# An analysis of requirements for improving the management of design for manufacturing knowledge in aerospace

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**Abstract.** In the manufacturing lifecycle of aerospace products, large amounts of data are generated throughout the activities involved. Much of this data contains useful knowledge for engineers to improve various aspects of Design for Manufacturing (DFM) of new or existing products that may help reduce defects in future manufacturing activities. An investigation is carried out at a large UK based manufacturer of aerospace products that aims to introduce an improved approach that supports design engineering activities to make use of the 'data' generated to drive the number of re-occurring defects down. This paper particularly focuses on analyzing the requirements for introducing a solution identified from questionnaires, observations and stakeholder reviews and proposes a framework of the components to enable its implementation. The research discussed the requirements and concludes the main findings toward implementing a fully integrated solution at the collaborating company in order to improve data usefulness and effectiveness.

**Keywords.** Knowledge Management, Design for Manufacture, High Value Manufacturing.

## 1. Introduction

Manufacturing companies are continuously under pressure to improve product design and its manufacturability through the use of knowledge related to Design for Manufacture (DFM) in order to reduce defects from re-occurring in future projects. However, the type of manufacturability knowledge needed for DFM in the aerospace industry is typically learnt after the design stage is completed – usually several months or years later when the design has been commissioned and handed over to the manufacturing teams to make for the first time. In addition, due to the growing complexity of manufacturing systems, processes and supply chains within extended enterprises' – the data collected from manufacturing activities that can be used toward carrying out DFM to improve new or existing designs becomes difficult to attain and manage [1]. In addition, this type of data is often collected during different types of manufacturing activities; such as in the case of a defect, quality management, corrective actions, lessons learned, supplier reports etc. that further adds to the complexity of how to communicate and use it. This project aims to use the data from these processes to

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significantly drive any potential defects from occurring in the future and improve the organizational learning in terms of generating DFM knowledge that can be beneficial to the different design and engineering teams involved.

### *1.1. Improving DFM practice through KM*

Researchers widely recognize DFM to be an important way of thinking for both manufacturing and design engineering disciplines. DFM techniques (also includes Design for 'X' "DFX", Design for Assembly "DFA" etc.) are cohesive, innovative ways of optimizing designs to better meet the manufacturing requirements and ultimately improve manufacturing efficiency by improving Quality, Cost and Delivery (QCD). Often DFM in industry is transcended and applied by individuals with a strong interdisciplinary background in both design, engineering, and manufacturing – however, as industries move toward future knowledge-based organizations (KBO), collaborative ways of working and zero-defect approaches, it is vital that the tacit knowledge gained from these experiences are made explicit, organized and readily available for others using Knowledge Management (KM) to make use of, in order to carry out DFM effectively. Additionally, with organizations becoming more virtually managed and most information being stored digitally of their manufacturing activities - the data collected throughout these activities that can be potentially be used as a basis to elicit DFM improvements from is extremely important to manage towards advancing knowledge-based systems in manufacturing industry. Furthermore, in larger organizations and extended enterprises, the potentially useful data collected throughout these activities to elicit DFM improvements can be large, unstructured, and often discrete in nature – and is virtually redundant and difficult to use if not structured, and represented in ways that design or manufacturing engineers can make use off.

### *1.2. Research Approach*

First, this paper examined some recent literature that tries to improve DFM practice in the way products are designed to reduce defects. The literature examination showed that there a need of an approach that aims at managing defect data in order to improve the elicitation and communication of DFM knowledge to improve product design. A structured approach to defect data management is proposed to link a set of collected data from various manufacturing activities of five complex products, to the engineering Bill of Material (BOM) within the existing product lifecycle management (PLM) approach to improve the knowledge feedback cycle. Furthermore, a feasibility study is carried out to show the potential effectiveness of the approach using a real set of defect data collected over a period of twelve months. A framework describing the requirements needed to implement a technical solution, is presented followed by discussions, conclusion and further work.

This project is carried at BAE Systems, Electronic Systems Rochester - mainly using an eighteen month observation study, various discussions and two questionnaires. The requirements are further validated through three stakeholder discussions lasting 2 hours each, six months apart. In addition, the requirements identified from the observation study were found to be largely supported by the findings from the questionnaire results of twenty key beneficiaries of the project pointing out to a need for an effective knowledge management framework.

## 2. Similar Research

There has been a very limited amount of research in the recent decade that attempts to make use of DFM techniques to reduce product and manufacturing defects through the use of data generated from the manufacturing activities. The little amount of research that can be found that does this - often falls short on proposing frameworks that aid industries in adopting new DFM focused technologies and integrate them into existing product or engineering lifecycle management activities. For example, Blanton et al. [2] used failure data from manufacturing integrated circuits (IC) to evaluate DFM effectiveness using a rule based methodology that correlates the type of defect against DFM rules. Galavis-Acosta et al [3] proposes and implements a method of multi-scalability of the different manufacturing processes to determine representations of DFM knowledge to improve product design. Wuest et al [4] aimed to link the product state (i.e. manufacturing processes as a system) to the core product system through mapping intra- and inter-relations between the processes themselves – in an attempt to support DFM feedback to the design teams. However, all the above attempts do not aim to address the requirements that manufacturing systems, design and manufacturing teams, and the organizational management needs to implement their proposed solutions.

On the other hand, several researchers have focused on using other types of data in order to improve manufacturing system efficiencies such as reducing lead time to customer, improving knowledge management and so on – but none were found that identify critical design factors that improve the manufacturability of products; (or DFM) to derive a knowledge re-use framework of requirements. In example, Evans et al.'s [5] work discussed the potential use of data from public social media platforms to capture consumer needs to improve future product concepts and the required change needed to adopt such approach in the industry. Similarly, Zammit et al. [6] tries to capture know-hows in the testing procedures to improve product failure knowledge. However, both works have not looked at possibly using their knowledge management frameworks to improve manufacturability of products through generating DFM knowledge found amongst existing defect data sets at their collaborative companies' manufacturing activities.

## 3. Industrial Investigation

The observation study resulted in collecting data of defects from five complex product manufacturing activities from the initial receiving raw material stages to finalizing system assembly, testing, and delivery to customer. A mix of five parts were selected from the five product assemblies, from both in-house and externally supplied sub-systems manufactured based on engineering specifications and hand over 3D CAD and 2D models/drawings. A knowledge management framework was designed (see figure 1) that aimed at analyzing each defect to classify it by the product type, and linked to the BOM of the part held within the engineering lifecycle management data at the collaborating company. The defects were then itemized into a separate spreadsheet for improving ease of testability, and then structured in regards to symptoms and reasons to elicit knowledge of the defect. The investigation data related to the defect record was itemized into causes, and supplier actions to elicit knowledge of the defect causes from the data. The data was pulled from the spreadsheet and represented in a design of an interface using Visual Basic Graphic User Interface in a CAD works package.

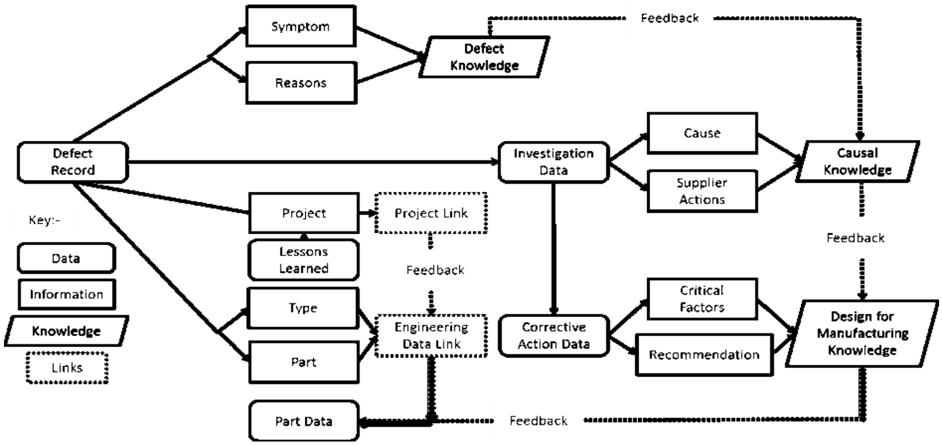


**Figure 1.** The framework used to structure defect data for the elicitation of DFM knowledge that can be used to improve product design.

The defect and causes were then represented in an engineering environment that pre-structured the BOM into parent and children representation, in order to generate critical design factors to be used to populate a DFM knowledge repository accessible directly from the part data. The repository were lines of text saved that could potentially be stored in the engineering lifecycle management as an add-on feature in order to be shared amongst other engineering teams to support their product design activities.

### *3.1. Method*

The approach was applied to carry out a feasibility test on an opto-mechanical subsystem that consisted of twenty individual parts. Three of the parts contained within the selected test subsystem were tagged with their subsequent defects from the data collected. From knowledge of the defects and causes, critical design factors, and some process capabilities were identified and used to populate the DFM knowledge repository. A presentation of the approach, and a demonstration of the tool designed in Visual Basic was given to the stakeholders to discuss, evaluate in order to analyze the requirements to integrate the solution at the collaborating company.

Twenty stakeholders were asked to evaluate the solution presented. The stakeholders consisted of managers from the technical design team, engineering, manufacturing engineering, supply chain management, technology and innovation, production engineering, business improvements and test and diagnostics team. The evaluation of the stakeholders were split into two phases. The first phase only evaluated the overall approach during the early stages of development of the framework, whereas the second phase evaluated the approach after the framework for the approach was applied and results were presented. This paper will treat both phases of the evaluation as equal due to the approach being the same at both presentations.

The evaluation was carried out through two pre-designed questionnaires that collected the answers from oral discussions lasting two hours each. The stakeholders were first asked what type of knowledge is required to be implemented in the design of the knowledge management tool that used defect data to elicit DFM knowledge. Then they were asked what knowledge is required to avoid the maximum amount of defects from re-occurring in the future or other similar designs. The third question was what would make the team be most willing to use the proposed solution. The fourth question was what other types of knowledge would be most beneficial to carry out design improvements in the engineering lifecycle. The fifth question asked about the barriers that may obstruct this solution from working. The sixth question asked what would make the organization more confident that this solution will work. The seventh question asked what problems and other benefits that could arise if a developed tool based on this approach is to be integrated with the existing engineering lifecycle management systems.

## 4. Discussions and Recommendations

From the discussions based on the seven topics above, an analysis of the findings was carried out in order to generate the requirements framework shown in figure 2 below. The requirements are shown linked to each component of the framework. The linkage describes what each component will allow or use in order to complete the implementation of the solution.

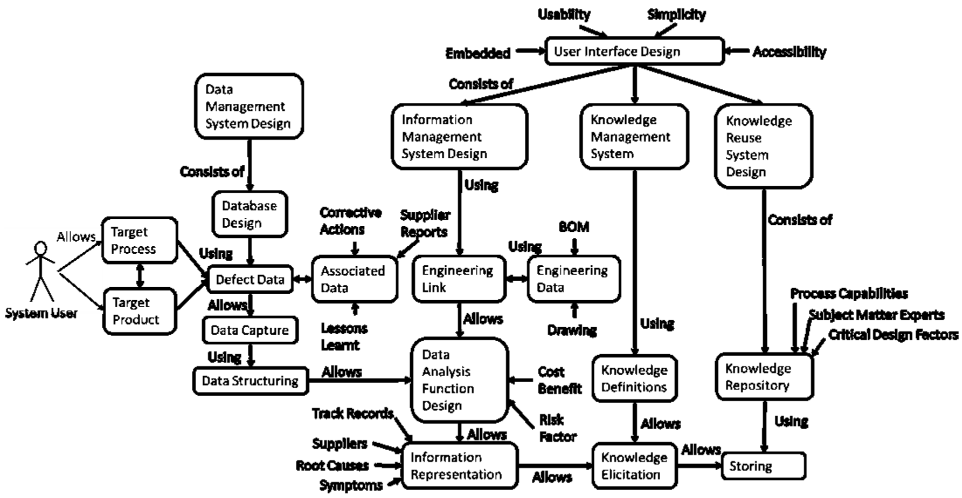


**Figure 2.** The main components of the framework and the requirements identified from the stakeholders.

There are three main requirements to complete the user interface design for the system user (design engineers) to be able to manage defect data for improving DFM – these are the information management system, knowledge management system and knowledge reuse system design. The data management system design has all ready been accomplished through populating a spreadsheet with the collected data and linked to the engineering data (such as BOM and drawings). The information management will contain the data analysis function design, the knowledge management system will allow knowledge elicitation from the represented information from the defect data after being structured. The knowledge reuse system will mainly include the knowledge repository that will allow storage of the DFM knowledge such as critical design factors and process capabilities.

## 5. Conclusion and Further Work

This research project collected raw data captured from defects on five complex aerospace products (both manufactured in-house, and by third party suppliers) over a duration of 12 months and applied a structured approach and data to part link model, in order to evaluate its effectiveness toward the elicitation of DFM knowledge that can be used to reduce re-occurring defects. The evaluation has been analyzed then used to create a requirements framework presented in the discussions section. The analysis has shown that knowledge management can have a significant effect on DFM practice when the collected raw data from defects and associated processes are structured, represented and linked to an itemized bill of material (BOM) in a design engineering environment. The study has significantly helped elicit critical design factors to be placed into a knowledge repository to better meet manufacturability requirements. The immediate steps of the project are to finalize the data captured from the complete set of values for the rest of the products. The next steps of the project will be the design of the user interface to be carried out with the design engineers at the collaborating company, to be tested and integrated as an add-on to their engineering lifecycle management systems for the next six months. Furthermore, the solution will incorporate the core information management system functionalities as well as the knowledge management system and processes to enable the effective use of the knowledge repository for carrying out DFM.


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