CRADLE

CENTRE FOR ROBOTIC AUTONOMY IN DEMANDING AND LONG-LASTING ENVIRONMENTS

ANNUAL REPORT

YEAR TWO
2024-2025

A Prosperity Partnership between

MANCHESTER 1824
The University of Manchester

amentum

THE PAST **12 MONTHS**

As we complete the second year of the CRADLE Prosperity Partnership, we reflect on the significant progress the project has made in advancing Robotics and Autonomous Systems for demanding and long-lasting environments.

The past 12 months has seen the core CRADLE team almost double in size, as well as the expansion of our affiliated talent networks within both The University of Manchester and Amentum. We've also seen the mutual exchange of team members between the two organisations, accelerating the transfer of knowledge between academia and industry.

Our programme of fundamental research continues at pace, informed by expanding knowledge of the complex challenges being faced by industry across multiple sectors. We have successfully translated research into the demonstration of solutions by deploying several robotic platforms in real-world environments. These have delivered considerable impact which has led to the project securing its first adjacent funding.

As we reflect on these achievements, we are excited to see where the next 12 months may take us and remain committed to shaping the next phase of Robotics and Autonomous Systems in the UK and beyond.

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ABOUT THE **PARTNERSHIP**

AMENTUM

Amentum, the industry partner in CRADLE, is a global, advanced engineering and innovative technology solutions company, with over 50 years' experience of deploying robotic and autonomous systems in hazardous and demanding environments to solve complex challenges. Acting as a systems integrator, but also with the ability to design, build, test and deploy bespoke robotic hardware and software systems, we remove humans from harm in sectors including nuclear, space, defence, and critical infrastructure. Employing more than 53,000 people across 80 countries, with 6,000 of these in the UK, our people apply undaunted curiosity, relentless ambition, and boundless imagination to challenge convention and drive progress.

"I'm so impressed with the progress that has been made by the CRADLE team over the past 12 months. The partnership has not only accelerated growth of Amentum's work in the field of Robotics and Autonomous Systems, but also continues to have genuine positive impact on our clients across multiple sectors.

Industry Engagement Activities (IdEAs) have continued at pace, strengthening relationships established in CRADLE's first year, but also initiating many more. Through this process, this year has seen adjacent revenue- and impact-generating projects emerge from CRADLE, in which ground-breaking academic research is being applied to solve real-world industry challenges.

I'm delighted to see the transfer of talent between Amentum and The University of Manchester, accelerating the transfer of knowledge between our two organisations. This has been enhanced by securing adjacent funding via the IAA scheme, from which we look forward to welcoming a postdoctoral researcher into our organisation for the next 12 months.

I'm excited to see where the next year will take us!"

Helen Simms
Vice President of Technology Consulting and Innovation

amentum

THE UNIVERSITY OF MANCHESTER

The University of Manchester is one of the UK's largest single-site universities, renowned for its academic excellence and vibrant student community. With 26 Nobel Prize winners and 93% of its research rated as 'world-leading' or 'internationally excellent' by the Research Excellence Framework, the university is at the forefront of innovation. The Faculty of Science and Engineering houses the Centre for Robotics and Artificial Intelligence, which brings together over 100 researchers from engineering, computing, and social sciences. A key focus of the Centre is responsibly developing advanced robotic systems for societal, economic and environmental benefit. Looking ahead, the university aims to diversify its robotics research into different sectors to address a wider range of societal challenges.

MANCHESTER 1824
The University of Manchester

"As a new arrival to The University of Manchester as Vice President and Dean of the Faculty of Science and Engineering I am extremely proud to have the honour of hosting the truly impressive CRADLE partnership.

This October, The University of Manchester launched its new strategy as a guiding path over the next decade. The CRADLE partnership embodies many of the elements of that strategy: research excellence with impact, a powerhouse of innovation, and partner enabled learning. We know that working with industrial and international collaborators through critical mass initiatives such as a Prosperity Partnership, we can ensure that the outstanding fundamental research which is produced by colleagues has the best chance of aligning with, and contributing to, societal and economic priorities. The University team's leadership of the national RAS network is also an important route to building networks of critical mass capability across the UK, as well as ensuring that we continue to focus on building diverse teams with the capabilities to solve real world problems.

A real strength of the CRADLE team is, alongside engagement with industry, a close alignment with Government policy. Robotics and Autonomous Systems are changing the way that we live and work, and partnership between scientists, engineers and Government policy makers is vital if we are to balance the considerations of safety, security, responsibility and economic opportunity as we see new technologies being deployed in our work and lives.

I am very excited to see what the next twelve months will bring. For me, CRADLE embodies the headline of the Manchester 2035 strategy. From Manchester, for the World."

Professor Sarah Sharples FREng
Vice-President and Dean of the Faculty of Science and Engineering

MEET **THE TEAM**

LEADERSHIP AND MANAGEMENT

Duncan Steel
Industry Director

Michael Fisher
Academic Director

James Kell
Industry Co-Director

Simon Watson
Academic
Co-Director

Barry Lennox
Academic
Co-Director

Kayleigh Jackson
Industry Project Manager, Delivery and Exploitation

Paul Baniqued
Academic and Technical Project Manager

Craig Burton
Industry Project Manager

Michael Oates
Industry R&D Manager

Stella Flint
Project Administrator

WORK PACKAGE LEADS

Marti Morta-Garriga
Components (WP1)
Industry Lead

Bruno Adorno
Components (WP1)
Academic Lead

John Brotherhood
Architectures (WP2)
Industry Lead

Michael Fisher
Architectures (WP2)
Academic Lead

Amber Drinkwater
Interactions (WP3)
Industry Lead

Angelo Cangelosi
Interactions (WP3)
Academic Lead

Frederic Wheeler
Assurance (WP4)
Industry Lead

Louise Dennis
Assurance (WP4)
Academic Lead

Matthew Goundry
Demonstrators (WP5)
Industry Lead

Simon Watson
Demonstrators (WP5)
Academic Lead

POSTDOCTORAL RESEARCHERS

Mohamed Atia
Components (WP1)

Yang Song
Components (WP1)

Raynaldio Limarga
Architectures (WP2)

Sen Zheng
Architectures (WP2)
and Interactions (WP3)

Federico Tavella
Interactions (WP3)

Joseph Bolarinwa
Interactions (WP3)

Dhaminda Abeywickrama
Assurance (WP4)
Research Fellow

Yasmeen Rafiq
Assurance (WP4)

Christopher Bishop
Demonstrators (WP5)

Moh Shahid Khan
Demonstrators (WP5)

PHD STUDENTS

Seyonne Leslie-Dalley
Components (WP1)

Joshua Bettles
Components (WP1)

Long Hoang Le
Architectures (WP2)

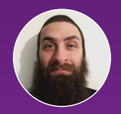
Xinyun Chi
Interactions (WP3)

Matthew Rolph
Interactions (WP3)

Divya Saravanan
Interactions (WP3)

Lewis Wheelhouse
Demonstrators (WP5)

Alexander Morley
Demonstrators (WP5)



Yehoshua Greenhaus
Demonstrators (WP5)

Sharun Arumugam
Demonstrators (WP5)

Toluwani Soboyejo
Demonstrators (WP5)

ACADEMIC AND INDUSTRY COMMUNITY

Murilo Marinho
Components (WP1)
Academic Researcher

Marie Farrell
Architectures (WP2)
Academic Researcher

Clare Dixon
Interactions (WP3)
Academic Investigator

Emily Collins
Interactions (WP3)
Academic Researcher

Sarah Clinch
Interactions (WP3)
Academic Researcher

Harry Newton
Assurance (WP4)
Industry Co-Lead

John Mackey
Assurance (WP4)
Industry Co-Lead

Kate Smith
Demonstrators (WP5)
Academic Researcher

Kieran Wood
Demonstrators (WP5)
Academic Researcher

Pawel Ladosz
Demonstrators (WP5)
Academic Researcher

Andrew Weightman
Demonstrators (WP5)
Academic Researcher

Keir Groves
Demonstrators (WP5)
Industry Robotics Specialist

TECHNICAL SUPPORT

Danish Khan
Robotics Technical Specialist

Kwai-Wa Tse
Robotics Software Technical Specialist

THE CRADLE TEAM
GROWING STRONGER TOGETHER

CRADLE began in July 2023 with 15 members, primarily from the leadership and management team.

As of November 2025, the team has grown to 53, including 10 postdoctoral researchers, 11 PhD students, and 7 project and technical support staff. The centre also benefits from reachback expertise and knowledge shared across the wider academic and industry community, strengthening collaboration and driving innovation in Robotics and Autonomous Systems research.

CRADLE'S **MISSION**

The CRADLE Prosperity Partnership brings together the industrial experience that Amentum has in applied Robotics and Autonomous Systems with the research expertise at The University of Manchester in this field, to create a collaborative research centre that is internationally leading and sustainable in the long term.

Our vision for CRADLE is that it will deliver novel and transformational technology for demanding, dirty and dangerous environments, removing humans from harm, allowing its benefits to be realised across wide sectors of UK markets and beyond.

In accordance with the ambitions of the Engineering and Physical Sciences Research Council (EPSRC), CRADLE demonstrates how business and academia can come together to co-create and co-deliver research and innovation that addresses industry-driven challenges and deliver economic and societal impact.

CRADLE works across multiple sectors, focusing on the identification of common challenges, enabling the transfer of knowledge and technology to enhance efficiency and innovation, to achieve cross-sector impact.

CRADLE INDUSTRIES

- SPACE
- NUCLEAR LIFECYCLE
- URBAN INFRASTRUCTURE
- TRANSPORTATION
- UTILITIES
- ENERGY GENERATION
- OFFSHORE
- PORTS AND MARITIME
- ASSURANCE AND REGULATION
- HEALTHCARE
- CYBER SECURITY
- DISASTER RESPONSE

Image: CRADLE robot deployment inside the Thames Tideway Tunnel – a 25 km super sewer in London. Credit: CRADLE Robotics and AI / Amentum / Tideway

WORK **PACKAGES**

The research programme is structured around five interconnected Work Packages (WPs) to ensure a collaborative and integrated approach to solving complex challenges using Robotics and Autonomous Systems.

Each WP comprises both an academic and industry lead, ensuring that research efforts are not only grounded in scientific rigor but also aligned with real-world industry needs. This structure fosters active collaboration across disciplines, promoting cross-pollination of ideas and solutions. Proactive engagement between WPs ensures that advancements in one area benefit others, leading to more cohesive and robust technological innovations.

The scope of the WPs has been designed to support the development of Robotics and Autonomous Systems across the sectors targeted by CRADLE. These sectors present high risk environments and as such are heavily regulated, requiring advanced robotic systems that can operate safely, securely, consistently, and often interfacing with a human.

Our collaborative WP structure ensures that the technologies developed are not only cutting-edge but also practical and scalable. By having a structured, cross-functional approach, CRADLE is better equipped to produce impactful outcomes, making it a leading force in advancing Robotics and Autonomous Systems for challenging environments globally.

1
COMPONENTS
- Modelling and Control of Complex Robotics Systems
- Risk-Aware Motion Planning and Control
- Robust Sensor Fusion
- Human-Understandable Confidence Metrics

2
ARCHITECTURES
- Architectural Transparency
- System Aware Architectures
- Mechanisms for Robot Collectives

3
INTERACTIONS
- Robots to Humans
- Humans to Robots
- From One to Many

4
ASSURANCE
- Evidence Generation
- Informing Future Standards
- Design for Assurance

5
DEMONSTRATORS
- Requirements and Benchmarking Analysis
- Design Tool Chains
- Simulated Environments
- Cyber-Physical Mission Environments

WORK PACKAGE 1
COMPONENTS

Improving the reliability of subsystems to ensure mission success in resilient robot autonomy.

SUMMARY

WP1 aims to develop reliable robotic system components that are tolerant to faults, self-aware, can provide confidence metrics about their performance, and are transparent to the wider robotic system. Developing these new components will enable safe decision-making and action by higher-level layers of autonomous robotic systems.

KEY HIGHLIGHTS / PROGRESS OVER THE PAST 12 MONTHS

People

Two researchers have joined WP1 in this second year: Yang Song, a PhD researcher coming from the University of Technology in Sydney, recruited as our second PDRA specialised in state estimation, whose research will focus on the robust sensor fusion and human-understandable confidence metrics; and Joshua Bettles, a second year PhD candidate moved from WP5, whose research developing a cobot radiological survey assistant links with the risk-aware motion planning and control theme. Joshua was awarded a NEST Fellowship for a placement in Japan focusing on radiation source localisation using mobile manipulators in high dose and cluttered environments.

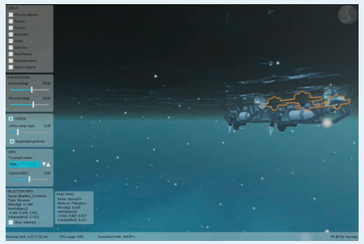
Research

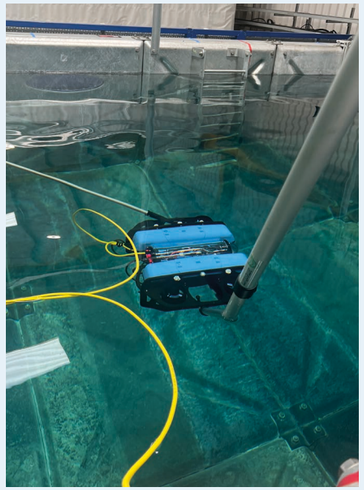
Research has continued developing tools for a holistic control framework using dual quaternion algebra as the mathematical backbone to provide formal guarantees to complex robot systems whilst being agnostic to morphologies.

In the bimanual manipulation using two independent underwater vehicles, PDRA Mohamed Atia finalised and verified the vehicle model collecting a dataset at RAICo1, whilst PhD Seyonne Leslie-Dalley extended the control framework to twist and wrench, and set-up a simulation with hydrodynamics that will enable the next phase of bringing the control framework underwater.

Real-life requirements and experience were gathered by Joshua in a secondment to Sizewell A for the development of a cobot radiological survey assistant. He developed and implemented a sample-based coverage planner and coverage informed control algorithms.

In order to provide state estimation to the framework, Yang Song started the formulation of an Extended Kalman Filter initially for Inertial Measurement Units.





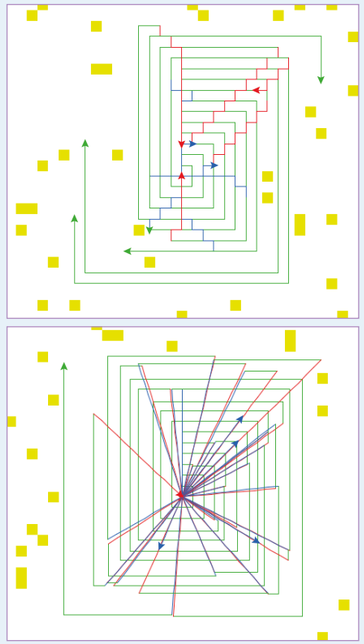
Collaboration

Enhancing collaboration was a WP1 goal this year. This was achieved across multiple WPs, for example by presenting Amentum's robotics architectures and diagrams to WP2, and leading supporting workshops. We have also collaborated on recruitment, workshops, and in a consultancy capacity with WP3 which produced an internal white paper on human factors and user interface guidance for the RAISE project (see page 26)

Non-academic collaboration involved being part of the ESA Space Resource Challenge team, the organisation of training for the Leica BLK-ARC and its point cloud registration software, and an Amentum short study and publication of an internal technical note on "Assessment on development on FPGA".

WORK PACKAGE 2
ARCHITECTURES

Designing flexible and transparent software architectures to enable autonomous robots to be deployed reliably and verifiably in demanding and long-lasting scenarios.



Credit: NetLogo

SUMMARY

In robotic systems, software architectures are often associated with modular components that, together, describe and implement the overall behaviour of the system. WP2 explores modular, transparent, resilient, and verifiable architectures applicable across sectors, targeting both individual and interacting systems.

KEY HIGHLIGHTS / PROGRESS OVER THE PAST 12 MONTHS

People

Ray Limarga (PDRA) joined WP2 in November 2024, Long Le (PhD student) began his studies, on the *Formal Verification of ROS nodes*, in September 2025, and Marie Farrell (Royal Academy of Engineering Research Fellow) increased her involvement in CRADLE over the past year. They joined Sen Zheng (PDRA), who works on the modelling and verification of robot collectives between WP2 and WP3.

Research

Core research concerns how to ensure reliability using agent-based controllers to cope with unexpected issues in dynamic environments (presented at the *First International Conference on Engineering Reliable Autonomous Systems*, 2025) and research transforming remote-controlled robots to reliable, transparent, autonomous robots. WP2 links to most other work-packages and we collaborate, for example, with WP4 on both ethical issues and design patterns and with WP3 on resilient robotic collectives, primarily robot swarms through the joint-WP work of Sen. Ray spent several months in Japan, undertaking a NEST Fellowship collaborating on *Multi-agent Planning for Nuclear Inspection* and we have worked with Brazilian academic collaborators on new foundations for programming of resilient robot teams.

Industry Engagement

Through the IdEAs process we are working on a range of practical studies, particularly in the Space domain. We have particularly become involved in capturing both the formal requirements and heterogeneous verification of space autonomy as exemplified by the collaborations with *Satellite Applications Catapult and Space Solar* (see later). We have also been organising UK workshops on the theme of *Autonomous Space Robotics*.

International

Our team has been involved in international initiatives around the IEEE P7009.1 *Standard for Safety Management of Autonomous and Semi-Autonomous Systems – Interventions in the Event of Anomalous Behavior*, the *Verification of Autonomous Mobile Systems, and Responsible Robotics*. Through our co-chairing of the IEEE Technical Committee on the *Verification of Autonomous* Systems, we are also involved in setting out a roadmap of priorities in this key area.

WORK PACKAGE 3
INTERACTIONS

Enhancing collaboration by addressing challenges in human and robot interactions for trustworthy and effective teamwork.

SUMMARY

WP3 addresses joint work and collaboration between people and autonomous systems including the move from classical dyadic interactions between a human user and a robot, to scenarios with heterogenous teams of multiple people and robots.

KEY HIGHLIGHTS / PROGRESS OVER THE PAST 12 MONTHS

Research

Advancements in *robot-to-robot interactions* were made by Sen Zheng alongside WP2 through swarm robotics, considering a litter picking case and formal verification. Xinyun Chi completed data collection for *human-to-robot* imitation learning research, using paired human-human and human-robot videos. Developments into whether human facial data can be used to infer trust in robots was undertaken by Joseph Bolarinwa. Joseph plans to further validate his model using industrial applications, considering a human supervisor of automated process control systems.

Matthew Rolph continues to develop a robotic model to predict viscosity of liquid samples, where future work will investigate robot-to-human interaction in chemistry applications. Federico Tavella's integration of Visual Language Model (VLM) and Large-Language Model (LLM) into robots tests the model's ability to recognise out of distribution data, such as recognising an incorrect tool.

Industry Engagement

WP3 led a workshop to develop feasible Human-Robot Interactions (HRI) case studies, with cross-WP attendance. We engaged in activities considering the robotic interaction in laboratory environments; a virtual tour of Amentum's laboratories led by Chemistry experts, and continued collaboration with chemistry robotics at the *University of Liverpool*. Joseph and Amber's collaboration with Amentum's Visual Engineering Lab uses a Virtual Control Room and Digital Twins to develop trust research. WP3 engaged in workshops surrounding robot teaming involved in building and inspection of a satellite with Space Solar.

International

Xinyun's *NEST Fellowship* in Japan investigates multi-model visual-tactile perception for human-like manipulation learning. Federico attended a workshop at the *International Conference on Social Robotics + AI*, and visited the *Honda Research Institute EU, Technische Universität Berlin and University of Hamburg*.

WORK PACKAGE 4
ASSURANCE

Generating better evidence and arguments for ethical, safe, and secure design and implementation of Robotics and Autonomous Systems.

SUMMARY

This WP focuses on the assurance challenges that come with autonomous robotic systems. What kind of guarantees do we need? We want guarantees of safety, but also security and potentially ethics. How do we design our systems so we can evidence those guarantees? And how can we curate and present that evidence?

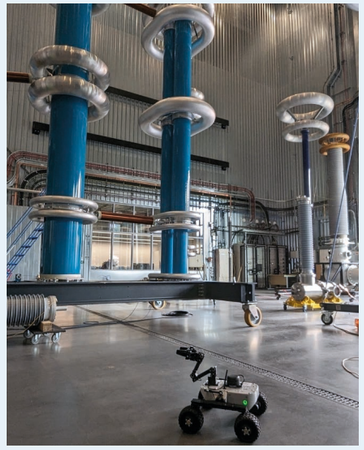
KEY HIGHLIGHTS / PROGRESS OVER THE PAST 12 MONTHS

People

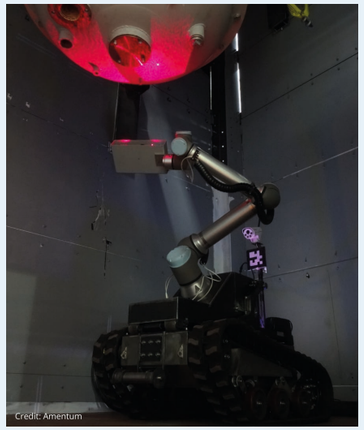
Dr Yasmeen Rafiq joined the team in April. She brought with her expertise in model-based software engineering and verification for robotic systems. She has been working with WPs 1 and 5 on the design and verification of a sewer inspection robot as well as proposing a new case study associated with Robot Assisted Dressing.

Reference Assurance Case

We have made exciting progress towards producing a *reference assurance case* for an autonomous inspection robot. Our vision is that this should present a case for the safe deployment of an inspection robot in a hypothetical nuclear environment. The assurance case will focus particularly on those aspects related to autonomy but with clear placeholders for whether other evidence is needed. This work is informed by the knowledge and experience shared during our year one regulator engagement workshop. The year started with scoping work to define our methodology and approach. This resulted in two publications (at ICSR and AREA 2025).



We had a follow up webinar in July with various regulators reporting on progress and receiving feedback on the proposed approach. Work has now begun in earnest with the aim of producing a draft report in the summer of 2026. Dr Dhaminda Abeywickrama has been leading this research strand.



WORK PACKAGE 5
DEMONSTRATORS

Showcasing next-generation solutions in a range of cyber-physical environments leading to the deployment of robotic platforms in the real world.

SUMMARY

WP5 aims to advance robotic systems to alleviate humans from dangerous and repetitive tasks. Its two main goals are to showcase novel CRADLE robotic technologies and to develop design toolchains which enable intelligent and efficient design of robots. To achieve this, WP5 is creating RoboAlchemy, a groundbreaking software designed to address these challenges effectively.

KEY HIGHLIGHTS / PROGRESS OVER THE PAST 12 MONTHS

RoboAlchemy

RoboAlchemy is one of the core research elements of WP5, and is a collaboration between Amentum, The University of Manchester and UKAEA to develop design toolchains to allow for efficient and intelligent design of robots. It aims to answer the questions "given a robot, what can it do?" and "given a task, what robot do I need?". We have secured funding through the EPSRC Impact Acceleration Account (IAA) scheme for a 12-month position starting January 2026 to develop a software tool which we then plan to spin-in to Amentum as a commercially viable tool.

People

Dr Moh Shahid Khan joined the team in September 2025 to undertake research into advanced digital environments using the Nvidia Omniverse suite of tools. He'll be working on process pipelines to efficiently develop Omniverse simulation environments from real-world robot scan data, then collaborating with WP4 to explore how high-fidelity simulation environments can be used in a Corroborative Verification and Validation (CV&V) framework.

Sharun Arumugam and Yehoshua Greenhaus joined the WP5 team in April 2025. Sharun's PhD research is on "Grasping Rover for In-orbit Servicing and Inspection" under the supervision of Prof Kate Smith, Dr Ben Parslew and Prof Simon Watson. Yehoshua has joined from Amentum to do research on "Aerial Deployed Surface Vehicles" under the supervision of Dr Kieran Wood and Prof Simon Watson.

Student Support

MEng student project "Inchtinuum: Inspection Robot for Complex Confined Spaces" has been completed, with knowledge transferred to the Amentum robotics team.

A second CRADLE-sponsored MEng project, developing autonomous litter-picking robots to support WP2 researchers, has also begun.

RESEARCH **SPOTLIGHT**

WORK PACKAGE 1

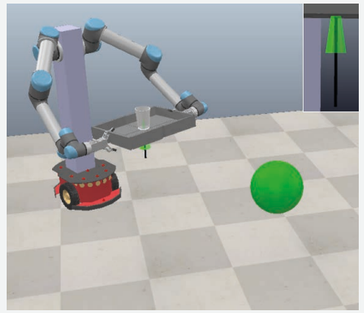

Dr Mohamed Atia and Seyonne Lesley-Dalley

UNDERWATER ROBOTS

Underwater environments are notably difficult to operate in, with a drive for safer operations removing humans from harm's way, there is a growing demand for robots to perform inspection and maintenance activities. Seyonne Leslie-Dalley's research aims to perform manipulation tasks coordinating multiple underwater robots equipped with manipulators. For their reliable and safe operation, their control needs accurate mathematical models of the robots under water, research carried out by Dr Mohamed Atia.

Seyonne developed the mathematical framework to describe tasks such as screwing or carrying a load (bottom left image) to serve as a goal input to her cooperative control strategy, initially developed without underwater constraints, currently adding them to the controller making use of a hydrodynamic simulation (bottom right image). Mohamed developed a robot model to be used in the controller. Its parameters were initially estimated using finite element analysis, currently identifying the model and tuning its dynamic parameters, from a dataset generated running extensive experiments conducted in the RAICo1 water tank (top Image), capturing control input signals and the feedback from an underwater motion tracking system. These datasets will be published for other researchers to use as a benchmark in their work.

Next steps will be integrating the model to the controller, extending the control framework to automatically select the task mode and use a decentralised approach, and finally validating the framework in real-life experiments with multiple underwater robots performing coordinated manipulation tasks.

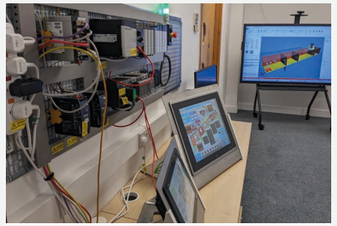


WORK PACKAGE 3

Dr Joseph Bolarinwa

A FACE OF TRUST?

Trust plays a critical role in effective human-robot collaboration, but how can a robot know if a human trusts it? These insights can inform the development of adaptive robots that respond to nonverbal behaviours of humans in real time, where full automation is not feasible or appropriate, such as in a personal care setting. Joseph's initial study investigated the relationship between human facial action units (AUs) and perceived trust ratings during a maze-solving task with a Furhat robot. Fifty-eight participants engaged in collaborative decision-making while video recordings of their interactions and AU activations were analysed using the OpenFace toolkit (bottom image). Results showed that specific AU variations reliably signal trust building and trust breaking. Joseph plans to further validate his trust model using a simple industrial process control task, working with the Human Factors and Visual Engineering team at Amentum (Top image). Human-robot collaboration in high-risk industries such as energy plants or transportation hubs may involve the human as a 'supervisor' to an automated process, with varying levels of shared control. If a human loses trust, they may override or ignore automation, even when it is functioning correctly. Detecting this early could allow the robot / automated system to offer confidence indicators, explain its logic, or suggest appropriate manual checks to reassure the operator.



INDUSTRY ENGAGEMENT ACTIVITIES

CRADLE IdEAs

The Prosperity Partnership model requires that research should be led by industry need, with work being co-delivered and co-created between the business and academic partners. In order to fully understand industry need, we have developed a programme of Industry Engagement Activities, or IdEAs, which is formed of three stages.

All WP Leads or empowered delegates ⟷ Industry challenge holders

STAGE ONE: CHALLENGE IDENTIFICATION

The CRADLE team facilitates an industry day where invited challenge holders share details of issues, ideas and challenges. This can take many forms, for example a workshop at CRADLE facilities or at a conference, with a single client, cross-sector representation or entire industry stakeholders. The aim is for the CRADLE team to gain a detailed understanding of industry challenges and their impact.

CRADLE Technical Lead(s) and PM → Down-selected CRADLE team* ← Challenge holder contact

STAGE TWO: CONCEPT DEVELOPMENT

The CRADLE team analyses the outputs of stage one, identifying cross-sector commonalities, concept solutions and realistic timescales to achieve them.

CRADLE Technical Lead(s) and PM → Down-selected CRADLE team → Industry challenge holders

STAGE THREE: NEXT STEPS

Based on the concept solution developed in stage two, the CRADLE team and challenge holders reconvene to agree next steps. This may include a demonstration of the concept, proposals for future work including technology development and/or research, the identification of funding routes, a decision to go no further, or something else.

Long-term relationship established

*Team selected based on an informed decision as to WP relevance founded on the information gathered at Stage One.

This process is offered to industry free of charge, and offers the following benefits to challenge holders:

- The chance to share sector or company challenges, ideas or requests at a targeted industry day.
- Access to world-leading Robotics and Autonomous Systems problem solvers via a CRADLE R&D concept development activity.
- The start of a long-term relationship.

It allows CRADLE to collate a library of valuable knowledge and information, which will enable the identification of cross-sector needs and challenges and influence our general research direction. It also establishes long-term relationships and a future pipeline of work which is crucial for the longevity of our Centre.

At the end of year two of the project, CRADLE has over 10 IdEAs in progress across multiple sectors, at various stages of maturity. We're delighted to report that the success of this process has led us to secure our first adjacent revenue-generating projects during the past 12 months.

Image: CRADLE's first IdEA field deployment at the National Highways Devevlopment Centre.

INDUSTRY **CASE STUDIES**

ESA SPACE RESOURCES CHALLENGE

Future lunar missions will rely on robotic autonomy to ensure sustainable operations. This is what Team CRADLE demonstrated as they took on the European Space Agency's (ESA) second Space Resources Challenge, held 13–17 October 2025 at the LUNA Analog Facility in Cologne, Germany.

As one of the eight finalists, the team successfully deployed the Mobile Lunar Excavation and Size Separation System (MoLES³) in lunar-like conditions for 2.5 hours, the duration set by the challenge organisers. Several constraints were also considered, including mass (<60 kg), power (<300 Wh), and dust mitigation — all of which the team managed to address within a development period of just over nine months.

The Space Resources Challenge is an initiative launched by ESA and the European Space Resources Innovation Centre (ESRIC) in 2021 to promote challenge-driven innovation and engage the community in developing novel solutions for Europe's exploration programme.

In its second edition, the challenge focused on developing technologies for excavating and processing lunar regolith that can be used to extract oxygen and building materials directly on the Moon.

In collaboration with The University of Manchester's Space Systems Research Group, the team was composed of academic researchers, robotics engineers, and industry experts with long-standing R&D experience in the fields of space and planetary exploration. The ESA Space Resources Challenge provides an excellent example of academic–industry collaboration with an exciting twist: the development of a modular lunar rover and a stationary beneficiation system.

"Team CRADLE aims to leverage our achievements and lessons from the ESA Space Resources Challenge to keep developing MoLES³ into a system that showcases reliable robotic autonomy for future lunar missions."

Dr Paul Dominick Baniqued
Technical Lead and Mission Director, Team CRADLE-MoLES³

Team Members: Prof Kate Smith, Marti Morta-Garriga, Paul Dominick Baniqued, Johnny Ionita, Danish Khan, Kwai-Wa Tse, Christopher Bishop, Mohamed Atia, Sharun Arumugam, Lewis Naylor, Talha Baig

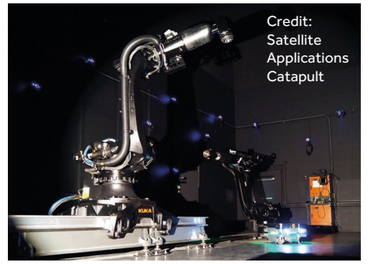
Credit: ESA

Image: Team CRADLE during their full mission rehearsal at the Ainsdale Sand Dunes Nature Reserve. Special thanks to Natural England.

SATELLITE APPLICATIONS CATAPULT

The Satellite Applications Catapult aims to grow the UK economy by supporting industry to accelerate the invention and adoption of space data and technology. It provides a range of support and facilities but, particularly relevant to CRADLE, the Catapult provides the unique ISAM (In-orbit Service and Manufacturing) Test Facility - a state-of-the-art facility for testing proximity operations and in-orbit servicing technologies. This facility is actually implemented by multiple robots simulating orbital interactions.

Following several CRADLE IdEAs interactions with the Catapult, we are working towards a study to help confirm the reliability and resilience of the Catapult's ISAM Test Facility. This involves defining the (formal) requirements for the multi-robot system, architectural descriptions, and a plan for heterogenous verification of the robot implementation against these requirements. This will also provide a verification harness for future developments and extensions.



Credit: Satellite Applications Catapult

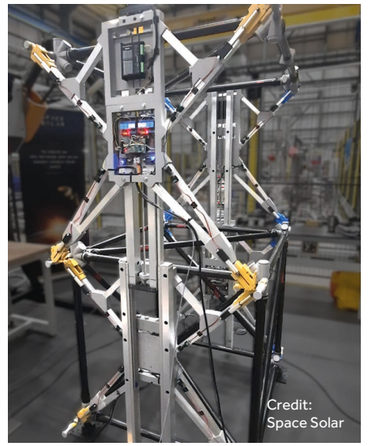
"Our collaboration with the CRADLE team will be instrumental in advancing the robustness and verification capabilities of our ISAM Test Facility. Their expertise is helping us shape a more resilient and future-ready platform for in-orbit servicing technologies, ensuring that the facility supports the UK's ambition to be at the forefront of ISAM innovation and global market."

Jeremy Hadall
Robotics Development Lead at the Satellite Applications Catapult

SPACE SOLAR

Space Solar is an organisation taking on a novel and extreme challenge – to construct a 4km solar power satellite in orbit, which will harness energy using photovoltaic cells, and transmit it back to Earth via radio waves. This is a revolutionary venture which has the potential of unlocking solar power, at a far greater efficiency than is currently available within the confines of our atmosphere. Crucially, the entire satellite will be constructed from individual structural elements, by bespoke autonomous assembly machines working collaboratively in pairs (Rightmost Image).

Space Solar reached out to CRADLE at the start of the year to work with us as part of the IdEAs scheme. We have held two in-person workshops, at The University of Manchester and at their site in Harwell, and since then have begun conducting two research investigations. The first of these is led by WP2, regarding the requirements capture and capability of the teaming of assembly machine pairs to build, maintain and inspect the satellite structure, and the second is led by WP5, focussing on how to achieve accurate alignment of the solar power satellite's structures and suitable sensing and inspection technologies that could be used to achieve this.



Credit: Space Solar

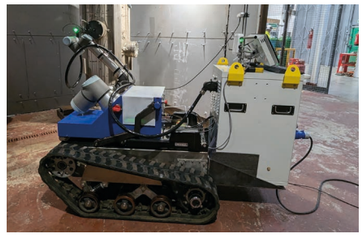
"Working with the CRADLE team on our Space Based Solar Power in orbit assembly projects has been a valuable collaborative experience. Their ability to engage with our challenges from a research-driven perspective has helped to highlight aspects of our system design and development we had not yet explored in earlier studies. We're excited about how this work could feed into our near-term assembly machine demonstrators and longer-term architectural decisions."
Space Solar

SCINTAM

Scintam Engineering are an SME spin-out from the University of Nottingham, who have developed novel EDM (electrical discharge machining) technology. Over the past 18 months, CRADLE has been working alongside Scintam to integrate this technology into robotic solutions, overcoming the barriers to implementation, and realising the potential impact of this technology in hazardous environments.

RAISE: Robotic Automation of Innovative Spark Erosion

Last year, CRADLE trialled the robotic implementation of Scintam's FastEDR EDM technology, with utilisation of machine vision for target identification, which culminated in the RAISE live demonstration in October 2024, where the technology was remotely deployed to showcase the removal of fasteners in a mock-up nuclear reprocessing cell.



Further development of this system is ongoing, informed by potential industry use cases.

FEEAD: FastEDR Expansion Enhancing Asset Dependability

CRADLE is currently working with Scintam for a major aerospace client. The scope of the project is to develop a robotic platform, capable of positioning Scintam's EDM probe to a translational accuracy of within 80µm, and to a rotational accuracy of ~0.1°, with the use case being the removal of damaged fasteners within helicoils, without any machining contact with the thread in the valuable aerospace component. To date, the CRADLE team has delivered a feasibility stage of the project, with a development and testing phase to follow imminently.

This work represents a key achievement and milestone for CRADLE, as it signifies both the establishment of a valuable SME partner in Scintam, and also the first commercial project to flow from the IdEAs process.

"Working with CRADLE has allowed us to access expertise and networks which are not normally available to SMEs, we expect this will expedite the development of robotic solutions and allow us to access new markets."
Peter Woodsmith
CTO Scintam Engineering

March 2024
Discussions Begin
IdEAs Process:
- Challenge day held in March 2024
- Projects discussed and down-selected

May – October 2025
FEEAD Task 1
FEEAD Task 1:
- Task 1: R&D feasibility study
- Lab trials conducted and report issued
- Highly precise (within 80µm) positioning of bespoke EDM tool, for extracting fasteners from high-value aerospace components.

July – October 2024
RAISE
Development:
- Collaborative team: Amentum, UoM and Scintam engineers
- Robotic deployment of EDM technology
- Automated target bolt detection and positioning

Demonstration Day – 2nd October 2024:
- Stuck bolt removal in a dummy nuclear reprocessing cell
- Demonstration to ~40 industry experts

November 2025 Onwards
FEEAD Task 2
Amentum commercial project spun-out from CRADLE:
- Scope discussions currently being defined with Scintam
- To deliver a functional technology demonstration to the end client – precise bolt removal in aerospace components
- Develop hardware, controls architecture and human-machine interface

The Future
Further opportunities
Current discussions for future deployments and developments:
- Cross-sector applications of RAISE
- In-situ defect implanting for test pieces
- Collaboration/integration with existing Amentum capabilities (automated welding)
- Dedicated research secondments from academics into Amentum

UNITED UTILITIES

United Utilities (UU) manages many underground water supply tunnels that are over a century old and several kilometres in length. Inspecting these tunnels with traditional methods means sending people into deep, confined spaces which is a hazardous and expensive undertaking. Due to the harsh conditions in the tunnel, there is no existing technology available for robotic inspection of the tunnels. This challenge prompted a collaboration with CRADLE to develop a robotic means of inspecting some of UUs more challenging tunnels.

Work completed to date

In an initial trial, the CRADLE team adapted a small aquatic robot to drive into one of UU's raw water tunnels. The robot, an unmanned surface vehicle resembling a miniature boat, was launched into the tunnel. The robot needs to be powerful and highly manoeuvrable to overcome the current and turbulence in the tunnels. The robot was untethered and carried lights, a camera and a long-range radio for communications. This initial trial demonstrated to UU that a small robotic craft can successfully navigate in fast flowing tunnels and gather useful inspection data, proving the concept's viability.

Building on this success, a joint site visit took place on 17 September 2025 to plan the next steps. CRADLE and UU engineers spent a day surveying four different tunnel sites, assessing each tunnel's access, flow conditions and potential hazards. The aim was to determine which tunnel would be the best candidate for a more in-depth robotic inspection trial. The outcome was positive, and a tunnel has been selected for the next stage of work.

"The CRADLE programme has enabled United Utilities to explore robotic solutions collaboratively with Amentum and The University of Manchester. We have had access to a high number of subject matter experts throughout the process to discuss the challenges we face as a business, and how these could be aided by robotics. Our experience with CRADLE has so far been very positive and we are excited to see what the next phase of work brings"
Suzy Hill – Project Manager (Engineering Innovation), United Utilities

Image: Aquatic vehicle testing in representative channel.

Upcoming work

The CRADLE team is now preparing for a robotic deployment. The next phase is designed to assess the capability of the proposed navigation and inspection sensor and software setup. A floating system will be equipped with a full set of sensors and floated into the tunnel while collecting data. Techniques that have been developed by CRADLE's WP1 team will be used to process navigation sensor data in real-time, to give exact positions and velocities of the robot in the tunnel. This data will then be used to design control systems that can keep the robot centralised in the tunnel and control the robot's velocity in the presence of hydrodynamic disturbance. The end effect will be that the robot can be driven on a virtual rail, either by an operator or autonomously, along the tunnel's centre, making surveying much simpler and improving the data output from the inspection payload by stabilising the robot. The output of the sensor test will guide the design of a more advanced inspection platform that will be deployed in subsequent project stages.

Benefit and relevance

For UU, this robotic approach promises to make tunnel inspections safer, more cost-effective and offer improved repeatability. With no personnel needed to enter the tunnels, the safety risks are drastically reduced and the costly preparations required for confined-space work can be minimised. Inspections of ageing infrastructure can also be done more frequently, since deploying a robot causes far less disruption to operations, ensuring that tunnel condition information is more readily available for asset management. The project fits CRADLE's mission to develop robust autonomous systems for challenging environments. Sensing and control technology that has been developed by UoM academics will be implemented by the CRADLE team to enable first of a kind inspection. It showcases the effective partnership between university researchers, CRADLE and industry, as teams combine their expertise to tackle a real-world infrastructure problem and improve how critical water tunnels are maintained.

NUCLEAR GRAND CHALLENGES

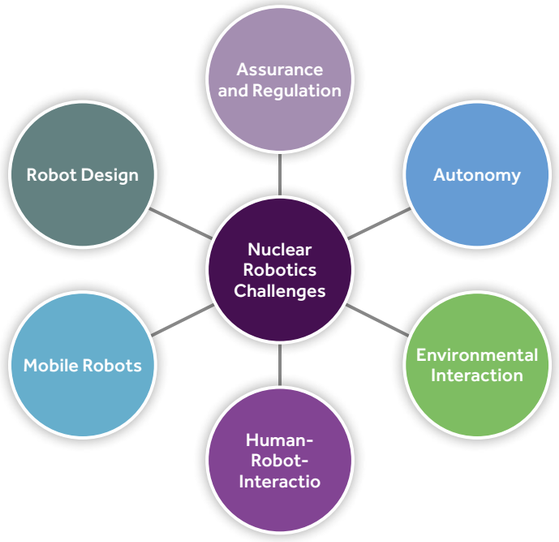
As part of its international engagement strategy, CRADLE has been supporting the IEEE RAS Technical Committee (TC) on Robotics for Nuclear Environments to grow and diversify. Both The University of Manchester and Amentum have a long track-record of developing robotic solutions for the nuclear sector and are internationally recognised as being leaders in the field.

The TC on Robotics and Automation for Nuclear Facilities was formed in 2011 following the Fukushima Daiichi accident to build a community of robotics experts that could support post-disaster clean-up and decommissioning. Over the past 5 years, robotics has started to become business-as-usual not just for decommissioning and fusion, but also for operations in active energy generation and big science facilities.

Under the leadership of Simon Watson, the TC was re-branded and re-launched in 2024 to become the TC for Robotics for Nuclear Environments. The co-chairs represent both geographic and application domain diversity; Dr Rob Skilton, UKAEA, UK, Dr Eloise Matheson, CERN, Switzerland, Dr Young Soo Park, Argonne National Lab, USA, Dr Kuniaki Kawabata, JAEA, Japan and Prof Yoshimi Takashi, Shibaura Institute of Technology, Japan.

The new mission of the TC is to "To connect people, technology, and challenges to accelerate real-world positive impact via robotics in nuclear environments".

The first major activity to support this mission was to develop a series of Grand Challenges in Nuclear Robotics.



These Grand Challenges were initially developed through the CRADLE project in a workshop that brought together domain experts from both Amentum and The University of Manchester. The outputs of the workshop were presented to key stakeholders from the UK nuclear sector to provide commentary and feedback.

Nuclear Grand Challenges Unveiling

The Grand Challenges were unveiled by James Kell at the IEEE ICRA 2025 conference during the "Grand Challenges in Robotics for Nuclear Environments: A Call to Action" workshop, which was organised by the TC.

Grand Challenges

Challenge 1: Assurance and Regulation
Challenge 2: Autonomy
Challenge 3: Environmental Interaction
Challenge 4: Human-Robot-Interaction
Challenge 5: Mobile Robots
Challenge 6: Robot Design

Each of these challenges represents an area where significant research is still required, however many of the sub-challenges are agnostic of domain (i.e. they are not specific to nuclear environments). A key driver behind the challenge creation was to enable research from other sectors, such as surgery, agriculture, construction, etc... to be demonstrated or transferred into the nuclear domain.

These challenges are in the process of being formally published and several of them form the basis of a workshop proposal for IEEE ICRA 2026.

Topic	To Enable	Open Research Areas
Assurance and Regulation	• Delivery of robot assurance of fitness to safely operate • Transparency in decision making for regulators and operators • Safe learning and adaptation • Determination of reliability of novel and new systems • AI to develop assurance cases and evaluate them • Techniques for validating simulations • Validation and Verification for generative AI • Develop international standards for robotics and AI regulations	• Processes for faster safety case approval • New standards for design and testing, enabling ease of approval • Dynamic continuous assurance • Scalable verification techniques • Assurance beyond safety and security, e.g. including ethics • Clear frameworks for liability, to aid deployment • Development of ALARP business cases of human vs robot • Better Verification and Validation techniques for AI • Standardised suites of simulations for robotics applications and datasets in training • Harmonisation (including standards) of assurance and regulation across sectors and countries
Autonomy	• Moving things around • Manipulating (cleaning, packing, etc.) • Dynamically changing behaviours • Long term operations • Eliminate boring tasks maintenance / repair of unexpected failure • Increase efficiency and accuracy • Monitoring of assets	• Flexible architectures – failure / learning / environments • Dynamic sharing of knowledge and skills between different systems • Self-healing autonomous system / fault tolerance / diagnostics • Self-documenting autonomous system • How do we manage a dynamic system knowledge over time and ensure bias is controlled • Dynamic decision making – adaptive autonomous decision making • Architecture for autonomy – design and enterprise architecture • Heterogeneous multi-robot teams • From one to many – autonomy shared across many platforms to complete complex and dynamic challenges
Environmental Interaction	• Haptic tele-operation • Adaptive grasping, failsafe handling and handling of unknown materials • Reliable and safe handling of heavy loads • Shared autonomy manipulation • Dexterous bi-manual manipulation of complex objects • Leveraging contacts for safe manipulation in constrained environments	• Bio-inspired and soft robotic manipulation and grasping • Complex grasping and manipulation with limited sensor data • AI-enhanced shared autonomy • Multi-contact planning and control • Tactile manipulation • Dexterous whole-body loco-manipulation • Multi-modal manipulation using vision, tactile, and force feedback
Human–Robot Interaction	• Bio-inspired and soft robotic manipulation and grasping • Complex grasping and manipulation with limited sensor data • AI-enhanced shared autonomy • Multi-contact planning and control • Tactile manipulation • Dexterous whole-body loco-manipulation • Multi-modal manipulation using vision, tactile, and force feedback	• Collecting and interpreting brain and human psychological data when using robots • Human's attention to data in interfaces, e.g. eye tracking? • Design for HRI – adaptability to different human characteristics • Risks and consequences of command/control modalities (for example voice) • Multi-modal interfaces, including natural language and gestures • Robot perception and detection of irregular conditions of a human collaborator (for example medical, behaviour, understanding) • Robotics-orientated organisation and structure, robots and people in teams • Digital twins for different stakeholders
Mobile Robotics	• Access areas that can't be accessed by humans or traditional robots • Undertake long-term repeated inspections of facilities • Traversing non-standard structures, e.g. climbing, pipework, etc. • Traversing in challenging environments (radiation, heat, etc.)	• How do we swap out/charge robot batteries in environments people cannot enter? • How do we improve power density in robots? Both in actuators and power packs? • How do we move through non-water liquids for example molten salt, molten lead? • How do we maintain wireless communications in industrial environments for example concrete, rebar, steel structures? • Bio-inspired mobility technologies
Robot Design	• Operation of robots in non-standard and/or hazardous environments • Intelligent co-design of robots and assets of the future • Sustainable design of robots at scale • Adaptable and modular design of robots for re-use and re-purposing (moving away from bespoke design)	• Standardisation of interfaces for modular design • Design frameworks for co-design of robots and assets • Design for trust and reliability, not just cost • Self-reconfiguration of robots to adapt to changing task requirements • Radiation tolerant components • Sensing through complex media • Materials for easy decontamination • Self-healing robots

PEOPLE **SPOTLIGHT**

CRADLE's core team has doubled within the past 12 months, during which time our affiliated network of professionals across Amentum and The University of Manchester has also significantly expanded. We're lucky to have access to a vast talent pool of world-leading experts, who are able to apply their knowledge and experience to enhance the CRADLE project.

KATE SMITH

Kate Smith is a Professor of Space Technology in the Department of Mechanical and Aerospace Engineering. She has over 20 years' experience developing space technologies. Her current research focus is on robotic systems for space exploration and exploitation including novel location methods for low and micro gravity conditions and technologies to enable in situ resource utilisation. Kate and her team have applied their research via engagement with CRADLE's space-sector activities, including the ESA Space Resources Challenge.

MARIE FARRELL

Marie Farrell is a Royal Academy of Engineering Research Fellow and Senior Lecturer in the Department of Computer Science. Her research focuses on "Strong Software Reliability for Autonomous Space Systems". In this work, she aims to devise new ways of describing, analysing and assuring the autonomous behaviour of robotic space systems. She is secretary of the working group developing the IEEE P7009.1 Standard for Safety Management of Autonomous and Semi-Autonomous Systems – Interventions in the Event of Anomalous Behavior.

SIMON WATSON

Simon Watson is a Professor of Robotics Systems in the Department of Electrical and Electronic Engineering. He has over 15 years' experience developing aquatic, aerial and ground robots to be deployed into hazardous and challenging environments and was the co-founder of the spin-out company, Ice 9 Robotic Solutions. His current research focus is on Design for Robot Accessibility; developing design toolchains which enable the co-design of robots, environments and missions which are verifiable and trustworthy.

FEDERICO TAVELLA

Federico Tavella is a Postdoctoral Research Associate (PDRA) working on foundation models and generative AI for Human-Robot Collaboration. He developed international collaboration through the UK-Italy Trustworthy AI Visiting Researcher Programme (a joint scheme in collaboration with the Alan Turing Institute and the Italian Future AI Research Foundation) and the Postdoctoral Networking Tour in Artificial Intelligence (funded by the the Federal Ministry of Research, Technology and Space, Germany). His interests include machine learning, visual-language models and human-robot collaboration.

MARTÍ MORTA-GARRIGA

Martí is a Principal Robotics Specialist with a multidisciplinary background. Over the past 15 years, he has contributed to the development of 3D lidar systems, mobile robotics platforms, machinery for the NDT industry, innovative decommissioning methodologies using robotics and mechatronics, and robotic systems integration for multi-modal surveying. Recently focused on technical management roles, he is engaged with the technical advances of the field, maintaining strong connections across research and industry. Through WP1, Martí aims to grow Amentum's robotics team and foster collaboration with the University, by providing industry challenges and integrating the state-of-the-art techniques developed within the partnership into Amentum's toolkit of solutions to address industry needs.

PAWEL LADOSZ

Dr Pawel Ladosz is a Lecturer in Robotics at The University of Manchester. His research focuses on applying machine learning and vision-based techniques to mobile robotic systems, including autonomous landing, navigation in low-light and/or cluttered environments, and robot team mission planning. Pawel is the Principal Investigator for the Robotics for Inspection of Water Supply Networks research project, which is a collaboration between United Utilities and The University of Manchester and is supported by CRADLE and Amentum. In this project, Pawel and his team will identify United Utilities' assets that could benefit from the use of robotics for inspection or maintenance and propose suitable solutions.

MICHAEL OATES

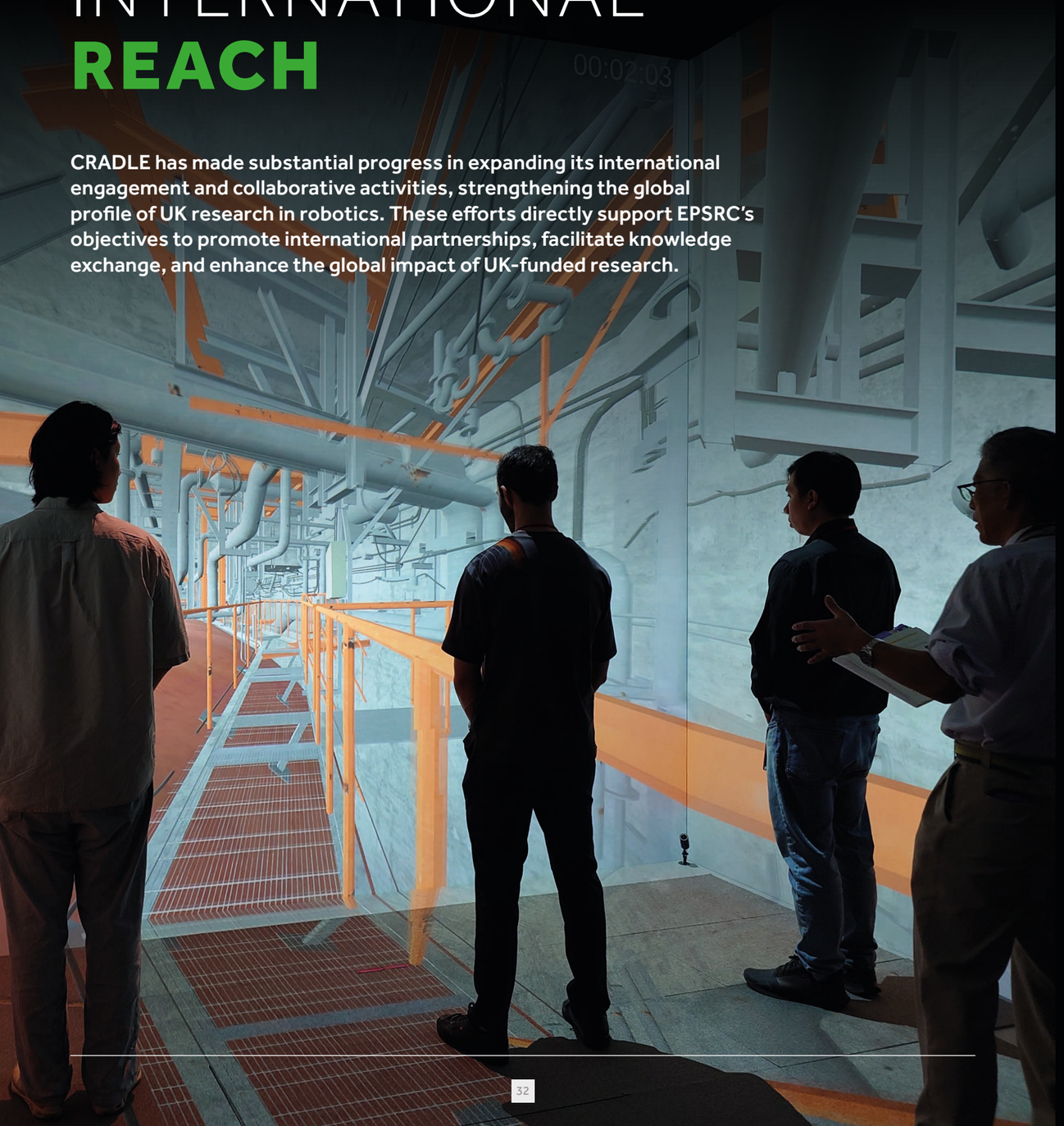
Michael is a Senior Robotics Specialist, who brings to CRADLE experience in robotics and engineering from a strong industrial and competitive background. Michael's professional career began as a summer placement student during his time at university, from which he has now developed to lead teams of engineers to deliver bespoke robotics projects, across multiple sectors including nuclear fission, fusion, national infrastructure and aerospace.

In his role as Research and Development Manager for the industrial side of CRADLE, Michael brings this experience in developing robotics for cross sector applications, to help identify and develop unique and interesting challenges facing robotics in the current landscape. This provides CRADLE with both novel research areas, and most crucially the opportunity to make significant impacts to the current state-of-the-art in industry.

Prior to his professional career, Michael's interest in robotics began through competing in combat robotics, a passion sparked by watching the BBC TV show "Robot Wars", which he ultimately went on to win whilst studying for his undergraduate degree. Robotic competitions at a high level have many cross-overs with the work we do as CRADLE – success requires innovation, unsolved challenges, and in the case of combat robotics, presents an extreme case of a "Demanding Environment".

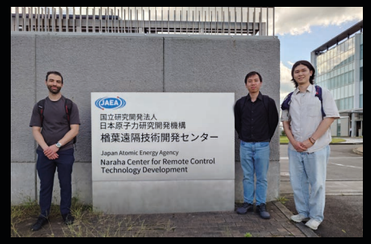
INTERNATIONAL **REACH**

CRADLE has made substantial progress in expanding its international engagement and collaborative activities, strengthening the global profile of UK research in robotics. These efforts directly support EPSRC's objectives to promote international partnerships, facilitate knowledge exchange, and enhance the global impact of UK-funded research.



FELLOWSHIPS AND SECONDMENTS IN JAPAN

A key achievement has been the placement of several research fellows in Japan through the Nuclear, Education, Skills and Technology (NEST) Framework led by the Nuclear Energy Agency (NEA). These research visits (one to three months) are hosted by leading institutions, including the Japan Atomic Energy Agency and the University of Tokyo. These placements have established valuable bilateral links between UK and Japanese research communities working in advanced Robotics and Autonomous Systems. The Fellows engaged in collaborative studies on robotic perception, control, and resilience, while disseminating CRADLE's methodologies in nuclear robotics and decommissioning. The placements have generated tangible outcomes, including the identification of prospective joint projects and the initiation of discussions on longer-term institutional partnerships.



CRADLE NEST Fellows

2023: Dr Paul Dominick Baniqued (Top 10 NEST Fellow)

2024: Dr Christopher Bishop (Top 8 NEST Fellow)

2025: Dr Raynaldio Limarga, Xinyun Chi, Joshua Bettles

INTERNATIONAL WORKSHOPS AND CONFERENCES

CRADLE's international visibility was further enhanced through its role as organiser of a workshop at the IEEE International Conference on Robotics and Automation (ICRA) in Atlanta, the leading global conference in the field. The workshop coincided with the launch of the CRADLE publication "Grand Challenges in Robotics for Nuclear Environments", which articulates a set of priority areas intended to encourage increased academic participation in nuclear research. The session facilitated dialogue between international researchers and industry representatives, highlighting the need for renewed academic engagement in the nuclear domain and positioning CRADLE as a focal point for cross-sector collaboration.

INTERNATIONAL COMPETITIONS

CRADLE extended its cross-domain and cross-sectoral reach through participation in the 2nd Space Resources Challenge by the European Space Agency (ESA) and the European Space Resources Innovation Centre (ESRIC), an international competition focused on autonomous robotic exploration in lunar and planetary environments. The team's entry demonstrated the applicability of technologies developed for other sector applications. navigation, and robust system design—to other extreme environments. This activity provided a high-profile example of knowledge transfer from nuclear robotics to the wider robotics and space research communities. At the time of writing we are awaiting the results of the competition.

GLOBAL REACH REAL-WORLD IMPACT

Collectively, these initiatives reflect CRADLE's strategic commitment to international engagement and the diversification of research impact. Through global secondments, cross-border workshops, and participation in international competitions, the programme is fostering a more active, connected, and globally recognised research ecosystem. These outcomes align with EPSRC's priorities for strengthening international collaboration, supporting interdisciplinary innovation, and maximising the global impact of UK research.

OUT**REACH**

CRADLE is committed to inspiring the next generation of scientists and engineers by engaging with communities in an exciting and proactive way.

CRADLE values interaction with the public in all stages of the research process through a variety of events including all members of our team, working with non-academic partners to ensure we reach further into the community. The centre commits to public engagement to inspire the public by showcasing our contribution and its benefits to life in the UK. These activities aim to attract people of all ages; especially young talent, to the range and desirability of Science, Technology, Engineering, and Mathematics (STEM), whether that be a career choice or engaging in clubs and societies at school.

HACK-A-BOT

As robotics continues to emerge as a critical technology, the demand for skilled workers to sustain and advance the UK's expertise in this field is becoming ever more pressing. Yet, the high costs associated with engaging with robotics make it difficult for pre-university students to gain hands-on experience. This lack of early exposure can limit both awareness and inspiration, discouraging young people from considering robotics as a potential career path and resulting in a significant skills gap.

Hack-A-Bot was born from an ambition to break down the barriers to opportunity in a values-led and socially responsible way.

The University of Manchester's Hack-A-Bot event is an annual robotics hackathon organised by RoboSoc, the university's robotics society. It is a dynamic 24-hour event where undergraduate and postgraduate students, across various disciplines including engineering, science, business, humanities and arts, collaborate to build innovative and impactful robotic solutions based on real-world, industry challenges.

Hack-A-Bot 2025 brought together over 300 students from various disciplines for 24 hours of innovation. Sponsored by CRADLE and other partners, the event featured hands-on robotics builds, expert talks, and career insights. This facilitated open, honest, targeted and inspiring discussion between students and industry in relation to career paths and opportunities, establishing relationships that continue post-event. This supports closure of the skills gap impacting the development of robotics as a global critical technology in a unique and innovative way.

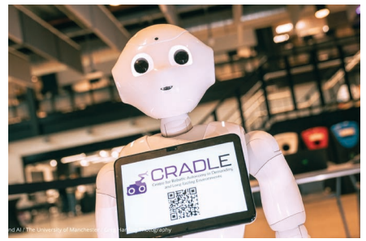
MANCHESTER TECH FESTIVAL 2025

CRADLE represented the robotics and AI sector at the Innovation and Tech4Good Showcase during Manchester Tech Festival 2025, held in the historic Victoria Baths. The event brought together more than 1,000 developers, engineers, and industry leaders from across Greater Manchester. CRADLE showcased its cutting-edge research and real-world applications, strengthening its presence in the regional tech community while building new connections and highlighting the centre's role in driving innovation.

PINT OF SCIENCE

CRADLE researchers and adjacent members led a Pint of Science 2025 event at the Withington Public Hall Institute titled "Learning to Decommission: Robots in the Nuclear World." The session introduced the public to how robotics navigates the complexities of nuclear decommissioning, how machine learning supports robotic decision-making, and how industry is deploying these tools in real environments.

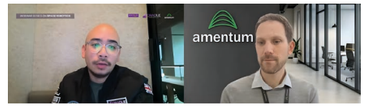
The programme featured three talks: Dr Federico Tavella's "Intelligent Machines: Teaching Robots Through AI," Dr Murilo Marinho's "(Semi)Autonomous Robots for Medicine, Space, Science, and Nuclear," and Dr Thomas Johnson's "Robots in the Nuclear Industry – A View From the Other Side." Together, they highlighted CRADLE's growing role in advancing robotics and engaging the wider community through accessible science communication.

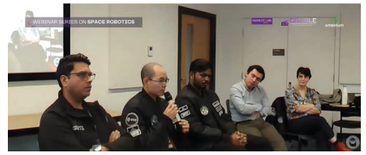


UK-RAS ENGINEERING EDUCATES

Through the UK Robotics and Autonomous Systems (UK-RAS) Network's Engineering Educates programme, CRADLE welcomed around 40 young visitors for a hands-on introduction to robotics. Pupils explored a range of robots, including the crowd favourite humanoid robot Pepper, giving them a chance to see real engineering in action and understand how robots are used in different environments.

Researchers explained, in child-friendly terms, what each robot does, how they contribute to the university's work, and how they themselves became involved in robotics. The goal was to spark curiosity, inspire future career aspirations, and show young people that a path into engineering and robotics is both exciting and achievable.





CRADLE TALKS

CRADLE Talks is a seminar series showcasing CRADLE's research and real-world case studies, open to anyone interested in the centre's work. The November 2025 edition took the shape of a two-part Webinar Series on Space Robotics. The first session was delivered by Dr Christopher Brunskill, Principal Consultant for Space at Amentum, who discussed recent advances and the future of autonomous robotics in the space sector.

The second session featured a Fireside Chat with Team CRADLE-MoLES³, who had recently returned from the ESA Space Resources Challenge in Cologne, Germany. The team shared their lessons learned from the competition, offering an inside look at the challenges of space robotics, mission operations, and deploying robots in demanding environments.

THE **FUTURE**

Amentum and The University of Manchester formalise their strategic partnership based on the best practice demonstrated by CRADLE.

Recognising the impact delivered and good practice established by the existing relationship between Amentum and The University of Manchester via CRADLE and The Dalton Nuclear Institute, April 2025 saw the expansion of the Strategic Partnership between the two organisations.

A Memorandum of Understanding was signed, expanding our relationship into areas including materials science, advanced energy, digitalisation, and social impact / regeneration.

This next phase of collaboration will see us delivering ground-breaking research and developing new technologies with the potential to change the world and applying them across the sectors and geographies in which Amentum operates.

Professor Richard Curry, Vice-Dean for Research and Innovation in the Faculty of Science and Engineering, The University of Manchester, said: "Our University has a proud legacy of research that transforms industries and improves lives – from initiating the computer revolution to isolating graphene. But it's what comes next that will define us. Together with Amentum, we share a bold ambition: to deliver research that is not only world-leading but world-changing."

As we reach the halfway point in CRADLE we are already thinking about what the follow on may be and what shape this may take to ensure an enduring capability to advance Robotics and Autonomous Systems in demanding environments. Expect to hear more about these exciting plans in the third Annual Report, which will include details on how other organisations can potentially get involved.

ADJACENT **PROJECTS**

- Scintam Engineering FastEDR Expansion Asset Dependability (FEEAD)
- National Highways Bridge Void Inspection
- Hertfordshire County Council Gulley Inspection
- RoboAlchemy Impact Accelerator Account (IAA)
- United Utilities Impact Accelerator Account (IAA)
- UK-RAS showcase panel on 'Internationalisation'
- UK space conference panel on 'Partnerships'
- PWI 'Route to Change' seminar
- Successful internal ISO44001 audit
- WP3 use of the Amentum Virtual Control Room
- Guest lectures, including Undergraduate BEng Mechatronic Engineering and MSc Robotics

Adjacent PhD/PDRAs

- Toluwani Soboyejo – UKAEA/UoM
- Joshua Bettles – Nuclear Decommissioning Authority
- Yuliang Li – Bicentenary Scholarship
- Farzad Shahabzi – RoboAlchemy

MEng projects

- 2023/24 – Inchtiniuum Robot – proof-of-concept (National Highways)
- 2024/25 – Inchtiniuum Robot • prototype (National Highways)
- 2025/26 – Litter Picking Robots – proof-of-concept (Hertfordshire County Council and National Highways)

SELECTED **PUBLICATIONS**

2024

A Nonlinear Estimator for Dead Reckoning of Aquatic Surface Vehicles Using an IMU and a Doppler Velocity Log
2024 IEEE International Conference on Robotics and Automation (ICRA)
Paterson, B.; Adorno, B.; Lennox, B.; Groves, K.

Applying the 'SOTEC' Framework of Sociotechnical Risk Analysis to the Development of an Autonomous Robot Swarm for a Public Cloakroom
Risk Analysis Journal
Winter, P.; Downer, J.; Wilson, J.; Abeywickrama, D.; Lee, S.; Hauert, S.; Windsor, S.

Control Strategies for the Task Definition of Constrained Bimanual Manipulation
5th UK Robot Manipulation Workshop, Oxford, UK
Leslie-Dalley, S.; Groves, K.; Adorno, B.

Control Strategies Using the Extended Cooperative Dual Task-Space
TAROS 2024 Proceedings, Springer Nature
Leslie-Dalley, S.; Adorno, B.; Groves, K.

Model Construction for Modal Clauses
IJCAR 2024 Proceedings, Springer Nature
Hustadt, U.; Papacchini, F.; Nalon, C.; Dixon, C.

Multimodal Immersive Digital Twin Platform for Cyber–Physical Robot Fleets in Nuclear Environments
Journal of Field Robotics
Baniqued, P. D. E.; Bremner, P.; Sandison, M.; Harper, S.; Agrawal, S.; Bolarinwa, J.; Blanche, J.; Jiang, Z.; Johnson, T.; Mitchell, D.; Lopez Pulgarin, E. J.; West, A.; Willis, M.; Yao, K.; Flynn, D.; Giuliani, M.; Groves, K.; Lennox, B.; Watson, S.

Towards a Computational Model for Higher Orders of Theory of Mind in Social Agents
Frontiers in Robotics and AI
Tavella, F.; Manzi, F.; Vinanzi, S.; Di Dio, C.; Massaro, D.; Cangelosi, A.; Marchetti, A.

2025

Autonomous Robotic Swarms: A Corroborative Approach for Verification and Validation
International Conference on Engineering Reliable Autonomous Systems (ERAS)
Abeywickrama, D. B.; Lee, S.; Bennett, C.; Abu-Aisheh, R.; Didiot-Cook, T.; Jones, S.; Hauert, S.; Eder, K.

Autonomy and Safety Assurance in the Early Development of Robotics and Autonomous Systems
ArXiv
Abeywickrama, D.; Fisher, M.; Wheeler, F.; Dennis, L.

Can Abstract Categories Be Represented by Shared Features in Concept Bottleneck Models?
Proceedings of the Annual Meeting of the Cognitive Science Society
Xie, H.; Wang, X.; Maharjan, R.; Tavella, F.; Cangelosi, A.

Cyber-physical-human systems for mobile robots in energy asset management: Current practices and future opportunities
Energy and AI
Mitchell, D.; Baniqued, P. D.; Kivrak, H.; Blanche, J.; Bremner, P.; Harper, S.; Jiang, Z.; Lopez, E.; Paterson, J.; Carrasco, J.; Groves, K.; Giuliani, M.; Herrmann, G.; Lennox, B.; Lim, T.; Watson, S.; Flynn, D.

Development and Extension of a Robot Network Platform Using RSNP
2025 SICE Festival with Annual Conference
Matsuhira, N.; Song, Y.-W.; Yao, K.; Bishop, C.; Yu, S.-C.; Groves, K.; Watson, S.; Sasaki, T.; Yamashita, A.

Embodied Intelligence: A Synergy of Morphology, Action, Perception and Learning
ACM Computing Surveys, 57(7)
Liu, H.; Guo, D.; Cangelosi, A.

From Traditional Robotic Deployments Towards Assisted Robotic Deployments in Nuclear Decommissioning
Frontiers in Robotics and AI
Lopez Pulgarin, E. J.; Hopper, D.; Montgomerie, J.; Kell, J.; Carrasco, J.; Herrmann, G.; Lanzon, A.; Lennox, B.

Reliable Robot Missions in Dynamic Environments Using Agent-based Controllers
International Conference on Engineering Reliable Autonomous Systems (ERAS)
Limarga, R.; Tse, K. W.; Dennis, L.; Dixon, C.; Faruq, F.; Fisher, M.

Safe-ROS: An Architecture for Autonomous Robots in Safety-Critical Domains
International Workshop on Formal Methods for Autonomous Systems, EPTCS
Benjumea, D. C.; Farrell, M.; Dennis, L. A.

Self-Attenuating Real-Time Vibration Control of a Flexible Long-Reach Robot
IEEE/ASME Transactions on Mechatronics
Chen, S.; Lopez Pulgarin, E.; Herrmann, G.; Lanzon, A.; Carrasco Gomez, J.; Lennox, B.; Brotherhood, J.; Sakaue, T.; Zhang, K.

Specification and Verification of the Alpha Swarm Algorithm Using NuXMV and GROOVE
Formal Aspects of Computing, Just Accepted (June 2025)
Ghaffari Saadat, M.; Dixon, C.; Fisher, M.

Towards Patterns for a Reference Assurance Case for Autonomous Inspection Robots
2025 IEEE/ACM International Conference on Software and Systems Reuse (ICSR) Proceedings
Abeywickrama, D. B.; Fisher, M.; Wheeler, F.; Dennis, L.

As well as academic publications, CRADLE has been referenced in a number of industry featured articles.

Delivering economic, social, and cultural prosperity to the UK and beyond, empowering industry with advanced Robotics and Autonomous Systems.

DELIVERING

- Deployment of novel autonomous robotic solutions, securing additional funding, and accelerating commercialisation and spin-outs.
- Enhanced international research and development profile.
- Impact and influence on standards and policy.
- Community building and outreach.
- Robust talent pipeline.
- Self-sustaining technology research centre, stimulating a stream of new, fundamental research.

MANCHESTER 1824
The University of Manchester

The Centre for Robotics and AI is an internationally recognised centre of excellence, delivering impactful world-leading research in the area of Robotics and Autonomous Systems for real-world applications that benefit society.

amentum

Innovative integration of Robotics and Autonomous Systems technologies, delivering value to clients by solving the most challenging problems across a wide range of sectors.

Bringing together the industrial experience of Amentum with the research expertise at The University of Manchester, established an internationally leading and sustainable collaborative research centre delivering novel and transformational Robotics and Autonomous Systems technology for demanding environments.

RESEARCH THEMES

- Resilience and predictability of hardware.
- Transparency and flexibility of software.
- Trust and understanding of human and environmental interaction.
- Assured autonomous system safety and security.
- Intelligent robot design and deployment.

GET IN **TOUCH**

CRADLE is looking for your problems and key challenges to drive our industry engagement activities and research direction. If you are interested in how CRADLE could help you, how we could work together, or simply want to know more, please contact info@cradlerobotics.co.uk.

CRADLE

CRADLE

A Prosperity Partnership between

MANCHESTER 1824
The University of Manchester

amentum

Centre for Robotic Autonomy In Demanding and Long-lasting Environments

1B.005 Engineering Building B
The University of Manchester
Booth Street East
Manchester
M13 9PL
United Kingdom

www.cradlerobotics.co.uk

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