Soft Systems Analysis of the Unification of Test and Evaluation and Program Management: A Study of a Federal Aviation Administration’s Strategy

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ABSTRACT

The strategic objective of a test and evaluation (T&E) organization is to detect defects, which must be fixed prior to system deployment in order to meet the operational needs and achieve customer satisfaction. Numerous process improvement models have been developed and applied to address the issue of preventing “critical” defects getting to the field. However, the escalating costs of system deployment (especially in government programs), due to critical defects found in the field, continues to be a major quality issue affecting customer satisfaction. The failure of programs to meet quality and performance objectives has been shown to be related to inadequate planning and an ineffective program management strategy. Thus, for a T&E organization, the program management strategy can greatly influence overall performance goals. While current literature on T&E quality improvement focuses primarily on T&E technical tools, equipment, and processes, little to no attention has been paid to integrating program management into the T&E organization’s strategy. We intend to demonstrate in this paper that taking a holistic view of both T&E and program management (PM) activities using the tools of systems thinking can provide new insights to understand and create a more effective T&E execution strategy. Using Boardman’s Soft Systems Methodology and Systemigrams (systemic diagrams), we evaluate the unification of a Federal Aviation Administration’s T&E program management into its T&E strategy. The resultant Systemigram model represents the alignment of T&E with program management. We conclude with recommendations on how other organizations may modify their T&E execution strategy to achieve better customer satisfaction. © 2009 Wiley Periodicals, Inc. Syst Eng

Key words: program management; program strategy; soft systems methodology; test and evaluation

1. INTRODUCTION

The primary objective of a test and evaluation (T&E) organization is to use effective verification and validation methods to detect defects in a system to ensure that critical defects are fixed prior to deployment [Kasser, 2000; Nagano, 2008; Voetsch and Whitehead, 2008]. Although it is not possible to
eliminate all defects, “critical” defects (i.e., resulting in hazardous or unsafe conditions) are not acceptable when found in the field (i.e., after deployment). Defects found in deployed systems and the associated rework [Crosby, 1979; Deming, 1986; Juran and Godfrey, 1999] result in the failure of programs to meet their overall performance goals. As a result, many organizations are seeking alternative solutions to their current T&E management approach, because defects are cheaper to fix when they are found earlier rather than later in the systems development lifecycle [Castellano, 2006, 2007; FAA, 2006c; Franz and Shih, 1994; Rao, Timmaraju, and Weigert, 2005; Riemer, 2007; Rothman, 2002].

Efforts by most organizations to address these inadequacies have focused primarily on verification, validation, and testing (VV&T) tools, equipment, or T&E processes, with limited attention to the impact of the program management and T&E strategies, as each of these efforts seem to work in isolation [FAA, 2003, 2006c, 2007b; Hoppe and Engel, 2005; Hoppe, Engel, and Shachar, 2007; Lévárdy and Wilcox, 2004; Simmons, Hoppe, and Honour, 2007]. Consequently, much of the literature has focused on how to improve the quality of test products and processes [Adolph, DiPetto, and Seglie, 2008; Conwell et al., 2000; Hoppe and Engel, 2005; Hoppe, Engel, and Shachar, 2007; Lévárdy and Wilcox, 2004; Simmons, Hoppe, and Honour, 2007]. However, the literature has been limited in addressing how to effectively unify T&E and program management (PM) into a strategy to support quality systems deployment [Boardman, 1994]. Therefore, it is our premise that designing a T&E implementation strategy that is attuned with program management practices can still contain the cost of rework and ensure the timely delivery of quality systems.

We intend to demonstrate in this paper that taking a holistic view of both T&E and PM activities using the tools of systems thinking can give deeper insights into the coordination of T&E and PM. We contend that this perspective can help to create a more effective T&E execution approach that can result in quality system deployment while still achieving customer satisfaction. We will analyze the unification of T&E and PM strategies using a Soft Systems Methodology [Checkland, 2000] expressed through Systemigrams (i.e., Systemic Diagrams) [Boardman and Sauser, 2008] and articulated within a case study of the Federal Aviation Administration (FAA). As a modeling and analysis tool, Systemigrams can identify the key elements of a formal system model with attention to parts, relationships, and networks. We will present a Systemigram model that represents the unification of T&E with PM within the FAA, and articulate this model with recommendations on how these results may relate to other organizations and the practice of T&E [Boardman, 1995].

2. TEST AND EVALUATION AND PROGRAM MANAGEMENT

Relevant literature shows that lack of attention to program management issues can contribute to ineffectiveness of T&E and the inability of programs to achieve strategic intent, e.g., inadequate planning prior to test program implementation [Castellano, 2006, 2007; FAA, 2003, 2006c, 2007b; GAO, 2004; Riemer, 2007]; insufficient technical assumptions, improperly phased and competing budget priorities, insufficient risk assessment, unrealistic schedule expectations [Castellano, 2006, 2007, FAA, 2006c]; and inadequately defined roles, responsibilities, and authority [FAA, 2006c, Riemer, 2007].

The strategic intent of a T&E organization is to consistently support the program office in delivering quality products that meet the customer’s operational needs (effectiveness and suitability) within cost and schedule constraints. The need to balance these program constraints with the strategic intent of programs makes it imperative for T&E managers to clearly understand and adopt strategies that will facilitate their ability to achieve success. It is also important to understand the dependencies between program management and the technical T&E processes, which have great influence on the program outcome [PMI, 2000, 2004a]. Making efforts to achieve program success and business objectives starts from selecting the right strategy at program initiation and aligning it with the organizational strategic intent [Poli and Shenhar, 2003; Shenhar, 2004; Shenhar et al., 2005].

Research also shows that applying standard PM processes can increase the probability of a program achieving success [Kerzner, 2000; Milosevic and Patanakul, 2005; Toney and Powers, 1999]. This emphasizes the role of PM practitioners who provide a function that is central to the success of the T&E’s organizational objectives. The value of this PM can only be achieved if it is clearly established and embedded within the organization structure and business management processes [Hobbs and Aubry, 2007; Morris and Jamieson, 2005].

Notwithstanding its familiarity and value to program success, effective implementation of PM continues to be a challenge for most organizations [Sauser, Reilly, and Shenhar, 2009; Shenhar and Dvir, 2007]. For example, studies show that some organizations fail to meet quality, cost, and schedule performance goals because they do not adequately involve appropriate stakeholders in the system development process [Sutterfield, Friday-Stroud, and Shivers-Blackwell, 2006]. The traditional approach to resolving systems development problems has been to focus on technical processes [Sauser, 2006] with little attention to management solutions.

Another common approach is to implement process improvement initiatives that end up as multiple parallel processes and quick fixes. There is no evidence in the relevant literature that much attention has been paid to a systems approach to T&E and PM unification as a coordinated strategy. Quick fixes have not produced the sustainable strategy needed to deliver consistent quality systems and achieve customer satisfaction. Organizations with mature processes (institutionalized best practices) have been found to have a better chance of achieving consistent and predictable program success. Such organizations apply historical data and lessons learned to new programs to prevent past mistakes from being replicated [Carnegie Mellon, 2005; Conwell et al., 2000; PMI, 2000, 2004a, 2004b; Wysocki, 2004].

Various strategies for conducting T&E (V&V) as a means for achieving customer satisfaction through the delivery of systems with no critical defects in the field have been proposed in the extant literature. However, not much attention has been paid to the issue of integrating T&E and PM into a
holistic strategy. For example, Stem, Boito, and Younossi [2006], RAND Corporation, observed that T&E processes have become more integrated in an effort to eliminate unnecessary duplication between developmental (DT) and operational testing (OT) activities. In addition to emphasizing DT & OT integration, the RAND Corporation Fox et al. [2004] study relating to trends and cost of T&E focused on the integration of engineering-related methodologies and testing tools such as cross-platform integration, modeling and simulation, and facilities, as well as contractor and government DT and government OT personnel.

In a study that makes a case for testing early as a best practice, the GAO [2000] noted that testing is a critical source of information on the progress being made when a concept is being translated into a real world system that people use. The study also noted that evaluation is the analysis and translation of the test results and the lessons learned from them. Test results must be credible and properly evaluated to be usable and valuable throughout the system lifecycle process. The study which draws on the experience of industries such as Boeing and Intel focused on the maturity of technologies, maturity levels of products, and the relationship between program managers and testers. In a related study, the GAO and Sullivan [2008] conducted a study that was designed to draw on the systems engineering experience of the industry to improve the quality of government acquisition products. The data collection from about seven companies focused on requirements, design maturity, and oversight. Also the NRC, Nair, and Cohen [2006] proposed an evolutionary acquisition approach based on the fundamental premise that some costs and development delays that are attributable to the single-stage development process could be reduced by focusing on early verification and validation of systems from concept through development.

For most government organizations, the role of T&E as a systems engineering function is often performed by a separate organizational unit that serves the function of providing V&V support to the program offices throughout the systems acquisition process. While the T&E roles may vary throughout the systems acquisition process for these government organizations, there are still distinct similarities in their approaches. The most visible role of T&E is in developmental and operational testing which may alternatively obscure its role in requirements verification and design demonstration or simulation. The focus of this paper, however, is to provide a more systemic understanding of the roles of T&E and PM in order to address defects throughout the process. Defects caught prior to deployment are fixed by the developer and the government pays for any defects found after the system has been accepted for full deployment before defects are detected in a Firm Fixed Price contract. The role of T&E after the system is deployed (in-service management phase) is outside the scope of this paper. Further detail of the FAA as the case study will be provided later in this paper.

3. RESEARCH APPROACH

3.1. Soft Systems Methodology and Systemigrams

The process of taking a program from conception through requirements definition, system development, and integration and testing involves multiple stakeholders that have different perspectives of the process that can be influenced by improperly aligned strategies. The program office, the contractor, and the test organization may have a common goal to successfully deploy a system, but their respective approaches on how to achieve that goal may vary. To understand the multiperspective stakeholder view, a question arises: How do you encapsulate an understanding of the conceptual thinking in more than a document or the minds of many? Further, suppose that understanding is to be captured by graphical and textual means, but in a different manner from the many diagrams that strategic and planning documents contain, those classical types so familiar to the engineering and management community. Capturing these multiple perspectives is about systems realization, and diagrams of all kinds point to these systems, describing what they should look like and how they could be brought into existence. At a conceptual thinking level, the question that arises is: How can a diagram itself be a system and also convey the very complexities of a program?

One approach is Soft Systems Methodology (SSM), which has been utilized in various application areas. For example, Munro and Mingers [2002] showed that SSM is the most prevalent approach used with a combination of other methods in multimethodological practice for addressing the question of how a diagram itself can be a system and one that expresses the very complexities that burden a program. SSM is an inquiring process that establishes the ‘hard/soft’ distinction in systems thinking and encourages a broader thinking about
systems [Checkland, 1999: esp. 175, Fig. 9, 1981]. In recent research to examine the extent to which SSM has been adopted in practice and to classify the literature, Water, Schinkel, and Rozier [2007] highlighted some areas where SSM has been successfully applied. SSM methodology has been mostly used to gain better insight into a perceived problem situation and problems related to the management of change with respect to organizational design and strategy formation [Ledington and Donaldson, 1997; Mingers and Taylor, 1992]. Kreher [1994] found that SSM was most frequently applied to organizational issues relating to “participation, complexity, degree of involvement, learning, political aspects, interaction,” and the use of a consistent language for discussion.

While the application and variation of SSM may be an effective diagrammatic expression of conceptual thinking, it is limited in its expression of documented strategic intent (i.e., text). Diagrams are essentially networks having two elements—nodes and links. A third element is text, which after “decomposition” into parts and relationships can allow the assemblage in diagrammatic form. This is the origin of a derivative of SSM: Boardman’s Soft Systems Methodology (BSSM) and Systemigrams. Systemigrams were founded upon an exposure to systems thinking, experiences in systems engineering, and a growing awareness of the complexities of communicating and executing strategic intent [Boardman and Sauser, 2008]. The expressive abilities as both prose and diagram make Systemigrams a valuable tool for identifying the key perspectives in a system of interest. The pragmatic application of Systemigrams is established by virtue of its employment in a variety of interventions [Boardman, 1995, 2005].

Systemigrams are intended to operate at high levels, but it must be possible to “recover” the sense of the original conceptual thinking from the diagram. The diagram is a tool to elicit stakeholder inputs and to generate relevant new ideas in a way that linear reading of text does not. These new ideas often involve the actualization of the convergence of values derived from the structure of the graphical representation, giving a basis for the establishment of a common culture across the diverse team members. The recognized common culture provides a framework for improved cooperation that can result in an emergent leadership of the whole [Boardman, 1994].

The synergy of prose and pictures conveyed by Systemigrams can be found in the field of neurophysiology [Mazoyer et al., 2002; Paivio, 1991]; business and enterprise architecting [Boardman and Cole, 1996], program management and engineering process improvement modeling [Boardman, 1994; Clegg and Boardman, 1996a, 1996b, 1998]; business process improvement [Boardman and Cole, 1996]; and business process improvement [Blair, Boardman, and Sauser, 2007].

3.2. Methodology
We discussed the background to the BSSM as a systems thinking tool derived from Checkland’s SSM, which describes seven stages that start with defining the unstructured problem situation and then transition between the “real world” to “systems thinking” and back to the “real world” ending with an action to improve the problem situation. As a derivative of this approach, BSSM starts and ends in the same place but produces an instantiation of the situation in a Systemigram (see Fig. 1). Hence, we use the BSSM stages to investigate our problem situation of the unification of T&E and PM strategy while using the FAA William J. Hughes Technical Center’s (WJHTC) T&E and PM organizations to explicate the situation. We adapted the following seven phases of BSSM:

- **Stages 1 & 2** defined and expressed the problem situation. To accomplish this, structured questionnaires were developed and administered to randomly selected stakeholders (e.g., test practitioners, managers, and executives). The questionnaires were analyzed by observing the patterns [Cloutier and Verma, 2007] of current practices and by using domain knowledge of the T&E organization. Subsequently, structured, open-ended interviews with respondents were conducted to collect additional information. Triangulation of data was then used from surveys, interviews, and official government artifacts and documentation.

- **Stage 3** conceptualized the problem situation in structured text. The structured text was developed to identify the key elements of a unified T&E and PM model with attention to Systemigram requirements as the modeling and analysis tool.

- **Stage 4** created a Systemigram model as designed from the structured text to capture and represent the essence of the original conceptual thinking in the diagram.

- **Stage 5** used the Systemigram to compare the present reality with the conceptual model. As a human activity system, human behavior and willingness to adapt to change are critical to success in any effort that involves culture, as is the case with adopting a new strategy to improve T&E quality objectives. Therefore, the data collection, analysis, and model design emphasized stakeholders’ inputs and the discovery of relevant new ideas from the diagram. This led to the realization of the convergence of values as the basis for establishing a common culture across the diverse organizational stakeholders.

- **Stages 6 & 7** yielded a feasible model that will facilitate the processes necessary to achieve the quality objectives of a unified T&E and PM. The recognition of a common culture through this process provided a framework for improved cooperation between T&E and PM practices. The final model derived from this study was tailored to fit into the current FAA organizational culture with maximum support from the stakeholders.
4. ANALYSIS AND RESULTS

An analysis of the current T&E and PM strategies was performed by creating a structured definition of the problem situation, translating this into a Systemigram model, and then using it to present a new approach with the objective of improving the management of T&E programs to achieve customer’s satisfaction. The succeeding subsections provide the detailed analysis and results of this study.

4.1. Problem Situation (Unstructured and Expressed) Analysis

Program managers are faced with a critical paradoxical challenge to reduce cost and deliver quality systems that meet operational needs on time [Deephouse et al., 1995]. A T&E organization is not responsible for correcting critical defects found in systems while conducting verification and validation. Such defects are referred to the developer who is responsible for fixing the defects. This may not cost the program extra depending on the contract and provided the system has not been accepted for initial deployment. However, if the system has been accepted and it fails to meet the intended need, the T&E organization is typically blamed for not catching the critical defects before deployment. The reason for such failures may not have anything to do with the testing or evaluation processes but other factors beyond the control of the T&E organization. For example, the ripple effects of PM constraints, such as budget and schedule experienced [Lambert, Jennings, and Joshi, 2006] from concept development and requirements definition phases to verification and validation manifests in the T&E phase, which is the last activity prior to deployment in the system development lifecycle.

In a current state assessment of the FAA’s T&E strategy [FAA, 2006c], causes of critical defects found in the field were linked to systemic inadequacies in the T&E engineering and PM process. The study found that T&E personnel are not fully involved early in the acquisition process to help ensure feasible requirements specifications and planning for effective testing. Consequently, some requirements are either not verifiable or not enforceable. In addition, PM constraints often force T&E schedules to be compressed due to overall acquisition schedule delays or funding constraints. Another major risk to T&E is the direct impact of political constraints on PM in terms of funding and schedule.

The current state assessment of T&E program management practices revealed a lack of institutionalized processes needed for a disciplined approach to project or program management. Also, there was no established program management support infrastructure. The T&E program management practices were assessed against a combination of the Capability Maturity Model Integration (CMMI®), the Project Management Body of Knowledge (PMBOK), and the Organizational Project Management Maturity Model (OPM3). It is believed that implementing a program management support infrastructure will provide the capabilities for effective T&E-PM, similar to a program management support office [FAA, 2003, 2007b; Knutson, 1998, PMI®, 2004a, 2004b].
In addition, lack of alignment between T&E and PM processes compounded by program management constraints [Lambert, Jennings, and Joshi, 2006] contribute to systems quality issues after deployment [Castellano, 2006, 2007; FAA, 2003, 2007b; Riemer, 2007]. For instance, a compressed program schedule or a reduction in test funding could limit planned testing and lead to a higher probability of deploying a system with more critical defects. Apart from the exponentially higher cost of fixing critical defects found in the field compared to finding and fixing them early in the test phase, the ripple effects cause delay in full deployment and budget overruns. Customer satisfaction is not achieved when program managers cannot deliver products that meet the user’s operational needs, deliver late, exceed the budget, or fail to meet any other performance metrics.

Hence, any new strategy designed to improve the quality of systems must not only address the T&E technical issues, but also the program management process alignment and other constraints on testing. For example, a Test Standards Board (TSB) can be established to develop and institutionalize T&E engineering processes. To be effective, a program management supportive infrastructure to establish and coordinate institutionalized program management processes as a critical-enabling component of the overall T&E management strategy [FAA, 2003, 2006c, 2007b] will be needed. The unification of both units will help to address budget overruns and late deployments.

4.2. Structured Text Definition

Based on the problem situation discussed above, we created the following structured text with information obtained from reviewing relevant government artifacts, surveys and interviews with FAA stakeholders. The primary documents reviewed were recent reports on the current state assessment of program management practices at the FAA WJHTC [FAA, 2003, 2007b], a white paper on a study of T&E best practices [FAA, 2006c], and the proposal for a Program Office Implementation at the FAA WJHTC [FAA, 2004]. Other documents include the organizational chart for FAA WJHTC (2007b), the Air Traffic Organization (ATO) Strategy Map [FAA, 2006b], and the Operations Planning (ATO-P) Strategy Map [FAA, 2007a]:

The Structured Text (BSSM) or Root Definition (SSM):
The FAA WJHTC is developing a strategy to achieve world-class system integration and test capability that supports effective management of T&E programs to meet sponsors’ expectations and achieve customer satisfaction. The strategy must address the unification of T&E technical and program management processes to facilitate effective T&E management required to achieve program integrity, accountability, and the deployment of quality air traffic control (ATC) systems that make up the National Airspace System (NAS). The NAS is used to provide safe and efficient air transportation services to the aviation industry and the flying public. Test program sponsors’ expectations are characterized by performance metrics, such as on-time systems delivery, on budget, and meeting the operational requirements (quality).

The T&E strategy must address budget overruns and late systems deployments by programs that do not meet customer satisfaction. It must minimize critical defects found in deployed systems that cause rework leading to cost and schedule variances. Critical defects are caused by inadequate test and evaluation of systems as a consequence of the overall program management constraints.

The strategy must address the need for a unified supportive infrastructure, which comprises a TSB and a Program Management Excellence Center (PMEC). To be credible, the supportive infrastructure must, at a minimum, be staffed with qualified test engineers and program management experts. The TSB will develop and institutionalize technical T&E processes, while the PMEC will coordinate, develop, and institutionalize program management processes (foundational) to facilitate the technical processes. The PMEC must address training, quality management, configuration management, and project management support services that are essential for consistent and predictable program performance metrics to achieve customer satisfaction. The FAA system integration and test organization must ensure that the supportive infrastructure collaboratively provides the necessary services to accomplish the strategic objective of achieving customer satisfaction.

4.3. Systemigram Model Design and Storyboarding

The Systemigram presentation is only a model of something that belongs to the T&E organization under study, since we are presenting a fresh perspective on the existing T&E management strategy with some added value. It is not a reality, but an insightful commentary on reality that serves the purpose of shaping future reality with greater effect [Boardman, 2006]. Therefore, the Systemigram model is an abstraction of the real world T&E strategy that unifies T&E and PM into a human activity system. In consideration for a real-world application of the model developed, the data collection and model evaluation involved managers at various levels in the T&E organization. This was achieved through storyboarding, which provided the respondent an opportunity to see the T&E strategy from the authors’ viewpoint and attracting discussions based on the insight gained from both viewpoints. Additional information obtained from these discussions provided the basis for refinement to derive the final model shown in Figure 2, which was evaluated by the respondents through storyboarding as well.

In crafting the prose, designing the graphics, and presenting the storyboard of the model, the key requirement for a Systemigram is to be faithful to the text whence it came. It must be possible to “recover” the essence of the original conceptual thinking from the diagram by inspection. It further imposes certain rules (details are beyond the scope of this study) on crafting both the prose and diagram, which have been followed [Boardman and Sauser, 2008].

4.4. Test and Evaluation Program Management Model Description

A systemic diagram software application, SystemiTool, is used to create the diagram and a storyboard as a slide show with color-coding to facilitate the audience’s understanding.
and interaction. The Systemigram model in Figure 2 translates the conceptual thinking, described in the structured text (Sec. 4.2), into a conceptual model of graphics and prose. Systemigrams typically read from the top left to bottom right. Strand 1 represents the primary statement with nodes, links, and relationships that describe the model objectives. It starts from the model title node labeled *FAA System Integration and Test Organization*, which intends to achieve customer satisfaction through *Effective T&E Management* as indicated by the nodes ending at the *Customer Satisfaction* node. The four nodes within a containment node along the mainstay are the program sponsor’s expectation for providing safe and efficient air transportation services to achieve customer satisfaction.

Strand 2 represents the structured problem situation that a new T&E strategy is intended to resolve with a sustainable unification of T&E and PM processes, and test capability. It starts by describing the nodes and links that will support the model objective, which is to minimize *Critical Defects in Deployed Systems* that cause Rework leading to the *Performance Variance* node that results in the failure to meet *Customer Satisfaction*. The model shows that critical defects are caused by inadequate testing of systems due to *Program Management Constraints* as a major issue that impact the current T&E management strategy, which the proposed model intends to help resolve.

Strand 3 represents the conceptual approach to integrate processes with a view to achieving a holistic T&E program management system. The strand starts off with *T&E Management Supportive Infrastructure* enclosing two categories of professional experts that are required by the title node to facilitate resolving the problem situation. A *Credible TSB* requires test experts to develop Core Technical (i.e. T&E engineering) Processes. A *Credible PMEC* staffed with qualified Project Management Professionals (PMP®s) is also required to coordinate the program management processes that are necessary to facilitate institutionalizing a unified T&E program management system.

The Test Engineers and Managers node needs institutionalized processes and program management support services to implement effective T&E activities. The Credible PMEC node coordinates the Facilitating (Foundational) Processes that provide support services required for Effective Organizational Program Management. Some project processes [ISO/IEC, 2008] such as project planning, project assessment and control, decision management, risk management, measurement, and information management defined as best practices for developing systems are not identified separately in the model shown in Figure 2. They are detailed parts of the project management node. We believe that defining and institutionalizing program management processes will facilitate....
the ability of the T&E organization to address Program Management Constraints and satisfy the Test Program Performance Metrics, i.e., deliver on Time, Budget, and Quality [Milosevic and Patanakul, 2005]. This strand represents the proposed T&E supportive infrastructure that integrates program management with the engineering support infrastructures as part of the unified T&E management strategy.

The storyboarding helped the stakeholders to better understand and make valued contributions needed to refine and evaluate the final Systemigram model. The exchange of views helped the author gain greater insight to the stakeholders’ perspective of the proposed model, which was used as additional input to the final model.

5. DISCUSSION

In conducting this study, we included executive and senior management in the data collection since no new idea can succeed without their support. It was interesting to learn that executive and senior managers were mostly interested in achieving the capabilities available through adopting best practices in program management. However, there was no evidence that the same interest was extended to providing the necessary resources and support for implementing such best practices.

Our problem analysis found a lack of program management process unification and alignment to the T&E management strategy which is consistent with views expressed by Branch [1976], Castellano [2006, 2007], and Riemer [2007]. Although no systems approach to execution existed, we found some documented technical and program management processes, which formed our basis of analyzing the prevailing situation [FAA, 2003, 2006c, 2007b; GAO, Siggerud, and Conquest, 2004]. Therefore, using a Systemigram model to analyze the current situation, we propose a T&E management model that incorporates program management with T&E processes to achieve customer satisfaction. The unified supportive infrastructure approach identified in the model provides managers with institutionalized (standard) technical and program management tools needed to make conscious and deliberate trade-off decisions that impact T&E program performance metrics [Kerzner, 2003; Milosevic and Patanakul, 2005; PMI, 2004a, 2004b].

The authors believe that credible program management support as an integral part of the T&E management strategy with specific roles and responsibilities assigned will provide the capabilities to implement best practices in project and program management [Kerzner, 2000; Knutson, 1999; PMI, 2004a, 2004b] and T&E [Branch, 1976; Burnstein, Suwansart, and Carlson, 1996; Castellano, 2006, 2007; Riemer, 2007]. For a real-world implementation, executive and senior management need to provide appropriate skilled resources and moral support for the integrated support infrastructure to achieve effective coordination and credibility required for success [Hobbs and Aubry, 2007; Knutson, 1999]. The unified T&E-PM system will facilitate best practices in PM and T&E to help the organization in achieving customer satisfaction through effective T&E management.

5.1. Elements of a Unified T&E Program Management System

The primary objective of this paper is to determine the key elements for integrating T&E with program management into a unified human activity system and creating a model of the system. The BSSM is used as a tool to gain greater insight into the T&E execution approach and the key integration elements identified as described in the structured text is used to create a model strategy for executing T&E programs. It was not considered prudent to create an as-is model because it did not exist.

The application of BSSM provided a learning tool for gaining greater insight to the T&E strategy, which helped to gain greater understanding of the holistic view of T&E and PM, and the synergy that is derived from adopting this approach to managing T&E execution. This insight was achieved through data collection and analysis from the T&E organization which was presented to the case study organization as a Systemigram model through storyboarding. The initial model was used to generate further discussions with the respondents to obtain additional information, which we used to refine and generate the final model presented in Figure 2. This model is neither the organization’s as-is T&E strategy nor a reality but an abstraction of reality that serves the purpose of shaping future reality with greater effect.

With the new insight and understanding of a T&E program execution, it is our contention that the TSB and the PMEC constitute the core elements of a unified T&E program management system. In the proposed model, the TSB will be responsible for developing and managing the core technical T&E processes. With the right skills available, a PMEC will coordinate and collaboratively work with the TSB to provide the standard tools needed to conduct and manage test programs effectively [Bell and Eng, 2008; Chang and Rohall, 2008; Clegg and Boardman, 1996a]. We propose that adopting this holistic support infrastructure approach combined with continuous process improvement would lead to consistent and predictable delivery of quality output that achieves customer satisfaction. The PMEC element of the model is comprised of project management, configuration management, quality management, and training, which we found to be most critical to T&E execution. It is important to reiterate that some project processes [ISO/IEC, 2008] such as project planning, project assessment and control, decision management, risk management, measurement, and information management are included as project management. The critical success factors for this model implementation are discussed under managerial implications for the current organization under study.

5.2. Managerial Implications for the FAA

Based on the elements of a unified T&E-PM system identified in the proposed model, the FAA and similar government T&E organizations need to pay more attention to the role of PM, typified by PMEC in the model as a critical coordination hub to unify and facilitate group synergy. The PMEC in collaboration with the technical units of T&E will ensure that test programs have skilled resources to create and manage test
program schedules. Schedule must be seen in the context of the PMBOK to include time, resources, and cost integrated into the planning and control mechanism [PMI, 2004b]. While each test program team may retain a scheduler, it is more cost-effective to acquire and assign skilled schedulers from a central pool. In addition to the benefits derived from resource sharing, that approach will improve integrated schedules management and interprogram coordination. The PMEC should provide the necessary organizational program management expert support such as coaching and mentoring to T&E managers and personnel. This will enhance the competency and practical application of program management principles and techniques. Various authors on program management support office have discussed a number of factors that are needed to achieve success in executing a project office or program management support office (PMO) [Hobbs and Aubry, 2007; Kerzner, 2000; Knutson, 1998, 1999]. Our recommendation for implementing the model draws on the existing literature and insight to the T&E PM practices within the FAA. Therefore, we propose the following five factors as the most critical for a T&E organization:

Tools: An established PMEC can help to replace the current variety of incompatible software tools with an integrated program management system, which will facilitate test programs coordination throughout the program lifecycle. The system should include appropriate tools with the ability to integrate acquisition milestones with the T&E schedules. This can provide the test organization the necessary situational awareness to all programs that are coming through the acquisition process to the T&E environment. Such unification and visibility will make T&E planning and control more effective and valuable to the organization than when multiple tools that do not foster effective communication are in use by individual program units.

Training: The personnel implementing programs must have basic understanding of program management to be effective in adopting the processes for achieving the technical and programmatic objectives of the T&E organization. Providing software tools without the prerequisite training cannot achieve the desired improvement because any program management software tool is only as good as the competency of its users. Therefore, senior management should provide training support and incentives for PMEC personnel and T&E technical managers to acquire and maintain program management competency. This can be achieved through professional vendor training, followed by internal mentoring and support by certified Project Management Professionals (PMP®). In addition, using certified PMP®s in appropriate roles requiring that level of competency and effective recognition can motivate managers and personnel to seek training to improve their capabilities and acquire certification. At a minimum, the PMEC lead must maintain the continuing education requirements for certified PMP®s.

Professional Credibility: Both engineering and program management support infrastructures must maintain professional credibility of the experts by demonstrating value-added support to the organization. The experts should be unbiased technical and professional advisers to all stakeholders. The TSB needs to continuously research industry best practices in T&E to update current engineering processes. Similarly, the PMEC should continuously research industry best practices and update current program management and related processes.

Executive Leadership: Executive and senior management need to provide the leadership and direction for program management by emphasizing the value of knowledge sharing that comes from process unification. Managers with program management training and discipline are more likely to understand the value that a program management support infrastructure brings to the organization and provide the necessary support that will facilitate the implementation of the proposed model. The implication for the organization is that effective leadership and direction by a manager with adequate understanding of PM discipline is a prerequisite for success. Establishing the PMEC at a strategic level within the organizational structure allows for executive management visibility, oversight, and support. Such visibility will enhance the PMEC’s ability to develop and implement coordinated processes, and provide program management support with adequate authority and oversight.

Continuous Improvement: One of the motivations for this paper was a need to search for a new strategy for implementing T&E activities to ensure customer satisfaction. Therefore, the recommended model is not intended to be an end by itself but a means to add value to the current practices and as a base for future improvements. Every good process improvement initiative involves compliance, measurement, and continuous improvement, and above all organizational culture changes. Implementing institutionalized best practices as proposed in this model involves compliance to processes, measurement, and continuous improvement. Technical and program management processes should be monitored and updated to ensure currency with the dynamic technological environment of the system. This can be achieved through the holistic support model proposed.

5.3. Implications for T&E Program Management

While this study focused on the FAA as a case study, the model could be applied to most government organizations that conduct in-house systems verification and validation prior to deployments. It provides deeper insight into how stakeholders perceive the program management function and greater understanding of how to improve the current approach. The common understanding of T&E and PM responsibilities gained from this study will help program managers to create an environment of mutual trust that will facilitate achieving customer satisfaction [Bell and Eng, 2008; Chang and Rohall, 2008; Clegg and Boardman, 1996a, 1996b; Cole, Wolak, and Boardman, 1995]. Also, the study shows that the goal of preventing critical defect in the field would be
achieved by adopting a systems approach to T&E and PM with attention to early T&E involvement. The adoption of this model will necessitate changes in the current structure, culture, and approach to executing T&E programs. It will also need commitment and direction from executive leadership to achieve success. The research result presented here will stimulate future research in addition to providing a model that will enhance the ability of program managers to achieve customer satisfaction.

5.4. Limitation on Applicability of This Model

This study examined one government organization, which provided the basic information for developing this systems approach to managing T&E programs. It could be applied to other similar organizations within the US government that have a similar systems acquisition lifecycle process and organizational structure as the FAA. However, additional case studies will be necessary to expand the generalizability of the model to organizations outside this framework with significant confidence. Therefore, future research will target additional case study organizations to provide the necessary information that can be used to refine the current model recommended here. The result of any future research will provide additional practical benefits to the systems engineering field with special emphasis on T&E phase.

6. CONCLUSION

This study was intended to identify the key integration elements of a T&E management strategy that can provide greater insight and understanding to model an innovative systems approach for achieving customer satisfaction. Figure 2 demonstrates that the critical elements of a unified T&E-PM have been identified and presented in a unique Systemigram model that was validated with data from the FAA T&E organization. In conducting this study, we selected an FAA test organization as a system under observation to provide greater insight and understanding for modeling a new approach, which can be applied to modify the current strategic practice of T&E execution. The study explored the organization’s current T&E-PM strategy for executing test programs using systems thinking concepts, methodologies, and tools.

Previous research on T&E execution by Burnstein, Suwanassart, and Carlson [1996] and Burnstein [2003] proposed a test maturity model (TMM) to assess the maturity of a T&E process, which does not describe how to integrate program management with T&E execution. Also, Branch [1976] proposed a systems approach to T&E management that would provide greater insight to resource management. While this approach opens up a valuable discussion on the concepts and methodology of the systems approach to management, it does not provide an implementation approach. As an extension of this approach, our research addresses this gap through the holistic implementation approach that we are proposing.

By using BSSM, we collected data from government artifacts with special attention to the FAA WJHTC and performed analysis to structure the problem situation. We created the initial T&E-PM Systemigram model with the critical elements and links that exist as the relationships between T&E and program management/project processes. We then articulated this unique model to the T&E subject matter experts through storyboarding, which provided them deeper insight to the holistic view of our conceptual synergistic T&E-PM process model. Storyboarding is a simulation of the conceptual model created by the authors to the T&E subject matter experts to stimulate a discussion on the validity and value of the model. The ensuing discussion provided deeper insight to both the T&E environment and to the model. With this new insight on the part of both the authors and the subject matter experts, we were able to obtain additional information relating to the critical elements and links within the T&E organization. The additional information obtained was used to validate the elements and identify additional parts, wholes, and relationships, which were incorporated into the final synergistic T&E-PM process model. This model did not exist at the FAA or in extant literature.

Therefore, by analyzing the current state of practice within the FAA using Systemigrams, we are able to recommend a modified approach shown in Figure 2, which aligns T&E technical and program management processes to maximize the T&E management strategy. This systems approach-based recommendation will ensure that the solution to T&E problems does not continue to focus solely on improving technical methodologies as is most often the case, but also to pay more attention to the project processes or program management. Also, the holistic view of T&E execution has brought the need for early involvement of T&E in the systems acquisition lifecycle process to the attention of the case study organization. In addition, the recommendation demonstrates that the application of Systemigrams made it possible for us to gain the insight necessary to understanding the organization’s practices and to create a unique T&E-PM model.

The lessons learned from this study will provide a basis for further research at program levels within the current organization and at the enterprise level within the US government T&E organizations with similar systems acquisition processes. Future research at program levels can focus on the details in T&E-PM practices across programs in comparison with the enterprise level findings to derive a new model. Another area of study would be to evaluate how adopting the systems approach to T&E execution may impact customer satisfaction, which has not gained much attention in the extant literature.

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