NASA SP-6101

ISSUES IN NASA PROGRAM AND PROJECT MANAGEMENT

edited by

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NASA

Scientific and Technical Information Division 1988
National Aeronautics and Space Administration
Washington, DC

FOREWORD

This collection of papers and resources on aerospace management is an outgrowth of recommendations issued in 1986 by the NASA Management Study Group, better known as the Phillips Committee. A key recommendation emphasized the need for formal training and development of program and project managers within NASA. A Program/Project Management Steering Group, established in 1984, set out to develop a management experience library to support those formal training and development programs, seeking lessons learned, policy, tools and development information. The result is Issues in NASA Program and Project Management.

The statements and opinions of the authors are their own, and do not represent official policy of NASA or of the U. S. Government. In fact, some viewpoints in this document will challenge those of other authors, encouraging a diversity of ideas and approaches for NASA managers, future managers and NASA alumni.

A few words about our authors and their offerings:

Deputy Administrator Dale D. Myers leads off this publication with a brief discussion of the Program Approval Document which served NASA so well in earlier years. He was NASA's Associate Administrator for Manned Space Flight from 1970 to 1974 and has since had a distinguished career in government and industry. James B. Odom shares the guiding management principles which he developed as Director of the Science and Engineering Directorate at Marshall Space Flight Center and NASA's Associate Administrator for Space Station. Aaron Cohen, Director since 1986 of the Lyndon B. Johnson Space Center in Houston, Texas, sets the stage with an overview of project management and the evolution of the matrix concept within the Johnson Space Center culture. He came to Johnson Space Center in 1962 and is recognized as one of NASA's premier program/project managers. Angelo Guastaferro, vice president of Lockheed Missiles and Space Co., Inc., and director of space station programs at the California corporation, had served 16 years for NASA at the Langley Research Center. After promotion as deputy manager of the Viking Project, he served as director of the planetary division of NASA's Office of Space Science and then as deputy director of the Ames Research Center for four years, until 1985. C. Thomas Newman, Assistant Deputy Administrator for NASA, presents a paper on controlling resources in the Apollo Program, in which he served as chief of resources control. He served also as deputy comptroller since 1977 and Comptroller since 1981. The late Homer Newell, former chief scientist for NASA, reflects upon the center/headquarters headaches, based upon his own experiences with the Goddard Space Flight Center in the early 1960's. He is author of Beyond The Atmosphere (1981) from which this article is excerpted. Jack Lee is deputy director of the Marshall Space Flight Center in Huntsville, Alabama. He writes about the evolution of the technical management organization at MSFC, zeroing in on the multinational Spacelab Program. Manny Peralta provides a broad overview of training and development initiatives for NASA program and project management workforce. He serves as Associate Administrator for Management in NASA's Office of Management after 30 years of industry experience in business, engineering and project management. William M. Lawbaugh, an associate professor of communications, also served as assistant editor of Issues in NASA Program and Project Management. Inquiries should be directed to Frank T. Hoban, program manager, Code ND, NASA Headquarters, Washington, DC 20546.

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The PAD is Back

by Dale Myers

Deputy Administrator of NASA

NASA has, since its inception, welcomed the opportunity to carry out programs and projects. Some of these have been technologically and managerially challenging, and NASA has evolved management processes to assist in the documentation and tracking of major program milestones and resources utilization. As part of these processes, the Program Approval Document (PAD) was introduced during the 1960s to record the authorization of newly approved agency projects. The document, prepared at a summary level, outlined the technical plan, number of launches, project costs and key milestones for management review. The PAD was intended to be a contract between the Program Associate Administrator and the NASA Administrator on the content, schedule, controls and resources of each project and was usually updated annually to reflect major changes. In the early 1970s, the PAD became an even more powerful document, changing from a budget orientation to a management one. The Administrator began to use the PAD to identify items and milestones he deemed critical to the orderly progression of the program and to make such items Administrator-controlled. In other words, once he and the Program Associate Administrator agreed to the critical items or milestones, they could not be changed without the Administrator's approval.

The use of the PAD as a management document declined in recent years, and the requirement for PADs was canceled in 1985. When I assumed the Deputy Administrator position, I became aware that there was nothing in the system that documented program agreements made between the Administrator and the Program Associate Administrators. I was very concerned that the documentation and control which the PAD had provided the Administrator no longer existed, and I soon began the process to reinstate the PAD.

First, the new PAD had to be a management document. It would indeed be the fundamental contract between the Administrator and Program Associate Administrator, and it would codify those critical items that could not be unilaterally changed.

Second, the PAD would contain significant resource information and program milestones that would become part of our monthly program and project reporting process.

Third, the PAD would be concise. We do not need additional paper in the system.

Finally, we would apply the PAD requirements selectively, not blanket all NASA programs and projects with unnecessary documentation. The PAD would apply only to those projects the Administrator deemed necessary.

During the past year we have piloted the application of the PAD to a number of programs and will shortly have 20 or so signed PADs. In the very near future we will publish a NASA Management Issuance, officially bringing the PAD back. I think this is a very positive step in the management and control of our programs and projects, since it represents the prime objective to be met by the Associate Administrators in their area of program management.

Guiding Principles for the Space Station Program

by James B. Odom
NASA Associate Administrator for Space Station

When I came on board in early April 1988, I set aside time to reflect on the principles that so far have guided my career and would be applicable to my new job. I was very comfortable with the configuration and management organization of the Space Station Freedom program. In the few years of its existence, the space station program had accomplished much, and becoming part of the "next logical step in space" would be personally gratifying. However, managing a program that would spend approximately $20 billion in the next 10 years would be a real challenge for me. I knew that the amount and complexity of hardware and the necessary interfaces were beyond anything I had worked on, including Apollo, Hubble Space Telescope, and the Space Shuttle External Tank programs. I concluded that to pull these thousands of pieces together and make them fly would demand strong leadership at all levels, good communication, and some rather innovative ways to define accountability, responsibility, and authority.

Any leader can get bogged down in detail and micromanage a program to death. What I needed last April were guiding principles, based on lessons I had learned, to apply to the challenges awaiting me. I'd like to very briefly share these principles with you and suggest that, in my experience, better decisions and actions result from such clearly defined principles.

1. Mission success is number one. This almost goes without saying in NASA. It's part and parcel of the NASA culture. For the Space Station Freedom program, however, mission success is not merely a single launch or even the final construction of a laboratory in space. Rather, Space Station Freedom will be multi-purpose, international, and evolutionary. It may be three decades before we can declare total mission success, and what we do today will determine tomorrow's successes. Mission success will be measured by a number of parameters; among these are crew safety, research capability, ease of maintainability, economy of operation and ability to evolve to meet future national goals.

2. Quality is planned in, designed in, and built in. Quality is not inspected in. Quality starts before designs are drawn and well before "metal is bent." The main message here is that each person and organization in the program must understand and believe in the need for quality performance from the onset of the program. You cannot wait until the hardware is built to decide you want quality and then attempt to "inspect" it in. I have often seen this tried but never successfully or economically.

The Technical Management and Information Systems (TMIS) will be a significant asset for collecting and disseminating information on our quality efforts. Quality encompasses more than just the delivered hardware. It includes management, requirements, design, development, testing, and documentation. Simply stated, the quality of every person's output is very important to the outcome of the program.

3. Keep it simple. As engineers we have a tendency to make systems more complicated than necessary. Our challenge is especially to make flight systems simple, thereby increasing reliability, minimizing training and crew on-orbit support, and reducing development cost. When we succeed, we get the added bonus of reducing on-orbit and ground logistics support costs. The most expensive component in orbit is the one that is not mandatory for mission success.

4. Minimize organizational and hardware interfaces, and maximize clear hardware and software accountability. An undisputed fact of

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NASA culture is that our strength resides in our field centers. On the surface it may appear that a single management team would be preferable to the three management levels currently in place. However, many of NASA's past successes have had multiple field center involvement. Each participating field center brings much added value to the program by the center management review process and the personnel and facilities which could not be duplicated at any single NASA installation or prime contractor's facility. We have established a clear requirements chain-of-accountability by having the appropriate requirements derived, controlled, and accounted for at the appropriate management level, In doing this we have placed the top level program responsibilities at Headquarters (Level I and II) and taken maximum advantage of the field centers' management and engineering expertise in design, development, manufacturing, and operations. Now, to further ensure that the program is fully integrated at the field centers and prime contractors, we have implemented an associate contractor role among the four major work package contractors. This means that the contractors share much more responsibility in the design and functioning of "components" and "boxes" that are delivered from one contractor to another. This was done to mitigate the thousands of pieces of government-furnished equipment identified for delivery between the work package contractors. Simply stated, the receiving contractor and the delivery contractor are jointly responsible for the item until the item is fit or functionally demonstrated in the next level of assembly. This is true for both hardware and software. This is the first time NASA has utilized an associate contractor role to this degree.

Another extremely important element initiated very early in the program is the Software Support Environments (SSE). The SSE will establish a program-wide set of rules and tools for software architecture and production. The SSE is mandatory for a highly software-driven program such as ours. I believe the SSE will be a model for large, complex programs of the future.

With the above plans in place, program requirements can be established and managed, and the proper accountability can be identified.

5. Maximize Margins. Margins of safety, cost, schedule, quality assurance, and the like must be maximized to the greatest extent feasible. The real costs and dangers come when things don't fit or work as they should. Add-ons or corrections after the hardware and software are developed are major cost drivers, time wasters, and sources of future problems. The best time to effectively manage resources is early in the program in order to ensure maximum safety, reliability, maintainability, and quality assurance in hardware and software. To over-subscribe such valuable resources as weight, power, volume and crew time early in the design without the ability for later add-ons will significantly complicate the job.

The long life of this program brings with it the necessity to intelligently provide the "hooks and scars" for future growth and subsystems upgrading. This is one of the most complex tasks facing us, and one of the most important.

6. Maximize redundancy. But also manage it. The space station program has built triple redundancy into critical systems. To extend redundancy further would make the system less manageable. Once backup systems are in place, you have to "manage " them to know you will be able to depend upon second and third levels of redundancy when called upon.

7. Automation, robotics and Artificial Intelligence capability not built in will be accommodated by hooks and scars. We can build the Freedom station with today's technology. We need to push hard on automation systems, robotics and expert systems, but not too hard. We plan in the future to incorporate new technologies, thus reducing long-term operations costs. On the other hand, Freedom can, through the use of hooks and scars, be designed to accommodate breakthroughs, and we are committed to incorporating such advances as they become available.

8. Authority will be delegated to the lowest level practical and commensurate with the demonstrated real accountability. Unnecessary layers of bureaucracy take too much time to unravel. People take real pride in their work when they are given the tools and resources commensurate with the job-- and the ultimate accountability for its success. Finding the right mix of accountability, responsibility and authority is no easy task, but emphasizing the necessity to do so to each program and project manager is mandatory. The management structure clearly identifies the

management levels and their accountabilities. If the accountability is not accepted, that portion of the program will be relocated.

9. Life-cycle cost will always be a key decision driver starting with development cost. The space station program spent much time and money in early definition work to identify and establish detailed designs that meet user requirements and life-cycle cost objectives within total and annual budgets. We know where we're going and what it will take to get there. We are saving a lot of time and money by preparing detailed plans, and listening to the good advice of potential users. An extensive cost model is being put in place to price all major program decisions that have an impact on development and operations. Close attention to detail in the development phase will save enormous amounts of time and money in the operational phase.

10. Space Station Freedom is not an end product but a key element of NASA and our nation's future. This principle could be considered a subset of number 9 above. I have identified it separately to give it the emphasis it deserves. In the early days it is easy for an organization to be buried up to its elbows in day-to-day problems, and equally easy to focus on the near-term solution that compromises future operational costs and performance.

Space Station Freedom will likely be our nation's gateway to planetary exploration, lunar bases, or missions to planet Earth. Therefore, we cannot over-emphasize the need for attention to growth capability or economic operability.

11. The international elements are vital to Space Station Freedom's success. For many years the United States and our international partners have successfully conducted complex joint space programs, and I am sure that this cooperation will continue and expand in the years to come. Freedom, however, will be the largest, most difficult and complex international cooperative space venture to date. Our international partners are contributing approximately 30% of the program development cost and will make a similar investment in the operational cost. They are significant members of the team.

There will be complications, of course. The interleaving of sub-systems, crew roles, training, and a very distributed science and station ground operational system are some that come to mind. We have dealt with similar problems before, and learning to do this effectively may be one of the best avenues for cooperation in many future peaceful initiatives.

12. Space Station Program Levels I and II manage the program; Level III and the prime contractors design, develop and fabricate Space Station Freedom. This principle was explicitly added to reinforce the fact that Levels I and II are management overview functions, and design and development responsibility rests with the Level III centers and their contractors.

13. Space Station Freedom Requirements. Space Station Freedom requirements are developed and managed by Levels I and II and satisfied and verified by Level III (a subset of number 12 above).

14. The Technical Management and Information System (TMIS) will be the key management tool, and the sooner the better. A program as large as this, as distributed as this, interleaved as this, requires an information system to gather, sort, compile, display, and disseminate current and accurate information. This includes requirements, design drawings, test, quality, and schedule and cost data, to name a few. Automated systems and software exist or can be built to perform this function in a highly automated mode. When you put them all together they are called TMIS. TMIS will allow the entire program to operate using timely and consistent information, with minimum input and retrieval effort. The extreme interdependence of each work package on at least one other work package requires current development status to be available across the program at a much lower level of detail than frequently required. TMIS will make this possible. Without this system in place, I do not believe it would be possible to maintain a proper program balance.

15. Every person in the Space Station Freedom organization must think and perform as a systems engineer or manager. This principle is most important but very difficult to implement. I cannot direct or legislate this to happen. I can, however, encourage our people to adopt this mindset. Most of NASA's large programs in the past consisted of major elements such as launch vehicle stages or spacecraft buses that accommodated a series of experiments delivered to an integrating contractor or center for assembly and check-out. In other

words, there were easily identified and defined interfaces. This program has anything but clean hardware/subsystem and management interfaces. Virtually all decisions made at the component and black box level can potentially affect another system component design or the attendant station operation. Significant changes can be controlled by the Interface Control Document and Architecture Control Document systems. However, lower level changes are not controlled in this way. These changes require the engineer and manager to think and function as a systems engineer and to question the real effect each minor change has on other elements of the program. This process is counter to the natural inclination to get the hardware delivered on cost and schedule. The need for this "system level" consciousness is present in this program more than in any previous NASA program. This management and engineering discipline will be even more necessary as this program continues to develop.

Here then are my guiding principles for the management of Space Station Freedom. It would be difficult if not impossible to codify any or all of these principles into hard, fixed policy. But I think we can benefit from knowing what and how a manager thinks and what is expected. It is part of the communication process.

Project Management: JSC's Heritage and Challenge

by Aaron Cohen

Director, Johnson Space Center
Houston, Texas

Introduction

Project management is one of the most trying jobs anyone can have, but it's also one of the most gratifying. As the director of the Johnson Space Center, I'm involved in project management decisions concerning the Space Shuttle and the fledgling Space Station Freedom every day. Earlier, I had the marvelous opportunity to manage two of the most challenging projects of my career -- development of the Apollo Command and Service Modules and the Space Shuttle Orbiter.

Now it's my duty to pass along some of the things I've learned about project management over the years:

- "Hands-on" experience is a prerequisite to effectively, efficiently dealing with the three classical elements of project management -- performance, cost and schedule.

- Performance is not everything -- cost and schedule are very important. Schedule drives cost, and cost drives what you can produce. Don't ever let anyone tell you otherwise.

- Patience, communication, honesty and treating people fairly are necessary elements of project management. You must be people oriented.

- Contract management and project control are as important to project management as technical expertise.

- You must do more than make decisions. You must make timely decisions.

- Compromise is acceptable and is an important component of success.

- Better is the enemy of the good. You can never solve all of the problems.

Before I go into detail about each of these lessons, though, I'd like to establish a common foundation of understanding on which we can build.

How Does JSC Use Project Management?

JSC's organization is designed to produce solutions -- through project management -- to the technical problems that stand in the way of safe, productive manned spaceflights.

A project is a single, nonrepetitive, organized enterprise undertaken to achieve an objective within a specified time and cost. Project management is the business of creating -- through a sensible sequence of efforts that utilize to best advantage the resources available -- a product that achieves the objective. A program is a series or group of projects that achieve a broader goal within an overall time limit and budget.

Our product at Johnson Space Center is to carry out agency objectives when they involve putting men and women into space, keeping them alive and productive while they're there and returning them safely to Earth. We design, develop and operate manned spacecraft and train the crews that use them. We conduct scientific research and medical experiments that help us understand how space affects both astronauts and spacecraft.

Working in concert with other NASA Centers and private industry, we manage projects and contribute to programs for America to survive, learn and expand. The goals our programs are designed to achieve include, but are not limited to, engendering national and international esteem, furthering scientific research, bolstering our country's economy and strengthening our national defense.

The JSC workforce must be able to solve very difficult and complex technical problems to achieve these ambitious program goals. They are supported by an organization and management process uniquely suited to the challenge.

JSC's Environment and Culture

JSC nurtures an environment and culture that motivate our people to strive for technical excellence above all else. The environment and culture also encourage open, effective communication at all levels on the premise that no surprise is a good surprise when it comes to human-rated systems.

These motivations tend to make us downplay rank authority at JSC and to encourage a "smart buyer" philosophy in the management of our contracts with private industry.

The de-emphasis of formal hierarchy at JSC has its roots in the peer review system that dominated decisions within NASA's predecessor organization, the National Advisory Committee for Aeronautics (NACA). The fact that JSC's original contingent was a "melting pot" of civil service engineers and scientists, industry experts and military and former military specialists contributed to an organizational structure and management process that was tolerant of dissent. These cultural characteristics encouraged a team concept at JSC that allowed each team member to feel free to present his or her point. The emphasis was and still is on technical excellence and awareness, not on toeing the hierarchical line.

This type of communication helps ensure that project managers are aware of all available facts, both those that pertain to the progress of each project and those that concern potential obstacles, because there is still one person who ultimately must make the decisions and be held responsible for them. Like the controlling stockholder in a large company, the project manager always has 51 percent of the vote.

JSC's management process also provides for the best contributions from private industry and government (both civilian and military) personnel in decision making. This highly interactive style produces excellent technical decisions, but sometimes makes it a challenge to distinguish between public and private employees. Some people criticize NASA for being too close to its contractors. But we are dealing with an extremely hostile environment in space, an environment that does not suffer mistakes graciously. Strong teamwork is required to produce the consistently high-quality equipment and procedures that allow humans to survive and work productively in space. That kind of teamwork cannot be generated in an adversarial environment on Earth.

We manage well because we have technical as well as academic experience. Government scientists and engineers can get hands-on experience in JSC's laboratories so as to manage projects from an educated and experiential perspective. Their hands-on research and development establish an understanding of what the various spacecraft systems can and should do, how much they should cost and how soon they can be ready for delivery.

Beneath this interactive management process, however, are differences in the way people view their jobs. Engineering, safety, reliability and quality assurance and science organizations are common at most other Centers. At JSC, the flight crew, mission and ground operations perspectives add a new dimension to project management. The project office is responsible for listening to concerns and suggestions from these organizations and, with the help of the contractor, arriving at meaningful solutions.

Decision making, furthermore, hinges often on some concerns outside of JSC. Since most manned vehicles carry payloads, the project office must also consider the advice from other NASA Centers and agencies that have prime responsibility for those payloads. External influences--such as the cultural differences between NASA's manned spaceflight Centers and research Centers, the increasingly divided management responsibility for manned spaceflight programs, the different styles of project management among the manned spaceflight Centers, and the increasingly demanding oversight of external authorities--also have marked effects on the programs and projects in which JSC is involved.

Therefore, project management at JSC must balance the three classical elements of cost, schedule and performance and face the challenge of balancing the pressures caused by these diverse internal and external influences as well.

Evolution of a Matrix

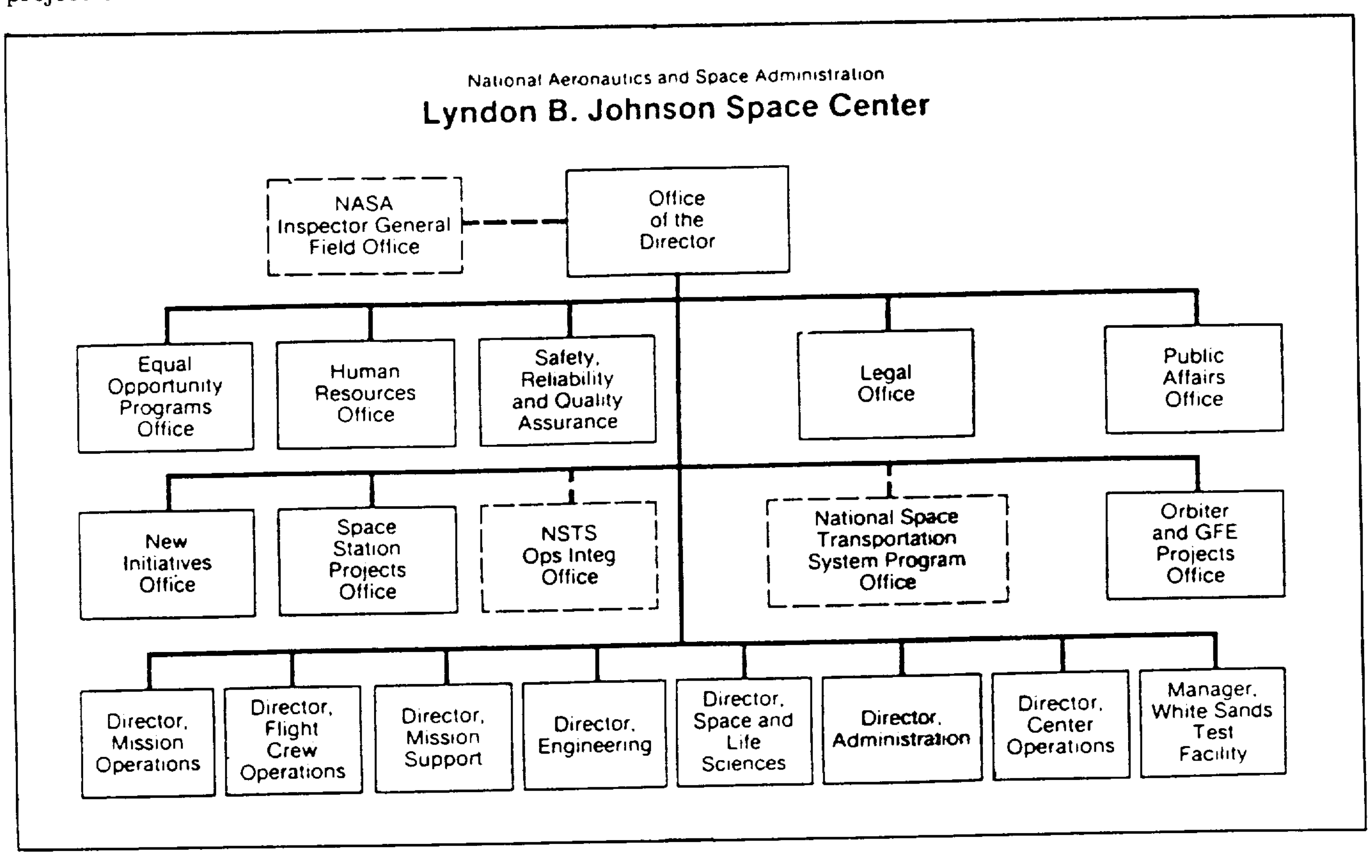
On paper, JSC is separated into line organizations that perform operations, engineering, and science. Separate from these line organizations are other organizations that perform support functions such as contracts; personnel; safety, reliability and quality assurance; legal; Center operations; flight crew operations; and public affairs. All ten organizations report to the Center director.

Project management organizations must integrate the products of all of these organizations, coordinate their efforts and manage the hardware and support contracts as they relate to each project. They, too, report to the Center director, but they are "more equal" than the other organizations, and they also must be responsive to the program directors at NASA Headquarters.

Together, these separate and distinct organizations intertwine to form a matrix organizational structure designed to support the effective management of JSC's project and initiative offices. To a limited extent, the program and project offices must compete for the resources provided by the line organizations. The line organizations must balance the needs of the project offices with the limited resources available and do their best to support all JSC program and project offices effectively. Decisions are made after consulting me and senior management staff from each functional directorate. This provides a check and balance for JSC project management decisions and the wise distribution of resources to each project.

While JSC has utilized a matrix organization since its formation in 1961, the alignment of that matrix has changed. As with any organization, what shows up on paper is only the tip of the iceberg. JSC's environment, culture, motivations and experiences all play a major role in determining how the organizational matrix acts and reacts. JSC's environment and culture support two overarching motivations -- technical excellence and no surprises. Manned spaceflight will always contain an element of risk. JSC's organizational experiences have included both successes and failures, and crisis has been a catalyst for change, as it has been in other organizations, both public and private.

I joined the Manned Spacecraft Center in 1962 as part of the industry contingent entering the Center's melting pot. We were managing the Mercury, Gemini and Apollo programs at the same time we were building the Manned Spacecraft Center. In those days, only the separate project offices and



directorates reported directly to Center Director Robert Gilruth. All of the organizations reported to the Center director when developing the support functions, but many of the Apollo decisions were made exclusively by the Apollo Spacecraft Program Office. Since the Center really was working on only one program, Apollo (Mercury and Gemini were basically stepping stones for the lunar landing program), JSC's organizational structure became a "vertical matrix" with most of its activities supporting that program.

The Apollo 204 pad fire that claimed the lives of astronauts Gus Grissom, Ed White and Roger Chaffee in 1967 represented an organizational crisis. It became obvious that the "vertical matrix" allowed the program office too much autonomy. Dr. George Low, who was also JSC deputy director, became program manager and brought a broader perspective and management style to the job. He required the participation of all JSC line organizations to a greater extent than had been the case before the Apollo fire. He expanded the Center's management process to include all of JSC's senior functional managers in major Apollo Program decisions. JSC's director and his senior staff were assigned a check and balance responsibility for the program. What had been a limited communication process between the program manager and each of the JSC organizational elements became more open, and the entire Center senior staff was encouraged through a more participative management style to help make the decisions of the program.

A separate safety, reliability and quality assurance organization also was established. The Center director began to oversee all decisions, whether they involved project management, operations, engineering, science or support. JSC's organizational structure has changed little since that time.

A Different Emphasis

I was project manager for the Apollo Command and Service Modules (CSM) from 1968 to 1972, and for the Space Transportation System Orbiter from 1972 to 1982. Throughout both projects, one of my principal responsibilities was to constantly make trades between performance, schedule and cost. Today's project managers are making similar trades.

While the need to make these trades is a constant characteristic of project management, the priority each assumes in relation to the other can change drastically. These priorities are driven by both internal and external forces that establish a goal, a mission and a management philosophy for each program. They are rarely black and white. More often than not, such priorities are shades of gray that lighten and darken on a case-by-case basis using the best information available at the time.

As I managed the CSM project, the priorities that normally held were performance first, schedule second and cost third. Our first challenge was to achieve the goal -- to build the Apollo spacecraft, train the crews and fly the missions that would accomplish the material goal of putting men on the surface of the Moon and returning them safely to Earth. Our second most pressing challenge was to do it on the schedule stipulated by President Kennedy. The element that received the least overall emphasis was cost.

At the height of the Apollo Program, nearly 4 percent of the national budget went to NASA. By contrast, NASA now receives less than 1 percent of the national budget to fund the Space Shuttle and space station programs. During Apollo, there were no starts and stops on the production lines. As we built the Space Shuttle Orbiter, we repeatedly had to assess which subsystems could wait to be produced and which could not because of variations in budgetary commitments to the space program.

The Space Shuttle program was conceived as a more cost-effective means of providing access to space and a necessary way of providing transportation to and from a future permanently manned space station. For a manned space station to remain operational for long periods, it would need continued resupply and crew exchanges. A vehicle was needed to carry people and cargo into orbit, return both safely to Earth and do it over and over again -- all on a tight budget. The goal had changed from reaching a destination to developing a transportation capability.

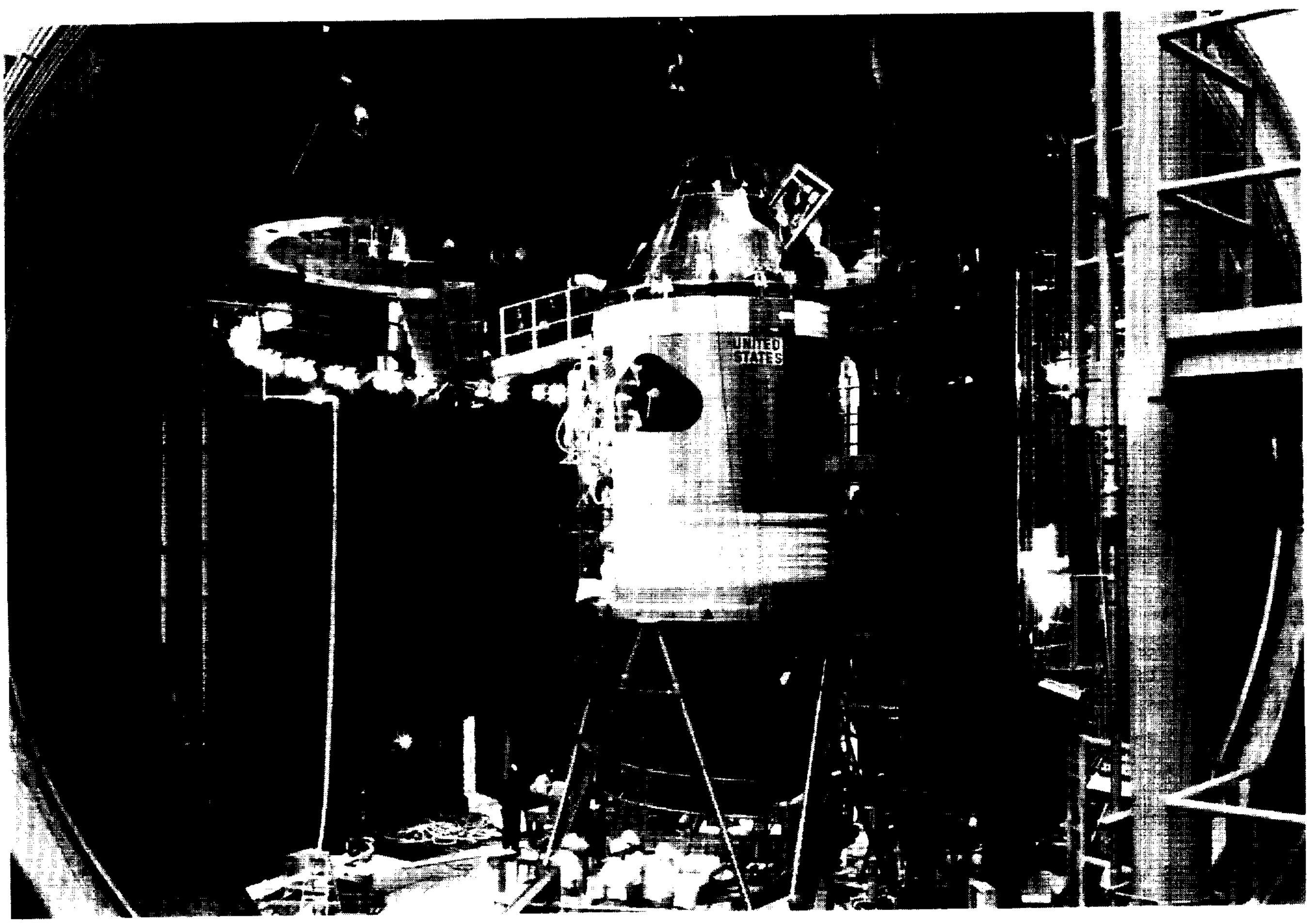
The order of priorities that normally held for the Space Shuttle Orbiter was performance first, cost second and schedule third. NASA was still required to achieve the desired level of performance, but because of budgetary constraints, cost requirements had to take precedence over schedule achievements in the early stages of the shuttle program.

I am not going to say that one program was easier to manage than the other, but the facts are that the programs of the 1970s placed a much greater emphasis on cost than the programs of the 1960s. This was not all bad because it forced us to pay closer attention to cost-effective technical solutions, and to keep in mind the goal of providing a less expensive means of access to space. And I don't mean to infer that safety and reliability can be sacrificed. As I mentioned earlier, performance was always the number one consideration. You can still obtain a successful product in terms of performance, cost and schedule, but when cost takes precedence over schedule, the ability to make the right decision the first time becomes more important. More productivity and innovation are needed to solve problems of equal or greater complexity with less money. This placed an added demand on the project managers because they were required to instill resource management discipline in technical organizations that were not used to giving so much attention to resource allocation.

The Apollo vehicle was not as technically complicated as the Shuttle Orbiter. However, the Apollo mission was much more complicated than the Shuttle's mission. During the Apollo program there was the luxury of solving problems by using multiple paths, due to resource availability. During the Shuttle program, budget constraints forced us to choose from among possible paths early and follow the one that looked the most promising.

Avoiding Pitfalls

Whatever priorities are dictated by the environment, a project manager can never equally satisfy all elements of project management. There is no exact project management formula or equation for making performance-cost-schedule trades. But the lessons I have learned from people like Robert Gilruth, Max Faget, Chris Kraft and George Low -- and from my own experience -- tell me that there are several important principles in maximizing the probability of success. Those factors sometimes contradict one another and they must be applied on a case-by-case basis, but they are nonetheless valuable.



APOLLO PTV-1 ACTIVITY -- View of the Apollo Spacecraft PTV-1 inside Chamber A, Space Environment Simulation Laboratory, Manned Spacecraft Center, prior to manned thermal-vacuum testing.

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First, you must fearlessly base your decisions on the best information available. As a project manager you will have many different considerations with regard to each programmatic issue. Simply by making a decision, you ensure that you probably will be right more than half the time.

Many times during the life of a project, a project manager will be faced with decisions that need to be made in a timely fashion, and either all the data is not available or it will not become available in time. In other words, the time and effort spent in trying to obtain additional information may not be worthwhile. A specific example of this occurred during the early design phase of the Orbiter. The avionics system was being formulated and a microwave scanning beam landing system (MSBLS) was being considered as a navigation aid. At the time, the MSBLS was pushing the state-of-the-art. The question before me: Should I use current, proven technology or should I try to push the state of the art and wait for such an advancement in the technology? I based my decision to push for the new technology on the data I had and the desire of my team to use the system. We made a decision, and it proved to be correct.

Second, you must make decisions in a timely manner. If you are decisive early and are wrong, you can still correct your error. During the Orbiter design, development, test and evaluation phase, I was forced to make many trades in terms of performance, cost and schedule. On one particular occasion, I was reviewing thermal system structural test requirements that contained a number of articles such as parts of wings, parts of the mid and forward fuselage and their thermal protection systems. The technical team needed to test all of the articles, but they were too large to test all at once, and I had a limited budget. After spending a full Saturday in review of all the test articles, I eliminated several despite the extreme concern of several of the technical experts I had supporting me. Weeks later they came back and argued their point of concern again. This time, their point struck home and I reversed myself and put the test articles back into the program. By making a timely decision, I had given myself a chance to correct a potential error.

Third, if you can fix a problem by making a decision, do it. During the checkout of Apollo 11, the Inertial Measurement Unit (IMU) of the lunar module was slightly out of specifications in gyro drift. The analysis showed that you could accept a little more degradation and still perform the mission. The questions before management: Do we understand the reason for the gyro drift, and could this lead to a greater degradation and threaten the success of the mission? Changing an IMU out of the lunar module on the pad was not an easy task, and we would be risking major damage to the fragile structure of the lunar module if one of the heavy instruments were dropped during a pad change-out. A group of us discussed this problem with George Low, then Apollo program manager. We strongly recommended to him that we should not change out the IMU. His comment was: "If you can fix a problem by making a timely decision, do it." We replaced the IMU.

Fourth, always remember that better is the enemy of the good. You can never solve all of the problems. If you have obtained an acceptable level of system performance, any "improvements" run the risk of becoming detriments. Right now, we are struggling with this very situation as we try to improve the design of the solid rocket motors and add emergency egress systems to the Orbiter. Each improvement brings with it a price in terms of weight. Each additional pound reduces the margin we have in the amount of thrust available to reach orbit. We have had to ask ourselves, "At what point do these new safety features become liabilities?"

Fifth, don't forget how important good business and contract management are to the successful operation of a contract. Project managers must realize that when they manage a contract they should do their best to be fair to both the government and the contractor. In order to do this, they need strong project controls on budget, schedule and configuration. The project manager must be sure the changes that are made are negotiated promptly and equitably for the government and contractor. Fairness in dealing with the contractor is the most productive way to do business. You want to penalize when appropriate, but you also want to reward when appropriate. To establish what is appropriate, you must set the ground rules early. The first signs of project management failure are budget overruns and schedule slips. This can be understood and potentially avoided or minimized by good project control and contract management.

Last, and most important, you must be people oriented. It is through people that projects get done. Dealing with people is extremely difficult for many project managers who have an engineering background and are more comfortable working with an algorithm than explaining how to use one. Good project managers surround themselves with talented people who will speak up when they believe they are right. They make themselves available to their bosses and to the people who support them. They listen when people express their concerns and make people want to express their concerns by explaining decisions that contradict the advice they've been given. They accept criticism without being defensive and are able to reverse their decisions when they are wrong.

One of the most vivid and memorable experiences I've had in this regard happened during the preparation for Apollo 8 in early December 1968. The preparations had been going very smoothly without any big issues needing to be worked for several weeks. Then it happened. About two weeks before the flight I was told by the contractor, North American Aviation, and JSC propulsion subsystem managers that we had a potentially serious problem with the service propulsion system (SPS). We had just finished some tests in the configuration that we were going to use for lunar orbit insertion.

Apollo 8 was going to place the CSM on a free-return trajectory, which meant that if we did not perform an SPS burn behind the Moon the spacecraft would automatically return to Earth. The SPS fuel injector was fed by a pair of redundant systems. We wanted both of them to be active during the lunar orbit insertion burn so that if one feeder line malfunctioned, the other would get propellant to the SPS. The tests we had just finished were in this configuration, but it was the first time they had been used and both lines had been dry before the test. The tests showed that if we started the burn with both lines dry, a pressure spike occurred that could cause a catastrophic failure in the SPS. If both lines were wetted, however, the pressure spike would not occur.

I got very upset when I was told this, but the test engineers stood their ground. They told me very firmly that the problem had to be addressed, and they presented a good solution. By firing the SPS on a single system out-of-plane burn during translunar coast -- which would not disturb the free-return trajectory -- we would have both systems wetted by the time we needed to use them together and, hence, avert the high-pressure spike.

Now it was my job to call my boss and let him know what I knew and how to fix the problem. I had no qualms about doing this because my boss, George Low, had taught me several important things by his actions and words: get out and touch the real hardware; pay attention to detail; when things go wrong, look for innovations, the unusual solutions, or try to meet your commitment no matter what; and have great respect for your fellow human beings.

Management Toolbox

The surgeon has a scalpel, the general has a battle plan and the project manager has still another arsenal of tools. The adept and effective use of these tools is a critical factor in the success of the project manager. Because almost 90 cents of every dollar budgeted for NASA is spent by a NASA contractor, these tools are used to assist the project manager in the contract management responsibilities.

The basic project management tool is the contract. A contract baseline is established through the development of a statement of work, a segmentation of the work by use of a work breakdown structure once a contract baseline has been negotiated between the contractor and the Government. Then the project manager must maintain a continuing awareness of the status of the project. The tools of the project manager at this stage include **management reviews** where technical and business staff conduct in-depth assessments of the project with counterparts from industry.

The project manager must delegate a portion of the responsibility to the matrix organization structured to support the project. The backbone of this matrix assignment is a three-party team composed of **subsystem management, project control**, and the **contracting officer**.

The best management tools are the ones that allow communication to flow in the most efficient manner. By efficient, I mean the presentation of a large amount of data in a small amount of time in a format that allows decisions to be made. I have primarily discussed the matrix management systems that JSC used during the Apollo and Shuttle programs and the term "subsystem manager."

Every day from noon to 1 p.m., I had a **"stand-up" briefing** in a control room on various subsystems and other aspects of the Orbiter project. We held these meetings in a room that had been structured with **schedule control boards** mounted on the walls. These boards served as our controlling display of the total project. A particular project individual was assigned to maintain current project status on each control board. This allowed a great deal of data to be transmitted in a very efficient manner. Issues were laid out for discussion and I then could schedule decision-making meetings. This proved to be a very efficient way in which to do business.

The next level of review that was created was a weekly or an "as needed" **Technical Status Review** meeting. The purpose of this review was to have a combined JSC technical and contractor review by teleconference.

One of the most critical project management tools that works in conjunction with the project manager's use of the contract and management review concept is the change control process. I used the **change control process** as a way to maintain a disciplined and detailed accounting of my contract baseline. At the heart of the change control process is the Change Control Board. The Change Control Board was a weekly meeting of JSC directorates and the contractor to make formal decisions on proposed changes.

The management tool used to ensure that the prime contractor was carrying out the contractual responsibilities in the most effective and efficient manner possible was the monthly **Orbiter Management Review** (OMR). The OMR was held at the contractor's facility and reviewed the total project. This review normally took two days. It was a review of the financial, contractual and technical status of the project.

These sessions at the contractor's facility enabled me to conduct an in-depth review of the status of the contractor's work in the same manner that I had been able to review the government teams' work in my daily noon meetings.

Another project management tool that aided the communication within JSC and from JSC to our contractor was the **Award Fee process**. The opportunity to identify for the contractor specific areas of project emphasis and to couple this emphasis with the awarding of a contractor fee based upon accomplishment of specific project objectives served as a very powerful management tool. I use a performance measurement system to help me objectively evaluate how accurately the contractors achieve their targets.

Conclusion

Project management is the heart of NASA's success. NASA in its relatively short lifetime has made some spectacular manned spaceflight accomplishments. Landing a man on the Moon and returning him safely to Earth, linking a manned U.S. spacecraft with a Soviet craft, launching and operating a manned space station, Skylab, for several months, and developing and operating the Space Transportation System--all have claimed the attention of a world that is inspired and challenged by technological advancement. Add to these all the unmanned probes of the universe, mapping of our solar system, fly-bys of orbital planets and the scientific advances in earth-sensing and aeronautics and you conclude that America has been well served by NASA.

JSC's product has been the formulation, management and execution of projects that put men, women and unmanned craft into space and allow them to do useful scientific research and work. All of these NASA endeavors are accomplishable because of NASA's utilization of project management. But there are several characteristics of the NASA utilization of project management techniques that are somewhat unique and thereby have served as an inspiration not only to the United States but to the free world.

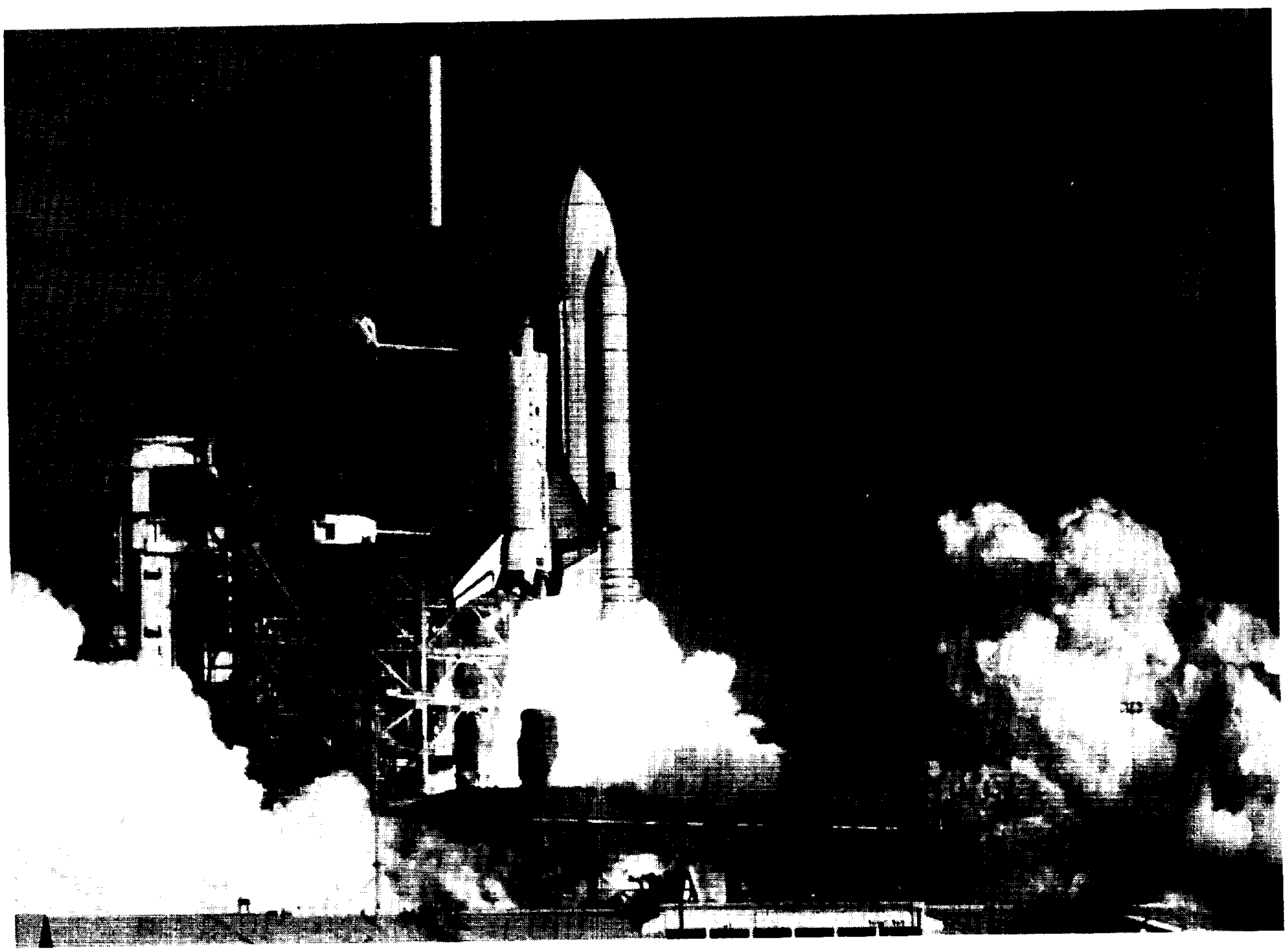
For the most part, NASA projects have had a clear statement of their goal or purpose,such as to land a man on the Moon and return him safely to Earth. Second, NASA projects have had a precise schedule for achievement of these goals. Third, NASA projects have been open for the world to observe. Because part of NASA's charter is to disseminate information about aeronautics and spaceflight, the whole world has been a spectator for our daily project accomplishments and failures. Fourth, at NASA we do more than produce and deliver "widgets" as many businesses do. We develop and build widgets as part of our work, but we build them to help us achieve our mission objectives. The world follows the successes and failures of our widgets in both their development and their use.

These characteristics have placed very great demands on the NASA project managers. The intensity of these demands has required an uncommon attention by NASA project managers to an openness and clarity of communication, a dedication to the project task and uncanny, almost single-minded, attention to detail.

As acute as these demands have been and as well as we have responded, I can guarantee that we will have to redouble our efforts in the future. The complexity of our projects will increase. The cost constraints will continue, and probably tighten. We will have to manage multiple programs, and make them work together as in the case of the Space Station Freedom and the Shuttle. We will be managing programs with lengthening or never-ending lifespans. International participation will increase and intensify. NASA's Centers and support contractors will work even more closely. We'll begin working with more private sector commercial ventures.

How we react to these intensified and diversified demands is the key to our future. Our reactions should be driven by the lessons we've learned, but we must move beyond those basics. Our project management capabilities must evolve in directions that have not yet been defined. We must carefully evaluate every adjustment and improvement we make to our program management methods, just as we evaluate every change in a spacecraft's systems to be sure that the change is beneficial and that the repercussions of any side effects are not detrimental.

I am confident we can meet the challenges today and in our future through the judicious use and continued refinement of our project management techniques. There is no simple formula for the success of project management, but the rewards of a job well done and witnessed by the whole world are well worth the effort.



Back on April 12, 1981, just a few seconds past 6 a.m., Space Shuttle Columbia rises off Pad 39A at the Kennedy Space Center, marking the launch of the Shuttle Era in manned spaceflight. STS-1 carried Commander John W. Young and Pilot Robert L. Crippen toward an Earth-orbital mission which represented the start of a new era in space transportation for NASA and the world.

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Shared Experience in NASA Projects

Some Tips and Observations

Wallops Island, Virginia
August 25, 1987

by A. Guastaferro
Vice President, Space Station Program
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It has been a real opportunity to serve in all but the first five of the 30 years of U.S. spaceflight. For program and project managers, these three decades have been filled with enormous challenge and exciting opportunities, mainly because there have been no clear precedents for managers. In those early years, we had to progress incrementally, if you wish. Each step along the way, NASA and industry expanded the knowledge base and technological capabilities to a point where each individual project became incrementally more complicated, expensive and challenging. Management of these projects--from the small unmanned payloads to the medium-sized Mercury-Gemini to the larger payloads of the Apollo-Skylab era--likewise presented new challenges and demands. The old ways of doing things simply did not work in this new complex and high-tech environment.

Nor will they work in the current phase of spaceflight development, with multiple payloads in the Shuttle era. New tools, new techniques are required as NASA and industry enter the long-term aspects of space station design, development and operations.

Yet, we all look back with pride to spaceflight programs of the past that worked efficiently. We respect the management tools that led to mission success in earlier projects. As we look toward the management challenges of spaceflight development of the 1990s, we must reflect on the accomplishments and failures of the past and apply the lessons learned in a constructive way. The NASA project manager represents the leadership of the U.S. in space exploration. It is critical that the NASA project manager learn from the past to build a space program second to none.

In other words, there are some things worth saving, others to discard and still more to build upon. When you add up all the marvelous advances and successful missions of the past 30 years of U.S. spaceflight, you can't help but think that the partnership between NASA and industry has become one of the more remarkable management feats of all time. The synergy and cross-fertilization of this partnership are worth exploring.

My purpose here is to provide a perspective of both NASA and industrial project management issues as they relate to research and development activities. NASA project managers represent the leadership of an organization. As such they have accepted a responsibility--better stated, an accountability--for the total aspect of a particular task. They must accept cost and schedule responsibility, along with the technical aspects of the assignment. A good manager views this assignment as if it were a personal business and tries to determine effectiveness by some predetermined measurement system. Following are observations on project management issues from both NASA and industry points of view.

First of all, the initial formulation of a NASA project is extremely critical to mission success. The advocacy phase must be carried out with very careful planning, timely marketing and with a clear understanding of the organization's mission and available resources. On the government side, the establishment of an approved project may take years. Early in the advocacy process, a strongly supportive outside constituency is needed, to help secure a budget line item for the next fiscal year. This

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constituency should include several aerospace contractors willing to direct their new business resources toward the project in return for an opportunity to compete in the design and formulation phase.

The industry formulation process is not very different. Contractors have limited resources and a large spectrum of opportunities. The successful contractor gets involved early, assigns qualified people, provides adequate resources and maintains a strong relationship with NASA so that critical resources are focused to the project objectives. Contractors are available to help NASA in the selling of the project during the formulation period.

Accountability

In accepting accountability for an organization unit, make sure you understand its objectives. In addition, find out what inter-organizational relationships are required and where your resources and constraints will come from. Understand what is expected of your unit. Get a contract between you and your boss, you and center management, you and headquarters, you and your family. If internal and external forces are going to influence the performance of your unit, get a commitment to:

- Cost
- Schedule
- Technical performance
- Risk

Make sure you are given sufficient authority to carry out your task. Don't put yourself in a "no-win" position at the outset. Get an understanding--and then the commitment. A successful business always does.

When I look back on my NASA years, it strikes me that the government system ordinarily does not provide a natural environment for full accountability. The typical organizational structures and the non-profit environment are impediments to accountability. On the other hand, the industrial R&D managers assume fiscal responsibilities very early in their career and are better prepared for project management responsibilities. Perhaps NASA managers should develop their own methods outside of the organizational system to provide the stimulus for accountable management. Essentially, the skill is there--but the environment is not.

Establish a Standard

After receiving a clear understanding of the management assignment and the resources and schedule constraints, make sure you develop specification, a standard of performance. Make your specification realistic and flexible. (Many a manager has died of hardening of the categories.) Divide your work into a logical structure. Avoid false competition, unnecessary overlap, or gaps. Find the right person for the right job. Delegate a portion of your contract to your subordinates and depend on them.

I believe that the discipline and the environment of NASA encourage individual performance in the development of hardware/software capabilities. Industry, driven by the profit motive, will find ways to meet performance requirements that avoid strict adherence to rules and regulations. NASA is experienced in setting standards but not compliance to them. Simply stated, it is easier to write the rules than to follow them. I believe that a healthy exchange of technical experience can benefit both parties.

Make a Plan

Establish an integrated plan. Assign accountability for accomplishment. Make sure you understand the critical elements and provide sufficient schedule margin for "work-arounds." Review performance versus plan, frequently. Detailed schedules should be realistic. (Be careful--do not become overly optimistic.) I believe in pressure scheduling only to meet a crisis. Crisis or stress management in a research environment should be the exception and not the rule. Schedules and plans should be highly visible.

There seems to be very little difference between planning in NASA and the aerospace industry. Both organizations are highly tuned and efficient in the aspects of integrated planning, and both have developed performance measurements systems significantly useful to the decision-making process. I cannot find any difference in technique, process, or effectiveness. Perhaps we have trained each other to be consistently good and bad in the areas of planning, review and analysis.

Communications

A good manager is a good communicator. You should develop a motto of "no surprises." Communicate frequently. A few ideas:

- Weekly staff meetings
- Management by walking around
- Electronic management information systems
- Teleconferences with contractors and grantees
- Thorough requirement and design reviews
- Frequent status reviews
- Outside reviews
- Visits to outside work activities (and show interest)
- Finding a way to involve your boss
- An open-door policy for your people
- Curiosity (ask questions)

In my short time in industry, I have been impressed that industry is far more bureaucratic than NASA in its communication methods. For instance, customer briefings are critiqued to a far greater extent than I experienced at NASA. It is apparent that the success of the project and, in turn, the company, are critically assessed. NASA's approach is to assume a degree of confidence in the program and competence in its people. It is an attitude that I appreciated and somewhat miss.

Contract Management

The easiest way to improve contract performance is to concentrate on the selection process. Make sure your contractor has the experience and personnel to carry out the technical aspects of the contract. Remember, a bad marriage between the government and contractor will always lead to a costly divorce settlement for the government. Some thoughts to keep in mind:

- Guard against expansion of requirements
- Expect the unexpected technical problems
- Temper optimism regarding schedule and cost
- Watch for engineering changes that make things better instead of make them work
- Expect an underscoping of the project control function

In industry, the contracting relationship is normally between two aerospace contractors. There is far less formality in this type of a relationship and, as a result, a lot more difficulty in full compliance and implementation. Although I have found the NASA procurement process to be stifling, it has benefits in long term implementation and compliance.

Getting Your Vote Canceled

One barrier to effective communications is the fear of senior management involvement in detailed decision making. It has been my management philosophy that when my boss is in the same meeting with me, my vote is canceled. This concept places the manager in the delicate position of deciding which meetings the boss should attend.

The industry performance incentive program insures your boss's personal interest in anything you do that can affect the bottom line and the boss's paycheck. However, a successful project leader must have control of the resources necessary to ensure success.

The Golden Rule

In both NASA and industry, the golden rule applies. The manager with the gold--rules. Make sure you receive and control the money needed to accomplish your mission. If either your boss or your boss's boss controls the money, they in fact control the project. A project manager simply must control all the resources necessary for mission success, or some method of accountability must be devised.

Find Something to Count

After you understand your objectives, establish your baseline and obtain a contract and resources, it is then necessary to check your progress by frequent reviews and analyses. Managers in government can't measure performance against the industry profit milestone. But they can find things to count and they can measure progress by establishing performance standards and by variance reporting. A few examples of countable items:

- Data points
- Computer runs
- Documents released
- Reports published
- Pieces of hardware
- Value of work performed
- Money spent
- Manpower expended
- Time lost or saved
- Test hours
- Major milestones reached
- Review points completed

Performance Feedback

Do not be afraid to alter plans, specifications, and resources, based on past performance and future expectations. Good managers know where they are going by a critical analysis of where they have been. When changing the baseline, make sure you communicate up and down and that all are working to the revised plan.

A good manager stays involved in the details through an effective review program. Stress early problem identification and aggressive application of remedial measures.

As in planning, both NASA and industry do an outstanding job of performance measurement. Mission success is a goal in both organizations, and management tools have been developed for effective control of large R&D projects.

Cost Management

The first rule of good cost management is to set aside dollars for a rainy day. Identify reserves and develop a management plan for control and allocation of those reserves. Perform a risk analysis and identify the program cost drivers. Have a shopping list of cost offsets to provide additional margin. Make sure you can reduce performance and schedule constraints to reduce cost. My industry experience indicates that the ability to retain cash reserves for effective cost management is extremely difficult. Matrix organizations tend to assign resources to functional organizations, thereby making it difficult to retain reserves. Industry can learn much from NASA in the art of contingency planning.

A Strong NASA/Contractor Project Relationship

Experience shows that the best relationships hinge on two major factors. First and foremost, the two parties must establish a strong and active communication network. Every effort should be made immediately after contract to start to generate an effective reporting system with strong emphasis on the early identification of problems and improvements in communication methods and tools. The parties must also agree to complete near-term action items early, to identify "one-on-one" relationships clearly and to secure senior management participation.

The second factor is to establish an honest and open relationship. This usually takes hard work on the part of both parties. It is critical to the success of the project that both parties are dealing from the same data base when formulating policies and making decisions. Remember, the NASA and the contractor are both interested in the same result--a successfully completed project within the cost and schedule constraints prescribed by the NASA. Experience in industry indicates that the profit motive is important to the contractor but not at the expense of NASA dissatisfaction. I believe the long-term involvement in civil space and aeronautics is rated higher than profit. The challenges of a NASA program help attract new technical skills to a company, thereby fostering long-term growth.

NASA managers should be sensitive to this emphasis on long-term capabilities vs. short-term profit by stressing a complete and honest relationship. If changes are caused by a NASA decision or event, the NASA team should expect the contractor to receive a fair adjustment in both cost and fee. On the other hand, if contractors have performance problems, they should be prepared to fix the problems without benefit of a fee adjustment. Both parties striving toward this type of open and honest exchange will establish the trust so critical to the achievements of project objectives and mission success.

This open and honest relationship between NASA and contractor hinges upon strong communication. The project manager can communicate in a number of ways: by computer, telephone, voice, the written word, gestures, tone, style, etc. But the successful project leaders communicate best by personal example. They are role models for the next generation of managers. Their ideas and aspirations, especially their vision, are communicated even more clearly than their words. That vision will have impact far beyond the day-to-day project and will invariably extend to relationships within NASA, the cooperation of contractors, the team spirit for mission success and the users of the project--the customers, taxpayers and beneficiaries of an on-time, on-budget project. The ripple effects of a well-managed project (as we have seen from earlier spaceflight programs) will last for years if not generations.

My Lessons Learned

1. *Never lose your capacity for enthusiasm.*
2. *Never lose your capacity for indignation.*
3. *Never judge and classify people too quickly; first assume always that they are good.*
4. *Never be impressed by wealth alone or thrown by poverty.*
5. *If you can't be generous when it's hard to be, you won't be when it's easy.*
6. *The greatest builder of confidence is the ability to do something, almost anything, well.*
7. *When that confidence comes, strive for humility, for you aren't as good as all that.*
8. *The way to become truly useful is to seek the best that other brains have to offer. Use them to supplement your own, and be prepared to give credit to them when they have helped.*
9. *The greatest tragedies in work and personal events stem from misunderstanding. Communicate.*

Controlling Resources in the Apollo Program

by C. Thomas Newman

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Following is a slightly modified version of a paper written as part of our training effort for new staff members and interns in the Apollo Resources Control group in the Office of Manned Space Flight. Some of the points may seem elementary today, but I think many of the points are worth repeating. My tendency is to emphasize personal involvement and responsibility for estimates and conclusions. To some extent, this paper reflects my concern that the emphasis on automation tends to de-emphasize these concerns. Nevertheless, today I would put more emphasis on cost rate analysis, discussed below.

What We Are Trying To Do

One objective is to make sure that the budget plan really reflects the intent of management. This means the estimates must cover the program that management has approved and that there must be a reasonable basis to believe that the estimated amounts will buy what they are intended to.

Conventional budget reviews have been directed toward making sure the estimates are not padded. In R&D programs, the real problem is often one of underestimating what it takes to do a job, in both time and money. Any energetic agency has more good ideas than dollars. The budget process is aimed at getting as much program as possible within the dollars available, and at the same time making sure that we do not unknowingly take on commitments which we cannot support within the available funding. An important part of our analysis effort is to make sure that the estimated resources are a reasonably valid reflection of what it would really cost to do each option.

An essential function of our office is to get obligational authority from the review levels above it. This means preparing and supporting budget requests and, more importantly, preparing our own top management to support the budget request.

Looking in the other direction, we must determine how much obligational authority the offices really need. What we want to do is to provide for a tolerably sufficient but somewhat uncomfortable allocation. There is no question in my mind that a certain amount of pressure caused by funding levels below apparent demands is essential to any sort of management discipline.

Other vital activities in monitoring progress are to determine if the use of funds is in accord with the agreed-to plan or known intent to deviate from the plan; any units are running too far over or under availability; or reallocation of funds is needed.

Another function is to keep management informed. The key here is to sort out the type of information and the level of detail that are really useful to management. This depends in large part on the personality and interests of the manager. I believe that the most common mistake in this regard is to try to give the manager too much unfocused detail.

Approach: How We Do It

The way you work depends somewhat on your level in the organization, the management relationships with other offices, and the people involved. I think, however, some general techniques are applicable to almost any sort of budget review function.

Personal contact is usually more important than paper work. In many organizations, you get your important points across to top management by telling them rather than writing to them. You learn more about what is really going on by talking to people than by reading reports. One important technique is assigning **reliability factors** to people. Over a period of time you come to know that information received from some sources will almost always be right and well considered, whereas other sources are relatively unreliable. Other people will form an evaluation of your reliability factor with respect to both the information they get from you and the use you are likely to make of information you get from them. Establishing a good reliability factor for yourself and assessing that of others are two of the most important things you do.

The concept of correlation and probability testing applies to just about any sort of learning and evaluation process. **Common sense correlation** is, to my mind, the most important technique in assessing data. This means that, over time, you formulate an idea of what things ought to cost and, when any new estimates are presented, you have a basis for comparison. You are constantly testing the probability that what you hear or read is correct. Does it make sense when put beside what you already know?

Besides correlating various inputs of information on costs, you need to compare dollar estimates with non-fiscal data such as progress against scheduled accomplishments, complexity of work to be done, possible knowledge of other work assigned to the same organization, and other relevant factors you know. Multiple sources of data should be sought and the results constantly compared.

The type of correlation I have in mind is more intuitive than mechanical. It becomes a habit; it grows on you. To promote its growth, you need to develop a reservoir of knowledge on your own programs and related programs. You need an understanding of what needs to be done to make the program succeed. You need a general grasp of the technical problems, the management problems, the political environment, and the capabilities of the people we are relying on to do the job. It takes time and effort to acquire this background. You need to conscientiously study the hardware and operational aspects of the program. You also need to spend time working with the numbers. You need to "own" the figures. I believe that you are more likely to develop this by personally working with the numbers rather than relying on automated data. Once you have done enough of this work with the proper frame of mind, the correlations will come naturally. Your mind will accept or reject figures, often without knowing the specific reasons, but you will usually be right.

A great deal of work has been done to establish mechanical means of correlating funding estimates with factors such as weight, complexity, speed, size, production rates, etc. So far, these efforts have been only partly successful and do not provide a substitute for well-developed intuitive judgment.

It is almost always true that the whole is better than the sum of the parts. In developing estimates, I believe in building up pieces to the extent that time and knowledge permit a reasonable job to be done, but this should always be correlated against a broad scope look at the overall picture. If there is a conflict in the results, I would base my judgment on what a common-sense look at what the overall picture says rather than a meticulous addition of the pieces. I believe that excessive immersion in detail is not only tedious but also can be detrimental to doing a good job at the overall program level. A balance between specific knowledge of details and judgment at the total level is needed.

Cost rate analysis is an important way to look at overall program trends. Contractors build momentum which is not easily changed. It is like a river that keeps on flowing no matter how hard you blow on the surface. In most cases you can safely judge that cost and manpower utilization rates will not change rapidly unless some very strong pressure is applied or some unusual program factors are involved.

A commonly misunderstood technique is what I call the "spot probe." In reviewing an estimate, you probe in depth into a specific item. You ask difficult and detailed questions and generally give the person defending the estimates a hard time. This can be done in a civil manner. You are not really interested in the specific details, but you are trying to determine how carefully the estimates have been developed. Probe several points. You should not judge too much by a test of any one area; but by probing several areas, you do get a feeling for the degree of confidence you can place in the work that went into developing the estimates. Be careful in applying this technique. Do not embarrass people unnecessarily. You will be dealing with them later. If a proper rapport is maintained, you can work with them to correct any deficiencies you find.

Communications Upward

The work of building a budget or resources plan and monitoring performance against the plan is wasted unless:

- It enables you to do a job that you need to do
- It gives your management the information it needs to do its job, or
- It answers questions that need to be answered.

Give management the answers it really needs and wants--not the answers you think it would be nice for them to have. They already receive more information than they can handle. If a part of management has been delegated formally or informally to the resources office, I believe that authority should be exercised with only as much feedback to top management as they really want. Try not to take questions to management take solutions and take them only when there is a real reason to do so.

Examples of key questions that the resources office needs to be ready to answer are:

- Are we staying within our fund availability?
- Do we have enough funding to get the job done?
- Are there some areas where we have allocated more than we really need?
- How much room do we have within our fund availability to expand our plan or to take on new work?
- What are our problem areas and what are we doing about them?

We need to be ready to go into detail, but I think the basic guideline is to tell management what it needs to know--not what you think would be interesting.

The other types of reporting upward involve Review Authorities and Public Information. My basic ground rule is: ANSWER THE QUESTION ASKED. Don't volunteer information not requested. Answer honestly and simply in a manner that is meaningful to the recipient. If, for policy or other reasons, you can't give an honest answer, don't answer at all. Better to take some guff for not answering than to destroy your reliability rating. One qualification is that so long as you are on the payroll, you must support the agency policy and decisions even if you don't agree. The top management knows things you don't know which may make their decisions the best possible under the circumstances.

Characteristics of an Analyst

What are the characteristics we look for and seek to develop in a budget or resources analyst? I think the main factors are:

1. Reliability
2. A "why" mentality
3. A numbers sense
4. Interest in the program and enough background to understand it
5. Ability to work with others under stress
6. Willingness to get involved in a lot of "spread-sheet" work
7. A feeling for the big picture, even when working the detail
8. Ability to express ideas, oral and written
9. A sense of timing
10. Common sense and sound judgment

<u>Reliability</u>. This is probably the main qualification for any job. The person you are working for needs to know that you can be counted on for your best efforts and good judgment in carrying out any assignment.

<u>"Why" Mentality</u>. Whenever you are given information, there should be an automatic questioning of why this can or cannot be accepted at face value and how it relates to what you already know. The approach is not one of questioning integrity of the persons providing the information; but, in many cases, they will not have gone through this thinking process themselves. Before we can really use the information, we need to understand it.

<u>Numbers Sense</u>. It is my observation that numbers talk to some people the way words do to others. A good analyst needs a real feel for the numbers. I don't know why some people seem to have this and others don't, but I believe it is largely a matter of habit, interest, and basic aptitude.

<u>Interest in the Program</u>. To enjoy budgeting, you need a real feeling of identification with the program for which you are budgeting. As a minimum, you

need enough interest to acquire the basic knowledge to understand what you are budgeting for. Usually your effectiveness will increase in direct proportion to your real concern for accomplishing the objectives of the program.

Ability to Work with Others. You are always reliant on the work of other people. Sometimes our requests on others are somewhat unreasonable and have the potential of working against their interests. There is necessarily a good deal of stress involved in a budget operation, but success is dependent on ability to maintain a satisfactory rapport with the people with whom you need to work. I believe the main elements in this capability are:

- Openness in letting them know what we are doing,
- Giving them a sense of confidence on how we will use data, and
- An ability to distinguish between friction that arises in business and your personal relationship with an individual.

Detail Work. I believe that an analyst should actually enjoy a certain amount of spread-sheet work, even if it is partially automated. In my opinion, you need to work with the figures before they really become part of your thought processes.

Big Picture. All of our detail work is done for a purpose. To be effective, you need to be able to keep the objective in mind even while you are working on the detail. You also need an ability to depart from the detail approach when the objective requires that you do so. You need to be prepared to accept the fact that those above you may reach conclusions which differ from the results of your detailed analysis. You need to realize that the detail work is only one input into a large arena of decision-making.

Communication. For the results of our work to be effective, we need to express our ideas and conclusions both orally and in writing. We need to learn to express them in a way that will reach the person for whom they are intended. Often, the ability to put the message into a concise written form is a good test of your real understanding. The approach will differ with different people and at different levels of management. For the top level, we need to say what needs to be said briefly and clearly when the opportunity presents itself.

Sense of Timing. This involves judgment as to which deadline needs to be met. It also means acceptance of the fact that a 70% job available a half-hour before a meeting is usually better than a 100% job a half-hour after the meeting. One of the most important aspects of providing support to management is providing it when needed. As an analyst, you need to be willing to take the risks involved in providing something less than a completely satisfactory product in time to do some good. This is a matter of accepting the goals involved in the overall purpose of the work rather than taking particular pride in any individual piece of the total effort.

Common Sense and Good Judgment. A requirement for these characteristics is inherent in any responsible job. It is implied in all of the above points. The need for common sense and judgment becomes especially important when guidance is inadequate, when there is not enough time to meet all requirements, or when dealing with matters which have become emotional issues. In much of our work, all three of these factors are present.

General Comment on Qualifications

No mention has been made on academic training. Over the years, I have worked with many excellent analysts, and I am not aware of any particular correlation of specific types of education and success in budgeting. Some accounting and management courses are probably desirable, if not taken too seriously. In programs such as space or defense, some background in science and engineering can be helpful. Training in written and oral communication has value. In general, I believe successful performance in the academic and work environment is more important than any specific training.

Programs, Projects, and Headaches

by Homer Newell

Former Chief Scientist, NASA
(from his 1981 book Beyond the Atmosphere)

As with its predecessor, the National Advisory Committee for Aeronautics, NASA's principal technical strength lay in the field centers. At the time of the metamorphosis into an aeronautics and space agency, NACA had three principal centers: the Langley Aeronautical Laboratory near Hampton, Virginia; the Ames Aeronautical Laboratory at Moffett Field, California; and the Lewis Flight Propulsion Laboratory in Cleveland. In addition there was a High Speed Flight Station at Edwards Air Force Base in California and a small rocket test facility on the Virginia coast at Wallops Island. The first four of these became under NASA the Langley, Ames, Lewis, and Flight Research Centers, the research orientation of which Deputy Administrator Hugh Dryden was so desirous of protecting. Wallops Station was assigned primarily to the space science program.

To the former NACA installations, NASA added six more: the Goddard Space Flight Center in Greenbelt, Maryland; the Jet Propulsion Laboratory in Pasadena; the John F. Kennedy Space Center at Merritt Island, Florida; the George C. Marshall Space Flight Center in Huntsville, Alabama; the Lyndon B. Johnson Space Center (which for many years was known as the Manned Spacecraft Center) in Houston; and, briefly, an Electronics Research Center in Cambridge, Massachusetts, which was transferred to the Department of Transportation. A sizable facility for testing large rocket engines was established in Mississippi not far from New Orleans and placed administratively under Marshall, which had prime responsibility for the Saturn launch vehicles used in the Apollo and Skylab programs. The Jet Propulsion Laboratory and Marshall were transferred to NASA from the Army; the others were created by NASA. As its original name suggests, Johnson was in charge of the Mercury, Gemini, and Apollo spacecraft and most of the research and development was related to those programs. Kennedy, originally the Launch Operations Directorate of Marshall, provided launch support services for both manned and unmanned programs, but the former required by far the greater capital investment and manpower. Both Goddard and the Jet Propulsion Laboratory were principal centers for the space science program, the former for scientific satellites, the latter for planetary probes.

Management at headquarters guided the space program, directed the overall planning, developed and defended the budget for the agency, and fostered the kinds of external relations and general support that the space program needed. In a very real sense headquarters people labored at the center of action where the political decisions were made that permitted the space program to proceed. Yet the story of headquarters activity is mostly one of context, of background--essential, indispensable, but background nevertheless--against which the actual space program was conducted. Research, the essence of the space science program, was done by scientists at NASA centers, in universities, and at private and industrial laboratories.

It follows that the mainstream of space science must be traced through the activities of these institutions. With occasional exceptions, like the upper atmospheric research of the Geophysical Research Corporation of America and the pioneering work of American Science and Engineering in x-ray astronomy, the contribution of industry was more to the development and flight of space hardware than to conducting scientific research. It remains, then, to take a look at the part played by the NASA centers.

The principal space science centers were the Goddard Space Flight Center and the Jet Propulsion Laboratory (JPL being operated by California Institute of Technology under contract to NASA). Wallops Island, which for a time was placed administratively under Goddard, provided essential support to the sounding rocket and Scout launch vehicle programs. But not all NASA space science was done at these centers. The Ames Research Center managed the Pioneer Interplanetary probes and took the lead in space biology and exobiology--a term coined to denote the search for and investigation of extraterrestrial life or life-related processes. Langley had responsibility for the Lunar Orbiter and later the Viking Mars probe. Most notable was the lunar research fostered by Johnson in the early 1970s with the samples of the moon and other Apollo lunar data, which for a time made Houston a veritable Mecca for lunar scientists. But Apollo lunar science was an exception generated by the special nature of the manned lunar exploration program; and, generally, Dryden's policy stood in the way of more than a limited participation of the research centers in space projects.

Over the years the NASA centers built up an enviable reputation of success on all fronts, in manned spaceflight, space applications, and space science. In the last mentioned, by 1970 Goddard had flown more than 1000 sounding rockets, more than 40 Explorer satellites, 6 solar observatories, 6 geophysical observatories, and 3 astronomical observatories, most of them successfully. In applications Goddard enjoyed comparable or better success rates with weather and communications satellites. The experience of the Jet Propulsion Laboratory was similar. By the end of the 1960s JPL had sent 3 Rangers and 5 Surveyors on successful missions to the moon and dispatched 5 Mariners to Mars and Venus. These achievements are bound to be recounted repeatedly and will rightfully be judged as success stories. Success, however, was not bought without a price of some mistakes, temporary failures, and occasionally severe personal conflict, which form an instructive part of the total history. In reviewing the struggles and problems that preceded the achievements, a proper sense of perspective is important, for troubles often tend to magnify themselves in the eye of the beholder. The difficulties were, after all, overcome in the ultimate successes that were achieved. Still, as part of the total story, perhaps as illustrating the natural and usual course of human undertakings, those difficulties are important to the historian. They should also be instructive to later managers. Thus, without at all deprecating their splendid achievements, it is appropriate to delve briefly into some of the trials endured by the Goddard Space Flight Center and the Jet Propulsion Laboratory.

The Character of the Field Centers

The different centers in NASA had distinctive personalities that one could sense in dealing with them. As might be expected the former NACA laboratories kept as NASA centers many of the characteristics they had acquired in their previous incarnation. One trait was the fierce organizational loyalty that had been displayed as part of NACA. Thus, while officials at those centers were convinced that the real power of the agency lay in the centers and felt very strongly that they should have some voice in formulating orders, and also that once given an assignment they should be left alone to carry it out, they also recognized that the ultimate authority lay in headquarters. Given marching orders, they would march much as ordered.

The new centers in NASA had their difficulties in this regard, to varying degrees. The Marshall center reflected the background and personality of its leader, Wernher von Braun, and his team of German rocket experts. Bold, with a bulldog determination, undaunted by the sheer magnitude of a project like Saturn, they could hardly be deterred by request or by command from their plotted course. The effort to superimpose the Juno space science launchings and the Centaur launch vehicle development on the Marshall team, when Saturn represented its real aspiration, simply did not work out. The Juno launchings had to be canceled after a string of dismal failures, which space science managers in headquarters felt was caused by lack of sufficient attention on the part of the center. Centaur, in the midst of congressional investigation into poor progress, was reassigned to the Lewis Research Center. The Manned Spacecraft Center developed an arrogance born of unbounded self-confidence and possession of a leading role in the nation's number-one space project, Apollo. A combination of self-assurance, the need to be meticulously careful in the development and operation of hardware for manned spaceflight, plus a general disinterest in the objectives of space science as the scientists saw them, led to extreme difficulties in working with the scientific community. But the art of being difficult was not confined to the manned spaceflight centers. In this both the Goddard Space Flight Center and the Jet Propulsion Laboratory were worthy competitors. So, too, was headquarters, for that matter.

The Goddard Space Flight Center's collective personality stemmed from its space science origins. As the first new laboratory to be established by

NASA, Goddard inherited most of the programs and activities of the International Geophysical Year, like the Vanguard satellite program and the Minitrack tracking and telemetering network. Also, many of the scientists and engineers of the Rocket and Satellite Research Panel and the IGY sounding rocket and scientific satellite programs joined Goddard to make up, along with the Vanguard team, the nucleus out of which the center developed. These origins indelibly stamped Goddard as a space science center, even though science accounted for only about one-third of the laboratory's work (and by the nature of things, most of that effort went into the development, testing, and operation of sounding rockets, spacecraft, and space launch vehicles required for the scientific research). In actuality only a small fraction of the Goddard Space Flight Center's personnel was engaged in space science research. Nevertheless, the presence of those persons in key positions, which they came to fill as charter members of the laboratory, imparted to the center a character that accounted simultaneously for its success in space science and for many of the difficulties experienced with upper levels of management.

As professional scientists, these persons were by training and experience accustomed to deciding for themselves what ought to be done in their researches. While subjecting themselves to a rigorous self-discipline required to accomplish their investigations, they nevertheless approached their work in a highly individualistic manner. They questioned everything, including orders from above. While they could and did work effectively as groups, their cooperation included a great deal of debate and free-wheeling exchange on what was best to do at each stage. To trained engineers in NASA--for whom a smoothly functioning team, accepting orders from the team leader as a matter of course, was the professional way of going about things--the seemingly casual approach of the Goddard scientists looked too undisciplined to work.

The Goddard scientists had also been accustomed to determining their own objectives and pacing themselves as they thought best. The accomplishment of an experiment that produced significant new information was what counted; costs and schedules were secondary. That a project took longer to carry out than had originally been estimated was of little consequence so long as the project succeeded, particularly if the additional time was put to good use improving an experiment and ensuring success. This peculiarly science-related sociology of the space scientists at Goddard reinforced the tensions that naturally come into play between a headquarters and the field in large organizations, and led to a major confrontation in the mid-1960s.

Field Versus Headquarters

Headquarters and field in any effective and productive organization support each other, working as a team in the pursuit of common goals--those of the organization. Yet many aspects in even the most normal of headquarters-field relationships serve to pit one against the other at times. When circumstances exacerbate those normal centrifugal tendencies, serious trouble can arise. To understand the nature of the problem, a few words about the difference in headquarters and center jobs in a technical organization like NASA are in order.

At the heart of the difference is the matter of programs and projects. The raison d'etre of an agency is reflected in its various programs, where the term program is used to mean a long-term, continuing endeavor to achieve an accepted set of goals and objectives. NASA's overall program in space included the exploration of the moon and the planets, scientific investigations by means of rockets and spacecraft, and the development of ways of applying space methods to the solution of important practical problems. Each of these programs could be, and when convenient was, thought of as a complex of subprograms, such as a program to develop and put into use satellite meteorology, a program to improve communications by means of artificial satellites, or a program to investigate the nature of the cosmos. Barring an arbitrary decision to call a halt, one could foresee no reason why these programs, including the subprograms, should not continue indefinitely. Certainly, if past experience is a good indicator, the effort to understand the universe must continue to turn up new fundamental questions as fast as old ones are answered. As for exploration, the vastness of space, even of that relatively tiny portion of the universe occupied by the solar system, is so great that generations could visit planets and satellites and still leave most of the job undone. And it would be a long while before diminishing returns would call for an end to applications programs.

Unlike a program, a project was thought of as of limited duration and scope, as, for example, the Explorer II project to measure gamma rays from the galaxy and intergalactic space. A program was carried out by a continuing series of projects, and at any given time the agency would be conducting a collection of projects designed to move the agency a number of steps toward the agency's programmatic goals and objectives. The Explorer II *project* contributed to the *programmatic* objective of understanding the universe by determining an upper limit to the rate of production of gamma rays in intergalactic space, which eliminated one candidate version of the continuous creation theory of the universe.

A project like a sounding rocket experiment might be aimed at only a single specific objective, last only a few months or a year, and cost but a few tens of thousands of dollars. Or a project could require a series of space launchings, many tens or even hundreds of millions of dollars, and take years to accomplish. The Lunar Orbiter, with five separate launchings to the moon, and the Mariner-Mars project that sent two spacecraft to Mars in 1971 were examples. Some projects were huge in every aspect, as was Apollo. In fact, because of its size and scope, Apollo was more often than not referred to as a program, although more properly Apollo should be thought of as a mammoth project which served several programs, among them the continuing development of a national manned spaceflight capability, the exploration of space, and the scientific investigation of the moon.

With these definitions of program and project in mind, one can describe rather simply the difference between headquarters and center jobs. Headquarters was concerned primarily with the programmatic aspects of what NASA was up to, whereas the task of the centers was mainly to carry out the many projects that furthered the agency's programs. The distinction is a valid but not a rigid one. Occasionally headquarters people participated in project work, but this was an exception to the general rule. The most notable exception was Apollo, the size and scope of which were such as to make the administrator feel that the uppermost levels of management for the project should be kept in Washington. Nevertheless, the prime task of headquarters, working with the centers and numerous outside advisors, was to put together the NASA program, to decide on the projects best designed at the moment to carry out the program and assign them to the appropriate centers for execution, and to foster the external relationships that would generate the necessary support for the programs and projects. As an essential concomitant to programming, much time was occupied in preparing budgets, selling them to the administration, and defending them before Congress.

Also, each center, while project-oriented, had its center programs toward which the center directed its own short- and long-range planning. Thus, the research centers conducted programs of advancing aeronautical and space technology. In addition to a program of space science, the Goddard Space Flight Center pursued extensive programs of space applications and space tracking and data acquisition, with tracking and acquisition occupying almost 40 percent of the center's manpower. Unmanned investigation of the solar system was the Jet Propulsion Laboratory's principal program.

Although the qualifications should be kept in mind to have the correct picture, nevertheless the main distinction between the responsibilities of headquarters and those of the centers is clear. Center personnel members were primarily occupied with project work, while headquarters people spent--or should have spent--their time on program matters. That is where difficulties arose, for numerous pressures drove headquarters managers to get involved in project or project-related work. Such actions could only be regarded by a center as undue interference from above.

Naturally, NASA space science managers were vitally interested in what was happening in the various space science projects. They were responsible for proper oversight. But there was more to it than that; project work was where the action was. That was where interesting problems were being attacked and where exciting results were being obtained. Alongside project work, programmatic planning often seemed like onerous drudgery. As a consequence oversight tended to degenerate into meddling, to the distress of project managers and center directors. Even when headquarters managers took pains to couch their thoughts in the form of mere suggestions, their positions in headquarters made suggestions look more like orders. That program chiefs in headquarters occupied staff, not line, positions often was lost sight of in the shuffle, and some headquarters managers became adept at wielding what amounted in practice to line authority.

To this natural tendency to get into the act were added the pressures of the job. As the NASA program grew in size, scope, and expense, upper levels of management demanded more and more detail on schedules, costs, and technical problems. Nor was the demand for information confined to NASA management. Becoming increasingly familiar with the programs and their projects, the legislators also demanded what seemed an impossible amount of detail, either to provide while still getting the job done or for the Congress to assimilate. On the science side, members of the authorizing subcommittee in the House, under Chairman Joseph Karth of Minnesota, frequently concerned themselves with the details of engineering design decisions and were not loath to second-guess space project engineers on matters that seemed to NASA people to lie beyond the competence of the legislators to judge. An example of this searching interest was furnished by the investigation of the Centaur liquid-oxygen and liquid-hydrogen fueled rocket stage which Karth's subcommittee undertook in 1962. NASA and contract engineers found it difficult to defend the propellant feed system which they had chosen and which could be shown to be most efficient for a rocket the size of Centaur, against a different system for which the committee expressed a preference and which admittedly would likely have more growth potential.

Because of this increasing demand for information of various kinds, headquarters in turn demanded of the centers the detailed reporting that centers felt was appropriate for project managers but went far beyond what headquarters really needed. While program managers were willing to concede that the information they were calling for was more than they ought to need, yet they were caught in the middle; to do their jobs as circumstances were shaping them, they did need the data. They were forced, therefore, to insist, and the extensive reporting required, with its implied involvement of headquarters with what were strictly center responsibilities, remained as a continuing source of irritation.

The irritation transferred to headquarters when centers were late or deficient in their reporting, especially when a center simply refused, sometimes through foot dragging, sometimes in open defiance, to supply the information requested. A center might be reluctant to respond when it felt that the request was premature, that the data were not yet properly developed, and that the center might later be called to task if the information supplied prematurely turned out to be incorrect.

A related source of irritation arose in connection with the center's management process. At almost any time throughout the year a program manager might be called upon to furnish information about projects in the program. It was essential, therefore, to be continuously aware of the status of projects which might have to be reported. For this it was not enough to rely on written reports which came only so often. In addition, space science program managers kept in close touch with the project managers and attended many of the meetings held by the project managers with their staffs and with contractors' representatives. This practice came to be a particularly sore point with the management of Goddard Space Flight Center.

Strains on the Family Tie

The Goddard Space Flight Center and NASA Headquarters, only half an hour's drive apart, were connected by close ties. Between the two staffs, many personal associations dated from the days of the Rocket and Satellite Research Panel and the sounding rocket and satellite programs of the International Geophysical Year. An easy relationship existed from the very start of the center. John Townsend--who served as acting director of the center until the permanent director, Harry Goett, formerly of NACA's Ames Aeronautical Laboratory, took over--had been associated with John Clark and the author at the Naval Research Laboratory. For many years Townsend had been the author's deputy in the NRL's Rocket Sonde Research Branch. Harry Goett and Eugene Wasielewski, whom Goett brought into Goddard as associate director, had long been acquainted with Abe Silverstein from the days of the National Advisory Committee for Aeronautics. These friendships served to mitigate the divisive forces between headquarters and field, but were not enough to avert an ultimate break.

Harry Goett assumed the directorship of Goddard in September 1959. As was his nature he quickly entered personally into every aspect of the center's work. From his first day until he left, he kept in close touch with every project. As an untiring battler for the center and his people, Goett endeared himself to his coworkers. He was a warm, emotional person who showed a deep interest in the men and women working for him, and on both sides a deep affection developed.

In the first weeks and months of NASA's planning for its program, many center people had been drawn into headquarters working groups to help get things under way. But as center project work grew, these assignments, which tended to persist, began to interfere with center duties. Finding Goddard people still working on headquarters tasks a year after NASA's start, Harry Goett began to protest that his personnel should be relieved as fast as possible of these additional duties. On the other hand, center people's taking part in headquarters planning was advantageous to the center. Both organizations tried to keep center participation within reasonable bounds.

As Goett, Townsend, and their people built up Goddard and launched their initial projects, program managers were developing their own methods of keeping themselves and their superiors informed. Simultaneously the Congress was increasing its demand for detailed information, which it was incumbent on headquarters to supply. As the requirements for reporting increased, project managers complained that they were spending too much time with program managers and in preparing reports, time that would be better spent in getting on with the projects. In mounting crescendo, Goett complained to the author and his deputy in the headquarters space science office, Edgar M. Cortright, that headquarters managers were getting in the way of center management. Goett urged that headquarters people keep their hands off project management.

While agreeing in principle with the Goddard director, Cortright and the author strove to get him to see that in the existing climate of continuing congressional scrutiny, keeping informed was an important part of headquarters work. That, space science management insisted, was an absolutely essential part of the program manager's job, but not to usurp the project manager's duties or to interfere with other work. Cortright and the author urged upon their people great care in working with the project managers to avoid any kinds of action that would undercut, or appear to undercut, the project manager's responsibilities and authority. It was no advantage to the program for any project managers to feel that responsibilities had been in any way lifted from their shoulders.

Headquarters was far from Simon pure in these matters, unfortunately, and there was considerable justice in Goett's complaints. The natural urge to meddle plus the incessant pressure to keep informed led many program managers to get into the project business. Sometimes this led to strong adversary relations between program and project managers; at other times to close "buddy-buddy" relations. Both situations caused problems for center management and called for continuing attention.

By the fall of 1962, Goett found the situation so disturbing that he felt impelled to complain openly at a NASA management meeting held at the Langley Research Center that headquarters got too much into projects and should stick to program management. His barbs were aimed not only at space science managers, but also at those responsible for applications programs and for tracking and data acquisition. He felt that there was not enough contact between the center director and the associate administrator. Goett also felt he did not have enough contact with the author. The last complaint stemmed from the mode of management the author had adopted, about which a few words are in order.

Being a scientist, the author felt it wise to name as deputy an engineer whose training and experience would complement his own. Edgar M. Cortright, an aeronautical engineer with considerable research experience in the National Advisory Committee for Aeronautics, filled the bill very nicely. An implication of this philosophy of organization was that the deputy should be more than an understudy, more than just someone to sit in when the principal was away. Rather, the deputy should take responsibility for important aspects of the top management job that came within his sphere of expertise. This was the arrangement agreed on between Cortright and the author. Cortright would handle engineering matters, which meant oversight of much of the project work, dealing with contractors, and a great deal of the relations with the space science centers. The author would work on program planning, advisory committees, and most of the space science program's external relations including those with the Academy of Sciences, the scientific community, and the universities. Such an arrangement had worked well at the Naval Research Laboratory, where John Townsend's engineering and experimental bent had complemented the author's theoretical background. Moreover, in addition to providing the top level of management in the office with talents and experience complementing those of the director, it was an effective way of providing a deputy with substantive work and to continue his professional growth. A deputy with nothing more to do than to wait around for the principal to be away must find life deadly dull, unrewarding, and stultifying.

Under this arrangement, problems of the kind Goett was wrestling with would normally have been taken up by Cortright. But Goett was not willing to deal with a deputy. As director of the Goddard Center--even though the author was meticulously careful to support agreements Cortright worked out--Goett felt that he should deal directly with the principal in the office for which the center was working. Under the circumstances the author took special pains to make it clear that he was available to Goett at any time, yet expressed the hope that Goett would work with Cortright in the normal course of day-to-day matters.

The strain caused by the project-management versus program-management conflict took increasing amounts of time and attention. A great deal of the time spent with Goett was devoted to this problem. John Townsend, Goett's man for space science matters, pointed out that if a program manager had only one project under way in his program, then it became very difficult to draw a line between program and project, and the pressure on the program manager to get into project management was overwhelming. Townsend recommended that programs be put together in such a way that a program manager would have several projects to deal with. Under such an arrangement a program manager could no longer give the single-minded attention required by a project, and should find it much easier to confine himself to program matters. Cortright and the author agreed and tried to avoid single-project programs.

Goett pointed out that it was not just the cases in which program and project managers were at odds that gave trouble. When the two got along well together, often they would team up to promote their project over other projects which the center management--taking into account existing constraints on dollars, manpower, and facilities--might judge to be more appropriate. Thus, program and project managers working hand in glove for their own projects--perhaps to enlarge them or to extend them beyond existing commitments--were not always working for the best interests of the center.

Goett was most disturbed to have program managers, in the name of keeping in touch, attend meetings with outside contractors. Even if the headquarters people came with the determination to keep their mouths shut, contractors' representatives had a penchant for tossing questions to the headquarters representatives, with the implication that that was where the final word would lie. And when headquarters people did volunteer comments, their comments tended to take on more weight than the word of the project manager. These difficulties became even worse when the headquarters man was technically more competent than the project manager--which Goett didn't feel could happen very often. In that case the project manager tended to defer to the headquarters person for decisions and recommendations that the project manager should make personally, and the contractors were easily confused as to who was calling the shots.

Goett's solution to these problems would have been to keep program managers away from project management meetings, and especially away from meeting with contractors. Considering the program manager's basic responsibility to see to the health of the program and the corresponding need to keep informed--a need that was enhanced by the growing amount of attention given by congressional committees to NASA's programs and projects--Goett's solution was not acceptable. Cortright and the author spent a great deal of time trying to get Goett to appreciate headquarters' needs and to agree to some middle-of-the-road way out of the dilemma. A written description was prepared of the distinction between program management and project management, and the author committed himself to ensuring that the program people understood the bounds of their authorities and responsibilities. But the author also insisted that the way be kept open for headquarters people to keep adequately informed. Goett was not satisfied. In a letter to Associate Administrator Robert C. Seamans 5 July 1963, he outlined some of the problems as he saw them. Shortly thereafter, on 26 July 1963, the Office of Space Science and Applications proposed a revision of NASA Management Instruction 37-1-1. In Appendix A were specific definitions of *program* and *project*. The instruction made the point that the headquarters job concerned itself with program matters primarily, while project managers normally were at field centers. On 5 November 1963 the author wrote Harry Goett on the subject of headquarters-center relations. The letter outlined agreements that it was hoped had been reached to keep headquarters people properly informed, without undercutting the center's position with contractors. But matters continued to deteriorate.

Complaints were not confined to the center side. In a talk given to a number of managers of space science and applications projects, at Airlie House near Warrenton, Virginia, the author spoke on relations between program managers in headquarters and project managers in the centers. By giving what was viewed by headquarters people as too much emphasis to the rights and prerogatives of project managers, the author drew forth some howls from the former. On 30 December 1963 the staff of the Office of Space Science and Applications met to discuss relations with the Goddard Space Flight Center. Program people complained that Goddard seemed to be waging a war to keep headquarters at arm's length. It was difficult to find out about contractor meetings in time to attend. Although Goett had stated that headquarters should keep itself informed by means of the reports it received, still Goddard habitually did not turn in reports on time. The center was being too independent in formulating its plans for supporting research; i.e., the general background research of the kind all centers undertook in support of their project work. Program chiefs felt a need to specify reporting requirements for this supporting research, since most of the money for such research came from portions of the budget for which the program chiefs had responsibility. Another complaint concerned Requests for Proposals, documents which centers sent to potential contractors asking for bids on work that the center wanted done. Program people were required to follow the progress of such RFPs through the headquarters paper mill and to assist in expediting their progress. It was important, therefore, for them to keep in close touch with the formulation of the work statements that would go into the Requests for Proposals. Yet the center appeared to be making it difficult for the program managers to keep in touch. The Interplanetary Monitoring Platform project was considered an illustration of the center's intentions in this regard. Since a decision that program people would attend "working group" meetings of projects, Paul Butler, manager of the IMP project, had ceased to hold working group meetings. Instead he held what he called "coordination meetings" with his staff, which headquarters people were explicitly told they were expected not to attend.

While the managers in the Office of Space Science and Applications were most intimately involved in the day-to-day relations with the center, the problems also had the continuing attention of Webb, Dryden, and Seamans. Concerned about overruns and schedule slips in NASA projects, the Administrator's Office noted that many of the bad examples were Goddard's. As general manager of the agency, Associate Administrator Seamans maintained pressure on the Office of Space Science and Applications to correct the deficiencies. Although Seamans had known and worked with Harry Goett since 1948 and admired him very much, Seamans could not accept Goett's insistence that headquarters leave Goddard to its own devices. As Seamans wrote years later:

> . . . it was essential if NASA was to continue to receive Congressional support, that we tighten the management of our projects in order to keep costs and schedules closer to plan. We could not, in the public interest, take it on faith that Harry Goett was doing all that could be done to manage these projects properly. It was necessary for NASA Headquarters to have direct access to a variety of management data as was the case with other NASA centers. I kept Dr. Dryden and Mr. Webb fully informed of the Headquarters/Goddard relationships and of important issues.

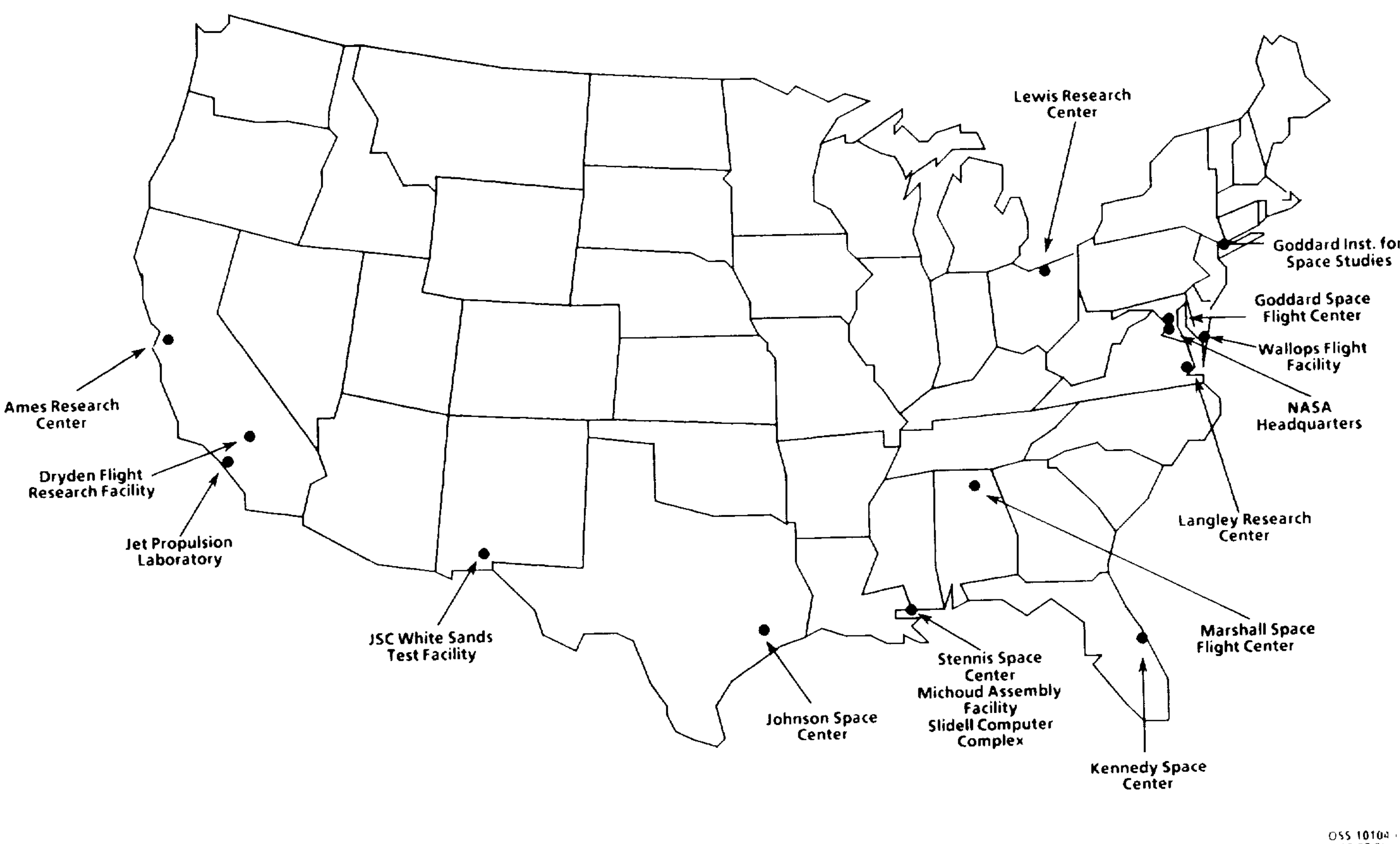
But the problems did not end. Discussions with Goddard management seemed to elicit too much explanation of why it was in the nature of things for schedules to slip and not enough desire to change matters. The Goddard scientists especially could not see why there should be any urgency about adhering to a schedule if additional work would produce a better experiment. As for the experiments, usually there was no reason why they should be done now rather than later, unless of course, they had to be timed to coincide with some natural event. But NASA's record of doing what it said it would do on time and within cost was important to those who had to fight for the agency's appropriations. Schedules and costs were most visible to a carefully watchful Congress, and for years NASA continued to feel that it had to sell itself. Besides, it was just plain good management to estimate costs and schedules correctly and then keep to those estimates.

Whatever opinion the Administrator's Office might have had as to who was the more to blame for the strains caused by projects versus programs, the apparent unresponsiveness of the center on tightening up project management overshadowed the other concerns. Both Associate Administrator Robert Seamans and his deputy, Earl Hilburn, pressed continually for better performance. But when, in a stressful meeting with Seamans, Goett took such a rigid position that he left no maneuvering room for headquarters, the associate administrator decided that Goett had to go. With the concurrence of both Webb and Dryden, on 22 July 1965 Seamans removed Goett from the directorship and replaced him with Dr. John F. Clark, who had been chief scientist in the Office of Space Science and Applications.

It was a traumatic experience for Harry Goett and for others. The author found it a most unpleasant duty to go out to the Goddard Space Flight Center to meet with key managers and inform them that their director was being replaced. Goett was beloved of his people; he had been a conscientious, hard-working, imaginative director, under whose regime the center had achieved most of the space accomplishments of NASA's first few years. Goett himself had played a key role in establishing a productive relationship with the academic community. Those accomplishments were, of course, the real story of the Goddard Space Flight Center, not the struggles over how to manage. It was tragic that Goett's obsession over one concept of headquarters-field relationships--born perhaps of his past experience in the NACA--made him unable to appreciate the new climate in which NASA had to operate. It was unfortunate that the author was unable to work out some accommodation that would have kept Goett at the Goddard helm. Harry Goett's departure was a distinct loss to NASA.

Not having Goett's flair for the controversial, John Clark projected a more pedestrian image for the center. Yet under his administration, Goddard continued its record of successful space science and applications flights. The problems remained, and both center and headquarters had to work continuously to keep them under control. But both sides approached the problems with a better understanding of each other's needs. In short order Clark was telling headquarters where to head in, and headquarters was pressing him to get on with the job of better resource and schedule management.

The difficulties experienced by the Office of Space Science and Applications with the Goddard Space Flight Center occurred in various forms and varying degrees with all the other centers. The task of finding ways for headquarters and field to work together harmoniously and effectively is never ending. Nor is it to be expected that tension between headquarters and field will ever disappear. Should this happen, one or the other will probably not be doing its best job.



Evolution of a Technical Management Organization

by Thomas J. Lee

Deputy Director, Marshall Space Flight Center

To accept that a particular philosophy or system of management is superior or even applicable, it is essential that its basis be identified and understood. To satisfy that objective and to provide some insight into what has and is working in the successful management of projects at the George C. Marshall Space Flight Center (MSFC) we first need to understand the background and evolution of the Center organization and then how major adjustments were made to accommodate the changing objectives. We can then examine specific "lessons learned" from the Spacelab Program, a highly successful, international cooperative program involving the United States and a consortium of 10 European countries.

BACKGROUND

MSFC was formed in 1960 from the nucleus of the Wernher von Braun team which, until it became a part of NASA, had functioned primarily as a propulsion development organization under the "arsenal concept" with the U.S. Army Ballistic Missile Defense Agency (ABMA). This concept was simply that all aspects of design, development, and initial production were under the direct control of ABMA. The concept worked well for limited production of research and development projects. In fact, it was under this concept that the first Redstone and Jupiter missiles and the first stages of Saturn I and IB and Saturn V launch vehicle systems were designed, manufactured, and tested at Redstone Arsenal and successfully launched by the Missile Firing Laboratory, which later formed the core of the Kennedy Space Center organization.

The apparent disadvantage to this concept was that it did not lend itself to high production or to optimum utilization of the U.S. aerospace industry, which was recognized in the early 1960s as essential to meeting the established lunar landing goal within the decade. Thus, the first major adjustment of the MSFC organization was recognized almost coincidentally with its establishment as a part of NASA in 1960. The challenge was to capture the very valuable experience and knowledge gained from in house design and development and to build an industrial management organization around it. The organization that ultimately evolved was not a unique management concept. It was patterned after other programs in which the project or program manager was given full responsibility for managing the available resources and for establishing the proper balance among performance, cost, and schedule. During the Apollo era, the MSFC role was primarily development of all propulsive stages of the launch vehicle systems; therefore, a simplified matrix organization was adequate to accomplish the technical management of the program. The technical capability resulting from the in house efforts of the late 1950s and early 1960s, coupled with a proven systems management approach, contributed significantly to the success of the Apollo program.

The second most important adjustment in the MSFC organization came at the end of the Apollo era. There were no agreed-to plans to build on or even maintain the experienced government and industry manned systems teams destined to become surplus in the late 1960s and early 1970s. This was particularly important to MSFC because its primary focus remained launch vehicle development. The solution encompassed two very important items for any dynamic technical management organization: the ability to (1) reorganize and (2) diversify while maintaining its vitality. Once the decision was made to diversify, detailed planning, both short and long range, was

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essential. The MSFC success in this endeavor came in the recognition that the project management team and the majority of the technical disciplines which had worked well for the Apollo Program were relatively easy to adjust to meet the short-term needs of the Skylab Program. This program, a spinoff of Apollo, was assigned to MSFC for management. The major organization adjustment was to introduce a full matrix organization to accommodate multiple program/project assignments.

The most difficult task was the development of long range plans. MSFC's 1969 reorganization established a major new organizational entity: the Program Development Directorate, chartered to identify the most feasible future program(s) compatible with the Center's technical expertise, and then to ensure the proper skill mix for their accomplishment. At that time, NASA's declining workforce introduced an additional complication in that reductions-in-force at MSFC were the rule rather than the exception.

SPACELAB

One program which gave NASA and MSFC the opportunity to exercise its system of technical management and expand its diplomacy came with the approval of the Spacelab Program, an international cooperative program between the European Space Agency (ESA), representing 10 European countries, and NASA, representing the United States.

The genesis of this program came from the 1969 Space Task Group (STG) report to President Nixon. Two of the STG recommendations concerned a reusable launch system later to become the Space Transportation System (STS); another covered the internationalization of space. These recommendations had a major impact on Marshall. The early concept and definition phase of STS utilization was performed by the newly established Program Development Directorate. This effort identified the need for a manned laboratory to be carried in the orbiter payload bay. The Laboratory would accommodate the experiments, which were to remain attached to the orbiter in low Earth orbit and which would require human interface.

The Europeans joined the Spacelab Program primarily to acquire a manned space flight development capability within the European Space Agency and the European aerospace industry. The basic arrangement was for ESA to manage, at its expense, and to an agreed-to set of requirements, the production and operation of the Spacelab spacecraft. Phases A and B were performed in house by an MSFC-designated task team as part of the NASA Shuttle payload planning and definition effort. The principal drivers of the configuration during the definition phase were Shuttle accommodation (functional and physical interfaces) and user requirements. Both were significant variables throughout the program.

The fact that MSFC had the assignment to gather Shuttle user requirements for NASA provided the opportunity to canvass the U.S. scientific and applications users for their needs, and to synthesize these into a practical set of requirements in the areas of power, data rate, weight, pointing accuracy, volume, cooling, etc. The Shuttle accommodations available to the payload--weight, power, heat transfer, center of gravity (CG) constraints and data capability were utilized to bound the Spacelab system capabilities. Once the initial user requirements and Shuttle accommodations were established, even though both continually changed, the problem facing the Phase B definition effort was to optimize the Spacelab configuration to provide a feasible system with maximum capability for the user. The output of the study came in the form of (1) a preliminary orbiter interface document, (2) preliminary U.S. user requirements which were later integrated with European user requirements, and (3) preliminary Spacelab system specifications. With these, NASA had a good understanding of the program requirements and a skeleton management organization at MSFC and Headquarters. This early program understanding proved to be invaluable through the entire program. When ESA agreed to participate in the program in 1973, the results of all Spacelab-related study efforts were provided directly to the Europeans. MSFC terminated any further system definition studies in order to concentrate the available manpower resources on working with ESA and its contractors.

MSFC's early involvement in Spacelab planning and definition, its experience with manned spaceflight from Skylab, and its long history of large pressure vessel (propellant tanks) design and development made MSFC the logical NASA lead center for Spacelab Program management.

At the beginning of the program, the political planning phase was to some people on both sides of the ocean as important to program success as program technical definition. It is not the intent here to downplay that importance. On the contrary, it proved during implementation and operation to be vital. This planning culminated in two very significant documents: (1) a Memorandum of Understanding (MOU) signed by the respective heads of NASA and the European Launch Development Organization (ELDO), later renamed the European Space Agency, and (2) a country-to-country agreement approved by the U.S. State Department and a representative of the 10 participating European countries.

It was evident that considerable thought and time were spent to make the MOU clear, concise, and easy to understand, yet general enough to allow the implementers flexibility to complete the program without the need to exercise the disputes clause. In fact, the document was so well written that during the development program there was never a disagreement sufficient to warrant changing the document.

IMPLEMENTATION

With such detailed planning, the implementation and development phases would appear to be relatively straightforward. In most programs, a high degree of early planning will minimize the problems commonly found in schedules, cost and performance during the development phase. This was true in Spacelab; however, a new set of variables was introduced in working with the Europeans. First, their industry did not have in place boilerplate standards and specifications for manned systems; these had to be developed. Second, ESA had to translate NASA requirements and specifications into its documentation system, which resulted in a pyramid of very fluid controlling documents, some of which required joint signatures by NASA and ESA. One of the more complex was the Interface Control Document (ICD) for Spacelab and the orbiter, requiring approval by NASA, ESA and the prime contractors for both Spacelab and the orbiter. The complexity was compounded by the Spacelab's dependence on the orbiter for accommodations and the fact that the two programs were being developed in parallel.

MSFC's early detailed planning revealed the requirement for considerable NASA resources to perform the technical evaluation and monitoring necessary to ensure that the overall system requirements and specifications were met, and to perform the operations development planning at KSC, JSC, and MSFC. It came as a surprise to MSFC management when, early in the program, the NASA Administrator questioned the level of effort required by NASA civil servants to technically evaluate and operate what was concluded to be a free Spacelab.

NASA found itself in unfamiliar waters in working with the Europeans, for whom a standard mode of operation is to develop systems through multi-national involvement. The key features of this mode are the geographical distribution of funds to each contributing country in an amount comparable to that pledged to the program and the introduction of the prime contractor and co-contractor rather than subcontractor relationships. These features were new to NASA but not to ESA, and the anticipated shortcoming, i.e., the inability to select the most competent subsystem contractor from each country, was only a short-range concern. Until the program had progressed beyond the critical design reviews, and subsystem and component development was well under way, there was a constant concern that ESA lacked the technical depth and breadth to manage such a large undertaking. MSFC, however, took comfort in the fact that an experience base did reside within NASA and that the ESA management team was dedicated to doing an outstanding job.

If one area had to be identified as a significant concern resulting from NASA's lack of familiarity with the ESA technical management system, it would be the assurance that top level specifications and requirements flowed from the prime contractor to the co-contractor and ultimately to the vendors and suppliers. This included traceability to indicate how and if the requirements and specifications were met. This became a real concern late in the program, when adequate recorded evidence of successful completion of qualification and acceptance testing was sometimes lacking. There was no question on the part of NASA engineers, who had worked closely with ESA and its contractors, that the qualification testing had taken place; it was simply a matter of formally documenting the data. This problem came about because no contractual requirements for formal documentation were placed on the co-contractor by the prime contractor.

One of the first management decisions the Spacelab Program Office made was to maintain heavy MSFC engineering involvement from the beginning to the end of the program. This involvement was used to generate and approve all technical requirements in a way that the engineers felt accountable for the technical performance of the Spacelab system even though the overall responsibility resided with the program manager. With the exception of propulsion, all MSFC technical disciplines were involved.

OPERATION

When the time came to provide the manpower resources, there were three alternatives: (1) utilize civil servants, (2) contract with a European contractor, or (3) contract with a U.S. aerospace firm. Using civil servants was not practical. Contracting with the European Spacelab contractor clearly had positive points; however, when long-term cost implications of retaining a foreign contractor in this country, not to mention that the only past experience in the required mission integration and launch operations resided in this country, the decision to contract with the U.S. aerospace industry came easily. The contract was written with two schedules, one to include launch operations and integration activities managed by KSC, and the sustaining engineering and hardware control administered by MSFC. The intent of the latter schedule was to phase down the MSFC civil service personnel from a peak during the development phase as the contractor came on board and the operations were well defined. This was accomplished as planned. The program was well into development when it was recognized that an organizational interface with the user community independent of the program office responsible for the design and development should be established at MSFC. This organization (Payload Project) would ensure that the user requirements were properly considered and ultimately satisfied where practical. The new organization reported to the center director, as did the Spacelab Program Office, and assumed the very significant role of payload mission planning and experiment analytical and physical integration. The efforts of this organization led to the establishment of the payload and mission specialists training facility and the Payload Operations Control Center (POCC) at MSFC. The Spacelab payload mission successes can be attributed more to this organization than to any other single organization in NASA. This organization and mode of operation will be used as a model for the Space Station Freedom Program.

CONCLUSION

MSFC's approach to project management and organizations has changed over the years, first to develop a project management capability and then to adapt to multiple projects utilizing a matrix approach. The center weathered this to become a very competent well-balanced research and development organization with flexibility to adjust to the nation's future space policy.

Building and maintaining such an organization demands the constant attention of the entire management structure. Even though it is not practical or feasible to establish a detailed set of standards and procedures to be used by each manager and supervisor, there are a number of common groundrules which allow any organization to function efficiently and effectively. The following are a few of the more important groundrules that have proven to be helpful to MSFC:

(1) Emphasize the planning phase as the most important part of any program. The more detailed the program plan, the better it is understood, and the more likely it is to be successful. Proper organizational placement and competence levels are essential.

(2) Develop and maintain an in house technical capability through the careful selection of in house projects and the recognition of the skills required for future programs.

(3) Establish a good understanding with Headquarters concerning what is expected of the Center. This should be done on a project-by-project basis.

(4) Require substantial involvement by the technical discipline from the planning phase through development and operation, but ensure that overall program responsibility (cost, schedule and performance) remains with the program or project manager.

(5) Establish a Center strategic plan which is understandable, realistic, and communicates to every person at the Center his or her respective role.

To manage a complex technical program through a matrix organization with involvement from other development and/or operation centers demands constant attention to detail and involvement by all levels of center management. The concept of armchair management, where the majority of the manager's time is spent in the management information control center concerning himself or herself only with cost and schedule, has not been acceptable in the past nor is it an acceptable mode for the future of NASA.

The Program and Project Management Training and Development Initiative

by M. Peralta

NASA Associate Administrator for Management

After the Challenger accident, a study team headed by General Sam Phillips conducted an assessment of NASA's management practices. The team, known as the NASA Management Study Group, conducted its review and prepared a report for the Administrator. A major recommendation was that NASA "institute formal training and development program(s) for program/project managers."

This recommendation confirmed a similar one that came from two project management workshops conducted in 1975. That recommendation resulted in the development of the Project Management Shared Experiences Program (PMSEP). The one-week PMSEP is an excellent interactive seminar, but it is limited in size and scope and cannot fulfill all of the agency's requirements.

The first step in implementing the Study Group's recommendation was to conduct an in-house requirements and feasibility study. This study, completed in October 1987, reached the following conclusions. First, the management of NASA programs and projects is becoming increasingly complex, and the demand for trained and experienced personnel is increasing as the available pool is being depleted. Second, in addition to our traditional programs and projects, we now have training and development requirements for people involved in research, facilities, and information systems activities that must be managed as projects. And last, the total population contained in these groups is approximately one-third of the NASA civil service workforce.

To assist in developing NASA user requirements, the study manager relied heavily on the project management knowledge, skills, and experience data developed at a Program and Project Management colloquium held at Wallops Flight Center in 1980. In addition to this most valuable data, interviews were conducted and a questionnaire was administered to approximately 125 NASA employees attending agency development programs.

At the same time, we looked at what industry and the Department of Defense were doing. We collected in-depth information from 11 aerospace and non-aerospace companies. We visited the Defense Systems Management School at Ft. Belvoir, Va., and also examined the many other excellent DoD programs. In brief, we found the following:

- There are no quick fixes or magic bullets.
- There is a concentration on on-the-job training combined with formal training.
- Advanced degrees are common and frequently encouraged.
- Time in training varies from weeks to years.
- Contractors and universities are frequently used to design, develop, and deliver training programs.
- The average time in the project management cycle, from entrance to project manager, is about 15 years.
- There are similarities in curriculum content.
- There are a number of readily available project management training sources on the market; however, they vary widely in applicability and quality.

We completed our study with a look at several university degree programs and an examination of what field centers were doing to train program and project management personnel. Although many centers offer short-term training opportunities, there is no comprehensive, requirements-driven program in place in NASA.

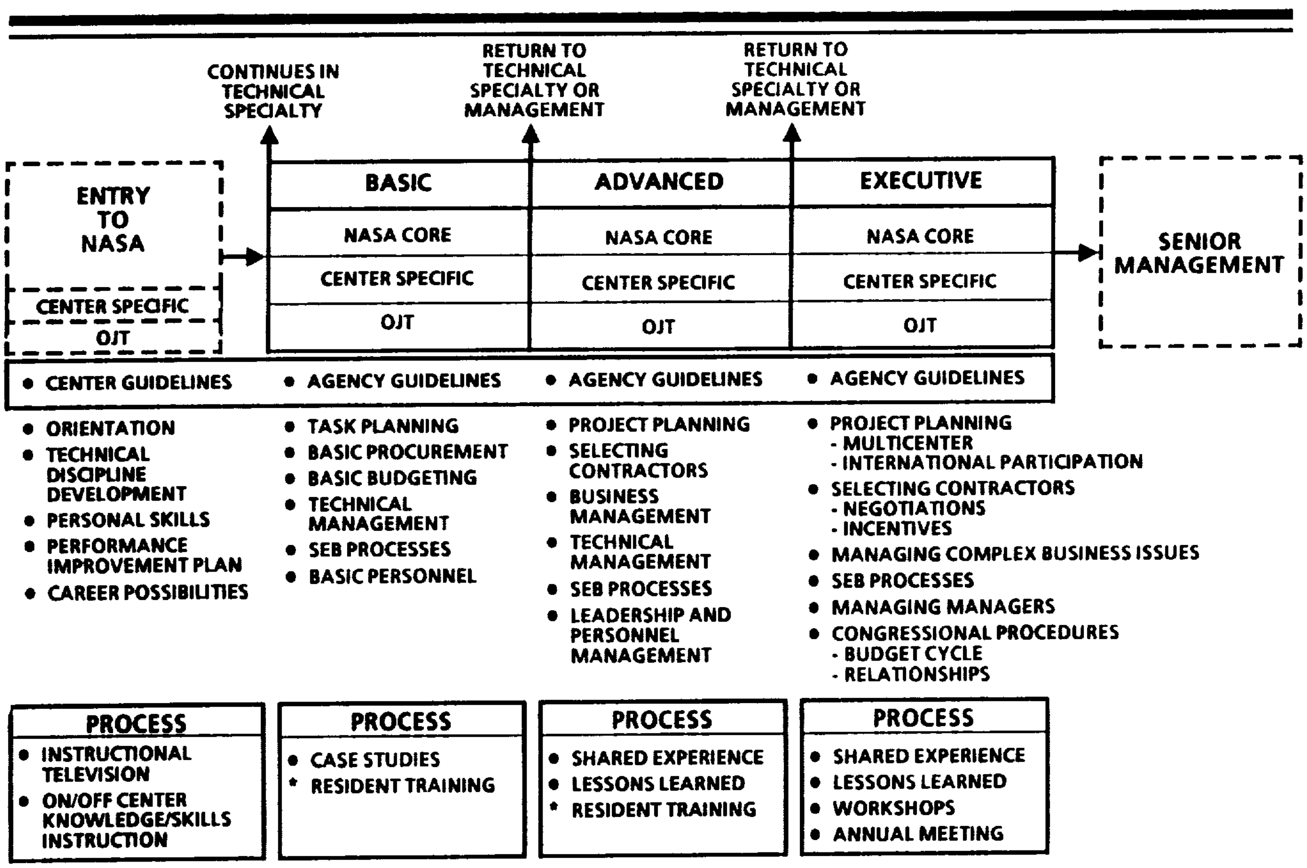
All of these findings were reported to the NASA Program Project Management Steering Group. This group, established in 1984, consists of members from the field centers and Headquarters program offices who have broad knowledge and experience in program and project management. The Group assists NASA management by providing a focus, although somewhat limited, for this most important function. The group has been active in reestablishing the Project Management Shared Experiences Program, has provided input to the Phillips Study Group, and advises management on appropriate NASA Management Instructions (NMIs).

The Steering Group accepted the study findings and tasked the study manager with developing a NASA training and development model complete with curriculum. A working group of the committee was appointed to assist. After three iterations, we have agreement on the model shown below.

Some important features of this model are:

- A commitment to training and development at any point in the cycle
- A partnership between the field centers and NASA Headquarters in the design and delivery of core curriculum
- Where practical, informal career paths and development plans will be used
- Training consists of knowledge and skills
- A modular design will be employed
- An employee may enter or exit the cycle at any appropriate level

PROGRAM/PROJECT MANAGEMENT INITIATIVE
NASA MODEL FOR DEVELOPMENT AND TRAINING OF PROJECT MANAGEMENT PERSONNEL



The working group also spent much time developing the core curriculum for the Advanced Project Management Course. It was decided to concentrate on this level due to a pressing need in this area. The core curriculum includes program/project planning, business management, technical management, acquisition reviews, and lessons learned. The first offering of the Advanced Project Management Course occurred in October 1988. Pilot courses in systems engineering and program control were offered this past summer.

In addition to training courses, a number of related activities were also undertaken. It is widely agreed that we must build on our past experience in managing programs and projects. To do this we must collect and disseminate the lessons learned and shared experience of past and present management teams. A pilot lessons-learned videotape is presently being prepared. Using the "lessons learned" from this pilot, we hope, with the cooperation of the NASA Alumni League, to document our experiences from Apollo to the present. We also plan to use live interactive television productions to deliver issues of interest to our program and project management workforce. We will soon establish a pilot computer network that will give us the potential for electronic mentoring. This publication, Issues in NASA Program and Project Management, is a direct result of our intention to capture and pass on our heritage and culture in the hope that some of this information will be of direct and immediate benefit to our workforce.

Our workforce is key to the agency's success, and this requires a highly motivated and competent staff. This is particularly challenging today because of the growing complexity of the agency's activities. As a result of the program/project management initiative, the agency has underscored its commitment to providing the very best training and development for our program and project workforce as well as providing them with the tools they need to meet the future challenges associated with the NASA mission.

Resources

Weekly Online Update Tool for Managers

Did you know that there is a weekly current awareness service entitled Managers on NASA/RECON? Are you interested in new developments in space commercialization, Congressional and legislative reports, new business methods and trends, research and development programs, and many more timely subjects?

Every Monday morning a list of twenty citations (including books) is compiled. Items of interest to managers and administrators of NASA Headquarters, NASA Centers, and NASA Contractors are selected for pertinence to NASA's mission, management, and foreign technology exchange.

Any NASA/RECON user may utilize the service by executing the Managers stored search from within File Collections A, B, D, N, O, and P, as follows:

QUERY EXECUTE MANAGERS (NAHQ).

Once the stored search has ceased execution, simply use the DISPLAY, BROWSE, or TYPE command to review the results.

Some of the subject areas covered by the weekly service are:

- Current aerospace technology on present and future NASA space missions, including aerospace medicine.
- Technologies of the European space programs as well as those of the U.S.S.R. and Japan.
- New management methods, business trends, and policies concerning procurement, financial, contract, personnel, and research management.
- Congressional and legislative reports, Federal budgets, and appropriations of the NASA programs.
- New developments in database management systems.
- Current reports on international trade, market research, and economics.
- Current research in artificial intelligence, expert systems, and robotic technology.
- Current technology transfer, assessment, and utilization.
- Current reports on international relations, cooperation, and space law.

Project Management: A Systems Approach to Planning, Scheduling, and Controlling, second edition, by Harold Kerzner, 1984. Van Nostrand Reinhold Co., New York.

Since his first edition just 10 years ago, Dr. Kerzner, a professor of systems management at Balwin-Wallace College and president of Cleveland-based Project Management Associates consulting firm, has expanded his college-level textbook to 937 pages. As a textbook, it contains a couple of final exams (multiple choice), 332 discussion questions, and 42 case studies. As a resource for managers and executives, it suffers from a thin and faulty index, making it difficult to look up needed information quickly. Nevertheless, the book is of value to those who desire a lengthy and broad overview of project management, as well as useful tips and ideas for management problem-solving. It is the leading book in a narrow field.

Resources

While NASA defines a program as a related series of efforts which continue over a long period of time, designed to pursue a broad scientific or technical goal, and a project as a defined, time-limited activity with clearly established objectives and boundary conditions executed to gain knowledge, create a capability or provide a service--this book uses the terms interchangeably in the index and rarely mentions program management in the text. Instead, the author creates a hierarchy of line managers who answer to the project manager who in turn answers to a functional manager or executive. Thus, his gag definition: "Project management is the art of creating the illusion that any outcome is the result of a series of predetermined, deliberate acts when, in fact, it was dumb luck."

Dr. Kerzner traces the concept of project management to its birth in the 1960s in aerospace, defense and construction, maintaining that the concept took off in the early 1980s and is the wave of the future in management techniques. Complexity and diversity set in during the late 1960s, forcing some companies to accept project management reluctantly. However, the real breakthrough came in 1970 when "NASA and the Department of Defense 'forced' subcontractors into accepting project management."

Likewise, the textbook is built around systems theory as opposed to other traditional or more conventional management theory. Management-by-objectives, for examples, places too much emphasis on the end item or goal, with little regard for people. Behavioral theory emphasizes human relations (person and job) or social relations (cultural relationships which involve social change). Decision theory, on the other hand, is too rational, using mathematical or scientific models. The empirical school of thought emphasizes the study of experiences of other managers, but all too often, situations are not similar. That leaves systems theory, which, in this text, is part and parcel of project management.

"Project management utilizes the systems approach to management by having functional personnel (the vertical hierarchy) assigned to a specific project (the horizontal hierarchy)," Dr. Kerzner says in his definition which guides the text. The systems approach is not clearly defined, roughly "a group of elements (that) can act as a whole toward achieving some common goal, objective, or end." More specifically, one of the hundreds of charts in the text indicates that the systems approach starts with an objective shaped by constraints, which is broken into requirements and then alternatives, leading to trade-offs (in terms of cost, time, performance or policy).

The first attempts to mark the boundaries of systems, programs and projects are attributed to the U.S. Air Force and NASA, but the text does not cite sources or indicate when such distinctions were made. Essentially, the text views project management as a "coordinative" function and matrix management as a "collaborative" function. Problems result when there is dual accountability between project manager and functional manager, and when there is a difference of opinion. Thus, in a matrix organization, the project manager "must continually negotiate," calling for interpersonal and communication skills.

The book does seem to indicate that a modified matrix organization is superior to both a pure functional structure and a pure product organizational structure, especially for labor-intensive projects, but not capital-intensive ones.

Project management does have a downside, the author notes. The main risk, observed in missile and space programs, is falling in love more with job than family. You know if you are to the edge if you take work home or on vacation. You know if you are over the edge if you consider 5 p.m. as the working day half over, or if you come in Friday and realize there are only two more working days until Monday.---WML

Project Management Handbook, edited by David I. Cleland and William R. King, 1983. Von Nostrand Reinhold Co., New York.

Although this "handbook" bills itself variously as a reference guide and how-to manual, it is really a collection of articles clustered around certain themes such as life cycle management and project planning.

Most of the 35 articles come from college professors of management, and more from the University of Pittsburgh than any other college. David Cleland is a professor of engineering management there, and William King is a professor of business administration there also. Five articles are co-authored, including one by Cleland and King on linear responsibility charts.

Two of the best articles in this book are from Fred Holenbach of the Bechtel Power Company. In one, he discusses project control at Bechtel in a no-nonsense, step-by-step manner. In the other, he outlines the advantages and disadvantages of the matrix approach, concluding simply: "The success of a project manager is measured by client satisfaction as a result of getting the job done on time and within budget."

Other articles, especially from the academics, are more esoteric. Readers who do not understand stochastic network analysis or cultural ambience may not even attempt articles with such terms in the titles. Technical terms and complex charts abound in this book which claims to be more pragmatic than theoretical.

Admittedly missing in this "handbook" are chapters on configuration management and value engineering, which the editors describe as "parochial interests," yet regarded as important in the aerospace industry.

In 724 pages, only four references to NASA are listed in the index, most of them clustered in a section called "The Successful Application of Project Management." One article in this section seems to be based upon a 1974 study by Murphy, Baker and Fisher on "Determinants of Project Success," sponsored by NASA (NGR 22-03-028). Actually, there are other references to NASA in this book, despite the index. The very first chapter, for example, tells how General Phillips came into the Apollo Program in 1963 and created one of the first successful matrix organizations, with 120 persons at the headquarters program office managing upwards of 30,000 persons in three Centers. NASA life-cycle management is discussed near the middle of the book. Twice, NASA studies are cited in an article at the end of the book, but not indexed. More so than other books, reference books need to be fully and accurately indexed for users as a reader service.

One of the liveliest pieces in the handbook is by Dr. Thomas E. Miller of the University of Missouri-Kansas City. Although it focuses on managing change in a fire department, the article describes four natural groups seen around any office. There are the technical-specialist organizational types who tend to be productive but standoffish. The social-specialist regulars are outgoing, popular and accepted by everyone except top management. Then there are the "underchosen" who are loved by management but who are out of line with peers and subordinates because of age, competence, ethnic background, education or just plain flat personality. Finally, there's the power specialist who is admired by social regulars but no one else because of a tendency to buck authority.

Yet, Project Management Handbook is useful even if it is not comprehensive, up to date and consistent. The "Behavioral Dimensions of Project Management" section has some good material on leadership, worthy of reflection and analysis. Each of the eight sections starts with a brief description of each article, and the different points of view may be of more value than a single author attempting to cover the whole field, from conceptual phase to phasing-out and evaluation.--WML

Project Manager Game, by Nancy Bingham, 1988. Ames Research Center, Moffett Field, CA.

An employee at Ames Research Center has devised a game that should put Monopoly out of business, at least among project managers in NASA.

Nancy Bingham's Project Manager Game is in production at the Ames Graphics Department, with about 50 boards and sets of gamecards set for the first of what may become many press runs.

According to the draft rules, the boardgame consists of bonus and penalty points in three categories: technical quality, cost and schedule. The objectives are "to perform your job as project manager to deliver the best technical, high-quality product at the least cost and minimum development time."

Like most boardgames, this one is driven by a pawn moving forward at the roll of a single die. The board itself is divided into four "phases": requirements definition, project planning, project performance and project closeout.

Each phase consists of spaces along the board, some of them labeled "crisis" and "zap." The player landing on a crisis space draws a crisis card which presents a problem and three possible alternatives, some of which will cost points. For example, here's one from the first phase:

Project funding is cut by 25% after requirements are finalized.

- *A) descope project to meet budget.*
- *B) advocate additional funding.*
- *C) assume budget risk (buy-in).*

Resources

If you select "A", you lose 15 points in technical quality (TQ), 10 points in cost (C), and 10 points in schedule (S). Choose "B" and you lose 15 points in C and 15 points in S. If you chose "C", you lose 15 points in TQ, 20 points in C, and 10 points in S.

The other set of cards, zap cards, may be given to another player at certain times. Here's one from the project planning phase:

All internal manpower is already assigned to key projects. You'll have to hire to fill your project's positions. Subtract 15 points for TQ, 10 points for C and 20 points for S.

The idea behind zap cards is connected to the "zero sum game" often played for real in companies. In other words, your requirements for resources will affect the other projects going on in the company at the same time.

Gradually, each player advances along the board, facing crises or getting zapped until bonus points are awarded for reaching the next phase.

But a project manager's career is not that simple or worry-free. At each of the four progress spaces, the player must draw both a crisis card and a zap card. The zinger, however, is at the end of the game. Most games end with the winner as the person with the most points. Ms. Bingham notes: "Other considerations may disqualify the winner with the most points. These will be explained at the end of the game." Sound familiar?--WML

In Brief

Managing Projects in Organizations, by J. Davidson Frame, 1987. Jossey-Bass Publishers, San Francisco.

This 240-page book is written primarily for those involved in information systems projects, claiming that the same project management techniques that yield products can be applied to information systems as well. Frame recommends a focus on people, though, not techniques, recommending the Myers-Briggs Type Indicator. In a requirements section, he claims that most projects are started too soon. In a third section, on tools and techniques, Frame notes that the cost of administering projects can be half or more of total costs, so the project should be measured from all angles.

Out of the Crisis, by W. Edwards Deming, 1988. MIT Press, Cambridge, Mass.

The guru of Japanese management, Deming, now 88, issues a new edition of his classic study in his twilight years. Foremost among the new corporate folklore principles here is his 85-15 Rule: production problems are the result of workers only 15 percent of the time; the rest is caused by management. In direct opposition to "search for excellence" theories, he is appalled at MBWA, management by wandering about, because most managers do not ask the right questions nor stop walking long enough to get the right answers. He deplores the whole idea of management-by-objectives, and he opposes performance appraisals and quality circles, the latter beyond management responsibility. What does he like? Dedication to quality which is contagious, spreading to an increase in productivity, a decrease of cost, satisfied customers and happy workers.

Management: A Bibliography for NASA Managers (NASA SP-7500) Scientific and Technical Information Division, annual. This is a selection of annotated references to unclassified reports and journal articles that are introduced into the NASA scientific and technical information system. Items are selected on the basis of their usefulness to NASA mangers, and they are grouped into 20 categories ranging from Human Factors and Personnel Issues to Management Theory and Techniques. They are indexed six ways. Available from the National Technical Information Service.

NASA/SCAN: Selected Current Aerospace Notices. Scientific and Technical Information Division, semimonthly. SCAN is a current awareness publication covering a full spectrum of aeronautic and aerospace information, segmented into about 75 categories, including management. Each SCAN topic resembles a newsletter and can be customized for an individual. SCAN topics are available free to NASA employees, university libraries, and contractors registered with the NASA Scientific and Technical Information Facility. Others may subscribe at a nominal charge.

*U.S. G.P.O. 1988-241-446:80041

NASA
National Aeronautics and Space Administration

Report Documentation Page

1. Report No. NASA SP-6101	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Issues in NASA Program and Project Management		5. Report Date October 1988
		6. Performing Organization Code NDS
7. Author(s) Francis T. Hoban, editor		8. Performing Organization Report No.
		10. Work Unit No.
9. Performing Organization Name and Address NASA Office of Management Human Resources and Organization Development		11. Contract or Grant No.
		13. Type of Report and Period Covered Special Publication
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, DC 20546		14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

This collection of papers and resources on aerospace management issues is inspired by a desire to benefit from the lessons learned from past projects and programs. Inherent in the NASA culture is a respect for divergent viewpoints and innovative ways of doing things. This publication presents a wide variety of views and opinions. Good management is enhanced when program and project managers examine the methods of veteran managers, considering the lessons they have learned and reflecting on their own guiding principles.

17. Key Words (Suggested by Author(s)) aerospace management project management human resources	18. Distribution Statement Unclassified - Unlimited Subject Category 81

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of pages	22. Price
Unclassified	Unclassified	56	A04

 Available from the National Technical Information Service, Springfield, VA 22161

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Block 12. Sponsoring Agency Name and Address. National Aeronautics and Space Administration, Washington, D.C. 20546-0001. If contractor report, add NASA installation or HQ program office.

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