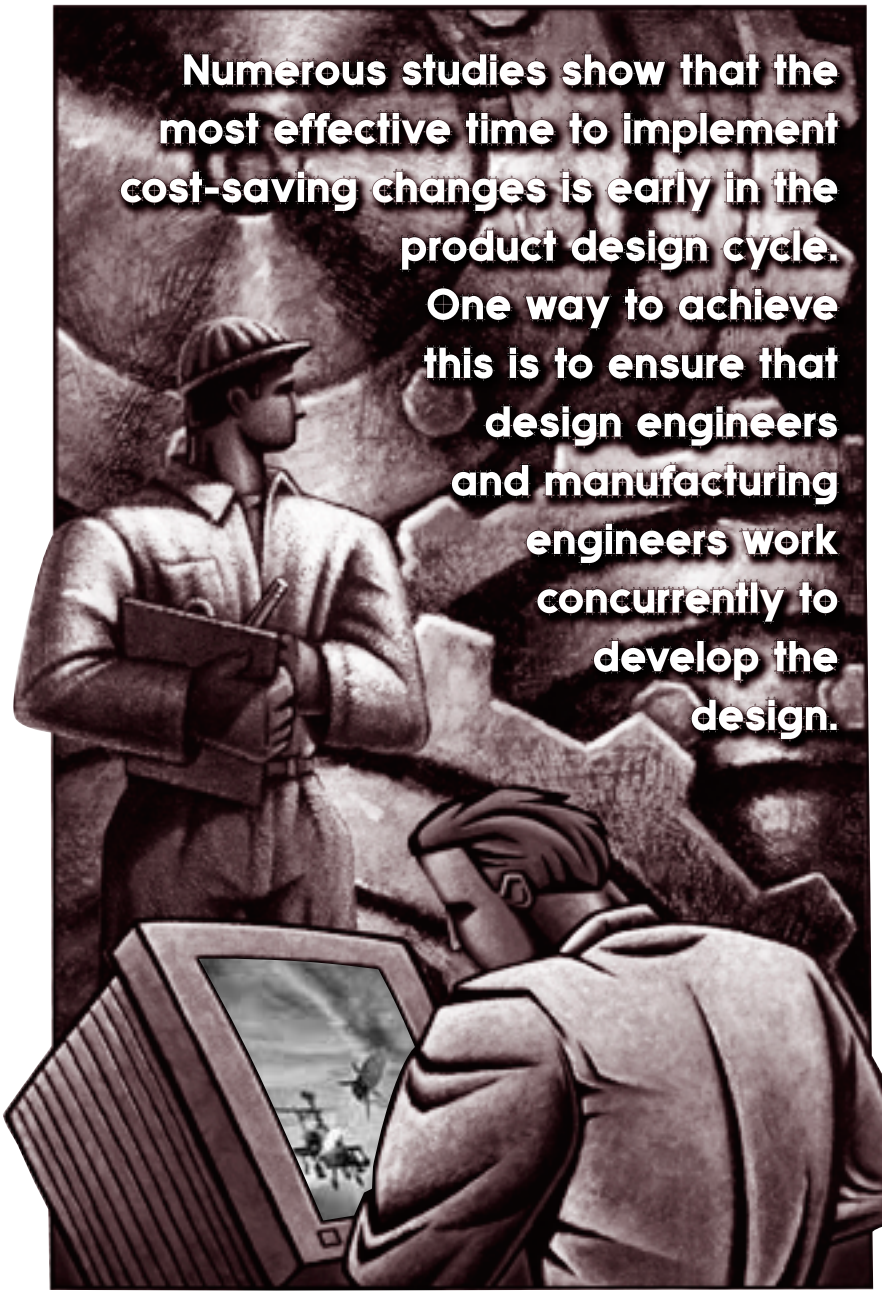
Using Design for Manufacture And Assembly To Meet Advanced Precision Kill Weapon System Cost Goals

Steve Watts



In our environment of state-of-the-art weapon systems development, the emphasis is largely on ensuring technological feasibility to meet performance requirements. However, for overall program success, the manufacturing processes and costs associated with the design must also be addressed. Numerous studies show that the most effective time to implement cost-saving changes is early in the product design cycle. One way to achieve this is to ensure that design engineers and manufacturing engineers work concurrently to develop the design. The Advanced Precision Kill Weapon System (APKWS) Program has created the opportunity for this type of environment through the implementation of design for manufacture and assembly (DFMA) workshops during the system development and demonstration (SDD) phase.

The Genesis of APKWS

The Army has identified a requirement for a low-cost precision weapon system to fill the critical weapon system gap between the current aimed Hydra-70 rocket system and the HELLFIRE anti-armor missile. Our nation's military strategy requires systems that are more precise, lighter, more deployable, and that produce higher ratios of kills per platform. The future projected military campaigns will be characterized by military operations in urban terrain, a proliferation of soft to lightly armored targets, fighting in close proximity to noncombatants, and a high potential for collateral damage.

In February 2003, the Aviation Rockets and Missiles Project Office of the Tactical Missiles Program Executive Office, Redstone

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Arsenal, Ala., awarded General Dynamics Armament and Technical Products a 30-month (incentivized to 25-month) SDD contract to develop the APKWS. General Dynamics has contracted with BAE Systems, Nashua, N.H., to develop a newly designed guidance section that integrates with the existing Hydra-70 components and launch equipment. Using a semi-active laser-guided seeker, the APKWS will be a highly accurate weapon that complements the HELLFIRE missile in a precision strike by offering a lower-cost alternative against soft-point targets, while minimizing collateral damage. This system will provide improved accuracy over the current Hydra-70 munitions used on the AH-64 Apache, the OH-58 Kiowa Warrior, as well as various other rotary and fixed-wing aircraft platforms. The APKWS fully embodies the Army's vision for a lighter, versatile, and decisively lethal force.

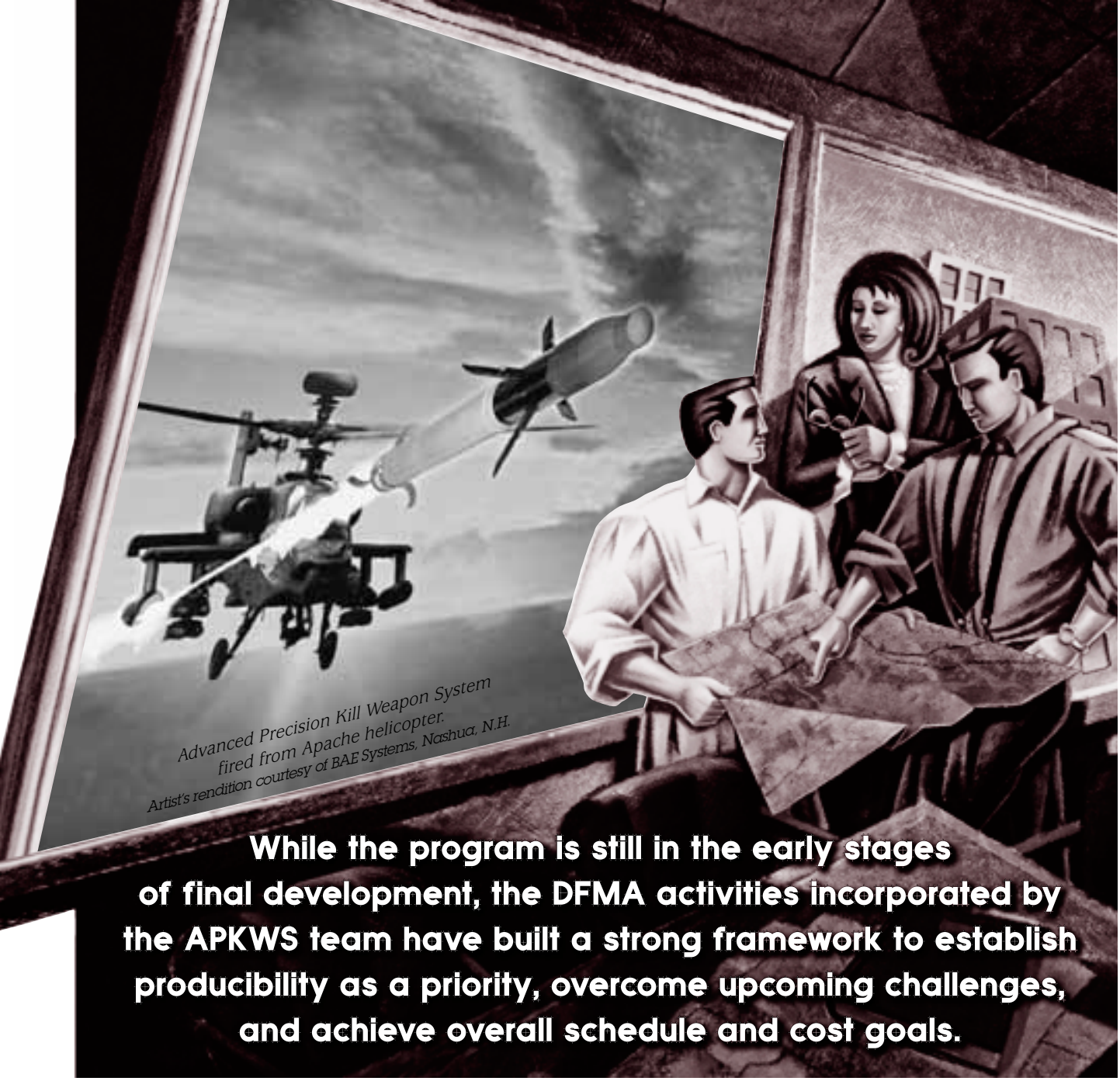
In September 2002 (five months prior to SDD award), the Army conducted an independent engineering and manufacturing readiness level (EMRL) review of the advanced technology demonstration (ATD) phase design of the APKWS. There is an ongoing effort by the Missile Defense Agency (MDA) and Future Combat Systems (FCS) to establish EMRLs to assess the manufacturing process maturity of a design—similar to the way the technology readiness levels address the technology maturity of a design. The review of APKWS was conducted by the production engineering division of the Aviation and Missile Research, Development, and Engineering Center at the U.S. Army Research, Development, and Engineering Command, Redstone Arsenal, Ala. It represents the first application to a major Army missile system. The purpose of the review was to assess the maturity of the manufacturing processes and materials associated with the design, identify producibility issues early, and assess the program's readiness to transition into SDD.

The conclusion from the EMRL review was that all the manufacturing processes and materials associated with the APKWS design were relatively mature, and no issues would preclude this program from transitioning into SDD. However, given the schedule constraints in SDD and the average unit production cost goals, producibility emphasis would need to be placed on several assemblies in order to meet rate requirements. The most significant concern was with the seeker optics assembly. The design was very complex, consisted of numerous parts, required substantial manual assembly by skilled optics technicians, and was not readily conducive to automated assembly processes. In addition, there were concerns with critical characteristics that made the design difficult and costly to manufacture and prone to breakage in handling and assembly of the optic fibers. The control actuation system also presented producibility concerns because it, too, consisted of numerous parts and required extensive manual assembly. Many of the parts were very intricate, requiring tedious assembly processes, and included an area that required match-drilling operations between two parts. The recommendation from the EMRL review was that several assemblies needed to undergo an extensive DFMA process to reduce the number of parts associated with the designs and to generate ideas that would make the designs more cost effective to manufacture.

The APKWS program has an aggressive 30-month SDD phase and challenging cost targets for the production unit price. These factors drive the need for innovative approaches during the SDD phase like DFMA workshops and other concurrent engineering techniques to quickly and efficiently focus the development team on meeting the schedule and cost targets.

DFMA: Principles and Benefits

DFMA is a process where a cross-functional team concurrently and proactively evaluates a design early in the development process. As a result, attention is given to the manufacturing process associated with a design, and potential manufacturing problems can be averted, thereby reducing manufacturing costs. It also promotes team buy-in and increases organizational ownership. The benefits include a simplified design with reduced cycle times and engineering changes, resulting in a reduced life cycle cost with improved quality.



Advanced Precision Kill Weapon System fired from Apache helicopter.
Artist's rendition courtesy of BAE Systems, Nashua, N.H.

While the program is still in the early stages of final development, the DFMA activities incorporated by the APKWS team have built a strong framework to establish producibility as a priority, overcome upcoming challenges, and achieve overall schedule and cost goals.

A major benefit of DFMA is that it enables product design engineers and manufacturing design personnel to come together and brainstorm the design. The best results are realized when there is a structured approach to these workshops and an independent party facilitates the DFMA process. General Dynamics and BAE Systems selected Boothroyd Dewhurst Inc. to facilitate their DFMA workshops. Boothroyd Dewhurst, regarded as one of the pioneering companies in the area of DFMA, provides initial training on DFMA and has developed several software tools that provide structure to the brainstorming activity and assist in the step-by-step evaluation of the design.

Boothroyd Dewhurst's DFMA® software provides a metric tool for analyzing and evaluating product designs for ease of assembly and manufacturing efficiency at the earliest stages of design. The early and accurate cost understanding provided by DFMA enables product development teams to manage product cost and consider alternative designs. The software is based on two interlocking approaches: design for assembly (DFA) and design for manufacture (DFM).

The DFA software guides engineers to evaluate the functional purposes of each component in the design of a total product. Data accumulate as the engineers question the relationships between items in the design according to the DFA methodology. DFA software also enables the designers to rate each component on its ease of orientation and assembly. The DFA software-generated data guide the design teams to focus on part count to achieve cost reduction through product simplification.

Boothroyd Dewhurst's DFM Concurrent Costing® software identifies the major cost drivers associated with manufacturing and finishing parts; it helps engineers choose the most cost-effective shape-forming process for a part and consider how individual part features might be modified to optimize manufacturing costs. The software contains an extensive library of data for varied materials, operations, and processes. A key benefit of DFM software is that in just a few simple steps, it quickly generates an initial cost estimate at any stage of design.

Longbow HELLFIRE Proves Value of DFMA

The Aviation Rockets and Missiles Project Office and BAE Systems have already experienced the benefits of a successful DFMA exercise on the Longbow HELLFIRE system. In the early 1990s, the program was experiencing difficulty in developing a receiver design that could be transitioned to rate production. In March 1995, the prime contractor, Lockheed Martin, facilitated a DFMA at BAE Systems as part of a cost reduction program. The DFMA methodologies and lean manufacturing activities have contributed significant cost reductions to the program. These initiatives have resulted in reduced parts count, increased test yields, reduced hours per unit by 20 percent, reduced number of operations by 20 percent, reduced layout square footage by 20 percent, and increased production output from 52 units per month to 220 units per month. The Longbow HELLFIRE program has now delivered over 10,000 receivers. The combination of these enhancements has established the program as a cost-effective solution for continued multi-year deployment.

Applying DFMA to APKWS

The APKWS team (the Army, General Dynamics, and BAE Systems) decided on a course of action for DFMA implementation on the guidance section and its major subassemblies, including individual workshops held at the source of the major subassembly or system. A cross-functional team of program managers, design engineers, producibility engineers, manufacturing engineers, design to cost engineers, and assembly technicians was established. Gerry Burke of J&J Engineering facilitated the workshops using the Boothroyd Dewhurst DFMA software.

Key to the success of the workshop is doing the required pre-work to establish a baseline: establishing a level breakdown, developing a product structure including detailed parts lists and data, and generating a complete assembly process. Loading these data into the tool prior to the workshop saves valuable time and accelerates the learning process. The software assigns assembly standards and tooling costs to the individual parts and operations by considering commodity, size, and complexity. The team then reviews the baseline data to find opportunities for part reductions and assembly simplifications. The next step is to agree on the ideas and perform a re-design analysis to determine potential cost savings and quality improvements. A concurrent cost model is then established for both the original and proposed re-designs to identify potential savings. The team agrees on a list of action items to incorporate the ideas developed during the workshop.

This process was instrumental in identifying significant cost reduction opportunities on the control actuator system and the guidance section of APKWS. Several other workshops are planned, and action item closure is being monitored to capture real savings.

DFMA parameters were also used to address producibility concerns on the seeker optics assembly. The team brainstormed alternative designs and fabrication technologies to aggressively reduce the number of separate piece parts in the seeker optics assembly. Fasteners were eliminated. Some parts were redesigned so they would be symmetrical and easier to install. Parts were also designed to be self-aligning, further reducing the complexity of the assembly process.

Early Results Show Promise

While the final results of the DFMA activities on the APKWS will not be fully realized until rate production is achieved several years down the road, the program has already generated several tangible and intangible benefits. The tangible benefits are the incorporation of significant simplifications to the preliminary design: things such as elimination of fasteners, overall parts count reductions, redesigns for ease of assembly, and self-alignment features. In addition, numerous ideas are still being evaluated. The intangible benefits have been the establishment of a true concurrent engineering environment for this program that has resulted in overall team buy-in and ownership and improved communication. While the program is still in the early stages of final development and several challenges remain, the DFMA activities incorporated by the APKWS team have built a strong framework to establish producibility as a priority, overcome upcoming challenges, and eventually achieve overall schedule and cost goals.

Editor's note: The author welcomes comments and questions and can be contacted at charles.s.watts@us.army.mil.

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