Why DFMA Efforts Fail

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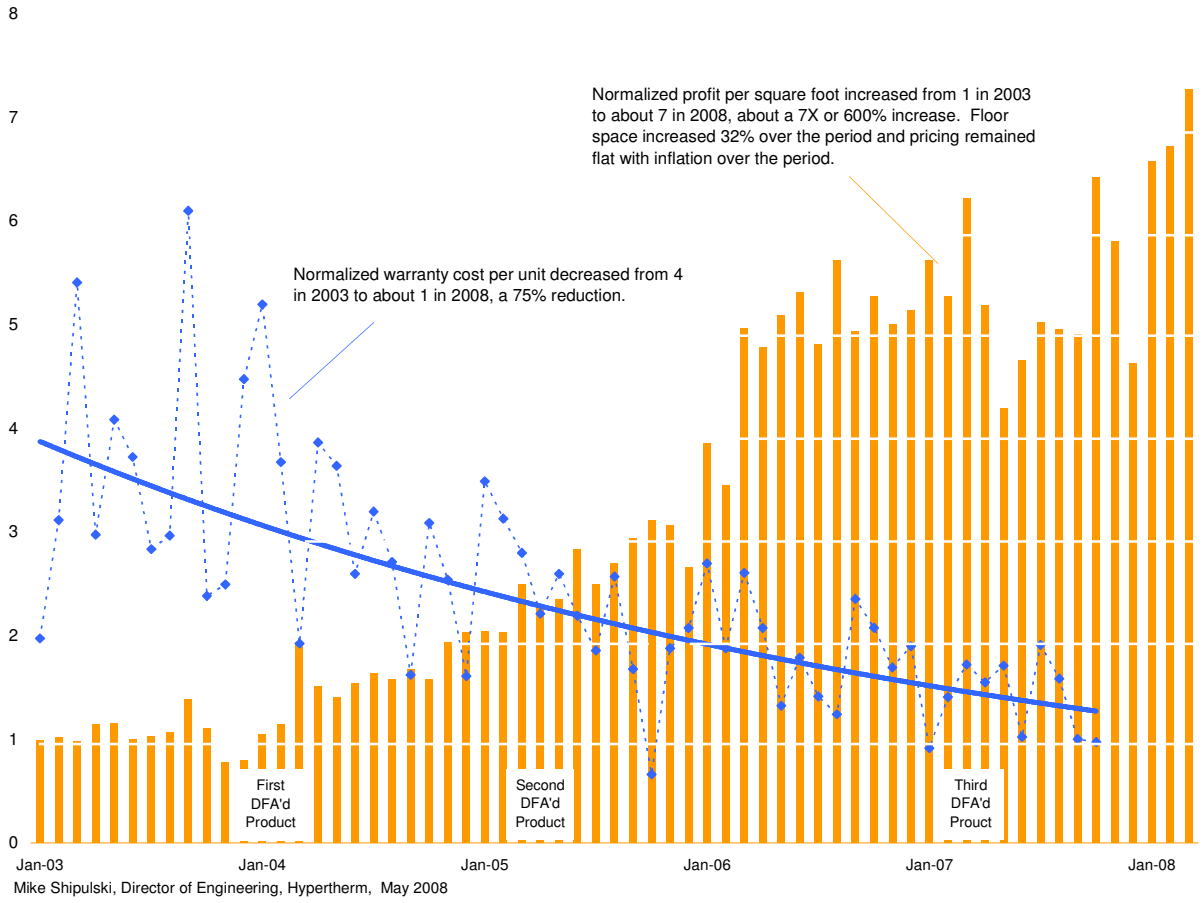
Savings - Staggering and Sporadic

The DFMA toolset has been around for decades The tools are well known and tested, the mechanics well defined, and the documented savings from their use is staggering. [1,2]

Below is an example of staggering savings. A multivariate chart showing profit per square foot of factory space (equations 1-3) and warranty cost per unit (equation 4) for a product family of Hypertherm plasma cutting systems looks like this:



profit per square foot = (sale price – cost) / factory floor space eq. 1

cost = labor + material + overhead eq. 2

factory floor space = factory space that makes parts, assembles parts, stores parts, and ships parts, measured using perimeter of the space eq. 3

warranty cost per system = replacement parts and service / number of systems under warranty eq. 4

Since 2003 DFA was used on new Hypertherm products. As of 2008, half the products have been DFA'd. Since 2003, profit per square foot for the product family increased about 7 times while warranty cost per system decreased by 75%. Prices have remained roughly flat with inflation since 2003 and all production was completed on a single shift. The results were achieved by a combination of DFA, robust design, and lean manufacturing, and some limited DFM.

What's Wrong?

There is little published on DFMA efforts that have gone poorly, as one would expect. Why would anyone advertise their failed efforts? However, there is significant value in understanding common mistakes and failure modes, as companies can learn from others' mistakes and avoid common stumbling blocks. The learning is captured through descriptions of most common DFMA failure modes along with their root causes, and some possible countermeasures to overcome or prevent the failure modes.

At the highest level, DFMA efforts fail due to a lack of knowledge of DFMA fundamentals. This lack of knowledge causes companies to violate the DFMA fundamentals which result in DFMA failure modes. Though this assertion sounds good, it is of little value because its level of abstraction is too high. The assertion must be broken down into an explicit set of DFMA fundamentals that are clearly defined; then the fundamentals must map in a clear way to specific DFMA failure modes which are observed in actual DFMA projects. Learning occurs when the failure modes map to their root causes and countermeasures. It is these all important countermeasures that can overcome or prevent the DFMA failure modes. The mapping of fundamentals to failure modes to root causes to countermeasures looks like this:

Mapping from DFMA Fundamentals

The remainder of the paper discusses the four most important DFMA fundamentals, their failure modes, root causes, and countermeasures which are summarized here:

Fundamental 1 Design must change or you are not doing DFMA	Failure Mode 1 Design Engineering not part of DFMA efforts	Root Cause 1 Design engineering resources are overbooked All product development projects are late Engineering leaders think DFMA takes too long	Countermeasure 1 Review all DFMA proposals and plans to make sure design engineering resources are allocated to make the necessary design changes.
Fundamental 2 Savings from DFA are significantly larger than savings from DFM	Failure Mode 2 DFM projects are done instead of DFA projects	Root Cause 2 Design engineering resources are overbooked All product development projects late DFM savings are easy to measure and predict DFA savings are difficult to measure and predict Leadership wants to believe that DFM can be done without design engineering resources	Countermeasure 2 Find an engineering leader with a radical cost reduction goal and help them use DFA on their project
Fundamental 3 Irresponsible DFM bankrupts suppliers	Failure Mode 3 Irresponsible DFM – DFM without changing the design	Root Cause 3 Significant cost reduction goal placed on Manufacturing Leadership wants to believe that DFM can be done by the suppliers Leadership wants to believe that the DFM banner can be used to take profits from the suppliers	Countermeasure 3 Secure engineering resources for DFM efforts or don't do it
Fundamental 4 DFMA requires systems thinking	Failure Mode 4 DFMA proposals and plans lack systems thinking	Root Cause 4 Systems thinking is not a formalized part of DFMA training	Countermeasure 4 Learn how to use systems thinking with DFMA

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Fundamental 1 – The design must change or you are not doing DFMA
The first fundamental is the most important. At first thought it seems a silly waste of time discussing something that everyone already knows. However, it is well worth discussion as our companies routinely violate fundamental 1 with severe consequences.

Fundamental 1 is true by definition.[2] If that's not enough, simply look at the steps involved with DFA and DFM. The original or baseline design is reviewed, high cost and high part count areas are identified, and redesign efforts are completed to design out parts and change the features that create cost. If the design does not change, the parts are not removed; the features don't cost less; and the desired cost reduction is not realized. So, how do companies violate fundamental 1 and what is the failure mode?

The failure mode of fundamental 1 occurs when companies attempt DFMA without allocating design engineering resources. Since design engineers are the only ones who change the design (through engineering change notices) why would anyone attempt DFMA without them? The root causes for this failure mode are straightforward: companies want to realize the savings from DFMA (we are all in business to make money) but cannot free up design engineering resources. Their engineering resources are always overbooked and all product development projects are late. Adding to that, engineering leaders think that DFMA takes longer and extends project lengths (not true). Putting all that together, our desire to make money blinds us to the fact that we're attempting to save money using methods that require the design to change, yet not allocating the resources needed to change the design at all. Rather silly of us.

A single, simple countermeasure can protect us from our silliness: review all DFMA proposals and plans to make sure design engineering resources are allocated to make the necessary design changes and validate the new design. It will be difficult for organizations to move engineering resources from existing projects to new DFMA initiatives since the resources will be committed to new product development projects already underway. Be careful not to over-commit and dilute engineering resources. The effects of dilutions are severe: projects slow to a crawl and more time is spent on prioritization of projects act the expense of working on them. It is easiest to allocate engineering resources when the DFMA work is planned as part of new product development projects. In that way, DFMA becomes "how the engineering work is done" rather than "incremental work we don't have time for". Standalone DFMA project are more difficult to staff with engineering resources and, if attempted, should be scoped as rifle-shot DFM projects where the top two or three highest cost parts are cost reduced with DFM methodologies.

Fundamental 2 – Savings from DFA are significantly larger than savings from DFM
As we know, DFA and DFM are different: each requires different activities and resources and each achieves different savings.[1,2] DFA savings are broader, more significant, more far reaching than DFM, and more difficult to measure.[1,2] DFA eliminates parts altogether while DFM reduces costs of parts. Downstream costs and wastes associated with parts—such as handling, moving, storing, rework, and overproduction--are eliminated with DFA.

The failure mode of fundamental 2 occurs when companies do DFM before DFA. When this happens companies spend time and resources to reduce the cost of parts (using DFM) that should have been eliminated in the first place using DFA.[3] Why do projects with the most significant savings (DFA) potential take a back seat to projects with lesser savings (DFM)? Some components of the root cause are repeated from the previous root cause: the design engineering resources are overbooked and unavailable. But there are more components to this failure mode. Since DFA savings are more difficult to measure than DFM, the savings cannot be used to justify the DFA projects. DFM savings are easier to measure and can be used to justify the DFM projects. Using traditional cost accounting to justify projects, the DFM savings actually look larger than the DFA savings and the DFM projects are proposed instead of the DFA projects. There is one more component to the failure mode. Leadership wants to believe that DFM can be done without using design engineering resources.

The countermeasure to failure mode 2 lies within design engineering. Find an enlightened engineering leader with a radical cost reduction goal and propose to help the leader with DFA. The cost reduction goal must be

radical enough (on the order of 30%) to warrant the perceived risk of DFA. Remember, since DFA savings are difficult to measure and predict with traditional cost accounting, the engineering leader must be enlightened enough to calibrate the predicted savings using data from other DFA projects (usually from other companies) to justify DFA (desperation helps in this regard). Your offer to help with the project can reduce the perceived risk somewhat.

Fundamental 3 – Irresponsible DFM bankrupts suppliers

Irresponsible DFM occurs when an OEM uses the DFM banner to take profit margin from their suppliers instead of working with the supplier to design out cost. With irresponsible DFM, the OEM has no intent to design out cost, rather, expects the supplier to do all the work and get none of the rewards. The tell-tale sign of this failure mode is when DFM is done without changing the design. These DFM projects are typically led by purchasing or manufacturing and have no design engineering resources allocated to the projects. To be clear, the responsibility for irresponsible DFM belongs to those who say "no" to allocation of engineering resources and not to purchasing and manufacturing folks who get stuck running the projects.

Like the previous failure modes, the lack of engineering resources is an important component of failure mode 3. Here's how the rest of the failure mode comes about. A significant cost reduction goal is placed on manufacturing or purchasing with the constraint that there are no engineering resources available to redesign the product or validate any proposed design changes. Leadership wants to believe that DFM can be done without changing the design. As we all know, the cost reduction goal must be achieved. Someone comes up with the idea to use DFM to work in a collaborative way with the suppliers using DFM. No one else has a better idea, so a DFM campaign is launched. But since the design cannot change, the only way to achieve the cost reductions is for the suppliers to reduce their conversion costs. Since the suppliers have already signed up for another cost reduction goal for the OEMs' lean initiatives, there are no conversion cost savings left to mis-allocate to DFM. The suppliers must reduce their profit margins to achieve the DFM initiative savings. After a few of these irresponsible DFM campaigns, the suppliers go out of business and the OEMs must spend lots of money developing and qualifying new supply bases. I think OEMs spend more money with the follow-on supplier development and qualification than they save with irresponsible DFM. The OEMs are better off not doing irresponsible DFM. The best suppliers will find a way to avoid irresponsible DFM and protect the OEMs from themselves.

The countermeasure for failure mode 3 has two components. The first is straight forward: secure engineering resources for DFM projects. The second component is less straightforward: before DFM work, create profit calculations with suppliers to demonstrate to the suppliers that they will make more money when they do the DFM projects. A contrived example of a high level profit analysis to be completed before DFM projects looks like this:

	Baseline Design	New Design (DFM'd)	Change	Change (percent)
Material cost	$3.50	$2.00	($1.50)	-43%
Labor cost	$1.00	$0.75	($0.25)	-25%
Machining cost	$2.00	$1.00	($1.00)	-50%
Overhead cost	$1.50	$0.75	($0.75)	-50%
Supplier profit	$2.00	$3.00	$1.00	50%
OEM total cost per part	$10.00	$7.50	($2.50)	-25%
Supplier profit per part	$2.00	$3.00	$1.00	50%
Volume (parts per year)	100,000	100,000	0	
Supplier profit per year	$200,000	$300,000	$100,000	50%
Incremental OEM profit per year			($250,000)	

cost is designed out

volume is unchanged

supplier makes more money

OEM makes more money

Supplier profits will increase by $100k and the OEM profits will increase by $250k. So, before starting the DFM projects, the suppliers (and OEMs) know that they will make more money through the DFM projects.

Most companies will not complete the profit analysis for one of several reasons: They don't know they are supposed to do the profit analysis pre-work; they don't want to waste time doing the unappreciated profit analysis; or they don't know how to do the profit analysis (just use the DFM software). Often the suppliers won't participate because they don't trust the OEMs. The OEMs' actions over the years have created a non-trusting, adversarial relationship with suppliers and suppliers are not comfortable declaring their profit per part data because they know the OEM will look at supplier profit as their own profit. Supplier profit data would become a target for the OEM. It will take consistent respectful behavior by the OEMs to overcome the mistrustful relationship they created. Only then will the OEM/supplier partnership yield staggering savings from DFMA.

Fundamental 4 – DFMA requires systems thinking

DFMA is usually thought of as a set of software tools to eliminate parts, reduce the cost of parts, and estimate the cost of parts. But DFMA is much more than a set of software tools--just as lean and six sigma are more than a set of software tools. There are systems attributes to good lean and six sigma initiatives that support and give context to the tools. The system attributes are now well defined for lean and six sigma initiatives. Not so for DFMA initiatives. There are black belts, report out mechanisms, standard work, clear timelines and deliverables, and clear expectations of roles and responsibilities to name a few. This is exactly the same "systems thinking" required by DFMA. Here is a working definition of systems thinking:

> Systems thinking - the thinking that defines the architecture, components, modules, interfaces, and data for a system to satisfy specified requirements.[4]

One component of systems thinking is defined and clear in DFMA: the specified requirements that must be satisfied are expressed in the form of explicit cost savings targets. However, the other components of systems thinking are lacking (architecture, components, modules, interfaces, and data) which lead to the failure mode for fundamental 4 - the lack of DFMA systems thinking in project plans and proposals. The best operational definition of the lack of systems thinking is a list of unaddressed questions from which look like this:

> What is the organizational structure of the DFMA initiative?
> Who is responsible for the timeline and deliverables?
> How will the initiative be paced and managed?
> What are the roles and responsibilities for purchasing, manufacturing, and engineering?
> Who manages the coordinated efforts across purchasing, manufacturing, and engineering?
> Will there be report-outs?
> Who will lead the report-outs?
> What data will be presented at the report-outs?
> Does anyone know how to run a DFMA report-out?
> How was this project chosen over the other projects?
> How will the work be different in the next projects?
> How will the learning be captured and shared?
> What is the continuous improvement mechanism for the DFMA initiative?
> Where is the training plan to develop organization capability in DFMA systems thinking?

Responsibility for creating plans and proposals with DFMA systems thinking does <u>not</u> rest on senior management's shoulders. To be clear, <u>responsibility rests with DFMA leaders who create the plans and proposals</u>. DFMA leaders must know the fundamentals well enough to put the right proposals in front of senior management – proposals with DFMA systems thinking. To go a step further, DFMA leaders must know the fundamentals well enough and have sufficient confidence in their knowledge to effectively redirect senior management when their thinking is out of alignment with DFMA fundamentals.

The root cause of failure mode 4 is the lack of knowledge of DFMA systems thinking. DFMA plans and proposals are strong on DFMA software and software training and weak on DFMA systems thinking. Much like systems thinking has evolved for lean and six sigma, DFMA systems thinking must be built out, formalized and given time to evolve. The countermeasure for failure mode 4 is to get training in DFMA systems thinking. Though the countermeasure is straightforward, it is difficult to achieve because there are few who know DFMA systems thinking well enough. If considering a consultant to help, ask to see evidence that they have used DFMA systems thinking to achieve staggering savings. A good consultant should be able to describe differences between the baseline and new designs, make direct links to savings due to those design differences, and show increasing savings that continue after their direct involvement with DFMA systems thinking. The last one is the toughest because it requires putting in place sustainable organizational culture, knowledge, and infrastructure to enable the work to continue.

The next best (and most likely) way to learn DFMA systems thinking is to partner with a non-competing company that has demonstrated the thinking. At first thought this type of partnership seems one-sided, impractical and unlikely; but when considered deeply the relationship is quite practical likely and two-sided. This type of partnership benefits both the company that wants to learn (learning company) and the company that wants to teach (teaching company). Firstly, it is a big compliment to the teaching company when the learning company asks for help. It feels good to the teaching company. Learning companies must keep this in mind when considering a relationship with a teaching company. It is clear how the learning company benefits – they learn how to use DFMA systems thinking. Benefits for the teaching company are more subtle, but just as significant. In order to teach, the teaching company must reflect on and formalize their knowledge which can be useful to further systematize their DFMA efforts. But more importantly, through formalization of their knowledge, the teaching company defines the limits of its knowledge. Once the limit of knowledge is defined, the next areas for maturation are made clear to the teaching company. I think there is more benefit for the teaching company than the learning company. Keep this in mind as you look for a partnering company.

Metrics

Lean and six sigma initiatives require metrics and DFMA is no different. As we know, metrics are hierarchical. At the lowest level are process metrics which are used to focus and align the low level detailed work. At the highest level are business metrics that result from good low level work. Business metrics either improve or not based on the quality of the low level activities. Profit per square foot and warranty cost per system are two of the best business metrics to represent the success of DFMA initiatives. Profit per square foot is the best surrogate to represent what is experienced by CEOs, senior management, and stockholders. Warranty cost per system is the best surrogate to represent what is experienced by customers.

Profit per square foot – what CEOs are experiencing

"No one escapes from profit per square foot." Profit per square foot represents performance of four groups in a single metric – engineering, sales, marketing, and manufacturing – which is why CEOs and senior management would like to see the metric calculated. Each group influences the metric in its own way. Engineering improves the metric by introducing a lower cost design to manufacturing which consumes less factory floor space and designing in high functionality which translates to increased customer value, increased sale price and volume, and increased profits. Marketing improves the metric by clearly and meaningfully articulating improved functionality into increased customer value, increased sale price and volume, and increased profits. Sales improves the metric by effectively communicating improved functionality and value to the customer leading to increased sales price and volume, increased profits. Manufacturing improves the metric by reducing floor space, labor cost, and overhead through lean practices resulting in increased profits. Profit per square foot is a clear measure of company profitability and efficiency.

Warranty cost per system – what your customers are experiencing

Warranty cost per system represents what your customers are experiencing in a single metric. Regardless of how it is measured (as long as the metric is measured consistently) a reduction in warranty cost per system is a good surrogate for what your customers are experiencing with your products. Warranty cost is a catch-all for customer happiness (more precisely a lack of unhappiness) and improving any component of warranty cost

improves the metric. Engineering improves the metric by creating robust products. Marketing improves the metric by accurately representing product performance and capability. Sales improves the metric by selling products based on their actual performance and capability. Manufacturing improves the metric by making products well, shipping products on time, and shipping the right products to customers.

Summary

Engineering resources are the key to avoiding DFMA failure modes. The theme of engineering resources runs through all DFMA fundamentals and failure modes. Extending this thinking a little, the four topics discussed in the paper can be thought of as four facets and manifestations of a single theme – engineering resources are required for all DFMA work.

References

1. Shipulski, "Six Lessons Learned from a Successful DFA Program." *Proceedings of the 2006 DFMA Forum*, Providence, RI, June 20-21: 5-15.

2. Shipulski, "Design for Manufacturing - what is it and how does it fit with Design for Function, Design for Assembly and Design for Cost?" *Proceedings of the 2007 DFMA Forum*, Providence, RI, June 19-20: 5-11.

3. Personal conversation with Nick Dewhurst, Hanover, NH, 2005.

4. Systems Design. *Wikipedia.* May 2008. <http://en.wikipedia.org/wiki/Systems_design>.