NMIS
National Manufacturing Institute Scotland

Future Factory

DeepWind Steel Floating Structures
Royal College of Physicians of Edinburgh

18th September

Dr Kenneth Burnham

ACT27 - *Lightweight WT Blade*

- 13m modular blade
- 4 blades manufactured at the @ NMIS
- Installed at Myres Hill wind farm
- Generated 350 kW in first 2 days
- Technology aims to reduce LCOE by 9% with a 10% energy gain
- 8% less material for same stiffness & WT performance.

Contents

NMIS Wind

NMIS Innovation Eco-System

One Scotland partnership

Operated by

University of Strathclyde Glasgow

Supported by

The Scottish Government Riaghaltas na h-Alba

Scottish Enterprise

HIE Highlands and Islands Enterprise Iomairt na Gàidhealtachd 's nan Eilean

CATAPULT High Value Manufacturing

Skills Development Scotland

Renfrewshire Council

Scottish Funding Council Promoting further and higher education

SOUTH of SCOTLAND ENTERPRISE

Academic partners

SRPe Scottish Research Partnership in Engineering

University of Aberdeen

University of Dundee

The University of Edinburgh

Heriot Watt University

Edinburgh Napier University

GCU Glasgow Caledonian University

University of Glasgow

University of Strathclyde Glasgow

Robert Gordon University Aberdeen

UWS University of the West of Scotland

NMIS Wind

High Value Manufacturing Catapult

The High Value Manufacturing Catapult has established itself as the ‘go-to’ place for advanced manufacturing technology.

Working with thousands of clients on thousands of projects, we have developed unique insights into manufacturing in the UK and have been central to many of the principal developments which will shape its future.

CATAPULT
High Value Manufacturing

Established and supported by Innovate UK

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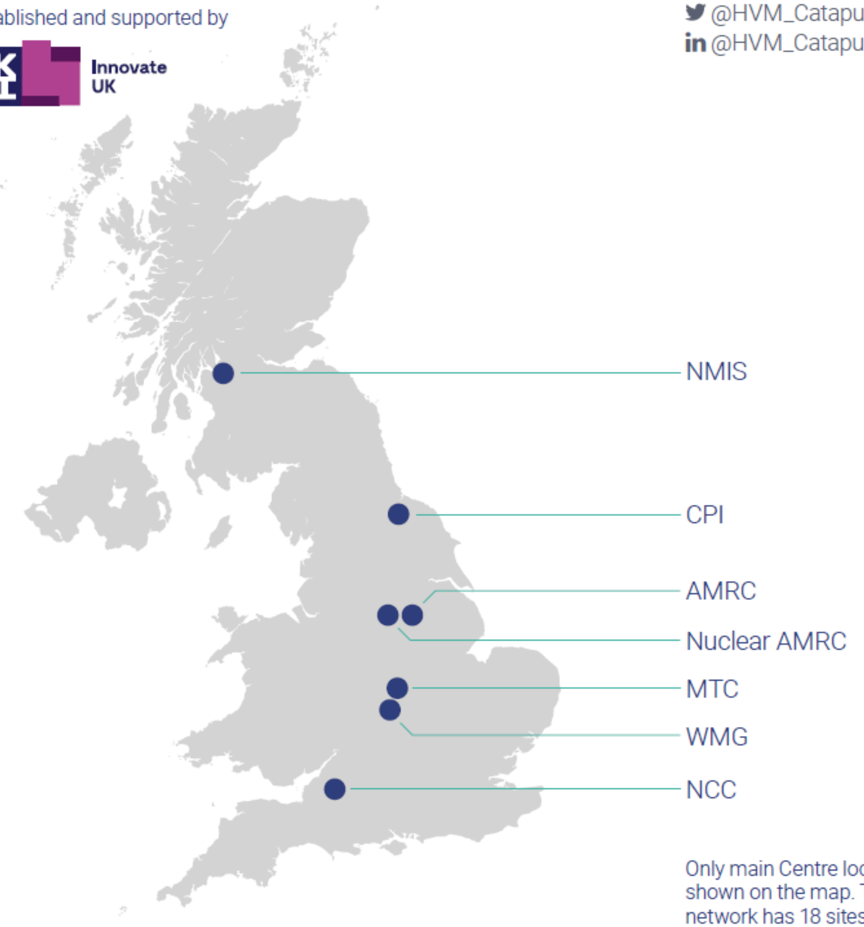

Only main Centre locations are shown on the map. The HVMC network has 18 sites in total.

NMIS Wind

The National Manufacturing Institute Scotland Group

NMIS
National Manufacturing Institute Scotland

- NMIS National Manufacturing Institute Scotland — **Advanced Forming Research Centre** University of Strathclyde
- NMIS National Manufacturing Institute Scotland — **Digital Factory**
- NMIS National Manufacturing Institute Scotland — **Lightweight Manufacturing Centre**
- NMIS National Manufacturing Institute Scotland — **Manufacturing Skills Academy**
- NMIS National Manufacturing Institute Scotland — **Digital Process Manufacturing Centre**

Manufacturing

"By 2035, the UK is a world leader in core turbine components and cable manufacture and has advanced deep water foundations to enable industrialisation of floating offshore wind. The UK's environmental installation and O&M services are technology-driven, reducing overall costs and equipment downtime for the UK and global offshore wind fleet."

- *OWIC, Renewables UK, The Crown Estate*

5 UK priorities:

1. Turbines
2. Deep Water Foundations
3. Installation
4. Environmental Services
5. Electrical Systems & Cables

RESPOND

EXPAND

DISRUPT

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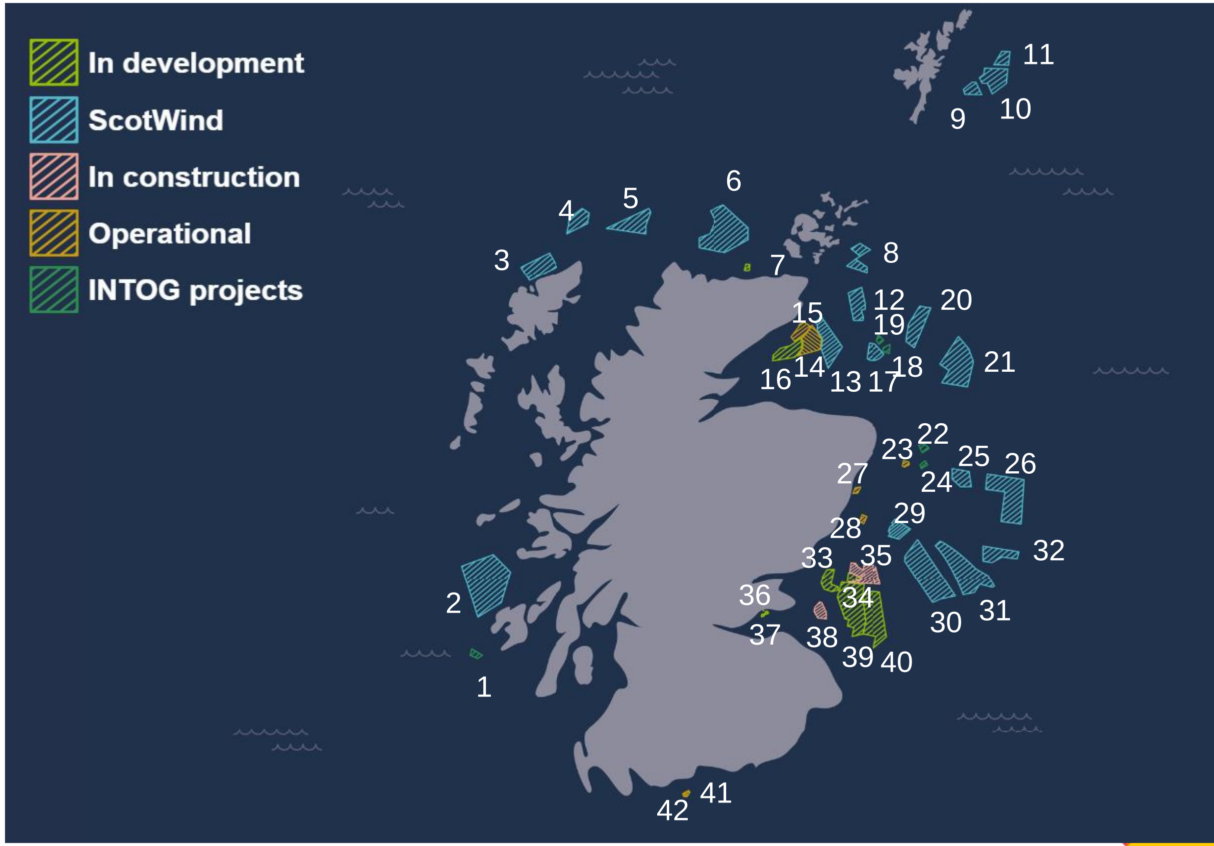
Manufacturing

IGP report references the following with respect to steel structures

- Grade thickness of steel towers
- Steel chains on mooring lines
- Weight reduction of steel components structures
- Reduction in carbon content of steel
- Green Steel

Wind Pursuit @ NMIS

Respond to the challenges of ScotWind & INTOG



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Wind Pursuit - Objectives

- Multidisciplinary approach to innovation across sectors
- Leveraging specialist centres by optimising, de-risking & scaling-up manufacturing processes
- Develop & validate manufacturing processes to expedite and integrate the supply chain
- Prioritising sustainable manufacturing practices to minimise environmental impact
- Ensuring parity of manufacturing & supply chain demands against a programme of skills and training

Technology

Skills

Supply Chain

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Wind Pursuit - 5 key areas

- Supporting the development and delivery of national wind sector growth plan
- Through-life extension of wind farm assets
- Advanced offshore substructure & mooring system manufacturing
- Enabling wind sector raw material supply & circularity
- Next generation high performance wind turbines

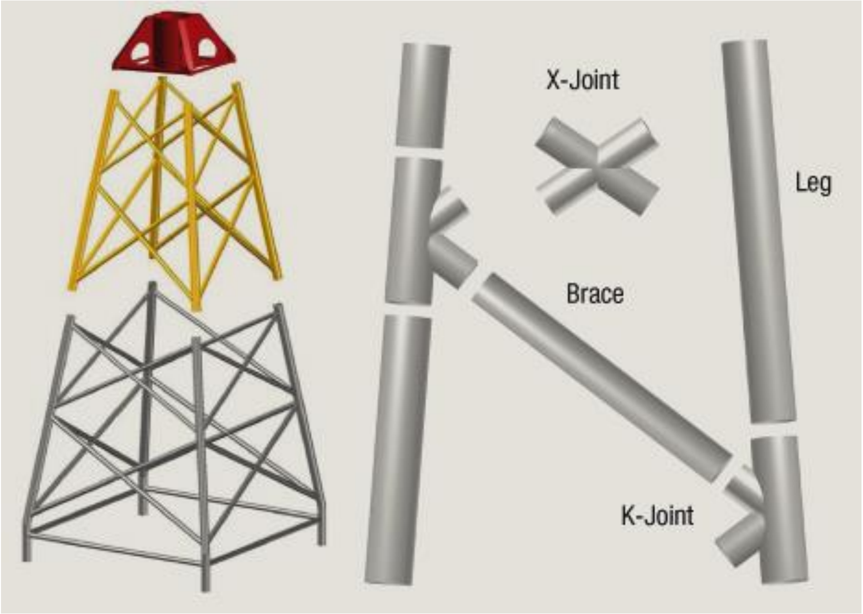
Technology | Skills | Supply Chain

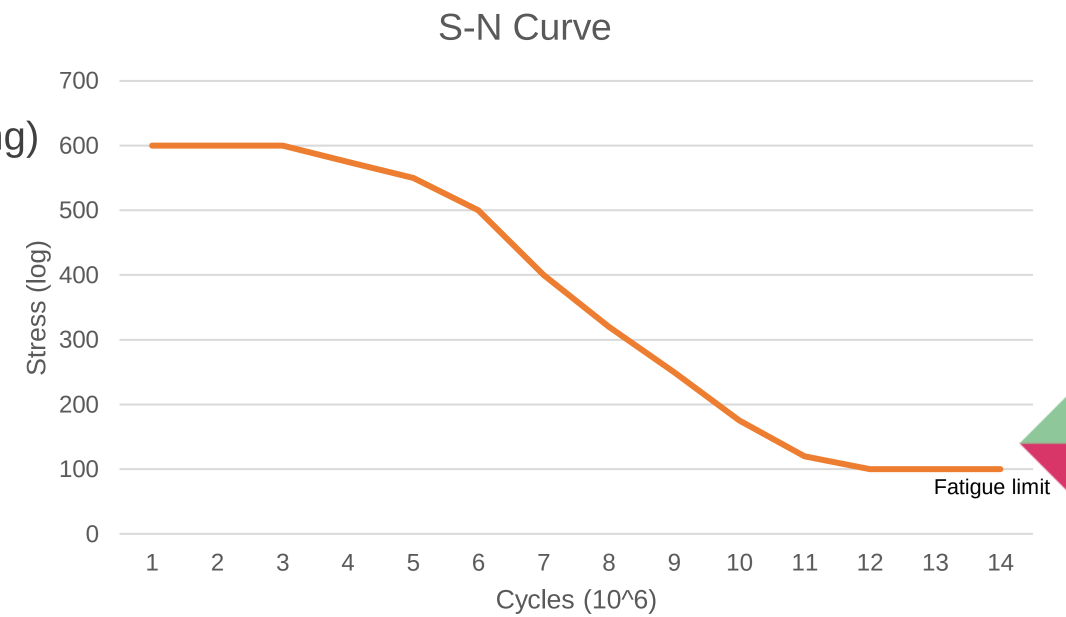
NMIS Wind

Response to IGP - Jacket Nodes

- Joint project with the Naval Architecture, Ocean & Marine Engineering (NAOME) department at University of Strathclyde:
  - *Routes to Volume Manufacture of Mooring Lines & Jacket Nodes*

- According to ORE Catapult, jacket nodes will likely dominate post 2030 due to challenge of existing proposed offshore wind sites
  - Susceptible to fatigue hot-spots due to environmentally exposed manual intensive welding
  - Move to deeper water will see demand outstrip supply by 2026
  - IGP has identified jacket nodes as an area for expansion in UK manufacturing sector (worth ~£100m)…research into:
    - Material efficiencies
    - Minimisation of fatigue hotspots (aero-, hydro-dynamic coupling)
    - Intersection profile control: enhanced joining
    - Sustainable green industrial base with respect to volume manufacture and automation





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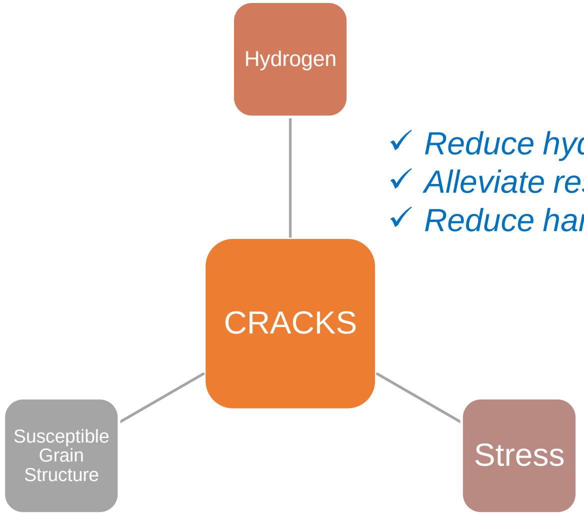
Welded Steel Structures

FUSION WELDING

- Arc Weld
  - MAW
    - MMA
    - SAW
    - FCAW
    - MIG
    - MAG
      - CO_2 Weld
    - Electro Gas Weld
  - Carbon Arc Weld
  - TIG
  - Arc Spot Weld
  - Atomic Hydrogen Weld
  - Arc Plasma Weld
- Gas Weld
- Electro-slag Weld
- Aluminothermic Weld
- Light Radiation Weld
- Electron Beam Weld
  - Laser Weld
  - Arc Image Weld

Weld Defects

- **Cracks**
  - Solidification cracks
    - ✓ *Change weld composition to one with a smaller freezing range*
  - Lamellar cracks
    - ✓ *Improved through-thickness ductility: better material selection; improved welding procedures; and improved joint design*
  - Reheat cracks
    - ✓ *Limit geometrical stress concentrators, control heat treatment procedure*
  - Hydrogen induced cracks
    - ✓ *Control of weld-metal cooling; pre-heating for removal of H, limit hardness in HAZ (C-content)*
- **Cavities**
  - Breakdown in de-oxidation practice
    - ✓ *Dry consumables, suitable filler wires, and adequate de-oxidant content, clean edge preparations*
  - Continuous contamination of parent metal surfaces
    - ✓ *Clean edge preparations*
- **Solid Inclusions**
  - Slag, flux, oxides, tungsten inclusions
    - ✓ *Improved operator skills*
- **Lack of fusion (LOF) and penetration (LORP)**
  - Incorrect welding current, voltage
    - ✓ *Improved welding technique*



- ✓ *Reduce hydrogen*
- ✓ *Alleviate residual stress*
- ✓ *Reduce hardness in HAZ*

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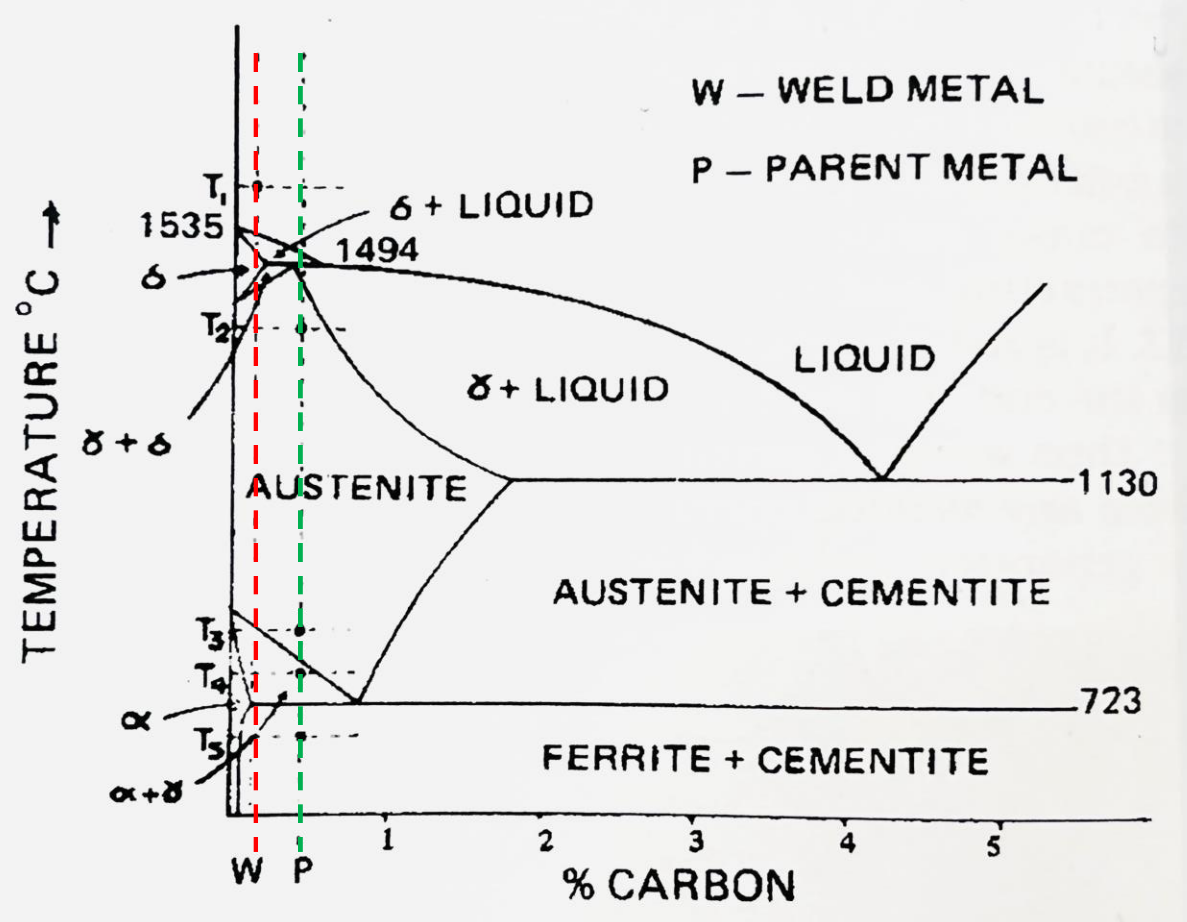
Weld Defects

- Different carbon contents in weld metal & parent metal
  - Weld metal has composition: $\frac{xF\ (\delta)}{Cx\ (liquid)}$
  - Parent metal has composition:

$$\frac{yF\ (\delta)}{Cy\ (liq)} \xrightarrow{peritectic} \gamma + liquid$$

  - A gradient of alloying elements
  - Composition varies from weld metal to parent metal across a volume of alloy



- Potential for lower melting point alloys or compounds around the weld grain too weak to withstand the contraction stresses during cooling ➔ *Hot Crack*
- Additional carbon leads to rapid rates of cooling ➔ *Hardening* *(crack under weld stress)*
- Insufficient ductility in the weld metal (lack of weldability), HAZ, and the parent metal to absorb stress ➔ *Crack*

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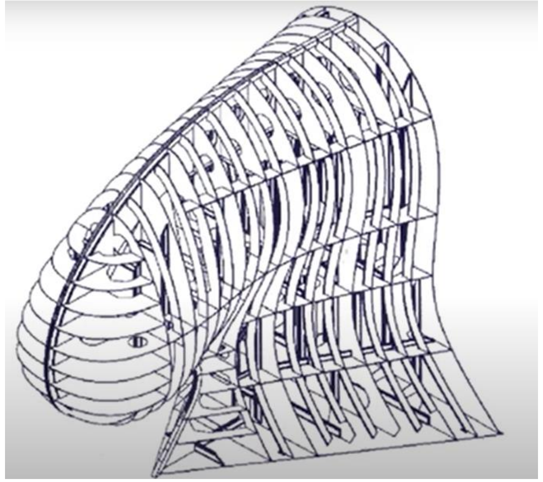
Automation

Advantages

- Repeatable and reliable process under the control of the fabrication team
- Correct alloy carbon content
- Correct alloy weldability: ductility, reduced hardness, reduced residual stress
- Eliminates dangers of exceeding process tolerance limits regarding alloy composition freezing range (Weld / HAZ / Parent metal)
- Ensures correct skill-application: current/voltage (MIG, TIG, SubArc); continued run / shielding from contaminants



Issues

- Component geometry with respect to welding sequence
- Depositing robot needs to know next run: arc-length important for material integrity
- Incorrect set-up implications
- May not be suitable for particularly complex geometries with hard-to-access areas
- e.g. Bulbous bow of a ship:
    - All parts need to be welded (plates, sections, seams)
        - ✓ Solution might be to print a shell, increase wall-thickness & mechanical braces
            - Thicker parts have faster cooling rates upon welding ➔ risk martensite formation: preheat required to avoid hardening

How to design steel structures which remove the need for welding: lessening issues re-dimensions, distortion, and need for NDT

If weld process can be automated, then so too can NDT process.

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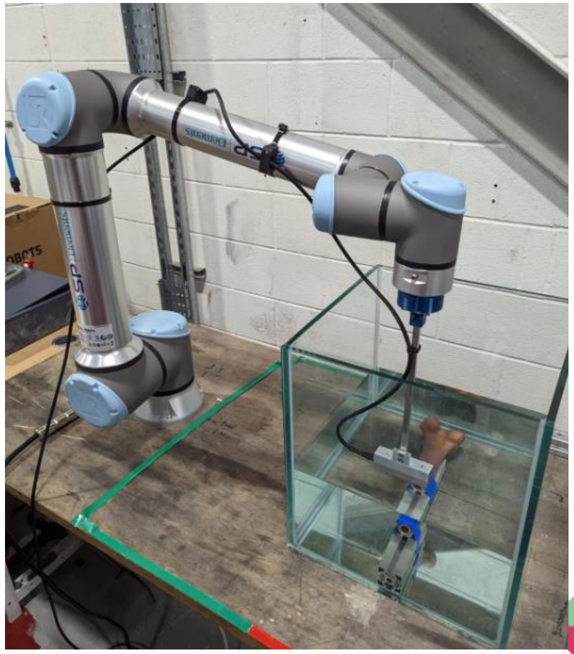
Robotic Inspection

- Robotic metrology and NDT
- Robot-enabled metrology using 6-axis and mobile platforms.
- Currently building NMIS robotic NDT capability with view to continuing a complementary collaboration with the Sensor Enabled Automated Robotics & Control Hub (SEARCH) at UoS.

Combined inspection cell from Wing of Tomorrow

Use of Spot for large volume metrology



UR10 integration with PEAK PAC for UT NDT

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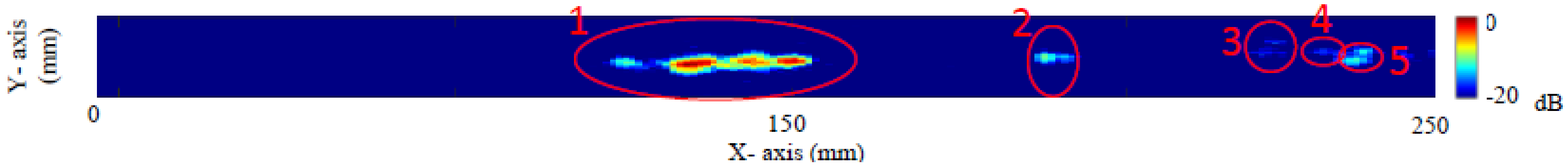
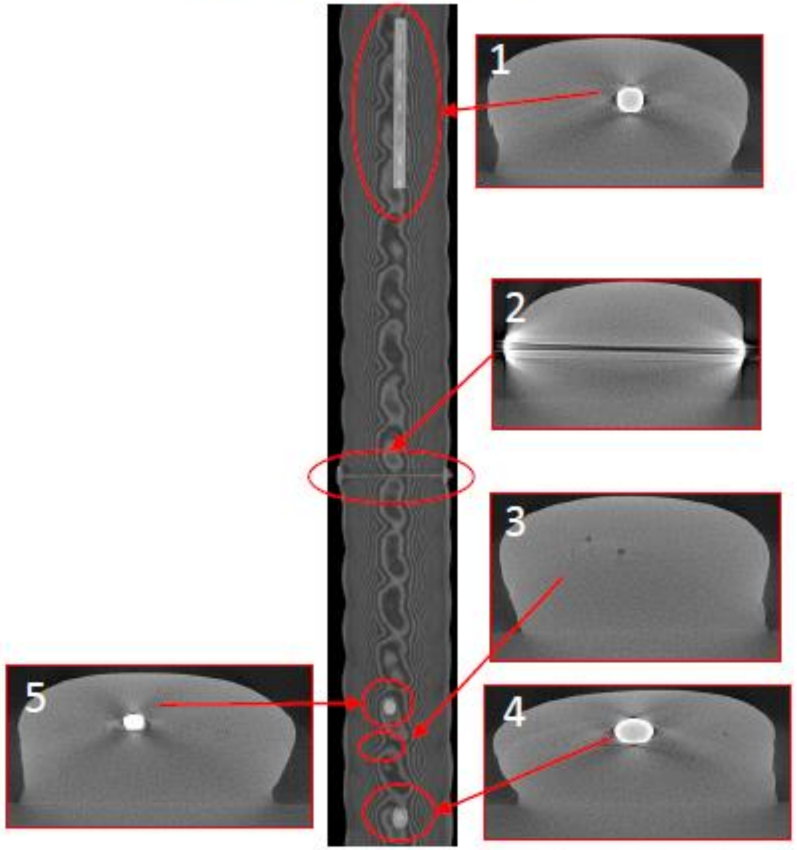
Automated NDT

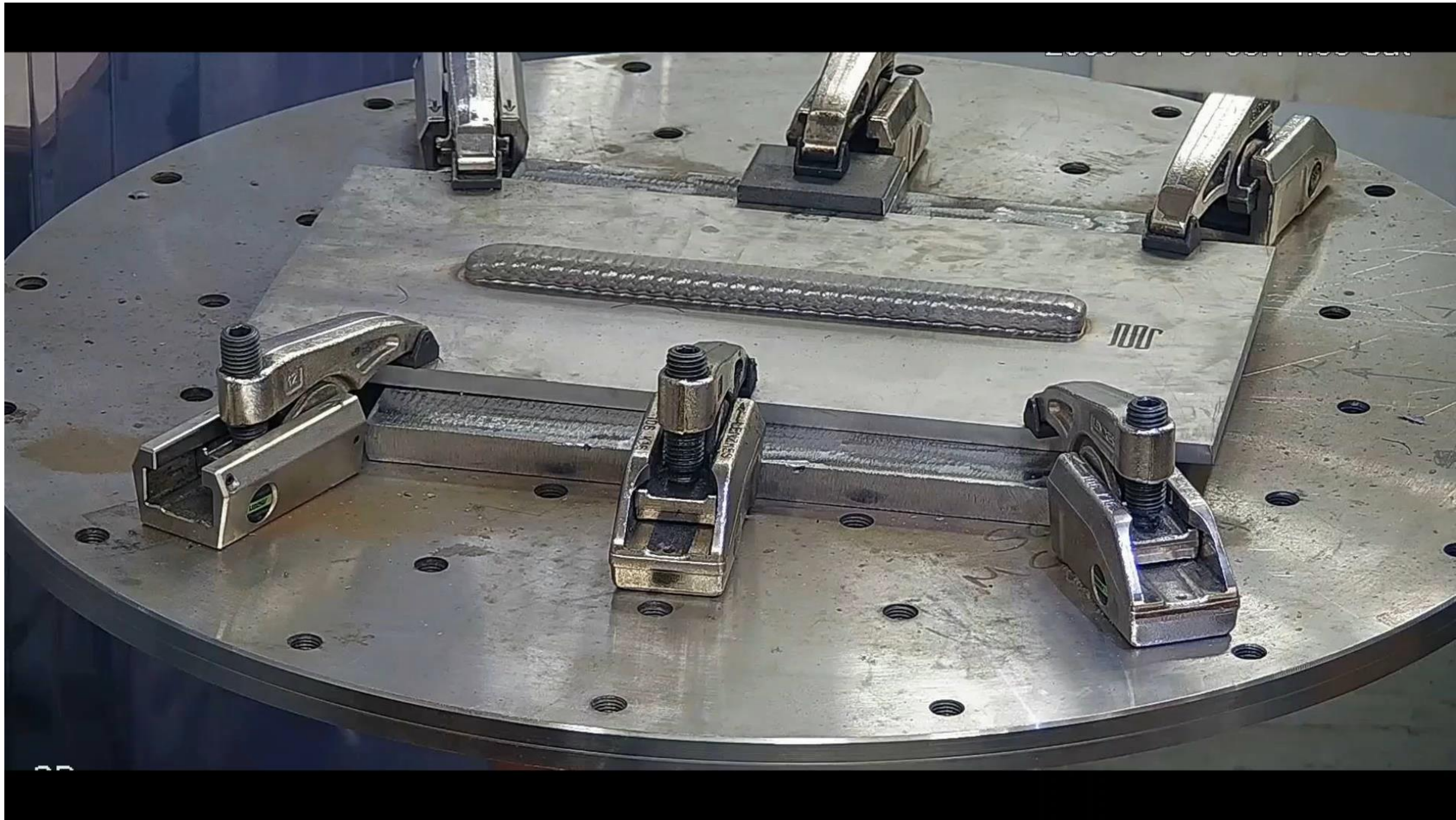
- Ti-6Al-4V sample
- Plasma arc deposition process with an argon shielding gas
- Artificial reflectors (Tungsten tubes and balls)

Ultrasound imaging using TFM



Verification X-Ray CT

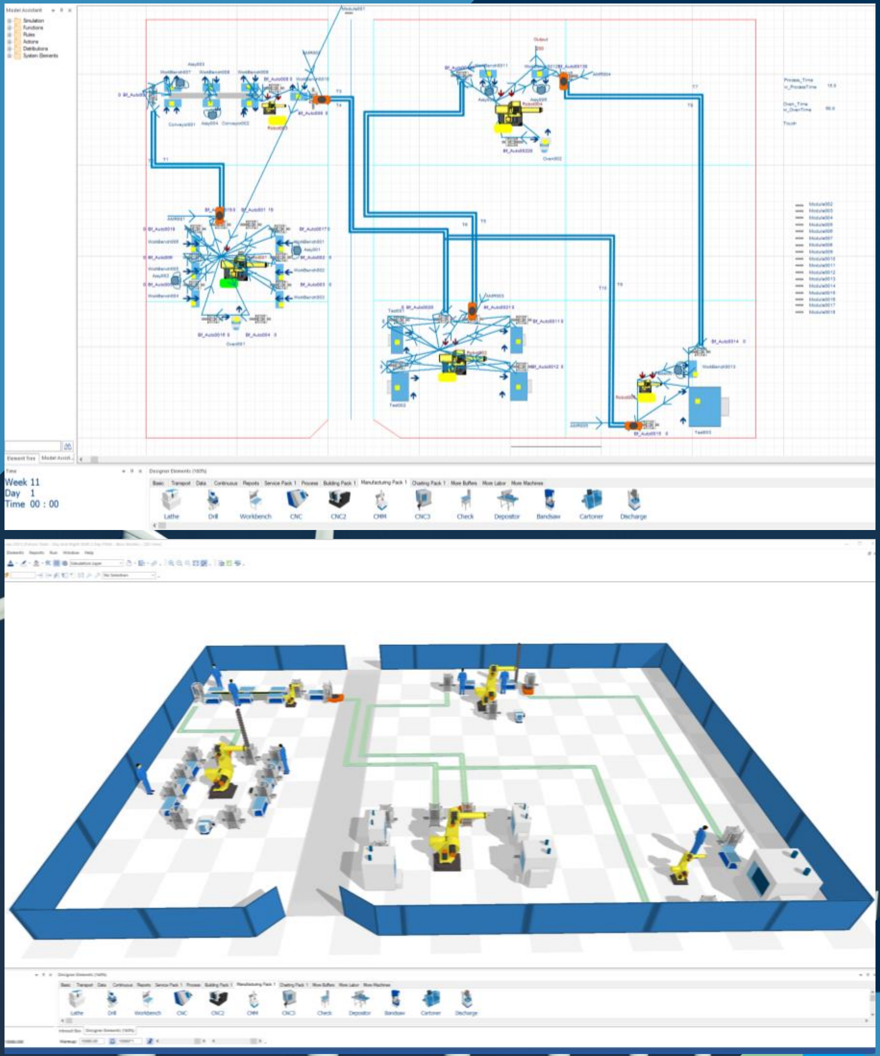




Future Factory

- Design verification
- Discrete Event Simulation to determine optimal future solutions
- Automated manufacture & process control
- Automated inspection for Industry 4.0
- Disruptive research & industry partnership
- Strategy planning & industry engagement
- Supply chain support & funding opportunities
- Circular economy, sustainability & reiterative design

Automated Manufacturing Cell (Defence)



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