PLEASE STAND BY

Episode 2: U. K. Nuclear Advanced Manufacturing Research Centre, Advanced Manufacturing Technologies July 30, 10:00AM - 12:00PM

CO HOSTS:

- **Joseph Bastien,** Manager, OCNI
- **Wilson Lam,** CNS G4SR-2 International Conference Chair; Senior Nuclear Technology Advisor, Ontario Ministry of Energy, Northern Development & Mine, Ontario, Canada

GUEST SPEAKERS

- **Charles Carpenter,** Senior Technology Officer, Nuclear AMRC
- **Matt Smart**, Project Technical Lead in the Nuclear AMRC's Machining Technologies Group

AGENDA

10:00 am - Webinar Instructions

10:02 am - OCNI and CNS Opening Remarks and Introduction of Invited Speakers

10:10 am - Advanced Manufacturing Technologies and Applications Under Development and How Manufacturing Innovation is Helping Cut the Cost of New Low-carbon Generation

10:35am - In-depth Look at Single-platform Manufacturing Techniques Developed Through The Nuclear Innovation Programme, Part of the UK's Nuclear Sector Deal

10:55 am - Q&A With Participants

11:15 pm - Closing Remarks

11:20 pm - CLOSE

G4SR-2 SMR WEBINAR SERIES

Canadian Nuclear Society
Société Nucléaire Canadienne

OCNI ORGANIZATION OF CANADIAN NUCLEAR INDUSTRIES

Clean Energy for a Low Carbon Economy

NUCLEAR AMRC

ADVANCED MANUFACTURING RESEARCH CENTRE

Advancing UK manufacturing

The University Of Sheffield.

MANCHESTER 1824
The University of Manchester
Dalton Nuclear Institute

Supported by the
Regional Growth Fund

CATAPULT
High Value Manufacturing

European Union
European Regional Development Fund

NUCLEAR AMRC

ADVANCED MANUFACTURING RESEARCH CENTRE

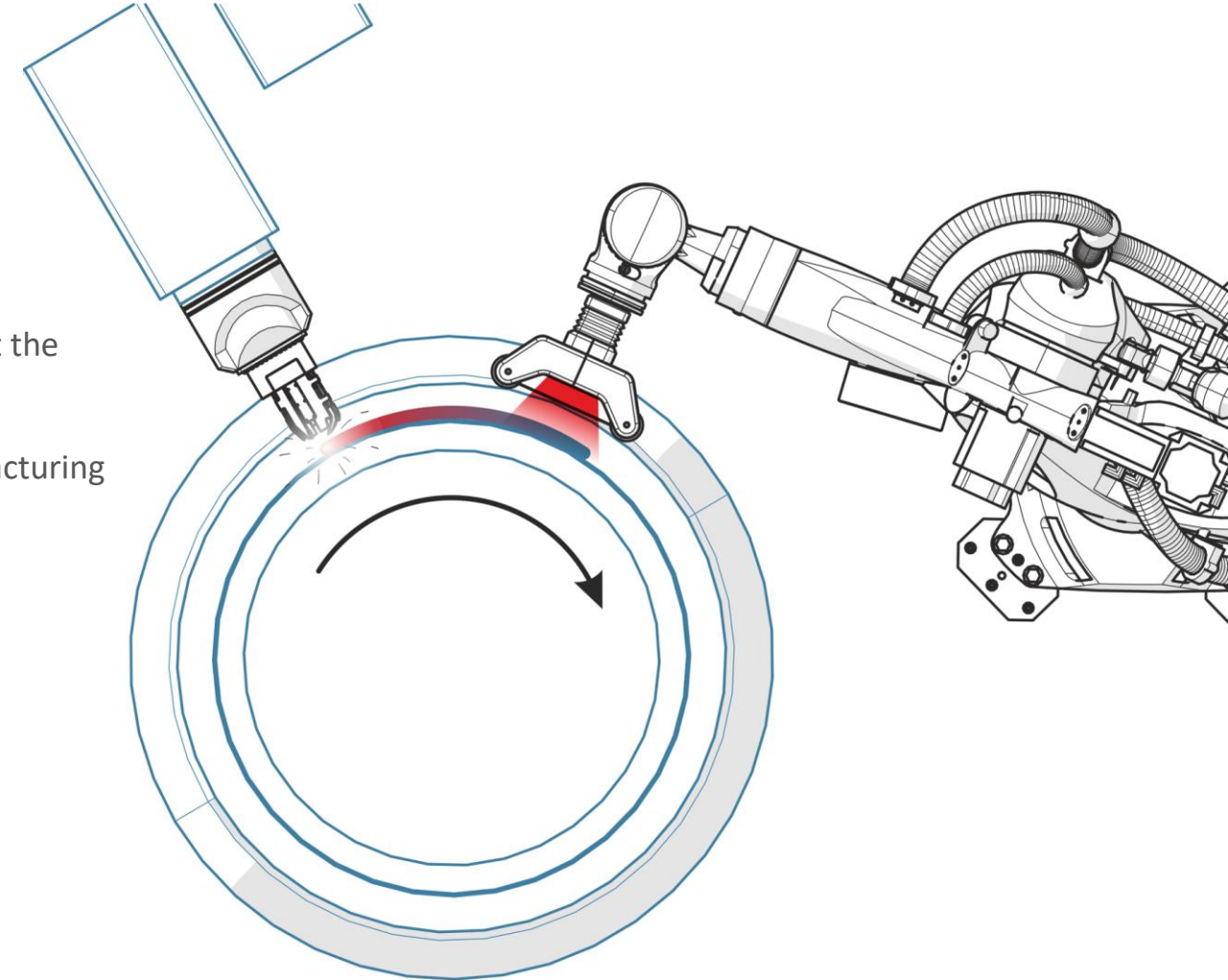
Charles Carpenter

Senior Technology Officer

30 July 2020

Overview

- Challenges
- Manufacturing innovation at the Nuclear AMRC
- Automated platform manufacturing
- SIMPLE
- Future work – AWESIM



Net zero by 2050

Total decarbonisation of electricity generation

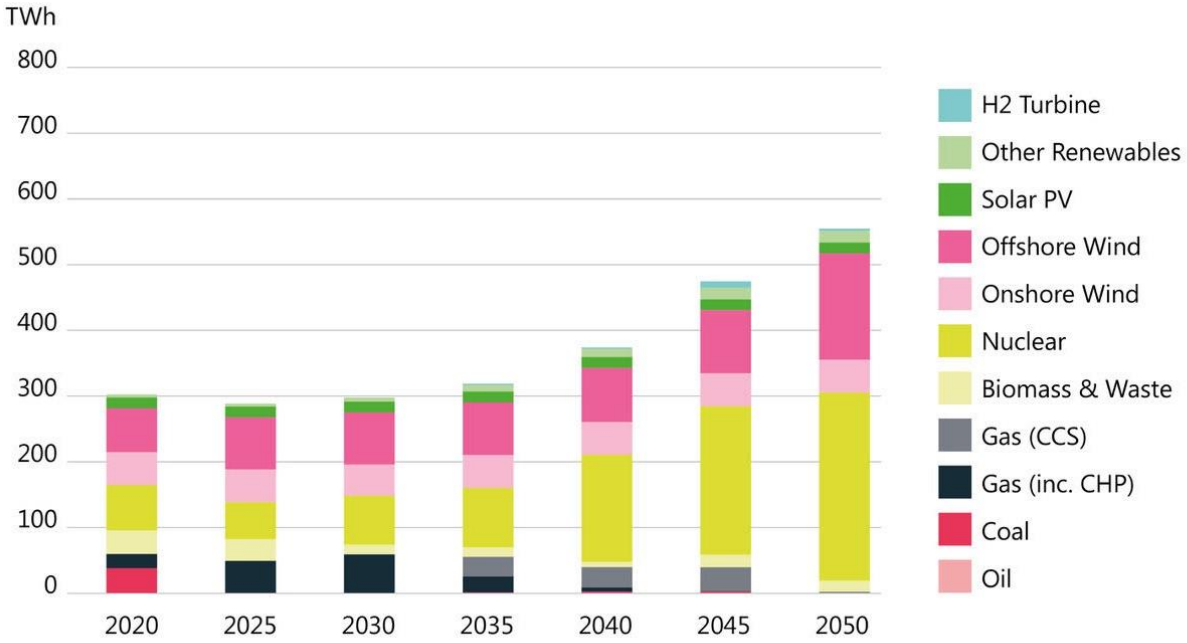
Total demand to double.

4x low-carbon generation.

Mix of renewables & low-carbon baseload.

Nuclear contribution:

- Significant growth from 2030.
- Up to 50% (c40GWe).
- Mix of large reactors and SMRs.



Electricity supply under centralised 'Clockwork' pathway: Energy Systems Catapult, *Innovating to Net Zero* (2020)

Nuclear Sector Deal

Industrial strategy

Investment in R&D: 1.7% to 2.4% GDP by 2027.

Nuclear Sector Deal

30% reduction in the cost of new build projects by 2030.

20% reduction in decommissioning costs to the taxpayer.

Competitive supply chain.

Innovation:

- National fusion technology platform.
- Advanced modular reactors.

Industrial regeneration

Orgreave in 1994:

Start of clean-up from 150 years of mining and coking.

Now: 100 acre Advanced Manufacturing Park & 740 acre Waverley community.

Changing landscape of manufacturing

World-leading advanced manufacturing park

- Training centres
- Research and technology organisations
- Industry
- Community

Nuclear AMRC: who we are

Improving capabilities and performance

Manufacturing innovation

- Improving cycle time and quality.
- Reducing lead time, cost and risk.
- Developing innovative techniques and technologies.

Supply chain development

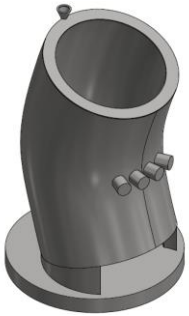
- Raising quality, capability and cost competitiveness.
- Helping companies meet nuclear industry requirements and expectations.

Manufacturing innovation

9 anchor technologies

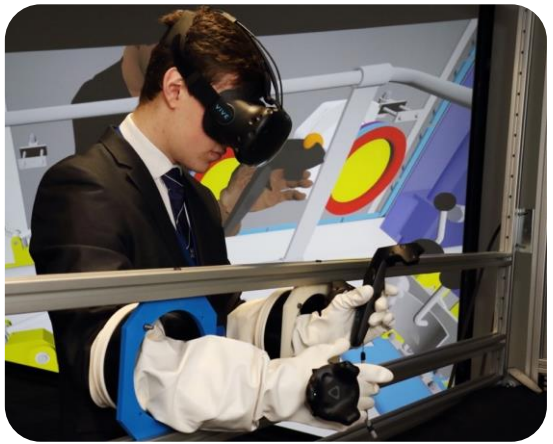
Additive manufacturing and near-net shape forming

High-integrity production and customisation of large metal components through the use of arc, power beam (electron beam and disk laser) and solid-state methods applied to structural steels, corrosion resistant steels, nickel-based alloys and other exotic alloys.



Analysis and simulation

Producing high-fidelity verification systems and models based on experimental validated data applied to processing and materials optimisation, power plant construction and extreme environmental operations.



Automation and digitalisaiton

Using robotics, artificial intelligence and data-driven manufacturing to improve productivity and develop new capabilities.

9 anchor technologies

Controls and instrumentation

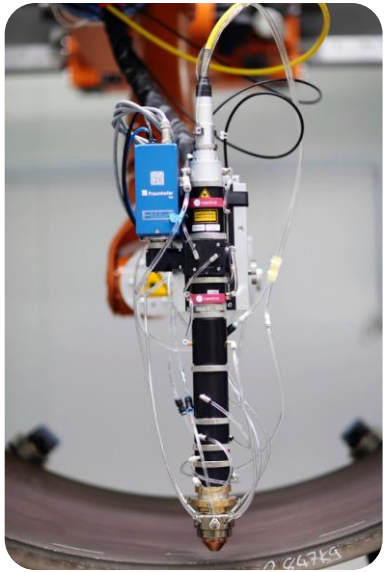
Digital sensors, instruments and reactor protection systems for nuclear power plants and other through-life safety security devices applied to HVM industrial sectors demanding safety critical monitoring.

Codes and standards

Ensuring innovative manufacturing techniques meet relevant industry standards.

Joining technology

Mechanised welding and solid-state bonding methods encompassing power beam, arc welding and HIP-DB systems applied to structural and CRES steels, nickel-based alloys, and other exotic alloys.



9 anchor technologies

Machining technology

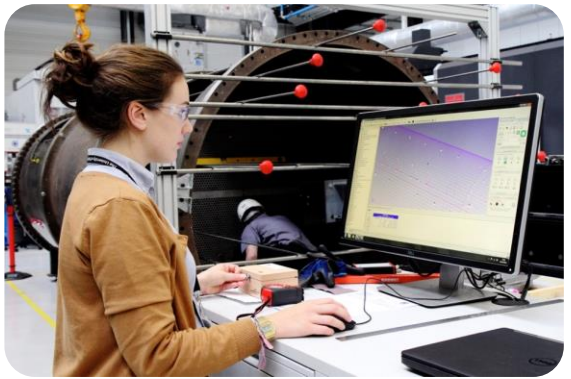
New and optimised processes for the machining of large and complex components integrating environmentally sustainable and crosscutting technologies.

Materials, surface, corrosion and thermal engineering

Applied to understanding and enhancing material characteristics and environmental performance in reactors and other extreme safety critical environments.

Product and process verification and validation

Providing high quality structural integrity data to develop performance models and through-life maintenance forecasts for nuclear and other high value manufacturing sectors.



Critical development programmes

- Through life engineering services
- Automated platform manufacturing
- Safety design, systems architecture and equipment qualification
- Standardisation
- Modularisation
- Reconfigurable tooling and smart facilities

Automated platform manufacturing

BASELINE

Rapid Machine Tool Verification

INSPHERE Rolls-Royce

NUCLEAR AMRC HEXAGON MANUFACTURING INTELLIGENCE

AMOS

Additive repair for aerospace

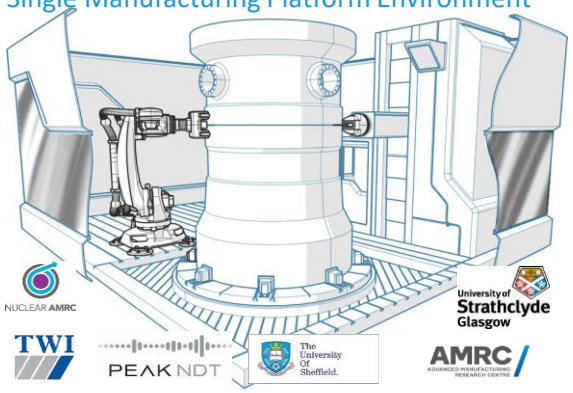
Pratt & Whitney Canada NUCLEAR AMRC uOttawa CENTRALE NANTES

LIBURDI HEROUX DEVTEK

DPS Digital Product Simulation GKN GKN AEROSPACE McGill

SIMPLE

Single Manufacturing Platform Environment



Vision

Single-platform manufacturing for large nuclear components.

- Enhanced manufacturing autonomy.
- Manufacturing process cognition.
- Fully integrated manufacturing platform.
- Predictive and prescriptive analytics.

NUCLEAR AMRC

ADVANCED MANUFACTURING RESEARCH CENTRE

Matt Smart

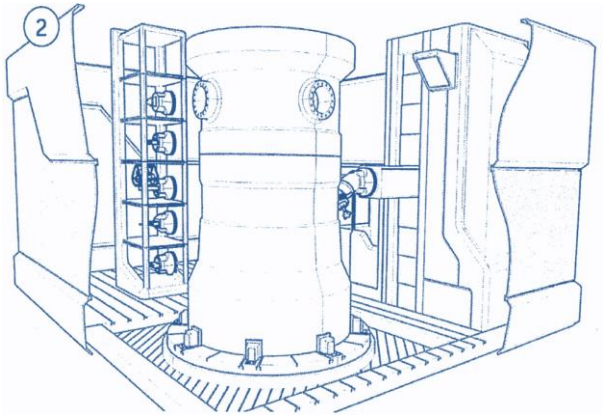
Projects Technical Lead

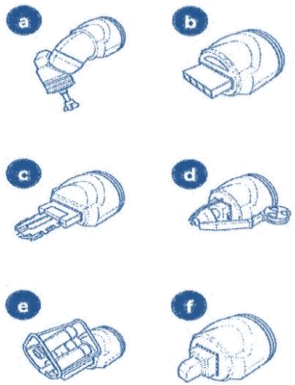
30 July 2020

Single Manufacturing Platform Environment

SIMPLE vision

- Manufacturing cost reduction by bringing additive, subtractive and inspection operations onto one single manufacturing platform.
- Reduction in factory footprint and risks and costs associated with the movement of large components.
- Quality improvements by implementation of process monitoring technologies.





SIMPLE concept multifunction machine
a) Multi-axis milling/drilling
b) Ultrasonic inspection
c) Automated arc welding and monitoring system
d) Cladding
e) Non-contact 3D laser scanner
f) Vertical turning

Single Manufacturing Platform Environment

SIMPLE Phase 1 – automated weld monitoring system

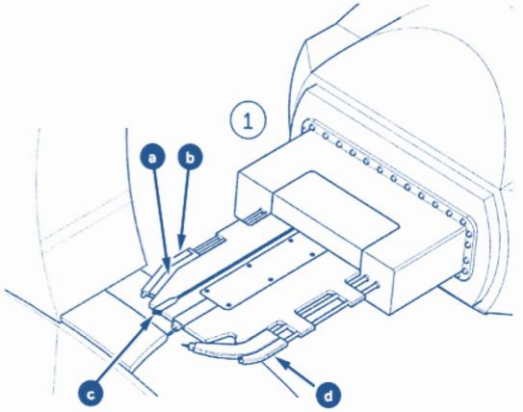
- Provide in-process identification of welding defects as well as additional information.
- Provide a digitised body of evidence to the quality and integrity of the weld.
- Minimal inter-stage NDT and reduced rework.

SIMPLE project:

- Evaluate and integrate a wide array of sensors onto an existing welding system.
- Integration of selected sensors within a versatile welding platform.
- Collect process data ready for analysis.

SIMPLE Phase 2 (at time of concept) – single platform manufacturing

- Development of multifunction manufacturing cell.
- Proof of concept for system integration.



Concept interchangeable welding head
a) Microphone
b) Ultrasonic transducer
c) Vision system
d) Laser scanner

Single Manufacturing Platform Environment

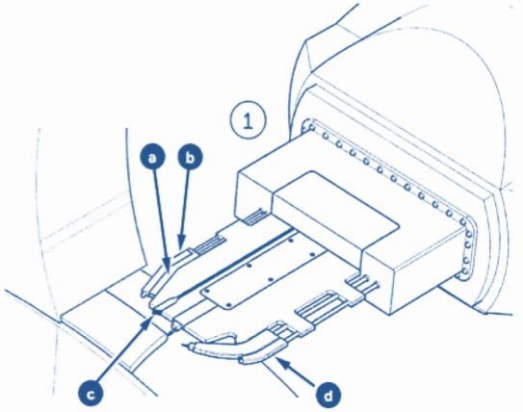
SIMPLE Phase 1

Parallel development of:

- Weld modelling (Nuclear AMRC)
- Visual sensor (TWI)
- Ultrasonic sensor (Peak NDT and AFRC)
- Acoustic sensor (Nuclear AMRC)
- Laser sensor (Nuclear AMRC)
- Emerging technology sensor (ESPI) (Nuclear AMRC)
- In-process signal monitoring (UoS Physics Dept)
- Systems Integration software (AMRC)

Project demonstrator:

- Gas tungsten arc welding of pressure vessel steel
- Concurrent data collection, storage and display of sensor technologies

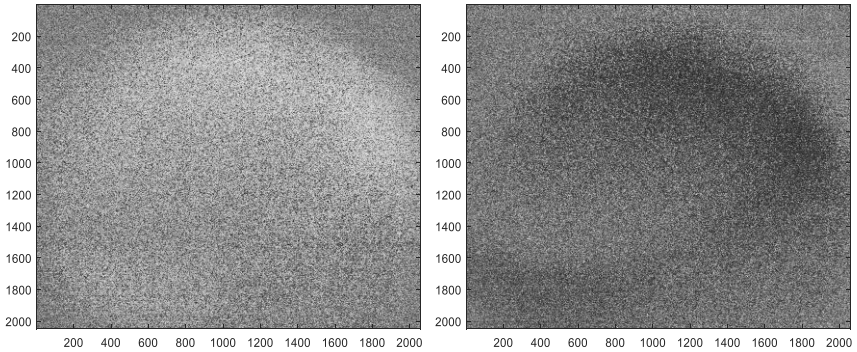


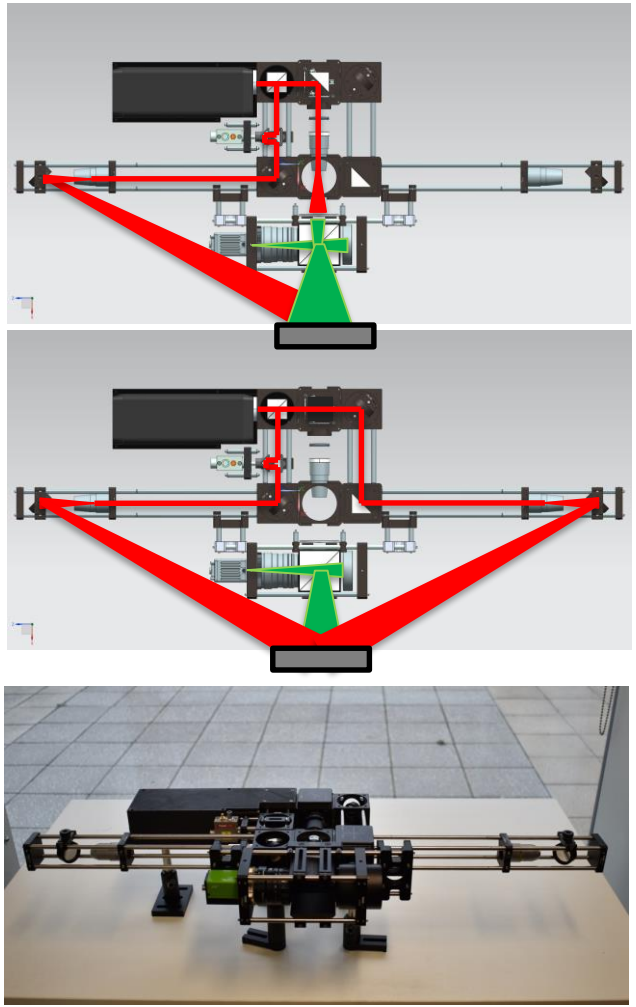
Concept interchangeable welding head
a) Microphone
b) Ultrasonic transducer
c) Vision system
d) Laser scanner

Low TRL development

Electronic speckle pattern interferometry (ESPI)

- Non-contact dimensional measurement to sub-micron scale.
- Scalable from 10cm x 10cm to 1m+ x 1m+
- Residual stress can be inferred from strain (in some applications).
- Unproven in industrial context.
- Fundamental testing to apply to residual stress analysis of welded surfaces – thin then thick section.





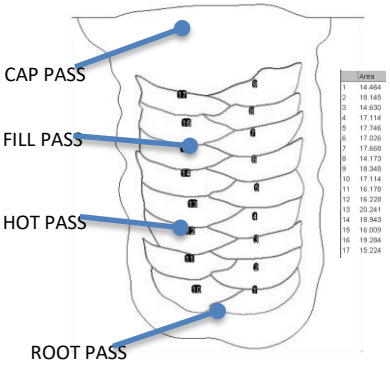
Geometric prediction through weld modelling

High level scope

- Use of novel simulation and modelling (machine learning) to use WPS input parameters to predict weld features such as HAZ and toe angle.
- Evaluation of technology concepts and proof of concept fundamentals.

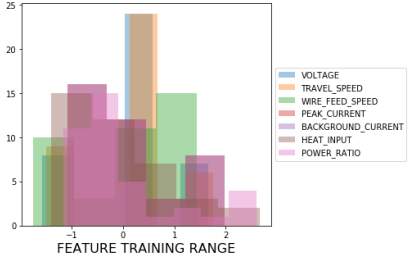
Future aim for deployment

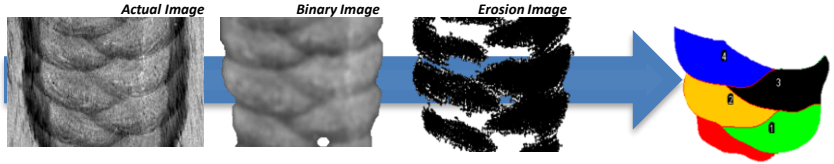
- Back propagation – tool kit where favourable weld properties are chosen and software calculates WPS parameters for testing.



FEATURES

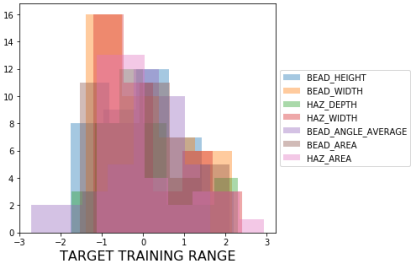
1) VOLTAGE
2) TRAVEL SPEED
3) WIRE FEED SPEED
4) PEAK CURRENT
5) BACKGROUND CURRENT
6) HEAT INPUT
7) POWER RATIO





TARGETS

1) BEAD HEIGHT
2) BEAD WIDTH
3) HAZ DEPTH
4) HAZ WIDTH
5) BEAD ANGLE AVERAGE
6) BEAD AREA
7) HAZ AREA



In-process high temperature ultrasonic inspection

PEAK NDT

University of Strathclyde Glasgow

Challenge

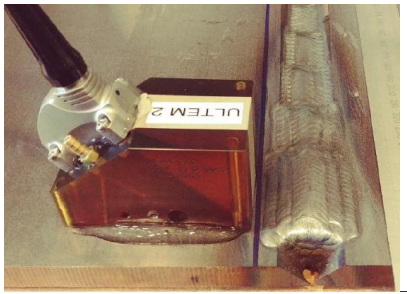
- High temperature causes transducers to lose piezoelectric properties.
- Constant contact with moving surface.
- Couplant must not contaminate weld.
- Speed of sound changes with temperature.
- Electrical noise from arc.

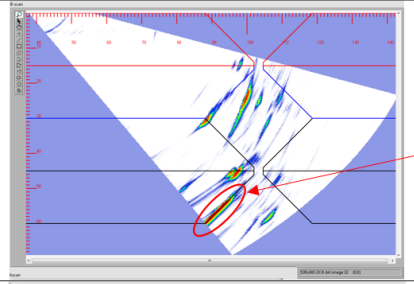
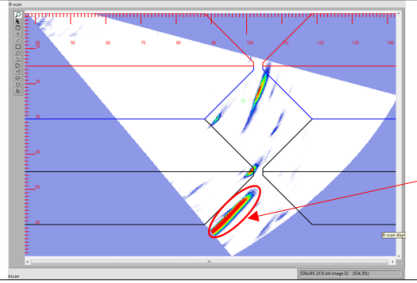
Near-term proof of concept

- Robotic actuation for intermittent contact.
- Thermal management.
- High temperature paste for couplant.
- Working temperatures up to 150°C.
- Modelling for temperature compensation.

Future work

- Constant contact tyre track system – no couplant, constant cooling.



Frame	Elapsed	Temp	Image	Comment
Ref		21.6°C		Reference feature is aligned with overlay
A0	5.24s	150°C		Reference feature is now shifted by around 3mm in range

Process monitoring system

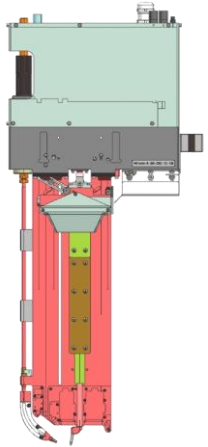
Equipment

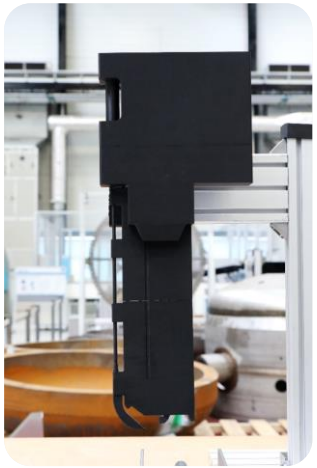
- Polysoude NG-8-300 narrow groove GTAW head.
- Column and boom travel 6 x 4m.
- Cold wire TIG.

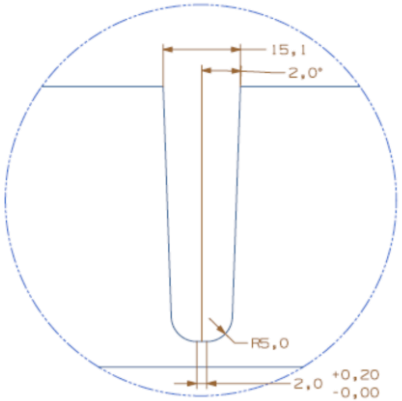
Welding application

Pressure vessel steel:

- Joint design as per ISO 9692-1.
- 2º wall angle groove milled in forged plate, simulating butt weld.
- 3–15mm root ligaments.
- 12.5–50mm deep weld preparations.







Process monitoring system: demonstration

2D laser profiler

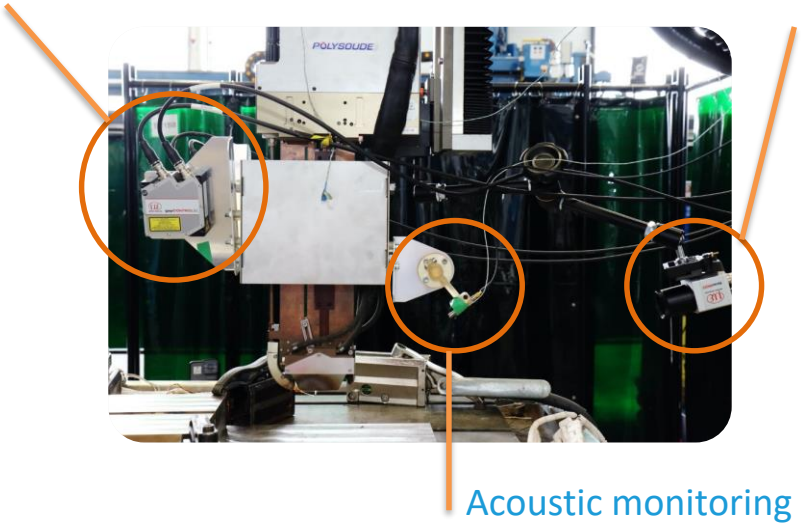
Scanning ahead of the weld torch to verify geometry and scan previous layer

Weld vision system

HDR images of the weld pool fed to neural network

Power monitoring, live processing and data storage

Custom high bit rate data acquisition system



Acoustic monitoring

Monitoring the arc output at the source

Ultra high frequency weld process monitoring

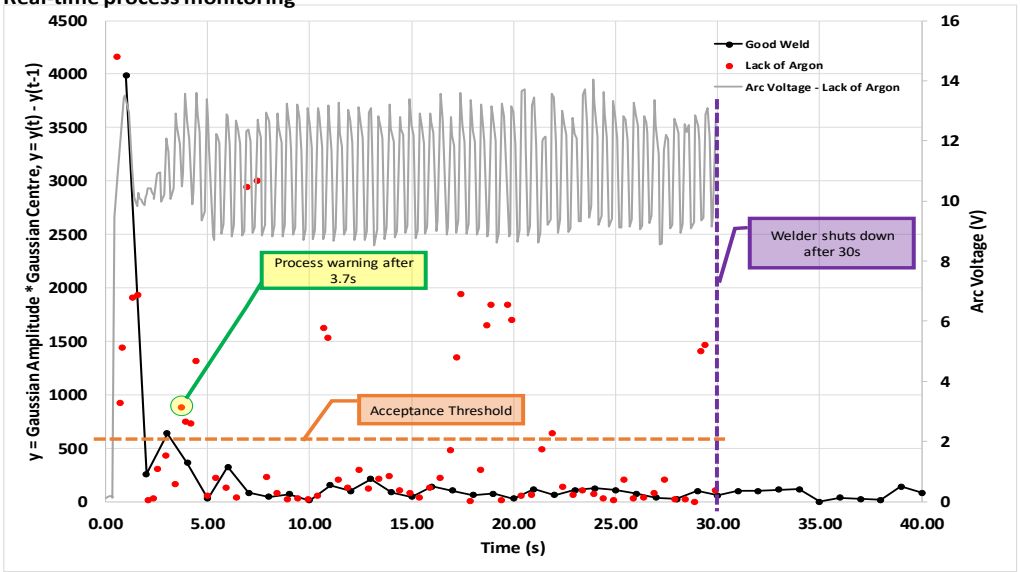
The University Of Sheffield.

E.S.I.M
Enabling Sciences for Intelligent Manufacturing

Industrially robust process monitoring at nano-timescales

- Voltage and current monitoring orders of magnitude faster than welding AVC system.
- Commercially ready system developed up to 500A – plans to scale to 1000A.
- 50A prototype for tubesheet welding baseline at start of project.
- Feature recognition and processing algorithms for flaw identification.

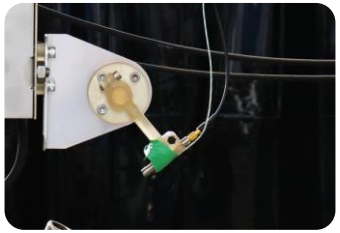
Real-time process monitoring



Acoustic monitoring

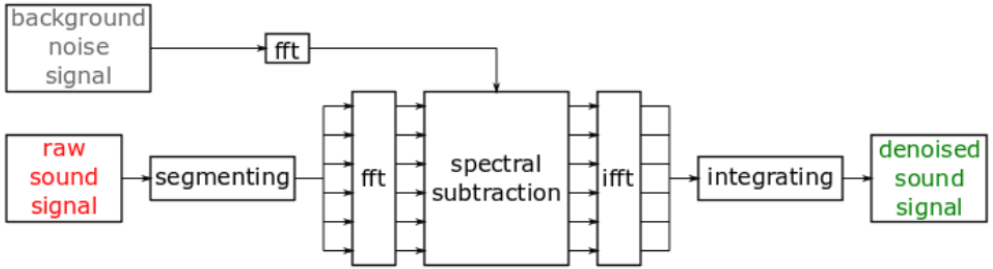
Signal processing of high frequency audio

Lab scale systems on single pass welding demonstrated to identify flaws and predict weld penetration.

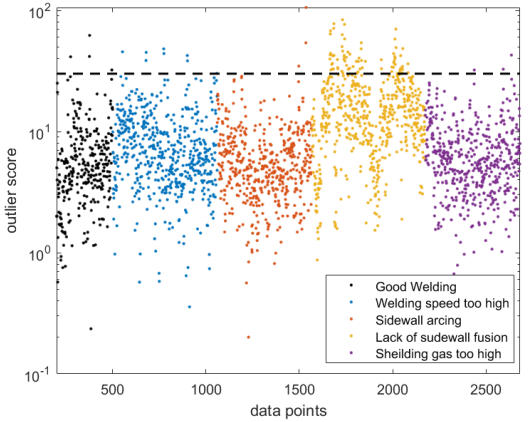


Application and development for industrial relevance:

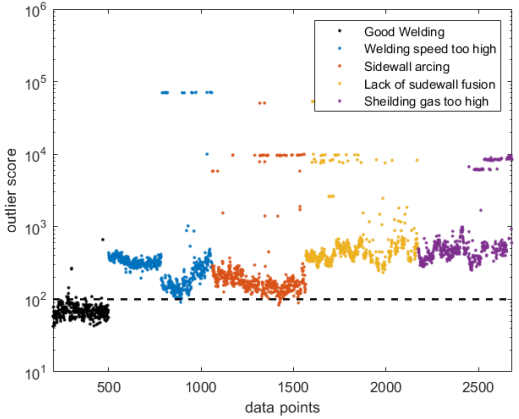
- Noise cancellation algorithm.
- Application to multi-pass welding.
- Real time defect identification.



Time domain analysis



Frequency domain analysis



Geometric verification

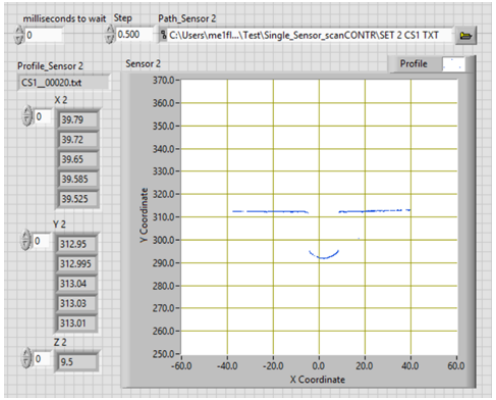
2D laser profile scanning

Single sensor unable to resolve side wall – twin sensors mitigates line of sight issue for this geometry.

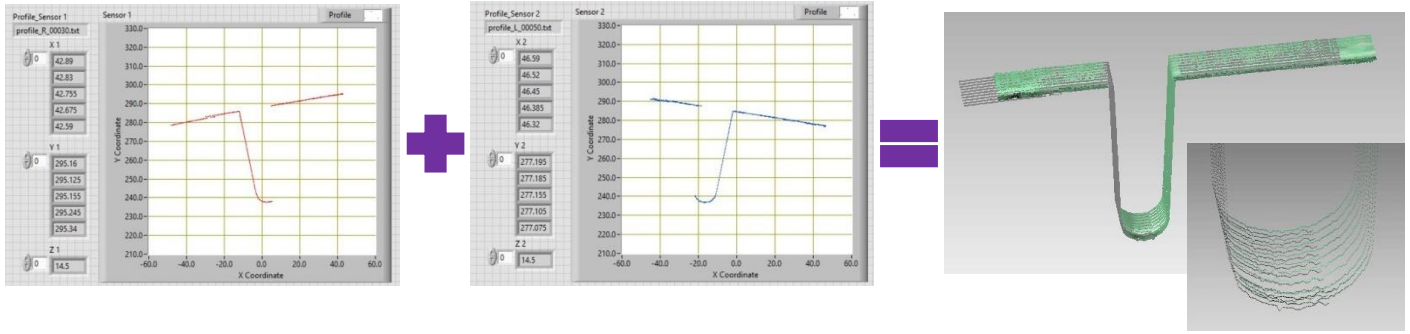
Outputs:

- Physical location of tungsten relative to sidewall.
- Groove width.
- Deflection angle.
- Surface vertical offset (misalignment).
- 3D point cloud of each bead/layer.

Single sensor



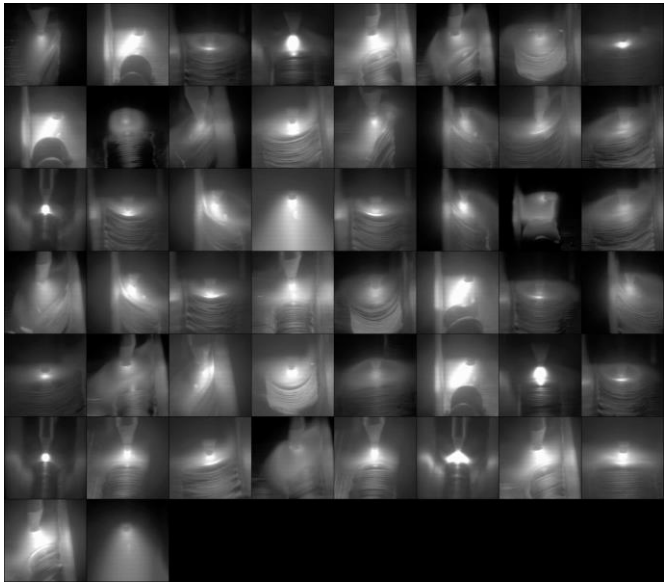
Twin sensors



Vision monitoring system

Neural network image recognition

- Image classification trained neural network analysis system.
- Welding specific HDR camera retrofitted to machine.
- System developed for local real-time processing.
- Constant training of AI system to increase confidence intervals.



Future work

Advanced Welding Equipment System Inspection and Monitoring

AWESIM goal – 4 year development programme to implement condition monitoring technologies identified in SIMPLE to TRL 7 (deployable prototype in production environment).

Near-term target – Nuclear AMRC demonstration (TRL 5/6) of process monitoring with live processing coupled with a near real-time weld inspection system developed by the Advanced Nuclear Research Centre (University of Strathclyde).

More details to follow – G4SR (online) November 2020.

NUCLEAR AMRC

Questions?

NUCLEAR **AMRC**

ADVANCED MANUFACTURING RESEARCH CENTRE

web: namrc.co.uk

email: charles.carpenter@namrc.co.uk

email: matthew.smart@namrc.co.uk

Twitter:@NuclearAMRC

Episode 2: U. K. Nuclear Advanced Manufacturing Research Centre, Advanced Manufacturing Technologies July 30, 10:00AM - 12:00PM

CO HOSTS:

- **Joseph Bastien,** Manager, OCNI
- **Wilson Lam,** CNS G4SR-2 International Conference Chair; Senior Nuclear Technology Advisor, Ontario Ministry of Energy, Northern Development & Mine, Ontario, Canada

GUEST SPEAKERS

- **Charles Carpenter,** Senior Technology Officer, Nuclear AMRC
- **Matt Smart**, Project Technical Lead in the Nuclear AMRC's Machining Technologies Group

AGENDA

10:00 am - Webinar Instructions

10:02 am - OCNI and CNS Opening Remarks and Introduction of Invited Speakers

10:10 am - Advanced Manufacturing Technologies and Applications Under Development and How Manufacturing Innovation is Helping Cut the Cost of New Low-carbon Generation

10:35am - In-depth Look at Single-platform Manufacturing Techniques Developed Through The Nuclear Innovation Programme, Part of the UK's Nuclear Sector Deal

10:55 am - Q&A With Participants

11:15 pm - Closing Remarks

11:20 pm - CLOSE

G4SR-2 SMR WEBINAR SERIES

Canadian Nuclear Society
Société Nucléaire Canadienne

OCNI ORGANIZATION OF CANADIAN NUCLEAR INDUSTRIES

Clean Energy for a Low Carbon Economy

PLEASE STAND BY