SYSTEMS ENGINEERING PRODUCIBILITY MODELING & SIMULATION NEEDS

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Producibility is routinely referenced as an important aspect to be considered in the systems engineering process, however it is usually neglected in the early conceptual and preliminary design activities because it is hard to quantify due to the lack of available analytical tools. And since producibility considerations are often neglected during these early systems engineering activities, a key customer input has not been included in the requirements definition process, the voice of the customer for manufacturing. The needs of this internal customer are equally as important as the external customer since they will be responsible for the long term production and profitability of the system that the development team is designing. Here the business needs of being able to meet the production cost, quality, delivery, and inventory targets must be considered as part of the trade study process when evaluating alternative design and industrial engineering concepts so that the impact of manufacturing capability, cycle time, test coverage, and yield can be taken into account and established as “design to” requirements similar to performance and weight targets. Figure 1 shows the results of a life cycle cost study that found 70% of the life cycle costs are locked in by the time conceptual design is completed when only 8% of actual development funds are spent[1]. Clearly the largest, and only, opportunity to make step change improvements in affordability is in the front end of the systems engineering process as design concepts are being conceived and analyzed.

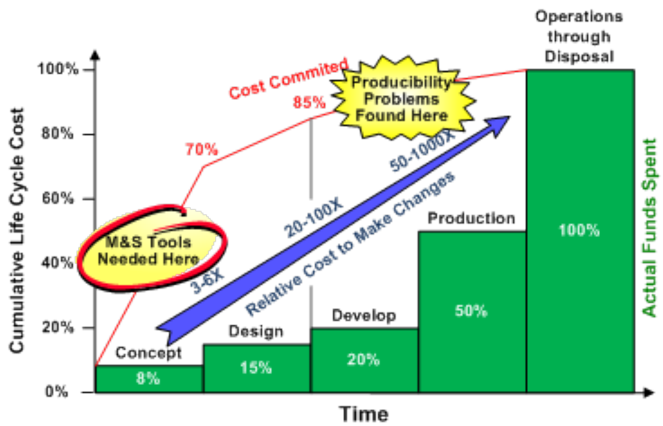

Figure 1: Life Cycle Cost Commitment as a Function of the System Life Cycle

Currently, inadvertently “designed in” producibility issues impact defense system affordability through “hidden factory” mechanisms that are difficult to predict in early acquisition yet often have significant long term impacts on the manufacturing operations over the life of the product. For example, controlling inventory is vital to controlling factory operating costs once the system is fielded yet little consideration is given to the impact that early design and industrial engineering decisions have on these costs during early systems engineering activities. One of the primary drivers of work in process (WIP) inventory is the manufacturing cycle time required to manufacture the components and then build, integrate, and test the final product. Producibility problems often drive up WIP inventory due the additional cycle time, safety stock, and lead time buffers required to address unanticipated yield fallout and manufacturing inefficiencies associated with inadvertently “designed in” producibility issues that are impacting production rate and delivery performance. In addition these same producibility issues often impact the factory cost of poor quality (COPQ) metrics, with additional WIP associated with the “hidden factory” rework loops and associated quality control and oversight required to ensure products continue to meet design specifications that are on the ragged edge of producibility once they enter production.

[1] INCOSE “Systems Engineering Handbook: A Guide for System Life Cycle Processes and Activities”, version 3, edited by Haskins, C., INCOSE-TP-2003-002-03, June, 2006.

Clearly producibility issues can have significant long term impacts on manufacturing enterprise operating costs due to the "hidden factory" rework, process inefficiencies, and overhead they introduce into the day to day production operations. Needed are the development of advanced simulation-based capabilities that can be used to analyze and "design out" producibility problems as requirements are being analyzed, designs are being conceived, and systems engineering "ility" trade-offs performed. These simulation-based capabilities would enable design and industrial engineers to identify potential producibility and manufacturing concerns during the "fuzzy" front-end of the design process where the flexibility exists to pursue alternative design and industrial engineering concepts that will satisfy both affordability and performance constraints. Currently simulation-based methods to predict system performance and functionality characteristics are routinely used to determine which alternatives are most viable early in the conceptual design process. However, comparable simulation-based methods suitable for the producibility analysis of large-scale complex weapon system components are severely lacking.

Design For Manufacturability and Assembly (DFMA) has been commonplace in the automotive and consumer electronic sectors for several years now, but mostly consist of high level guidelines such as reduce part counts, simplify assembly operations, standardize parts, loosen tolerances, etc. If DFMA evaluation criteria do exist, they are usually in the form of checklists, or at best automated CAD-based rule checkers used to determine if the designer has adhered to recommended best practices or not. The limitations of these approaches are threefold: first they are only as good as the rules that are loaded into the checklists or software, second they are go/no-go and do not "quantify" the impact of not adhering to the rule, and third they are usually applied when the design is near final and enough information is available to answer all the checklist questions or run the CAD analysis, at which point it is too costly to implement significant design changes. For large-scale complex defense and aerospace systems where maximum functionality in the smallest and lightest package is the primary driver, it is quite common for numerous DFMA violations to occur as the design layout is being completed in order to meet competing performance, functionality, size, and weight objectives with producibility an afterthought.

The need for improved simulation-based capabilities and frameworks to integrate producibility and manufacturing considerations into early systems engineering activities was recognized the National Defense Industry Association (NDIA) in 2008, with a Joint Committee for Systems Engineering and Manufacturing (JCSEM) formed and chartered to identify current analysis capability gaps and define future analysis capability needs[2]. The NDIA Manufacturing Division has recently added a fourth committee to its current structure aimed at identifying "engineering-based" approaches to enhance the affordability of weapon system development, production, and sustainment that is in the process of being kicked-off. The primary near term objective of the NDIA AMEC committee will be to bring together subject matter experts in industry, government, and academia to help develop short and long term roadmaps for the following top six focus areas identified in the JCSEM M&S final report:

- Systems engineering trade study and design decision methodologies
- System integration, assembly, and test modeling
- Electrical, mechanical, and assembly yield modeling
- Enterprise level supply chain design and analysis methods
- Quantitative DFX analyses including complexity characterization
- Should cost modeling including uncertainty and risk impact

The end goal of developing the roadmaps is to both spur government investments in new areas as well as provide use-inspired research guidance to university, government lab, and CAD tool vendors that is of high importance and interest to the defense industry. In addition, the complexity of the industrial base has increased almost lock-step with that of the physical weapon system, having evolved into a complex adaptive system of systems with characteristics that conventional supply chain management approaches fail to address. The overall vision is thus to define a roadmap for the development of advanced simulation-based producibility and supply chain analysis capabilities and frameworks that will enable true concurrent engineering and virtual prototyping of both product,

[2] Sanders, A., "Modeling & Simulation Investment Needs for Producible Designs and Affordable Manufacturing: Systems Engineering Implications", NDIA JCSEM M&S Sub-Committee Final Report, February 2010.

manufacturing, and industrial base design concepts through the use of advanced modeling and simulation and systems engineering techniques.