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The Case for Change: The Need for Stronger Engineering Program Performance

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Abstract

Programs to develop and deliver new and enhanced defense systems require strong technical and business management. That requirement means that program managers and chief systems engineers must work closely together as program leadership to enable program team collaboration using aligned tools, practices, and capabilities. While there is plenty of published material focused on enhancing the performance of each individual discipline, very little published matter spotlights how the two disciplines align their efforts and work collaboratively. Extensive research conducted by MIT's Consortium for Engineering Program Management (CEPE), the Project Management Institute (PMI), and the International Council on Systems Engineering (INCOSE) over the last five years has identified opportunities and approaches for improving engineering program management. This paper presents highlights from the research and key factors in integrating systems engineering and program management.

Introduction

> *Taking on large-scale engineering programs is one of the most difficult, risky, and—when done well—rewarding undertaking a government or company can attempt. It not only pushes the envelope of what is possible, but defines a new envelope. It generates capabilities, technologies, products, and systems that are innovative and unique, and generates tremendous societal benefits—from hybrid cars to a trip to the moon, from road networks to GPS navigation, and from carbon-neutral electricity sources to the "smart" city.* (Oehmen, 2012)

So began the text to *The Guide to Lean Enablers for Managing Engineering Programs*, which explored how program managers and systems engineers could impact engineering program performance through collaborative improvement efforts. *The Guide to Lean Enablers* was groundbreaking not just for its application of lean to engineering program management, but also because it has spurred a multi-year conversation and focus on how to build effective inter-disciplinary collaboration capable of solving wicked problems and delivering impactful results.

Engineering programs that incorporate or are reliant upon emerging or evolving technologies are among some of the most challenging to manage. Developing completely novel technologies and then integrating those technologies into systems with other novel technologies requires strong technical and management capabilities. Within the federal government, the U.S. Department of Defense (DoD) has some of the most challenging and expensive engineering programs of any federal agency. In a 2015 report to Congress, the Government Accountability Office (GAO) noted that "The Department of Defense (DoD) has 78 major weapon system programs under way with a total estimated acquisition cost of over $1.4 trillion. These include **some of the most advanced weapons in the world**" (emphasis added). But despite having the most extensive and mature systems engineering and program management capabilities among federal agencies, a 2009 GAO assessment estimated the accumulated cost overrun of the largest 96 engineering programs within the DoD at nearly $300 billion with an average schedule overrun of close to two years (see Figure 1). As the DoD portfolio of state-of-the-art weapon systems are executed through programs that experience extensive cost and schedule overruns, it is clear that the current situation for the DoD is not sustainable.

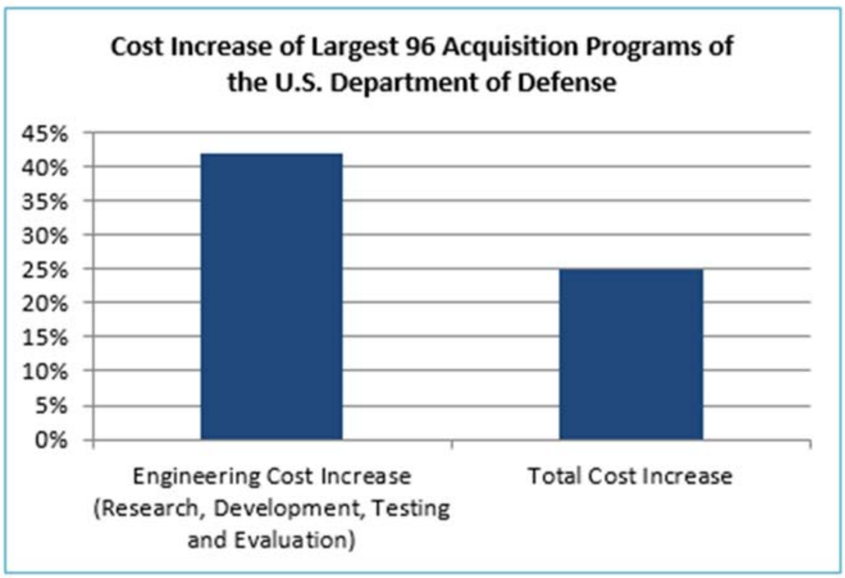

Figure 1. Engineering Programs Are Plagued by Significant Cost Overruns

Demonstrating similar challenges across the federal government, the GAO's High Risk List (GAO, 2017) identifies agencies and program areas that are high risk due to their vulnerabilities to fraud, waste, abuse, and mismanagement or are most in need of broad reform. The GAO's 2017 list includes 34 government operations that are high risk, including a number of agency program areas:

- IT Acquisition Management: "…federal IT investments too frequently fail or incur cost overruns and schedule slippages while contributing little to mission-related outcomes. We have previously testified that the federal government has spent billions of dollars on failed IT investments. These investments often suffered from a lack of disciplined and effective management, such as project planning, requirements definition, and program oversight and governance" (GAO, 2017).
- Department of Homeland Security: The GAO has cited numerous elements of DHS acquisition and program management that need improvement, including

"…tradeoffs stemming from the acquisition affordability reviews; and require components to establish formal, repeatable processes for addressing major acquisition affordability issues" (GAO, 2017).

- National Aeronautics and Space Administration: "NASA manages a portfolio of projects that will always have inherent technical, design, and integration risks because its projects are complex, specialized, and often push the state of the art in space technology. NASA has already taken steps to reduce acquisition risk from both a technical and management standpoint. … However, more needs to be done with respect to anticipating and mitigating risks—especially with regard to large programs, estimating and forecasting costs for its largest projects, and implementing management tools" (GAO, 2017).

Federal authorities recognize the need to transform program performance. The recently enacted Public Law No. 114-264 (Congress, 2016), the Program Management Improvement Accountability Act (PMIAA), outlines specific requirements related to the following:

- Use of standards, policies, and guidelines for program and project management within federal agencies
- A job series for project and program management professionals within the U.S. federal government
- A five-year strategic plan for developing and improving project and program management capabilities
- Establishment of a Program Management Policy Council and portfolio reviews of government programs
- Designation of program management improvement officers
- Adoption and use of best practices in project and program management

Effective transformation efforts like those expected from PMIAA can be better enabled when the key transformation influencers can be identified and leveraged. This paper presents some of the key influencers for better aligning technical and management practices within programs to improve collaboration and drive stronger program performance.

Throughout this paper, the term *program leadership* is used and refers to the technical and management leadership within the engineering program. The majority of research studies upon which this paper is based identified those roles of the program manager as the management leader and the chief systems engineer as the technical leader. Those roles were defined in the following manner:

- *Program manager refers to the job position that has the ultimate authority and accountability* for the overall program.
- *Chief systems engineer* refers to the job position that has ultimate technical authority and accountability for the product or system being developed by the program.

Common Challenges Affecting Engineering Program Performance

In industry and government, there are common challenges that can affect engineering program performance. Research conducted by MIT, PMI, and INCOSE in 2012 explored the application of lean principles to engineering programs in order to eliminate waste and to produce better program performance. Through extensive stakeholder engagement, data collection, and analysis, this research endeavor collected, validated, ranked, and aggregated the most common challenges that affected engineering program performance. The findings consolidated into 10 major challenges (Oehmen, 2012):

- *Insufficient Program Planning*: Program planning may be inaccurate, unable to accommodate uncertainties, or both, which leads to unrealistic expectations and plans.
- *Firefighting*—Reactive Program Execution: The program is executed in a reactive mode toward inside and outside influences, instead of proactively managing and coordinating stakeholders, risks, and issues.
- *Unclear Roles, Responsibilities, and Accountability*: The roles, responsibilities, and accountability of individuals, teams, projects, staff functions, and line functions are not clearly defined in this theme.
- *Mismanagement of Program Culture, Team Competency, and Knowledge*: The expertise and knowledge of individuals, teams, and the organization are insufficient, not transferred properly, or not applied appropriately during the program. It is difficult to establish a productive program culture.
- *Unstable, Unclear, and Incomplete Requirements*: Changing, unclear, and incomplete requirements from customers and other stakeholders seriously affect the efficient and effective execution of the program.
- *Insufficient Alignment and Coordination of the Extended Enterprise*: The complex network of organizations and departments involved in delivering the program value is not aligned to its priorities. This includes the alignment and optimization of strategic priorities and portfolios.
- *Locally Optimized Processes That Are Not Integrated Across the Entire Enterprise*: When processes are only locally optimized, there is a lack of visibility for the value stream, and/or barriers between organizational units to implement a seamless flow. There are insufficient tradeoffs between units to reach an overall optimum.
- *Improper Metrics, Metric Systems, and KPIs*: The metrics and KPIs used during the program do not capture the intended performance attributes, incentivize the wrong behavior, or are lagging instead of predictive.
- *Lack of Proactive Program Risk Management*: Budgetary and time constraints force limited or no risk management activity to be undertaken by the program team. The program team attempts to function without clear off-ramps and mitigation approaches. Ownership of risks is ill-defined.
- *Poor Program Acquisition and Contracting Practices*: Policies and other constraints restrict the program's ability to apply emerging and best practice in complex program acquisition or contracting.

All of the program challenges identified by the lean research are influenced to varying degrees by factors that are external to the program and over which program leadership may have little, if any, control. For example, program leadership may have limited input or influence related to such things as human resource policies or legal and regulatory requirements imposed on programs. Still, program leadership has substantial control over the degree to which some of the above challenges affect the program team, culture, and performance. And while program leadership may not be accountable for such things as advancing best practice across the entire enterprise, leadership can play a proactive role in sharing and facilitating adoption of program management best practices. Table 1 highlights some of the major program challenges from *The Guide to Lean Enablers* over which program leadership may have influence and where strong leadership can mitigate the impact of the associated program challenges.

Table 1. Challenges Internal and External to the Program

Challenges Internal to the Program		Challenges External to the Program	
People Factors	**Process Factors**	**Policy Factors**	**Strategic Factors**
Unclear Roles, Responsibilities, and Accountability	Planning: • Insufficient Program Planning • Firefighting—Reactive Program Execution • Improper Metrics, Metric Systems, and KPIs	Insufficient Program Planning	Insufficient Alignment and Coordination of the Extended Enterprise
Mismanagement of Program Culture, Team Competency, and Knowledge	Lack of Proactive Program Risk Management Unstable, Unclear, and Incomplete Requirements Insufficient Alignment and Coordination of the Extended Enterprise Locally Optimized Processes That Are Not Integrated Across the Entire Enterprise	Unstable, Unclear, and Incomplete Requirements Poor Program Acquisition and Contracting Practices	Unstable, Unclear, and Incomplete Requirements

The remainder of this paper will detail findings from research aimed at exploring the people and process factors over which program leadership can exert influence to help their programs produce stronger results.

Research on Integrated Engineering Program Management

The joint lean research by CEPE, INCOSE, and PMI exploring ways to overcome the 10 engineering program challenges included a second phase of research. That phase collected, validated, and aggregated 43 potential mitigation approaches called “lean enablers” that could be applied to the challenges. That research included specific examples from engineering programs illustrating how the “lean enablers” were applied within actual programs to positively impact program results (Oehmen, 2012). An unstated but underlying presumption in that work was that the program manager and chief systems engineer would lead the application of these “lean enablers” within their programs. However, none of the previous research had explicitly explored how effectively these program leaders collaborated in leading program teams. To address that presumption, a new multi-year, multi-phase research effort was undertaken. The research has culminated in the recent publication of the book *Integrating Program Management and Systems Engineering: Methods, Tools, and Organizational Systems for Improving Performance* (Rebentisch, 2017), which seeks to help program managers, chief systems engineers, and their executive leaders enhance joint effort, joined thinking, and common language.

Integration Research Phase I

Phase I of the integration research was exploratory in nature and was designed to (1) understand how well program managers and chief systems engineers collaborated and (2) detail the degree to which the two disciplines integrate practices from each discipline to effectively manage engineering programs. The research results provided key insights into four areas: roles and authority; use of standards and guidelines; formal alignment of technical and management processes; and the causes and degree to which unproductive tension affected program team performance.

On the point of unproductive tension, differences in the approaches, objectives, and incentives of program managers and chief systems engineers, respectively, to execute their responsibilities can result in tension. This tension can be productive if it forces the different disciplines to share, collaborate, create common understanding, and make tradeoffs in the pursuit of a common set of solutions. Innovation can result from this collision of different perspectives as new ideas are introduced on how to solve a challenging problem. But tension can become unproductive if the parties dig in and cling to their own perspectives about why they are right. The integration study asked individuals to rate the extent to which they had experienced unproductive tension between program managers and chief systems engineers.

Unproductive Tension

As shown in Figure 2, the research uncovered that almost one-third of respondents reported there was unproductive tension between the chief systems engineer and program manager to the point that the tension affected program performance. Slightly more than half (52%) reported minimal unproductive tension that did not substantially affect program performance because the program manager and chief systems engineer were able to work through their problems (Conforto et al., 2013a).

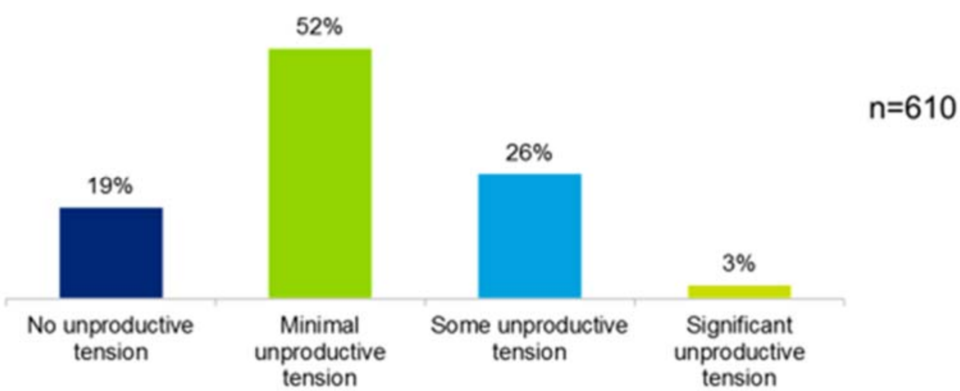

Figure 2. Level of Unproductive Tension

As highlighted in Figure 3, unproductive tension linked back to people and process issues such as unclear roles, lack of planning, and conflicting practices (Conforto et al., 2013a).

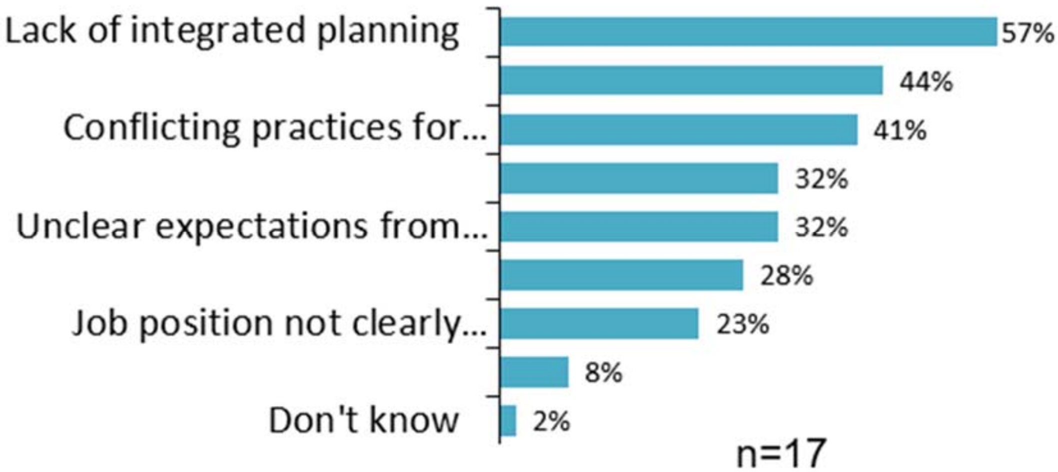

Figure 3. Sources of Unproductive Tension

Roles and Authority

The research found key discrepancies in the degree to which roles and accountabilities were formally defined, whether through position descriptions or in program chartering documentation. The program manager role and authority tended to be more formally defined while both the role and authority of the chief systems engineer were less likely to be formalized, as identified in Figure 4 (Conforto et al., 2013a).

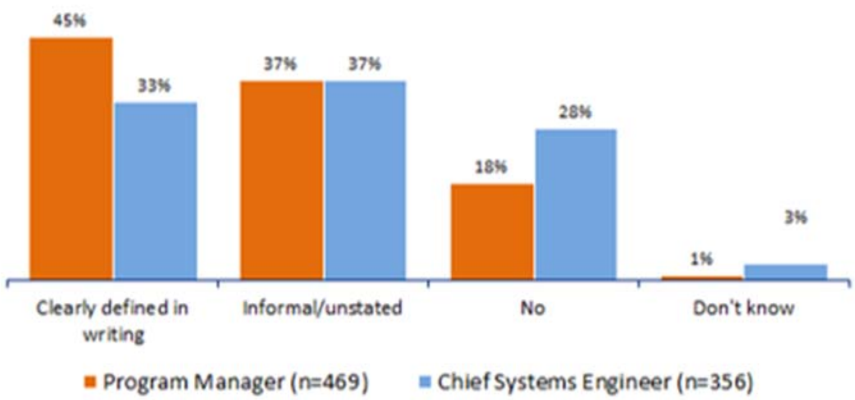

Figure 4. Degree to Which Roles Are Formalized

This discrepancy seemed to influence the chief systems engineers' perception that unproductive tension with the program manager existed because of unclear authority (Conforto et al., 2013a).

The research also indicated that while each role had distinct responsibilities, there were also shared responsibilities in key areas including program/project risk management, external supplier relations, quality management, and lifecycle planning, as shown in Figure 5 (Conforto et al., 2013a). So where role and authority were unclear and where responsibilities overlapped, these factors seemed to contribute to unproductive tension within program leadership.

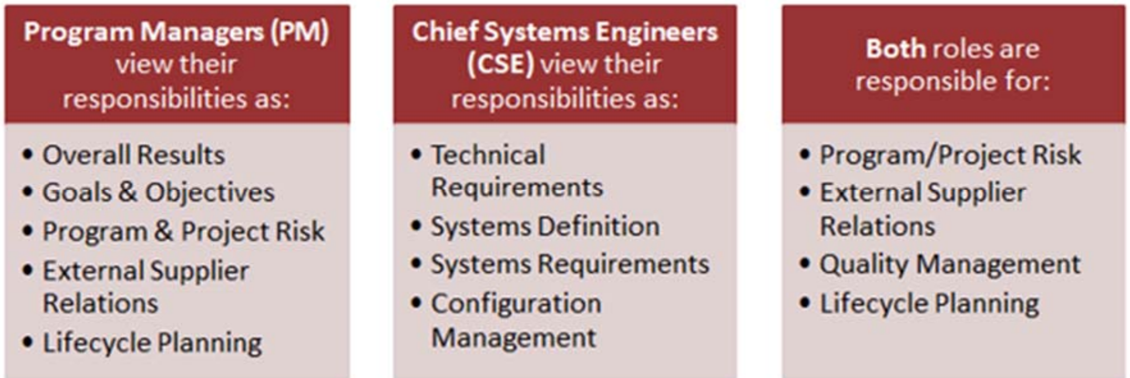

Figure 5. Distinct Roles With Some Overlapping Responsibilities

Integration of Standards

The research found that the majority of chief systems engineers and program managers used domain-centric standards within their programs, as illustrated in Figure 6. It also uncovered that there was not significant use of standards spanning disciplines (Conforto et al., 2013b). So as with unclear roles and authority, the lack of aligned ways of approaching common areas of responsibility was sometimes a contributing factor to unproductive tension within program leadership.

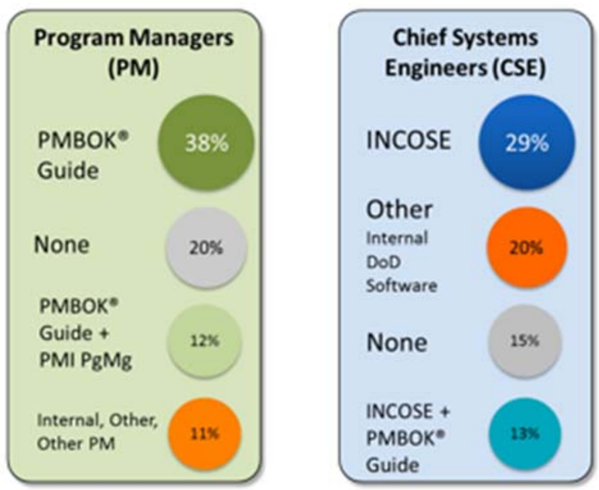

Figure 6. Use of Standards by Each Discipline

How Integration/Alignment Occurs

The research explored how program leadership integrated and aligned practices and standards from the systems engineering and program management domains within their programs. Only 48% reported that program practices were fully or mostly integrated. Where integrated approaches existed, they came about through a mixture of organizational process requirements and of program team members taking the lead to align practices (Conforto et al., 2013a). Both of these results are highlighted in Figure 7.

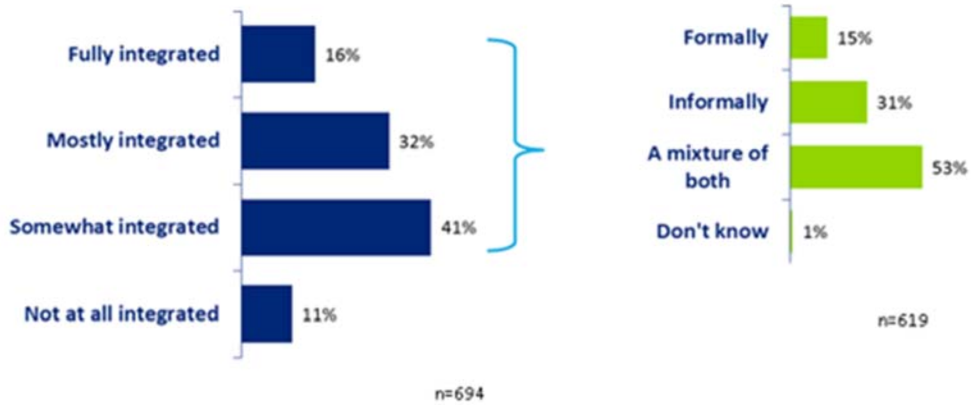

Figure 7. Level and Formality of Integration Efforts

Most respondents (60%) reported that the level of integration was only somewhat effective (Conforto et al., 2013a).

Key Finding From Phase I: Higher Integration Impacts Unproductive Tension

Further analysis was applied to the collected data to determine whether there were statistically significant relationships between integration, unproductive tension, and use of standards. The first analysis explored the use of standards by level of integration and found that the group that used a standard had a higher and statistically significant different level of integration compared with those that did not use any standard. So the research found that aligning inter-disciplinary processes contributes to greater integration between program managers and chief systems engineers (Conforto et al., 2013).

Additional analysis was conducted to explore whether there was a relationship between the level of integration between program managers and chief systems engineers and the formality of the approach to integration. Again, the analysis looked for statistically significant differences by exploring respondents' answers to two questions—one asking about the level of integration and a second asking whether integration occurred formally (e.g., processes transcend the boundaries across the job position) or informally (e.g., people make the integration occur). The analysis found a statistically significant relationship between the formality of the approach for integrating the two disciplines and the level of their integration where higher levels of integration were associated with a greater degree of formality in the approach to integration (Conforto et al., 2013).

Another level of analysis found that integration reduced the level of unproductive tension between the chief systems engineer and the program manager. The analysis found that lower levels of unproductive tension were more likely to exist at higher levels of integration between the chief systems engineer and the program manager. Further, as integration between the program leadership becomes more effective, unproductive tension becomes minimal or non-existent (Conforto et al., 2013).

Integration Research Phases II & III

The next two phases of research sought to understand the key aspects and practices that differentiated organizations with higher integration levels between program managers and chief systems engineers from those with lower integration levels. It also explored the sources and causes of unproductive tension. All of the data collection and analysis aimed to identify how to achieve better program performance by improving integration between program management and systems engineering. Phase II and Phase III research involved in-depth interviews with respondents whose organizations were at each pole—high integration/low unproductive tension and low integration/high unproductive tension. There were nine interviews with respondents who reported no unproductive tension, and there were seven interviews with respondents who reported facing unproductive tension (Rebentisch & Conforto, 2014).

Defining Components of Integration and Unproductive Tension

The interviews explored what the term integration meant to each of the respondents. Using cluster analysis techniques, key themes began to surface that resulted in defining key components of integration as (Rebentisch & Conforto, 2014):

- Having a shared set of objectives defined by the success of the overall effort
- Everyone knowing what those objectives are
- Clarity and understanding around roles and how each role contributes to achieving the objectives
- Respecting the value of the other's role and contribution to achieving the objectives
- Valuing and promoting "collaboration" over "competition"

A similar exercise surfaced key themes associated with defining unproductive tension and its key components which included the following (Rebentisch & Conforto, 2014):

- Failing to communicate and establish a common set of objectives shared by all
- Individuals/groups focused on achieving objectives defined by their own disciplinary identity and/or processes
- Being unable to work together to achieve the globally-superior outcome
- Not valuing the other's role and contributions to achieving the globally-superior outcome

Building Effective Integration

Additional themes surfaced from analysis of the interview data related to effective integration. These themes were stronger in organizations with high levels of integration and low levels of unproductive tension and weaker in those organizations with low levels of integration and high levels of unproductive tension. The emergent themes related to effective integration and their key components clustered into three key factors (Rebentisch & Conforto, 2014):

- Process, Practices and Tools: Encourage continuous improvement and change management through integrated planning and problem solving techniques, use and evaluation of combined practices from each discipline, application of integrated performance measures.
- Organizational Environment: Establish and nurture an organizational environment that builds trust, collaboration, and empowerment to achieve shared goals and objectives with clear roles and accountabilities.
- People Competencies: Utilize engagement, communication and knowledge transfer to promote cross-training and understanding, encourage active listening and recognize the value of multiple competencies and skills.

These factors can be visualized as shown in Figure 8 (Rebentisch & Conforto, 2014):

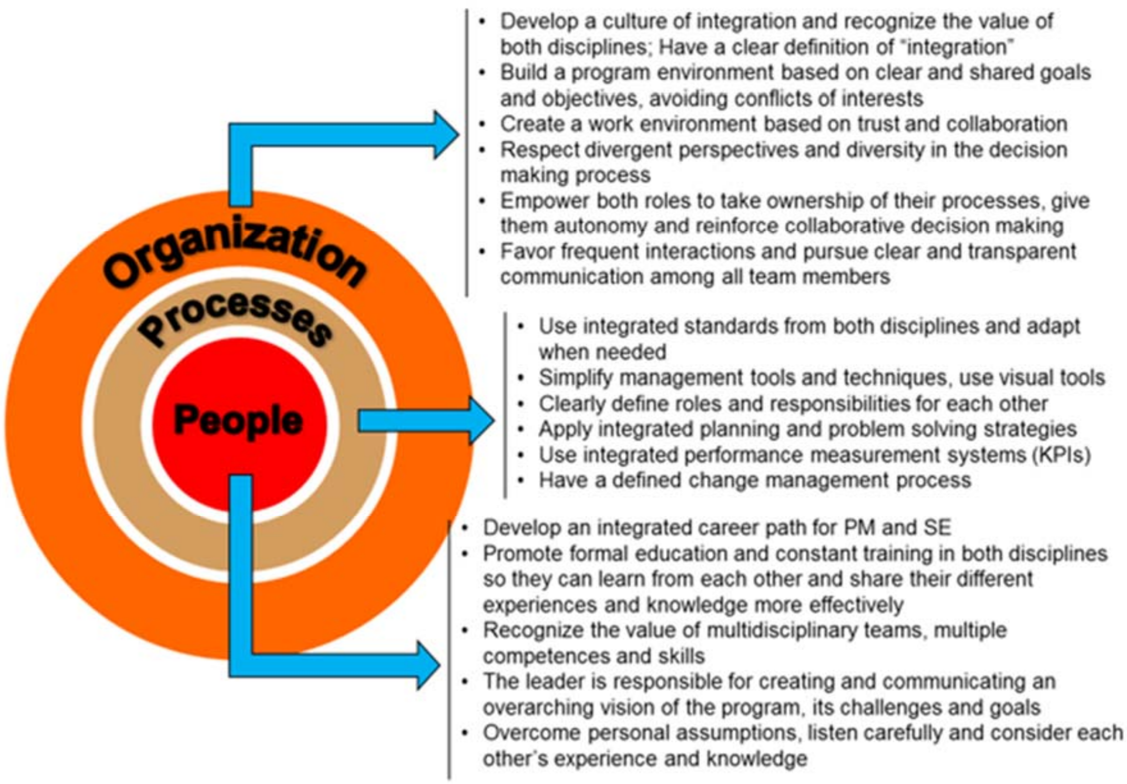

Figure 8. Components of Effective Integration

The positive presence of the components of these themes indicated effective integration.

Conclusions

The complex nature of engineering programs can give rise to significant challenges that can result in cost overruns, schedule delays, poor products, and dissatisfied customers. Program leadership—program managers and chief systems engineers—can greatly influence program performance by collaborating effectively. A key component of strong collaboration involves effective inter-disciplinary integration of people and processes that affect the inner workings of programs. A strong working relationship between the program manager and chief systems engineer enables the type of leadership that can rally a team to overcome hurdles the team might encounter as the program is being executed. The absence of that strong working relationship and the united leadership it provides may exacerbate or amplify the challenges a team encounters while executing a program.

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Integration in Practice Case Studies: FA-18 E/F Super Hornet

By Elizabeth "Betsy" Clarke—Software Metrics

Abstract

The development program for the FA-18 E/F demonstrated deliberate attention to integrating the program management and systems engineering activities within the program. It also represents one of the few Department of Defense weapon systems programs to finish ahead of schedule, under budget, and with additional functionality beyond original specifications. The program reflected a significant shift from a traditional model of disciplinary stovepipes to a collaborative environment with strongly aligned technical and management leadership. That shift resulted in the following:

- More effective and rapid decision making
- Stronger collaboration and team empowerment
- Clearer alignment of work to product requirements
- Proactive risk management
- Enhanced communication

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Integration in Practice Case Studies: Electronic Support Upgrade for the Royal Australian Navy's Anzac Class Frigate

By Elizabeth "Betsy" Clark—Software Metrics Inc.

Abstract

This program was an outstanding success, delivering a high priority capability ahead of schedule, within cost, and with minimal defects. It involved the coordination and collaboration of technical staff from seven different companies whose systems and subsystems had to integrate seamlessly. In the early days of the program, the program manager, working closely with the chief engineer, sponsored a series of risk reduction workshops to bring all contractors together to identify key risks and issues and to work together toward their mitigation and resolution. In addition, the program manager and chief engineer fostered an outcome focus on delivering capability to the Navy. This resulted in the following: 1) A high degree of collaboration among all contractors; 2) effective information sharing: Contractors were able to communicate directly without having to channel their communications through third-party bottlenecks; contractors provided each other with computer simulations of their system or subsystem interfaces to allow early integration testing; and 3) rapid and effective decision making in spite of major barriers put in their way.

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Integration in Practice Case Studies: F-35 Lightning II

By Jeffrey Morris—Lockheed Martin (Ret.)

Abstract

The U.S. Department of Defense's F-35 fifth generation fighter aircraft is the largest development program undertaken by the department and eight partner countries. Effective integration, as experienced on the F-35 Mission Systems software development effort, required experienced leadership, world-class engineers and foundational methods surrounding Earned Value Management (EVM) and Change Management (CM). Organizational and program performance is most effective when program management and engineering functions collaborate during the planning phases. Once the plan is cast, adherence to EVM and CM practices ensure measures are in place capable of predicting deterministic program performance. Post the F-35 Nunn-McCurdy breach, the Mission Systems software re-baseline plan included the following:

- Sensing sessions with individual engineers to assess needs
- Definitive accountability via a revamped EVM process
- Information sharing via a single Change Management system
- Improved workflow via a revised software build and release tool suite
- More effective flight test planning via a new integration process

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