Tools for Convincing Skeptics of the Need to Invest in DFMA

By

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Abstract

Those that attend DFMA conferences are usually already onboard with the benefits of the practice, yet we all deal with people, co-workers, executives, customers who are not fully convinced that DFMA is worth their time and money. This paper shares practical tools and methods that can convince people that DFMA will make a valuable improvement in their products, projects and businesses. The author uses case studies to exemplify how to target valuable DFMA efforts and influence others to invest in DFMA.

Introduction and Background

There are many methods used in product development to better innovate, improve quality, and ultimately provide customer value and sustain profit. Among the many newer or time-tested product development tools, DFMA persists as a valuable method to control cost [1]. Success stories from the practice of 'Design for Manufacture and Assembly' are presented, through conferences, papers, or often through apocryphal anecdotes, as evidence and persuasion to incorporate the practice to late adopters.

Companies who value best practices often prescribe DFMA in their internal design procedures. Despite a wealth of external advice and internal imperatives to perform DFMA, some product development stakeholders resist investing in DFMA efforts in their projects. Proponents of DFMA can apply the following methods to elicit buy-in from others:

- Analyze stakeholder values to create a strategy of influence.
- Use Design-to-Cost analysis to establish cost targets and discuss cost drivers.
- Facilitate DFMA efforts, and ownership of the most impactful cost reductions.

Often, the mismatch between best practices and actual practices, lies in cultural inertia, departmental or personal priorities that seem to conflict with DFMA activities. Thus, anyone acting as an agent of change needs to link the value of DFMA activities to the interests of stakeholders.

Stakeholder Analysis

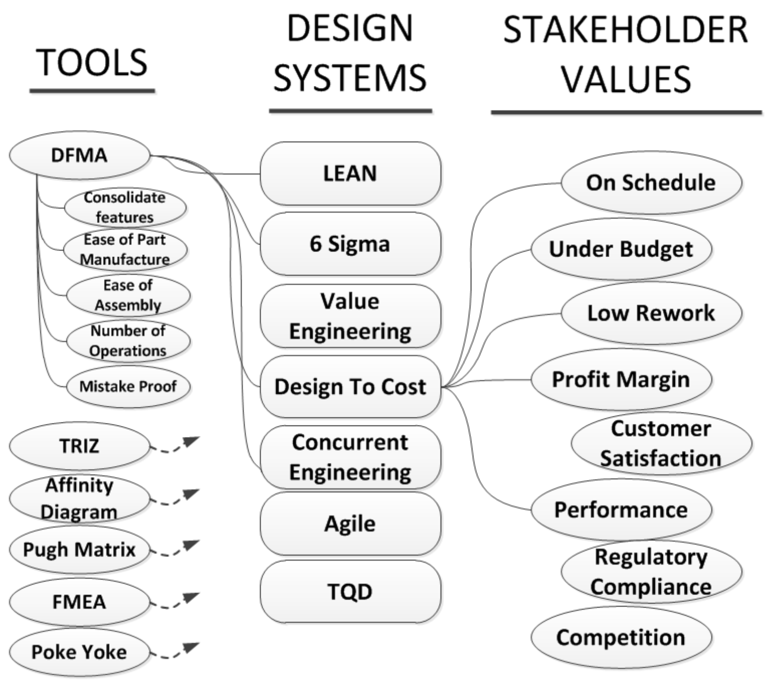
According to the Project Management Institute (PMI), the term project stakeholder refers to, "an individual, group, or organization, who may affect, be affected by, or perceive itself to be affected by a decision, activity, or outcome of a project" [2]. If we want to better understand how the 'activity' of DFMA 'affects' a stakeholder we can benefit by appropriating a project management tool called a Stakeholder Analysis matrix [2]. A project manager is a leader that influences others to ensure project success, which benefits all project stakeholders. Similarly, a DFMA practitioner is a leader who influences others on behalf of a profitable product, which, we can agree, everyone ultimately wants. To prepare for engaging others in persuasive conversations about DFMA, the following stakeholder analysis matrix helps to assess stakeholder interests and suggest a strategy.

Figure 1: Modified Stakeholder Analysis Matrix example

Role	Values / Performance Metrics	Perceived Constraints	Value-Add Strategy of DFMA
Program Manager	1.) On-time delivery 2.) NRE under Budget 3.) High Margin 4.) No Customer Returns	- DFMA is expendable - Extra design delays project - Assembly costs are invisible	- Reduces risk of schedule delays - R.O.I. >1 - Low costs = higher profit - Reduces returns' root cause
Engineer	1.) Comply with spec 2.) Robust Design 3.) Complete Milestones 4.) Elegant design	- Optimization takes time - DFMA requirements vague - Lower cost = less robust - Design ownership	- DFMA = Reliability = Robustness - DFMA now = less ECNs later - Shows due diligence to concurrent engineering
Operations	1.) On-time shipments 2.) Low Rework 3.) Available Material 4.) Passes Inspect/Test	- Collaboration is inconvenient - Not the design expert - Late involvement	- Less variation = less rework = ship on-time - Improves drawings and instructions

The stakeholder analysis matrix seems simple, but the inputs and outputs are not always intuitive, nor are they constant for groups or roles. To get an accurate understanding of the 'values' and 'constraints' inputs the influencer should have informal interviews with people and observe the systems and terminology they use. This is also a good opportunity to build rapport, ask advice and opinions. We have found value in the advice "Go to the Gemba", as the Japanese Lean principle recommends, to learn about processes, systems, and people in their own environment. To construct a value-add strategy, it helps to have a broad understanding of how DFMA fits within the context of complementary methods. Similar design systems enable the efforts of DFMA. The relational map below shows how some complementary design systems are related to DFMA.

Figure 2: Map of Complementary Tools and Methods



Some design systems may have more internal traction or be more established or accepted at a given firm. They can serve as a framework within which DFMA is implemented. In fact, DFMA efforts can be enhanced, directed or sheltered via a complementary initiative. We've discussed the potential of leveraging performance metrics and internal systems. Even so, to successfully influence others who have their own concerns, priorities and agendas; it's important to use the best methods to influence them on their own terms.

Methods of Influence

John Ullmen, Ph.D., is a published expert in the science of motivation and influence. His 'Influence Advantage Checklist' summarizes proven methods that help to engage others and plan conversations [3]. Care should be taken to focus on not only near-term persuasion but to engender longer-lasting commitment to DFMA. Every interaction is an opportunity to make future influence even stronger. Case studies later in this paper will illustrate some of the following methods.

Figure 3: John Ullman's Influence Advantage Checklist (referred to later as e.g. :'(#1)')

1. Provide Rational Analysis
2. Cite credible Sources
3. Reference Legitimate Policies and standards
4. Establish urgency or scarcity
5. Demonstrate Pain and Gain
6. Build alliances and coalitions
7. Use social Proof
8. Initiate reciprocation or exchange
9. Encourage commitments and consistency
10. Present striking comparisons or contrast
11. Add impact to your ideas
12. Align with shared values, principles or purposes
13. Connect to strategy or high level goals
14. Build rapport relationships and trust
15. Like and be likeable
16. Request help or advice
17. Be influenceable
18. Lead by Example

The most influential approach integrates multiple methods. In a cost-driven environment, rational analysis (#1) is foundational to creating impartial awareness of pros and cons, but more convincing when paired with an appeal to shared values, high level strategy, and policy (#12, #13, #3). Appealing to someone's sense of social awareness is a key dimension of influence. Citing authorities, building alliances, or using social proof (#2, #6, #7) leverage a person's employment, industry, or expertise network and can build unity to embrace change. Before any conversation or presentation, it is essential to build a convincing case based on knowledge of risks, resources and consequences. Establishing urgency/scarcity, demonstrating pain/gain, presenting striking comparisons or contrast, and adding impact to your ideas (#4, #5, #10, #11) make use of knowledge to build a convincing case. Stakeholder analysis supports these methods. Long term influence is built upon trusting interpersonal relationships.

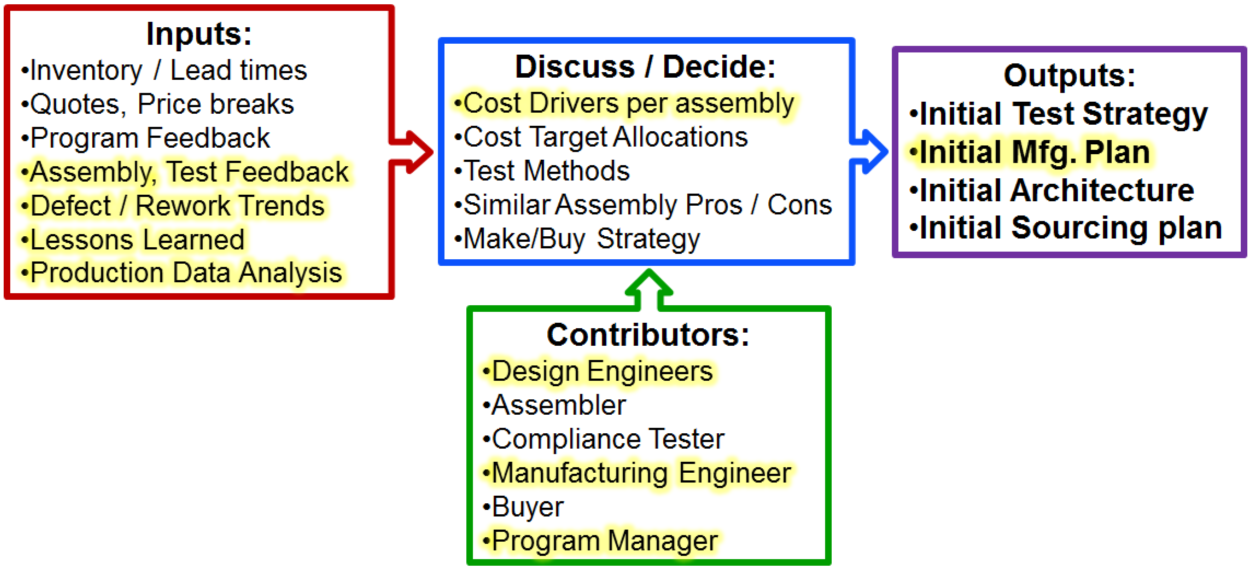
Reciprocity, rapport, likeability, asking advice, and leading by example (#8, #14, #15, #16, #18) help to build relationships and can yield long term commitment to DFMA.

Inevitably some stakeholders will have objections to DFMA. Objections should be used as clues to uncover what will more effectively influence a stakeholder. As an example, a program manager that cares most about yield may see DFMA as a delay to starting production. A case could be made that hours spent on DFM will reduce defects at the manufacturer and shorten material lead time. Or, DFA will avoid hours of rework during assembly, and avoid the cost of scrapping and replacing parts which lengthen the duration of a build. The investment in design features that reduce lead time, and reduce rework connects to the program manager's need for production yield. Thus, objections help to find a path of persuasion that is mutually beneficial.

Design to Cost

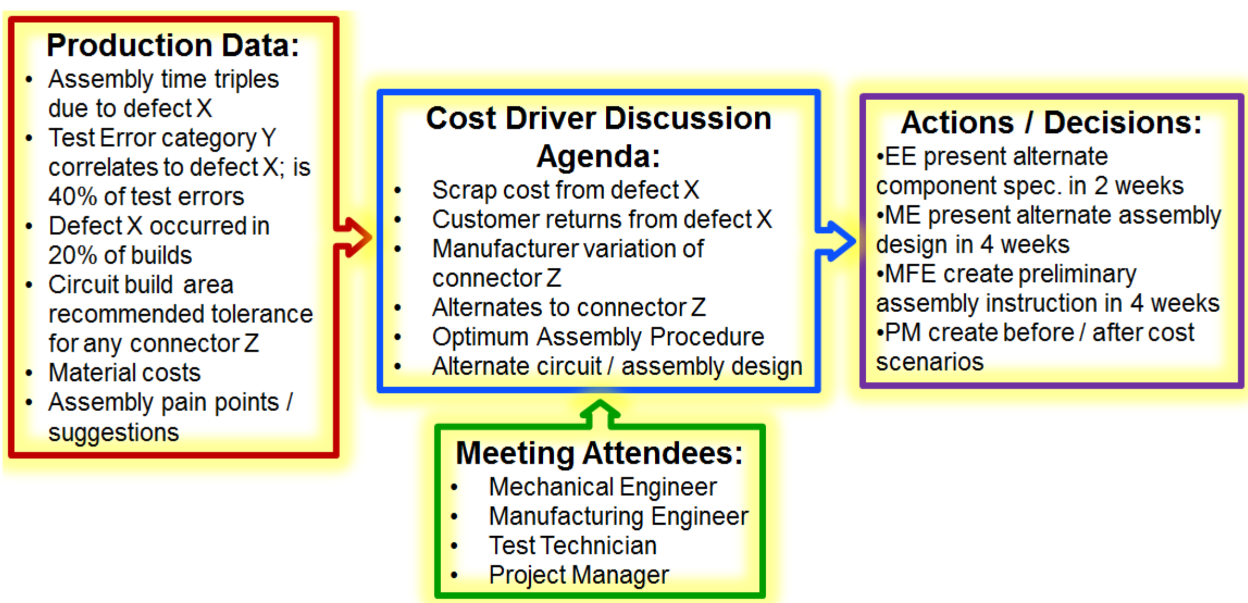
As mentioned before, Design-to-Cost (DTC) is a potential vehicle for implementing DFMA. Within a program driven business environment like L-3 Communications, DTC creates a common language of cost with which all proposed improvements are evaluated. Cost goals often have labor and material components, and can be rolled up as a 'Cost of Goods Sold' (COGS) recurring cost. Worthwhile DFMA activities can be described as efforts with a return on investment. This creates justification for DFMA amidst competing project priorities. Cost conversations are time sensitive to the product development schedule and are most valuable when planned ahead of time to include the Right people, at the right time, with the right supporting information. Following is an illustration of how DFMA is incorporated in design to cost discussions within a program near Concept Stage of a typical stage-gate development cycle. Figure 4 shows the Design-To-Cost framework.

Figure 4: Design-To-Cost Discussion Framework in Concept Phase



Highlighted within the DTC framework is an "assembly cost driver discussion". Figure 5 shows specific examples of the kind of production data needed to discuss cost drivers. It also shows the right people needed to make design decisions that improve manufacture and assembly. It is assumed that contributors have done due diligence such as, analyzing and reporting data, and conducting root cause analysis. DFMA discussions like that illustrated are iterative and rely on planned, informed discussions with the right stakeholders.

Figure 5: DFMA Actions resulting from Design-To-Cost Discussion



Target Costing

Using a target cost as a goal can help drive disparate metrics into a common language around cost and value. Target costs are often market driven but can also be internally set. When customer or market data is lacking, an internally set target can also create strong rationale to help drive ownership of a cost goal. A Cost Target Graph shows the gap to bridge between the current rollup of product costs and a more competitive cost threshold. Any combination of labor and material cost reductions will reach the new target. Thus, scenarios can be entered representing incremental DFMA effort. This invites discussion about the most impactful ways to reduce cost. See the cost target graph for the Radio Equipment in a case study below.

Prioritize Cost Drivers

With a reasonable product cost target set, further data analysis will help to decide what DFMA efforts are most impactful. Historic Design, Operations, Procurement and Industry data can be used to build a convincing business case. Pareto charts of labor, material and defect costs help to categorize and monetize what improvement efforts are worthwhile, who should be involved, and what the expected savings will be. Grouping costs can also help prioritize cost reductions and DFMA efforts by vendor, by material type, by method of manufacture, or by labor type. Data accuracy inconsistency is a real world given, so decision processes and proposals need to be robust enough to deal with it. See examples of prioritized DFMA recommendations in the case studies below.

Facilitate DFMA efforts

The aim of facilitating DFMA efforts is to link the intrinsic value of DFMA to what the organization and stakeholders value. If “Lean” is a strong internal imperative, then explaining how DFMA reduces “waste” will likely garner support. If dedication to “6 Sigma” is part of company culture, then describing how DFMA controls “variation” can initiate buy-in. If program cost is of utmost importance, then addressing cost drivers will better win hearts and minds to champion DFMA. The following case studies exemplify how awareness of cost drivers led to DFMA collaboration.

Case Study – Radio Equipment

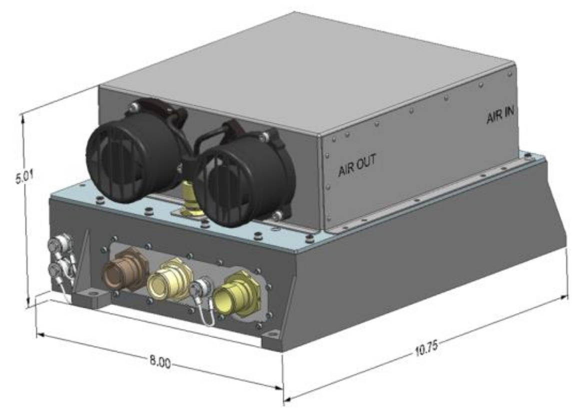
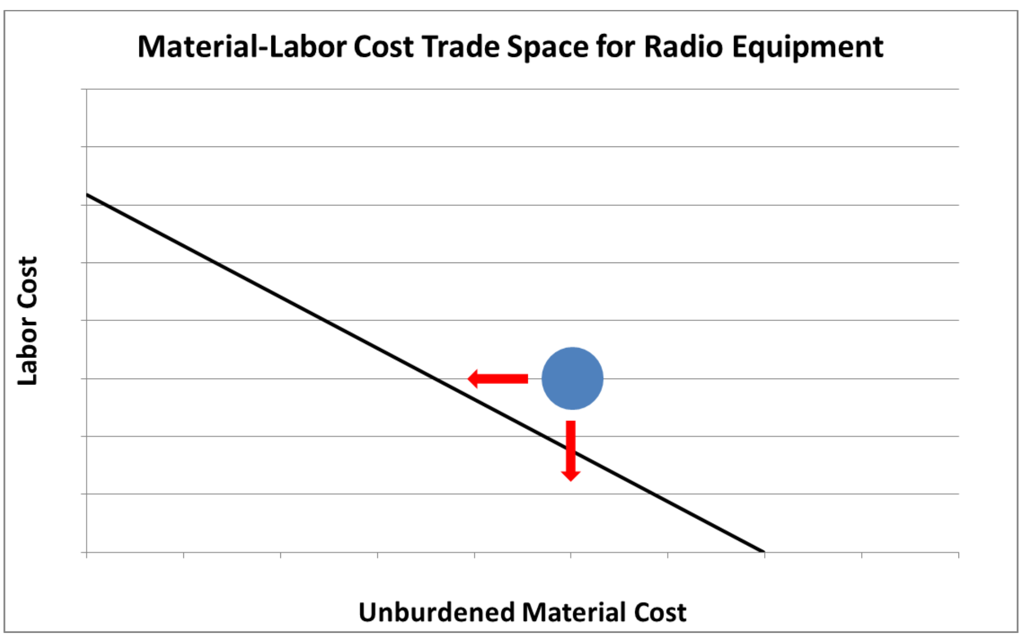


Figure 6: Design Concept of Radio Equipment

In the Concept Phase of a Radio Equipment project, the program manager gave the product cost target. Historic material and labor cost data from builds of a similar assembly were pulled from the Enterprise Resource Planning (ERP) production database. This provided the likely initial cost of the new design. The Cost Target Graph (see Figure 5) showed the team at the outset of design, the cost boundary constructed from the rolled up material costs from the BOM and the labor costs tradeoff commensurate with the established product target cost. Estimates are plotted on the curve and quickly identify the "gap" between the current estimate and the desired outcome. The blue dot represents current cost rollup. Its diameter represents variance in cost among different builds. The graphic shows that we can bridge the gap with different combinations of material and labor reductions. This visual provides a clear picture as to the desired goal and some potential paths to meet the goal.

Figure 7: Cost Target Graph for Radio Equipment:



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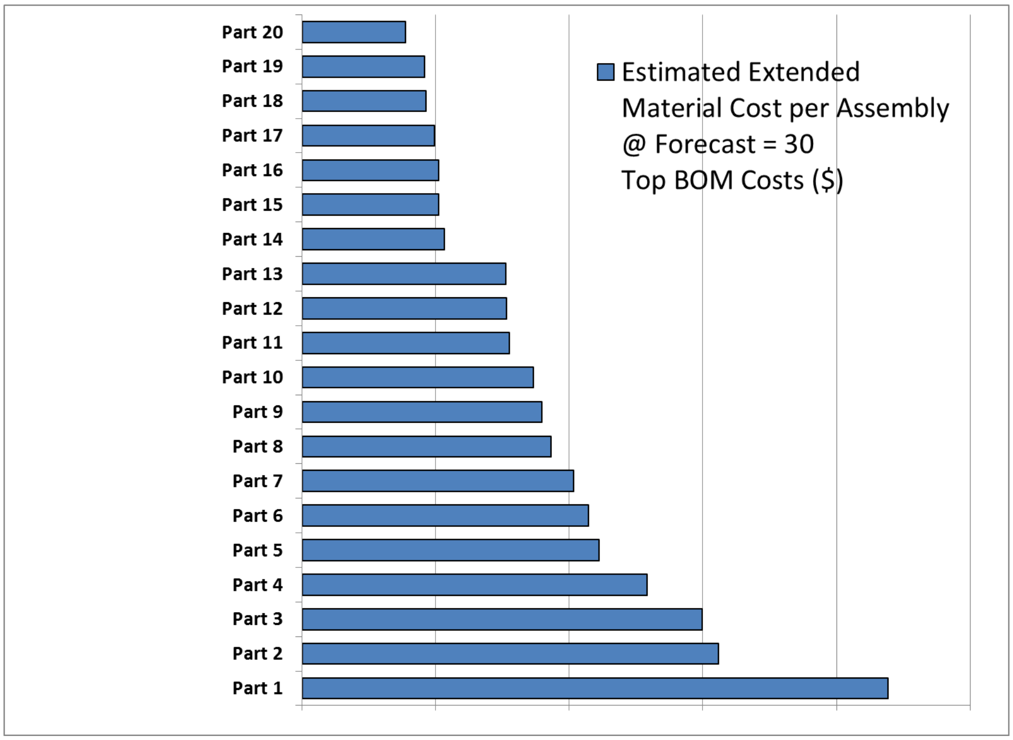
As design progressed we kept a spreadsheet of anticipated material costs based on quotes and cost history. Highest material costs in the preliminary bill of materials were graphed as a Pareto chart and shown in a design review (see figure 7). The Pareto chart shows the power of grouping and ranking to draw attention to the most impactful costs (#10). Most people are familiar with material costs displayed as a Bill of Materials where costs are organized by line item or subassembly. Not until costs are prioritized by highest cost do we get a sense of the ratio of one cost to another, and of the percentage cost in relation to the whole assembly.

Figure 8: Pareto Chart showing Priority of Material Cost Reductions for Radio Equipment



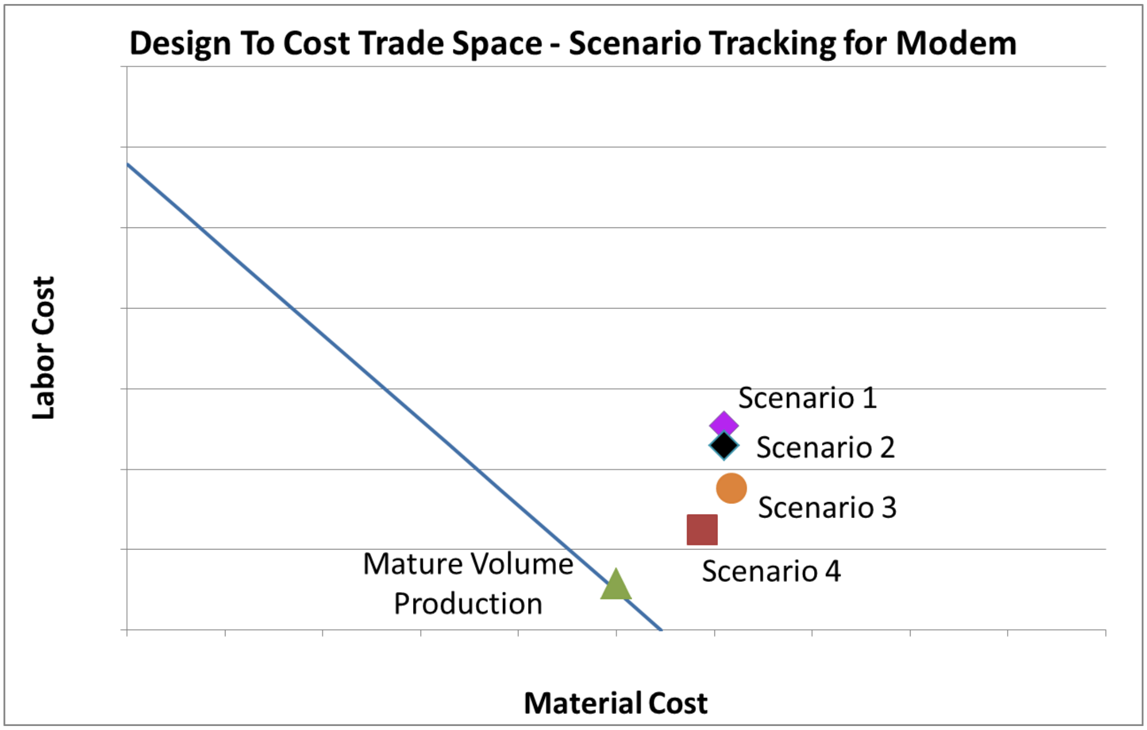
A senior designer who was present for peer review stood up and praised the insight that the Cost Curve and Pareto graph gave. This social support (Influence Checklist #7) bolstered the rational analysis (#1) and validated recommendations on what parts and subsystems to redesign, combine or procure differently in order to meet the cost threshold, focusing the DFMA efforts to areas of greatest impact. This focused effort influenced the PM, by aligning with that stakeholder's values (#12) of desiring to keep non-recurring expenses (NRE) in control as well as minimize schedule diversions. The resulting redesign did in fact replace an expensive heat exchanger and electronic components with less expensive alternates that met performance requirements and simplified the build and test cycles, further reducing costs and build times.

Having shown diligence to accurate data mining and having shown alignment with the program manager's goals, the manufacturing engineer and mechanical engineer were open to discussing assembly topics early in concept phase. Two hours of collaborative prototype and model review between 3 people resulted in a preliminary assembly plan and 9 action items for the mechanical engineer. She agreed to change drawings which solved pain points for production while avoiding 20 hours of time spent on eventual engineering change notices (#5, #8). This meeting also empowered the manufacturing engineer to request additional improvements as the drawings went to release, saving additional labor cost by avoiding build issues and the subsequent Change Requests to resolve them late in development. Follow-up on action items from meetings encouraged commitment to DFMA efforts (#9). In meetings, we asked advice (#16) to elicit mental assembly simulations that helped present a contrast between an assembly method that took longer and scratched paint, versus one that didn't (#10).   This simulation helped establish urgency (#4) that the time to address alternate assembly options was immediate, making ability to change relatively painless (#5). Equally as important, both parties could claim the benefits of concurrent engineering in design reviews (#12).

Case Study – Modem

A subassembly of a modem was due for redesign. This was an opportunity to apply DFMA to reduce testing failures and field failures.   No marketing cost target existed, so an aggressive threshold was set as a goal. The threshold was derived as a long-term, high-volume production goal. Material cost reductions were limited, so rework labor became the focus of attention.

Figure 9: Cost Target Graph for Modem: 5 Scenarios of Material + Labor cost combinations are shown.



Analysis of historic labor data pointed to defect types that were atypically high in occurrence and in labor hours incurred compared to other similar assemblies. The cause was identified as assembly over-constraint conditions, driving tolerances to extremes. The redesign of the modem focused on eliminating the over-constraints at assembly junctions resulting in reduction of testing defects and thus, rework. Anticipated assembly steps were outlined and illustrated in detail using DFMA principles with an experienced manufacturing engineer. A new assembly time for the modem was estimated. Given that the design changes addressed mechanical root causes of testing defects, stakeholders had confidence that the design change would have the labor savings impact projected.

Figure 10: Modem Subassembly Redesign with DFMA

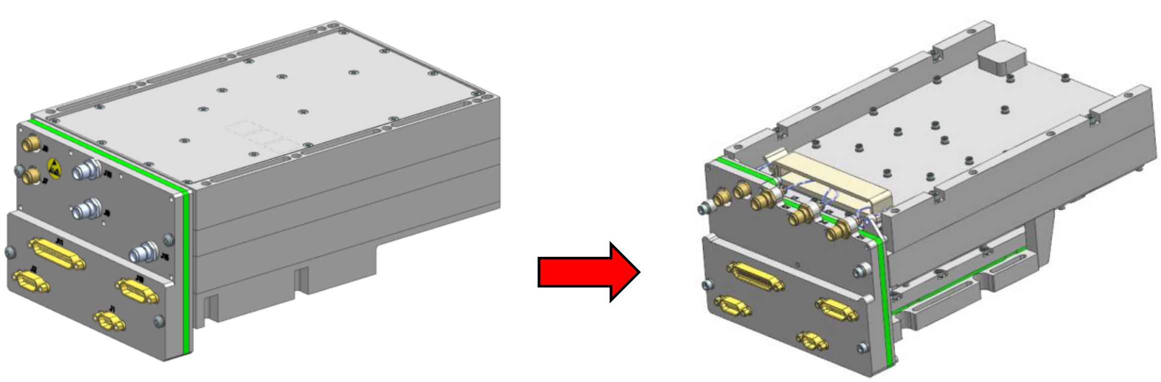
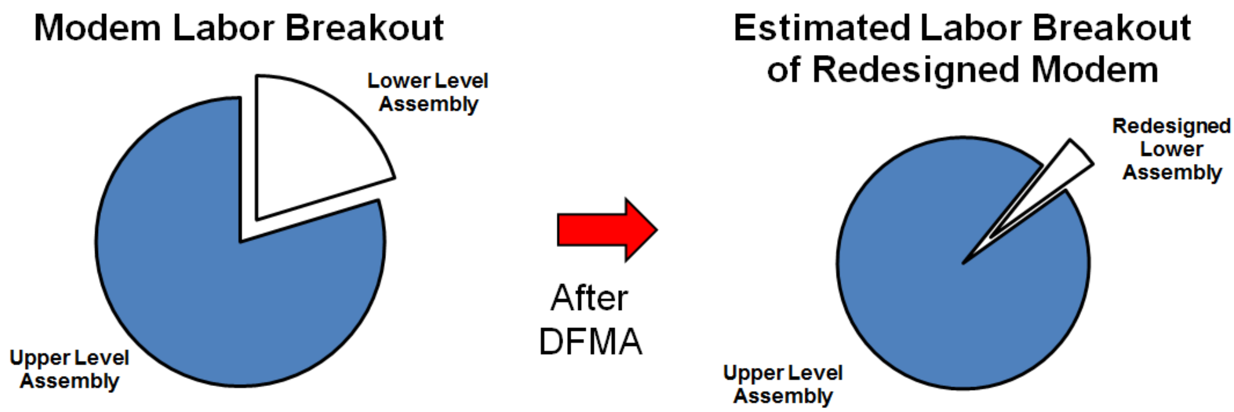


Figure 11: Modem Assembly - Estimated Labor Reduction from DFMA.



It was insightful to discuss, with a Testing Engineer, the range of testing non conformances that resulted from mechanical alignment in the modem assembly (#2). He helped to decipher the meaning of error codes recorded in the production database and match them back to junction alignment accuracy between subassemblies. In our facilitation of communication between Design and Production experts it was helpful to preface our effort with the intent to help the CEO meet the shared high-level goal of reducing Unit Production Cost in the new assembly design (#13). Being willing to set up meetings, do detailed data analysis, outline assembly steps, and seek advice and learning from production and testing systems went a long way in justifying DFMA collaboration with all involved (#18).

Case Study – Antenna System

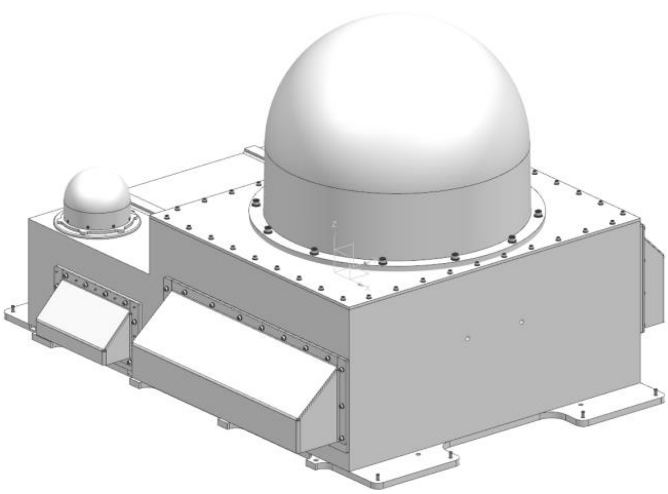
Sometimes an engineer wants to do DFMA, and has great DFMA ideas, but is primarily concerned with finishing a functional design by a schedule milestone. Facilitation of DFMA conversations helped relieve schedule pressure in the case of an Antenna System design.

In general, engineers appreciate both well defined functional requirements and autonomy to apply creative license to their design embodiment. The customer or program can supply detailed technical performance specifications. However, there is not always a detailed DFMA performance specification. Cost allocations can spark innovation by imposing the necessity to reduce labor or material cost, but DFMA can still seem like a vague requirement. In facilitating DFMA brainstorming for the Antenna System, it was helpful to review the following 11 principles associated with DFMA [4].

Eleven Principles associated with DFMA:

1) Mistake-proof the design
2) Minimize the number of parts
3) Minimize the use of fasteners
4) Minimize reorientation during assembly
5) Provide accessibility
6) Use modular subassemblies
7) Standardize parts and processes
8) Use self-locating features
9) Minimize operations and process steps
10) Make tolerances as liberal as possible
11) Avoid the need to make adjustments

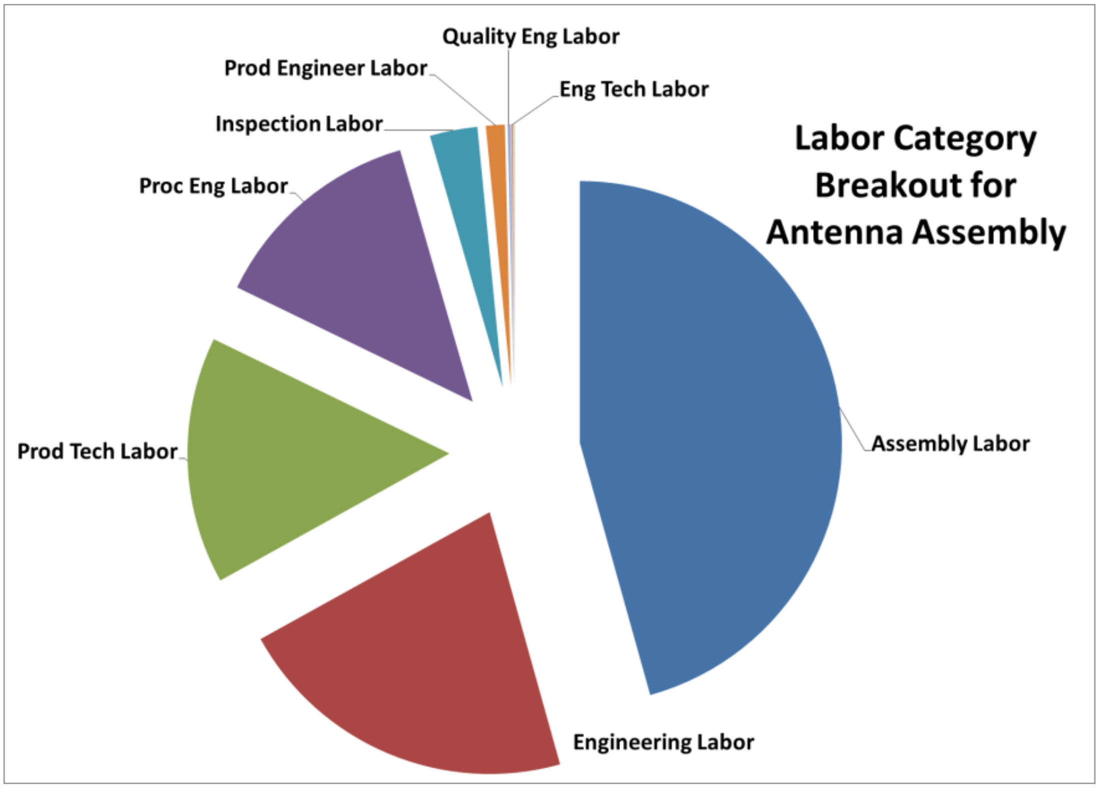
Figure 12: Antenna System DFMA saved assembly labor and rework by following 11 Principles.



Based on these ideas, engineers and designers reduced the type and count of fasteners, planned for efficient cable assembly, reduced assembly steps, incorporated features for a rotating fixture, partially designed a fixture, and did so early enough to save significant labor hours in transition to production as well as recurring assembly labor. Facilitation of DFMA helps others to focus on their standard work, while giving participants from differing functional areas a voice to express opinions. This allows pain points and shared interests to be addressed. No one person has to be an expert at DFMA as long as a template of DFMA principles is followed and the improvements are worthwhile.

A theme throughout L-3 DFMA case studies is the prioritization of effort by data analysis. While DFMA is a standard part of the design procedure, the following pie graph highlighted categories of labor incurred by a similar, legacy design.

Figure 13: Labor Category Breakout for Antenna Assembly.



Another facilitated effort was the creation of a preliminary assembly outline. This was done while fixture features could still be incorporated into the design model. A few things made this facilitation effective: 1.) the manufacturing engineer did minimal research with the machine shop and assemblers on fixture options. 2.) The design engineer outlined the sequence of steps how he thought assembly would go. 3.) A plastic prototype was printed to have a simple hands-on model for all to see and handle. 4.) The facilitator had a cursory discussion with each of the immediate design stakeholders by phone or in person to ask input. (#16, #17) The resulting assembly outline, shown below, was enough to score assembly efficiency in an excel spreadsheet and have a rough idea of build time. Of most value was the discussion where each person's assembly assumptions by could be visualized, modified and agreed upon by all involved.

Figure 14: Assembly Outline Scoring Tool for the Antenna System

Task (e.g. Fasten to XYZ)	Total Repeats (if > 1)	Approach	Fastening	Comments	Operation Score	Assy Time (sec)
Install cable plate b/w main and small box	6	Side with hold	Screw, stud, connector	Brazed Box starts upside down, inlet facing you	45	90
Install cable plate to side of PS enclosure	8	Side with hold	Screw, stud, connector		45	120
Install big inlet plate	15	Side with hold	Screw, stud, connector	partial screws	45	225
Install small inlet plate	7	Side with hold	Screw, stud, connector	partial screws	45	105
fasten cables to RFE	7	Side with hold	Screw, stud, connector	outside of box	45	105
install RFE	4	Top without hold	Screw, stud, connector	counterweight or support underneath RFE if the box tips	70	48
connect and route RFE cables	7	Side with hold	Screw, stud, connector	4 tie downs?	45	105
Install fan tubes over RFE fans		Side with hold	Snap together	spin brazed box on table 180, outlets face you	75	6
fasten small outlet plate	3	Side with hold	Screw, stud, connector	partial screws	45	45
fasten big outlet plate	11	Side with hold	Screw, stud, connector	partial screws	45	165
install outlet fans	2	Side with hold	Screw, stud, connector		45	30
install PS module	6	Top with hold	Screw, stud, connector		60	90
install control module	10	Side without hold	Screw, stud, connector	(perhaps mount PS and control modules after inlet plates)	50	120
connect outlet fan power cable	1	Side with hold	Screw, stud, connector		45	15
connect, route power cables	7	Side with hold	Screw, stud, connector	6 tie downs?	45	105
connect, route control cables	3	Side with hold	Screw, stud, connector	3 tie downs?	45	45
Install small antenna	6	Top with hold	Screw, stud, connector	flip brazed box upside up	60	90
Install big antenna	5	Top with hold	Screw, stud, connector		60	75
fasten antenna rivets and nuts	2	Top with hold	Screw, stud, connector	swivel antenna	60	30
Install big antenna cover	12	Top without hold	Screw, stud, connector		70	144
connect and route antennna cables	4	Side with hold	Screw, stud, connector		45	60
fasten cover of brazed box	38	Top with hold	Screw, stud, connector		60	570
fasten small inlet cover	9	Side with hold	Screw, stud, connector	fasten covers as one of the last steps	45	135
fasten big inlet cover	14	Side with hold	Screw, stud, connector	fasten covers as one of the last steps	45	210
fasten small outlet cover	7	Side with hold	Screw, stud, connector	fasten covers as one of the last steps	45	105
fasten big inlet cover	13	Side with hold	Screw, stud, connector	fasten covers as one of the last steps	45	195
fasten small bottom plate	26	Top without hold	Screw, stud, connector	Can be done earlier, after small antenna cable fastened to antenna	70	312
fasten big bottom plate	48	Top without hold	Screw, stud, connector	ONE of the last steps, requires flipping the heavy box back over	70	576
All cable tie downs	13	Bias(angle) with hold	Snap ring, cable tie	min. 13 tie downs, depending on vibes and cable assy standard	45	234

The Antenna System case study is an example of facilitation, guided by data analysis and DFMA principles, which enabled participants to focus on their primary interests while collaborating to prevent future rework.

Conclusion

A history of successful collaborations like those mentioned above can help others champion DFMA. As an example, a senior engineer at L-3 recently told a meeting of managers how he incorporated DFMA in one of his projects. He engaged stakeholders early to produce more robust designs that consider manufacture and assembly.

While the methods set forth in this paper are not all technical, they nonetheless require planning, dedication, and practice to master. Persuading stakeholders is less about correcting biases and more about adding value in terms of performance metrics that matter most to them. However, perceived constraints can guide you to choose the right influence technique. In a broader view of change management, we recognize the overarching need for management to incentivize practices in each role that support DFMA. But, the aforementioned strategies have proven successful as a parallel effort to leadership initiatives. Convincing our co-workers to invest time and money in DFMA during product development is possible by: 1.) setting a competitive cost target to focus efforts on profitability as well as function, 2.) describe the benefits of DFMA in terms of values and performance metrics, 3.) Focus on only the most impactful improvements 4.) Facilitate collaboration between subject matter experts with the right information.

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