Addressing the Challenge of Integration Management Through Government/Industry Collaboration

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ABSTRACT

Many Air Force training simulation programs currently encounter integration issues that corrupt test schedules, resulting in late trainer deliveries, trainers fielded with significantly degraded performance, or both. While the implementation and testing of individual hardware and software components generally proceeds as expected, unanticipated problems begin surfacing when subsystem integration begins. Issues cascade as the system proceeds through successive stages of integration and test. Hardware-software integration is rarely completed on the timetable laid out in the Integrated Master Schedule, and subsequent testing often reveals problems that should have been detected earlier. Consequently, trainer programs which had been on-track throughout the entire design phase suddenly stumble, resulting in late delivery and/or unresolved deficiencies. The Training Systems Product Group (TSPG) is frustrated by this problem. There are a number of reasons an integration plan can go awry, and we are able to deal with many of them effectively- but we have never examined our acquisition and development processes to determine and prevent such late breaking problems.

The NTSA Ohio Chapter recently hosted a Technical Forum with Air Force and Industry simulator engineers, to discuss causalities of our integration woes and some possible adjustments the TSPG can make in its acquisition management processes, to reduce the risk of delays. The Forum addressed a set of questions that ranged from identifying the keys to successful integration experiences, to relating integration horror stories. It addressed the addition of formal reviews specifically for integration, and examined how well we execute our current reviews (SRR, PDR, and CDR). This paper summarizes the discussions of the Forum, and identifies specific issues agreed upon by the group, along with initiatives being examined and instituted by the TSPG. It also addresses management strategies useful to both Government and contractor developers to mitigate integration risk in their programs.

ABOUT THE AUTHORS

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INTRODUCTION

The purpose of this paper is to provide an introduction to the problems frequently experienced by United States Air Force (USAF) training system acquisition programs, as they transition from implementation into the integration and test phases of their development. The struggle to remain on schedule through this activity has become a pervasive issue in recent years, and consequently the USAF has initiated a dialog with its industry counterparts, in an effort to find a solution. The paper documents the proceedings of a conference held in early 2008 to address this issue, and outlines the USAF's plan to implement the recommendations from that meeting. This paper was developed under the presumption that the issue reaches beyond the USAF training systems domain, and that the observations and recommendations documented herein will be of value to the larger training systems community, and potentially other applications as well.

Systems Engineering Application

Systems Engineering (SE) is generally recognized as a mature discipline, applied effectively in the development of complex systems, both military and commercial, throughout the world. The SE process, as currently implemented within the USAF and other Department of Defense (DoD) organizations, originated in the 1960s. SE arose in recognition of the growing complexity of weapons systems, and the need to manage their development in a methodical and controlled manner. The standard SE process for application to U.S. military systems was documented in Military Standard (MIL-STD) 499, first published in 1969. Revision A to the standard was released in 1974, and MIL-STD-499A served the systems acquisition community without change for over two decades. Although Revision B was being prepared for release in 1995, it fell victim to a DoD-wide Acquisition Reform initiative to cancel many established MIL-STDs. The requirement for compliance with MIL-STD-499B was removed from Government contracts, under the seemingly visionary but ultimately mistaken notion that industry would prefer to develop its own SE process, rather than having the Government dictate one. Since that time, the anti-MIL-STD sentiment has waned somewhat. Despite its official "cancelled" status, MIL-STD-499B continues to be cited as the definitive reference for SE by many military programs, including those managed by the TSPG.

In 2004, the DoD reaffirmed its commitment to the application of the SE process, requiring its application on all DoD acquisition programs[1], and mandated the development of Systems Engineering Plans (SEPs) to formally document its implementation. As this requirement flowed down through the Air Force hierarchy, training system acquisition programs managed by the 677 AESG placed greater emphasis on the application of SE. The TSPG Engineering Division defined and implemented an internal process to implement SE across the organization[2], and began developing SEPs for all of its programs.

Figure 1 provides a graphical depiction of the steps involved in the SE process, as typically implemented on TSPG programs. This diagram is often referred to as the "V Model."[3]

The TSPG strives to implement its engineering processes "by the book," that is, in accordance with standard MIL-STD-499B practices and DoD and Air Force acquisition policies. Trainers are designed and built using well-established industry engineering practices, as applied by experienced, competent companies. Conscious effort is made to minimize cost and risk: designs make substantial use of commercial standards and components, and technology changes are evolutionary and deliberate.

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[1] OUSD(AT&L) Letter, Subject: Policy for Systems Engineering in DoD, 20 February 2004

[2] The development of the TSPG SEP implementation process was also accomplished with the assistance of the NTSA Tech Forum discussed in this paper.

[3] Many variants of the "V Model" diagram exist in the SE literature, and are not uniquely the province of the DoD. This particular diagram was retrieved from http://ops.fhwa.dot.gov/publications/regitsarchguide/73useprojimp.htm.

The SEP, Integrated Master Plan (IMP) and Integrated Master Schedule (IMS) are used as tools to plan and manage engineering tasks, and to maintain awareness of program technical status. In-process development is evaluated through the conduct of time-tested engineering reviews, as defined decades ago in MIL-STD-1521B.

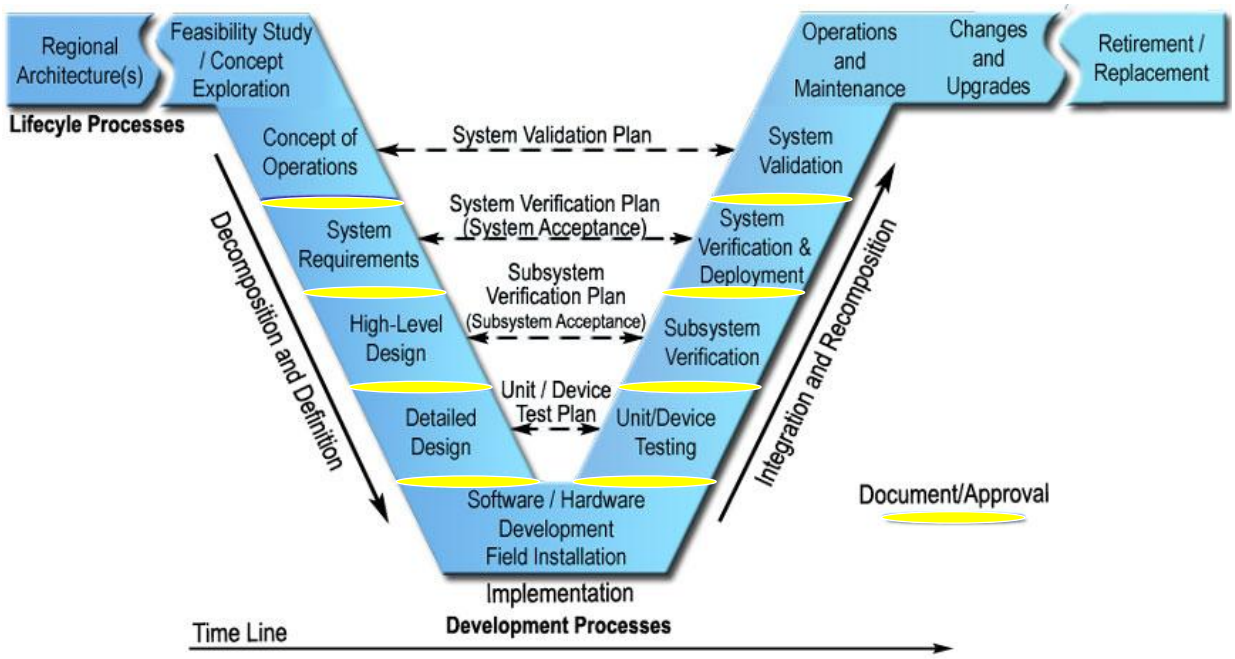

Figure 1. Systems Engineering "V Model"

Government engineers and their contractor counterparts generally communicate openly, sharing information, highlighting concerns, and resolving technical issues as the effort progresses.

THE INTEGRATION MANAGEMENT PROBLEM

Despite the best efforts of both the Government and contractor to adhere to a robust SE process, the 677th's implementation somehow appears to be flawed. While the implementation and testing of individual hardware and software components of our training systems generally proceeds as expected, unanticipated problems begin surfacing when subsystem integration begins. Issues cascade as the system proceeds through successive stages of integration and test. As a result, hardware-software integration (HSI) is rarely completed on the timetable laid out in the IMS, and subsequent testing often reveals problems that should have been detected during earlier design phases. Trainer programs which had been on-track throughout the entire design phase suddenly stumble, resulting in late delivery and/or unresolved deficiencies.

The rapidity with which this schedule degradation occurs, as well as its magnitude, often comes as a surprise to the program team. It is suspected that, although the team is able to maintain good awareness of the program status through the design phase, the lack of any formal technical review during the long period following Critical Design Review (CDR) creates an awareness void, during which progress can go awry with little indication. Figure 2 provides a notional depiction of this void. In this example, half of the program schedule lapses without the conduct of a formal milestone review of any kind. Notably, the activity which takes place during this period comprises the most substantial portion of the effort – the actual implementation of the approved design.

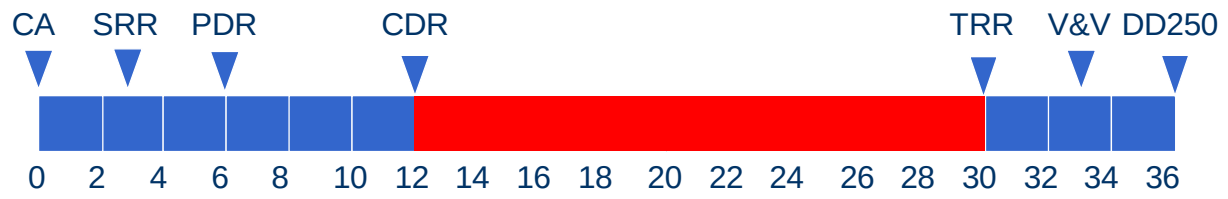

Figure 2. Program Timeline

During this time, implementation of the approved design creates embedded flaws, but since the implemented components are not scrubbed with the thoroughness of a formal review, such flaws are not detected. These latent problems only emerge when the integration proceeds to the point that interaction among components reveals their existence. The need to pause integration and testing to identify the cause of the problem, design and implement a solution, and perform regression testing can create delays which ultimately result in program schedule slips, late deliveries, and dissatisfied customers. The TSPG has seen this situation arise on a significant percentage of its programs, in varying degrees of seriousness.

The TSPG has repeatedly observed programs that need to accomplish an excessive amount of design rework during the integration phase. In a perfect world, a complete design would be implemented exactly as described in the CDR-approved documentation. In practice, it is fully expected that some design changes will need to be made when hardware is fabricated and software code is written, as the implementation reveals latent problems. Program schedules are therefore typically constructed with adequate "pad" to accommodate a nominal quantity of such rework. However, the TSPG is finding that the amount of redesign which is taking place is much more extensive than anticipated, consuming all of the available schedule flexibility, and then some. Ready for Test dates and all subsequent milestones slip by weeks, then months.

While any individual TSPG project can expect to experience some hiccups, the pandemic nature of this problem is disturbing. Rather than being confined to a particular subset of trainer programs, it affects a wide variety of systems and developers. This suggests that no single training system program or team is to blame, but rather that the process itself is somehow defective.

Potential Causes

While the symptoms are clear, the root cause is not so apparent. Our integration issues may relate to compressed schedules, insufficient designs, inadequate integration planning, ill-defined interim integration results, or some combination of these factors. In order to resolve this problem, the TSPG must start by determining why it occurs. The quest to unearth this information has been an increasingly intense activity within the TSPG engineering office.

Based upon the TSPG's internal experience, as well as information gleaned through the dialog with industry discussed later in this paper, the main cause can probably be summed up as: "poor requirements." This is not a single problem, but rather a broad spectrum of issues involving the entire requirements lifecycle, encompassing their identification, specification, interpretation, implementation, and verification. Indeed, a major aspect of the SE process deals with requirements definition and management. Referring back to Figure 1, it is noteworthy that the entire left half of the "V" involves the stepwise derivation and allocation of requirements at increasingly finer levels to create the components of a system. Correspondingly, the right half addresses the progressive unification of this result into a finished system, assuring that the implementation remains compliant with requirements at all levels. Clearly, the correctness of requirements at all levels is critical to the system's ability to meet its intended purpose. It comes as no surprise, then, that problems with requirements will create impediments to the completion of a system.

The requirements management problem is multifaceted and complex. Not confined to simply listing a series of numerical attributes, the specification of requirements typically involves issues of understanding, expectations, and volatility. In other words, despite the best efforts to specify requirements in explicit and unambiguous terms, there remains a subjective element in many cases. Nowhere is this more evident than in training systems, where requirements may be specified in terms of a desired result (e.g. "trained crewmember") which is in itself personal and variable. This environment makes the specification of requirements an inexact science, at best.

Even if it is possible for requirements to be stated unambiguously initially, once on contract, their

interpretation can be a subjective, emotional, and even selectively applied process, which often comes to a head within the context of a program with growing financial and schedule challenges. As pressure mounts, both Government and contractor tend to gravitate toward the hard-line interpretation which best supports their organization's overall objective. The matter is exacerbated by the nature of the relationship between the parties – the more adversarial the relationship is to start with, the less likely each side is to care about the concerns of the other. However, the definition of requirements ultimately needs to reflect a compromise, reached through a sort of negotiation. The solution does not converge on the absolute right answer, but rather on one that everyone can live with. And this process is repeated for the next program, where the personalities, funding, and other factors are different.

Once requirements have been defined and their meaning is agreed to, it is desirable that they remain constant. Changes in requirements result in missteps and rework – and typically increase cost and schedule. Accordingly, the emphasis tends to be on resisting change, rather than embracing it. However, due to various external influences, it is often necessary for requirements to evolve as a program progresses, regardless of the team's objective to maintain stability. Sadly, despite its many strengths, the traditional SE process is not especially conducive to accommodating change; the V Model is optimally intended to be traversed only once, with all requirements being addressed to the same level of maturity prior to progressing on to the next step. Relatively recent innovations such as Evolutionary Acquisition acknowledge that requirements change over time, and provide an SE framework for structuring programs to facilitate the incorporation of new capabilities incrementally; but even this construct assumes that requirements remain stable for a period of time. The lack of a practical mechanism for rapidly incorporating volatile requirements into an ongoing system development therefore remains a challenge.

Other Factors

While the lack of a well-defined approach for handing the definition and management of requirements is the suspected primary cause, there are a number of potential contributing factors as well. As indicated previously, the lack of awareness of detailed technical status post-CDR, while not technically a causal factor, passively contributes to the escalation of technical issues by masking them, thereby hindering early problem identification and resolution.

Obsolescence in certain aspects of the SE process itself may also be a factor. Although it has evolved over time, the SE process remains based on the fundamental assumption that the system design and implementation is under the control of the entity applying the process, at all levels. The Government can direct the prime contractor to follow the process, the prime can direct the subcontractors, and so on. Under this assumption, the decomposition of requirements, and subsequent synthesis of the system, can be effected in a consistent manner as defined by a single process. This model works as long as every part of the system is being designed and built to detailed Government specifications. However, in recent years, there has been a "paradigm shift" in the way in which the Air Force buys its systems, and in the nature of the components which make up these systems. Today, the USAF and its prime contractors have relatively little control over the design and implementation, especially at the lower levels. In fact, may training system components – computers, for example – are bought as commodity items, without any insight into the processes by which they were designed, developed, and manufactured. The change from Government-driven to commercial development occurred slowly and gradually, and has yielded some significant benefits, in terms of lower acquisition cost, better reliability, greater availability of replacement parts, and lower support cost. But the downside is that all technical processes and data may remain proprietary to the vendor, with no insight either to the USAF or its prime contractors. The lack of information requires the system integrator to make the assumption that the component meets all of its allocated requirements, which may not in fact be true. This uncertainty creates the potential for problems to occur as latent incompatibility issues begin to surface, contributing to the overall integration problem.

Government Impacts

The TSPG is concerned about this problem for a number of reasons. The detrimental effect on schedule is undoubtedly the most serious. When a training system schedule is developed, it is based on a training need date established by the warfighting command, as determined by some operational requirement. Development schedules are typically very tightly coupled to a series of established processes of fixed duration. This invariably causes a "domino effect" whenever a hiccup occurs anywhere in the pipeline. The longer a trainer is in development, the later production can begin; delayed production results in later delivery of training assets; tardy delivery leads to rescheduled installation and

checkout. This series of cascading events finally impacts the Ready for Training (RFT) date.

A late RFT can result in multiple adverse effects. Lacking a simulator, air or maintenance crews may be forced to accomplish more training tasks on operational equipment, rather than in trainers. For aircrews, this means spending more time flying the aircraft on training missions, burning increasingly expensive jet fuel and putting additional hours on the airframe and engines. For maintainers, this typically means taking an aircraft out of service, and dedicating it for use as a training aid. It can be seen that each of these workarounds will negatively affect the availability of an aircraft to be used for operational missions. The problem is compounded if delays occur in both aircrew and maintenance trainers for the same weapon system.

Another effect of delayed training is the inability to train certain tasks altogether. For safety reasons, flight-critical systems such as engines, electrical systems, and hydraulics cannot be shut down while in actual flight. Malfunctions affecting such systems can only be trained in the forgiving environment of the simulator. Ironically, these are some of the most important tasks to be trained, just because the systems they involve are so safety critical.

A training system schedule is also closely coordinated with an established funding profile. The Air Force budget is based on the Congressional appropriation process, which establishes tight controls on how and when different portions of the Federal budget can be spent. For example, training system development is normally conducted using money from appropriation category 3600, which must be spent within two years of the Fiscal Year (FY) in which it is appropriated. Production of training devices uses appropriation 3010 dollars, which must be spent within three years. Sustainment of trainers used appropriation 3400, which can only be spent in the year that it is appropriated. In order for a training system program to be executable, the correct amounts of each of these appropriations – known colloquially as "colors of money" – must be allocated in the correct fiscal years. When the TSPG assumes responsibility for the execution of an acquisition program, it agrees to do so with a funding profile that has an appropriate mix of colors of money for each fiscal year of the program. A notional example of this is depicted in Figure 3 below.

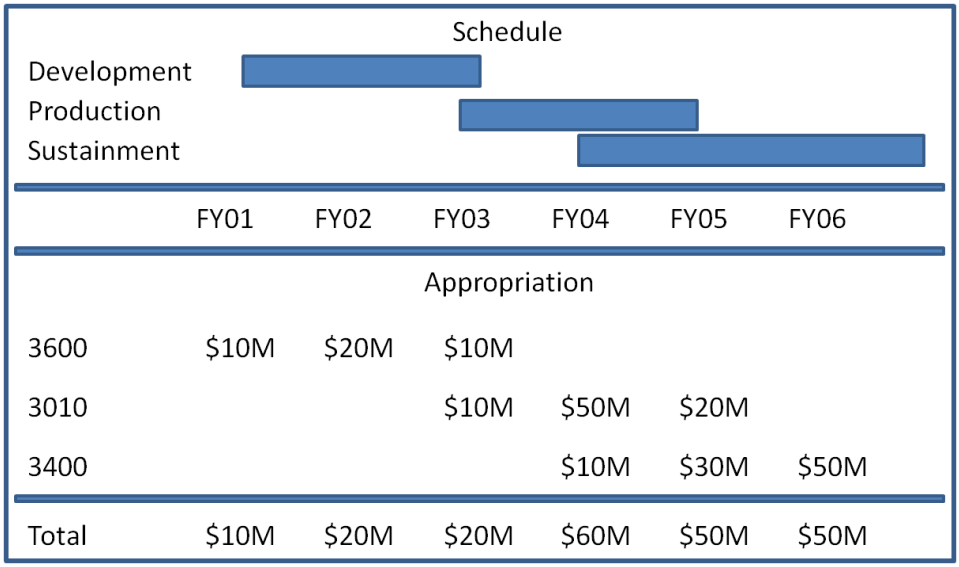

Figure 3. Notional Funding Profile

In this hypothetical example, the program has a total budget of $210 million, with the distribution of appropriations into fiscal years as shown. The budget is synchronized with the plan for completion of development and start of production in FY03. There is no development money available in FY04 to accommodate any ongoing development in that year. Unless it is a Fixed-Price contract (which most trainer contracts are not), if all of the development funds programmed for FY03 are spent, and integration problems slip the development end date into FY04, the Government cannot pay for it, even

though sufficient total program budget exists, unless funds of the correct "color" can be added. Securing the appropriate funds can be a time-consuming process, compounding the program's schedule woes even further.

Government Manpower Issues.

Over the past twenty years, the Air Force has experienced an unbroken string of force reductions. Since its peak of 603,000 members in fiscal year 1986, the active duty Air Force has shrunk to under 329,000 in 2007[4]. The number of Air Force civilian employees has decreased in roughly the same proportion, to a total of 167,000 in 2007, and continues to shrink. The USAF acquisition community, including the 677th, has been affected by these reductions, losing numerous experienced personnel to retirement and other attrition without replacements. In contrast with years past, when a team of engineers was assigned to provide oversight of the various technical aspects of each 677th program, today it is common for all engineering activities to be overseen by a single individual. The workload this imposes on the individual makes it virtually impossible for him or her to maintain insight into the status of a program on a daily basis, thereby becoming more reliant upon the contractor to provide an accurate assessment of the program's technical state of affairs. The loss of the Government's capability to track progress and provide direction at a technical level has significantly degraded – if not completely eliminated – an important check-and-balance from the contractual relationship, and is probably at least partially responsible for the inability to identify and address integration problems early.

Contractor Impacts

The negative impacts of integration issues are not the exclusive domain of the Government customer. Development contractors, too, are affected in undesirable ways. In most cases, the contractor is penalized for any failure to meet schedule or performance requirements. The Government may have the ability to invoke financial penalties, write an unfavorable Contractor Performance Assessment Report[5], or take other punitive measures. These actions can adversely influence the contractor's ability to earn what it would consider to be an acceptable profit from the immediate effort; and, more damaging in the long run, it may develop a negative reputation which can impair its ability to win future contracts.

It should be apparent that the issues associated with integration management are not exclusively the Government's concern, but rather a shared problem, affecting both partners in the contractual relationship. From this perspective, both Government and Industry have a stake in it, and should be expected to commit resources to its ultimate resolution.

NTSA Technical Forum

The National Training and Simulation Association (NTSA) is the generally recognized central trade organization for the military training and simulation industry. As the NTSA describes its role, it "provides the training, simulation, related support systems and training services industries a focused, formal organization to represent and promote their business interests in the market place. The Association provides a forum to communicate the full capability and broad characteristics of all of the elements of training systems and services to include associated support services."[6]

Desiring to actively implement the communication forum as described by this mission statement, several NTSA member companies with representatives located in the vicinity of Wright-Patterson AFB took the initiative to establish a local NTSA chapter, to serve the needs of the Air Force training system acquisition community led by the 677th. Chartered in 2003, one stated objective of the NTSA Ohio Chapter is to "provide a bi-lateral, common, non-attribution, environment for industry and government to exchange ideas, information, and strategies to further meet the warfighter's training and simulation needs."[7]

The NTSA Ohio Chapter has implemented its mission through the conduct of several events. One of these is the Technical Forum, which facilitates open dialog among senior engineers on technical issues of widespread interest. Unlike the APBI, Tech Forums are not conducted on a set schedule, but rather when appropriate discussion topics are identified, either by the NTSA Ohio Chapter technical representative, or the 677 AESG Engineering office.

[4] Data retrieved from http://wwa.afpc.randolph.af.mil/demographics/nu_demos/AF%20STRENGTH.xls

[5] The CPAR is effectively the Government's "report card" on the contractor's performance. CPARs from all applicable contracts are maintained in a DoD-wide database, for reference in selecting contractors for new work.

[6] Retrieved from NTSA website, www.trainingsystems.org

[7] From the Bylaws of the NTSA Ohio Chapter, 5 Sep 2003.

Tech Forum topics are selected on the basis of their applicability across multiple TSPG programs, and the perceived interest level of the community at large. When a potential topic is identified, the 677th engages the NTSA Ohio Chapter for support in pulsing its industry base for interest, and ultimately to organize and execute the Tech Forum meeting. Thus, the Tech Forum is manifested through a collaborative effort between Government and Industry, and its conduct involves the full dedication of participants representing both sides of the community.

Since its initiation, the NTSA Tech Forum has addressed topics including the TSPG's implementation of the Revitalizing Systems Engineering initiative, and the definition of the Common Dataset Standard[8]. These meetings were well-received by their industry participants, and it was unanimously concluded that the discussions benefited both Government and Industry. It therefore seemed a natural deduction that the Tech Forum would provide an appropriate and effective means to address the Integration Management issue.

INTEGRATION MANAGEMENT TECH FORUM

This episode of the tech forum was convened to address the TSPG's issues being experienced with longer than planned hardware software integration efforts. The intended outcome of the meeting was for the TSPG to have a better understanding of the root causes of their integration problems, and to define some strategies for reducing risk in the integration process.

The forum was attended by 21 representatives from 9 companies plus the TSPG. For the most part, the representatives were systems engineers and/or engineering managers with a significant background in Air Force simulation development. The Air Force kicked off the meeting with a short discussion of their perception of the problem and the forum participants took it from there. The ensuing discussion broached a number of topic areas that can loosely be categorized as topics related to integration experience, requirements, risk management and design reviews. The structure of the meeting included a general discussion of the issue, followed by a group breakout session where a number of prefabricated questions were assigned for discussion. These questions included 1) "What are your integration and test horror stories?" 2) "What were the shortcomings of the integration process as currently implemented on your programs?" 3) "Does requirements definition play a part in this issue?" 4) "What are your integration and test success stories?" 5) "How can we manage integration risk more effectively?" 6) "Are the current engineering milestone reviews conducted with sufficient depth?" 7) "What issues have arisen as the result of greater integration of COTS/NDI components into training systems?" 8) "Should additional reviews be added during the long hiatus between CDR and TRR?" and 9) "What should the TSPG change to improve the situation?"

Following the discussion of its assigned topics, each group summarized and out-briefed its conclusions to the entire forum. The Government took this information and formulated its own action plan, which was further discussed in a wrap-up session the following morning.

Integration Experience

When reliving integration "horror stories," the issues identified by the participants were just what one might expect. Integration was wedged between a hard delivery schedule and either late design milestones, or just plain inadequate time allowed for the integration effort. Source data was not available as planned, and the Integrated Product Team could not come to terms on how to manage the data voids – whether to suspend those activities and resources that depended on the data, move on to other tasks until the data became available, or leave data dependent tasks in suspension while anticipating the miraculous appearance of the wayward information. Similar to the data issue was the lack of consistent subject matter expertise. A common theme throughout the twelve hours of discussion was that simulator programs come to depend upon their Subject Matter Experts (SMEs), who provide the operational knowledge necessary to fully understand system requirements. But this dependency is a double edged sword. Air Force personnel change assignments, or they may deploy, leaving critical gaps in the design teams data source. If alternate sources have not been developed, the team then must adapt to a replacement SME. While one might expect that the training and knowledge levels of SMEs will be similar, their experiences and their emphasis may not. Some programs have experienced a revolving door of SMEs, resulting in a frustrating integration and test effort. The lack of an upfront understanding of how the simulator would be used and what the user should expect has led to issues that did not appear until late in the integration phase. Whether documented in a Concept of Operations (ConOps), an Expectations Management Agreement (EMA) or fully elucidated throughout requirements discovery, the intended use of the trainer must be understood. It is important for

[8] This is a TSPG-developed standard to facilitate the reuse of terrain databases among different simulator systems.

the team to get beyond the specific function of the "bells and whistles," and look at the larger function of the equipment, how it fits in the curriculum, and what the receiving organization expects to see once the equipment is delivered.

When polled to determine how these issues were overcome, the discussion group responded that greater communication between users and design teams to define expectations and gain greater understanding of trainer utilization, i.e. through the ConOps and some sort of expectations agreement, were helpful. Designation of a single SME focal point, i.e. a "Golden Arm," helped to funnel and screen all SME input, and eliminated contradictions in requirements or understanding. Also, it was mentioned that SME involvement way up front in the program, even prior to the development of the Request For Proposals (RFPs), as well as their participation in Industry Days, would help potential bidders put the training requirements in perspective.

Participants in the Tech Forum generally agreed that programs succeed when there is early buy-off of requirements, data is available as early as System Requirements Review (SRR), there is shared responsibility between contractor and Government, and the allotted schedule is commensurate with the task at hand.

Requirements

Despite starting with different questions, all of the discussion groups invariably found their way to the requirements issues. The discussion group that specifically addressed the role of requirements in the integration process concluded that a more rigorous discussion of requirements at all reviews was necessary, to avoid requirements discovery during integration and test. It was agreed that requirements changes after Critical Design Review (CDR) played a major role in the genesis of integration problems. TSPG programs may need a more extensive requirements review process, including multiple detailed SRRs, versus the current practice of treating the SRR as a kick-off meeting for the program. A discussion immediately following contract award, to clarify how the device will be used, was recommended. Additionally, the development of a training ConOps, even as simple as training missions narratives, could help; and the earlier in the program the better. The issues of SME continuity and early involvement were raised again. The prevailing attitude was that it didn't seem to matter who the Government designated as the SME, as long as that person was acknowledged by all sides to be the single focal point for user input. It was recommended that an exchange program with industry be instituted to give the SMEs an understanding of industry's perspective on development issues. Apart from requirements issues, the frustration with obtaining source data was briefly addressed. From Industry's perspective, data collection seems to be getting harder, and the participants were all in favor of any Government action that could relieve this obstacle, such as the use of open source data.

Risk Management

During the discussion on risk management, it was suggested that integration risk can be managed more effectively by implementing such techniques as:

- gaining early feedback on system capabilities through early system level testing with attendant test discrepancies;
- designing-in customer capability assessments; and
- conducting frequent discussions on integration-related risks and risk management activities.

The Air Force practice of "big bang" capability, that is, all performance requirements met at initial fielding, contributes significantly toward integration complexity. Use of "spiral" or incremental capability may, in the long run, better support training need dates. Incrementally delivering capability to meet evolving curriculum priorities, and pushing off more complex capabilities until a stable platform is established and utilization of the device is understood, reduces risk of expanded integration and delivery schedule delays. Complexity can take on many forms, some of which have greater impact than others. Limiting the device quantity (i.e. 2-ship vs. 4-ship) does not necessarily take the heat off the integration team as much as the gradual introduction of complex threat interactions, weapons engagements and avionics modes. The desire to introduce complexity gradually is often overshadowed by the constraints inherent in the acquisition process, however. Rigid funding profiles as discussed earlier and existing training gaps tend to force the Government into procurement strategies that lack flexibility in the gradual deployment of capability. Additionally, the impression of "straight off the shelf" simulation capability subjugates the necessity for more conservative delivery profiles or lengthier integration phases.

The discussion on managing integration risk took the group on a discussion of "Agile" software development methodologies[9] and the suitability of this approach to Air Force simulator programs. The

[9]Information about Agile development may be retrieved from: http://www.agilealliance.org/

Agile development approach requires aggressive up-front planning to define increments, but the increments should be accomplished in small time periods – two to eight weeks - with the preference being toward two weeks each. Each increment ends with a customer evaluation that enables early feedback to the design team. Each increment is fully planned out and documented, but the increments are short enough that the team should not fear the possibility of having to throw an increment out and start over. Agile development is a cultural shift from the "waterfall" developments common in the defense industry. It comes complete with a manifesto and set of guiding principles (see http://agilemanifesto.org) that set the stage for close collaboration between customer and developer, allowing the software to evolve into a useable end product. Whether this approach would fit for Air Force simulator developments depends upon the needs of the team, but may be worth considering.

The earlier discussion on the loss of design control imposed by the flood of commercially available products was not lost on the forum participants. The common perception that Commercial-Off-the-Shelf (COTS) software enables immediate capability is true to some extent, but it comes with some baggage. Demonstrations of COTS products in an exhibition booth may come nowhere close to performance achievable in an embedded application, requiring considerably more (unplanned) integration effort, as well as dealing with customer expectations vs. the reality of the operating environment. Seemingly straightforward issues such as operating system and version upgrades can wreak havoc on systems that include numerous COTS packages.

When using COTS/Non-Developmental Item (NDI) software and equipment, the program teams should consider that the lifespan of such products is relatively short, and some strategy for technology refresh or replacement should be included in the program. Suppliers of critical capabilities should be included as an integral part of the contractor design team, with support tasks sufficiently funded. The Government might consider RFP requirements and criteria that address integration of COTS suppliers into the overall development. Taking advantage of the pre-established functionality and interfaces inherent in COTS components, Contractors should start integration of COTS from day one, to help refine requirements and identify issues prior to hardware software integration.

Design Reviews

The traditional and predominant means for the Air Force and contractors to interact during the course of a development is at the formal design reviews. As discussed earlier, there is plenty of guidance from "gone but not forgotten" military standards on what must be covered in the reviews. With thinned out staffs, compressed schedules and emphasis on commercially available components, fewer man-hours are being spent on the preparation, conduct, and follow-up associated with technical reviews as of late. Consequently, the quality of these reviews seems to have taken a downward turn, from the perspectives of both the Government and Contractor. The discussion group complained that there was a lack of appropriate Government participation in the reviews; not enough emphasis on requirements; reviews are being held at too high a level; a lot of the wrong people attend the reviews; and that it is difficult to qualitatively review a design via slideshow with a roomful of people. The group recommended smaller incremental reviews and performance assessments but with system level awareness; emphasis on well documented interfaces; and additional depth and rigor than is currently practiced.

Rather than serving as a program kickoff meeting, System Requirements Reviews should occur later in the program, particularly if a Training System Requirements Analysis (TSRA) is being conducted. The Forum supported incremental SRRs to allow for greater understanding of requirements. A flexible requirements development phase might actually codify and accommodate what has been experienced in most programs to date – stretched out requirements definition. This concept will eliminate the pressure to hurriedly define all requirements immediately at program initiation, and allow for a more deliberate approach which will improve the chances of getting them correct.

One idea posited by the TSPG was the potential insertion of a formal technical review during the hiatus between CDR and TRR. The group overwhelmingly agreed that there was not a need for an additional formal review between CDR and test in order to assess integration progress. Rather, the answer to the improvement of technical awareness seems to lie in the addition of mission oriented performance assessments; more SME interaction; and if needed, informal in-process reviews or technical interchange meetings, to address risk areas and for the customer to gain insight of the integration activities.

Wrap-up

There were a number of wrap up topics that, while not directly related to the integration management issues, still may be useful for the Government to

consider when planning an acquisition. There were several suggestions on types of contracts, fly-offs, alpha contracting, contract schedules, proposal development time, ramp up after contract award, etc. that, while related to this subject, are complex enough to merit the development of a different paper. There was some discussion on the effectiveness of the Air Force-hosted "Industry Days" that precede the release of an RFP. The group was adamant that there should be SME involvement as part of the RFP development, and SMEs should actively participate in the Industry Days. Communication with industry in the development of requirements, assessment of risk with regard to technologies, development schedule, and cost would be welcome.

The Air Force participants condensed the tech forum discussions into a set of action plans that may help to resolve integration issues on upcoming programs. One includes the establishment of a data plan on new programs to ensure a complete understanding by all parties on the availability and risk of source data. By establishing an early and in-depth understanding of the data issues, the team can appropriately plan their activities, and initiate a more comprehensive approach to work around data voids. The Air Force execution of design reviews will be evaluated, and specifically, the effectiveness of the System Requirements Review will be assessed, and possibly redefined. More emphasis on requirements throughout the program will be emphasized. Pre-RFP activities to illuminate requirements, through the more up-front use of Subject Matter Experts, development of program ConOps, and greater interaction (and candor) with industry will be evaluated and implemented as opportunities allow.

CONCLUSION & FOLLOW-UP

While planning for the tech forum, it was apparent that the short answer to simulator integration failures lies in effective systems engineering, and more specifically, in well defined, well understood, and well managed requirements. Still, the organizers felt it worthwhile to have this discussion with industry in order to focus the TSPG's energies in areas of improvement. The rigor with which the product teams manage the program requirements is, from the forum's perspective, inconsistent and not particularly well executed. In the near term, the TSPG will take an inward look at how System Requirements Reviews are scheduled, how closely success criteria are followed, and what corrective actions should be applied to future reviews. All engineering reviews will be scrutinized in order to ensure sufficient and appropriate support, and that requirements get the attention they deserve.

Requirements can be better communicated to the contractor by establishing an operational context through the use of a ConOps, and with consistent and available subject matter expertise. An informal action was taken to perform a census of programs that employ subject matter experts within the Simulator Systems Group, and to address shortfalls. Additionally, a discussion on the need for consistent SME support will be an agenda item at the annual All-Command Simulator Summit, which at the time of this writing, is planned to be held in October, 2008. Source data management plans will be established on emerging programs where it makes sense. A data plan format is being developed for use by the new KC-45 Tanker Training Team. The parsing of design and integration tasks into small, manageable chunks through extreme programming methods such as Agile or Scrum does not appear to be an easy transition for our industry, but shouldn't be discounted. One should not expect a TSPG RFP to explicitly solicit such development methodologies in open competitions. However, well established program teams that have a track record of collaboration and good SME support might consider such an approach, especially on modification efforts that must respond to a dynamic set of requirements and depend upon significant user input.

The interaction and candor of the Tech Forum participants was refreshing. While TSPG personnel might have come to the same conclusions during a Tuesday morning staff meeting, the industry input and perspective added credibility both to the problem and potential solutions. Unfortunately, experience with past forums has shown that while the TSPG may fully embrace the recommendations resulting from the meeting, it is sometimes difficult to implement them as quickly as desired, due to resource availability issues. It may therefore take some time, but eventually, industry will see results of the Tech Forum in RFPs and revised management techniques of existing programs. Industry may be able to expedite this process by exerting a "pull" to augment the TSPG's "push." By addressing the issue in a collaborative environment, the industry teams are also sensitized to the Air Force concern and can hopefully pull from the industry end to correct shortfalls where they see fit. As stated earlier in this paper, the integration management challenge is truly a shared Government-Industry problem, and its solution requires the participation of all stakeholders.

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