Institution: Cranfield University		
Unit of Assessment: 12		
Title of case study: Development of PAS 280 for through-life engineering services		
Period when the underpinning research was undertaken: Nov 2017 - March 2018		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	**Role(s) (e.g. job title):**	**Period(s) employed by submitting HEI:**
Prof. John Erkoyuncu	Professor of Digital Engineering/ Head of Centre for Digital Engineering and Manufacturing	2010 –present
Prof Andrew Starr	Professor of Maintenance Systems and Head of the Centre for Life-cycle Engineering and Management	2011-present
Prof Ian Jennions	Technical Director and Professor of IVHM	2008-present
Dr. Pavan Addepalli,	Lecturer in Degradation Assessment	2013-present
Dr Nic Morar,	Research Fellow in Surface Manufacturing	2017-present
Prof Essam Shehab	Professor of Digital Manufacturing	2004-present
Dr. Yifan Zhao,	Senior Lecturer in Data Science	2013-present
Lawrence Tinsley	Research Fellow in Industrial Inspections	2017-present
Prof. Rajkumar Roy	Director of Manufacturing	1996-2019
Period when the claimed impact occurred: March 2018 – December 2020		
Is this case study continued from a case study submitted in 2014? N		

1. Summary of the impact (indicative maximum 100 words)

Cranfield University's research on through-life engineering services has significantly improved the capability and productivity of the UK industry base, relative to international competition. Our researchers led the development of a Publicly Available Specification (PAS 280) document based on their research into TES (the benefits of through-life engineering services for UK industry) and the life cycle of complex engineered assets (CEA - such as planes, ships, and trains). PAS 280 has enabled the pro-active application of TES across industry, to win business, gain market share, generate revenue, and increase profitability; notably **saving** the Ministry of Defence **GBP33,000,000** and **creating 30 new jobs**, and up to **GBP2,000,000 early savings** for Rolls-Royce and BAE Systems seeing "*more cost-effective investment in technologies and a significant reduction in lifecycle costs*".[S4]

2. Underpinning research (indicative maximum 500 words)

Through-life engineering services (TES) are a set of capabilities, techniques, business thinking and network behaviours that, when applied to major assets, optimise their value and cost (e.g. keeping major assets working better, for longer, and more economically) [R1].

Cranfield University first started its research in TES through the EPSRC Centre in Innovative Manufacturing (CIM) in Through-life Engineering Services (2011-2016, EP/I033246/1). The research contributed to formalising the development of the TES marketplace that relies on 'engineering services', which constitutes 16.8% of UK annual GVA [R2].

The research problem centred on the need to gain a better understanding of the root causes of component failure driven by degradation (e.g., corrosion, wear, and oxidation) or other key factors (e.g. no-fault found, risk, and obsolescence). Implications were measured at the component and system level in terms of cost and asset availability.

The research that underpins PAS 280, was generated through four key projects at the CIM TES Centre:

1. The first work of its kind was undertaken on new methods to improve System Design Processes for whole life cost reduction: understanding the full life cycle of complex long-life assets in terms of better planning and cost implications [R3]. This included new analysis of the trade-offs between different maintenance approaches (e.g., corrective, preventive) across the life cycle, considering cost and asset availability outcomes.

2. Further novel methods were developed in coefficient clustering analysis to characterise in-service component feedback for system design [R4], offering innovative ways to characterise component degradation using Non-destructive testing (NDT) methods. This allowed for new approaches to containing the health of assets and initiate early planning for recovery from failures. A degradation knowledge base was developed, which offers a novel way to map the evolution of asset health across its life cycle.

3. The first toolkit in the literature was developed for pro-active reduction of no-fault found (NFF) through system design by applying agent-based modelling to optimise the cost of NFF [R5]. The toolkit outlined the root causes of NFF and developed a new process to estimate costs experienced.

4. A study of cross sector challenges encompassed whole systems design documented the theoretical, empirical, and practical aspects of contracting, managing, designing, leading, delivering, marketing and operating services associated with complex engineering products [R6].

Together these projects developed knowledge, technology and process demonstrators, novel methodologies, techniques, and associated toolsets, providing the capability for the concept design of a coupled whole system based on system design for engineering services

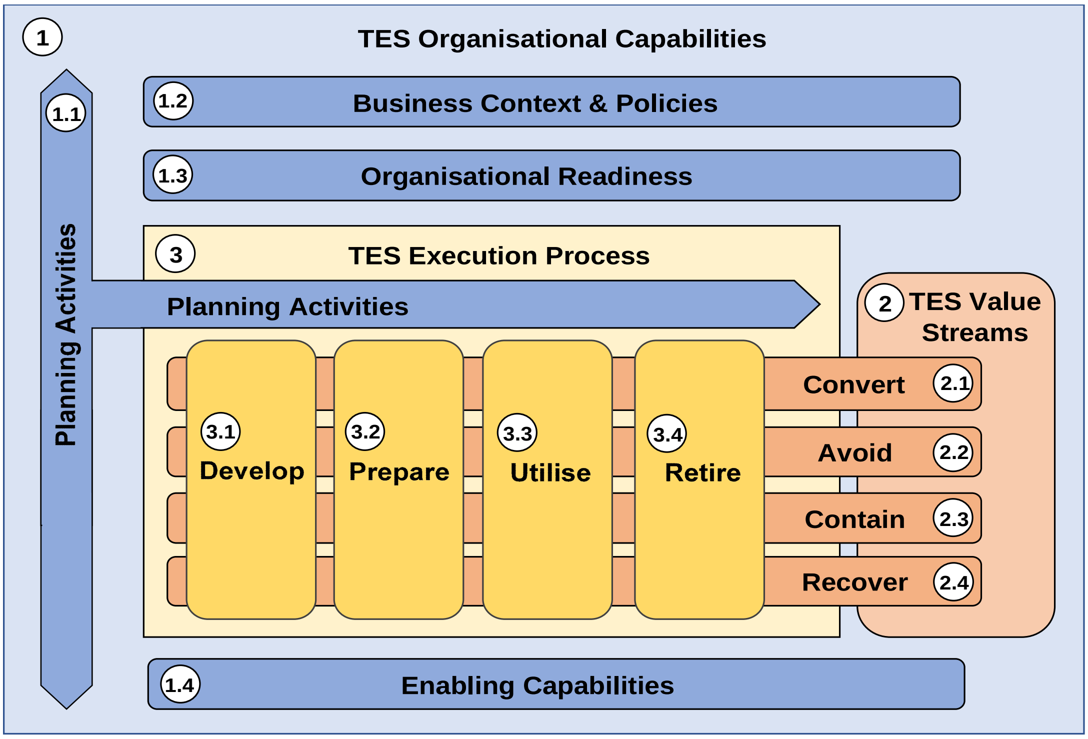

Figure 1: The Common TES Framework – BSI (2018)

Research findings in TES design and implementation were brought together through the development of PAS 280 to create a novel and comprehensive framework to maximise value for all stakeholders over a major engineering asset's lifecycle. The research findings were integrated within a framework that outlined the key functions, which are needed to come together to deliver productive TES. (See Figure 1)

3. References to the research (indicative maximum of six references)

[R1] PAS 280:2018
Through-life engineering services. Adding business value through a common framework. Guide. BSI, https://shop.bsigroup.com/forms/PASs/PAS-28020185/
(See S1 for downloaded guide)

[R2] Roy, R., Shaw, A., Erkoyuncu, J.A. and Redding, L., (2013). Through-life Engineering Services, *Measurement and Control*, 46(6),172-175. Through-Life Engineering Services - Rajkumar Roy, Andy Shaw, John A Erkoyuncu, Louis Redding, 2013 (sagepub.com)

[R3] Roy, R., Stark, R., Tracht, K., Takata, S. and Mori, M. (2016). Continuous maintenance and the future – Foundations and technological challenges. *CIRP Annals - Manufacturing Technology*, 65(2), 667–688. Continuous maintenance and the future – Foundations and technological challenges - ScienceDirect

[R4] Zhao Y., Tinsley L., Addepalli Sri, Mehnen J., & Roy R., (2016) A coefficient clustering analysis for damage assessment of composites based on pulsed thermographic inspection, *NDT and E International,* 83 (October), 59-67. A coefficient clustering analysis for damage assessment of composites based on pulsed thermographic inspection - ScienceDirect

[R5] Erkoyuncu J.A, Khan S., Hussain S.M.F., Roy R., (2016) A framework to estimate the cost of No-Fault Found events, *International Journal of Production Economics*, 173, 207-222 A framework to estimate the cost of No-Fault Found events - ScienceDirect

[R6] TES Strategy Report “A National Strategy for Engineering Services – Delivering UK Economic Growth by Making Things Work Better for Longer, EPSRC Centre for Inventive Manufacturing Through-life Engineering Services (June 2016)

4. Details of the impact (indicative maximum 750 words)

The TES Market Research Study (reported by the Centre for Economics and Business Research in February 2020) assessed the market size and economic impacts of through-life engineering services in the UK from 2018 to 2045, illustrating the financial opportunity and the value of practical guidance to industry. The total market opportunity across industry sectors including energy, transport, defence, construction, and agribusiness for TES in 2018 was estimated at GBP127,200,000,000. This is predicted to reach GBP251,600,000,000 by 2045. [R7]

The British Standards Institute (BSI) commissioned Professor John Erkoyuncu to lead the preparation of a Publicly Available Specification (PAS) document on TES between November 2017 and March 2018. The PAS 280 offers guidance to leaders in UK industry, enabling manufacturing and solution providers in all sectors to win business, gain market share, generate revenue, and earn profits from the proactive application of TES. [R1] [S1]

PAS 280 has been implemented by major organisations and industrial companies:

Ministry of Defence (MOD), UK

The Ministry of Defence embarked on a four-year programme to apply PAS 280 thinking into practice, ‘Forecast & Resource Planning’ (F&RP), represented more than GBP50,000,000 in assets.

The MoD implemented PAS 280 to focus business process improvements across Defence Equipment Support. PAS 280 helped to focus the improvement in an internal team and created in excess of **30 new jobs** as Defence Equipment Support change consultants.

Significant initial financial benefits (e.g., less spare part usage) and non-financial benefits (e.g., improved customer satisfaction) have been realised from improvements in integrated business planning processes. PAS 280 has meant a clearer understanding of the link between the business opportunity in terms of cost to the customer, and profitability to the supply chain, including the associated delivery of support services (e.g., spares and resources), leading to a reduction in waste.

> "*Initial gains have been reported…. in the area of helicopters and related equipment… This initial, interim benefit of* ***GBP33, 000,000*** *has already been delivered. Additional financial benefits in excess of* ***GBP300,000,000*** *over a ten-year period have been identified across an additional 4 Equipment Types". (*F&RP ESCIT Deputy Head, MoD) [S2]

Rolls-Royce

Rolls-Royce is currently evaluating the impact of PAS 280. Early figures suggest a realisation of up to **GBP2,000,000** improvement in costs, within the REF impact period, (for delivering the same, if not better, level of asset performance) from ongoing Rolls-Royce projects.

All improvement programmes in Rolls-Royce are now evaluated according to their impact across the PAS themes, establishing a common language for TES. This has enabled capability mapping across Rolls-Royce global sectors and teams in line with a common framework. PAS 280 has reduced duplication of effort and under-investment in capability (e.g., over-purchase of spare parts)

The company's 'Engineering for Services' function capability strategy is now organised around PAS 280 (avoid/contain/recover breakdown), representing a significant change in business processes [S3].

> *"The ability to understand the future cost impact of current design decisions is pivotal to exerting an influence over the design at the point in time when the design is open to change."* (Engineering Fellow, Rolls-Royce) [S3]

BAE Systems

PAS 280 is being used as a common language and framework across the Though-Life Services element of 'Team Tempest'. The Tempest programme is a multi-billion pound UK partnership that brings together core partners BAE Systems, Leonardo UK, Rolls-Royce, MBDA UK and the MoD (https://www.baesystems.com/en/the-future-of-combat-air). The partnership is working to generate the technologies and experience required for the UK to lead development of a next generation combat air system.

A technology prioritisation toolkit - outlining TES value streams and support activity assets - has been used on the Tempest programme to inform decision-making over which technologies should be invested into.

> *"The toolkit means there is a more effective mechanism to identify and prioritise the technological landscape;* ***more cost-effective investment in technologies*** *used to support a future combat air system; and a* ***significant reduction in lifecycle costs***

relating to inbuilt technologies within the support solution. The total amount of benefits is yet to be measured". (Technical Manager R&T, BAE Systems) [S4]

The PAS framework has been used to gain a common understanding of TES principles across the Tempest Consortium, reducing the time and effort of getting individuals to the same point and facilitate change.

"… practical delivery (of PAS 280) has been fully supported by the research undertaken by the Cranfield Team …. A valuable contribution directly contributing towards the UK Prosperity Agenda" [S2]

5. Sources to corroborate the impact (indicative maximum of 10 references)

[S1] To demonstrate the key role of Cranfield University in the technical development of the - PAS 280:2018 Through-life Engineering services- Adding business value through a common framework - Guide

[S2] F&RP ESCIT Deputy Head, MoD

[S3] To demonstrate the contribution of PAS 280 to the growth of investment in key capabilities and the accelerated realisation of the benefits – Rolls-Royce Engineering Fellow – Service System Solution & Global Chief of Transformation

[S4] To demonstrate the use of PAS 280 in 'Team Tempest' multibillion pound partnership to reduce time & effort and facilitate change - Technical Manager R&T, BAE Systems