

Prepared for:  BOOTHROYD DEWHURST, Inc. 30th International Forum on Design for Manufacture and Assembly

MISSION:

A WORLD OF INNOVATION

**Expanding the application of
DFMA and creating an
affordability culture**



June 2nd 2015

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Integrated Defense Systems

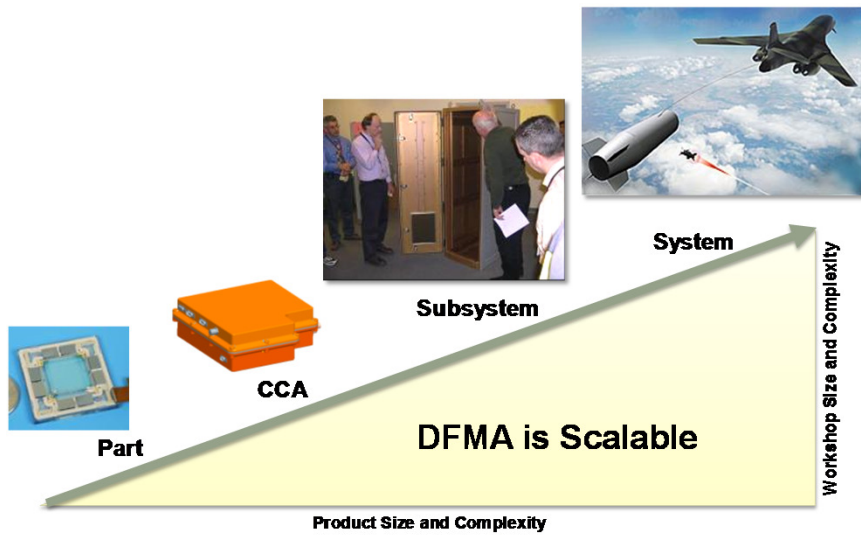
Raytheon Company

Raytheon Company

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



Products range from small to big



Raytheon

Fifteen Years of Gallium Nitride Innovation

Sophisticated research on gallium nitride continues today at the Radio Frequency Components Foundry in Andover, Mass.



Products Land, Air, & Sea Training & Support Services

Raytheon
Integrated Defense Systems



**Products & Services are...
High Mix
Low Volume
High Reliability, Robust
Lives depend on them**

Burning Platform



Tom Kennedy
Raytheon Company Chief Executive Officer and Raytheon Six Sigma Champion

"It's not just having a better performing solution than our competitors, which is vitally important, but true competitive advantage comes when we deliver those superior solutions at a lower cost,"

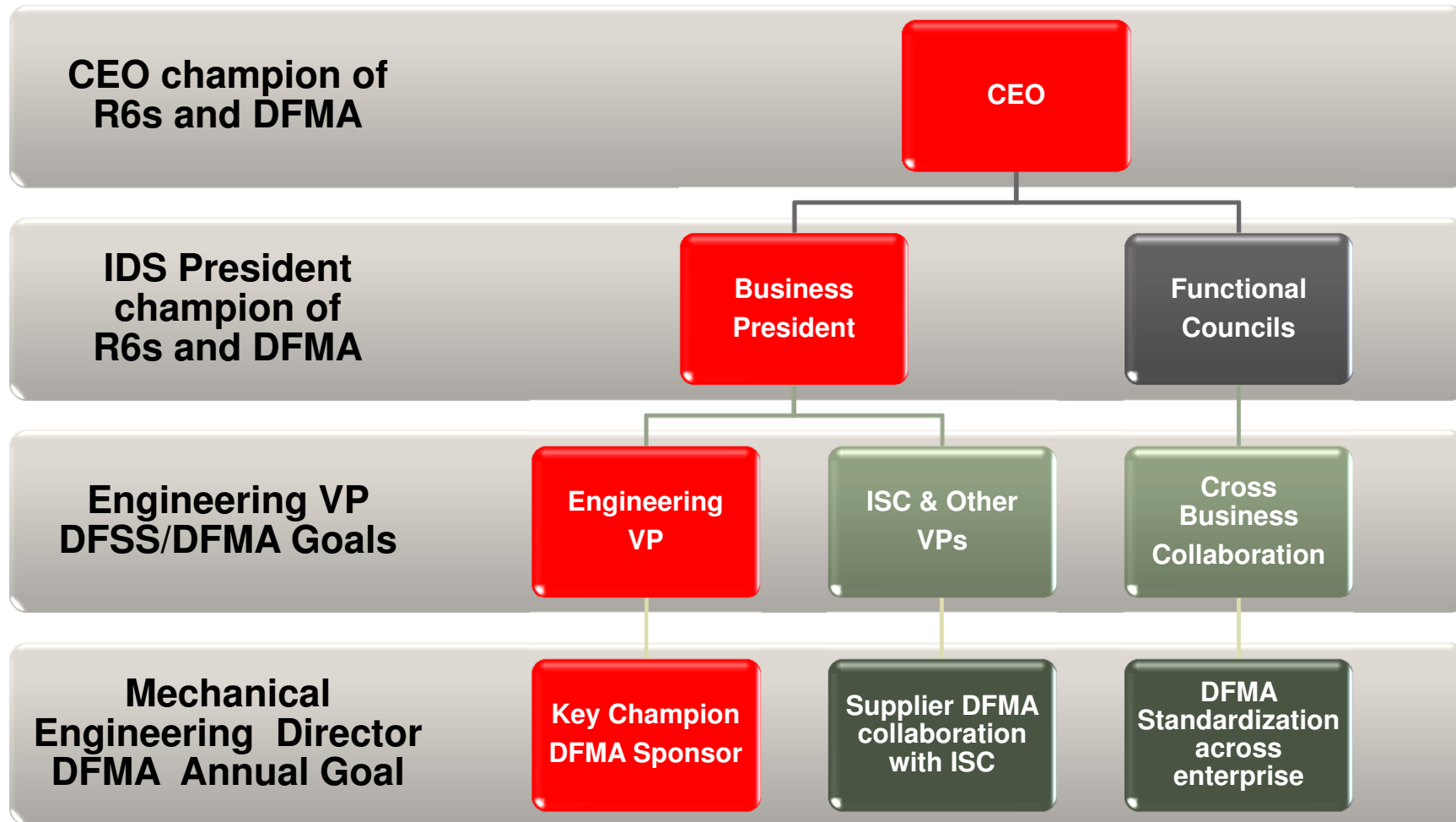
Affordability Tools:

1. Design to Cost (DTC)
2. Design for Six Sigma (DFSS)
3. Design for Manufacturing and Assembly (DFMA)

"Need to make design-to-cost part of our culture to remain competitive in the marketplace."



Leadership Commitment

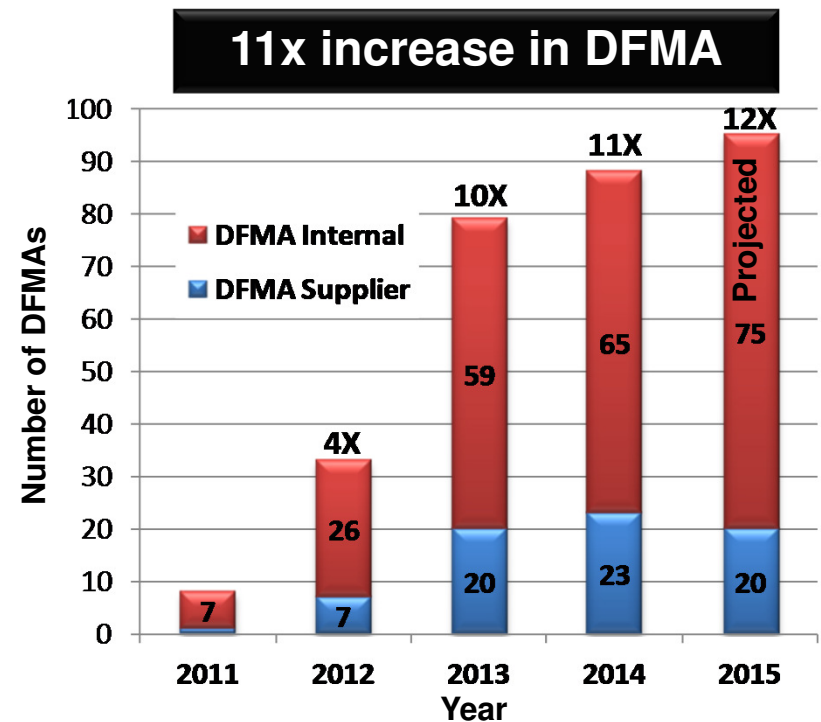


Leadership support is key to success

DFMA Journey

DFMA team drives to integrate DFMA into IDS programs, culture, and deliver customer affordability

- Started with limited capacity to run DFMA workshops.
- Improved the DFMA capability, capacity and infrastructure.
- Mentored 16 IDS DFMA Leads.
- Qualified 10 DFSS R6s Principle Specialists.
- Increased DFMA **11x** from 2011 (8) to 2014 (88).
- International, supplier and cross business engagements.
- Over 1000 DFMA workshop participants (Raytheon and suppliers).
- Raytheon DFMA is recognized as a best practice by Air Force, Navy and CMMI Level 5 Assessor.



Delivered affordability to meet business needs

2013 RAYTHEON
SIX SIGMA
awards

Raytheon
Integrated Defense Systems

DFMA project recognized for 2013 results at Enterprise level with the CEO and leadership team.



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.

- Specify value in the eyes of the customer
- Identify the Value Stream: eliminate waste and variation
- Make value flow at the pull of the customer
- Involve, align, and empower employees
- Continuously improve knowledge in the pursuit of perfection

Visualize & Commit

■ Vision:

- Provide affordable systems to our customers by increasing the number of DFMA (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:

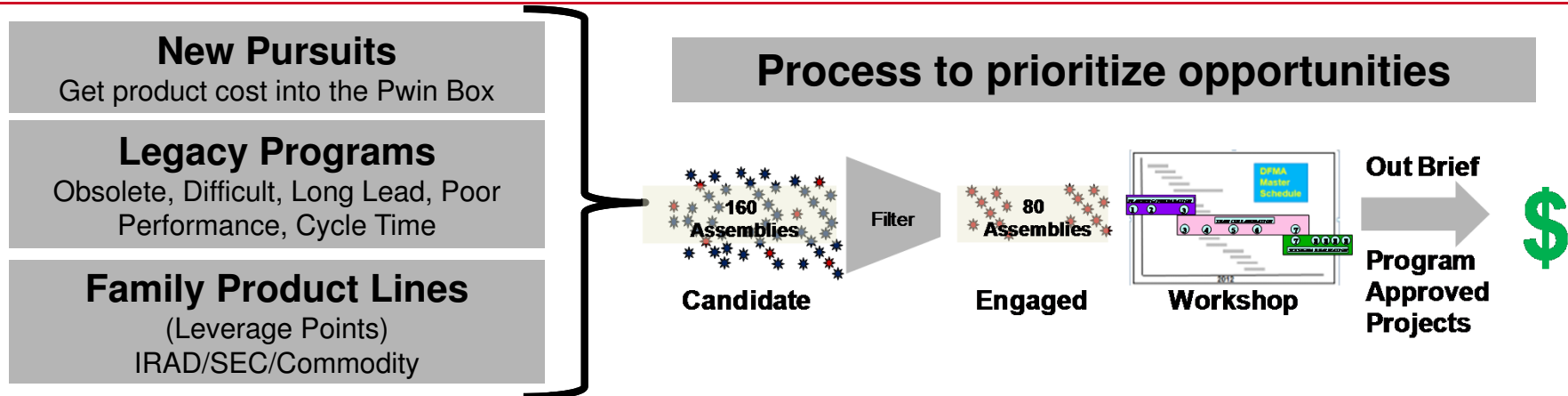
- MED Director set increasing goals of 30 DFMA in 2012 up to 95 DFMA in 2015
- Cross-functional teams, qualified leads, funding secured from 20 programs.



Design for Manufacturing and Assembly Team

**Infrastructure established to deliver on
DFMA opportunities**

Prioritize - Increased use of DFMA



▪ Capture:

- Target high value opportunities
- Develop process to prioritize opportunities
- Create pull through flowed down goals

▪ Execution:

- Develop DFMA leads by identifying best candidates and create training
- Create standard process, templates, and reporting Newly-created accessible storage location DFMA database and digital Library
- Engage stakeholders through weekly steering team meetings

Characterize & Improve

Initial DFMA State (2011):

- Just 8 DFMA deployments conducted by one lead.
- DFMA, while identified in IPDS, was sporadically used and almost always tailored out.
- The DFMA process was not a good fit for smaller opportunities.



Improved DFMA State (2014):

- Developed DFMA standardized tools and process accessible from engineering database.
- Created DFMA SME training aligned to DFSS Principle Specialist requirements.
- Shifted the culture to focus on affordability: early in design phase
- Incorporated DFMA into bid review package, engineering standards, and partnered with ISC
- Utilizing DFMA in Immersive environment
- Completed improvement projects:
 - Sustainment
 - Standard Integrated DFMA Template
 - DFMA immersive environment techniques
 - Corporate DFMA project
 - Electronic brainstorming tool and process
 - Continuous improvement of DFMA people, process, & tools

**Cultural shift achieved – earlier is better
(more IRAD & EC)**

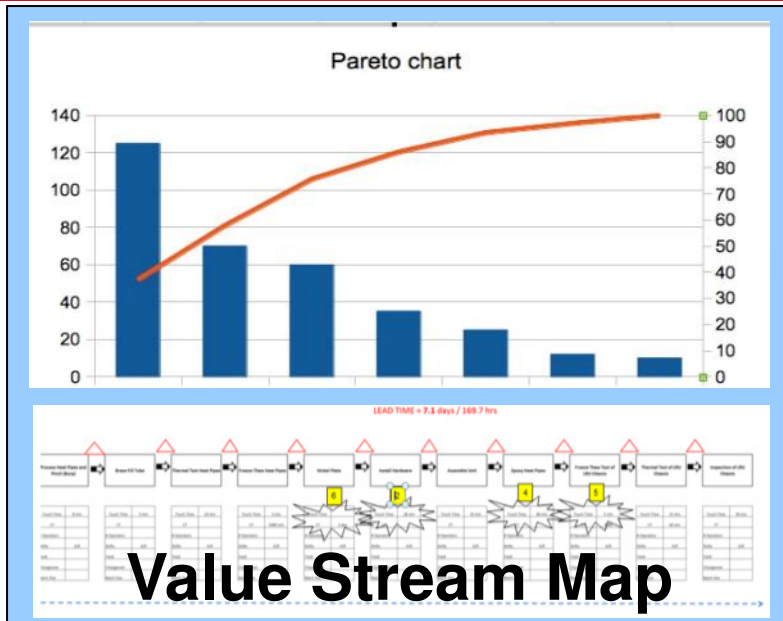
Achieve (as of 2014)

- Engineering-led, institutionalized DFMA as THE go-to methodology delivering affordable customer solutions in an increasingly competitive marketplace.
- Delivered 208 DFMA and iDFMA deployments
- Shifted culture to execute DFMA earlier and more frequently.
- Qualified 16 DFMA leads, with additional in the pipeline Experiential DFMA learning for more than 1000 Raytheon and supplier employees.
- Applied DFMA principles, creating data-driven decisions.
- Updated Gate Review HW Design Checklist to include DFMA with sustainment principles and questions.



**208 DFMA's conducted to help us
achieve must-win programs**

DFMA Summary Supplier Chassis



Design for Manufacturing and Assembly

• Challenge

Objective: Reduce Cost and Weight

- Identify cost and yield improvements through collaboration between Raytheon and supplier to meet Affordability Targets
- Identify alternative manufacturing methods and sources

Overall Goal:

- Improve affordability of chassis to improve future sales
- At least 30% Cost reduction from target baseline

• Approach

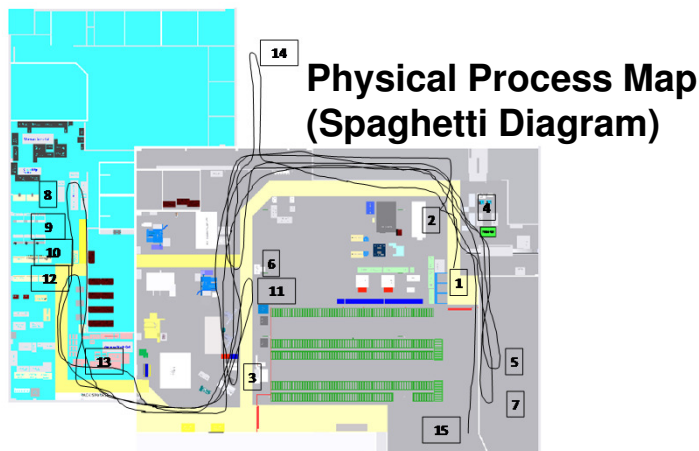
- Apply Design for Manufacturing and Assembly (DFMA) principles using the DFMA Workshop approach
- Applied Lean principles, VSM

• Process

- Engaged multiple programs Design team and independent SMEs
- Leveraged manufacturing and test process capabilities
- Brainstormed over 31 improvement ideas parts, process changes and labor
- Prioritized ideas by ease and impact assessment
- Created outbrief for cost reduction initiatives

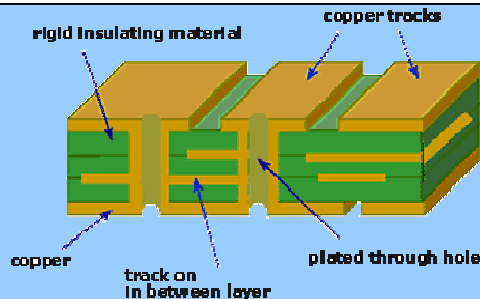
• Results

- **43%** cost reduction and **31%** parts reduction

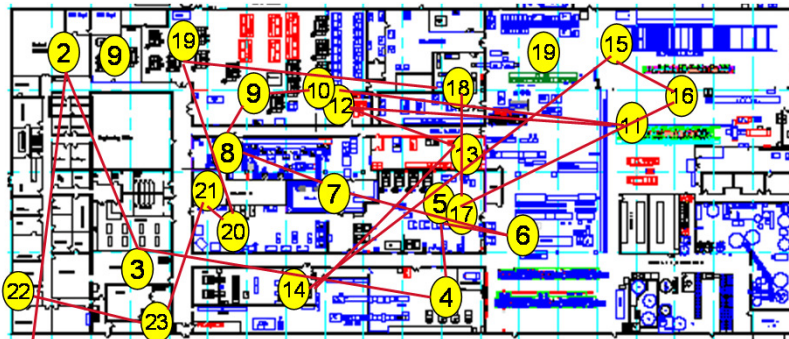
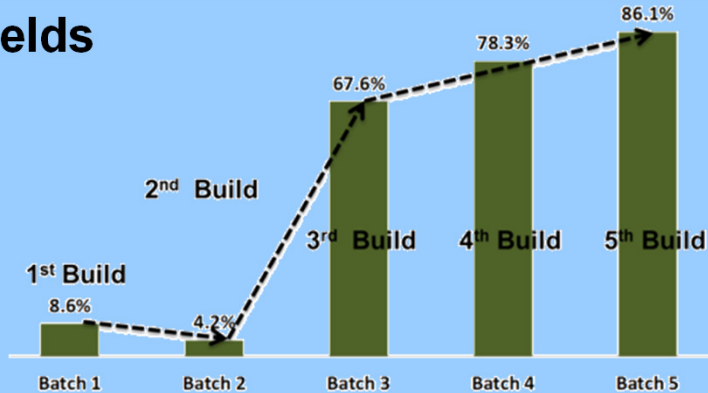


DFMA Summary Supplier PWB

PWB Types



Yields



Design for Manufacturing and Assembly

• Challenge

- Need more affordable PWBs to improve Business Capture
- Goal: 30% to 90% Cost reduction from baseline pricing

• Approach

- Apply Design for Manufacturing and Assembly (DFMA) principles using the DFMA Workshop approach

• Process

- Engaged Design team and independent SMEs
- Brainstormed over 56 improvement ideas
- Prioritized ideas by ease and impact assessment
- Created outbrief for cost reduction initiatives

• Results

- Parts /Material reduction of 4 layers on PWB
- Increase panel utilization (#Parts per panel)
- Eliminate and optimize plating
- Eliminate features and relax non critical material finish
- **PWB–28% cost reduction**

DFMA IDS Results as of 2014

- IDC DFMA identifying defects earlier and more effectively
“I wouldn’t have seen that defect until much later without the IDC”
- Enterprise wide “Pull” created
- Recognized best practice
- People and DFMA:
 - New DFMA leads
 - **24%** of MED personnel trained

Example DFMA Teams



“...Need to make design-to-cost part of our culture to remain competitive in the marketplace...”

Business Impact

Raytheon:

- Raytheon Program Manager:
“Best implementation of DFMA I have seen in my 35 years.”
- Growth: Pwin on must win programs improved by early DFMA engagements.
- Program Performance: Improvements in Cycle Time, Quality and Yield.
- People Impact: We have **16** DFMA Leads, including **10** DFSS Affordability Principle Specialists carrying the DFMA torch to sustain and grow in what we have done and what we will do in the future.

Customer:

- Raytheon IDS DFMA recognized as a best practice by our Navy and Air Force customers.
- CMMI Level 5 Assessor recognized DFMA as one of five IDS best practices with world-class expertise to support these activities

NAVY CHOOSES RAYTHEON FOR NEW AIR AND MISSILE DEFENSE RADAR



RAYTHEON AWARDED \$2.4 BILLION CONTRACT TO PROVIDE THE STATE OF QATAR WITH PATRIOT AIR AND MISSILE DEFENSE SYSTEM

QATAR BECOMES LATEST GLOBAL PATRIOT CUSTOMER



FIRST U.S. ARMY MISSILE-FIGHTING RADAR BLIMP AIRBORNE ON EAST COAST

JLENS TO DEFEND D.C. FROM CRUISE MISSILES, DRONES, AIRPLANE THREATS

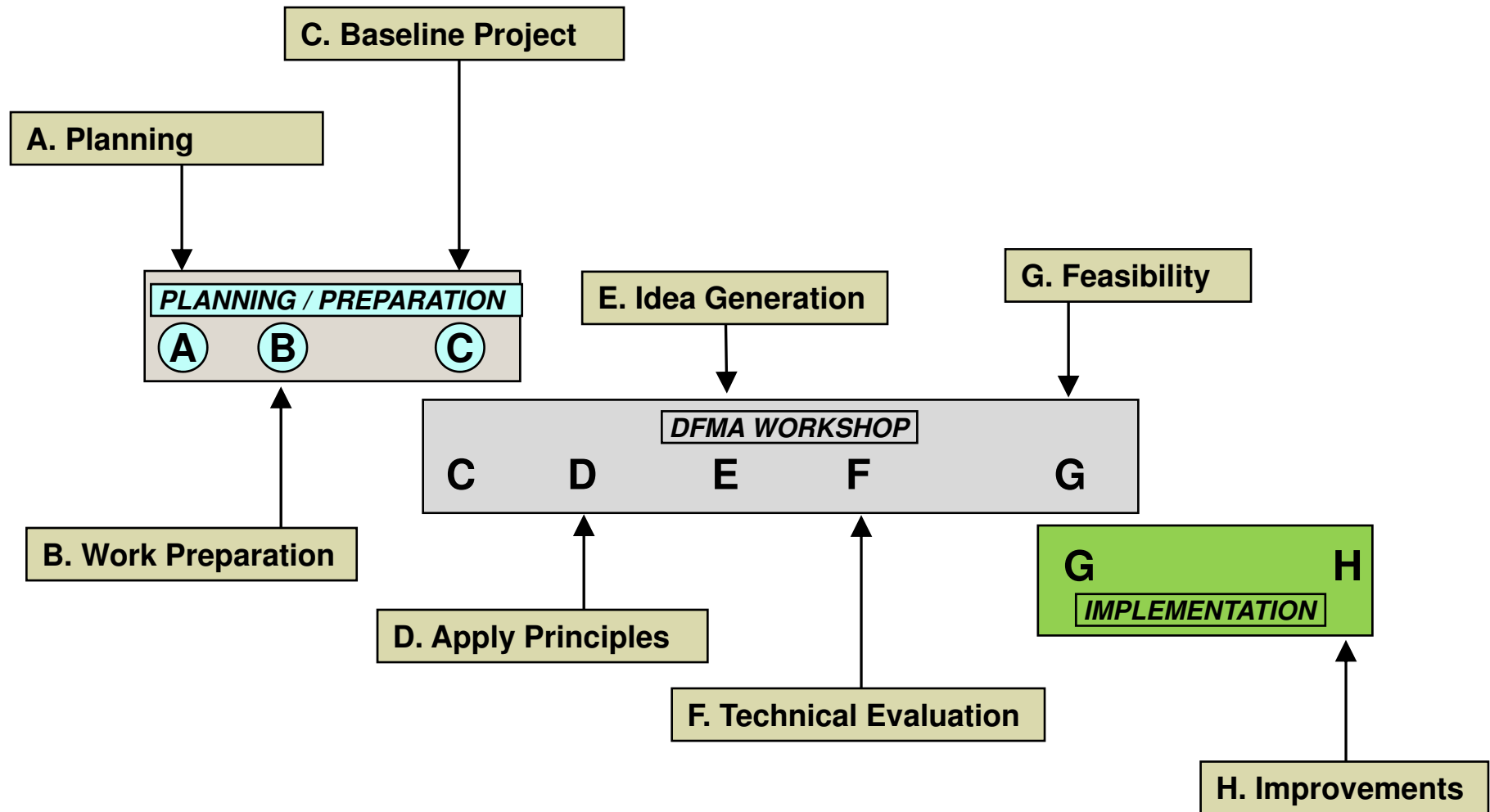


Raytheon DFMA Process and Tools

DFMA Objective & Principles

- Objective of DFMA is to develop the best product or process design that meets:
 - All requirements & has competitive quality and cost
 - Avoids foreseeable downstream problems
- DFMA's are conducted using the **DFMA Principles** to impart discipline and thoroughness
- DFMA's use cross-functional teams applying a broad knowledge base to:
 - Design hardware, software, and processes
 - Build teamwork with a focus on specific technology integration
 - Foster interactive communication, stimulate numerous alternatives, and resolve problems quickly

DFMA Process



**Established Raytheon wide Standard
Process & Templates 2014**

DFMA Standard Process & Tools

- To improve productivity and flexibility with multiple leads:

- Developed standard work, standard tools, standard process
- Check List
- Pre-work shop templates
- Workshop templates
- Out brief templates
- Templates for introduction
- Standard Invitations & communications



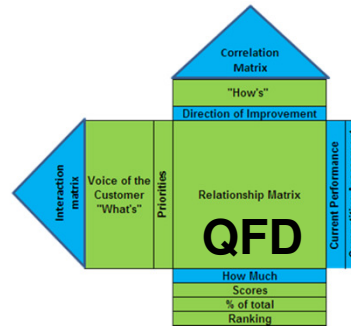
- All available and linked in web based accessible location
- All workshop metrics are available, except proprietary data
- Easy to hand off from one lead to another if conflicts arise

**Standard Work, Process, Tools, Templates in Common Data Base
and Store Completed Artifacts and Manage Metrics**

DFMA Tools Utilized

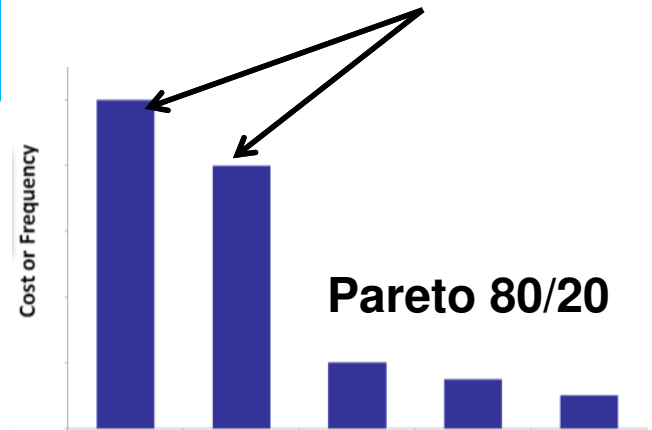
Standard Process & Tools

- Cost Modeling & Analysis
- Quality Function Deployment
- Risk Assessment Tools
- Ease Impact Charts
- SCAMPER, FMEA, PFMEA, PCAT
- Value Stream Mapping
- Reverse Planning
- Lean Methods
- Additive Manufacturing
- Immersive Technology



Brainstorming
*All ideas are good
Some have higher ROI*

The Vital few (80/20 Rule)

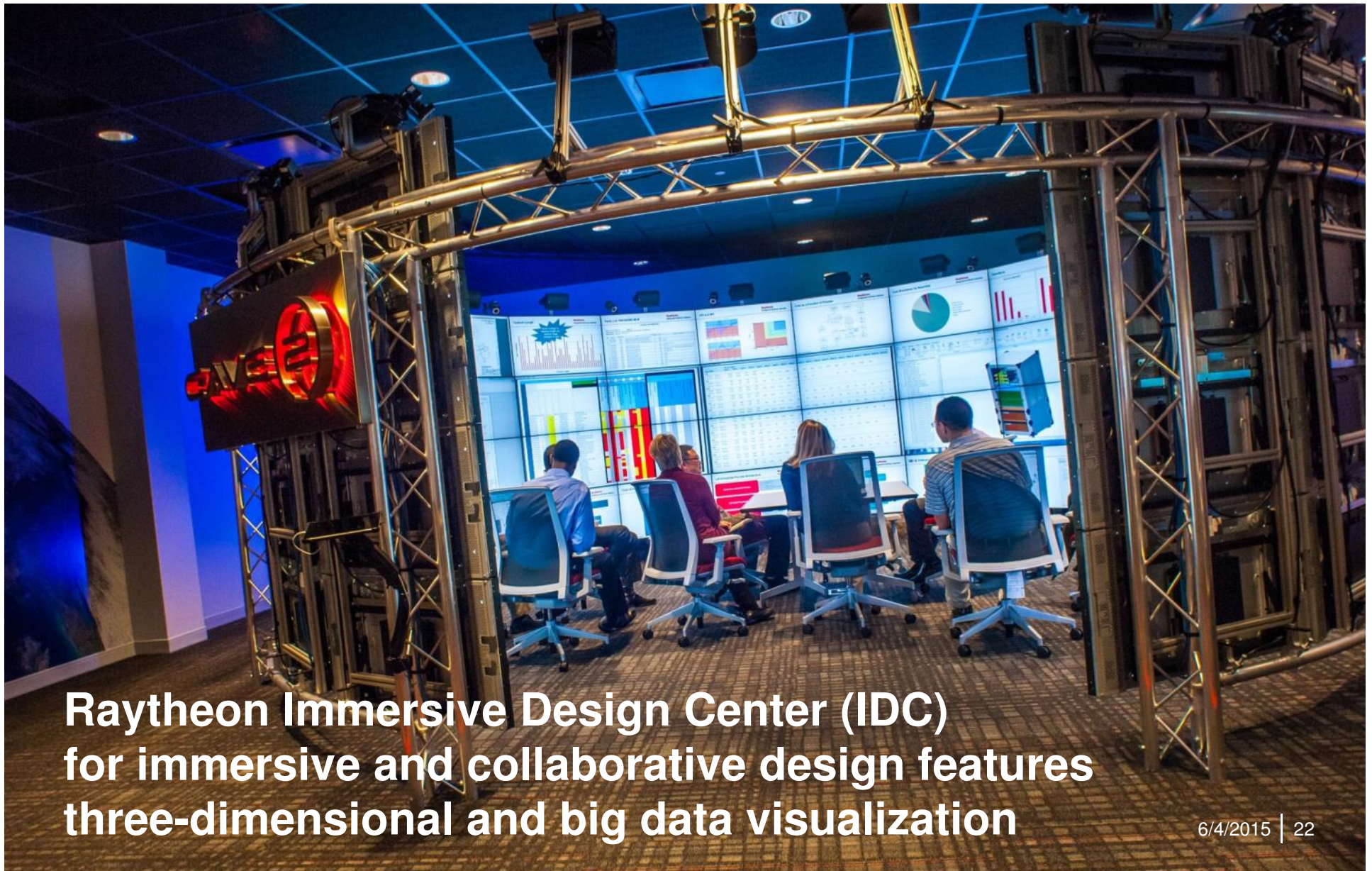


Ease-Impact

	High	Plan	Seriously Consider
Impact	Low	Drop	Consider
		Hard	Ease Easy

**Be Data Driven! Goal Focused!
Affinitize & Prioritize ideas!**

CAVE2™ Configuration is First in Industry



**Raytheon Immersive Design Center (IDC)
for immersive and collaborative design features
three-dimensional and big data visualization**

Synergies and Tools



Augmented Reality
3D Laser Scanners
3D Printers

Synergies

Tools



CAVE2™
Mobile CAVEs
Motion Capture Suit
Head Mounted Displays

IDC CAVE Focus Areas

Model Based
Reviews



Design for
Manufacturing
and Assembly
(DFMA)



Facility
Design and
Layout



Remote
Collaboration



Customer
Relationships
and Business
Development



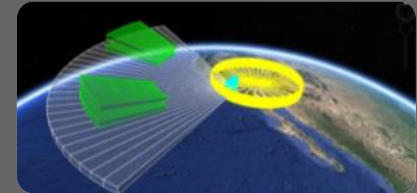
Supplier and
Industry Partner
Engagement



Immersive
Training



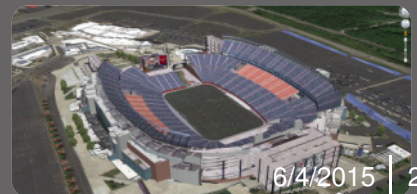
Operations
Analysis and
Simulation



Human Factors
Analysis



STEM and
Community
Outreach



Design for Manufacturing and Assembly

Raytheon
Integrated Defense Systems



- 72 individual displays become one coherent canvas
- Supports multiple file formats 2D and 3D
- Allows remote participation
- Teams are immersed in highly technical content
- Increased level of participation and cooperation
- Using data to drive design

Knowledge Collaboration

Raytheon Internal Symposiums

- Material & Mechanical System Network Symposium
- Manufacturing Technology Network Symposium

Presentations Cross-business Collaboration

- Improved DFMA process to the Raytheon DFSS COP
- Cross Business DFMA practices meeting at RMS
- Corporate project standardizing and expanding DFMA across Raytheon

Industry

- Conducting Supplier DFMA training and workshops
- Boothroyd Dewhurst 30th International Forum on Design for Manufacture and Assembly (DFMA)
- Commerce Rhode Island STEAM ENGINE project (Product development & manufacturing growth initiative for RI)



ET&MA
Mechanical, Materials and Structures Technology Network



New England Council and Deloitte

Raytheon
Integrated Defense Systems

“Advanced to Advantageous: The case for New England’s manufacturing revolution”



Raytheon’s Immersive Design Center: Creative fires burn bright in “The Cave”

Raytheon Company is a technology and innovation leader specializing in defense, security and civil markets throughout the world. At its Andover, MA missile center, Raytheon has built a tool for assembling and inspecting highly complex and large products – the Immersive Design Center.

“The Cave,” as it is affectionately termed by the scientists and engineers that work with it, has an eight-foot-high stack of 72 ultrahigh-definition television sets arrayed in a 320-degree panorama,

featuring 3-D technology with highly realistic views.¹⁴

In the Cave, Raytheon and its suppliers can see how a product such as the Patriot missile system is coming together, from the assembly of a multi-ton command truck to the shape of a tiny component such as an electronic circuit. Multiple users can be in the center at the same time – even remotely – and see how their work is being integrated with others’ work and the project as a whole.

The technology allows people to solve complex problems more efficiently, to literally “see” what the problems might be. As Bill Tice, an engineering manager at Raytheon stated: “In 3-D, you can literally dive in, look under it, around it, take it apart, and put it back together. We’re getting designs that are more efficient and easier to produce.” In addition, Tim Glaeser, the VP in charge of the Patriot program succinctly stated, “If we put the right people in this room, they’ll solve any problem.” Different people with different perspectives and areas of expertise can all access and see the same product and tweak it based on their views. Raytheon calls this the “common language of visualization.”

Raytheon’s Immersive Design Center reduces the time required to develop a product by enabling users to view multiple product components in three dimensions and to explore problems in a collaborative and virtual environment. In this way, the Cave exemplifies the game-changing nature of digital design in manufacturing.

Photo Credit: Raytheon

New England Council and Deloitte

“Advanced to Advantageous: The case for New England’s manufacturing revolution”

The potential benefits of this new digital technology are manifold:¹⁵

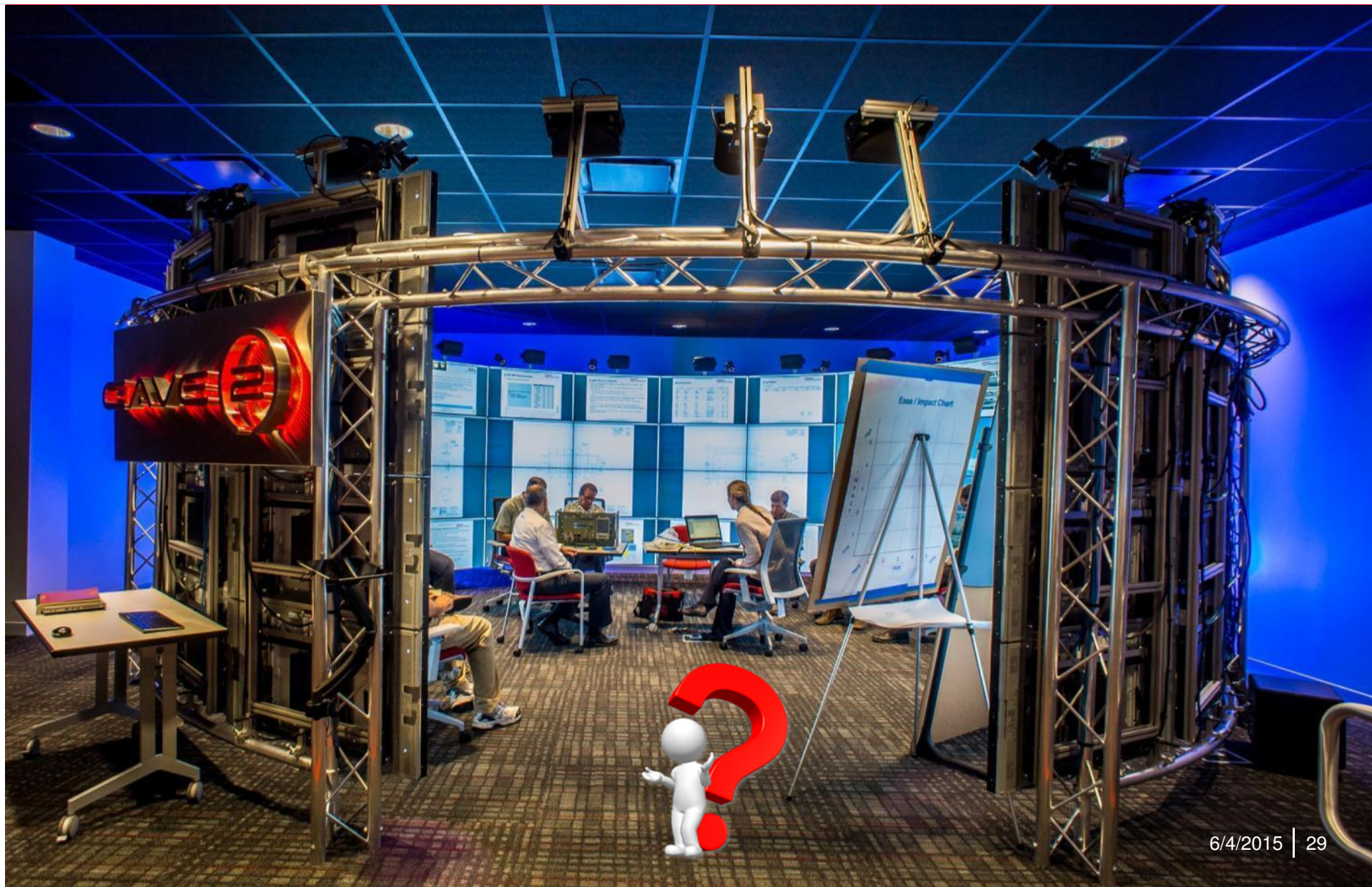
1. Faster product development, time to market and production ramp-up
2. Digital link between design, fabrication, and controls engineering
3. Reduced prototyping and physical mock-ups with virtual simulation
4. Improved collaboration and joint problem solving with the consumer and supplier network by providing joint access to design, production, and quality processes
5. Validation of manufacturing processes, resources, and work cells through simulation
6. Visibility into supplier factories
7. Higher initial quality and reduced cost by validating production processes and design for manufacturability
8. Work instructions and shop floor documentation, automatic generation of controls logic, and material flow planning
9. Performance reporting and metrics for continuous improvement
10. Data aggregation across the product life cycle

With President Obama’s 2014 announcement of the Digital Manufacturing and Design Innovation (DMDII) Institute in Chicago, we can expect an increase in investment and research, focused specifically in three areas: Product Life Cycle Management, Digital Design and Prototyping, and Digital Manufacturing and Visualization. These digital enhancements are already making an impact on the industry clusters in New England, as discussed in the section that follows.

¹⁴ Adams, D. “Now Showing at Raytheon: Missiles in 3-D.” *Boston Globe*, November 2014.

¹⁵ Browne, J. *Integrating Product Design and Development Environments*. Tech Clarity Inc., 2014.

Questions



Authors



Mark Steudel

- Raytheon Company IDS DFSS/DFMA Lead
- Mark has over 30 years of product design development and leadership experience, is a member of the Raytheon Mechanical Engineering Directorate, and is a certified Raytheon Six Sigma Expert. Presently Mark is improving product affordability by leading DFMA/DFSS workshops to optimize products and manufacturing processes for cost, quality, producibility, and on time delivery. Previously Mark was the Test Director leading the environmental requirement verification for the JLENS program at Aberdeen, DPG/UTTR, and White Sands Missile Range. Mark holds a BS in Mechanical Engineering from Bucknell University and a MSIE in Engineering Management from Northeastern University



Brian Foley

- Raytheon Company IDS DFSS/DFMA Lead
- Brian Foley is an Engineering Fellow within Design For Six Sigma part of IDS Engineering Strategic Development. During his 33 years at Raytheon, Brian has held positions of increasing responsibility within Design Engineering. Brian is a certified R6σ Expert Leading Design for Manufacturing and Assembly, Design for Six Sigma with Suppliers, Lean, and Innovation. In 2010 Brian and his Ceradyne team received The R6σ CEO and Presidents Award. Brian is a USAF Veteran and holds a BS in Electrical Engineering from University of Lowell, a MS in Microwave Electrical Engineering from UMass Amherst.



Dan Bardsley

- Raytheon Company IDS DFSS/DFMA Lead
- Dan Bardsley has been working for Raytheon for 13 years. He is currently working in the Design For Six Sigma (DFSS) team under the Strategic Development department. He has hands-on experience in the DFSS technical focus areas of: Design For Manufacturing and Assembly (DFMA), Critical Chain Project Management with reverse planning, and Critical Parameter Management. His experience at Raytheon includes five years on the IDS Engineering Process Group as Assets Manager across all process disciplines and as a CMMI- SCAMPI Class A - Level 5 appraiser. Other experiences include: Deputy Configuration / Data Manager within Zumwalt Program Management Office. He has a Mechanical Engineering and a Materials Management background servicing DoD, Dot, and commercial based companies.

Notes & Credits

- Boothroyd Dewhurst, Inc.
 - Host of the 30th Annual International DFMA forum
- Contributors:
 - The success we have realized is a result of many Raytheon employees that embraced DFMA and brought its practice into Raytheon years back and the Operations council that sponsored a cross Raytheon DFMA initiative.
 - Raytheon leadership from our Mechanical Engineering Director and up to the CEO (past and present) that have supported R6s and DFMA.
 - Our suppliers.