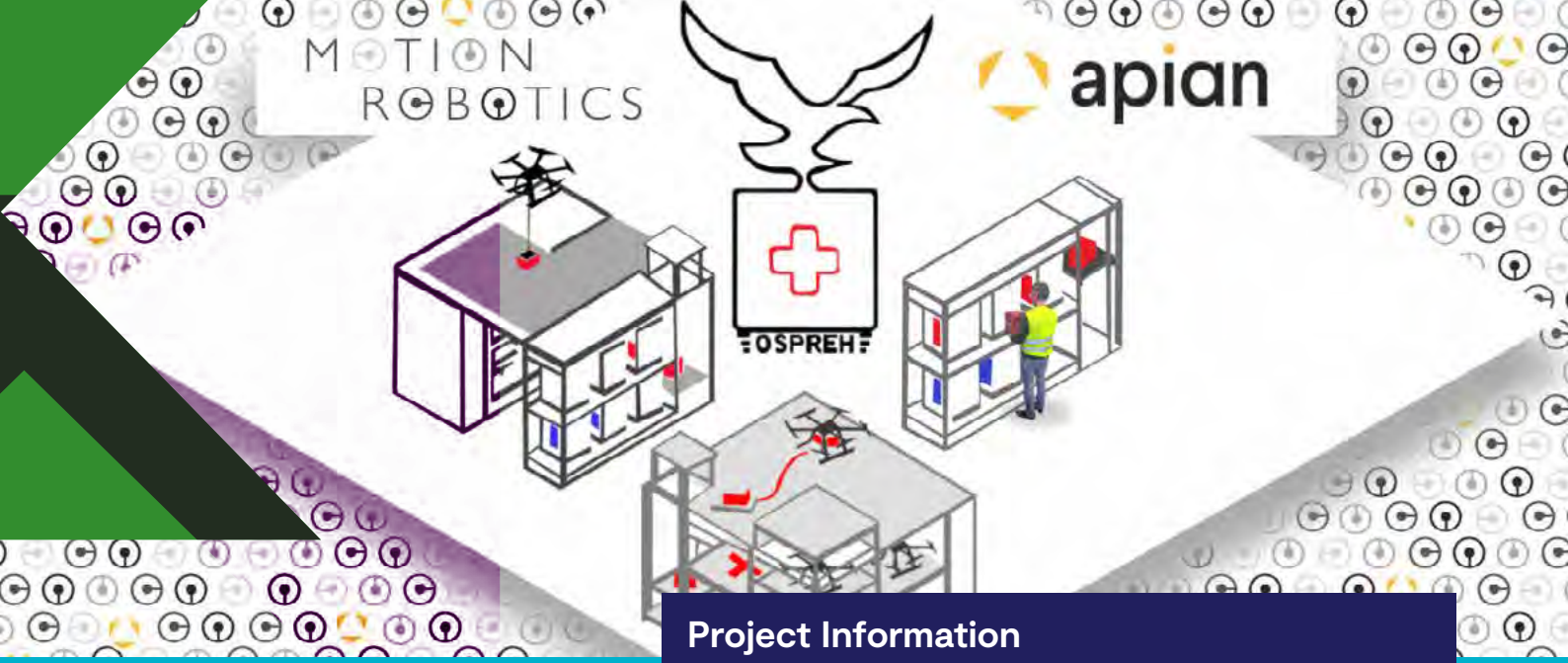
https://www.motion-robotics.co.uk

MOTION ROBOTICS apian



OSPREH's intelligent droneport providing autonomous robotic ground services for cargo handling and drone maintenance

Project Information

Project lead: Motion Robotics Limited
Collaborators: Apian Limited
Project type: Collaborative research and development
Total project cost: £280,072
Grant award: £196,050
Start date: April 2021
End date: March 2022

What is the value or size of the addressable market?

Currently it is the NHS and NHS Trusts, however the technology is being adapted to support search and rescue drone applications, e-commerce delivery, shore to sea delivery and environmental monitoring.

Project Plan / Progress

We are now at the end of the 12 month project and have achieved all of our main goals. The next phase post project will be to collaborate with drone operators and end users to develop fully operational systems.

OTFT based e-skin for robots in picking and packaging of agriculture produce (ESIPP)

Summary of the project aim

The project integrates NeuDrive's technology of organic transistor-based active-matrix fabrication on flexible and conformal surfaces with pressure sensing components to make tactile sensitive artificial skins (e-skins) for robots. This approach will significantly improve the performance of robotics for applications ranging from industrial robots to future humanoids & prosthetics.

Executive Summary

NeuDrive was established to commercialise organic thin-film transistor (OTFT) technology. NeuDrive has already succeeded in establishing a technological platform for various chemical/biochemical and physical sensors. In ESIPP NeuDrive is addressing an important market need, namely furnishing fruit picking and packaging robotic hands and grippers with the dexterity of a human hand to increase automated harvesting potential. Indeed, there is a pressing need to reduce the labour (and associated costs) of fruit/veg peaking. With about 10+ new harvesting robots being near commercialisation worldwide, the state-of-the-art approach to evaluate fruit/vegs harvest readiness through imaging is only partially successful mostly due to cameras being oblivious to hidden fruits.

NeuDrive uses its patented propriety technology to develop electronic skin with real-time tactile sensors. The project integrates the existing expertise in active-matrix for displays on flexible and conformal surfaces with pressure sensing components to make tactile sensitive artificial skins (e-skins). A significant advantage of NeuDrive is its capability to fabricate multi-arrayed sensors and electronic circuits on flexible conformal substrates. Moreover, the utilisation of OTFT technology provides an unparallel opportunity to significantly reduce the weight, physical sizes and cost of the sensor arrays in comparison to those based on the conventional silicon-based transistors. Various resistive and capacitive pressure sensing materials are already available - combining them with OTFT based arrays will make the sensor output real-time capable of sensing extremely low-pressure changes (in both dynamic and static modalities). Such sensors empowered with Artificial Intelligence algorithms will allow object shape and texture recognition and hence harvesting success.

Contact:
http://www.neudrive.com/

Project Information

Project lead: Platform Kinetics Limited
Collaborators: Rothamsted Research
Project type: Research and development
Total project cost: £99,977
Grant award: £69,984
Start date: April 2021
End date: March 2022

What is the value or size of the addressable market?

The e-skin market is relatively new and fast-growing: its size exceeded $6b in 2019 and is predicted to reach $16b in 2026 [Statistics Report 2026]. Although agricultural robotics is still a minor component of the e-skin market share, it is expected to significantly increase driven by the urgent need to tackle the shortage of farm labour. Apart from agricultural robots, e.g. manufacturers of agri-food picking and packaging robots, where grip dexterity is crucial, additional customers will be sought out from manufacturers of robotics for healthcare, industrial and customer applications (e.g surgical assistance, utility, warehouses and drone robots, prosthetics etc).

Project Plan / Progress

As a result of this one-year project, NeuDrive Ltd has both undertaken extensive market research among dozens of renowned SME companies to verify the market need and accomplished a feasibility R&D study to develop the first demonstrator that employs (OTFT) technology for arrayed pressure sensors as a first prototype of e-skin. Specifically, in this project, NeuDrive has demonstrated that NeuDrive's bespoke OTFTs can be used simultaneously as both transducers and switches within circuits for either piezoelectric or piezoresistive (or even both of them) arrayed sensors fabricated on organic polymer-based substrates. This gives the opportunity to create e-skins that are formable (i.e. they can be bespoke to various shapes and surfaces), cost-effective, lightweight, have a significantly diminished number of wired connections and, importantly, capable to collect data for both dynamic (ie fast-changing) and static (ie constant) pressures and therefore mimic human skin better than existing pressure sensing solutions and thus well-suited to multiple robotics applications.

The next stages of R&D post-ESIPP NeuDrive will focus on the further optimisation of the arrayed system, the development of an all-integrated system capable of collecting both dynamic and static pressure data at various ranges of pressures and/or forces on a single platform and, lastly, devising Artificial Intelligence fuelled algorithms for shape and force direction recognition.

RICHE – Robots In Controlled Healthcare Environments

Project Information

Project lead: Westfield Sports Cars Limited
Collaborators: University Hospitals Birmingham NHS Foundation Trust, Cranfield University
Project type: Collaborative research and development
Total project cost: £493,968
Grant award: £389,079
Start date: April 2021
End date: March 2022

Executive Summary

Westfield Technology Group will be leading an innovative project in collaboration with University Hospitals Birmingham NHS Foundation Trust and Cranfield University to demonstrate the application of cutting-edge driverless electric mini pod logistics, with temperature controlled lockers, linking into an existing robotic pharmacy.

The project will be testing a prototype interchangeable ("hot swap") temperature controlled locker system for fast deployment, within which medication will be securely transported. A "one-to-many" delivery concept will be trialled, whereby multiple orders will be delivered to a single location, eradicating the need for additional delivery and / or collection related journeys, providing an innovative way for members of the public / departments to receive goods, and in doing so conglomerating orders, targeting the reduction of vehicle miles between sites, related carbon emissions, allowing staff to be better deployed for direct care and reducing lead-time for patients.

The lockers will be loaded onto the mini pod by the pharmacy robot, with the mini pod then completing the defined routes. The mini pod will remain on site for an extended period of time so as to allow maximum flexibility for staff / public to collect at their convenience within a pre-booked window, to coincide with their departure from site or visits to the wards.

A complete chilled locker system will be manufactured for the mini pod integrating both facial recognition and QR code technology to provide locker access. To complement this, a supporting app will be created to provide information on locker location, delivery time, shopping top-ups and interactive messaging, to provide maximum flexibility to the consumer and staff. In addition, a supporting operator app will be created to provide information on locker location, delivery time, state of charge, on-board temperatures, remote locker override, mini pod and system errors.

Finally, through working alongside Cranfield University, the project will be fully integrated with their existing mechanical and software engineering faculties to provide hands-on experience in product development, as well as creation of new courses for IOT technology.

RoboCapture – Automated and agile robotic platform for image and 3D scanning data capture in construction

Project Information

Project lead: Motion Impossible Limited
Project type: Research and development
Total project cost: £76,442
Grant award: £53,509
Start date: April 2021
End date: March 2022

Executive Summary

To assess the feasibility and discover the technical needs and market opportunities that arise from utilising an autonomous, stabilised, wheeled robotic device to aid and improve image and 3D data capture for scanning, inspecting and monitoring environments, primarily on building works within the construction industry, with an interest in brownfield (dangerous) land, and with secondary use cases in a number of other industries such as healthcare, agriculture, warehouses, deep mining, security, airports and more. As such, we are exploring robotics to increase resilience for repetitive, dangerous and strenuous tasks.

Objectives

- To gain deeper understanding of the technical needs of end users in the construction market
- To produce demonstration equipment of an innovative new agile wheeled robot that will allow us to engage with end users in real world scenarios
- To assess the commercial opportunities that we know to exist on a deeper level

Main areas of focus

- To dramatically reduce the costs associated with using robotic solutions for automated inspection tasks
- To increase the quality, coverage and frequency of captured data
- To explore in detail how Motion Impossible (MI) can diversify its core technology and expand into new markets

How it is innovative?

MI has been producing robotic solutions for high quality image capture within high end TV/film productions worldwide for over 6 years. The technology MI has developed is directly transferrable to solve similar problems in other markets, and MI has a strategy of market diversification that they wish to action.

This feasibility study will explore the combination of pre-existing MI stabilisation technology and integrate it with a brand new innovation in wheeled omni-directional movement that will provide a cost effective solution for mimicking human like agility and stability in many different operating scenarios.

Whilst wheeled robots and omni-directional solutions exist and are relatively cost effective, they have weaknesses which prevent them being viable for many terrains and situations. Walking robots offer significant improvements in agility, but this comes at a cost prohibitive level that reduces the number of viable market opportunities.

This study will produce a roadmap for a cost-effective solution that fits in the space between current wheeled and walking robots. It will move and stabilise image and 3D data capture devices in a way not currently available.

Robotics for Resilient Environmental Gravimetric Surveying

Project Information

Project lead: M-Squared Lasers Limited
Project type: Research and development
Total project cost: £98,202
Grant award: £58,921
Start date: April 2021
End date: March 2022

Executive Summary

Gravity surveys of construction sites are often legally mandated to check for features such as historically significant remains or uncharted utilities. However conducting these surveys is a role where the construction sector lacks resilience. This task is monotonous, but still reliant on a skilled job role where there are significant labour shortages. In spite of the survey being legally mandated, the results are often of low value, with the current state of the art sensing equipment is often inadequate to detect smaller underground features.

In this project we shall demonstrate the world's first robotic quantum gravimeter, capable of performing a raster pattern across a site negotiating around obstacles, autonomously conducting the survey and improving resilience by reducing the personnel dependence. A successful outcome would also make the profession of surveying more accessible and inclusive.

Robust Automated Discovery (RAD)

Project Information

Project lead: Gearu Limited
Collaborators: Centre for Process Innovation Limited, Johnson Matthey PLC
Project type: Collaborative research and development
Total project cost: £452,411
Grant award: £327,145
Start date: April 2021
End date: March 2022

Executive Summary

In some respects, laboratory work has changed little from the lab benches of the 1800s; certainly, the image of laboratories packed with scientists in white coats still holds today. As for many industries, the emergence of COVID-19 has had a major effect on research-intensive industries, and we need to mitigate for this in the future. In 2020, researchers at the University of Liverpool developed a new technology: a mobile robotic chemist that is able to work by itself, 24 hours a day, making decisions about which experiments to do next using artificial intelligence (see BBC News feature, June 2020). Based on this technology, a new spin-out company, Gearu, was formed. In this project, Gearu will partner with Johnson Matthey, a UK science and chemicals company, and global leader in sustainability, along with ABB Robotics and the Centre for Process Innovation. By combining their skills in chemistry, robotics, software, and artificial intelligence, this multidisciplinary team will create a resilient solution that will allow companies in the future to operate their research remotely, even in periods of lockdown or social distancing. We will also demonstrate the concept of a "backup lab" – that is, a mirrored robotic facility in another site that can be controlled securely over the internet. This will allow companies to be more resilient to disruption in the future, not only related to COVID-19 or other diseases, but also in terms of problems with supply chain, infrastructure, or 'spikes' in demand. This programme builds on areas of core UK strength where we hold an international lead and will catapult this new technology into a range of sectors, including pharmaceuticals, home and personal care products, and clean energy (e.g., new battery materials). Societal benefits will include greater flexibility for staff and the ability of researchers to work from home where needed. Longer term, this technology also has the potential to make research more inclusive – for example, for people with disabilities who might not be able to work within a more conventional laboratory environment.

SARbox – Developing AI to enable unmanned search and rescue

Summary of the project aim

1.89 million people work offshore, set to increase with global demand for energy and trade. When someone needs rescuing mariners are required to risk their own lives to save others. We aim to eliminate this risk with our unmanned rescue vessel, keeping people out of harm's way.

Executive Summary

Saving lives at sea is time critical, the sooner you can get someone out of the water the better your chances of recovering them alive.

Current rescue vessels must wait for the vessel operators to put their emergency kit on before the vessel can deploy. Our unmanned rescue vessel deploys immediately and has no human limitations in terms transit speed through rough weather. We can therefore reach the incident location quicker whilst our operators remain dry and out of harm's way.

The next challenge is finding the person in the water. The human eye has its limitations, in bad weather or low light finding someone is more like a game of chance. This project focussed on the development of SARbox, which provides real-time AI enabled automatic casualty detection in all conditions, night or day storm or fog – making unmanned search and rescue possible.

SARbox, our eyes in the storm, identifies and actively tracks casualties drifting in the water enabling the unmanned rescue vessel to navigate to them and position for recovery. Thereby taking the search out of search and rescue. The solution developed is sensor and platform agnostic to enable casualty detection from a vessel, drone or static mount.

This project focussed on selecting the optimal sensor array and developing the AI for casualty detection and tracking. Culminating in the development of a processing algorithm able to actively track up to 4 casualties simultaneously.

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www.zelim.co

Project Information

Project lead: Zelim Limited
Collaborators: Offshore Renewable Energy Catapult, Orsted Power Limited, Everoze Partners Limited, Saviour Medial Limited
Project type: Collaborative research and development
Total project cost: £495,356
Grant award: £363,267
Start date: April 2021
End date: March 2022

What is the value or size of the addressable market?

The end users for unmanned rescue vessels are large vessel operators across offshore energy, construction, shipping and passenger markets. As well as offshore site operators such as offshore wind farm owner operators and offshore oil & gas platform operators.

There are currently over 74,000 vessels in the global merchant fleet which are all legally required to carry a fast rescue craft. This is expanding to 78,742 by 2026 as global population growth continues to push up demand for energy and trade. Offshore wind is also going through major expansion from 35GW installed capacity today to 270GW globally by 2030.

Project Plan / Progress

Outputs achieved:

- Identification and testing of sensor solutions to provide the optimal sensor array for casualty detection in the marine environment, night or day storm or fog
- A machine learning / AI solution that, under supervised Similarity Learning, creates an augmented sensory view and pattern match to identify casualties in the water
- A processing algorithm able to determine both the bearing and heading of a casualty relative to the search asset
- A processing algorithm able to actively track up to four causalities from the search asset
- Off the back of the Innovate UK funded project Zelim have secured demonstration opportunities with end users for SARbox

Aims for next project:

Using the same object detection techniques developed in this project for casualty detection we are aiming to extend the capability of SARbox to include collision avoidance to support safety of navigation. This will enable our unmanned rescue vessel to operate in complex marine environments, such as offshore wind farms or offshore oil and gas installations.

SeaLens – Autonomous marine robot for seaweed and shellfish aquaculture

Project Information

Project lead: Plant Ecology Beyond Land (PEBL) CIC
Project type: Research and development
Total project cost: £41,016
Grant award: £28,711
Start date: April 2021
End date: March 2022

Executive Summary

Industry Challenge:
Near-shore coastal waters have highly dynamic physical, chemical and biological environments which can be subject to dramatic changes due to extreme weather, tidal currents and human activities. Monitoring this environment provides crucial information for the effective set-up and management of aquaculture operations. For example, when identifying new aquaculture locations it is essential to first characterise the local marine environment in order to comply with water quality standards, to establish effective mooring designs and to provide a baseline of the environmental conditions.

Typical monitoring programs rely on in-situ sampling, where data is temporally sparse and is often irregularly sampled (e.g. dependent on vessel access, weather and tides). On the other hand, semi-permanent monitoring instruments (e.g. on a buoy or mooring) that measure continuously over long periods of time are able to capture temporal variations. However, due to their high capital costs (\> £20k–1M) few of them exist and the ones that do are almost exclusively used by large organisations (e.g. harbour authorities, research institutes or large-scale aquaculture businesses)

Solution:
PEBL CIC is developing an affordable (total cost < £2,000) autonomous monitoring system for small and medium sized aquaculture organisations. The system is modular in design and integrates sensors for monitoring various water quality parameters, such as seawater temperature, salinity and pH as well as recording video and images.

The data gathered from this system benefits marine aquaculture organisations by:

- Minimising mortality of species due to disease, extreme weather and pollution through early-onset detection and response.
- Optimising marine-farm siting and design based on understanding of the local environment.
- Developing operational strategy through the prediction of biomass, health indicators and market value based on data-driven models.
- Enabling the management of sustainability objectives by monitor long-term changes to the local marine environment and biodiversity.

The feasibility study will design, build and deploy the system at five different aquaculture locations across the UK to test its robustness and the quality of data captured.

SUPERIOR – SUPer-immErsive remote working via Virtual Reallty cOntrolled Robotics

Summary of the project aim

Organisations and Academic Institutions need an easy-to-use, cost-effective way to create virtual reality (VR) training and assessments, viewable on any VR/AR device, whilst allowing control of a robot in real time, from any location with 5G connectivity. Our solutions is a VR authoring tool, which is a browser-based, SAAS product.

Executive Summary

The academic fields of robots and virtual reality are both highly relevant to the future prospects of industry. They are usually separated conceptually as one is dynamic in real space and the other dynamic in virtual space. Combining the two fields for education seems a natural symbiosis, enabling the scaling of academic teaching methods beyond the restrictions posed by attendance in a robotics laboratory.

eNetReality is eCom's virtual reality authoring tool, using WebVR and A-frame to develop a Software-as-a-Service application that works in a browser. Combining this with the robotic expertise at the University of Glasgow and the 5G testbed for communication, to create a real-time link between the user and the robot and "twin" the movement in the virtual world with that of the robot arm in the physical world.

Using eNetReality to build assessments that mirror those in the lab, creates an environment similar to that experienced in the physical lab, using any haptic device to allow users from any geographic location to access the physical robot and complete an observable assessment on which feedback can be provided in real time.

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eCom Scotland

University of Glasgow

Project Information

Project lead: Ecom Scotland Limited
Collaborators: University of Glasgow
Project type: Collaborative research and development
Total project cost: £99,844
Grant award: £69,891
Start date: April 2021
End date: September 2021

What is the value or size of the addressable market?

The target market is academic departments where robots are used to assist with technical training, robotic companies needing to train purchasers, and commercial training companies who provide robotic training. They can use SUPERIOR in real-time, through their VR headset to control a range of robotic hardware from any location, revolutionising how this type of training or assessment is done.

Many organisations have been shipping expensive equipment to technical staff globally, to build in isolation without the ability to fully test. Our solution will provide remote access to specialised equipment, expanding the use and availability of robotics to a wider catchment.

Project Plan / Progress

In this feasibility study, we have created a prototype of a virtual reality (VR) experience to carry out real-time electronics engineering practical assessments for International students. Using an immersive VR environment, they can remotely control a physical robotic arm in labs in China and Scotland. This prototype process is being developed using eCom's VR platform, eNetReality and University of Glasgow's robot arm.

eCom intend to develop eNetReality to provide features that allow haptic integration, enabling use with a number of the robotic hardware options in widespread commercial use. This will offer a simple, easy-to-use, plug-and-play solution that is both low-cost and effective for training, controlling and maintaining robotic hardware operations.

There is currently a Knowledge Transfer Partnership application under consideration in conjunction with the University of Glasgow, looking at developing the SUPERIOR project further. By combining the software development skills within eCom with the University of Glasgow's knowledge of robotics, the aim is to create a fully realised commercial product for a number of markets including, but not limited to, Education, Engineering, Construction and Health.

Swimming through the Grains: Robotic Device for the Autonomous Monitoring of Cereal Grains in Long-Term Storage

Summary of the project aim

A CROVER is the world's first granular drone, in the sense of a device able to move semi-non-destructively through bulk solids and powders. The first application of the CROVER is a Grain Storage Monitoring system, to help grain storage operators maintain the quality of their stock. #SavingGrains

Executive Summary

Estimates place the value of mass and quality losses due to spoilage of grains in long-term storage at ~£10B annually in developed countries alone, making storage the single mid-stream phase in grain production with the highest losses. Pests are to blame, with grain moisture content and temperature being the most significant factors.

Cereal storage sites such as farms, grain merchants, millers and breweries, experience these challenges, which have high-cost implications in terms of lost revenue and cost to rectify.

A CROVER is the world's first 'underground drone' and the first small robotic device able to 'swim' through grains stored in bulk, such as in wheat and barley in sheds and silos. The CROVER Grain Storage Monitoring system is intended to improve grain packing and to use on-board sensors to scan the grains and build a map of conditions within grain bulks.

The project is made possible by a new ground-breaking physical discovery enabling locomotion in bulk solids and powders (e.g. sand dunes, chemical/mineral powders) by the Founder of Crover Ltd and covered by a granted UK patent. The granular-matter-equivalent of plane or drone wings in air, or a boat's rotor in water, it allows an object to move between solid grains.

The project focuses on advancing the development of the CROVER Grain Storage Monitoring system for monitoring temperature and moisture in grain bulks, with a particular focus on assessing the feasibility of extending of the initial CROVER proof-of-concept self-propelling device into a complete system demonstrator for grain storage monitoring.

Contact:
info@crover.tech
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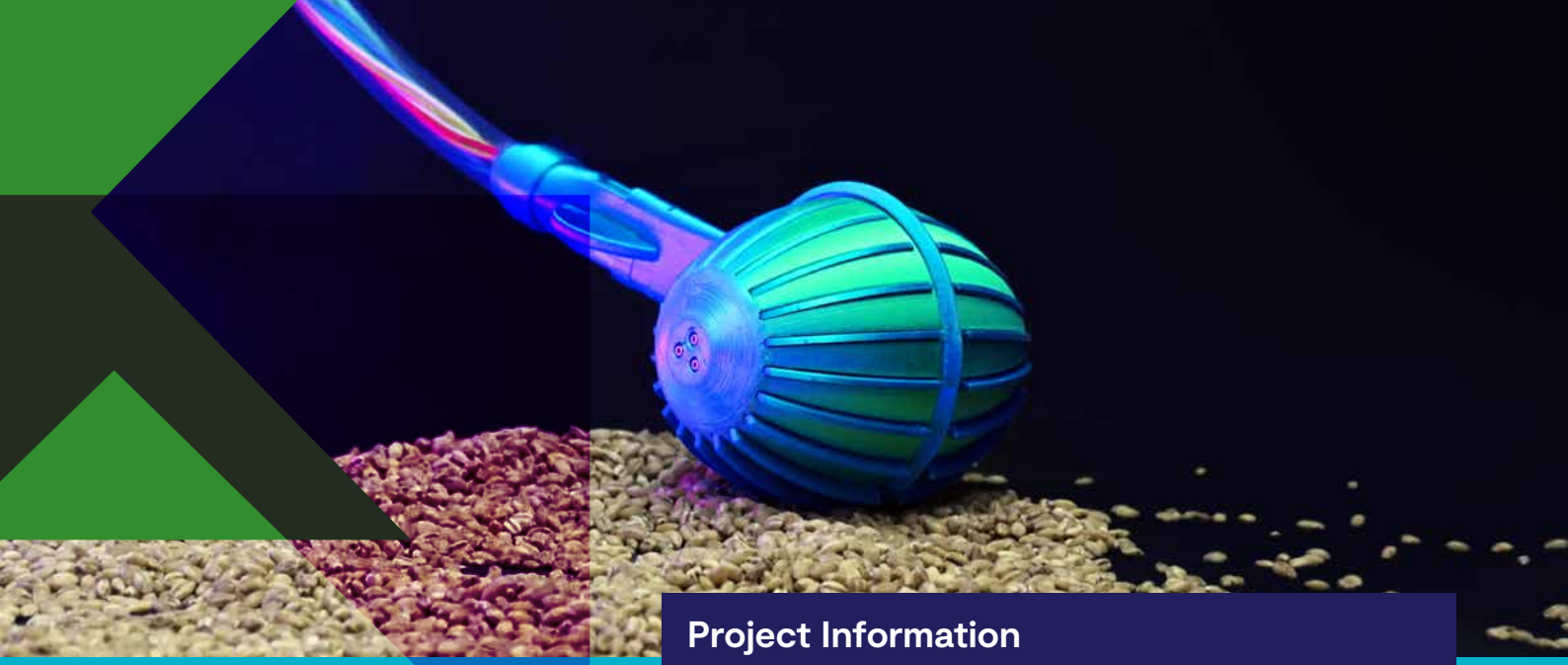
CROVER
GRAIN STORAGE MONITORING



Project Information

Project lead: Crover Limited
Project type: Research and development
Total project cost: £99,977
Grant award: £69,984
Start date: April 2021
End date: March 2022

What is the value or size of the addressable market?

The main target of the project are centralised grain storage hubs with at least 20,000t of storage capacity that store for a continuous period of at least three months – these are generally owned by grain merchants, co-operatives and port operators.

Estimates place the number of grain storage units in the addressable market segment at more than 3M worldwide, for a total addressable market of >£9B.

Driven by population increase, there is a constantly growing trend in the market: world cereal stocks by the close of seasons in 2021 are now forecast at 811M tonnes.

Project Plan / Progress

Now in its 3rd quarter (out of 4), through the project we have been able to:

- Develop algorithm to estimate the absolute heading of the robot
- Integrate different components of the CROVER system in the Robot Operating System
- Fuse the system's sensors for motion control and localisation
- Developed web application to control actuators and get sensors feedback
- Build a local control unit for the Grain Storage Management system
- Develop an autonomous cable management system
- Simulate and improve the heat dissipation within the robot and limit the heating of internal components and of the external environment
- Conduct tests in grain sheds

During the course of the project we have receive interest from key players in the grain storage and grain trade market, as well as from companies handling different types of bulk solids and powders.

Recently the CROVER has been featured in the BBC Click COP26 Special: https://youtu.be/VhWGZtqh5ao?t=634 as well as winning the Food and Agriculture track at the Hello Tomorrow Global Summit, the world's leading deep-tech gathering: https://twitter.com/hellotmrc/status/1466824741155651589 and the Wevolver / Mitsubishi Chemical Advanced Materials challenge: https://www.wevolver.com/article/subterranean-drone-tackling-food-security-wins-the-high-temperature-carbon-fiber-3d-printing-challenge

TEK7 RBT

Project Information

Project lead: B.E. Design Consultancy Limited
Project type: Research and development
Total project cost: £99,683
Grant award: £69,778
Start date: May 2021
End date: March 2022

Executive Summary

The aim of this project is to develop a robot assembly which serves as part of a first-generation smart football training system which incorporates IOT, autonomous robotics and data visualisation to aid coaches and improve youth players individual dribbling skills.

The application of robotics for the automated installation of tunnel mechanical, electrical and communication systems

Project Information

Project lead: Tunnel Engineering Services (U.K.) Limited
Project type: Research and development
Total project cost: £95,508
Grant award: £66,856
Start date: May 2021
End date: March 2022

Executive Summary

It is recognised in the industry that large transportation infrastructure tunnels are usually constructed using Tunnel Boring Machine's (TBM's) which are highly automated for cutting through the ground and installation of the tunnel lining behind the boring machine.

However, once the tunnel is constructed, the fitting out of the tunnel for mechanical, electrical and communication services are traditionally installed manually in a labour intensive manner, involving the fixing of bracketry and containment to support services.

Project aims
The purpose and projected outcome of this feasibility study is to innovate, design and establish a robotics and artificial Intelligence (RAI) technology and process to deliver a robotic automated solution to facilitate the installation and maintenance of the mechanical, electrical and communication services within the constructed tunnel environment.

The study shall also examine how this equipment can be utilised in all types of tunnel construction and sizes, used for road, rail transportation and energy infrastructure.

Outputs
Some of the key output objectives of the study are to minimise health & safety issues at the workface, reduction of overall risk to the operatives and increased levels of quality assurance and productivity.

In addition to this the following key outputs shall be recognised:

- Reduced construction plant movement and number of visits to the workface
- Delivery reductions
- Reduced installation costs material wast.
- Carbon footprint reductions
- Reductions of operatives within the tunnel

Focus areas
The main area of focus will be the automation of the installation process through the use of technology, robotics engineering and artificial intelligence to provide industrywide improvements.

This feasibility study shall identify the whole life process for design, manufacturing and installation of the mechanical, electrical and communication containment services and where this innovative technology can be used in other construction sector markets.

Innovation
The feasibility will consider the use of modular services development, tunnel layout and positioning surveying technology, logistics engineering, tyre and track access to work face, software integration, automated positioning and fixing of services.

The Distributed Automated Cutting System project (DACS)

Summary of the project aim

Infrastructure projects that involve cutting and laying paving causes widespread disruption to the public through road closures and environmental nuisance. DACS will incorporate metrology, robotics, AI and off-site processing to reduce disruption from paving operations, whilst improving productivity, safety and environmental impact.

Executive Summary

The Distributed Automated Cutting System (DACS) project, led by Eurovia UK, in partnership with Loop Technology and The University of Sheffield Advanced Manufacturing Research Centre (AMRC), will deliver a ground-breaking robotic paving slab cutting process. DACS will produce bespoke paving units; cut to measure, in a controlled environment to minimise on-site disruption and accelerate Britain's urban regeneration.

The current practice of cutting paving in town centres and other public places to fit within set boundaries or around street furniture, is normally performed manually on site. A process which can be noisy and disruptive. To reduce this on-site disruption and environmental impacts, the DACS process will automate the manufacture of bespoke paving units; tailor made to fit unique ground conditions.

DACS will modernise paving operations to deliver a safer and more sustainable process along with a significant improvement in productivity. For a typical year-long scheme this could cut disruption by almost a month.

DACS will take scan data from areas to be paved and automatically create robot cutting paths. Artificial intelligence will be employed to assess the available slabs and offcuts to choose the optimal piece to maximise material usage and minimise waste.

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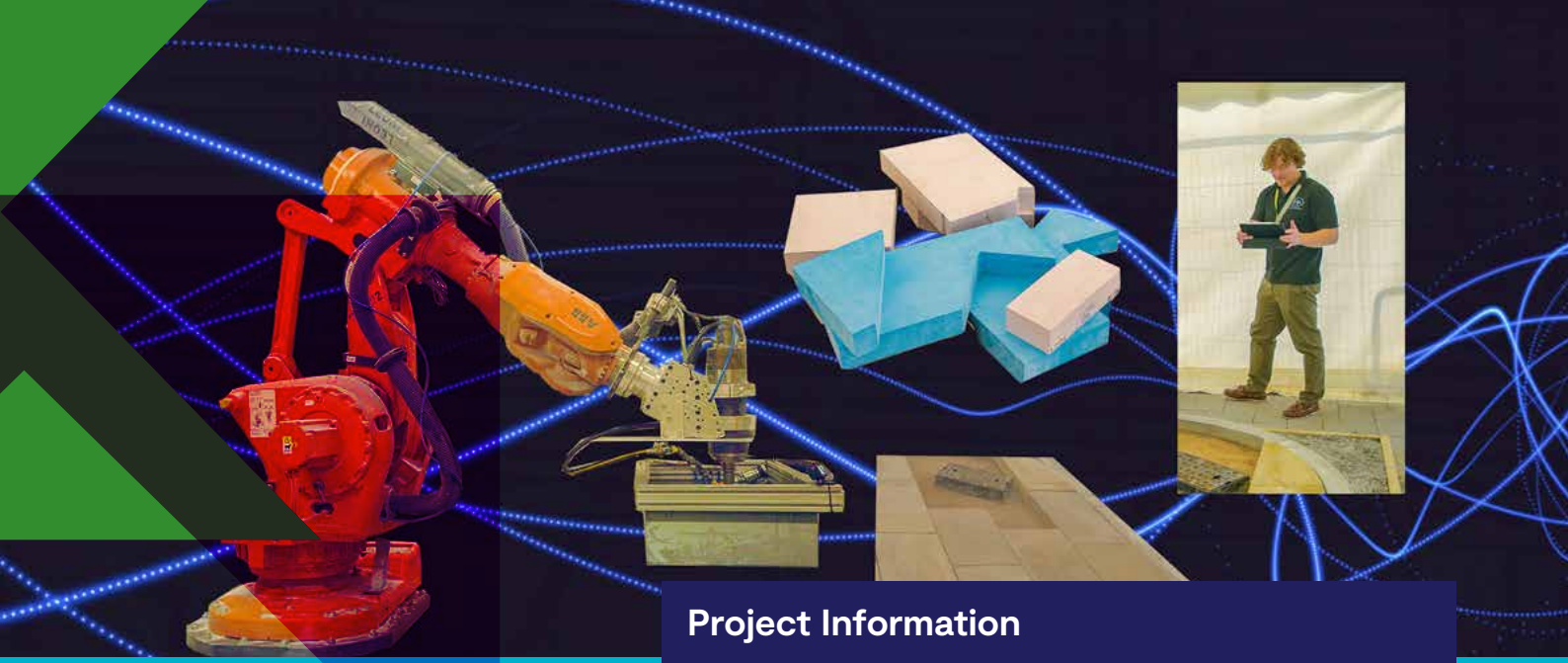
https://www.eurovia.co.uk

EUROVIA UK | The University Of Sheffield. AMRC Advanced Manufacturing Research Centre | Loop Technology



Project Information

Project lead: Eurovia Infrastructure Limited
Collaborators: Loop Technology Limited, The University of Sheffield Advanced Manufacturing Research Centre
Project type: Collaborative research and development
Total project cost: £497,474
Grant award: £373,031
Start date: March 2021
End date: March 2022

What is the value or size of the addressable market?

Infrastructure makes up 12.5% of the UK construction industry and requires ~11 million sqm of paving annually. The medium-sized (£1–£30m), publicly-funded, urban-realm improvement market in the UK is worth ~£100m per annum.

Growth is expected to continue with upcoming projects including HS2 station infrastructure, and the escalating concerns revolving around climate change, and environmental legislation to reduce automotive impact on air quality.

The end users for DACS are initially expected to be Tier One or Tier Two contractors engaged in public realm improvements, with future expansion into other construction trades such as tiling, floor-laying, plasterboard, and drainage.

Project Plan / Progress

This first year, supported by Innovate UK has taken the project from a suggestion to a working prototype of the solution including development of software, scanning and cutting elements.

This first stage has delivered a demonstration robot cell in a factory setting along with a mobile app and back-end processing and database solutions. This will be followed by the development of a deployable product that can be containerised, making DACS accessible anywhere.

Loop Technology has developed a mobile application that automatically identifies and measures the void for which cut pieces are required then takes the paving design and automatically generates the three-dimensional cutting list.

The generated cutting paths are then used to produce the finished slabs through a robotic cutting processes. Various scanners and technology solutions have been trialled and a demonstration of the final solution will be given in Spring 2022.

The AMRC have performed cutting trials, designed the cutting solution and have developed the logistics and part marking solution, as well as completed robot cell designs and a nesting solution to optimise material use and reduce waste.

Unmanned Coastal Air Bridge

Project Information

Project lead: UAVAID Limited
Project type: Research and development
Total project cost: £99,205
Grant award: £69,444
Start date: October 2021
End date: February 2022

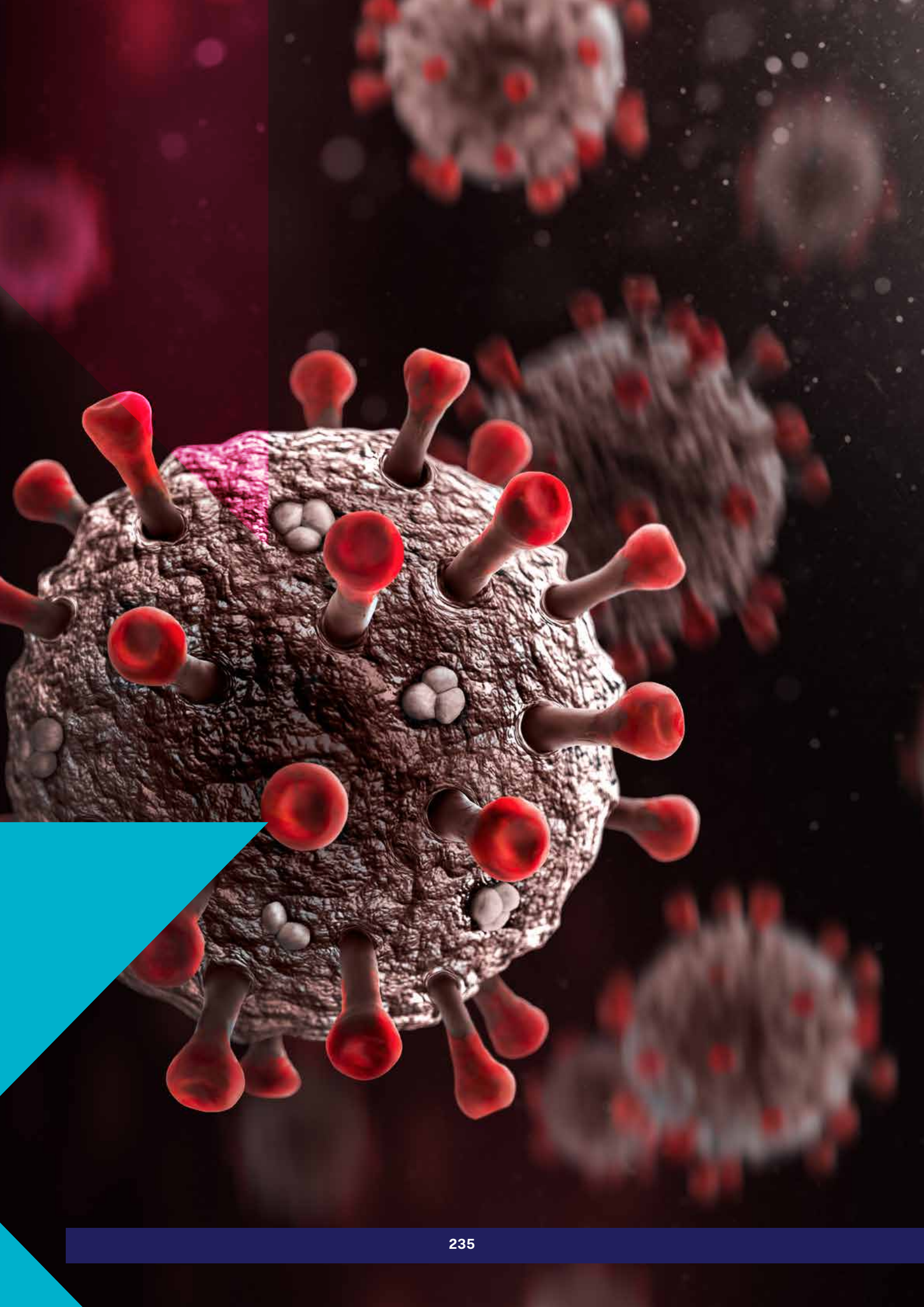
Executive Summary

The Unmanned Coastal Air Bridge (UCAB) project is a feasibility evaluation to assess the practicality of establishing a UAV (unmanned aerial vehicle) drone 'air-bridge' between the Scottish mainland and the Isle of Lewis, and by extension further into the Western Isles, for rapid and flexible deliveries of healthcare supplies. The use of UAV's presents an attractive option for logistics in areas of challenging geography as they are able to fly over and bypass the restrictions of the terrain. However, the 60km+ span (each way) of coastal water between the mainland and Western Isles presents significant contextual challenges for UAV technologies. This project will evaluate the feasibility of using a repurposed long-range drone for use in this application, supporting island communities and building long term sustainable resilience.

COVID-19 Fast Start

The projects in COVID-19 Fast-start include 16 projects, totalling £800k of investment, that were successfully funded as part of a wider effort to support the UK's next generation of innovative businesses in response to impact from the global pandemic. This was awarded as a part of a larger £40 million of government funding.

These high impact, short duration projects included facilitating development of applications in disinfection, medical logistics, food handling and teleoperation.



ADR – Autonomous Disinfection Robots

Project Information

Project lead: Q-Bot Limited
Project type: Research and development
Grant award: £48,922
Start date: August 2020
End date: January 2021

Executive Summary

Q-Bot is the UK leader in applying robotics in construction and hazardous environments. Q-Bot's robotic system received British Board of Agrément (BBA) accreditation for an approved construction process in 2017, a first in the UK and, indeed, Europe. Q-Bot's robots are now used on projects across the UK making sites safer and more efficient. Q-Bot's vision is to adapt this robust robotic platform to keep UK's public spaces clean and free from infection.

The aim for this project is to enable regular and effective disinfection of surfaces in hospitals, care homes, shops and other public places (such as gyms for example after the lock down). This will not only help to limit the spread of infection by increasing the regularity of treatment but also remove people from the harm's way. Q-Bot envisages disinfecting robots autonomously roaming between hospital wards or supermarket isles, scanning and mapping the spaces around them, assessing the time elapsed since the previous deep clean or analysing the footfall to prioritise next targets.

During the immediate project Q-Bot will scope, research and design the required alterations to the robotic and mapping platform, research infection, breath residue and touch detection methods, research relevant disinfectants and their methods of application (and unintended consequences) in detail and simulate application methods on surfaces (including detailed CFD simulations of air/droplet movement of treatment, spray or jet application). Q-Bot will also digitally prototype, specify components and cost the above options integrated into a new robotic disinfecting system, together with researching the economic and investment case to ensure successful commercialisation post-project.

An autonomous, modular robotic platform, enabling disinfection and telepresence in a care setting

Project Information

Project lead: Ice Nine Limited
Project type: Research and development
Grant award: £44,176
Start date: July 2020
End date: November 2020

Executive Summary

This Innovate UK project enables Ice Nine to focus on developing an autonomous, modular robotic platform to be used primarily in hospitals and care settings. Initially developed payloads include a disinfectant device and a telepresence device. This would allow an empty room to be disinfected by an autonomous robotic platform, repeatably and reliably, without the need for personnel to physically move a disinfectant device around a room. The robotic platform includes obstacle avoidance and safety features to avoid damage to equipment, humans and itself.

A telepresence device will free up valuable care worker time and improve safety in quarantine zones. By offering "communication on wheels", it would be possible for the robotic platform to navigate to a patients bed, call family or friends and be there as long as is required. Alternatively, a nurse or doctor could complete a generalised check of a quarantine area without PPE. This would by no means act as a replacement for human-to-human care, but may offer a reduction in PPE waste and reduced likelihood of care workers becoming sick.

These are just the initial payload devices. The platform will enable iterative improvement to the functionality of the platform through design of new payloads. It would be possible to offer laundry basket, patient entertainment or emergency medical equipment to the base robotic platform, expanding its functionality, reducing electronic waste and improving cost-effectiveness.

COVID-19 has taken a lot of people by surprise and we need to act fast to help as many people as possible. We also need to look to the future, to reduce the likelihood of anything like this happening again. Ice Nine hopes, that by developing robotic systems for care settings, we can improve the chances of recovery for patients and reduce the burden on the front-life staff that everyone depends on.

Autonomous Cargo Aerial Last Mile Resupply (A CALM-R)

Project Information

Project lead: Hybrid Drones Limited
Project type: Research and development
Grant award: £49,655
Start date: July 2020
End date: November 2020

Executive Summary

The problem:
The current Covid-19 pandemic has highlighted the need for rapid drone delivery of large amounts of medicine/food to remote households/communities who have symptoms, and therefore should not leave their homes. There is also a need to supply hospitals and other the medical staff with large amounts of personal protective equipment (PPE), with 742 million pieces of protective gear delivered to date.

The government has stated that it has been a logistical problem and a 'enormous challenge' to deliver to 58,000 organisations, including pharmacies, care homes, GP surgeries and hospitals.

This crisis has highlighted the inability of supermarket home delivery methods to cope with high demand. Tesco has recently announced that up to 90% of shopping will still need to be conducted in person, in store. Our innovative solution of a flexible, compact and reconfigurable heavy lift hybrid drone, will tackle the new or emerging societal or industry needs in the wake of the Covid-19 pandemic, within the subject area of couriers and delivery (rural and/or city based).

Our solution:
Hybrid Drones Ltd are developing a game changing solution, which involves a novel combination of jet turbines and rotors. Our target is to be able to autonomously carry a maximum payload of 100 kg (with a volume of up to one cubic metre), over a distance of 10 km, within 10 minutes. The current generation of fully electric drone delivery systems are typically limited to 1–2 kg of payload and an endurance of 20 minutes. Our flexible jet turbine-electric hybrid design also enables the carriage of smaller payloads out to a range of 32 km.

The wider context:
In a wider context, such a system could have wide applications in disaster relief. From 1992 to 2014, floods, droughts and storms affected 4.2 billion people (95% of all people affected by disasters) and caused US$1.3 trillion worth of damage. The first quarter of 2020 has seen both wild fires in Australia and floods in the UK, in addition to the Coronavirus impact.

Organisations such as the Department for International Development (DFID) in the UK, and the European Commission (Affordable High-Tech for Humanitarian Aid), are just starting the reap the benefits of using drones for disaster relief.

By 2050, flood damage in the world's coastal cities is expected to reach $1 trillion a year, as sea levels rise and global warming triggers new extremes of heat, windstorms and rain.

Autonomous Mobile Irradiation Robot (AMIR)

Project Information

Project lead: Peacock Technology Limited
Project type: Research and development
Grant award: £50,000
Start date: August 2020
End date: March 2021

Executive Summary

This project will create a mobile robot that will use ultraviolet light for rapid disinfection of items that are placed inside it. It will be able to autonomously self-navigate itself around a building and will be "on call" to arrive at a specific location on demand to perform disinfection services. Alternatively, it could act as a delivery robot performing disinfection whilst en route. Its capabilities will include regular and reliable disinfection of PPE such as face masks, face shields and goggles. The robot will be suitable for deployment in hospitals to enable staff to regularly disinfect their PPE to make sure their protective performance is maintained and to reduce the extent to which replacements are necessary. It will also be suitable for the disinfection of other equipment such as mobile phones, or could be deployed for the disinfection and delivery of medical equipment or documents.

Developing a novel web platform for remote control and communication with industrial robots

Project Information

Project lead: E-Nano Limited
Project type: Research and development
Grant award: £49,900
Start date: August 2020
End date: January 2021

Executive Summary

According to a new Ellen MacArthur Foundation report launched at the World Economic Forum "at least 8 million tonnes of plastics leak into the ocean" – which is equivalent to dumping the contents of one garbage truck into the ocean every minute. If no action is taken, this is expected to increase to two per minute by 2030 and four per minute by 2050.

Simultaneously, in what appears to be unrelated, industrial robots are on the rise and 5G is being deployed in the UK in the crucial context of industrial automation.

At E-Nano, we are currently developing OSCAR (Optimized Smart 5G-Controlled AI Robot), our novel 5G-enabled robot platform that can be controlled remotely. The two robot versions we developed so far aim to: clean rivers, lakes and oceans and disinfect closed environments with UV lighting. We intend to help NGOs, (local) governments and industries address the lack of manpower that is needed to clean our environment.

This 6-month project will focus on developing and delivering a white label MVP of our online control and communication platform to allow industries that have been severely impacted and/or permanently disrupted by unforeseen events, such as the Covid-19 outbreak, to continue operations by controlling their semi-automated production lines through the cloud.

While this platform will be used internally to control the PLC that is used in OSCAR, it will also work with any other compatible hardware allowing operators from various industries to work remotely.

Fugro Marine Remote Operations Centre

Project Information

Project lead: Fugro GB (North) Marine Limited
Project type: Research and development
Grant award: £49,832
Start date: July 2020
End date: September 2020

Executive Summary

Fugro in Aberdeen are a marine geodata services provider to the EUAF (Europe & Africa) energy markets, predominantly Renewables and Oil & Gas. Two business lines, which have a subset of service lines, operate from Aberdeen:

- Marine Site Characterisation
- Marine Asset Integrity

Fugro has identified delivering its services via remote or autonomous operations as its long-term strategy and has currently executed over 150,000 hours globally to date.

To support Fugro's remote and autonomous operations strategy, significant investment into the Aberdeen ROC (Remote Operations Centre) has been made. The first ROC room was commissioned in 2019 and the ROC is fully functional. This enables people to be removed from the offshore environment and sited in the dedicated Aberdeen ROC without compromising on quality of service. It also facilitates fully autonomous operations.

Many projects in the UK energy sector have been postponed due to the COVID-19 restrictions. Other projects are proceeding, but with major implications. These implications include:

- Personnel being unable to mobilise or return home
- 7-day pre and post mobilisation quarantines
- Increased project costs
- Inability of UK personnel to travel and losing work

Using Fugro's ROC in Aberdeen brings many benefits to the UK economy, including:

- Wellbeing
- Exportable technology and processes
- Allowing operations to be carried-out anywhere in the world from Aberdeen
- Improving diversity (no need for offshore medicals etc)
- Supporting world leading technology
- Supporting the UK commitment to Climate Change Act 2008 and Maritime 2050

Using remote Fugro services enables removal of all Fugro & 3rd party personnel from an offshore Vessel and relocated into the ROC for specific operations. Other operations provide reductions of PoB (Personnel on Board) by between 29% and 75%. Whilst remote operations will become the norm in the future, giving Client's the opportunity to execute remote operations now will enable projects to potentially proceed when they would otherwise be cancelled due to COVID-19.

Fugro have received increased enquiries about the ROC since the COVID-19 restrictions, but it still relatively unknown. The purpose of the project is to ensure all potential Clients are aware of the ROC and how it can benefit them. This is especially relevant for Client's struggling with crewing their Vessels or the safety and financial implications of having to quarantine multiple people before and after crew changes. Remote Operations will also help reduce the possibility of transmitting COVID-19 onboard.

General Purpose, Form Agnostic, Robot oversight and Tele-operation

Project Information

Project lead: Reach Industries Limited
Project type: Research and development
Grant award: £49,962
Start date: July 2020
End date: December 2020

Executive Summary

We are creating cloud-based back-end tools and services that cover things from secure access and authentication to customer facing dashboard, so that Robotics companies can quickly and securely get their robots online and better serve their customers, meaning they can focus on product differentiation and get to market faster.

Low cost and fully integrated Robotic fruit & vegetable handling & packing line for distributors

Project Information

Project lead: Wootzano Limited
Project type: Research and development
Grant award: £50,000
Start date: July 2020
End date: December 2020

Executive Summary

UK consumers can be found scavenging amongst the boxes and empty shelves of the produce aisle. In the fields, fresh fruit and veg lay to waste. The agriculture industry heavily relied on seasonal overseas workers to bring in the crops but with Brexit, followed by a nationwide lockdown, workers are scarce.

As COVID-19 reaches over 1 million worldwide with no foreseeable end, long term measures need to be taken to ensure hunger doesn't add to the nation's concerns. Rising to the challenge are engineers in the field of Artificial Intelligence.

Although not new to the industry, AI has enhanced the production of crops from collecting analytical data, sanitation, packaging and delivery. This allows farmers to do a lot more with a lot less. With labour shortages during these uncertain times, rapid development is needed to ensure the food security is maintained.

British fruit and vegetable packaging facilities are struggling and the answer lies in the rapid integration of robotic systems to pick and package fresh produce. At Wootzano, huge strides have been taken in a relatively short space of time. With the use of our new innovative Wootzkin technology, fruit and vegetable packaging facilities can reduce their reliance on manual human labour to do the dexterous jobs and can have more sustained and reliable robotic systems doing the job for them.

Millions of pounds are spent each year by these companies just to recruit temporary labour and even then they struggle to meet the demand. Using Wootzkin, a robot can feel and sense like humans do with their own skin. One robotic system can potentially replace at least 1 human worker and an expected ROI is around 1 year taking into account the increased productivity and more reliable packaging.

Despite the lack of workers, companies are not only able to meet demands, but also adjust to the increased pressure brought on the epidemic.

Minimal Infrastructure Robotic Delivery System for Non-Contact Logistics

Project Information

Project lead: Toshiba Research Europe Limited
Project type: Research and development
Grant award: £49,964
Start date: August 2020
End date: March 2021

Executive Summary

Minimal-Infrastructure Robotic Delivery System for Non-Contact Logistics (MILo-RDS) will develop a fleet of logistics robots capable of autonomously coordinating delivery of vital supplies in ad-hoc arenas, such as the Nightingale hospitals, quickly established in response to the COVID-19 pandemic. The rapidly deployed nature of such spaces necessitates the need for a solution that doesn't rely on the cumbersome and time-consuming installation of communications infrastructure, and can facilitate the remote delivery of items, such as food and medicines. This both reduces the risk of exposure to frontline staff and helps protect patients. This project will draw for cutting-edge engineering research to develop a prototype solution for minimal infrastructure deployment, non-contact autonomous delivery of supplies to multiple fixed destinations, and disinfection of robotic agents.

Multi-purpose dexterity tele-operation robot for remote working and healthcare

Project Information

Project lead: Extend Robotics Limited
Project type: Research and development
Grant award: £49,379
Start date: August 2020
End date: January 2021

Executive Summary

The COVID-19 pandemic presents a unique challenge for society and industry; how to protect lives, open up the economy and ensure a functioning healthcare sector whilst social distancing and restrictions on travel remain. These challenges come in the form of a potential significant drop in GDP, threats to UK infrastructure due to lack of in-situ professionals for critical inspection and maintenance tasks, difficulties maintaining social distance in physical work environments and staff shortage due to self-isolating healthcare professionals.

Extend Robotics' (ER) aim is to develop, scale and commercialize a cloud-based, teleoperated, highly dexterous robotic system which will extend remote working into the physical domain. The system will offer a highly effective universal solution at an affordable price point allowing massive adoption across a wide range of sectors during the crisis. This will result in improved safety and operating efficiencies that will be carried forward into normal operations.

ER's remotely operated robotic system offers:

- User Hardware – Low-cost scalable solution, using consumer Virtual Reality (VR) equipment
- User Interface – Intuitive and immersive user interface for non-expert users to operate offering "real world" experience
- Robotic Manipulator – Dexterous (6 degrees of movement) and robust teleoperation by augmenting human intelligence
- Remote Working – Users can operate from home over internet cloud servers

The aim of the system is to aid the user and augment human capability, not replace human interaction. This is critical in maintaining efficient working practices. The current concept prototype garnered interest in the telecom infrastructure maintenance sector with an ongoing development plan which lead to seed funding in April 2020. The management team has strong connections with the utility and telecommunications sector, but many other use cases exist such as:

- Allowing immunosuppressed healthcare professionals to remotely perform tasks from home preventing contamination
- Self-isolating inspection and maintenance professionals providing "hands-on expertise" to critical infrastructure sites

This grant will be used to improve the core technology, seek trials and business cases in the healthcare sector; a case study that will drive a larger scale implementation for a mass production system in multiple applications.

No Human Contact Deliveries Via Semi-Autonomous Vehicles

Project Information

Project lead: Academy of Robotics Limited
Project type: Research and development
Grant award: £49,881
Start date: July 2020
End date: December 2020

Executive Summary

Our project proposal aims to perform semi-autonomous last-mile delivery in which medicines can be delivered from the pharmacy to care homes without human contact, simultaneously laying the groundwork for future autonomous delivery. This project will be run by the Academy of Robotics Ltd and in partnership with Eurovia UK Ltd.

Over the last four years, the Academy of Robotics Ltd has been working on a way to automate last-mile delivery and as a result, we built Kar-go. Kar-go is an electric autonomous last-mile delivery vehicle able to pick up a package and then take it to any target address. In summer 2019, we unveiled Kar-go, the first of its kind, UK-made, self-driving electric vehicle. Able to compete with US-owned systems such as Starship, Google, and Tesla's autonomous systems, the difference with Kar-go is that it was designed specifically for last-mile delivery in residential areas in the UK.

Up until Jan 2020, we had reached the stage of planning our first series of live trials in 2020 with a couple of corporate partners until COVID struck and temporarily halted everything. We aim to use this cutting edge technology to help in one of the hardest-hit areas being care homes.

The operational capabilities of essential services and ensuring their maintenance is vital. Not just during the COVID pandemic but for all future potential pandemics and scenarios that require proactive mitigation solutions. As such, ensuring that they can remain active in situations requires an innovative solution to supply chains and the delivery industry that this project intends to provide. Prescription and medical delivery is our focal delivery type for this project. Beyond this project, however, once no-human-contact is demonstrated as a viable delivery method. There is a grand scope for further application to alternative essential services and a constantly expanding digital infrastructure to support the foundation of semi-autonomous and full autonomous last-mile delivery.

Robotic sanitising Care Homes and Health Care Facilities

Project Information

Project lead: The Perfect Little Company Limited
Project type: Research and development
Grant award: £46,555
Start date: July 2020
End date: March 2021

Executive Summary

This project will deploy an existing and tested technology to the front line of the fight against COVID 19, namely care homes.

We are planning to run a live test in 20 care homes to refine the cleaning processes to maximise the use of robotic vacuum cleaning to reduce human contact between cleaning staff and care home residents and staff while improving cleanliness.

We will also test the effectiveness of the use of our mopping tool to disinfect and reduce COVID 19 prevalence within care homes, this without the need for extra staffing and costs.

The project will last four months and will be in four phases:

- Pre-deployment and Mobilisation 2 to 3 weeks
- Deployment 2 weeks
- Implementation and Testing 10 weeks
- Reporting 2 weeks

We will have initial findings after about 6 to 8 weeks from the start of the project.

The project in itself will improve cleanliness in 20 care homes in Oxfordshire and will test both cost-effectiveness and clinical effectiveness of the deployment of robotic vacuum cleaners in care homes.

At the end of the project, we will have delivered:

- A clear protocol of how to use robotic vacuum cleaners to reduce human interaction between cleaners and residents and improve social distancing
- Measure the effectiveness of using robotic vacuum cleaners to reduce dust and parasites in care homes compared to current methods
- A clear protocol to use mopping tool to disinfect and minimise pathogen, particularly COVID 19

Skyfarer – Autonomous medical logistics by drones

Project Information

Project lead: Skyfarer Limited
Project type: Research and development
Grant award: £49,943
Start date: July 2020
End date: December 2020

Executive Summary

Imagine a world of autonomous Just In Time delivery with no impact on road congestion and no increase in fossil fuel emissions. The kind of delivery that can be carried out by a drone, fast and direct, applicable in any logistical application, from medicine to food, from organs to mobile phones. We have the technology to do this today.

Although organisations, NGOs, charities and companies see great value in using drones for logistics, they don't yet have access. They can go out and buy a drone, but they can't fly it commercially for logistical operations in the UK. For this, not only does the drone need to be understood on a technical level, but it also requires specific systems and regulatory approval to operate within UK airspace commercially and autonomously. We have the solution, and with the support of this funding, it will be robust, simple, and accessible.

Skyfarer's solution is a system of systems, neatly packaged into a robust operational process, leveraging the expertise and technology from our technical partners. It is a platform that allows any organisation to access an ecosystem of drones, to then be used in diverse logistical operations, safely, autonomously and cost effectively with very low capital investment. With this service, we can distribute medication, blood, test kits, food, digital devices and much more within a Just In Time operational framework with very low infrastructure.

This project is a prerequisite for the commercialisation and utilisation of this system. By obtaining initial approval from the CAA to conduct a short-range flight demonstration, we will begin to showcase the capabilities that Skyfarer and our partners have amassed with drones for logistics. Along with a feasibility study and scoping exercise, this will validate and enable the next phase of work with the creation of a drone corridor, allowing us to develop and implement autonomous UAV logistics services to deliver essential supplies like medicine, vaccines or food without the need for a person driving. This will reduce trips that would usually require travel and face to face contact in congested areas. Long term, it provides a blueprint for UAV based logistics service to be tested and implemented in other areas of the UK (and abroad), paving the way for widespread adoption of the technology, and positioning the UK at the forefront of an exciting emerging industry that's poised for growth.

Smart Robotics for Crisis Resilient Food Fulfilment Centre Operations

Project Information

Project lead: Smartia Limited
Project type: Research and development
Grant award: £49,690
Start date: August 2020
End date: January 2021

Executive Summary

The food and groceries retail industry has been overwhelmed during the current COVID-19 epidemic and fulfilling customer orders in a timely and safe manner has been particularly challenging.

Online shopping has seen a 74% increase during this period, significantly increasing the workload at fulfilment centres around the country. One of the main reasons is that the bulk of the labour is still largely done by humans and the adoption of automation and robotics is low.

Robots are proficient at specific, repeatable tasks for which they are programmed. To get these systems to do something else takes expensive, time-consuming reprogramming and requires a series of complex, sophisticated software and hardware solutions.

Smartia are experts in industrial intelligence and automation, and aim to build a cost effective and scalable demonstrator for the food retail industry in this project. This could increase fulfilment centres throughput by 20% thus reducing delivery times, through the use of robotics and AI.

In the short term the project will benefit backend activity at retail fulfilment centres but the technology could be used across other industries like food processing and advanced manufacturing in the medium to long term.

The specific innovation consists of the integration of an object detection AI model with a robotic system using Smartia's intelligent platform MAIO, for on-demand pick-and-place tasks for automated food and groceries order preparation.

The solution proposed offers a much higher level of customisation and versatility than other solutions and will allow incremental abilities to be added to the automated system.

The project will benefit from more than 15 man-years of research and development in MAIO, Smartia's industrial intelligence platform.

Smartia has complete freedom to develop, integrate and market the solution that will be developed and has access to the physical systems required to build the demonstrator.

The UK food and groceries retail market worth £40billion/year. The market for the innovation is estimated to be £100million/year based on 1000 fulfilment centres in the UK. Globally the opportunity is estimated at £5billion/year.

The route to market would be via our Software as a Service business model, with the capabilities available to all customers. The hardware components of the solution would be offered through partner companies such as Lenovo and Automata Technologies.

Smartia would leverage its channel partnership with Lenovo to grow the market where it benefits from strong relationships with many large retailers including John Lewis (Waitrose) and Asda.

UAV Crowd monitoring

Project Information

Project lead: Level Five Supplies Limited
Project type: Research and development
Grant award: £49,772
Start date: August 2020
End date: October 2020

Executive Summary

The UAV Crowd monitoring tool measures the location of people in open spaces, covering up to 30,000 sq m (line of sight) per system, be they tourist destinations, construction sites or any space in which social distancing should be observed but could continue to operate safely. If social distancing advice is not being followed, a drone will be automatically deployed to the group and an automatic audio message played via loudspeaker to encourage people to move to a safe distance. The project aims to allow for these businesses, which are important local employers and also valuable for wellbeing, to stage a degree of return to operating in line with public health guidance.

VR collaborative robotics, enabling remote physical work

Project Information

Project lead: Titan Reality Limited
Project type: Research and development
Grant award: £50,000
Start date: August 2020
End date: March 2021

Executive Summary

The Covid-19 crisis has put over two billion people in lockdown, revealing unpreparedness for businesses to adapt to social distancing rules and physical work disruption. While some office work can be done from home – pressing everyone into video-conferencing – the impossibility to achieve physical tasks remotely is an immense stumbling block. The Manufacturing industry employs 2.7m people, generating over £380Bn in the UK alone. From manufacturing, engineering, scientific research, education to healthcare, many professionals wish they could achieve physical work remotely.

Titan Reality's key vision and motivation is to help these many industries to get back to work safely, and become more flexible and resilient with the fast adoption of a remote collaborative robotics solution upskilling their workforce. With years of leading-edge work in this field, Titan Reality can build an affordable solution using VR and natural hand motion to remotely interact with robotics and achieve physical tasks in collaboration with the workforce. The solution is human-centric and interactive, empowering the user and remote teamwork.

Our VR solution uses natural motor skills and senses we use every day with high precision and makes the robotic arm or cobot reproduce those movements instantly. Hands motion tracking ensures programming is based on teaching the robot practical skills, which are very difficult to program with code. Our virtual robotics controller handles instant translation into machine language. VR enables easy training with expected results. Feedback sensors and IP cameras ensure safe remote operation of the robot.

Agile, fast, adaptable and affordable the VR collaborative robotics solution is the "video-conferencing" equivalent, physical businesses desperately need.

Innovate UK

Engineering and Physical Sciences Research Council

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