

Key Findings to Support the Development of a Framework for the Implementation of Product Lifecycle Management in Engineer to Order Products

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Abstract. BAE Systems Naval Ships has undertaken a comprehensive overhaul of all aspects of its approach to the engineering, design and manufacture of complex warships. Through a partnership with the University of Strathclyde, research has been completed on the implementation of Product Lifecycle Management (PLM) to meet organisational objectives in the development of Engineer to Order (ETO) products. Engineer to Order (ETO) products include characteristics such as high capital value, large-scale, long-life, no prototype, highly customised and few or one off. An overview of PLM is provided highlighting the challenges specific to the characteristics of ETO products. The paper then provides a summary of the key findings of approximately 30 semi-structured interviews with leading industry personnel, in the UK and internationally, on PLM implementation in ETO products. These participants are engaged with PLM in ETO products either as an implementer or as a key stakeholder with an interest in its successful use within their organisation. The findings have been used to support the development of a framework to ensure that PLM implementation supports the business objectives of ETO product development.

Keywords. Product Lifecycle Management, PLM, Engineer to Order, ETO

1. Introduction

BAE Systems Naval Ships is the UK's leading provider of complex warships and through-life support, a world-class industrial partner for the UK Ministry of Defence and a leader in the global market for warships and innovative naval warship support.

At BAE Systems Naval Ships, a comprehensive overhaul of all aspects of its approach to the engineering, design and manufacture of complex warships has been undertaken. Significant investment in technology, infrastructure, people and processes is enabling a step change in efficiency, quality and safety, helping to ensure Naval Ships remains competitive and delivers the best value for money to its customers.

BAE Systems has established a long-term partnership with the University of Strathclyde, one of the UK's top centres for engineering research and education. The partnership aims to encourage close co-operation in the development of advanced maritime research and technology. This paper describes research collaboration between BAE Systems and the University of Strathclyde on the implementation of Product Lifecycle Management (PLM) on Engineer to Order (ETO) Products. The paper demonstrates that a tailored approach to PLM implementation is needed for ETO products to ensure that PLM aligns with the organisation's strategic objectives, related processes, requirements and technology. The paper provides an overview of PLM followed by a description of specific PLM challenges on ETO products compared to other product types. The paper summarises the key findings of approx. 30 semi-structured interviews with leading industry personnel, in the UK and internationally, on

PLM implementation in ETO products. These participants are engaged with PLM in ETO products either as an implementer or as a key stakeholder with an interest in its successful use within their organisation. The findings have been used to support the development of a framework to ensure that PLM implementation supports the business objectives of ETO product development

2. PLM Overview

Sääksvuori and Immonen describe the benefits of PLM as providing easy access to up-to-date, relevant and configured information [1]. This enables tasks such as design or planning to be improved and timescales reduced as the approved information can be presented, used and reused in a more efficient way. PLM supports the extended enterprise by ensuring not only that information is available to all those who require it, but at the same time controlling access to only those who have authority to view or update this information. This is especially true in BAE Systems Naval Ships where the design and build takes place across multiple locations with multiple stakeholders. Information access must be carefully analysed, configured, implemented and managed, to ensure quality and that the organisation is compliant with its security and regulatory obligations.

Information management in the context of PLM is not only to aid the delivery of a product configuration chosen by a customer, but to ensure the design, build, support and disposal is robustly managed. PLM ensures that during the product's lifecycle, the information is properly structured and that any design changes are highlighted and effectively communicated, aiding improved decision making, decreased approval time, decreased rework and improved quality as relevant information is presented to those who need it when it is required [1]. Robust Configuration Management processes and technology across the entire project and supply chain are needed, which is a requirement from the high volume of evolving information which affects the design of Naval Ships, resulting in a critical need to capture, understand, communicate and action new information concurrently with the design, manufacture and support phases. A full audit history of the timing and responsibility of change is critical for decision traceability. This not only contributes to the organisation's knowledge but is also necessary for managing the maturity of the design and to support business measurement for targeting areas for improvement.

These descriptions and benefits can be summed up as PLM being a product centric business model which is supported by Information Management Technology (IMT) across the entirety of a product's lifecycle, involving people, processes and organisations in order to achieve a product performance or service goal [2]. Brunsmann and Wilkes describe the main goal of PLM as supporting the integration of people, information, process and systems, to provide an information backbone to the business [3]. What is certain is that "IT Applications that support PLM have assumed critical importance as companies focus on enhancing the efficiency and effectiveness of their innovation across the enterprise" [4]. These benefits are especially important for major defence products given the limited budgets but increasing demand for advanced capability [5].

When implementing PLM, the organisation should first understand its strategic objectives and core processes and use this to decide on the PLM approach, which in turn should influence the PLM system implementation.

3. Challenges with Engineer to Order New Product Development

Engineer to Order products, such as first of class Naval Ships, require careful consideration of the PLM implementation approach due to their unique characteristics and challenges. The unique nature and related challenges require PLM implementation to be tackled differently compared to other product types, e.g. aerospace or automotive [6]. A summary of ETO challenges are described below.

3.1. Complexity and uncertainty

The level of complexity is one of the greatest challenges to manage within the development of ETO products as they have a large number of different types of elements interacting across its lifecycle in difficult to predict ways.

3.2. Customer interaction and procurement

The customer in ETO products commits to the order early in the design lifecycle and therefore has a significant input into the design, manufacture and procurement strategies, such as the supplier tendering process for each programme.

3.3. Product Customisation

ETO products have a high level of customisation due to their low volume and high-complexity [7]. If incorrectly managed this will result in higher levels of risk relating to longer lead times and increased costs.

3.4. Bill of Materials (BoM), change and maturity management

Customer commitment early in the design lifecycle requires significant product information management to ensure the evolution of the design is managed to conform to their specific requirements. Naval ship products have an evolving Bill of Material (BoM) where the product information gradually matures and requires careful configuration and change management.

3.5. Project management

Amongst the challenges of ETO delivery are the complexity of the product due to emerging patterns which impact the initial cost estimations and requirements resulting in cost increases and schedule overruns [8].

3.6. No prototype

With ETO products there is a critical need to ensure that it is 'right-first-time' due to the lack of a prototype which in turn is due to the small number of similar products produced [5]. Typically physical prototyping allows error removal and efficiency improvements through their various iterations, this includes aspects relating to the design, manufacture and in-service support which are not possible for ETO products.

4. PLM Implementation Research

BAE Systems Naval Ships has made significant improvements on its approach to PLM including process, information and toolset integration, and its data quality methodology [6]. Through the partnership with the University of Strathclyde, research has been completed to create a framework for PLM implementation guidelines for large-scale, complex, long-life, no prototype, highly customised, one-of/few-of a kind Engineer to Order products to meet organisational objectives. This section will provide a high level summary of aspects of the research findings.

4.1. The approach undertaken to capture PLM Implementation findings

Approximately 30 semi-structured interviews on PLM implementation were undertaken with senior personnel from 10 ETO related organisations in the UK and internationally. A set of questions were developed to identify the key objectives and challenges of PLM implementation on ETO products as well as the enablers to ensure their success. The interviewees were selected based on their relationship with PLM in ETO products either as an implementer or as a key stakeholder with an interest in its successful use within their organisation. To generate the results of the interviews, Thematic Analysis was used as a means to codify and generate themes [9]

4.2. Summary of selected findings

The findings were categorised into those related to information, process, people and technology and are in line with Brunsmann and Wilkes recommendations. A summary of the findings for PLM implementation enablers are stated below.

4.2.1. Information

- Develop a policy to capture what information is required and how it will be used for an evolving complex product. This is to ensure organisational resources are focused on the capture, management and presentation of meaningful information.
- Create a central team with suitably qualified and experienced personnel (SQEP) for PLM information integration, policy development, standardisation, learning from experience (LFE) and adherence across the organisation.
- Develop a Data Quality and Governance policy, team and adherence approach. This is to ensure when PLM is implemented those data rejections and errors across an integrated environment are captured, analysed and rectified.
- Develop a Configuration and Change Management approach across ETO product classes and variants. Configuration Management is a mandatory requirement in major new product development but this must be focused on the specific challenges in ETO products as described in this paper.

4.2.2. Process

- Create a central team with SQEP for PLM business process ownership, development, standardisation, LFE and adherence across the organisation.
- Implement guidelines and governance over processes to ensure they are simple and usable thereby reducing complexity. This is due to overly complex processes often being introduced to manage the challenges in ETO product development, such as with electronic workflows.
- Mandate utilisation of PLM processes internally, for partners and the supply chain. This should be embedded with the engineering business model, and its related processes, and is to ensure that all stakeholders adhere to the PLM approach introduced into the programme.
- Implement sustainable benchmarking across related industries and vendors for ongoing business improvement and confidence. This is to ensure that the PLM approach undertaken is tested against best practice to maintain quality, reduce risk and to provide ongoing confidence.

4.2.3. People

- Capture and provide continuing evidence of PLM benefits to senior management to enable support and maintain sponsorship. PLM implementation is costly and high risk, therefore senior management must not only be convinced of the benefits initially, but must continually be presented with the benefits of the approach across the ETO lifecycle.
- Develop and implement a comprehensive business change initiative on PLM. The implementation of PLM will result in new processes, information and toolsets which will have an impact on the people within the organisation such as those moving from another ETO product where they have used a different approach for many years.
- Develop and implement a cross functional PLM education programme, embedded within the core business training approach, emphasising core values and objectives. This is to ensure that PLM education is not just focused on processes and toolset training but is integrated with the business culture.
- Provide PLM support and training to partners and the supply chain. It is often the case that those outside the core organisation are not given the required support to ensure the success of the PLM implementation.
- Create a central team with SQEP to develop PLM objectives, education and support to the business. This will assist in utilising key resources to deliver the enablers for successful implementation of PLM.

4.2.4. Technology

- Identify and implement configurable PLM toolsets with minimal customisation. Due to the long lifecycle of ETO product development, customisations will otherwise impact the ability of the toolsets to be maintained and upgraded, resulting in considerable risk to the programme.
- Drive integration of information through toolset rationalisation. This will force otherwise disparate information sources to be integrated into the core toolsets
- Focus toolset development on business objectives, priorities and ease of use to reduce complexity of technology and processes. This should be managed through a central PLM approval authority.
- Scale and implement IT architecture improvements to support new ways of working and ensure toolset performance, especially focusing on large volumes of data. This is to ensure IT architecture is maintained against information growth and toolset integration.

5. Conclusion and next steps

ETO products have considerable challenges to overcome when implementing PLM to meet organisational objectives. PLM is central to BAE Systems Naval Ships approach to delivering world class products and through the partnership with the University of Strathclyde a framework to successfully implement PLM on ETO products has been developed and validated.

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