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Centre for Robotics and AI

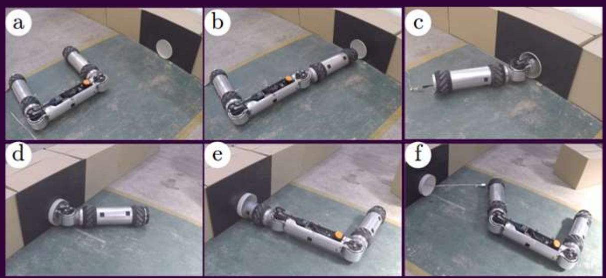
Designing Robots for Nuclear, Offshore and Subterranean Mine Environments

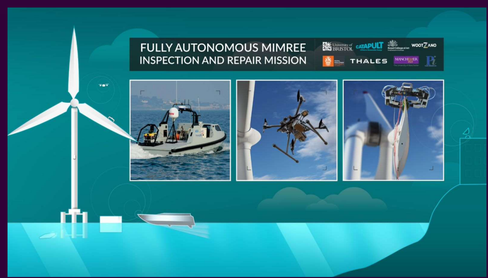
Dr Simon Watson

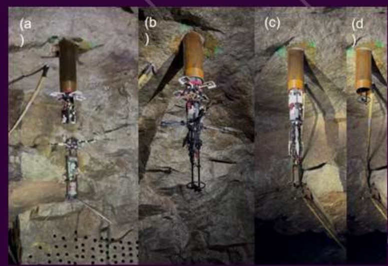
February 2023

Agenda

- Introduction to the University of Manchester
- Design of Robots for the Inspection of Nuclear Facilities
- Design of Robots for the Inspection of Offshore Wind Turbines
- Design of Robots for the Inspection of Subterranean Mines







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Bio

- 2003 – 2008
  - MEng Mechatronic Engineering with Industrial Experience
  - UMIST / The University of Manchester
- 2008 – 2012
  - PhD “Mobile Platforms for Underwater Sensor Networks”
  - The University of Manchester
- 2012 – 2013
  - Post-Doctoral Research Associate – Nuclear Robotics
  - The University of Manchester
- 2013 – Present
  - Lecturer / Senior Lecturer / Reader in Robotic Systems
  - The University of Manchester

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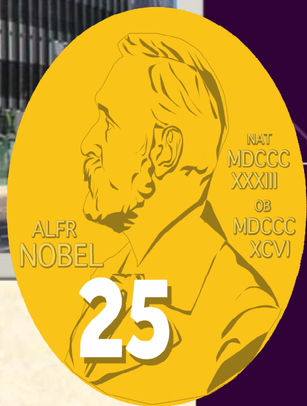
The University of Manchester History



- Rutherford first split the atom,
- Thomson discovers the electron
- Kilburn and Williams built the world's first stored-program computer – The Baby
- Lovell built the largest steerable radio telescope
- Geim and Novoselov isolated graphene for the first time

1900
JJ Thomson, Physics (1906)
Ernest Rutherford, Chemistry (1908)
1910
William Lawrence Bragg, Physics (1915)
1920
Archibald V Hill, Physiology or Medicine (1922)
Niels Bohr, Physics (1922)
CTR Wilson, Physics (1927)
1930
Arthur Harden, Chemistry (1929)
James Chadwick, Physics (1935)
1940
Walter Norman Haworth, Chemistry (1937)
George de Hevesy, Chemistry (1943)
1950
Robert Robinson, Chemistry (1947)
Patrick Maynard Stuart Blackett, Physics (1948)
John Cockcroft, Physics (1951)
1960
Alexander Todd, Chemistry (1957)
Melvin Calvin, Chemistry (1961)
Hans Albrecht Bethe, Physics (1967)
1970
John Richard Hicks, Economic Sciences (1972)
Nevill Francis Mott, Physics (1977)
1980
Arthur Lewis, Economic Sciences (1979)
John Charles Polanyi, Chemistry (1986)
1990
Michael Smith, Chemistry (1993)
2000
Joseph E Stiglitz, Economic Sciences (2001)
John Sulston, Physiology or Medicine (2002)
2010
Andre Geim, Physics (2010)
Kostya Novoselov, Physics (2010)

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Manchester Engineering Campus

- £500m Investment in Engineering Facilities
- Over 76,00m^2 of teaching and research space
- Largest home for Engineering and Materials in the UK
- Home to over 8000 students and academics

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RAICo One

Collaboration between Sellafield, Nuclear Decommissioning Authority, UK Atomic Energy Authority and UoM

Funding will be available for UK academia to engage in the RAICo programme

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Welcome to the Centre for Robotics and AI

Distinctive profile cutting **across many disciplines** in science and engineering, reaching out to social science and healthcare (>100 members)

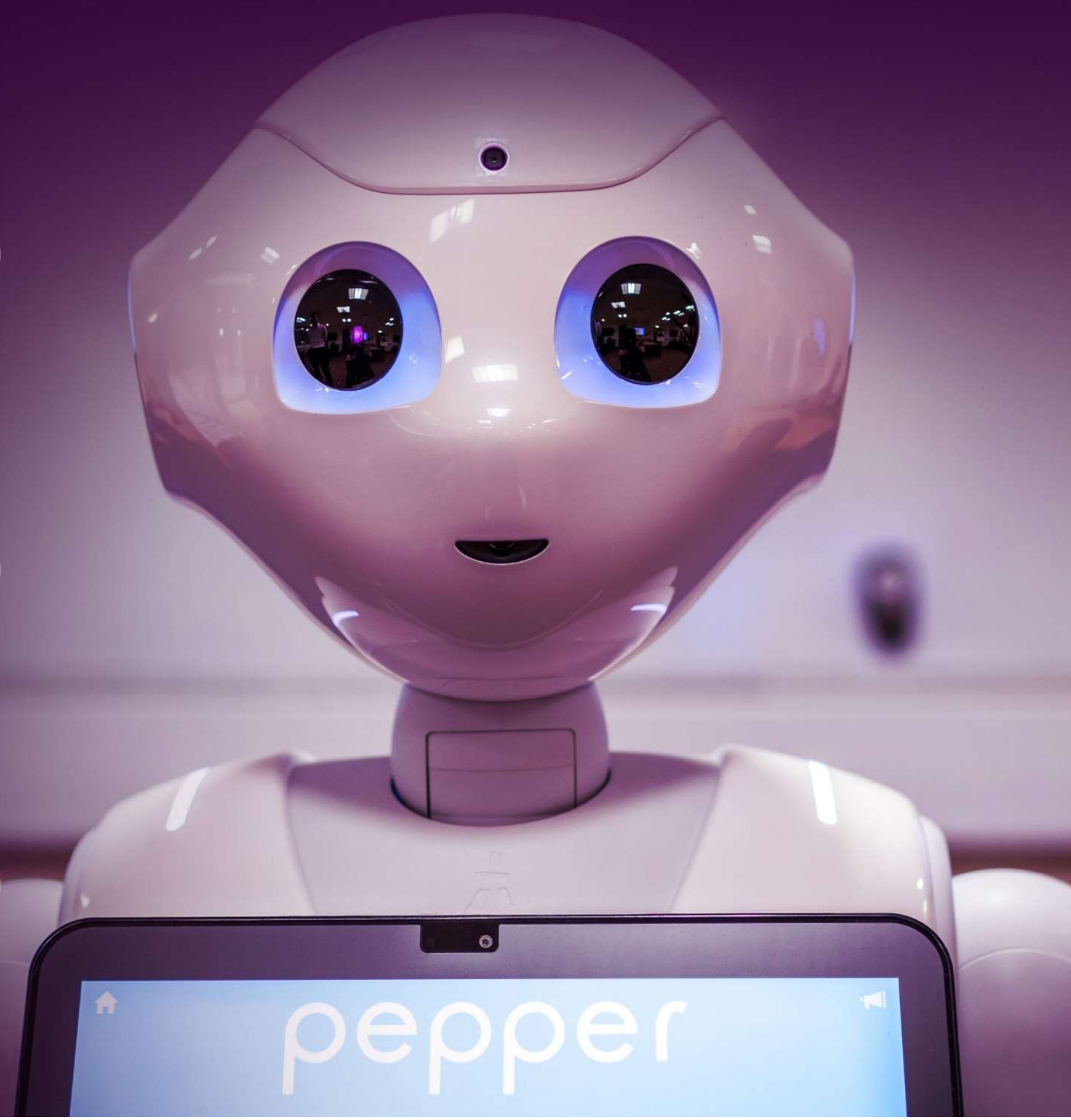
Focus is on the development, integration and application of **human-Centred AI** approaches in the design of robots and autonomous systems for real world applications.

We work extensively with **industry and users** in various sectors, including nuclear, healthcare, infrastructure and space.

Centre leads

Equipment and facilities

Our research



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Centre of Robotics and AI

Centre leads

Equipment and facilities

Our research

At our state of the art facilities we have the following robotics:

- Fixed testing arenas for aerial and ground based robots
- Vicon positioning systems
- Aquatic testing facility (4.8 m x 3.6 m x 2.4 m)
- Qualisys underwater positioning system
- 2 x Kinova Gen 3 7 DOF manipulators
- Kuka LBR iiwa 14 R820 manipulator
- 4 x UR5 manipulators
- 1 x Franka Emika Panda manipulator
- Ground robots including: A1 robot quadruped; Clearpath Jackal; Clearpath Huskey; Agile X Scout 2.0; Agile X Scout Minis; ICE-9 Lyra; MIRRAX
- Aerial robots including: DJI Matrice 300 RTK; Yuneec H520.
- Aquatic robots including: BlueROV2; ICE-9 MallARD; DeepTrekker DTG 3; Blueprint Alpha 5 manipulator.
- Range of sensor systems including Ouster, Sick and Velodyne LiDARs; thermal cameras; LORD inertial measurement units; Waterlinked Doppler velocity log; blueprint Occulus 3000 multibeam sonar; Hydromea underwater communication system; XRF; STS Safe-miniSource.

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Key themes

Platform design, mechatronics and control

Focus on the development of robotic platforms for nuclear, offshore, mining and space.
E.g. soft robotics and robotic solutions for deployment into congested and demanding environments.
Development of low-level systems to enable autonomy, such as control and communications.

Verification, security and trust

Address the key problems of how to provide verification evidence for the safety, security and trustworthiness of robotics, autonomous systems, and AI.
Important impact upon regulation and standards, thus involved with a wide range of national and international activities.

Human-robot interaction and cognitive robotics

Applications of social robots for healthcare and education, to remote handling in extreme environments.
Investigating methods to improve how people interact with robots, as well as how robots interact with each other.
Focus on reliable, resilient and trustworthy systems.

AI, machine learning and data

Development of novel AI and learning-based methods to robotics and autonomous systems.
Includes work on machine learning for vision, methods for multimodal robot sensing and for data integrating robots within distributed IoT and ambient intelligence environments.

Ethics and society

Concern with what robots do, why they do it and how users can understand and trust them.
Multidisciplinarity for responsible, ethical deployment and sustainability.
Key focus on transparency of behaviour, for strong verifiability, trustworthiness and explicit ethical behaviour.

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Design of Robots for the Inspection of Nuclear Facilities

Industrial Need at Sellafield


The Observer
Nuclear power

Sellafield: the most hazardous place in Europe

Last week the government announced plans for a new generation of nuclear plants. But Britain is still dealing with the legacy of its first atomic installation at Sellafield - a toxic waste dump in one of the most contaminated buildings in Europe. As a multi-billion-pound clean-up is planned, can we avoid making the same mistakes again?

- Highly congested
- 170 major nuclear facilities
- £70bn programme of decommissioning

Various beta/gamma facilities need to be characterized and dismantled.

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Nuclear Challenges


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© Sellafield


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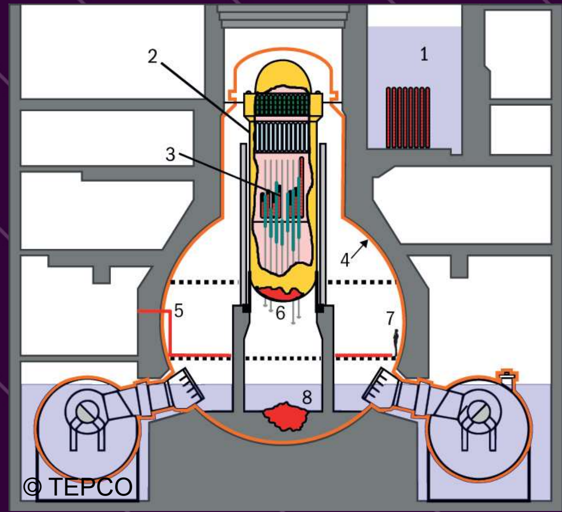

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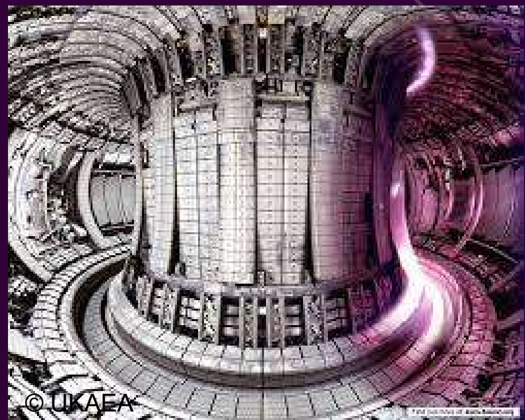
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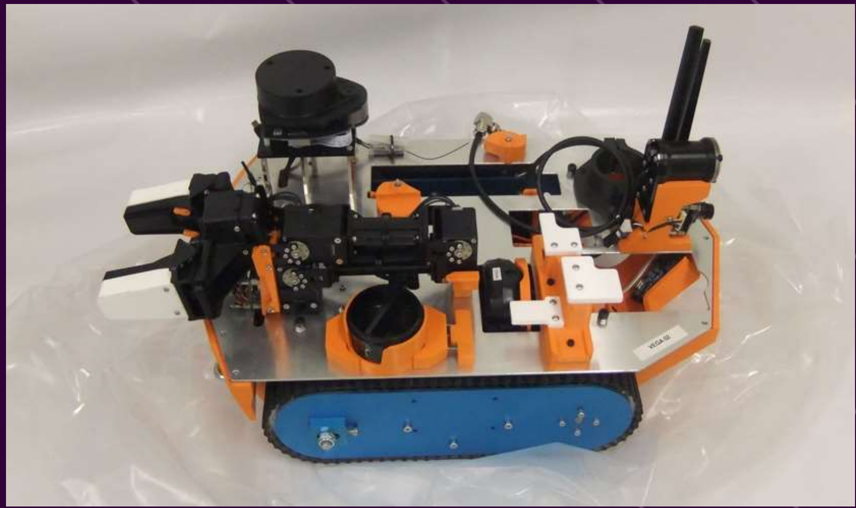
Dounreay Deployment (RAIN – ISCF, UKRI)

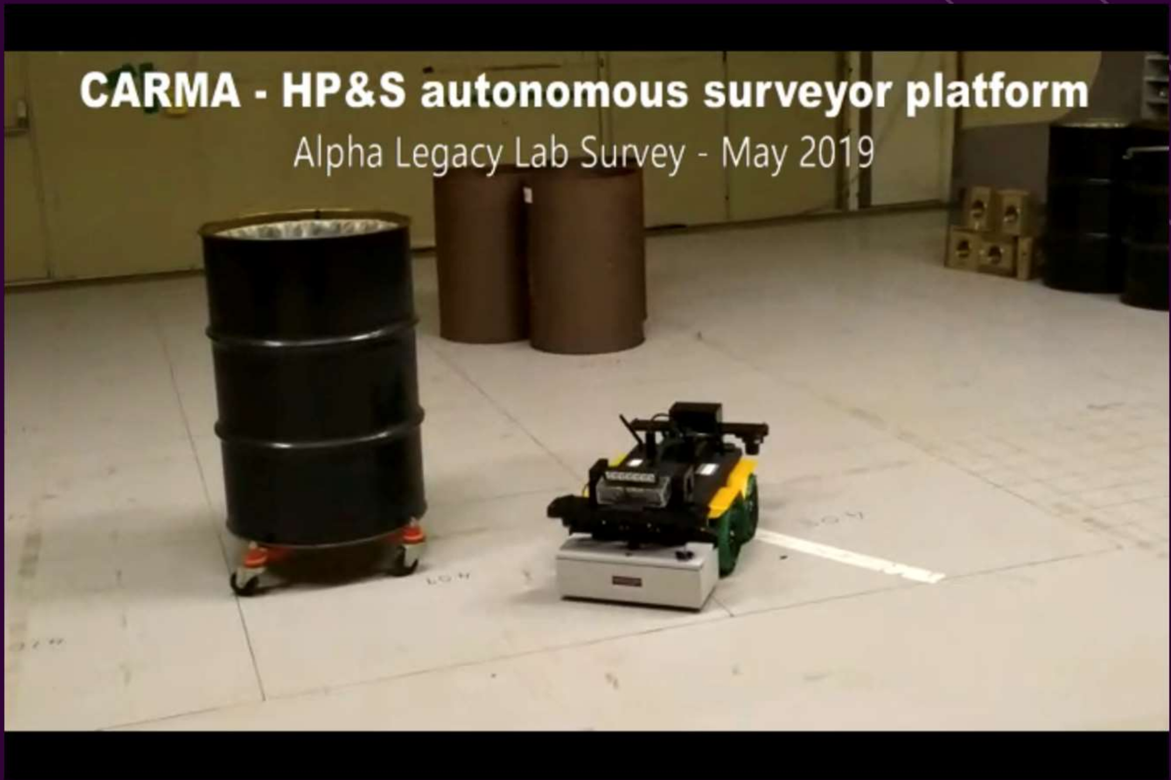
Low-cost disposable robot developed to inspect a ventilation duct on the Dounreay nuclear site.

Successful deployment of the robot in Sept 2021 and February 2022.

Saved Dounreay:
- £45k in costs
- 2250 hours of airline suited entries



CARMA: Deployment at Sellafield (SL, EPSRC – IAA, RAIN)



CARMA is designed to survey large floor spaces and identify areas of contamination.

CARMA is fully autonomous. It:

- determines the area it needs to explore
- maps a route that will cover all the floor space.
- avoids obstacles and radiation
- produces a map highlighting any areas of contamination.

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Bird, B, et al, (2019), 'Radiological monitoring of nuclear facilities using the CARMA robot', IEEE RAM, 26 (1), 35-43

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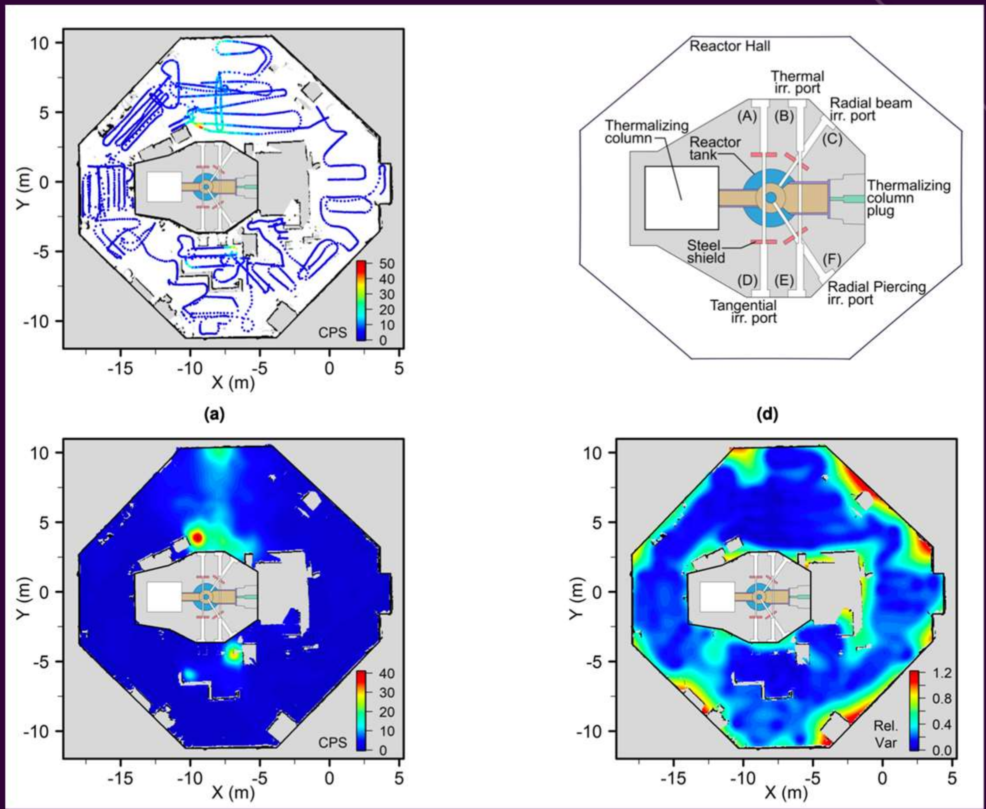
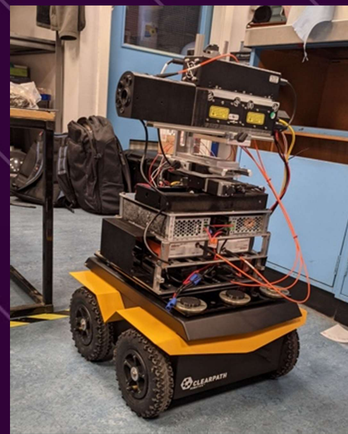
Mapping of a Nuclear Reactor (TORONE – EPSRC)



Robot used to provide radiation map of operating nuclear reactor (Franz-Josef, Slovenia)



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West, A. et al., (2021), ‘Use of Gaussian Process Regression for Radiation Mapping of a Nuclear Reactor with a Mobile Robot’, Scientific Reports, 11 (1), 1 - 11

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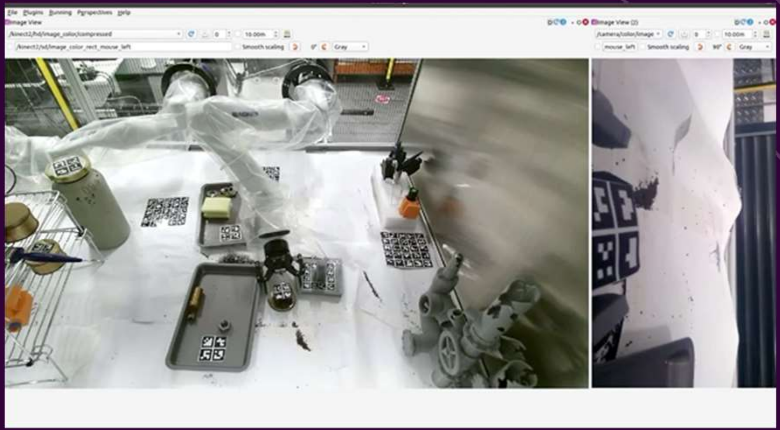
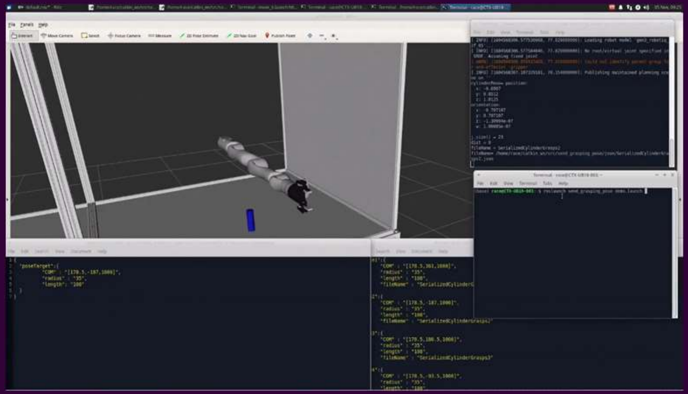
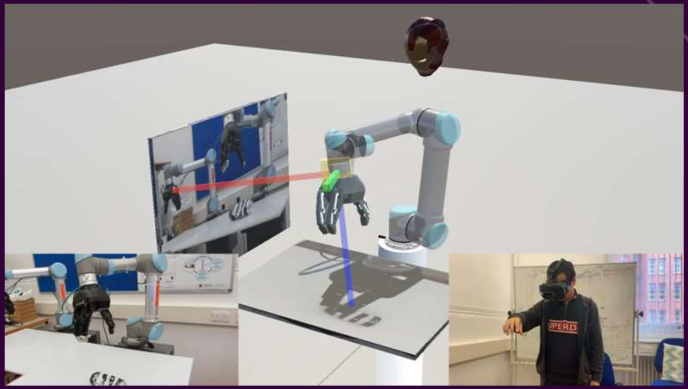
Hands out of Gloveboxes (RAIN – EPSRC; UKAEA)



Led by UKAE

Developing low-level systems to enable gloveboxes to be operated using manipulators. Requires HRI, control systems, automated grasping, fault detection etc.





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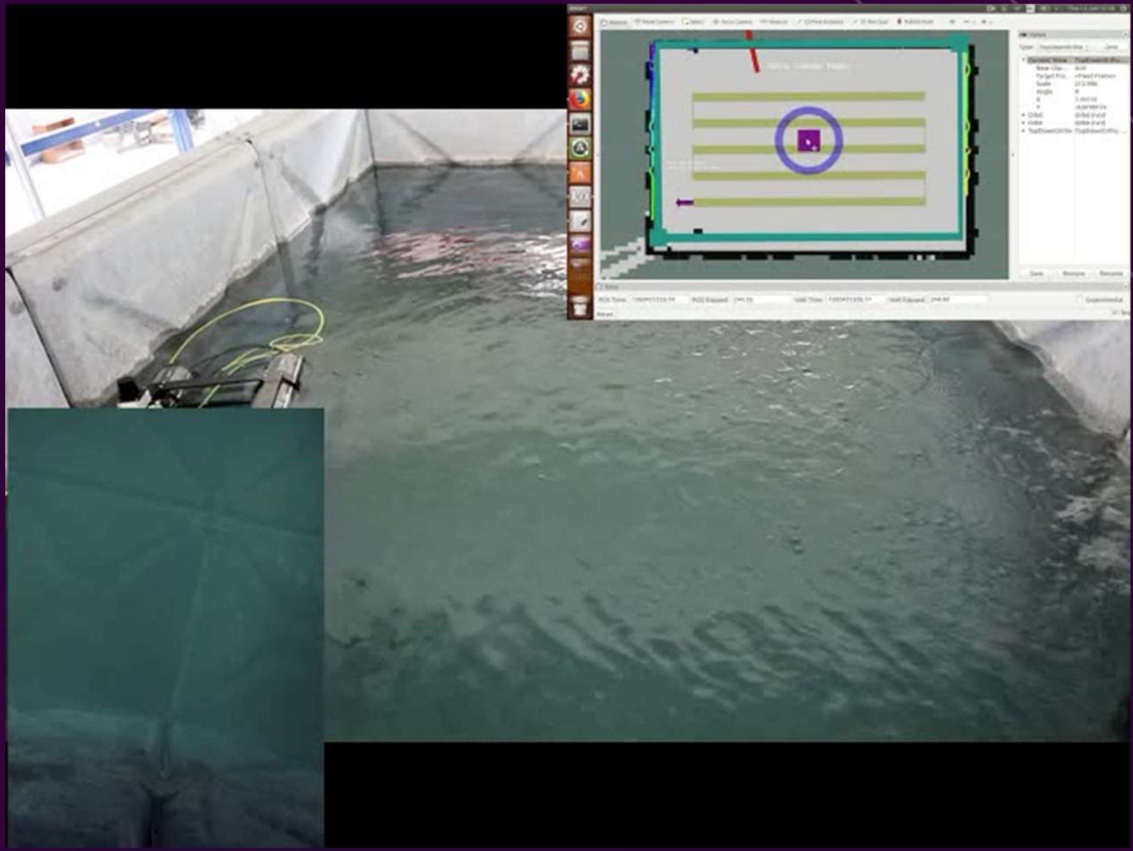
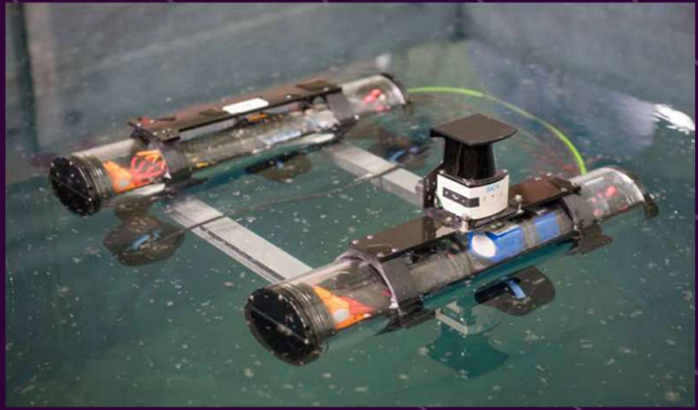
MallARD: Floating Platform (RNE Programme Grant, EPSRC)



MallARD has been designed to inspect nuclear storage ponds.

Software systems similar to those on ground based robots, highlighting the modularity of the hardware and software systems.



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Groves, K. et al., (2019), 'MallARD: An Autonomous Aquatic Surface Vehicle for Inspection and Monitoring of Wet Nuclear Storage Facilities', Robotics

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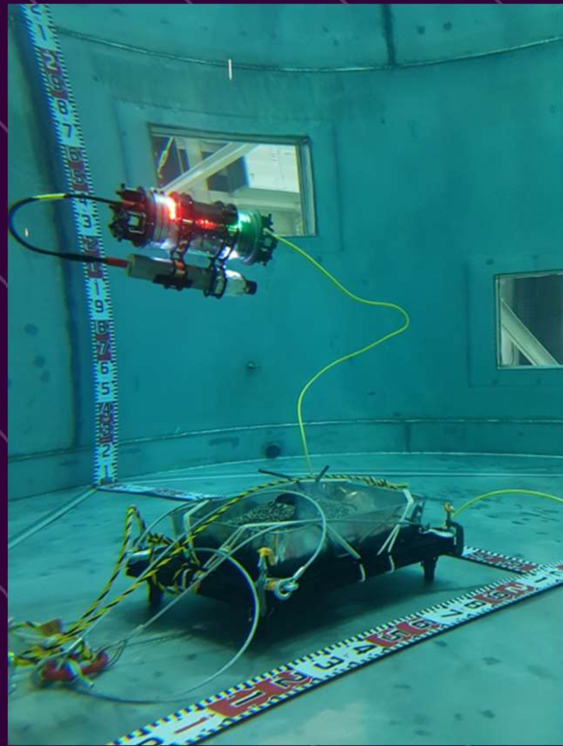
AVEXIS: Submersible Robot (DAMSEL – EPSRC)

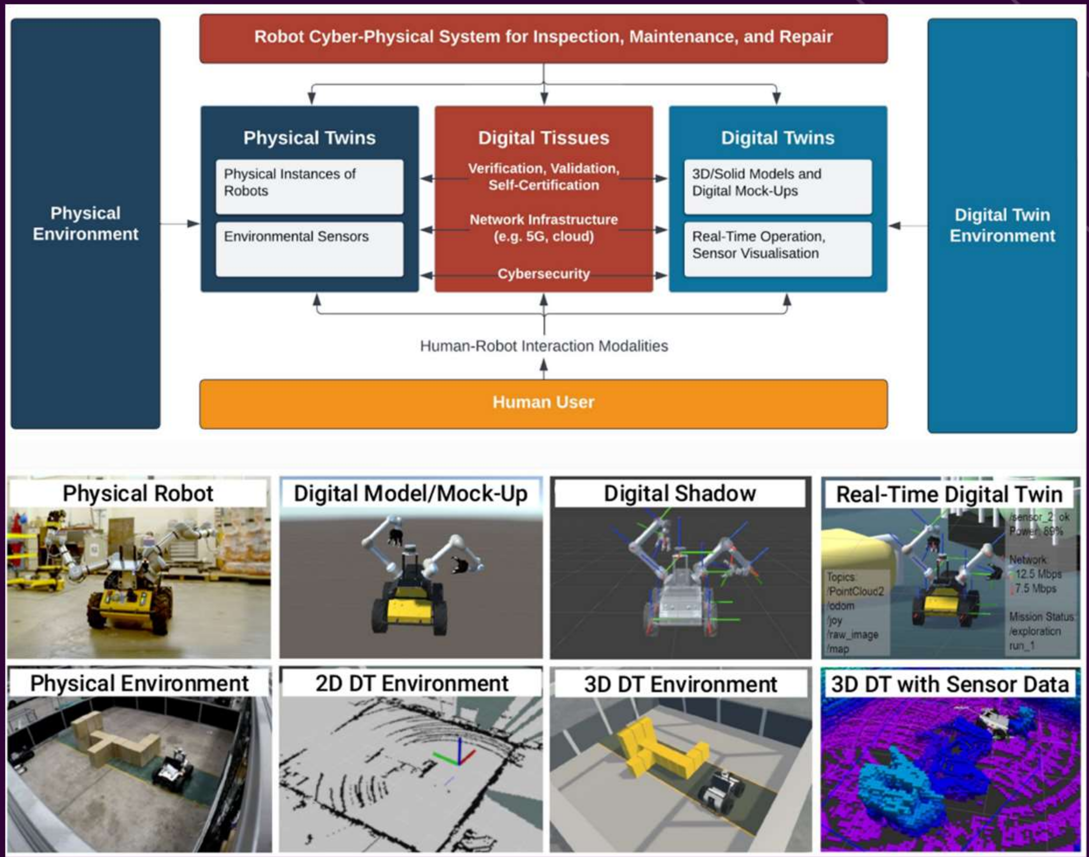
First submersible to be deployed into MSSS, Sellafield



Naraha, Japan

Nancekievill, M. et al., (2019), 'Detection of Simulated Fukushima Daichii Fuel Debris using a Remotely Operated Vehicle at the Naraha Test Facility', Sensors

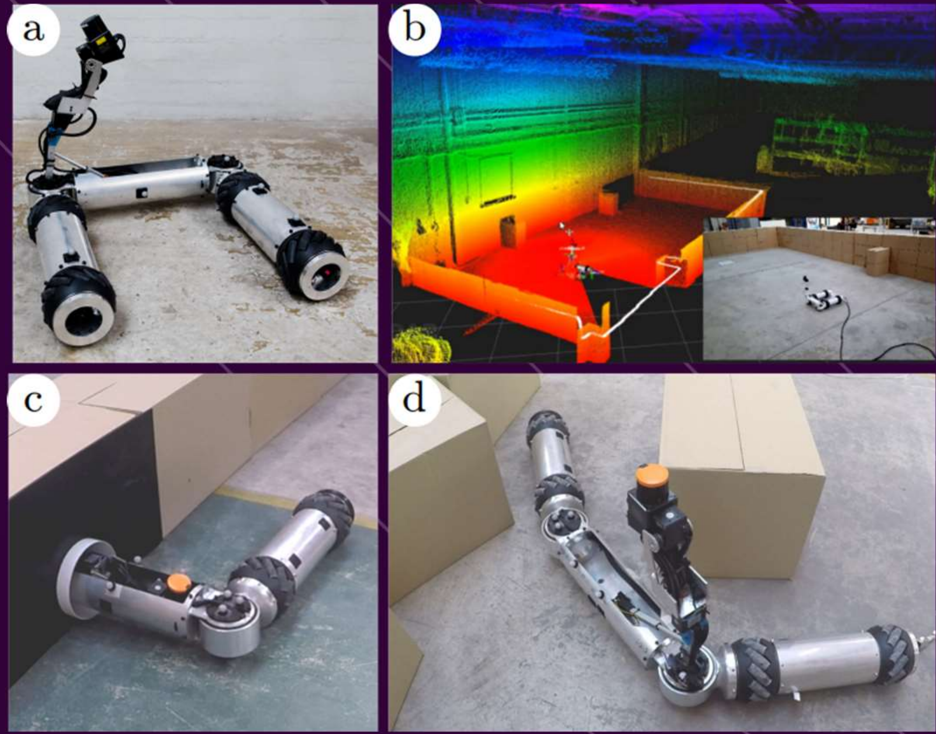
Cyber-Physical Systems for Inspection, Maintenance and Repair



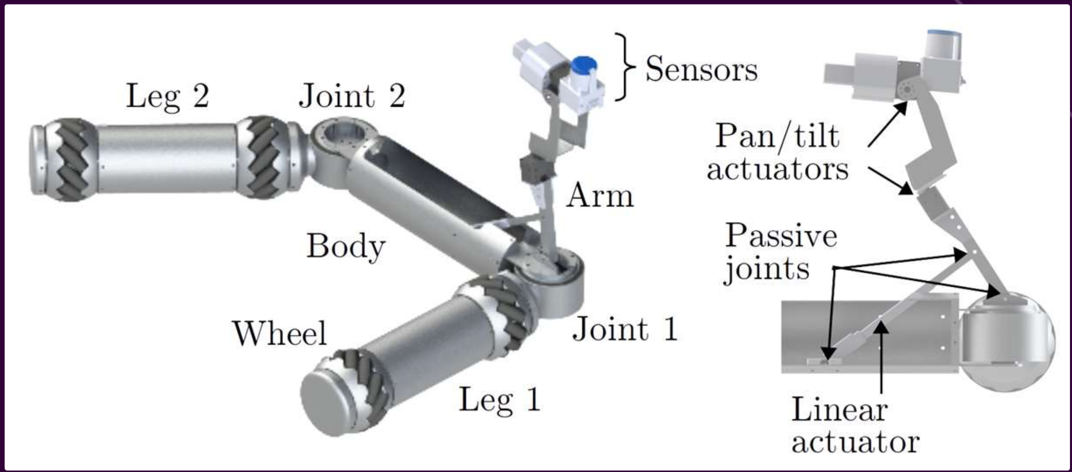
Baniqued, P. et al (2022), ‘Cyber-physical systems and digital twins for inspection, maintenance, and repair robots: a systematic review’, under review Robotics and Computer-Integrated Manufacturing

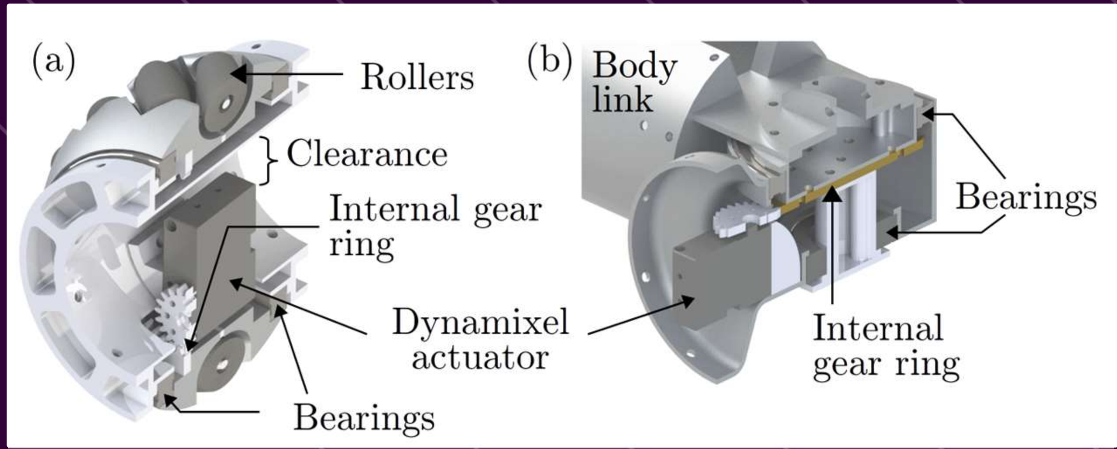
Robotic Inspection – MIniature Robot for Restricted Access EXploration (MIRRAX)

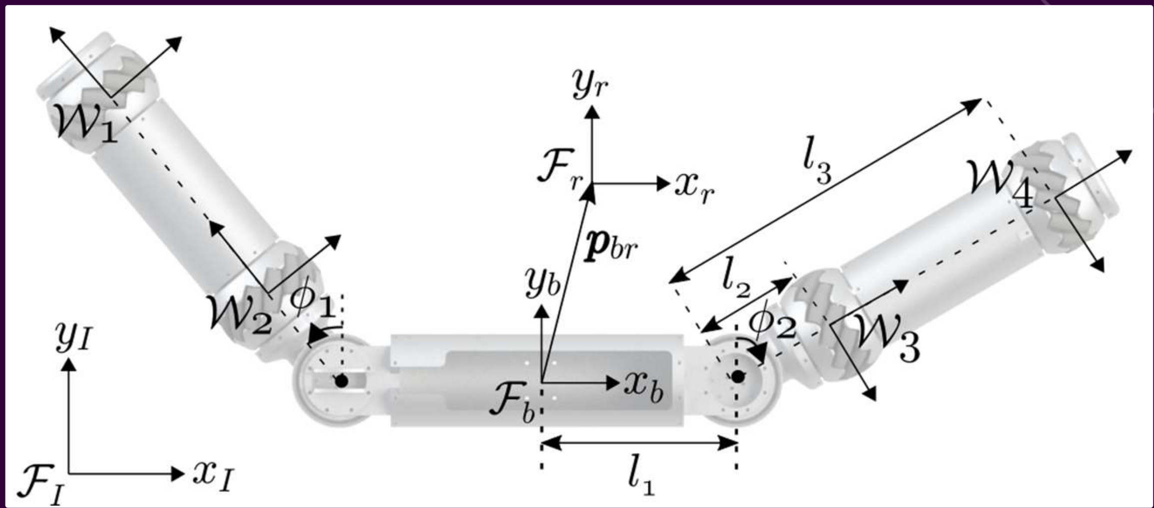
- MIRRAX designed to be deployed through 140 mm ports.
- HD rad-hardened cameras, radiation sensors, LIDAR
- Can generate 3D images once deployed.



Design of MIRRAX







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MIRRAX Operations

Cheah, W. et al., (2022), 'MIRRAX: a reconfigurable robot for limited access environments', IEEE Trans. Robotics

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Design of Robots for the Inspection of Offshore Wind Turbines

Industrial Need

- Asset Inspection, maintenance and repair
- Extreme environment -
  - Hazardous deployment
  - Hazardous working conditions



MULTI-PLATFORM INSPECTION MAINTENANCE & REPAIR IN EXTREME ENVIRONMENTS (MIMREE)

THALES

CATAPULT Offshore Renewable Energy

University of BRISTOL

ROYAL HOLLOWAY UNIVERSITY OF LONDON

Royal College of Art

WOOTZANO

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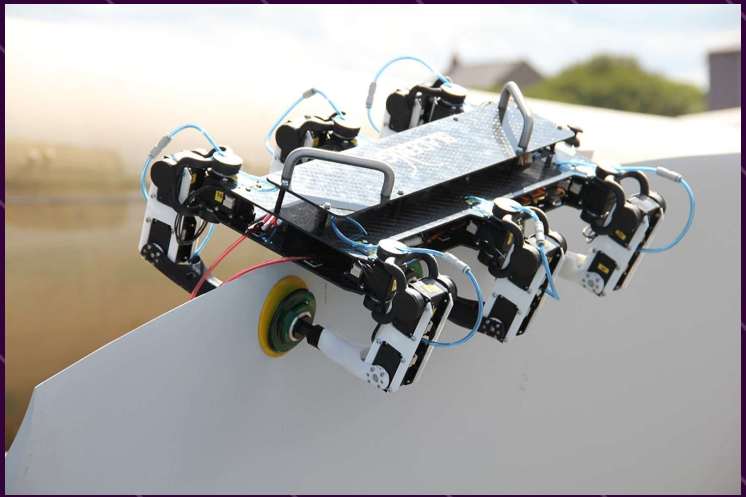
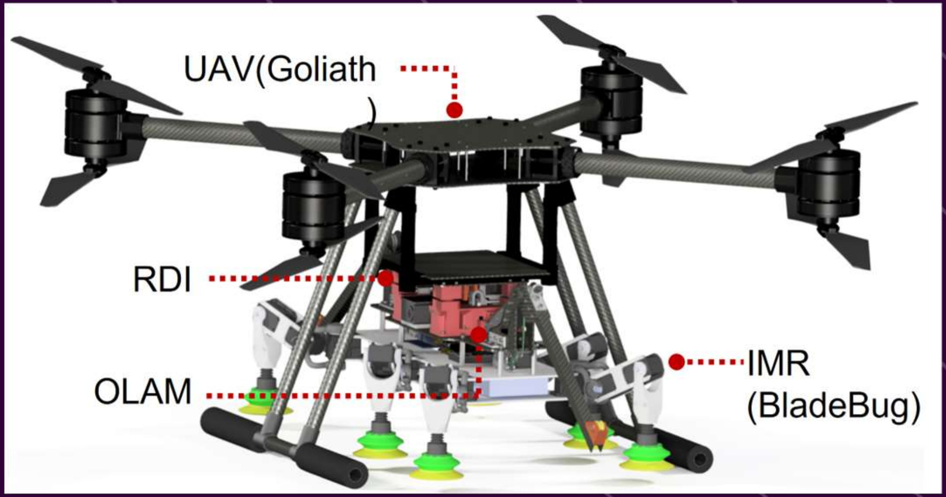
Design Challenges

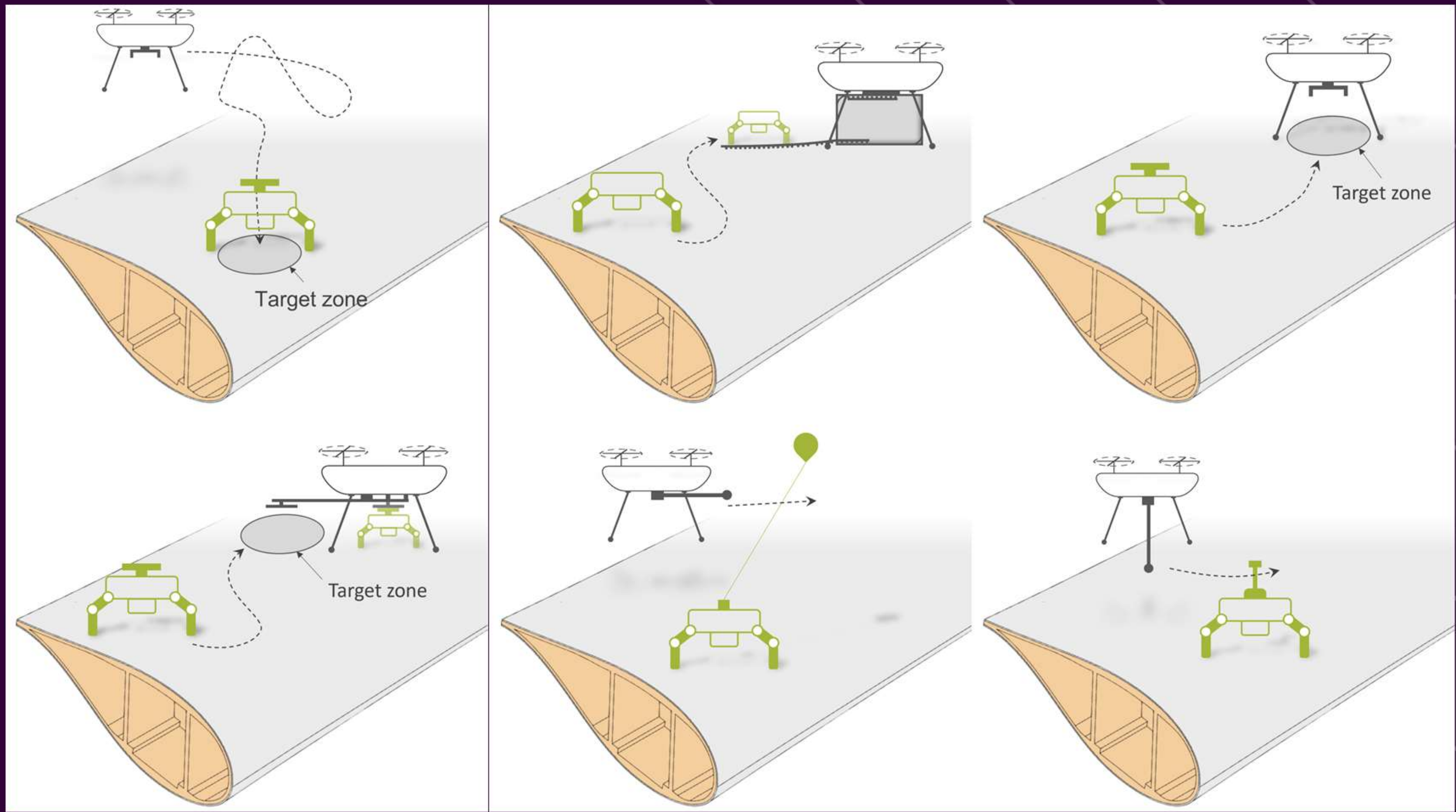
- How to deploy a blade inspection robot onto a wind turbine blade

- How to retrieve a blade inspection robot from a wind turbine blade





Retrieval Mechanisms



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Jiang, Z. et al., (2023), 'Development of a UAV system for retrieval of a robot in extreme environments', Pending Submission, Mechatronics

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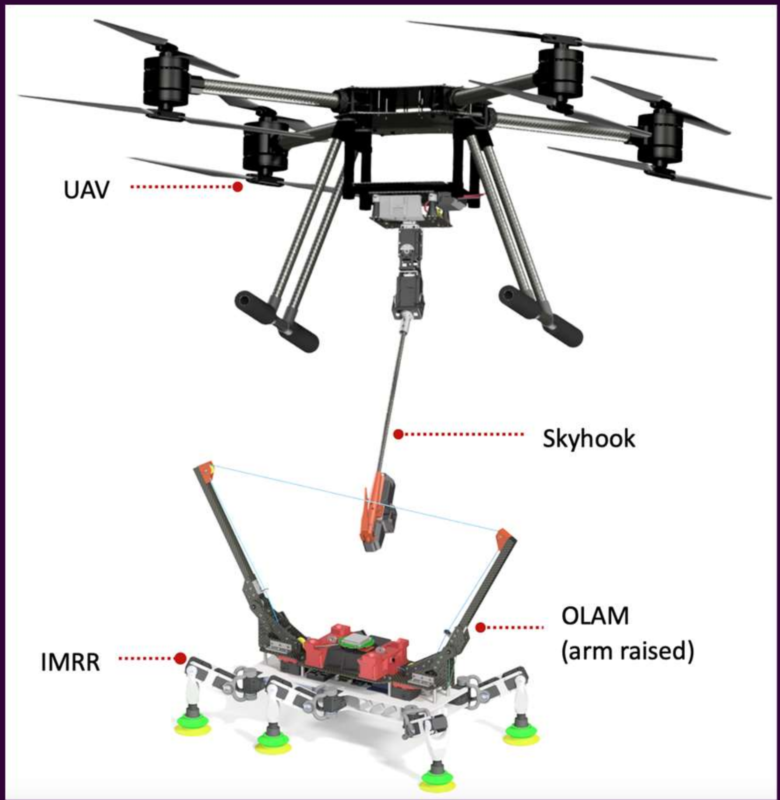
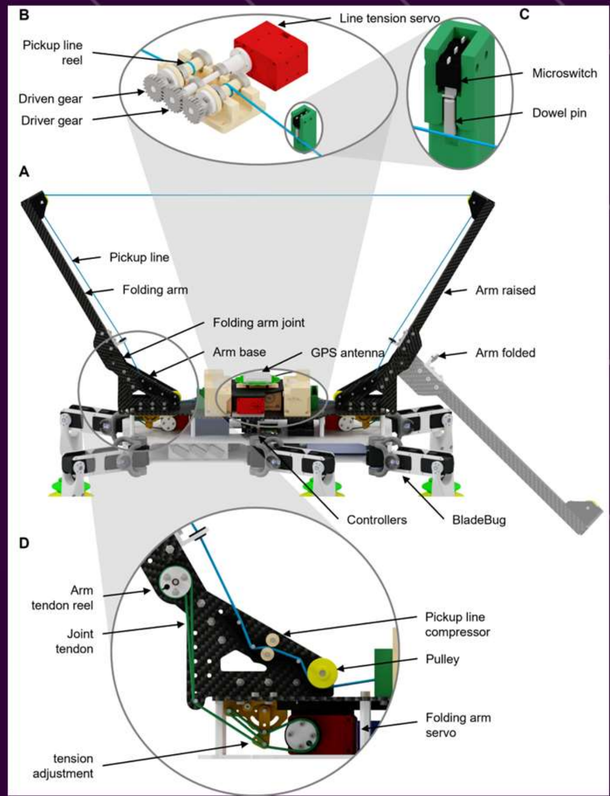
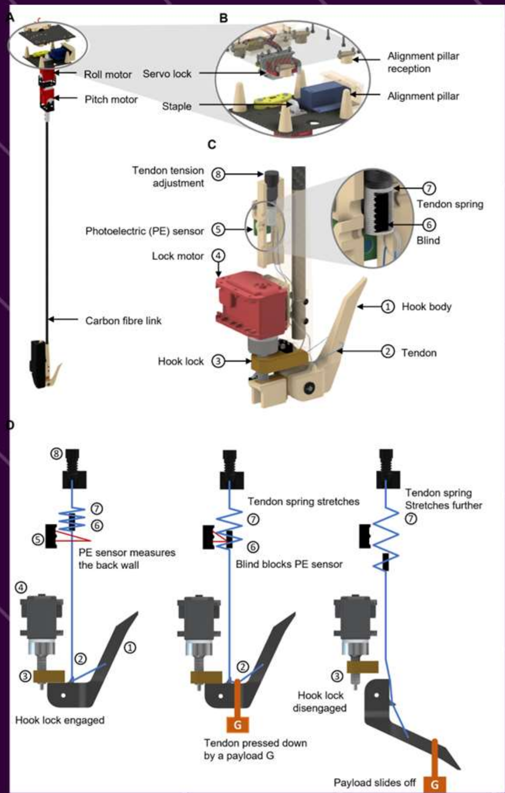
Skyhook Retrieval System







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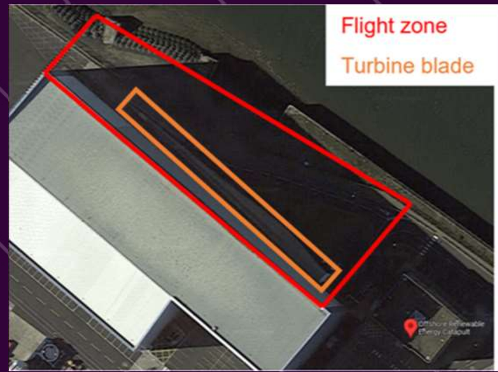
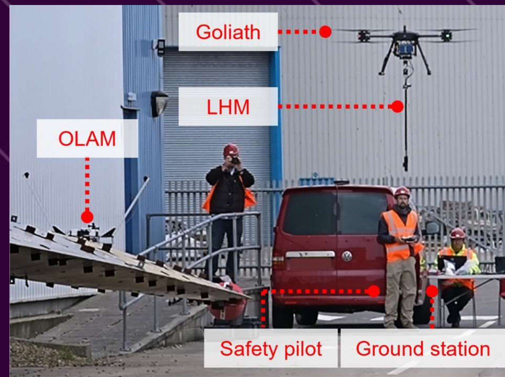
Proof of Concept Testing





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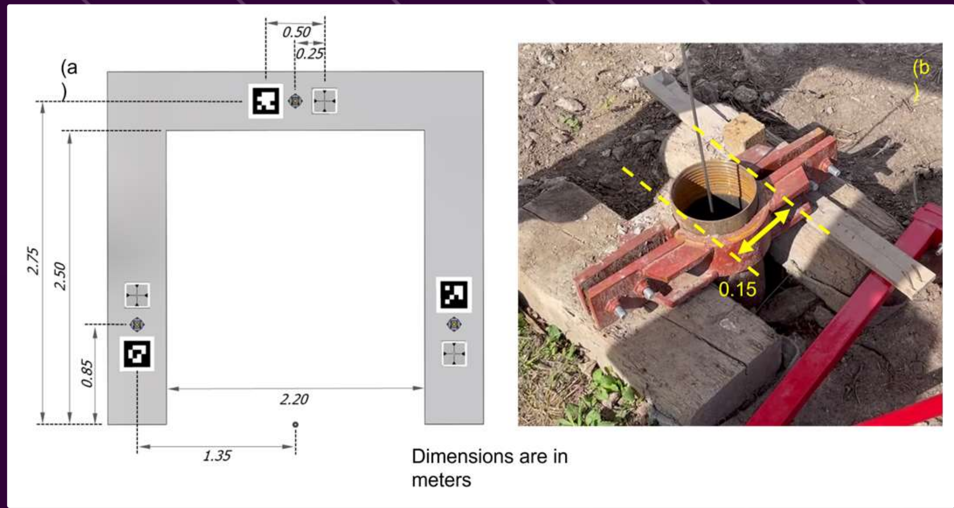
Design of Robots for the Inspection of Subterranean Mines

Industrial Need

- Monitoring of subterranean mines underneath railway lines
  - ~5000 mines under the UK rail network
- Extreme environment -
  - Deployment through 150 mm bore hole through 30 m of rock
  - Dark, GPS denied, BVLOS



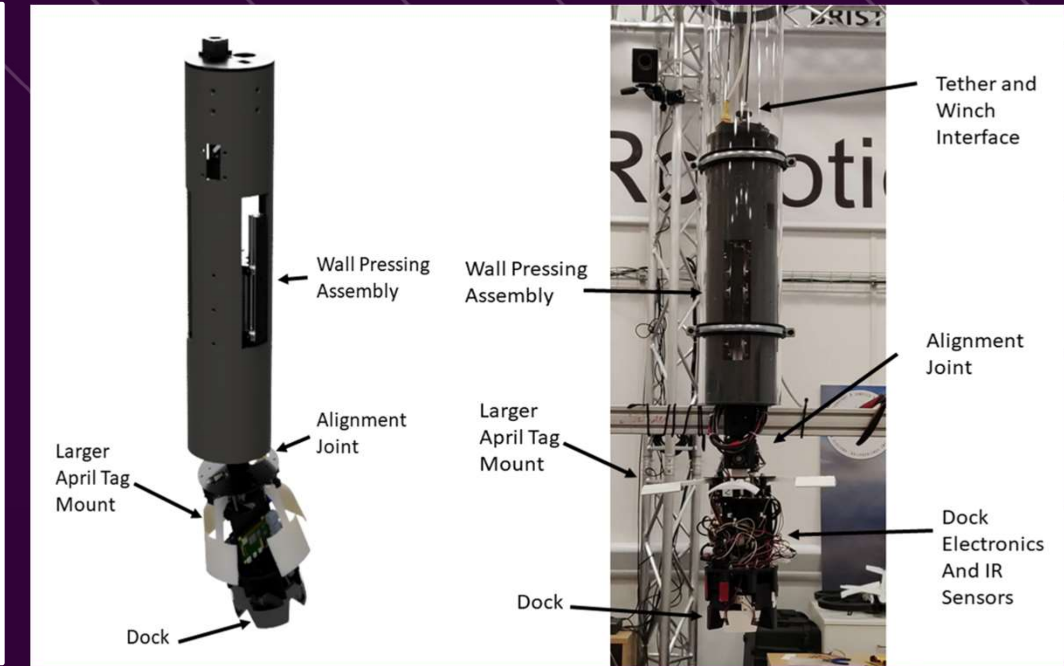
Headlight AI — Intelligence that illuminates | THALES | University of BRISTOL | MANCHESTER 1824 The University of Manchester | ROYAL HOLLOWAY UNIVERSITY OF LONDON | Callen-Lenz | NetworkRail

Prometheus Concept

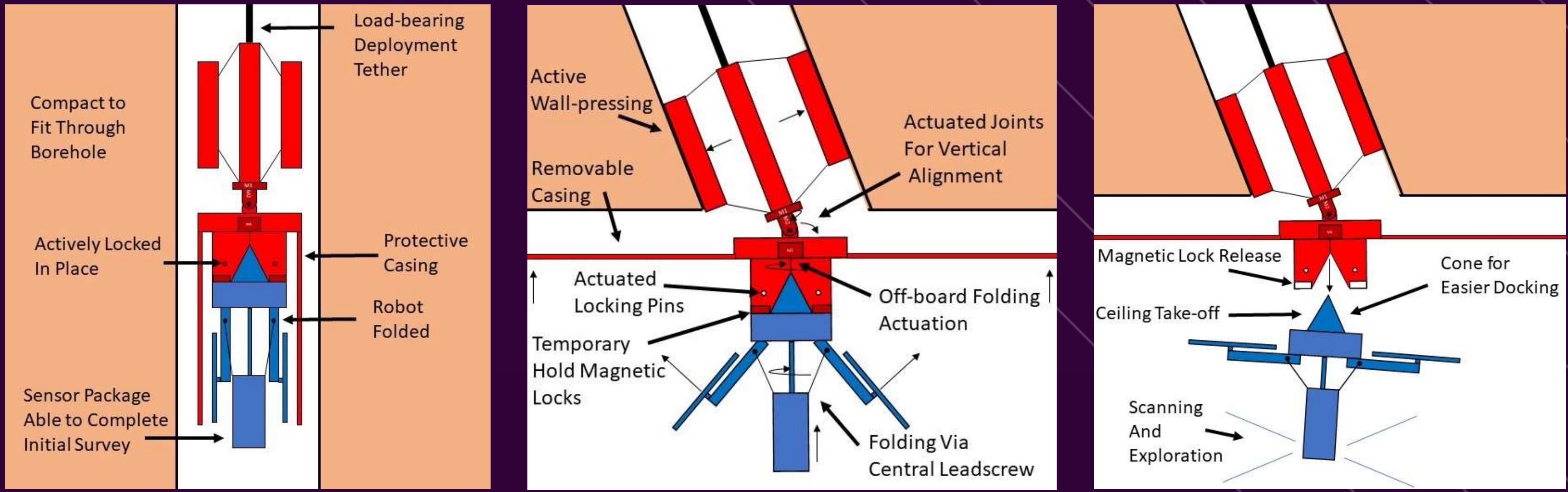
PROMETHEUS

Brown, L. et al., (2020), ‘The Design of Prometheus: A Re-configurable UAV for Subterranean Mine Inspection’, Robotics

Reconfigurable Drone



Borehole Deployment



Deployment Mechanism

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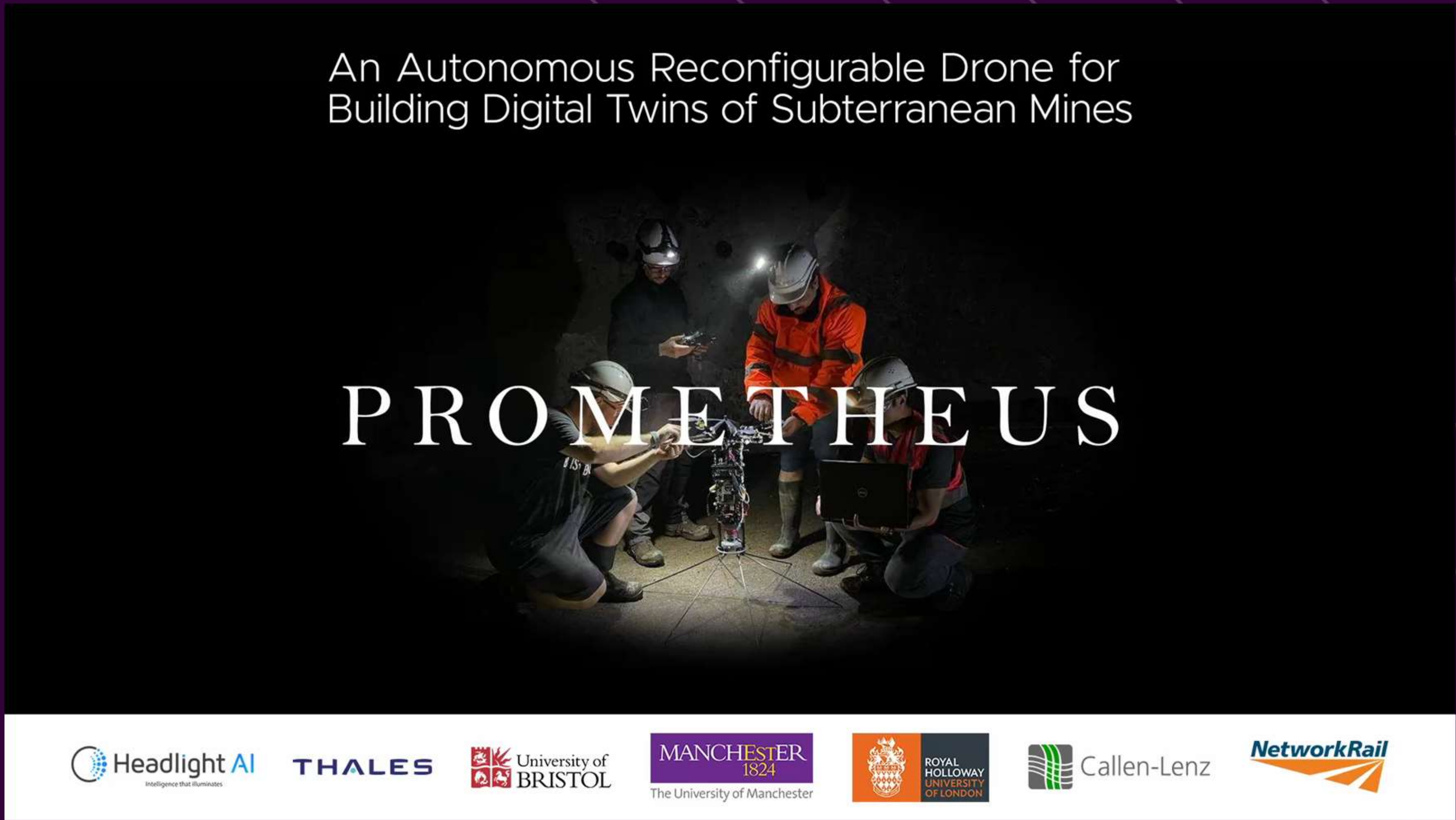
Prometheus Deployment



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Questions?