



JOINING
INNOVATION
AND EXPERTISE

Business Review
July 2018

Contents

Message from the Chief Executive	4
TWI Council	6
TWI Executive Board	8
Business and Financial	10
Research and Innovation	14
Structural Integrity Research Foundation	20
Focus on Industry - Case Studies	28
Regional and International Impact	44
Corporate Social Responsibility	48
TWI Industrial Members	54
Contact	60

Jordan Hollingsworth
Software Development



Connor Brookfield
Non-destructive Testing



Catherine Leahy
Materials Performance

Bethany Richards
Stainless Steels



Tyler Thurgood
Fatigue Integrity




Alec McIntyre
Site Services



Efan Jones
Non-destructive Testing

TWI first-year
advanced apprentices
and their current specialisms

Message from the Chief Executive



"Our performance turnaround is due to the capabilities and efforts of TWI's people and I would like to thank them for their commitment."



Christoph Wiesner
Chief Executive

Following a two-year period of consolidation, 2017 was the year during which TWI returned to growth and achieved the following highlights:

- Single client order intake reached a new high of over £24m; this shows that we are continuing to demonstrate the value we provide to our Industrial Members.
- Publicly funded collaborative R&D income grew to almost £13m thanks to strong order intake from the European Framework Programme Horizon 2020 and an increasing order volume from Innovate UK, the British innovation agency.
- TWI's Innovation Network (comprising eight Innovation Centres with a number of universities) expanded to incorporate strategic engagement with several Industrial Members through our Accelerated Innovation Programme and three large, dedicated innovation partnerships with Industrial Member companies.
- Our global training, examinations, certification and professional income streams returned to a growth trajectory after a two-year slow-down caused by the oil price collapse in the second half of 2014.

Following over £50m of investment in new facilities and laboratory equipment in the UK and South East Asia during 2015-16, we now have a tremendous opportunity to develop new capabilities, to enhance our reputation for industry-ready technology leadership, and to grow our business by assuring our long-term ability to add value to Industrial Members.

TWI's financial position improved markedly in 2017 due to higher levels of collections, faster cash repatriation from the overseas subsidiaries and an addition to our bank facility

enabled by the successful multi-million-pound sale of our Teletest technology to Eddyfi Technologies – a Canadian NDT equipment company.

Further positives for TWI's outlook are: the improving R&D funding landscape – including a much-increased budget for Innovate UK; a growing order book length – the longest since 2013; and several multi-million pound, long-term projects in materials and structural performance, integrity management and fabrication for key Industrial Members.

Our plans for 2018 and beyond show a cautiously optimistic return to growth, with the major caveat that this assumes a relatively smooth Brexit process and ongoing TWI access to European R&D funding programmes.

TWI's business priorities for 2018-20 are:

- Continued development of strategic relationships with Members and customers.
- Build TWI's reputation by delivering value to industry.
- Develop innovative products and services in response to market demand.
- Recruit, train and retain the next generation of TWI experts.
- Generate cash for reinvestment to 10% of TWI Group turnover.

Our performance turnaround is due to the capabilities and efforts of TWI's people and I would like to thank them for their loyalty and commitment. My sincere appreciation also goes to our external boards and governance bodies for their support and guidance throughout the year.

A stylized, handwritten signature in blue ink, appearing to read 'Christoph'.

Christoph Wiesner
Chief Executive

TWI Council

The Council is the governing body of TWI and consists of elected representatives from Industrial Member companies and Professional Members.

Steve Dearden FREng, MSc, FIMechE – Rolls-Royce Plc – President of TWI Council
Paul Tooms – Kosmos Energy LLC – Chairman of TWI Council
Eur Ing Nigel Knee – EDF Energy – Vice Chairman of TWI Council
Professor Steve Jones CEng, FWeldI – NAMRC – Chairman of TWI Professional Board
Professor John Irven MA, CSci, CChem, FRSC, HonFWeldI – Consultant – Chairman of TWI Research Board
Grahame Nix OBE, FRAes – Non-Executive Director
Professor Steve Yianni FREng, MA(Cantab), MBA, FIMechE – Non-Executive Director
Eur Ing Alan Denney BSc, MSc, CEng, MIMMM, FWeldI – Professional Member
Dr Andrew Nowicki CEng, FWeldI – Professional Member
Eur Ing Robert Sawdon CEWE, FWeldI – Professional Member
Dr David Taylor – Professional Member
Eur Ing David Millar CEng, CEWE, FWeldI – Professional Member
Iain Boyd CEng, IWE/EWE, FWeldI – Professional Member
Jeffrey Garner CEWE, CEng, FWeldI – Professional Member
Eur Ing Johann Krancioch BSc(Hons), CEng, IWE, MIMMM, FWeldI – Professional Member
Dr Stephen Beech CEng, FRSA, FIMMM, FWeldI – Professional Member
Stephen Webster CEng, FIMMM, FWeldI – Professional Member
Dr Kevin Slattery – The Boeing Company
Eur Ing Professor Norman Cooper CEng, CSci, FIMMM, FWeldI – BAE Systems Marine Ltd
Simon Webster CChem, FRSC, FRSA – BP Plc
Dr John O'Brien CEng – Chevron Corporation
Dr David Mallaburn CEng, CPhys – EDF Energy Generation
Eur Ing Andrew MacDonald CEng, IWE, MIMMM, AWeldI – Lloyd's Register Foundation
Dr Ruth Boumphrey BSc – Lloyd's Register Foundation
Dr Brian Robb CEng, FIMMM – Rolls-Royce Plc
Dr Peter Boothby CEng, FWeldI – Rosen Group
Professor Scott Lockyer CEng, MIMMM, MWeldI – Uniper Technologies Ltd

Council Boards Governing TWI Activities

Board/Committee	Chairman
Research Board	Professor John Irven
Finance and General Purposes	Paul Tooms
Professional	Professor Steve Jones
Certification Management	Julio Tolaini



TWI Council, left to right:
President: Steve Dearden / Chairman of Council: Paul Tooms / Vice Chairman: Nigel Knee

TWI Executive Board

Dr Christoph Wiesner OBE, FREng, Dipl-Ing, Dr és sci tech, HonDEng, FIMMM, FWeldI – Chief Executive
Mrs Gillian Leech FAIA, MBCS – Director, Finance and Services
Dr Paul Woollin FREng, MA(Cantab), FIMMM, FWeldI – Director, Research
Professor Aamir Khalid BSc, MSc, MBA, CEng – Director, Technology
Dr Mike Russell MEng, PhD, CEng, MWeldI – Director, Operations
Eur Ing Chris Eady BSc(Hons), MSc, CEng, FWeldI – Associate Director, Professional Affairs and Certification
Mr Steve Yianni FREng, MA(Cantab), MBA, CEng, FIMechE – Non-Executive Director
Mr Grahame Nix OBE, FRAes – Non-Executive Director
Mr Maurice Whittaker MBCS, FInstAM, MIET – Associate Director
Dr Arnaud Tronche PhD, MBA – Associate Director
Dr Shervin Maleki PhD, CEng – Associate Director and Business Group Manager
Dr Robert Scudamore BEng(Hons), MSc(Eng), MBA, CEng, CMgr, FCMI, SenMWeldI – Associate Director and Business Group Manager
Dr Steve Shi BSc, MSc(Eng), CEng, EWE, MIMMM, SenMWeldI – Business Group Manager
Eur Ing Professor Tat-Hean Gan BEng(Hons), MSc, MBA, CEng, CMgr, FIET, FCMI, FWeldI, FInstNDT, IntPE, FISEAM, FISCM – Associate Director and Business Group Manager
Mr Keith White ACA – Associate Director

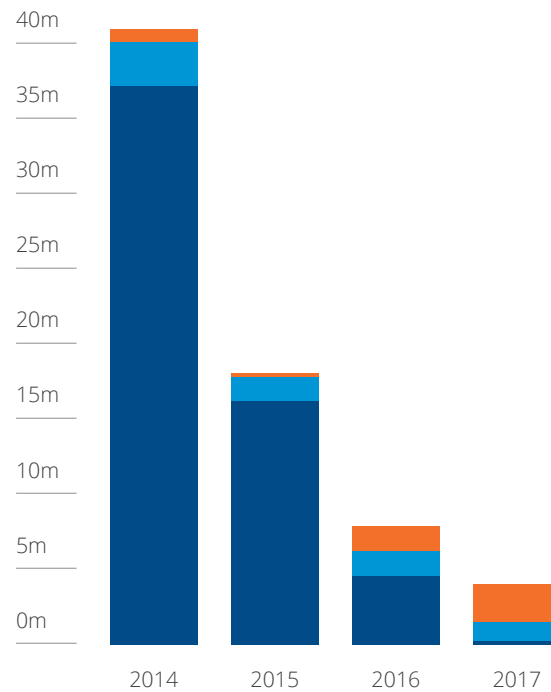


TWI Executive Board, left to right:
Robert Scudamore / Mike Russell / Paul Woollin / Keith White / Christoph Wiesner / Aamir Khalid / Gillian Leech / Grahame Nix
Steve Yianni / Shervin Maleki / Steve Shi / Maurice Whittaker / Tat-Hean Gan / Arnaud Tronche / Chris Eady

Business and Financial

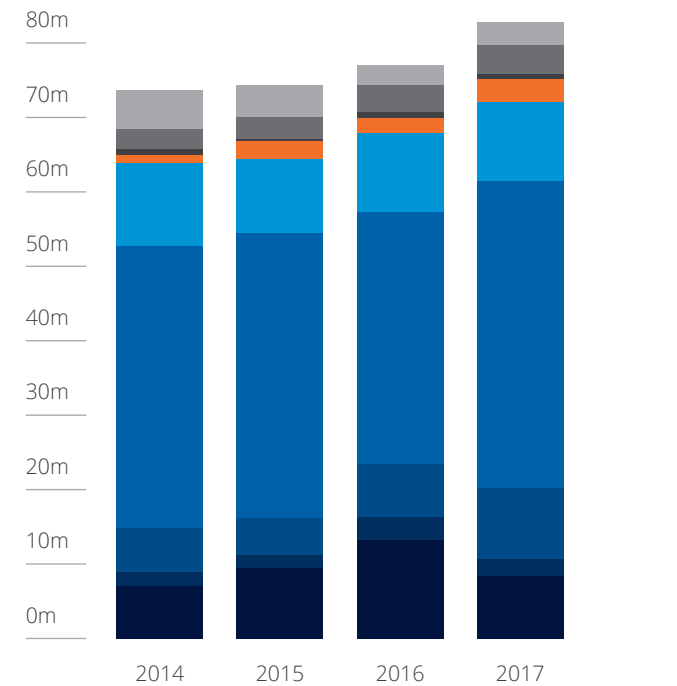


Asset Acquisition



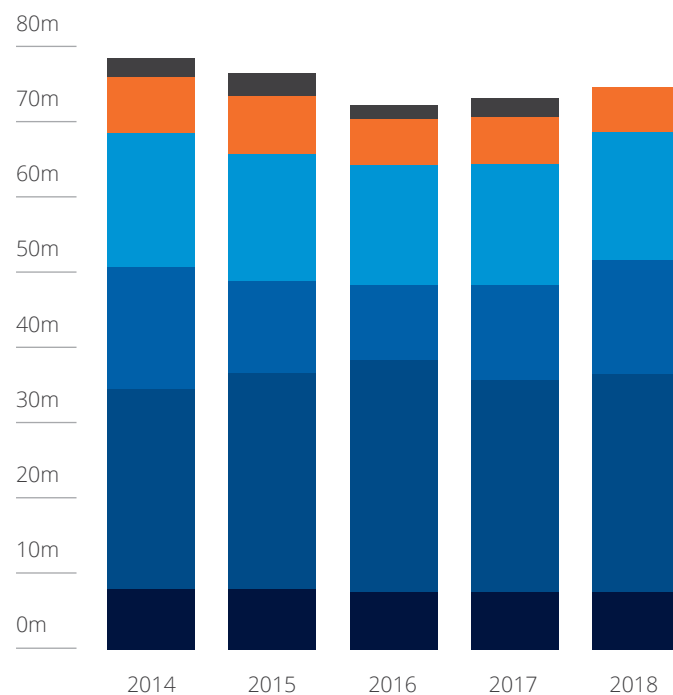
- Land and Buildings
- Plant and Equipment
- Project Plant and Equipment

Order Intake by Industry Sector



- Aerospace
- Automotive
- Power
- Oil and Gas
- Construction
- Electronics and Sensors
- Medical
- Equipment
- Other

Product Income



- Membership
- Single Client and Joint Industry Projects
- Collaborative R&D and Technology Transfer
- Training and Examinations
- Licensing and Other
- Teletest

Projects per Annum



700
SINGLE
CLIENT



55
PHD
AND MSC



110
COLLABORATIVE



31
ACCELERATED
INNOVATION
PROGRAMMES



65
CORE
RESEARCH



14
JOINT
INDUSTRY

Business and Financial

TWI Group

The Welding Institute (holding company)

TWI Ltd
TWI Technology Centre North East
TWI Technology Centre Yorkshire
TWI Technology Centre Wales
TWI Aberdeen
TWI Certification Ltd
The Test House Ltd
NSIRC Ltd
SIRF Ltd
Plant Integrity Ltd
Granta Park Estates Ltd

TWI Azerbaijan
TWI Canada
TWI China
TWI Gulf
TWI Gulf WLL Abu Dhabi
TWI India
TWI Indonesia
TWI Middle East
TWI North America
TWI Pakistan
TWI Services (SEA)
TWI Technology (SE Asia)
TWI Thailand
TWI Turkey

TWI Networks



11
GROUP OR
ASSOCIATED
COMPANIES



2000
INDUSTRIAL
MEMBER COMPANIES
WORLDWIDE



120
STANDARDS AND
GOVERNMENT
COMMITTEES




8
ON-SITE
INNOVATION
CENTRES



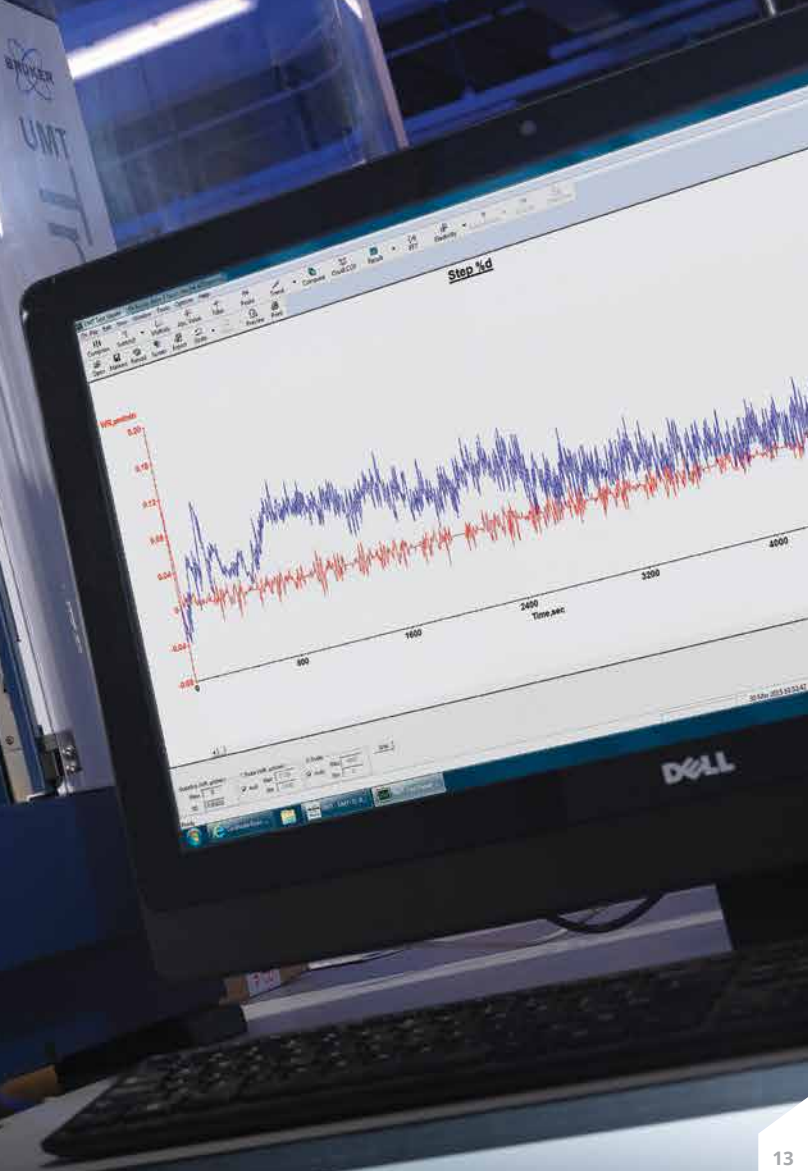
40+
UNIVERSITY
PARTNERSHIPS



5200
PROFESSIONAL
MEMBERS IN
18 BRANCHES



Amit Rana working on high resolution tribological testing using a Bruker tribolab



Research and Innovation



Paul Woollin
Director, Research



Aamir Khalid
Director, Technology

Overview

The core of TWI's mission is to help industry solve its problems. Firstly, we solve today's problems through expert advice and by assisting with the application of available technology, while, secondly, we train future experts and develop new processes and products, in conjunction with industry, to address tomorrow's challenges.

Achieving these goals requires sustained research activity. TWI's Core Research Programme (CRP) invests half of the Industrial Membership subscriptions into research on developing expertise and new processes for manufacture, material property characterisation, inspection and quantification of structural integrity. CRP research activity is supplemented by collaborative projects, publicly funded via Innovate UK and the EU Framework Programmes. These projects are focused on the development of new technology that can be readily exploited by industry, often via prototype products. In 2017, our research funding included £4m of CRP and £12.5m of collaborative projects.

To underpin this research activity, we have developed a mechanism for aligning postgraduate student research to the needs of industry via the NSIRC student cohort at TWI and TWI Innovation Centre partnerships with universities, which together allow co-ordinated development of technologies from technology readiness level (TRL) 1 to 9.

In combination, these research activities represent a powerful research and innovation engine to create technology impact on behalf of TWI and its Industrial Members.

Research Direction

To ensure that TWI's research develops capabilities and products that are of direct use to the Industrial Membership, the future direction and dissemination of the Core Research Programme (CRP) is steered by the Research Board, which is comprised of 40 expert representatives of world-leading companies, predominantly from the aerospace, oil and gas, and power generation sectors and their supply chains. The individual projects are mentored by Research Board Members to ensure industrial relevance throughout.

Collaborative projects bring a second perspective to the research direction, as they involve proposal writing in response to specific calls that express UK and EU priorities and ensure a sound business case exists for the commercialisation of the new technologies developed.

Together, the core research and collaborative projects provide multiple opportunities to create positive societal, economic and environmental impacts on behalf of TWI's Industrial Members.

Research Board

The Research Board is a committee of representatives from Industrial Member companies. It determines the content and guides the progress of the Core Research Programme.

Chairman, Research Board:

Professor John Irvén MA, PhD, CSci, CChem,
FRSC, HonFWeldI – Consultant

Chairman, Engineering Committee:

Professor Bob Ainsworth MA, DPhil, FRS, FIMechE,
FREng – University of Manchester

Chairman, Materials Committee:

Gareth Hopkin MA, CEng – Office for Nuclear Regulation

Chairman, Joining and Fabrication Committee:

Dr Ernst Miklos MSc, EWE – Linde Group

Dr Abdulaziz Al-Meshari BSc, PgDip, MSc – Saudi Basics
Industries Corporation (SABIC)

Tareq Al-Sabti MSc – Aramco

Dr Rob Backhouse BEng, EngD, FIMMM – Rolls-Royce PLC

Julien Banchet BSc, MSc, MA(Hons) – Areva

Dr Carl Boettcher – Rolls-Royce PLC

Martin Bolander – Westinghouse Electric Sweden AB

Marcel Buckley – GKN Aerospace

Professor Gary Coleman – The Boeing Company

Chris Dash BScH(Eng), MS, PE – Conoco Phillips Company

Dr Nabil El Barbari – GF Piping Systems

Dr Fernando Fernandez BSc(Hons), MSc, MBA – Embraer

Sebastien Garnier – Areva

Brett Hemingway – MAI Manufacturing Operations

Eur Ing Peter Hilton BSc(Hons), CEng – Shell

Robert Holmes – Canadian Nuclear Laboratories

Craig Hunt BSc(Hons) – Air Products PLC

Jimmy Johansson – GKN Aerospace

Shinji Koga – Kawasaki Heavy Industries

Dr Bruno Leduey – Air Liquide

Zhiqiang Li – AVIC Beijing Aeronautical

Dr Mario Macia PhD – ExxonMobil Production Company

Dr Ian Merchant – Consultant

David Milliken – The Boeing Company

Kelly Moran – The Boeing Company

Roberto Morana – BP Exploration Ltd

Dr David Panni CEng – J C Bamford Excavators Ltd

Holly Phillips MRINA, MCMI, MIIMS – RNLI

Cheryll Pitt BSc(Hons), CEng, FIMMM – Ministry of Defence

Dr Marcelo Piza Paes MSc, DSc – Petrobras / CENPES /
PDEP / TMEC

Howard Price – BAE Systems

Javad Safari – TechnipFMC PLC

Andrew Schofield BSc(Hons) CEng, MIMMM – BAE Systems

Christopher Thornton MA, CEng, MIMMM SenMWeldI –
BP Exploration Ltd

Naoki Urai – OTC Daihen Europe GmbH

Jitesh Vaja BScEng(Hons) – AWE PLC

Darren Wilson – Smith & Nephew UK Ltd

William Wistance – Lloyd's Register Foundation



Alex Russell inspecting a joint made using diffusion bonding and brazing with the aid of interlayers, for the European Space Agency

Research and Innovation

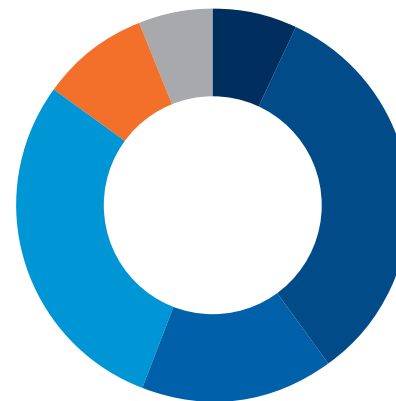
Core Research

The TWI Core Research Programme (CRP) develops underpinning capabilities (including expertise, processes, equipment and methodologies) for the benefit of its Industrial Membership. We supported over 70 internal research projects and 30 PhD projects in 2017, with the value of the CRP at £4m, representing approximately one ninth of total research and technology income. We published sixteen Industrial Member Reports and two Technical Literature Reviews, including:

- Detection and Characterisation of Stress Corrosion Cracking in Austenitic Weld Overlay Cladding for Non-Intrusive Inspection
- Automatic TIG Ambient Temperature Temper-Bead Technique for Nickel-Based Weld Overlay Repairs of Nuclear Components
- Development and Understanding of Wire-Fed Electron Beam Additive Manufacturing
- M_k Solutions for Fatigue Assessment of Flaws at Weld Root Toes in Girth Welds*
- Fatigue Reassessment of Ageing Pressure Vessels: Life Extension and Change of Use
- Laser Surface Processing to Alter the Elastic Properties of Nylon-Elastane Fabrics: An Initial Study
- The Benefits of Preheating for Rotary and Linear Friction Welding

* Winner of the Richard Weck Award

The CRP also supports TWI's activities to represent the interests of Industrial Members when drafting and reviewing standards.



Standards Activity by Technology

■ Corrosion
■ Structural Integrity
■ Welding
■ Non-Destructive Testing
■ Polymers
■ Brazing and Diffusion Bonding



Standards Activity by Industry Sector

■ Oil and Gas
■ Power
■ Aerospace
■ Transport
■ Construction and Engineering
■ Electronics and Sensors
■ Medical
■ Equipment

Interdisciplinary Research Themes

From 2017 the CRP has had an increased focus on interdisciplinary projects, initially looking at broad research themes:

- Additive manufacturing: Manufacturability and integrity
- Additive manufacturing: Quality assurance and quality control
- Digital manufacturing – 'Joining 4.0'
- Additive manufacturing: Repair
- Dissimilar metals joining
- Management of ageing assets
- Sensors
- Metal to non-metal joining
- Sour/hydrogen assisted fracture

We carried out a review of industry needs and prepared a gap analysis for each of these themes, leading to recommendations of a number of topics for research within each. Topics were reviewed and prioritised by Research Board in November 2017, generating a shortlist for review with the wider Industrial Membership, and identification of a small number of pilot projects to be started in 2018.

You can read more about TWI's Core Research Programme in our accompanying Research Review.

Research Themes 7	Number of Ideas 95	Number of Topics 31	Pilot Project Titles 4
Additive Manufacturing			Additive manufacturing round robin - comparison of microstructures and properties
Digital Manufacture 'Joining 4.0'			Taking the expert skill (manual element) out of the welding process
Management of Ageing Assets			
Sensors			
Metal to Non-Metal Joining			Composites to metal joining
Dissimilar Metals Joining			Best practice guidelines and design data for arc welding of dissimilar metals
Sour/Hydrogen Assisted Fracture			

Research and Innovation

Research Outputs

TWI research is disseminated via peer-reviewed Industrial Member reports, workshops, webinars, and around 100 industry-focused articles per year. More importantly, the research creates a pipeline of new technical experts for our Industrial Members to consult, and prototype processes and products for the use of Members, plus the creation of new industry standards to advance the effectiveness of the joining and integrity of structures across a range of industry sectors.

Corporate Impact

 **1200**
STAFF TECHNICAL
LIAISON VISITS

 **22,000**
PEOPLE
TRAINED

 **1600**
LIBRARY
ENQUIRIES

 **13,000**
VISITORS
TO TWI
LABORATORIES

 **9000+**
STUDENTS
REACHED
VIA EDUCATION
OUTREACH

 **2600**
NEW
WELDASEARCH
ABSTRACTS

 **50+**
TECHNOLOGY
CONFERENCES
AND SEMINARS

 **10**
MAGAZINE ISSUES:
CONNECT,
WELDING AND
CUTTING

 **300+**
WELDING
SOFTWARE
LICENCES



Charting the Value of Industrial Membership

■ **£7.5m** in Membership subscriptions

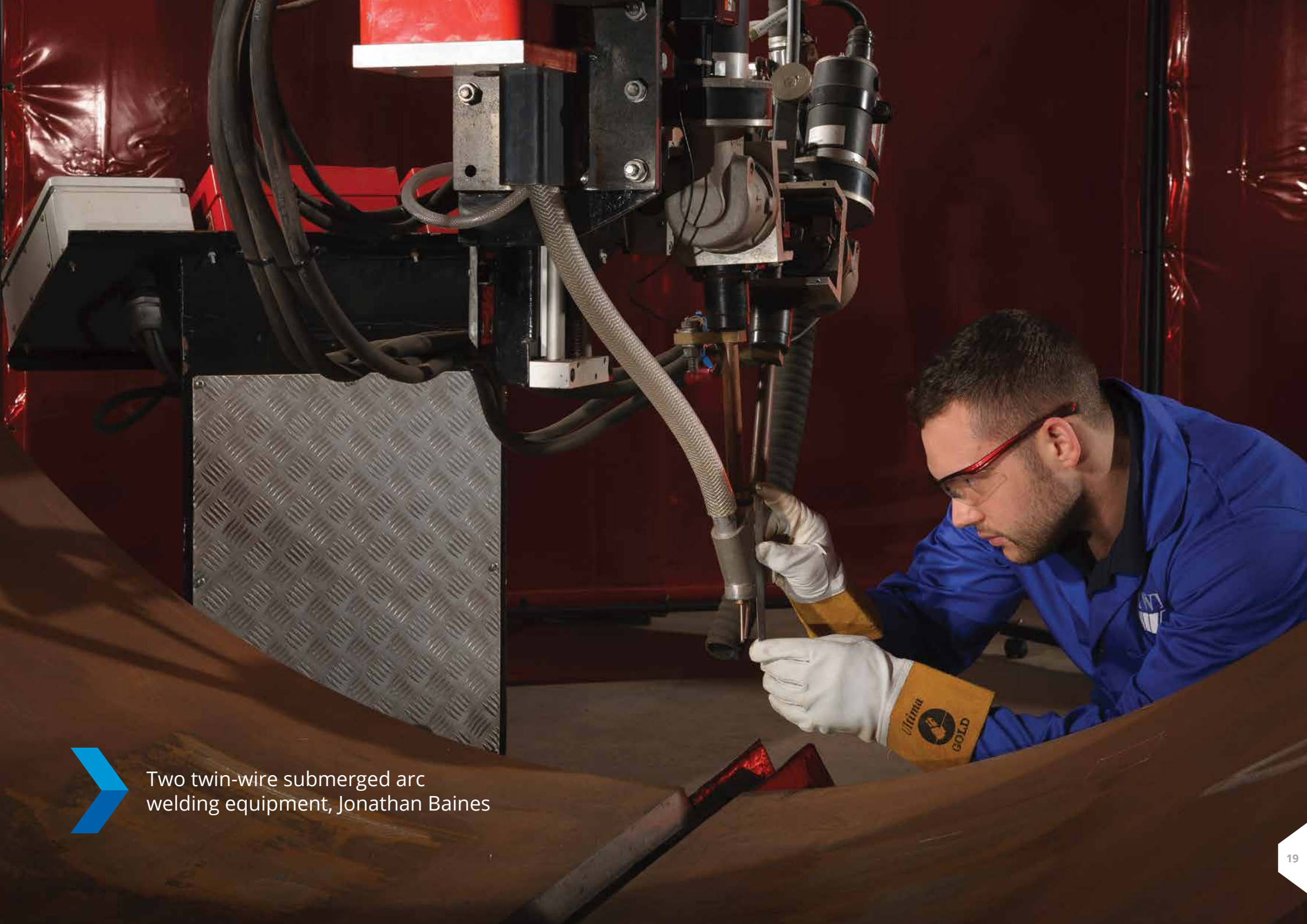
■ **£3.7m** for capital equipment

■ **£4m** for core research

■ **£26.9m** from industry projects

■ **£12.6m** through collaborative and
technology transfer projects

■ **£38m** via Innovation Centres



Two twin-wire submerged arc
welding equipment, Jonathan Baines

Structural Integrity Research Foundation



Dissimilar weld of silicone
nitride and niobium-hafnium
alloy for a European Space Agency
rocket thruster combustion chamber

SIRF and the TWI Innovation Network

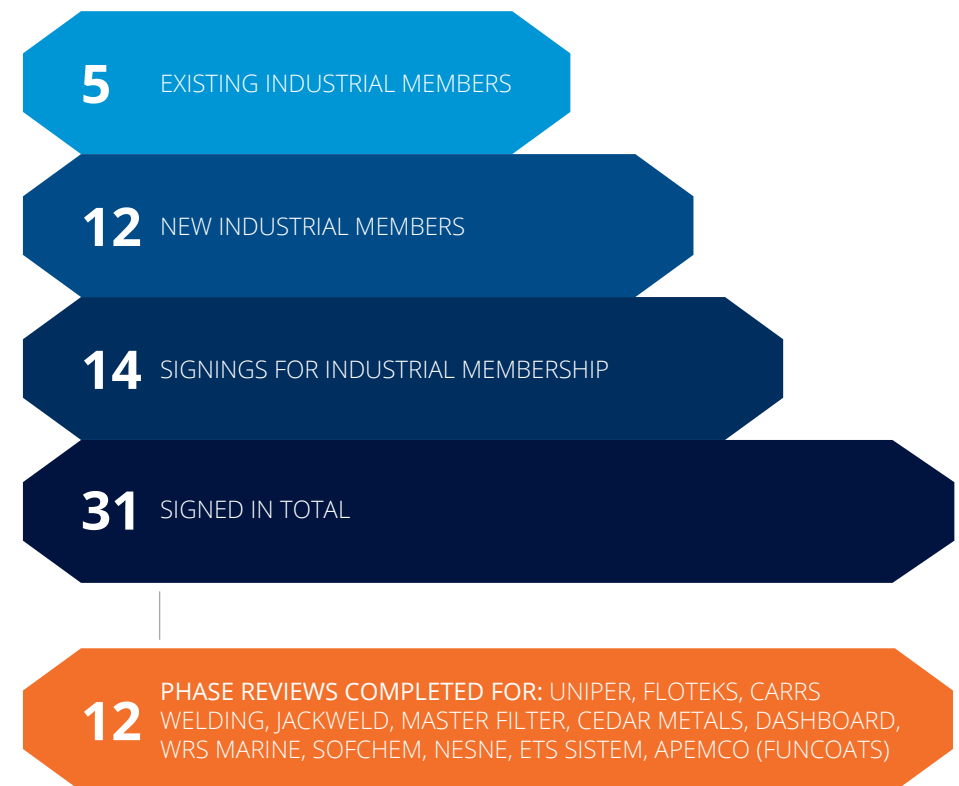
The TWI Innovation Network was originally set up under the umbrella of the Structural Integrity Research Foundation (SIRF) in 2012, an industry-funded partnership to bridge the gap between academia and industry by advancing industrial research and training the next generation of structural integrity engineers.

Now half way through a ten-year programme, SIRF has seen the creation of eight Innovation Centres on-site at TWI in partnership with five universities, with the goal of accelerating research, while the National Structural Integrity Research Centre (NSIRC) develops 500 PhD and Masters students into the technical experts of the future.

Alongside this is the Accelerated Innovation Programme (AIP), which sees small and medium-sized Member companies working on projects alongside TWI and focusing on Innovation to drive business forward. Elsewhere, newly formed Private Technology Innovation Partnerships (PTIP) see TWI working with large Member organisations to foster home-grown innovation and work with their customers to address their technology priorities covering the full TRLs.

The impact of the TWI Innovation Network as a whole is to provide expertise, knowledge and staff for the future of industry.

Accelerated Innovation Programmes



Structural Integrity Research Foundation

TWI Innovation Centres

TWI's eight Innovation Centres are advancing focused research and securing a high level of funding through Innovate UK and the EC, allowing them to continue to grow and attract more partners to the TWI Innovation Network. With new projects secured, publications released, and new staff recruited, each centre is proving the success of the industry / academia collaboration. The coming months will see further centres opened to advance research in artificial intelligence, data science and more.

The Brunel Innovation Centre (BIC): established in 2009, has achieved over 100 publications, including many for high impact journals, whilst securing £17.5m of projects allowing 35 members of staff to be recruited to deliver research projects.

The London South Bank Innovation Centre (LSBIC): more than ten papers published and secured £2.7m in funding through the EC and Innovate UK. The robotics centre is now looking to commercialise the prototypes realised by the research team based at TWI.

Advanced Resins and Coatings Technologies Innovation Centre (ARCTIC): the ARCTIC centre has done very well since being established alongside London South Bank University in 2016. The centre is delivering two innovative projects with more than £750,000 of funding.

Smart Asset Management Innovation Centre (SAMIC): a collaboration with Transport Systems Catapult with over £900,000 of funding won, the centre is delivering innovative projects and looking forward to new opportunities.

The Healthcare Innovation Centre (HIC): established with Teesside University in February 2017 and won three Innovate UK projects with over £260,000 of funding. A research assistant has just joined the centre to deliver these projects.

Joining 4.0 Innovation Centre (J4IC): established in April 2017 with the University of Lancaster and secured £200,000 in funding for an Innovate UK project, hired a PhD student, and is now starting the recruitment process for researchers.

Brunel Composites Innovation Centre (BCC): this second Innovation Centre associated with Brunel, won two Innovate UK projects with over £250,000 of grants. Meanwhile, a first PhD student was recruited in October 2017 to progress research on data transfer through composite risers for the oil and gas industry. Plus, a researcher will soon join the centre director to work on the new projects.

Materials Innovation Centre (MatIC): officially launched with the University of Leicester in the last quarter of 2017, the centre has submitted proposals to different funding bodies and is awaiting the outcomes.



Mehrnaz Behray examining a solar panel treated with an innovative transparent anti-soiling coating for the SolarSharC® project

Structural Integrity Research Foundation

The National Structural Integrity Research Centre

The first success resulting from the SIRF programme, the National Structural Research Centre, is a postgraduate engineering facility established and managed by TWI. It unites academia and industry, working with lead academic partner Brunel University London and more than 35 universities worldwide, and alongside founder sponsors BP and the Lloyd's Register Foundation.

NSIRC will deliver 530 postgraduate students over a ten-year period from 2012-2022. With almost 110 PhD and over 70 MSc students enrolled, NSIRC is exceeding targets – thirteen of its PhD students have graduated and another ten will submit theses before the end of the year. To date there is a 100% employment rate amongst the graduates, all securing jobs in their specialist fields upon completion of research.

Typical research programmes include:

- Developing and testing robots for inspection of storage tanks
- New techniques for joining dissimilar materials for future automotive structures
- Understanding the effects of cold spray additive manufacturing on nanostructured high entropy alloys

Students come from over 25 countries. 30% of the current cohort is female, which is significantly higher than the national average of 9%. Notably, over an initial five years, NSIRC students have disseminated research by writing more than 100 papers for peer-reviewed journals and conferences. They have also won over 30 awards and secured work placements at leading international institutes.

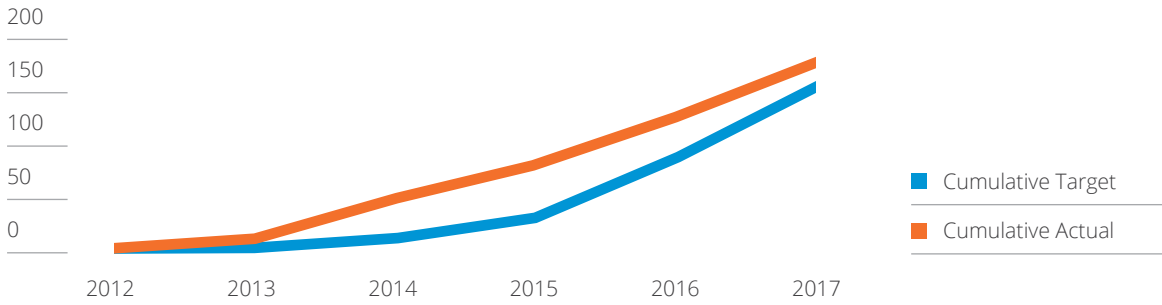
NSIRC celebrates and presents the PhD students' research at its Annual Conference and, in 2017, 150 delegates attended to hear presentations and view posters from over 40 students.



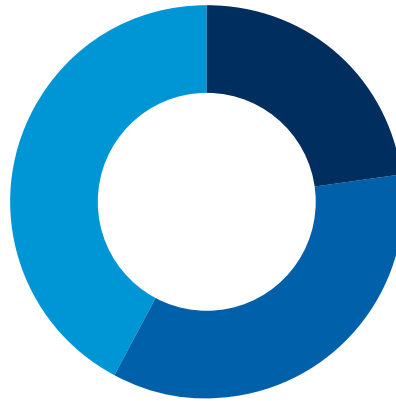
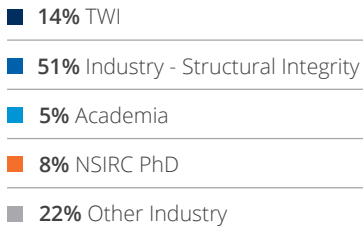
Student, Muntasir Hashim at the NSIRC Conference 2017



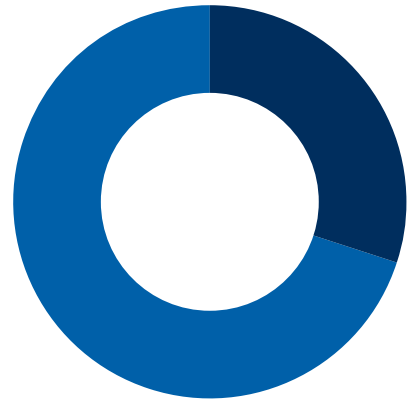
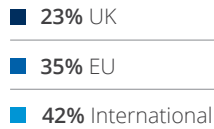
Cumulative Total NSIRC Students



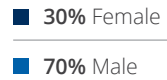
NSIRC MSc Alumni Destinations



NSIRC Students by Nationality



NSIRC Students by Gender





NSIRC Annual Conference 2017



Focus on Industry Oil and Gas



Achievements

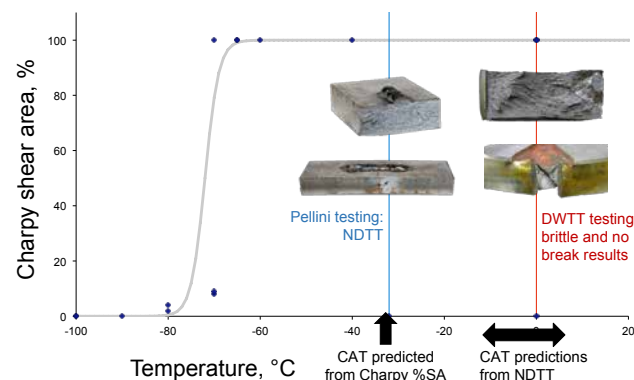
- Purpose-built pressure testing facility
- Improved molten salt corrosion testing
- AI-based monitoring of arc welding processes
- Acoustic emission hydrogen induced cracking testing
- New version of RiskWISE® released

Predicting Crack Arrest Behaviour using Small-Scale Specimens

Modern high strength pipeline steels are designed to achieve high initiation toughness, based on Charpy impact tests, but can show poor crack arrest behaviour. It is desirable to identify steels that might have poor crack arrest performance from routine small-scale tests. Drop weight tear tests (DWTT) on these steels can show 'inverse fracture' where fracture initiates as ductile but later becomes brittle (the opposite of the test's intention). Inverse fracture may characterise the actual behaviour of running cracks in the steel, or it could be an artefact of the DWTT specimen design and loading conditions, but it is misleading when trying to use DWTT to determine the actual crack arrest performance of the steel.

When testing an X65 pipeline steel using different small-scale tests, the results showed ductile behaviour from Charpy tests, while the same test temperature gave unstable brittle fractures in Pellini tests. Determining the crack arrest temperature (CAT) based on the Pellini results gave closer predictions of the mixed-mode behaviour of DWTTs at 0°C, where Charpy-based CAT predictions were non-conservative.

Using Pellini tests in addition, or as an alternative to DWTT can give better characterisation of crack arrest for linepipe steels, which have nonetheless shown high initiation fracture toughness.



Charpy ductile to brittle transition curve plotted alongside the Pellini nil ductility transition temperature and temperature where drop weight tear tests showed brittle and ductile behaviour

Study of Decommissioned Oil and Gas Structures

A joint industry project with Shell, Allseas, the Health and Safety Executive, the Petroleum Safety Authority, and ADNOC is improving understanding of the degradation of offshore oil and gas structures as well as informing structural integrity management and highlighting implications of service life extension.

The project provides a unique opportunity to study the impact of extended environmental exposure under controlled conditions, and is a result of the decommissioning by Shell of five of its North Sea structures installed between 1970 and 1986.

The project team is also investigating structures that were originally installed in the Arabian Gulf in the 1960s. The ongoing programme at TWI involves detailed non-destructive and destructive inspection, as well as material characterisation tests and full-scale/strip fatigue testing of nodal joints of selected nodes and piles to establish the condition and remaining fatigue lives of the structures.

This will combine to improve the management of risk in extending use beyond the original design life of the structures. The data also aids understanding of the effects of extended environmental



Decommissioned North Sea oil structure of the type being studied

exposure while supporting the decision-making process for the lifespan of existing platforms. The team is also making use of previous inspection reports, including known material properties at the time of fabrication and fracture mechanics assessments using the derived properties. The industry consortium will share data at the end of the study.



Focus on Industry Power

Achievements

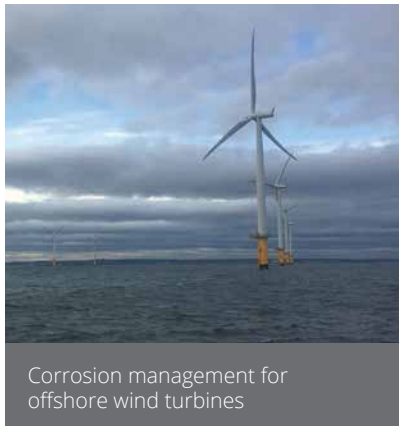
- Operational support for existing UK nuclear power plant – urgent safety/time critical projects successfully completed during planned outages
- Investigation and supervision of remediation activities on defective welds in new-build thermal power plant
- Research supporting the introduction of thermally sprayed aluminium for corrosion mitigation on offshore wind energy structures
- Continued research and development of advanced joining processes for new-build fusion and fission reactor plant

Offshore Wind Project Commended for Work on Thermally Sprayed Coatings

TWI has partnered with Industrial Member companies LIC Energy, EDF Energy and Ørsted (formerly DONG), along with Wilton Engineering Services, Universal Coatings and Metallisation to work on a 12 month project funded by Innovate UK to investigate low-cost corrosion management for offshore wind turbines.

The £1.2m Cost Reduction for Offshore Wind Now (CROWN) project focused on the development of a thermally sprayed aluminium (TSA) coating as an alternative to conventional protection based on paint and anodes, innovating in four areas:

- Demonstrating that a service life of 25 years can be achieved even if the TSA coating is subjected to mechanical damage
- Numerical design modelling incorporating TSA and lifecycle cost modelling
- Assessment of mechanical piling damage and mudline corrosion assessment
- Manufacturing sequence and productivity



The collaborative project was commended at the 2017/18 Rushlight Awards for its 'strength and outstanding nature'. Its quick completion speaks also of the quality of the consortium involved. In April 2018, the consortium was joined by two more major wind farm developers and won an additional £1.1m project to continue the research in a follow-on project, CROWN2.

Materials Development for Geothermal Power Plant Applications

Geothermal sources are aggressive natural environments. High temperature and pressure conditions, as well as corrosive salts, represent a major threat to the integrity of the components of geothermal power plants including liners and well casings, well heads, turbines, pumps, valves, heat exchangers, pipes, separators and condensers. Current materials, transferred from oil and gas applications to these harsh environments, are not capable of performing, leading to a constant need to inspect and repair damage.

The Geo-Coat project, co-ordinated by a team at TWI, is developing new resistant materials in the form of high performance coatings of novel targeted 'High Entropy Alloys' and Cermets, thermally applied to the key specified vulnerable process stages (components in turbine) in response to the specific corrosion and erosion forces at each point. The project team will also capture the underlying principles of the material resistance, to proactively design the equipment for performance and minimise the overall cost of these expensive materials.



The Geo-Coat consortium has members from geothermal plant operations and equipment manufacturers to ensure the project's focus on real-world issues, coupled with world-leading experience in the development of materials, protective coatings and their application to harsh environments.



Focus on Industry Aerospace



Achievements

- Completion of a project for the European Space Agency to electron beam and laser weld safety-critical valves
- Significant collaborative work awarded in additive manufacturing – laser, EB and arc technologies – with support from further TWI functions including materials and modelling, and non-destructive evaluation
- High-profile project for the space industry to test materials in high-pressure hydrogen
- Turnkey process for rapid non-destructive inspection of fan cases for a large aerospace equipment manufacturer

Revolutionary Data Transmission Technology – Three Times Faster than Internet Cabling

TWI has developed SurFlow™ – an innovative system for transferring data that could see an end to the use of wiring in everything from aircraft to robotics, and consumer electronics to automobiles.

Rather than using wiring to send signals, this technology uses composites in the structure of the item itself, directly transferring information capable of moving servos, turning lights on and off, and even relaying audio or televisual data. Described as the future of composite data highways, the novel data transfer technology removes the need for wires or fibre optics, also eliminating the remote interception risks associated with wireless data transfer.



SurFlow™ composite data transmission

The patented SurFlow™ technology (patent GB 2522344A) uses electromagnetic surface waves to transmit data directly through composite structures. It allows data to be transmitted at speeds up to 3Gbps – three times faster than using internet cables.

The technology works by passing electromagnetic energy through composite structures using a combined substrate of dielectric and conductive materials. These waves are transmitted and received by transducers which can be placed anywhere along the smart composite. These smart composites can continue to function even when damaged.

SurFlow™ has opened up a slew of potential applications in a variety of industries, notably aerospace, robotics, consumer electronics and power, and projects have been carried out for companies in the aerospace and defence sectors.

TiFab: Using Linear Friction Welding to Reduce Costs and Improve Productivity for Aerospace Manufacture

Increasingly costly and difficult to machine materials are pushing designers to find alternative production methods for aerospace components. One such method is linear friction welding (LFW), which allows for near net shape manufacture of advanced titanium components. For the aerospace sector, this process saves money by reducing wastage and production time, with the advantages of being robust, highly repeatable and able to join complex geometric components.

The TiFab project aimed to develop the LFW process for aerospace by creating a modular tooling system for LFW tailored blanks, setting welding parameters, assessing joint and weld performance, and identifying process monitoring and testing methods. These developments allowed for the assessment of more than 170 structural components with a 100% success rate.

The economic benefits of the TiFab project are evident due to the high material utilisation and reduction in titanium wastage. In addition, higher operating efficiencies and improved manufacturing performance helped create cumulative raw material savings of 60-80% - equivalent to over \$7.9m per annum in costs. The part production also equalled energy savings of 48.1 GWh, enough to power 15,516 homes for a year, and reduce CO₂ emissions by 22,200 tons per year. The study also showed that for comparable equipment investment, the manufacturing by LFW could potentially produce parts in half the time or quicker.



Linear friction welding for near net shape manufacturing

The project will strengthen the UK's position at the forefront of LFW technology, realise an estimated 10% increase in job generation among partner companies and supporting industries, and see an estimated £90m of new part sales, plus a further income of £40m in subcontract sales and services.



Focus on Industry Transport

Achievements

- Improved welding practices for current and future vessel builds, working closely with a major European maritime organisation
- Contribution to the Naval Authority Industry Alliance (NAIA) serving the UK Naval Authority Group (MOD), and participation in important collaborative projects
- Review of all mechanical fastening technologies for steel to aluminium joining, benchmarking mechanical performance, also process speed, cost, weight per joint, and primary equipment cost
- Friction stir welded tailored blanks in 2xxx, 6xxx and 7xxx series aluminium alloys, as part of the Innovate UK funded LightBlank project. Blanks were hot formed and quenched to demonstrate performance for automotive applications

Quality and Integrity in the Remanufacturing of Rail Wheels

TWI was one of the partners in a successful Innovate UK project to develop a remanufacturing cell for railway wheels, combining high performance cladding and both in process and post-process inspection to ensure the accuracy and integrity of parts. The development of the cell will enable novel business models to become commercially viable, including leasing 'wheels by the mile'.

The TWI team completed a down-selection to ensure the optimum process and welding consumables were used for the cell, and to give the best chance of achieving properties synonymous with the parent material. It identified that, of all the deposition processes, only submerged arc welding was capable of depositing material quickly enough to maintain process pre-heat.

The outcome was the successful design, construction and partial validation of a remanufacturing cell, with further work planned to increase the TRL for future production acceptance.

The project's added success was that it enabled collaborative working across a range of industries which might not typically be engaged.



Development of a remanufacturing cell for railway wheels

Low-Cost Aluminium Joining Process Marks Change for Car Manufacture

A collaboration with Industrial Member company Luvata Special Products has resulted in the development of a spot welding process for high-speed low-cost aluminium joining on automotive production lines. The organisations worked with Luvata's newly developed H-Trode™ electrode, conventional resistance spot welding guns and tip dressers to automate a new, stable aluminium welding process.

The development can be applied to the volume car market, dramatically reducing the cost of aluminium vehicle production and allowing car manufacturers to reduce vehicle weight and improve fuel economy.



Investigating aluminium joining for automotive production

The majority of automotive companies employ self-piercing riveting for aluminium joining, but this process is still significantly more expensive than standard spot welding – the riveting equipment requires larger production lines, leading to increased manufacturing costs. Under normal circumstances, the spot welding performance of aluminium is poor with a very rapid rate of electrode degradation. Consequently, the market has seen only a small proportion of systems with expensive special process adaptations.

The automated spot welding development marks an important step forward for automotive manufacturing, as the price of the H-Trode™ electrode is comparable with a standard electrode and no further process modifications or costly equipment is required.



Focus on Industry Construction and Engineering

Achievements

- Significant interaction with European and US off-highway original equipment manufacturers on long-term strategies and support
- High-level interface with a leading UK construction company responsible for delivery of multiple major infrastructure projects, on medium- to long-term development plans

Using Advanced Materials to Increase Fuel Saving and Efficiency of Off-Highway Diggers

'Composites and adhesives experts have contributed to an Innovate UK funded collaborative project on Efficient Lightweight Structures in Off-Highway Applications (ELSOHA) with the ambitious goal of reducing the weight of the dig-end components by as much as 25%.

In this industry, many project tenders are now won or lost based upon the predicted amount of CO₂ emitted during the construction phases and a lighter, more efficient off-highway vehicle will deliver reduced CO₂ emissions and lower fuel costs.

Reducing the weight of those components which are close to the bucket is expected to contribute to increased efficiency or more productive machines.

The ELSOHA consortium partners TWI, JCB and TATA Steel will develop the innovative joining, material and simulation technologies to contribute to an operating fuel saving anticipated to be greater than 5% over the life of the vehicle. Some of these technologies have already been deployed in other industries (aerospace, automotive) and ELSOHA will adapt these to the challenging and aggressive off-highway environment.



Lightweighting of off-highway diggers

Mobile App Links to Welding Coordinator to Improve Shop Efficiencies

TWI has developed a mobile app which complements its Welding Coordinator weld tracking and production weld management system. Developed for two major US fabricators, the new app works on a mobile phone or tablet and allows on-site supervisors and inspectors to record information completely offline. The app comes into its own at fabrication sites where wi-fi or wired access to IT systems for recording information is not possible:

- Welding supervisors will be able to track completion of welds and record welders and filler materials used on welds
- Welding inspectors can record inspection data (completion and results)



Demonstrating the Welding Coordinator mobile app

The Welding Coordinator program allows tracking for all aspects of welded fabrication, from design through production, to quality control and, once the app on the mobile device connects back with the central IT system, the information is automatically uploaded to the Welding Coordinator database. Instant fabrication progress reports are then available and components can be signed off as complete.

Focus on Industry Electronics and Sensors

Achievements

- Identification and selection of adhesive types for high-volume consumer electronics products
- Laser welding process development of revised sensor body material for new harsh environment applications
- Vacuum brazing procedure development for silicon wafer production equipment
- Laser welding process development for high performance battery interconnection

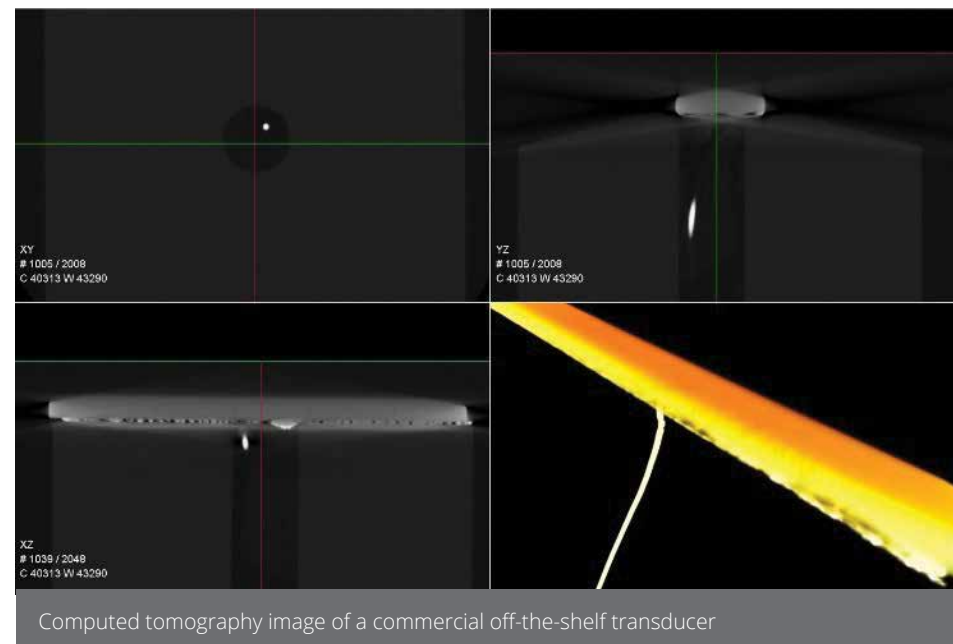
Sensor Technology Development for Critical Applications

Electronics and sensors expertise is routinely applied in projects which find end applications in many industrial products and processes. Increasingly, our involvement focuses on sensor element and system design, manufacturing processes and testing.

Research is underway to address a need for radiation resilient sensors for the long-term monitoring of low and intermediate level nuclear waste containers. Currently, assessment is carried out manually using ultrasonic techniques. Not only is this hazardous for personnel, but commercially available ultrasonic sensors generally fail after relatively low accumulative gamma radiation doses. These sensors could be deployed remotely, but the need for regular replacement would be time-consuming and expensive.

The new project is looking at materials and manufacturing/assembly techniques that will enable production of sensors capable of withstanding high radiation doses delivered over an extended time. This will ensure that sensors are compatible with the requirements for longer term monitoring of low and intermediate level waste material at ambient temperatures.

The data gained from the sensors will be used for integrity management of a nuclear storage facility and will provide evidence to support the viability of long-term nuclear waste storage.





Focus on Industry Medical

Achievements

- Development of an in-vitro model jaw, simulating human chewing to scrutinise denture adhesives qualitatively and quantitatively
- Development of high-precision laser welding solutions for polymeric micro-fluidic devices within healthcare applications
- Ultrasonic welding development for the assembly of state-of-the-art medical devices and healthcare products
- Failure investigations of medical implants
- Investigation into joining technologies for cardiovascular implants and their influence on thermo-mechanical properties of Nitinol wires

Chewing Simulation to Test Denture Adhesives

TWI engineers, led by Dr Farshad Salamat-Zadeh, have designed, developed and manufactured a machine to simulate the chewing actions of the human mouth in order to test denture adhesives.

The electro-mechanical Articulated Denture Adhesive Monitoring (ADAM) prototype is able to mimic chewing and a mouth-like environment (eg temperature, humidity and bite force) to save time when undertaking research and testing of dental adhesives by offering detailed quantitative and qualitative information.

The prototype also allows users to create programs related to different meals (breakfast, lunch, dinner) with their own applied loads and number of cycles to accurately model real-life use.

ADAM collects and displays live load, displacement and environmental data on a screen and in Excel file formats, as well as simulating the data in 3D heat maps with 360 degree movement.

The prototype was fully inspected and gained CE marking before being delivered to TWI's client in June 2017.



Articulated Denture Adhesive Monitoring (ADAM) prototype

A close-up photograph of a white industrial robotic arm with a welding torch attached, positioned over a workpiece. The background is dark with some green and blue lighting. The image is partially obscured by a large blue diagonal graphic element.

Focus on Industry Equipment, Consumables, Materials

Achievements

- Translating Member input to TWI's Core Research Programme
- Smart multi-functional composite materials
- Commitment to a regular TWI-led UK Welding Exhibition
- Real-time non-destructive testing and adaptive control for process equipment (Industry 4.0)

Correlation between Heat Tint and Corrosion Resistance of Duplex Stainless Steel Welds

As part of its Core Research Programme, TWI has been investigating the relationship between weld discoloration and oxygen levels in the purging gas of duplex stainless steel welds, to determine the effect of weld discoloration on pitting corrosion resistance. It is hoped the work will provide a guideline for specifying oxygen content in the purging gas for welding duplex stainless steel based on the effect of weld discoloration on ASTM G48 Method A test performance.

The study was undertaken based on autogenous welding trials performed on thin-wall UNS S32750 and UNS S31803 duplex steel pipes using an automatic gas tungsten arc welding (GTAW) process. The research team used a Fronius tungsten inert gas (TIG) power source (orbital system controller FPA 3030) and Polysoude (MUIV 128) orbital welding head, kindly lent by these organisations.



Welding trials on thin-wall duplex steel pipe

Regional and International Impact



Mike Russell
Director, Operations

Regional Development – TWI Technology Centres

TWI continues to make good progress on the development and expansion of our UK regional technology centres. This growth has been possible thanks to enthusiastic support from the local authorities and associated development organisations in these regions. We are very grateful to these organisations for their ongoing assistance and advice.

TWI Technology Centre North East

- In Middlesbrough, we are establishing a new non-destructive testing and plant integrity team based on significant business growth in 2017. Ten new staff are being recruited in the North East to support this expansion.
- Our numerical modelling and optimisation team is also growing, based on our ongoing reputation for excellence in this area.
- The Middlesbrough team has recently won local government support towards the development of our Teesside facility. This funding will help us to establish new office areas and laboratories, in addition to upgrading and improving a number of existing facilities and systems.
- Longer term there is also a possibility to establish a new advanced hydrogen testing facility adjacent to the current building, in support of growing interests from the aerospace and transport sectors.

TWI Technology Centre Wales

- We will be taking on new expansion space in 2018 to provide much needed extra accommodation for the delivery of the £12m Advanced Engineering and Materials Research Institute (AEMRI) project.
- A new team of ten condition and structural monitoring staff will be established to support the delivery of their growing order book (following significant business development success in 2017).
- We are also continuing to investigate the options for a permanent TWI-owned facility in Wales and are working with local authorities and relevant agencies.

TWI Technology Centre Yorkshire

- In Sheffield, we will embark on a new Aerospace Technology Institute-funded Open Architecture Additive Manufacturing project in 2018, working with a number of our key clients. This is an important development area for TWI and this new three-year project brings £2.1m of funding for new equipment and capabilities in support of UK supply chains for additive manufacturing.

Outcome from Technology Transfer



20
REGIONAL
DEVELOPMENT
PROGRAMMES
ACROSS THE UK



6800+
JOBS CREATED
OR SAFEGUARDED



£369
MILLION IN
ADDITIONAL
OR SAFEGUARDED
TURNOVER

International Impact

TWI's international focus is on training engineers in field-based certification as well as undertaking engineering work and providing services and support to Industrial Members via our overseas subsidiaries.

With training and examination being particularly strong in India and the Middle East, our overseas trading was better than expected in 2017. This has allowed for continued support in upskilling of disadvantaged people across the world and creation of a competent base of skilled workers operating in industries in Europe, North America, Southeast Asia, the Middle East, India, China, Japan and elsewhere.

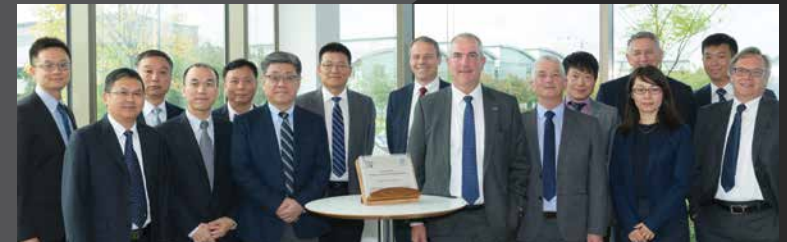
TWI has also seen more than half of new Industrial Members coming from abroad, with most of them coming from China, Japan, Italy, the United States, Turkey, and the United Arab Emirates.

As an example, China will benefit from our strength in innovation and R&D. China sees a future in international markets and welcomes access to the best international expertise. Sectors where our work will have impact include high-speed train manufacturing, using friction stir welding and new technologies, and the oil and gas industry where knowhow will increase safety.

There have been some notable collaborations with overseas businesses, including agreements struck with AVIC, Aero Engine Corporation of China (AECC), Beijing Institute of Aeronautical Materials (BIAM), and also Saudi Aramco.

Elsewhere, TWI also showed support for the Access India initiative to offer confidence to UK SMEs to expand into India.

Between the extensive training and certification operations, the various agreements with business and the continued expansion of Industrial Members overseas, TWI's international impact remained strong through 2017.



Opening event for the AVIC Centre for Materials Joining and Surface Engineering. Dr Xin Guo Zhang, AVIC Executive Vice President and Dr Christoph Wiesner, TWI Chief Executive (left and right of table)

Regional and International Impact

Training and Examinations

2017 was another good year for TWI Training and Examinations Services, although not without its challenges.

The decline in the oil price has impacted on many businesses, and Training and Examinations has not been alone in feeling the effects. Encouragingly, however, the past year has seen a rise in our training numbers across the globe. This is in part due to our strong and trusted brand, our strength and depth of courses, and our innovative approach to take training into the digital era.

We are proud to have had both a strong demand and positive feedback for our new blended learning products, which reduce the amount of classroom time, and allow greater flexibility for the learner to engage with a subject. TWI Training and Examinations now offers blended learning for its

standard portfolio of non-destructive testing courses as well as advanced ultrasonic testing methods.

Being innovative is one of our strengths – we listen to industry demands and, where appropriate, are able to match training and certification to real-world situations. Some of the highlights of recent course development include Phased Array Ultrasonic Testing Data Analysis, Time-of-Flight Diffraction Data Analysis, Protective Coating Inspection, Pulsed Eddy Current Inspection, and Cathodic Inspection.

The IIW Welding Diploma is still a popular course with wide industry recognition. Taking the lead from the NDT blended learning, some of the modules will now have a digital counterpart, including the Materials and their Behaviour module.



Time-of-Flight Diffraction training

The standard offering of CSWIP welding inspection courses is still very strong worldwide, and these courses and exams are constantly updated and revised to reflect industry changes.

TWI Training and Examinations has also diversified into other markets and sectors with new courses – we have successfully launched Lean Six Sigma quality training courses and aim to extend these up to black belt level. As far as infrastructure is concerned,

we invest in new NDT training equipment to keep pace with the latest developments in the NDT world and this also applies to our IT. The UK Training and Examinations website now has the facility for online booking and payment for a selection of training courses. Candidates also have their own personal page with all their relevant data and course notes. This facility will be rolled out to our global operations over the coming year.

Finally, a new venture for Training and Examinations Services is our involvement in collaborative projects. We are currently participating in a number of training and apprenticeship related initiatives, looking to upskill the European workforce in welding and additive manufacturing. We are keen to develop our involvement in such important and landscape-changing programmes.



■ TWI INTERNATIONAL TRAINING PRESENCE



Corporate Social Responsibility

Making a Positive Contribution

As an organisation dedicated to creating a good outcome for its Members and customers, TWI is committed to building the positive contribution of its business to a sustainable society. We adopt a strategic approach to the technology impact of our work for industry in materials joining and engineering, and integrate social, environmental, ethical, human rights and consumer concerns with business operations and core strategy:

- Helping to prevent plant and equipment failure, and setting international standards
- Training skilled workers for employment or new working environments
- Assuring the competence of personnel and organisations
- Guiding professional development and registration of technicians and engineers and overseeing commitments to rules of professional conduct and continual learning

In 2017, we began working with a corporate impact assessment management model, allowing us to identify activities in five areas – business and technology; health, safety and environment; educational outreach; community; and employment – against which we can establish pathways for reporting and the setting of realistic targets. We present some of our achievements on the following pages.



Promoting professional development,
left to right: Marcello Consonni, Dorothy
Winful, Joshua Hale and Laura Crean

Corporate Social Responsibility

Community

TWI's UK education outreach programme received a boost in 2017 from Tipper Group member participation and a technical programme offered by The Welding Institute's Younger Members' Committee. Highlights included an in-depth industry experience project and presentation on the properties of high-strength steels for two TWI Arkwright Scholars studying their A Levels in Cambridgeshire, a Welding with Chocolate day with Year 7 and 8 students from Eckington School in Sheffield, and an increased number of work experience placements for 14-17 year olds across several TWI offices.

The wider outreach programme focused on a series of laboratory tours and fun engineering or careers based activities across the academic year and reported an annual reach of 9000+ young people from primary to university-level ages.

Among TWI's community contributions were its help with the purchase of a school bus for the Satkaarya Trust in Chennai, India, annual Christmas donations to organisations identified by staff, and a sports and social charity-giving programme.

As a business, we are also committed to developing our people to reach their full potential. We offer a range of learning opportunities including coaching and knowledge sharing, as well as internal and external development courses covering a range of topics from leadership development to business and soft skills. In addition, we sponsor our employees to obtain professional qualifications to help with career development, and encourage young people into engineering with our modern advanced apprenticeships.

Environment

Looking after the environment is an important part of any modern business and TWI demonstrated its dedication to this by achieving transition of its Environmental Management System to ISO 14001:2015 in July 2017, well ahead of the required deadline of August 2018. TWI's conformance to the ISO standard was assessed by Lloyd's Register Quality Assurance (LRQA) and, at the time of transition, TWI was among the first 18% of LRQA's clients to achieve certification to the new standard.

ISO 14001 is implemented in over 160 countries and is designed to provide organisations with a standard model for protecting the environment by offering a systematic approach for their activities, processes, products and services. TWI has been committed to following this standard for over a decade, having held approval since 2005.

The new standard has a number of changes when compared to the 2004 version including context, leadership, risk-based thinking, communication, life-cycle thinking, improvement, terminology, documentation and clarity.

In 2018, TWI expects to bring TWI Aberdeen within the scope of certification for the first time, joining the other UK offices as well as affiliates The Test House, Plant Integrity Ltd, and the Granta Centre in Cambridge.

By adhering to the requirements set down by ISO 14001:2015, TWI will continue to protect the environment and respond to changing environmental conditions, all in line with the business-related, socio-economic needs of the organisation.



TWI Arkwright Scholars,
Oscar Jopp and Adam Cliff

Corporate Social Responsibility

The Tipper Group: Supporting Women in Engineering

Around 25% of engineers at TWI are female, compared to just 9% across the UK engineering workforce

In 2016 and 2017, the Tipper Group organised five inspirational talks from guests including Professor Dame Ann Dowling, Professor Dame Athene Donald, South Cambridgeshire MP Heidi Allen, Dr Hugh Hunt and Professor Tim Minshall. It also arranged a confidence workshop to examine the challenges of female career progression, and made plans for further training to aid professional development and improve the awareness of unconscious bias.

Among the Tipper Group's goals are the facilitation of opportunities for networking, peer support, mentoring and a focus on issues related to returning from a career break (eg parental leave). It achieves this through talks, seminars and one-to-one mentoring, as well as through social media, webinars and out-of-work social activities. The group is also an active part of the TWI education outreach programme.

Within the group, the National Structural Integrity Research Centre provides support to its female PhD and MSc students, The Welding Institute looks after diversity issues, and TWI itself pursues the recruitment and development of female engineers.

Launched in 2016, the group takes its name from Constance Tipper, a female Cambridge fracture engineer who investigated the wartime Liberty ship failures. The Tipper Group holds events and networking opportunities to support and inspire female engineers in welding, joining and associated technologies.



Tipper Group Committee and founder members left to right: Marion Bourebrab, Catherine Condie, Marta Alvarez, Farnoosh Farhad, Kamer Tuncbilek (Chair) and Philippa Moore

Industrial Member Companies



Australia

Australian Nuclear Science & Technology Organisation (ANSTO)
Cooper Energy Limited
DST Group
MCA Australia Group
SPEE3D
Woodside Energy Ltd



Austria

MARK Metallwarenfabrik GmbH
PLANSEE SE



Azerbaijan

MQS Representation in Georgia



Belgium

ArcelorMittal Belgium NV
Laborelec C.V.B.A.
NV Bekaert SA
SABCA - Brussels
Safran Aero Boosters
Toyota Motor Europe NV/SA



Brazil

Embraer
PETROBRAS - Petroleo Brasileiro SA
Petroleo Brasileiro SA – PETROBRAS



Canada

Canadian Nuclear Laboratories Ltd
CanmetMATERIALS Natural Resources Canada
Etalim Inc.
Evraz Inc NA
NOVA Chemicals Corporation
Servo Robot
ShawCor Ltd
Soudures JM Tremblay (1987) Inc



China

AEC Beijing Institute of Aeronautical Materials
AVIC Manufacturing Technology Institute (MTI)
Baoji Petroleum Steel Pipe Company
Baoshan Iron & Steel Co Ltd
China Academy of Launch Vehicle Technology
China Offshore Oil Engineering Corporation
COMRI
Dongfang Boiler Group Co Ltd
General Research Institute for Non Ferrous Metals
Harbin World Wide Welding Technology Co Ltd
Hefei General Machinery Research Institute
Hunan Joinfront Welding Technology Co Ltd
Jiangsu Industrial Technology Research Institute

Jiangsu Linrui Electric Technology Co Ltd
Shanghai Aerospace Equipment Manufacture
Shanghai Institute of Special Equipment Inspection and Technical Research
Shanghai Oriental Maritime Engineering Technology Co Ltd (SOMET Ltd) (Dongfang)
Shipbuilding Technology Research Institute of CSSC (STRI)
Southwest Institute of Technique and Engineering (SITE)
Suzhou Nuclear Power Research Institute Co Ltd
Tong Qiang Tie Bi Science and Technology Co Ltd



Denmark

Danfoss Industrial Automation
National Oilwell Varco Denmark I/S
Ørsted Wind Power A/S



Dominican Republic

OECI - Odebrecht Engenharia & Construção Internacional S.A. - Proyecto Punta Catalina



Egypt

Egyptian Refining Company
VTCO Petroleum Services



Finland

Huawei Technologies Oy (Finland) Co Ltd



France

ACB
APERAM Stainless Steel France R&D
AREVA
Aubert & Duval
Bureau Veritas Group
CNIM
EDDYFI EUROPE SAS
EDF SA
Honeywell Turbo Technologies
ITER Organization
MCI-Electronics S.A.R.L
Naval Group
Polysoude SAS
Safran Tech
Sofchem
Total
Vallourec Group - Pipe Projects Division



Germany

Aleris Rolled Products Germany GmbH
Europipe GmbH
Evonik Technology & Infrastructure GmbH
H Butting GmbH & Co KG
KAEFER Isoliertechnik GmbH & Co KG
Linde Group
MT Aerospace AG

MTU Aero Engines AG
Pro-beam AG & Co KGaA
Siemens AG - Corporate Technology
Berlin



Greece

Consolidated Contractors Group S.A.L
(Offshore) (CCC)
Corinth Pipeworks Pipe Industry SA



Hong Kong

MTR Corporation Limited



India

Bharat Forge Ltd - India
Larsen & Toubro Limited - Engineering
& Construction Projects (E&C) Divn
Larsen & Toubro Limited - Heavy
Engineering Independent Company
Powergen Technical Services Pvt Ltd
Seamec Limited
TATA Steel Ltd - Growth Shop
Technocraft Industries (India) Ltd
TVS Motor Company



Indonesia

PT Pupuk Kalimantan Timur



Ireland

Aughinish Alumina Ltd
BS&B Safety Systems Ltd

ESB Power Generation
Kostal Ireland GmbH
Medtronic Vascular Galway Ltd
Mincon International Ltd
MSD Ireland (Ballydine)
OpenHydro
Stryker Instruments Ltd
Timoney Technology Group



Israel

Haifa Chemicals Ltd



Italy

Alfa Laval Olmi SpA
Ariston Thermo Group
Cooltech Srl
ENI SpA - Exploration & Production
Division
ETS Sistemi Industriali Srl
Mecc.AL Srl
Nooter/Eriksen Srl
Saipem Group
Sinterleghe Srl
Tenaris
Thales Alenia Space SpA



Japan

AeroEdge Co Ltd
Daido Steel Co Ltd
Daihen Corporation
Dai-ichi High Frequency Co Ltd
Futaba Industrial Co Ltd

Hitachi Ltd - Rail Systems Business Unit
(Kasado Works)
Hitachi Zosen Corporation
Honda Research & Development
Co Ltd
IHI Corporation
INPEX Corporation
ISEL Co Ltd
JFE Steel Corporation
JGC Corp
JXTG Nippon Oil & Energy Corporation
Kawasaki Heavy Industries Ltd
Kobe Steel Ltd
Nakayama Amorphous Co Ltd
Nippon Light Metal Co Ltd
Nippon Sharyo Ltd
Nippon Steel & Sumitomo Metal
Corporation (NSSMC)
Nippon Steel & Sumitomo Metal
Corporation (NSSMC) (Formerly
Sumitomo)
Osaka Gas Co Ltd - Pipeline Business
Unit
Sanoh Industrial Co Ltd
ShinMaywa Industries Ltd
TADA Electric Co, Industrial Apparatus
Works
The Japan Steel Works Ltd - Muroran
Plant
TLV Co Ltd
Tokyo Gas Co, Ltd
Toyo Kanetsu KK
Toyobo Co, Ltd
Yamaha Motor Co Ltd



Republic of South Korea

ANSCO
GS Engineering & Construction Corp
KEPCO KPS - Pusan Decommissioning
Centre and Naju Head R&D Centre
Samsung Heavy Industries Co Ltd -
Shipbuilding Divn



Kuwait

Kuwait Oil Company (KOC)
Kuwait Pipe Industries & Oil Services
Co KSC



Luxembourg

APEMCO SA



Former Yugoslav Republic of Macedonia

ZAVAR Company



Malaysia

Contraves Advanced Devices Sdn Bhd
MFE Formwork Technology Sdn Bhd

Industrial Member Companies



Netherlands

Allseas Engineering BV
 Bayards Aluminium Constructies BV
 European Space Agency, Materials & Processes Divn - ESTEC
 Heerema Group
 Huisman Equipment BV
 SIF Group BV
 TN Netherlands BV
 WRS Marine



New Zealand

Optimech International Ltd



Norway

DNV GL
 Kvaerner Verdal AS
 Metalock Industrier AS
 Nexans Norway AS
 Norsk Titanium
 Petroleum Safety Authority Norway
 Saint Jean Wheels AS
 Scansense AS
 Seram Coatings AS
 Siemens AS
 SINTEF Raufoss Manufacturing AS
 Statoil ASA



Oman

TMK Gulf International Pipe Industry LLC



Qatar

Dolphin Energy Ltd
 HOT-HED Middle East LLC
 Qatar Liquefied Gas Co Ltd
 Qatar Petroleum - Engineering Technical Services Division (TSD)
 Qatar Petroleum - Offshore Projects Department
 Q-Chem
 RasGas Company Limited



Saudi Arabia

KONE Areeco Ltd
 SABIC
 Saudi Aramco Technologies Company (AramcoTech)



Singapore

Cladtek Holdings Pty Ltd
 Keppel FELS Ltd
 Professional Testing Services Pte Ltd



South Africa

DB Thermal - Division of DBT Technologies (Pty) Ltd
 ESKOM Holdings SOC Ltd
 PetroSA (Mossel Bay)



Spain

Equipos Nucleares S.A., S.M.E.
 Fusion for Energy
 Gamesa Corporation - Tower Competence Centre
 Grupo Nicolas Correa Laser S.A.
 Navantia S.A. - Cartagena Shipyard
 SENER Ingeniería y Sistemas S.A.
 Tecnicas Reunidas S.A.



Sweden

Arcam AB
 ECAPS (Ecological Advanced Propulsion Systems)
 ESAB AB
 ETP Transmission AB
 Freemelt AB
 Hydro Extruded Solutions AB
 Livbag SAS
 Shiloh Industries - Europe (Gothenburg)
 Sol Voltaics AB
 Westinghouse Electric Sweden AB



Switzerland

CBMM Technology Suisse SA
 Georg Fischer Piping Systems Ltd
 MEGGITT SA
 Nagra
 Sulzer Management Ltd - Pumps Equipment



Thailand

CUEL Limited



Turkey

AKU Automation - Turkey
 Floteks A.Ş.
 FNSS Defence Systems Inc
 Integrity NDT Engineering
 Nesne Elektronik
 Sabanci University - SU-IMC (Integrated Manufacturing Technologies Research and Application Centre)
 Yesilova Holding AR-GE Centre



United Arab Emirates

Abu Dhabi Co for Onshore Oil Operations (ADCO)
 Abu Dhabi Marine Operating Co (ADMA-OPCO)
 Abu Dhabi Oil Refining Co (TAKREER)
 Abu Dhabi Polymers Company Ltd (Borouge)
 Acteon Middle East FZE
 Archirodon Construction (Overseas) Co. S.A.
 Dolphin Manufacturing Ltd
 Exterran Energy FZE
 Petrofac Engineering & Construction International Ltd
 Proclad Group
 Zakum Development Company



United Kingdom

ABB Automation Ltd, Water & Industrial Business Unit
Air Products Plc
Airbus Group S.E.
AIXTRON Ltd
Allied Holdings and Consultants Ltd
ALTEK Group
AMG AI UK Ltd
Andritz Powerlase Ltd
Ansaldo NES
Apache North Sea Production Limited
API Microelectronics Limited
Applus RTD UK Ltd
Aquam Water Services
Aquasium Technology Ltd
Aquaterra Energy
Arc Energy Resources Ltd
Arc Machines Inc
Arcadis Consulting (UK) Limited
ATB Group UK Limited
Atkins Energy
Avingtrans Plc
AWE Plc
Babcock Integrated Technology
Babcock Marine (Clyde)
Babcock Marine Rosyth
BAE Systems Plc
Baker Hughes - A GE Company
Balltec Limited
Bechtel Ltd
BEKO Plc - Cambridge
Biomet UK Healthcare Ltd
Bladon Jets Ltd
BMC (Engineering Solutions) Co Ltd

BOC Ltd
Boeing Company, The
Bombardier Aerospace Shorts
Bombardier Transportation (Derby)
Bosch Thermotechnology Ltd
Boustead International Heaters Ltd
BP Exploration Operating Company Limited
Braemar Technical Services (Engineering) Ltd
British Engineering Services Limited
British Steel Ltd
Brose Ltd
Bruel & Kjaer VTS Limited
Brush Turbogenerators
BSP International Foundations Ltd
BWI UK Ltd
C4 Carbides Limited
Cairnhill Structures Ltd
Calla Lily Personal Care Ltd
Cambridge Aerothermal Ltd
CamdenBoss Ltd
Capenhurst Nuclear Services Ltd
Carl Zeiss Microscopy Ltd
Carrs Welding Technologies Ltd
Caunton Engineering Ltd
CAV Advanced Technologies (CAVAT)
Cavendish Nuclear
Cedar Metals Ltd
Ceres Power Limited
City Technology Ltd
Clayton Engineering Ltd
Cokebusters Ltd
Comau UK Ltd
Composite Metal Technology Ltd (CMT Plc)

Connect Plus M25 Ltd
Corewire Ltd
Costain Limited
COWI UK Limited
Cox Powertrain Ltd
CRC-Evans Offshore Limited
Cross Manufacturing Co (1938) Ltd
CT Engineering Group UK Ltd
Cummins Generator Technologies CWT Ltd
Dage Precision Industries Limited
Darchem Engineering Ltd
Dashboard Limited
Datapaq Ltd
Daventry Metal Products Ltd
DePuy International Ltd
Devonport Royal Dockyard Limited
DNA Electronics Ltd
Domino UK Limited
Doncasters Bramah
Dril-Quip (Europe) Ltd
Dunlop Oil & Marine Ltd (Grimsby)
E.ON Climate and Renewables UK Limited
EBTEC Corporation
EDF Energy Nuclear Generation Ltd
EDO MBM Technology Ltd
Electron Beam Processes Ltd
Elekta Ltd
Elektron Technology UK Ltd
Element Six Group
Encocam Ltd
Energy Power Resources Limited
Erlson Precision Ltd
Esterline Advanced Sensors
Eversholt Rail (UK) Ltd

EWM HIGHTEC WELDING UK Ltd
Express Engineering Ltd
Expro Group
Fairlead Maritime
FAUN Trackway Limited
Forum Subsea Technologies
Fronius UK Ltd
G4S Monitoring Technologies Ltd
Gardner Aerospace Derby Ltd
Gatwick Technologies Ltd
GE Power Conversion UK Ltd
GE Power, Gas Power Systems, Materials & Processes Engineering - Systems Materials
Gems Sensors Ltd
Gestamp Tallent Limited
GHD Cambridge
GKN Plc
Goodwin Steel Castings Ltd
Graham Engineering Ltd
GSI Group, Westwind Air Bearings Division
Gyrus Medical Ltd
Harland and Wolff Heavy Industries Ltd
Harris Pye UK Ltd
Hayter Ltd
Health & Safety Executive (HSE)
Heatric Ltd
Henderson Engineering (N.E.) Ltd
Henrob Ltd
Henry Technologies Ltd
HiETA Technologies Limited
Highways England Company Limited
Hollygate Fabrications Ltd
Holroyd Precision Limited
Houlder Ltd

Industrial Member Companies

Howden Technology
HS Marston Aerospace Ltd
Huntingdon Fusion Techniques Ltd
IHC Engineering Business Ltd
IMRA Europe S.A.S.
Industrial Plastic Fabrications Ltd
International Oilfield Drilling Supplies Ltd
International Power - UK Power Generation Operations
Invibio Ltd
IPP Mardale Ltd
J C Bamford Excavators Ltd
Jackweld Ltd
Jacobs UK
James Fisher Nuclear Ltd
James Fisher Testing Services
James Purdey & Sons Ltd
JDR Cable Systems Ltd
Johnson & Starley Ltd
Johnson Matthey Battery Systems Ltd
Johnson Matthey Davy Technologies Limited
Jost UK Ltd
Joy Global (UK) Underground Ltd
Kazakh Projects Joint Venture Limited
Kellogg Brown & Root (UK) Ltd
Klinger UK Ltd
Kone Escalators
Krohne Ltd
Kuka Systems UK Ltd
Laing O'Rourke Plc
Laker-Vent Engineering Ltd
Lander Automotive Ltd
Landis + Gyr Ltd
Leonardo MW Ltd

LiCenergy UK Ltd
Lincoln Electric Europe SL
Linx Printing Technologies Ltd
Lion Engineering Services Ltd
Lloyd's Register
Lockheed Martin UK Ampthill Limited
London Underground Ltd
LPA Niphan Systems
LTi Metaltech Ltd
Luvata Welwyn Garden Ltd
Luxfer Group Ltd
M. S. C. M. Ltd
M+W Group UK
MAATS Tech Ltd
MacGregor Welding Systems Ltd
MacTaggart Scott & Co Ltd
Magnox Limited
Marshall of Cambridge Aerospace Ltd
Master Filter Ltd
Materialise UK Limited
MBDA UK Ltd
Meggitt Control Systems Birmingham
Meggitt UK Ltd
Mercedes AMG High Performance Powertrains Ltd
Meritor Aftermarket UK Ltd
Metaldyne International (UK) Ltd
MetalYSIS
Micromass UK Ltd
Ministry of Defence
Molecular Products Ltd
MTCe Ltd
National Nuclear Laboratory Ltd - Workington Laboratory
Neptune Offshore Services Ltd
Network Rail

NG Bailey Offsite Manufacture
Norma UK Ltd
NquiringMinds Ltd
Office for Nuclear Regulation
Oil States Industries (UK) Ltd
Oliver Crispin Robotics Ltd
Olympus Keymed Ltd
Orchid Orthopedic Solutions Sheffield Ltd
Ove Arup & Partners Ltd
Oxford Instruments Nanoscience
Oxford Technologies Ltd
Pall Manufacturing UK Ltd
Pankl Racing Systems UK Ltd
Paradigm Precision - Burnley Ltd
Perenco UK Ltd
Peter J. Douglas Engineering Limited
Philips AVENT
Phillips 66 Limited
Photocentric Ltd
Pipeline Engineering & Supply Co Ltd
Portsmouth Aviation Ltd
Premier Oil Plc
Prima Dental Group
Primetals Technologies Limited
Proserv Offshore Abandonment & Decommissioning
PSI (Phoenix Scientific Industries) Ltd
Pure Fishing (UK) Ltd
Qualfab Ltd
QuantuMDx Group Limited
Quartzelec Ltd
Radioactive Waste Management Ltd
RAL Space
Ransomes Jacobsen Ltd
Rapiscan Systems Ltd

Reaction Engines Ltd
Red Bull Technology Ltd
Redman Controls & Electronics Ltd
Renishaw Plc
Repsol Sinopec Resources UK Limited
Responsive Engineering Ltd, Fabrication & Welding Division
Rhyal Engineering Ltd
Ricardo Cambridge Technical Centre
Rolls-Royce Plc
ROSEN UK
Royal Dutch Shell Plc
Royal Enfield UK Technology Centre
Royal National Lifeboat Institution
RTN Ltd
RTS - International
Rutherford Appleton Laboratory - ISIS
Safran Electrical & Power
SC Group-Global Limited - Supacat
Schlumberger Cambridge Research Ltd
Scottish & Southern Energy (Generation Divn)
Scottish Power - Generation Division
Scottish Power Renewables
Scurrah Nassau Ltd
Sellafield Ltd
Serious Engineering Ltd
Sheffield Forgemasters International Ltd
Siemens Industrial Turbomachinery Limited
Siemens Magnet Technology
Silverwell Energy Ltd
Skycraft Services Ltd
Smith & Nephew Plc - Wound Management

Soil Machine Dynamics Ltd
 Somers Forge Ltd
 Spectus Window Systems
 SPI Lasers UK Limited
 Spincraft ETG Limited
 Spiral Weld Ltd
 Springfields Fuels Ltd
 SPS Aerostructures
 SPTS Technologies Ltd
 SST Technology
 Stork Technical Services (RBG) Ltd
 Subsea 7
 Subsea Components
 Sustainable Drainage Systems Ltd
 T J Smith & Nephew Ltd - Trauma Division
 Talga Technologies Ltd
 TAQA Bratani Ltd
 Taylor Studwelding Systems Limited
 Technetics Group
 TechnipFMC Plc
 TEi Ltd
 Teledyne e2v Limited
 Teledyne Marine
 TenCate Advanced Composites Ltd
 Terex GB Ltd - Dungannon
 Terex Materials Processing - Omagh
 Tesla Engineering Ltd
 Test Company
 Thales UK (Maritime Mission Systems)
 The Welding Alloys Group Ltd
 Thermal Engineering Limited
 Thomas Broadbent & Sons Ltd
 Timet - Waunarlwyydd Site
 Titan Steel Wheels Ltd
 Tokamak Energy Ltd

TPS Weldtech Ltd
 Trackwork
 Transvac Systems Ltd
 Tremco-Ilbruck Limited
 Triton Electronics Ltd
 Tullow Oil Plc
 Ultra Electronics - Nuclear Control Systems, Wimborne
 Ultra Electronics Controls Division
 Underwater Cutting Solutions
 Uniper Technologies Limited
 United Construction and Manufacturing
 United Kingdom Atomic Energy Authority
 UTAS
 UTS Engineering Ltd
 Vantrunk Ltd
 Warehouse Planning Ltd
 Warren Services Limited
 WD Close Ltd
 Weir Engineering Services Ltd - Turbomachinery Engineering
 Weir Valves & Controls UK Ltd
 West Special Fasteners Ltd
 WFEL Limited
 Whessoe Engineering Ltd
 Whittaker Engineering
 William Cook Cast Products - Leeds Plant
 WSP UK Ltd
 Wykes Engineering Co (Rushden) Ltd
 ZF Lemforder UK Ltd
 Zytec Automotive Ltd



United States

AAR Mobility Systems
 ABS Americas
 Advanced Metal Products Inc
 AFGlobal Corporation
 American Engineering & Manufacturing Inc
 Anadarko Petroleum Corporation
 Arconic
 BHP Billiton Petroleum Pty Ltd
 Caterpillar Inc
 Chevron Corporation
 ConocoPhillips Company
 Emerson Electric Company
 ExxonMobil Upstream, ExxonMobil Midstream & ExxonMobil Corporate Strategic Research
 Hess Corporation
 Honeywell Aerospace
 Kaiser Aluminum Fabricated Products, LLC
 LORD Corporation Aerospace and Defense
 LPI Inc
 Manufacturing Technology Inc
 Mattson Technology Inc
 McDermott International Inc
 MIC Group - LLC
 Microalloyed Steel Institute LP
 Miller Electric / Hobart
 MODEC Group
 OneSubsea (A Schlumberger Company)
 Orbital ATK UK

Parker Hannifin Corporation - Gas Turbine Fuel Systems Division
 Praxair Metal Fabrications Group
 ROHR Inc (Goodrich Aerostructures)
 Romeo Power Inc
 SBM Offshore NV
 Sciaky Inc
 Space Exploration Technologies
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 Transocean Ltd
 Williams Corp

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Manual MAG welding process







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