

DFMA[®] at DELLEMIC

Presented by
Steven Huynh, Van Jabagjorian and Chelsea Jelaska

International Forum on DFMA
June 6-7, 2017
Warwick, Rhode Island, USA



Table of Contents

About Dell Technologies and Dell EMC	3
DFX at Dell and Dell EMC.....	3
Why DFMA®	4
Deployment of DFMA® at Dell EMC	4
Applications of DFMA® at Dell EMC.....	6
Early Design Team Support.....	6
Benchmarking.....	7
Design Improvement.....	8
Example 1	8
Example 2	9
Example 3	12
Future Plans.....	14
Summary.....	15



About Dell Technologies and Dell EMC

Dell Technologies is a collective force of innovative capabilities trusted all over the world to provide technology solutions and services that accelerate digital transformation. Dell Technologies consists of Dell, Dell EMC, Pivotal, RSA, SecureWorks, Virtustream, and VMware. Dell Technologies collective capabilities help customers redefine how they do business with world-class products, services and solutions. Dell Technologies helps drive businesses through their Digital Transformation journey, while helping them through key transformation initiatives across the organization.

- *Dell* innovates across devices, ecosystem and services to design solutions specifically for the way people work, from award-winning thin clients, tablets and laptops to powerful workstations and rugged devices.
- *Dell EMC* provides the foundation to help modernize, automate and transform your data center with industry-leading servers, storage, cloud computing solutions, and converged infrastructure technology.
- *Pivotal* transforms how companies build and run software so they can innovate at start-up speed by using cutting-edge software development methodologies, a modern cloud platform, and analytics tools.
- *RSA* delivers business-driven security so organizations of all sizes can take command of their evolving security posture in this uncertain, high-risk world.
- *SecureWorks* develops data-driven security solutions for your organization to detect and prevent breaches and cyberattacks.
- *Virtustream* provides cloud solutions built for the enterprise that are designed to run your most complex and critical applications with performance, security, and resilience.
- *VMware* accelerates your digital transformation through software and services that let you run, manage, secure and connect all of your applications across clouds and devices.

Dell EMC, previously known as EMC Corporation, serves a key role in providing the essential infrastructure for organizations to build their digital future, transform IT and protect their most important asset, information. Dell EMC enables enterprise customers' IT and digital business transformation through trusted hybrid cloud and big-data solutions, built upon a modern data center infrastructure that incorporates industry-leading converged infrastructure, servers, storage, and cybersecurity technologies.

Dell EMC brings together Dell and EMC's respective strong capabilities and complementary portfolios, sales teams and R&D. Dell EMC seeks to become the technology industry's most trusted advisor, providing capabilities spanning strategy development, consultative services and solution deployment and support to help our customers and partners drive the digital transformation of their businesses.

Dell EMC works with organizations around the world, in every industry, in the public and private sectors, and of every size, from startups to the Fortune Global 500. Dell EMC's customers include global money center banks and other leading financial services firms, manufacturers, healthcare and life sciences organizations, Internet service and telecommunications providers, airlines and transportation companies, educational institutions, and public sector agencies.



DFX at Dell and Dell EMC

DFX stands for Design For eXcellence, where the 'X' can represent manufacture, assembly, test, environment, service, manufacturing cycle time, cost, reliability and more. At Dell EMC, 'X' typically means manufacture, assembly, service and environment. The DFX Team is a small specialty group of mechanical engineers within the Dell manufacturing organization supporting Dell EMC. The Team focuses on ensuring that cost, cycle time, yield, and design quality targets are achieved within Dell EMC products. The mechanical DFX Team achieves this through the application of DFX guidelines, a DFX review process, best practices and analytical tools concept through the products end of life.

In 2006, the DFX role consisted of one engineer, a set of tools and best practices that were limited to teardowns, FMEA and a DFX scoring process. Later in 2006, a DFX "hands on" review process was developed to better use the tools that were currently available and increase overall impact and effectiveness of the DFX role. As the Team grew, and as new products were developed and product lines expanded, it was clear that a more effective tool was needed to evaluate design improvement opportunities and issues early in the design cycle; the FMEA approach may indicate risk levels, but it does not offer any cost guidance.

Why DFMA[®]

Given the growth of the DFX group and expansion of the product portfolio, Van Jabagjorian, Principle DFX Engineer who had previously implemented DFA at another company, initiated a proposal in 2011 to acquire a DFMA[®] software license at EMC, now Dell EMC. A trial version of the software was evaluated and the results were presented to management. The results showed a substantial improvement to the Team's analytical capabilities were possible and the proposal was accepted. A DFMA[®] license was purchased in 2012.

DFX is an influence based role, where DFX Team members give design or process inputs to the cross-functional development team. Prior to the introduction of DFMA[®] in 2012 the DFX Team used a scoring system and other tools where data was not readily available, such as FMEA (Failure Mode and Effect Analysis). This limited the Team's ability to influence product designs because results were qualitative.

In 2012 the DFX Team implemented Boothroyd Dewhurst DFMA[®] in order to gain quantitative capabilities. The Team then began the process of determining the best analytical approach to maximize the value of design improvement suggestions given aggressive product development schedules and limited resources. This paper will step through the details behind the different deployment strategies that were tried and later followed by a discussion of how DFMA[®] is currently being used at Dell EMC.

Deployment of DFMA[®] at Dell EMC

The DFMA[®] software deployment, as originally proposed, consisted of a 2-phase strategy, with DFA analysis being used within the DFX Team and then potentially expanding to supply base engineering for DFM should-costing.

Deployment of DFMA[®] has been evolving to fit Dell Technologies fast paced changing business. After purchasing the software and learning the key functionalities, the DFX Team started analyzing full-scale Dell EMC products. As a team focused on improving designs, and not focused on the



manufacturing should cost of individual parts, the DFX Team decided that DFA would likely be the most beneficial tool for our function.

First, the Team began conducting DFA analyses by importing a detailed BOM (Bill of Materials), which included all low-level detail, including circuit board components. The Team would then step through to verify that the parts were in the correct order of manufacture and that all sub-assemblies were broken out in the way they would be manufactured. In addition, all parts not relevant to the analysis were removed. For example, if the imported BOM includes individual components of a circuit board, then those parts would be consolidated to make an unanalyzed subassembly. Next the Team would complete the basic DFA steps, analysis picks and reports generation. The results would then be rolled up and shared with the cross functional team members. While this approach gave the DFX Team a very detailed mechanical understanding of the design, there was not much “bang for the buck”. Doing the analysis was extremely time consuming and the cross functional team could not make good use of the overly detailed results. Therefore, the DFX Team decided to take a different analytical approach that would be timelier and produce useful results.

The next strategy the Team tried was to focus only on high level integration analysis. This means that only high level subassemblies from an imported BOM were kept for analysis. Once again reports were run and the results were rolled up to share with the cross functional team. This approach saved the DFX Team a few hours per analysis, but the analysis did not provide enough detail and therefore the results were not compelling enough to the cross functional teams.

Although the cross functional teams found this information to be too high-level, the DFX Team felt the results were a good high level picture of each product. Therefore the next approach was to conduct a high level integration analysis, but then each major functional component would have its BOM imported and would be analyzed in full detail. Examples of major functional components include power supplies, fans or disk drives. For the major functional components the same BOM clean-up rules from the product detailed analysis were applied. This third approach took more time than conducting only the high level integration analysis, but a little less time than doing a detailed BOM analysis. Once the analysis was completed, the results were rolled up and shared with cross functional team members. That is when the DFX Team started to see some positive responses to the analysis results.

Finally, with a promising third approach, the Team began to improve and refine the process, which led to the final approach still being used today. This approach includes high level integration analysis, high level functional component analysis and a detailed analysis of key areas. The high level integration analysis and high level functional component analysis are completed in the same way listed in previous paragraphs. The detailed analysis of key areas is where the DFX Team began incorporating DFM analyzed parts into DFA analyses. The Team will analyze specific components or design features that may have opportunities for design and cost improvements. A DFM analysis will be run on the parts of the specific area, and implemented into DFA if necessary. The results of this analysis will be shared with the cross functional team to influence cost effective design change. By completing analyses with these three steps, the DFX Team gains a thorough understanding of the design and the analysis is completed in timely manner without compromising the effectiveness of the results. Best of all, the Team can have a positive impact on the product design.



Applications of DFMA® at Dell EMC

The Team's current analysis approach uses both DFA and DFM. Utilizing both parts of the DFMA® software allows the tool to be leveraged in many different applications within Dell EMC. The DFX Team has three major applications of the software:

- Early design team support
- Benchmarking
- Design improvement

The following sections will discuss each application in detail along with some examples for each.

Early Design Team Support

At an early product development stage, the DFX Team conducts DFMA analysis of a product to get an in-depth understanding of the mechanical design and its current design costing. The DFMA analysis reports provide an early cost profile for each current product design and a basic recommendation for redesign proposals. These two outputs allow the design team to make an effective decision. There are different options of improvement and potential part elimination that can result in more efficient function, easier assembly and improved part costing. These recommendations can greatly benefit manufacturing and other functions, such as field service engineering, test engineering, supplier engineering and others areas, before decisions are solidified and become locked in place.

In some cases, when products have an aggressive schedule, the Team can focus on particular design elements rather than conducting DFMA analysis on the entire design. This allows the DFX Team to better prioritize and focus on the most impactful design enhancements given tight time constraints.

Another benefit of using the DFMA analysis tool is the DFX Team can challenge the design team to think out of the box or consider nontraditional approaches. Figure 1 shows some of the considerations the DFX Team makes when using the DFMA tool for early design team support.

- Concerns & Suggestions**
- Interferences
 - Complexity
 - EMI shielding
 - Poke Yoke/keying
 - Tool-less securing
 - Reduce screw count
 - Simplify design
 - Accessibility/visibility

Figure 1: Early Design Team Support Suggestions Example



Benchmarking

Product benchmarking is something that the DFX Team does using the results of a DFA or DFM analysis. The goal of product benchmarking is to compare products against one another and determine potential trends and opportunities. Dell EMC products come in a variety of heights and can therefore make benchmarking different sized products against one another difficult. This height difference in products in the data center industry is referred to as U size: a U is equal to 1.75 inches and is a standard unit of measure for designating the height of the product in rack cabinets where Dell EMC products are installed (see Figure 2). For example, a 4U chassis is 7 inches high and a 40U rack cabinet is 70 inches high. The different U sizes of Dell EMC products can mean diverse complexities and larger U products can typically house a larger number of components; this can make comparing products against one another difficult. A good example would be comparing a 1U design with a 5U design. The 5U design is larger and can therefore fit more components inside, making the results of a comparison between the 1U and 5U designs unsuitable.

Due to the complexities of different sized product, when the DFX Team first started benchmarking, only products of the same U size were compared against one another. For example, the results of a 4U analysis would be compared to the results of only 4U designs. The problem that the DFX Team ran into by segregating benchmarking comparison to U size was that there were not a lot of products that could be compared against one another in each group. This meant that the results of the benchmarking analysis were not being used to their full potential.

Therefore, the DFX Team generated a benchmarking tool that would input the results of a DFA or DFM analysis, but then break down the results in a manner useful to the Dell EMC business. The first key aspect of the benchmarking tool is that it will break down a DFMA analysis result on a per-U basis. This normalization allows the Team to “level the playing field” and compare a 1U design against a 5U design equally.

Another feature of the benchmarking tool is that it will take DFA cost results and break those costs down based on part functionality (i.e. candidate for elimination, fastener, or required part). For example, if the overall assembly cost is \$5.00, and there are 4 TMNP (theoretical minimum number of parts), 15 fasteners and 10 CFE (candidates for elimination), and 3 operations, the benchmarking tool could give the following cost breakdown: \$1.30 for fasteners, \$1.25 for TMNP, \$1.45 for CFE, and \$1.00 for operations. This breakdown allows the DFX Team to give impactful feedback to the design team by showing how much of the assembly cost is actually associated with parts and operations that are needed.

In addition, this benchmarking tool allows the DFX Team to compare one product against any other products. This helps produce results that are more meaningful to the design teams and can highlight potential areas of design improvement. The results also allow the DFX Team to identify where the design team is excelling as compared to other Dell EMC products.

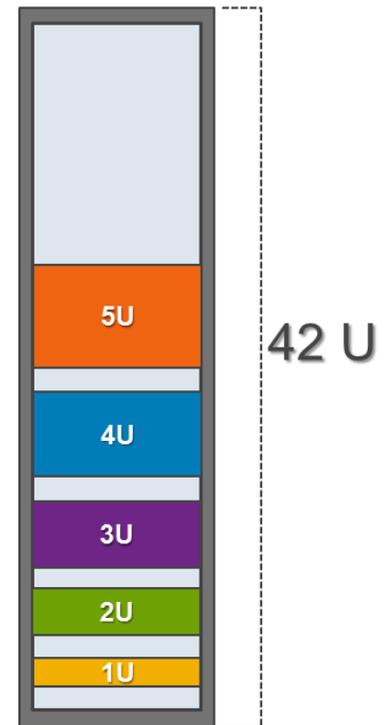


Figure 2: U-Sizes in a Rack



Design Improvement

The goal of conducting design cost-optimization analysis is to help mechanical designers make cost effective design decisions. This is not should costing. Instead the purpose is to determine costs of different design options before the product is released to production. The DFX Team refers to this as *relative costing*. It is an analysis approach that only looks at parts that are changing from one design option to another with the objective of determining the cost delta. Next, the paper will discuss real examples of DFX Team cost-optimized design improvement analysis.

Example 1

This is a DFM example of a multiple drive holder design called a drive sled currently being used in Dell EMC products (Figure 3). During this early product development stage, the DFX Team reviewed the available SolidWorks models and observed that design engineers used 0.5 mm pre-plate steel for the model, but the designers were not certain which material was the most cost effective option.

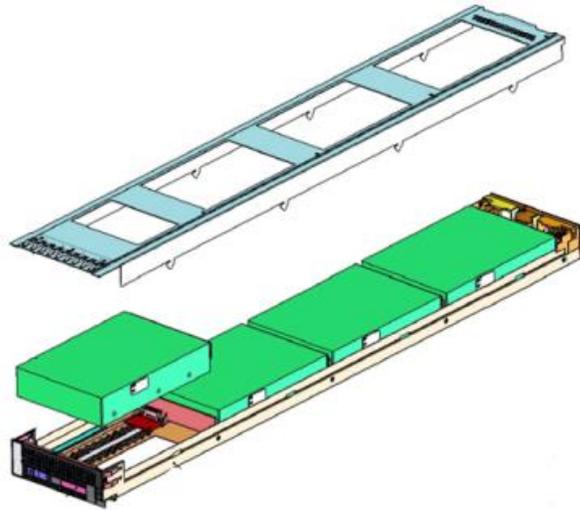


Figure 3: Drive Sled Model

The Team applied DFM to validate four different possible materials recommended by the mechanical design team: 2 mm ABS plastic, 0.5 mm stainless steel, the current 0.5 mm pre-plate steel and 0.8 mm pre-plate steel. The DFX Team ran the DFM analysis report and held a meeting to explain the report in detail. The DFM analysis result is shown in Table 1.

Table 1: Drive Sled DFM Results

	2MM MODIFIED ABS PLASTICS	0.5MM SS	0.5 PRE-PLATE STEEL	0.8 PRE-PLATE STEEL
PER PRODUCT COSTS, \$				
Assembly process	0.22	1.10	1.10	1.10
Manufacturing piece part	1.72	4.95	1.80	2.38
Total cost w/o tooling	1.94	6.05	2.90	3.48
Total tooling cost	1.23	0.96	0.96	0.96
Total cost	3.17	7.01	3.87	4.44
TOTAL TOOLING INVESTMENT, \$				
Assembly tools & fixtures	0	0	0	0
Manufacturing tooling	122,880	96,411	96,411	96,448
Total investment	122,880	96,411	96,411	96,448
PRODUCTION LIFE DATA & WEIGHT				
Life volume	100,000	100,000	100,000	100,000
Total production life cost, \$	316,637	701,461	386,705	444,378
Total weight, lb	0.75	0.10	0.10	0.16

The results showed that the plastic was the lowest cost on a per unit basis, but the design team felt the plastic did not meet the electromechanical functionality that was required. Therefore, the design team chose the 0.5 mm pre-plate steel as the most cost-effective option that did not jeopardize the key functionality of the design.

Example 2

This is a design improvement example that uses DFMA, which illustrates the value of early engagement with the design team.

Dell EMC products typically use a drive carrier, which is a sub-assembly that captures a drive and provides insertion and extraction functions. A spring-loaded drive carrier handle latches the drive into an enclosure or ejects the drive from the enclosure. However, the design team was directed to take a more aggressive, lower cost, carrier-less approach. This was a significant departure from the standard design practice of using a drive carrier.

There are twenty-three drive module assemblies in one product. One drive module assembly consists of four drives. The drive module assembly consists of an enclosure with a circuit board, light pipes and an extraction sub-assembly. (See Figure 4)



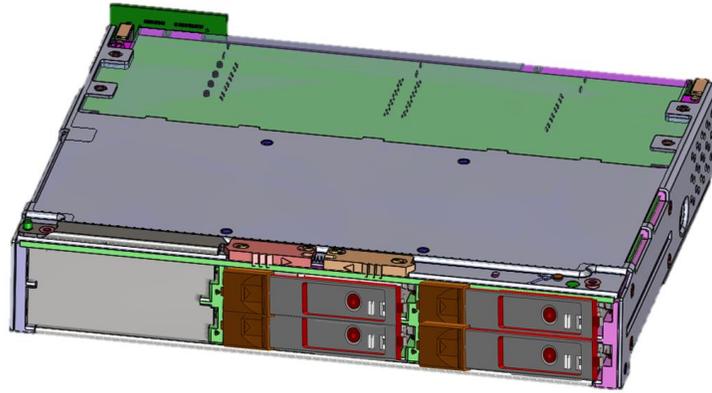


Figure 4: Drive Module Assembly

The DFX Team decided to take a focused approach by analyzing only those elements of the design directly involved in the extraction and latching functions. Those elements consist of a drive divider, latch handle sub-assembly and polyester strap (see Figure 5).

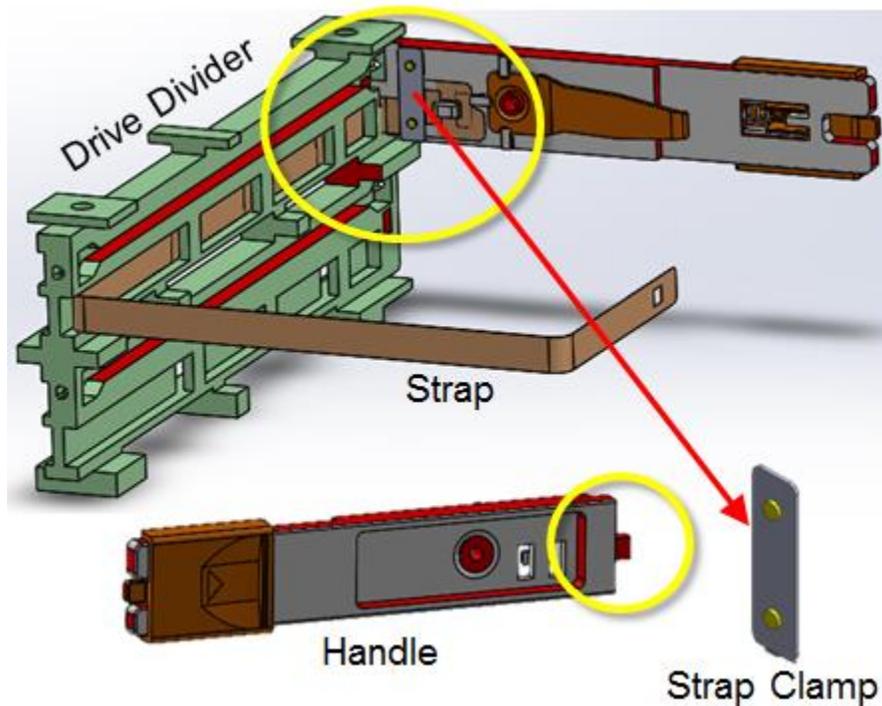


Figure 5: Current Design

The first step was to do a DFM analysis of the existing parts in the current design, which consisted of a drive divider, a handle and a strap clamp, and then import that into a DFA analysis.

The second step was to do a DFM analysis of the proposed redesign, which consisted of a modified drive divider, a modified handle, plus a new hinged retainer, which replaced the strap clamp. Those results were then imported into a DFA analysis. (See Figure 6)

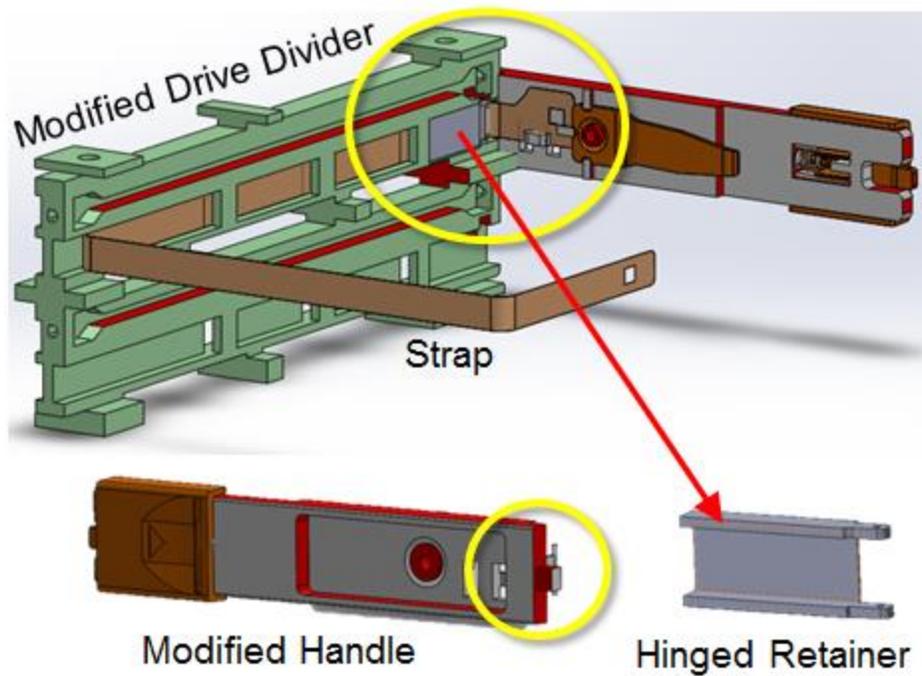


Figure 6: Proposed Redesign

The results showed that the redesign had a savings of \$0.18 per extraction sub-assembly, which is a 9.5% cost reduction (see Table 2 and Table 3).

Table 2: Current Design Results

	Piece Part Cost	Assy Process Cost
Divider	\$0.38	\$0.16
Strap	N/A	\$0.10
Handle	\$0.62	\$0.40
Strap Clamp	\$0.05	\$0.18
Sub-Total	\$1.05	\$0.84
TOTAL		\$1.89

Table 3: Proposed Redesign Results

	Piece Part Cost	Assy Process Cost
Modified Divider	\$0.37	\$0.16
Strap	N/A	\$0.10
Modified Handle	\$0.34	\$0.63
Strap Support	\$0.09	\$0.02
Sub-Total	\$0.80	\$0.91
TOTAL	\$1.71	

Since there are 4 extraction sub-assemblies per storage module, there is a total savings of \$0.72. Since there were 23 storage modules in each product, the total savings on a per product basis amounted to \$16.56 (see Table 4). The design team then accepted this concept as the way forward.

Table 4: Results per Drive Assembly Module

Latches per Assembly	Total Savings per Assembly	Assemblies in Product	Total Savings per Product
4	\$0.72	23	\$16.56

Example 3

This is another DFMA example that suggests removal of a component that the Team believed was unnecessary, adding no additional functionality and adding cost to the overall assembly.

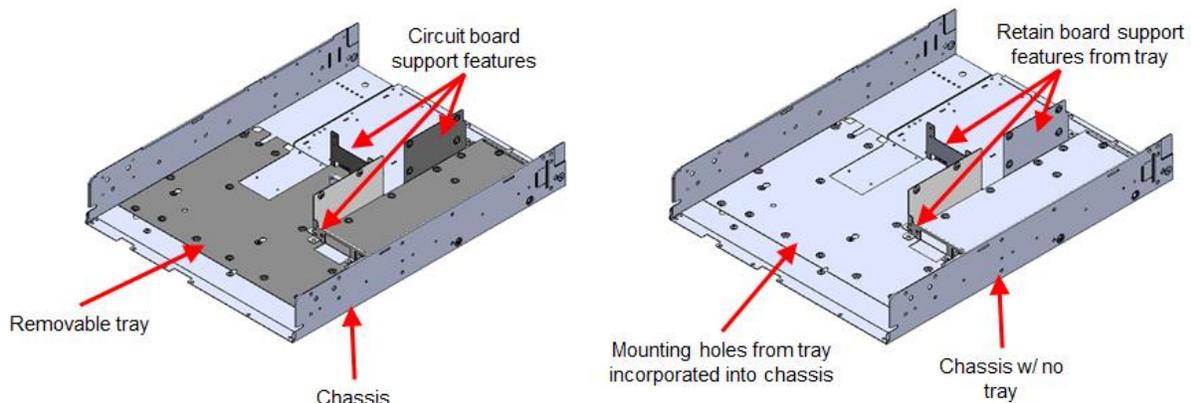


Figure 7: Current Design (L) vs. Proposed Redesign (R)

The current design consisted of a chassis and a removable tray for the circuit boards, leveraged from a prior product. The tray was intended to allow for quick and easy removal of all circuit boards in the chassis. The tray also reduced the risk of circuit board handling damage. However, due to a new



arrangement of circuit boards the removable tray was now trapped in the chassis, and in order to release the tray the circuit boards had to be removed first. In other words the tray no longer worked as intended. Therefore, the DFX Team proposed a redesign that would eliminate the tray but incorporate key board support features into the chassis. See *Figure 7* for an illustration of the current design and the proposed redesign.

In order to do this, the Team ran a DFM analysis on the key components of the current design. These key components included: current chassis, removable tray and circuit board support (attached to the tray). These DFM components were then imported into a DFA analysis in order to generate the total cost associated with the manufacturing and assembly process.

Then the Team ran a DFM analysis on the proposed redesign by modifying the original design; no CAD model was used only photo renderings helped the Team to determine appropriate modifications. The DFM analysis consisted of the following key components: redesigned chassis, which included all tray mounting holes and features, and a redesigned circuit board support, which had to be modified from the original since the tray was no longer present. These two components were then imported into a DFA analysis in order to generate the total cost associated with the manufacturing and assembly process.

The analysis was not intended to show the accurate cost of manufacturing these components, but instead show the cost delta between the current design and the proposed redesign. The DFM results are shown in Table 5 and Table 6

Table 5: Current Design Results

Current Design (w/ Tray)	Piece Part Cost
Base Chassis	\$5.25
Tray (assy)	\$4.06
Board Support	\$1.08
TOTAL	\$10.39

Table 6: Proposed Redesign Results

Proposed Redesign (No Tray)	Piece Part Cost
Chassis w/ Tray Features	\$5.25
Tray	\$0.00
Updated Board Support	\$1.30
TOTAL	\$6.55



These DFM results were then imported into a DFA analysis in order to bring together the piece part cost with the assembly process time and cost. The DFMA analysis results are shown in Table 7.

Table 7: DFMA Results

	Process Time	Process Cost	Piece Part Cost	Total Cost
Current Design (w/ Tray)	1.97 mins	\$1.55	\$10.39	\$11.94
Re-Design (No Tray)	1.55 mins	\$1.22	\$6.55	\$7.77
SAVINGS	0.42 mins	\$0.33	\$3.84	\$4.17

In summary, the results show that the proposed redesign would save in total \$4.17 per chassis without compromising functionality.

Future Plans

The DFX Team plans to continue developing the Global DFX Strategy, which was started in 2015. The Global DFX vision is to extend DFX best practices and methodologies across Dell Technologies both cross-functionally and globally.

The Global DFX Strategy consists of three areas: DFX Services, Education/Training, and DFX Advocates programs.

- The goal of DFX Services is to provide cross functional teams the choice of specific DFX Services that fit the needs of their programs schedule, versus an “all-or-nothing” approach. This allows the DFX Team to be more agile within Dell Technologies rapidly changing business.
- The goal of the DFX Training is to educate others on the DFX process at a high level, so others can gain a basic understanding of DFX best practices and principles. Over the past year and a half, the DFX Team has been developing CBT (Computer Based Training) modules on DFX and DFMA®.
- DFX Advocates are those individuals who are stakeholders and pass all of the required DFX and DFMA CBT training. The Team plans to roll out the training later in 2017. As soon as CBT development is completed, the DFX Team will begin planning DFMA workshops.

Additionally, the Team’s future plans include applying DFA to system-level rack products. Data Center products are very large, very heavy and complex assemblies. These products are high-level integration of chassis-level products, complex cable assemblies and other components; building these products involves paddle lifts, assembly operators moving from the front to the back of the rack and sometimes multiple operators. It will be a challenge to capture all aspects of a system-level build in the DFMA tool, but it is a challenge the DFX Team wants to take on. Once the Team overcomes



these challenges, a potential benefit of a system-level DFA analysis would be estimating the product configure-to-order cycle time.

Summary

DFX Engineering uses a different model when using DFMA, unlike the traditional supplier engineering model. Given that DFX is an influence role, the DFX Team:

- Negotiates with the design team vs. the supplier
- Looks at relative costing vs. should costing
- Strives to improve the design vs. lowering the cost of already designed parts
- Focuses on assembly level vs. part level
- Primarily uses DFA vs. DFM

The benefits of using DFMA[®] started shortly after its introduction in 2012. The progression of learning how to use the software along with identifying where it can add the most value took some time. Once the DFX Team moved beyond the discovery phase, benefits of using DFMA[®] included gaining a more thorough understanding of the design structure and manufacturing processes. The biggest win was that the DFX Team gained the ability to determine whether a design improvement proposal would have a net savings or not. Furthermore, the ability to determine the most cost-effective design options early in the development cycle greatly improved the DFX Team's ability to add value. The improved influence capability means that the DFX Team is adding value to the overall development effort by helping to ensure that products are cost-effective and high quality.

Another benefit of becoming proficient in DFMA[®] has been earlier and more effective engagement with the design team. DFMA[®] is now part of the Global DFX Strategy.

DFMA[®] has been a key enabler for the Global DFX Strategy and significantly improving the effectiveness of the DFX Team's influence model at Dell EMC.

