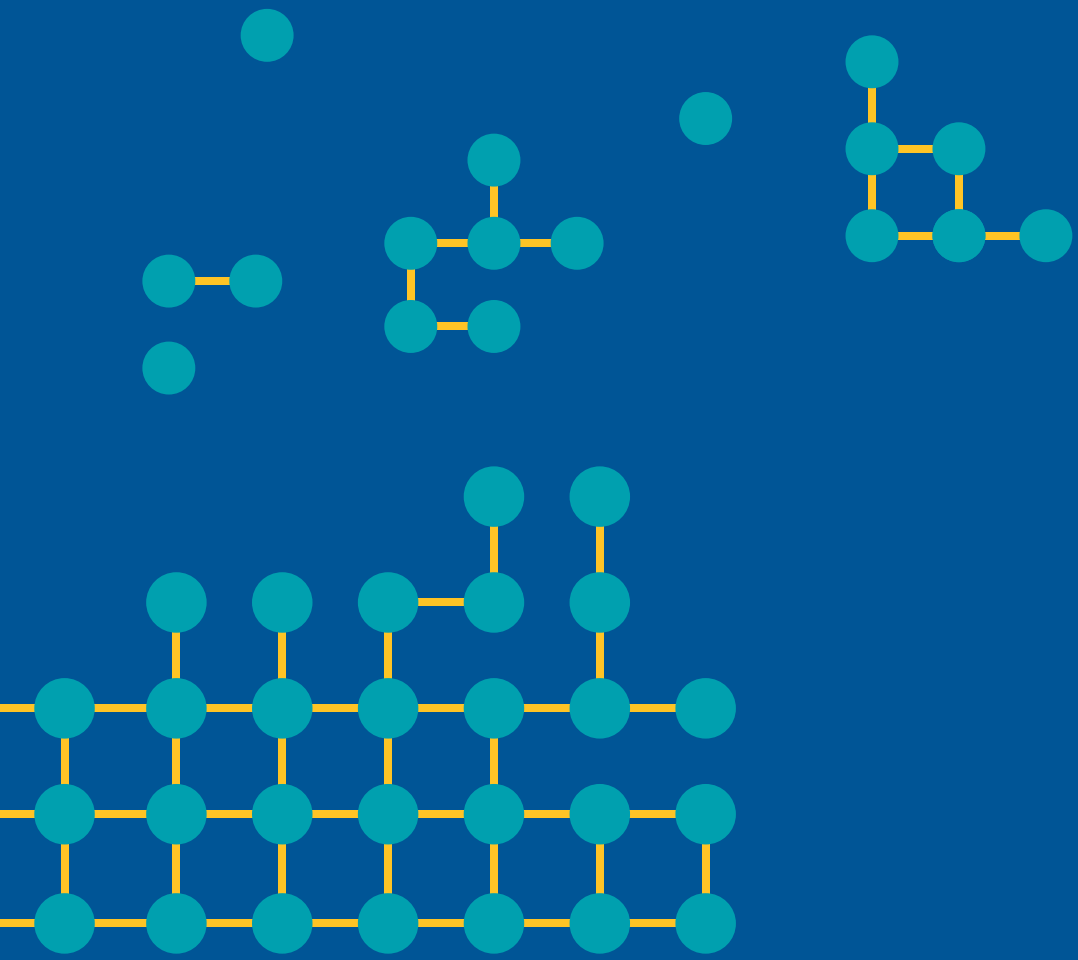
Technology Strategy Board
Driving Innovation

Collaboration Nation

Nuclear R&D feasibility studies



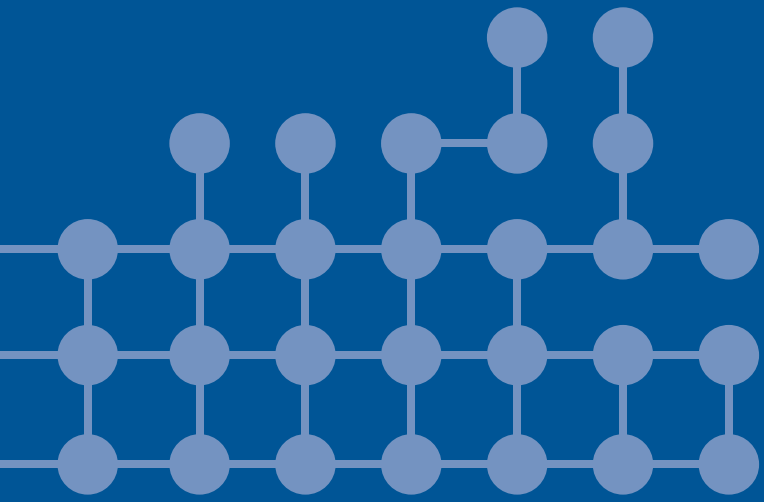
Contents

Introduction

Nearly two thirds of commercial innovation stems from small companies – a vital source of wealth-generating new products.

As part of its energy generation and supply investment programme, and in support of the national and global resurgence of civil nuclear power generation, the Technology Strategy Board funded 20 collaborative feasibility projects covering a wide range of nuclear R&D technologies. They included: condition monitoring, construction, non-destructive testing, waste handling and decommissioning. We invested up to 75% funding in each project with the maximum project value being £100k. Each project was led by an SME, with at least one other partner, and had a maximum project duration of 12 months.

This directory provides a snapshot of the funded projects, their highlights and their proposed steps in taking the technology forward. This will enable potential collaborators, investors and organisations interested in nuclear technologies to get to know more about the companies involved and the technologies they are developing.



Aquasium Technology Ltd

Forgeman

The consortium consists of a well established supplier of high-quality open die forgings to industry (Somers Forge), a research provider with wide experience in welding and materials technology (TWI) and an SME supplier of bespoke electron beam welding systems (Aquasium Technology Ltd). The combination of the three organisations represents a complete supply chain for forged and welded products.

Potential application area: manufacture of large forgings.

What problem have you tried to solve?

There are few worldwide sources of large forgings for primary circuit nuclear power plant. As demand increases, unique suppliers of large monobloc open die forgings can command higher prices and delivery schedules are extended. Several smaller forging facilities have the capacity to produce component parts which could supply structures fabricated from smaller sub-assemblies. We have investigated the feasibility of reducing or eliminating the requirement for in-service weld inspection.

What approach have you taken?

The Forgeman project has examined the feasibility of fabricating large components from smaller forgings, joined by the electron beam welding process. We have demonstrated in a nuclear pressure vessel steel grade that the use of this autogenous welding process can produce joints which are virtually indistinguishable from the base forging in terms of microstructure, chemistry, mechanical properties and ultrasonic response.

What have been the key findings?

We produced high quality welds in steel to ASTM A508 Grade 3 Class 2 international standard, in thicknesses of up to 150mm. Welds in rectangular and hollow sections were subject to detailed non-destructive testing and metallurgical assessment after a normalised quench and temper heat treatment and after re-forging. We showed that the welds were difficult to detect in the resulting structures and had matching composition and microstructure to the base forging, except for some subtle differences in inclusion distribution.

Partners
Aquasium Technology Ltd
Somers Forge Ltd
TWI Ltd

Project 1

Cogging of rectangular sections for testing.

What are the potential benefits?

We demonstrated the feasibility of the method, with the potential benefit that components can be fabricated using the methodology developed, avoiding some of the existing constraints in the current supply chain. The additional benefits are that flexibility for design is offered in the production of structures from small multi-part forgings and through the potential use of dissimilar metals.

What are the next steps?

We intend to introduce the concept to the potential end users in the UK and elsewhere, to arrange more detailed discussions with nuclear code bodies and to explore other opportunities outside of the nuclear sector. In particular, the use of this method for the manufacture of hot work forging tools appears to be an attractive proposition.

Aquasium Technology Ltd
43 Pembroke Avenue
Denny Industrial Centre
Waterbeach
Cambridgeshire
CB25 9QX

Bob Nicolson
Managing director
E bob@camvaceng.co.uk
T 01223 863481
W http://camvaceng.com

Beran Instruments Ltd

Intelligent condition monitoring for civil nuclear structures

Beran Instruments is an innovative SME developing novel condition monitoring solutions for the power industry. Operating in nuclear, conventional and renewable markets, our systems protect, diagnose and predict the health of rotating machinery. Our collaboration with the University of Bristol is enabling the research and development of intelligent algorithms, providing condition indicators, wider coverage, optimised maintenance and through-life cost savings.

What problem have you tried to solve?

We identified a need to develop automated data processing in order to identify key features and trends in measured data. This would expose hidden features and reduce the manual workload needed for each piece of machinery as well as facilitating the expansion of condition monitoring to balance-of-plant. It would also provide improved early warning detection to help prevent machinery breakdown and reduce risk.

What approach have you taken?

We worked closely with EDF Energy and performed a comprehensive review of five years' historic fleet data for turbines, feed-pumps and coolant circulators, classifying exception type and prior diagnosis. We then undertook a study of time-domain analysis techniques from adjacent domains (aerospace and medical) to determine

Potential application area:
condition monitoring of turbines, pumps and circulators.

Graphical representation of relationship between vibration and rotor current.

genuine relationships between vibration and control systems data. Rather than looking for data at single measurement points, we identified data relationships using windowed data mining techniques, resulting in the development of novel condition Indicators.

What have been the key findings?

We discovered that 40% of historic exceptions were due either to signal faults or relationship to an operational condition. Additionally, we identified hidden features that had previously remained undetected using conventional exception analysis techniques. Multivariate algorithm implementation also promises significant time savings during the routine vibration monitoring process while our novel dashboard display provides powerful visual representation of machine health.

What are the potential benefits?

Following trials with EDF Energy, the project has demonstrated a 25% potential saving in the time taken to perform routine condition monitoring. Potential benefits include wider asset coverage, optimised maintenance and through-life cost savings. Assuming future commercial exploitation, the new technology will improve business competitiveness, result in export market growth and allow diversification into markets beyond the nuclear industry. This in turn will result in expansion of market share, leading to job creation and further investment in new product development.

What are the next steps?

Beyond this project, we anticipate further development of the technology in collaboration with University of Bristol, leading to commercialisation within one to two years. In parallel, we will build up our product team and gearing through further fund raising. We will implement our commercial roadmap, targeting the nuclear industry and actively transfer the technology to conventional, renewable and aerospace markets.

Beran Instruments Ltd
Hatchmoor Industrial Estate
Torrington
Devon
EX38 7HP

Peter Morrish
Technology manager
E peter.morrish@beraninstruments.com
T 01805 624304
W www.beraninstruments.com

Caunton Engineering Ltd

Design of steel concrete steel (SCS) modular construction for nuclear facilities

Caunton Engineering Ltd (CEL) is a steel fabricator with over 40 years experience in fully automated structural steelwork and 'just in time' manufacture. AMEC is an engineering consultancy with significant experience of working in the nuclear energy construction sector. The Steel Construction Institute promotes use of steel in construction through research, development and authoritative design guidance and standards development.

Potential application area: new power plant construction.

What problem have you tried to solve?

Our study addressed the feasibility of developing a design standard for SCS structures. We performed a mapping exercise of existing design information, test data and analytical work against performance and reliability requirements. We also assembled guidance that could be adopted in its present form and identified new information needed to fill any gaps. We then defined the scope of work, time and cost required to develop a standard.

What approach have you taken?

AMEC defined the performance requirements for structures used in nuclear plant and provided specifications for such structures. SCI assessed the suitability of existing design information to satisfy those requirements. Where no information existed, SCI identified experimental and analytical data and assessed its suitability as a basis for developing design clauses and additional work was scoped to fill gaps. CEL reviewed fabrication, erection and inspection specifications to determine the manufacturing capabilities required to supply SCS components and sub-assemblies.

What have been the key findings?

The project scoped the technical requirements for developing European design rules for SCS structures. It also assessed the opportunities for SME fabricators to enter the supply chain with sub-assemblies and components for SCS modules by considering the fabrication requirements (complexity, quality, scale and transportation). We found it was possible to

Steele concrete steel (SCS) construction of a module in a nuclear power plant.

bring together a group of European energy companies, steel companies and researchers to take forward the recommendations of the feasibility study in a subsequent phase, which is now under way.

What are the potential benefits?

SCS creates a new market for high quality welded steel plate construction. Harmonised European design rules would remove the technical barriers to the use of SCS structures. SCS modular construction can shorten construction time to three years (from start of basement concreting to fuel load), compared with historical construction periods in excess of five years. It also reduces the risk of over-runs by moving much construction activity into factory controlled environments.

What are the next steps?

We used the information and contacts developed through the feasibility study to initiate the next phase, which will develop Eurocode-compliant design rules.
This entails large scale test programmes as well as advanced numerical simulations. We have secured partial funding from European energy corporations and steel companies and are planning a submission to the European Commission.

Caunton Engineering Ltd
Moorgreen Industrial Park
Moorgreen
Nottingham
NG16 3QU

Simon Bingham
Managing director
E simonb@Caunton.co.uk
T 01773 531111
W www.caunton.co.uk

Claresys Ltd

Improved imaging solutions for decommissioning and fuel path applications

Claresys Ltd, a spin-out from the UK's Defence Science and Technologies Laboratory (DSTL), develops and supplies novel surveillance optics systems for the defence and law enforcement sectors. Mirion Technologies is the acknowledged leader in radiation-tolerant cameras and CCTV systems for the nuclear industry, its range of products offering customers a broad spectrum of inspection options.

Potential application area:
monitoring and inspection of nuclear processes.

What problem have you tried to solve?

The opportunity was to design a cheaper, more compact, nuclear imaging system based on patented optical technology transferred from the defence sector. The proposed system could be used to safely monitor and inspect nuclear processes throughout the nuclear life cycle. The compact nature of the package would enable cost-effective retrofitting to existing nuclear process cells or buildings that are currently being decommissioned, with minimal civil works disruption.

What approach have you taken?

Our study focused on adapting the existing defence design to incorporate radiation tolerant components and to provide for localised shielding where this was not feasible. We redesigned the front end of the device to use the limited non-browning glass types available and folded some optical paths in order to allow for shielding of other critical components. We then generated a mechanical design to package the optics into a minimal footprint while meeting shielding requirements.

What have been the key findings?

The project has shown that it is technically possible to design a product using the novel Claresys patented technology. We also demonstrated that it would be capable of meeting the bulk of the target technical specification derived at the start of the project and could offer an attractive alternative approach for endoscopic surveillance.

Mirion's successful thru-wall endoscope system.

What are the potential benefits?

The new approach based on the Claresys technology has resulted in a product design that is potentially cheaper, more reliable and capable of being retrofitted in decommissioning situations as well as in new installations. We have characterised the system to the point where we can assess its potential with prospective customers.

What are the next steps?

The new design offers a different "mix" of optical performance, lifetime cost and installation simplicity to existing solutions. Mirion IST, as the lead exploitation partner, will now be reviewing this approach with potential customers before deciding whether to commit the design to manufacture.

Claresys Ltd
154E Milton Park
Abingdon
Oxfordshire
OX14 4SD

Andrew McLeod
Chief executive officer
E andy.mcleod@claresys.com
T 01235 364580
W www.claresys.com

Cosworth Electronics Limited

Monitoring the condition of nuclear pumps, electronic data logging

Cosworth Electronics is a world leader in high performance instrumentation and control systems. It is part of the Cosworth Group, which allows it to offer complete mechanical and electronics engineering solutions. ClydeUnion is one of the world's leading pump companies, specialising in pump technology, hydraulic design and engineering and operating in eight key markets, including the nuclear industry.

Potential application area: condition monitoring of pumps.

What problem have you tried to solve?

Remote monitoring of high value capital equipment is commonplace outside the nuclear industry. Within the industry, instrumentation is extensive but there is no holistic approach to data collection, analysis and dissemination. Cosworth sought to address this by fitting data loggers to nuclear pumps. This data could then be used to identify whether a pump has been run outside design limits and to improve understanding of real life operating profiles.

What approach have you taken?

Cosworth installed a high speed data capture unit at ClydeUnion's test facility to carry out logging during performance runs of nuclear booster pumps. The initial approach was non-invasive, using the sensor suite already present on the pump, thus reducing any further capital cost on a final product. The main innovation for the nuclear industry is the integration of the data sources and real time analysis to provide the information necessary to detect potential pump performance loss.

What have been the key findings?

The data has identified a number of signatures of the pump during the performance test. With further testing we could identify a larger subset of signatures which would allow development of an individual pump type signature. These long term signatures could then be used as references to actual 'in field' data, hopefully allowing early detection of pump performance decay.

What are the potential benefits?

The characterisation of each pump will enable early detection of a potential performance drop in nuclear pumps. This will allow planning of scheduled maintenance, minimising potential downtime of critical plant components. The product could be introduced into other industries using pumps, the main criteria being non-invasive with any additional capital expenditure kept to a minimum.

What are the next steps?

Our recommendation is for an additional set of trials. These need to include a larger set of sensors, allowing the pump signatures to have more inputs, for better signature generation and recognition. Finally, there needs to be a study into how to turn the test apparatus into a commercial silent witness product.

Cosworth real-time data capture system installed on a ClydeUnion pump.

Cosworth Electronics Limited
Brookfield Technology Centre
Twentypence Road
Cottenham,
Cambridge
CB24 8PS

Maximiliano Lotto
Programme manager
E maximiliano.lotto@cosworth.com
T 01954 253600
W www.cosworth.com
@cosworth

C-Tech Innovation Ltd

Electrochemical enhancement of nuclear decontamination solutions (ELENDES)

C-Tech Innovation provides a consultancy service to maximise innovation and business opportunities. We help organisations implement new processes and create new products, assisting them in knowledge transfer, commercialisation and business support. The National Nuclear Laboratory is the UK's leading nuclear technology services provider in the areas of fuel cycle solutions, waste management and decommissioning and reactor operations support.

What problem have you tried to solve?

Our overall goal was to establish the feasibility of using electrochemical enhancement of a decontamination process to achieve rapid decontamination and a spent decontamination solution suitable for downstream processing and storage using a conventional process. We have successfully demonstrated this at laboratory scale, with inactive simulants.

What approach have you taken?

We chose to combine practical demonstration (C-Tech) of the core technology with modelling of the decontaminant throughput and analysis of the balance of plant requirements by NNL. This was supported by the generation of process flow sheets for mobile and fixed plant decontamination modules and a favourable techno-economic assessment of the process for a number of candidate applications.

Potential application area: novel nuclear decontamination.

Partners:
C-Tech Innovation Ltd
National Nuclear Laboratory (NNL)

Project 6

Practical demonstration with inactive simulants at laboratory scale.

What have been the key findings?

We have demonstrated the concept of their treatment on a laboratory scale, developed a flow-sheet that describes ancillary plant requirements and, based on the results, we have also drawn up a technology development plan to bring the technology to the market.

What are the potential benefits?

The success of this project, with a further active trials stage, can lead to significant increases in the effectiveness of decontamination processes by the innovative deployment of new decontamination solutions. It will therefore deliver improved efficiency through increased levels of decontamination along with cost reductions such as those from potential reclassification of nuclear waste. It has also opened up the potential to treat isolated plant and to remove reliance on centralised infrastructure, thereby accelerating decommissioning timescales.

What are the next steps?

The principal barrier to exploitation is that the nuclear industry typically requires deployment of off-the-shelf, proven technologies. We have identified stakeholders interested in using the technology to meet their decontamination challenges, but they require demonstration of the technology with active trials. We are seeking funding to design and build a prototype cell and apply this to a suitable decontamination challenge.

C-Tech Innovation Ltd
Capenhurst Technology Park
Capenhurst
Chester CH1 6EH

Steven Brewer
Project manager
E steven.brewer@ctechinnovation.com
T 0151 347 2967
W www.ctechinnovation.com

Cybula Ltd

AURAalert: novel condition monitoring

Cybula promotes its advanced pattern recognition systems for use in early detection of potential fault conditions in complex equipment and systems. Cybula's team of 10 people is supported by a strong research group at the University of York. Doosan Power Systems Ltd is a world leading energy services company operating in the thermal power, nuclear, oil & gas and petrochemical industries.

Potential application area:
condition monitoring of nuclear components.

What problem have you tried to solve?

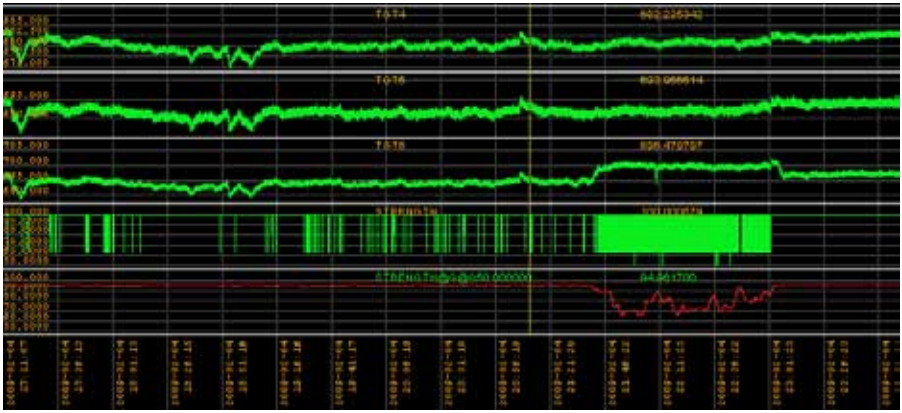
Traditional condition monitoring techniques depend on relatively simple models of expected behaviour and often fail to detect small changes in performance which may indicate early signs of a failure or fault condition. The case for implementing advanced event monitoring in the nuclear industry is clear, offering the opportunity to embed such systems in new plant as well as more rigorous monitoring of plant working beyond their intended design life.

What approach have you taken?

We first developed a software tool allowing us to build a model of asset performance in a given operating mode, based on previous performance. We then used advanced pattern matching techniques both to detect abnormal performance and then to explore unusual patterns by searching across a fleet of similar assets. Innovations included applying pattern matching techniques to build models of behaviour and fast search engine algorithms to large, distributed data.

What have been the key findings?

We developed AURAalert to monitor very small cumulative damage, predicting failure of a fixed structure subject to rapid cyclical load conditions under varying pressures and temperatures. We then used AURAalert with Signal Data Explorer, a software tool for searching similar patterns across multiple parameters, to assess the performance of a steam generator. Using archived data from 40 parameters collected at one minute intervals over a 10 year period, it detected differential changes in performance over this time.



AURAalert application showing abnormality alerting.

What are the potential benefits?

This is a novel approach to condition monitoring which supplements existing techniques and opens up the opportunity to extract knowledge from the vast amounts of asset performance data which is normally archived and forgotten about. These advanced techniques could be considered as disruptive technology in a £1.5bn global market since they offer the opportunity to widen participation to a vast installed base of unmonitored equipment.

What are the next steps?

We are already demonstrating the tools we have developed and successfully used during this project and there is interest from a number of sources. We are interested in working with channel partners in aerospace, marine, power generation and process industries. Cybula is now working on a web service application to demonstrate how asset monitoring can be run as a service.

Cybula
Deramore Lane
Heslington
York
YO10 5GH

John McAvoy
Commercial director
E mcavoy@cybula.com
T 01904 427855
W www.cybula.com

Graham Engineering Ltd

Safer, low-cost nuclear material storage through cold spray-formed boron carbide coated components (SafeStore)

Graham Engineering has been associated with the nuclear industry for over 25 years. Virtually all levels of nuclear waste containers have been developed with Graham Engineering input. TWI is one of the world's foremost research and technology organisations. Almost 700 staff give impartial technical support and conduct contract R&D in welding, joining, materials science, structural integrity, non-destructive testing (NDT) and surfacing.

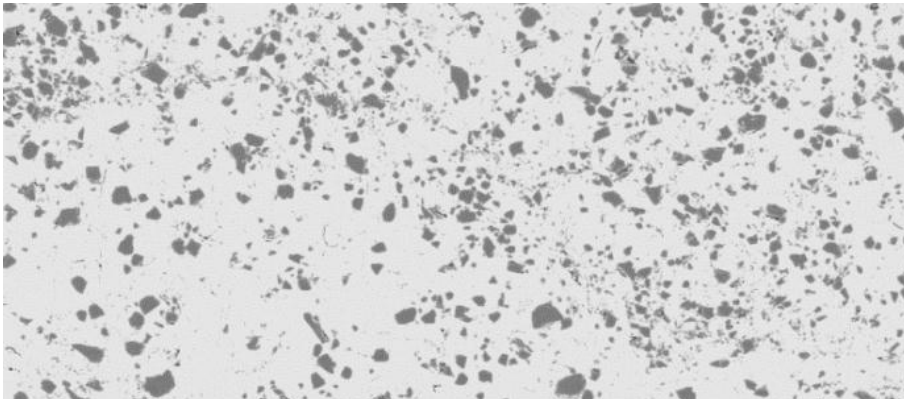
What problem have you tried to solve?

Boron (B) has high neutron-absorbing capacity and hence is used widely for nuclear material containment, usually deployed in the form of boron-rich metal composites which are expensive to produce with limited mechanical properties. Potentially, the use of B-rich coatings applied to low cost metal fabrications offers an attractive manufacturing route for nuclear waste containers. However, existing coating processes cannot produce B-rich coatings with adequate mechanical, thermal and chemical stability.

What approach have you taken?

We deposited thick coatings comprising boron carbide (B_4C) particles in an aluminium matrix using cold spray technology. Cold spraying facilitates the co-deposition of thermally sensitive and/or easily oxidised materials such as aluminium (Al) and B_4C without thermal degradation, offering the potential to form

Potential application area: nuclear waste containment.



Dense, oxide-free coating of boron carbide particles in an aluminium matrix.

a thick, durable, radiation absorbing layer on metal fabrications. The coatings were developed and applied to steel samples and plates and the deposition parameters were then further improved to obtain higher levels of B_4C in the coatings.

What have been the key findings?

We deposited dense adherent coatings up to 25mm thick. The maximum achievable B_4C content was 20% by volume, below our target of 30%. The deposition efficiency (D.E.) was less than 20%, significantly lower than expected, based on previous work on pure Al. As a result of the lower-than-expected maximum boron content and the low D.E., the projected production cost of the coating is not commercially viable, although further work could increase both B_4C percentage and D.E. and is being considered.

What are the potential benefits?

If the deposition efficiency and boron content of the coatings can be improved significantly, this B-rich composite coating could result in a more flexible solution for manufacturing ordinary metal fabrications able to shield radiation, so that for example low-cost steel or aluminium plate profiles and tubings can be made useful for containing radioactive waste and fuel.

What are the next steps?

If there is sufficiently strong market interest in the coating we may consider funding additional work to further optimise the coating in order to make it commercially viable.

Graham Engineering Ltd
Whitewalls Industrial Estate
Edward Street
Nelson
Lancashire BB9 8SY

Michael Hubbert
Head of engineering
E mhubbert@graham-eng.co.uk
T 07917 893187
W www.graham-eng.co.uk

Imetrum Ltd

Nuclear Vision

Imetrum, a spin-out from the University of Bristol, is a leader in the field of video-based, non-contact precision measurement for material testing and structural monitoring. Rolls-Royce has a long history in designing and supplying integrated systems and equipment for civil and naval nuclear reactors. The University of Manchester undertakes research across the nuclear field, from engineering and physical sciences to the humanities.

Potential application area:
structural and condition monitoring.

What problem have you tried to solve?

Our project addressed four problems: firstly, whether an engineering surface finish provides sufficient detail for Imetrum's image correlation software to determine strain measurements; secondly, whether the oxidation provides enough contrast for the measurement of strain; thirdly, whether evolution (degradation) of a surface due to on-going oxidation was a limiting factor for the use of Imetrum Ltd image correlation software; and fourthly, the ability of the correlation software to detect sub-surface defects.

What approach have you taken?

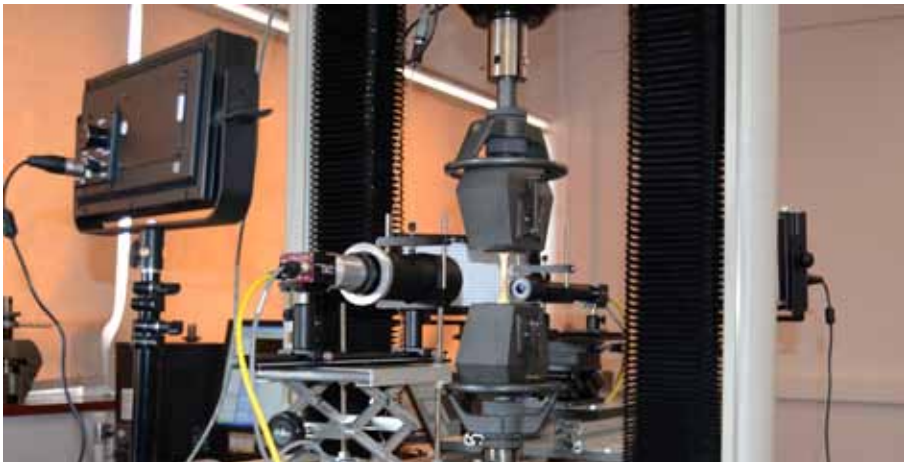
The early project work identified more than 30 potential applications. The technology was refined to meet each identified application and we concentrated on those applications where the following applied: access is difficult; multiple measurements are required; movements must be measured; surface effects could indicate sub-surface issues; fast time response is required; the surface is dirty or corroded. These are areas where the technology has a technical edge on the competition.

What have been the key findings?

The first experiments focused on the surface quality that was required for measurements to be successful. We then looked at the ability of the technology to detect sub-surface defects. The results demonstrated that the technology managed to track the surface accurately, with different finishes and fields of view showing good correlation to alternative technology.

Partners
Imetrum Ltd
Rolls-Royce plc
The University of Manchester

Project 9



Video gauge test set-up.

We also demonstrated that, once refined, the technology could comfortably identify the presence of sub-surface defects.

What are the potential benefits?

We gained valuable knowledge of the technology, not only in its worth to the consortium but also in raising awareness to key energy contractors. Imetrum gained experience within the nuclear sector while increasing and strengthening contacts and information channels. Robust measurement technologies that overcome the challenges of the nuclear industry are few and far between but Imetrum technology has shown potential in overcoming these challenges and, based on the work carried out, shows significant potential for a wide range of nuclear applications.

What are the next steps?

The nuclear industry is conservative and the best route ahead is to find an application that will allow the technology to be understood and accepted. Applications that fall into Technology Readiness Level (TRL) 7-9 may be the first, but those in TRL 4-6 open up a wider range of opportunities. The medium term items need further testing.

Imetrum Ltd
Unit 4, Farleigh Court
Old Weston Rd
Flax Bourton
Bristol
BS48 1UR

John Brewster
Managing director
E john.brewster@imetrum.com
T 01275 464443
W www.imetrum.com

James Fisher Inspection & Measurement Services Ltd

Optimising the design and implementation of non-destructive testing (NDT)

JFIMS offers a full range of non-destructive examination services backed up by a comprehensive quality framework and accreditations, including UKAS and NADCAP. KANDE International has many years' experience in the development and delivery of technological solutions to safety critical inspection problems, including nuclear power generation. JFN has experience in designing remote handling tools and systems for remote operations and inspection.

What problem have you tried to solve?

This feasibility study develops new approaches to NDT implementation for new build nuclear power plants (NPP). The approach is designed to deliver a highly reliable NDT technique at a reduced development cost for design and validation. In addition, it should deliver a high quality inspection at reduced cost and burden on the inspectors, while reducing the risk to the NPP build schedule.

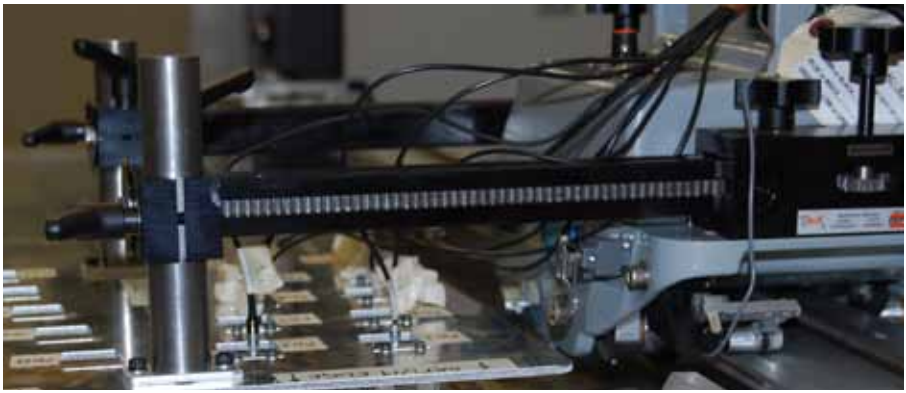
What approach have you taken?

The project looks at the following issues: methodologies to identify the correct NDT technique to be deployed; the ultrasonic testing techniques to be considered include using phased arrays; validation of these methodologies to demonstrate that the technique measures correctly; a practical implementation which ensures that the technique can be deployed with a high reliability; and evaluation of analysis support

Potential application area:
non-destructive testing of critical parts.

Partners
James Fisher Inspection and Measurement Services Ltd (JFIMS)
KANDE International Ltd
James Fisher Nuclear Ltd (JFN)

Project 10



Probe calibration.

tools to ensure that inspection can be carried out rapidly and reliably with less need for expert intervention.

What have been the key findings?

We have successfully designed a reliable technique for the inspection of AP1000 containment vessel welds. The technique is significantly quicker than the baseline technology and we have demonstrated that it gives excellent defect detection probabilities. The data analysis techniques reduce the workload of the inspector.

What are the potential benefits?

We can see a reduction in the risk to schedule from NDT inspection during the UK nuclear power plant build programme. The containment vessel weld inspections are delivered more efficiently, allowing the vessel build schedule to be shortened. There is also potential to exploit the same techniques at new reactor build projects abroad. The techniques used in the feasibility study can be deployed on other inspections, extending the scope of the potential benefits.

What are the next steps?

For the AP1000 containment vessel weld: gain formal approval for the technique; build a production inspection system incorporating the lessons learnt during the development; and deploy on a containment vessel weld. For other inspections: identify those which will benefit from the approach; develop the inspection technique in collaboration with the client; and implement the solution.

James Fisher Inspection and Measurement Services Ltd
Factory Road
Sandycroft
Deeside
Flintshire CH5 2QJ

Ian Moore
Business development manager
E ian.moore@jfims.co.uk
T 01244 520058
W www.jfnl.co.uk

Lab Impex Systems Ltd

Tenbee – a Boron-10 lined neutron detection system for waste assay

The Tenbee consortium comprises a detector manufacturer, a nuclear monitoring systems supplier and a large sensors specialist from the defence industry. Lab Impex is an SME which has been supplying nucleonics systems since 1976. Centronic, established in 1945, is a detector manufacturer employing around 100 people. SELEX Galileo, a Finmeccanica company employing 4,000 people in the UK, specialises in sensor systems.

Potential application area: nuclear waste monitoring.

What problem have you tried to solve?

We looked for an alternative to Helium-3 (He-3) detector based waste assay systems. He-3 is the default material for neutron detection, but reduced production, high cost and government control of supply mean an alternative is needed. Tenbee aims to prove the suitability of the Boron-10 lined tubelet detector and the capability of a full system to replace He-3 based systems. This is a priority for sites dealing with and monitoring nuclear waste.

What approach have you taken?

We sought to engage end users and industry experts for requirements, to produce a prototype detector with enhanced amplification electronics and to provide a plan for further development of the technology. The innovation in the sensor technology is to use a robust Boron-10 based tubelet that is less fragile than alternatives such as scintillators, is non-toxic, unlike boron trifluoride, and provides close to the same sensitivity as He-3.

What have been the key findings?

The project has shown that the technology has potential to replace He-3. Further testing is required to gain industry acceptance, but we have proven the feasibility. The detector is slightly less efficient than He-3, but faster and better gamma rejection mean it will have improved performance in some applications. Feedback from industry has been very positive since there is real desire to find an alternative to He-3. We have identified other markets for the technology, such as safeguards and fuel processing.

Partners
Lab Impex Systems Ltd
Centronic Ltd
SELEX Galileo Ltd

Project 11

Boron-10 lined tubelet detector.

What are the potential benefits?

To end users, the new technology will reduce cost in initial detector supply and increase reliability compared to other alternatives. It will offer a ready supply that is not reliant on He-3, better gamma rejection, long service life with easy detector disposal and safety integrity level design of the electronics to meet the most modern safety standards, such as IEC61508. The consortium estimates the market size in this area to be approximately £20m annually.

What are the next steps?

We will pursue further testing at leading test houses and also sensitivity improvements, with the eventual aim of developing a full system prototype. We will disseminate enhanced results to end users by offering prototypes with which to obtain performance data from real site use. Further development funding would increase the rate at which this work could be carried out.

Lab Impex Systems Ltd
21 Harwell Road
Nuffield Industrial Estate
Poole
Dorset
BH17 0GE

James Parkin
Principal physicist
E james.parkin@labimpex.com
T 01202 684848
W www.labimpex.com

NDT Consultants Ltd

Advanced remote visualisation interface (ARVI)

NDT Consultants Ltd has more than 20 years experience in non-destructive testing (NDT) and has extended its expertise into all aspects of NDT – training, testing, calibration services, consultancy, research and consumable products. Doosan Power Systems is a world-leading provider of cleaner technology, products and services for power generation, from steam power plant projects to boilers, turbines and nuclear power.

What problem have you tried to solve?

We sought to use image stitching in order to improve the accuracy of defect location and sizing, using visual inspection inside nuclear power station components.

What approach have you taken?

We took representative images using visual inspection equipment currently used for power station inspection. We then analysed the quality of the images in terms of contrast, positional accuracy of camera and illumination levels. Trials of image stitching routines compared automatic and positional-based image stitching.

What have been the key findings?

The technology requires accurate camera centralisation and positional control. This is not always possible in small diameter or complex geometry pipe work with restricted access.

Potential application area: non-destructive testing of nuclear plant.

Partners
NDT Consultants Ltd
Doosan Power Systems Ltd

Project 12

What are the potential benefits?

This feasibility study has shown the limitations of remote visualisation equipment being used currently and has identified parameters needed for improved hardware.

What are the next steps?

We are seeking funding for a follow-on study to investigate improved equipment which has become available since this project was completed.

On site NDT inspection.

NDT Consultants Ltd
Middlemarch House
Siskin Drive
Coventry
CV3 4FJ

Chris Edwards
R&D manager
E chris.edwards@ndt-consultants.co.uk
T 02476 511151
W www.ndt-consultants.co.uk

OC Robotics Ltd

Remote decommissioning of contaminated structures using laser cutting – LaserSnake

OC Robotics develops robotic solutions for hazardous and confined spaces. Customers have included the UK Ministry of Defence, US Department of Defense, Ontario Power Generation, Sellafield, Areva, Airbus and the AMRC. TWI Ltd has performed pioneering work in the use of lasers for nuclear decommissioning, enhancing the technology readiness level of laser cutting and laser scabbling.

Potential application area:
to enable component repair, inspection and plant decommissioning in remote access areas.

What problem have you tried to solve?

Plant life extension and end-of-life decommissioning are critical issues across processing industries in all sectors. These are generally unplanned, multi-stage projects. Solutions that reduce time and cost without compromising safety have significant commercial value. Snake-arm robots will form part of a generic, multi-purpose remote handling tool kit. This project showed the utility of a snake-arm combined with a high power laser to conduct rapid disassembly of complex structures.

What approach have you taken?

With support from Sellafield, the project demonstrated the combination of a snake-arm robot with a high power laser to dismantle vessels, support structures, flasks and pipe work in confined radioactive spaces. The LaserSnake project provides industry with a dexterous non-mechanical, non-contact cutting process for confined spaces. The significance of this combination is that both the laser power source and the snake-arm control system remain outside the contaminated area.

What have been the key findings?

OC Robotics has been able to advance the development of snake-arm robots for the nuclear sector, including adapting hardware to integrate with a 5kW laser cutting head and associated services. TWI Ltd has improved the laser cutting process so that it meets nuclear decommissioning needs. The project has shown that is it possible to dismantle thick walled pipes from one side,

Partners
OC Robotics Ltd
TWI Ltd

Project 13

Cutting target pipes after cutting obstructing pipes within the vessel.

cut stainless steel plates, and cut concrete in a selective manner, delivered by snake-arm, all inside a confined environment.

What are the potential benefits?

The scale of impact on the nuclear decommissioning sector is significant. A fully developed LaserSnake system will allow nuclear decommissioning to occur safer, faster and at reduced cost. It is estimated that this system could increase decommissioning productivity by 10%, worth up to £150m annually to Sellafield Ltd alone. Lasers have many functions, including cutting, welding and also sensing. LaserSnake demonstrates that all of these tasks can be delivered precisely by a snake-arm robot.

What are the next steps?

OC Robotics is discussing with end customers globally to apply this technology to real tasks. Within the nuclear sector the next stage is to further validate the process by considering specific decommissioning tasks. Financial and trade investment is being considered to prepare for significant growth.

OC Robotics Ltd
Unit 5, Abbey Wood Business Park
Filton
Bristol
BS34 7JU

Rob Buckingham
Managing director
E rob@ocrobotics.com
T 01173144700
W www.ocrobotics.com
@ocrobotics

Parker Hannifin Ltd

Gen III Actuator

The consortium is led by Parker Hannifin, a world leading diversified manufacturer of motion and control technologies and systems, providing precision-engineered solutions for a wide variety of mobile, industrial and aerospace markets. Genlec Ltd is an electrical design and manufacturing SME.

What problem have you tried to solve?

Our project is a feasibility study for a new gas spring actuator for the nuclear sector; current actuators are too small and will soon no longer be licensed to operate in GEN III nuclear reactors. The design has to incorporate new materials and be lightweight and scaleable, with a low centre of gravity. It will need to use new techniques, driving down cost and improving the product's competitive position.

What approach have you taken?

The feasibility study, which included the employment of specialists and consultants, investigated the scaleability, identification and use of new materials and manufacturing techniques that could be exploited by the consortium. This is with a view to improving upon the quality of the currently available actuators while at the same time reducing the cost considerably, making them more attractive for the current nuclear market.

Potential application area: new gas spring actuators.

Partners
Parker Hannifin Ltd
Genlec Ltd

Project 14

What have been the key findings?

By optimising the actuator to the end user's specification we have been able to reduce its size while maintaining the force and stroke requirements. New manufacturing techniques have enabled us to limit the number of components which make up the main pressure envelope of the actuator, thereby reducing the number of sealing interfaces and leakage paths.

What are the potential benefits?

The weight reduction means that the valve supports can be made smaller and of a scaleable design, providing significant cost savings. A successful Gen III actuator will lead to a less expensive, safer product for new nuclear facilities and will help develop a UK supply chain in this area.

What are the next steps?

We want to establish the technology as a credible alternative with the end users. Demonstrating the reduced risks and costs of ownership over the life of the installation can generate export sales to the established and emerging markets for nuclear power.

Computer generated image of the Gen III actuator.

Parker Hannifin Ltd
Tachbook Park Drive
Tachbrook Park
Leamington
Warwick
CV34 6TU

James Playdon
Manager
E james.playdon@parker.com
T 01926 833700
W www.parker.com

Peak NDT Ltd

Ultrasonic phased array application – dynamic focal law (DFL) programming

Peak NDT is a world leader in the design and development of ultrasonic non-destructive inspection equipment. Together with DPSL, a global provider of cleaner technology, products and services for power generation and EDF Energy, one of the largest UK home and business energy suppliers, the consortium forms a vertical supply chain from equipment provider though inspection specialist to plant owner.

Potential application area:
non-destructive testing and remote analysis of critical parts.

What problem have you tried to solve?

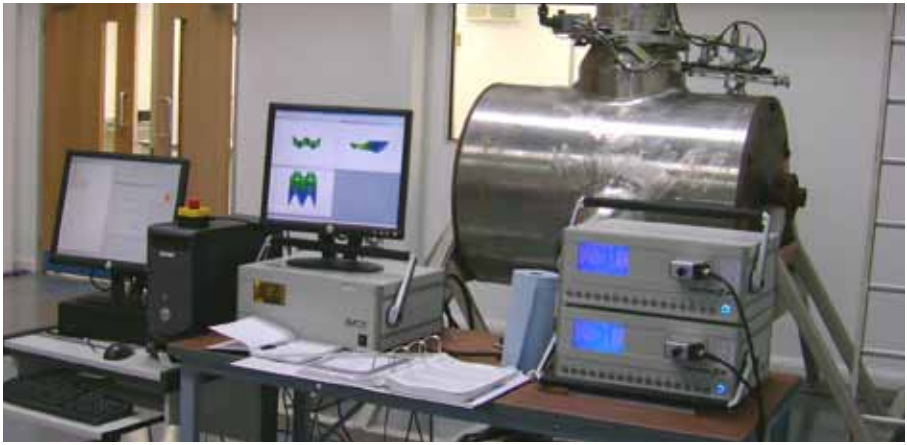
Ultrasonic non-destructive examination (NDE) plays a key role in assuring the integrity of nuclear power stations but, with components of complex geometry, NDE needs beams of many angles and skews. This may result in long scanning times and frequent entry by the operator into a potentially hostile environment to change probes and data sets. Reducing plant downtime and radiation dose uptake while simplifying the data analyst's task offers obvious benefits.

What approach have you taken?

Using a phased array probe, the ultrasound beam can be programmed electronically to generate many angles and skews. By linking this capability with the specific requirements for beam angle and skew at a given location, fewer probes/skews are applied, – reducing scanning time and the number of interventions by the operator. Furthermore the amount of data collected is reduced and the analysis task simplified. We explored the feasibility through a combination of modelling and practical trials.

What have been the key findings?

Computer modelling showed that a 256-element matrix array would be needed to generate the required ranges of angles and skews, so the project saw the first use of a MicroPulse with 256 channels. The prototype inspection, implemented within the framework of existing software and equipment, clearly demonstrated the benefits offered by dynamically programming beam angles and skews. The results also showed the potential



The data collection system at PNL labs.

that collecting a range of skew angles has for improved detection and characterisation of misorientated defects.

What are the potential benefits?

The benefits of the DFL project are wider than just its technical achievements. Implementing dynamic focal law programming within the framework of existing software with which operators are already familiar reduces the costs of operator training. Where an inspection methodology has already been qualified, replacing multiple probes with one or two array probes performing the same function makes the task of inspection qualification less onerous than if an inspection had to be completely redesigned. This offers further opportunity for cost reduction.

What are the next steps?

Building on the results of the feasibility study the current ambition is to foresee a full exploitation of the inspection on EDF Energy power plants, initially back-to-back with the current inspection. Before this can happen, further work is needed to productionise the implementation, to write inspection procedures and technical justifications and to carry out further trials on test-pieces containing known defects.

Peak NDT Ltd
Unit 1 Enterprise Way
Jubilee Business Park
Derby
DE21 4BB

Andrew Whittle
Operations Director
E andy.whittle@peakndt.com
T 01332 738752

Shadow Robot Company Ltd

From telerobotics to teleautonomy

Shadow Robot manufactures and develops robots and associated technologies. RU Robots is one of the UK's foremost advanced robotics and cognitive science companies. Advanced Robotic Technology specialises in systems engineering, consultancy and projects in robotics and remote handling for hazardous environments, automation, machine vision and industrial automation. The National Nuclear Laboratory is the UK's leading nuclear technology services provider.

Potential application area:
advanced robotics for decommissioning.

What problem have you tried to solve?

We sought to understand how the capabilities of advanced robotics – in particular autonomous operation – could be brought to bear on the problems of nuclear operations and decommissioning, in order to reduce risk and cost over both planned and future work.

What approach have you taken?

We analysed problems within the industry, researched technical approaches used in this and other industries and generated visions of possible future robotics products and systems that could solve these problems. We then produced a detailed roadmap analysing how the nuclear industry could move to the use of advanced robotic capabilities, as well as producing some prototype implementations of key technologies.

What have been the key findings?

There is a need for joined-up thinking and funding of research in new technology for the nuclear industry. Cross-project research and development would help here, as well as the adoption of a common strategic roadmap across the industry. There are technologies that could be brought across from other areas where robotics is used, but nuclear-specific development is needed to enable this.

Partners
Shadow Robot Company Ltd
RU Robots Ltd
National Nuclear Laboratory
Advanced Robotic Technology Ltd

Project 16

A dextrous robotic manipulator used in the project feasibility work

What are the potential benefits?

Advanced robotics has the potential to reduce decommissioning costs by 10-20% over the existing decommissioning plans as well as allowing more flexible working with reduced risk to workers.

What are the next steps?

We need to develop a critical mass to fund a nuclear roadmap, as well as to begin research – possibly at a European level – into some of the key challenges required to get teleautonomy used in the nuclear domain

Shadow Robot Company
251 Liverpool Road
London
N1 1LX

Rich Walker
Managing director
E rw@shadowrobot.com
T 0207 7002487
W www.shadowrobot.com

Sound Mathematics Ltd

Automated ultrasonic non-destructive evaluation (NDE)

SML produces advanced software for ultrasonic non-destructive examination. Doosan Power Systems is a leading provider of cleaner technology, products and services for power generation: from turnkey steam power-plant projects to boilers, turbines and nuclear power.
NI UK is a subsidiary of a leading international developer and manufacturer of software and hardware for measurement, control and embedded systems.

Potential application area:
automated non-destructive testing of critical parts.

What problem have you tried to solve?

Automated phased array ultrasonic inspections in nuclear power stations still use humans to interpret results. We addressed a high-level, long-term challenge to support the deployment of an innovative ultrasonic unit for flaw characterisation and interpretation, leading to cost-effective and reliable automatic NDE. When commercialised, the new unit would allow for automatic characterisation of safety-critical defects, presenting plant owners with clear and unambiguous reports for plant.

What approach have you taken?

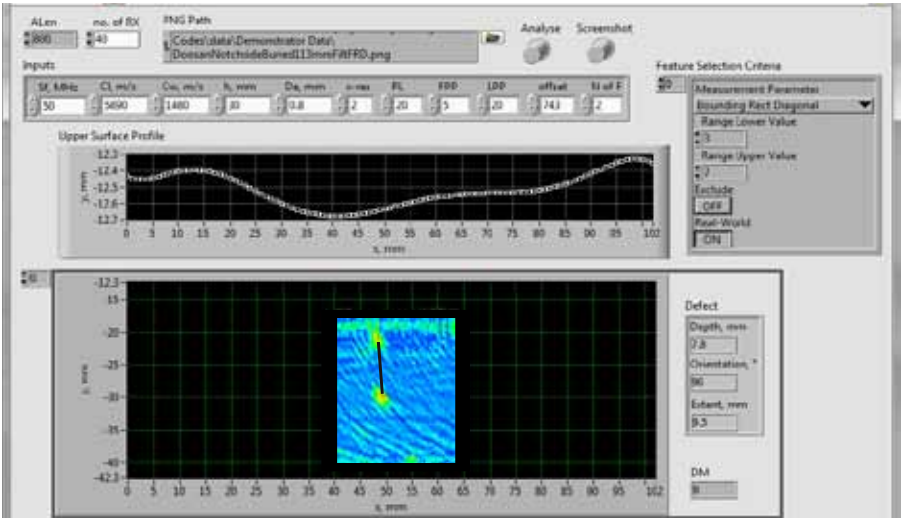
Real-time automatic flaw diagnostics are not offered by existing non-destructive testing (NDT) units. The demonstrator our consortium developed utilises PXI-based acquisition boards with field programmable gate arrays (FPGAs) to handle the high data rates from parallel channels. These same devices affect the real-time imaging based on total focusing method (TFM). We achieve image interpretation with a fast model-based version of the TFM, implemented in LabVIEW. It incorporates feature selection filters based on geometrical acoustics and geometrical theory of diffraction.

What have been the key findings?

We built a demonstrator that uses modular hardware in the industry standard PXI platform. It has been shown to achieve acquisition and processing at real-time imaging rates at relatively low cost, without compromising flexibility. We developed a version of TFM which produced much clearer

Partners
Sound Mathematics Ltd (SML)
Doosan Power Systems Ltd (DPS)
National Instruments UK Ltd (NI UK)

Project 17



Graphical user interface for ultrasonic non-destructive evaluation.

and interpretable images than straightforward TFM when applied to realistic defects in the test specimen manufactured by DPS.

What are the potential benefits?

With new nuclear build already under way in the UK and globally, there is likely to be a severe shortage of suitably qualified and experienced personnel (SQEP). Following this project a demonstrator of a novel ultrasonic flaw characterisation unit confirmed the possibility of reducing the requirement for SQEP for characterisation and interpretation of data generated during automated phased array inspection of nuclear plant. At the same time it eliminated variability in interpretation of results by human operators.

What are the next steps?

The consortium is seeking additional longer term investment in order to undertake further development work to widen the applicability of the flaw reconstruction algorithm and carry out performance / probability of detection (POD) trials to obtain necessary approvals and to interface with' automated inspection system(s).

Sound Mathematics Ltd
11 Mulberry Close
Cambridge
Cambridgeshire
CB4 2AS

Larissa Fradkin
Managing director
E l.fradkin@soundmathematics.com
T 01223 355310
W www.ultrasoundmathematics.com

Stopford Energy & Environment Ltd

Assessing the feasibility of using a novel chemical process for the *in situ* treatment of low-level metals waste in the nuclear industry

Stopford Energy & Environment (SEE) is an energy and environment consultancy with engineering design and project management expertise. SEE excels in the development and implementation of green technology development programmes globally. BDB Dismantling specialises in the removal of redundant equipment and structures across a broad spectrum of industries, with expertise in site clean-up operations for the chemical industry.

Potential application area: nuclear waste treatment.

What problem have you tried to solve?

The UK's low-level radioactive waste repositories are estimated to reach capacity as early as 2037. This places the industry under increasing pressure to develop new technologies to reduce its waste, of which metal components contribute a significant fraction of the total. Our consortium has developed a technique for on-site decontamination of metal components, which is cleaner, faster and less destructive than contemporary methods and allows metal components to be recycled.

What approach have you taken?

We have developed a novel chemical process, enabling the on-site decontamination of low-level metals waste. Our approach removes the contaminated metal surface layer, leaving the component free to be released. The process liquor is subsequently treated in a secondary process, enabling safe on-site disposal, with the solid residues disposed of to a waste repository.
The approach therefore provides a low-cost, highly efficient process for in situ decontamination of low-level metallic waste.

What have been the key findings?

Together with National Nuclear Laboratories, our consortium has undertaken preliminary trials to assess the effectiveness of the decontamination process. Using gamma ray spectrometry and liquid scintillation analysis of a range of radionuclides, shows that there was a better than 90% reduction in surface contamination within the first three hours of the treatment.

Partners
Stopford Energy & Environment Ltd
BDB Dismantling Ltd

Project 18

These preliminary results suggest that this novel chemical treatment of contaminated metal components has the potential to reduce the volume of metal wastes entering low level waste repositories.

What are the potential benefits?

Our project has seen the development of a novel method for the treatment of low-level metal wastes. Given the rapidly increasing demand for treatment technologies in the UK, commercialisation of this technology presents the nuclear sector with a significant opportunity. It presents the following advantages: waste minimisation; recycled components; reduced disposal costs; on-site component treatment; reduced transportation costs; fast processing times; reduced carbon footprint; low operating costs.

What are the next steps?

In order to successfully develop and commercialise the technology further, the process will require additional scale-up and optimisation. Further work will be specifically aligned with the needs of industrial end users and will progress in line with market developments. To achieve this, the project partners will be looking for further investment and collaborative opportunities within the nuclear sector.

pH monitoring during chemical soaking process.

Stopford Energy & Environment Ltd
The Gordon Manley Building,
Lancaster Environment Centre
Lancaster University
Lancashire
LA1 4YQ

Ben Herbert
Director of research and environment
E ben.herbert@stopford.co.uk
T 01524 510604
W www.stopfordenergyandenv.co.uk

System Level Integration Ltd

Wireless extended equipment health management for nuclear installations

SLI is a 12-person research institute, established in 1998, developing enabling technologies. Specialist areas include embedded electronic systems and wireless communications. Rolls-Royce is a global business providing integrated power systems and has a long history in the nuclear industry. Its experience spans the design and supply of integrated systems and equipment for civil and naval reactors across the life cycle.

Potential application area:
wireless health monitoring of nuclear plant.

What problem have you tried to solve?

Equipment health management (EHM) is delivering operational benefits across many industries but has achieved limited penetration in civil nuclear power plant (NPP). Part of the difficulty lies in the challenges and very significant costs of deploying wired solutions. If EHM is to bring benefits to NPP seen elsewhere, this needs to change. We tried to identify ways of reducing the cost and increasing the flexibility of EHM systems for NPP deployment.

What approach have you taken?

Our principal objective was to evaluate a range of wireless technologies for their ability to deliver against the needs and limitations of EHM within the setting of a nuclear plant facility. It was about understanding and evaluating systems' potential to deliver solutions against a range of needs. In comparison with incumbent (wired) solutions, wireless offers greater flexibility and faster deployment with less impact on infrastructure.

What have been the key findings?

The civil nuclear industry has particular issues which restrict the ability of suppliers to deploy currently available commercial wireless solutions on a general basis. This is further complicated by the differences between factors affecting existing (historic) fleet and those expected to pertain to new build. The combined picture is somewhat complex, but we have identified pathways through this to products appropriate for deployment now and evolution to future scenarios. These solutions will require a novel combination of several current technologies.

What are the potential benefits?

We are working to quantify the accessible market size, but believe these to be substantial. A system of the type we have identified would have application not just in NPP but in several other industries characterised by dangerous or heavily regulated environments, such as oil and gas and petro-chemical. We see clear potential for development of intellectual property rights-protected systems within the UK for sale into these markets and which will additionally benefit systems and service integrators in the UK.

What are the next steps?

With regard to shorter term developments, we are investigating proof of concept-type funding to develop the ideas to field demonstrator stage. We then expect to engage with an equipment supplier who has the supply chain capability to realise production and market entry. A longer term technology option, for wireless bridging into previously inaccessible areas, is also under consideration.

Test equipment in the control room for the anechoic chamber, showing an arbitrary signal generator running at 5.7GHz.

System Level Integration Ltd
Research Avenue North
Heriot Watt Research Park
Edinburgh
Midlothian
EH14 4AP

Mark Begbie
Director
E mark.begbie@isli.co.uk
T 0131 510 0670
W www.isli.co.uk

TSC Ltd

Electromagnetic inspection of nuclear plant (EINP)

TSC (SME) develops and manufactures advanced instruments for non-destructive testing (NDT) and stress measurement. TSC's patented alternating current field measurement (ACFM) technique has been used worldwide for more than 20 years. Doosan Power Systems is a world-leading provider of cleaner technology, products and services for power generation – from turnkey steam power-plant projects to boilers, turbines and nuclear power.

What problem have you tried to solve?

Nuclear power plant regularly undergoes the most stringent of inspection procedures, to ensure that each part of the plant is operating safely and at optimal performance. Creep cracking can occur on pipe work at both high and low temperatures. Currently this is detected using magnetic particle inspection and dye-penetrants. The aim of our project is to replace these older techniques with ACFM to avoid the use of chemicals.

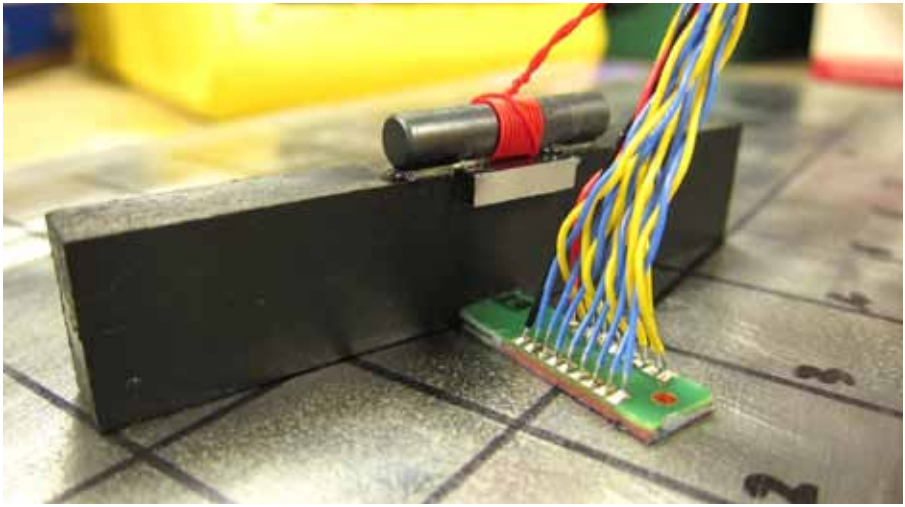
What approach have you taken?

ACFM has been used in industry for over 20 years. It is used to detect and size surface-breaking fatigue cracks. Until now, typical defect sizes are larger than 10mm in length, and 1mm deep. To find creep defects 2mm in length, and less than 0.5mm deep, we have used giant magneto restrictive (GMR) sensors to replace traditional coil sensors, which are too large for the application.

Potential application area:
defect detection in high-temperature parts.

Partners
TSC Ltd
Doosan Power Systems Ltd

Project 20



A sub-miniature ACFM (alternating current field measurement) array on sample.

What have been the key findings?

Sensor coils are typically 2mm in diameter, so their centres can never be less than 1mm from the surface of the inspection piece. GMR sensors are much smaller, and can be placed less than 0.2mm from the inspection piece. This allows for the detection of smaller defects. The use of these sensors is more problematic and we have overcome a number of technical problems during the course of the project.

What are the potential benefits?

The use of GMR sensors has enabled us to make the world's smallest ACFM array, which consists of eight sensor pairs in an array just 8mm in length. This sub-miniature array has successfully detected surface breaking cracks just 2mm in length and 0.2mm in depth. Using this technique instead of magnetic particle inspection dramatically reduces the speed of inspection and unnecessary downtime.

What are the next steps?

On successful completion of the project, we would be looking to work with printed circuit board and sensor manufacturers to develop commercially viable arrays for the inspection of creep cracking over a variety of industries, including nuclear power.

TSC Ltd
6 Mill Square
Featherstone Road
Milton Keynes
Buckinghamshire
MK12 5RB

Bruce Blakeley
R&D projects manager
E bruce@tscinspectionsystems.com
T 01908 317 4444
W www.tscinspectionsystems.com

Acknowledgements

The Technology Strategy Board would like to acknowledge the role of our Nuclear R&D Collaboration Nation delivery partners

Energy Generation & Supply Knowledge Transfer Network

Supported by the Technology Strategy Board, the role of the EG&S KTN is to simplify the UK energy innovation landscape by providing a clear and focused vehicle for the rapid transfer of high-quality information on technologies, markets, funding and partnering opportunities. The KTN works in eight priority areas: carbon abatement technologies; fuel cells and hydrogen; future and emerging opportunities; maximising oil and gas resources; nuclear; offshore wind; smart utilities; and wave and tidal.

National Nuclear Laboratory (NNL)

The UK's National Nuclear Laboratory is the EG&S KTN's delivery partner for nuclear technologies. It offers an unrivalled breadth of technical products and services to customers across the whole nuclear industry. It covers the complete nuclear fuel cycle from fuel manufacture and power generation, through to reprocessing, waste treatment and disposal and including defence, new nuclear build and homeland security. NNL is supported by international research organisations, academia and other national laboratories.

Nuclear Advanced Manufacturing Research Centre (Nuclear AMRC)

The Nuclear AMRC is a collaboration of academic and industrial partners from across the nuclear manufacturing supply chain. Its mission is: to enhance the capabilities and competitiveness of the UK civil nuclear manufacturing industry; to work with members to develop world-leading manufacturing processes and technologies; to help British manufacturing companies compete for nuclear contracts worldwide; and to become the focal point for Britain's civil nuclear manufacturing industry. The Nuclear AMRC is part of the High Value Manufacturing Catapult (formerly the Technology & Innovation Centre for High Value Manufacturing), supported by the Technology Strategy Board.

Photography

We are grateful to the following organisations for allowing us to use images from their picture libraries: British Energy, Magnox Ltd and Sellafield Ltd. Images used on the first page of a project are for illustrative purposes only.

The Technology Strategy Board is a business-led executive non-departmental public body, established by the Government. Its role is to promote and support research into, and development and exploitation of, technology and innovation for the benefit of UK business, in order to increase economic growth and improve quality of life.

Disclaimer

The entries in this directory were provided by the individual companies. The Technology Strategy Board cannot guarantee the accuracy or completeness of any of the information about the projects.

Technology Strategy Board
North Star House
North Star Avenue
Swindon
SN2 1UE

Telephone: 01793 442700

www.innovateuk.org