Lessons Learned
What I’ve Learned Growing Up in Defense Acquisition

Lesson 1

Lesson 2

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Lesson 8

Image designed by TSgt James Smith, USAF
Many projects and programs fall short of meeting their initial intended goals. Tracing these shortfalls to their common set of root causes and analyzing these root causes to find common threads illustrates opportunities for lessons learned. The authors of this article examined these common threads and referred to their professional experience in defense acquisition and academic backgrounds in project management and systems engineering to address these issues and propose strategies for countering their ill effects on program performance.

Programs succumb to the same pitfalls, regardless of lessons learned documentation. Lessons learned must be institutionalized into the acquisition learning curve. Documentation does not ensure institutionalization. Why do we not learn from the past and continue to make the same mistakes on weapon system after weapon system? Doing what has not worked before, but doing it harder or with more process, usually produces the same poor results. As aptly put in this anonymous quote:

If you always do what you always did, you always get what you always got. If you do not want what you got, do not do what you did. If you like what you got, do it again.
INSTITUTE SCOPE MANAGEMENT TO AVOID SCOPE/REQUIREMENTS CREEP

Managing the project scope is essential to maintaining cost and schedule target dates. Increasing the scope will almost assuredly increase cost and delay the schedule (see Figure 1). It is good practice to follow the old adage, “It is not a requirement until someone is willing to pay for it.”

The incorporation of unfunded or under-funded requirements leads to uncontrollable scope growth. A detailed analysis of the impacts to the cost, schedule, and technical baselines should be performed prior to implementing a change proposal. Any potential adverse impacts must be documented in the risk registry and managed until either realized or successfully dispositioned via mitigation, transference, avoidance, or acceptance (active or passive). A signed change proposal does not relieve the contractor from meeting cost and schedule constraints.

Never use management reserve to cover the cost of additional product features and functions. Incorporating features and functions into a product that are not part of the contractual statement of work results in resources being applied to noncontractual work, effectively putting the project schedule and cost at risk. Even if the project comes in ahead of schedule and under budget, it should be at the discretion of senior acquisition officials, not the rank-and-file acquisition workforce, to determine whether the cost and budget reserve should be used to add functionality to the product or applied to another acquisition that may require additional funding.

**FIGURE 1. THE TRIPLE CONSTRAINT DIAGRAM**
The Guide to the Project Management Body of Knowledge (PMBOK®) states: “Project Scope Management includes the processes required to ensure that the project includes all the work required, and only the work required, to complete the project successfully” (Turner, 1992). Create a scope management plan, perform scope verification, and actively exercise scope control, as described in Chapter 5 of the PMBOK® Guide. During initial scope planning, prioritize the triple constraint variables. For example, quality tends to be an inflexible variable, whereas availability, maintainability, and reliability are components of quality. Determining relative sensitivities among triple constraint variables will facilitate system requirements trades performed during critical points in the program.

Not all requirements are equal. Another area requiring detailed discussion and documentation in requirements specifications is the relative priority of sets of requirements. This allows the systems engineer and the project engineer to make concessions, changes, and alternative approaches based on the current design reality.

RECOGNIZE IMMATURE TECHNOLOGY

Immature technology can bring a program to its knees. Schedule elongation on a research and development (R&D) project that is composed almost entirely of the technology development core team is relatively inexpensive compared to holding up a large program, burdened with sizable overhead and product teams unrelated to the emerging technology. When technology fails to mature at the rate estimated during initial planning, the costs of overhead and labor grow. Considerations to keep in mind:

- A key technology should always be thoroughly evaluated prior to formal program kick-off to ensure adequate confidence in the technical maturation process. A small team of scientists, engineers, and technicians is less expensive than a large management infrastructure and the associated inefficiencies.

- Where feasible, allow for technological advances to be spiraled into a product, thereby allowing the product technical maturity to grow with the state-of-the-art, or state-of-the-industry, whichever is the desired goal.

- The buyer must do due diligence in determining the technical risk associated with product technical maturity and avoid being blinded by the wow factor. If the seller is advertising technical capability for a price that is out of line with the other bidders, raise the flag and investigate.

- Contracts should be customized to dissuade the seller from over-promising capability to the buyer for the sole purpose of winning the contract. A stepped procurement may be the answer, with upgrades or more capable systems to follow as technology evolves to the point of acceptable risk.
AVOID IMPROPER USE OF MANAGEMENT RESERVE

Management reserve is a budget reserve set aside to address the unknown-unknowns (unk-unks) on a project or program. The probability and impact of these risks are not only unknown, even the presence of the potential risks may be unknown. Management reserve is money set aside to address such unexpected emergencies.

Often, this money is used to add scope to the program in order to keep the customer happy. It is easy to fall into the trap of conceding to unfunded scope modifications. The danger lies in the realization of these unk-unks, and not having sufficient reserve remaining to address them without increasing project completion costs.

Another purpose of the management reserve is to guard against the statistical likelihood that some people overestimate while others underestimate the budget. A key input to building selected reserves is the individual uncertainty and risks associated with specific project tasks. The management reserve should be used strictly for the purpose of addressing unforeseen obstacles to program success, never to add additional scope.

ENSURE ADEQUATE SCHEDULE RISK ANALYSIS

The Critical Path Method (CPM) is a useful tool and, when combined with Program Evaluation and Review Technique (PERT) analysis, can give good results for planning purposes. However, as the schedule matures, one should always go back and run a Monte Carlo simulation against the schedule to avoid being overly optimistic—a documented side-effect of CPM. David Hulett (1996) characterized the optimistic bias of CPM in his paper, *Critical Path Method Scheduling: Some Important Reservations*.

Ignore the assertion that completion dates are best represented as single points in time. They are best represented as a finite probability distribution with corresponding confidence intervals. When a date is stated, it should be accompanied by a confidence level (e.g., the task will be completed on February 5, 2007, with a confidence of 70 percent, or 2/5/07 [70%]). Most scheduling tools offer the ability to perform Monte Carlo simulation analysis to determine schedule confidence and risk. In addition, Dr. Hulett recommends that the project or program manager (PM) analyze the network and look for nodes that represent a high risk due to excessive implosion or explosion, and consider adjusting the schedule to make the network less sensitive to the effect of statistical variances of parallel activities. *Merge bias* is the term used to refer to the elevated risk levels experienced at schedule nodes where multiple paths converge into a single path.

Though relatively new to project management, the concept of Critical Chain Project Management (CCPM) addresses the risk of multitasking on schedule visibility and viability based on sharing critical path resources.
IMPLEMENT EFFECTIVE COMMUNICATIONS

Communication is the most important responsibility of the PM. Ninety percent of a PM’s time will be spent communicating, which facilitates collaboration and reduces inefficiencies. Concurrent engineering, collaborative design, systems integration, systems engineering, and high performance work teams depend on fluid communication between teams, individuals, contractors, and customers/clients. It is not merely enough that communication take place, but that the communication be effective. Be aware of the barriers and facilitators of communication. Use clear and concise communication, as well as active listening.

Those in management must take care not to lose touch with the information grapevine: peer-to-peer information flow at the design- and user-working level.

Management must actively engage the engineering workforce and the user community and seek their input and advice. Those in management must take care not to lose touch with the information grapevine: peer-to-peer information flow at the design- and user-working level. Even those with the best of intentions to stay connected to their former colleagues must take note that a managerial position elevates an individual above the day-to-day, word-of-mouth conversation about what is working and what is not. Those actively engaged in solving the design issues have first-hand information about what is and is not working, so it is advisable to pay attention to their concerns. Often, this communication flow is hindered by a belief that management knows better than those in the trenches what is and is not working. And often, when input is sought from management, the response is not taken to task.

Do not be afraid of bad news, and never shoot the messenger, lest the free flow of communication be inhibited. Better to learn of bad news while there is still time to correct or mitigate it than when it is too late to react. Never conceal unfavorable information about project or program progress. Analyze the threat and probability levels, and search for solutions. By doing so, when the sponsor is briefed, you have shown that there is a negative issue or risk, but that it is being actively addressed. Always give the sponsor an opportunity to participate in the solution. It is, after all, the sponsor’s product. While industry has become diligent in documenting lessons learned, communicating that information has not been as successful. Fear of reprisal is the leading cause of bad news not flowing up the chain of command.
REDUCE PROGRAM OFFICE ROTATIONS

Continuity of leadership is essential to effective and efficient program execution. When program officers are rotated out every few years, the learning curve recycles before utility of the previous learning cycle can be harnessed. In effect, once an officer gains the background understanding of the program, keep the individual in place long enough to realize their talent in that position. Turning over leadership every few years keeps the program office in a state of constant redirection, shifting priorities and expectations, and confusion. It generally takes several years on a particular program or project to reach peak performance.

Plans should be in place for an orderly transfer of responsibility and knowledge. Only a small part of project activities and communications are in some form explicit. Much, including off-the-table agreements, are tacit and need to be transferred or acknowledged by new folks coming into the project. Succession planning is essential to program or project success.

The success of the U.S. Navy Strategic Systems Project Office in the management of the Polaris, Poseidon, and Trident Programs is due at least in part to the fact that key PMs stayed on the job and, when rotated, moved into other parts of the program, so that key tacit knowledge remained available. Aside from the Navy’s Fleet Ballistic Missile (FBM) program and, to a lesser extent, the F-18 E/F, rapid turnover and a punch-your-ticket mentality is prevalent in defense acquisition. Despite the laudable results achieved on the FBM and F-18 E/F programs, the rest of the acquisition/procurement world did not follow the model the Systems Projects Office and the Strategic Systems Project Office developed regarding time in place and rotating within the program. There have been studies and the subject has been extensively discussed at the Naval Postgraduate School in Monterey as well as at the Defense Systems Management College (DSMC).

RECOGNIZE OVERLY AGGRESSIVE BIDDING

Be cautious of over-aggressive bidding, and protect against bids that are unrealistic. Ensure that all scope has been accounted for, and review the scope against cost for any inconsistencies. Use the change clause for protection, and incentivize the bidding contractors to be reasonably accurate in their estimated costs. Share the budget savings, as well as the losses, with the contractors, if possible.

Past experience should serve as a reality check on what is achievable and what is overly optimistic. If greater capability of a previous, similar system is being proposed at a cost that is not proportional to that capability, seek justification for this discontinuity. The contractor may be bidding aggressively under competitive pressures, with the intent to make up any losses during the production and/or operations and maintenance phases. The buyer usually ends up paying for cost growth, regardless of the contract agreement.
One vehicle for the seller (contractor) to recoup lost income is to buffer the engineering change proposals, or contract change proposals. If the seller is not meeting their fair profit goals, expect to pay more for design changes than if they are meeting goals. This does not mean that the seller is trying to take advantage of the buyer. The seller is interested in making a fair and reasonable profit, while the buyer is interested in receiving the most capability for their expenditure.

Keep procurement dialogue open and honest on both sides of the contract. Mistrust of the other side is not in either side’s best interest. A realistic should cost model must be used to examine bids for reasonableness. Bids that are too low should be questioned in detail regarding how the organization plans to meet the low-cost targets.

“In nature, the optimum is almost always in the middle somewhere. Distrust assertions that the optimum is at an extreme point.”
— Professor David Akin, University of Maryland

ESTABLISH STAFFING AND RESOURCE PLANNING

It is not uncommon for new employees to wait months for proper security clearances to move through the process. It is important not only to account for this delay in the staffing plan, but also to use the time to prepare for productive integration of the new team member. Plan for the individual’s arrival by ensuring a computer and other needed work equipment and items are on his/her desk and in working order. Nothing is more frustrating and unproductive than waiting several months for a security clearance to come through, only to find out that it will take a few more days to get a working computer set-up, and a few weeks to order more licenses for the software tool required to perform primary job responsibilities (e.g., computer-aided design and analysis software). If you have several months’ notice of an individual’s start date, take advantage of this time to set up the workspace and determine if more software licenses are required. This is an easy money saver, but often overlooked, thus costing a fortune in lost productivity.

LEVERAGE SYSTEMS ENGINEERING WITH PROJECT MANAGEMENT

The ability of a project team to successfully complete a project, and the follow-on work associated with it, is tied to the team’s ability to leverage the capabilities of systems engineering and project management, enabling collaborative teaming among various engineering disciplines. Leveraging the synergies between the two disciplines (as shown in Figure 2) is a critical aspect of collaboration.

The two disciplines overlap in some respects and complement each other in others. Where they overlap, systems engineering and project management are motivated by different objectives resulting from their unique perspectives. The PM is concerned with maintaining cost and schedule commitments, whereas the systems engineering
emphasis is on requirements management and verification. Today’s technology often results in a family-of-systems or system-of-systems environment where various technologies are connected through an information grid in which systems interoperability is a leading success criterion for project success. Methodical systems engineering is essential to a well-integrated system. The PM and systems engineer must work together to achieve optimal results.

It is helpful to review the formal definitions of project management and systems engineering, as used by their industry governing bodies. The Project Management Institute defines project management as:

The application of knowledge, skills, tools, and techniques to a broad range of activities in order to meet the requirements of a particular project. Project management is comprised of five processes—initiating, planning, executing, controlling, and closing—as well as nine knowledge areas. These nine areas center on management expertise in project integration, project scope, project time, project cost, project quality, project human resources, project communications, project risk management, and project procurement. (PMI, n.d.)
The International Council on Systems Engineering defines *systems engineering* as:

An interdisciplinary approach and means to enable the realization of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, then proceeding with design synthesis and system validation while considering the complete problem: operations, performance, test, manufacturing, cost and schedule, training and support, and disposal. Systems engineering integrates all the disciplines and specialty groups into a team effort forming a structured development process that proceeds from concept to production to operation. Systems engineering considers both the business and the technical needs of all customers with the goal of providing a quality product that meets the user needs. (INCDSE, n.d.)

In the complex world of system-of-systems, project managers have their hands full just managing the job. It is the role of the systems engineer to provide the management of the technical issues including quality, conformance with requirements, and other targets of the specific procurement (flexibility, adaptability, reliability, etc.).

**ENSURE FOR ADEQUATE PLANNING**

Under pressure to perform, many PMs proceed to the product development and execution phase prematurely, without sufficient attention to the planning phase. It is important to note that upfront, advance planning becomes more critical as budgets become more constrained. Proper planning dramatically reduces scrap, rework, and redesign. A good rule-of-thumb for planning is to spend approximately 15 to 25 percent of the overall budget on planning: *planning for success*.

However, it is equally important to ensure that the budget spent on planning is value-added. Structure must be enforced on the planning phase to make certain that the planning is disciplined and documented. The PMs and systems engineers are essential disciplines to the planning process. Working together, they can efficiently produce an integrated set of project management (e.g., scope management plan, risk management plan, quality management plan) and technical management (e.g., systems engineering plan, systems engineering management plan, etc.) plans.

**RECOGNIZE SHOULD COST VS. WOULD COST**

If one builds in a *should cost* clause in the contract or includes it as part of a value engineering section, one has the ability to propose alternative approaches to
the sponsor in order to save both time and money. It is one of the least-used tools of systems engineering in that once the contract is signed, alternative approaches tend to cease. Negotiate a percentage sharing basis with the sponsor; a 50/50 sharing arrangement is a good initial objective.

**UTILIZE SYSTEM ARCHITECTURE STUDIES**

Another area that causes failure is an upfront lack of, or non-use of, system architecture studies related to topics like functionality, modularization, placement of risk, determination of design margins, etc. Often, this may be done by the systems engineering team and included as a deliverable, but may never get into the project planning activity.

**CONCLUSION**

A root cause of a failure is often not sufficient in and of itself to cause a catastrophic failure. It is when secondary variables are present, in a specific sequence, that all the factors align to cause the worst-case scenario to become reality. For example, the common thread between the two shuttle tragedies is the prior observation and documentation, during multiple flights, of a technical design flaw that had the potential for causing a catastrophic failure. If repeated O-ring failures on the Challenger led to disaster, then why, within 20 years, was repeated tile damage to a shuttle’s heat shield from break-away insulation allowed to continue, until eventually a piece struck in such a manner as to cause catastrophic damage to the integrity of Columbia’s heat shield?

The answer lies in the knowledge management of lessons learned of not only the root cause itself, but also the associated factors and circumstances. We have become very good at documenting lessons learned, but not so disciplined in the institutionalization of those lessons. Documenting lessons learned is only the beginning of knowledge management. Those lessons must be socialized among colleagues to the degree that they are transferred to upcoming generations. How do lessons learned become generally accepted best practices? Some lessons should change the foundations of our organizational culture permanently. We have mastered the archiving of lessons learned. Now we must master their retrieval, and give them life, not just a life cycle.

A final quote, attributed to Andy Grove, chairman emeritus of Intel: “Individuals, processes and organizations are perfectly designed to achieve whatever results they are currently getting, so if you’re not happy with what you are achieving, its time to reconsider your assumptions and approaches to your process and product design methods.”
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REFERENCES


