EPSRC Centre for Innovative Manufacturing
Through-life Engineering Services

White Paper

Making Things Work
Engineering for life – developing a strategic vision

31st August 2015

Contents

Overview

This paper briefs the thinking from a cross-sector industry conference held in London on 13th May 2015 to consider the case for a National Strategy in Through-life Engineering Services and has been updated to take account of comments received up to 31 July 2015. The conference was hosted by the industrial sponsors of the EPSRC Centre for Innovative Manufacturing in Through-life Engineering Services, and facilitated by Cranfield University. Throughout the paper text in blue represents direct consensual quotes from the conference.

A national, industry-led collaboration is proposed that will rapidly develop capability in "through-life engineering services" (TES) to improve productivity and provide high-value employment whilst improving UK competitiveness in a large global market.

TES provide the technology and technical processes that guarantee the safety and performance of high-value products, assets and infrastructure whilst minimising investment: as such they will be a critical enabling capability for future manufacturing.

Increasingly, users will rent the assets to support the services they offer allowing more frequent upgrade and agility in the "value in use" they provide. To be successful manufacturers will need to change fundamentally, integrating the very different cultural and technical approaches of manufacture and service, transforming customer and supplier behaviours accordingly.

The UK has a national strength in innovative engineering and some of the world's most complex, long-life product and infrastructure to maintain but there is little focus on "engineering systems for life" or "through-life engineering services".

A national, industry-led collaboration to rapidly develop capability in TES – a national industrial strategy – that shares knowledge and coordinates investment, will transform the way we manufacture and deliver sustainable products for future generations enabling access to a considerable global market whilst improving public value from our long-life complex assets.

[1] Engineering and Physical Sciences Research Council

Part 1: Strategic Context

Through-life Engineering Services (TES) are the technical services necessary to guarantee the required and predictable performance of a complex engineering system throughout its expected operational life with the optimum whole-life cost, taking account of design, manufacture, maintenance, repair, overhaul and disposal or re-use.

They (TES) will be key to manufacturing productivity and high value jobs in the circular economy of the future.

With increasing interest in the circular economy and the need to get more from ageing infrastructure and other long-life assets, taking an "end-to-end" perspective on design, manufacture, maintenance, repair, overhaul and disposal, enabled by TES, will be a critical discriminator in the very large global market for engineering support and services - approaching £1 trillion in 2025. Despite having leading capabilities in the field the UK currently enjoys only about 5% of the current global market and this will decline if no action is taken. Nevertheless, TES is significant to the UK with around 6,000 companies employing over 107,000 people in engineering support and services with an average wage of £42,000 as compared to an overall industrial average of £27,000, demonstrating the "high-value" nature of TES employment.

TES are the vital, but currently missing link for sustainable manufacture and infrastructure, and for the circular economy. It is vital to enable the transformation from "open-loop" linear, transactional or "throw-away" business models to circular "closed-loop" collaborative, outcome-based alternatives that integrate engineering with other business functions and customers with the supply chain.

In the future customers will only buy services: product-only providers will not exist in many technically complex fields leading to a polarization of manufacturing between the "throw-away" and circular economies.

In this vision of the future economy nobody and no company will ever buy major assets again: they will simply pay for some kind of service or functionality and will not think about products and services being separated. The Internet of Things and "incomplete products" where the product or asset, no matter how complex, is configured for and remains an integral part of the service delivery will drive this service economy. In this economy there will be two types of players:

- Service providers who will dominate profit recovery, sharing this with the service supply chain who are able to understand the operating context and make a value-add contribution to managing the assured performance of the underlying assets through-life, and
- "Traditional" manufacturers providing products and parts without an ability to support or understand the service supply chain and whose profits will be marginalised through global competition: competing in a race to the bottom – driven there by customers who understand TES and therefore get real value for money for the in-service support of their assets.

The UK can be at the forefront of these evolving business models and technologies for productivity in high-value manufacturing focused on customer value and the circular economy. World-class TES can drive infrastructure investment and the re-skilling of the engineering and manufacturing workforce creating new high-value jobs within the economy: increasing productivity and building the brand of UK manufacturing.

An industry-led, integrated approach, or "National Strategy" for TES will help by developing the 'high gearing' national capabilities, such as collaboration across sectors, necessary to deliver this transformation, at pace.

Such an approach will focus the critical TES contribution to a number of the UK's existing industrial strategies and initiatives, and highlight those from which it is worryingly absent.

Collaboration is an important high gearing function that will be enabled by such a strategic approach, encouraging the cross-fertilization of experience between industrial sectors, and how intellectual property (IP) is shared in a regulated and controlled way: differentiating the UK's capabilities in a high-value global market.

Part 2: The TES Market

The TES Centre has produced a report on the UK and global market for engineering support and services[2] that has initially considered data across eight sectors.

Successful engineering companies made the switch to service-centric business models from the mid-1990s to early 2000s and now derive between 50% and 60% of their revenue from these activities with margins much greater than that from selling the product alone. There are many instances where the service and support revenue has sustained companies through periods of low demand for new product, such as during the recession. Many companies classified as manufacturers such as those specializing in "maintenance, repair and overhaul" (MRO) derive 100% of their revenue from engineering services and support.

Companies that have made a success of support and service have identified a clear vision, focus and execution of their transformation to being a service provider. They have designed and implemented a service supply chain, managed divestments, mergers and acquisitions and made strategic alliances to grow in their market and win long term business. They have also employed capital to improve facilities and infrastructure, and invested between 5% and 8% of total revenue in focused research and development.

In financial year 2014-15 the UK Support and Service industry generated revenue of over £23bn (£23,000 million) comprising £11bn within the UK and over £12bn in global exports to a world market of around £500bn. More than 50% of the UK companies' revenue comes from exports representing approximately a 5% share of the global market. On current trends, in 2025 the value to the UK will be over £35bn with exports accounting for 65% but representing a diminishing share of a greatly expanded global market of over £700bn. A national focus on TES will enable this forecast to be exceeded significantly.

Around 6,000 companies employ over 107,000 people with an average wage of £42,000 as compared to an overall industrial average of £27,000[3], demonstrating the "high-value" nature of TES employment.

We are scratching the surface. As well as improving the value of engineering employment it is clear that a focus on TES, through establishment of a more strategic National approach, will improve domestic productivity and support access to a greater proportion of a very large global market.

Although circumstantial evidence from early adopters of engineering services such as Rolls-Royce, BAE Systems and Bombardier Transportation suggest that the UK is in a world leading position in understanding TES, there is clearly an opportunity to do much more at a national and global scale and, indeed, to more effectively sustain our own ageing infrastructure. Conversely, if we do not take a lead on this our industries are at risk of being taken over by others. We need to be able to further differentiate the UK's capabilities in this high value global market.

Enabling other UK Industrial Strategies

This initial market analysis has highlighted the apparent importance of TES. It is surprising therefore that TES capabilities and opportunities are given worringly little, if any prominence in existing sectorial industrial strategies. Several of the sectors considered in the market analysis illustrate this concern including Rail, Nuclear, Maritime and Aerospace, although the recent

[2] UK Support and Service Industry as a High Value Employer and Net Exporter, Raj Mehta, TES Centre, Cranfield University 2015
[3] Source ONS data from December 2014 SIC Division 33

BDO Aerospace Report[4] recognizes a consensus that "think the UK should invest strategically in through-life engineering services and product-service systems".

The development of a National, strategic approach to TES capability development and the wider TES market could be instantiated for each of the above industry sectors, along with others. This would provide a framework for collaboration between industries such that TES capability and capacity could be developed on common principles, with economy of cost and effort, whilst enhancing the individual sectorial strategies.

Improvement in TES is important to any sector that is technically-based and where there are operational and safety performance benefits. Many different types of assets have a complex operating environment and technical equipment requires training, standardization and other support to ensure operating and cost efficiency and effectiveness. TES provides these benefits with improvement in equipment life and reliability, and in safety performance that is crucial in this litigious era where there is risk to life for 1st (direct operators), 2nd (other work environment persons) and/or 3rd parties (general public). If a single economy were known to have a mature, common strategy for effective engineering services to improve operational and safety performance across all sectors, the reputation of any associated business would be enhanced from the outset increasing their competitiveness in the world market.

[4] The Aerospace Report, BDO LLP, July 2015

Part 3: Opportunities and Challenges

The UK leads today. TES is mission critical for long-term growth and export in high-value manufacturing – if we do not continue to lead we will lose out.

Opportunities

- Continue to lead, through differentiating UK capabilities
- Focus on UK engineering innovation and technology: "export reliability and availability"

Challenges

- Commoditization of the service element continues – need to develop skills and behaviours that break free of goods-dominant thinking in manufacturing
- There is presently no clear national TES focus without which we will lose sight of the opportunities
- Long-term thinking is a missing piece in UK productivity – can this be supported by better incentives?
- Engineering institutions (and other institutional stakeholders) and many initiatives such as the Catapults and industrial strategies are fragmented and stove piped

TES provides an essential link to, and enabler for new business models critical to the realization of the circular economy.

Opportunities

- Provide a global lead for the manufacturing transition to the circular economy
- Develop TES technologies and standards to drive "circular economy" thinking, and leverage relevant EU legislation
- Share learning and scarce resources to accelerate development and support the aspiration to be world leaders
- Add value to the economy based on skills and cooperation

Challenges

- Move from open-loop to closed-loop business models and thinking (beyond engineering and the firm)
- How is this driven into the rest of the business ('closing the loop')?
- Developing and engaging the broader skill base, with the appropriate culture, to deliver on service excellence

Government contracts, especially those for infrastructure, energy and transport are critical and could provide a game changer for TES and competitiveness in the future

Opportunities

- Government can lead by being a service customer, improving value for money in government contracting

Challenges

- How to get Government to act as a service customer?

Transactional, lowest tendered price competition for manufactured goods and infrastructure is driving a “race to the bottom” where the UK is increasingly unable to compete against the rest of the world resulting in weakening margins and negative growth. The successful early adopters of servitized manufacturing and TES have demonstrated the ability to grow by providing better value to customers and shareholders, as well as higher value jobs. Government and private sector customers, and industry leaders can strongly influence and support rolling out the approach across the service supply chain and SMEs in particular.

Part 4: Delivering Priority Capabilities

There are four clear thematic areas where "TES-based" capabilities can make a real difference to UK productivity, leadership and competitiveness in high-value manufacturing and the global circular economy: Technology, Standards, Supply Chain and Skills. Overall, however, it is clear that we must work to develop collaborative behaviours and address the cultural challenges of working together in flexible, outcome-based relationships: an essential, unifying approach that runs through all these capability themes.

Technology (and analytics)

Better tools and techniques are needed for data integration and analysis, performance prediction and maintenance that work "end-to-end" across the product life cycle and across the service supply chain. These should support the transformation from "open-loop" to "closed-loop" business models with multi-functional management and collaborative behaviours.

In particular there is a need for better through-life cost and risk models, and better condition management and fault analysis capabilities: a focus on the management of deterioration. These will improve performance assurance (predictability) with automation and self-repair technologies to reduce system downtime for essential maintenance interventions. Without such models there will be little chance of building in sustainability or maintainability to complex assets. Effective cost and risk models are particularly important to allow the trade-off necessary across research, design, operations and overhaul, and recycling needed to support an optimum cost service within the future circular economy.

Technology developments to facilitate management, transfer, integration and analysis of contextual data, with no technology limit to the "mash-ups" available for meaningful operational performance analysis, allowing knowledge transfer and development whilst helping to manage intellectual property, will be key enablers for TES – "data is going to do it for us".

Standards

Formal standards, and regulation, will be key enablers for innovation in TES, for knowledge transfer and behavioural alignment across the service supply chain and knowledge transfer across industries to accelerate capability development.

A TES "standards strategy" will build on the success of ISO 55000 (Asset Management) other recent standards (such as BS 11000 Collaborative Business Relationships, IEC 60300 Dependability and BS 8887 MADE[5]) and, of course ISO 9001/9004, to work towards an integrated set of behavioural, process and technical standards, many of which already exist, to codify emerging best practice in TES. It will represent a wider perspective on the economics of design, manufacture, commissioning, maintenance, upgrade, and decommissioning/re-use of complex physical assets than that taken by previous standards. Whereas ISO 55000, as an example, provides a generic process standard for managing the main asset groups that contribute to business objectives, TES seeks to address how these assets are effectively integrated across a wider enterprise so that the "through-life" management of complex, physical or capital assets remains optimised for value creation.

[5] Manufacture, Assembly, Disassembly and End-of-life processing

Supply Chain

The supply chain needs revolutionary change to adapt to the circular economy. The future service supply chain must embrace service and TES-thinking and behaviour or otherwise compete in a race to the bottom.

TES, or engineering service supply chains of the future will need to be very different: they will be highly collaborative comprising suppliers who are able to understand the operating context and make a value-add contribution to managing the assured performance of the underlying assets.

Whilst those firms that have been pioneers of engineering services – for example "availability contracting" – have made progress towards understanding the issues, technologies and behavioural changes needed, the supply chain has not generally been engaged in this "new thinking". Customers – governments and service operators – and the associated service providers have an obligation to broaden the engagement of the supply chain in TES thinking to accelerate TES capability development, particularly in SMEs.

Skills

TES create multi-functional, high-value jobs requiring new skills and collaborative behaviours but have not been recognised as an attractive or interesting area of work resulting in particular difficulties in developing the workforce.

As with engineering as a whole there is a skills shortage. TES require a skilled workforce and is amenable to inclusive employment. It creates multi-functional, high-value jobs with average wages in engineering services 1.5 times those of engineering as a whole, yet is not seen as an attractive or interesting "mainstream" area of engineering. This is not an argument to create yet another professional specialization but rather to mobilize interest across the engineering and associated professions and their institutions. This will provide a joined-up narrative that engages interest and develops consistent capabilities across each of the contributory disciplines.

A TES skills programme is needed to generate interest and expertise, but also to promote the major change in attitude and behaviour to support the new sharing and collaborative operation of service supply chains. "Generation Z" are well disposed to these behaviours but need to have their interest in engineering and TES in particular engaged. Providing TES, and operating within the service supply chain, are not cases of just winning new types of contract: they fundamentally spin the business on its head with a significant "soft side" to the change. Companies, and their people need to fundamentally change their thinking to capture value from TES.

What can we do about it?

Industry, government and academia all have potential roles to play in delivering these capabilities through new initiatives or leveraging the "TES dimension" of other industrial strategies.

Industry leaders can do more to develop "TES-thinking" and share knowledge in TES to accelerate capability development in the supply chain and within SMEs in particular.

Private sector customers (of engineering services, such as owner / operators) and industrial suppliers need to fundamentally change their thinking to capture value from TES, and can do more to enable a focus on the importance of TES and the needs for new technology, skills and collaboration or knowledge sharing. Industry and the early adopters of TES in particular, will

need to lead on this new thinking, improvements in knowledge sharing and the acceleration of capability development in SMEs and their inclusion within the service supply chain. Industry, with academic support, can work with the engineering and professional institutions to ensure that an appropriate "through-life" or TES perspective is taken in education and the requirements for institutional membership.

Successful companies have pushed the need for "design for TES" into the engineering culture and supply chain. Whilst this is the start of a journey for these early adopters, the approach and expertise can provide a pathway for others to follow.

Industry and Government can work together to shape future technologies, standards and skills, ensuring that the "TES-dimension" of other initiatives and industrial strategies are coordinated.

Collaboration in the development of new and existing formal standards will in particular enable cross-sector skills sharing and inclusion of all parts of the service supply chain.

The initiative for new formal standards might, for example, take the form of a national TES Standards Institution set up as a collaboration between BSI, the High Value Manufacturing Catapult and industry on a similar basis to the Smart Cities Standards Institution. Within such an initiative, government and industry might usefully collaborate on the development of standard role and capability definitions for TES to enable broader participation and accelerate skills development.

Government can support development of TES practices through effective commercial leadership: by setting aspirational targets for public infrastructure and assets.

Government can do more to encourage development of TES practices by defining alternative commercial policies to be followed for TES based service contracts, establishing the data and performance models for setting realistic aspirations for value for money and continuous improvement, and by understanding and developing the management skills to deliver these contracts. Aspirational targets could be set for public infrastructure by exercising leadership in contracting for service and availability of high value manufactured products and infrastructure; and in integration of capability development across current initiatives with a balanced public investment in research and development for TES technologies and skills.

These measures could allow government to lead practice development by ensuring it acts as a "service" customer wherever possible: particularly with the renewal and regeneration requirements in defence, infrastructure (including utilities), energy and transport. Government could also look at European Union legislation to open up and drive the circular economy towards servicing products.

Government and Academia can ensure that current and future manufacturing initiatives, including research, are better integrated with TES elements being developed consistently.

More can be made of taking a "transverse" view of TES needs and capabilities across current industry strategies and research initiatives. This should be the primary responsibility of government and academia, with the support of industry, to ensure that current and future manufacturing initiatives are better integrated and that the TES elements are developed consistently.

Conclusion

Innovation in TES and the development of these capabilities across the UK supply chain will contribute significantly to manufacturing productivity and the development of high-value employment across the UK manufacturing sector. Development of TES capabilities will also provide improved competitive access to a significant global market in engineering support and services. But industry and government need to do more to change their thinking to capture value from TES.

TES are the vital, but currently missing link for sustainable manufacture, infrastructure, and the circular economy. They are vital to enable the transformation from “open-loop” linear, transactional or “throw-away” business models to circular, “closed-loop” collaborative, outcome-based alternatives that integrate engineering with other business functions and customers with the supply chain.

An industry-led, integrated approach for TES – a new, integrating “National Strategy” for TES – will help by developing the “high gearing”national capabilities, such as collaboration across sectors, necessary to deliver this transformation, at pace. It will ensure development of the enabling technology and standards so that the leading practitioners engage productively with all levels of the supply chain, particularly SMEs, with confidence that appropriate skills will be developed for the future. It will furthermore promote access for UK firms to a very substantial global export market.

Such an approach will build on the opportunities, and mitigate the challenges associated with what is currently a leading position in building manufacturing productivity and high-value employment during the transformation to a global circular economy. Developing capability in TES is key to future growth in high value manufacturing and manufacturing productivity.

List of Attendees

Name	Organisation
Neil Barnett	ADS Group Limited
John Duthie	AMEC
Sam Turner	AMRC with Boeing, University of Sheffield
Peter Stuttard	Aspîre Consulting Ltd
Mark Norris	Atkins Limited
Tim King	Babcock International
Stewart Leinster-Evans	BAE Systems
Ian Laurence	BAE Systems
Paul Thorley	BAE Systems
Rob Cowling	Bombardier Transportation UK Ltd
Ben Sheriden	British Standards Institution
Steve Wilson	British Standards Institution
Bill Bardo	Centre Advisory Board Chairman
Ian Blackman	COG UK
Raj Mehta	Consulting
Andrew Gill	Consulting Partnership
Eleanor Collins	Cranfield University
Jose Endrino	Cranfield University
John Erkoyuncu	Cranfield University
Jorn Mehnen	Cranfield University
Rajkumar Roy	Cranfield University
Andy Shaw	Cranfield University
Andrew Starr	Cranfield University
Paul Tasker	Cranfield University
Juan Matthews	Dalton Nuclear Institute, University of Manchester
Yvonne Elsorougi	Department for Business Innovation & Skills
Peter Brook	DLA Piper
Alan Purvis	Durham University
Nick Frank	Frank Partners
Geoff Hanson	GE Aviation
Chris Bell	GE Intelligent Platforms
Rachel Gollin	GKN Aerospace Services Limited
Russell Hargrave	Hitachi
Prasanna Gundi	HP Enterprise Services
Ian Collier	HVM Catapult
Victoria Abbott	Hydro GmbH
Jonathan Farnfield	Hydro GmbH
Derrick Dunkley	IAM
Phillipa Oldham	IMechE Management Group

Jeremy Lovell	Intelligent Energy
Richard Pitman	KTN
Alex Stallman	Labinal Power Systems
Chris Owen	Marshall Aerospace and Defence Growth Partnership
Richard Denning	MOD
Ken Young	MTC
David Hogan	Nuvia Limited
Mal Bruce	Pilotwise Internation Ltd
Rob Smithq	Plexus Planning Limited
Dave Benbow	Rolls Royce
Steve Gregson	Rolls Royce
Andy Harrison	Rolls Royce
Roddy Beat	Segin Global
Steve Foxley	Siemens
Will Stirling	Stirling Menia
James Selka	The Manfuacturing Technologies Association
Chris McDonald-Bradley	TRW Conekt
Paul Calver	UKTI
Bernard Molloy	Unipart Logistics
Dan Somers	Warwick Analytics
Pasquale Franiosa	Warwick University

EPSRC Centre for Innovative Manufacturing
Through-life Engineering Services

Organised by the EPSRC Centre for innovative Manufacturing in Through-life Engineering Services

The national research centre is hosted by Cranfield (lead) and Durham Universities. Our core industrial partners are Rolls-Royce, Bombardier Transportation, BAE Systems, Babcock International and the UK MOD. We also have another eighteen industrial partners and continue to grow.

The mission of the Centre is to develop knowledge, technology and process demonstrators, novel methodologies, techniques and the associated toolsets for the design, manufacture and in-use support of high value engineering systems for guaranteed safety and performance whilst minimizing the investment needed. We aim to improve the availability, predictability and reliability of complex engineering products to deliver the lowest possible whole life cycle cost by developing technologies and processes to improve the design, manufacture, maintenance, upgrade and re-use of such systems. Our vision is to provide thought leadership in through-life engineering services and be the first choice for UK manufacturing companies as a source of technological solutions, research and development capability, knowledge, skill and advice.

TES Centres website:
www.through-life-engineering-services.org

TES Market Size Report - Full Paper:
www.through-life-engineering-services.org/news-and-events/news/tes-market-size-report

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