Delivering the UK MoD's support DEAM

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Synopsis

The Royal Navy has an increasing number of standing commitments coupled with resurgent peer state aggressors. It is having to achieve more with the finite number of vessels it has at its disposal and is currently forward deploying complex assets. A key tactic in ensuring that these commitments can be met is by measurably increasing the availability of current in-service platforms for tasking. Central to this is the critical analysis and improved "up-time" of a small number of key, complex engineering systems.

These systems, and by result, the platform, can be kept in a high state of availability through a variety of methods. Last year, a Type 23 platform forward deployed in the Middle East and supported by Babcock, achieved record levels of availability at over 98%. However, balancing the requirement for availability against reducing defence budgets is key. The Royal Navy and other global operators are turning to digital tools to achieve this increase in availability in the most cost-effective manner possible.

Helping the Royal Navy deliver this vision, Babcock has recently deployed the Digitally Enabled Asset Management (DEAM) toolset in support of a Type 23 frigate during a 2021 deployment. Babcock's DEAM was configured to collate and trend data, monitor usage against a baseline and deliver recommendations relating to the use of the newly installed MTU based power generation system on board the vessel. This enabled the user to actively monitor generator usage in order to optimise equipment maintenance regimes and maximise system up time whilst minimising spare parts consumption and actively manage equipment time between overhauls.

Babcock are currently investigating developments of this technology to incorporate further systems and de-risk the introduction of digital tools and technology on board vessels that will be transitioned in to service in the near term. This paper discusses the customer demand, technical requirement and process of developing the toolset; culminating in the successful deployment of DEAM on deployment. Lessons learned and future development ambitions are discussed, alongside exploration of future applications on board Babcock's AH140 type vessels i.e., Type 31, future Type 26 vessels, or indigenously designed vessels for foreign navy programmes.

Keywords: Digitally Enabled Asset Management, Condition Based Maintenance, Life Models, Availability, Marine Systems

Biographies

William Edge is the Senior Engineering Manager within Babcock's Future Programmes team, having joined the company in January 2021. William has experience in the design, integration, and support of a range of marine engineering systems having spent time working on major UK and international naval programmes for both Thales Naval and Rolls-Royce. William is a Chartered Marine Engineer and holds both an MSc and a BEng in Marine Engineering from Newcastle University.

Michael Fox is a Senior Supportability Engineer working on the in-service support solution for the Type 26 Frigate. Michael joined Babcock on their engineering graduate scheme in 2015 before spending time in the Warship Technical Authority being responsible for the design intent of complex warships based in Devonport. Michael is an Incorporated Engineer working towards an MSc in Systems Engineering Management at UCL and Chartered Status with the IMechE.

1. Introduction

The Royal Navy (RN) currently has 18 front line combatants in the fleet comprising 12 Type 23 frigates and 6 Type 45 destroyers. These vessels are a complex, integrated network of systems and equipment which deliver both a peacetime and warfighting capability (Royal Navy, 2022).

The availability of a small number of critical systems underpins the RN's ability to deploy these assets. Subsequently, when considering a sharp, short-term increase in operational requirement, which cannot be met through the construction of additional hulls, the most feasible solution in deploying an increasing number of vessels to sea is to improve the availability of current vessels via the key systems that enable the vessel's Fight, Move and Float functions (Gilbert & Stevens, 2009).

As alluded to in the challenge laid down by International Naval Engineering Conference and Exhibition 2022, emerging technologies such as autonomous systems and artificial intelligence is one option that can generate new approaches to maintenance and repair to build resilience through assured availability. Advances in digital technology during the past decade has enabled better exploitation of data and information, from a wide variety of sources that can be collected during the design, manufacture, operation and maintenance of a range of key systems onboard these vessels. This data can then be leveraged to derive useful information that can result in the proactive management of equipment, systems or platform material state in order to maximise whole ship availability through recommendations for maintenance or operational procedure modification.

In a desire to support the RN in tackling challenges to ‘Availability, Sustainability and Lethality’, as identified in the RN’s support transformation programme, Project RENOWN (DE&S, 2022), Babcock have looked to leverage these developments in digital technologies as a member of the Surface Ship Support Alliance (SSSA). The SSSA was formed in 2009 between the UK Ministry of Defence (MOD), Babcock and BAE Systems and introduced a range of commercial innovations that revolved around a “risk and reward” incentive; linking vessel availability to financial reward (Ford, Rowley, & McMahon, 2014).

As such, innovation that results in increased platform availability would enable delivery against the aims of Project RENOWN, with the RN operator benefiting from increased platform availability via a range of digital toolsets. The pilot toolset was the ‘Digitally Enabled Asset Management’ (DEAM) programme. This forms a key component of Babcock’s Technology Strategy being deployed under a digital and technology programme named ‘iSupport360’ (Babcock, 2021).

This paper describes the scope and creation of the DEAM tool and discusses the experience gained from utilising this tool for the benefit of a Type 23 vessel during a recent Carrier Task Group deployment. Requirements capture, project implementation and lessons learned are discussed, alongside exploration of future applications on board AH140 type vessels, future Type 26 vessels, or indigenously designed vessels for foreign navy programmes.

2. Finding the ideal case study: Type 23 Power Generation and Machinery Control and Automation System Upgrade

Historically the ability to undertake DEAM has been constrained by a number of factors. Key to this is the challenge around monitoring key systems, in particular, capturing data and then exporting this data off the platform to allow for the information to be interrogated. This is particularly notable for legacy platforms and systems that were designed before the advent of the digital age.

The Type 23 Life Extension (LIFEX) and Power Generation and Machinery Control and Automation System (MCAS) Upgrade (PGMU) programmes for the RN’s Type 23 vessels provided an opportunity to remove these barriers. Babcock is the prime contractor for the system design and integration lot of the Type 23 PGMU programme in addition to being awarded the contract for the Type 23 LIFEX programme.

During these programmes a range of updates have been incorporated into the Type 23 platform in order for the vessels to maintain their military relevance. Central to the LIFEX programme was a range of capability upgrades to the main radar, sonar systems, combat management system and point defence missile system which, alongside through life updates and the extension of vessel life from its design requirements have contributed to the erosion of platform power generation margins.

At build, the Type 23 frigates were fitted with 4 Paxman Valenta VP12 RP2000CZ Diesel Generator sets powering a Combined Diesel Electrical and Gas (CODLAG) propulsion plant. In order to restore electrical power generation margins new diesel generators would be fitted. This was also an opportunity to improve Diesel Generator availability and address obsolescence issues within the MCAS. The resulting PGMU programme sought to integrate 4 new 1.64MWe MTU 12V4000M53B diesel generator sets in addition to the rework of the ships low voltage power distribution system and provide an update to the Rolls-Royce VTAS MCAS system, as shown in Figure 1. These updates meant the vessels were an ideal candidate for a digital technology demonstrator.

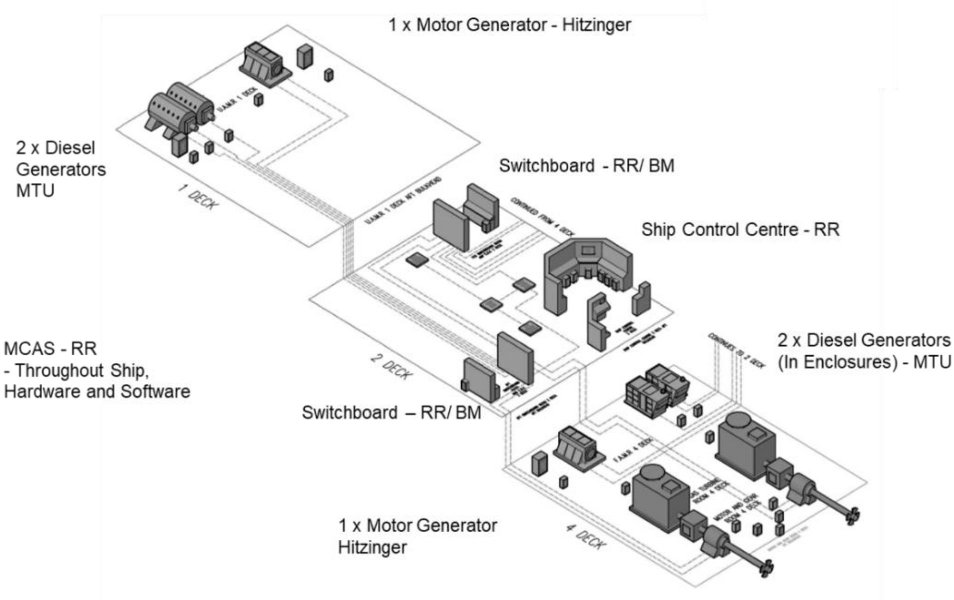

Figure 1: Type 23 Frigate PGMU Overview

The introduction of MTU 4000 series diesel generators from Rolls-Royce Power Systems provided a digital data source. The power units feature a range of on-unit transducers which monitored a range of prime mover parameters such as unit power output, running hours and condition-based monitoring capabilities. When paired with the data logging capabilities of the updated Rolls-Royce VTAS system it was deduced that the system could be easily interrogated for operational data of the power units, their health, and the overall performance of the vessel's 600V power generation system. Given the equipment and systems procured for the PGMU programme featured these sensors and data capture capabilities inherently – that is to say, without costly modification from the Original Equipment Manufacturer (OEM) or a third-party, the case for harnessing the data from this system was compelling.

Additionally, due to the power generation and propulsion arrangement of the vessel, this system provided electrical power for both ship services, combat system loads and propulsion power making it a compelling 'critical' system to monitor. The subsequent introduction of monitoring and trending tools on this system would also serve to 'de-risk' the overall installation of 'new to RN' equipment on board the vessel during its commissioning, trials and maiden deployments.

Babcock are responsible for the physical and functional integration of the entire PGMU scope; delivering an integrated solution to the UK RN Customer. Work commenced on the first of class in 2017 and the vessel is now back at sea having undertaken operations as part of the UK RN Carrier Strike Group 2021 deployment.

3. The DEAM Project

DEAM is envisioned to efficiently handle complex data with many of the processes and workflows being automated to provide the operator, maintainer and design authority the knowledge they require to make decisions that directly impact vessel availability and through life cost.

In this project the focus was to demonstrate the ability to generate a 'dynamic material state', i.e., a real time view of equipment, systems and platform health such that an assessment can be made of that platforms capability to undertake a given mission. The project would achieve this by understanding the real time capability of the platform's power generation machinery and related systems. The output of which would be used to improve the service provided to the RN by the Type 23 Class Output Management (COM) Warship Technical Authority (WTA) as undertaken by Babcock, as an industry support partner in the SSSA. The overall approach to the DEAM project focusses on a number of steps outlined in 3.1, 3.2 and 3.3.

3.1 Establish a Baseline

With the MTU 4000 Series of diesel generators having been in use since 1996 the reliability and failure modes are well understood. Therefore, it is possible to infer the parameters which need monitoring and modelling in order to provide a forecast of timely interventions against threats to unit failure.

Whilst the 'on-paper' reliability and failure modes of legacy diesel prime movers may have been understood on prior platforms, the optimisation of maintenance against a more modern condition-based approach relies upon the availability and recording of accurate data on which decisions can be based. As mentioned earlier, this historically had not been achieved due to a lack of the required sensors and data recording capability. Consequently, establishing the amount of 'life used' by the equipment would have to be assumed based on paper logs compared against a static life estimation provided by the OEM. This is ineffective in the context of customer demand for a more optimal regime of maintenance and usage of spares.

The introduction of new MTU 4000 Series diesel generators facilitated the recording of accurate data from both factory and field testing which could be exploited effectively to formulate digital models.

Given the wealth of engine data collated since the engine's introduction, the OEM can specify a mean power output for the unit, known as the load factor – as shown in Figure 2. This load factor is commensurate with a predetermined, OEM assumed unit operating profile with a resulting engine overhaul periodicity and a bespoke maintenance task schedule assigned for each load factor (i.e., prime mover life is equal to power output vs unit utilisation). As such, each load factor is matched to a maintenance schedule.

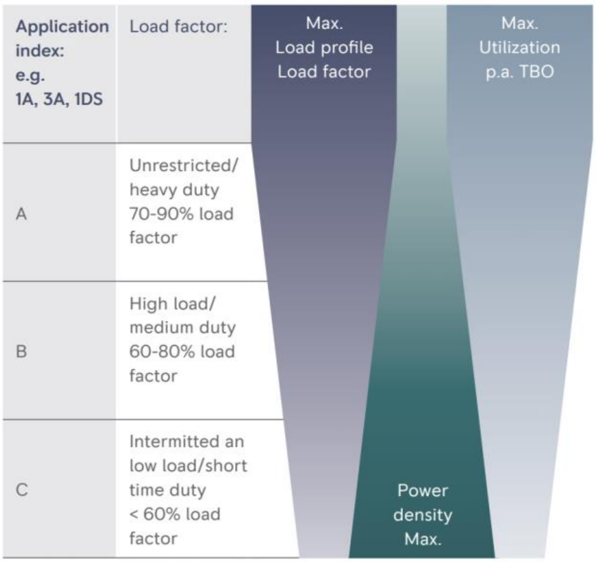

Figure 2: MTU Load Factor Overview (image courtesy of MTU - RR Solutions via Solutions Guide 2019)

By taking these variables of power, unit operating profile and time between maintenance intervals, a digital model can be derived. This can be used to interrogate actual operational data against the various OEM load factors to determine which load factor the as-operated unit 'actually' resides within. Resulting engine life and time between overhaul can be derived and the corresponding maintenance scheduling for the adjusted load factor updated.

Subsequently, engine operating habits can be used to inform the operator on whether they remain within the OEM suggested load factor, or whether they are deviating into a different band and the potential ramifications this may have on unit life, maintenance and systems availability.

In addition to establishing a baseline for the diesel generators with the aspiration to move towards conditioned based maintenance it was possible to establish a baseline against the platforms ancillary systems that support the operation of the diesel generators. This includes monitoring of the vessels high pressure air, high pressure salt water and chilled water systems for example. By recording performance data of these systems during the commissioning of equipment and systems post upkeep, an understanding of the current performance of these systems could be established. Once on deployment, operational data could be captured and analysed to determine any performance degradation of these systems during operations in order to understand how these systems were operating and what impact, if any, this deterioration in performance had on Diesel Generator availability.

3.2 Improve planning of maintenance interventions

Historically all RN equipment maintenance has been planned against this single OEM estimated operating profile and corresponding maintenance schedule. This produces a time-only based maintenance schedule with the various maintenance tasks triggered against running hours. This precludes the ability to account for load variations against the predicted operational profile. By establishing the baseline and being able to monitor and record the data of key parameters from the initial running of the PGMU Diesel prime movers it is possible to use the derived life model to move towards true Condition Based Maintenance. The toolset created as part of DEAM programme could subsequently be used to;

a. Assess operations against a life model of the Diesel prime mover within the Diesel Generator sets. This model would establish the life consumed for each unit, deriving the remaining life of the unit and, by extension, its individual components.

b. Monitor individual parameters to establish if components, equipment and systems were operating within their design intent.

Combining the two methods of system monitoring offered the WTA an ability to assess the risk to the operation of the equipment and systems, and provided a dynamic material state. It thus provided the WTA with the authoritative evidence required to recommend changes to the RN Maintenance Recommendation Advisory Board. These changes would optimise the maintenance schedules of the units if they were operating outside of their predetermined load factors. This would be required to reduce the platforms risk of unavailability if the planned maintenance was deemed unsuitable against the monitored real-world use.

3.3 Assure and improve the availability and required performance targets of the PGMU (Power Generation at System Level).

Having established a dynamic material state of the diesel prime movers it was seen that there was the potential to impact four factors which affect availability and performance targets of the equipment, i.e., the ability of a system or component to perform it's required function at a given point in time. These were;

a. Reliability – How long can the unit perform at design intent.
Monitoring life consumed by the engines allows for models to be run to assess their point of failure. This can alleviate operational concerns and permit changes to operations to allow either an increase or decrease in demand. Alternatively, alterations to their operations can be suggested to potentially prolong their life until the next maintenance opportunity.
b. Maintainability – Optimise maintenance to maximise the units or components life.
Understanding the life consumed of components and monitoring trends in their individual parameters against design intent allows for the timing of maintenance to be adjusted based upon actual use as required. Maintenance can be bought forward to minimise risk of failure or if assessed as a tolerable risk pushed back such that the platform can remain on operations for longer. This greatly reduces the quantity of corrective maintenance which affects the availability of the equipment.
c. Supportability – Performance of support functions
Creating accurate maintenance schedules that are bespoke to the equipment usage allows for more accurate planning for support functions, including the procurement of spare parts or Line Replaceable Units (LRUs).
d. Testability – Ability to fault find
By recording and monitoring data from the engines it is possible to identify faulty replaceable components before they fail.

4. Result of the DEAM trial

The DEAM project captured data from the power generation system for over 2 years during the factory testing, commissioning, sea trials and subsequent deployment of the vessel's power generation system. A key finding of the DEAM project during this period was that the diesel generators were found to be operating in a manner that led to an 8-12% increase in consumed life compared to the baseline. This increase in consumed life would result in the diesel prime movers for a number of generator sets on board needing an overhaul up to 1 year ahead of schedule. In addition, this has a subsequent impact on component and equipment useable life – i.e., Life of the unit and its components were being consumed quicker than planned.

It should be noted however, that this increase in life consumption, and the average power output that the unit produced, did not change sufficiently enough to warrant a change in the diesel units load factor. As such, whilst there is an impact on overhaul schedule, no change to the load factor, and by association, the OEM derived maintenance schedule is required at this stage.

This meant the maintenance and operating philosophy proposed between the OEM, the RN operator, and Babcock (as the SSSA support partner) which had been based on a subjective assessment was validated by DEAM, an objective assessment. i.e., It proved that the RN had set the correct requirement, with the OEM selecting the correct load factor of the Diesel Engine and, by function, the RN operator maintainer was conducting the correct maintenance on each unit to ensure adequate levels of availability were maintained.

This project showcased the ability of the support enterprise to offer validation of the assumptions made during the requirements capture phase of the PGMU programme and offer a unique insight into generator operation habits of the RN. It also confirms that, whilst deviations occurred over the course of a single deployment, the maintenance routines proposed for follow on PGMU vessels are largely correct.

This improves command awareness of equipment health and overall operating and maintenance philosophies all whilst leveraging sensors and equipment that are inherently fitted to the new hardware – offering a minimal impact to the host vessel.

However, whilst after a single deployment the DEAM project delivers the initial benefit of confirming generator load factor selection, it should be noted that the Diesel generator units were utilised within design intent for that one deployment only. In the future the operation of these Diesel units across a large number and variety of operations as part of a larger surface fleet will change.

Ongoing monitoring of the power generation system beyond this single deployment will be beneficial as the findings to date will not be true of every deployment. Due to different missions, operating tempo, or command posture, operating profiles of the platform and the subsequent power generation system will change – each having various impacts to the overall availability of the system. Therefore, in the future the operation of these diesel units will change. The facility to quantify this change and it's impact on maintenance, parts consumption and through life cost is the subsequent value of DEAM. Further developments of DEAM and the overall intent of the iSupport360 programme will serve to increase this benefit to the operator.

5. DEAM's impact on Vessel and Enterprise Spare Part Consumption

DEAM subsequently has delivered a digital tool that can assess prime mover operation against the derived life model. This yields an awareness of overall unit life. However, as alluded to in an earlier section of this paper, this life model output can also be used, in accordance with OEM maintenance schedules and component replacement periodicity to determine discrete component life.

An example of this would be a component unit such as a turbo charger which may feature, for example, a 15,000 hour life when fitted to a unit of a given load factor. However, due to higher exhaust temperatures or differing operating conditions, that same turbo charger may have a reduced component life if the prime mover unit as a whole is operating within a different load factor.

By deriving the real-world load factor of the prime mover, the correct maintenance schedule for the unit can be matched against its usage. With this updated maintenance schedule, DEAM can then interrogate component replacement periodicity which can be updated if required. This means the operator can replace this component, in accordance with the updated maintenance schedule before it fails. This is presented to the operator using a simple red, amber, green illustration which visualises the amount of life consumed; an example of which is shown in Figure 3.

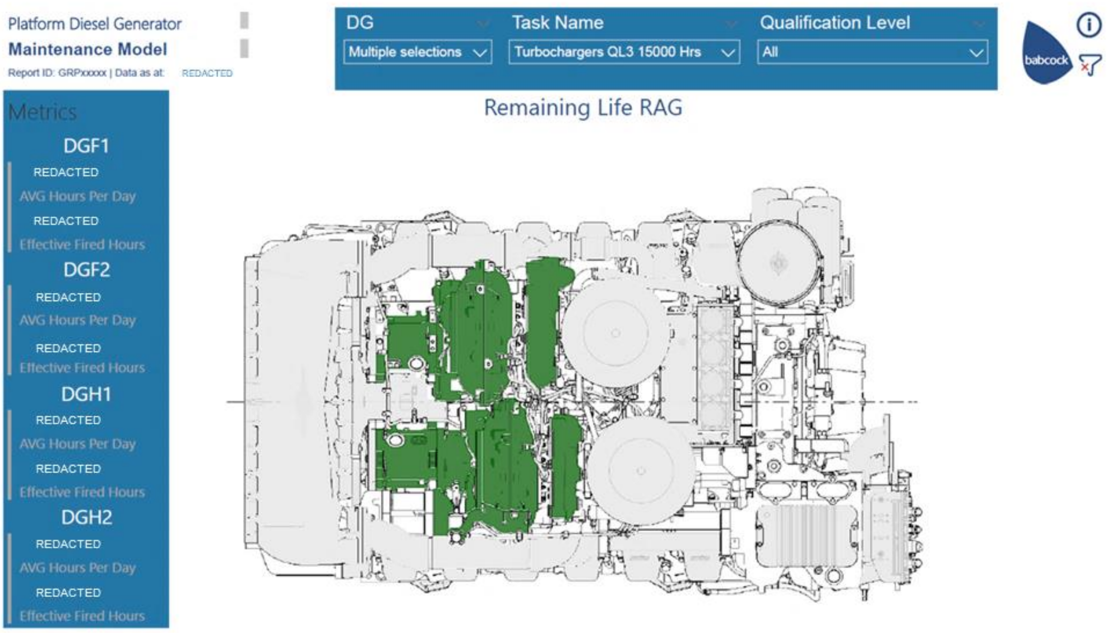

Figure 3: A visual representation of component life dashboarding

As such, DEAM can estimate the real-world life of all key components against the actual utilisation of that prime mover. This gives the DEAM tool the ability to analyse Diesel prime mover component life and assess this against operational trends – predicting when key equipment items will need to be changed and the subsequent forecasting and consumption of spare parts as a result.

This spares forecasting and consumption data can be used in combination with Babcock's RedCube^{TM} tool. RedCube^{TM} is a digital spares forecasting tool, which aims to optimise the provision of both base held, and on board spares.

Subsequently, this spares consumption and forecasting capability allows for the RN operator to understand its own spares usage – and an opportunity to realise benefits such as reducing base held inventory or optimising the Consolidated Allow Lists or spares carried on board. A visual representation of this is illustrated in Figure 4.

This allows the operator to hold on what is needed and carry on board those spares that will have the most impact on availability

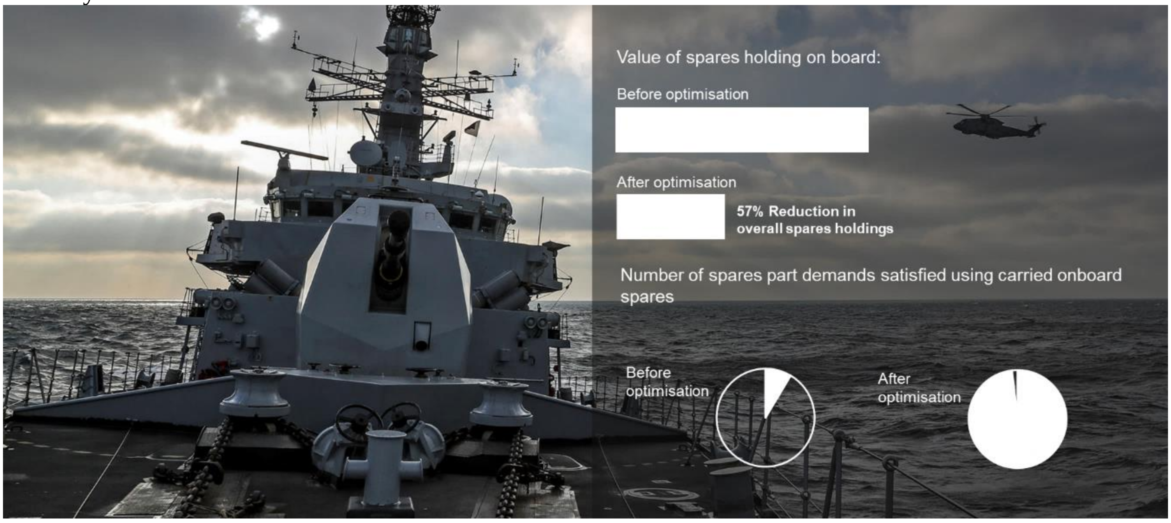

Figure 4: Example of reduction in base held spares holdings and utilisation of carried on board spares resulting from digital data analytics (Source: MOD)

Furthermore, this allows equipment manufacturers to gain greater understanding of which spares are consumed, and when – enabling the enterprise support partners and OEMs to plan the ordering and manufacturing of spares. This results in increased foresight for spare parts manufacture, the easing of supply chain risks and reduces the probability of unit and component obsolescence compared against traditional spare part procurement strategies of bulk ordering at infrequent intervals. This delivers the overarching benefit of reducing cost to the entire support enterprise.

6. Project Conclusions and Further Work

A range of benefits from the DEAM programme and the subsequent utilisation of Babcock's RedCube™ toolsets can be realised as part of future vessel programmes – particularly those based on Babcock's AH140 General Purpose Frigate. Both the RN, future operators of AH140 and operators of indigenously designed vessels can benefit from the experiences and benefits gained as a result of the DEAM programme.

The DEAM toolset has enabled Babcock and the RN operator to validate the maintenance regime of the Diesel Generator units on the Type 23 PGMU vessels against a real-world deployment and optimise the spare parts holdings that the customer is required to purchase to ensure platform availability. This has increased command confidence in the power generation solution onboard the trial vessel and enabled the operator to hold fewer spares; intelligently procuring a reduced number of parts at more regular interval based on actual utilisation. This has demonstrably benefitted the wider support enterprise including both the OEMs, who can subsequently reduce component obsolescence concerns as well as the RN operator.

In addition, lessons learned and methodologies used around data capture, manipulation and implementation into complex toolsets can also be leveraged to benefit the future RN customer in its embodiment of the Navy Digital Kraken programme. This environment will utilise digital technology to enhance the support solution for the upcoming Type 26 and Type 31 Frigate programmes.

Babcock is actively rolling out a development of the DEAM programme as part of its wider digital support programme, iSupport360, to support AH140 users with ongoing optimisation of equipment fits, equipment specification and spares provision resulting in a reduction in whole life costs, optimised maintenance philosophies and an overall improvement in platform availability.

Whilst it is noteworthy that the AH140 design features Diesel prime movers in both a propulsion and power generation capacity from the same OEM as the DEAM trial, the DEAM project methodology is applicable to a range of equipment and system items and is agnostic of the OEM. Babcock is currently developing their range of digital toolsets to provide insight on a wide range of platform and marine systems from any OEM resulting in a service that is not wed to a predetermined technical solution.

DEAM has demonstrated that Babcock can leverage a range of sensors and equipment that are inherently fitted onboard legacy platforms and derive a quantifiable benefit to the end user. Babcock is using this experience to refine their digital services offerings in order to bring that same benefit to new customers and future operators of its AH140 platform.

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