Project-Line Interaction

Implementing Projects in JPL's Matrix

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Abstract—Matrix structures are common in highly technical organizations. The matrix structure is most defined by this characteristic: that most people in the enterprise have two bosses. One resides in the programmatic organizations that make direct contact with the enterprise's customers, *and organize and manage work to meet customer expectations.* The other boss lives in the line organizations, functional and service organizations that *provide the enterprise with capability to accomplish the work.*

The JPL enterprise is organized as a matrix because that structure can optimize retention and development of knowledge, as well as flexibility in applying that knowledge to the programs and projects JPL conducts. A matrix is usually considered most effective for accomplishing current project and technology development work while maintaining and developing institutional capability for the future.

Can programmatic and line organizations really work *interdependently,* to accomplish their work as a community? Does the matrix produce a culture in which individuals take personal responsibility for both immediate mission success and long-term growth? What is the secret to making a matrix enterprise actually work?

This paper will consider those questions, and propose that developing an effective project-line partnership demands primary attention to personal interactions among people. Many potential problems can be addressed by careful definition of roles, responsibilities, and work processes for both parts of the matrix -- and by deliberate and clear communication between project and line organizations and individuals.

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1. INTRODUCTION

A matrix enterprise can be easily distinguished by one important characteristic: everyone who works within the "matrix" has more than one boss. This fact makes many managers (especially American managers) uncomfortable, but it is the distinction of matrix structures; and is reflected in the typical matrix organization chart, which draws more attention to internal organizational interfaces than to the traditional managerial hierarchy. Managing those interfaces and making the structure work is a challenge, and the subject of this paper. Meeting the challenge requires creative and persistent effort, but the rewards to the organization and its members can be very great: longevity, stimulation, personal development, and many other motivating factors. I will use NASA/Jet Propulsion Laboratory as an example throughout, because it is a handy sample of the structure, the challenges, the problems and the successes.

The term "matrix" developed along with the American aerospace industry, but there are many other organizations that share the structure, from consumer goods companies to service organizations and others. A matrix organizational chart (see Figure 1 on the next page) shows, on one axis, the organizations that come in direct contact with the enterprise's customers, and organize and manage work to meet customer expectations. At JPL these programmatic directorates (on the vertical axis) initiate and manage the *projects* and *tasks* that provide products and services to JPL's customers (sponsors). Notice that the programmatic organizations at JPL are focused on specific types of space science activities, from Mars and solar system exploration, to Earth science and technology development.

The other (horizontal) axis shows the functional and service organizations that *provide institutional capability to accomplish the work.* At JPL these *line* organizations perform technical and administrative or business functions. In the short term, the line must meet project or task commitments, by executing the required development of a mission, a scientific instrument, or a new technological advance. In the long term, line organizations must develop and maintain the institutional capability for future work. They do this by training and mentoring people; developing new tools, facilities and technologies; and improving the

work processes for project implementation.

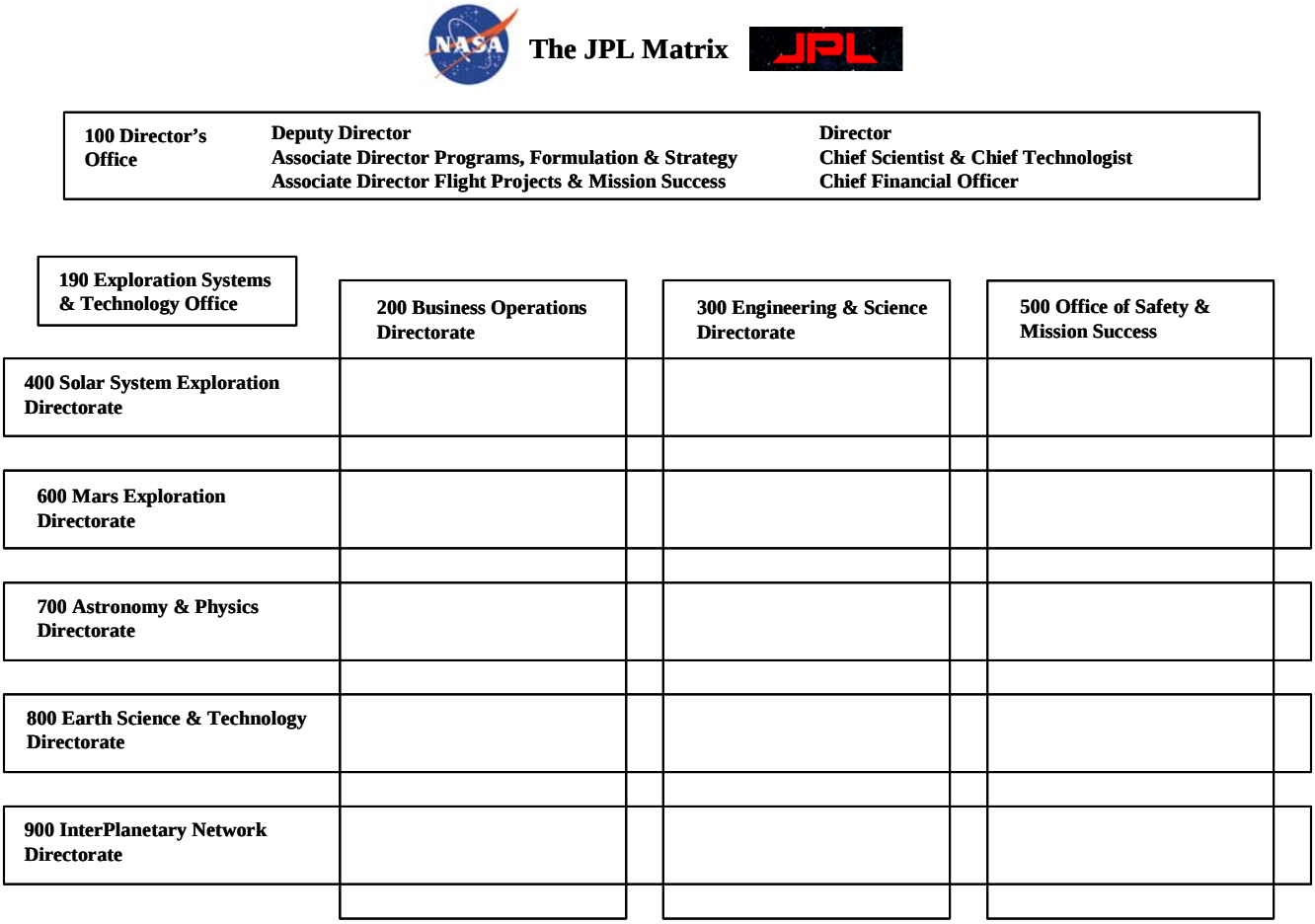

Figure 1 - The JPL Matrix

2. ORGANIZATIONAL ROLES

Matrix structures are common in highly technical organizations. They have some advantages over strictly-project and strictly-functional structures -- and some disadvantages, too.

In a *project-based* enterprise, projects are the primary unit of employment, formed to accomplish specific work or to develop and operate specific programs for an established life cycle. Project-based enterprises are vulnerable to attrition, especially when projects are drawing to a close or when programs are affected by funding changes. Individual team members seek to preserve their employment, and will leave projects before completion, to find continuing work. Also, the scope of project teams is limited to the product they are developing, making a long-term view very difficult for project management. However, project-based organizations have some advantages too. The project groups are usually flexible and can usually make decisions and changes very quickly, because of their unified focus on the product, their tight communication interfaces, and their control over the entire product development life cycle.

In a *functional* enterprise, different groups specialize in different parts of the product development process, and products are typically passed from group to group as they move through the development life cycle. Functional enterprises support the development and growth of highly skilled specialists, who are focused on specific operations or bodies of knowledge. But a disadvantage is that functional organizations frequently do not support the development of generalists or synthesists who are capable (or interested) in tying together functional work into a finished operative project; and functional organizations have difficulty putting together effective, interdisciplinary project teams.

In a matrix enterprise, the project management dimension is added to the functional dimension. Specialized functional groups still exist, but the project managers guide products through their development life cycle, taking responsibility for internal communication. The disadvantage of matrix organizations is the possibility of conflict between project management and functional groups management. This potential problem can be addressed by a careful definition of roles, responsibilities, and work processes for both parts of the matrix -- and by deliberate and clear communication between project and line organizations. (Within JPL's

matrix organization, there is a line division specializing in aspects and various applications of the systems engineering discipline, at all levels of program and project work. The "synthesists" are usually developed here for at least some part of their careers, and most project and program management personnel have spent part of their careers in this line organization as well.)

At JPL, project and program organizations are generally responsible for:

- Establishing and maintaining project and program management processes;
- Acquiring work, and developing the flow-down of requirements for work to be done;
- Obtaining the funding necessary to do the work;
- Managing project work, project cost, and project quality; and
- Delivering an integrated product that completes and meets the customer requirements.

JPL line organizations are generally responsible for:

- Establishing and maintaining engineering and business work processes and procedures;
- Planning and execution of technical activities, and cost and quality management, during project Formulation and Implementation;
- Coordinating technical and business activities for multiple ongoing projects;
- Transferring knowledge among projects, and managing knowledge for future projects; and
- Providing expert staff, quality facilities, and discipline-related guidance.

(Line organizations at JPL establish relationships with external commercial organizations for the purpose of sub-contracting work and/or providing work force; this is a part of their responsibility for providing work capability, since physically fabricating so many projects in-house is not possible.)

3. Work Agreements and Processes

For a matrix to be effective, project and line management must agree to accomplish the work together. At JPL, they describe and formalize their partnership in approved Work Agreements (WA's) – these should form the basis for the agreement between JPL and NASA to implement the project.

A Work Agreement is a plan that must be prepared for the *cost account level* of work activity in a project's Work Breakdown Structure (WBS). The WA identifies work to be performed, and defines the scope, schedule, and cost of that work, based on the expected effort required. A Work Agreement is a *contract* between project and line that describes how each will use their established *processes* to produce the project's unique product. The signature of a project manager should indicate that the WA defines the required scope of work accurately, and describes constraints and uncertainty (risks) that may affect work. The concurring signature of a line manager should indicate understanding and agreement with the WA; it is a commitment by the line organization to provide the required resources and capability, and to perform the work using the appropriate work *processes*.

Processes are linked sets of work activities, initiated by the needs of a customer and resulting in an output that satisfies the customer's needs. JPL project-related processes capture the expertise and best practices of over 40 years of space exploration; and they are continually being improved by people who use them. These processes exist to guide project teams and maximize their likelihood of success. JPL's processes are documented so they can be learned and practiced consistently and persistently, across organizational boundaries, throughout the project life cycle.

Project organizations are the interface with outside customers, so projects and programs "own" and apply the JPL processes for *acquiring, planning and managing* project work. Line organizations provide the technical expertise and institutional infrastructure to accomplish the work, and they "own" and apply the processes for *implementing* project work. Remember that processes are by nature cross-organizational, and people from many organizations may participate in any given process. The requirements and procedures associated with the use of JPL's processes are developed by the process owners and recorded in the *JPL Rules!* on-line data base to help maintain JPL's ISO 9001 compliance. Process owners are also charged with helping members of the JPL community learn to use their processes effectively, through training and education.

4. Individual Roles

Effective partnership in a matrix enterprise requires that individuals fulfill various roles that are required for the accomplishment of the work. At JPL, these roles are defined by the expectations of our leadership, by customer expectations, by the expectations of other members of the project team, and by our special work environment.

Project organization roles performed are usually related to planning and managing project work, and applying the project management processes. The project organization interprets sponsor objectives and functional requirements, developing a set of physical requirements that will meet project success criteria. Line organization roles are usually related to developing and sustaining human and capital resources needed to do work, applying the project implementation processes, and assuring the quality of the

work. Line organizations interpret requirements into physical specifications, and produce project elements that meet those specifications. (JPL maintains formal role statements for project and line management roles are available in *JPL Rules!)*

The *project manager* is responsible for overall success of the project, and is the primary interface with the sponsor (the NASA customer). The project manager builds and leads the project team, manages the project resources, manages risk and project performance, safety and mission assurance. The project manager may have general and specialized knowledge in many areas, but he or she is not likely to be expert in every one of the myriad technical disciplines required to complete a space mission. So the project manager interacts with *line managers.* Line managers are typically knowledgeable in the processes the people in their organization perform, and may even be the *process owners.* They are usually accomplished in one or more of the technical or business disciplines practiced by people in their organizations, and can identify discipline experts to participate in project work.

Line managers provide capabilities, both intellectual and production capabilities for all current and future project work. They are responsible for helping the people in their organizations to develop their expertise in both discipline and process. They promote peer interactions, and ensure that expertise is spread as widely as possible among the personnel in their organizations, so that no individual becomes a "single point of failure" in the execution of intellectual work. Line managers are responsible for acquiring, creating and developing resources such as facilities, tools, processes, knowledge, equipment and enabling technologies which will be used by multiple projects.

A *Project Element Manager (PEM)* manages and integrates the line activities that produce a design or products required by a project. The PEM manages cost, schedule, and technical deliverables of the project element. The element may be a subsystem or other significant part of a spacecraft or mission, or a service provided for a mission. A PEM delivers the project element, using appropriate processes, according to the WA between project and line organizations.

PEM's are members of a line organization. They receive project element requirements from, and report progress to, the project manager who is their customer. A PEM is the primary interface between project and line, and may lead a team consisting of members from their own and other line organizations. A PEM approves the WA's for the project element.

There are Program Element Managers as well, who hold similar line responsibilities for accomplishing program-level technical activities. Programs are long-term continuing development or research activities that are designed to accomplish broader scientific, technical, or operational objectives. They usually include a family of related projects or missions, and many other components as well.)

A *Cognizant Engineer (CogE)* is also a member of a line organization, responsible for a definable deliverable component of a project, project element, or technology task. CogE's usually lead teams with members from their own line organization. The CogE may be assigned either full or part time, to support one or more teams, and project CogE's usually receive day-to-day work instructions from a PEM.

5. PROJECT-LINE INTERACTION

The goals that line and programmatic managers must achieve are very different, and in that difference is the potential for conflict. Most of the differences are related to the way people work on projects, and both perspectives are justifiable.

Potential for Conflict over Project Staffing

The project manager's primary goal is to accomplish the project successfully, on time, within budget. Project managers realize that the way to do this is with the most capable, experienced people working on each project activity, for exactly as long as the project activity lasts and no longer. In the project manager's perspective, this minimizes the resources required, and reduces risk by reducing the likelihood of problems or delays.

The line manager's primary goal is to apply the total work force to serve the entire current set of tasks and projects optimally, creating a "best overall" situation for all current work. A second goal is to support the enterprise's need for future capability, by developing personnel in breadth and depth of discipline expertise and experience. Line managers must develop all the people, so that those who are currently less capable or less experienced will be able to assume more complex and difficult responsibilities in the future.

A line manager may even be faced with the necessity of reassigning people from one activity to another, as situations change and needs arise. It may be necessary to reassign an individual with a specific skill to a project that requires that skill urgently. Or it may be necessary to reassign personnel as one project nears completion and another project begins to increase activity, in order to maintain continuous work authorization for the people in the work unit.

Potential for Conflict over Scope of Work

Line managers represent their line organization in making and meeting the commitment to perform project work as defined and interpreted by the project management. Such a

commitment signifies that, in the manager's best judgment, the work planned is feasible in terms of implementation approach, schedule and cost projected, technology available, and resources required. As Kenneth Atkins indicates in his referenced paper "How to Plan and Manage Reserves Effectively," it is easy for management within project, line, and sponsor organizations to be overly aggressive in early stages of a project, emotionally focused on possibilities of a mission while paying less attention to the details of current technical capabilities. It is also common for requirements to "creep" as projects progress through the formulation phase, without correlated change in project resource allocations. A "can-do" culture has pervaded NASA since its inception, and all our leaders are eager to accomplish as much as possible with each mission.

But most JPL missions contain a large number of activities that are without precedent; both line and project managers may (in the excitement of the moment) agree to work scopes and resource allocations that do not contain sufficient margin to deal with "unknown unknowns" that surprise them later in the project life cycle. The conflict can arise when project managers find themselves in a position where they must defend unrealistic work scopes to their sponsors on one side, and unrealistic resource allocations to line managers on the other side.

Potential for Conflict over Project Bidding

Every NASA project is divided into two major phases. During the *Formulation* phase, the project concept is defined, and a Project Plan is prepared which will meet the mission objectives or technology goals of the sponsor. During *Implementation* phase, the Project Plan is carried out, resulting in delivery of products to the sponsor – a completed mission in space exploration.

During Formulation phase, project cost is estimated based on the best information available at the time about project objectives, current and expected technical capability, and the risk inherent in the project. At JPL, the work effort expected is documented in Work Agreements by the line organization; this includes work effort from internal as well as external people, as well as contingency estimates based on the uncertainty contained in the project (usually called reserve or margin). The sum of these estimates from the line organization, plus the cost of project management, is presented to the sponsor in the Project Plan.

In the time-honored American tradition of "bargaining for the best deal," sponsors push center program and project managers to reduce cost estimates; program and project managers in turn push line managers to do the same. The hidden argument in favor of low cost estimation is the unspoken threat that if the estimated cost is too high, the project won't be authorized at all.

The dangers of this all-too-common cultural practice are never realized until the Implementation phase, when costs overrun, and people work extreme overtime to accomplish the project by its scheduled launch date. By this time, there is usually grave resentment between project and line management, who blame each other for allowing a "low ball" estimate to be presented to the sponsor, but who privately blame themselves as well – and who realize they will probably do the same thing again for the next project proposal.

Potential for Conflict over Technical Responsibility

In September 1999, NASA's Mars Climate Orbiter (MCO) mission was lost during the maneuver that should have inserted it into orbit around Mars. JPL's Special Review Board investigated this incident and reported that the loss was caused by a software error that should likely have been recognized by the mission design personnel at the center. The Review Board found that there was "insufficient interaction between the MCO project and the line organization… A timely involvement of experienced navigation experts would have revealed the small forces inconsistency or, failing that, should have led to an appropriate characterization of the targeting uncertainty."

Since line organizations hold comprehensive functional and discipline knowledge, they are the logical place for programs and projects to find technical help for the anomalies that invariably occur. In many cases, however, there is cultural sensitivity related to asking for technical help from outside the project – or there may be a financial difficulty in doing so, related back to the potential for conflict over project bidding.

JPL has formally published guidelines directing projects and line organizations to work together in specific, collaborative ways. The roles of each are defined clearly, and the responsibilities of each toward project work are explained. But although these guidelines are institutional policy, "owned" by JPL's Deputy Director, sometimes cultural constraints are stronger than rules, and prevent the interaction that would make project work easier for everyone.

6. MAKING THE MATRIX WORK

I have studied project-line interaction at JPL for several years and in other companies for much longer. The benefits of a matrix structure to the working community are very great, especially where the community is made up of highly specialized disciplines which change state-of-art frequently and quickly. The potential for conflicts is also very great, because the basic motivations and goals of project and line organizations – and individual managers – are inherently in conflict.

I'm sure we all agree that "good interpersonal relationships" would make matrix organizations work most effectively as

communities, because these relationships will allow inherent conflicts to be resolved without lasting bitterness and residual acting-out behavior. But this is a simplistic or incomplete view at best, because what creates and supports a "good" relationship varies with the context and purpose of the relationship. (Consider both similarities and differences in characteristics between a "good" relationship among sales associates in a shoe store, and a "good" relationship between those sales associates and their customers.)

Organizations are not abstract entities, they are communities of individual people; individuals have separate motivations and perspectives, separate expectations and perspectives, in addition to their collective ones. This is not an abstraction for real people: it means that you have a driving need to add a neat new investigation to the project, and I have a driving need to prevent my employees from working 80-hour weeks; and you and I may have some serious arguments about our differences, both sides based on individual perspectives on what best contributes to "the future of space exploration."

Effective relationships in the context of project-line interaction require *clearly defined roles and responsibilities* that *allow and support self-actualization and a sense of personal value* on both axes of the matrix. Discussing and agreeing about these things is touchy, filled with the type of emotional risk we didn't learn to mitigate in The College of Engineering.

My conclusion is supported by a series of focused group meetings conducted at JPL, among first-line managers (Group Supervisors) and Project Element Managers. The meetings were intended to identify reasons for difficult relationships or conflicts between project and line managements, at the working level. Equal numbers of line and project element managers were invited to each of the meetings, and they discussed feelings and attitudes about the project-line relationship. They identified barriers to effective implementation of JPL's matrix organization, and developed strategies for overcoming or avoiding those obstacles. The barriers fell into several categories, but at the top of the lists were barriers related to roles and responsibilities; these included:

- Need for ownership/responsibility for technical products by line managers – feeling that this role was taken away by project element managers, and that line role in the work was devalued.

- A sense of imbalance of power between line and projects, with project management personnel as "kings" and everyone else as servants.

- Supervisor activity coaching and developing technical personnel were not perceived as added value by project management.

- Project element managers struggled to please and satisfy both line and project, did not have a clear sense of belonging to either.

- Lack of clear processes to helps PEM's manage their elements – there are clearly defined project management processes, but at higher levels.

Both line managers and project element managers viewed the physical location of project team members as a major issue in the project-line dichotomy. When engineers were co-located with their project element rather than with the other members of their line discipline, line management perceived that the loss of interaction and communication prevented them from receiving technical knowledge and support. Additionally, line managers complained that they had difficulty keeping track of how well their employees were doing, because they rarely received feedback from project management. But when employees were not co-located with the project element, project management perceived inefficient communication among the team members, and delays in achieving project goals.

The solution to the problems of both perceptions is always focused effort at communication between line and project management at all levels – easier said than done. The discussion sessions provoked interest in devising ways to communicate, though, as well as ways to solve some of the other problems in the project-line relationship.

A proposed solution to *responsibility* problems was for project and line management to must meet early during the project life cycle, and jointly plan implementation of each project or task. This recommendation is now included in JPL's Flight Project Practices, rules that guide project conduct. Additionally, project status meetings include both line and project management. Collaborative approaches to work of this type were not the norm at JPL, and the success of this approach required development of a structured process at first, to make interactions between line and project people easier. (A note: as the number of projects in the enterprise increases, so does the need for stronger and more consistent line management involvement.)

There were several solutions recommended for problems of *workforce management and project staffing*. All of these require line management to interact with project management more frequently. For example, supervisors and PEM's must identify individuals whose work will be completed on the project several months in advance, so that transition to other work can be planned and carried out with no threat to the quality of current project work. PEM's must participate fully (provide real, behavioral input) in the performance review process for employees working on their project elements, and document the employees' performance through discussion or memo.

An important and interesting result related to the focused discussion groups was this: *there was a marked decrease in the levels of antagonism between line and project element discussion group members over the period the groups were conducted, as observed in the interpersonal dynamics of the groups.* Also over the period the discussion sessions were conducted, the general descriptions of identified problems changed, from mostly role-related barriers (directly related to conflict between people) to mostly institutional and organizational barriers, not directly related to the personal interfaces. For these reasons, I believe the discussion sessions themselves are a proof source for interpersonal communication as a means of easing project-line conflict.

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BIOGRAPHY

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