A Leveraged Approach to Systems Management in a Highly Diversified Government Research and Development Environment

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Abstract— Minimizing a project’s risk has always been a challenging problem, especially in the face of numerous and often conflicting requirements. In addition, challenges arise that are dependent on the projects’ purpose and environment. The projects undertaken by the NASA Ames Research Center face these and many other challenges that are unique due to the institutional (Governmental), technological and scientific breadth (fundamental to applied research), and target application (space hardware/software, astrobiology, air transportation, and information technology) nature of their constraints. Thus, to address these challenges the Center formed a Systems Management Office (SMO) to improve and maintain competence in the areas of project management, systems engineering, and cost estimating. This paper describes an approach the SMO used that was based on leveraging a very small number of direct resources with existing Center expertise and best practices. This approach has enabled the SMO to balance its role between facilitation and consultation with independent assessment. The SMO’s lessons learned, best practices, and results stemming from this leveraged approach are summarized.

TABLE OF CONTENTS
1. INTRODUCTION .............................. 1
2. ARC SMO .................................. 2
3. ARC SMO FUNCTIONS ........................ 3
4. CONCLUSIONS ................................ 5
5. REFERENCES .................................. 6

1. INTRODUCTION

The programs and projects undertaken by the National Aeronautics and Space Administration (NASA) Ames Research Center (ARC) face many unique challenges due to their institutional (Governmental), technological and scientific breadth (fundamental to applied research), and target application (space hardware/software, astrobiology, air transportation, and information technology) constraints. Thus, to address these challenges and several Agency failure-related lessons learned, the Center formed a Systems Management Office (SMO) to improve and maintain competence in the areas of project management, systems engineering, and cost estimating. This paper describes an approach the SMO used that was based on leveraging a very small number of direct resources with existing Center expertise and best practices. This approach has enabled the SMO to balance its role between facilitation and consultation with independent assessment. This paper summarizes the background of the ARC SMO in context with the Agency and Center’s mission and provides details of the SMO’s approach, functions, and results.

NASA

NASA has always been known for its technological triumphs and scientific breakthroughs and has routinely achieved undertakings that have been too difficult or too risky for any other institution to accept. However, during the last half of the 1990’s, NASA experienced several unfortunate losses and setbacks, including the Mars Polar Lander and Climate Orbiter Spacecraft and faulty Shuttle wiring, respectively [1], [2]. While it is generally accepted that the success rate for inherently risky ventures is normally low to moderate, the Agency felt that their success rate should be higher. This was primarily due to several factors, including the discretionary funding nature of the Agency, the inspirational aspects of being stewards for the Nation’s intellectual capital, the Agency’s critical role in preserving and advancing the Nation’s well-being, and the catastrophic results (loss of life and high dollar one-of-a-kind resources) that could occur, should the Agency experience a loss. Additionally, it had been learned,
through various postmortem reviews, that several of the Agency’s losses were not caused by the failure of a single high risk technology or operation but rather by the failure of fundamental project management and systems engineering processes (such as the use of inconsistent units, which was a key factor leading to the Mars Climate Orbiter loss [1]). Therefore, the then NASA Administrator, Dan Goldin, challenged the Agency to improve these processes [3] and in 1999 established the concept of the SMO to foster this improvement. Herein Systems Management (SM) is defined to mean the integration of systems engineering and project management processes. The SMO’s basic mission is to ensure that the Agency’s project management and systems engineering processes are effective and efficient. However, since the Agency consists of 10 Field Centers, including the Jet Propulsion Laboratory, with varying missions (from research and development to operations, from atmospheric to space flight; from biological and physical sciences to information technology research) and resources, each Center was given the responsibility to implement an SMO appropriate to their environment. The details of how the ARC accomplished this are described in later sections; an overview of the ARC and its SMO is given next.

Ames Research Center

The ARC, which was established over 60 years ago, is located on 2,000 acres in the heart of the Silicon Valley at Moffett Field in California. The Center, which houses both world-renowned researchers and an array of state-of-the-art national facilities, has an annual budget of $800 million, and a workforce of 1400 civil servants. It is responsible for the following:

Technology Core Competencies
- Information Technology
- Biotechnology
- Nanotechnology
- Aerospace Operations

Scientific Core Competencies
- Astrophysics
- Fundamental Space Biology
- Computer Science

Unique Expertise Areas
- Rotorcraft/Runway Independent Aircraft
- Thermal Protection Systems

Specific programs that the Center has primary responsibility for are shown in Table 1.

Historically, ARC has performed well in meeting program objectives. However, there have been some cases of poor performance, where in hindsight, application of more rigorous systems management practices likely would have prevented the problems. For these reasons, the Center instituted an SMO based on process improvement rather than complete process development.

<table>
<thead>
<tr>
<th>Program</th>
<th>Focus</th>
</tr>
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<tbody>
<tr>
<td>Airspace Systems (AS)</td>
<td>Advanced air traffic management technologies</td>
</tr>
<tr>
<td>Computing, Networking and Information Technologies</td>
<td>High end computing, networking, and autonomous software</td>
</tr>
<tr>
<td>Engineering for Complex Systems (ECS)</td>
<td>Risk management, resilient software, and knowledge</td>
</tr>
<tr>
<td>Integrated Vehicle Health Monitoring (IVHM)</td>
<td>Monitoring and understanding vehicle performance</td>
</tr>
<tr>
<td>Stratospheric Observatory for Infrared Astronomy</td>
<td>747 aircraft-based 3 meter infrared telescope</td>
</tr>
<tr>
<td>Space Station Biological Research Project (SSBRP)</td>
<td>Biological research equipment for the International Space Station (ISS)</td>
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2. ARC SMO

The ARC SMO is focused on process improvement with respect to project management and systems engineering and was designed to be efficient and effective by using a small core team with Senior Management sponsorship (authority) to apply existing Center resources to address critical systems management processes. Thus, the operational philosophy used by the SMO is one of resource leveraging such that a relatively small amount of focused resources can significantly reduce the Center’s risk. Specifically, the operating characteristics of the ARC SMO are:

Efficiency
- Small core team
  - 2 permanent full time civil servants, 2 rotating temporary civil servants and 1 support contractor
  - Annual budget about 0.025% of Center’s
- Focused resources (project management, systems engineering, cost estimating)
- Center-wide applicable tool and training development
- Leveraging of best practices and lessons learned
- Short-term use of known experts (either internal or external to NASA)

Effectiveness
- Direct reporting to the Center Director and Senior Management sponsorship
- Membership on the Center’s Program Management Council (PMC)
- Use of recognized experts (either internal or external to NASA)
Formulation

Approval

Implementation

**Project Starter Kit

**P/P Plan Evaluations

**Lessons Learned

**SM Tools

**7120.5 Planning Template

**P/P Consultation

*Independent Assessments

**Training

*Ames PMC Reviews

Figure 1 - SMO Products and Services Related to Life Cycle

A NASA Program is delineated by a capital "P" and refers to an activity that has defined goals, objectives, requirements, and funding levels, and consisting of one or more projects (delineated by a lowercase "p").
by providing critique and recommendations from experts, and for senior management, by appraising them of the current P/p status and likelihood of success in fulfilling the P/p’s commitments. The IA teams typically are comprised of eight to twelve members selected based on appropriate expertise in technical areas, project management, systems engineering, cost estimating/analysis, acquisition, mission assurance, and risk management. The team members must be independent of the P/p and any performing organization that receives project funding. The reviews consist of a combination of document review, multi-day briefings, and interviews with key personnel. Assessment criteria are identified in NASA project management guidelines [4] and IA team judgment. Particular attention is given to verifying that P/p objectives are clear and there is flow down and decomposition of requirements vertically through the P/p. Assessment results are compiled and document the positive findings (best practices), weak areas, and recommendations for improvement. The results are presented to P/p (managing organization) and senior line (performing organization) management simultaneously for a complete airing of the issues. The entire assessment process typically takes four to six weeks. Afterwards, feedback is gathered from the P/p and line managers via a customer satisfaction survey to gauge the effectiveness of the assessment and note areas of potential improvement. To date all the assessment feedback has been positive.

Program/project Consultation

As mentioned previously, P/p that get off on the right foot with rigorous planning, proper tools, processes and qualified personnel have a higher degree of success. With this in mind, the SMO emphasizes interactions with projects early in formulation to establish a relationship where best practices, advice, and lessons learned from other P/p can be transferred and incorporated. A specific collection of resource information and recommended project management and systems engineering tools is our Project Starter Kit. Using the Kit, a nascent project team can readily access pertinent information on all aspects of project building such as NASA requirements and applicable tools to establish the way they will do business. Application of the information from the Kit, coupled with appropriate PM training, can be an effective way to bootstrap the P/p team and its processes.

The SMO has a growing library of P/p plans that are used to assist new project managers develop their own. The SMO has conducted Project Plan Evaluations where the plans have been evaluated and rated according to NASA requirements and accepted best practices in order to assist the inexperienced P/p managers in identifying which plans are the most relevant and highest quality. While the ratings are subjective, they still are useful by providing relative comparisons.

As is seen from the literature, commercial publications, and the World Wide Web, there is a plethora of project management and systems engineering tools commercially available and many others developed within NASA. It can be overwhelming for new P/p managers to sort through all the possibilities and select the optimal combination for their needs. The SMO has researched and compiled a database of leading SM Tools in use at ARC to narrow down the field and help focus the effort for the P/p manager. Information about the tools, their capabilities and local ARC contacts knowledgeable about the tool are provided. In addition, an expanded database of available tools not in use at ARC has also been compiled and is periodically updated to further communicate tool options.

A 7120.5 Planning Template has been developed to aid the P/p manager in assuring all the required steps, analyses, decision points, and deliverables throughout formulation are addressed. Based on NASA’s primary P/p management requirements guide NPG 7120.5 [4], the tool utilizes a Microsoft Project platform to delineate all the requirements and organizes and links them in a logical flow. Initial task durations are also provided based on complexity and likely resource loading for P/p just getting started. The tool is tailored by the P/p to fit their needs by adding or deleting tasks and changing dependencies and linkages.

Center and Agency Committee, Board, and PMC Support

The SMO plays an important role in SM policy development and implementation by continually participating in Center and Agency level working groups, boards, and committees. One such group, the ARC Program Management Council (PMC) which is comprised of senior management from the technical and service organizations, conducts regular reviews of the most significant P/ps at the Center. The SMO, in addition to participating on these reviews, helps the PMC establish which P/ps are reviewed, their frequency, and what performance information is required based on the P/p risk.

<table>
<thead>
<tr>
<th>Table 2. ARC SMO Functions</th>
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<tbody>
<tr>
<td><strong>Core Functions</strong> (Functions in common with all Agency SMOs)</td>
</tr>
<tr>
<td>Independent Assessments</td>
</tr>
<tr>
<td>Independent cost estimation &amp;/or analysis</td>
</tr>
<tr>
<td>Requirements Assessment</td>
</tr>
<tr>
<td>Program/project consultation</td>
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The leverage gained from these efforts is significant, since not only do they enable the SMO to apply authority on the Center Director's behalf but to also influence the policies by which the P/ps will be assessed.

Assess & Maintain Center Systems Engineering Core Capability

The SMO uses both informal and formal mechanisms to address the core SM capability of the Center. Informally, all the SMO led reviews in addition to those that are not, such as other NASA reviews, Capability Maturity Model Integrated (CMMI) assessments, and ISO audits, are used to assess the Center's weaknesses and strengths. Additionally, the SMO has a mutually supportive relationship with the Center training office and the Agency's Academy of Program and Project Leadership (APPL). Formally, the SMO has formed a SM Council that is responsible for guiding the SMO efforts to ensure that the Center's critical SM needs are being addressed. These assessments have led to the particular focuses shown in tables 1 and 2 and discussed in other sections of the paper.

Knowledge Sharing and Lessons Learned

While all NASA P/ps are required to document their lessons learned (LL), it is usually an activity that does not take place until the end of the PLC. This introduces two significant difficulties, namely the availability and memory retention of key personnel. Perhaps more importantly, all P/ps are required to apply the LL of past experiences to current activities in order to reduce risk. LL are documented and shared by various mechanisms, both formal (LL databases, processes, procedures, and policies) and informal (mentoring and meetings). However, the Agency's formal LL database was considered cumbersome and not very efficient at providing relevant LL with respect to SM, making it difficult for beginning P/ps to incorporate the LL into their risk reduction efforts. Therefore, the SMO initiated an activity to capture and disseminate Center specific SM LL. The SMO-led process consists of interviews structured around critical SM areas [4] with P/p personnel. The SMO facilitates the process by gathering relevant background P/p information and providing interviewees with LL samples and SM focus area topics, such that the actual interview's efficiency and effectiveness are maximized. The SMO drafts the LL according to the format used by the Agency LL system. The interviewees have complete control over the contents of the LL such that they feel able to speak freely. To date this activity has produced over 25 significant SM LL which have been posted to the SMO's website as well as to the Agency LL system. This approach has helped the P/ps remain in compliance with Agency LL policy both in using and in documenting LL, while conserving their own resources and reducing their risk.

Develop SM Tools, Techniques & Training

Perhaps the most leverage the SMO uses to enhance the overall SM capability of the Center is by providing carefully targeted tools and training. Equally important, this also allows the SMO to extend its rather small number of resources to reach a widespread community. Therefore, the SMO uses the experience gained from all the other functions shown in Table 2 in addition to others such as non-SMO led reviews and knowledge sharing forums to determine the types of tools and training that would provide the biggest payoff and address the most critical Center needs. A brief description of the various tools, some of which have been mentioned in other sections, and training provided by the SMO is shown in Table 3. It should be noted that the Center has other organizations and resources committed to training and that the SMO partners with these when appropriate. However, in certain cases the SMO has developed training to address a very specific, critical, and/or otherwise unavailable course to enhance those already existing.

<table>
<thead>
<tr>
<th>Tools &amp; Training</th>
<th>Description</th>
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<tbody>
<tr>
<td>Project Starter Kit</td>
<td>An initial set of tools, aids, information sources, and guides to support program/project execution</td>
</tr>
<tr>
<td>NPG 7120.5 Planning Template</td>
<td>Planning tool based on the NASA P/p life cycle (PLC)</td>
</tr>
<tr>
<td>SM Tool Database</td>
<td>Assessments, contact points and demos for computer based SM software tools</td>
</tr>
<tr>
<td>Microsoft Project</td>
<td>Customized training for the NASA PLC</td>
</tr>
<tr>
<td>Lessons Learned (LL) Database</td>
<td>SM LL from specific Center P/ps</td>
</tr>
<tr>
<td>Model Based Systems Engineering (MBSE)</td>
<td>Customized training for MBSE tools</td>
</tr>
<tr>
<td>SMO Website</td>
<td>Website containing links to all the SMO tools and services</td>
</tr>
</tbody>
</table>

4. CONCLUSIONS

As has been demonstrated by the NASA ARC SMO, it is possible to leverage a very small amount of resources to greatly enhance a much larger organization's P/p performance and risk reduction activities. The principal characteristics enabling this successful leveraging, when integrated, are: using existing best practices, focusing process enhancements and new developments with critical needs (especially with regard to the early stages of the PLC), staffing with few but highly competent people and augmenting them with other experts when necessary, and
having the support of the organization’s senior management. However, it should be noted that the SMO concept is not intended to replace traditional P/p support organizations such as quality and mission assurance, systems engineering, and training but to augment them. In addition, the requirement that an SMO be independent from the P/p’s must be preserved in order to maintain its broader perspective and objectivity. These last two points are critical in enabling the SMO to balance its role between facilitation and consultation with independent assessment.

REFERENCES


Donald R. Mendoza is currently assigned to the NASA Ames Research Center Systems Management Office (SMO), where he serves as a System Engineer and Risk Analyst. His current duties include: conducting independent research and development of risk management processes and application tools for operations, facility and program management; providing system safety analysis and hazard resolution for high-risk operations, facilities and activities; and conducting specialized systems engineering training for Ames Research Center personnel. He is also a member of the Center’s Engineering Process Group (EPG) charged with improving the processes and procedures used to research and develop software. Dr. Mendoza holds an M.S. and Ph.D. in Mechanical Engineering from the University of California at Berkeley.

Ronald Johnson has been Chief of the NASA Ames Research Center Systems Management Office (SMO) since its inception in 1999. Previously he was Branch Chief of the Aeronautical Facilities Branch managing engineering and maintenance of several large high speed and subsonic wind tunnels. He was the deputy Project Manager of the Unitary Plan Wind Tunnel Modernization Project that resulted in significantly improved productivity, reliability, and aerodynamic flow quality to transonic and supersonic tunnels. He received his bachelor’s degree in Mechanical Engineering from the University of California, Santa Barbara. He is a registered professional engineer in the state of California.