EPSRC Centre for Innovative Manufacturing
Through-life Engineering Services

A National Strategy for Engineering Services

Delivering UK Economic Growth by

Making Things Work Better for Longer

SECTOR REPORT

June 2016

Contents

Context, Objective and Approach

This document reports on consultation and sector analysis in the development of a national strategy for Through-life Engineering Services (TES). It outlines conclusions as to potential 'TES penetration' in high value manufacturing (HVM) sectors in the UK.

Development of the TES strategy[1] has drawn on:

- Three regional strategy development workshops attended by over 80 representatives from a range of industrial sectors – including automotive, aerospace, defence, marine, energy, nuclear, electronics, and logistics – and from manufacturing trade associations, government agencies and academia
- Sector perspective discussions, with sector leads in the Department for Business, Innovation and Skills (BIS) or equivalent, selected industrialists and in some cases literature review (this report)
- A market and data review prepared by Professor Alan Hughes and Jonathan Hughes[2].

The focus here is on the sector perspective discussions noted above. Their objective was: *to review the industry sector under discussion against the emerging themes from the TES strategy workshops, and understand the potential for penetration as input to further market/data analysis*. Output from the discussions has fed into the market and data review.

Sectors reported are: food; pharma and biopharma; agritech and agriscience; medtech; defence and security; aerospace; space; automotive; rail; marine; energy; nuclear; oil and gas, built environment; machinery manufacture; chemicals (including bio renewables); electronics and ICT.

The strategy project team held discussions with members of BIS sector teams, or equivalent in other departments, industrial representatives, steering group members and relevant representatives from the Catapult network. In addition, in some instances the project team has

[1]A National Strategy for Engineering Services, Cranfield University 2016. http://www.through-life-engineering-services.org/strategy

[2]Through-life Engineering Services (TES) Market and Data Review, Alan Hughes and Jonathan Hughes, Cranfield University 2016 http://www.through-life-engineering-services.org/strategy

reviewed available documentation to create a first-pass view of TES potential penetration in the sector under review. The discussions were designed to explore:

- level of awareness and application of TES principles
- estimates of market size
- the strategic context
  - global needs and opportunities
  - TES value propositions
  - TES capability
  - enablers

Prior to the discussions, the authors of this report made estimates of upper and lower bound potential percentage penetration of TES within the sector, meaning the extent to which TES-related business models might be taken up by makers and/or users in the sector. These estimates were updated following the discussions and have been used as input to the market data report.

In advance of the discussions, interviewees were given the following definitions of TES and draft vision for TES 2025.

Definition of TES[3]

Through-life engineering services – TES – encompass the design, creation and in-service sustainment of complex engineering products with a focus on their entire life cycle, using high-quality information to maximize their availability, predictability and reliability at the lowest possible through-life cost.

Vision for TES 2025[4]

- The UK leads in a competitive world market where sustainable service models are available globally across many high value manufacturing sectors
- Government, industrial buyers and consumers emphasize total lifecycle cost and long-term value creation in their buying decisions

[3] Definition based on A National Strategy for Through-life Engineering Services consultation paper presentation by EPSRC Centre for Innovative Manufacturing in Through-Life Engineering Services. Launch event held at the Houses of Parliament, 10 September 2015.
[4] Source: TES strategy development workshops December 2015 and January 2016.

- The provision of services rather than products is the standard offering in high value manufacturing
- UK companies understand their customers and the potential of new home and export markets better than anyone else
- TES skills and capabilities enjoy robust institutional support. Financial models reward long-term value creation, contributing to firm and national productivity. Risk management and cost efficiency are supported by IP ownership rules

The following sections outline the key messages that emerged from the sector reviews, give a brief summary by sector, and finally, some observations and recommendations. More detail on each sector review is given in annex 1, followed by the discussion framework in annex 2. Annex 3 lists steering group members, expert contributors and project team.

Key Messages

The following messages emerged from the sector discussions:

- The prime driver for adoption of TES will be from users
- Indications are that there is a considerable market opportunity in the UK alone, with a significant element of gross value added (GVA) delivered by TES solutions by 2025 if pursued through a concerted strategy
- TES can support competitive new customer propositions across all of the HVM sectors considered
- A national TES strategy could help UK better exploit the significant opportunities in a number of emerging markets

In terms of current position and future opportunity by sector:

- Sectors where it appears TES is presently extensively practised, and where strengthening of competitiveness might be expected from a national strategy include: aerospace; rail; defence; and ICT
- Sectors which may within ten years gain significant benefits from TES, supported by a national strategy might include: healthcare (pharma/biopharma and medtech); renewable energy; biorenewables and built environment.
- Space may be regarded as a sector already fully converted to TES principles and growing very quickly
- TES offers significant opportunities for the machinery sector which has a high proportion of small and medium-sized enterprises (SMEs) – penetration will be dependent on original equipment manufacturer (OEM) pull and increasing willingness in the sector to offer service-related value propositions
- Significant opportunities in emerging markets include: biopharmaceuticals; biorenewables; and small modular nuclear reactors

Sector Summaries

Sector	Commentary	Penetration %*
Food[5]	Food processing relies extensively on complex equipment, but also has a high labour content in some areas.	0%–75%
Pharma/ biopharma	Cost pressures on established products may drive transformation of the supply chain to TES models. Personalized and stratified medicines, additive manufacturing (AM) and eHealth offer the opportunity for suppliers to move to TES solutions, which might also benefit new product introduction (NPI).	10%–50%
Agritech and agriscience	Much of the sector output is based on complex equipment, and this looks set to increase for precision and optimization. The sector is perceived as lagging internationally, and will grow steadily, building on the current take up.	10%–50%
Medtech	National Health Service (NHS) could have the major role in driving uptake of TES, in response in part to the need to tighten budgets and improve information quality.	20%–50%
Defence and security	The national data is focused on land, weapons, and information, surveillance, target acquisition and reconnaissance (ISTAR). While air and marine are relatively developed in relation to TES, application of TES approaches in land, weapons and ISTAR is now in train, driven by increased outsourcing.	30%–80%
Aerospace[6]	Potentially all air transport could be provided through TES-enabled business models. Already 40% of new sales (and hence aftermarket) is to leasing companies. Aircraft manufacturers are likely to move more into maintenance, repair and operations (MRO) to take share from third-party suppliers.	70%–90%
Space	Satellite applications in the UK – growing rapidly, with target of £40bn contribution to UK economy by 2030 – may be regarded as fully based on TES. Although equipment is a major part of balance sheets this is invisible to the information and communications service users.	
Automotive	Whilst new car stock is extensively enabled for TES and leasing is increasingly common, the term is not in common use and individual users need to approve data extraction. New 'mobility as a service' offers based on autonomous vehicles are likely to have penetrated the market extensively by 2025.	20%–90%
Rail	TES is the common way in the UK today, driven by privatization and growing internationally, where there may be major opportunities linked to infrastructure investments. UK providers will need to continue to advance their capability to maintain share and win internationally.	70%–100%

Cont./

[5] No interview conducted. Conclusions based on literature review.
[6] Aerospace national data includes defence air.

Sector	Commentary	Penetration %*
Marine	Manufacturing is largely for the defence sector, and here there is and will be penetration of TES through MOD procurement practices. Opportunity exists to develop more mature practices through learning transfer from aerospace and the civil marine support sector.	10%–40%
Energy	With focus on renewables (particularly offshore wind), penetration of TES might be achieved by transferring expertise from the oil and gas sector. Present economics leads equipment to be 'used once' and replaced.	0%–90%
Nuclear	New build offers/requires radical new business models. Small modular nuclear reactors offer significant opportunity for TES.	30%–60%
Oil and gas	UK has leading capability in this sector, for example underwater vehicles which could offer significant opportunities for TES. Gain share MRO contracts may already be common.	30%–100%
Built environment	TES concept is similar to 'whole-life costing', adopted in the industry. Moves towards modular construction and smart buildings offer the opportunity for TES in both supply and use. Government makes a significant proportion of the national spend.	5%–50%
Machinery manufacture	TES offers a significant opportunity for this sector, which has a high proportion of SMEs. Whilst there are examples today, penetration will be dependent on OEM pull and increasing offer of service-related value propositions.	10%–40%
Chemicals	Contract maintenance is common in the industry. Downstream and specialist and emerging markets (e.g. biorenewables) may benefit from TES. TES may benefit NPI through offering shared access to capital equipment.	30%–50%
Electronics and ICT	This is a very diverse sector involving electronic systems and components. UK manufacturing in this sector is generally high value. TES is broadly applicable in electronics although the industry is not mature today, with significant obsolescence issues. ICT is highly TES-susceptible, with a significant uptake already in, for example, computing services.	15%–90%

Table 1: Sector Summaries. Key: (*) Potential for penetration of TES estimated by TES project team as percentage range of sector GVA.

Observations and Recommendations

The interview survey has been a shallow review, not intended to establish a TES strategy by sector. The interviews and desk review have, of necessity, covered only a very narrow sample of, albeit well-informed, contributors over a short period of time and cannot be considered fully representative of the relevant sectors.

Few interviewees were prepared to hazard a guess at potential market size in the UK and none as regards exports. The ranges of possible TES uptake indicated for individual sectors in this survey are therefore very large, and as a result, comments highlighting particular sectors as 'targets for TES' should be treated with some caution.

Most interviewees expressed enthusiasm for TES concepts and the associated business models and felt they were directly relevant to their sector.

Deeper engagement with individual sectors and, where available, appropriate Catapults should be undertaken as part of the strategy implementation plan, following which more reliable indications of the market potential might be developed.

Annex 1: Individual Sector Reports

Pharmaceuticals and biopharmaceuticals

Cost pressures on established products may drive transformation of the supply chain to TES models. Personalized and stratified medicines, additive manufacturing (AM) and eHealth offer the opportunity for suppliers to move to TES solutions, which might also benefit NPI. **Potential penetration estimate**: 10%–50% GVA
Market assessment data + supporting commentary+ illustrative examples (actual and possible) *Timing of development*: Later in the period – little uptake today *Commentary*: Most of the sector output is based on complex equipment. The approaches required by TES are rather contrary to the established norms in the industry; however, they offer real benefits and potential enhancements to competitiveness. The sector is primarily a User today, but the move to personalized and stratified medicines may offer a later opportunity – it might move to the servitization of the pharmaceutical supply chain, linking diagnostics with treatment, compliance regime and condition monitoring. *Examples*: Recent partnership agreement between Pfizer/GEA and GECON, now joined by GSK.
Global needs and opportunities The pharma industry is producing fewer blockbuster drugs and bringing more niche products to market, many of which could use continuous manufacturing. AM is currently being examined for clinical trial manufacture. The development of stratified medicines is replacing the quest for blockbusters. eHealth and new technology offer the opportunity to re-shore and convert existing manufacture to new technologies.
Through-life engineering services value propositions • Rented open-access development centres with multiple users for maximum equipment utilization. Linkages with end-user companies and suppliers • Gaps include digitization of the supply chain and building patient compliance
Through-life engineering services capability development Proving technology and de-risking involvement. Get slicker at gathering, analyzing and using the data we have. Improve patient compliance and reduce waste in the supply chain to the patient. Develop big data and sensors for remote condition monitoring.
Enablers Catapult-type innovation centre providing rented space. Patient-centricity could be driven through National Health Service's 'single voice', linking effectively with Department of Health to scope out novel supply chains and what that might mean for the health service.

Agritech and agriscience

Much of the sector output is based on complex equipment, and this looks set to increase for precision and optimization. The sector is perceived as lagging internationally, and will grow steadily, building on the current take up. **Potential penetration estimate**: 10%–50% GVA
Market assessment data + supporting commentary+ illustrative examples (actual and possible) *Timing of development*: Already in progress *Commentary*: Much of the sector output is based on complex equipment, and this looks set to increase for precision and optimization. The potential for adoption of technology and practices is recognized as huge. The UK is behind the state-of-the-art in this, but may be able to close the gap with other countries through adoption of more advanced equipment and better use of data and data-sharing through the value chain. *Examples*: Sensing and technological assessment of animals as they grow in order to understand the value gain every day can be linked to the end-user and their needs. Too big or too fat an animal costs money on trimming in the abattoir and wastes money spent on surplus nutrition during the growth stage. It also releases more saturated fats into the food chain. Lifecycle analysis suggests that £600m p.a. in costs could be avoided by 2020.
Global needs and opportunities Agritech has a need for greater sharing of information throughout the value chain to reduce cost, minimize waste and improve the quality of food.
Through-life engineering services value propositions Real-time assessment of animal growth; technology enabling data collection and sharing; cost-sharing of equipment and maintenance across the value chain.
Through-life engineering services capability development Enabling technologies such as data collection and analysis; quick response to demand; accurate assessment of current state.
Enablers Understanding the value to be achieved by supply-chain integration – and describing a mechanism to best achieve this. The current model is not the most conducive to sharing investment costs which ultimately benefit the entire chain.

Medical technologies

NHS could have the major role in driving uptake of TES, in response in part to the need to tighten budgets and improve information quality. **Potential penetration estimate:** 20%–50% GVA
Market assessment data + supporting commentary+ illustrative examples (actual and possible) *Timing of development*: Not estimated by interviewee(s) *Commentary*: Likely to apply to high capital expenditure items – diagnostic or imaging kit such as MRI scanners, ultrasound scanners, ophthalmic equipment, some IVD diagnostic equipment and robotic-assisted surgery systems (for instance, intuitive surgical, currently 60 are used in the UK) and X-ray sets, which may form approximately 20% of the total industry. The NHS is a user and equipment providers who would be the suppliers are serving a highly fragmented global market. Examples: The medtech equipment manufacturers could be providers if driven by their primary customer – the NHS. Given the limitations the NHS and other healthcare providers have in buying large expensive capital items, many manufacturers have already developed alternative business models and lease equipment or provide a managed service offering (e.g. Philips, Medtronic) so they might be expected to offer bundling of service contract as part of that, either directly or with partners. This capability may therefore increasingly be needed and developed.
Global needs and opportunities Needs: • Restricted capital budgets may force the issue of buying capability rather than equipment, as this transfers expenditure to revenue budgets which may be seen as preferable • Insulation against software and hardware obsolescence • Interoperability of equipment • Target of £22bn of savings through efficiency improvements in NHS.
Through-life engineering services value propositions Viable business and operational models that are easy to adopt.
Through-life engineering services capability development New thinking would be required in procurement practices to support 'through-life' economics. The onus may be on the original equipment suppliers or specialist engineering firms offering services to develop such capability.
Enablers Policy change would be required to support through-life costing.

Defence and security

The national data is focused on land, weapons and ISTAR[7]. While air and marine are relatively developed in relation to TES, application of TES approaches in land, weapons and ISTAR is now in train, driven by increased outsourcing. **Potential penetration estimate**: 30%–80% GVA
Market assessment data + supporting commentary+ illustrative examples (actual and possible) Aviation and marine are very experienced in TES, but land and ISTAR, the focus of the national data, are less experienced in the field. However, there is a wealth of MOD-wide experience. There are examples within ISTAR, which has health and usage monitoring. Field guns have limited data such as number of shots fired. Munitions is heavily focussed on through-life principles, but the service remains fully within MOD. The MOD is a user of TES, so suppliers are 'Makers', and perhaps 95% by value of supplies are complex equipment. Possibly 30%–40% by value of equipment is currently covered by TES-related contracts and this may rise to 80% by 2025 with planned outsource programmes.
Global needs and opportunities Customer simplicity, as MOD skills need to focus on war fighting; progressing the maturity and understanding of contracting for availability (CfA). Some disadvantages have been identified in ensuring commonality of sub equipment types, and supply chain complexity for IT-support solutions. Industry value needs to be focussed on engineering rather than logistics movements, as MOD needs to be able to maintain control of the key aspects of the supply chain.
Through-life engineering services value propositions There are a number of support options, with varying degrees of industry penetration and levels of complexity of the platform. These range from 'beyond CfA' in which MOD buys the whole capability right forward into theatre across all DLODs,[8] e.g. ship drone manned and managed by contractors, through CfA with hourly or daily models, to 'contract for logistics support' (effectively a manpower contract), and contracting for information.
Through-life engineering services capability development Priorities include: establishment of a common defence taxonomy across industries; open standards; supply and engineering skills; and IT coherence and standards.
Enablers A standards-setting body for support across the TES spectrum and a benchmarking hub with a reference body to create open standards which would facilitate the engagement of SMEs.

[7] Information, surveillance, target acquisition and reconnaissance

[8] Defence line of development

Aerospace

Potentially all air transport could be provided under TES-enabled business models. Already 40% of new sales (and hence aftermarket) are to leasing companies. Aircraft manufacturers are likely to move more into MRO to take share from third-party suppliers. (National data includes defence air.) **Potential penetration estimate**: 70%–90% GVA* (Note(*) with Space)
Market assessment data + supporting commentary+ illustrative examples (actual and possible) *Timing of development*: Presently approximately 40% (based on lease sales) and likely to rise steadily *Commentary*: Estimated potential penetration 2025 of 70% assumes the trend towards leasing continues and OEMs increasingly offer through-life propositions. TES concepts are well known in the industry, which is potentially a supplier of TES: all GVA is generated by complex engineering products, with 40% of all aircraft sales to leasing providers. *Examples*: Significance of leasing models in new aircraft sales; Rolls-Royce Power-by-the-Hour.
Global needs and opportunities It might be anticipated that aircraft manufacturers will increasingly adopt TES offerings themselves to attack the market share of independent MRO providers, with whom competition is fierce. Growth is rapid, particularly in developing markets. Whilst UK aerospace companies have the opportunity to benefit from this global growth, increasing competition especially from the emerging economies may limit this – although this threat is offset by increasing pace of technological advance.
Through-life engineering services value propositions There is considerable strength in the service model. Finance is not an issue, as evidenced by the preponderance of leasing, and new models may emerge. MRO often moves offshore as an offset in developing markets as OEMs seem to offer this first as opposed to setting up local manufacturing operations. Independent MROs are being squeezed. Expected higher margins might lead OEMs to offer 'capability' contracts to lock in airlines.
Through-life engineering services capability development Whereas top-tier suppliers are investing significantly, for example in building the necessary skills, lower tier supplier investment is presently seen as inadequate. Growth will be driven through technological innovation; for example, data analytics, robotics and advanced materials have the potential to transform aircraft maintenance and repair.
Enablers The TES strategy should encourage and support the growth of expertise within the UK aerospace supply chain and industry should continue to take advantage of opportunities to access government support where available and appropriate.

Space

Satellite applications in the UK – growing rapidly with target of £40bn contribution to UK economy by 2030 – may be regarded as fully based on TES. Whilst equipment is a major part of balance sheets this is invisible to the information and communications service users. **Potential penetration estimate:** 70%–90%* GVA (Note(*) with aerospace)
Market assessment data + supporting commentary+ illustrative examples (actual and possible) *Timing of development*: There are ambitious growth plans to take the UK to 10% of global share in satellite applications by 2030. *Commentary*: The sector is a service provider – the equipment, whilst dominating the balance sheet of most companies, is invisible to the user of the services provided. Space contribution to the UK economy is £11bn, of which 'Direct to TV' services (for example Sky), which contributed approximately £6bn to the UK economy in 2012/13. There is a national target to achieve £40bn through new satellite applications by 2030. Large high value platforms (geostationary orbits) are multi-decade programmes with repurposing through software changes. Satellites are built to high standards and often outlive their design life. Micro satellites have very different economics, but both offer repurposing through software upgrade either by design or adaptation. UK satellite activity is entirely private sector. *Examples*: Clyde Space offer bespoke 3U CubeSats tailor-made for around £200,000, with equivalent cost of launch (in round numbers).
Global needs and opportunities Rapidly reducing cost (and size) of getting into orbit; repurposing/flexibility by design. As smaller satellites grow in number (and are used in 'constellations') the opportunity might arise for 'renting' value propositions without the significant up-front investment for current high orbit (equipment cost 10 x turnover). 'Space port' plans to encourage UK launch capability development.
Through-life engineering services value propositions 1) Remote sensing: small satellites in low Earth orbit are low cost, with strong UK presence (initial models based on knowledge transfer projects are moving to turnkey design to mission and sometimes operations); 2) telecommunications: either owner service providers – e.g. Inmarsat– or capacity renters – e.g. Avanti; 3) navigation: these are national with institutional owner operators.
Through-life engineering services capability development Remote monitoring and control (TTNC – telemetry, tracking and control). Transferring data management skills into the space sector and using space data for new applications. Business model skills are already well developed.
Enablers Development of skills in STEM, which is a common need across a number of industries.

Automotive

While new car stock is extensively enabled for TES and leasing is increasingly common, the term is not in common use and individual users need to approve data extraction. New 'mobility as a service' offers based on autonomous vehicles are likely to have penetrated the market extensively by 2025. **Potential penetration estimate**: 20%–90% GVA
Market assessment data + supporting commentary+ illustrative examples (actual and possible) *Timing of development*: Presently at a low level, rising steadily over the period. *Commentary*: Automotive industry supplies complex engineering equipment and is presently a user of TES. However, although elements of the concept are practised, this is not in name. New top-end vehicles have the necessary sensing and data. However, the onus is on the manufacturer to ensure there are adequate data protection measures under the current EU data protection framework, but on the customer to authorise the collection of data as part of using certain in-vehicle applications. New service models are arising through autonomous vehicles which will lead in time to the sector being a provider of TES as car ownership falls. This will be a global phenomenon, particularly in urban areas. *Examples*: 'Mobility as a service' concepts under development.
Global needs and opportunities Improved maintenance and lifetime costs; growing share of vehicle leasing compared to ownership. New service models associated with autonomous vehicles.
Through-life engineering services value propositions Increasing lease of new vehicles is occurring now in the private sector. New business models are required for 'mobility as a service', but, presently, profitable options remain to be found. It is likely the UK offer will be focused on test and deployment of connected and autonomous vehicles.
Through-life engineering services capability development Developing and implementing the technology for autonomous vehicles. Building necessary business models.
Enablers For widespread exploitation of increasingly available service and performance data user education and 'hearts and minds' will be required. Autonomous vehicles will require intervention in the enabling environment, e.g. LTE 4G coverage, possibly 5G coverage and new insurance liability frameworks. Data and privacy protection arising from the use of telematics, dongles and black boxes for usage-based insurance cannot be guaranteed by manufacturers; drivers install these devices at their own risk.

Rail

TES is the common way in the UK today, driven by privatization and growing internationally – where there may be major opportunities linked to infrastructure investments. UK providers will need to continue to advance their capability to maintain share and win internationally. **Potential penetration estimate**: 70%–100% GVA
Market assessment data + supporting commentary+ illustrative examples (actual and possible) *Timing of development*: TES-based business models have been the norm since privatization. *Commentary*: UK leads in service-based rail delivery, although other countries in Europe are changing, even in state-owned rail networks. UK suppliers need to continue to advance and adopt new approaches to avoid getting caught up by the competition. *Examples*: Rail franchise bidding and associated ownership models.
Global needs and opportunities Growth will be extensive in the developing world, with large integrated infrastructure opportunities arising on a 'once-in-a-lifetime' basis. UK has an opportunity to gain significant export advantage with its reputation for technical excellence and leading practice in TES-based services for rail.
Through-life engineering services value propositions TES-based equipment + service and support contracts are the norm in the industry, indeed a commodity in the UK. The next generation of value propositions needs to encompass more collaboration both vertically in the supply chain, and horizontally between potential competitors – particularly as regards responding to the large-scale international opportunities which will arise in developing-country infrastructure expansion.
Through-life engineering services capability development Skills need to develop as technology develops much faster than the asset lifecycle and constant upgrades are required. Prognostics and data collection, analysis and exploitation are vital and remain 'work-in-progress'.
Enablers Continue with the engineering skill set at early-stage careers. The UK needs to retain its reputation for leading technical skills.

Marine

Manufacturing in this sector is largely for the defence market, and here there is and will be penetration of TES through MOD procurement practices. Opportunity exists to develop more mature practices through learning transfer from aerospace and the civil marine support sector. **Potential penetration estimate**:10%–40% GVA
Market assessment data + supporting commentary+ illustrative examples (actual and possible) *Timing of development*: Presently perhaps 10%–15% penetration, rising steadily over the period. *Commentary*: Marine manufacturing in UK is largely defence. Service and support also include the commercial and cruise markets. The sector is relatively immature in current practices, with defence lagging civil. UK practice may be ahead of other countries with the possible exception of USA. *Examples*: Babcock 'Phalanx' availability contracting; Devonport dockyard operations contracts.
Global needs and opportunities TES already adopted at a relatively immature level but more complex asset management will be driven by reducing customer (e.g. MOD) budgets, supported by availability of information (e.g. condition monitoring).
Through-life engineering services value propositions Availability contracting. Whole dockyard provision. Design and technical authority for smaller companies in an ecosystem, as a support agent with widening umbrella. Fully integrated asset management might be regarded as the most mature business model. License fees might replace manufacturers' supply where remote AM is possible.
Through-life engineering services capability development Understanding of usage and conditions in support of preventative maintenance. Use of additive manufacturing for repairs. Big data – ability to process a large amount of data. Use of information for predictive maintenance and to drive long-term design improvements. Integrated logistics support with prediction, delivery and ERP[9] systems linked up. In the most mature case the monitoring system would recognize the potential for failure, understand BoM[10] and lead times and automatically order. Artificial intelligence can address this as the rules are relatively simple but many and there are many items of equipment to consider.
Enablers Learning transfer from e.g. the aerospace sector. Defence may also learn from civil marine.

[9] Enterprise resource planning

[10] Bill of materials

Marine defence – submarines

UK providers will need to continue to advance their capability to maintain share and win internationally. Manufacturing in this sector is largely defence, and here there is and will be penetration of TES through MOD procurement practices. Opportunity exists to develop more mature practices through learning transfer from aerospace and the civil marine support sector. **Potential penetration estimate:** 10%–40% GVA
Market assessment data + supporting commentary+ illustrative examples (actual and possible) *Timing of development*: Elements of TES are in place through the service contracts, but any change to 'full TES' arrangements would only occur through e.g. the Successor programme. *Commentary*: The industry is providers of TES to MOD. The MOD equipment budget is £4bn pa for subs, split 50/50 supply and support across all DLODs, some but not all of which are amenable to TES offerings. *Examples*: Presently design and build and in-service support are separate from design. Build and support integrated only for the power system.
Global needs and opportunities For the complex systems and equipment in this area traditional supplier arrangements cannot keep capability at the level it needs to be or keep pace with the required change. Some change to the arrangements is required to sustain necessary capability.
Through-life engineering services value propositions There will be a need for more alliance-type models with interested parties working to the benefit of the enterprise, including MOD working more closely with the suppliers. This could happen on Successor.
Through-life engineering services capability development Enabling technologies such as data and the skills of those staff who use and interpret the data. There is a lack of prognostics and diagnostics and of understanding of what to do with feedback data, understanding trends. There is limited exchange between enterprise partners.
Enablers Clarify the boundaries between the players. The MOD is presently the design authority but this may change. Changes will occur around the implementation of major programmes, for example Successor.

Energy

With focus on renewables (particularly offshore wind), penetration of TES might be achieved by transferring expertise from the oil and gas sector. Present economics leads equipment to be 'used once' and replaced. **Potential penetration:** 0%–90% GVA
Market assessment data + supporting commentary+ illustrative examples (actual and possible) *Timing of development*: Presently £3bn/year, growing as renewables grows. Estimated potential is £5bn a year by 2025 for renewables. *Commentary*: This sector includes renewables (onshore and offshore wind, solar etc.) and coal- and gas-fired generation. There is a scope for a through-life offering particularly in offshore wind where sub-sea expertise may be transferred from the oil and gas sector. The sector (including offshore wind) is a user of TES. Offshore wind has perhaps 60% of output based on complex equipment. *Examples*: There is potential to develop combined power generation and local heating solutions, possibly in small packages for schools, hospitals, factories and other institutions.
Global needs and opportunities Technology advances quickly and older machines are not life extended but replaced, driven by economics. The reduction and removal of subsidies for the renewables sector is focusing attention strongly on costs.
Through-life engineering services value propositions • Ownership of capital assets by a bank or government • Operated and/or maintained by third parties • Technology vendor leasing to an operator
Through-life engineering services capability development Better business models and improvements in design life of wind energy are needed.
Enablers All technology and IP comes from overseas: there is presently no domestic capability (Vestas, Siemens).

Nuclear

New build offers/requires radical new business models. Small modular nuclear offers significant opportunity for TES. **Potential penetration:** 30%–60% GVA
Market assessment data + supporting commentary+ illustrative examples (actual and possible) *Timing of development*: May grow from current £0.5bn to up to £2.0bn as new builds come on-stream. *Commentary*: Whilst in the existing fleet there may be little scope for TES, in new build the opportunities may be substantial. The sector would be predominantly a user of TES with all outputs attributable to complex equipment. *Examples*: Current business models under development for the new nuclear build are highly complex with different arrangements at different stages in the lifecycle.
Global needs and opportunities The industry is based on long-term partnerships and relationships. Technology has been unique to each site and therefore a TES solution is valued. Prime considerations are the reduction of risk and minimizing planned outage windows for maintenance. The industry lends itself to a trusted maintenance provider and long-term relationships. Longer term focus on micro and small reactors.
Through-life engineering services value propositions • Ownership of capital assets by a bank or government • Operated and/or maintained by third parties • Technology vendor leasing to an operator
Through-life engineering services capability development Capability to make the biggest forgings is lost in the UK. For the Small Modular Reactor we may have the capability but not the capacity. Reactor IP is no longer held in the UK. There will be a bottleneck of skilled people especially sector technical experts.
Enablers Career structure and appropriate training for sector technical experts. Embed UK people in any construction and development programme to reduce our dependency on foreign know how – not just in the science but also in the practical aspects of creating the solutions.

Oil and gas

UK has leading capability in this sector, for example underwater vehicles, which could offer significant opportunities for TES. Gain share MRO contracts may already be common. **Potential penetration**: 30%–100% GVA
Market assessment data + supporting commentary+ illustrative examples (actual and possible) *Timing of development*: Development may depend on the price of oil. *Commentary*: Primarily a user of TES. Key capability in this sector, such as remote underwater guided vehicles, could with the current downturn in oil and gas be employed in offshore wind. Output of the sector is completely based on complex equipment. Take up could increase with the low price of oil and sector consolidation. *Examples*: Not discussed
Global needs and opportunities Significant restructuring likely in the aftermath of the collapse of the oil price.
Through-life engineering services value propositions • Ownership of capital assets by a bank or government • Operated and/or maintained by third parties • Technology vendor leasing to an operator
Through-life engineering services capability development Shrinking, with potential for some transfer of skills.
Enablers • Encourage repatriation of the diaspora of skills in the industry worldwide to train new generations of engineers • Identify where their key skills are transferable to other sectors and focus on those where there is true growth potential

Built environment

TES concept is similar to 'whole-life costing' adopted in the industry. Moves towards modular construction and smart buildings offer the opportunity for TES in both supply and use. Government has a significant proportion of the national spend. **Potential penetration**: 5%–50% GVA
Market assessment data + supporting commentary+ illustrative examples (actual and possible) *Timing of development*: May build successively over time from a low base, if supported by government action/stipulation in public procurement. *Commentary*: Equates to the industry concept of 'whole-life costing' which is seen a potentially very significant opportunity. However, no attempt has been made to put a figure on the value other than 'it is large'. The industry could be both a user (modular construction) and supplier of TES (smart buildings). *Examples*: Hospital design, build and run contracts. PPP outcomes may give better value for money if TES principles were applied.
Global needs and opportunities For large public construction projects there is a real problem or mismatch between design and functionality with the outputs not working as required on handover and proving difficult to maintain without significant disruption.
Through-life engineering services value propositions Highly fragmented market with major element of public procurement, looking for/needing new procurement models with improved value for money.
Through-life engineering services capability development Designing/building for optimum use and whole-life cost, and maintaining the building with utility and whole-life cost in mind.
Enablers Because of the fragmented nature of the industry there is no strong track record of industry-funded research and development initiatives with the industry generally looking to government for leadership.

Machinery manufacture

TES offers a significant opportunity for this sector, which has a high proportion of SMEs. While there are examples today, penetration will be dependent on OEM pull and increasing offer of service-related value propositions. **Potential penetration**: 10%–40% GVA
Market assessment data + supporting commentary+ illustrative examples (actual and possible) *Timing of development*: Already starting from a low base but will be user driven. Client sectors could switch suddenly based on e.g. software industry examples. Therefore TES penetration 2025 could be higher than 10%–40%. *Commentary*: The sector has a high proportion of SMEs and will primarily be a supplier of TES services. A high proportion of the output is complex equipment and much of it has an increasing amount of software as part of the value proposition. This increasing software proportion makes residual values hard to establish and encourages the shift to TES. There is evidence that overseas competitors are moving ahead in this area. *Examples*: • There are a number of providers of turnkey service solutions e.g.: ETG (Engineering Technology Group- http://www.engtechgroup.com) • There are reports of significant reductions both in cost and time to market.
Global needs and opportunities If not adopted there will not be a business in many target markets. Depending on the appetite of the relevant users this will come quickly. As an example, the software business has changed very rapidly.
Through-life engineering services value propositions These will, and in some cases already do, range from equipment leasing to 'output contracts'. New models will provide more even risk share and better matching to the demand pattern.
Through-life engineering services capability development The industry possibly lags others in take-up of the principles because of a traditional approach amongst SMEs – positioning themselves as offering equipment and spares supply as opposed to hiring/leasing-based business models.
Enablers If OEMs need to set the pace down the supply chains, SMEs will adjust their mind set and exploit new financing approaches available. The financial community is seen as coming to understand the opportunities. The Catapults have a role to play bringing suppliers together with OEMs to get pilots and demonstrators together and building education, but with a strong focus on business models and mindset change. New IPR exchange rules are required to encourage the necessary information exchange throughout the value chain.

Chemicals

Contract maintenance is common in the industry. Downstream and specialist and emerging markets (e.g. biorenewables) may benefit from TES. TES may benefit NPI through offering shared access to capital equipment. **Potential penetration**: 30%–50% GVA
Market assessment data + supporting commentary+ illustrative examples (actual and possible) *Timing of development*: Contract maintenance of large kit is very common, and these approaches are probably being adopted there already. *Commentary*: Most of the sector output is based on complex equipment. Wholesale outsourcing of processes in bulk petrochem is unlikely, but in plant maintenance it is very common. Applications in support of emerging markets and new product development and niche and downstream applications would offer a powerful proposition. *Examples*: Bio fermenters even on the small scale are expensive and as alternative financing becomes available, there would be distributed manufacture.
Global needs and opportunities Enhancing the business case for capital investment in innovation and NPI including industrial offers and match funding. The sums involved are significant.
Through-life engineering services value propositions The ability to rent rather than buy may be an attractive proposition for NPI – leasing to consortia might be a useful catalyst for clustering, which would be supportive for supply chain development.
Through-life engineering services capability development In 'hi tech' applications, understanding is required of how to manage the supply and variable feedstocks etc. so that combining the lease and maintenance of equipment with operational knowledge will be key. Gaps include new contractual models, but effective TES technical capabilities are well established and understood, particularly amongst the global players, although they may be less well developed in smaller companies.
Enablers Good fit with the Chemistry Growth Partnership (http://ukchemistrygrowth.com/Home.aspx) strategy. Promotion of the concept may suffice – however, market failures might occur through an asymmetry of knowledge both in terms of potential providers and purchasers. Cont./

Chemicals – biorenewables

Potential penetration: 80% GVA
Market assessment data + supporting commentary+ illustrative examples (actual and possible) *Timing of development*: immediate – this is happening now *Commentary*: Potentially the sector, which is just getting off the ground, could be a big user and supplier. Equipment is essentially complex and expensive. *Examples*: • Some companies in the sector are selling products to boost the value of biogas yield with gain share on the benefits • Michelin is providing high quality bio-based products and is moving to renting tyres • Johnson Matthey is a current example – they do not sell a catalyst but 'rent' and recover at the end of life for re-use • Mobile equipment for primary separation for de-watering
Global needs and opportunities Greener products, end of life re-use, and legislation for no organic waste to landfill is on the horizon. Following on from the focus on energy costs the latter is increasingly important.
Through-life engineering services value propositions Joint ventures, shared services, mobile equipment fleets, 'built-in recycle' propositions, equity arrangements.
Through-life engineering services capability development • The sector needs a multidisciplinary approach including biology, chemistry, engineering • Development of new business models • Ability to gather, interpret and act on large volumes of performance data as the market grows • Gaps: Bring TES expertise together with this sector in order to support growth. Link TES thinking into the sector strategy
Enablers Policy development for the biofuels sector to give a long-term stability to encourage investment. We are lagging in UK in investment because of changes in policy.

Electronics and ICT

This is a very diverse sector involving electronic systems and components. UK manufacturing in this sector is generally high value. TES is broadly applicable in electronics although the industry is not mature today, with significant obsolescence issues. ICT is highly TES-applicable, with a significant uptake already in, for example, computing services. **Potential penetration**: 15%–90% GVA
Market assessment data + supporting commentary+ illustrative examples (actual and possible) *Timing of development*: The estimated potential penetration by 2025 is moderate-high as a producer of TES-sensitive products (electronic components, rather than products, are perhaps not, but are a small percentage of the overall sector). ICT is inevitably high, with the focus on integrated. Timing is not clear, but the initial trajectory is clear, as below. *Commentary*: The electronics sector deals with manufacture of components and systems in the supply chain. The interviewee was aware of the 'TES concept' and 'power-by-the-hour' as a classic example of TES and servitized manufacture. However, this supposition is not common in electronics sector, where the focus is on innovation of new (consumer) product – with an industrial perception of TES influenced by 'make-do-and-mend' and a long-term issue of component obsolescence. However, the direction of travel is clearly that electronic products become or support a service – for example the incomplete product that is a smart phone supporting communications services, or wearable technology. The Waste Electrical & Electronic Equipment Directive is also relevant, increasing the need to properly consider sustainability and disposal. Collaboration is also a growing trend.
Global needs and opportunities The UK is strong in design and systems, key components of TES. We focus on high-value, mostly complex products.
Through-life engineering services value propositions 'The importance of TES is a reasonable proposition' given UK focus on design, systems and high-value products.
Through-life engineering services capability development Component obsolescence – currently under development
Enablers Better measurement of TES?

Annex 2: Interview Framework

The interview combined general discussion questions with ones designed to explore market size.

General discussion

- Is this concept something of which you are aware influencing how business is done either in your sector or others?
- How important is TES potentially in the sector, looking out to 2025?
- Would you see the sector as primarily a user or provider of TES, or both?

Market size

- For the sector in question could you suggest the current % of your GVA outputs which may be attributable to TES now and in 2025
- What percentage of this sector's activity do you consider to be based on the design, creation and/or use of complex engineering products?
- What percentage of the total world market in this sector would you expect to be accounted for by companies who have adopted or use TES-enabled strategies by 2025?

Annex 3: Steering Group Membership and Programme Collaborators

Steering Group[11]

Dave	Benbow	Rolls-Royce	Chair
Phillip	Cartwright	HVMC	Chair
Andy	Harrison	Rolls-Royce	Member
Vaughan	Meir	BAE Systems	Member
Alan	Murdoch	BAE Systems	Member
Clare	Marett	BIS	Member
Rajkumar	Roy	Cranfield University	Member
James	Selka*	Manufacturing Technologies Association	Member
Rob	Cowling*	Bombardier Transportation	Member
Steve	Foxley	Siemens	Member
Richard	Drake*	Babcock International	Member
Andrew	Cannon-Brookes*	MOD	Member
Neil	Barnett*	ADS	Member
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Andy	Neely	IfM Cambridge University	Member
Neil	Bowering	EPSRC	Member
Tim	Baines	Aston University	Member
Laura	Smith	CBI	Member
Andy	Sellars	Innovate UK	Member
Michael	Folkerson	APMG	Member
Chris	White	Member of Parliament	Advisor

External Expert Assessors[12]

Clive Badman	GSK
Neil Barnett	ADS
Barry Blackwell	BIS
Roger Bourne	BIS
Chris Brunskill	Catapult
Andrew Cannon-Brookes,	MOD
Rob Cowling	Bombardier Transportation
Adam Crooke	BIS
Fabien Deswarte	Biorenewables Development Centre
Richard Drake	Babcock International

[11] (*) Asterisk denotes steering group members interviewed for this study
[12] All interviewed

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Ian Harrison	BAE Systems
Siobhan Jones	BIS
Jean Llewellyn	National Skills Academy
Brian Payne	BIS
Phillip Robinson	BASF
Duncan Scott	BAE Systems
James Selka	MTA
Jon Taylor	BAE Systems
Willie Thomson	Harbro
Mark Turner	BIS
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