

Enabling Six Sigma with a New Approach for Detailed Design

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ABSTRACT

Many aerospace & defense organizations have placed an increased emphasis on reducing the time to transition products from engineering to manufacturing while simultaneously reducing the product technical risks. One area with the greatest impact on these objectives is detailed design. This is the stage in the product development lifecycle when the development team addresses the detailed product definition and "Design for Six Sigma". Unfortunately, most aerospace & defense manufacturers still follow a serial process for creating the detailed design. In addition, producibility is often not formally addressed because it is treated as an additional step that requires extra engineering effort that delays completion of the product definition.

This paper presents a solution piloted at Aerojet for the detailed design and manufacture of missile propulsion systems. The software tool at the core of the solution captures manufacturing engineering expertise and provides real-time, quantitative information to link design requirements to the manufacturing processes. This practical approach to Six Sigma-enabled design has been created to help engineering create the detailed design documentation, while simultaneously addressing producibility analysis and characteristic accountability. The result is a reduction in the time to complete detailed design. As importantly, by ensuring compliance with requirements, the solution helps to reduce non-conformances, design changes, and quality escapes.

INTRODUCTION

In the product lifecycle, the transition from development to production is historically the most difficult step. This is particularly true for the complex, highly engineered and integrated systems represented by most aerospace & defense products. The problem is well documented among defense programs. A GAO report on the cost overruns associated with the F-22 noted that among the major contributing factors were "engineering changes to the airframe and engine" [1]. While the F-22 is highly

visible, it is not alone. A subsequent GAO analysis revealed that 43% of programs reviewed "are already expecting... cost overruns greater than 30 percent or have delayed the delivery... to the war fighter by at least 1 year" [2].

Based on these findings, there is a tendency to blame the Government's acquisition process or other factors outside of the product engineering process for delays and overruns. However, recent highly publicized problems with both the Airbus 380 and Boeing 787 reveal that the commercial sector is not immune to the same development-to-production transition issues that have historically impacted military programs. The A380 is affected by "continuing industrialization challenges" [3]. The 787 team found the need to "reconcile partner engineering with our production records... very onerous and time consuming" [4].

For almost two decades, the aerospace & defense industry has worked to address these issues, adopting new product introduction processes, establishing integrated product teams, and pursuing Design for Six Sigma. Despite these efforts, transition issues for both military and commercial programs persist. A key element in the dialogue surrounding this critical juncture in the product lifecycle is to find the point in the process when the most influential factors come together and to systematically address them. Based on extensive assessment of the key stages in the product lifecycle, a strong argument can be made that this point occurs at detailed design.

SIX SIGMA AND DETAILED DESIGN

Detailed design is the stage in the product development lifecycle when product definition and manufacturing process capability must come together. It is a stage that may occur multiple times over the life of a single product as it evolves. That is, a product goes through detailed design when it is first conceived, but may effectively return to this stage multiple times as modifications, upgrades, and derivatives occur. Every time a design is reached, the same factors must be considered: Can it

be produced? Can it be made affordably? Can it be produced to meet a schedule? Will it meet performance requirements? Figure 1 illustrates how the path through detailed design is followed over the full product lifecycle.

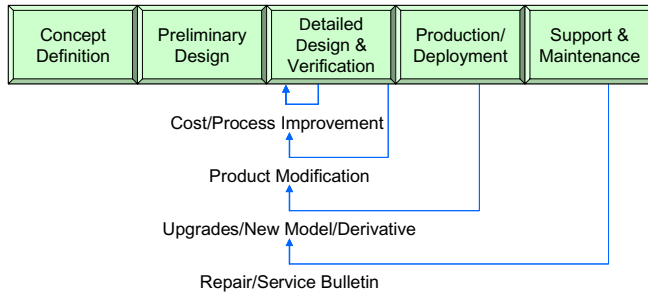


Figure 1 - Detailed design iterations over the product lifecycle

Ideally, detailed design is a highly collaborative stage, during which design intent is thoroughly considered in relation to the capability of the full range of anticipated production processes and sources. In effect, this means that the materials and processes -- coupled with the known and anticipated capabilities of the full supply chain -- are concurrently evaluated, and risks are identified and systematically addressed. If executed properly, this effort will enable a transition from development to production that is relatively seamless, with a significant reduction in the cost and delays that programs have experienced in the past.

In the model-centric environment, the preliminary design is typically a “naked” 3D digital representation of an assembly or component. The design engineer has multiple options regarding the level of detail incorporated in this electronic model. Extensive discussion with a wide range of aerospace companies indicates that design practices influence the richness of the data [4]. Some design engineers provide only a nominal rendering of the design, which is subsequently “fleshed out” by a detailer. Others incorporate a full complement of tolerance data and annotations, including product manufacturing information (PMI). It is not uncommon for a digital image to be accompanied by a reduced dimension drawing (RDD), which is a 2D depiction of the design with associated notes, specification callouts, and related annotations. Through these various approaches aerospace companies move through preliminary design and into detailed design (see Figure 2).

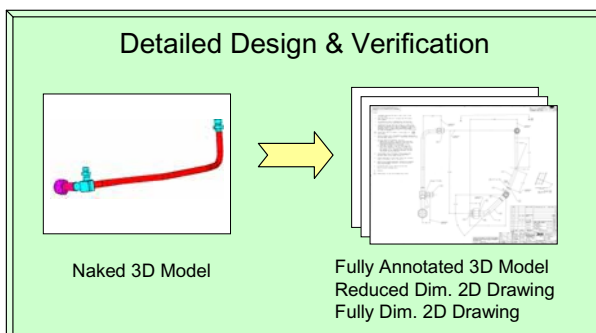


Figure 2 - Detailed design and digital product definition

CURRENT DETAILED DESIGN REALITIES

The realities of detailed design are quite different than the theoretical aspirations. Based upon research in the aerospace & defense industry over a two year period [7], the project team identified a convergence of five “realities” in detailed design that highlight the need for a revised business process along with an appropriate set of software tools. These five realities are described in the paragraphs that follow:

1. The creation of the detailed design documentation is still a laborious bottleneck for many companies.

Whether it is creating an annotated model, fleshing out the detailed drawings, or organizing the technical data package, converting design intent into an unambiguous set of detailed requirements is a time-consuming process. In fact, the majority of aerospace companies declare that “drawing release” is on the critical path of the product lifecycle. As a result, many of these same companies are exploring a model-centric environment in the hopes that providing a 3D model to the supply chain will be sufficient and can help reduce time and labor in detailed design. In reality, this approach to model-based design is just shifting the detailed design burden to organizations farther removed from the design intent, adding more work for the supply chain, and actually increasing quality risks.

2. Producibility or Design for Manufacturing is frequently not addressed as part of detailed design.

Most aerospace & defense manufacturers still follow a serial process for creating the detailed design. The design engineer drives the process, and he starts the effort by providing his 3D model to the specialized analysis engineers (e.g., thermal, structural, etc.). Based on their feedback, he updates the model and then passes the data package to a detailer. The detailer works to complete the detailed product definition. In this environment, the disciplined integration of design requirements with process capabilities is often not fully addressed because it is treated as one more step, requiring extra engineering effort that delays completion of the product definition. In short, incorporation of producibility becomes an added cost and schedule driver in the design/development process at a point in the product lifecycle when time and money are typically in short supply. The result is that fundamental producibility issues are pushed to the right in the lifecycle, where they become part of the downstream “engineering changes” that GAO cites as driving cost overruns and schedule delays [2].

3. The proper completion of the detailed design really depends upon the manufacturing processes considered.

The completion of a successful detailed design is dependent on both the “what” of the part, and the “how” of the manufacturing processes. Design for Six Sigma is dependent upon finalizing design requirements in the