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Simulation Modelling for Scenario Planning to Evaluate IVHM Benefit in Naval Ship Building

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Abstract

Naval ships are long life assets that could be called upon to perform missions not considered in their original design. The through life support arrangement is influenced by the military requirement as well as contracting practice. In navies that contract out the building and support of ships in different competitive packages, condition monitoring technology for through life health management may be stripped out to reduce ship building cost. This paper investigates the potential benefits of incorporating health management for the test and commissioning stages in naval shipbuilding to reduce the overall cost of a ship programme. Scenario planning using simulation suggests that for ships of high complexity in a multiple ships programme, health management is likely to enhance the lessons learnt process. The benefits to the follow on ships could justify the investment.

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Keywords: Naval Ship Testing, Integrated Vehicle Health Management, IVHM, Scenario Planning, Simulation, AnyLogic.

1. Introduction

Integrated Vehicle Health Management (IVHM) is an approach to deliver the capability to recognise, evaluate, isolate and mitigate faults to enhance the reliability and safety in complex engineering systems. Up-to-date information of system health supports operations and maintenance decisions in Through-Life Engineering Services. Many of the component technology in sensing and monitoring have been developed over the last few decades and begin to be used effectively to provide engineering asset and system health information.

The UK has a strategic military naval shipbuilding industry. New build naval ships are designed with condition monitoring on key systems and generates volumes of data that could be used to support ship operation and maintenance. However, there is a possibility to reap benefits of the information gathered during the build, test and commissioning stages of the ships. Effective use of health information in the test and commissioning phases can inform the design and build of follow on ships. This paper reports on the scenario planning simulation to model the potential benefits of using IVHM in the test and commissioning of naval ships.

1.1. Background

The Cranfield IVHM Centre has developed a systematic engineering approach to design IVHM systems according to the failure and maintenance characteristics of the engineering assets, in the context of the concept of operation. The approach combines operations and maintenance analysis to evaluate the full business case for IVHM. This approach provides the design of the IVHM technical system and the changes in operation and maintenance practice to exploit the information advantage for business advantage.

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In some navies, the acquisition and support of naval ships is managed as contacts issued to different commercial and naval dockyards and service providers. When budget cuts are imposed, condition monitoring equipment that benefits operations and maintenance, but increase ship building costs, are likely targets to be removed.

The justification for IVHM in these situations will only be based on the benefits that could be gained in the build and commissioning stages of the ships. If IVHM can speed up the learning of test failure lessons, and the associated engineering changes to design or build out the fault, then the next repeating component/sub-system could avoid the testing and repair work for repeating the same fault. In a programme of multiple ships, the follow on ships could be completed faster as faults in earlier ships are avoided.

1.2. Aims and objectives

1.2.1. Aim

The aim of this project is to define the scenario planning problem to justify IVHM in naval shipbuilding and commissioning, and advise shipbuilders the potentials of IVHM in different scenarios.

1.2.2. Objectives

- Model naval ship engineering and system structure, ship building, test and commissioning procedures; and the lessons learnt and engineering change paths.
- Develop and test simulation tool in AnyLogic.
- Conduct scenario planning analysis to investigate IVHM benefits potential.

2. Literature review

2.1. IVHM

IVHM technology enables the collection of accurate data by embedding smart sensors to engineering assets. It provides information on performance, failure and health conditions for the system [1]. IVHM enhances engineering assets' availability and reliability with diagnostic and prognostic techniques using the data collected. The implementation of system monitoring technology in modern civil aircraft has proven its cost saving benefits for maintenance [1].

It is also reported that IVHM system enables fault isolation quicker and more accurate, which reduces labour cost and time [2]. In a study that investigated accidents and incidents, correlation between equipment malfunction with the non-usage of IVHM is suggested [3]. The result shows that 80% of aircraft mechanical defects could be detected, thus avoiding accident and failure. In practice, engine manufacturers have also adopted IVHM principles to reduce cost and improve safety by detecting and predicting engine faults before they reach safety-critical levels [4].

Many cases have shown the benefits of IVHM technology in aircraft manufacturing and flight operations.

2.2. Naval ship quality assurance

2.2.1. Naval ship classification and testing

The safety and reliability of commercial ships are regulated in the naval classification process to provide confidence that the ships and their systems are in compliance with the relevant regulations. It is usually done by independently auditing the design, equipment and material supply, construction and though life maintenance of the ships [5]. Classification of ships through the standards provides assurance for materials and equipment verification. Class assignment means that the ship and all of its features has been benchmarked against international legislation. As military/naval ships sail in the high seas alongside commercial ships, naval ships are expected to meet at least similar standards. Each navy has its own regulations and processes, some of them are published in the public domain. A good resource is the US Department of Navy Standard Ship Test and Inspection Plan, Procedures and Database [6], which covers the typical testing procedures of an oil tanker sized ship, and can be further customised to other types and tonnages.

2.2.2. Ship systems testing

A ship is made up of many sub-systems and components, provided by an eco-system of suppliers, and integrated at the dockyard. There are different shipbuilding philosophies. Traditionally a ship is built from keel up to a floating structure, then took to water and fitted out. Another approach is to build sections of ships partially fitted out, and then connecting the sections together. Components are typically tested at the manufacturers and then at the dockyard before being installed in the ship structure. There are further tests at the multiple stages of build until the whole ship is complete. Tests are normally run in parallel with fitting out. Any issues identified at tests are rectified. In principle, rectifying issues earlier in the build process is cheaper than later. The final set of tests are sea trials when the ship is taken to sea and proved before handing over to the customer. The fitting out, test and commissioning of a complex naval ship takes several years.

2.2.3. Ship systems breakdown

Health condition monitoring are specific to the failure behaviour characteristics of the components and sub-systems. The naval ship industry has multiple, but not an universal, models to divide a ship into systems and sub-systems [7]. The ship breakdown shown in Figure 1 combines two existing classifications that is used in naval ship industry.

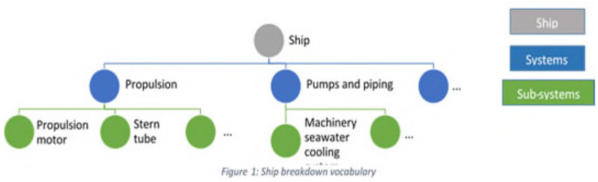

Figure 1 Ship systems breakdown

The Ship Work Breakdown Structure used by the U.S. Navy identifies each of the naval ship's sub-systems with a unique