

# **Expanding the Application of Design for Manufacturing and Assembly (DFMA) and Creating an Affordability Culture**

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## **Summary**

This paper presents how DFMA is essential as business opportunities require affordable solutions in Raytheon's and suppliers' designs. A team of sixteen DFMA SME leads was developed and yielded an eleven fold increase in deployments. Topics include successes in applying DFMA to new products earlier in the development cycle and on legacy products, changing corporate culture, inclusion of cross functional teams, procedural innovations, and adaptations of DFMA for product sustainability. Case studies illustrate the inclusion of lean manufacturing initiatives and design for service and ownership.

## **How did Raytheon come to utilize DFMA?**

Raytheon Company is a technology and innovation leader specializing in defense, security and civil markets throughout the world. With a history of innovation spanning 92 years, Raytheon provides state-of-the-art electronics, mission systems integration and other capabilities in the areas of sensing; effects; and command, control, communications and intelligence systems; as well as a broad range of mission support services.

Raytheon adopted and started deploying its own brand of six sigma developed by internal and external experts. The purpose was to bring together newly acquired businesses and change the culture to solve business related problems using the same processes. The R6s process structure has six steps: Visualize, Commit, Prioritize, Characterize, Improve, and Achieve. All the tools of process improvement fell under the Raytheon Six Sigma umbrella. One of the major four major areas in Raytheon Six Sigma is Design for Six Sigma (DFSS). We deployed Design for Six Sigma enterprise wide fifteen years ago and continue to expand deployments across programs and product lines. Prior to 2011, the DFSS team averaged only two DFMA engagements per year. Other Raytheon businesses also struggled to increase the use of DFMA. We institutionalized DFMA into our product development processes.

Our DFSS group started with an ad hoc approach for engaging programs and products that were far from their cost targets. We remained in this mode for 10 years, while developing and refining our process, templates and documenting success stories. Adoption of the DFMA process was slow during these ad

hoc years, and was lacking a continuous improvement advocate. There was a strong need for a director/ vice president champion to help elevate the DFMA process as an engineering imperative.

We created companywide communications with DFSS training newsletters, briefings, internal papers, and technical presentations. After a communications campaign, our Mechanical Engineering Director (MED) started setting goals within his organization. This shift in culture caused the Vice President of Engineering to set DFSS deployment goals and enable the proliferation of DFMA.

## DFMA Institutionalized 2011 - 2014

Business opportunities drive the need to achieve the highest performance at the lowest cost. DFMA improves affordability and producibility of Raytheon and supplier’s designs. In 2011 we were limited to one person to run DFMA affordability workshops. A core team with a DFMA champion leader was developed to build DFMA capacity and capability. 16 IDS DFMA leads transformed the organization achieving 88 DFMA Deployments on 22 programs and 26 suppliers in 2014. This extraordinary achievement yielded an 11 fold increase in deployments. This expansion required standardization of training, tools, process and templates accessible through a web based (SharePoint) database. The following has been achieved through 2014:

- Improved the DFMA capability, capacity, and infrastructure.
- Mentored 16 IDS DFMA Leads.
- Qualified 10 DFSS R6s Principle Specialists (Equates to six sigma green belt)
- Increased in the number of DFMA deployments **11x** from 2011 (8) to 2014 (88).
- International, supplier, and cross business engagements.
- Over 1000 DFMA workshop participants (Raytheon and suppliers).

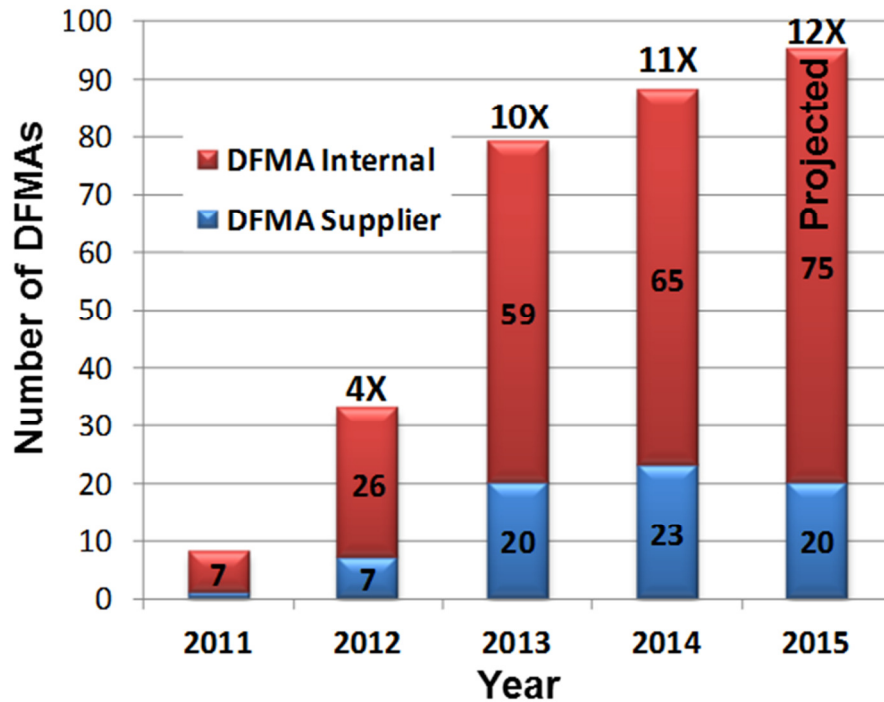


Figure 1. DFMA Proliferation at Raytheon Integrated Defense Systems

DFMA has become recognized as a best practice within our business. The Navy Best Practice team was first to recognize DFMA, performed on a limited basis, as a best practice, with suggestions from the assessors to proliferate DFMA further into the business. In 2013 DFMA was recognized by an Air Force assessor during an early customer gate review “Best Practices...on the DFMA Process and Process Capability Analysis Toolset (PCAT) Producibility tools...”. In 2014 the CMMI level 5 Assessor recognized DFMA as one of five IDS best practices with world class expertise to support these activities. In 2014 the IDS DFMA team was recognized by the IDS president and Raytheon CEO as a top R6s project.

## DFMA Deployment using the Raytheon Six Sigma™ process

Raytheon Six Sigma™ is our disciplined, knowledge-based approach designed to increase productivity, grow the business, enhance customer satisfaction and build a customer culture that embraces all of these goals. Instead of the industry DMAIC five step process, R6s uses six process steps.



Figure 2. Raytheon Six Sigma™ Wheel

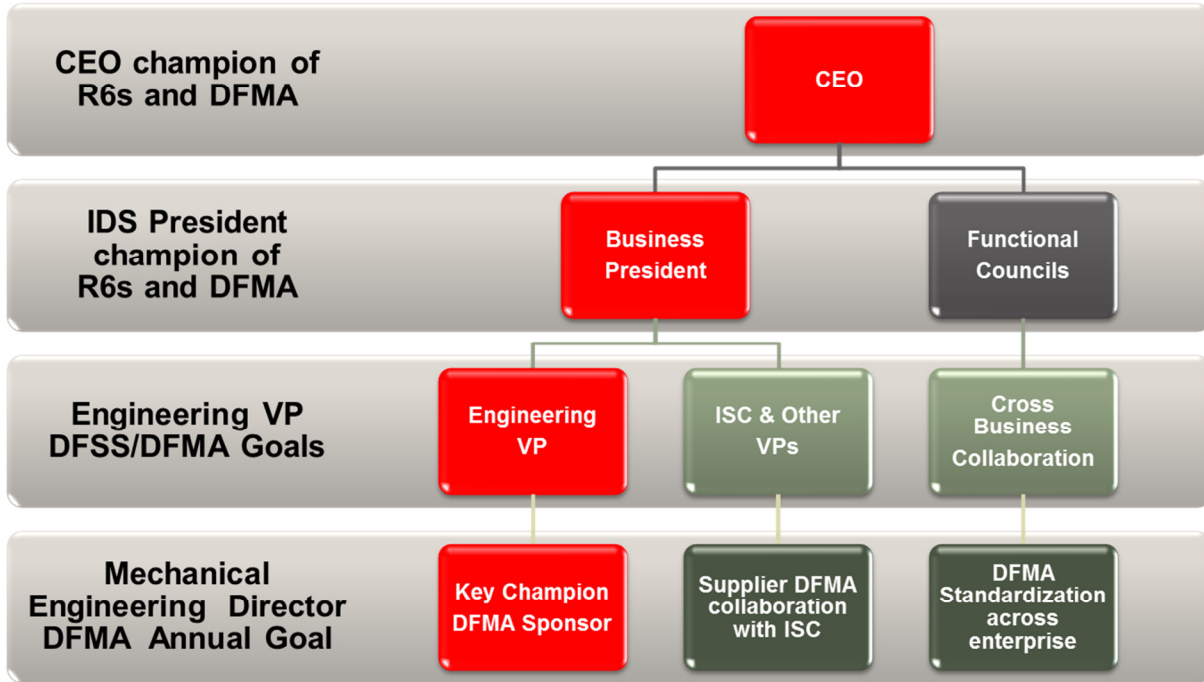
### Visualize

Visualize starts with a problem (or opportunity) statement: Need to make design-to-cost part of our culture and as result we address the risk of losing our competitiveness.

Vision: We need to provide affordable systems to our customers by increasing the number of DFMA's (MED goal), supporting IDS programs and suppliers. Embed the DFMA process as part of what we do to meet cost as a requirement objectives.

### Commit

R6s projects are more successful with leadership support. Commitment starts with a champion: the CEO of Raytheon identified DFMA and DFSS as two strategies to achieve affordability. Division Vice Presidents have had DFSS annual goals since 2012. The MED Director set increasing directorate goals of 30 DFMA's in 2012 up to 95 DFMA's in 2015. This top down commitment enabled the team to influence the culture and obtain team commitment to increasing the application of DFMA.

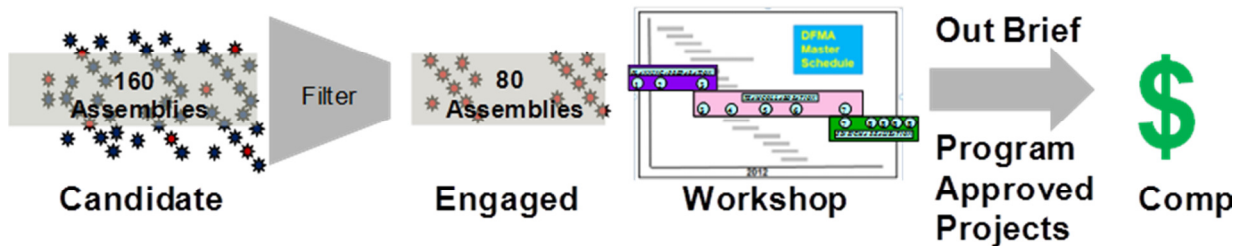


**Figure 3. Management Commitment**

DFMA team representatives “Point of Contacts” in each MED department identify DFMA opportunities across the business. Over twenty programs demonstrated commitment by funding DFMA activities. Each opportunity is an assembly or part that requires a committed DFMA cross-functional team. Each of those teams requires the commitment of DFMA deployment lead facilitators.

**Prioritize**

In Prioritize we capture identify which DFMA opportunities, what order, and when to act.



**Figure 4. Point of Contacts Identify Opportunities**

## Capture opportunities

First we create pull for DFMA events through flowed down organizational goals and the department “Points of contact”. Then we identify through Pareto analysis the high value DFMA opportunities, typically there are 8 to 10 products on every program that can easily be identified as benefiting from a DFMA. These opportunities are derived from new pursuits, legacy programs, and family product lines. We developed a process to prioritize those opportunities into three possible engagement types (Design to cost, DFMA workshop, and integrated DFMA) based on the design phase and the cost/complexity of the assembly. We determine the probability of the DFMA event occurring and place them in our first work flow process step that we call “**Engaged**” and is waiting for program funding.

## Execution

Execution requires capability and capacity: DFMA subject matter experts, a standard process and points of contacts to feed the DFMA opportunities to DFMA leads through completion. Standard process had to come first including standard templates, with accessible storage location: DFMA database and digital library. Capacity requires DFMA lead development, first we identified the best candidates, created SME training, and trained the candidates through a structured mentored learning program: DFMA class room training, observing DFMA, co-leading DFMA, leading DFMA and then certify as a DFMA lead. We pulled this all together by engaging stakeholders, points of contact, and DFMA subject matter experts through weekly DFMA steering team meetings. The DFMA leads and co-leads are assigned an opportunity based upon availability, program, and lead expertise. Leads take the DFMA event from funded through completion stages.

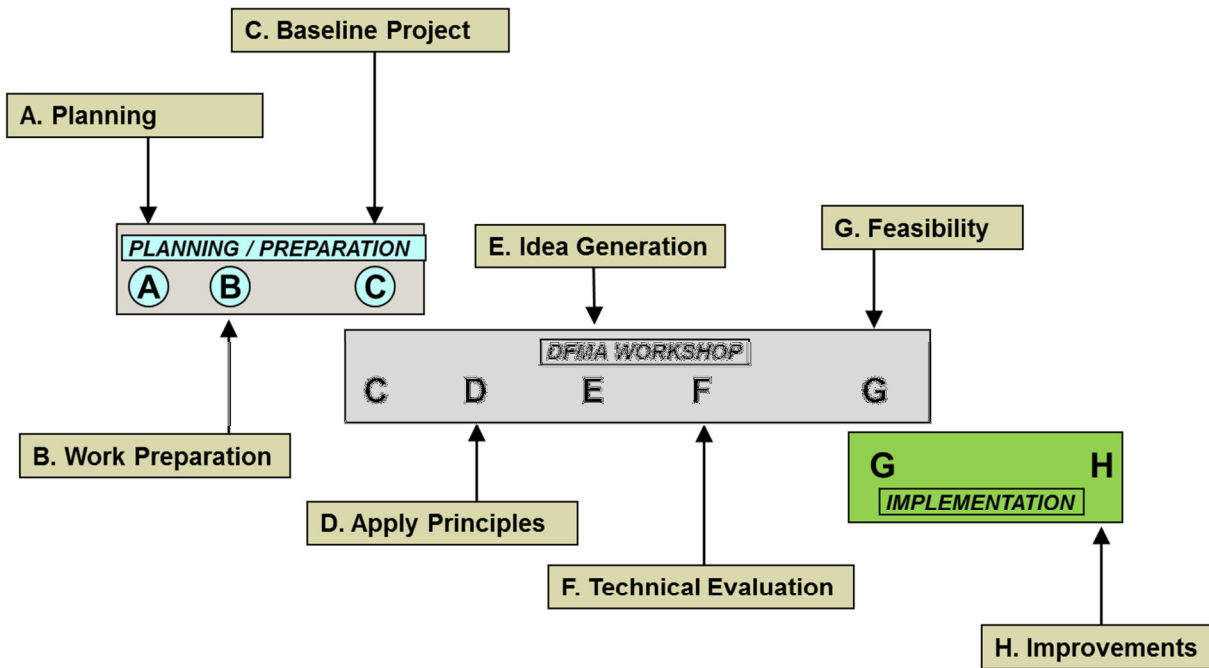
## **Characterize**

In 2011, eight DFMA deployments were conducted and completed by one DFMA subject matter expert lead. DFMA, while identified in Raytheon’s integrated product development system, was sporadically used and almost always tailored out. The DFMA workshop process was not a good fit for smaller opportunities as the results had little or no pay back. To summarize: We had one lead which meant limited capacity for workshops. We needed a way to identify DFMA opportunities and we needed a method to expand DFMA to additional assemblies.

## **Improve**

A core team was created to develop DFMA standardized tools and process, accessible from a web based database. These included process templates, check lists, prework packages, workshop training, and brainstorming collection prioritization, out-brief package, A3 Project template, and success story template.

We created DFMA SME training aligned to DFSS Principle Specialist requirements. This team also documented the process, roles and responsibilities and the processes to utilize the tools. After five years we have shifted the culture to focus on affordability early in design phase and utilizing design to cost workshops prior to design start up to shape the concept of future delivered hardware. DFMA is now incorporated into the bidding process, engineering standards, and integrated into supply chain supplier engagements.



**Figure 5. High level DFMA Process**

**Continuous Improvement projects to the DFMA process and tool set**

Sustainment project

Some programs are won or lost on sustainment (Ownership) costs and typically DFMA covers the acquisition cost but not the cost of operation and maintenance. Sustainment involves the supportability of fielded systems and their subsequent life cycle product support from initial procurement to supply chain management (including maintenance) to reutilization and disposal. Sustainment includes initial provisioning, cataloging, inventory management and warehousing, depot and field level maintenance and begins when product has been fielded for operational use.

We pulled a cross functional team from engineering supply chain and whole life to bring sustainment into each of the DFMA principles and added principles where there was a no fit.

Developed DFMA immersive environment techniques

DFMA execution has adapted the use of 2-D and 3-D visualization with the 2014 addition of an Immersive Design Center at the Raytheon Andover Integrated Air and Defense Center (IADC). The center has a collaborative space with 3-D capability on screens 8 feet high wrapping 320 degrees and is referred to as the “CAVE”. The CAVE has capacity of up to 20 design team members with real time model interrogation & idea capture. The design team can have physical hardware present and the entire team immersed in virtual technical content. The multiple monitors can be structured to display a data rich environment showing parts and labor cost, product value stream maps, parts lists, assembly drawings, and a product design 3D model.

The CAVE has many use cases; the two highlighted are where DFMA engagements are prevalent.

- Model based reviews
- **DFMA**
- Facility design and layout
- Remote collaboration
- Customer Relationships and business Development
- Immersive training
- Human factor analysis
- **Supplier and Industry partner engagement**
- Operations analysis and simulation
- STEM and community outreach

The results of DFMA's utilizing the CAVE have been so outstanding; we now require all DFMA workshops to first consider the CAVE as the venue for the event. The result is increased collaboration, alignment and team motivation, with a high level of participation and cooperation through the common language of visualization. The DFMA environment can be data rich. We have measured across many DFMA's and have determined that a 20% DFMA process productivity improvement i.e. Ideas because of the environment capability. Other Raytheon Businesses are requesting more DTC/DFMA and use of the CAVE. The IDC CAVE is allowing us to conduct DFMA earlier (Pre-drawing design phase).

- CAVE technology is contributing to additional ideas
- IDC Design To Cost workshops on new program pursuits
- Virtual assembly or serviceability capability



**Figure 6: CAVE and the DFMA Process**

## Electronic brainstorming tool and process

When we first started using the CAVE we had a DFMA process problem. Brainstorming traditionally uses paper Post-it's on paper ease-impact charts and easels. We wanted to go to a more real time electronic capture. An electronic brainstorming process tool captures the team's ideas as they are identified, with category project titles, prioritized using ease impact charts, and are automatically translated electronically in a prioritization spread sheet including project category, idea, assembly, and ease impact numbers. Since every idea is individually evaluated real time with the team, missing information or unclear information is corrected on the spot. This results in cleaner, more understandable ideas and ultimately more ideas as others are generated in the process. Typically an 8 hour DFMA event can generate 80 to 200 ideas to improve affordability, quality, schedule, and producibility. Remote DFMA events are easier to conduct with the electronic tool allowing people to type in ideas during electronic collaboration DFMA events with suppliers and across the enterprise.

## 2015 continuous improvement

We are continuously improving our DFMA process, tools, and people. We are challenged annually to expand the use of DFMA even more, and that goal is easier to achieve with improved productivity, capability, and capacity. As our business and customer needs change, we need to adapt our process to meet those needs. The use of immersive technologies will continue to be an area of continuous improvement for DFMA.

## References

1. Boothroyd Dewhurst, Inc. 30<sup>th</sup> Annual International Forum on Design for manufacture and Assembly (DFMA) 2015. Website: <http://www.dfma.com/forum/index.html>
2. Commerce Rhode Island STEAM ENGINE project (Product development & manufacturing growth initiative for RI). Website: <http://steamengineusa.com/>