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

Prepared for:

2017 International Forum on Design for Manufacture and Assembly

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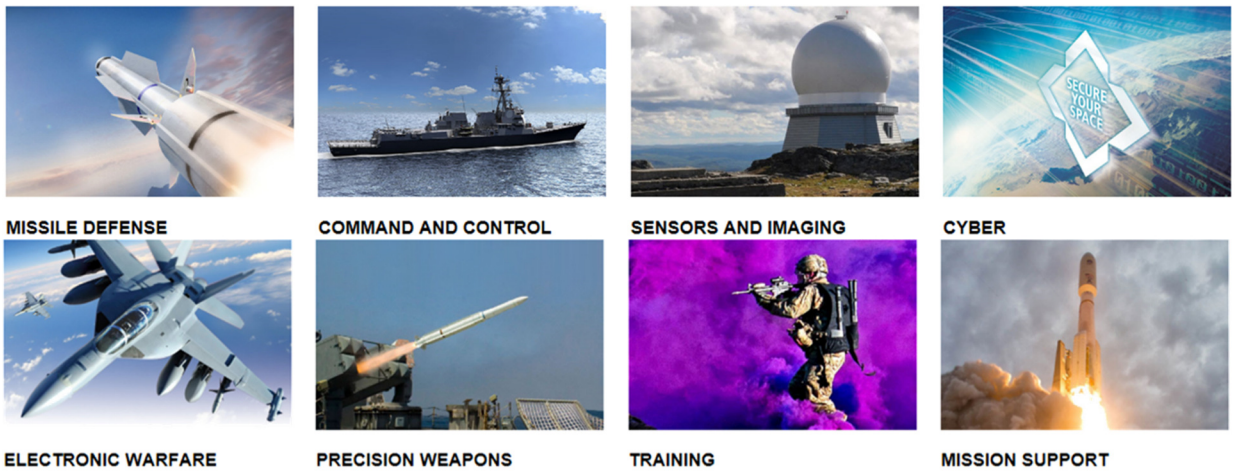
Raytheon introduction

Raytheon is a technology and innovation leader specializing in defense, civil government, and cyber security solutions throughout the world. Founded in 1922, Raytheon continues to be a manufacturer with $24 billion in annual sales and 63,000 employees worldwide.

Raytheon's vision is "One global team creating trusted, innovative solutions to make the world a safer place" and has three goals: global growth, enterprise collaboration, and competitive advantage. DFMA addresses the enterprise collaboration and competitive advantage goals, ultimately contributing to global growth.

Raytheon has multiple business units and a variety of products and services. Raytheon provides state-of-the-art electronics, mission systems integration and other capabilities as well as a broad range of mission support services.



Our Products & Services are high mix, low volume, high reliability, robust, and lives depend on them.





Expansion and standardization of DFMA application across a large enterprise

DFMA is a methodology combination of Design for Assembly (DFA) and Design for Manufacture (DFM). The methodology includes tools, process, techniques, the applications of DFMA principles, and a collaborative activity such as a workshop or design review. The DFMA objective is to develop the best product or process that meets all requirements, has competitive quality and cost, while avoiding foreseeable downstream problems.

Raytheon has used DFMA since 1999 when acquisitions introduced new people and capabilities. Recently there has been a dramatic improvement in the coordination and collaboration across the enterprise DFMA users. Raytheon expanded and standardized DFMA application across the enterprise, to achieve the organizations goals of collaboration and competitive advantage. DFMA is tool number thirty-seven in our umbrella of Raytheon Six Sigma™ (R6σ) tools.

Methods implemented to improve effectiveness and productivity include:

- common tool sets
- project infrastructure
- cross functional collaboration
- supplier engagements
- electronic brainstorming
- digital model and advanced visualization
- incorporation of lean manufacturing initiatives
- overcoming challenges include changing the corporate culture
- earlier product development engagement

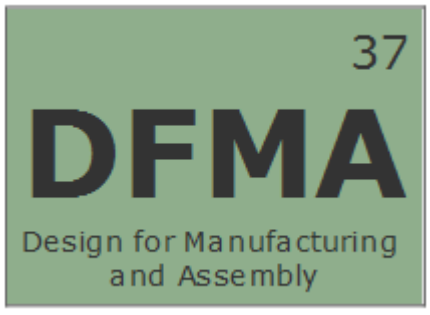
Common tool sets

In order to achieve our DFMA objectives, we established common tool sets by collecting and consolidating best practices from across the organization. We made these standard tools available to all business units and established a steering team, both locally and at the enterprise level for governance. Our standard processes, tools, templates, and training included:

- Check list
- Pre-work shop templates
- Workshop templates
- Out brief templates
- Templates for introduction
- Standard Invitations & communications
- Electronic training

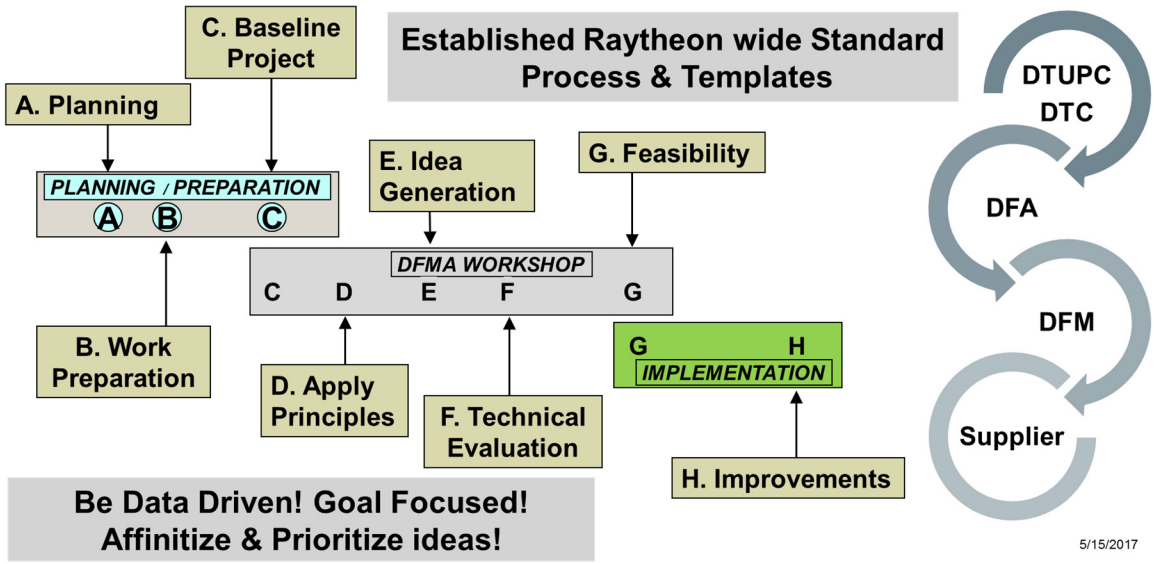
Common DFMA process and tools could include:

- Cost modeling & analysis
- Quality function deployment (QFD)
- Risk assessment tools
- Ease impact charts
- FMEA, PFMEA, producibility tools
- Value stream mapping
- Reverse planning
- Lean methods
- Additive manufacturing
- Immersive technology



The Vice President of Engineering championed the DFMA methodology and established goals, which were flowed down to individual employees, using the annual HR employee performance process. We established clear roles / responsibilities and obtained organizational leadership commitment as sponsors, promoters, and champions of DFMA.

The benefits of a common enterprise processes and tools is that it creates a repeatable workflow that improves over time. Having defined roles and responsibilities improves the handoffs amongst DFMA leads and participants, and improves accountability to goals. We have witnessed a dramatic improvement in the collaboration on cross-organizational/business DFMA events.



Project infrastructure

In order to expand the depth and breadth of implementing DFMA processes and tools, a defined process infrastructure was needed for planning, tracking, and monitoring events across the organization. We established a database to track and capture artifacts across the workflow of each Design for Six Sigma and DFMA event. Having the proper database attributes, such as programs, suppliers, departments, assembly types, points of contacts, etc., allows for accessibility and the leveraging of lessoned learned from similar event types. A centralized library of processes, tools, templates, and training were made available across the enterprise. The use of an engineering steering team proved very useful in creating and monitoring the DFMA events through the defined DFMA process flow.

Cross-functional collaboration

Cross-functional collaboration is a critical component to the success of all DFMA events. Selecting subject matter experts from multiple disciplines allowed for diverse perspectives and resulted in the team's best affordable and producible solution. Having a trained six sigma and DFMA SME to lead these teams through a defined process also allowed equitable participation (elimination of seniority dominance) across the team.

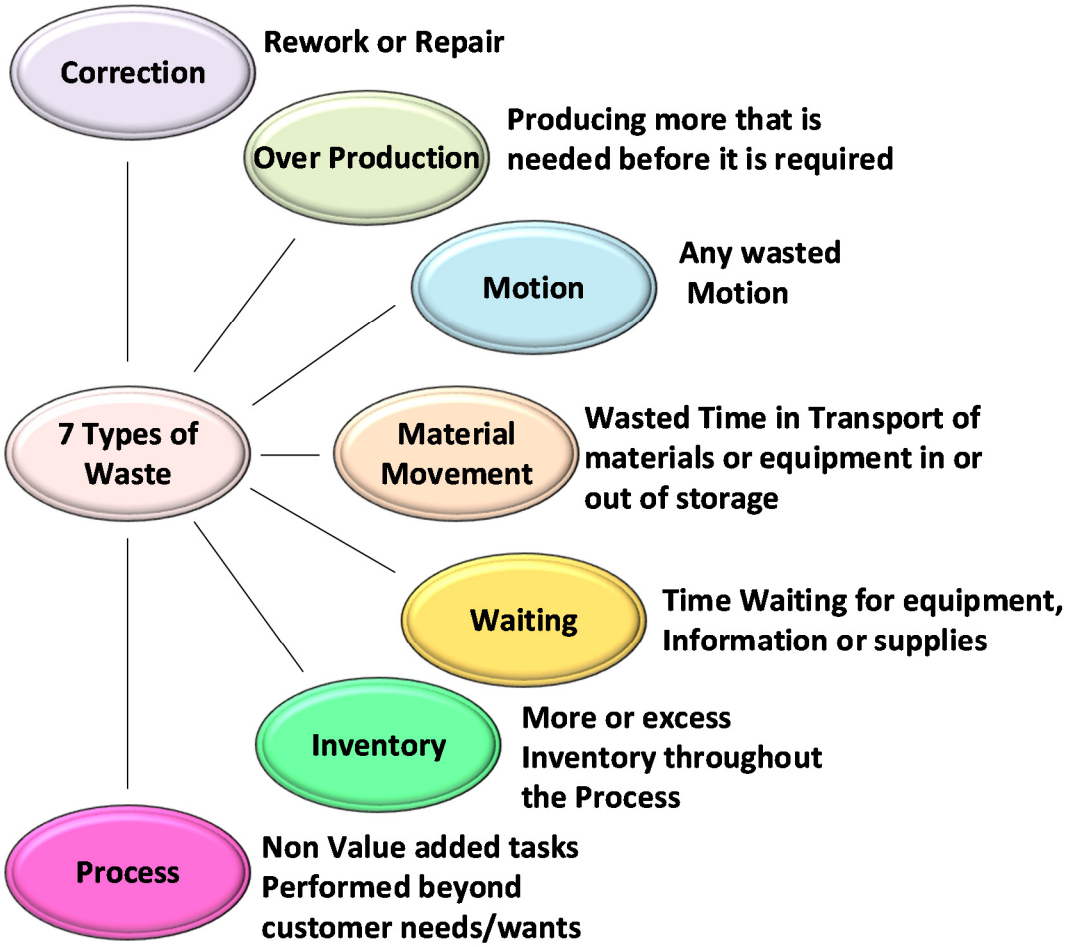
Supplier engagements

Since 80% of product cost is typically material, DFMA with supplier involvement is imperative to business success. Suppliers typically understand what drives their cost, but do not always understand what is driving the product requirements. Raytheon team members understand the requirements, but they do not always understand the constraints and upper capabilities of their suppliers, which are driving the cost, quality, yield, and product cycle time. Improved supplier collaboration and understanding of requirements, design, producibility, cost, manufacturing methods, and other supplier's domain knowledge resulted in optimal affordability and producibility opportunities.

Incorporation of lean manufacturing initiatives

During early product development, combining DFMA and Lean manufacturing initiatives allows for both design and manufacturing process optimization. Methods such as value stream mapping, visual sources of data to analyze, manufacturing process models, 3D workflow models, visual controls, and identifying waste (COMMWIP) identifies ideas to improve both the design and manufacturing process.

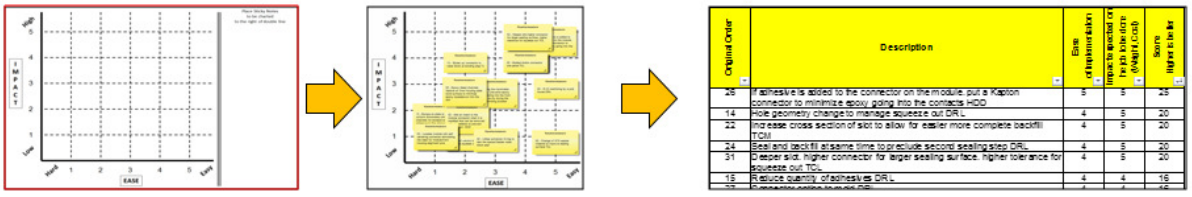
COMMWIP is an acronym for the seven types of waste:



Electronic brainstorming tool and process

The demand to lower the cost and duration of DFMA events drove the need for a more efficient DFMA process. Process improvement was continually part of the mission and culture for the DFMA Steering team and participants, so the non-electronic based, manual methods were targeted for automation. Electronic brainstorming process and tool to capture ideas in a single idea flow and eliminate batch entry of brainstormed ideas. This process improvement eliminated non-added value time to the DFMA event. Presenting electronic brainstormed ideas improved the team's understanding of each other's ideas, sometimes resulting the generation of additional ideas, and the agreement of prioritization of ideas.

Ease Impact Chart



Original Order	Description	Ease of Implementation	Impact to cost of the pin (Weight Cost)	Score (Higher is better)
26	If adhesive is added to the connector on the module, put a Kapton connector to minimize epoxy going into the contacts HDD	5	5	25
14	Hole geometry change to manage squeeze out DRL	4	5	20
22	Increase cross section of slot to allow for easier more complete backfill TCM	4	5	20
24	Seal and backfill at same time to preclude second sealing step DRL	4	5	20
31	Deeper slot, higher connector for larger sealing surface, higher tolerance for squeeze out TCL	4	5	20
15	Reduce quantity of adhesives DRL	4	4	16

Digital model and advanced visualization

The adoption of digital models and advanced visualization allows much earlier DFMA application and a higher return on investment before drawing creation. The Cave Automatic Virtual Environment (CAVE) provides the capability of advanced visualization, reduces costs, drives product excellence, and accelerates time to market through the deployment of immersive visualization and remote collaboration.

Design for "X"

We tailored the DFMA process and tool set to optimize products and services for goals other than product cost. The DFMA principles below allow for product total ownership by including the field sustainment considerations.

1. Minimize the number of parts and obsolescence
2. Minimize the use of fasteners
3. Standardize / commonality
4. Avoid difficult components
5. Use modular assemblies and subassemblies
6. Use multifunctional parts
7. Minimize reorientations

9. Use self-locating features
10. Avoid special: tools, test and support equipment
11. Design and provide accessibility
12. Minimize process steps
13. Design for service life and reliability
14. Minimize footprint in the field
15. Design for Exportability
16. Ergonomics & Safety

Broader application of the DFMA process is adapted for optimizing for "X" where "X" could be:

- Assembly
- Manufacture
- Test
- Safety
- Quality
- Corrosion
- Automation
- Serviceability
- Virtual simulation and risk reduction
- Cycle time for on time delivery
- Sustainment (Ownership cost)
- Additive manufacturing (DFAM)
- Specialty engineering

DFMA results

In the past three years, Raytheon executed 100's of enterprise wide DFMA's including supplier engagements, resulting in millions of dollars in business benefit. Through years of successful DFMA projects, leadership support, goal flow down, SME training, and internal messaging, the company culture has changed. Raytheon institutionalized DFMA as THE go-to methodology across the enterprise delivering affordable customer solutions in an increasingly competitive marketplace. DFMA is proliferating across the enterprise enabling global growth through affordability to position Raytheon with competitive advantage.

Raytheon DFMA received external recognition:

- Raytheon DFMA recognized as a best practice by our Navy and Air Force customers
- CMMI Level 5 Assessor recognized DFMA as one of five best practices with world-class expertise to support these activities
- Due to the High CMMI Maturity of DFMA the DFSS Team received 2016 IEEE Computer Society/SEI Watts S. Humphrey Process Achievement Award

References

1. Boothroyd Dewhurst, Inc. 32nd Annual International Forum on Design for manufacture and Assembly (DFMA) 2017. Website: http://www.dfma.com/forum/index.html
2. Raytheon internal document eTPCR IDS-11164