JPL's Approach for Helping Flight Project Managers Meet Today's Management Challenges[1,2]

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Abstract—All across NASA project managers are facing tough new challenges. NASA has imposed increased oversight and the number of projects at Centers such as JPL has exploded from a handful of large projects to a much greater number of smaller ones. Experienced personnel are retiring at increasing rates and younger, less experienced managers are being rapidly promoted up the ladder. Budgets are capped, competition among NASA Centers and Federally Funded Research and Development Centers (FFRDCs) has increased significantly and there is no longer any tolerance to cost overruns. On top of all this, implementation schedules have been reduced by 25 to 50% to reduce run-out costs, making it even more difficult to define requirements, validate heritage assumptions and make accurate cost estimates during the early phases of the life-cycle.

JPL's executive management, under the leadership of the Associate Director for Flight Projects and Mission Success, have attempted to meet these challenges by improving operations in five areas: (1) increased standardization, where it is judged to have significant benefit; (2) better balance and more effective partnering between projects and the line management; (3) increased infrastructure support; (4) improved management training; and (5) more effective review and oversight.

Areas for increased standardization included a uniform set of design rules, a Lab-wide development life cycle, new flight project practices and increased use of templates and engineering processes. Improved reliability and implementation efficiency were the two most important criteria that were applied when determining what to "standardize".

The design rules were based on JPL's 40 years of experience and, once documented, quickly gained acceptance. Standardizing the development lifecycle was more difficult but equally as important. JPL senior management was finding it difficult to track progress across a growing number of projects and, because there were no standards, project managers were having trouble defining all their deliverables and making accurate cost estimates. Standardization was needed in order to improve management oversight, project planning and efficiency. As a result, a Standard Lifecycle was developed that included lifecycle phases, major project reviews and NASA commitment milestones. Criteria for passing through the gates between phases and the products and maturity of products required at each gate were also agreed upon and added.

Adjustments also had to be made in the relative roles and responsibilities of projects and supporting line organizations. Until the early nineties JPL operated as a strong matrix organization. But at about that time, in order to reduce costs, "soft projectization" and "Faster, Better, Cheaper" were adopted. Under these new paradigms, individual projects were free to reengineer and invent new processes, thus effectively disenfranchising the line organizations. It became difficult to train personnel and maintain any "corporate memory. Checks and balances and communication between the projects and line organizations were being adversely affected.

These problems became obvious in the late 90s after several failures. JPL's response was to set minimum standards and begin providing projects with more institutional help. The most fundamental change was to create a new position, the Associate Director for Flight Projects and Mission Success. Under this Associate Director, a Project Support Office was created and, within it, a Planning Office, an Implementation Office, a Costing Office and a multidisciplinary Project Formulation Support Team. The Support Team works with projects and assists them during the early Formulation Phase, helping them tailor new NASA and institutional requirements, structure a WBS, develop project plans, create more accurate cost estimates and access available institutional data when needed. Additional assets

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developed to support projects included a project support website, a cost database with historical records, easier to use cost estimating tools, system models, engineering databases, planning templates, and libraries of previous project examples. Training programs were also revamped and a new Project Manager Course was initiated to familiarize project and system managers with the new requirements, processes and applicable lessons learned.

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1. INTRODUCTION

Flight project managers are facing tough new challenges all across NASA. Recent problems within both the manned and unmanned space programs have prompted NASA to impose increased oversight. At Centers such as JPL there has been an explosion from two or three larger projects to over forty smaller ones. Experienced personnel are retiring at increasing rates and younger, less experienced managers are being rapidly promoted up the ladder. Budgets are capped, competition among NASA Centers and Federally Funded Research and Development Centers has increased significantly, and sponsors are no longer willing to accept cost overruns. On top of all this, implementation schedules have been reduced by 25 to 50% to reduce run-out costs, making it more difficult to define requirements, validate heritage assumptions and make accurate cost estimates early in the life cycle.

These issues became critical to JPL in the late 90s after several failures. In response to the failure boards it was decided to increase the amount of institutional guidance and support provided to flight projects. New, minimum design and management standards would be generated and projects would be provided with additional infrastructure support to increase efficiency. The dominant theme was to avoid having projects "re-invent the wheel". In order to coordinate and manage this effort, the Lab created the new position of Associate Director for Flight Projects and Mission Success, responsible for overseeing the conduct of projects across the five JPL flight directorates. Under this Associate Director, a Project Support Office was created and, within it, a Planning Office, a Costing Office, an Engineering Office, and a Configuration Management Office.

JPL Approach

JPL has focused on five areas for improvement: (1) establishing top level rules; and increasing the standardization of routine management, engineering and mission assurance processes in areas where it will have significant benefit; (2) developing better balance and more effective partnering between the projects and the line management; (3) providing more infrastructure support to projects during the early Formulation Phase; (4) improving management training; and (5) providing more effective review and oversight.

2. INCREASED STANDARDIZATION

Following the Mars failures, the failure review boards noted that JPL lacked Laboratory -wide rules for implementing flight projects. These had existed up until the time of "Faster, Better, Cheaper" in the mid-nineties, but had become obsolete and fell into disuse. As NASA and JPL got more conservative in levying design, test and reliability requirements, the number of problems and cost overruns began to increase. It became obvious that increased rigor wasn't the total answer. Something also had to be done to increase efficiency. The potential areas for standardization included a set of design rules, a Lab-wide development life cycle, new flight project practices and increased use of templates and engineering processes. Improved reliability and implementation efficiency were the two most important criteria that were applied when determining what to "standardize".

One of the first initiatives was to define a set of principles to guide the spacecraft development process. The scope of these principles included system design margins for mass, power, memory and processor speed, spacecraft grounding and interface requirements, electronic parts design criteria, software design rules, environmental test requirements and flight operations and ground system design. These principles drew heavily from JPL experience over the last 40 years and became commonly known as the "Design Principles[1]". They are not viewed as requirements but as a recommended baseline from which projects can deviate if they have valid rationale. These design principles were discusses and debated in an extended series of meetings with "graybeards" and project managers over a year's time until a broad consensus was reached. Projects can request deviations in the Design Principles by completing and submitting a compliance matrix as an appendix to the Project Implementation Plan (PIP). The Design Principles have been in place for three

years, and are well accepted by Headquarters and our industrial partners.

The next attempt was to increase the standardization of the flight project development lifecycle. There was no common lifecycle in use across JPL Program Offices. Lifecycle phases and major reviews were referred to by different names and there was little documentation or agreement on what it took to pass a review or move successfully through a lifecycle gate. This was exacerbated by the fact that NASA Code S and Code Y used different interpretations of a NASA Lifecycle that included different review milestones. Code Y adopted a lifecycle that included a Formulation and an Implementation Phase. Code S still preferred a lifecycle that contained Phases A, B, C, D and E. JPL senior management were finding it difficult to track progress across a growing number of projects and, because of the lack of standards, project managers were having trouble defining their deliverables, making accurate cost estimates and meeting the expectations of their management. Increased standardization was needed in order to improve institutional oversight, project planning and efficiency. As a result, a decision was made to develop a lifecycle that would be compatible with the NASA Lifecycles but used across all of JPL. It would include lifecycle phases, major project reviews and NASA commitment milestones. Criteria for passing through the gates between phases and the required products and maturity of products at each gate were also defined.

Again, the approach was to develop a consensus among all the principle stakeholders. Much of the discussion focused on the minimum set of required reviews and on the maturity of the products required at each gate. The gate products are documented in a five-page matrix that includes twenty-four planning products, seven costing products and sixty-four engineering products. Convergence among the stakeholders was finally reached and today the JPL Project Life Cycle, depicted in Figure 1, and companion Gate Product List are routinely used by flight projects.

It was also felt that more "standardization" was needed in the way management, engineering and mission assurance practices were implemented. Projects were following different approaches and, in order to meet very tight cost caps, were sometimes taking imprudent risks in system engineering, mission assurance and test validation. It was difficult under these circumstances to develop databases and templates, pass on lesson learned or improve process efficiency. Mission reliability and cost effectiveness were beginning to suffer. Addressing this situation, a decision was made to establish a set of top-level, institutional rules, called Flight Project Practices. These rules would be followed by all projects unless a waiver was granted by a Program Director. Similar to the process for generating the Design Principles, the Flight Project Practices were derived from successful experiences over the last 40 years, but with significant additional effort expended to incorporate new requirements from NASA and to increase cost effectiveness.

The process for defining the Practices took more than a year and was highly interactive with management and technical personnel at the Lab. Peer Review groups were established in each area and recommendations were approved by a review board of project, division and program managers. The results are an 80-page document with 23 management practices, 18 engineering practices and 8 mission assurance practices. All NASA and institutional requirements that are relevant to flight projects are incorporated. The Flight Project Practices also act as a portal to lower level processes and procedures. These latter are currently being reviewed for compliance and updated at the Group level (10 –20 personnel per group). A flight project practice compliance matrix summarizing the requirements has been developed to assist project managers document their compliance and obtain approval for requested deviations.

Other areas lending themselves to standardization were those that tended to be routine from project to project but could be improved in efficiency through the use of templates, libraries of previous project examples and databases. Examples included project planning, requirements definition, cost reporting and configuration management.

In order to facilitate project planning and cost reporting a standard, product-oriented, "tailorable" work breakdown structure (WBS) was developed. This standard WBS helped assure that projects would include all relevant activities in their plans and cost estimates. This "standard" WBS was a difficult challenge for the JPL culture to accept. Project managers feared that it would overly constrain them on how they organized their projects. However it was decided that project organizational structures could deviate from the WBS providing they remained compatible with it, so this has not been the case. The Standard WBS has now been accepted by project managers and has proven quite beneficial during proposal activities.

Adopting a standard WBS also allowed the development of a web-based historical cost database that could be used to archive costs and improve the accuracy of cost models and future project grass roots estimates. Improving the accuracy of cost estimates has been a major JPL challenge over the last five years. One of the contributing factors is that our subsystem cost data has been maintained in a variety of non-electronic media not widely available or usable. The Historical Cost Database will institutionalize the data archive and make it available to proposal teams,

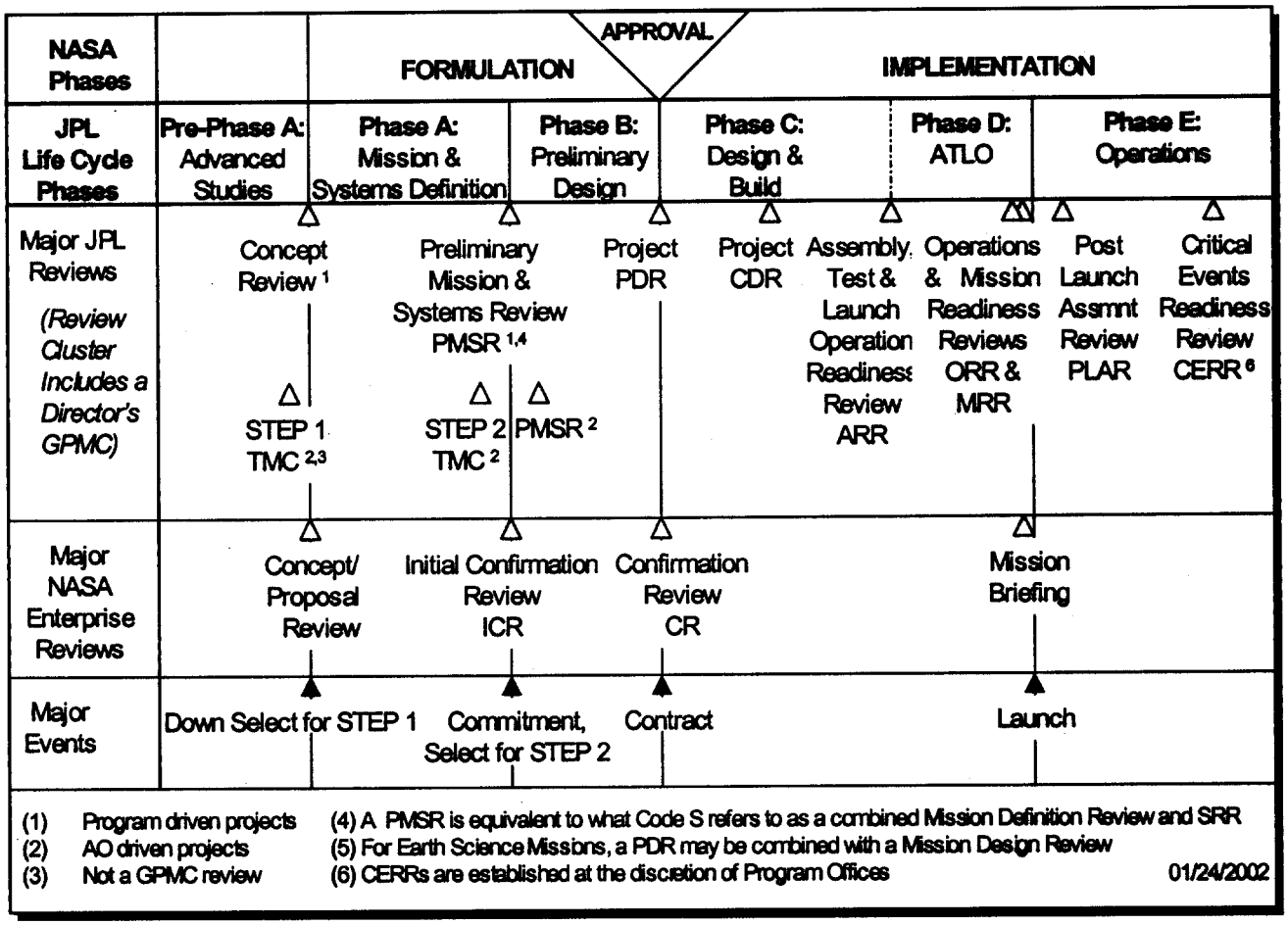

FIGURE 1- JPL Project Life Cycle

concept development teams, cost modelers, projects and upper management. The Database is nearly complete and will become operational at the beginning of FY04.

Lastly increased standardization made it easier to document and incorporate JPL and NASA lessons learned into institutional processes, to structure and identify meaningful training programs, and to assess project risks and implementation status.

3. Stronger Partnership between the Projects and Line Management

The second area identified for improvement was the relationship between the projects and line management. To fully utilize all of the available institutional resources responsibilities had to be realigned. During the four

decades through the early nineties JPL operated as a matrix organization with the line organizations responsible for delivering the products. Budget negotiations between the project and line were perceived to be a major cost driver. Because of this a new management paradigm called "soft projectization" was adopted. This strengthened the role of the projects and relegated the line organizations to recruiting, training and limited oversight. At about that time projects were also being encouraged to reengineer and invent new processes. It became difficult to train personnel when every project was inventing new methods. Because much of the institutional memory resided in the line organization, lessons learned in past years were being forgotten and mistakes were being repeated. The system of checks and balances was no longer functioning and lines of communication were breaking down. There were innovations that saved money but many incurred unacceptable risks. Overall, JPL's effectiveness was hurt.

To counter these trends JPL reestablished accountability within the Line Organizations. Section managers were assigned responsibility to peer review proposals, chair subsystem reviews, and approve implementation plans and budgets. They were also requested to participate in monthly and quarterly progress reviews and are now generally accepted as full partners.

4. Increased Infrastructure Support

A third area targeted for improvement was the institutional support to projects. In response to the increasing number of requirements being levied on projects by NASA and JPL, several organizational changes were made. The two most fundamental were the creation of the Associate Director for Flight Projects and Mission Success and the creation of the Project Support Office.

Within the Project Support Office a Project Formulation Team was set up to support new projects through the early Formulation Phase. The team is comprised of specialists in planning, system engineering, software, cost estimation, scheduling, acquisition and launch vehicle support. A representative is assigned to each new project to act as an interface. Help is provided in accessing, understanding and tailoring NASA and JPL requirements, templates and examples. In addition a project support website backed by a library and database have been established to guide project personnel. The website is designed to help the project manager understand the NASA and JPL requirements, lifecycle, review requirements and products required at each gate. It provides templates, examples and guidance in areas such as planning, WBS, cost estimation, scheduling, and in engineering disciplines such as mission design, system engineering, software engineering, configuration management, CAE tools and much more.

5. Improved Project Training

Because of the number of new requirements and the large number of younger personnel being asked to take on responsible management roles it became obvious that the training programs needed to be revamped. A Project Manager Course was started to familiarize the project and system managers with NASA and JPL institutional requirements, practices, lessons learned and resources available for help. As mentioned above, the increased standardization allowed a degree of focus that would have otherwise been impossible. The result is a highly rated course held for 5 days at a remote site combining presentations, panels and guest speakers. The topics are presented in an order that aligns with the JPL Life cycle and include such subjects as what is new in the Washington environment, a project manager responsibilities in the for public outreach and legal environments, interactions with the science community, mission design, life cycle gate products, review agenda, system engineering, software design, procurement, cost estimation and control, configuration management, integration and test, launch and mission operations. It focuses on what needs to be done, why, where to go for help, and lessons learned about what works and what doesn't. Over 170 students have attended.

Another course recently initiated is a hands-on course for cognizant engineers and subsystem managers on planning, cost estimation and control. Students are presented a case study in which they plan the task, develop a linked schedule, adapt and populate the JPL standard WBS, estimate costs and assess earned value.

Additional management courses are offered for subsystem managers, subsystem cognizant engineers and contract technical managers.

6. More Effective Review and Oversight

Lastly, because of the JPL Lifecycle and standard set of reviews and gate products, upper management's oversight of proposals and projects was improved. Concerns over potential cost overruns had prompted more rigor by upper management in review of Step 2 Proposals. Many issues were being uncovered late in the proposal process without adequate time to address solutions. Earlier attention to potential cost issues was needed. In addition, the objectives of several of the reviews were beginning to overlap and there often wasn't enough time to adequately address review board concerns. As a result the proposal process review objectives, content and review board membership were reviewed and updated to improve coordination and the time available for incorporating comments.

In addition to the improvements in the proposal review process, upper management oversight of projects was greatly facilitated by the increased standardization of the life cycle, reviews and requirements. Review boards up to and including the Executive Council began reviewing project status against the required Gate Products, Flight Project Practices and Design Principles. Cost risk metrics were identified and applied to assess reserve posture. Risks would still be taken but they were measured risks. The oversight and decision-making processes were much improved.

7. CURRENT STATUS

Most of the above innovations have been fully incorporated into the way of doing business. The Life Cycle, Flight Project Practice, Standard WBS, Design Principles and Gate Products are accepted by Lab personnel as baseline. The Formulation Team supports over twenty-five Step 2 proposal teams and Phase A / B projects at any given time. Overlap between the Design Principles and Flight Project Practices have been addressed. Training programs are fully aligned with the new approaches. Projects, line organizations and upper management all understand what is expected at each of the various Life Cycle Gates. New project managers appreciate knowing in advance what is expected of them, know where to go for help if it is needed, and eagerly access the Project Support Website for requirements, templates and examples.

8. FUTURE

Feedback is being collected from the JPL projects and line organizations, our industrial partners and NASA. The Project Support Office is monitoring the implementation of the new practices and processes and taking the initiative to help projects and fix process problems when they are uncovered. Efforts are being made to provide tailoring guidelines for use by smaller projects. Criteria to be used by the Executive Council for recommending whether proposals and projects pass through Life Cycle Gates are being validated. Development of a historic cost databases structured around the JPL standard WBS will be completed by the end of the fiscal year and improved cost estimation tools and cost risk identification processes will be piloted and adopted. Cost reserve requirements are being reviewed based on recent project history and correlated with project specific attributes that can be identified by the end of Phase A. Detailed implementation processes are being upgraded, coordinated across line organizations and piloted. JPL will be able to capture its institutional heritage and memory without having to depend on a dwindling number of "graybeards". JPL is moving towards a future that will enforce rigor in areas where it is needed such as cost estimation, materials processing and parts design, but will allow creativity in science investigation, mission and system design.

9. CONCLUSIONS

Improvements in project management at JPL over the last three years have benefited the projects, programs and institution as a whole. New design and implementation guidelines, templates and support structures such as the Project Support Office, Formulation Support Team, project support website, templates, examples and historical cost database have increased efficiency, cost estimation accuracy and probability of mission success. Training programs and review pass/ fail criteria have been designed around the new standards and projects are getting the institutional help they require in order to get off to an efficient start and tailor their requirements to their unique project needs during Phase A and early Phase B.

BIOGRAPHY

Jeff Leising has had thirty-six years experience at JPL in various engineering, project and program management positions. He has worked on such projects as Surveyor, the Mariner missions to Mars, Venus and Mercury, and the Voyager and Cassini missions to the outer planets. He is currently the manager of the Project Planning Office supporting over twenty-five formulation phase projects and proposals. His primary background is in propulsion, system engineering and management. He graduated from Cornell University with a Bachelors and Masters in Mechanical Engineering.