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NASA APM-23
Special Study Group

FAST TRACK STUDY

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with support of
Advanced Project Management Class 23
NASA PPMI

NASA Fast Track Study

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Executive Summary

The NASA Fast Track Study supports the efforts of a Special Study Group (SSG) made up of members of the Advanced Project Management Class number 23 (APM-23) that met at the Wallops Island Management Education Center from April 28 - May 8, 1996. Members of the Class expressed interest to Mr. Vern Weyers in having an input to the NASA Policy Document (NPD) 7120.4, that will replace NASA Management Institute (NMI) 7120.4, and the NASA Program/Project Management Guide. The APM-23 SSG was tasked with assisting in development of NASA policy on managing Fast Track Projects, defined as small projects under $150 million and completed within three years.

The approach of the APM-23 SSG was to gather data on successful projects working in a "Better, Faster, Cheaper" environment, within and outside of NASA and develop the Fast Track Project section of the NASA Program/Project Management Guide. Fourteen interviews and four other data gathering efforts were conducted by the SSG, and 16 were conducted by Strategic Resources, Inc. (SRI), including five interviews at the Jet Propulsion Laboratory (JPL) and one at the Applied Physics Laboratory (APL). The interviews were compiled and analyzed for techniques and approaches commonly used to meet severe cost and schedule constraints.

Findings Summary

From the analysis, the following findings were derived:

Within an improved Product Development Cycle (PDC) process that compresses the time needed to go from concept to operation, three primary project management applications were discovered necessary for Fast Track Project success:

1. Thorough planning (including Risk Planning, metrics for management and use of concurrent engineering).
2. Teamwork (including use of Integrated Product Teams).
3. Minimizing disruptive outside events and their potential for consuming time and resources (including extra reviews and second guessing team decisions).

This study found that success was not achieved by omitting steps in the Life Cycle Development (LCD) process, but by innovatively tailoring the process to fit the constraints of the specific project.

Additionally, related management applications that should be considered for use by each project manager as applicable: the use of Risk Management; the use of facilitating technology or tools, such as Rapid Prototyping, Computer Aided Design software, and communication tools; and, training for specific project management applications, team operations, and available supporting management information resources.

From these findings, recommendations for Fast Track Projects were formulated:

1. Require and allow time for the actual project manager and team to plan at the front end of Fast Track Projects (especially entering Phase C/D), to include Risk Management Planning and Design-to-Cost, with the understanding of the importance of controlling project technical and programmatic requirements throughout the life cycle.
2. Use Program Commitment Agreement concept at all levels of the project as a series of bilateral agreements, used to ensure common requirement understanding and to control requirement creep.
3. Use metrics for each project that will measure progress and value.
4. Use team management and cross functional integration as a tool to achieve success.
5. Educate project managers in innovative techniques for managing reviews, documentation, oversight and risk to minimize disruptions in a schedule constrained project.

6. Provide NASA Program/Project Managers access to an educational/corporate knowledge information system addressing issues of Fast Track Project management, available as an on-line resource to support both project management and career development.

Fast Track Study Feedback

Was the information helpful to you? ❑ Yes ❑ No

Why/Why not? ______________________________

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I have ideas/experiences to share. Contact me!

Name ______________________ Phone ______________________

e-mail ______________________ Office Address ______________________

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Acknowledgments

The following members of the APM-23 Class contributed significantly to the writing of the draft Fast Track Guide and to the research and data gathered for this study.

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Dr. Edward Hoffman	NASA HQ/Code FT
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NASA Fast Track Study

Introduction/Background

This study is a result of the thinking, concern and efforts of a number of members of the NASA Advanced Project Management Class number 23 (APM-23), and the encouragement of Mr. Vern Weyers and the Program/Project Management Working Group (PPMWG), charged with developing NASA Policy Directive (NPD) 7120.4. The class convened at NASA's Management Education Center, Wallops Island, Virginia from April 28 through May 8, 1996. Mr. Weyers, the speaker for the graduation session as Chair of the PPMWG, discussed the issues surrounding new approaches to smaller projects. Following Mr. Weyers' presentation, the class expressed their concern for NASA to provide guidance, not only for smaller projects, but also for the accelerated project structure needed to meet NASA's "Better, Faster, Cheaper" objectives. Mr. Weyers challenged the class to provide their issues, concerns and recommendations to the full PPMWG. The class met with the PPMWG on June 19, 1996, and recommended gathering information and data from visionary managers within NASA on their experiences and ideas on how to do "Better, Faster, Cheaper" projects. The PPMWG chartered the class members as a Special Study Group (SSG) and tasked them to research Fast Track Projects. The SSG was also tasked to produce a Guide for Fast Track Projects as part of the NASA Program/Project Management Guide. In addition to looking within NASA, Code FT tasked Strategic Resources, Inc. (SRI) with supplementing the SSG's findings by performing similar research with industry and non-NASA government agencies that have successfully addressed compressing the development cycle.

The interest in "Better, Faster, Cheaper" at NASA grew from studies performed in 1991 and 1992 showing that out of 29 programs evaluated, NASA had experienced approximately 65 percent cost and schedule overruns, and programs averaged 12 years. NASA Administrator, Mr. Daniel Goldin, focused on the concept of "Better, Faster, Cheaper" for NASA in response to declining federal finding. In light of this, sustaining exploration of the solar system, placing a Space Station in orbit and developing a follow-on to the Space Shuttle, requires different approaches throughout NASA than those of the programs referenced in the 1991/92 study.

NASA rewrote its basic Program Management policy for Life Cycle Development, NASA Management Instruction (NMI) 7120.4, in 1993 in response to the study's results. However, much of the evidence applied only to traditional, large programs. The PPMWG is now rewriting this document, as NASA Policy Directive (NPD) 7120.4 to apply to the broader range of programs and projects, including relatively smaller projects defined as "Better, Faster, Cheaper." This directive will be accompanied by a new NASA Hand Book (NHB) 7120.5 that will provide guidance for Program/Project Management with the draft Fast Track Guide, produced in conjunction with this study, addressing "Better, Faster, Cheaper" projects.

This study documents, summarizes and discusses the methodology, findings, conclusions and recommendations of individuals within and outside NASA experienced in "Better, Faster, Cheaper" projects. The findings are summarized below and discussed more thoroughly in the body of this study. The draft Fast Track Guide is provided as Appendix A. The compiled interviews at Appendices B, C, and D, and Supplemental Information provided by interviewees is at Appendix E.

Methodology

The SSG was tasked to produce the Fast Track portion of the NASA Program/Project Management Guide. The SSG determined that data for this effort should be based on the experiences of managing projects that may be defined as Fast Track. These projects are usually constrained by cost and/or schedule.

This study was designed as a compilation of interviews conducted at NASA's Centers or coordinated by the members of the SSG. NASA/Code FT, responsible for NASA's Program/Project Management Initiative, tasked SRI to support the SSG by compiling the SSG interviews, coordinating the editing of the draft Guide, and researching Fast Track type projects in industry and other government agencies. The objective of both the SSG and SRI research was to examine a cross section of projects to provide a better understanding of how to manage cost and schedule constrained projects.

The SSG and SRI developed interview protocols as a common framework for the study, however, the actual interviews also included information outside the protocol. Although each project manager interviewed differed with regard to what was important and what to focus on when managing a Fast Track Project, several common elements emerged.

NASA Interviews: The NASA interviews occurred at all Centers except Dryden and Ames. There were a total of 14 project interviews and four related data gathering efforts focused on defining what is needed for Fast Track Projects. These were compiled into the areas listed on the following page, to provide a common basis for examining the data from all of the interviews.

Non-NASA Interviews: Identifying potential Non-NASA interviewees required research to select candidate projects, an interview point of contact, and making appointments for conducting the interviews. Of note were the Jet Propulsion Laboratory (JPL) personnel, who were very cooperative, as were those contacted at the Applied Physics Laboratory (APL) at Johns Hopkins University. These interviews complemented data from the NASA Centers as several of the JPL and APL projects are managed as "Better, Faster, Cheaper."

The industry and other government agencies' projects also provided supporting evidence on managing the development of new products from concept to operation. Although there is not a one-for-one correspondence with NASA's efforts, many of the problems faced by these project managers are very similar.

Compilation Format: The compilation format emerged from the common threads revealed in both the NASA and non-NASA interviews. Each interview was evaluated for applicability to one of the four areas: Practice Oriented Ideas, Policy Related Comments, Cultural Changes and Technology/Tools. Points made that were determined as applicable to Fast Track Projects, but which did not clearly fit into one of the four areas, were listed in Other Observations.

Interview Compilation Format	Examples
A. Practice Oriented Ideas	• Use of Teams • Use of Risk Management Practices vs. Risk Avoidance • Use of Metrics • Use of Co-location/Partnering
B. Policy Related Comments	• Reduction in Level of Oversight • Reduction in Rigidity of Life Cycle Development Process • Increased Training Uniformity for New Personnel • Evaluation of Hierarchy of Project Management by Cost, Risk, Size, etc. • Reduction in Documentation Requirements
C. Cultural Changes	• Location of Program Manager and Project Manager • Use of Cross Functional Integration • Use of Up-Front Agreements • More Up-Front Planning • Use of Concurrent Engineering
D. Technology/Tools	• Use of Rapid Prototyping • Use of CAD/Simulation Software • Use of Communication Tools
E. Other Observations	

Analysis, Findings, Conclusions, Recommendations: Once compiled, the interview data was analyzed for commonality of concepts. This commonality was further organized into areas that project managers identify as those that must be managed. Conclusions were drawn, and recommendations provided based on ensuring successful Fast Track Projects. The Draft Fast Track Guide is supported by these Findings, Conclusions, and Recommendations.

Fast Track Guide Development: The Draft Guide used an evolutionary development process that included a session at Wallops Island to consolidate ideas in a facilitated, focused environment. Much discussion and reflection was invested in this Guide through cooperation and involvement from all NASA Centers.

Findings

The interviews and research process identified a wide variety of approaches to managing development of new products in a cost and schedule constrained environment, but common elements emerged among the managers interviewed. These included: the primacy of good planning at the start of a project; the use of teams, such as Integrated Product Teams (IPT); and solid project management that adheres to the plan.

The interviews revealed that success is not achieved by omitting steps found in the conventional Life Cycle Development Process, but is achieved by examining the entire process to:

a) minimize resource consuming activities that do not add value to the project;
b) move activities forward in the process where possible;
c) compress or shorten process steps; and
d) understand that cost and schedule constraints will affect design decisions.

Success is also achieved in projects by controlling project execution to minimize or eliminate changes to original requirements, objectives and the project plan. This requires taking time to develop understanding and ownership of the requirements and objectives, to develop a credible, comprehensive management plan appropriate for the project size and complexity, and to adhere to the plan.

Teamwork was seen by the project managers interviewed as a value-added approach that requires an up-front investment over other non-team approaches, but pays dividends during project execution, where both time is saved and product quality ensured.

The definition of team varies by project, but several notable examples, such as the Joint Direct Attack Munition (JDAM) Program show that all individuals involved in a project add value to the project when deliberately made part of the team.

The interviews revealed an array of approaches, even when using common techniques, as well as varying levels of emphasis for each area. This reinforces the finding that there is no detectable, one-size fits all way to manage Fast Track Projects, but that success will be achieved by tailoring the management approach to the uniqueness of the project. One of the hallmarks of the successful project is the use of innovative cost and schedule controls. Everything in the Life Cycle Development Process is open for examination by the Fast Track Project Team to define ways to maintain the schedule and control costs. In the Findings Summary that follows, the concepts of Planning, Teamwork and Day-to-Day Management are discussed with attention given to specific techniques or ideas provided from the interviews.

1.0 Planning

1.1 Up Front Planning: Planning is the key to successful management of a Fast Track Project constrained by cost and schedule. The time taken in the early stages to think through all of the aspects of the project alleviates the potential for the project manager, in the later stages, of having to redirect. The project managers who made this point referred to the conventional attitude toward planning, which is based on the belief that there will be sufficient time and other resources to react to any issues as they arise and to change the course of the project as needed.

1.2 Resource Availability (i.e., project information library, lessons learned): For many project managers, Fast Track is a new operational concept requiring training and sharing of knowledge. While formal classes provide a foundation for Project Management, sources of data and information on management approaches for Fast Track Projects, available on demand, are also desired.

1.3 Planning Areas

1.3.1 Risk (Identification of Issues/Strategy to Manage): Many saw Risk Management as a key planning activity. To be able to identify those potentially stressing aspects of a project, arrive at an assessment of probability of occurrence, and determine the cost impact to the project if a risk event occurred allows a project team to plan mitigation strategies. Many felt that conventional projects avoided risk by simply spending more money. For the cost constrained Fast Track Project, this is not an option and risk must be aggressively managed in ways other than avoidance.

1.3.2 Design (Design-to-Cost): The need to understand the nature of cost driven activities is fundamental. Several project managers mentioned that few seem to understand the concept of Design-to-Cost (DTC) as it relates to the technical-scientific environment. Successful application of DTC within NASA will be necessary to support Fast Track Projects.

1.3.3 Schedule (Design-to-Schedule): Similar to DTC, it is critical for project managers to understand that in the Fast Track environment, cost and schedule are independent variables and must be controlled. This means that, while flexibility must be available in the technical design, it should be built into the project plan from the beginning.

1.3.4 Test (Design-to-Test): While not addressed as strongly, many found this to be an area that can provide both cost and schedule savings. By asking questions about what needs to be tested during the design phase, testing may be accomplished earlier in the process, leading to earlier, less costly and less schedule-disruptive testing. Incremental testing is a key approach allowing users to gain insight into design assumptions and how they impact the satisfaction of user requirements.

1.3.5 Manufacturing/Production (Design for Manufacturing): Several project managers indicated that costs could be controlled very effectively by involving those responsible for manufacturing in the initial design and planning phases. This allows the team to identify opportunities for design decisions that allow earlier selection of alternatives, thereby lessening or shortening the manufacturing schedule. Cost controlling efforts in the area of single process engineering in factories was also revealed as a significant cost saving methodology.

1.3.6 Decision Points (Reviews, Tailoring of Life Cycle Development Process): An area discussed by almost all interviewees was the need to manage disruptive, outside influences. Most elected to incorporate review processes into the project and to not allow them to be seen as being accomplished for only the benefit of individuals outside of the project, such as upper-level management. Instead, reviews are conducted as communication events, or 'peer reviews' to foster team knowledge and to encourage team synergism. Where interface with mandated reviews occurred, it was managed so that the oversight panels or board reviews were conducted as part of the planned reviews and scheduled based on the project's requirements. Minimal time was spent on producing documentation for reviews as well, using only those management products actually used by the team.

1.3.7 Metrics (Earned Value, Performance Measurement, etc.): All stressed the importance of being able to know how the project is progressing. This means that for most project managers, a well thought-out set of project metrics, sometimes unique for each project team, must be identified during planning. The metrics should answer the questions, "What will we have?" and "How will we know it?" They should always be used for high probability, high impact risk management areas. Many mentioned using Earned Value and Performance Measurement methods.

1.4 Requirements Definition: The understanding and management of requirements in the constrained environment of Fast Track Projects is absolutely key to success. The project team must have a common understanding of requirements before planning begins. The customer must also understand that planning will 'freeze' requirements, as cost and schedule constraints will not allow course corrections, unless the customer is willing to pay for the changes and/or accept schedule realignment. The team, including the customer, should understand that the requirements at the end of the project, should match the requirements identified at the start of the project.

1.5 Operations: Operations must not be neglected during the development process. Decisions made in the design and development phases will have cost impacts on the operations phase. In addition, several interviewees pointed out that significant schedule and cost savings are available for most projects when transitioning to operations. Consideration must be given to the entire life-cycle for a true understanding of potential schedule and cost savings.

2.0 Teamwork

2.1 Teamwork: Teams and teamwork is a developing area in government project management. The overall project management structure as a team, and the IPT concepts have been used on many successful Fast Track Projects. These team concepts are characterized by openness, concern for each other, and loyalty to team objectives. Less visible, but equally important, is the team's understanding of the project and its goals.

2.2 Why Teamwork (Rationale): Teamwork was mentioned by many interviewees as one of the most important areas for project management of cost and schedule constrained projects. Many also mentioned that all on the team, including the project leadership, must understand the benefits of teams in order to accept the up front costs associated with team management versus the more traditional, leader-decision maker management style. Some of these benefits follow.

2.2.1 Cross-Functional Integration-Functional Synergism: The most obvious benefits identified are in the area of empowering all project participants with insight and input in the planning and design phases. The interfaces, interactions and integration activities are much more effective and efficient. All individuals that may impact the project are candidates for inclusion on the team, as all must be part of the effort of staying on cost and schedule. All team members must understand the goals of the project and be encouraged to provide innovative ideas on meeting those goals. The Fast Track environment cannot be supported by stove-piped organizations that simply throw the product over the fence to the next function in the process.

2.2.1.1 Eliminate Problems Early Rather than Late: Many of the savings in cost and schedule occur because problems are identified early and can be solved before sunk costs accumulate and schedule redirection is needed.

2.2.1.2 Save Money and Time by Fixing when it's Cheaper/Easier: This approach allows the project team to make any necessary changes in design before design is frozen or before bending metal. It is much less expensive to make corrections early in the process.

2.2.1.3 Better Design through User/Other: By involving the user on the team, insight into user-peculiarities and perceptions may be gained to provide a better product from the start and prevent the need for late stage corrections.

2.3 Making It Work: A team environment is new for many managers, requiring a new set of skills and abilities. Many project managers emphasized that training to lead teams or be a team member is absolutely essential.

2.3.1 Culture Change (Badgeless Environment): In the environment characteristic of many NASA projects, there will be both in-house and contractor/ subcontractor involvement throughout the life of the project. An environment of trust and openness must exist between project members. For example, Near Earth Asteroid Rendezvous (NEAR) Project used the idea of a badgeless environment to describe the working relationship they created where all team members were encouraged to share openly.

2.3.2 Selecting the Right Members: Many interviewees pointed out that selecting both government team members and corporate partners able and willing to work in a team environment is a must. It is very easy to break trust and difficult to get it back. Procedures to obtain government members and contractor selection must be well thought out and planned from the beginning.

2.3.3 Cross-Functional Integration (Working Agreements): The idea of working agreements for lower level teams and for the overall team as a way of focusing everyone on the goals and boundaries has proven effective.

2.3.4 Communication (Technology/Process): Communication between team members is a must. The project leadership must do whatever it takes to make this happen. Electronic forms of communication seem to be effective if supported by existing equipment. Several interviewees mentioned that the payoff of good communication was so evident that the purchase of common equipment was a good, essential investment.

2.3.5 Co-Location: Communication on a daily basis is desired for effective cross-functional integration, and several interviewees indicated that co-location should be a requirement.

3.0 Day-to-Day Management

3.1 Day-to-Day Management: Ability to manage to the plan is another key to success. In a constrained environment, there will be little opportunity to conduct reactive management and redirect the project.

3.2 Risk Management: Managing risk during the project is essentially staying on top of those things identified during risk planning through the effective use of metrics. The idea mentioned by many is being able to see things occurring as they start and initiating mitigation activities as early as possible. The activities may be tailored to the situation by the team.

3.3 Oversight: Insight vs. Oversight was an idea put forward by several of the interviewees. This means that project management must work with oversight boards to create a climate of confidence in the team and in the project leadership. The project manager/program manager must strive to develop the same open atmosphere for the team as well.

3.4 Continuous Improvement: Each team member is a potential source of cost and schedule savings, and project managers must establish an environment conducive to fostering ideas from all team members.

3.5 Reviews: As mentioned above, reviews in a Fast Track environment should be minimally disruptive. They should address only open issues and be well planned. The idea mentioned by Motorola regarding the use of reviews to manage the white spaces between different activities or different teams within the project seemed to be an effective approach. The idea of having reviews when the project is ready for them, and not at times determined artificially outside of the project, was also emphasized.

3.6 Documentation: In keeping with the theme that time is a limited resource on Fast Track Projects, all potentially time extending activities must be held to a minimum. Documentation was singled out as a management tool that may needlessly consume time. Only the documentation planned for use by the team for specific project activities, or required to proceed to subsequent stages, should be produced.

Conclusions

Successful project management within the cost and schedule constrained world of "Better, Faster, Cheaper" requires an experienced project manager and the ability to manage to the plan. There is little, if any time, for major changes in requirements or to the established plan during project execution in this new focus for space mission science and spacecraft development projects. Managers must clearly understand the structure in the Life-Cycle Development model used by NASA and how to use this model to create a comprehensive project plan. Planning skills, along with the ability to communicate the understanding of requirements to the ultimate customer and project management team, are critical.

Team structure and teamwork are essential to the successful Fast Track Life Cycle Development process. Teamwork is associated with cross-functional integration and elimination of the stove-piping of disciplines of past approaches. A variety of disciplines must work together to be able to shorten the development cycle. Teamwork provides the ability to achieve that compression, and to identify and eliminate problems early, rather than late, in the project development process. Team leadership and team management are very important for the project manager to be successful in the Fast Track environment.

Since there is little time to recover from false starts or mid-project redirections in this time constrained "Better, Faster, Cheaper" management era, trust becomes very important. For trust to exist, the right project management team, whether in-house or contracted, must be selected and given authority and responsibility for the project. This requires the ability of the team selected to demonstrate from past experience that the capability to work in this environment exists, and that the necessary and appropriate management tools are assembled for the challenges of the project. Working closely with procurement personnel and the ability to manage the contractor selection effort are absolute requirements.

Risk must be identified and risk mitigation planned, along with a reporting system that allows the project management team to implement risk management. Oversight must be as least disruptive as possible. For this reason, documentation and project reviews should only be those that are used by the team to actively manage the project. Higher level reviews should accommodate the project team by allowing those required reviews to fit the project team's plans and to present status reports from the project team's management tools and metrics.

Innovation must be encouraged, both in technical and managerial approaches. For the technical team, cost and schedule will drive the design. This does not mean that science needs to take a back seat, but management must recognize early what good enough will be and use better as a design margin. Simplicity and industry-standard design plus off-the-shelf must be used wherever possible. Design-to-Cost and Design-to-Schedule must be taught as a way of life for the "Better, Faster, Cheaper" project team.

On the managerial side of the project, the entire team must look for opportunities to perform activities in parallel, to help each other identify opportunities, to begin work as early as possible in each functional area, and to identify and minimize disruptive but necessary activities. In other words, approaches such as concurrent engineering will also become a way of life and must be well understood. Communication of information is more important than ever and innovation here can provide significant benefits in time and cost savings as well. For this reason, meeting and review management are also key skills for the "Better, Faster, Cheaper" project manager.

Recommendations

1. Require and allow time for the actual project manager and team to plan at the front end of Fast Track Projects (especially entering Phase C/D), to include Risk Management Planning and Design-to-Cost, with the understanding of the importance of controlling project technical and programmatic requirements throughout the life cycle.

2. Use the Program Commitment Agreement concept at all levels of the project as a series of bilateral agreements, to ensure common requirement understanding and control requirement creep.

3. Use metrics for each project that will measure progress and value.

4. Use team management and cross functional integration as a tool to achieve success.

5. Educate project managers in innovative techniques for managing reviews, documentation, oversight and risk to minimize disruption in schedule constrained projects.

6. Provide NASA Program/Project Managers access to an educational/corporate knowledge information system addressing issues of Fast Track Project management, available as an on-line resource to support both project management and career development.

Appendix A

NASA Program/Project Management Guide for Fast Track Projects

Provided under separate cover.

Appendix B

APM-23 SSG Interview Compilations

I. Interviews

1. **X-CRV Project Background:** The X-CRV is a six-passenger lifting body reentry vehicle that is to remain docked with the space station. In the event of a life threatening emergency, the space station crew would board the vehicle and reenter for a parachute landing.

A) Practice Oriented: The X-CRV project will proceed through the development of a flying prototype using civil servants for the project staff. Research and development, experimental, or ill-defined projects are well-suited for development by civil servants. Operational production, and other well-defined projects are good candidates for total delegation to contractors. Competitive procurement will be initiated for the production phase of the X-CRV project.

The X-CRV team is housed in a small building isolated from the main buildings at Johnson Space Center (JSC) and they use a hands-on hardware approach to development. The manufacturing team is sitting with the design team and working issues and problems one-on-one on a daily basis. Rapid communication occurs because everyone is collocated.

The project manager must continually communicate the importance of completing the project as planned

B) Policy Related: Because of the sensitivity of human space flight, NASA people should negotiate, manage, and make decisions on human space flight projects.

A big project should be built as a set of individual smaller projects working towards accomplishment of incremental milestones. The key is to set up 'deliverables' (performance milestones) to show progress. A core set of team members decide how to divide up the project and build up milestones. This type of plan must be done by the program or project team.

The project philosophy is to "build things small, throw them away, and move on" to the next phase of the project.

Progressive formalization should be used to build the project plan and conduct the project. Using progressive formalization, you minimize the amount of documentation up front and put more emphasis on documenting as built.

ISO 9000 is important for production organizations; but, it does not apply for rapid prototyping, Skunk Works™ type projects. Instead of written specifications and processes, the project manager ensures the technician and designer work together to build the project.

C) Cultural Changes: The procurement process tends to treat all procurements the same. A Fast Track project team should include dedicated procurement and business personnel. As part of the team, they are dedicated to the project, not the procurement process. They need to understand that the biggest risk is the failure of the project, not of the procurement.

The best way to reduce cost is to understand the technical details that are required and how much it costs to implement them. Once the technical decisions have been made, "ignore the rules and go get it done".

D) Technology/Tools: All announcement and selection work on the X-CRV project is done electronically. This minimizes paperwork and gives competitors instant access to the data they need, and the project team has instant access to contractor proposals.

Minimize the project plan. The X-CRV project plan is graphically depicted in five stages on a poster. The X-CRV original written project plan was a one page document with about a dozen top level goals. It has evolved to about five pages, but is still minimal.

NASA middle managers are the "keepers of the culture". Most resistance to getting things done smaller, faster, cheaper has occurred in middle management. The failure of most projects is usually due to a "gap in leadership." Projects with strong leaders—succeed; and projects without strong leaders—fail. The project manager must be totally, personally committed to the success of the project.

E) Other Observations from Interviewee: None

2. **<u>LANDSAT Project</u>**: NASA took LANDSAT over from the Air Force midway between Preliminary Design Review (PDR) and Critical Design Review (CDR). As an existing contract, it had less flexibility in terms of "new ways of doing business" than a new start program would have. Nonetheless, significant changes to the management and implementation style of the LANDSAT project makes it a non-traditional Goddard project.

Three management principles are: communicate, communicate, communicate. Beyond that, the project manager's most important responsibilities are: (1) technical and programmatic performance, and (2) staff development.

A) <u>Practice Oriented Ideas</u>: The original 150 CDRL items in LANDSAT were reduced to five by asking the civil servants and the two contractors to identify the minimum documented information needed to do the job, dropping all preconceptions for "how we always did it."

NASA should play the role of referee, not overseer.

LANDSAT has a dedicated person to keep the Risk Management Plan relevant and risk assessment meetings are held every two weeks among all senior managers.

There must be an Action Plan for every problem. If you've got a problem and no recommendation, a solution can be found driven solely by cost and schedule constraints, which you may not like.

Growing people is the most important non-project role of the manager. To avoid burnout, the project manager must make sure each player:

- Has a job they can complete
- Gets a sense of satisfaction
- Has a means to avoid frustration
- Understands the constraints and limits, knows which are pushbacks
- Owns the problem or task, is part of its definition, isn't a sniper at meetings
- Knows the project manager's constraints and limits - what can be changed and what can't

A good Peformance Measurement System is a must, but it has to be flexible. It should rigidly track analysis tasks early in the program and be less rigid during implementation and test to allow creative solutions for emerging events.

If the reporting format doesn't match your internal tracking format, keep two sets of books: one to manage from and one to present. Don't get bogged down in awkward or inappropriate formats. Work from one preferred format and translate to another as needed.

Cost models are for scholars and research. They are completely relevant to the resource Analysis Office (RAO), but not applicable at the project level. Comparing project estimates against the RAO is an excellent sanity check, a way to identify misunderstandings and shortcomings, and to identify tall pole cost drivers. Detailed historical tracking of costs from many missions is not relevant to execution of the specific project.

B) Policy Related: The most significant constructive change management could make is to hold individuals responsible for their own work. Reward excellence and penalize stupidity.

Procurement rules can be changed to secure contracts faster with less formal approval at each evaluation step, while still maintaining fair and open competition.

Teams and people need to be rewarded for completing their jobs.

A whole new Center could result from rotating the directorate-level office staff laterally among the nine Codes, independent of background, interest, or skills.

The new project management NMIs don't really apply to LANDSAT because of its mid-project transfer to NASA; however, the NMI management principles still apply.

The travel budget must be enough to support site visits.

There is absolutely no chance for a budget increase in LANDSAT. The best way to handle this is to allocate budget performance to responsible levels, and replace those who can't perform to budget.

C) Cultural Change: There needs to be fewer "empires" at the Center, making track teams function-specific with minimal people and fixed project lifetimes.

Independent Annual Reviews (IAR) can be very productive, depending on who is on the panel. People proud of their cleverness in finding fault will make you jump through a lot of hoops with no value added. People who understand the project limits, who are tough but fair, and who are interested in the mission, will provide a meaningful review.

Generally, the problem with selling new ideas and getting innovations approved is not with senior management anyway, but with all the layers in between. A clever manager can brief red and yellow issues with complete disclosure, adhering absolutely to the Monthly Status report (MSR) style and content, yet never really addressing the project issues that affect mission success. It is very hard to be forthright in this kind of review environment.

D) Technology/Tools: It would be valuable to set up a structure to capture lessons learned from all projects to learn what works, what doesn't, and the reasons why. Besides providing practical advice and insight, this would also present a "report card" on project managers, so their performance could be seen by the general staff in terms of applied management abilities, not just word of mouth and formal newsletter articles.

Home pages and electronic data transfer are tools that allow team members to communicate and update the general knowledge pool quickly and accurately, as long as they don't take a lot of resources to set up and maintain.

E) Other Observations: In terms of new Fast Track thinking, new approaches and ideas won't come out of traditional hierarchies and empires. Radically stressing the organization, maybe even by moving key people across directorate boundaries, could shake out inefficiencies and result in new ideas.

The lack of constructive stress makes it too easy to rely on old solutions (i.e., more people, more money) and too difficult to recognize the real problems and to see new solutions. Old solutions are usually not valid in today's environment; new insights can best be gained from challenging the norms.

If Fast Track means making rapid progress, then the existing obstacles are the procurement rules, documentation, and contractor interfaces. Here are three ways to Fast Track:

- Run a minimally-staffed project (i.e., four heads and a fixed-price, hands-off contract).
- Partner with the contractor - exclude government oversight. Rely on sharing the workload where one side does specific tasks for the other in a role like a subcontractor, with task definition, schedule, completeness criteria, etc., defining the task envelope. Don't allow duplication of work.
- Put a small, focused staff on a short (three-year) mission. The project manager decides how it will be staffed even if the total headcount is predefined by the Directorate, (i.e., the Project Manager decides on the evolving need for project support, software manager, Deputy Project Manager, Resources (D/PMR), Integration and Test (I&T) and all other roles).

If the budget doesn't support the mission, make it clear to management what you can do for the budget - accepting $100 million to push a rope will end up with an stationary rope and all the money spent.

3. **Earth Orbiting Satellite (EOS):** The EOS Ante Meridian (AM) Project has proceeded through all project life cycle phases, (i.e., A, B, C/D) but has done so within a number of different Projects and Programs. The Life Cycle Cost of EOS AM, which was originally set at $2 billion, was reduced twice during Phase C; first to $1.3 billion and later to $1 billion.

Originally, the EOS AM Project was expected to be an Integration and Test (I&T) Project, receiving a spacecraft bus from the Space Station Work Package C Polar Orbiting Platform Project, instruments from the EOS Instruments Project, and a ground system from the Earth Science Data and Information System (ESDIS) Project.

The launch vehicle was not determined until early 1995, around Critical Design Review (CDR), and resulted in significant additional cost due to carrying the flexibility to fly on a number of different launch vehicles all the way to CDR. Additionally, mergers/restructuring of the spacecraft contractor, a major instrument contractor, and the solar array contractor caused substantial problems for the project. These included loss of key technical personnel, changes in accounting systems, rate increases and government payment of Restructuring Fee Agreements.

A) Practice Oriented Ideas: A project plan for the EOS AM Project was written and approved, but not until long after the project had started. In this case, it might have been better to use the Phase B work, culminating in the Preliminary Design Review (PDR), to replace the project plan. Documentation requirements for the Prime Contractor, LMMS, were reduced to approximately 100 CDRLs, with only ten requiring government approval; a decrease of more than 800 CDRLs.

Two key goals of the risk management activities were:

(1) To significantly reduce the amount of new design hardware in the program, replacing much of it with heritage hardware from other programs.

(2) To integrate civil servants into the IPTs giving the government better insight into EOS AM-1 development.

A Performance Measurement System is probably most useful for initial planning, identifying forgotten items, and replanning at the end of CDR. In a development program the linkage between cost, schedule and performance is difficult to predict a priori; however, as copies are produced, a valid PMS with strong coupling between cost, schedule and performance is possible and would be a useful tool. Probably the most significant lesson learned is to not duplicate work. Every task should be done once, by whoever is most appropriate to do it (whether government or contractor) with participation by all appropriate personnel. Nothing should be undertaken from scratch unless it is specifically necessary to achieve mission objectives. Use heritage designs wherever they will achieve mission objectives, rather than going to new designs. New design efforts which typically increase cost and risk should be pursued to meet mission of programmatic goals.

B) Policy Related Comments: Eliminate the Program Operating Plan (POP) review and use the Independent Annual Review (IAR) to replace it, or combine the two reviews.

A massive three day PDR or CDR does not add value to the project. For reviewers to be helpful, they should be involved in the subsystem PDRs and CDRs, working with the technical team to improve the designs.

The system-level PDR and CDR should be more of a summary review, with most of the issues worked out with the review team before hand. The Center Flight Assurance Directorate, refused to structure the EOS AM-1 reviews in this manner, although they have subsequently changed to this structure for LANDSAT 7 and other missions.

NASA needs an exemption or flexibility from the FAR to respond to the Research and Development (R&D) nature of our activities. Often it is desirable to accomplish tasks in a more streamlined fashion, or by forging partnerships with industry and academia or between companies.

NASA should pursue Phase B/C/D efforts that allow the science team, industry and government to develop an early understanding of the goals, risks and methodologies to accomplish the mission. This will reduce the risk and time required for detailed design and build. The NASA procurement system should support this type of an activity.

C) Cultural Changes: A management structure based on the use of Integrated Product Teams (IPT) comprised of both civil servants and industry partners in a specific discipline, frequently a specific spacecraft subsystem, is needed. The government gains and maintains insight into contractor efforts through normal IPT interactions by incorporating civil servants and contractors into a single project team.

D) Technology/Tools Recommended: Use early breadboards and technology demonstrations, and proper incorporation of computer models and analyses. Engineering models can reduce risk, but only if original designers and manufacturing team remain.

E) Other Observations: Having worked both the DoD and NASA side, it is clear that NASA works in a more efficient manner and typically employs more aggressive technology.

4. **Explorers:** Small Explorers (SMEX) was managed out of Code 700, Engineering Directorate and Medium Explorers (MIDEX) was managed by Code 400, Flight Projects Directorate. Each have a very small project office with all discipline support, including system engineering, matrixed from the appropriate directorates. MIDEX has a project office with a mission manager and, if the instrument is procured outside the Center, an instrument manager for each mission that falls under MIDEX. The project office provides overhead functions, Configuration Management, office support, etc., for each of its missions. Matrixed personnel are appointed by their home organization and selected by the skills needed for the project.

Each mission has internal meetings as needed with a monthly report provided to the Project Manager. SMEX had informal weekly reports to the Program Manager at Headquarters until the latest organization of Headquarters was established. Reporting to Code 400 for MIDEX is standard at the Center. Within the project, most communication is kept informal.

A) Practice Oriented Ideas: A project plan has no value for these missions. The proposal responses to the Announcement of Opportunity (AO) have become, in effect, the project plan in combination with the information in the PDR and the NAR. It was found on the first two small explorer missions that the project plan was not useful and, in fact, was signed after the launch, or not at all. A project plan was never written for the third mission. The consensus was that writing a formal project plan for these small missions was a waste of time and the same purpose could be served by using the information in the proposal, the Preliminary Design Review (PDR) and the Non-Advocate Review (NAR). Therefore, a project plan was considered bad for Fast Track Projects.

- Solar, Anomalous and Magnetospheric Particle Explorer (SAMPEX) - Project plan signed off one month after launch
- Fast Auroral Snapshot Explorer (FAST) - Project plan never signed off
- Sub Millimeter Wave Astronomy Satellite (SWAS) - No project plan

No pre-Phase A or Phase A studies. The process of developing the proposal could be considered the equivalent of a Phase A study, with the project immediately entering Phase B upon proposal selection. Mission performance requirements were developed from Level One requirements during the definition phase reflected in the PDR. Metrics are in the form of technical accomplishments, schedule, and cost. A full Peformance Measurement System is not used. In lieu of a full formal performance measurement system, key parameters were chosen for performance measurement assessment. As this saves time and money, is good for Fast Track Projects.

Areas of risk are identified prior to Phase C/D, and watched closely throughout Phase C/D. Cost tradeoffs are done continuously and contingencies are created throughout Phase B. By the end of Phase B, the mission has been descoped as far as it can and should be. Formal descope plans are not necessary or valuable, as there isn't time or money to do descoping in Phase C/D in fast, low cost missions.

Firm funding commitments are obtained prior to starting the project. Procurement is completed using the AO process. Contracts are cost reimbursable with cost capped missions. Mission requirements are defined by performance, but are not totally divorced from technologies.

The project was not guided by NMI 7120. The documentation and deliverables in the NMI were considered too burdensome for a small project. Specific items, such as the timing of the end of Phase B, the funding profile, and some of the reviews, were selected and followed if appropriate for the project. Project reviews added value, particularly in getting the team together at key points in the development process.

Share the wisdom. A Fast Track Project should build a team as early as possible to effect tradeoffs. They should have early agreements on how to work as a team. At the start, define the project and mission design, have a plan to match the budget, then "go for it." Early agreements are needed for deciding how to measure performance.

Instruments require special attention. Principle Investigators (PI) generally don't have the full infrastructure that should be provided to them. Control gates should be the PDR/NAR followed by a running gate with a cost cap. If the project is expected to exceed the cost cap, the project manager and PI's should immediately see the Associate Administrator (AA).

Barriers were overcome by working one-on-one with other Organizations/Directorates. This has proven to be a long and sometimes painful process. For example, problems with Flight Assurance took three years to resolve.

B) Policy Related Comments: As currently conducted, independent reviews don't have value added of inside and outside people in key areas of expertise of the project. Having input into the selection of a mix would improve the independent reviews.

Regarding management controls by the Center, action items from the institution take away from the streamlined process and use up resources, particularly staff time, that is needed elsewhere.

C) Cultural Changes: Most barriers are due to the Center. For example, the project manager feels that it is part of his/her job to respond to changes made by Headquarters, and therefore, does not consider them to be barriers. Barriers have typically been in the areas of procurement, review process, flight assurance, the cost, and sometimes lack of engineering support. The environment at the Center has been geared towards large projects and the tendency is to throw large numbers of people at a project and/or problems.

Overcoming barriers is very specific to the people the project deals with, and the resolutions agreed to by those people are not always supported by their home organization. Small teams with creative ideas are often shot down by their own organizations. A Fast Track Project is different from other projects by its lack of bureaucracy, its approach, and its willingness to be flexible.

D) Technology/Tools Recommended: Use paperless Configuration Management (CM) with all documents on the Web. The standard CM process is quite involved with large databases of changes to documents, etc., a great deal of paper required to be filled out, and a long time is required to get changes approved through formal boards. This generally requires at least one full time person to manage the effort. The recommendation is to keep all documents in a location accessible through networks of the Internet, and to handle change control through electronic means.

E) Other Observations: Full Cost Accounting would not really change the way the project is managed. It would, however, provide more visibility as to where the money is spent, particularly for in-house hardware. The project would also pay closer attention to overhead functions.

The least successful experience was dealing with the technology on SMEX. New technology and its infusion needs to be visible, with a well understood agreement on its status. It should be managed separately and kept highly visible.

The most successful part of the project was that missions were ready on time and within cost. People had a tendency to overwork. Since Explorers are a continuing line, individuals could endure perhaps two missions, but not a third. Recommendations to resolve this include:

- Manage time carefully from the beginning of the project and streamlined processes from the start.
- Do not keep a rolling wave of undone work moving into Integration and Test (I&T).
- Be willing to pay overtime early, as the hours are expended, then save time later on.
- Attain depth in understanding the mission as early as possible.

The most innovative aspects were the architecture of the technologies that simplified the design and were more cost effective.

The combination of training and experience have been very valuable. The Project Manager completed a large amount of formal training in addition to experience gained at GSFC. The additional training was considered valuable for conducting a Fast Track Project.

5. Marshall Space Center (MSC) Interviews

a) Optical Transient Detector (OTD): The OTD payload was originally scheduled as a six month development project with a firm $4.9 million budget and classified as a Class C payload but was Class D referenced. The OTD slipped to nine months, however, estimates show it should have been a 12 month project. The project plan stated that the payload had an up to 65 percent probability of failure.

A) Practice Oriented Ideas: OTD employed some Quality support, but no receiving inspections. OTD used Project software to develop logic schedule diagrams and it used critical path methodology. Weekly scheduled reviews were conducted which, eventually, became daily tag-ups.

Two major reviews were conducted:

- Pre-environmental - considered worthwhile
- Pre-ship - not considered to be value-added

System level specifications were used, but, in retrospect, specifications should have flowed down to the box level. There was no formal tracking of specification verification, and only Principle Investigator (PI) acceptance of payload performance. OTD used unreleased drawings as it was felt that formal Configuration Management/Verification was not needed for building one of a kind. There was formal approval of the project plan by the Center and NASA Headquarters.

There is a need for coherent parts procurement and recommend strongly that a dedicated materials acquisition specialist track all parts procurements.

B) Policy Related Comments: Recommend eliminating low level procurement requests. Government credit cards should allow for increased spending limits to expedite small project-related procurements. Surge capacity is critical. It is felt that Full Cost Accounting will constrain surge capacity ability.

C) Cultural Changes: The chief engineer role is absolutely critical to motivate the S&E troops to get the job done.

D) Technology/Tools Recommended: None

E) Other Observations: None

MSC Interviews (cont.)

b) AXAF: The AXAF project is cost-driven with recognized and accepted increased risks. The program has few equipment spares, an avionics engineering breadboard, and the protoflight model which is being flown. Project cost is $750 million with an operational life expectancy between five and ten years. The project employs about 200 FTEs in the S&E labs and about 500 FTEs overall, including TRW, Kodak, Ball Aerospace, MIT and SAO.

The project has faced numerous reviews with review teams checking review teams. While there is a need for external oversight, teams need to keep the same people from start to finish to minimize the learning curve and enhance the ability to streamline reviews.

A) Practice Oriented Ideas: Internal reviews at the Center that used Earned Value and were led by the Comptroller's Office were considered helpful.

The project plans were not really used other than to get initial commitment, to serve as an audit trail, and to allow project people to initially get their arms around the project.

Tracking and scheduling were performed by TRW using monthly scheduling and tracking teleconferences.

While one materials acquisition specialist was used at TRW to track all procurements, another dedicated specialist is recommended to procure/track the EEE parts.

Requirements must be defined up front. AXAF baselined requirements at the SRR allowing requirements to change only in response to problems.

The project office maintained configuration control with support from SAIL and tried to resolve issues below the CCB level.

Used Center Quality Personnel and placed them at the prime contractor site.

No interface with Headquarters except for formal reviews. The Program Management Council (PMC) is perceived to add to the overhead burden or, at minimum, add another layer with which to deal.

Risk assessment should be performed in the project office and driven by fiscal reserves constraints, resulting in risk ratings of high-medium-low and assigned dollar values.

Audits are performed every six months for every subsystem and Center personnel are invited to observe. These audits provide a wealth of information for Center people.

B) Policy Related Comments: None

C) Cultural Changes: Chief Engineer functions could be in the project office itself, not worrying about whether someone is assigned to S&E Directorate or Project Office.

Cost of program was driven by political issues and decisions that forced the use of the Shuttle as the launch vehicle.

Need dedicated S&E personnel on the project who are co-located and have accountability regarding the end product.

D) Technology/Tools Recommended: None

E) Other Observations: Lesson learned is not to use universities for science instrument development.

It is critical to have a strong systems engineer and chief engineer with key people integrated on the team.

Most successful aspects of the project dealt with the competence of the prime, the reviews, international agreements/contracts, and tracking.

Least successful aspects dealt with schedule variances caused by university involvement.

MSC Interviews (cont.)

c) **Systems Analysis and Integration Laboratory (SAIL)**: SAIL handles requirement's definition, Configuration Management, Systems Engineering, etc., for all Center projects. SAIL is working with Preliminary Design (PD) Office (Program Development Directorate) to work the requirements up front. When PD starts work on a new concept/project, SAIL is invited to attend meetings early on. This really helps to work things on a system level, including requirements. However, a lot of the PD concepts never work out for whatever reasons (political, funding, etc.) and cause a manpower drain for SAIL.

A) Practice Oriented Ideas: Many projects fail to identify the requirements up front (especially in-house projects), so people just start designing with requirements as an afterthought. Need better Systems Engineering and up front staffloading. Need to strengthen the up front planning and development of a valid schedule.

Need to allow more flexibility in Configuration Management. Advocate the Responsible Equipment Engineers (REE) role of cradle to grave responsibility.

B) Policy Related Comments: Full Cost Accounting will make matters worse in regard to Systems Engineering and up front staffloading; people will be assigned only as they are viewed as adding value to the project.

Each project must have clearly defined systems integration responsibilities. There is now a push for Design Certifications Reviews (DCRs) which seems to be another layer of overhead.

C) Cultural Changes: There is a general problem of declaring when reviews will be conducted and then executing the review regardless of whether the team is ready or not.

Responsibility and accountability for project success (or some portion of the project) is often delegated without the authority to carry it out. There is also a tendency to start projects without knowing really what is wanted.

There must be communication between laboratories; especially designers with the avionics and propulsion personnel.

D) Technology/Tools Recommended: None

E) Other Observations: None

MSC Interviews (cont.)

d) <u>Transient Pressure Test Article (TPTA) Facility</u>: The TPTA Facility Fast Track Project began in January 1987 and ran nine months at an approximate cost of $39 million with up to 600 personnel and 29 companies plus vendors. USBI performed all procurements. The project used dedicated co-located Quality personnel. A standard six day workweek was used with work on Sundays as well. Cost was not a driver since the objective was to get the Shuttle returned to flight. Requirements definition and facility design were worked concurrently. Critical design drivers included access and serviceability.

Industrial safety should have been brought in earlier. All design reviews (TRRs, PDR, CDR) were informal and only action items. Other than weekly briefings to the Center Director, no outside briefings were conducted. The project enjoyed top priority status throughout the nine month period.

A) <u>Practice Oriented</u>: The Center Configuration Management system was employed for the project. All Center personnel were dedicated full-time to the project and were co-located. There was no formal project management plan. The project's own full-time administrative officer was key to the team.

The project often worked to red-lined drawings. They held weekly and sometimes twice-weekly tag-ups that were usually oral discussions with team leaders.

There was significant customer involvement from the beginning which was sometimes difficult, but critical for project success.

B) <u>Policy Related Comments</u>: People need to be assigned to the project full-time, rather than part-time, if the project lasts more than a few months. The personnel should be co-located.

C) <u>Cultural Changes</u>: Center supervisors need to be willing to give up people for short range projects and still ensure that their people get credit for their work.

NASA Barriers include:

- NASA Matrix structure (people detailed to project vs. being assigned full-time)
- NASA Site Security had to get a guard out to the compound each time someone had to go in or out on Saturdays which impacted morale and productivity.

- **Communications problems with various parts of the contractor organization.**
- **Management oversight (need minimum management involvement).**

D) Technology/Tools Recommended: None

E) Other Observations: None

MSC Interviews (cont.)

e) STABLE: No background information available.

A) Practice Oriented Ideas:

- Total communication.
- Timely decisions.
- Bring all disciplines on board at beginning and describe tasks and schedule.

B) Policy Related Comments:

- No creep in basic requirements.
- Create only the documents required to verify integrity and safety.
- Limit reviews to those absolutely necessary; STABLE had only PDR with no RIDs and only action items; every meeting was normally a technical review less than one hour weekly but, sometimes up to three times a week.
- CCB drawing system streamlined by review/signing meetings (one day turnaround).
- Credit card purchases essential.

C) Cultural Changes:

- Team dedication to end product.
- Technical respect required.
- Must have management priority.

- Must have a realistic schedule (originally four months allotted was too short; actually was a nine month project).

- The Fast Track approach needs to be embraced by all Center personnel.

D) Technology/Tools Recommended: None

E) Other Observations: None

6. **Advanced Solid Rocket Motor (ASRM):** ASRM was a Shuttle project canceled by Congress in late 1993. The Center's responsibilities for ASRM were limited to the design/construction of the test stand, Data Acquisition and Control System (DACS), test stand activation, and motor testing. Overall project responsibilities resided at another Center. The ASRM project is a typical example of a large NASA project that followed the dictates of NMI 7120.4 and NHB 7120.5 with all the resulting phases, reviews, and reporting requirements. It should be noted that the project was canceled during Phase D, Development, prior to entering Phase E, Operations.

A) Practice Oriented Ideas: Maintaining an accurate cost tracking system is imperative to a successful project.

Don't micro-manage. Projects Management should be delegated, and budgeted at the lowest practical level with managers held accountable.

A key component to a successful cost tracking system is a strong resource control manager. The project manager is primarily involved in the technical aspects, schedules and high level resource control of a project. The day-to-day cost functions should be delegated to resource control personnel to allow the project manager to concentrate on the technical and schedule aspects of the project.

A strong project team is one that is small, co-located and dedicated to the project. Co-location results in improved team coordination, communication, and decreased distraction from the institution.

Environmental permitting processes are difficult and drawn out. Adequate planning is imperative to ensure schedule impacts are minimized.

The Earned Value of a sub-contractor must be verified (failure to do so on ASRM resulted in a cost overrun on the Data Acquisition and Control System (DACS)).

Match contractor capability to the job. Center had a high-technology aerospace company in charge of brick and mortar construction which led to high cost forecast. NASA made the decision to cancel the construction part of the contract, brought the construction contract in-house, and were able to bring the construction back in line for both cost and schedule.

B) Policy Related Comments: As a Space Shuttle Project, ASRM followed all the requirements outlined in the 7120 series of instructions and handbooks. The National Space Transportation System (NSTS) 07700 series of controls forces a tremendous amount of paper on the system.

C) Cultural Changes: A specific NASA barrier that interferes is the "mind set" or "culture" of middle level NASA managers that are loyal to the infrastructure requirements with resulting reporting and management requirements. This culture drives a large infrastructure that is self-sustaining and self-justifying.

D) Technology/Tools Recommended: None

E) Other Observations:

Non-NASA barriers included:

- Environmental Permitting
- Restricted Air-Space Identification
- Congressional Budgetary Processes

7. **Evolved Expendable Launch Vehicle (EELV):** The EELV is a medium to heavy payload launch vehicle to replace the Delta, Atlas and Titan launchers. It is a DoD created program to fulfill the nation's need for a lower-cost, more reliable space launch system. One of the potential contractors for EELV is proposing to use the Space Shuttle Main Engine (SSME) as the engine for the EELV. The SSME would then jettison during flight, parachute for water recovery, be refurbished and re-used for another launch. The Center's participation, through a Space Act Reimbursable Agreement with Boeing, is to conduct a SSME drop test and recovery. Following recovery, the SSME will be test fired .

A) Practice Oriented Ideas: Small co-located teams ensure effective communication and minimization of outside distractions. Team members must be self-motivated, dedicated, and committed to the project. Matrix management of the team allows the project manager to adjust manpower levels to meet the activities' peaks and valleys. A strong project manager leads by example. It is hard to expect team members to put in extra hours if the project manager doesn't. Additionally, people need to be allowed to do their jobs; they do not need micro-management. Let people know what is expected and what they are responsible for and hold them accountable for results. The project manager should have final authority in the selection of the team.

If the project team does not have resource control assistance, the project manager should maintain close contact with the customer, support contractors and Comptroller's Office to ensure costs are contained.

Small projects should use a simplified project plan that includes the purpose, scheduling, and issues/concerns. Requirements should be maintained in the Project Requirements Document (PRD).

B) Policy Related Comments: Under Full Cost Accounting, the proposed overhead rates applied to civil servants both for Headquarters' overhead and local site's overhead rates, may exceed the cost of using a contractor. In this case, project managers may choose to spend scarce project dollars on contractors which could have the opposite effect on NASA's stated goal of maintaining the core capability, knowledge and experience within NASA.

C) Cultural Changes: A project manager must be careful concerning the issue of using a contractor versus government personnel. It is felt that, as a general rule contractors will comply with the project manager's directions, while government personnel are more likely to challenge or question the project manager's decisions. This makes it imperative that the contractor team members should be strong individuals that are equal members of the team, willing to voice their opinions.

The NASA procurement system is a slow to react, bureaucratic system with many gates, statusing, and reporting requirements. It is much faster to have the contractor do procurements and, many times, a contractor is an expediter whose sole function is to make sure the procurement is completed and the product delivered when needed.

The cost reporting system does not adequately status for short projects. Data is at least a week old and may be as much as a month old.

The biggest barrier to project management, is statusing to senior management. NASA management needs to be more proactive in finding out what goes on and come to where the action is.

D) Technology/Tools Recommended: None

E) Other Observations: A Fast Track Project is defined by time frame and not cost. It is more an aspect of time with respect to complexity and cost is not a factor.

8. Halogen Occultation Experiment (HALOE): The HALOE project was one of ten instruments on the Upper Atmosphere Research Satellite (UARS) Platform launched in September 1991. HALOE was designed to take polar (northern) region measurements during two consecutive winter seasons. It was required to operate on orbit for a minimum of two years. UARS was originally designed as a recoverable platform to operate two years on an orbit operational lifetime and contained international experiments. Total cost for the UARS mission was approximately $700 million. The HALOE life cycle schedule was approximately 20 years from concept to launch.

Technical performance was treated as the number one risk factor required to meet technical performance at the 100 percent level. Once UARS was identified as the platform then the HALOE project schedule was fixed and was non-negotiable. Resources were manager (controlled) to ensure schedule did not slip. Schedule was the driving metric, and could not slip at any cost.

The HALOE project was originally under contract to TRW, but was brought in-house about eight years prior to launch and reworked. The Systems Engineering Division of the Systems Engineering and Operations Directorate provided the project management function.

A) Practice Oriented Ideas: NASA needs to pay more time and attention to the details of system integration and system testing as part of the planning done during early Phase A.

- A NASA integration team was sent to the General Electric Astro Division in Heightstown, NJ during spacecraft integration.
- A standup briefing was held between all personnel of the changing shifts; line workers did most of the talking during the standup briefings.
- Clear lines of authority existed, no ambiguity of responsibility.
- Leadership was provided, there was no management by consensus. (This was helpful to this project and would probably be critical to a Fast Track Project).
- To obtain key team personnel, Branch approval was required for a person within the same Division and Group Director approval was required if the desired person was in a different Division.

- Project Status reporting requirements:
    - Weekly status reports on the formal Action Item list
    - Monthly reports to the Group Director
    - Quarterly Center Director's management meeting

- HALOE had a written and approved project plan. (This was helpful to this project and would probably be critical to a Fast Track Project).

- A formal process operated out of the Project Office was used to maintain configuration control. Several of the fabrication technicians a lso served as QA technicians. (Helpful to this project).

- Funding and workforce profiles were re-baselined almost annually. The workforce profile tended to follow the funding profile.

- No form of official risk management was performed.

- Launch was controlled by KSC and/or JSC. The instrument due date was controlled by the Integration Manager at General Electric.

- Daily morning stand up information exchanges were very useful/successful.

- Having a written contingency plan for the failure event during Thermal Vac testing was very successful.

- More early discussion and detailed planning of the integration and test activities would enhance Fast Track management, and reduce the amount of resources expanded during this time frame.

B) Policy Related Comments: Under Full Cost Accounting, the total life cycle cost of the project (instrument only) would be about the same.

Recommend no Preshipment Readiness Review (PSRR) for a Fast Track Project. The PSSR occurs too late in the development to really help identify problems.

C) Cultural Changes: A good project manager has a hard time returning to the line organization. They become used to the intensity of project work, exercising authority and life at a faster speed.

The Integrated Management Team (IMT) was viewed as ineffective. Firm lines of authority are required to expedite the decision process. (This is critical to a Fast Track Project).

This instrument was built in the era where science requirement creep was expected. If anything, scope was added not subtracted.

The current relation between NASA and space platforms is in the process of changing just like the past relationship between NASA and sounding rockets. A fundamental shift is occurring in the nature of how NASA does space platforms.

D) Technology/Tools Recommended: None were prevalent at the time HALOE was built.

E) Other Observations: HALOE was driven by science requirements, however due to the extremely long life-time of the project from original concept to flight a lot of technology driven requirements crept into the mission.

In-house managers (two Deputy Project Managers and two Technical Project Engineers) were replaced due to advancement. No one was removed due to incompetence.

9. **<u>In Space Technology Experiment Program (INSTEP)</u>:** Code X Small Flight Experiments started in 1988. One hundred ninety were proposed to the Announcement of Opportunity (AO). Thirty experiments were funded for Phase A ($50-100K), six for Phase B, and four advanced to Phase C/D and flew in space. The total life cycle cost of the project was approximately $5 million and the total life cycle schedule was 12 months.

Risk was limited to the individual projects. There was not a written and approved project plan due to the small size of the project. The project lost funding in the last year.

A) <u>Practice Oriented Ideas</u>:

- Quarterly written reports to Headquarters.
- Agency control gates: Request for Proposal (RFP), AO, Non-Advocate Review (NAR), Flight Experiment Board (FEB), Formal Annual Review.
- Pre-Phase A was done on Center funding; Headquarters funded Phase A study.
- Mission Performance Requirements were developed from "years of experience."
- Configuration control managed by individual projects.
- Project status and progress tracked by simple schedule, Assessment by Project Manager's feeling on cost and expense.
- A barchart of resources was used as a periodic report of costs and funding.
- Funding profile was a classic ramp-up over two to three years for Phase B. Workforce profile was uncontrolled; management did not know what labor was needed.
- Procurement process began when funding was received from Headquarters at the end of Phase A.
- Recommend working with one procurement person for a general standard contract.
- Technical Division at Center shared approximately $3 million of the $5 million total cost.
- If using Graduate Students, quality and quantity of workforce is variable.

- Fast Track management should get the right people (discipline and experience) around a table to brainstorm before initiating design, including technical input, as they know what has worked in the past.

B) Policy Related:

- May have driven some projects over cost if Full Cost Accounting was used.
- A realistic schedule to actually build the project should drive the location of reviews for a Fast Track Project. Magnitude of work should drive the schedule.
- Recommended project control gates for a Fast Track Project; NAR, chaired by Headquarters, System Requirement Review, and some Design Reviews. Reviews force a project to stand up and explain all details and to explain why internal decisions were made. The Systems Requirement. Review is the real key review. There needs to be a methodical process to decompose goals and objectives into specifications.

C) Cultural Changes: Overhead of a shuttle or space station (MIR) experiment not well thought out in the planning phase. Upfront planning is essential for Fast Track Projects. International projects may be impacted by language barriers and require careful planning.

Finding a Project Manager and Principle Investigator (PM/PI) who wanted the job is a barrier. Keep pushing on upper-level Center management to reject proposal if no people are available. Need to ensure that PM's and PI's knowledge, skills, abilities and expertise match the project's goals and objectives.

D) Technology/Tools Recommended: None

E) Other Observations:

- Most projects were US; concerned about spending US dollars to fund technical development overseas.
- The most challenging part of the project was finding a competent project manager at Headquarters to sponsor.

- Most projects that flew were successful.
- Most significant lessons learned: make processes orderly with reasonable schedules; not too short and not too long (between phases).
- Most innovative practices: not too rigorous; minimal paperwork; possible because of low cost ($1 million to $5 million).

10. **Lidar In-Space Technology Experiment (Lite Instrument)**: A totally in-house project with mostly civil servant workforce with local contract support. Project was shuttle space experiments with a $25 million Research and Development (R&D) budget, (including civil servant personnel funding). The total life cycle was ten years and started in January 1985. Post flight test was in January 1995.

The project management function was performed by the Lite Project Office for five years, moved to project development for four years; then the project development was reorganized into five project offices.

Project success was defined by 45 hours Light Direction and Ranging (Lidar) data over many of different atmospheric conditions (no metric on data quality).

A) Practice Oriented Ideas:

- A written and approved project plan was developed.
- Approval for key personnel was up to Flight Electronic Division (FED) if within own line or up to Director Level if within Directorate.
- Project Status and Reporting requirements:
  - Weekly staff meetings
  - Monthly Mission Information Control (MIC) [no longer used].
- Reporting driven by Center Director.
- Did not use IPTs used classic hierarchy. Project Manager (PM), Assistant Project Manager (APM), and IM were co-located.
- Center level control gates were not formal. Went through Center Director.
- Agency level control gates: a few presentations in late 1985 and CDR at Center in January 1986 with visit by Headquarters and approval for year two.
- Center sent representative to Headquarters on task to generate job for Center on laser development. Feasibility study conducted by NASA personnel from January 1984 to January 1985.
- No formal process to develop Mission Performance Requirements.

- A Product Assurance Plan called for configuration control to start at instrument integration. Latitude given on electronics design up to instrument integration.

- No formal metrics were established. Weekly status staff meeting fostered environment of open communication where it was okay to state problems.

- Project was re-baselined annually due to fluctuations in funding source. Code at Headquarters would fund what was left in budget.

- Risk management was not formally addressed.

- Funding profile changed annually. Workforce profile was independent of funding profile.

- Wrote Laser SOW and Center issued RFP to attract potential mission partners. Contract was a cost plus fee and Center managed.

- Design requirements: bottom up to build best Lidar possible for available funding. Should have a technology demonstration.

B) Policy Related Comments:

- Near the end of 1993, Mr. Dan Goldin, NASA Administration, imposed Independent External Independent Readiness Review (EIRR). This was a waste of time as it came too late in the project (three months prior to launch). Review panel had no authority.

- Keep the Critical Design Review (CDR), Preliminary Design Review (PDR), Flight Readiness Review (FRR); but not the EIRR.

- Recommended project control gates for a Fast Track Project: Conceptual Design Review (CODR), PDR, CDR, Preshipment Readiness Review (PSRR), FRR

C) Cultural Changes:

- Under Full Cost Accounting, approximately $50 million for Full Time Equivalent (FTE) over ten years and $25 million Research and Development (R&D) funds for instrument development.

- Funding was to be as Level of Effort (LOE), but actual funding varied as project expanded from five to ten years.

- Consumed a lot of time and people to prepare and do reviews when they should have been training for operations.

- Procurement is a problem. Barrier is education of procurement people that space flight parts are not going to be procured the same way as office supplies are; lots of sole source buy.

- Have to live with barriers and work the problem (Space Tec and other Centers); contractor taking direction from civil servant at Center and incurring cost that project office did not budget.

D) Technology/Tools Recommended: None

E) Other Observations:

- Project was not process oriented.

- Most important lessons learned from experience with this project:
    - Entire management was school of hard knocks, and no failure resulted in loss of career potential

- A Fast Track Project must be strictly focused and use readily available technology; Instrument and Spacecraft, no technical development.

- Recommend a "not to break" 36 month development Authority to Proceed (ATP) to launch for full mission; part of mission for less time.

- If really looking to do Fast Track Projects, PM must have full authority and resources; PM needs autonomy to do job; if PM fails, fire PM, don't try to direct the work; and be receptive to request for problem/resolution suggestions.

II. Non-Interview Data Gathering

1. <u>Goddard Space Flight Center (GSFC) Senior Group Fast Track Brainstorming Ideas</u>: This is not an interview, but a summary of a Senior Project Manager Group Brainstorming session conducted July 17, 1996. The group was asked to brainstorm new ideas on Fast track Project management.

A) <u>Practice Oriented Suggestions:</u>

The Project Organization:

- Should be co-located, a skilled team
- Centralized support office
- Project tailors activities to the mission

Risk Management Approaches:

- Project delivers a risk plan
- Same team does similar missions (product line)
- Low technology requirements

Engineering:

- Choose from a Component Supermarket (Off-the-Shelf)
- Use System Engineers (SE) as architects
- Must provide an early bridge with customer
- Do Concurrent Engineering

Resources:

- Partnering arrangements
- Reinvestment
- Encourage unsolicited proposals

Status Reporting: Limit to chosen metrics

B) Policy Related Suggestions:

Project Organization:

- Multi-faceted, cross-trained
- Cycle or rotate "doers and watchers"
- Report to a single management level
- Project "contact" with agency
- Put trades in project plan

Risk Management:

- Portfolio of risk (low & high)
- Up front definition of success
- Project does Quality Assurance (QA) oversight
- Minimize Center requirements
- High level acceptance of failure
- Allow for trades
- No added requirements

Engineering: None suggested

Resources:

- Total up front, timeless dollars
- No Federal Acquisition Regulations (FAR)
- Liberal interpretation of NASA FAR Supplement
- Unrestricted subcontracting
- Go to fixed funding cap arrangements
- No unfunded mandates

Status Reporting:

- Team self-assessment
- Respond to single customer
- Status problems only
- Limit performance reviews

C) Cultural Changes:

- Project Organization is an enabled, small team
- Risk Management should be a no fault experiment in the early years of Fast Track Projects.
- Engineering should make the customer part of SE team.
- Management should add incentives for saving money on contracts
- Status Reporting: no suggestions

D) Technology/Tools: Recommend use of electronic status reporting

E) Other Observations: None

2. **GSFC Junior Group Fast Track Brainstorming Ideas:** This is not an interview, but a summary of a NASA/GSFC Junior Project Manager Group Brainstorming session conducted July 25, 1996. The purpose of the session was to brainstorm radical ideas on fast track project management. Participants were asked "how I would manage my own company" in a Fast Track Project environment. The results emphasized minimizing paperwork, presentational status reporting, and duplication of efforts.

A) Practice Oriented Suggestions:

- The Project Organization:
  - Teams consist of less than five people each
  - Concentrated project team
  - Co-located project team, including contractor
  - Replace handbooks with cookbooks; (ideas rather than rigid guidelines)
  - Annual internal re-assessment of project

- Risk Management:
  - Build Quality Assurance (QA) into design; not an oversight function
  - Benchmarking at start of project
  - Risk assessment of new technology
  - Bottomline threshold of pain on risk (acceptable impact assessment)
  - Minimize new technology
  - Document Lessons Learned for the future

- Resources:
  - More cooperative agreements with contractors
  - Use contractor's procedures in WBS, minimize scheduling, Reporting, QA, etc., to avoid duplication
  - Liberal interpretation of Federal Acquisition Regulations (FAR), NASA FAR Supplement
  - Use past performance as primary means for choosing suppliers
  - Maximize objectives in award fee determinations
  - Use blanket travel orders to minimize paperwork

- Status Reporting:
  - Daily videoconferencing
  - Replace formal reviews with peer reviews
  - Eliminate paper documents
  - Review hardware and software, not presentations
  - Hands on reviews
- Miscellaneous:
  - Limit specification and requirements documents to less than six pages
  - Build items that are more integrated
  - Minimize technical interfaces
  - Take advantage of every loophole
  - Eliminate redundancy
  - Use existing software and ground systems

B) Policy Related Suggestions:

- Project Organization:
  - Phases should be fluid and flexible
  - Use merit pay to reward accomplishments; negative pay for failures
  - Project manager has more authority/responsibility for project
  - Government project office located at contractor's plant
- Resources:
  - More Commercial Off The Shelf (COTS) contracts
  - Develop penalties to your suppliers for poor performance
  - Modify cost sharing in cooperative arrangements
  - Up front, timeless funding including reserves
  - Shorten, simplify procurement
  - No mandatory goals in contracting
  - Tie award fee into on-orbit performance
  - Utilize cost incentives in contracting
- Miscellaneous: None

C) Cultural Changes:

- Project Organization:

  - Minimize power centers
  - Rotate people
  - Term limits on management

- Risk Management: Up front risk management philosophy

- Status Reporting:

  - Fewer major reviews, less people
  - Interactive around the table rather than presentational

- Miscellaneous: think small, fast in all project areas

D) Technology/Tools:

- Resources: computerized Configuration Management (CM)

- Status Reporting: do electronically

E) Other Comments: None

3. **Lewis Research Center (LeRC) Pyramid Team (Pare Down suggestions for NHB 7120.5):** This is not an interview, but a collection of suggestions from LeRC. The team consisted of three persons, two experienced Space Experiments Division Project Managers, and a new Aeronautics Program Project Manager who has Reliability/Quality Assurance experience. They were chartered with using the existing (Nov 1993) version of 7120.5 and paring down the stated requirements to the core elements necessary to adequately plan and execute a Fast Track Project. Their output was related back to specific elements of the 7120.5, with appropriate interpretive comments and ideas. Background discussion output from APM-23 SSG deliberations on the nature of Fast Track Projects was shared with the group. The group was briefed on the overall charter, and tasked with a separate focused approach to developing Fast Track guidelines, and were encouraged to define the nature of a project that could be deemed Fast Track.

A) Practice Oriented Suggestions:

- Each Center should develop a Fast Track implementation plan, consistent with the types of projects for which they are responsible.
- For a project to go the Fast Track route it must:
    - State the intent for Fast Track at RDR/NAR (in Phase B) and in the Project Plan, agreed to by primary stakeholders (project manager, program manager, principal investigator, industry partners, etc.)
    - Receive approval for Phase C/D/E Fast Track at Authority to Proceed (ATP).

B) Policy Related Suggestions:

- The Fast Track definition applies only to phases C/D/E of the project life cycle:
    - Not required to pay for the assurance of lowered risk (per risk definition of NHB 7120.5, 11/95 version, table 6-1), which is manifested by removing control gates such as formal reviews, inspections, etc. (safety requirements will not be compromised).

- A project is appropriate for Fast Track when:
  - There are no undeveloped technologies necessary for mission accomplishment.
  - Requirements are clearly and completely defined (system design specifications are complete with no development issues) at RDR/NAR.
- The minimum requirements for Fast Track Projects are:
  - Phase C Requirements
    (NHB 7120.5A, Table 2-3, p. 2-25)
    - Validated PCA - annually
    - PMC Review Baseline - as necessary
    - CDR Specs Baseline - as necessary
  - Phase D Requirements
    (NHB 7120.5A, Table 2-4, p. 2-29)
    - Validated PCA - annually
    - PMC Review Baseline - as necessary
    - IRR Reports - per PCA
    - Operational System - end of Phase D
  - Phase C/D Requirements and Reviews
    (NHB 7120.5A, Figure 4-1, p. 4-2)
    - Omit all IARs
    - Omit first IRR review and maintain only second one (at end of Phase D)
    - Have PMC review in Phase C or D only as necessary
    - Omit all QSRs

C) <u>Cultural Changes</u>: None

D) <u>Technology/Tools</u>: None

E) <u>Other Comments</u>: None

4. **<u>Lewis "Clean-Sheet" Team</u>:** **This is not an interview, but a collection of suggestions from Lewis Research Center. Background discussion output from APM-23 SSG deliberations on the nature of Fast Track Projects was shared with the group. The group was briefed on the overall charter, and tasked with a separate focused approach to developing Fast track guidelines.** They were encouraged to define the nature of a project that could be deemed Fast Track.

> Our team spent some time discussing what a Fast Track project should be in terms of size, schedule, complexity, safety risk, and so forth. We concluded that the definition of what project should be Fast Tracked was really not critical to the determination of how the project should be managed if it is to be successful in the world of "Better, Faster, Cheaper". In fact, we felt that these particular changes to project management were relevant to all projects around NASA in the interest of getting them done at whatever rate

Key assumption: The project manager on a Fast Track program must be experienced and motivated.

A) <u>Practice Oriented Suggestions</u>:

- The Fast Track Project manager must have been through the traditional project development so that he/she is aware of what things are necessary and what are not. Experience is a must to be able to make the decisions that are required throughout the project.

- The project manager must also believe in the value of the project itself, otherwise he/she will not be able to motivate the team.

- There must be a clear agreement on deliverables between project manager and his/her single point of contact.

- Project requirements are agreed upon at the beginning of the project.
  - Whatever the nature of the project, the mission goals need to be explicitly spelled out in the beginning of the project. The project manager needs to be able to make trade-off decisions during the development of the project that will effectively get the project completed but not at the expense of the mission goals.

  - Goals are agreed to directly between the project manager and the customer, whoever that may be.

- Procurement must be streamlined for Fast Track projects.

- Positive incentives should be used to meet schedule and cost.

B) Policy Related Suggestions:

- The project manager needs the freedom to choose his/her own team members and to change them during the project if necessary.
- The project manager reports to a single person for project progress reviews
- The format of the project progress review would be at the discretion of the project manager as a way for him/her to best represent the project status.
- The design reviews are for the project manager and are held within the project team. The review process should include reasonable but not burdensome documentation.
- The project manager must have financial and schedule flexibility.
- The project manager must have direct access to decision makers, both programmatic and financial.

C) Cultural Changes:

- If a project manager saves money, he/she is usually rewarded with less money to spend in the future. This system does not encourage practical spending of money throughout the life-cycle of a project and certainly does not provide for a management reserve which is imperative in a program.
- Individual recognition for doing a job well needs to be improved. People work better when they are appreciated and when their work accomplishes something that is valuable to someone.

D) Technology/Tools: None

E) Other Comments: None

Appendix C

SRI Space Programs Interview Compilations

I. Jet Propulsion Laboratory (JPL)

1. **JPL Reengineering Effort:** A 1991-1992 benchmarking study looked at development process reengineering in industry and divided companies into two categories: Product Organizations for those with Space oriented products similar to JPL; and Process Organizations if they had different products but similar development issues and processes. An example of the later would be an automobile company with the process of developing a new car line.

Documentation had been lost for this study, but contacts from the interviews were made available. Results showed that success for these organizations was due to about 10-20 percent as a mix of technology applications, and 80-90 percent as cultural change. JPL has proven these results, cultural change is what ensures success. This study also interviewed business managers in the organizations contacted to do a capabilities evaluation and arrived at similar conclusions.

Following this study, the JPL director, adapted the principles of Michael Hammer, Hammer & Champy (Reengineering the Organization). One of Hammer and Champy's basic tenets, is that you cannot re-engineer everything, you must be selective. JPL sculpted this selectivity with key JPL process personnel, focusing on JPL customers and stakeholders. It initially encompassed four basic JPL processes with a fifth added several months ago. These processes are: 1) Development of New Products; 2) Growth and Assignment of People; 3) Development and Management of the Institutional Environment; 4) Business Systems; and 5) Enterprise Information Systems. These five areas were seen to have the best potential influence along the lines detailed by the JPL Strategic Plan. While Development of New Products perhaps has the most influence in this study's areas of interest, it was clear that each of the areas contributed to the ability to identify beneficial change leading to operation in a "Better, Faster, Cheaper" environment.

2. Mars Exploration Program: Ms. Donna Shirley is the JPL Program Manager for the Mars Exploration Program series of missions. The Mars Exploration Program is one of the pioneering approaches to "Better, Faster, Cheaper" space exploration which will be active at least over the next ten years and perhaps longer.

The Program's goal is to visit Mars as often as possible within budget constraints with a "continuous infusion of new technology".[1] Much of Ms. Shirley's ideas are in her paper, *Mars on $300K A Day*, reprinted in Appendix E of this study. In addition to a summary of the overall Program, there are valuable thoughts on a business analysis approach to the Program, a summary of the Program Strategic Plan, and Program organization, including industry and science partnering, and cost containment practices.

A) Practice Oriented Ideas: Donna identified a problem with organization buy-in to projects by those who hope to buy-in just to be sure to be in on a project. Buy-in has been a common practice for projects. There is nothing wrong with a company being aggressive to capture a program and make up for an initial low profit through efficiencies on later missions. However, buy-in could be a real barrier to long term success in a "Better, Faster, Cheaper" era. The first mission in a series could achieve goals, but later missions could become more expensive. It is important to get a good solid bid the first time that will carry through an entire project. Once on the project, it is very important for project managers to be able to hold really good cost reviews and descope if necessary to hold costs. There are several other practice related suggestions in her paper.

B) Policy Related Comments: A very large barrier to cost and schedule management in any project relates to project requirements. Ms. Shirley's First Law of Project Management is: "A requirement ain't a requirement until somebody's willing to pay for it." Ms. Shirley further stated that "This is the key to everything." She even suggested expunging the word requirement from the NASA Project Management lexicon until we can get to a better, common understanding of just what we mean when we say requirement. Requirement should mean that desires and capabilities have been defined, compared and matched. Once this is competed they can become a contract. When requirements for a project are agreed to, management must hold firm to that common definition with respect to cost and schedule objectives until, and unless, a sponsor for changed requirements steps forward with the ability and willingness to pay for their addition and accept the schedule impact.

[1] "Mars on $300K per Day": The Mars Exploration Program, Donna Shirley

In addition, the project office, when soliciting participants, must learn that in order to keep costs low we must change from detail specifications of the past to performance (minimalist) specifications. This is analogous to the military's move away from Military Specifications (MilSpec) and Military Standards (MilStd). Other benefits also accrue with this approach, in simplicity of development and integration.

C) Cultural Changes: Ms. Shirley's suggestions here dealt mostly with the need to have a more business-like approach, including knowing how to relate to your gain (profit) from the program and to know your competition. Her paper also addresses these ideas in more detail.

D) Technology/Tools Recommended: None

E) Other Observations: None

3. New Millennium Program

a) Deep Space 1 (DS1) Project. First in a series of New Millennium Program missions, DS1 will validate technology for use on future space missions into the 21st Century. There is a list of primary requirements and secondary goal technologies to validate, plus Mission Goals that are not part of Primary Mission Success Requirements. These Mission Goals include a plan to fly by one comet and one asteroid, returning imagery and spectral data. The basic Project is capped at $138.5 million. The Project is managed for JPL by David H. Lehman as the JPL Flight Lead. The spacecraft development contractor is Spectrum Astro Corporation, and were interviewed separately for this study.

A) Practice Oriented Ideas: This project drew much from the JPL Reengineering Process Action Team (PAT) output and these included using a revised parts development/procurement process and an improved schedule-receivable/deliverable process system.

Another practice which aided in successful management of a "Better, Faster, Cheaper" project was in selection of suppliers for the development effort. The project management team saw that there would be six Integrated Product Development Teams from which would flow 13 technologies. Requests for Proposal (RFP) were released for each of the teams, requesting a three to five page proposal. After a down-select process, more detail was asked from those remaining. This submission was scored and a final selection made.

B) Policy Related Comments: The management approach which is most responsible for any success achieved to date is the variable scope and capabilities given by NASA for this project. This came from the above mentioned definition of primary requirements and secondary goals for mission success. In the past everything was a requirement, leaving the project manager with little latitude if part of the development for the mission ran into difficulty. Reserve may be better applied on just the primary requirements, with secondary goals not driving cost and schedule

A second area, the result of ongoing efforts within JPL for better management of projects, is an attempt to limit documentation to only that necessary for the project. Documentation requirements had been cut by one third between Casini and Mars Pathfinder. DS1 has cut that by another half. This makes the project more cost effective, with the team making decisions based on planned management needs during the course of the project.

C) Cultural Changes: Encouragement of innovation and improvement in processes to meet firm requirements was a key tool to ensure cutting development time. Previous missions would have been given, and would have taken, six years from start to launch. It is now given two years, and the team expects to make it. In other words, everyone works together as a team on cost, schedule and technical performance to ensure project success.

D) Technology/Tools Recommended: A good communication system is a big factor in holding down cost for the project. The key tool in this system is a top of the line video conferencing capability, paid for by JPL, both at their end and with their primary partners, in this case Spectrum Astro. The system was paid for with approximately one month's savings in travel costs. Time away, travel time and non-productive spin-up/spin-down time for individuals has also been cut drastically, making for more productive project activities.

E) Other Observations: A copy of the DS-1 Project Plan is provided in Appendix E of this study.

3. New Millennium Program

b) Mars Microprobe Project. Mars Microprobe is one of several experiments planned for missions to the Planet Mars into the 21st Century.

A) Practice Oriented Ideas: Teamwork is the key to success. Management basics are reduced for the project manager: 1) getting the right people and keeping them motivated; 2) being the one person who steps and stands back to see the big picture and big problems; and 3) having a plan and making sure everyone understands it. These are expanded in order.

Getting the right people is somewhat subjective and involves knowing the necessary discipline/functional areas to be used, the people in them, and asking for them by name when the project starts. Motivation involves giving team members real responsibilities on the project and with the team; "ensuring they all understand that..." which involves directing team members to write down their plan and schedule, and expecting it to be followed. This further involves enabling team members to be able to communicate and be involved with the rest of the team.

Directing things to be done, means getting the team to sit down, deal with the project from a big picture standpoint and ensure that they understand that they will live with their plan.

Being the Big Picture person for the team means making sure things make sense overall. This again involves ensuring "they all understand that..." which involves getting the team members to understand each other's activities as well as their own.

Having a good plan comes from two management concepts. The first is having and documenting good requirements. This will include using common terminology that is thoroughly documented. The second is using this documentation to lead the team in creating a bottom-line schedule from each of the detailed schedules.

B) Policy Related Comments: Functional and design reviews are team functions, held when needed, not at a fixed date, and kept as informal as possible. "Better, Faster, Cheaper" is not an excuse for sloppiness, and documentation of issues and necessary actions is very important. The project manager must strive for distinction between excessive formality and making the review process be a good solid communications tool.

Each element of the project (sub-systems, QA, ME/SE, Packaging, etc.,) is required to have three reviews leading up to corresponding Project Reviews. Reviews at the element level are in-process peer reviews and are called Conceptual, Interim and Final Reviews, as are the corresponding Project Reviews. They take the place of the more formal Preliminary Design Review and Critical Design Review.

Since these reviews are focused on issues, much of the work is resolved at the element level. Outside team members are brought in to ensue that the reviews are real team functions. Action items for these reviews are called advisories and are consolidated and documented before the meeting ends.

The end objective for the reviews, as for the project, seems to be to have a plan that everyone understands. This is accomplished by documenting the plan and ensuring that it is built on good requirements.

C) Cultural Changes: No specific changes were listed, but allowing the project manager the flexibility to set and manage the project design review process may be something that would enable Fast Track Projects to move ahead smoothly with minimal disruption.

D) Technology/Tools Recommended: Contract Management is a tool the project manager must have in order to ensure subcontractors can fully participate as team members. The project manager must understand FAS.

E) Other Observations: None

4. **Pluto Express Project.** **The JPL Ice and Fire Pre-Project Manager, which includes Pluto Express, Europe Orbiter and Solar Probe, is Mr. Robert Staehle. Several times Pluto Express** was mentioned by others in the past few months as an icon for "Better, Faster, Cheaper" projects. Pluto Express is an effort which will launch two sciencecrafts to explore Pluto and its moon Charon at the end of a 10-13 year set of trajectories. The idea of a Sciencecraft approach identifies "scientists and engineers working together with a high degree of communication, from the beginning." [2]

A) Practice Oriented Ideas: A large part of Mr. Staehle's focus for success in "Better, Faster, Cheaper" is on Design-to-Cost (DTC) as a way of managing. The design process also considers Test and Operation requirements. It is easier to ask questions related to these areas in the design phase, and to make necessary changes based on objective conclusions, than it is to determine problems and issues later in order to resolve negative impacts. The approach that allows this to occur naturally is to form teams based on Cross Functional Integration, including the Flight System Design Team, mission assurance, software, mission operations, launch systems, radioisotope approval, procurement, etc. Team member co-location was not possible on this project, so Mr. Staehle said that he considered it important to get the team together frequently, in lieu of co-location.

B) Policy Related Comments: Mr. Staehle had no specific recommendations for policy related changes, but provided a list of process improvement initiatives developed for Pluto Express by the team. This list is in Appendix E of this study. One item, commonly discussed by other organizations meeting with some success in reengineering development processes, and present in this program, is minimal formal documentation to help hold down costs. Examples given for areas being looked at currently include on-line documentation; requirement documents no more than one page; and, documenting new designs by as-built next-earlier generation documentation, plus deltas.

C) Cultural Changes: Mr. Staehle said that as Pre-project Manager he wanted to move from a normal mode of periodic operation to one of continuous operation. This refers to managing team members from all areas continuously, rather than as a series of short and periodic project involvement. This has implications for dedication of matrixed personnel from the line organizations, and translates to a project goal of maintaining equal to or greater than 0.90 dedicated personnel time, supplemented by equal to or under 0.20 consultant time, referring to ratios of Full Time Equivalent personnel. It is also very important to carry as many Pre-Project personnel into the project as dedicated personnel as possible. In this part of the discussion he referred to Robert Townsend's Up the Organization as a source of ideas for this approach.

[2] JPL Pluto Express Brochure, version 1.1, 6/6/96

D) Technology/Tools Recommended: A Cost Analysis Tool, PCAT is recommended by Mr. Staehle that allows everybody to do Design Analysis and Cost Impact Analysis together. It is a simple spreadsheet tool developed at JPL that allows each area to separately develop Work Breakdown Structures based on cost estimates that roll up into a total project cost analysis. A related project trade-off model allows quick assessment of end-to-end cost impacts of proposed mission and design changes.

E) Other Observations: None

5. <u>Clementine I Project</u>: Clementine I was a Ballistic Missile Defense Organization (BMDO) sponsored program from the Naval Research Laboratory (NRL), performed in conjunction with Lawrence Livermore Labs and NASA. Science objectives led to methodology which included a lunar fly-by and asteroid rendezvous. The project was characterized by a very short, tight schedule and a very limited, capped budget.

A) <u>Practice Oriented Ideas</u>: Clementine I used a less conservative approach to this project than other space projects. There was more of a willingness to try new, untried approaches to meet cost, schedule and science objectives. The severe budget and schedule constraints forced the team to constantly consider different, innovative ways to solve management problems.

Also, there was a very streamlined Program and Project Management structure with a definite lack of management layering. This enabled decisions to be made quickly and their implementation to happen quickly.

In addition, ACT Corporation, hired to do imagery data management and daily archiving of science and engineering data, were responsive and innovative. ACT Corporation used a PC based system versus a mainframe, handling up to 25,000 images per day, and managing the daily archiving of data with only three people. They implemented their approach in a very short time, and did it at one quarter to one tenth the usual cost for such a mission.

A pro-active, hands-on approach used by the Clementine BMDO Program Manager was effective in creating the team approach which characterized Clementine, and in managing cost and schedule parameters. The teamwork importance was also recognized in comments made by both men about the importance of 'cradle-to-grave' assignment of engineering team members and the effectiveness of training and co-location of team members.

It is important to closely monitor cost and schedule data.

B) <u>Policy Related Comments</u>: The project management limited the number of standard reviews. This was found extremely effective from an efficiency standpoint. Reviews were primarily to satisfy issue resolution held, and was an effective methodology for staying on schedule.

C) Cultural Changes: Clementine embodied many approaches useful for "Better, Faster, Cheaper" projects. NASA should consider adopting these successful approaches, but they will involve significant cultural changes.

D) Technology/Tools Recommended: None mentioned outside of comments referenced above regarding the role ACT Corporation played. This indicated that standard approaches using computer technology may need to be revisited as capabilities within such tools as PCs become more sophisticated.

E) Other Observations: See attached view-graphs from Dr. Garrett's *Personal Perspective and Recommendations* for future "Faster, Better, Cheaper" projects.

RECOMMENDATIONS FOR FUTURE "FASTER, CHEAPER, BETTER"

PROGRAMMATIC:

- BE A PROACTIVE PARTICIPANT/MANAGER IN PROCESS
- ESTABLISH CHEAP, SMALL "TRAINING" MISSIONS (E.G., ISAS)
- ENCOURAGE TECHNOLOGY DEMONSTRATION FLIGHTS (ACCEPT MORE RISK)
- LIMIT MANAGEMENT TEAM, REVIEWS, CONSULTANTS
- CLOSELY MONITOR COSTS AND PROGRESS
- MAINTAIN STRONG CONGRESSIONAL CONTACTS

PROJECT:

- ASSURE CRADLE TO GRAVE ENGINEERING TEAM MEMBERS
- COLLOCATE ASSEMBLY FUNCTIONS
- EXPLORE "JUST IN TIME" PHILOSOPHY
- DEVELOP "NEW" QA/RELIABILITY PROCEDURES FOR CLASS D MISSIONS

A PERSONAL PERSPECTIVE
(H. GARRETT)

KEY ISSUES:

DOD:

- BMDO HAS A UNIQUE TECHNOLOGY PRODUCT BASE
- 4 YEAR/UP OR OUT MANAGEMENT PHILOSOPHY
- DOD WILL TERMINATE A PROJECT—HARSH POLITICAL CLIMATE
- FAILURE NOT THE END OF THE WORLD!

PROGRAM:

- PROGRAM MANAGER/CUSTOMER ASSUMED ACTIVE PROJECT MANAGEMENT ROLE
- PROCUREMENT PROCESS EASED SUBSTANTIALLY BY GOING THROUGH EXISTING CONTRACTS AT HOST FACILITIES
- TOUGH FISCAL CONTROL BY PROGRAM OFFICE
- MISSION SHORT DURATION, OCCURS AT SOLAR CYCLE MINIMUM, AND USES ULTRA-RELIABLE LAUNCH SYSTEM

A PERSONAL PERSPECTIVE

KEY ISSUES (CONTINUED):

NRL:

- TEAM VERY YOUNG, ENTHUSIASTIC BUT WELL TRAINED
- WORKSITES COLLOCATED/LIMITED
- NRL INDUSTRIALLY FUNDED
- QA/RELIABILITY ROLES COMBINED AND SHARED BETWEEN QA AND COGNIZANT ENGINEER
- CONTAMINATION CONTROL DELIBERATELY LAX (EXCEPT FOR PROPULSION SYSTEM)
- PERCEIVED "JUST IN TIME PHILOSOPHY" FOR ALL FACETS OF PROJECT INCLUDING MISSION OPS

II. Applied Physics Laboratory (APL) at John Hopkins University

1. <u>**Discovery Program, Near Earth Asteroid Rendezvous (NEAR)**</u>: NEAR is the first of a series of missions under the Discovery Program which are designed to explore space from the moon out to Mars and the Asteroid belt. NEAR was awarded to APL in the late fall of 1993, with a total cost to launch of $150 million. NEAR achieved their success at under $112 million. It is designed for rendezvous to orbit with the large near-earth asteroid, Eros in January 1999.

A) <u>Practice Oriented Ideas</u>: It is important to receive and understand fixed project objectives. "The objectives at the start must be those you finish with." The project must maintain focus. These are not only the Level I technical objectives but the cost and schedule objectives as well. One key to success is having support, not oversight, from the NASA Program Manager. The program office maintained a single point of contact approach on all matters, keeping interruptions down to a minimum.

It is important to understand the cost and schedule driven nature of "Better, Faster, Cheaper". A Design-to-Cost (DTC) and Design-to-Schedule (DTS) focus was evident throughout all discussions which translated to delivering project products. A true DTC approach requires a technical design that recognizes performance as the dependent variable with the design being changed to meet cost objectives. Design margin is critical to success. Should any requirement changes be contemplated, cost and schedule impact questions must be answered. Because of this, it must be understood that the first three months are the most important part of the project. In the first three months the project management team for NEAR:

1. Set policy (DTC/DTS, team environment, communication),
2. Picked partners properly (a most important step), and
3. Set philosophy of simplicity in the project plan.

Picking partners properly was stressed. The corporate flexibility for a partner to work in the planned environment is critical. Flexibility must be evident at least one level above the partner project manager to ensure the team leader will be able to do what is needed. This is critical because of the flatness of the project management team structure and the need to create a badgeless community. During the project, team members develop an allegiance to each other and to the project manager, based on trust.

The APL approach to the structure of the project team was to use a lead engineer concept over an entire subsystem, working under the Project System Engineer. Scope was defined with the lead engineer who was held to it. The subsystem team leader was also a worker and had ownership of the problems and the problem solutions.

The team environment extended to ensuring that all those working on and affecting the project were made part of the team as early as possible. The contracting officer was assigned to the team. Manufacturing and purchasing were brought in early, attending daily meetings, discussing problems, and developing on the spot solutions. The extra insight and belief in the schedule gained by manufacturing and fabrication was deemed invaluable. Other team members also gained appreciation for involvement and overtime impact of schedule decisions.

Throughout the process, extra hours worked came as a result of commitment to other team members. Prior experience had seen commitment to the boss versus the team.

Having short term goals, such as fixed delivery dates, hardware-on-the-floor dates, etc. became team rallying objectives. People believed in the objectives and in achieving them.

Team communication was also stressed. Person-to-person communication was used wherever possible. Low-level design reviews were used to build in quality and to communicate.

In the cost and schedule constrained environment of NEAR, this depended on being able to leverage people with a track record of experience. (It is mentioned as a concern that a more standard process on some projects should be available to teach newer people, in order to be able to provide those with experienced track records in the future.)

B) Policy Related Comments: The low level design reviews worked into scheduled Project Reviews. The Project Manager worked with NASA to schedule mandatory NASA reviews (NARS) in conjunction with the Project Reviews to minimize disruption. The NAR panel was asked to attend the Project Reviews with a day added to address remaining NAR objectives. The NAR panel's willingness to fit into a different format provided for a less intrusive, less costly approach.

C) Cultural Changes: Although the DTC focus has been mentioned, all stressed that this is truly different from past practice in these types of projects. Performance margin must be designed in. Buying the 90 percent version gains you wiggle room in the development process.

It must be accepted up front that performance optimization will be limited and perhaps not possible. The project manager uses margin gains in one subsystem to help relieve another team member. This was aided by 50 percent use of the shell equipment.

From the beginning, the approach used on NEAR stressed the need to be able to use simplicity, standards and cleverness to solve problems in lieu of a more expensive high technology solution. "What made this program go was keeping it simple." An example given was that the analysis of space craft geometry at the asteroid with respect to the earth and sun allowed use of less costly, less complex fixed solar panel arrays and communications antennae.

Another cost and time saving innovation was the use of standard aerospace 1553 data bus architecture for the first time on such a craft. Designing to an existing standard that people are used to saved time over designing a unique interface. This saved an estimated month of test and integration time.

D) Technology /Tools Recommended: While use of tools was not stressed, the use of CAD/CAM tools is standard at APL.

E) Other Observations: Appendix E contains the paper, *Cost Estimation and Modeling for Space Missions at APL/JHU*

III. Hughes Electronics Space and Communications Company

1. Communications Satellite Manufacture and Launch: Hughes has re-engineered their design-to-launch cycle for communications satellites to stay competitive in the world market. Past practice took as long as five years from contract to launch date and Hughes is now working toward a 12 month cycle.

A) Practice Oriented Ideas: There is a great value in consolidation and co-location in the space craft development and delivery process. Hughes has moved from a development, assembly and test process using several buildings and locations to a single facility large enough to accommodate co-location of people and functions. While the program manager provides customer interface and budget management, the design engineering team, using a work-cell, or production line approach, moves with the space craft as it develops. More and better dialogue with the government customer regarding cost-containment practices is recommended.

The continuous improvement approach in the evaluation of Hughes' completion of spacecraft to launch process has allowed them to advertise a ship and shoot time of 31 days. This has encompassed the entire launch integration and processing focus. They have tightened their launch team requirements to a team of only 15 people. This came by examining all costs and functions with a view to reducing cycle time. Shipping, decontamination, fueling, etc. have all been examined and reduced in time and cost where possible. Launch operations achieved a reduction from 38 days to 17 days in fueling the spacecraft. A 33 percent reduction had been achieved just by looking at the model of the process cycle time. Savings have also been achieved by going to off-the- shelf resources as well. For instance, a commercially available stainless steel container used in the dairy industry was found adequate for use in the process at a significant savings.

B) Policy Related Comments: The government should examine the procurement turnaround time which is currently cumbersome and costly for the commercial provider. Allowance for more creativity in the type of contract offered with an eye to the possibilities allowed in the FAR is also important in a "Better, Faster, Cheaper" environment.

C) Cultural Changes: No specific areas were mentioned, except to note that as government tightens its belt, industry is also tightening its belt. Corporations such as Hughes are looking at participation more and more in terms of return on net investment and feel they can contribute on that basis with their cost reduction efforts.

D) Technology/Tools Recommended: None

E) Other Observations: None

IV. Lockheed Martin Corporation

1. **IRIDIUM Global Cellular Satellite Program:** Lockheed Martin is a subcontractor to Motorola on the IRIDIUM Global Cellular Satellite Network. The founder company for IRIDIUM has designed the network to consist of multiple satellites in low earth orbit. Each satellite will be able to be produced from scratch in five days and put into orbit eight days later. It is designed to allow phones of only six ounces to communicate with any other phone on the network anywhere on earth.

A) Practice Oriented Ideas: Earned Value management is a practice that promotes cost control. This grew out of a need to be more competitive, and seems to drive down all costs. The concept began by performing a comparison between military and commercial practices, benchmarking commercial practices and comparing them to MILSTAR. The resulting approach focuses on identifying indicators that will be standardized on a set of those things Senior Management will look at; the things everyone must do.

Two most important concepts which are part of this approach are:

1. Emphasis on insight versus oversight; answering the question, "Is the management system doing what it is supposed to do?"

2. Replacing rule-based Cost/ Schedule Control Systems Criteria (C/SCSC) with analysis and judgment.

The benchmarking effort examined what was working, and identified those best practices that, for example, combined management of cost, schedule and technical performance.

Lockheed Martin's approach is to use Integrated Product Teams (IPT) and keep project manager reviews to one and a half hours using charts that communicate information, but are not expensive or time consuming to produce. The charts being used to brief the program should be the variance charts/reports that are used by the project team. The chart should show trends, indexes, and other necessary data and provide an opportunity for the team leader to say "This is what I need to fix this problem." MILSTAR has accepted the commercial practices identified. The president of Lockheed Martin refers to this as "the basic block-and-tackling of management."

B) Policy Related Comments: The way NASA funds accruals with the 533 system and mitigates the benefits of using Earned Value. This is at least partly because NASA is not funded for termination liability. Actuals differ for the two systems.

C) Cultural Changes: First NASA should recognize that the practices described above differ from past practices. Second, these new practices will require education for these practices to be standardized.

D) Technology/Tool Recommended: None

E) Other Observations: None

V. Spectrum-Astro Corporation

1. New Millennium Program, Deep Space One Project: Spectrum Astro is the Prime Contractor to the Jet Propulsion Laboratory for Spacecraft development on the Deep Space One (DS1) mission (see earlier description of DS1 under JPL).

A) Practice Oriented Ideas: As a small company, Spectrum Astro examined practices and organization structure of larger competitors. They saw that in the past, 20 percent of the people on such programs did 80 percent of the work and added 80 percent of the value. Spectrum wanted to try to structure its involvement so that they could get that 20 percent number to be 100 percent. They used inherently smart people, that could take on end-to-end responsibilities. In addition, the organization adopted a work as a skunk works organization model, encouraged innovation and minimized outside interference. This was supported by the JPL Project Management team.

Cost and schedule need to be treated as main drivers. The project manager must control creeping requirements. "Anything impacting cost and schedule goes through a Spanish Inquisition; it is very painful to add new things."

There is also a need to treat design in the same way. Spectrum Astro uses a flexible bus architecture to accommodate the various technologies which are to be part of the mission. Once the Integrated Product Development Teams baseline specific technology demonstrations, the specific accommodation to the spacecraft can be rapidly evaluated and resolved

Although, the interfaces provided by Spectrum Astro as integrator needed to be flexible, the project manager moved the participants forward and allowed interfaces to be frozen at a reasonable time. The key is early flexibility, with the realization of a set time for freezing design.

Spectrum Astro realizes that innovative ways must be found to control cost and schedule. Their spacecraft design is a proven, low risk architecture that allows accommodation of a variety of technologies on a variety of missions, allowing for accommodation of DS1's rather high risk, and high pay-off approach to science.

Management of the team recognized the need to have split division of responsibilities between Spectrum Astro and JPL, but end-item responsibilities must be given to one. This decision is based on company or organizational strengths and discrete responsibilities are assigned.

B) Policy Related Comments: None

C) Cultural Changes: In keeping with the search for innovative ways to save costs, Spectrum Astro heartily endorses JPL's investment in video teleconferencing (VTC) capability as a way to maintain momentum and to avoid unnecessary disruption. While Spectrum Astro is located in Phoenix and only one hour away by air from JPL, such travel can still be disruptive.

Using VTC, team members can have daily meetings, including small team or working group meetings of one to two hours, while only planned all-day meetings require team members to travel to a single site.

D) Technology/Tools Recommended: For data and information communication/dissemination, a system using a collaborative file server checked on each end is used. The system resides on a Web site and includes Level I, II and III Requirements, a daily project calendar, phone list, PDR/CDR documents, etc. The system is working and allows Spectrum Astro and JPL to do project management as part of daily business.

E) Other Observations: None

Appendix D

SRI Non-Space Industry Interview Compilations

I. U.S. Air Force/ Office of Secretary of Defense

1. **Joint Direct Attack Munitions (JDAM)/ Joint Aid-to-Surface Standoff Missile (JASSM):** Both are developmental programs jointly managed by the U.S. Air Force and the U.S. Navy. Mr. Terry Little was government program manager for JDAM during a critical period and is now government program manager for JASSM. JDAM is considered a success within DOD for its use of new management approaches. These approaches are being refined by Mr. Little for JASSM.

A) Practice Oriented Ideas: Mr. Little's view of project management is that the government should have a very limited role, which includes: stating requirements; choosing the contractor able to do the job; facilitating; expediting; and working interfaces. It is the contractor's role to figure out the 'how -to' and then to do it. It is the primary role of the government program office to help the contractor be successful. The government can almost totally leave the how-to to the contractor. The only exception to this is in identifying and helping to manage safety issues.

A significant factor in proposal selection criteria on JDAM, expanded to 50 percent of the selection criteria in choosing the right contractor for the job on JASSM, is use of past performance. The contractor proposal is used only to present the design and technical issues. Past performance was used as the exclusive (or sole) means to evaluate contractor processes. This is done by examining past on-time development and technical performance. As will be seen, there is a true atmosphere of trust in the contractor, but the basis for trust is primarily past performance.

Contractor management capabilities are examined to determine:

1. The ability to manage cost and schedule,
2. Responsiveness to problem resolution actions, and
3. The extent the contractor has required past government intervention.

In short, the government must look for proven ability to meet cost, schedule and performance objectives. Also critical to success of Mr. Little's approach is that the government and the contractor team operate as a team. Because of this there was initial training, provided by the contractors through an external source, followed by reinforcements at six to nine months into the effort. Mr. Little's office also provided a facilitator to help spend time with the team to "define one or two goals which could be measured to determine progress and value added."

Mr. Little indicated that this approach works for him because he is comfortable with delegation and with trusting those on the team to make decisions. He indicated that with both those above him and those working for him, the atmosphere is one of creating expectations and then trusting people to live with those expectations and to rise to them.

B) Policy Related Comments: Because the JDAM program was being managed in an atmosphere of acquisition reform, still on-going in JASSM, Mr. Little was given broad policy waiver authority. Some of the waivers are being examined to see if they make sense for broader application to other programs. The key factor, as seen in other interviews, is the need to minimize activities and functions that add cost or time to a program by looking at the value they add.

One of the unique (for DoD) actions taken was to not require formal design reviews. The review process was put in the contractor's hands. Design reviews were run as peer reviews. There was no government requirement of contractor satisfaction of action items. This is in keeping with allowing the contractor to be responsible for the how-to.

There is a recognition within OSD of the need to streamline documentation. For instance, there is a tailored Defense Acquisition Executive Summary (DAES) and the monthly Acquisition Report, a single bulleted page.

Also, while there is still a requirement for a quarterly program review, it is much more informal and cognizant of the IPT structure. There is more trust and less looking for problems. There is also a recognition of a need to manage "By the Budget" as provided by Congress through the services.

C) Cultural Changes: Mr. Little mentioned that to achieve real teaming the government roles mentioned above needed to be real. This was done by significantly reducing the size of the government program office. The current JASSM office is one fourth the size of a previous attempt at a conventional cruise missile program. Program office members are grouped on one of the three team alignments, consisting of Helpers, Interfacers and Resourcers.

Each group has a charter which specifically excludes responsibility for oversight of the contractor. They truly are there to help. The Helpers are integrated into contractor IPTs and their role is to assist the contractor in fulfilling obligations. They take directions from the contractor program manager and input from him/her is a major input on that Helper's annual performance review. Interfacers help the contractor deal with problems outside the contractor's control. The Resourcers work issues of money and facilities, etc.

Because this is such a change from prior relationships with contractors and a reformed style of management, those not comfortable with this approach are moved to other more traditionally managed offices. Mr. Little believes however, that this is the management approach of the future and raises the issue of the need to educate people on this new approach and to reexamine the way program/project managers are selected.

It was also noted that the program made those with traditional oversight or inspector roles part of the team. The OSD oversight team developed more of a stakeholder mentality and attitude. Mr. Little fostered the attitude that it is every members' job to make this program successful with the result of the OSD team moving from oversight and inspection to a helping hand approach.

The difference that this management style makes was seen clearly in comparison to a traditionally-structured program. The same OSD team that was fully integrated under JDAM, was not integrated on the team of another program. They filled the traditional inspection/oversight role with that program and became adversaries rather than advocates. Mr. Little has clearly demonstrated that trusting your team and valuing their opinions yields good results.

D) Technology and Tools recommended: None

E) Other Observations: Further information about JDAM is in Appendix E.

II. Natick U.S. Army Laboratories

1. **Soldier System Science and Technology Development Program:** A concept program which treats the U.S. Army soldier as the system, the objective is to design the soldier's clothing and equipment that acts in concert to both protect and enhance warfighting capabilities, including communication. This effort is analogous to the technical challenge of many NASA missions where several different science and technology applications must be separately developed and integrated within a constrained schedule and a limited budget.

A) Practice Oriented Ideas: The most critical aspect for success is team structure and buy-in to that structure. It is also the most difficult aspect to get up front, especially making the user part of the team. Many users in DoD are accustomed to "Telling the developer what we want, then coming back at the end of the effort and telling the developer how bad they did." Making a way for the user to be involved throughout the effort is a challenge.

The philosophy of trust in those chosen to be on the team to perform a necessary management function is evident. We should refuse to pay for something twice. There was no government duplication of contractor positions. This allowed for a smaller than usual government staff and more reliance than usual on the contractor to assist in such things as cost management.

Due to the nature of the need to develop science and to manage cost and schedule closely, there were six Contracting Officer Technical Representatives (COTR) versus the usual one, each assigned to an IPT. This allowed each team to make decisions quickly that made sense, and still be responsible for cost, schedule and performance.

Reviews were managed as internal project tools for the benefit of the teams. Outsider involvement and input at these reviews was carefully limited. Major reviews were opportunities for IPTs to share information. In this project management approach, one is either part of the team or is an outsider.

Contractor selection is seen as very important also. Selection is based on choosing someone with a proven history of managing multiple subteams, system integration and an approach to Integrated Product Teams/ Integrated Product and Process Development (IPT/IPPD). How well the contractor has worked with sub-contractor in a team environment was examined (Was the best person selected to lead a team, or were teams always led by the prime?).

Once a contractor is selected, it takes time to get IPTs working well together, perhaps as much as six months. All of the teams are taught the tools to be used (Metric Measurement, Design for Manufacturing, Six Sigma, Quality Function Deployment, etc.,) as well as team building/team formation. A new set of management/ personnel skills is needed to be successful in this environment, including consensus building, team leading and others. While the special skills were not explicitly provided in training for the IPT leaders, they probably would be in similar future projects. While it takes longer to build team consensus and to work in IPTs than in a leader-directed environment, the decision achieved is better and restarts are significantly reduced. In addition, late discovery of integration problems are also greatly reduced. This moderated the fact that 70 percent of downstream cost is cemented in the design phase.

As mentioned, the teams are responsible for managing their cost, schedule and performance. This was facilitated by requiring each IPT to develop at least eight metrics to be tracked, four each for performance (weight, power, etc.) and four more which addressed such items as cost, management reserve, estimated spend rate versus actual, software reuse rate, etc. The management functions for the project also developed four performance and four cost metrics for the overall project, as well as a project risk mitigation plan. Risk mitigation was addressed at each review.

The project also analyzed how well the IPTs seemed to be doing in general by examining qualitative metrics, including team turn over rate, and how issues and action items are closed/handled, etc. This type of metric may be used to identify problem areas early without micro-managing.

B) Policy Related Comments: None

C) Cultural Changes: The entire area of close teamwork with the contractor, as well as inclusion of the user as part of the process, can be cultural change for many. Recognizing this and addressing it early in the project's life can help. Underlying the success of teamwork is the issue of trust. It takes time to develop and it is easy to break. The bearer of bad news must be given consideration and the information treated fairly.

D) Technology/Tools Recommended: None

E) Other Observations: None

III. Motorola

1. **Soldier-System Science and Technology Development Program:** The program is described in the previous interview compilation. Motorola is the prime contractor for this effort.

A) Practice Oriented Ideas: Motorola echoed the thoughts of the government Project Manager, in that teamwork is a key to the success of this project. The objectives in this are to be cross-functional/cross disciplinary wherever possible so that people talk with each other. Teamwork removes walls. To this end, the project manager must foster communications and either convert skeptics or remove them.

Motorola backs this both internally and on the projects they manage. Internally Motorola provides up to four weeks of training yearly to employees on teamwork, quality and related material. On projects, time is invested up front, on training in project management tools to be used and team building. This is done for each product IPT, including contractor, subcontractor and government team members.

In general, the Motorola philosophy is to push down the decision making process to the lowest level. It is both a privilege and a responsibility designed to empower the managers. In other words, it is done deliberately to develop managerial capability. The objective, beyond human development, is to have distributed versus centralized control and management. On this project in particular, the situation of the project forced distributed control. There were several technologies for which Motorola did not have all the organic technical capabilities required.

It is valuable to include the user on the project team. This allowed significant involvement of the user at the practical level, ensuring that specifications really represented operational requirements. For one example, a subcontractor identified a specification which was proving to be a significant recurring cost driver. By working closely with the user/customer to gain a better understanding of minimum requirements, the cost was better contained.

One way that teams worked to manage the limits was to develop effective metrics. These metrics are not things you measure because you can quantify them, but things you measure that will make a difference; those which will tell the manager there is a problem on the horizon. Since the design of this system was soldier-driven, not all of the performance metrics were easily quantifiable. As mentioned by the government project manager, each team was tasked with metrics that were drivers for the project that needed monitoring. As the project progressed, the manager/team was able to propose changes to metrics chosen due to program dynamics, or if the chosen metrics proved to be ineffective. Choosing which project drivers to watch was an output of good Systems Engineering and Risk Management practices. Each team also developed a risk chart or table to depict probability of risk and impact as High, Medium, or Low, and planned risk mitigation strategies.

Management of reviews was very important. The IPTs were allowed to manage quite freely, holding their own reviews that took the place of pre-reviews for larger, inclusive reviews. The larger design and management reviews were developed to address "the white spaces" between the IPT boundaries, including interface and integration issues.

Even the larger design reviews at the project level, including the government project manager, were active discussions about the white space issues, an interactive design interchange versus a military briefing. As seen in several other Fast Track Projects, the reviews are held for the project management team rather than for oversight purposes.

A Motorola initiative to shorten the developmental cycle by using incremental development was also successfully used on this project. It is a more piecemeal approach and can be more difficult to manage, but also saves time. This includes incremental design reviews, held in a cross-functional, user influenced environment, rather than comprehensive reviews. This approach also provided the user pieces/parts to test throughout the process which, in turn, provided the developers early useful feedback when change was easier to manage.

B) Policy Related Comments: None

C) Cultural Changes: While there was none mentioned explicitly, it is important to note that Motorola has established a climate which includes teamwork, a focus on quality (continuous improvement) and acceptance of change. This is brought into the project environment through training and the corporate structure.

D) Technology /Tools Recommended: None

E) Other Observations: None

IV. Boeing Vertol

1. **V-22 Vertical Take-off and Landing Aircraft Program:** The V-22 is in the DoD Engineering and Manufacturing Development (EMD) Phase of development, which corresponds to NASA Phases C/D of the Life Cycle Development process. The management approaches applied on this program have resulted in significant cost and schedule control with a proven track record of meeting or exceeding most design objectives. The objectives here were not to constrain the schedule, but to contain and reduce costs on the final product.

A) Practice Oriented Ideas: Boeing has applied many of the lessons learned from their commercial aircraft experience with the 777 aircraft. The concept of the 777 Design-Build Teams has translated well to Integrated Product Teams in use on V-22. One of the lessons learned from 777 experience was a need to provide a way to bring separate team activities together. On the V-22 this is done with Analysis and Integration Teams (AIT). Older, experienced 'gray-beards' are brought in for short periods to help work integration issues. This concept is carried forward to the air-vehicle Integrated Product Team.

Communication between contractor components and between contractor and government was obviously important in a team environment. Close contact is important and can be provided by video teleconference capability. There were periods where the team used video teleconferencing up to six hours per day with the government. This is especially important in the team environment of the V-22 effort where both contractor and government are committed to sharing information with each other as soon as possible.

Design-to-Cost (DTC) plays a significant role in the ability to provide a final design which comes in at or under the program cost target. As mentioned earlier, the goal of the V-22 team was to reduce final production and other lifecycle costs of the V-22. As such, their approach is applicable to any team based engineering-design effort. In this approach each IPT set their own targets for cost reduction from initial estimates and were also given discrete performance improvement targets, such as weight reduction, part unit reduction, etc. This was based on analysis of data provided by the IPT. As the project progressed, in some cases goals could be re-allocated where needed.

B) Policy Related Comments: To create the team environment, the type of contract in place should be examined. A Firm Fixed Price type of contract tends to develop an adversarial, non-stakeholder atmosphere. The Cost Plus Award Fee contract provides more incentive to a team.

C) Cultural Changes: In addition to the proper contracting vehicle and the enabling communication technology, it takes time and effort to create and sustain a team attitude between government and contractor, and between functional disciplines. A change in culture is worth the effort because the payoff is significant.

D) Technology/Tools Recommended: A Boeing tool with value derived from their experience with the 777 is an enhanced CAD/CAM capability. Drawing on an engineering database, it allows designers and producers on the team to see the product in a three dimensional moving presentation. Interfaces are displayed for multiple teams to examine simultaneously. The tool is programmable to highlight tolerance problems. As with team related cultural changes the cost of implementing this tool was more than paid back in savings of both cost and schedule. There were significant reductions in error, change and rework, as well as elimination of the need for several costly, standard machine modeling approaches and mockups. This tool became the central design hub of all IPT activities.

E) Other Observations: None

V. Boeing Laboratories

1. **General Downsizing:** While not directly tied to Fast Track projects, several comments were considered worth including with regard to reengineering and cultural change.

In 1989-1990, Boeing examined its laboratory structure and recognized a larger, broader structure was present than necessary to support its needs (456 separate laboratory organizations). In 1991, all labs were centralized under one head, which is now Boeing Defense & Space Group Laboratory Operations. The problem was how to move faster in process change in support of Boeing's corporate mission. In the process of consolidation the lab structure was reduced to 128 laboratories over a four year period. At the same time, Boeing tried to maintain the level of scientists and scientific capability (i.e., The goal was better management, not reduction in technical personnel).

In evaluating the structure, everything was put up against the corporate strategic plan. Anything not connected to the mission and goals identified in the plan was considered for consolidation. Part of this structural examination was to examine the customer's definition of requirements and criteria. This is part of an overall process of walking through consolidation corporation wide. Boeing has developed this process to a high level of detail. The exact details were not shared because they are considered competition sensitive.

There have been many lessons learned from the success of Boeing 777 effort. Process change was a big focus for that venture. In this area of embracing process change, care must be taken to evaluate impact and to keep the number of process changes manageable. It is easy for the impacts of several on-going changes to be compounded and very difficult, if not impossible, to manage. There were three or four major process changes associated with the 777 effort. There are now three to four dozen candidate process changes identified that could cause loss of the ability to control the overall change.

VI. Texas Instruments (TI)

1. **Single Process Initiative/Common Process Factory:** With the move in the military to adopt commercial practices versus MilStds/MilSpecs, TI has seen an opportunity to provide significant savings to its customers and to itself. This falls under the title of Single Process Initiative. This describes an attempt to arrive at single acceptable commercial processes for several customers replacing multiple approaches of the past. In doing this they have replaced 65 versions of 38 Mil Specs with just eight Commercial Specifications. TI has done a block modification to implement this on 770 separate DoD contracts. They are now extending this concept to those companies for which TI is a subcontractor, to either do block modifications or some other implementation of this idea.

They are also working with the DoD as a designated Reinvention Lab and they include the Defense Contract Management Agency (DCMA) as a team member. They are working with the U.S. Navy on an effort termed Alpha Acquisition which is working toward a highly streamlined cost estimation.

Appendix E

Supplemental Information

"MARS ON $300K A DAY": THE MARS EXPLORATION PROGRAM

Second IAA International Conference on Low-Cost Planetary Missions

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ABSTRACT

The Mars Exploration Program is pioneering a series of "better, faster, cheaper" missions to Mars over at least the next 10 years, and possibly well into the 21st century. The overall cost of the program is somewhat over $100M per year, including launch vehicles and operations, for two launches every 26 months. (This works out to about $300K per day.) A programmatic strategy has been developed involving selection of a science theme for the program, a long-term industrial partnership for spacecraft development, continuous infusion of new technology, and integration of the individual projects into an overall program so that synergy between projects can be maximized. A number of process improvements have been made in procurement, concurrent engineering, rapid prototyping, and integrated payload selection, among others.

INTRODUCTION AND PROGRAM DESCRIPTION

The Mars Exploration Program Office was formed at the Jet Propulsion Laboratory in July 1994 to integrate the robotic exploration of Mars. The two major elements of the program are Mars Pathfinder (one of the first two Discovery missions) and the Mars Surveyor Program (a program to send missions to Mars every opportunity within severe cost constraints). The Mars Surveyor Program was established in the wake of the loss of Mars Observer in 1993. The first of its missions, Mars Global Surveyor, will carry six of the eight Mars Observer instruments, and the other two instruments are planned to be flown in 1998 and 2001. The content and implementation strategy of the Mars Exploration Program are described in Reference 1.

The Mars Exploration Program will continue the investigation of the red planet by robotic spacecraft that began in 1965. The new U.S. program of exploration will begin with launches in late 1996 of the Mars Global Surveyor and Mars Pathfinder missions and extend through at least 2005. And studies are under way for activities leading up to a human mission to Mars as early as 2018. The focus of the first 10 years of the Mars Exploration Program is on building up knowledge steadily and incrementally to a thorough characterization of the planet in terms of life, climate, and resources.

Mars Pathfinder will be the second mission in the Discovery Program of planetary exploration. It will launch in December 1996 on a McDonnell Douglas Delta 7925 rocket, and land on July 4,

1997. It will image the terrain in 14 different spectra, monitor the weather, and deploy a small rover to explore the region around the lander and measure the composition of the surface.

Mars Global Surveyor, which will launch in December 1996 (also on a Delta 7925), will go into orbit around Mars in September 1997 and, after aerobraking into a circular polar orbit, will scan the surface of Mars for a full Martian year (about two Earth years) using six of the eight instruments that were originally flown on Mars Observer (which was lost in 1993—the first planetary spacecraft failure in 27 years).

After Mars Global Surveyor, the Mars Surveyor program will fly two missions to Mars every opportunity (about every 26 months) and, with Pathfinder, is pioneering the "better, faster, cheaper" approach to planetary missions. In late 1998 Mars Surveyor 1998 will launch an orbiter and a lander on a Delta 7325 launch vehicle (at a savings over a Delta II). The orbiter will carry an infrared spectrometer to survey the atmosphere over a yearly cycle. The lander will place a payload near the south pole to search for volatile elements such as water.

The final element of the lost Mars Observer payload (a gamma ray spectrometer) is being considered to search for water in 2001 on the Mars Surveyor 01 orbiter, and another lander payload is planned to have a rover investigate an ancient highland lake bed to study the climate history of the planet. One of the 2001 missions may be conducted in partnership with the Russians. For the 2003 opportunity the Mars Surveyor program is exploring a partnership (InterMarsNet) with the European Space Agency to place three landers on the surface. And the Mars Surveyor 2005 mission will be part of an attempt to return a sample from the Martian surface.

Over the next 10 years the Mars Exploration Program will result in a detailed understanding of Mars, which is of interest not only to Mars scientists but will help in understanding more about the Earth's environment, and can eventually provide the basis for human exploration of Mars. The entire program will be conducted for about one-third the cost of the Viking missions, which orbited and landed on Mars 20 years ago. Each mission costs about the same as a major motion picture, and the total cost of 10 missions to Mars is about the same as that of a single major military aircraft.

Figure 1 graphically illustrates the program—including a U.S.-only mission set (on the bottom)—which can be augmented by international partnerships (on the top). Each launch year is shown across the top from 1996 through 2005.

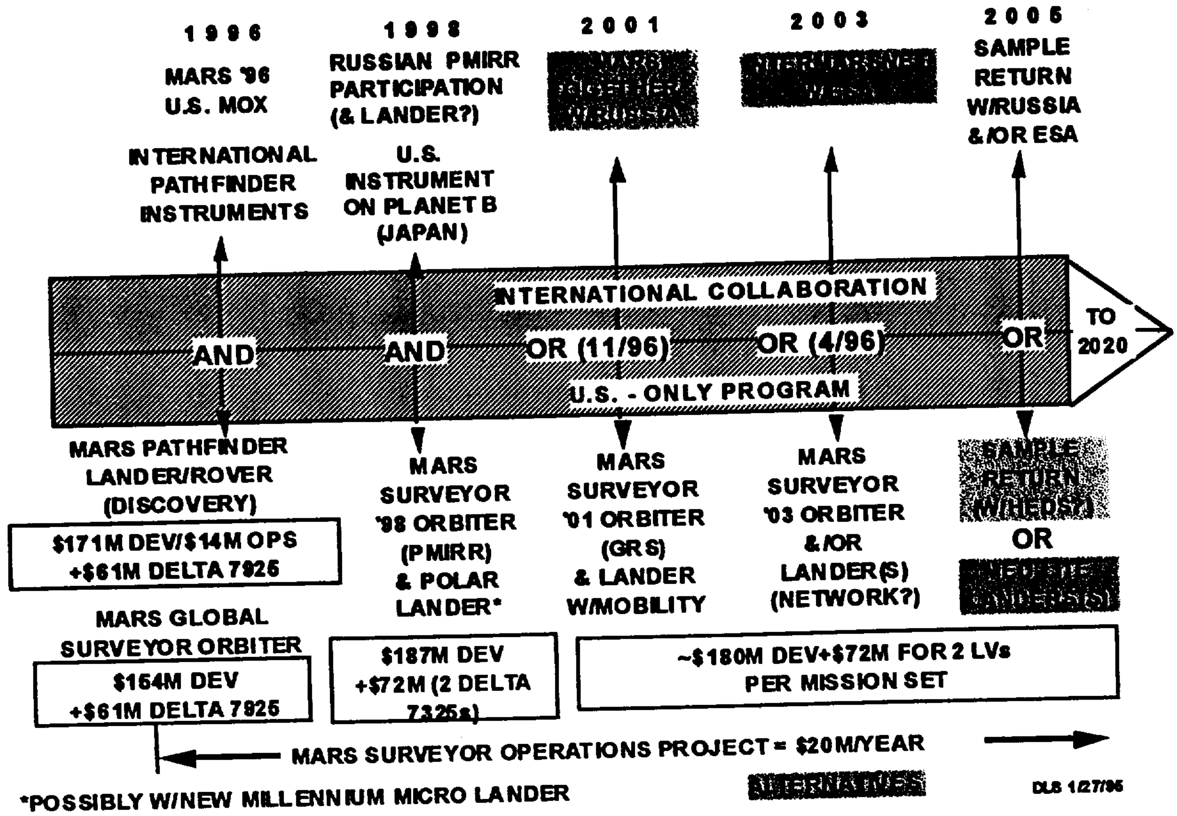

Figure 1. Mars Exploration Program Strategy

The funding available for each mission is shown in the boxes in real-year dollars: the first number is development cost, the second is launch vehicle cost. (The assumption here is that Delta 7325s cost only $36M each, but this may not be the case when the "Med-Lite" contract is finally negotiated.) For Pathfinder, a $14M operations cost is shown for the 7-month cruise and a year of surface operations. For the Mars Surveyor Program, a project has been formed to operate all the missions, and there is $20M per year available for this (not including tracking and data acquisition costs of the Deep Space Network).

STRATEGIC PLANNING—THINKING LIKE A BUSINESS

Because the new Mars exploration missions were to be conducted at only a fraction of the cost of previous missions, cost became the major driver—with performance and risk being the dependent variables —a major paradigm shift for NASA missions. Consequently, it was decided to approach planning for the program as though it were a business. This approach was based on a methodology for business planning described in Reference 2. A diagram of the approach is shown in Figure 2, mapped as a series of questions.

Since Mars Global Surveyor and Pathfinder (including the rover technology experiment being funded by NASA's technology program) were in existence when the Mars Exploration Program was formed, they were our "current business." Businesses of the future were the remainder of the U.S. Mars Surveyor Program, plus international missions that could augment Surveyor. We

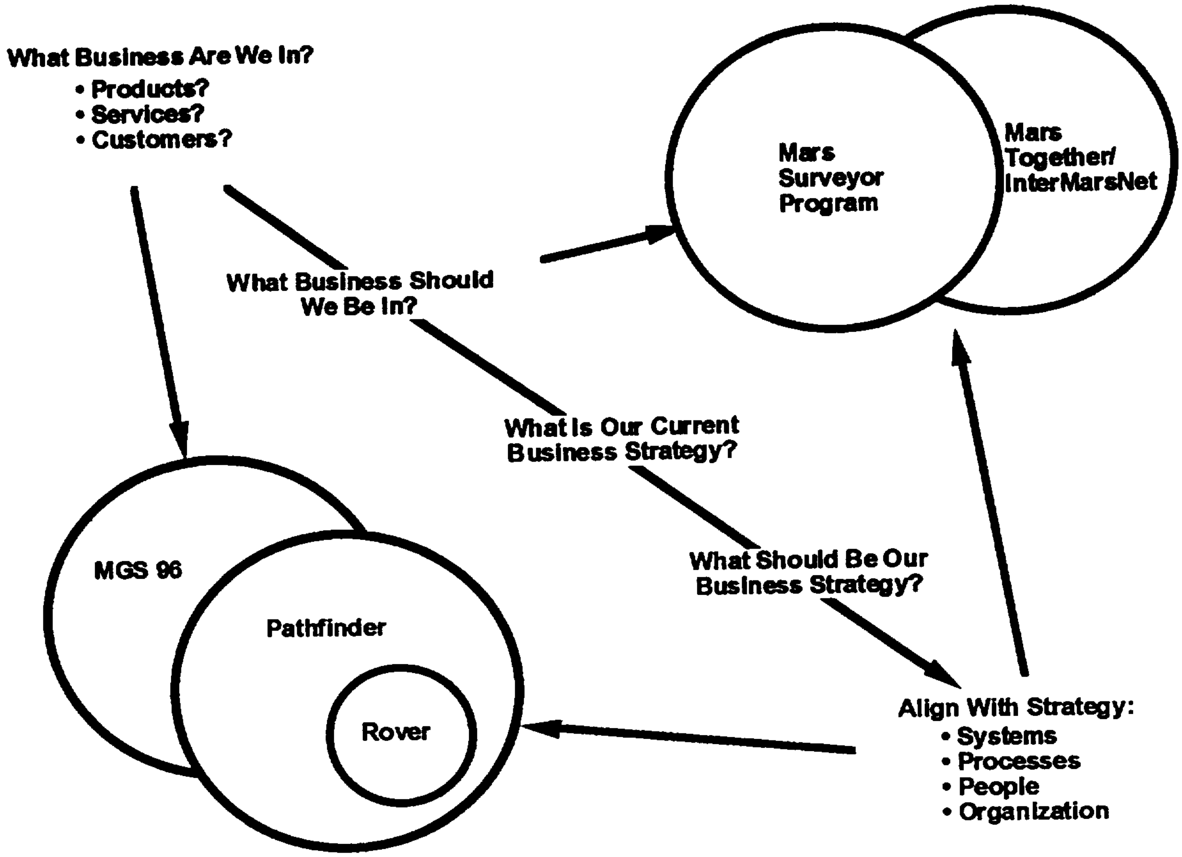

Figure 2. Mars Exploration Program Strategic "Business" Planning Process

investigated several "businesses" which we must be in to conduct a program of Mars exploration in today's environment, and arrived at five: knowledge generation, exploration, education, inspiration, and technology development/transfer. For each business we identified the customers and the specific products and services we would be providing these customers. We identified how we were currently meeting the needs of these customers; that is, what our current business strategy is. Then we identified what our business strategy should be to meet the customer's needs. We selected which businesses should be our primary focus, and which should be primarily carried out by "partner" organizations at JPL. We identified the systems, technology, and processes needed to carry out our business strategy. Then we staffed the program office, and, finally, we evolved an organization to conduct the selected businesses.

Table 1 shows the selected "businesses" with their descriptive information (summarized).

This business analysis showed us that the "knowledge" and "exploration" businesses are very similar in terms of the missions needed to produce the knowledge products. These knowledge products (an understanding of Mars, plus knowledge about the technology and processes of conducting missions to Mars) could be produced synergistically by current and future Mars Exploration Program missions, provided the missions are conducted properly. If the information received from the missions can be synthesized and translated into products suitable for the classroom, the needs of the "education" business can be met. And if the information is presented in a clear and exciting way, the Mars Exploration Program can provide "inspiration" to the public.

Since the only way to conduct a series of Mars missions on the very low budgets allocated is to use new techniques, processes, and technologies, the "technology" business becomes a by-product of the knowledge and exploration businesses. The step of transferring technology developed or transformed by the Mars Exploration Program is needed to infuse that technology into other applications (preferably commercial). We decided to focus on the knowledge and exploration businesses as primary, with education, inspiration, and technology as secondary businesses. We then began developing a strategic plan to conduct our "businesses." The following is from a draft of this plan.

Table 1. Mars Exploration Program Business Analysis (Summary)

Business	**Product**	**Technology in Product**	**Technology to Produce Product**	**Features of Product**	**Customers**
Knowledge	Information about Mars	Information management	Mars Missions	Understandable information	Scientists, everyone
Exploration	Information about Mars	Information management	Mars Missions	Synthesized information	NASA
Education	Educational products	Information presentation	Translation of knowledge	In curricula	Educators, students
Inspiration	Inspiring information	Information presentation	Computer graphics, etc	Exciting	The Public
Technology Development & Transfer	Advanced technology	Technology itself	Techniques for technology production	Cost-effective	Missions, industry

MARS EXPLORATION PROGRAM STRATEGIC PLAN

Mars Exploration Program (MEP) Vision

To Know Mars

MEP Mission

Explore Mars to understand it in terms of life, climate, and resources.

Provide a first step in the search for life beyond Earth.

Better understand the processes that shape the solar system, including the Earth.

Pave the way for human exploration of Mars.

MEP Goals

1. Pave the way for human exploration of Mars.
2. Find evidence of past or present life (or find evidence that life never existed on Mars) to understand the potential for life elsewhere in the universe.
3. Better understand the climate—the weather, processes, and history—in order to understand the relationship to Earth's climate change processes.
4. Identify and learn to utilize the resources available on Mars—understand the solid planet, how it evolved, and what resources it provides for future exploration.
5. Identify and characterize safe, interesting, and productive sites for human landings.
6. Find and learn to use water and other resources.
7. Characterize Mars' atmosphere, surface environment, and other factors that bear on the design of human missions.
8. Pioneer technologies for low-cost, high-return planetary exploration.

MEP Strategies

Strategies are specific actions and approaches we will take to guide the Mars Program toward our customers' goals.

- MEP will operate in the manner of a business, determining the needs of our customers and developing "contracts" with them for meeting those needs.
- Our primary products are knowledge and exploration. Our secondary products—technology, education, and inspiration—will be produced in partnership with other elements of JPL.
- We will employ best business practices and will create technical and managerial innovations to manage our projects within the terms of the "contracts."
- We will implement our projects with common processes and support operations to minimize costs.
- We will partner with NASA, industry, the science community, the educational community, and other elements of JPL to accomplish our goals.

- International participation will be sought for each MEP mission within the program constraints.

Top-level Program strategies are supported by specific thematic emphases in knowledge, exploration, technology, education, and inspiration.

<u>Knowledge Strategy</u>

- Build a progressively deeper knowledge of Mars by implementing a series of missions that build on the knowledge gained by previous missions.
- Partner with other countries to acquire and analyze information.
- Maintain a global compendium of the state of knowledge of Mars.
- Provide a steady stream of new Mars informational and educational products that summarize the state of knowledge and the remaining unanswered questions about Mars.

<u>Exploration Strategy</u>

- Implement a series of missions focused on discovery.
- Use new instruments and instrument deployment techniques.
- Land at different sites.
- Investigate more of the Martian surface and more aspects of the atmosphere over longer periods of time with more capable sensors as the MEP progresses.
- Return samples to the Earth.
- Tailor investigations to support future human exploration of Mars.

<u>Technology Strategy</u>

- Utilize new technology at every opportunity.
- Promote cost-effectiveness by integrating MEP technology needs with the needs of other JPL flight projects.
- Partner with the JPL Technology and Applications Program (TAP) Office to develop technology products tailored to MEP needs.
- Partner with industry to develop and demonstrate technology and infuse it into our projects.
- Support TAP in the transfer of our technology outside JPL.

<u>Education Strategy</u>

- Transform our knowledge of Mars into educational products.
- Partner with universities to disseminate these products and to train educators to understand and use them.
- Partner with the JPL Public Education Office to insert these products into curricula.

<u>Inspiration Strategy</u>

- Share the excitement and knowledge generated by discoveries about Mars with the world.
- Partner with JPL Public Affairs Office and with museums, NASA Centers, and other organizations to disseminate our information products widely and in innovative ways.
- Partner with industry to develop commercial products based on our program.

ORGANIZING TO CONDUCT OUR BUSINESSES

Figure 3 shows the Mars Exploration Program Office organization that has evolved over the last 20 months. Before the JPL reorganization that created the office, preprojects were in one organization, ongoing projects in another. Now the preprojects and flight projects have been brought together so that there can be maximum benefit to the new projects by close association with the old projects. There is considerable personnel sharing. At the program level, the Business Operations and Outreach offices were created to allow resource sharing between the projects. The program office staff is very small, and this has enabled our overhead to be reduced from about 15% of the project business base to under 6%, of which less than 1% is program office overhead. (The rest supports the JPL technical infrastructure.)

The Mars Pathfinder spacecraft is being developed by JPL in a subsystem mode. All Mars Surveyor spacecraft will be system contracted. Mars Global Surveyor selected Martin Marietta Astronautics in Denver as its spacecraft system contractor, and Martin Marietta also won the contract to build both Mars Surveyor 98 spacecraft. JPL and (the now) Lockheed Martin Astronautics (LMA). are thus in a long-term partnership. We are working to "mirror" our organizations to facilitate teaming and communication. Spacecraft design and operations are to be conducted at LMA, with mission design and operations being at JPL.

Payloads for the spacecraft are procured through the announcement of opportunity process from NASA Headquarters, with support from the projects in defining the allowable envelopes for accommodation of the payloads.

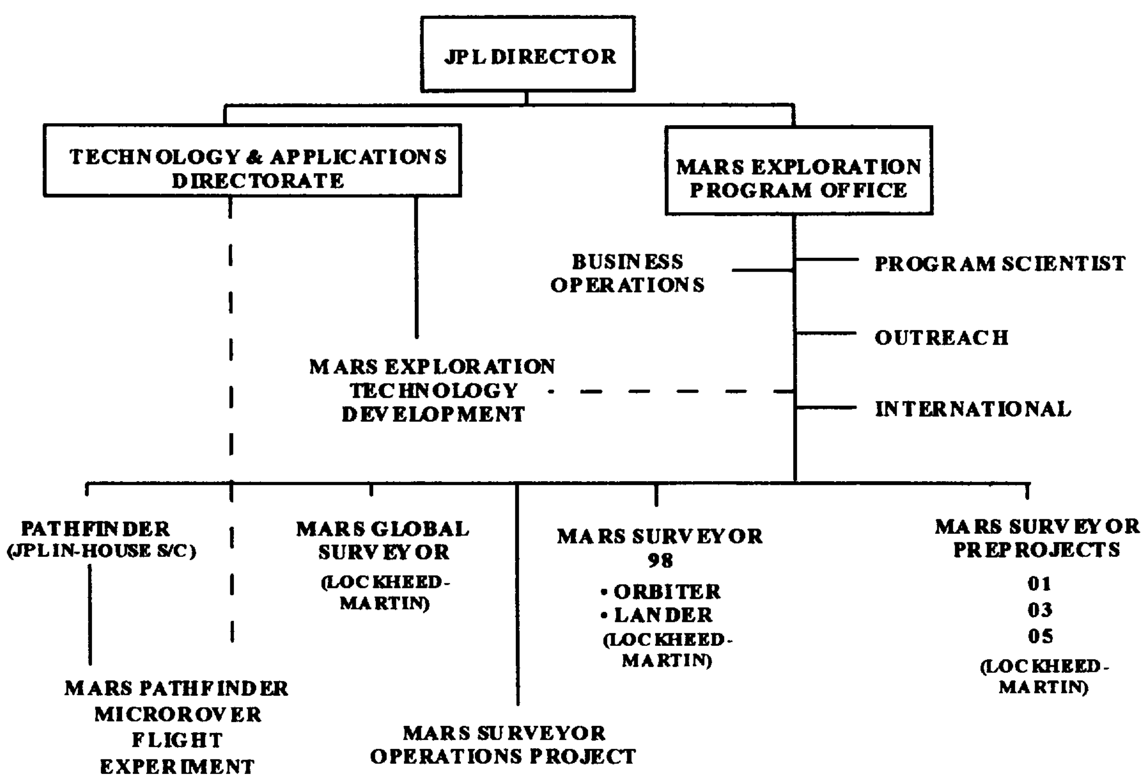

Figure 3. Mars Exploration Program Organization Chart

As personnel roll off Pathfinder and Mars Global Surveyor, some are going to Mars Surveyor 98 and Mars Preprojects, while others are transferring their knowledge of "better, faster, cheaper" to other programs. For example, the project manager of the first New Millennium mission was formerly the task manager for the Pathfinder Attitude and Information Management subsystem. Because of the relatively short development times for Mars projects, this training and knowledge diffusion can be efficiently done.

PARTNERSHIP WITH INDUSTRY

The Mars Surveyor Program is built around an industry partnership for the spacecraft (both orbiters and landers). Payloads are procured through an announcement of opportunity process, except for the reflight of the Mars Observer instruments on Mars Global Surveyor and the 1998 and 2001 orbiters. So not only has the overall cost of Mars exploration declined drastically, but there has been a major shift from in-house JPL spacecraft workforce to contractor workforce. In real-year dollars, Mars Observer (not counting launch vehicle and operations) cost about $460M, of which 54% was spent in industry (mostly through a system contract). Mars Global Surveyor, carrying six of the eight Mars Observer instruments, costs $154M, with 69% going to industry. Mars Surveyor 1998 has $187M for two missions, and 83% of the money is spent by industry. Figure 4 shows the continuing decline in overall funds for the follow-on missions, and the continued trend to spend the lion's share of the money with industry.

The Pathfinder spacecraft is being built in subsystem mode and assembled at JPL. LMA is the contractor for both the MGS and Mars Surveyor 1998 spacecraft. These were two separate procurements, with the second being for both the orbiter and lander. Under the terms of the Mars Surveyor 98 contract, LMA can be selected as the contractor for follow-on missions, provided their performance is adequate for Mars Surveyor 98. JPL and LMA are developing a teaming relationship. The JPL/LMA partnership entails a division of labor rather than oversight of the contractor by JPL. For instance, on Mars Surveyor 98, JPL personnel are located in Denver as part of the Lockheed Martin spacecraft team, where JPL skills can augment LMA skills. This enables a very small JPL project office. The LMA spacecraft team will operate the Mars Surveyor 98 spacecraft from Denver, while JPL will operate the mission.

Use of commercial products. A commercial computer, the IBM (now Loral) RS6000 has been flight qualified for Pathfinder. This computer is now the basis for not only future Mars programs, but for Discovery missions, New Millennium missions, and other projects being planned well into the next century. A commercial operating system is being used by Pathfinder, and the Pathfinder flight software developed at JPL is being transferred to Lockheed Martin for use by Mars Surveyor 98. Commercial products used in the Pathfinder rover (Sojourner) include motors, radio modems, and power converters. Use of commercial electronics has required new processes for determining how to flight qualify them.

Standard business practices and techniques. The formation of the Business Operations Office has allowed us to standardize financial and reporting formats and scheduling tools and techniques, and to integrate an electronic library for the program.

Partnering. As described above, the program is providing JPL "workers" to LMA. The possibility for long-term partnering with LMA also allows an evolutionary approach to—and is key to—keeping the costs down for future missions. This reduces procurement costs, enables the project to be done on 26-month centers, and increases efficiency of long-term planning.

New technology infusion. Mars Global Surveyor will be the first planetary spacecraft to utilize a composite structure. Pathfinder is using the RS6000 computer and has developed a new approach to entry, descent, and landing. Sojourner, the rover, is a technology demonstration to prove that small rovers can operate on the surface of Mars. Mars Surveyor 1998 is improving the RS6000 -based computer system and is introducing a robotic arm as part of the lander payload. For 2001 and beyond, technology infusion is absolutely required to reduce the mass of the spacecraft (because the launch energy requirements are higher in 2001 than in 1998) and to allow more payload percentage. LMA and JPL have developed a joint plan for utilizing technology developed with LMA IRAD funds, for infusing New Millennium technologies such as advanced electronic packaging, and for developing technologies such as the Small Deep Space Transponder (SDST) currently being built by Motorola. The SDST is being funded by a consortium of future flight projects, including Mars, New Millennium, Discovery, and Pluto Express.

Partnering with universities for outreach. The Outreach Program has a series of small contracts with universities to develop and apply educational products in their states. They utilize graduate and undergraduate students for outreach to schools and communities, and they train teachers in understanding Mars information, how to use the Internet, and other skills. All this is done at a fraction of the cost of other methods of providing these services.

SUMMARY AND CONCLUSIONS

The Mars Exploration Program is pioneering the use of "better, faster, cheaper" techniques within a program structure to achieve a steady advance in knowledge within an extremely limited budget. We have made great strides in streamlining, partnering, improving our processes, empowering our colleagues. However, much remains to be done. In particular, things still needed to protect the viability of the program include:

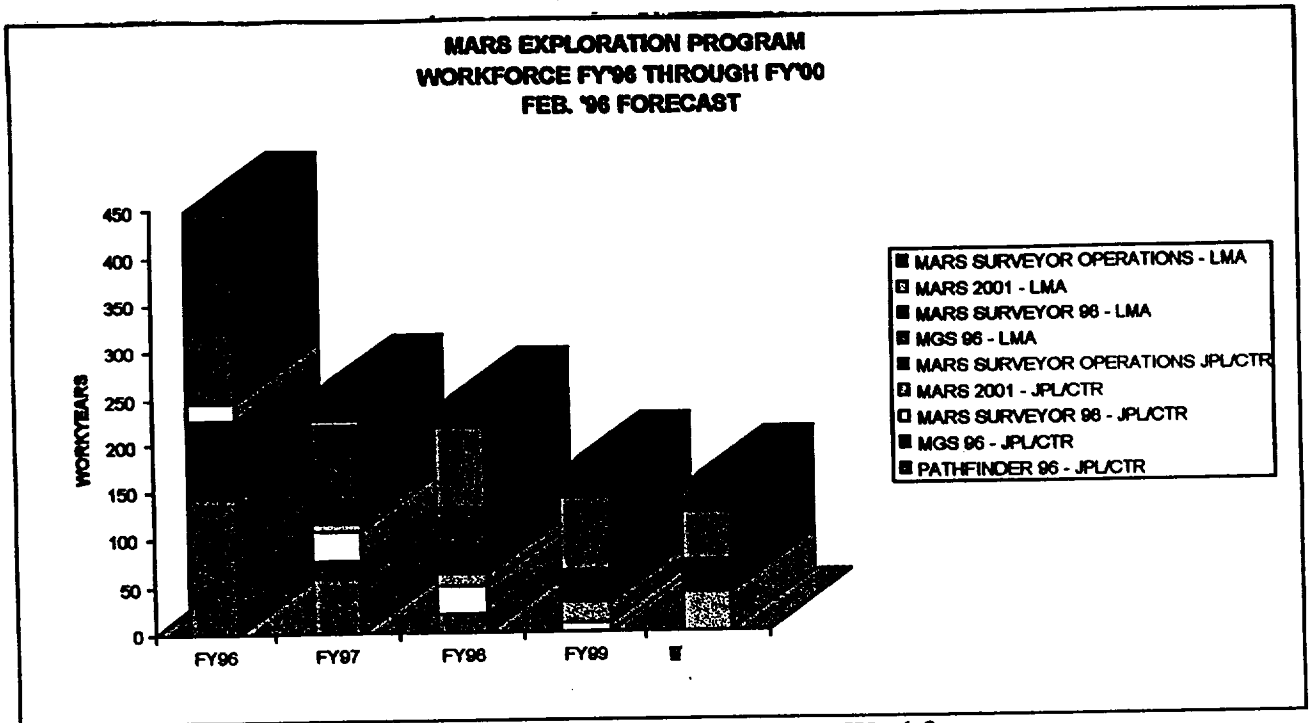

Figure 4. Mars Exploration Program Workforce

PARTNERING WITH SCIENTISTS

Science instruments are procured through the announcement of opportunity process, but are then managed by the projects. In some cases JPL is also partnered with the scientists to develop payload elements. For example, the Mars Surveyor 98 lander payload includes an integrated instrument/robot arm suite where the arm is being developed at JPL and the payload is being integrated by JPL, while the instruments are developed outside JPL. The principal investigator for the integrated payload is at a university. In these cases the announcement of opportunity proposals that involve JPL are kept carefully segregated within JPL from the Mars Exploration Program Office or any of its projects.

SOME COST CONTAINING PRACTICES

The Mars Exploration Program is pioneering several practices required to contain costs while still conducting rewarding missions. These include the following (with a few examples):
Rapid, goal-based procurement. We have reduced the lead-time for spacecraft procurement by a factor of four, from ten to twelve months for previous flight system procurements to ten weeks for Mars Surveyor 98 and twelve weeks for MGS. New procurement strategies have been introduced for one-day turnaround for small commercial items, and for drastically reducing the procurement time for electronic parts, etc.

Concurrent engineering. Pathfinder pioneered concurrent engineering of the ground and flight systems. The new Mars Surveyor Operations Project is supporting all aspects of the project development cycle so that this concurrent engineering can continue throughout the program.

- Adherence to a steady, incremental, evolutionary set of missions within a stable program structure, including a long-term industry partnership.
- Access to low-cost launch services.
- A stable base of support for evolutionary technology development and infusion.
- Establishment of a minimal set of requirements for the program, i.e., "achieve the maximum knowledge within the cost constraints."
- Clear and stable programmatic priorities between knowledge acquisition, foreign policy, commercialization, science, education, small business objectives, etc.
- Continuous improvement in JPL and contractor support services for the projects ; e.g., financial services, technical infrastructure, streamlined management processes.
- A process for information synthesis and translation into layperson's language and educational products.

With the two initial launches of the Mars Exploration Program this fall and winter, a new and exciting era of planetary exploration will ensue. We plan to land on Mars on July 4, 1997 and orbit in September 1997, and then we will visit Mars every 26-months or so for at least the next decade. There are many risks because of the minimal funds available, and because of the need to do things that have never been done before, on 26-month centers. These risks are being mitigated by creative new processes in management, engineering, and science. The jury is out on the eventual success of the program, but we believe that we have started well.

ACKNOWLEDGMENT

The research described in this publication was carried out by the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

REFERENCES

1. Donna L. Shirley and Dr. Daniel J. McCleese, AIAA-96-0333, "Mars Exploration Program Strategy: 1995–2020," 34th Aerospace Sciences Meeting and Exhibit, Reno, Nevada, January 15–18, 1996.
2. Dan Thomas, *Business Sense: Exercising Management's Five Freedoms*, The Free Press, Division of Macmillan, Inc., New York, 1993.
3. Glenn Cunningham, "Management of Mars Global Surveyor Mission," International Academy of Astronautics IAA-L-0801, Low-Cost Planetary Missions Conference, Laurel, Maryland, April 19, 1996.

4. John B. McNamee, "1998 Mars Surveyor Orbiter and Lander Project," International Academy of Astronautics IAA-L-0403, Low-Cost Planetary Missions Conference, Laurel, Maryland, April 17, 1996.
5. Sylvia L. Miller, "Mars Surveyor Missions: 2001 & Beyond," International Academy of Astronautics IAA-L-0404, Low-Cost Planetary Missions Conference, Laurel, Maryland, April 17, 1996.
6. Anthony J. Spear, "Mars Pathfinder Project Progress Report" International Academy of Astronautics IAA-L-0401, Low-Cost Planetary Missions Conference, Laurel, Maryland, April 17, 1996.

New Millennium Program (NMP)
Deep Space One (DS1)

Project Plan

Document No. JPL D-13510, Rev. 1

David H. Lehman

August 19, 1996

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California 91109-8099

NMP DS1 Project Plan

Contents

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Section 1
Introduction

1.0 Introduction

The Deep Space One (DS1) mission is the first in a series of New Millennium Program (NMP) missions. The NMP will enable 21st-century space and Earth-science missions through the identification, development, and flight validation of key technologies. Breakthrough technologies are selected from the existing technology "pipeline" - consisting of ongoing NASA technology programs, other government agencies, industry, nonprofit organizations, and academia - and are developed in partnership with these organizations. These technologies will be flight validated so that future science missions can take advantage of them without assuming the risks inherent in their first use. NMP technology-validation flights are to be launched during fiscal years 1998 and beyond. While these flights are essentially for technology validation they will also provide meaningful science.

In addition to developing and validating key enabling technologies, NMP will pioneer new ways of partnering with industry, nonprofit organizations, and academic institutions. Further, the development and implementation of NMP's innovative management practices will advance the competitive edge for NASA and other high-technology organizations. An overview of the DS1 team approach to implementing the project has been documented in a memorandum of agreement which is provided as Figure 1-1.

1.1 Purpose

This document defines requirements accepted by the DS1 mission (See Section 3.0) from NMP. This plan also defines the management and technical approach to be used by the NMP DS1 project team. It includes an overview of the plans to manage the development of the flight, ground, and mission operations systems.

1.2 Scope

The requirements in this document pertain to the DS1 project objectives, technical approach, budgetary and schedule constraints, and certain institutional and management relationships between DS1 and NMP. It represents the understanding between NMP and the DS1 Project and spans the entire project life cycle.

1.3 Governing Documents

This document is governed by NASA guidelines and JPL institutional policies and practices, and shall be implemented in accordance with them, recognizing that NMP flights are technology validation flights as opposed to science driven missions.

1.4. Organization of the Plan

This plan is composed of 5 sections in addition to the Introduction. Section 2 discusses documents governing, and applicable to the conduct of the project. Section 3 details the Level 1 guidelines for DS1 from the program office. The technical and management approaches are described in Sections 4 and 5, respectively. Section 6 describes the resources necessary to implement DS1.

Figure 1-1 DS1 Memorandum of Agreement

JET PROPULSION LABORATORY **INTEROFFICE MEMORANDUM**

DS1-DHL-96-012
May 24, 1996

TO: Charles Elachi

FROM: E. Kane Casani and David H. Lehman

SUBJECT: Deep Space One Memorandum of Agreement

We have agreed that DS1 will have the following characteristics:

Launch date: on or before 31 July 1998

Mission type: Comet and Asteroid Flyby

Launch vehicle: Delta 7326 (or Taurus XL/AUS-51 with no Comet flyby)

Technology

IPS NSTAR Ion Propulsion System
SCARLET Advanced Solar Array
SDST Small Deep-Space Transponder
MICAS Miniature Integrated Camera And Spectrometer
RA Autonomy - Remote Agent Architecture
AUTONAV Autonomy - Onboard Optical Navigation
3DS 3D-Stack Processor
PEPE Plasma Experiment for Planetary Environments
PASM Power Actuation and Switching Module
LPEX Low Power Electronics Experiment
BMOX Autonomy- Beacon Monitor Operations
KAX Ka Band Solid State Amplifier

Funding: The funding required to support DS1 is as shown in Table 1.

Table 1 DS1 Funding Requirement

DS1 Life Cycle Costs	FY96 $K	FY97 $K	FY98 $K	FY99 $K	FY00 $K	Total $K
DS1	33,530	33,550	17,020	3,900	2,100	90,100
Reserves	0	6,000	4,000	0	0	10,000
Subtotal	33,530	39,550	21,020	3,900	2,100	100,100
DS1 Launch services	0	0	32,000	0	0	32,000
Total DS1 Funding Needs	33,530	39,550	53,020	3,900	2,100	132,100

Assumptions:

- SDST consortium funding and reserve provided as detailed in the SDST Consortium Plan.
- IPS provided at no charge to DS1 as detailed in the NSTAR/DS1 MOU.
- SCARLET provided by BMDO at no charge to DS1 as detailed in the BMDO/DS1 MOU.
- Multi-mission electrical GSE and ion drive (low thrust) mission design, navigation, and trajectory control software provided by JPL institutional funding.

Figure 1-1 DS1 Memorandum of Agreement (Cont'd)

- MSTI hardware provided by BMDO at no charge to JPL (includes battery & solar array gimbal).
- Funding for the Ka Band SSPA will be provided by C. Elachi totaling $500K split as follows: $330K in FY'96, $120K in FY'97 and $20K in FY'98.
- Mission operations funding in FY'99 and FY'00 only includes funds to collect data for technology validation; it does not include funding for technology validation and analysis. The responsibility for this work is with the IPDT co-leads and separate funding for the analysis will be provided to the co-leads from the program office. Finally, mission operations funds in FY'99 and FY'00 are very preliminary estimates (allocations that do not even include project management) and are subject to change as the design evolves.
- For launch services, it is assumed that any cost increase to the above allocation will be covered by the program office and/or NASA.
- IPDT co-leads will deliver their specified technologies in accordance with the agreed upon funding from the project. Needs for additional funds and/or attendant descopes will be the responsibility of the IPDT co-leads. Descopes that impact the system design must have the concurrence of the project. This approach to covering the funding needs is not common and results in high risk to the project - it is being done because of low funding to the project. Therefore, if funding is not available from this approach, and descope options prove to be fruitless and the reserves of DS1 are insufficient, JPL management will work to provide alternate sources of funding.
- Funds to cover NEPA compliance will be paid for by the program office.

Management:

- Program office is responsible for NASA headquarters interface functions. Program office will work with the DS1 team and NASA headquarters to close on the definition of the DS1 launch services approach. This issue needs to be resolved now.
- Program office is responsible for all TAP interface functions.
- DS1 project manager will have full authority to manage the budget noted above (including Code X funds). The DS1 project manager will be provided and have full control of the reserves noted above; he will have full authority to use them at his discretion to ensure a successful project. A formal reserves usage plan (request and usage) will be developed that ensures that reserve usage is minimized to the extent feasible. The NMP program office will not be in series with the approval of DS1 reserve usage.
- DS1 project manager manages the DS1 mission including the IPDT technologies (budgets, schedule and risk) - program office will not "end run" his decisions. Any decisions or direction on DS1 from the program office must be discussed with and agreed to by the DS1 project manager before they can be considered to be in effect.
- Monthly project reviews will be conducted by the DS1 project manager wherein the program office will be invited to attend. At these meetings technical progress, schedule, cost and use of project reserves will be addressed. No other reviews are required except those authorized by the DS1 project manager (e.g. DDC, pre-ship and internal peer reviews).
- The DS1 project manager will work with his team members to develop a descope plan highlighting concrete savings that are available vs. time. Once developed he will have full authority to implement the plan. He will make a diligent effort to find savings in the current plan to pay for cost growth as they occur. However, once the reserves usage has become excessive (baseline approach is always to have a minimum of 11% reserves with respect to the current cost to complete), the descope plan will be implemented. Once forced to make the above decisions, the NMP manager will fully support the DS1 project manager. Dropping of advanced technologies will be performed after the NMP manager has been informed of the reasons for the change in the technology manifest.
- Co-location of DS1 personnel of 45 people will be allocated in building 301. Approximately 10 of these people will occupy the "Design Hub." The move must occur in the June time frame. Monies for the move will come from non-DS1 funds.
- A DS1 management counsel will be formed to provide advice and counsel to the DS1 project manager. This group will meet on a regular basis (monthly or quarterly) and report its findings to the program manager.

Figure 1-1 DS1 Memorandum of Agreement (Cont'd)

- **A DS1 finance person will be hired to assist in managing the project. In addition, the restrictions on the approval of procurements for DS1 by the program office will be raised from $5K to $1000K.**
- **Effective and timely execution of DS1 in a "better, faster, cheaper" mode will be employed.**
- **DS1 will work with industry to build effective partnerships and productive technology transfer.**

Kane Casani

David H. Lehman

Concurrence: C. Elachi

Distribution:

B. Wilson
R. Metzger
IPDT co-leads
DS1 team members
DS1 management counsel (M. Sander, J. Savino, and T. Spear)

Section 2
Governing Documents

2.1 Project Documents

The document tree detailing the project documents for DS1 are shown in Figure 2-1. The definition of the documents are shown in Table 2-1.

Figure 2-1

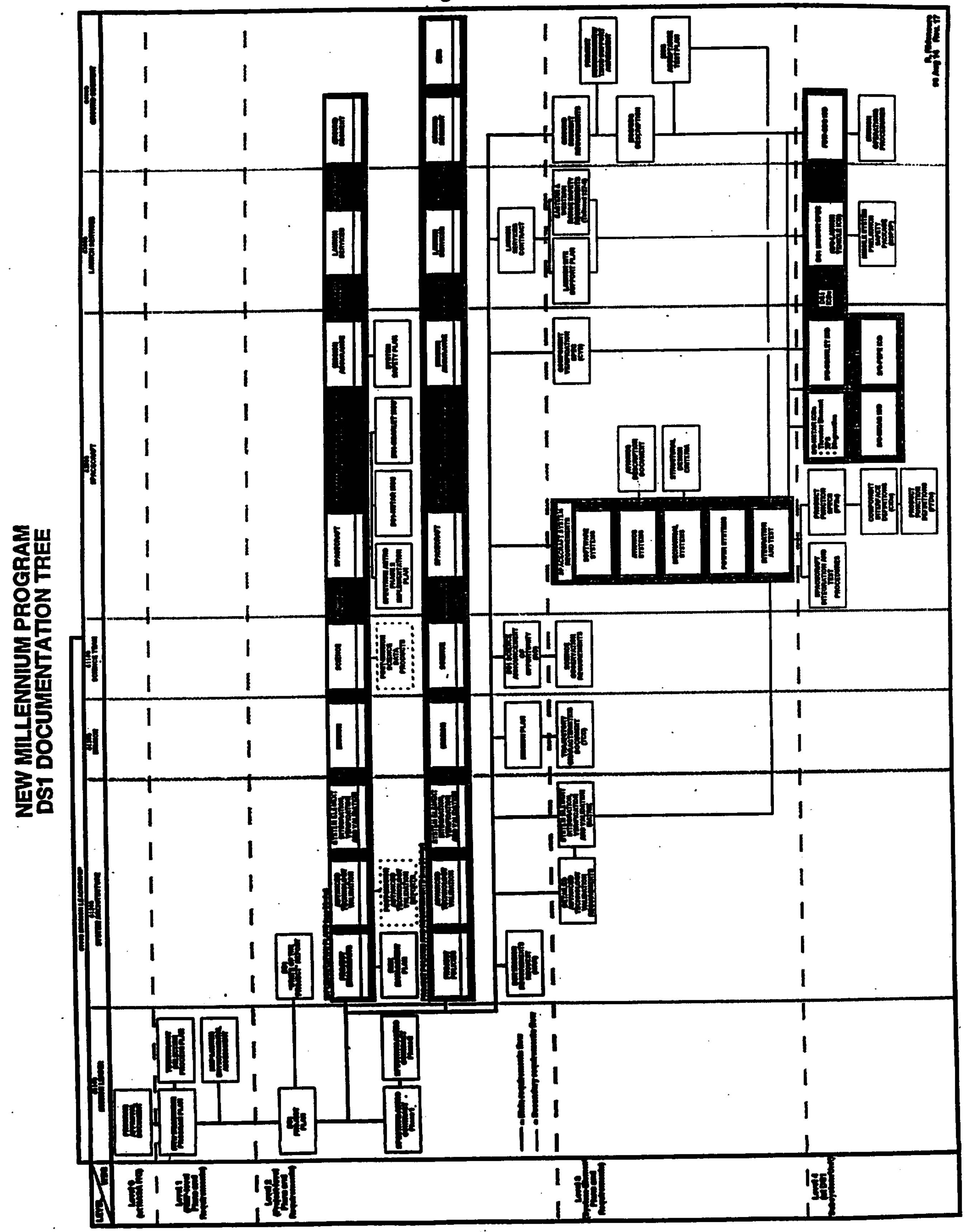


Table 2-1

DS1 DOCUMENTATION RESPONSIBILITIES

LEVEL	FILED?	DS1 CODE	JPL CODE	RELEASE DATE(S)	DOCUMENT TITLE	ACRONYM	CONTENTS	RESPONSIBLE PERSON(S)
HQ								
0			JPL IOM #NMP-[illegible]-96-272	96 Dec 6	New Millennium Program Task Plan		NMP approved document with NASA Code S for 96 Nov 13 through 99 Sep 30; hi-level HQ guidelines for NMP	K. Casani (NMP) & W. Huntress (HQ)
NMP								
1			JPL D-[illegible]	96 Apr 14	New Millennium Program Plan		Overall NMP Implementation Plan	K. Casani (NMP)
1			JPL D-13661	96 Jan	New Millennium Program Technology Selection Process Plan		NMP technology selection process; technology risk-management approach; Use of [illegible]	S. Wilson (NMP)
1			TBD		New Millennium Program Launch Environmental Assessment		Launch environmental impact assessment for each NMP mission	[illegible] (NMP)
DS1 — [illegible] LEVEL								
2		6440-200	JPL D-13610	I: 96 Apr 26	DS1 Project Plan	: 96 Apr 2	NMP/DS1 agreements on what will be done on DS1; Overall DS1 technical and management plan; WBS and budgets	D. Lehman
2		6440-201	JPL D-[illegible]	96 Oct 2	DS1 Industry Partner Contract — Phase 1		Plan for SAI's support to DS1 mission and system definition phase	D. Lehman, S. Dolan
2		6440-202	JPL D-[illegible]		DS1 Industry Partner Contract — Phase 2		Plan for SAI's support to DS1 development and implementation phase	D. Lehman, S. Dolan
DS1 — SYSTEM ARCHITECTURE								
2		6440-20[illegible]	JPL D-13617	Monthly	DS1 "State-of-the-Project" Report		DS1 State of the Project summary (monthly)	R. Ridenoure & J. McClelland (eds.)
2		6440-205	JPL D-13611		DS1 Project Implementation Plan	PIP	More detailed follow-through of Project Plan; Summary of key programmatic [illegible]	R. Ridenoure (ed.)
2		6440-210	JPL D-13616	D: 96 Apr 8; I: 96 Jun 28	DS1 Project Policies and Requirements	PPR	Summary of all requirements/guidelines/constraints/policies at the mission and system level, including rationale	R. Ridenoure & M. Rayman (eds).
2		6440-211	JPL D-13620	I: 96 Mar 11; P: 96 Jun 28	DS1 Mission Requirements Request	MRR	DS1 tracking request info; Link info; Navigation support info; mission design info	R. Ridenoure; Assist from M. Rayman, P. Varghese, G. Chen
2		6440-21[illegible]	JPL D-[illegible]	After end of mission	DS1 Post-mission Advanced Technology Validation Reports		Summaries of all relevant validation and engineering data	R. Ridenoure; Assist from All
3		6440-210	JPL D-[illegible]		DS1 Detailed Advanced Technology Validation Requirements		Detailed advanced technology validation reqts	R. Ridenoure (ed.)
3		6440-211	JPL D-[illegible]		DS1 System Element Integration, Verification and Validation Matrix		IV&V matrix for all DS1 system element requirements	R. Ridenoure (ed.); assist from G. McGrath
DS1 — MISSION								
2		6440-220	JPL D-13624		DS1 Mission Plan		Detailed mission plan and event sequences; Spacecraft, MOS and DSN activities; Summaries of relevant mission engineering and MOS data; High-level mission rehearsal plan	M. Rayman and P. Varghese
3		6440-22[illegible]	JPL D-[illegible]		DS1 Trajectory Characteristics Document	TCD	Detailed trajectory design data and associated engineering and geometric data	M. Rayman (ed.)
DS1 — SCIENCE								
2		6440-240	JPL D-[illegible]		DS1 Science Announcement of Opportunity	AO	Formal announcement of DS1 science opportunities and call for proposals for DS1 Science team	R. Nelson (DS1)/W. Huntress (HQ)
2		6440-245	JPL D-[illegible]	After end of mission	DS1 Post-mission Science Data Products		Summaries of all relevant science and engineering data; Publications; Archived data	DS1 Science Team
3		6440-2[illegible]	JPL D-[illegible]		DS1 Science Observation Requirements		Detailed specs for all planned science observations	R. Nelson; Science Team
DS1 — SPACECRAFT								
2		6440-204	JPL D-[illegible] and SAI CDRL [illegible] from Phase 1 contract		DS1 Industry Partner Phase-2 Implementation Plan		Detailed summary of SAI's planned programmatic and technical contribution to DS1 implementation	S. Dolan; Assist from D. Lehman, R. Fradet, G. Trester
2		6440-205		96 Nov 6	DS1/NSTAR MOU		All programmatic and top-level technical agreements between DS1 and NSTAR	D. Lehman/[illegible] (NSTAR)
2		6440-206	JPL D-[illegible]		DS1/SCARLET MOU		All programmatic and top-level technical agreements between DS1 and SCARLET	D. Lehman/[illegible] (BMDO)
2		6440-207	JPL D-[illegible]	D: 96 Nov 14	DS1 System Safety Plan		Detailed S/C safety data for launch site activities	K. Barrow
3		6440-300	JPL D-[illegible]		DS1 Spacecraft System Requirements		All Level-3 spacecraft requirements, partitioned into Software Systems, Avionics Systems, Mechanical Systems, Power Systems, and Integration & Test	J. McClelland (ed.)
3		6440-301	JPL D-[illegible] and SAI [illegible]	I: 96 Jan 31	DS1 Component Verification Specification	C/S	Generic Parts, reliability, QA, safety and test specs for DS1 components	T. Hall; Assist from J. Howell
3		6440-302	JPL D-[illegible]		DS1 Avionics Description Document		Useful info on how the avionics works, constraints, [illegible], etc.	D. [illegible]
3		6440-303	JPL D-[illegible]	D: 96 Jul 17	DS1 Structural Design Criteria Requirements		Similar to Cassini's D-199	S.K. Tsang
4			See [illegible]		DS1/NSTAR ICDs		All typical ICD data	
4		6440-[illegible]	JPL D-[illegible]		DS1/SCARLET ICD		All typical ICD data	A. [illegible] (SCARLET)
4		6440-[illegible]	JPL D-[illegible]		DS1/MICAS ICD		All typical ICD data	A. [illegible] (MICAS)
4		6440-[illegible]	JPL D-[illegible]		DS1/PEPE ICD		All typical ICD data	TBD
4		6440-[illegible]	JPL D-[illegible]		DS1 Spacecraft Integration and Test Procedures		Detailed procedures, including detailed verification procedures	G. McGrath (JPL) and S. Hall (SAI)
4		6440-470	JPL D-[illegible]		DS1 Product Function Specifications (PFSs)		Unit specs	Cog-Es
4		6440-471	JPL D-[illegible]		DS1 Component Interface Definitions (CIDs)		Unit "ICDs"	Cog-Es
4		6440-472	JPL D-[illegible]		DS1 Product Function Definitions (PFDs)		Unit as-built summaries	Cog-Es
4		6440-473						
DS1 — LAUNCH SERVICES								
2		6440-2[illegible]	JPL D-[illegible]		DS1 Launch Services Contract		All programmatic and top-level technical agreements between DS1 and the launch vehicle services provider; Includes RFP as an appendix	D. Lehman; Assist from R. Fradet, G. Trester
3		6440-2[illegible]	JPL D-[illegible] and KSC K-PSM-11.[illegible]	D: 96 Apr 14	DS1 Launch Site Support Plan (LSSP)	LSSP	All key agreements between DS1 and Range for launch integration and launch ops support	R. Fradet (JPL) and R. [illegible] (KSC)
3		6440-2[illegible]	JPL D-[illegible]		DS1 Eastern and Western Range Safety Requirements Document (Tailored 127-1)	127-1	Tailored range safety documentation, per launch approval/integration plans	R. Fradet (JPL) and R. [illegible] (KSC)
4		6440-[illegible]	JPL D-[illegible]		DS1 [illegible]		All typical ICD data	R. Fradet and TBD (KSC)
4		6440-[illegible]	JPL D-[illegible]		DS1 Missile System Prelaunch Safety Package (MSPSP)	MSPSP	Safety hazard analyses, etc.	K. Barrow
4		6440-451						
DS1 — GROUND SEGMENT								
3		6440-270	JPL D-[illegible]		DS1 Ground Segment Requirements		Operability requirements; Operations concept; Telemetry requirements; Other ops constraints	P. Varghese
3		6440-271	JPL D-[illegible]	D: 96 Jul 1	DS1 Project Requirements/TMOD Support Agreement	PR/TSA	Detailed DSN and TMOD support service requirements and agreements	P. Varghese/[illegible] (TMOD)
3		6440-272	JPL D-[illegible]		DS1 MOS/GDS Description		Same as title	P. Varghese
3		6440-273	JPL D-[illegible]		DS1 MOS Acceptance Test Plan		Detailed plan for phased development of MOS	P. Varghese
4		6440-470	JPL D-[illegible]		DS1 FSW/GDS ICD		All typical ICD data	P. Varghese/[illegible]
4		6440-471	JPL D-[illegible]		DS1 Mission Operations Procedures		Same as title; Includes "cmd" and tlm dictionaries	P. Varghese

Section 3
Level One Requirements, Goals and Mission Success Criteria

The following two pages provide the DS1 level one requirements, goals, and mission success criteria. The requirements and goals listed have been agreed to and signed off by NASA headquarters, the NMP office, and DS1 personnel. The primary difference between the requirements and the goals listed on the first page is that changes (descopes or deletions) to the goals do not require headquarters approval. The mission success criteria has not been finalized, though its contents have been tentatively approved by NASA as a working document. It is not required to be finalized until one week prior to the launch of DS1.

DEEP SPACE ONE LEVEL-1 REQUIREMENTS & GOALS

Requirements

1. Validate the following prime technologies through space flight

   - Solar electric propulsion as primary propulsion
   - Advanced solar array
   - Autonomous navigation as primary navigation
   - 3-D stack computer as the flight computer
   - Miniature imaging camera spectrometer

   It is expected that other advanced technologies vital for 21st century science missions will also be validated on DS1 to the greatest extent possible within the approved funding (see goals below).

2. Launch by the end of July 1998.

3. Obtain validation data for the technologies demonstrated on DS1 within 2 years of launch.

4. Complete the Project within a Project cost cap of $138.5M. This cost cap includes funding from the Office of Space Science, the Office of Space Access and Technology, and all costs for launch services funded by the Expendable Launch Vehicle Program. Contributions from separately funded technology programs, such as NASA's NSTAR and BMDO's SCARLET Programs, are not capped.

Goals

1. Fly by one asteroid and one comet and return images and spectra. Monitor solar wind throughout the mission and measure the interaction of the solar wind with the targets during the flybys.

2. Validate the following additional technologies through space flight:

   - Small deep-space transponder
   - Autonomy - remote agent architecture
   - Miniature ion and electron spectrometer
   - Autonomy - beacon monitor operations
   - Ka-band solid state power amplifier
   - Low power electronics experiment
   - Multi-functional structure
   - Power actuation and switching module

Prepared by: ______________________
David H. Lehman, Flight Team Manager
Deep Space One

Approved: ______________________
E. Kane Casani, Program Manager
New Millennium Program

Concurred: ______________________
David A. Gilman, Program Executive
Office of Space Science
Mission & Payload Development Division

DS1 Level 1 Requirements
August 13, 1996

New Millennium Program DS1

MISSION SUCCESS CRITERIA

40%	• For successfully completing the pre-flight qualification and ground testing program for the advanced technologies.
90%	• For validating the suite of advanced technologies flown, with a focus on assessing the applicability (or non-applicability) of the technologies for use on 21st-century science missions, including diagnosis of failures and anomalies.
100%	• For successfully returning science data from the flybys

The mission is minimally successful if DS1 performs a valid space test of the prime technologies

JPL

SPECTRUM ASTRO

Mission Success Criteria-7/31/96

4.1 Introduction

This section provides a top-level description of the spacecraft, the technologies to be incorporated, and the technical implementation strategy to be used by the DS1 project. The technical plan will be implemented by a team that is described in more detail in the Management Section (5) of this plan. The DS1 flight team is composed of the following elements:

4.1.1 JPL Flight Team

The JPL flight team has primary responsibility for the detailed mission and system design, system integration and test, launch integration, and mission operations.

4.1.2 Industry Partner Flight Team

An industry partner has been selected competitively and is a member of the flight team. A general approach is that the industry partner provides all spacecraft hardware (and software) except those that are part of the advanced technology payload.

4.1.3 Integrated Product Development Teams

The NMP advanced technology Integrated Product Development Teams (IPDTs) score the advanced technologies to be flight validated by NMP missions. Once an advanced technology is selected, a hardware and/or software cognizant engineer, technical manager or project element manager is selected to lead the development. This leader is appointed by the IPDT co-lead and concurred upon by the DS1 flight lead. The technology development leader and his/her team are also members of the DS1 flight team.

4.2 System Description

4.2.1 Advanced Technology Payload

Through validation on NMP missions, the risk associated with key enabling technologies will be reduced sufficiently to facilitate rapid (and affordable) incorporation into future missions. The new technologies employed by DS1 have gone through the NMP selection process, and the selection has been concurred upon by NASA. The list of technologies to be flight validated on DS1 are as follows:

<u>Technology</u>		<u>Category</u>
IPS	NSTAR Ion Propulsion System	I
SCARLET	Advanced Solar Array	I
SDST	Small Deep-Space Transponder	I
MICAS	Miniature Integrated Camera And Spectrometer	II
RA	Autonomy - Remote Agent Architecture	II
AUTONAV	Autonomy - Onboard Optical Navigation	II

Technology		Category
3DS	3D-Stack Processor	II
PEPE	Plasma Experiment for Planetary Environments	III
PASM	Power Actuation and Switching Module	III
LPEX	Low Power Electronics Experiment	III
BMOX	Autonomy- Beacon Monitor Operations	III
KAX	Ka Band Solid State Amplifier	III
MFS	Multi-Functional Structure	III

Note that the MFS shown above has been added to the payload since the MOA shown in Figure 1-1 was signed off. All advanced technology payload items noted above must demonstrate readiness through a series of technology readiness gates as defined in the New Millennium Program Technology Selection Process Plan (JPL D-13361).

4.2.2 Spacecraft Overview

Instrument Payload: Miniature Integrated Camera Spectrometer (MICAS)
Plasma Experiment for Planetary Environments (PEPE)

Attitude Control: 3-axis spacecraft with:
- Spacecraft-mounted HGA
- Solar array gimbaled in one axis
- Spacecraft-mounted science instruments
- NSTAR SEP thruster gimbaled in 2 axes.
- Slew rate requirements consistent with comet/asteroid flyby for technology validation of the science instruments.

Power: SCARLET solar concentrator from BMDO which produces 2600 W (at 1 AU) for both SEP engine and s/c loads.

Propulsion: Solar electric propulsion (using NSTAR supplied components) and a hydrazine chemical propulsion system for attitude control.

Telecommunications: X Band using the SDST and the Mars Pathfinder lander antenna. Ka band down link communication using the Ka band SSPA.

Lifetime: 24 months (excludes extended mission)

4.2.3 Launch Vehicle

The launch vehicle for DS1 is a Delta 7326 which will be provided through NASA Goddard's Orbital Launch Services office. The DS1 performance requirement at a Declination of Launch Asymptote (DLA) of 28 degrees is 437 kg to a C_3 of 0 km^2/s^2. Note that the costs listed in the MOA of Figure 1-1 have since been updated (see Table 6-1) to reflect the cost of the Delta - the prior estimate was based on a Taurus launch vehicle.

4.2.4 Mission Operations System and Ground Data System (Ground Segment)

The approach for the ground segment for DS1 is to utilize the Mars Pathfinder and MGS ground data systems and baseline and upgrade them to support the mission. The main difference between these projects and DS1 is the incorporation of autonomy for the mission.

Section 5
Management Plan

5.1 Management Philosophy

This project must be conducted efficiently and economically in order to meet cost and schedule requirements. There are several guiding principles that will be employed to facilitate this outcome:

- Select the right people for the job and empower them to do it. Encourage team members to stretch beyond their capabilities.
- Make agreements simple and interface designs robust.
- Project leaders will strive to facilitate the execution of tasks given team members by giving them what they need to get their jobs done faster, better and cheaper.
- Find new ways of doing business; the DS1 team will support new ideas, processes and practices that have the potential to improve productivity and have acceptable risk..
- Attack multi-discipline problems by using concurrent engineering
- Encourage open communication among team members.

We will also develop and foster for our team members a "DS1 mind set." This mind set will include the following thoughts:

- Design to cost - and the recognition that we must maintain our schedule to maintain our cost.
- Capability driven mission - recognition that the project will be dynamic because of our extensive use of concurrent engineering and because we are flight validating breakthrough technologies.
- Everyone must be a system engineer - we must all look at the big picture.
- People must feel that they are empowered to solved there own problems - and they aren't waiting for others to get their job done
- Work to create a "can-do attitude" through out the team

5.1.1 Low-Cost, Quick-Reaction Approach

Table 5-1 contains an overall approach intended to be used by the project to meet the objectives of developing a high quality product at low cost and short schedule.

Table 5-1. Quick-Reaction, Low-Cost Project Implementation Mode

NMP DS1 Quick-Reaction, Low-Cost Project Implementation Mode

JPL and its industry partner will establish and support a DS1 team motivated to do more for less. This team will:

- Work closely with, be responsive to the customer, achieve up front agreements which cannot change
- Establish a clear set of mission objectives that are understood by all parties
- Strive to do more for less, walk line between over enthusiasm and ultra conservatism
- Be projectized, make use of and be co-located near the JPL flight system testbed
- Include in team dedicated finance, procurement, product assurance personnel
- Use a mix of scarred old timers and bright energetic youth, give them responsibility. Trust them
- Focus application of resources to mission objectives, avoid unnecessary institutional charges, work around unneeded bureaucracy, minimize external interfaces
- Sensitize team members to cost, give engineers cost, schedule and technical responsibility
- Move technical planners to designers to testers to operators: womb to tomb
- Establish a thorough WBS, cost cap major WBS items, accomplish thorough cost estimates, track actual costs vs. plan monthly, maintain adequate reserves
- Accomplish IDC early in project. Hit the street with procurements as early as possible
- Establish and maintain an integrated project schedule and control milestones, track performance weekly
- Use streamlined product assurance, less documentation, fewer independent checks, more reliance on implementors, more reliance on extensive system test prior to launch
- Go to best sources, use their methods, use expert consultants and peer reviews
- Be aware of the status of the JPL re-engineering teams. Serve as a proto-type for their concepts where appropriate.
- Achieve adequate margins, robust designs
- Do up front planning, analysis and design, but assemble quickly and test thoroughly
- Start rapid prototyping testbed activities at project start for the flight system & GDS.
- Demo new concepts ASAP, such as autonomy, MICAS and SEP in simulated environment
- Accomplish concurrent engineering, push to get necessary funding profile for this
  - Emphasize up front mission and system engineering
  - Design mission, system, flight, and ground segments, including instruments.
  - Accomplish integrated flight and ground system S/W development teams
  - Establish incremental deliveries with demonstrable capabilities for progress checks
- Clearly communicate status, plans, problems, solutions on a weekly basis

GDS = Ground Data System
H/W = Hardware
MOS = Mission Operations System
IDC = Interim Design Concurrence Review
S/W= Software
WBS = Work Breakdown Structure

5.2 Program Relationships and Responsibilities

5.2.1 Program Office

The agreement between the NMP manager and the DS1 flight lead on how they will work together is documented in a memorandum of agreement (see Figure 1-1).

5.2.2 Integrated Product Development Teams (IPDTs)

The IPDTs provide advanced technology road maps and candidate technologies for the mission. The NMP program office, IPDT co-leads, and the DS1 flight team work together to select recommended technologies which are presented to NASA for a decision (see JPL D-13361, "The NMP Technology Selection Plan").

A closely integrated, working, non-adversarial relationship between the flight team and the IPDTs will be fostered. This approach is needed for the following reasons:

- The flight team must ensure that candidate technologies from each of the IPDTs are compatible and can be successfully integrated into the first flight.
- Technical and integration issues must be addressed early in the design process.
- It is consistent with concurrent engineering and a teaming environment.
- NMP's tight cost and schedule constraints will not allow a "throw it over the wall" approach.
- It fosters a "team concept" for future missions.

Selected technology providers will become part of the Flight Team while maintaining membership on their IPDTs. This approach is needed to ensure successful integration of the technology in the flight system. The relationship between the IPDT Cog. E and the Flight Team will be one of supplier and customer.

5.2.3 Flight Team

An industrial partner, Spectrum Astro, Inc. (SAI), has been selected as a DS1 flight team member working as a true partner with JPL. The flight team (industry partner and JPL) will identify, define, develop, and document a detailed mission and spacecraft system design. The flight team, including SAI, will perform the following tasks:

(1) Complete and document, with other flight team members, the DS1 detailed mission and system design.

(2) Define, with flight team members, the following spacecraft capabilities and design:

  (a) Details of the spacecraft system design, functions, interfaces, subsystems, assemblies, flight software, and advanced technology hardware and software. Advanced technology hardware and software will be identified and delivered to the flight team members from the IPDTs

(b) Long-lead items with required procurement dates
(c) Spares philosophy and approach
(d) Spacecraft advanced technology and payload interfaces, including but not limited to, the following:
   (i) Mechanical interface descriptions
   (ii) Electrical interface descriptions
   (iii) Command and data interfaces
   (iv) Environmental descriptions, including thermal envelope, static and dynamic loads, and electromagnetic fields
   (v) Cruise performance for onboard cruise autonomy
(e) Spacecraft metrics including, but not limited to, the following:
   (i) Mass at launch
   (ii) Power and thermal margins at launch

(3) Participate, as a flight team member, in the following meetings:

(a) System Requirements Review
(b) Mission Interim Design Concurrence (IDC) Review
(c) Mission Detailed Design Concurrence (DDC) Review
(e) Sage Review
(f) Pre-Ship Review
(g) Launch Readiness Review

A contractual relationship with SAI will be established to facilitate and encourage a good teaming arrangement. The goal is to have a "badgeless" environment, with clear communications of and buy-in to project goals, and minimal formal documentation. In addition, high speed data links and video communications will be established between SAI and JPL.

It is understood that the industry partner's role will continue to grow in scope and responsibility, with the intent that they become long term suppliers of deep space spacecraft for science missions of the 21st century.

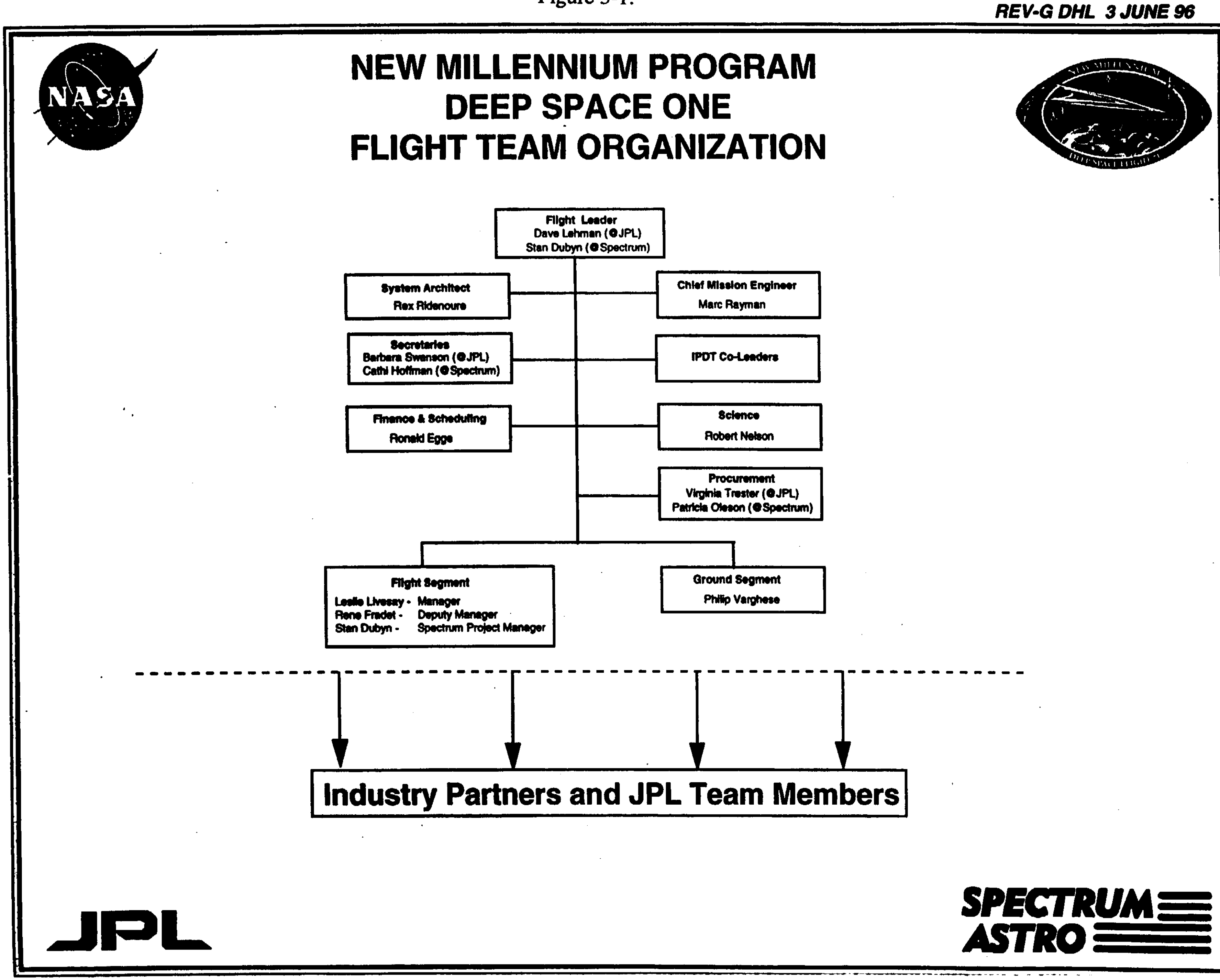
5.3 Organization and Work Breakdown Structure

5.3.1 DS1 Team Composition

Figure 5-1 shows the project flight team composition. The roles for the lead individuals on the team are as follows:

Flight Lead (JPL)	Responsible for achieving DS1 mission requirements and the planning, implementation and control of the DS1.
Flight Lead (SAI)	Responsible for overall planning, control and direction of the SAI team. Project manager for all SAI work. Assistant to the JPL flight lead.

Figure 5-1.


REV-G DHL 3 JUNE 96
NEW MILLENNIUM PROGRAM
DEEP SPACE ONE
FLIGHT TEAM ORGANIZATION
Flight Leader
Dave Lehman (@JPL)
Stan Dubyn (@Spectrum)
System Architect
Rex Ridenoure
Chief Mission Engineer
Marc Rayman
Secretaries
Barbara Swenson (@JPL)
Cathi Hoffman (@Spectrum)
IPDT Co-Leaders
Finance & Scheduling
Ronald Egge
Science
Robert Nelson
Procurement
Virginia Trester (@JPL)
Patricia Oleson (@Spectrum)
Flight Segment
Leslie Livesay - Manager
Rene Fradet - Deputy Manager
Stan Dubyn - Spectrum Project Manager
Ground Segment
Philip Varghese
Industry Partners and JPL Team Members
JPL
SPECTRUM ASTRO

System Architect	Responsible for the overall mission and systems technical design and the achievement of the DS1 technical requirements.
Flight Segment Manager	Responsible for the flight segment (including spacecraft and launch vehicle integration) and the overall planning and control of the effort.
Deputy Flight Segment Manager	Deputy to the Flight Segment Manager. Has full authority as the Flight Segment Manager
Chief Mission Engineer	Responsible for the mission design development for DS1 mission engineering and navigation planning, and the overall planning and control of the effort
Chief Mission Operations Engr	Responsible for the mission operations development and mission operations for DS1 and the overall planning and control of the effort
Procurement Lead	Responsible for the overall management of all DS1 procurements
Finance & Schedule Lead	Responsible for development of budgets and schedules for DS1
Science Lead	Responsible for DS1 science

The above team leaders will work together and form sub-groups (or teams) to implement the mission. The DS1 working groups are shown in Figure 5-2. The charters of the groups are defined in Table 5-2. As the project evolves it is expected that the charters of the groups will change to fit the needs of the development cycle.

5.3.2 Work Breakdown Structure

The major Work Breakdown Structure (WBS) for DS1 is shown in Table 5-3 below.

WBS Item
Project Office
System Architecture
Mission Engineering
Spacecraft
Science Advisory Team
Ground Segment Development
Ground Segment Operations
Launch Vehicle
Project Reserve
TMOD

Table 5-3 Project Work Breakdown Structure (WBS)

Figure 5-2 DS1 Working Groups

NEW MILLENNIUM PROGRAM
DS1 WORKING GROUPS

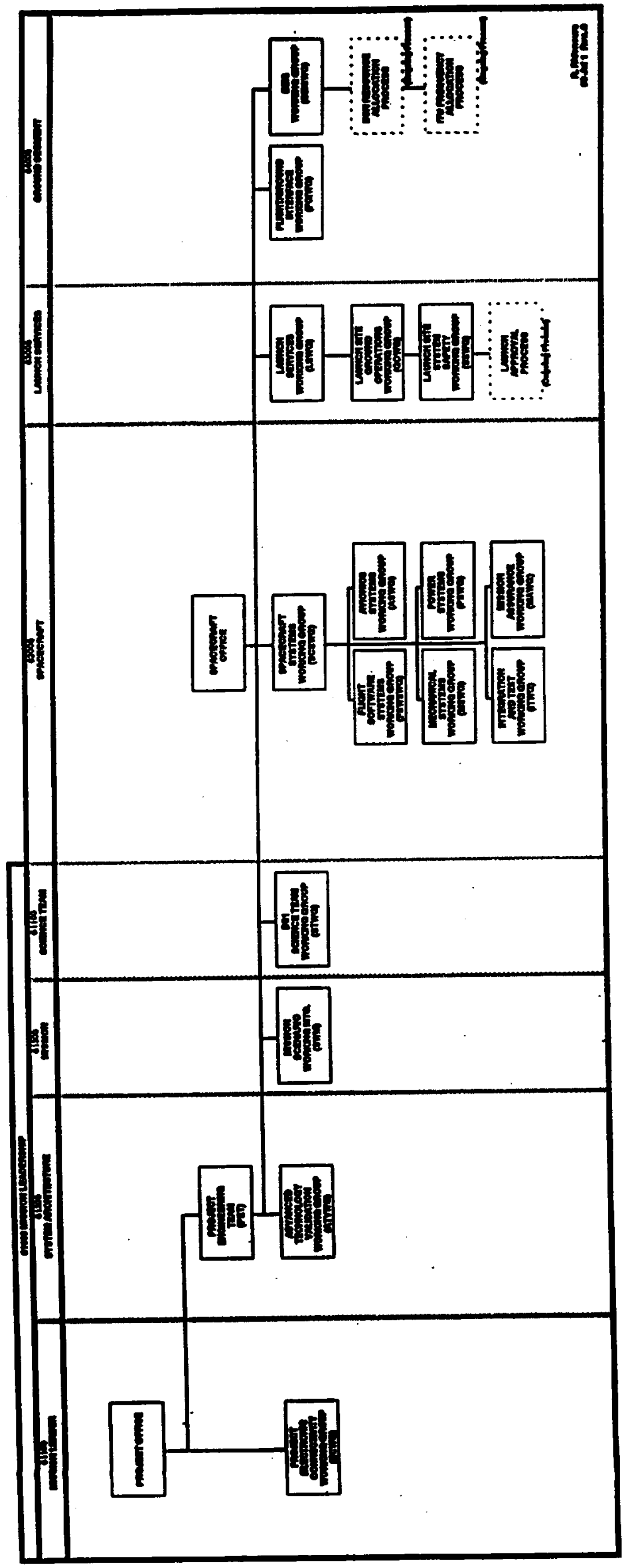


Table 5-2 DS1 Working Group Charters

DS1 WORKING GROUPS

96 Aug 14

PROJECT- AND SYSTEM-LEVEL WORKING GROUPS

	PROJECT OFFICE	PROJECT ENGINEERING TEAM (PET)	ELECTRONIC CONNECTIVITY WORKING GROUP (ECWG)	ADV TECH VALIDATION WORKING GROUP (ATVWG)	MISSION SCENARIO WORKING MTG. (SWM)	DS1 SCIENCE TEAM WORKING GROUP (STWG)	SPACECRAFT OFFICE	SPACECRAFT SYSTEMS WORKING GROUP (SCSWG)	LAUNCH SERVICES WORKING GROUP (LSWG)	FLIGHT/GROUND INTERFACE WORKING GROUP (FGIWG)	[illegible] WORKING GROUP ([illegible])
Meeting frequency	Weekly	Weekly	Bi-weekly	Weekly	Weekly	~Quarterly	Weekly	Weekly	Bi-weekly	Weekly	Weekly
Day of week	Mon	Thu	Mon	Fri	Fri	Various	Mon	Thu	Mon	Mon	Wed
Time	1-2:30	8:30-10	11-Noon	10-Noon	1-2:30	Various	3-4:00	10-Noon	8:30-10	9-11:00	10-Noon
Place	301-367	301-367	301-367	301-367	301-367	JPL	301-367	301-367	Telecon	301-235	[illegible]
Chair	Lehman	[illegible]	Fradet	[illegible]	Rayman	Nelson	Livesay	[illegible]	Davis	[illegible]	[illegible]
Alternate	[illegible]	Livesay	Jordan	Rayman	[illegible]	—	Fradet	Jordan	Fradet	Bernard	Kraemer
	• DS1 Top 10 • Programmatics • Level-1 reqts • Weekly schedule • Strategy • Outreach • Coordination • Key events • Status reports	• Systems Top 10 • Project engr • Level-2 reqts • Tech validation • IV&V • System interfaces • System integration • System Req/Dsds • DS1 Desgn Doc • Ad hoc issues	• Connectivity • Cost'n approach • Videoconferencing • WWW • DS1 data bases • Rev/Del sys	• Validation reqts • Mission/Ops I/F	• Mission plan • Scenarios • Nav strategy • LV performance • Trajectory • SWG I/F • Xenon budget	• Science reqts • Ops/Nav review • Tech valid'n rvw • Outreach • Science I/F	• S/C programmatics • S/C status	• S/C Top 10 • System engr • System integr'n • S/C reqts • System budgets • Config'n control • ICDs	• Procurement • All I/Fs • Integration plan • KSC I/F • Safety • LVS integr'n suppt	• Miss operability reqts • Ops concept • Cmd/telemetry lists • High-level S/C-FSW I/Fs	• MOS reqts • [illegible] • [illegible] • Ops I/F [illegible] • Detailed S/C-FSW I/Fs

SPACECRAFT SYSTEMS SUB-GROUPS

	FLIGHT SOFTWARE SYSTEMS WORKING GROUP (FSWSWG)	AVIONICS SYSTEMS WORKING GROUP (ASWG)	POWER SYSTEMS WORKING GROUP (PSWG)	MECHANICAL SYSTEMS WORKING GROUP (MSWG)	INTEGRATION AND TEST WORKING GROUP (ITWG)	MISSION ASSURANCE WORKING GROUP (MAWG)
Meeting frequency	As needed	As needed	As needed	As needed	Weekly	As needed
Day of week					Wed	
Time					3-4:30	
Place					301-367	
Chair	Bernard	Caldwell	Nieraeth	Goodman	McSmith	T. Hall
Alternate	Kraemer	Rey	Rashold	Wester	S. Hall	Newell
	• S/W reqts • S/W Fault protection • FSW models • S/C ops concept (auto) • Uplink strategy • FSW [illegible] • Testbed/I&T S/W plan	• Avionics reqts • Avionics architecture • Electrical SD & I/F • Cabling reqts • Ops constraints • H/W fault protection • Budgets and margins • ACS performance • EGSE design	• Power reqts • Power architecture • Power I/Fs • Power profiles • Power budget • SCARLET ICD (elec) • NSTAR ICD (elec) • EMI/EMC • Grounding • I&T support	• Mechanical reqts • Configuration • Mass properties • Alignments • Temp control • Structural loads • Mechanisms • RCS • SCARLET ICD (mech) • NSTAR ICD (mech) • Cabling design • S/C Models • MGSE design	• Plans • Testbed reqts • I&T reqts • In-orbit ver'n reqts • MGSE/EGSE reqts • Facilities • Procedures • Data capture • Config'n control	• Plans • CVS • Tailoring • I&T review • Safety • "Ilities" • Radiation

EXTERNAL PROCESSES DS1 SUPPORTS

	LAUNCH SITE GROUND OPS WORKING GROUP (GOWG)	LAUNCH SITE SYSTEM SAFETY WORKING GROUP (SSWG)	LAUNCH APPROVAL PROCESS	DSN RESOURCE ALLOCATION PROCESS	[illegible] ALLOCATION PROCESS
Meeting frequency	As needed	As needed	As needed	~Quarterly	As needed
Day of week					
Time					
Place				JPL	JPL
Chair	DS1/K. Barrow	DS1/K. Barrow	NMP/Dave Skinner	TMOD/[illegible]	DS1 [illegible]
Alternate	—	—	—	—	—
	• Launch ops flow • Procedures • Safety (general)	• Safety (detailed)	• Launch approval • Environmental impact • LVS integ'n support	• DSN tracking requests • DSN conflict resolution • DSN special services	• Frequency approvals
	KSC-OWNED PROCESS	KSC-OWNED PROCESS	NMP-OWNED PROCESS	TMOD-OWNED PROCESS	TMOD-OWNED PROCESS

5.4 Resource Estimation, Allocation, and Reserve/Descope Strategies

5.4.1 Resource Estimation and Allocation

At least once each fiscal year, or as directed by the Flight Lead or designee, each person responsible for a DS1 work breakdown structure (WBS) element shall:

1. Estimate the element's resource needs to complete the work.
2. Negotiate a resource budget with the element's funding source.

5.4.2 Reserve Strategy/Descope Plan

Because of the tight budget reserve for the project a detailed reserve strategy/descope (or risk management) plan has been developed. This plan highlights the uses of the reserves for the project and where they can be applied. In addition, the plan shows how descopes in the implementation plan will be made vs. time as reserves are used up throughout the life of the project. (see JPL IOM DS1-DHL-96-016A, dated 7/25/96).

5.4.3 Resource Transfers and Fiscal Year Carryover

Resource transfers may be traded among different WBS elements.

Individual WBS elements with unused budgetary allocation at the end of a fiscal year, based on the concurrence of the Flight Lead or his designee, may carry the allocation forward into the next year.

It is the responsibility of the NMP office to ensure that sufficient total funds are carried over at the end of each fiscal year to provide funding for DS1 until the new fiscal year funding from NASA is on contract at JPL and available to the Project.

Funds allocated for a future year cannot be advanced to an earlier year without the approval of the NMP manager.

5.5 Project Control

5.5.1 Work Package Agreements

At the start of each fiscal year, each team element (cost account) leader will prepare a Work Package Agreement (WPA) using standard JPL format. The WPA will be negotiated with the Flight Lead, or designee, and will establish the cost account budgets, key deliverables, and schedule for the task. WPAs can be revised and a new WPA generated with written concurrence from both parties.

5.5.2 Project Reporting

Project reporting will be kept to the minimum level required to track progress, assess problems, and inform project, program, Laboratory, and NASA management. The reporting plan includes the following elements.

5.5.2.1 NASA

Weekly reports of significant events will be provided to NASA management personnel via the program office.

Weekly teleconferences with NASA Headquarters covering the Flight Lead's assessment of project status, accomplishments, issues and concerns will be conducted.

Inputs will be provided to the NASA's Program Operating Plan as requested.

5.5.2.2 JPL

Weekly reports of significant events will be provided to JPL management personnel.

The DS1 Flight Leads will have weekly quiet hours with the NMP manager to discuss the status of the project.

Monthly Management Reviews (MMRs) will be held at the project level by the flight lead wherein the NMP manager is invited to attend. Topics to be addressed include accomplishments, goals for next month, cost status, cost to complete analysis, reserve status, staffing status, schedule status, and issues and concerns (plus resolution plans).

A DS1 management counsel will be formed to provide advice and counsel to the DS1 project manager. This group will meet on a regular basis (monthly or quarterly) and report its findings to the program manager.

5.5.2.3 Technical Reporting

The system architect, with the support of the DS1 system element leads will prepare a "state-of-DS1" memorandum on a monthly basis. This memo will detail the status of the mission design and current margins for key parameters and metrics defining the mission.

5.5.2.4 Administrative

Weekly tracking of labor will be made by the flight lead, finance & schedule lead, and chief engineers. In addition, informal Monthly Management Reviews (MMRs) will be held for each mission element and/or spacecraft subsystem. At these meetings, the following general items will be covered:

- -Accomplishments of last period
- -Goals for next period
- -Schedule status
- -Cost and work force status
- -Cost to complete analysis
- -Issues and recommended closure plan
- -Help needed from flight team leads

5.5.3 Schedule

Schedule control will be achieved as a result of the weekly schedule reporting meetings. Figure 5-3 shows the overall schedule for DS1. The level 1 milestones are as follows:

a) Project start [October 1995]

b) Complete DS1 Mission and Systems Interim Design Concurrence (IDC) Review [December 1995]

c) Complete Sage Review [May 1996]

d) Complete DS1 Mission and Systems Detailed Design Concurrence (DDC) Review & Sage Review [September 1996]

e) Complete Sage Review [May 1997]

f) Deliver Partial Bus from SAI to JPL. Commence Assembly, Test and Launch Operations (ATLO) [August 1997]

g) Complete system tests & ship to KSC [April 1998]

h) Launch Commitment to NASA [July 1998]

i) Complete advanced technology flight validation [January 1999]

j) End of Primary Mission [July 2000]

At a detailed level, each system lead will develop and coordinate REC/DELs for all inter-subsystem and key intra-subsystem milestones. The Finance/Schedule Lead will coordinate this system and provide a weekly status report to DS1 team leaders

Table 6-1 NMP DS1 Cost Summary (Cont'd)

SPACECRAFT DEVELOPMENT COST BREAKDOWN (FY 96/97/98)

Project Work Element	Total Cost ($K)	Cost FY96	Cost FY97	Cost FY98	Total Work Years	Work Yrs FY96	Work Yrs FY97	Work Yrs FY98
S/C Total Cost	$ 64,718 K	28,643	28,786	7,289	219.1	62.5	118.0	38.5
Spacecraf Office	$ 3,323 K	1,008	1,384	931	17.5	5.4	7.3	4.8
Digital Avionics	$ 4,358 K	1,945	1,997	416	10.6	2.1	7.3	1.1
3D Computer	$ 7,913 K	3,027	4,724	163	17.2	5.0	11.3	0.9
Flight Software	$ 9,678 K	3,719	4,445	1,514	54.0	17.0	27.9	9.2
G & C HW	$ 3,137 K	1,235	1,761	141	5.0	1.1	3.3	0.5
Power	$ 1,220 K	557	649	14	3.7	1.0	2.7	0.0
SCARLET Array	$ 777 K	562	141	75	2.2	1.3	0.5	0.4
Telecom	$ 7,282 K	3,301	3,074	907	21.0	5.6	11.4	4.0
MICAS	$ 7,569 K	5,631	1,704	234	19.6	10.2	7.8	1.6
PEPE	$ 4,053 K	2,515	1,402	136	0.8	0.2	0.4	0.2
Structure	$ 3,255 K	971	2,252	33	11.6	3.9	7.5	0.1
Mechanism	$ 659 K	165	494	0	0.0	0.0	0.0	0.0
Thermal Control	$ 1,145 K	119	787	239	3.3	0.6	1.8	0.9
RCS	$ 2,154 K	368	1,416	371	9.6	1.4	6.1	2.2
Flight Cabling	$ 441 K	124	317	0	1.1	0.4	0.7	0.0
MGSE	$ 597 K	25	572	0	0.0	0.0	0.0	0.0
EGSE	$ 1,850 K	1,671	0	179	7.4	1.6	4.6	1.1
Mission Assurance	$ 2,489 K	728	1,317	445	11.6	2.2	6.5	2.9
I&T	$ 2,721 K	877	351	1,493	22.4	3.0	10.9	8.5
Other	$ 96 K	96	0	0	0.6	0.6	0.0	0.0

KEY: Project Work Element / Total Cost ($K) / Cost per FY (96/97/98) / Total Work Years / Work Yrs/FY (96/97/98)

Table 6-1 NMP DS1 Cost Summary

DS1 DEVELOPMENT COST BREAKDOWN (FY 96/97/98/99/00)

Project Total Cost

	FY96	FY97	FY98	FY99	FY00	Total
Cost ($M)	38.9	42.1	51.8	3.6	2.1	138.5
Work Years TOTAL	72	125	61	20	10	287
Work Years JPL	52	89	54	20	10	
Work Years SAI	19	36	8	0	0	

KEY: Project Work Element / Total Cost ($M) / Cost per FY (96/97/98/99/00) / Total Work Years / Work Yrs/FY (96/97/98/99/00)

Project Work Element	Total Cost ($M)	Cost per FY (96/97/98/99/00)	Total Work Years	Work Yrs/FY (96/97/98/99/00)
Project Office (SA & JPL)	3.8	2.0 | 1.3 | 0.6 | 0.0 | 0.0	24.2	11.0 | 8.5 | 4.7 | 0.0 | 0.0
System Architecture	0.5	0.2 | 0.2 | 0.2 | 0.0 | 0.0	3.0	1.0 | 1.0 | 1.0 | 0.0 | 0.0
Mission Engineering	1.3	0.5 | 0.4 | 0.3 | 0.0 | 0.0	10.8	3.4 | 4.1 | 3.4 | 0.0 | 0.0
Spacecraft	64.7	28.6 | 28.8 | 7.3 | 0.0 | 0.0	219.1	63 | 118 | 39 | 0 | 0
Science Advisory Team	0.6	0.0 | 0.3 | 0.3 | 0.0 | 0.0	3.7	0.2 | 1.8 | 1.7 | 0.0 | 0.0
Ground Segment Dev.	3.3	0.8 | 1.3 | 1.3 | 0.0 | 0.0	16.7	3.5 | 6.7 | 6.6 | 0.0 | 0.0
Ground Segment Ops	6.4	0.0 | 0.0 | 1.4 | 3.1 | 1.8	6.8	0.0 | 0.0 | 6.8 | 15.5 | 8.5
Launch Vehicle	44.9	5.5 | 7.2 | 32.3 | 0.0 | 0.0	2.3	0.3 | 1.0 | 1.0 | 0.0 | 0.0
Project Reserve	10.7	1.3 | 2.0 | 7.4 | 0.0 | 0.0		0.0 | 0.0 | 0.0 | 0.0 | 0.0
TMOD	2.2	0.2 | 0.6 | 0.7 | 0.4 | 0.3	8.2	1.0 | 3.1 | 4.1 | 4.1 | 1.6

Section 6
Resource Plan

6.1 Funding Plan

See Table 6-1 which shows the cost plan for each major work element of DS1. Major costing assumptions for this table are shown below:

DS1 Funding Assumptions	FY'96	FY'97	FY'98	FY'98	FY'99	Total
Re-engineering team support	770	4926	1325	330		7351
SDST funding per Consortium Agreement	400	1100				1500
Ka Band SSPA funds from Dr. Elachi	140	160	10			310
Multi-functional structure from E. K. Casani	6	90	18	18	6	138
Low power experiment from L. Alkalai		TBD	TBD	TBD	TBD	TBD
IPDT funds for DS1 data/analysis & science				1000	1000	2000

The difference between the costs shown in Table 6-1 and that provided in the MOA of Figure 1-1 is as follows:

Current estimate includes updated costs for launch services.
Current estimate shows revised assumptions for support from the JPL re-engineering team.

6.2 Facilities

NMP has developed a co-location plan (JPL D-13425). As part of that plan, DS1 will co-locate in building 301 by July 1996. The initial parts of that plan have been executed with the core team in place. In addition, the following support is needed and is described in the following documents:

PDC/DS1 Support Plan, IOM by C. Briggs dated 16 Feb. 1996

FST/DS1 Support Plan, IOM by P. Gluck dated 16 Feb. 1996

TMOD/DS1 Support Plan (D-13548, dated 3 July 1996)

Detailed Design Concurrence (DDC) Review

- Systems or Subsystems shall conduct DDCs at the time detailed designs/ drawings are ready for release and before fabrication begins. Minimize coverage of areas known to be in good shape.
  - Minimal overview tutorial, including configuration and/or block diagram
  - Dominant Level-2, 3, and 4 functional requirements/ capabilities driving System or S/S
  - Major external and internal interfaces affecting design
  - Details of design (and analysis, if appropriate)
  - Solutions to major problems from IDC (functional and interface)
  - Applicable test data
  - Design/resource margins (timing, memory, torque margins, etc.)
  - Drawing status
  - QA document/aids/test plan/safety status
  - Key schedule items/schedule problems
  - Issues/planned actions
  - Cost and W/F summary for board's "gut level" assessment

- NOTE 1: Any requirement not being met (formal or informal) shall be a review item

- NOTE 2: The DDC is not met to be a decision point for a go-ahead for procurements.

Table 5-7 DS1 System or Subsystem Detailed Design Concurrence (DDC) Review

Interim Design Concurrence (IDC) Review

- IDCs shall be conducted after design concepts are established and detailed design is beginning. As little time as possible shall be spent on routine description of areas that are in good shape. The agenda shall emphasize items selected from new, controversial, or problem items including the following areas, as appropriate:
  - Minimal overview tutorial
    - Major task description
    - Configuration and/or block diagram
    - Major design options considered
  - Dominant Level-2, 3, and 4 functional requirements/ capabilities driving System or S/S
  - Major external and internal interfaces affecting design
  - Inheritance review of h/w & s/w as appropriate
  - Design details/description
  - Safety design approach
  - Proof-of-concept test results (as appropriate)
  - Schedule
  - Issues/planned actions
  - Cost and W/F summary for board's "gut level" assessment
- NOTE: Any violation of Project Requirements (PDs, FRs, etc.) or other requirements not being achieved will be a review item

Table 5-6 DS1 Interim Design Concurrence (IDC) Review

Review Process

- Utilize a series of system or subsystem-level peer reviews for IDCs and DDCs
  - Reviews are chartered under the Flight Lead (system reviews) or Chief Engineer (subsystem review) and conducted by the system or subsystem lead (as appropriate)
  - All reviews are attended by a core board selected by the Chief Engineer and chaired by a senior JPL engineer outside the project
  - Attendance will be limited to a small set of:
    - Technical specialists and peers from the System or S/S being reviewed
    - Representatives of the flight team and key interfaces
  - Attendance shall be limited to JPL/industry partner personnel, except where special outside expertise is required. Non-team attendees to be approved by JPL lead.
  - All attendees are members of the "board" and expected to contribute
- Review board responsibilities:
  - Probe technical approach and schedule for adequacy and practicality
  - Bring experience from past programs to identify potential problem areas
  - Recommend areas for special attention
  - Recommend on the continuation of the effort to the next phase
- Review secretary (e.g., Review chairman or System or S/S Lead) will capture all action items, advisories, and comments in a running memo during the meeting (no RFAs)
  - To be reviewed at and issued after the review
  - Focus should be on identifying potential problems and potential solutions

Table 5-5 DS1 System or Subsystem Review Process

5.5.4 Review Plan

Consistent with the NMP policy of minimizing cost and expediting schedule performance, project reviews will be held to a minimum. All reviews are in accordance with NMP requirements. The following reviews are planned.

- Initial Technology and System Requirements Review [October 1995]
- Mission and System Interim Design Concurrence(IDC) Peer Review [December 1995]
- Sage Review [May 1996]
- Mission and System Detailed Design Concurrence(DDC) Peer & Sage Review [September 1996]
- Sage Review [April 1997]
- Spacecraft Pre-Ship Review [April 1998]
- Launch Readiness Review [June 1998]

DS1 reviews at the system level and below will be peer reviews, with the major objective to help engineers get their job done. They are not intended to be status reviews for management. The summary purpose of the reviews are as follows:

Review	Purpose
Requirements and Design Reviews	Peer review of the design
Sage Reviews:	Sage review of mission implementation plan
Technology Readiness Review Gates:	Reviews to assess development status of a technology product and to determine the likelihood that the product will meet its objectives
Spacecraft Pre-Ship Review	Assess readiness status to ship the DS1 spacecraft to KSC
Launch Readiness Review	Assess readiness status to launch the DS1 spacecraft

The IDC and DDC reviews will be conducted in accordance with the objectives and approach shown in Tables 5-4, 5-5, 5-6, and 5-7. Technology readiness gates for all new developments will be conducted in accordance with NMP JPL D-13361.

Design Review Objectives

- Detailed, "shirtsleeves," hands-on peer review of a system, subsystem (S/S) or part of a S/S. Not a push up for management. These reviews are to help engineers
- Demonstrate technical definition consistent with the phase of development
  - IDC
    - Complete system S/S architecture (block diagram, configuration, flowchart, etc.)
    - Preliminary designs (layouts, circuits, algorithms, procurement specifications, ICD's, etc.)
    - Inheritance review of h/w & s/w as appropriate
  - DDC
    - Complete system or S/S designs, ready for fabrication/coding (drawings, data flow & state transition diagrams, proto code, etc.)
    - Design analysis, failure modes & effects analysis, error detection and recovery
- Demonstrate adequate definition and understanding of driving requirements, interfaces & capabilities, and verification method
- Demonstrate adequacy of margins
- Demonstrate understanding of driving technical risks, means for handling risks & safety
- First-order "gut feel" assessment by core board of whether designs and problem/risk areas are consistent with planned work force, budget, and reserves
  - Following technical, schedule, and issues, a one-page budget summary will be presented by the Cog E
  - Core board will be asked to react with nothing more than "looks OK" or "I think you've got a problem"

Table 5-4. DS1 System or Subsystem Review Objectives.

Figure 5-3 DS1 Schedule (Cont'd)

ID	Task Name	Duration	Start	Finish
57	SS1(50MHz) to PAPA bed	0d	12/2/96	12/2/96
58	SS2 (50MHz) to FSTB	0d	2/3/97	2/3/97
59	EM1(50MHz) to hot bench	0d	3/3/97	3/3/97
60	EM2(50MHz) to partial bus integration	0d	3/3/97	3/3/97
61	EM3 (50MHz) to partial bus integration	0d	5/1/97	5/1/97
62	FM1 (50MHz) to ATLO	0d	9/2/97	9/2/97
63	Cable Mockup (CMU) to JPL	0d	1/2/97	1/2/97
64	CMU/Cable Harness to SAI	0d	5/1/97	5/1/97
65	TPA Harness to RCS	0d	7/1/97	7/1/97
66	Thrust Plate Assy (TPA) to RCS	0d	5/1/97	5/1/97
67	TPA/Structure to ATLO	0d	9/2/97	9/2/97
68	IEM Flight Models to SAI	0d	4/15/97	4/15/97
69	SAI Bus Integration	15w	4/15/97	7/30/97
70	Bus, RPS to ATLO	0d	7/30/97	7/30/97
71	MICAS to ATLO	0d	7/15/97	7/15/97
72	PEPE & NSTAR to ATLO	0d	8/1/97	8/1/97
73	SCARLET to ATLO	0d	8/29/97	8/29/97
74	ATLO & Launch	233d	8/1/97	7/1/98
75	ATLO	17w	8/1/97	12/2/97
76	STV & VB	7w	12/3/97	1/22/98
77	Schedule Reserve	66d	1/23/98	4/28/98
78	KSC	44d	4/29/98	6/30/98
79	Launch	1d	7/1/98	7/1/98
80				
81	GDS & MOS Development	722d	10/2/95	7/31/98
82	EEIS Phase #1: Initial Setup	106d	11/2/95	3/29/96
	IDC	1d	5/22/96	5/22/96
	EEIS Phase #2: Validate data transport mechanism	84d	3/29/96	7/26/96
	EEIS Phase #3: Integrate telemetry functions	80d	7/26/96	11/15/96
86	DOC	1d	11/1/96	11/1/96
87	EEIS Phase #4: Command by Goals	79d	11/15/96	3/10/97
88	EEIS Phase #5: Complete uplink capability	75d	3/7/97	6/20/97
89	GDS to ATLO	1d	6/20/97	6/20/97
90	EEIS Phase #6: End-to-end RF checkout	69d	6/20/97	9/26/97
91	Launch operations delivery	79d	9/26/97	1/15/98
92				
93	DSN	66d	7/1/96	10/1/96
94	Mission Requirements Request (MRR)	1d	7/1/96	7/1/96
95	Detailed Mission Requirements (DMR)	1d	10/1/96	10/1/96
96				
97	Launch Vehicle	606d	3/8/96	6/30/98
98	Issue Draft RFP	1d	3/8/96	3/8/96
99	Delta kick off meeting	1d	7/29/96	7/29/96
100	Develop launch vehicle	490d	7/30/96	6/30/98
101				
102	Science	722d	10/2/95	7/31/98
103	AO Draft	1d	10/15/96	10/15/96
104	AO Release	1d	2/17/97	2/17/97
105	Science Team Selected	1d	7/15/97	7/15/97

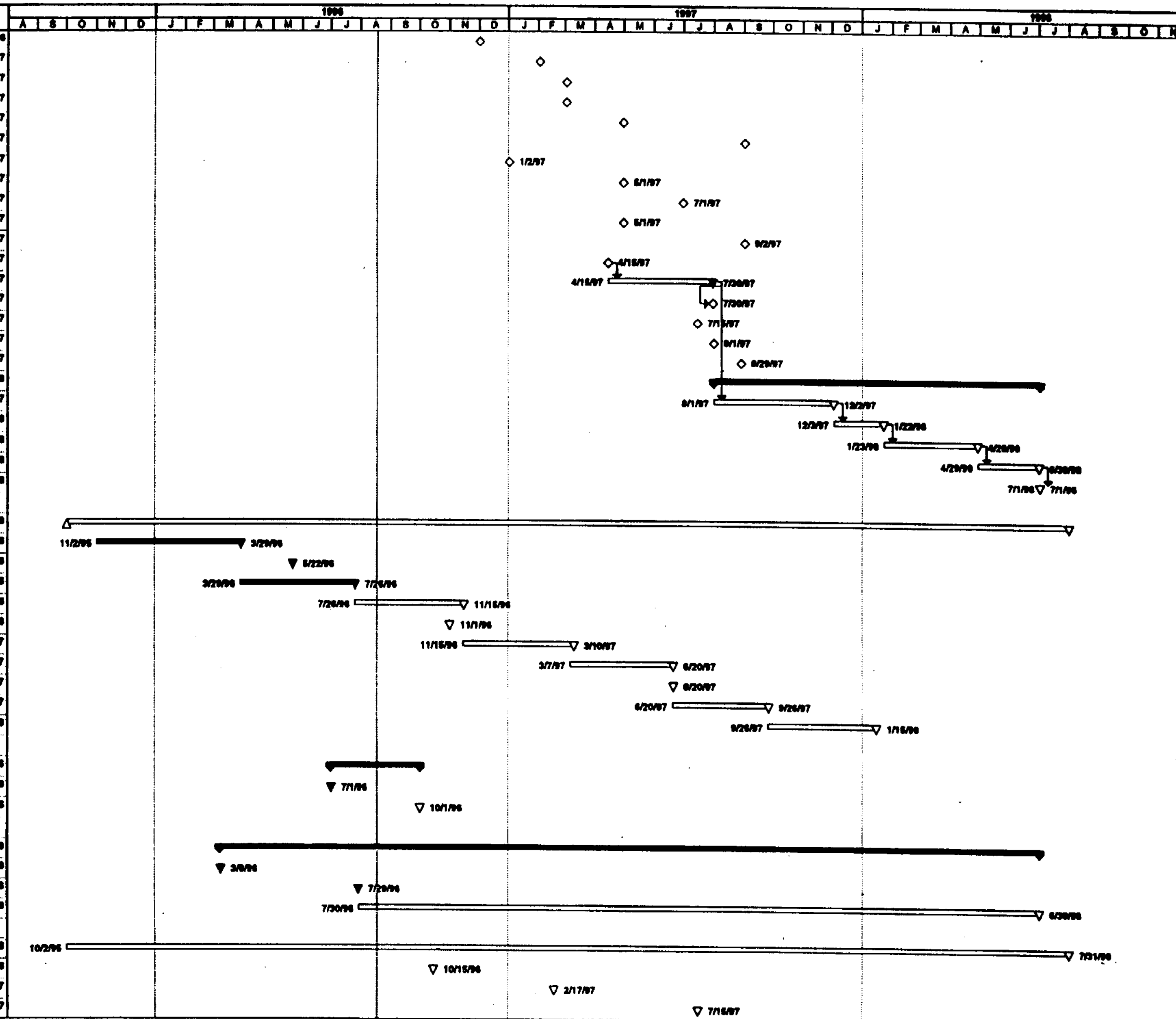
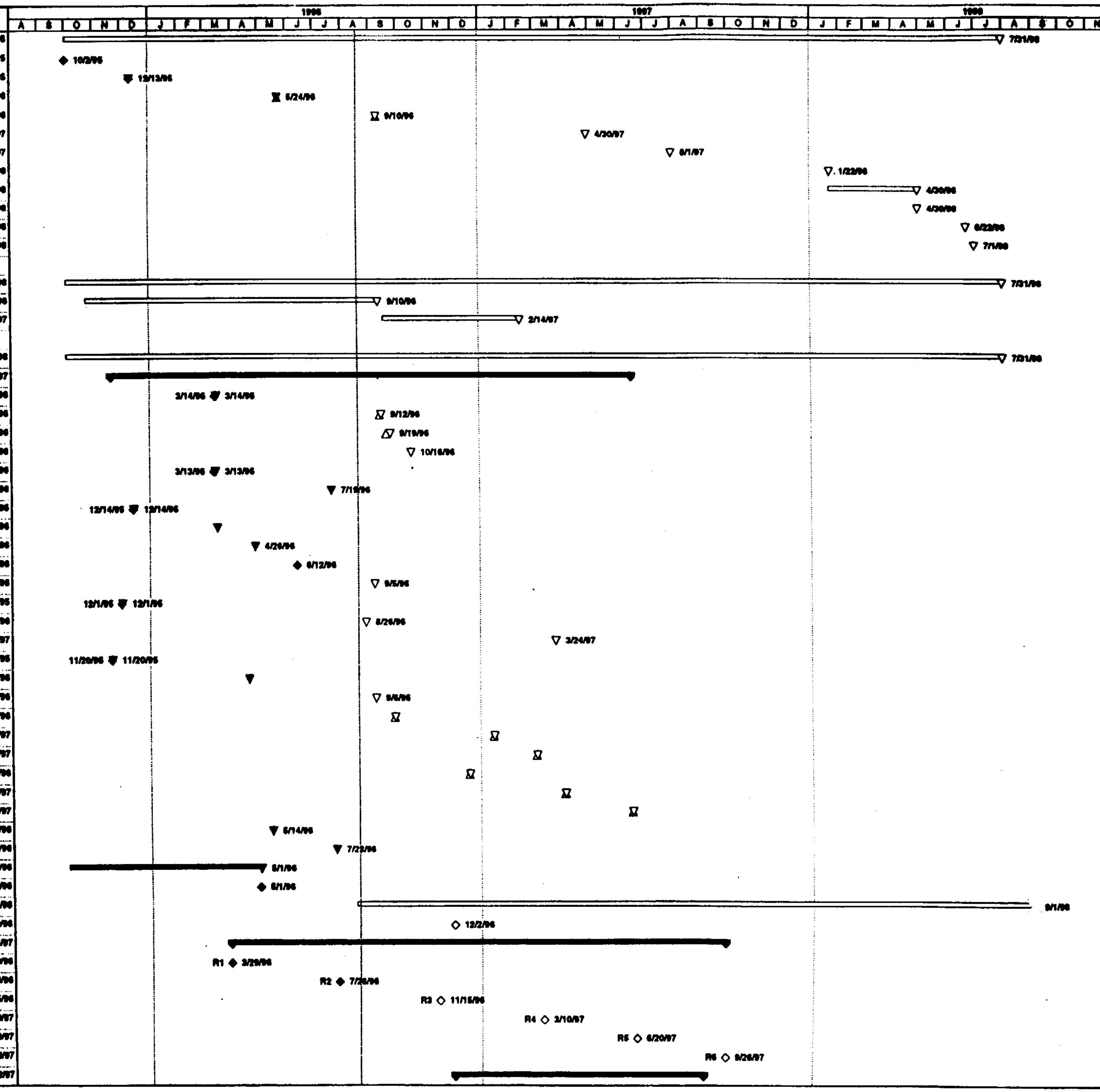


Figure 5-3 DS1 Schedule

ID	Task Name	Duration	Start	Finish
1	Major Project Milestones	722d	10/2/95	7/31/98
2	Project Start	0d	10/2/95	10/2/95
3	Interim Design Concurrence Review	2d	12/12/95	12/13/95
4	Sage Review	3d	5/24/96	5/29/96
5	Detailed Design Concurrence/SAGE Review	3d	9/10/96	9/12/96
6	Sage Review	1d	4/30/97	4/30/97
7	Start ATLO	1d	8/1/97	8/1/97
8	Complete ATLO	1d	1/22/98	1/22/98
9	Schedule Reserve	71d	1/22/98	4/30/98
10	Pre-Ship Review	1d	4/30/98	4/30/98
11	Launch Readiness Review	1d	6/22/98	6/22/98
12	Launch	1d	7/1/98	7/1/98
13				
14	Mission Design	722d	10/2/95	7/31/98
15	Scenario development-preliminary	220d	10/24/95	9/10/96
16	Scenario development-final	100d	9/10/96	2/14/97
17				
18	Spacecraft Development	722d	10/2/95	7/31/98
19	Technology Reviews/Gates	491d	11/19/95	9/16/97
20	NSTAR PDR	2d	3/13/96	3/14/96
21	XFS CDR	2d	9/12/96	9/13/96
22	Thruster Element CDR	3d	9/19/96	9/23/96
23	NSTAR CDR	2d	10/15/96	10/16/96
24	SCARLET PDR	2d	3/12/96	3/13/96
25	SCARLET CDR	2d	7/18/96	7/19/96
26	Remote Agent & OPNAV : TRR	1d	12/14/95	12/14/95
27	Beacon Mode #1: Tech. Readiness Review	1d	3/15/96	3/15/96
9	Autonomy Gate #2: Technology Demo	1d	4/29/96	4/29/96
2	Autonomy IDC	1d	6/12/96	6/12/96
30	Autonomy Gate #3: System Demo	1d	9/5/96	9/5/96
31	Micro-Elec Gate #1: Tech. Readiness Rvw	1d	12/1/95	12/1/95
32	Micro-Elec Gate #2: Technology Demo	1d	8/26/96	8/26/96
33	Micro-Elec Gate #3: System Demo	1d	3/24/97	3/24/97
34	SOST Gate#1: IPOC	1d	11/19/95	11/20/95
35	SOST Gate#2: Design Progress Review	1d	4/19/96	4/19/96
36	SOST Gate#3: FPOC	1d	9/6/96	9/6/96
37	MFS gate #1	1d	9/27/96	9/27/96
38	MFS gate #2	1d	1/15/97	1/15/97
39	MFS gate #3	1d	3/3/97	3/3/97
40	Ka Band SSPA gate #1	1d	12/19/96	12/19/96
41	Ka Band SSPA gate #2	1d	4/3/97	4/3/97
42	Ka Band SSPA gate #3	1d	6/16/97	6/16/97
43	MICAS CDR	1d	5/14/96	5/14/96
44	PEPE CDR	1d	7/23/96	7/23/96
45	Work Element I @ SAI	151d	10/2/95	5/1/96
46	Work Element II Start @ SAI	1d	5/1/96	5/1/96
47	Flight System Test Bed (FST)	104w	8/15/96	9/1/98
48	Engineering Models to FST	0d	12/2/96	12/2/96
49	Autonomy	380d	3/29/96	9/26/97
50	R1	0d	3/29/96	3/29/96
51	R2	0d	7/26/96	7/26/96
52	R3	0d	11/15/96	11/15/96
53	R4	0d	3/10/97	3/10/97
54	R5	0d	6/20/97	6/20/97
55	R6	0d	9/26/97	9/26/97
56	3D Stack Processor	191d	12/2/96	9/2/97



Project: NMP
Date: 8/19/96

Task | Progress | Milestone ◇ | Summary | Completed Milestone ◆

Design Review Objectives

- Detailed, "shirtsleeves," hands-on peer review of a system, subsystem (S/S) or part of a S/S. Not a push up for management. These reviews are to help engineers
- Demonstrate technical definition consistent with the phase of development
  - IDC
    - Complete system S/S architecture (block diagram, configuration, flowchart, etc.)
    - Preliminary designs (layouts, circuits, algorithms, procurement specifications, ICD's, etc.)
    - Inheritance review of h/w & s/w as appropriate
  - DDC
    - Complete system or S/S designs, ready for fabrication/coding (drawings, data flow & state transition diagrams, proto code, etc.)
    - Design analysis, failure modes & effects analysis, error detection and recovery
- Demonstrate adequate definition and understanding of driving requirements, interfaces & capabilities, and verification method
- Demonstrate adequacy of margins
- Demonstrate understanding of driving technical risks, means for handling risks & safety
- First-order "gut feel" assessment by core board of whether designs and problem/risk areas are consistent with planned work force, budget, and reserves
  - Following technical, schedule, and issues, a one-page budget summary will be presented by the Cog E
  - Core board will be asked to react with nothing more than "looks OK" or "I think you've got a problem"

Table 5-4. DS1 System or Subsystem Review Objectives.

5.5.4 Review Plan

Consistent with the NMP policy of minimizing cost and expediting schedule performance, project reviews will be held to a minimum. All reviews are in accordance with NMP requirements. The following reviews are planned.

_ Initial Technology and System Requirements Review	[October 1995]
_ Mission and System Interim Design Concurrence(IDC) Peer Review	[December 1995]
_ Sage Review	[May 1996]
_ Mission and System Detailed Design Concurrence(DDC) Peer & Sage Review	[September 1996]
_ Sage Review	[April 1997]
_ Spacecraft Pre-Ship Review	[April 1998]
_ Launch Readiness Review	[June 1998]

DS1 reviews at the system level and below will be peer reviews, with the major objective to help engineers get their job done. They are not intended to be status reviews for management. The summary purpose of the reviews are as follows:

Review	Purpose
Requirements and Design Reviews	Peer review of the design
Sage Reviews:	Sage review of mission implementation plan
Technology Readiness Review Gates:	Reviews to assess development status of a technology product and to determine the likelihood that the product will meet its objectives
Spacecraft Pre-Ship Review	Assess readiness status to ship the DS1 spacecraft to KSC
Launch Readiness Review	Assess readiness status to launch the DS1 spacecraft

The IDC and DDC reviews will be conducted in accordance with the objectives and approach shown in Tables 5-4, 5-5, 5-6, and 5-7. Technology readiness gates for all new developments will be conducted in accordance with NMP JPL D-13361.

Review Process

- Utilize a series of system or subsystem-level peer reviews for IDCs and DDCs
  - Reviews are chartered under the Flight Lead (system reviews) or Chief Engineer (subsystem review) and conducted by the system or subsystem lead (as appropriate)
  - All reviews are attended by a core board selected by the Chief Engineer and chaired by a senior JPL engineer outside the project
  - Attendance will be limited to a small set of:
    - Technical specialists and peers from the System or S/S being reviewed
    - Representatives of the flight team and key interfaces
  - Attendance shall be limited to JPL/industry partner personnel, except where special outside expertise is required. Non-team attendees to be approved by JPL lead.
  - All attendees are members of the "board" and expected to contribute
- Review board responsibilities:
  - Probe technical approach and schedule for adequacy and practicality
  - Bring experience from past programs to identify potential problem areas
  - Recommend areas for special attention
  - Recommend on the continuation of the effort to the next phase
- Review secretary (e.g., Review chairman or System or S/S Lead) will capture all action items, advisories, and comments in a running memo during the meeting (no RFAs)
  - To be reviewed at and issued after the review
  - Focus should be on identifying potential problems and potential solutions

Table 5-5 DS1 System or Subsystem Review Process

Interim Design Concurrence (IDC) Review

- IDCs shall be conducted after design concepts are established and detailed design is beginning. As little time as possible shall be spent on routine description of areas that are in good shape. The agenda shall emphasize items selected from new, controversial, or problem items including the following areas, as appropriate:
  - Minimal overview tutorial
    - Major task description
    - Configuration and/or block diagram
    - Major design options considered
  - Dominant Level-2, 3, and 4 functional requirements/ capabilities driving System or S/S
  - Major external and internal interfaces affecting design
  - Inheritance review of h/w & s/w as appropriate
  - Design details/description
  - Safety design approach
  - Proof-of-concept test results (as appropriate)
  - Schedule
  - Issues/planned actions
  - Cost and W/F summary for board's "gut level" assessment
- NOTE: Any violation of Project Requirements (PDs, FRs, etc.) or other requirements not being achieved will be a review item

Table 5-6 DS1 Interim Design Concurrence (IDC) Review

Detailed Design Concurrence (DDC) Review

- Systems or Subsystems shall conduct DDCs at the time detailed designs/ drawings are ready for release and before fabrication begins. Minimize coverage of areas known to be in good shape.
  - Minimal overview tutorial, including configuration and/or block diagram
  - Dominant Level-2, 3, and 4 functional requirements/ capabilities driving System or S/S
  - Major external and internal interfaces affecting design
  - Details of design (and analysis, if appropriate)
  - Solutions to major problems from IDC (functional and interface)
  - Applicable test data
  - Design/resource margins (timing, memory, torque margins, etc.)
  - Drawing status
  - QA document/aids/test plan/safety status
  - Key schedule items/schedule problems
  - Issues/planned actions
  - Cost and W/F summary for board's "gut level" assessment

- NOTE 1: Any requirement not being met (formal or informal) shall be a review item

- NOTE 2: The DDC is not met to be a decision point for a go-ahead for procurements.

Table 5-7 DS1 System or Subsystem Detailed Design Concurrence (DDC) Review

Section 6
Resource Plan

6.1 Funding Plan

See Table 6-1 which shows the cost plan for each major work element of DS1. Major costing assumptions for this table are shown below:

DS1 Funding Assumptions	FY'96	FY'97	FY'98	FY'98	FY'99	Total
Re-engineering team support	770	4926	1325	330		7351
SDST funding per Consortium Agreement	400	1100				1500
Ka Band SSPA funds from Dr. Elachi	140	160	10			310
Multi-functional structure from E. K. Casani	6	90	18	18	6	138
Low power experiment from L. Alkalai		TBD	TBD	TBD	TBD	TBD
IPDT funds for DS1 data/analysis & science				1000	1000	2000

The difference between the costs shown in Table 6-1 and that provided in the MOA of Figure 1-1 is as follows:

Current estimate includes updated costs for launch services.
Current estimate shows revised assumptions for support from the JPL re-engineering team.

6.2 Facilities

NMP has developed a co-location plan (JPL D-13425). As part of that plan, DS1 will co-locate in building 301 by July 1996. The initial parts of that plan have been executed with the core team in place. In addition, the following support is needed and is described in the following documents:

PDC/DS1 Support Plan, IOM by C. Briggs dated 16 Feb. 1996

FST/DS1 Support Plan, IOM by P. Gluck dated 16 Feb. 1996

TMOD/DS1 Support Plan (D-13548, dated 3 July 1996)

Table 6-1 NMP DS1 Cost Summary

DS1 DEVELOPMENT COST BREAKDOWN (FY 96/97/98/99/00)

Project Work Element	Total Cost ($M)	FY96	FY97	FY98	FY99	FY00	Total Work Years		FY96	FY97	FY98	FY99	FY00
Project Total Cost	138.5	38.9	42.1	51.8	3.6	2.1	287	TOTAL	72	125	61	20	10
								JPL	52	89	54	20	10
								SAI	19	36	8	0	0
Project Office (SA & JPL)	3.8	2.0	1.3	0.6	0.0	0.0	24.2		11.0	8.5	4.7	0.0	0.0
System Architecture	0.6	0.2	0.2	0.2	0.0	0.0	3.0		1.0	1.0	1.0	0.0	0.0
Mission Engineering	1.3	0.6	0.4	0.3	0.0	0.0	10.8		3.4	4.1	3.4	0.0	0.0
Spacecraft	64.7	28.6	28.8	7.3	0.0	0.0	219.1		63	118	39	0	0
Science Advisory Team	0.6	0.0	0.3	0.3	0.0	0.0	3.7		0.2	1.8	1.7	0.0	0.0
Ground Segment Dev.	3.3	0.8	1.3	1.3	0.0	0.0	16.7		3.6	6.7	6.6	0.0	0.0
Ground Segment Ops	6.4	0.0	0.0	1.4	3.1	1.8	6.8		0.0	0.0	6.8	15.6	8.5
Launch Vehicle	44.9	5.5	7.2	32.3	0.0	0.0	2.3		0.3	1.0	1.0	0.0	0.0
Project Reserve	10.7	1.3	2.0	7.4	0.0	0.0			0.0	0.0	0.0	0.0	0.0
TMOD	2.2	0.2	0.6	0.7	0.4	0.3	8.2		1.0	3.1	4.1	4.1	1.6

KEY:
Project Work Element
Total Cost ($M)
Cost per FY (96/97/98/99/00)
Total Work Years
Work Yrs/FY (96/97/98/99/00)

Table 6-1 NMP DS1 Cost Summary

SPACECRAFT DEVELOPMENT COST BREAKDOWN (FY 96/97/98)

Project Work Element	Total Cost ($K)	Cost FY96	Cost FY97	Cost FY98	Total Work Years	Work Yrs FY96	Work Yrs FY97	Work Yrs FY98
S/C Total Cost	$ 64,718 K	28,643	28,786	7,289	219.1	62.5	118.0	38.5
Spacecraf Office	$ 3,323 K	1,008	1,384	931	17.5	5.4	7.3	4.8
Digital Avionics	$ 4,358 K	1,945	1,997	416	10.6	2.1	7.3	1.1
3D Computer	$ 7,913 K	3,027	4,724	163	17.2	5.0	11.3	0.9
Flight Software	$ 9,678 K	3,719	4,445	1,514	54.0	17.0	27.9	9.2
G & C HW	$ 3,137 K	1,235	1,761	141	5.0	1.1	3.3	0.5
Power	$ 1,220 K	557	649	14	3.7	1.0	2.7	0.0
SCARLET Array	$ 777 K	562	141	75	2.2	1.3	0.5	0.4
Telecom	$ 7,282 K	3,301	3,074	907	21.0	5.6	11.4	4.0
MICAS	$ 7,569 K	5,631	1,704	234	19.6	10.2	7.8	1.6
PEPE	$ 4,053 K	2,515	1,402	136	0.8	0.2	0.4	0.2
Structure	$ 3,255 K	971	2,252	33	11.6	3.9	7.5	0.1
Mechanism	$ 659 K	165	494	0	0.0	0.0	0.0	0.0
Thermal Control	$ 1,145 K	119	787	239	3.3	0.6	1.8	0.9
RCS	$ 2,154 K	368	1,416	371	9.6	1.4	6.1	2.2
Flight Cabling	$ 441 K	124	317	0	1.1	0.4	0.7	0.0
MGSE	$ 597 K	25	572	0	0.0	0.0	0.0	0.0
EGSE	$ 1,850 K	1,671	0	179	7.4	1.6	4.6	1.1
Mission Assurance	$ 2,489 K	728	1,317	445	11.6	2.2	6.5	2.9
I&T	$ 2,721 K	877	351	1,493	22.4	3.0	10.9	8.5
Other	$ 96 K	96	0	0	0.6	0.6	0.0	0.0

KEY: Project Work Element; Total Cost ($K); Cost per FY (96/97/98); Total Work Years; Work Yrs/FY (96/97/98)

Pluto Process Improvement Initiatives (select list 93/10/4)

key a) already implemented or included with baseline
b) *in progress or planned*
c) possible under consideration

How We Do Business

Workforce Cap

Tight Team development
- Sciencecraft implementation of integrated science and eng'g. teams
- *Skunk Works^{TM} collocation and management style*
- all people >0.9 (near full time) or <0.15 (consulting only) FTE
- LeRC, SM, SR, Univ Ops & *Contractors* as Full Partners
  - Groupware
  - *All project meetings avail by telecon or in person*
- multimission applications
- Make/buy based on cost

"Flat" Organizational structure
- Concurrent development team from start
- Clear accountability for WBS elements
- Less hierarchy-->team members comfortable suggesting improvements to peers and for Project as a whole

Within-cost, history of meeting all deliverables from start
- *Earned value, up-to-date accounting*; product-based WBS
- Responsive to redirection as environment changes: ATI, NMP Coordination, Life Cycle cost

Should stick to plan from here forward

Difficult objectives-->Conservative estimates-->often exceed performance

Minimum documentation
- *All documentation on-line, maintained by WBS-element Cog*
- No >1 page Requirements Docs; proceed direct to draft interface specs and equipment descriptions/designs
- *Document new design by As-built next-earlier generation plus deltas*

Team Life Cycle Cognizance
- *Now until data returned (attitude: new people "carry the mantle" of predecessors on infrequent attrition)*
- Cognizant individuals responsible for their element's reliability
- Cognizance by individual, not line organization

Build early to work out interfaces, find flaws
- *Design to Test* and Operations
- Rapid prototyping of hardware and software
- Sim-->prototype-->flight units in testbed

Software & workstation flow development-->testbed-->ATLO-->Operations
Common high order language, RISC processor
Quantitative technology advancement goals placed on designers
facilitates alliance between industrial technology developers and
JPL equipment and operations designers

Science Teams
Minimal Pluto science team during cruise
Compete added encounter team slots E-2 yrs for final encounter plan

No-Nonsense contracting
Set difficult specs where they count: cost, mass, power
Not over-specified where unimportant
Hardware & software; not designs & studies
Select best bid from qualified source, not last mission incumbent
Limit cost with conviction; No ATI overruns so far
Firm fixed price development contracts and cost-capped contracts
Minimum RFP addenda
No contract mods without Preproject mgr. permission; none so far
Streamlined university contracting; latest @ 2 pg + cov letter
Use contractor product assurance to meet lifetime spec.
Use contractor reporting format
Frequent informal cost & schedule status discussions between JPL & contractor Cogs
Communicate importance of cost performance to CEOs
Solicit ideas on commercial applications, competitiveness, educational benefits, and ways JPL & NASA can help amplify.
Compete next prototype w/ option for flight; keep ATI/NMP incumbent if best.
Active promotion of small business, SDB, and HBCU/MI involvement.

Simple contract cost/schedule monitoring & management tools
frequent informal reporting
JPL contract technical monitors & negotiators work closely

Wide contracting and geographic involvement [see Pluto Participants Map]
We have gone for best, rather than chosen location; *we will continue to select the best.*

Lower burden (went from 2.1 to 1.8 x salary FY95 > FY96), or recycle burden to augment development where available
Among first users of JPL flight system testbed, project design center, PCAT, PTM

Young, mixed team.
Mix of JPL workforce
Creative and innovative
Balanced with senior experience *(more to be recruited)*

Clearly defined, highest priority science objectives; nothing else drives design.

TQM-driven empowerment and awareness
Focus on customer needs
Primary accountable team members, cognizant engineers, accountable as

individuals.
Cheaper, faster and better as everyday design metrics.
Senior JPL management listening and helping

Draft Generic Instructions to Project or Task Managers

INSTRUCTIONS FOR LEADING THIS PROJECT

1. You are responsible for successful execution of the mission on time and within budget. [1]

2. You may not go back to the well.

3. You must be ready to launch on yy/mm/dd. Successful integration with the launch vehicle is your responsibility.

4. You may recruit and dismiss personnel to and from your project at will. (This amounts to authorizing use of one of your charge numbers.)

5. You must provide technical, financial, and schedule visibility into your project at any time, but only to (N) designated individuals. You may use tools and service organizations at your discretion to assist with this.

6. You must maintain explicit schedule and budget margins. You may use up to (X%) of any margin without prior management approval.

7. You may alter the performance of your system in order to meet schedule and budget constraints. Your performance will be evaluated in part based on how much performance your system delivers. If the customer is dissatisfied with the performance of your system, you may be reassigned or dismissed.

8. You are responsible for operating within the laws and regulations applicable to JPL and its employees. The Lab will make available to you, for use at your discretion, skilled personnel to assist with procurement, safety, product assurance, media relations, launch approval....

9. System performance requirements will be given to you on one page, and will not be altered after yy/mm/dd without an opportunity to revisit schedule and budget commitments.

10. The Laboratory will stand behind the implementation plan agreed to between you and your ALD, and will not re-assign the personnel or facilities needed by your project until the release dates in your approved implementation plan.

---

[1] Among the three variables, schedule, performance, and cost, two may be fixed. These instructions are based on fixing cost and schedule, based largely on you reports of what Headquarters managers are calling for. Other activities, such as technology development, may call for a performance objective on a go-as-you-pay basis, leaving schedule as the dependent variable.

11. **Upon the successful completion of various phases of your project, you will be provided with promotion and associated raises as agreed in a memorandum of agreement between you and your ALD.**

2nd IAA International Conference on Low Cost Planetary Missions
April 16-19, 1996

COST ESTIMATION AND MODELING FOR SPACE MISSIONS AT APL/JHU

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ABSTRACT

Cost estimation of space science missions at APL over the past two decades has been singularly successful in arriving at program costs that are within a few percent of the actual costs at program completion. The most recent example is the Near Earth Asteroid Rendezvous (NEAR) mission which was estimated at approximately 112 million FY–92 dollars and came in at approximately three percent under the estimated cost. This demonstrated performance has been achieved without the benefit of a formal cost model, such as those used in government and industry (GSFC, MSFC, SAIC, etc.). In light of this performance, it is important to understand the parameters that are used in the cost estimating process in an effort to quantify those elements in a program that are most important to the final cost. We have identified a number of areas which contribute to eventual cost performance; these include: (a) spacecraft and mission complexity; (b) use of already–developed (facility–class) instruments versus "to be developed" new instruments; (c) synergism among programs being implemented concurrently; (d) program implementation length; (e) design–to–cost practice for all major subsystems and instruments without contingency; (f) lead engineer responsibility throughout design, layout, fabrication, test, integration, and initial flight operations; (g) designed–in quality and testability to minimize rework; (h) incorporation of reliability and quality assurance engineering within the program structure; (i) minimization of documentation and encouragement of oral and electronic communication as required. We have found that gross parametrization of costs such as the traditional weight, power, and length of the program commonly included in typical models do not reliably predict actual costs. A methodology will be presented, whereby, the elements identified above plus others are used to describe the process implemented by APL in previous missions to generate cost estimates and to control costs. Actual data over several missions during the past two decades will also be presented that illustrate APL's cost performance while utilizing this methodology.

INTRODUCTION

In today's funding-constrained environment, governments are searching for solutions that permit the current robust national and international space programs to continue while their science and technology budgets decline. To reduce the cost of space science missions, and thus to allow more missions to be conducted for the same dollars, they are demanding that space hardware and software be produced faster, cheaper and with equal or better capabilities. All of these goals are to be accomplished through technology insertion with acceptable risk (read this as low risk!) and through improved design, fabrication, testing and other procedures that are more efficient. NASA's Discovery Program was established in 1992 to implement this faster, cheaper and better process for future planetary space missions. The Near Earth Asteroid Rendezvous (NEAR) Project being conducted by the JHU/APL is the first of the NASA Discovery Program missions. With the spacecraft successfully launched on a Delta II rocket on 17 February 1996, it began its journey to a rendezvous with the asteroid Eros. To date, the NEAR Project has exceeded all Discovery Program cost, schedule and performance goals.

The extreme pressure placed on meeting cost goals for space science missions has resulted in a search by private and public organizations to find ways of reducing the costs of space systems, of predicting these costs and of actually achieving the originally estimated costs at the end of the project. A few papers are beginning to appear in the literature that attempt to address cost reduction via small satellite development and technology insertion and that discuss the associated relationships needed for cost-estimating. Very little attention has been given in the literature, however, to cost control. Cost control is perhaps the most important element in this regard since, in the end, it is the magnitude of the cost and its comparison to the initial estimate that ultimately matters in today's environment. In an attempt to arrive at simple cost-estimating relationships for small satellites, previous efforts have focused on relating a few technical parameters such as schedule, dry bus mass, pointing accuracy, data storage, average power and others to development costs. While these simple relationships are instructive and certainly have some value, we believe that they are not very good estimators of cost for the general case. Each project is unique and, therefore, has its own cost drivers that differ from cost drivers for other projects. With a very large number of possible cost elements and with each project having its own unique constraints, simple relationships between costs and a few technical parameters have not proven to be very useful in predicting costs of space science missions conducted at APL. Consequently, no formal cost estimating formulas are currently used at APL.

This paper will present cost estimation of space science missions at APL. We will discuss the system elements involved in establishing and controlling the costs of our space systems, we will identify many of the important cost drivers and we will discuss cost control techniques. A methodology will be presented, whereby, the elements identified above plus others are used to describe the process implemented by APL to generate cost estimates and to control costs for previous missions. Actual data over several missions during the past two decades will also be presented that illustrate APL's cost performance while utilizing this methodology.

SYSTEM ELEMENTS AND COST CENTERS

In discussing cost estimates and cost control for space science missions, it is important to capture all of the major cost centers and all of the major external factors that either influence cost or affect cost control. Our view of this system of cost centers and external factors is shown in Figure 1. Besides capturing the traditional spacecraft bus and payload systems, our system view includes Government Furnished Equipment (GFE), the APL management system element and the customer driven external environment system elements. These three entities, the Project, consisting of the spacecraft bus, payload systems, and the GFE interface, the APL organizational unit and the customer interact from a cost perspective. They are principally responsible for the magnitude of the initial cost estimate and the subsequent actual cost at Project completion. Each of these will be discussed separately below.

Project

The work breakdown structure (WBS) and cost centers shown below are the ones typically used at APL, and are similar to those used by other space systems development organizations (also see Reference 5, Figure 9). They are also many years ago, APL has developed a way of doing business that minimizes the organization's impact in these areas. In this regard, some of the important attributes of our culture that minimize cost impacts are:

1. Foster quick program execution with short overall development schedules (< 36 months).

2. Enforce design-to-cost practice for all major subsystems and instruments without cost contingency.

3. Empower lead engineers with responsibility throughout design, layout, fabrication, test, integration, and initial flight operations (proposal to post-launch.)

4. Practice designing - in quality and testability to minimize rework and the associated cost and schedule impacts.

5. Incorporate a reliability and quality assurance engineer within the Project structure as a team player rather than an outside adversary.

6. Minimize written documentation required by the APL organization and encourage oral and electronic forms of communications.

7. Empower Project Manager with complete responsibility and authority to execute all aspects of the project.

8. Recognize the synergism among programs being implemented concurrently and the consequent cost-savings potential for customers.

9. Minimize Project reporting requirements to upper management and oversight requirements by upper management.

10. Attempt to establish a single customer interface with minimum customer imposed documentation, oversight and other extra cost-generating requirements.

11. Reduce Project Management overhead - a typical project office structure would include a project manager, a system engineer, and a part-time secretary.

12. Provide a stable work environment to reduce annual staff turnover and permit giving a large portion of a job to a single person.

Customer

This system element is not a cost center per se either. However, the customer can significantly affect cost estimation and control at his own organization and at the contractor's organization through the customer's policies, procedures and practices. Listed below are some of the important attributes of some of our customers that have helped to minimize cost impacts in the past.

1. Establishment of clear and achievable Project cost, schedule and performance requirements and goals.

2. Ability to stay focused on achieving the project goals and remain committed to them in the face of a changing environment.

3. Management of APL by the sponsor with a single person interface and practice a hands-on-lightly management approach to minimize imposed documentation, oversight and other extra cost-generating requirements.

4. Creation of a problem-solving, trust-me atmosphere with APL to promote open communications and to create an environment where the customer helps in arriving at solutions.

METHODOLOGY

Our performance record during the past two decades will be presented later after discussing here the formal methodology utilized to manage it. At APL, our principal focus is to manage the end product of a project which involves delivering a specific technical product, for a specific cost and within a specific schedule, rather than solely managing cost for cost sake. This focus begins early in the project life cycle during which an initial cost estimate is generated that meets project cost, schedule and technical goals. The same focus continues throughout the life of the project until the technical products are delivered, within

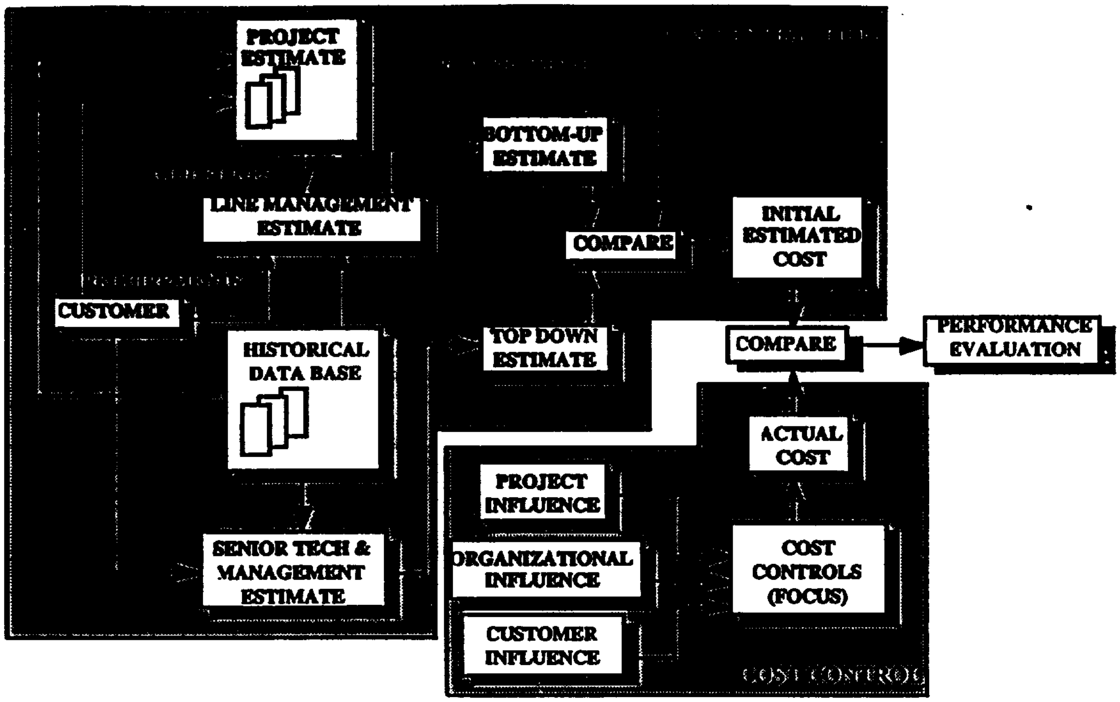


Figure 2 Cost Estimation Methodology

the cost and schedule goals. The difference in the initial cost estimate and the actual incurred cost is then one figure of merit used for evaluating project performance. We will present next, our formal methodology for generating our initial cost estimate followed by a discussion of the methodology utilized to control those costs during project execution. This methodology, shown in Figure 2, will be presented in the context of the system elements discussed above and involves assessing the impact that the project, the APL organizational unit and the customer have on both cost estimation and cost control.

<u>Cost Estimation</u>

Cost estimation of space science missions at APL is a process that makes minimum use of cost-estimating relationships generated by statistical regressions of industry-wide or even company-wide actual space systems cost data. The process involves interactions among the project, the APL organizational unit and the customer, draws on our historical data base and utilizes the experience of our technical staff acquired over decades of functioning in a stable work environment. The process consists of executing the following five steps; (a) Identify Customer Requirements; (b) Generate Project Rough-Order-of-Magnitude (ROM) Cost Estimate; (c) Generate Bottom-Up Cost Estimate; (d) Generate Top-Down Cost Estimate and (e) Generate Initial APL Cost Estimate. The first four of these focus on a cost risk (and schedule and performance risk) as a design driver. Thus the initial cost estimate is supported by a risk management approach.

1. Identify Customer Requirements

The first step is to establish open and frequent communications with the customer at both the APL Project Office level and at the APL organizational management level. The outputs from this step provide the answers to three key questions that drive the initial magnitude

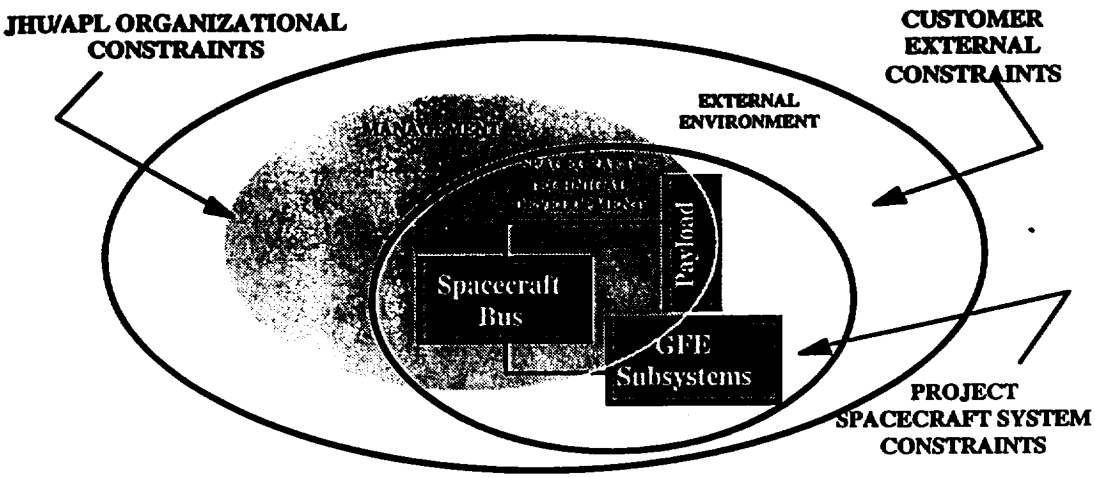


Figure 1 APL Spacecraft Development System View Point

similar to those found in the literature for typical satellite programs[4].

1. Spacecraft Bus Cost Center

(a) Program Management and System Engineering; (b) Mechanical; (c) Telecommunications; (d) Power and Thermal; (e) Attitude; (f) Ground Support Equipment; (g) Integration, Test and Launch; (h) RF System (Antennas & Transmitters); (i) Reliability and Quality Assurance (R&QA); (j) Propulsion.

2. Payload Cost Center

3. GFE Government Furnished Equipment Interface Cost Centers

The Project staff's role in the estimating process for the initial costs is to ensure the lowest possible project cost is developed consistent with the Project's cost, schedule and performance goals. During the execution phase, the Project staff is the front line of defense for APL in controlling the actual cost incurred. The Project Manager implements APL's policies, procedures and cost practices described in the section below during the execution of the Project. Additionally, the Project practices the following guidelines to minimize impacts to cost:

1. Focus the team's effort on delivering the end product of the Project which involves delivering a specific technical product, for a specific cost and within a specific schedule.
2. Design for simplicity. We have found that perhaps the biggest single factor that drives space systems cost and our ability to control cost is spacecraft and mission complexity.
3. Where possible, we use already-developed instruments (facility-class) and components versus "to-be-developed" new systems.
4. Immediate placement and tight technical monitoring of subcontracts and use of incentive-based controls.
5. Tight technical monitoring of GFE. A separate interface engineer is assigned to each GFE component for the purpose of ensuring that the GFE is delivered on time and that it's fit, form and function are consistent with the spacecraft bus development.

<u>APL Organizational Unit</u>

This system element is not a cost center per se, but through an organization's business policies, procedures and cost accounting practices, it could significantly affect cost estimation and control. Having recognized this point of our cost estimate and ultimately our ability to control the actual project costs. These questions (cost drivers) are: (a) What is the customer really trying to accomplish as reflected in the stated project technical, cost and schedule parameters? It is important to establish, particularly at this early stage in the project life cycle, which customer desires are hard and fixed requirements and which customer desires can be treated as goals. (b) How does the customer intend to manage APL during the execution of the project? We always attempt to establish a single customer interface with minimum customer-imposed documentation, oversight and other extra cost-generating requirements. We believe that our organization functions best under these conditions as reflected in our past performance and that this approach results in lower overall cost to the customer. (c) Is the customer's attitude, commitment and/or will strong enough to stay the course in holding the line on project requirements and goals? Although the answer to this question is subjective, the commitment or, more importantly, the lack of commitment of the customer's will, significantly affects our ability to control actual project cost.

2. Generate Project Rough-Order-of-Magnitude (ROM) Cost Estimate

A small technical team led by a Project Manager empowered with complete responsibility and authority to execute all aspects of the project, develops a conceptual solution that satisfies the customer's technical, cost and schedule desires. This is the point where the system engineering practice of designing a system that is good enough rather than attempting to find the perfect or optimal solution is employed. The goal at this stage of the system definition is to develop at least one acceptable conceptual solution and to identify any possible show-stoppers. This solution includes a functional block diagram, a ROM cost estimate, a ROM schedule and a list of assumptions, key cost and risk drivers and other project level constraints and guidelines. In arriving at this solution, lead engineers use a design-to-cost approach without identifying any contingency.

3. Generate Bottom-Up Cost Estimate

Next, the Project-derived preliminary concept definition as described in step 2 above is presented to skill center line supervisors in APL's matrix organization. The line supervisors, working with their technical staffs, then generate a separate detailed cost estimate for each technical area. In generating their cost estimates, the line supervisors and the technical staff draw heavily upon their past experience and upon our 40 year historical space systems performance data base as they analyze the preliminary concept. The most recent history carries the most weight. Comparisons are made between the current mission requirements and those of previous space missions conducted at APL. Analysis of these differences is a critical component in establishing initial cost estimates and in establishing mission feasibility. Each of these cost estimates is then reviewed separately with the project staff to ensure consistency with the project direction and to ensure the lowest possible cost estimate has been obtained. The Project Manager then sums all cost center estimates to obtain a bottom-up project cost estimate.

4. Generate Top-Down Cost Estimate

In a manner similar to the bottom-up cost estimation process described above, an independent estimate is generated by a few senior technical staff members and a few senior managers. Using the project concept definition along with the project level constraints and guidelines and using the relevant aspects of our historical data base, they generate a separate cost estimate. This estimate is called a top-down cost estimate. It is generated by the top level managers and technical staff having analyzed the proposed space

TABLE 1 RECENT JHU/APL SPACECRAFT BUS COST HISTORY

PROGRAM	SPONSOR	WEIGHT BUS (LBS)	LAUNCH DATE	PROGRAM DURATION (MONTHS)	RELATIVE COST*	COST GROWTH** %
MAGSAT	NASA	349	1979	24	1.3	8
AMPTE	NASA	343	1984	36	1.3	0
GEOSAT-A	NAVY	1198	1985	37	1.6	7
POLAR BEAR	USAF	208	1986	24	0.9	-5
DELTA 180	SDIO	713	1986	12	1.0	-3
DELTA 181	SDIO	2384	1988	17	5.6	-1
DELTA 183	SDIO	558	1989	13	1.1	8
NEAR	NASA/HQ	946	1996	26	3.8	-3

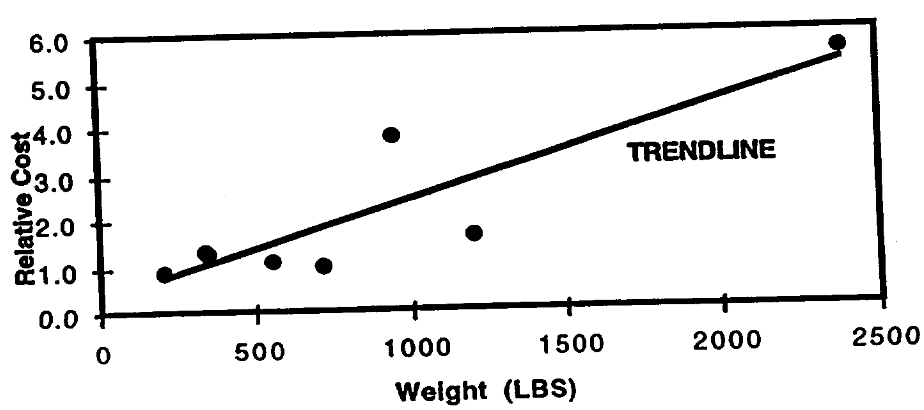
* Cost in constant year dollars relative to cost of Delta 180 (as 1.0) at project completion (Launch +30 days)

** Percent cost growth from initial cost estimate at start of Phase C/D

Table 2
Spacecraft Bus Cost by WBS Element (% of Total Bus Cost)

WBS COST CENTER	AMPTE	GEOSAT	POLAR BEAR	NEAR
Program Management & System Eng.	12	12	13	4
Mechanical	11	9	11	6
Telecommunications/RF	13	14	19	25
Power & Thermal	13	15	13	8
Attitude & Propulsion	13	13	12	30
Doppler Beacon		4		
Ground Support Equipment	7	9	3	11
Integration & Test	17	14	20	4
Reliability & Quality Assurance	14	10	9	12

Figure 3 Spacecraft Relative Cost vs. Weight



months, and relative costs varying from one to about six.

Table 2 shows the cost breakdown for four previous APL missions (AMPTE, GEOSAT, POLAR BEAR and NEAR) according to the WBS mentioned earlier. The data are presented as a percentage of the total spacecraft bus cost. While instructive, it is clear from examination of this data that additional information is required to interpret the obvious variances. For example, NEAR is the only deep space mission listed in Table 2. Consequently, the NEAR propulsion, attitude, telecommunication and RF mission requirements were unique among this set of APL missions and represent significant cost drivers relative to our previous experience. This situation is an example of how mission unique requirements or complexities can dominate total mission costs and can render useless cost estimates derived from overly simple cost estimating formulas.

Shown in Figure 3, is a graph of spacecraft bus relative cost versus weight. Again, while instructive, there can be significant variances from the indicated trendline for a specific mission. It is clear, however, that there is a definite dependence of spacecraft bus cost on the bus weight.

COST PERFORMANCE RESULTS

Included in Table 1 is the cost growth of various Projects experienced during spacecraft development through launch plus 30 days. Cost growth is defined as the difference between the initial cost estimate as determined by the methodology described above and the actual incurred cost following launch plus 30 days. This cost growth is used as a parameter to characterize our cost performance on each Project. As can be seen , within the experience base listed in Table 1 and by applying the methodology described in this paper, APL has a very good demonstrated performance record. We are as likely to return money to the customer as we are to ask for additional money. The range of cost growth is between -5% and + 8%.

GENERAL COMMENTS AND CONCLUSIONS

In developing space science mission hardware and software in today's environment of limited funding, the most important element to focus on is the final cost at project completion, defined here as the time period ending at launch plus 30 days. Initial cost estimates matter only if costs can be controlled during project execution allowing favorable actual costs to be realized at project completion. We have tried to highlight the key features associated with APL's spacecraft development history extending over 40 years. These feature are: (1) recognizing that the customer and the performing contractor's organizational unit, as well as the project goals effect initial cost estimates and the ability to control cost, (2) having a process in place that supports the generation of accurate initial project cost estimates and finally, (3) being able to control cost during project execution leading to minimal overall project cost growth. Key parameters to note are simple hardware and software systems designs, favorable business policies, procedures and practices at both the executing contractor and the customer and a focus and dedication by the project staff, the executing contractor and the customer to delivering specified technical products or schedule and within cost in the face of a changing environment. Specific details on these topics have been presented reflecting APL's extremely good performance in the past 20 years of conducting space science missions for several government agencies.

REFERENCES

[1] *The Marshall Space Flight Center's NASA cost model (NASCOM) data base,* Vol. 1, Executive Summary, Ver. 2.1, Applied Research, Inc. Dec. 1993.

mission at a gross level concentrating on analysis of the similarities and differences with previous missions conducted at APL. It can occasionally result in management decisions to make major changes in the concept or approach and require a revised step three. This approach could be characterized as looking at the forest rather than looking at the trees.

5. Generate Initial APL Cost Estimate

The final step in APL's cost estimating methodology is accomplished in a short meeting between the Project staff, the skill center supervisors and a few of the senior technical staff members and managers. The purpose of this meeting is to determine APL's official cost estimate by reconciling differences among the Project generated ROM cost estimate, the bottom-up cost estimate and the top-down cost estimate. This estimate may be adjusted by management, depending on the requirements of the customer. The estimate obtained from this process is called our initial Project cost estimate.

Cost Control

As the customer, the APL organizational unit and the Project staff execute the program, they each have a role to play in controlling costs. Having set the project technical, cost and schedule goals, they must never lose focus on achieving them in light of the constantly changing internal and external environments. Open and frequent communications with the customer are essential to controlling costs. The customer must keep the funds flowing into the project and resist the temptation to involve other organizations that would provide unnecessary and unproductive oversight.

For APL's management part, we empower a Project Manager to deliver the desired products on time, within budget and to satisfy all technical requirements. The Project Manager is completely responsible for all deliverables and is given the corresponding authority to exercise this responsibility. This situation allows for quick and low cost solutions to problems by solving them on-the-floor. Additionally, a reliability and quality assurance engineer is integrated directly into the Project as a team player. The engineer is empowered to find ways to "get it done" as reliably and as economically as possible rather than operate in an adversarial and usually more costly role.

Projects usually function as small teams, holding weekly team meetings, often in the presence of the customer. Management of technical subcontracts and Government Furnished Equipment (GFE) require special attention in order to manage costs. They are tightly monitored by a single APL technical person and interfaces are designed to be as simple as possible to minimize problems during integration. This approach reduces the risk of cost overruns and helps assure that projected costs can be achieved.

APL HISTORICAL DATA BASE

In APL's forty year history of developing space mission system hardware and software, we have delivered 55 spacecraft and over 100 instruments with a reliability record exceeding 95%. Our most recent history is summarized in Table 1 which lists spacecraft data for the last twenty years. This time period was chosen as being the most relevant to today's missions. The data are parameterized according to a few key cost drivers. These are program sponsor, project duration through launch plus 30 days, spacecraft weight, and spacecraft relative cost at completion in constant year dollars. Spacecraft currently under development at APL will be added to this table after they have been launched. As the data indicate, our recent experience extends over several government customers (NASA, USN, SDIO/BMDO, USAF), with spacecraft weights varying from about 200 pounds to about 2,500 pounds, development schedules through launch plus 30 days of 12 months to 36

[2] Burgess, E. L., N. Y. Lao, D. A. Bearden, *Small-satellite cost-estimating relationships,* 9th Annual AIAA/Utah State University Conference on Small Satellites, Sept. 18-21, 1995.

[3] Pisacane, V. L., R. C. Moore, *Fundamentals of space systems,* Oxford, 1994.

[4] Wertz, J. R., W. J. Larson, *Space mission analysis and design,* Kluwer Academic Publishers, 1991.

[5] Peter, J. J., *Use of engineering development life cycle model for determining weighted progress,* In Control, Vol. 3, No. 2, Performance Management Association, March, 1991.

[6] Augustine, N. R. *Augustine's laws,* Penguin, Revised Ed., 1986.

JDAM - The Value of Acquisition Streamlining

PURPOSE:

The purpose of this paper is to briefly describe some of the successful JDAM acquisition reform approaches applied over the past 18 months. Specifically, this paper presents some of the contributors to getting the price from $40,000 dollars per round at the 40,000 unit, to McDonnell's price of $18,000 per round at the very first unit.

BACKGROUND:

The JDAM program has evolved substantially since the Milestone I DAB. The primary reasons have been the designation of the JDAM as a Defense Acquisition Pilot Program in the 1994 Federal Acquisition Streamlining Act (FASA) and the extraordinary support from the Undersecretary of Defense for Acquisition. This support has more than any other factor, allowed us to break down traditional barriers by asking "why does it have to be this way—why can't we accomplish the task using commercial approaches?" Our focus is to reduce acquisition management costs—costs related specifically to the way the Government does business rather than to the nature of the product the Government is buying.

PROGRAM DESCRIPTION:

- Joint Air Force/Navy program to develop a very affordable, adverse weather, and accurate guidance kit for 1000 and 2000 pound bombs currently in inventory
- INS/GPS guidance kit attaches to the bomb and uses controlled tail fin movements to direct bomb to the target
- JDAM is planned for integration on B-1, B-2, B-52, F-15, F-16, F/A-18, F-22 and AV-8
- Designated as DoD Pilot Program by Federal Acquisition Streamlining Act (FASA) of 1994

PROGRAM STATUS:

- Two 18 month EMD-1 contracts awarded to Lockheed Martin and McDonnell Douglas in Apr 94
- EMD-1 emphasis on lowering average unit cost and manufacturing risk
- Downselected to one contractor (McDonnell Douglas) occurred on 11 Oct 95
- EMD-2 will complete development and emphasis development and operational testing
- EMD-2 is scheduled for 40 months; Lot 1 Production begins delivery in FY98
- Contract types
- Cost plus fixed fee for EMD-1
- Cost plus award fee for EMD-2
- Firm fixed price for initial production

HOW HAS JDAM STREAMLINED ITS ACQUISITION PROCESS?

The number one reason JDAM has been able to successfully implement acquisition streamlining is ATTITUDE!

- JDAM asks "why can't we do it another way" a "cheaper/faster way?" instead of complying with "the way its always done" EVERY RESULT IS A SYMPTOM OF THIS ATTITUDE
- JDAM compares itself with an analogy of an individual building a house, how would that individual react?
- Most of the initiatives implemented by JDAM were in the realm of common sense, i.e., things that could always be done before but the environment and culture were not right to allow execution of the ideas
- The number one objective of JDAM's first development phase was acquisition reform
- The contractor is responsible for his design
- The number one objective of JDAM's second development phase is to help MDA beat schedule
- The number one objective of JDAM's production is to help the contractor maximize his profit, GIVEN
- MDA delivers JDAM at the price he has projected to the Government

Contracts

Selecting the "Right" Contractor

- Selection of smart contractors with known commercial buying experience
- Developed a "Rolling Downselect" process
- Provided feedback along the way - helped the contractor work his weak areas
- Used common sense - A parent wants his student to receive continuous feedback to ensure student does his/her best
- Helped ensure the Government would have a "tough" final decision between two viable contractors
- Reduced timeline to final downselect
- Reduced chance of protest - contractors knew where they stood

Statutory - Regulatory Relief

- Statutory - the most significant relief provided by FASA was allowance to use commercial practices
- From a regulatory standpoint, JDAM requested waivers for 25 FARs and 13 DFARS; OSD granted waiver approval for 15 FARs and 11 DFARs
- No mandated use of military specs or standards, although the contractors elected to use a few mil specs where no commercial equivalents were available interface with the Warfighter

Oversight

- Streamlined oversight of both the program and the contractors including little audit and DCMC involvement with the contractors
- Minimal—Contractor responsible for his design—Government works the interfaces

Warranty

- Use of a commercial type warranty which guarantees the contractor will repair or replace any defective item; any warranty costs are included in the price

Dispute Resolution

- Avoid the costs and timeline normally associated with resolving Government/Contractor conflicts
- Allowance for Alternate Dispute Resolution instead of the normal legal means of solving disputes (EMD 2 and later)
- Impanel independent 3 person team (1 nominated by KR, 1 by Government, 1 selected by other two)

Management Process

Personnel

- Critical use of Integrated Program Teams (IPTs) including the actual inclusion of government people as part of the contractor's team at their facilities
- JOB 1 for each Government IPT during 1st phase of JDAM EMD was to help his contractor WIN
- Decreased overhead accounts—use multi-faceted direct charge talent both in Government and MDA

Manufacturing

- Heavy use of Manufacturing Development Initiative, meaning concentration of the actual manufacture of hardware very early in the development cycle and the allowance of tradeoffs within the design cycle for manufacturing and cost
- Emphasis on a long term relationship with the primes and their subcontractors
- Management at a higher level—the systems specification only, no sub-tier specs
- Contractor formats for critical design reviews and PRRs—held during 1st 18 months

Data/Config

- Significantly reduced data requirements—support system safety and flight clearance organizations mainly
- Use of earned value reporting from the contractors in their own format
- At the beginning of EMD-2, configuration control is being given to the contractor for all Class II changes

TECHNICAL Interface with the Warfighter

- TRADITIONAL: An unfortunate aspect of military acquisition is "requirements creep." When the dollars aren't yours, human nature is to want more. The Air Force recognized this trend several years ago and instituted a "4-Star Summit" process 4-Star Summit helped control this costly aspect, but extremely painful and demands huge resources.
- JDAM: JDAM wanted to capture the benefits of the 4-Star Summit process and eliminate the burden
- JDAM instituted an "0-6 Requirements Review Council" consisting of 0-6s from ACC, N88, PMA-201, and the JDAM program office
- JDAM contractors told to bring any requirements/$ trades or questions for clarification to council
- RESULTS: Both JDAM contractors took advantage of this forum—reducing unit costs of their design

- EXAMPLES:
- McDonnell asked for reduction of low altitude captive carriage time in "worst case ops scenario"
- Warfighters approved and plastic encapsulated parts became baseline—Saved $535 per
- Lockheed Martin presented a trade offering $250 per round savings for trades using DSU-33 fuze

Aircraft Interface

- TRADITIONAL: Smart Weapons create their own interface with their aircraft using MIL-STD-1760
- Hire a weapon contractor to create their own implementation with each aircraft
- Time consuming, and expensive - new learning curve each time
- JDAM: Hired some aircraft interface support during JDAM original source selection to create strawman
- Capitalized on TSSAM and JSOW existing interfaces with those aircraft in common with JDAM
- Supported commonality working group with JSOW and WCMD programs
- Reduced costs to prepare and execute aircraft interface
- Test Warranty motivates contractor to move reliability growth to the left providing a production representative weapon earlier in program
- Characterization of weapon and any problems earlier in the program
- True combined DT/OT
- Worked with AFOTEC and COMOPTEVFOR to achieve extremely close working relationship
- OT will help plan DT missions—DT data will feed and help reduce OT sorties—less cost
- "Networking" with related programs (e.g. Joint Programmable Fuze) to piggyback testing
- Results in reduced costs for JDAM and the other programs
- Learn from past programs—conduct more operationally representative missions early
- Get away from rote traditional DT test cards early—wring the weapon out in warfighter environment
- Use warfighter to provide "rapid prototyping" feedback while developer has chance to fix
- Helps warfighter develop tactics and helps developer streamline training
- Base testing requirements on whole program, not piece parts
- AF using Navy FA-18 results to reduce (not eliminate) required sorties on AF aircraft
- Tests feeds composite, integrated test matrix
- Warfighter requirements in JORD—DT testing normally oriented to specification

Motivation

- Milestone billings will also be allowed to improve the cash flow of the contractor in later phases of the program
- Innovative use of "price based negotiation": allows the use of price rather than cost as a basis for negotiation; also allows the use of rewards and punishment for a contractor's commitment for first five lots of production price
- "Carrots and Sticks"
- Carrots (Contractor price meets or is better than their commitments to the Government)
- Contractor submit a price—no need for cost data as long as contractor meets price commitments
- Contractor has configuration control—as long as changed does not affect system specification
- No in-plant, in-process oversight of prime or his subs
- Government will help prime reduce his costs—not his price
- Contractor will receive an incentive fee if his units' reliability is met or bettered
- Long term commitment—Government will not recompete if contractor meets his commitments
- Sticks (Contractor price is greater than the commitments made to the Government)
- Contractor must deliver certified cost and pricing data
- Configuration control reverts to the Government
- Contractor must develop a qualified 2nd source at no cost to the Government
- Government may place in-plant, in-process oversight
- Incentive fee goes away

"Measures of Effectiveness"

MEASURE	RFP (19 AUG 93)	EMD AWARD	PILOT (JUL 94)	EMD II (OCT 95)
MIL STDS/SPECS	87	80	0	0
SOW PAGES	137	100	10	SOO-2
CDRLS	243	250	85	29
PERF SPEC	YES	YES	YES	YES
WARRANTY	5 YRS	5 YRS	20 YRS	20 YRS
AUPR ($93)	68K	48K	40K	<20K
SPO SIZE	70	70	70	63(96/1)-40 (96/4)
DEVELOPMENT$	$380M			$310M
DEVELOPMENT TIME	46 MOS			30 MOS
PRODUCTION TIME	15 YRS			11 YRS
PRODUCTION SAVINGS	0	0	0	$1.5B
DEVELOPMENT PRODUCTION PROPOSAL	NO LIMIT			15 PAGES
DOWNSELECT DURATION	3 MOS			6 WEEKS

- JDAM combined DT/OT considers JORD early and up front
- Eliminate oversight and checking the checkers
- Contractor is responsible for his design—Government fly's the aircraft, but
- Contractor is customer for results
- Emphasize "margin " testing up front
- Find out where design breaks, not just that design performs to spec
- Significant testing to break design and characterize performance early in program
- Treat DT/OT and OSD as partners
- Developed partnership with all TEMP organizations
- TEMP is continually updated for program changes—not signed and ignored until next milestone
- **SUMMARY:** The first phase of the JDAM development program met with many successes and some failures—some ideas did not pan out. However, the concepts that did work fostered an environment for the contractors to reduce costs. We've seen for the first time contractors who never before would bid a Government contract submit bids. We've seen significant prime/subcontractor teaming relationships in a "selfless manner" where a member may propose a change which decreases his profit, but reduces system cost and price.

We are not able to quantify a cost savings with each of the initiatives and new ways of doing business that JDAM pursued. In the aggregate though, the change in attitude, the change in paradigm, has allowed the JDAM team to reduce unit cost by approximately 60% below the JORD requirement. There also have been attendant savings in development which allowed the JDAM program to free FY97 and 98 funding to accelerate the JDAM program and provide funding for earlier capability on the B-1 and B-52 bomber aircraft.

In summary, JDAM is experiencing lower development costs/faster schedules, lower production costs/faster schedules, and lower unit costs.

There remain some barriers to acquisition reform—some of which are outlined below.

Barriers to Acquisition Reform

- Chief among these barriers are:
- Continued functional (engineers, procurement specialists, etc) resistance to change
- Risk adversity, mistrust by both the government and contractors to wide scale changes
- Substitution of templates for innovation; people want a checklist on how to do a task—quick/easy
- Some people don't recognize the need to change attitudes—to tailor new ideas to their own program "personalities"
- Too much consensus decision making and conservatism, especially on the part of the government
- Increased inspection/audit for Pilot Programs since it is "new"
- Strong senior DoD leadership, but continued mistrust by staffs