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APPLIED SIX SIGMA IMPROVEMENTS IN SE INTERFACE WITH PROJECT MANAGEMENT – BOTH SCIENCE & ART

William Maholick SSBB, MBB, CQA, DFSS
Infinitech, Inc
White Lake Township
Michigan

Carl J Godell PMP, CQA, SSGB, CHRS, LSS
CJL Communications Inc
West Bloomfield Township,
Michigan

ABSTRACT

The key to a better correlation between the interface of systems engineering and project management is in fact a strong sigma relationship. In the recent past this would be termed Value Engineering and was that activity that took place prior to cutting the tools, but it is considerably more common today with the computer systems and software suites in use for modeling and the emphasis on Design for Six Sigma and time to market. All of these tools and methodologies are placing the focus on the final product performance, quality and cost and in so doing helping to again strengthen the manufacturing posture and job outlook of America and re-shore much of the work that was outsourced to save money. Whether of Military or U.S. vehicle manufacturing requirements, for the safety of our programs this work can and should stay in the United States when appropriate. This paper will develop better tools solutions, to provide better risk decisions which improve safety, budget, predictions, and time to market all toward improving risk identification to the systems engineering interface and to project management.

INTRODUCTION

In the decades the United States spent procuring advanced weapon systems, those weapons have grown only more complex over time. In the 1960's, aircraft took roughly five years to develop, but by the 1990's, as the number of parts and lines of code ballooned, the figure reached ten years. Today, it takes 15 to 20 years to design and build the most advanced fighter aircraft, and military satellites can take even longer. This is according to Stephen G Brooks and William C. Wohlforth in their forthcoming book America Abroad, taken from an article in Foreign Affairs titled The Once and Future Superpower [1]. They go on to explain, what makes the United States a superpower is its ability to operate globally and the bar for that capability is high. It means having what the political scientist Barry Posen has called "command of the commons" – that is, control over the air, space, and the open sea, along with the necessary infrastructure for managing these domains. Further, command of the commons, they write, also requires the ability to supervise a wide range of giant defense projects. The United States has built up a massive scientific and industrial base. China is rapidly enhancing its technological inputs, increasing its R&D spending and its numbers of graduates with degrees in science and engineering. But it is noted in this article that there are limits to how fast any country can leap forward in such matters.

We agree with the authors, command of the 'commons' also requires the ability to supervise a wide range of giant defense projects. Through all the discussion pros and cons within politics in the United States, research labs, contractors, and bureaucrats have acquired this expertise over many decades, and Chinese counterparts do not have this collective knowledge. This type of learning by doing experience resides in organizations, not in individuals. It can be transferred only through demonstration and instruction, so cyber theft or other forms of espionage are not an effective shortcut for acquiring it.

In this reality, the more details a project can control and predict the better the outcome. This is always the goal of project managers and systems engineers and it has steadily yielded to the efforts and discipline of increasing detail in definition and analysis in each phase of a program. We can then conclude that the key to a better relationship between the interface of systems engineering and project management is in fact a strong sigma relationship.

We will develop a comparative look at a design development from the perspective of the 1990's to one today where the shift is adding another dimension to the considerations of form, material, weight, cost and Kaizen, and improving the material product and cost with updated virtual tools. This paper will develop better tools solutions, provide better risk decisions which improve safety, budget, predictions, and time to market all toward improving risk identification to the systems engineering interface and to project management.

Eliminating Variation

Eliminating unknown variation and the cost associated with maintaining a critical path might as well be subject to contrarian thought processes, that is, one has the tendency to negate the other, especially with the more complex the project or program. Stakeholders are influencers, and may change perspectives during a project that can shift during a very dynamic effort to control variation while maintaining other critical pathways that will influence the work within systems engineering, finance, purchasing, engineering, manufacturing, customers, suppliers and human resources. Over time it might affect sales and marketing, along with domestic and host country government regulations. Part of this total ongoing assessment should be to predetermine when it is absolutely in the best interest of all stakeholders to keep a project re-shored and much of the work within the United States. Off-shoring is not mutually inclusive of a higher quality project event whether in product, timing, ongoing management of engineering changes, quality including the work to maintain desired sigma values, or the hidden costs of opportunity risk.

We have resolutely pursued the perfect duplication of the design represented in the CAD with the thoroughness of six sigma defining its function and prediction of risk. Onto the manufacturing design fixtures and tools that hold, cut, punch, sequence, weld and finish the successive sub-components and assemblies into the final product with unquestionable quality and accuracy. Finally through to the manufacturing floor where the identified risks [4] are evaluated and assessed with appropriate gages and metrics and the flawless product is shipped with an unquestioning faith in its performance.

If the above sounds like the mantra of every design and manufacturing organization, that may be correct, but it is far from the typical reality. Understanding the minutia in a developing design is an art until it is suitably defined to give it repeatable results that brings it into the scope of science or engineering and further refined until it is nearly commonplace and placed in curriculum. Those engineering feats that demand rigor in precision and economy today are not always easily realized following the standard toolset that has been available. There is certainly a better method and the following implementation aids tremendously.

Project

This is essentially the fourth phase of a six sigma improvement project that was started over five years ago to eliminate unknown variation and provide enhanced risk prediction, resource leveling, minimized dimensional variation, and improved tracking of variation from CAD, CMM [2] checks, assembly fixtures and gages. Working primarily with mechanical systems, the start of the project worked from a concept to a Systems FMEA and developed the concept further in a Design for Six Sigma study [3] that drove the DFMEA where the RPN (Risk Priority Number) was entered into an algorithm with its activity placement in the project management critical path and an estimate of its sigma value from the DFSS study to determine a forecast of the impact for risk over and above what a standard RPN designates and advises action. The current best FMEA practice identifies risk with a severity ranking but does not support a quantitative prediction for additional resources and consequent leveling nor the impact to the timing of the event with regards to the critical path, all of which the algorithm is able to estimate fairly accurately. With this information contingency planning is less probabilistic with the advantage of better timing estimates, resource leveling and control of costs.

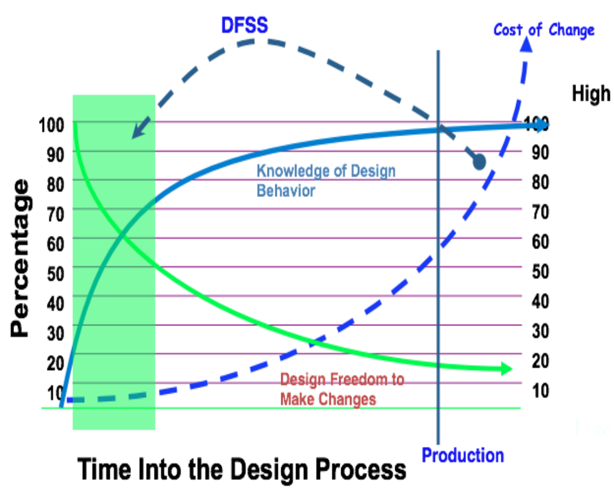
Figure 1: RPN System

Risk	S-Level	R-Index	Task	Description	Duration	Start	Finish	Crit Path	% Comp
3	5	1	10	Component / Process Definition (VOC)	100	11/8/2010	2/16/2011	Y	100
5	3	3	20	Component Specification Requirements	60	1/18/2011	3/19/2011	Y	86
7	2.3	30	30	Component Concept Design Review	10	3/31/2011	4/10/2011	Y	73
4	3	7	40	Feasibility Review	18	4/18/2011	5/6/2011	Y	56
5	2.9	57	50	Detailed Project Review	3	4/18/2011	4/21/2011	Y	34
2	6	4	60	Detailed Cost Review	8	4/20/2011	4/28/2011	N	0
3	4.5	13	70	Market Selection and Evaluation	5	4/29/2011	5/4/2011	N	0
7	2.5	93	80	Engineering Detail Design	3	5/5/2011	5/8/2011	Y	0
8	2.3	43	90	Manufacturing Review	8	5/10/2011	5/18/2011	Y	0
1	6	1	100	Detailed Timing Review	20	5/10/2011	5/30/2011	Y	0
3	5.8	2	110	Implementation	25	2/27/2012	3/23/2012	N	0

Risk prioritization changes throughout the project. We must admit that very few efforts are typically continually reviewed with reassigned risk priorities moved high risk to low, or to elimination and at the same time low risk to high where there is a small shift in product or process that creates a large shift in the project perhaps not today, but into a future event. Working the RPN continually is more efficient and an effective predictor model of a future event that can orchestrate significant improvements in communication influencing stakeholder assessments and actions. It mitigates how long and how many signatures will it take to evaluate and drive a single change. For example, within our own work we are aware that different cultures have different views of risk tolerance and this is significant within this discussion. Clearly, consensus is long and painful where time is money. Sigma work produces facts, and reduces the labor to clear data collection and this helps the decision process greatly where consensus is required.

The results of the studies for high-risk items showed that they were primarily generated from new designs or new methodologies or materials and that the sigma evaluation of risk was never accurately determined in the design phase. For our purposes, a Design for Six Sigma analysis is conducted for the concept and a detailed summary of the benefits and risks are available to incorporate into the project management algorithm as a sigma value and launches the Design FMEA with vastly improved risk numbers. The Process FMEA likewise benefits from the improved design development and analysis and avoids needless waste to the tooling timeline and associated tooling costs from the front-loading. A side-by-side comparison of a typically developed program and one completed with a Design for Six Sigma analysis feeding the DFMEA and project timeline shows an easy 30% improvement to the cost, timing and quality of events.

Figure 2: Time into Design Process



Project Analysis

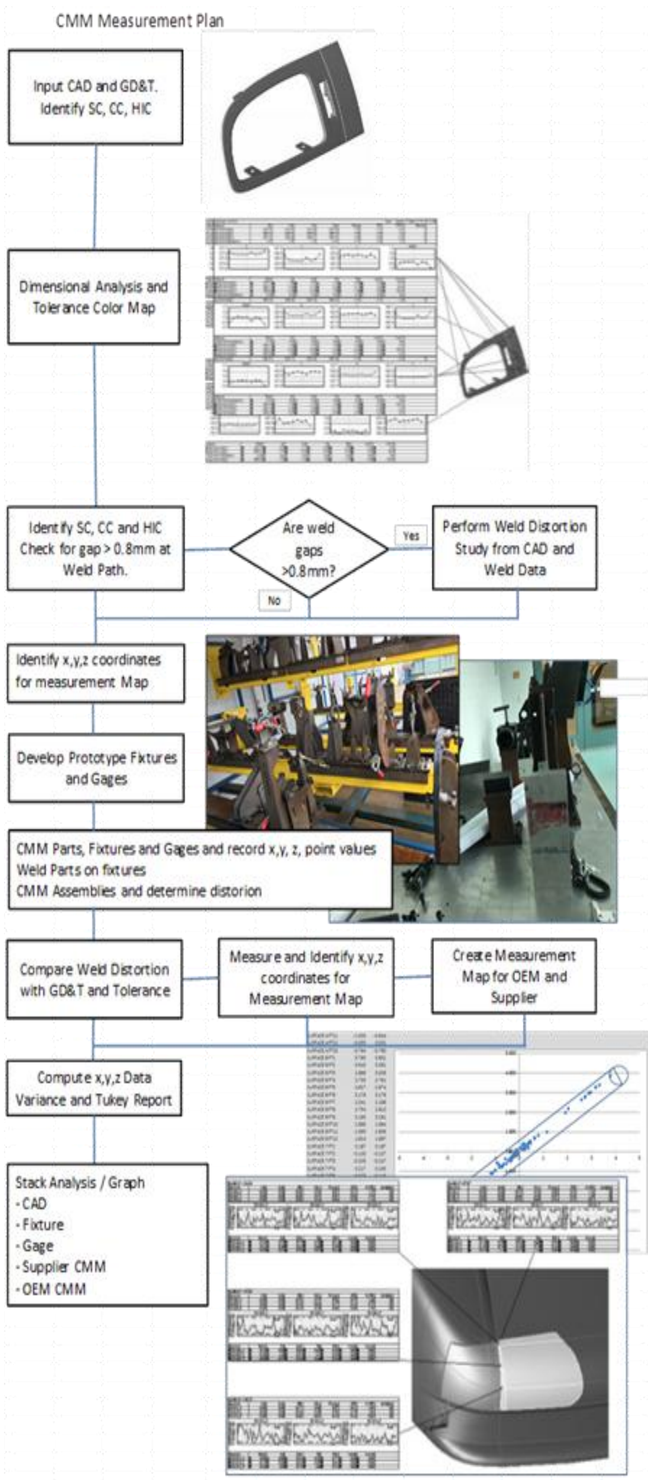
Having outlined the fundamentals of the process, detailed step definition and metrics were kept on two different classes of stamping and machining projects over a period of three years. A group of eight projects were maintained as a control group with the legacy methods of project management, quality and metrics. Six new projects were initiated and utilized the new process described herein and utilized the new deliverable definitions and predictive metrics developed to identify risk on the critical path, define tolerances statistically, stack all measurements to the same CAD model, minimize Gage Repeatability and Reproducibility to under 5% utilizing match-marked parts and the Tukey [5] Isoplots method, and maintain production quality according to the Taguchi [6] Loss-Function. This was essentially an ongoing Design for Six Sigma application that worked ahead of each project step and maintained a continuous review of risk factors and design stacks. Upfront costs for improved statistical stacks and supplier Cpk were assessed against the costs from the legacy programs quality recovery methods that required higher quality costs due to the tolerance methods and lowered production capability.

With the refinements to the process, the new projects created a 13.7% greater upfront cost due to the added engineering and project management task, but had Launch costs that varied from -29% to over -376% down in line changes, fixturing adjustments, overtime for line readiness, engineering changes, supplier readiness and PPAP, and design changes over the legacy projects. Additionally, the timeframe for the Launch Readiness was much flatter with fewer glitches and surprise events as the risks were already identified and resources leveled to the predictive level. The added upfront project detailing validated the design cycle and the "Cost of Change" as the design with increasing process maturity. This is significant.

Flowcharting Cost Improvements

The included flowcharts, as illustrated in figure 2 and figure 3, defines the new process steps with the milestones and tollgates remaining fundamentally identical to historical timelines. The cost justification for the additional upfront engineering easily showed a life-time betterment with the Launch Phase, and Launch plus 90 days, highlighting the greatest benefit of greater than 34% over historical costs in manpower and time for launching similar products. Having this knowledge makes it possible for greater success in many such projects.

Figure 3: CMM Measurement Plan



The key to a better relationship between the interface of systems engineering and project management is in fact a strong sigma relationship. In total there is a good deal more time put into the development with sophisticated tools that provide vastly better projections of performance and assembly and also at a stage of the program where the costs are significantly lower than after a design has been frozen and tool steel has been ordered and the cutting initiated. In the recent past this would be termed Value Engineering and it was that activity that took place prior to cutting the tools, also it is considerably more common today with the computer systems and software suites in use for modeling and the emphasis on Design for Six Sigma and time to market. All of these tools and methodologies are putting the focus on the final product performance, quality and cost.

Conclusion

Whether one has heard the quip about expecting a different result from the same process from Einstein, or Dilbert, the truth is the same. The problem is basically the same as well, at least for mechanical systems, with the majority of issues resulting from dimensional origins that are easily characterized and handled with Six Sigma and statistical methods. The benefit of Six Sigma is a tool set that evokes the corollary of continuous improvement with demonstrated statistical data for decision sets as the improvement compass. The tool set developed from our experience has basically been reduced to the following:

1. Risk management determined from the DFSS of the design with software projecting issues and critical path resource leveling available for that event if timing falters.
2. Tolerance stacks that go beyond those typically employed including Monte Carlo simulated runs for GD&T features, geometric factors that may multiply small tolerances into aggravated realism, and even the pin float that allows drift.
3. Developing manufacturing and assembly fixtures with the suppliers that hold RFS (Regardless of Feature Size) that control or minimize the influence of large tolerances and maintain critical characteristics required by the customer.
4. Enhance the quality system measurement by providing the Coordinate Measurement Machine program to the suppliers for each manufactured subcomponent, thus specifying the touch points and achieving very high correlation numbers that do not subtract from the tolerance range.

5. Track the tolerance stack from CAD design, to tooling, tooling check gages, subcomponents and to the final assembly with software developed specifically to characterize and graphically superimpose the individual items and their variation against the tolerance range.
6. Utilization of isoplots first developed by John Tukey and later Dorian Shainin to compare and analyze different measurement techniques and sources of variation thus identifying acceptable manufacturing methods and standards.

In its simplicity, these six steps add a level of refinement to developing the design through the product development process and tracking the allowable variation within the end assembly. The upfront engineering work is cost justified in the time and cost results both from the customer and the final project numbers.

The art form is in the ability of the SE or PM to improvise, to find the creative elements within the project that when applying these six steps continually move the project forward while maintaining cost, timing, scope and quality both in product and quality of the event. The six steps are like the written sheet music format, the symphony, the orchestra understands what the steps are, how to read the data, how to work together, each bringing their own sense of professionalism and creativity. The conductor is the SE and or PM at any stage of the project.

Considering that projects/programs last from 6 months to 15 years identifying and controlling costs from the beginning throughout the project life through Six Sigma event understanding and control is the key. Since this is about control systems, we can logically say that without this approach you are either extremely lucky, or simply out of control, or professionally, out of a controlled state.

As we wrote about in our book ‘Spectrum of Change’ this is about maximizing the use Intellectual Capital that is the total sum of maximizing Human Capital, Organizational Capital, and Customer Capital. Remove one part of the equation, IC= HC+OC+CC, within this context, and project costs will escalate [7].

With a few projects completed and the results evaluated, you may not hear the phrase ‘your costs are too high’, at the front of the program again. And the next step that historically followed - to place the project offshore - with the illusion that the world is believed to be a better place may be avoided.

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