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Sigma Value, Enabling Workforce in Systems Engineering Thinking

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ABSTRACT

Systems Engineering (SE) would always benefit from the inclusion of the Six-Sigma perspective in both the planning and execution of project systems. This applies to not only System Engineers but also to Systems Extended Team Members, all who must provide cumulated knowledge along with competency to the project. It is difficult to obtain a high level of competency among single members of the team to be highly successful. Strength in one area is very often an underlying factor of weakness in another area. Determining and integrating sigma characteristics from the development cycle into all remaining phases of the product project, especially at critical component interfaces, with a resultant sigma value given to those connections that develop a sigma-risk factor for each function and process pathway within the operational configuration. This sigma-risk factor concept is the key in uniting knowledge with experience.

INTRODUCTION

We point out that within Six Sigma Human Sigma addresses the competency of Systems Engineers as a key input in the risk of, perhaps, identifying the wrong problem or not enough emphasis on a foreseen problem, and therefore the lack of a solution, or unachievable solution. Six Sigma analysis with the application of newly introduced sigma-risk values can go still further by melding into an algorithm and determining the most suspect branches of a design or process [1]. Further, the introduction of the sigma-risk values to Systems Engineering training is an evolutionary step for academia and continuing education beyond current competency measurements to prepare the engineer or professional in forecasting a quantifiable measure to each system element and function. The result raises the bar with improved effectiveness and efficiency by greatly increasing communication, education and consensus integral to the SE approach.

DEPTH IN UNDERSTANDING OF RISK

There are many things, many relationships that simply cannot be explained, perhaps incommunicable! We research, reflect, predict, then we rethink, rework, reengineer, redesign. At any level when we finally run out of project time we apply this work with the hope to advance by one degree what it is we knew from a last assumption. The degree of success is dependent upon the depth of our understanding of Risk [2]. The word courageous also has adventure, daring, and risk as synonyms of the definition. It also has reckless, foolhardy, and hazardous within that same definition. Thus the better one can control and manage risk, is effective enough that there will be changes that look like the antonyms; careful, cautious, prudent and unadventurous. Which type of Systems Engineer would you prefer working on your project? Through a number of published studies we have this long list of necessary skills the Systems Engineer must possess [3], then you have the ever present deadlines and stakeholder demands and what we know about complex systems within complex systems is that we narrow the field for the attributes of the desired type of individual required for successful systems engineering and we find it is probably, at best, 1% of the total population. We argue, having courage to manage risk rather than viewing it as time consuming non-effective work is key. The point being that if it does not currently answer the right question, complete the thought so-to-speak then it is to discard for a reactive management of the situation. Can we get closer to having a better tool is the key? We believe there is a way.

HISTORICAL SIGNIFICANCE

Prior to the American Civil War the translated writings of Henri Jomini were the only works on military strategy taught at the US Military Academy at West Pointe. [4]

In his famous theoretical Ch 25 of the “Traite’de grande Tactique”, he stressed the exclusive superiority of interior lines. “War in its ensemble is not a science, but an art.” Regulated by fixed laws resembling those of positive sciences, but this is not true of war viewed as a whole.

Among other things, combats may be mentioned as often being quite independent of scientific contributions, and they may become essentially dramatic. Personal qualities and inspirations and a thousand other things frequently being the controlling elements…poetry and metaphysics of war will have permanent influence on its results.

Further, the issue with statistics in determining when strategy and emotion cross paths toward a mostly correct decision is based on historical significance, that is, data collection along with lessons learned from previous events. The complexity of the human brain is a mass of emotions, instincts, memories, reactions, and thoughts. Either approach will always be limited but as many who have written on this subject, each attempts to get closer. We can indicate that a good tool dashboard with good information, along with good training and understanding is another step closer for academia and continuing education beyond the current competency model measurements to prepare the engineer or professional in forecasting a quantifiable measure to each system element and function. Fault testing at some level of reliability is perhaps a key.

THE KEY

The top companies today and the leading technologies produce and manage their projects with a full background of information that melds the proof of concept with the manufacturing complexities and compresses the timing to optimize the market introduction or critical need, and minimize the cost equation. However, with common methods and standards in place, manufacturing organizations also share a daunting challenge with the overwhelming amounts of data stored in disparate systems resulting in the inability to easily access pertinent data for review or resource assignment [9]. The challenge is in bringing in the facets and phases of the projects to meet those milestones and provide the support and resources exactly when required. According to the Systems Engineering experts at the Sandia National Laboratory, state that a systems engineer and project manager is 50% efficient after graduation, 80% efficient after ten years at his trade and a fully seasoned and effective expert after 20 years managing a diversity of projects. The naiveté of the freshly minted project manager and systems engineer is compounded by the error-prone manual methods and obviates the need for a simple user-centric interface for direct, on-demand access to all the data from these sources [ibid].

As such, the best managers for critical projects are often the system developers and technical experts as their expertise in the project proves invaluable when contingencies arise in the timing, but the costing will often suffer, as the technical experts are less than familiar with the funds management and the interwoven commercial aspects. Additionally, the system developers and technical experts would be better utilized developing the next projects and only assigned as a resource exactly when, and if, the need arises within that critical path phase that deals with their specialty.

The current standard project management format maintains an adherence to the critical path and tracks progress and forecasts needs primarily on a time-based correlation to events completed against the estimated planned event timing. While the estimated event timing usually has good correlation to historical performance or best industry estimates, it does not account for contingencies or future state planning that is only similar to previous events, new technologies or manufacturing methods that were developed for a modified or breakthrough technology even though these were reviewed in the proof of concept and had contingencies developed.

This may appear to be conventional wisdom, as with the above conditions, the most dangerous combination is an unseasoned project manager, who is not necessarily a technical expert, working on a project that involves new or breakthrough technology. A fresh look at the situation would indicate that the seasoned project manager has better data gathered from a diversity of experience and if a representation of the critical data set could be formalized for each project the decisions by the SE or PM could be better estimated and the resources better placed at critical times.

The compendium of data that results from a proof of concept investigation and a systems engineered project is impressive. Subsystems are evaluated with their interfaces and "because there is no single optimal solution to complex systems problems … Systems Engineering creates a set of alternative designs that satisfy these performance and cost criteria to varying degrees" [8], and these become the contingency solutions. They become part of the project history and are not normally accessed unless an alternate plan is required, but almost certainly also drive different resource requirements that were not in the original timeline. A question of when contingency is not only appropriate and timely is critical in this discussion. Contingency planning is evaluated in a proactive manner when risk is analyzed. This is risk for both sides of the equation, opportunity risk as well as what might go wrong if not identified and managed correctly. Good contingency planning is akin to building increased confidence toward a desired outcome. It is literally a game of chance utilizing available historical data, knowledge, experience, logic, skill and vigilance. The better the contingency planning the greater the confidence.

Another aspect to the resource assignments is the confidence in the plan both as a statement of risk and a statement of quality or its sigma value. These sigma and risk estimates are normally reciprocals or each other, although that is not necessarily true, because they can vary in terms of safety, resources and cost. These values are now fairly traditional and built into the woof and warp of engineering and manufacturing and have become a standard feature of designs and processes required prior to sign-off by the customer.

Let me reference again the future state plan mentioned above, and the general tasks of the project manager, first with an example. The driver of any race car looks far forward, well down the course, and understands that, due to the speed of the vehicle, he is not likely to win the race if he concentrates on the track directly in front of the vehicle. The driver's further focus develops a path that becomes more of a trajectory the vehicle is propelled along. Much has been written about this method, but the fact remains that future planning is 70% of the race as the current tasks are executed.

In another book, the Second in the Spectrum of Change series, the role of almost every manager or leader is in the planning and looking at the future state of their unit, be they a plant manager, department head, section chief, or project manager, and plan for the speed and growth of their organization within core competencies and those available resources leveled. This is also a mantra espoused in the earlier book in the Spectrum of Change series that suggested the use of Human Six Sigma to develop resources and enrich productivity.

With the above in mind, a process was developed to include more critical data into the project management cycle to both capture the detail from the earlier project systems studies and enrich the future state look for resource leveling. The detailed information was tested with several projects and then fully integrated into project management software with an algorithm that draws the focus of the project manager to those items on the critical path that have a higher tendency to require increased attention from resources specialists, manufacturing involvement or supplier support.

The value of this method is to envelope more of the early work performed on the subsystems and carry it forward in the timeline to identify the sections of the critical path that may be more pernicious to the tasks completing on time and within budget. This prepares the Systems Engineer / Project Manager with a future look as to what resources would be expected when and labels those events with mathematical value that establishes a priority for focusing as all things are not equal, not even on the critical path. We might then say, going back to the Sandia National Laboratory quote at the beginning of this discussion, if a potential SE is roughly 50% effective or efficient right after graduation and reaches 80% effectiveness after 10 years why not make it possible to learn this tool during education, have it become second nature once graduated and move the mark to 60% and reach effectiveness for a greater number in 5 years, or at the least less than the 10 years stated now.

DEVELOPMENT

A detailed investigation of the tasks in a series of projects was conducted through a variety of statistical techniques. In the process, the tasks that produced the most deviation from the schedule in a series of nine projects revealed a correlation of each being high-risk situations that were all on the critical path, while analysis of events that completed on time showed a high-sigma value and low-risk whether they were on the critical path or not. Resolution of project errors, or tasks that exceeded the event timing that required either additional resources or contingency plans were most easily corrected when there was ready information and multiple contingency replacement events available.

Considering these results, several steps were taken to enable a better forecasting method to alert the systems engineer and project manager of upcoming issues. The first step was to bring forward the number of contingencies that an event was reviewed and qualified at in the planning stages of the system. Not just the number but also the details of the alternatives must become readily accessible to be considered should a contingent opportunity be required. The number of the contingent opportunities reduces the overall risk, although it must be noted that each potential contingent solution will change the overall systems operation and will change the performance even if slightly. This is normal but the performance must stay within the system requirements set form in the customer expectations and statement of work. In other words the project must remain in Scope or it is renegotiated as it becomes something different and that has ramifications to one or all of the following; cost, duration, safety, effectiveness, timing, etc.

Also, as a primary predictor of future project issues, each event in the project is identified with the sigma value and the risk value that was assigned to it during the planning stages. These values are becoming quite common and fairly routine from a reliability point of view and the sigma value is the assessment of a component or system based on the design, manufacturing and quality properties. As mentioned earlier, the risk value is the prediction of the inherent difficulty in the design, manufacturing and quality, but may also include the safety, resources and cost issues.

The placement of the event on the critical path also becomes a factor in the sigma-risk algorithm along with the event duration and these will heighten the importance relative to other events not on the critical path or of shorter duration. At this point it is important to remember that critical path, risk assessment, contingency planning are all iterative processes that continually change as any project continues along the path toward completion. This is like coming to a fork in the road, which path to take.

PROCESS

The actual process developed requires that the factors mentioned above are input into the project management algorithm and produce a numerical value that establishes a ranking and a focus that sets a priority for resources. The correlation of these factors to historical performance is greater than 85% and the pre-emptive action of placing resources in these areas ahead of the actual event to track, review and plan for alternate action always proves effective at minimizing the any impact.

Once these event data values are input and the resultant Sigma-Risk numerical component shown to the left of the event and creates a ranking that correlates to the largest number is the highest priority. These resources leveled at these events may then be re-established and additional or redistributed manpower readied, or at a minimum planned, to support the probability of need.

The advantages are clear. A combination of the event's sigma value, risk value, placement and duration in the timeline, or on the critical path, provide an early warning to systems engineering and project management. The alert further indicates what type of resources will be required and the likelihood of a delaying occurrence and references other contingency possibilities that were developed to work through potential problems.

While these sigma and risk values are usually identified early in the project that information is not always carried forward or a different project lead than the developing engineers are running the project and the event pedigree is not fully represented.

Figure 1, Graphic Key

RI = 0 to 10	**Green**	**Normal range proceed with alertness.**
RI = 11 to 50	**Yellow**	**Increased attention required.**
RI = 51 to 100	**Red**	**Urgent. Recalculate Risk index plans**

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

Figure 1, SRV Graphic

The Sigma-Risk Value, or SRV, is a tool that focuses the attention of the management and supporting resources at an area that most probably will have a deterring effect to the project. SRV adds a layer of vision and confidence to navigating the first-time complex project and increases the odds of delivery on-time and within budget.

HUMAN SIGMA

As explained, the above method was developed working with the Systems Engineering and Project Management models and extending them to include the sigma and risk values that improve upon the forecasting of potential issues. In concert with this, a human factors six sigma study also indicated that developing and managing a multi-layered project is best likened to listening to competing conversations at a party. The probability that all the pertinent information is obtained from each conversation is in probability very low and the manager needs to have an assessment tool that derives a quantifiable value for success.

Information relevant to specific acts is communicated effectively when rapid response is necessary. The issue may be that any action as a result of this tool is only going to be available to limited sets of individuals. A systems engineer and including in the discussion extended project team members, in fact, no matter what the team configuration, some individuals will be expert in some competencies they would be intermediate in some competencies and foundational in yet other competencies. We can then say that it is highly unlikely that any one individual person would be expert in all the behaviors and competencies in this model.

NASA identifies 49 Systems Engineering competencies Grouped by competency areas, competencies, and competency elements.

The challenge that most studies of this nature address is twofold. First the complex nature of Systems within Systems in an increasingly complex communication environment, in an ever increasingly small world, compared with what was known thirty years ago for example, is overwhelming. Second, this drives the required skill and knowledge level for the systems engineer as a person who understands what needs to be accomplished and can successfully function within an environment, along with a process to do it successfully. This of course explains a single event because clearly every event is different even though some elements remain the same, the real issue is that however competent, can this individual or team member repeat that exact performance time and again? Knowledge is accumulated, and however perfect we might imagine collateral damage for instance in the event of war it will affect how one thinks about their approach to a given situation. Logic and emotion are facts that affect decision-making. The questions that organizations such as NASA face where managing risk at a very high level of involvement have driven these 49 SE competencies and the need to get as close to perfection in system engineer selection.

With our SRV model we begin this approach by understanding that competencies are the basic need, every project is different, no two individuals are equipped the same, no project is the same, no environment is the same, battlefields and culture affect combat changes, and then knowing all of this as a continually changing environment does not lead to one answer. What it should formulate is a method where the change to one part of the equation increases, or has the potential to increase the degree of risk in some areas, lessen the degree of risk in others and develop opportunity as a result.

This third dimension by adding the Sigma value takes a little more work initially transferring the data into the program, but once the system engineer develops this competency it increases their ability to be successful by that one additional degree leading to better decision making. It also measures as a running meter of criticality completeness to the critical path. Knowing this information is not enough. The SRV tool should allow quick field evaluation to determine whether the level of risk is escalating or diminishing close to real time. This may reduce the risk of an emotional conclusion, mixing that emotion with logic.

EDUCATION

Given the idea that by the time a Systems Engineer accumulates enough education, skills and knowledge to be truly successful, many mistakes will have been made along that path. This is also apparent in the rigid requirements that we have mentioned. Experience tells us that we need better knowledge and skill. History tells us that we need analytical tools as well.

We understand the situation and the need having devoted our careers to the management of projects and programs for over 30 years. We have watched seemingly intelligent human beings by-pass the system to meet deadlines. Any project and the more capital investment the greater the risk, financial risk that is, the greater the risk to side-step the system and forge ahead regardless of education, tools, skills, ability, and stakeholder buy-in.

The International Council on Systems Engineering (INCOSE), Certified Systems Engineering Professional (CSEP) examination [INCOSE, 2008] is designed to test the applicant's knowledge of the contents of the INCOSE Systems Engineering Handbook [Haskins, 2006, 2011]. The handbook focuses on processes according to ISO/IEC 15288, does not address cognitive skills and individual traits in an objective manner. There must be a follow-up evaluation of the career experiences of the candidate. [3]

As we are skilled in the professional certifications of our trade we understand the knowledge-testing environment. Many argue that it tests the ability of the individual to test out. What we have found is that it opens the door to raise the level of competency. It is a vehicle of professionalism. As a PMP through the Project Management Institute [2] or as a QM through the American Society of Quality or associated world connections do not automatically give one the skills to manage, only the tools. The skills are learned through use of the tools and gained experience. What it will do is link the individual to a world-wide grouping of likeminded professionals enabling a communication link that is a great enabler toward success. This is fairly common knowledge through certifying organizations. It lets the potential client know that there is an effort to know more about a given focus. This is important.

CONCLUSION

Inadequate systems engineering is repeatedly cited as a major contributor to failed projects especially in the National Aeronautical & Space Administration and the U.S. Department of Defense (DoD). [5]

Having an understanding of knowledge, skills and abilities we believe that this ever increasing complexity of systems within systems, the increasing need for more experience and at a young enough age to withstand the rigors of project pressures, the tools are moderately sufficient. A new tool that increases the success of not only the Systems Engineer but for the extended team members and the stakeholders holds even greater value and looks to the future. One thing is very clear, the complexity of systems will continue to increase! We believe that placing this tool within the System Engineer's tool bag will increase their ability to grow [6] and to increase success within this complex world view and that will raise the bar another notch for those who chose to use it.

There is some good research on the economic value of intellectual capital (IC), the knowledge based equity of a company. IC impacts the bottom line where profit and high quality come together and placing the right individual resource is key to optimizing costs. There is a shift occurring in corporate employment. IC includes the placement and leveling of skilled, experienced human capital, organizational capital, and customer capital. Remove one part of this equation and the very survival of your enterprise is at risk especially in a very competitive, fast paced market place. What to cut when is not an easy task! [7]

The answer lies in understanding risk, and then how to execute risk management.

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