DFMA Helps Improve A Future Combat System Missile

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Design for manufacturing and assembly (DFMA) is a proactive and concurrent design process that allows for early consideration of manufacturing aspects, especially with the Army's Future Combat Systems (FCS). In the DFMA process, a cross-functional team works to optimize the design for cost-effective manufacturing. The use of DFMA workshops should be an integral part of the overall systems engineering process. The workshops are most effective when conducted prior to the critical design review, allowing changes to be incorporated to the design, although cost-saving benefits can be realized by conducting workshops during low-rate initial production and cost-reduction efforts.

The DFMA workshops are a brainstorming activity, generating numerous ideas that ultimately may or may not be incorporated. The ideas resulting from the DFMA workshop should be fed into the trade-study process for formal consideration. This makes the trade-study process more efficient, even for ideas that are not incorporated, by clearly defining producibility versus performance tradeoffs.

The DFMA workshops should consist of multiple functional disciplines with the specific goals of improving the design, allowing for easier assembly processes and less-costly manufacturing processes while still satisfying performance requirements. The workshops focus on how to standardize components and materials, avoid difficult components, use self-locating features, minimize operations and process steps, avoid blind assembly steps, and reduce the number of parts needed. In particular, reducing the number of parts can result in significant costs savings, especially since an eliminated part reduces the costs associated with purchasing, shipping, inspecting, performing inventory, kitting, and assembly. Also, an eliminated part means no worrying about its being shipped late or being defective.

It is important to understand that the DFMA process is not a quick fix or a magic bullet, and it will not necessarily solve all the average unit production cost issues. Because weapons systems that are developed must protect the lives of American warfighters, the performance, safety, and reliability requirements will take precedence and usually cannot be traded for cost savings.

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Benefits of DFMA

The most significant benefits of DFMA are the tangible results in avoiding potential manufacturing problems and reducing manufacturing costs in production. However, DFMA also provides several important, intangible benefits such as improving communication within the entire design team, promoting teamwork, and increasing organizational ownership. The DFMA activity brings manufacturing personnel into the design cycle very early and allows for the incorporation of knowledge, insight, and perspective that the traditional design engineers may not have considered. Experience shows that design engi-

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neers perform an excellent job in considering options and alternatives. However, they cannot foresee everything.

DFMA workshops also provide everyone on the development team a sense of ownership in the design. Manufacturing personnel now have an understanding of the design and its associated requirements. While manufacturing personnel may still have to live with designs that are not optimal from a production standpoint, they understand why the designs are not optimal and have had the opportunity to provide their input. This eliminates the brick wall syndrome, in which designers hand off a design to manufacturers with little or no communication.

DFMA Supports DoD Acquisitions Requirements

DoDD 5000.1 and DoDI 5000.2 require that acquisition programs be managed through the application of a systems engineering approach and be designed for producibility. In addition, the July 2002 General Accountability Office Report 02-701, "Capturing Design and Manufacturing Knowledge Early Improves Acquisition Outcomes," stresses the importance of early consideration of manufacturing aspects in the design process to provide a better opportunity to achieve predicted cost, schedule, and quality targets.

Numerous lower-level requirement and guidance documents have identified best-practice approaches to satisfy these requirements. One of the most prevalent is concurrent engineering, which is a systematic approach to the integrated concurrent design of products and their related processes, including manufacture and support. This approach makes developers consider all elements of the system life cycle, from requirements development through disposal, including cost, schedule, and performance.

The principles of concurrent engineering are sound and are designed to eliminate the brick wall syndrome. The problem comes with how to effectively apply these principles. DFMA workshops serve as an excellent best practice tool to incorporate concurrent engineering principles. What follows is an example of how DFMA effectively helped improve a future combat missile.

Applying DFMA to NLOS-LS

The Non-Line-of-Sight Launch System (NLOS-LS) is a core part of FCS. It consists of vertically launched precision-attack missiles (PAMs) and a highly deployable, platform-independent container launch unit (CLU) with self-contained tactical fire-control electronics and software for remote and unmanned operations. Each CLU consists of a computer and communications system and 15 PAMs, and each can be fired from the ground, vehicle, or ship.

The PAM is a direct-attack missile that is seven inches in diameter, weighs approximately 117 pounds with a 45-pound container, and is effective against moving and stationary targets at ranges from zero to 40 kilometers. It will include a boost-sustain motor; a dual-mode, precision, uncooled infrared/semi-active laser seeker; and a large multi-mode warhead that is effective against both hard and soft targets. The missile will receive target information prior to launch and can receive and respond to target location updates during flight. It will support laser-designated, laser-anointed, and autonomous operation modes, and it will be capable of transmitting near-real-time information in the form of target imagery prior to impact. The PAM is designed to defeat heavy-armored targets.

The NLOS-LS program is midway through a five-year system development and demonstration (SDD) program. The program is managed by the NLOS-LS Project Office of the Program Executive Office (PEO) for Missiles and Space, located at Redstone Arsenal, Ala. The NLOS-LS system is being developed by NetFires, Limited Liability Corporation (LLC), which comprises of Raytheon Missile Systems in Tucson, Ariz., and Lockheed Martin Missiles and Fire Control in Dallas, Texas.

The NLOS-LS program implemented a robust producibility engineering and planning statement of work to promote producibility and manufacturing planning in the development program, and the program required that producibility be considered in all design decisions. The statement of work required the contractor to conduct DFMA workshops on the NLOS-LS assemblies and major subassemblies. Because weapon system prime contractors often acquire critical subassemblies from suppliers, the flow-down of this requirement to major subcontractors is critical. Early planning discussions between the government and contractor on implementing this requirement were crucial to the overall success. Although the details as to how to implement the DFMA workshops were not dictated in the statement of work, many major defense companies are very knowledgeable in this area

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and have internal organizations designed to execute such activities. In addition, there are a number of consulting companies that specialize in this area and can offer beneficial services.

Upon award of the NLOS-LS SDD contract, Raytheon Missile Systems immediately employed an internal producibility division to implement, manage, and facilitate the DFMA workshops. The producibility division selected skilled individuals, independent of the NLOS-LS program, to support these activities. For the next couple of years, the Raytheon Missile Systems and Lockheed Martin Missiles and Fire Control teams conducted workshops on the missile and launcher with support from both the supplier and management. Having first-class knowledge of the DFMA methods and philosophy, the teams maximized the effectiveness of each workshop. In addition, these events forced essential communication early in the life cycle of the program and resulted in a solid and unique relationship between the supplier, contractor, and customer.

How to Prepare for a DFMA Workshop

Several pre-workshop activities must take place in order to ensure a valuable event. These activities include workshop planning and work preparation; a baseline for the workshop must also be provided. Planning consists of identifying goals and objectives, preparing a schedule (because staying on track can be challenging), and most important, composing the appropriate attendance list. Attendance lists should be broad, cross-functional, and all encompassing. For example, it's beneficial to include a member from every discipline that touches the product. Design engineers, manufacturing engineers, shop-floor employees, material handlers, and facility managers represent a good mix of personnel. However, each event will be unique, so it is imperative that the right formula of personnel be obtained. Successful workshop preparation consists of collecting appropriate documentation, drawings, hardware models, cost information, and workshop supplies. For example, team members with ideas need a means to immediately capture them. Providing a baseline for the workshop involves informing every participant of what to expect. This requires reviewing the current design and discussing the principals, methodology, and tools of DFMA. Once these details are finalized, the workshop can begin.

Conducting a Workshop

The first step of the workshop is to discuss the current design openly. Participants should be made aware that this is done using a formal academia environment and that scrutinizing the design should not offend anyone. Discussion is a notable way to identify non-essential and non-value-added design features, as well as isolate complexity drivers. It is important to remember that the team is not trying to solve every design issue during this workshop. Rather, they should use the workshop setting as a vehicle to discuss issues and apply creative reasoning to them. Once room-for-improvement areas have been identified and discussed, the team can begin brainstorming ideas. During this activity, all ideas should be captured regardless of complexity, simplicity, or feasibility.

As soon as ideas and concepts have been captured, the team can apply a form of technical evaluation to each idea. This process gives the team an opportunity to assign priority to specific metrics of the design—technical, manufacturing, cost, weight, etc. Following this exercise, it is imperative that the team determine how the ideas impact the current design, whether they are positive, negative, or have no effect. For instance, a reduction in fasteners will have no impact on technical matters, a positive impact on manufacturing, a positive impact on cost, and a positive impact on weight. When all ideas are assigned impacts, the team can sort them to distinguish the simple ideas from the complex ideas. This exercise will assist in determining what ideas should be explored for implementation into the design.

An artist's rendition of the Non-Line-of-Sight Launch System (NLOS-LS).
Dept. of the Army illustration

The follow-up phase is the designated time to appoint actions to team members, analyze any quality improvements, calculate cost savings, and discuss implementation of the resulting ideas. The event is concluded by

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presenting management with the number of ideas generated, a candidate list of ideas to be explored, potential cost savings, potential reduction in assembly times, and any key lessons learned during the event. It is important to note that the follow-up phase is hard to define because it extends beyond the formal workshop. The team members should continue to focus on the ideas generated, monitor progress of action items, and avoid losing sight of the DFMA goals, even after the workshop has concluded.

Key Lessons Learned

Upon completion of a DFMA workshop, the facilitator should take the opportunity to poll the team for any suggestions and lessons learned. While each DFMA workshop is unique in its own way, there are a number of lessons learned that resonate time after time. First, always have a facilitator to orchestrate the workshop. This individual can be from an outside agency or from an internal organization, but it does help to have someone independent of the program or design. A good facilitator can sense when the event is beginning to transgress and make appropriate changes to redirect the group. Second, attendees from various functional backgrounds and disciplines are essential to a successful workshop. Look for individuals who can be creative and think outside the box. Additionally, the knowledge of a shop floor worker or shop floor manager can be priceless in this environment. Third, always be respectful of everyone's thoughts and ideas. If respect is not observed between team members, communication will not flow. Last, but certainly not least, try to have fun at these events. It's a good idea to step away from the everyday grind, clear your mind, and have a good time.

NLOS-LS Program Results

The strong management commitment from the NetFires, LLC, has resulted in a successful DFMA activity. A total of 16 workshops were conducted on the PAM, container launch unit, and major subassemblies, generating more than 360 ideas for evaluation. Of these, 112 have been incorporated into the NLOS-LS design. Examples of the ideas incorporated include:

- Combining primary mirror and telescope housings to reduce parts count and eliminate assembly operations
- Reorienting torquers for accessibility
- Developing better identification of pins to prevent incorrect placement during assembly
- Redesigning the removable forklift structure to eliminate the need for special tooling
- Making all electronic unit circuit card assembly heat sinks identical for standardization.

It is often difficult to accurately quantify the exact cost savings of DFMA activities during SDD because the baseline is an estimate. The true results of this DFMA activity will not be fully recognized until rate production is achieved several years in the future. However, the NLOS-LS program has seen benefits of reduced assembly and test-time estimates and reduced average unit production cost estimates in many areas. The program has also seen intangible benefits through the establishment of a true concurrent engineering environment during development, with improved communication and overall team buy-in. The incorporation of DFMA in the development program has played a major role in obtaining a successful critical design review and in serving as a vehicle for the implementation of the DoD regulation requirements to establish producibility as a design priority.

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