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ISSUES IN NASA PROGRAM AND PROJECT MANAGEMENT

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ISSUES IN NASA PROGRAM AND PROJECT MANAGEMENT

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Issues in NASA Program and Project Management

A Collection of Papers on Aerospace Management Issues

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To the Next Generation of Program and Project Managers

by J.R. Thompson

The success — or failure — of the next generation of NASA program and project managers will depend on how well we do our jobs today. We will either pass along a tradition of achievement or leave a difficult path for those who follow us. I would like to pass on a stronger, more capable agency to the next generation of NASA employees.

Long after the majority of today's leadership is retired from NASA, many of the programs we advocated or worked on will still be operational, for better or worse. One day, I expect to turn my television on to a 24-hour special access channel to see what the Space Station Freedom crew is working on. I expect to marvel in the preparations for flight of the Lunar-Mars Mission, the grandest global enterprise of humanity to date, and wonder at the latest planetary discoveries. I hope to see the U.S. flag on the tail of the world's first aerospace plane. I hope that people in 2010 will be able to marvel at these feats with the same enthusiasm and respect that we have now for the accomplishments of our space programs of the 1960s and 1970s.

It is clear to me that our performance today will determine what kind of NASA we will have at the turn of the century. What we do today at our desks, in our laboratories, in our conference rooms and at our job sites matters a great deal if we are to succeed in the new century. Today is the first day of NASA's future, and I believe it is a very good one.

For example, we have achieved a good balance of science, manned spaceflight and technology, not just one at the expense of the others. We must maintain that balance, realizing that science depends on technology and that there is no substitute for human presence in space. By challenging the frontiers of science, we will advance the technology and make human presence in space more useful.

However, we can't afford to "fall in love" with a new program to the detriment of existing programs. Almost every day I hear of interesting new ideas coming to us from the laboratories and the universities. Some of these ideas have merit, but we may have to bypass many of them so we can do well with the opportunities we are already committed to.

This is not to say that NASA is unwilling to hear new ideas. We are always seeking better, more cost-efficient ways of managing the programs we now have. Innovative opportunities are already being identified in such areas as space station payloads and the Space Exploration Initiative, and we should incorporate other good ideas as the work progresses. But our primary job is to focus our efforts on making our existing program commitments a success. Most of NASA's budget is to manage and develop our ongoing programs and projects; only a small portion is earmarked for new initiatives. No matter how much we want to tackle new projects, we must first perform those that have been mandated by the President and endorsed by the Congress.

What We Can Do Better

NASA's senior scientists, engineers and managers have excellent opportunities now to define and manage NASA's current programs to ensure future successes. The outcomes of our decisions and accomplishments will be felt for years to come. Since NASA is a highly integrated institution, mistakes and missteps can affect us all.

One area that I have noticed as a major source of problems is in defining program requirements. It seems that just about everyone connected with a relatively simple project can add on any number of requirements, which may get included without being challenged. When all the requirements are finally compiled further up the line, we find that we simply do not have the resources to implement what we have said the project needs!

The cost growth needed to accommodate useless requirements can paralyze a program or project. One way we can save money and precious time and achieve better performance is to do a better job in Phase A and Phase B. We need to scope out the requirements up front and then challenge them internally.

We also need better ways of estimating and controlling costs. I could name project after project that was estimated to cost millions and ended up costing billions instead. It is good that we say we are willing to compromise cost but not content, but better checks and balances are needed all along the way. Upper management is part of this problem.

Our institutional reputation is built upon competence. In this time of tightening up, NASA's competence in the area of budget and finance needs to be improved. I'd like to see a little more tension between project management and financial management. If we don't do a better job of estimating and controlling costs, I can guarantee that someone else will come in and do it for us.

Qualities of the New Manager

We must consider who will replace our current management teams and where the new leaders of NASA will come from. I've seen the age distribution figures on NASA personnel, which show that there is a big gap between Apollo-era managers and relatively new hires. Quite frankly, the numbers don't scare me all that much because young people don't scare me. I've found that whenever young people were thrust into leadership positions, nine out of ten times they did just fine. I'm not so sure that middle-age managers have much of a better record of success, but I am sure that chronological age is not the main factor in the success or failure of a program or project manager.

I think that there are three basic qualities an aspiring program or project manager should have. First, I'd look for leadership capability. Leadership can be interpreted in a lot of different ways, but we all know leaders when we see them. More often than not, such leaders possess personal integrity. They command, rather than demand, respect from subordinates. They eagerly take charge of a program or project, plan it out thoroughly and communicate clearly with those who are under them, above them and beside them. They are not too proud or reluctant to incorporate proven technologies, or to tap the expertise and talents of outside agencies or institutions.

You know what to expect from a good leader, there are no surprises. When things go right, these leaders praise the subordinates; when things go wrong, they take all the blame on themselves, then make sure the problem is corrected and put the project back on the right track.

Second, I'd look for common sense in managing people and contractors. The first step is to pick the right people to manage. Perhaps nothing is more important than finding the right person for the job. Common sense will tell you that incompetent or mismatched people will kill a project, but a good team will function well.

Once the best and brightest have been selected for the team, the manager must delegate responsibility and authority to the lowest level possible. Management is difficult and time consuming enough without having to do someone else's job or question the dependability of the people you pick. Contractors, too, deserve to be treated as full partners. Increasingly, NASA programs and projects have an international flavor. International partners must be treated with the respect they deserve.

Third, I'd ask: Does this potential project manager have technical moxie? To lead others, sometimes you have to guide them. Now technical moxie doesn't mean the technical knowledge to do everyone else's job, but rather the ability to learn all the technical matters that are the manager's responsibility. A new manager isn't expected to know the form, fit and function of every little piece of a project at the start, but sometime before test and verification the manager had better learn those things. I'd pick a manager who was a quick learner and had solid technical know-how, rather than someone with a long list of varied technical accomplishments.

The fact of the matter is, in NASA today, few projects stand alone. As manager of the Main Shuttle Engine, for example, I had primary responsibility for that project, but other Shuttle projects depended upon our schedule and performance. They had to know what I was doing, and I had to know how they were putting all the pieces together to make the Shuttle fly. Technical collaboration across these projects was critical to our mutual success.

Technical moxie involves some innovation and creativity on the part of an aspiring manager. Take a look at the job in front of you now and look for ways to achieve better performance with lower cost, in less time. One way to do that is to use existing technologies, observe what others are doing in allied fields, and take an item off someone else's shelf instead of recreating it each time. It takes creativity to find the best solution for the problem at hand.

Looking at your present work and finding new ways of doing all tasks better is perhaps the best exercise one can do as an aspiring program or project manager. Be open to new ideas, and stimulate new ideas among your colleagues. Stimulation is at the heart of everything we do at NASA, and I hope I have stimulated a few ideas for you to do your job extraordinarily well. The future of NASA depends on you.

There is a connection between where NASA is today and what it takes to become a good program or project manager. The key to both is to maintain your balance. Just as NASA today strives to keep a good balance of science, technology and manned

systems, the aspiring manager needs to keep a good balance of leadership ability, common sense and technical knowledge.

NASA's Future is Now

Although NASA is evolving, it has actually shrunk in terms of work force and real dollars since the days of Apollo. As NASA continues to change, projects will probably have to be performed by fewer people, which will force new solutions and bigger challenges. Strong leadership skills can go a long way in handling tough decisions and tradeoffs.

No matter what happens, I don't think that you should try to guess the future. Instead, you should be looking at the job in front of you, trying to do it better, more safely and more efficiently. The answer is not out there or coming later — it's right in front of you, right now.

In closing, I'd like to suggest that there are some other things we can and should be doing to leave NASA a better agency than we found it. One thing is to stimulate an interest in aerospace among children, the next generation of NASA program and project managers. Volunteer for a hitch on NASA speaker's bureaus at Headquarters and each Center. Schools, social organizations, churches, and fraternal societies are hungry for news and views about the aerospace industry. The interest is there, but it needs to be cultivated.

Take advantage of the NASA Program and Project Management Initiative. Take the courses and read the literature or, if you're an experienced veteran, volunteer to teach or write so the corporate memory of NASA is not lost. Shared experiences and lessons learned are legacies we can leave behind for the next generation.

Finally, I would suggest to all, young and not so young, to be open to new ideas. I'm constantly on the lookout for ways I can do my job better, here and now, not in some vague, distant future. Since we came on board, NASA's new leadership has made a lot of changes. Change is a sign of growth, but what I want to leave with you is the notion that growth doesn't mean just size or numbers — it also means quality. In the final analysis, I'm not asking you to do more, but rather to do better. No doubt, the best way to succeed is to inspire our young people by doing the common tasks uncommonly well and building a better NASA.

Project Management in NASA: 1980 and Today

by Donald P. Hearth

NASA's public image has been damaged during the past year by a growing public perception that "NASA doesn't manage complicated space projects very well — certainly not as well as they used to." The experiences with the Hubble mirror, the hydrogen leaks in the Shuttle, and the continuing cost and management changes in the Space Station Freedom Program suggest that the public perception has some justification. This situation was, probably, a major factor in the creation of the Augustine Commission which is examining the future U.S. space program as this article is being written.

We should recognize that the problems noted above are isolated ones and that there have been many recent successes; for example, Voyager and Magellan. Moreover, the "good old days" weren't always "good"; we also had technical, cost and management problems in the "old days." Perhaps, one could argue, NASA is being held to a more rigorous standard of project management performance than during its first 30 years. This may very well be the case. Nevertheless, I believe that NASA occasionally deviates from some of its established principles of sound program and project management, and the such deviation may contribute to some of today's problems.

In 1980, I had the privilege to lead a team that examined NASA project management experience since the early 1960s and the problems in the management of then current NASA projects. This study resulted in the identification of factors that encouraged cost growth and schedule slips as well as factors that contributed to successful project management. The findings of the 1980 study are summarized in this article along with a personal set of "Project Management Principles."

The 1980 Study

In the late 1970s, NASA experienced major costs overruns and schedule slips with projects such as Shuttle, Hubble, and IRAS (the infrared astronomical explorer). The NASA Administrator established a study to examine NASA project management and to make recommendations on how to improve the agency's performance.

The team we assembled included individuals with extensive management experience in NASA Headquarters and the NASA Centers, as well as experience with unmanned and manned projects. The team was first rate, including individuals such as Jack Lee (Spacelab Project Manager and current MSFC Director), "Gus" Guastaferro (Director of Planetary Programs in OSSA and currently a Vice President at Lockheed), Charlie Hall (former Pioneer Project Manager), and Tommy Campbell (current NASA Comptroller).

We worked closely with the Administrator's Office, the Headquarters Program Offices, the NASA Centers, NASA contractors, former NASA employees, and congressional committees. As far as we know, no information was denied us, and all of the people interviewed in government and industry were extremely open and candid

The study was conducted over a four-month time period in the three phases outlined in Table 1. The major Conclusions and Recommendations are listed in Tables 2 and 3. Many of the findings relate to actions taken before formal project approval.

Project Management Principles

Most individuals who have been associated with the management of technical projects have their own principles of project management. The 1980 study and the NASA experience have resulted, in my opinion, in the principles noted later. They include activities that occur before a project is approved, since these establish the baseline for implementation of the project. (Many of these principles are included in a memorandum from the NASA Administrator on February 6, 1985, and NASA Management Instruction 7120, approved on the same date.)

Table 1 - The Process Used in the 1980 Study of NASA Project Management

Phase 1

- Cost and schedule data were collected for all NASA projects (spaceflight, aeronautical and large construction) since 1958. The data collected included initial estimates, at the time of "commitment" to the OMB and Congress, and final (or current) figures. In addition, information on all NASA competitive procurements was examined.
- Discussions were held with NASA personnel at various management levels in order to develop a list of potential factors that they felt contributed to cost and schedule growth of NASA projects. Factors identified included contractor "buy in," turnover of NASA project managers, inflation, inadequate NASA travel money, technical complexity, etc.

Phase 2

- The study team selected a group of projects for detailed examination. The 13 projects selected included some that met initial cost/schedule estimates and some that overran initial estimates, as well as projects that were implemented by various NASA Headquarters Program Offices and NASA Centers, some that were implemented in-house and under contract, and some that were implemented at various times in NASA's history. In other words, we attempted to select a representative cross section of NASA projects for intensive study.
- The study team divided itself into two-person teams; each team examined two of the selected projects. Project documentation was examined, interviews were conducted with past and present managers in NASA Headquarters and the Centers, and interviews were conducted with industry personnel that were involved in the preparation of the company's proposal and/or with NASA or the industrial firm. Each team identified, to their satisfaction, the reasons for the cost and schedule performance of each project.
- The study team examined the experience of other government agencies in the management of projects with advanced technology; particular attention was given to development projects in the U.S. Air Force.

Phase 3

- The results of the first two phases were analyzed to identify "generic" factors.
- The study team prepared a final report comprised of a set of briefing charts and a written statement on its conclusions and recommendations.
- Results of the study were reviewed with NASA management, a representative group of NASA project managers, industry, and the Congress.

My principles for the successful management of NASA space flight projects are as follows:

1. NASA should be realistic and honest with itself, with the Executive Branch, with the Congress and the public in terms of the goals, capabilities, costs, schedule, and technical risks of a new project when it is under consideration for approval to proceed into design and development. NASA should not overstate goals and not be deluded into a success-oriented cost and schedule in order to obtain project approval.

2. Advancing the national technology base is an important purpose of the space program. Thus, NASA should not reduce the technical challenges of NASA projects simply to reduce the possibility of cost growth and schedule slips. NASA must, however, consider the project's technical risks during the pre-approval phase and in designing the implementation phase as well as the project organization. NASA, OMB and the Congress should expect up to a 30 percent cost growth even if the project is well managed and there are no **major** technical surprises.

3. A NASA project should be well understood before it is approved for design and development. A through definition of the technical aspects, management (including the roles of the NASA Centers), cost and schedule is required to estimate potential risks to NASA management, the Executive Branch, and the Congress as they contemplate approval. Up to 5 to 10 percent of the runout cost of a project should be expended during the definition phase. NASA managers must not assume that approval of definition funds automatically means approval and funding of the project itself.

4. When a project is approved by NASA management, the OMB, and the Congress for implementation, the project's technical goals, schedule, runout cost, annual funding, organization, etc., are established. If the project stays within the agreed upon boundaries, the OMB and the Congress should ensure continued funding during future annual budget cycles and allow NASA to manage the project.

5. Both the NASA Headquarters Program Offices and the NASA Centers have important management roles during project formulation and implementation. The Headquarters Program Offices have the lead during project formulation and are supported by the Centers. **Except in very rare cases**, project management should be delegated to a NASA Center during formal project definition and during project implementation. Headquarters should then perform the oversight function and "represent" the project in Washington. Delegation to a Center is necessary in order to ensure that the project management organization has direct access to NASA's technical expertise so as to staff the project and have the technical resources available to deal with the technical problems that will inevitably arise in the project. In those cases where the project management role is retained in Headquarters, NASA must provide a workable mechanism that will ensure the same availability of the technical expertise of the NASA Centers to the Headquarters project management organization as if project management were at a Center.

6. The line of management responsibility, authority, and accountability for project management should be from the Administrator to the Program Associate Administrator to the Center Director and then to

the Project Manager. A Headquarters "Program Director"/"Program Manager" will normally represent the Associate Administrator and interface directly with the Project Manager in the Center. Thus, the Project Manager reports directly to Headquarters as well as to the Center Director. It is critical that the Center Director retain a portion of project accountability to ensure that the full technical capability of the Center is applied to the project as required.

7. NASA should minimize the management and technical interfaces within its projects. The number of NASA Centers assigned management responsibilities on a particular project should be minimized. If it is necessary to have two or more Centers assigned to a project, one Center should be designated as the Project Management Center and be assigned overall project authority (including the allocation of funding to the supporting Centers). In addition, the management and technical interfaces between the Centers should be defined and documented prior to the approval of the project to proceed with implementation.

8. The individual who is most critical to the success of a project is the Project Manager. That person must be provided the appropriate authority, responsibility, resources (including access to NASA internal technical expertise), and access to NASA management. The Project Manager is then held accountable for the performance of the project. Project reserves (i.e., contingencies) should be managed by the Project Manager and be used to deal with technical and schedule problems; not with budget cuts. Project management in NASA should be viewed as a desirable and long-term career path for NASA employees.

9. NASA and selected industrial contractors should form a working team to implement the project. There should not be an adversarial relationship between NASA and a contractor. The selection of a contractor during the acquisition process should be based primarily on technical considerations, the bidder's management capabilities, implementation plans, and the bidder's past performance. Contracts on tasks that have a high technical uncertainty should be cost plus, not fixed price.

10. The Project Manager should implement a technical and management information system which will enhance close communication among all project elements in government, industry and other participating organizations. The Project Manager must maintain a day-to-day understanding of the status and problems of work being performed so that technical problems can be anticipated and dealt with in a timely manner. This will require project reviews, in-plant representation, person to person contacts, etc., in addition to a formal Management Information System.

11. NASA management should minimize the extent of project elements outside of the authority of the Project Manager which are also in development. NASA must be realistic in recognizing and providing in its project plan for those supporting elements that are not fully operational.

None of the above are meaningful without the most important ingredient to successful project management in NASA — capable and committed people within the NASA project organization as well as in those parts of NASA Headquarters and the Centers that support the project during both normal times and during project emergencies.

In light of NASA's current problems and the relatively low public perception of the agency, what should be done about NASA? This is a question that the Augustine Commission is, no doubt, considering as it ponders the nation's future in space.

A major restructuring of NASA would be a mistake. I believe that following the project management principles proven by NASA experience will result in improved NASA performance in the management of flight projects and increased public confidence in the space program.

In addition, the roles and missions of the NASA Centers need to be clarified since they have become blurred in recent years, thereby contributing to some of NASA's current project problems. The Research Centers (ARC, LaRC, LeRC) should concentrate on aerospace research, technology (R&T) and support to the industry, other government agencies, and projects managed by the NASA Development Centers. The project management roles of the Research Centers should be restricted to those small flight projects which are vital elements of their R & T programs.

The NASA Development Centers should concentrate on development projects that closely match their technical expertise and experience. For example, GSFC should concentrate on unmanned science projects in Earth orbit, JSC on manned space system projects, JPL on science projects in deep space, and MSFC on rocket propulsion and launch vehicle projects.

Other steps may also be needed. For example, new mechanisms may be necessary to continue to attract and retain high quality, motivated people in NASA. NASA's in-house technical capability has been the key to its success over the past 32 years and sets it apart from many government agencies. It is vital to the nation's future in space that this unique characteristic of NASA not be lost.

Table 2 - Major Conclusions of the 1980 Study

1. There were four major reasons for cost/schedule growth in several NASA projects:
   a. Technical risk. NASA projects generally include high levels of technical complexity.
   b. Inadequate definition of technical and management aspects of a project (including the specific project to be implemented) prior to seeking approval to proceed from OMB and the Congress. This problem is exacerbated in that, in many cases, only advocates of the project review its readiness and the adequacy of cost/schedule estimates prior to submittal of the proposed project to the NASA Administrator for approval. Inadequate definition was judged to be the most significant contributor to cost/schedule overruns.
   c. Industry's recognition of NASA's tendency to select the low bidder in the competitive acquisition process. (When the study results were reviewed with NASA senior management, they were surprised that NASA tends to select the low bidder.) This has an adverse effect on project performance when artificially low bids are accepted by NASA and used to rationalize low project costs.
   d. Poor tracking of contractor accomplishments against approved plans in a timely fashion, leading to late identification of problems.

2. The following have been significant contributors to good cost and schedule performance:
   a. The function of the NASA Project Manager who is provided the appropriate authority, responsibility, and resources (including access to internal NASA technical expertise) and who is held accountable for the performance of the project.
   b. Adequate definition of the project to be implemented prior to commitment of its cost and schedule to OMB and the Congress.
   c. Proper planning and management of project contingencies.

d. Early understanding between NASA and the implementing contractor(s) of the project's scope, implementation plans, and interfaces.

3. Some NASA space projects have experienced cost growth in the development of their ground segments. This has been due to a lack of understanding of the design complexity and inadequate definition of the ground segment. This situation has been particularly evident in high data volume projects.

4. In some cases, the management of technically complex projects has been assigned to multiple NASA Centers without sufficient and timely consideration of the management relationships between the Centers and the technical interfaces between the project elements assigned to the various NASA Centers. The resulting project management complexities have contributed to cost growth and schedule slips.

5. A project will experience increased technical, schedule, and cost risk when it is dependent on the parallel development of critical supporting elements that are outside the Project Manager's control. An example is the dependence of the Hubble managers on the Shuttle.

Table 3 - Major Recommendations of the 1980 Study

1. The technical challenges of NASA projects should not be reduced in order to minimize the possibility of cost growth and schedule slips. Rather, NASA should allow for the technical risks in the extent and type of the pre-approval work performed, the estimate, annual funding plan and the project schedule. NASA, OMB, and the Congress should expect up to a 30 percent cost growth even if the project is well managed and there are no ***major*** technical surprises.

2. The NASA Administrator should require a complete definition of technical and management aspects of all new projects prior to submittal for new start approval; this should include the specific project proposed for implementation. Five to 10 percent of the funds required for the complete project should be expended during definition. If a budget "line item" is required for project definition, NASA should update its estimate of cost and schedule to OMB and the Congress after definition is completed. This update should be viewed by all parties as the NASA commitment (subject to Recommendation 5). Finally, Program Associate Administrators should organize a review of all proposed projects by a group of "non-advocates" who have project management experience and understand the technologies associated with the proposed project.

3. Selection of contractors should be based primarily on technical considerations and the bidder's management capabilities, implementation plans, and past performance.

4. NASA projects should have adequate visibility of each contractor's technical performance and utilization of resources. NASA Project Managers should have access to the technical capabilities of the NASA Centers in order to monitor the contractors, oversee the government's technical work, and examine contingencies and work-around plans that will be required by technical problems. NASA Center Directors should be accountable to ensure that their Project Managers receive the technical resources required and that their Centers support, where appropriate, projects at other Centers.

5. After the implementing contractor is selected, the first months of the contract activity should be devoted to developing an early NASA/contractor understanding of the project scope and interfaces. The project's commitment to OMB and the Congress should be updated after this "early understanding" period.

6. All NASA projects should have adequate financial reserves (i.e., contingencies). These reserves should be under the control of the Project Manager and be used to deal with technical problems; they should not be used to deal with budget cuts by NASA management, OMB, and/or the Congress.

7. NASA should minimize the management and technical interfaces within its projects. The number of NASA Centers assigned management responsibilities on a particular project should be minimized. If it is necessary to have two or more Centers assigned to a project, one Center should be designated as the Project Management Center and be assigned overall project authority (including the allocation of funding to the supporting Centers). In addition, the management and technical interfaces between the Centers should be defined and documented prior to approval of the project.

Building the Project Team

by Howard T. Wright

After reading the papers on project management by Aaron Cohen and Angelo Guastaferro in an earlier publication of *Issues in NASA Program and Project Management*, I find it difficult to add to the excellent advice provided by these experienced authors. I believe that they have provided very sound advice on the "how to" in project management, and, therefore, I have decided to explore the human element of motivation in a project team effort. In addition, as I would like to stimulate some thought on "industrial teaming" in today's international political and economic environment.

Much has been written about the relationship between morale and productivity, as well as the difference between a leader and a manager. I have experienced the feeling of both motivation and demotivation while working on project activities in which the intentions of the leader are clearly to bring about a successful conclusion to the project. Why is there a motivating environment in some projects and a demotivating environment in others? Although I cannot provide a cookbook answer to this question, I do want to describe some of the specific actions that I believe successful leaders have taken to provide a positive motivating environment.

There is no doubt in my mind that morale and productivity are directly related. To be very direct, I believe that most aerospace managers would improve the productivity of their organizations if they were to take steps to improve the morale of their people rather than spend their time and energy trying to solve the endless chain of interesting technical problems that are ever present in most aerospace projects. I must admit that I have been significantly influenced by Robert Ranftl's book *R&D Productivity* primarily because his conclusions are totally consistent with my experiences and observations. Where productivity is concerned, studies show that attitude and motivation — not I.Q., education, graduate study, etc. — are most important. The productivity of an organization is determined by the top five percent of the people of any organization. Managers are reactive, but leaders are pro-active (they focus on the horizon and are sensitive to the effect of change). The most often cited reason for poor performance is over-managed, under-led organizations. And Ranftl asserts organizations are like nations: they begin stoic, they end epicurean. (By the end of the Roman Empire 50 percent of the normal work days were holidays.)

Let me offer some other references that I have found particularly helpful in understanding morale and leadership: *In Search of Excellence* by Thomas Peters and Robert Waterman, A *Passion for Excellence* by Tom Peters and Nancy Austin, *Intrapreneuring* by Gifford Pinchot III, and *The Management* of *Research Institutions* by Hans Mark and Arnold Levine. In my view these references are strong confirmation of the premise that productivity is closely related to morale and leadership. Let me now share some experiences that I believe are characteristic of those leadership traits that promote high morale and productivity.

While working for Grumman on the Apollo program it was my job to be the Lunar Module contractor representative at George Low's Change Control Board meeting in Houston. I flew from New York to Houston every Thursday night for more than two years to attend the Friday meetings. When George said, "Let's begin," you could set your watch because it would be 12:30 p.m. sharp. It may seem like a small point; however, a great deal of preparation involving many people was at stake. Starting on time gave each of us a clear signal that George felt that the meeting and our time were both important. I do not like to think of the numbers of times I have been summoned to a meeting only to be kept waiting for 45 minutes or more. Delay is an unintentional demotivating activity that is more characteristic of a manager than a leader. To keep employees waiting sends a clear signal that you don't think their time is very valuable.

After joining NASA in 1973 to work on the Viking project, I was fortunate to have found myself in a very highly motivated project office. It is sometimes difficult to be specific about the reason for the high level of motivation. However, the first thing to come to my mind in looking back at those days is the integrity of the leaders. Both the Project Manager, Jim Martin, and the Center Director, Ed Cortwright, were respected by everyone for their undisputed support and concern for the rest of the project team, as well as their open and clear communication. The Viking organization was not unique. If you were to look at the organization chart you would have to agree that it was typical of most project organizations. What was unique, however, was the feeling of responsibility that every member of the organization had. When Jim said ***you*** have the responsibility to work a problem, he would make the assignment in an open meeting in such a way that the recipient of the assignment really felt responsible — and the rest of the project office also knew it. Everyone was motivated to help solve the problem. Additionally, a personal note of thanks was typical of Jim Martin's reaction to a job well done.

Team Building at NASP

Most recently, for about four and a half years, I had the pleasure and excitement of working as NASA's deputy on the National Aerospace Plane (NASP) project. This joint Air Force/NASA project office is located at the Wright-Patterson Air Force Base in Dayton, Ohio. The first project manager for the Air Force was Brigadier General Kenneth Stayton. General Stayton is another natural leader whose inspiration is contagious. Although General Stayton employed all of the traditional project management tools for planning, organizing, directing and controlling, like all great leaders he was concerned about people — plus, he had a great sense of humor. Some of the motivating activities that I can attribute to him may seem trivial, but I think they are responsible for creating the team spirit that exists in the NASP project office:

> Communication. An important aspect of project management was always stimulated by a daily senior staff meeting at 8 a.m. sharp. If your calendar happened to be full, a brief note to General Stayton would be answered by a return note the next day. This kind of response gave you the feeling that your participation and concerns were important to him. Weekly all-hands staff meetings kept everyone informed.

Spirit Building. Leaders and followers are all mere humans and in many ways are very much alike. Getting to know one another is an important ingredient to working well together. To facilitate an interaction between the project team members, one person was asked to provide lunch for the rest of the organization for a nominal charge every other week. The ground rule was, no talking about business during these lunches. Some organized special events for their turn, and I can fondly remember winning the lasagna contest with my wife's favorite recipe. I called it "NASP (Noodles and Sauce Poquoson) Lasagna." There were cookie contests at Christmas time, and every year we were all sure to be present at the luncheon immediately following Chuck Anderson's vacation. Chuck would always return from Minnesota with some of the greatest sausage and grill it on a charcoal fire right outside the office. Birthdays were always celebrated with a cake, now done on a monthly basis. At the family pig roast scheduled each year, there was something about getting out at 5 a.m. with pick and shovel to dig a hole to roast your own pig that brought together those early birds like no amount of office experience. Celebrations and special lunches were anticipated and remembered like no other management tool or technique in NASP's spirit building.

Work as Fun Time. The clocks on the project office walls had no numbers on them but were shaded green between 8 and 4:30, yellow between 4:30 and 6, and red between 6 and 8:30. All were labeled "fun" clocks to remind us that works is enriching and fulfilling, but can be overbearing. Productivity goes down as the hours add up. Family and rest are important, too, for team spirit.

Team building is nurtured by a genuine interest in people — not just their professional but also their private and family lives should be of concern. Every success story in *A Search for Excellence* reinforces this conclusion. All of my experience tells me that when adversarial conditions develop within a project, you are headed for trouble.

Team Building for the U.S.

Perhaps I am a little obsessed with the notion that working together toward a common goal is not only more productive but also more satisfying than working in competition. A U.S. executive at a Washington Conference on foreign competition, recorded in Ira Magaziner's *The Silent War*, said, "No matter how hard we try on our own, we can't compete by ourselves." What the electronics industry needed, he said, was a Washington-backed strategy to combine the strengths of America's companies, universities, and government labs. The competition has been doing that for years, he said; if the United States didn't do the same, we'd lose a piece of our living standard.

I personally believe that this statement can apply to much more than just the electronics industry. I believe it is particularly true for the aerospace industry. It is common practice in Europe and Japan, where government-supported industry consortia teams are rapidly increasing their share of the market at the expense of the U.S. manufacturers in this high-technology field.

The NASP program has taken a bold step in the direction of teaming the U.S. indus-

try to improve the combined productivity of their companies while rapidly and efficiently developing and improving those technologies essential to compete effectively in the world marketplace. The resources available in the U.S. aerospace industry are a national treasure, and I believe it is in the best interest of the U.S. for the government to try to eliminate the duplication of effort that exists when each company attempts on its own to develop the same technologies as its competitors. Today the high-tech market is global, and we must consider what the overseas competition is doing in order to develop a strategy for the U.S. This strategy must rely heavily on the development of new technologies and the synergistic combination of ideas that are generated not only in industry, but also in the universities and government laboratories across the country. I think it is appropriate for the government to take the lead and organize a team effort involving all potential contributors.

In order to implement a consortium of contractors to develop new materials for the NASP, the joint Air Force/NASA program office organized the National Materials and Structures Augmentation Program. I selected this name because the acronym was easy to remember — National Materials ASAP. All five major NASP contractors — McDonnell Douglas, Rocketdyne, Rockwell, General Dynamics and Pratt & Whitney — agreed to divide the materials development into areas that each could lead, and they agreed to share the results of their efforts with each other. In a very short time, contract arrangements were agreed upon and implemented, and soon a national team was in place, all working together to develop new materials. This team is shown in Figure 1. Even at the outset, the number of government laboratories and universities across the country involved in the program was impressive.

For those who would still argue that the NASP program lost the element of competition, I would say, yes, perhaps so; however, it has been replaced with some things that are even more motivating to the people at the working level. First of all, there developed a level of peer pressure among the five prime contractors. Since there was a semiannual review with the senior management of each company present, each company wanted their part of the effort to be progressing on schedule with subcontracts let and progress to report. It was interesting to me to see individuals from one company helping another company to expedite this effort when in the normal competitive environment they would not even speak to each other. The second observation that I would make is that everyone involved was a winner. There would be three big losers if all five contractors were working in competition (the case for many years) before the government would select two winners. One way to look at the situation was to conclude that three-fifths of our national resources would have been wasted. Morale of the losers would have plummeted.

Recently the NASP program has taken an even bolder step by forming a team of the same five contractors to develop NASP program configurations. Only time will tell how effective this team will be, but I predict it will result in a significant improvement in productivity, and certainly eliminate redundant and costly activities.

I believe that cooperation is the only way for U.S. industry to survive in this fiercely competitive international marketplace. Teamwork and morale contribute more to

productivity than all of the formal project management tools put together. Times are changing and we should think of national team building in large projects, but government must lead the effort to integrate and coordinate the efforts of the U.S. industry, universities, and government laboratories in specific technology areas. In other words, the same technique to build a project team can be applied nationally. Such an effort will require strong leadership and sustained motivation and morale.

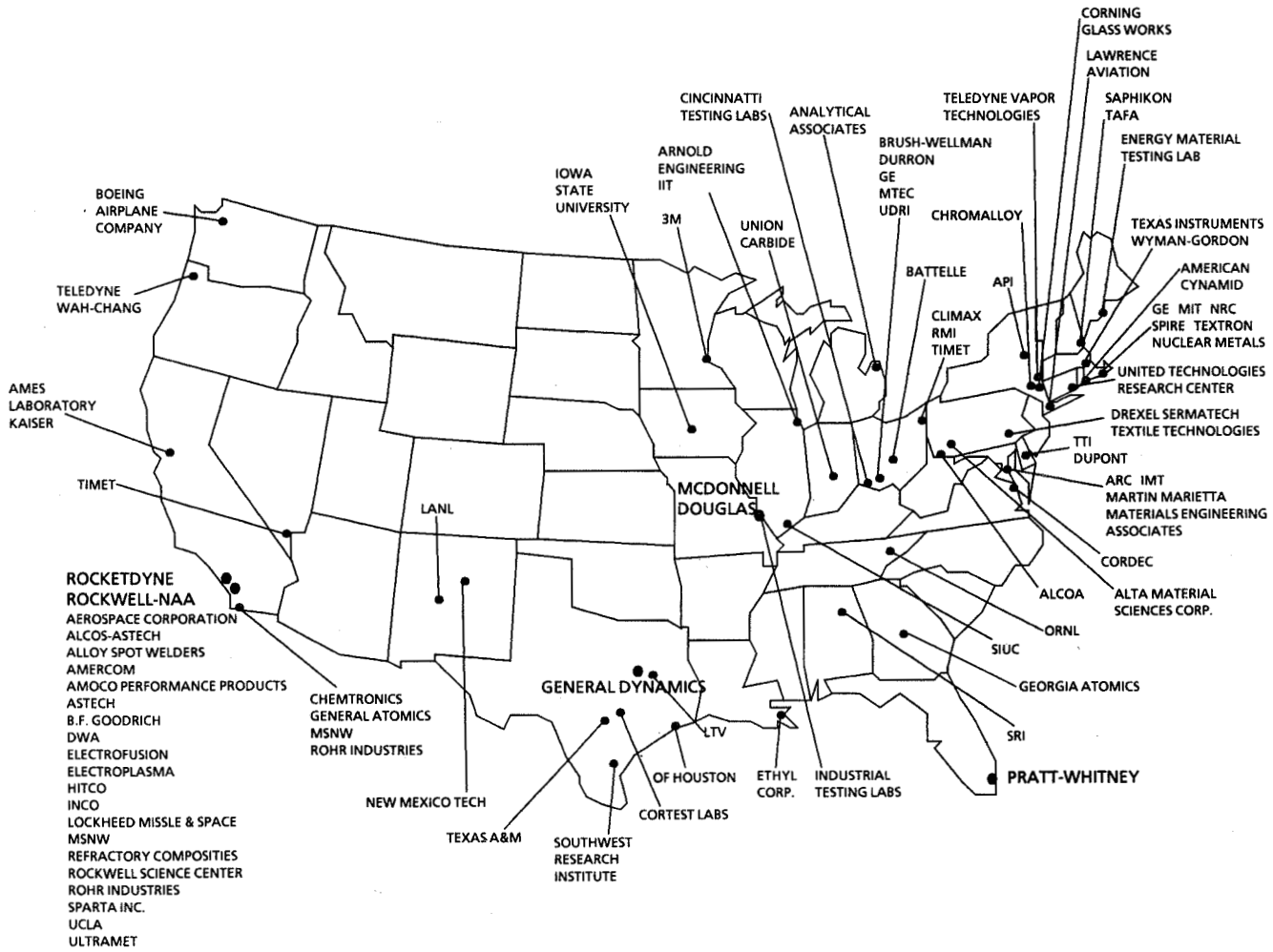


Figure 1. - National Materials and Structures Augmentation Program Subcontractors

Space Science and Satellite Applications: Ingredients for Success

by John W. Townsend, Jr.

Dr. John Townsend retired from NASA as Director of the Goddard Space Flight Center in August of 1990. A memo he wrote to Goddard branch heads and project managers on January 21, 1963, recently surfaced and permission was granted to share it with a wider audience. While the memo is dated, it does capture the philosophy of one of the agency's up and coming leaders. That same year, 1963, Dr. Townsend won the Arthur S. Fleming Award as Goddard's Assistant Director of Space Science and Satellite Applications.

There have been a number of instances in the past several months when I have had opportunity to pause and reflect on Goddard's past flight program record. This has come about both as the result of our successes and failures, and those on programs run by other groups active in space research. In addition, I have also been reviewing our history to try to draw conclusions that would be meaningful in the preparation of a Goddard-wide "Reliability Assurance Policy."

To begin with, I must admit that our record is not perfect. However, on the positive side, there are some factors which have guided our performance and led us to such success as we have had. Some of these have been conscious and some, to a certain extent, have developed unconsciously.

The purpose of this discussion is to outline the basic philosophy that I believe we have been following, and by so doing, to help ensure that our younger generation at GSFC is aware of this thinking so that they can be guided accordingly. As I see it, the principal problem at the Center will be to assure that the knowledge and experience of our senior people are passed on in spite of the fact that our explosive growth has spread all of us too thin and made communications much more difficult.

I find, as the result of this exercise, that there are two sets of factors which have influenced us. The first set is, in a sense, environmental and includes many things that have just happened or are not under our direct control, such as management principles that we influence but do not set. The second set are rules that we do have under our control and have developed through experience.

Environmental Factors

In the first category, I would include the Center's personnel and culture.

Goddard's greatest asset is its personnel. We were fortunate, indeed, to inherit several large and skilled groups from the Department of Defense. Many of these people have had as many as 15 years experience with rockets and rocket instrumentation for scientific research. They have had their own successes and failures and have seen these in other programs. There is no substitute for such first-hand knowledge. I recognize that everyone is interested in "management theory" nowadays and that we get much free advice (and sometimes instructions) in this category. What pains

me is that some of the people giving such advice have never even seen a rocket firing.

We have been successful, by and large, in keeping our best people only through a policy of insisting that they be allowed to work on jobs that they wish to do and are good at. This presents a difficult management problem since management goals are not always the same as the personal goals of people doing the work, but the fact remains that there is no substitute for the person who really wants to do a job so badly that all else is of little importance. Where we have been allowed to assign our people in accordance with this policy, we have retained them. Where we have failed — for example, booster vehicles — we have lost good people.

We have been fortunate to date in not having "production" programs at GSFC. Since most of our missions have been "one of a kind" flights, we have all been impressed by the seriousness of one mistake — there haven't been "four more to fly in case this one doesn't work." I think this circumstance has resulted in closer identification of our people with the job and greater personal pride of accomplishment.

Most of us believe that the least management is the best management in an R&D effort. Goddard has relatively clean management lines with few splits in responsibility, authority, and accountability. We have also gotten along without large staff groups (at least in the technical areas).

I believe our basic policy of mixing the projects in with functional groups is a good one. This item may be controversial, but considering the job GSFC has to do, the people it has to do it with, and conditions under which we operate, I think the policy is wise. Conditions may change in the future, but for the present, organizing this way ensures a maximum cross-fertilization and prevents the projects from going off in a vacuum where the basic mission of the project is obscured by its size and importance.

We have insisted that we have "in-house" competence and experience in each area of endeavor where we monitor the work of others. We have also managed our projects and have done our mentoring with people who are scientists and engineers first and "management types" second.

The above factors, as I said before, are not completely under our control; further, several of them represent a philosophy based on personal opinion and are hence debatable.

Policies and Rules

The second category is considered to be more substantive and can be shown by our experience to have contributed directly to our success:

We have scaled our mission objectives to the possible.

We have followed a policy of assigning our experimenters and design engineers the task of following their units from birth to death, i.e., from concept through writing a final report. This procedure is somewhat unique in that most organizations of our type build up a system, bypassing subsystems, and the responsibility for them, from a design group, to a development group, to a fabrication group, to QA and test, and finally, to an integration group. In many cases, field operations are carried out by

still another group or by another agency.

By the time flight data wanders back, the design engineer frequently doesn't even recognize it and is at a loss to explain "what happened."

GSFC technical personnel have a suspicious nature — they don't take anything for granted. We try to follow the habit of assuming that the mission could fail and try to correct things before, rather than after, the fact. This is a mental attitude that I consider highly important. Be pessimistic about success up to the last minute; never stop trying to find the weak links.

Our better designs have either incorporated redundancy or have provided for isolation so that a single failure or a few failures do not ruin a mission. In this connection, it is good design to avoid a situation in which several events must occur in series before a desired operation takes place.

In general, it has been our practice to use components with very conservative ratings.

Resist schedule pressure if technological problems are pacing. There is no excuse for letting management deficiencies result in schedule slips, but when the problem is a research or development one, insist that the unit is 100 percent right before it is flown.

Testing Approach

The principal cornerstone of our development philosophy has been our belief and reliance in a strong testing program. This subject is in itself a matter for much more thorough coverage than possible in this note, but the following aspects are considered to be of paramount importance:

GSFC believes in the FULL SYSTEMS test approach. Every reasonable attempt should be made to test the entire system under as realistic conditions as possible and as early in the development cycle as feasible.

GSFC believes in 100 percent flight acceptance testing at expected average flight levels plus 2 sigma (95 percent level).

GSFC believes in testing a flight unit, designated a prototype, at approximately 150 percent of the flight acceptance tests.

After the testing program, the system should remain intact and last-minute changes avoided like the plague (firing jitters problem). In almost every instance of failure I can remember, the explanation began with the famous last words, "but we only changed..."

I would like to close this discussion with the comment that this Center is in no position to get big-headed about its progress. In the observatory class of spacecraft (Nimbus, OGO, OAO, AOSO) we have a new generation of problems to face that are at least an order of magnitude more difficult. It would be my hope that this discussion may serve to focus our attention on this situation and point a way towards success.

Program Control: A Growing Career Opportunity

by Bill Sneed

Program control, an integral part of program and project management, is emerging as a management discipline in its own right. Program control can be a career goal in itself, or can become a steppingstone to project and program management and even beyond. There are various ways to achieve a position in program control, and we will discuss some of these routes in the following pages.

Program Control: A Definition

The discipline of program control covers a lot of territory. According to the Phillips Model, developed in 1987, program control covers program plans and requirements, resources management, schedule management, documentation and data management, and configuration management. Each of these subdisciplines is in itself complex (see Figure 1). These functions will vary from organization to organization and with the size and complexity of a program or project. Additional functions sometimes assigned to the program control organization are logistics management and management information systems. Program control involves planning, organizing, directing, budgeting, and controlling; and it involves measuring performance against the baselines of content, scope, configuration, schedule, and cost of a project or program.

Program control management also requires the manager to develop and maintain an integrated planning base of program requirements and development plans. Once the baselines are set, the manager is expected to analyze and evaluate performance and alternatives each step of the way and to revise the baselines if necessary. For ultimate program control, the successful manager needs an efficient system of reports, reviews, and action feedbacks.

Program Control at NASA

At NASA, program control as a management science took hold in the 1960s with the Apollo program — a demonstrated success that was listed as the greatest engineering achievement of the past 25 years by the National Academy of Engineering. With the proliferation of exciting and challenging new programs and projects made possible by recent increases in the agency's budget, the need for program control is increasing. Especially with the recent loss of many senior managers, NASA needs and will continue to need additional people to implement its on-going and emerging programs and projects. This growth will create tremendous career opportunities for people who have a desire to participate in a direct and meaningful way in the management of programs and projects having great national, scientific or technological significance.

Program control functions are organizationally grouped in different ways by the various NASA Headquarters program offices and the Field Centers. The Office of Space Flight (OSF) and its Centers group most all of the functions under an organiza-

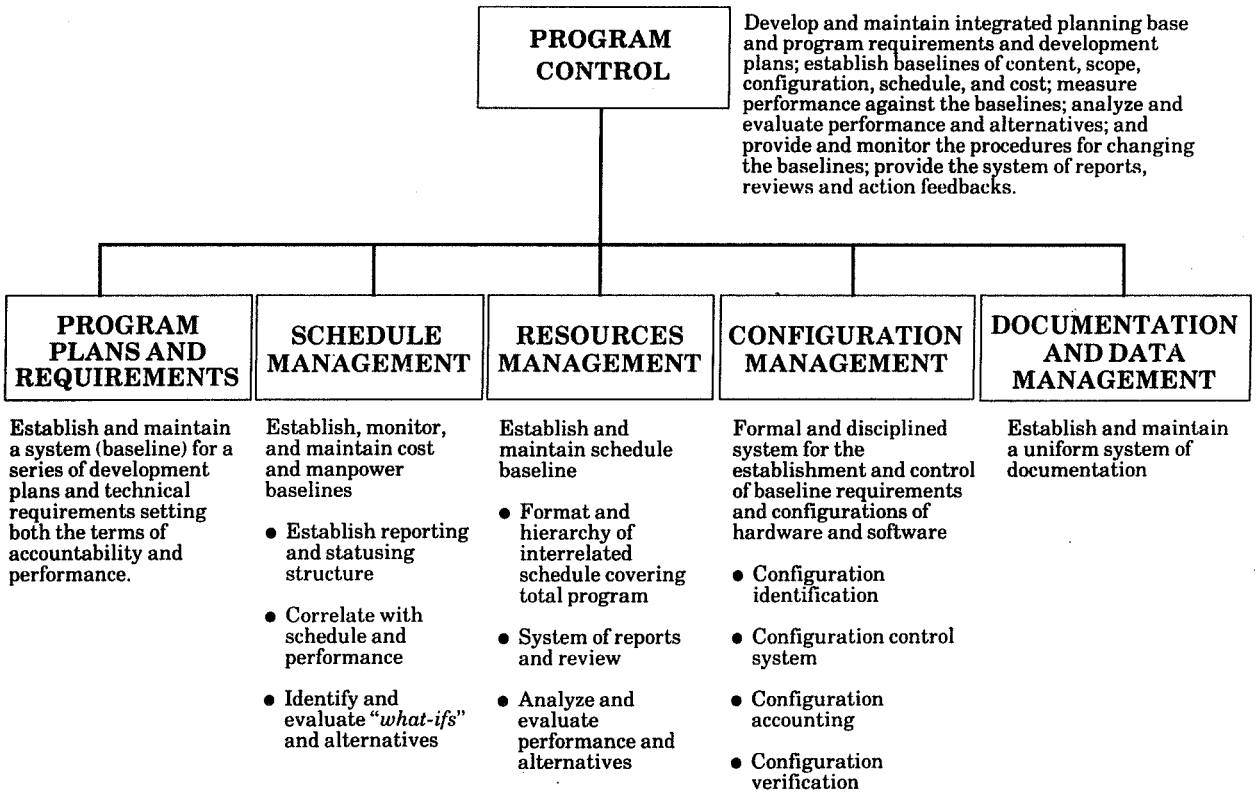


Figure 1. - The Phillips Model of Program Control Disciplines

tional entity referred to as "Program Control." On the other hand, the Office of Space Science and Applications (OSSA) and its Centers normally assign most of the program control functions to the Deputy Project Manager for Resources. Both concepts have met with varying degrees of success, demonstrating that the way the functions are grouped is not an issue for discussion.

What does vary is the relative importance of each function to a particular project or program. Program plans and requirements require the Program Control Chief or Deputy Project Manager to establish and maintain a system — a baseline — for a series of development plans and technical requirements, setting terms for both accountability and performance. Resource management involves the monitoring of both cost and personnel. The manager establishes a reporting status structure, correlates resources with schedule and performance, and assesses "what-ifs" and their alternatives.

Schedule management is the very center of program control, constantly playing off cost and performance baseline requirements. Schedule is a hierarchy of values covering the entire program, with milestones for reports and review, evaluation points and alternatives. Tradeoffs among schedule, performance, and resources are continual concerns throughout a project or program.

Documentation and data management in the Phillips Model simply require the manager to establish and maintain a uniform system of documentation. Configuration management is a bit more complicated. Configuration identification, control system, accounting, and verification are all re-

quired. The manager is expected to develop a formal and disciplined system to establish and control baseline requirements and configurations of all the hardware and software needed in the project. The Technical and Management Information System (TMIS) now being developed by the Space Station Freedom Program is expected to facilitate these functions.

The effectiveness of the program control functions is indeed measurable. The results of a General Accounting Office audit of 940 projects indicated that costs exceeded plan about 50 percent and that projected schedules ran over by about 33 percent. An analysis of NASA programs indicates that NASA program and projects experience similar cost and schedule performance. With only minor improvements in program control, the cost savings would be enormous.

The importance of the program control discipline to the project manager is readily evident from assessing a typical project management organization structure (see Figure 2). Note that the program control manager reports directly to the project manager. Because of the nature and importance of the program control functions, it is essential that the program control manager be involved in each and every project activity, since nearly all decisions or actions of the project manager will affect project plans, schedules, cost, or configuration.

The program control functions encompass two of the three performance parameters for which a project manager is responsible (technical, schedule and cost performance). Given the importance of the role of the program control discipline to the project management process and the increasing number of programs and projects under way or

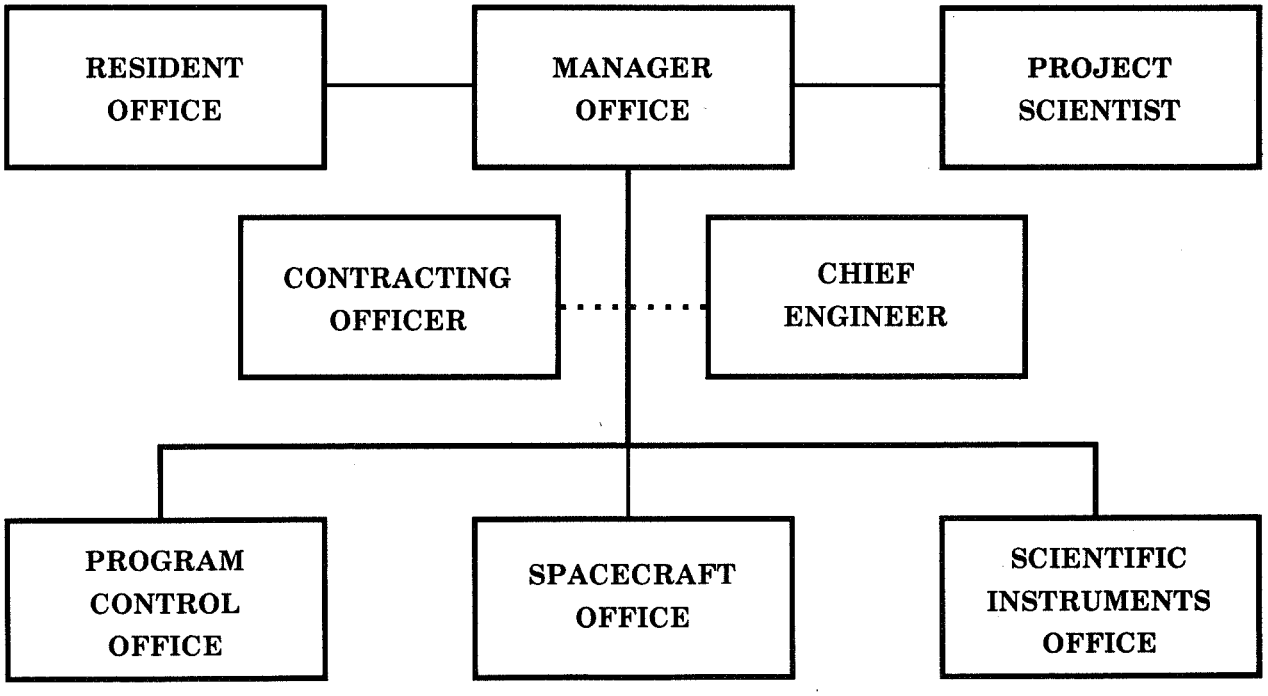
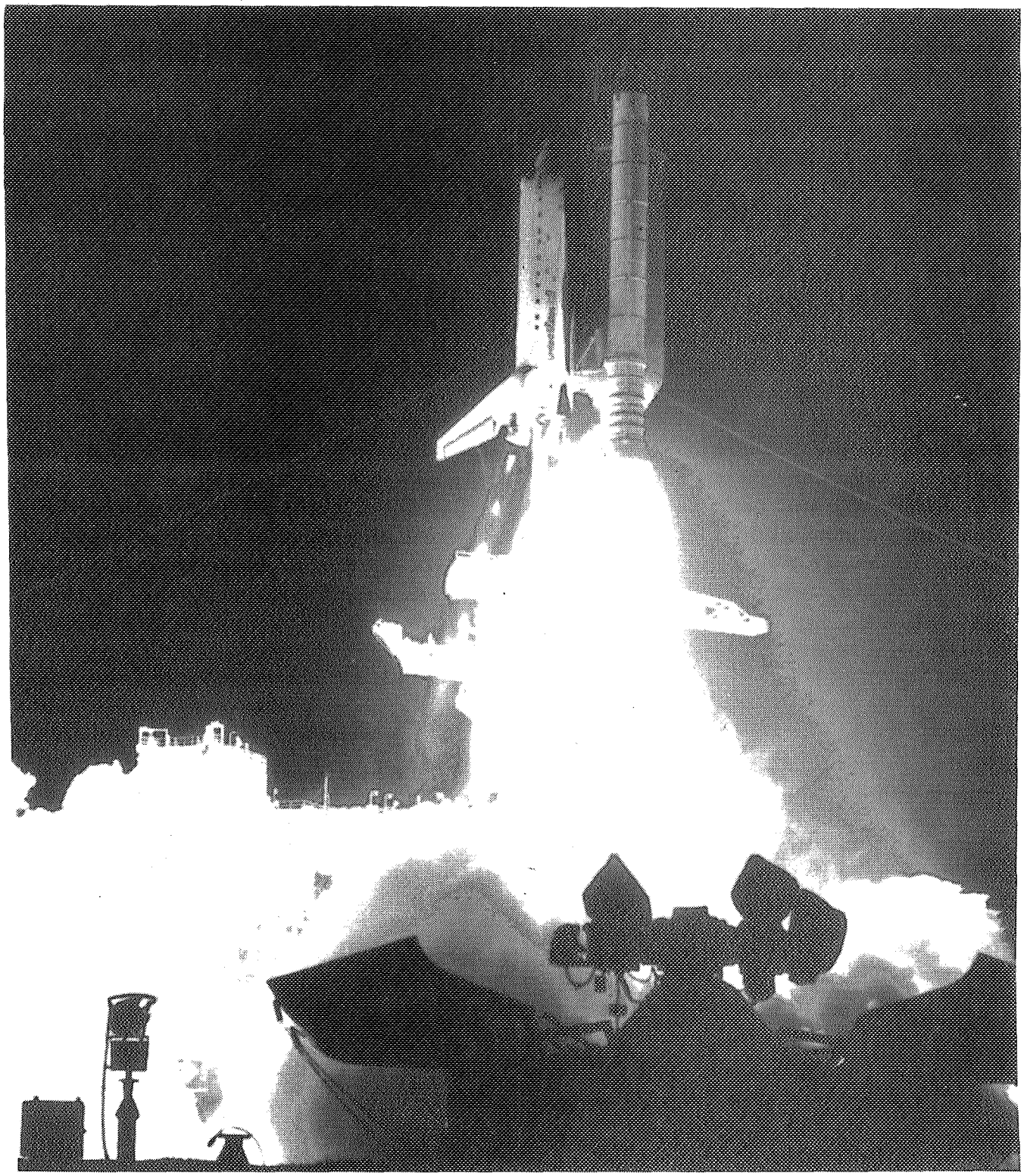


Figure 2. - Typical Project Management Organization Structure



The Space Shuttle Discovery heads for low Earth orbit on the first post-Challenger nocturnal launch. The launch occurred at 7:23 a.m. on November 22, 1989, from Kennedy Space Center. This picture shows a side view of Discovery, one of its two solid rocket boosters and the external tank. Seen from the main engines is the "diamond shock" effect often associated with Shuttle launches.

scheduled to begin in the near future, there will be an increasing demand at NASA for people interested in program control — either as a career in itself or as a pathway to other career objectives.

Training in Program Control: The MSFC Experience

Recruiting and training personnel interested in career opportunities in program control and beyond, especially those already working in the technical disciplines, have been somewhat of a problem at NASA in recent years. This challenge has been met in various ways.

At the Marshall Space Flight Center (MSFC), two training programs were initiated to encourage people to enter into program planning and control and into program management. The first of these training initiatives was established in the Program Development Directorate. It allowed intermediate-level technical personnel to cross over from their technical specialties to program control. After two years of on-the-job training, these people were assigned to a permanent program planning position in a program office or in an institutional directorate.

The second training program was initiated in the Shuttle Projects Office to accommodate aspiring project managers. This program required its participants to serve a period of time in the program control discipline, after which they were moved into key project management positions as the positions became available.

Both of these training programs were highly successful in fulfilling MSFC's critical need for highly qualified program control managers and project managers. They also provided an effective means for allowing aspiring individuals to achieve their career objectives in project planning and control and project management.

These and other training programs throughout the agency have been instrumental in allowing employees to pursue career goals while at the same time preparing them for key management positions in NASA. Typical positions currently or previously filled by employees who thus rose through the program control ranks are NASA Comptroller, MSFC Comptroller, MSFC Shuttle Projects Manager, Shuttle External Tank Project Manager, Shuttle SSME Project Manager, Shuttle Advanced Solid Rocket Motor Project Manager, Hubble Space Telescope Project Manager, MSFC Assistant Director for Policy and Review, Johnson Space Center Deputy Director for Administration, and Stennis Space Center Associate Director.

Formal Training in Program Control

As an alternative or adjunct to on-the-job training, the NASA Program and Project Management Initiative (PPMI) of the Office of Human Resources and Organizational Development at Headquarters offers courses in project management, advanced project management, program management, and executive project management, as well as a specific skills course in program control.

The Program Control course has as its objective "to present NASA and industry perspectives on the processes used to plan and control resources during the life of a NASA project." Topics covered include resource management; configuration management; logic network and schedule development;

development performance measurement; barriers to assessing progress; parametric cost estimating; contract management; project control system design; and project control procedures and technical requirements. Instruction is by lecture, panel discussions, case studies, and problem-solving exercises. Instructors are NASA managers, aerospace specialists, and professional trainers.

Too frequently, for expediency, employees are promoted or placed into positions for which they are not exceptionally qualified in certain critical skills. Requisite training and progressive job assignments are not properly planned or accomplished in such a way as to prepare the employee to fully assume the many demanding responsibilities of the new position. This has been and still is a fairly common practice for people ascending into key project management and institutional positions — not because of choice, but because of the pressing needs to fill those positions. The results are often the cost and schedule performance trends noted above.

Formal training in program control will qualify aspiring program control managers and project managers to perform the program control functions competently and effectively. Coupled with on-the-job training, completion of the course work that NASA offers will produce qualified, skilled program control personnel.

Planning a Career in Program Control

In planning a career development path, consider the skills and cross-training required to facilitate progress through various job assignments along the career ladder. Many key positions in NASA require an intimate working knowledge of the program planning and control skills enumerated above.

People who select a career in aerospace management should consider both formal training — and a job assignment of a year or two in program planning and control. Proper qualification for any position is important not only for the individual, but for the efficient and cost-effective management of all of NASA's programs. As one of the NASA officials listed above said recently, "Working in the program control discipline for a period of about two years was one of the most valuable, broadening and fulfilling assignments of my entire career."

Those who choose to make program planning and control their ultimate career goal will find tremendous rewards awaiting them as NASA embarks upon new initiatives that will extend human presence in space, expand the frontiers of our knowledge, push the technologies for the betterment of human existence, and afford us a better understanding of ourselves and the universe.

Shared Experiences from NASA Programs and Projects: 1975

by Frank Hoban

This paper summarizes the lessons learned from two workshops held at the National Academy of Sciences in 1975. The workshops were sponsored by NASA in conjunction with the National Academy of Engineering. Vince Johnson, former deputy administrator of the Office of Space Science and Applications, chaired the sessions. The National Academy of Engineering was represented by retired NASA executives Robert Gilruth and Abe Silverstein, retired USAF General King, and Sid Metsger of COMSAT.

The first workshop was held on February 24 and 25, 1975, and covered nine projects:

Atmospheric Explorer Project Goddard Space Flight Center

David Grimes, Manager

The Atmospheric Explorer Project consisted of three Earth orbital missions, each utilizing a spacecraft of approximately 1,500 pounds with a payload of approximately 210 pounds. The science objectives were to investigate the proton chemical process accompanying the absorption of solar ultraviolet radiation in the earth's atmosphere by making closely coordinating measurements of the reacting constituents from the spacecraft. The spacecraft was placed in orbit by the Delta launch vehicle. The project staff never exceeded 14 GSFC employees. The orbital mechanics of the mission permitted an unrestricted launch window, and the launch dates were met within 30 days of the target.

Mr. Grimes offered the following cost control techniques:

- Spread project subsystems throughout the industry, thereby lessening overall risk; do not keep too many subsystems with the prime contractor. (There was not unanimous agreement on this point.)
- Motivate the contractor to keep costs low.
- Have the prime contractor use fixed-price contracts where possible
- Ensure that the project office and the contractor accept one leader, the project manager, for all elements of the project.

Mr. Grimes offered the following recommendations for future projects:

For Contractors:

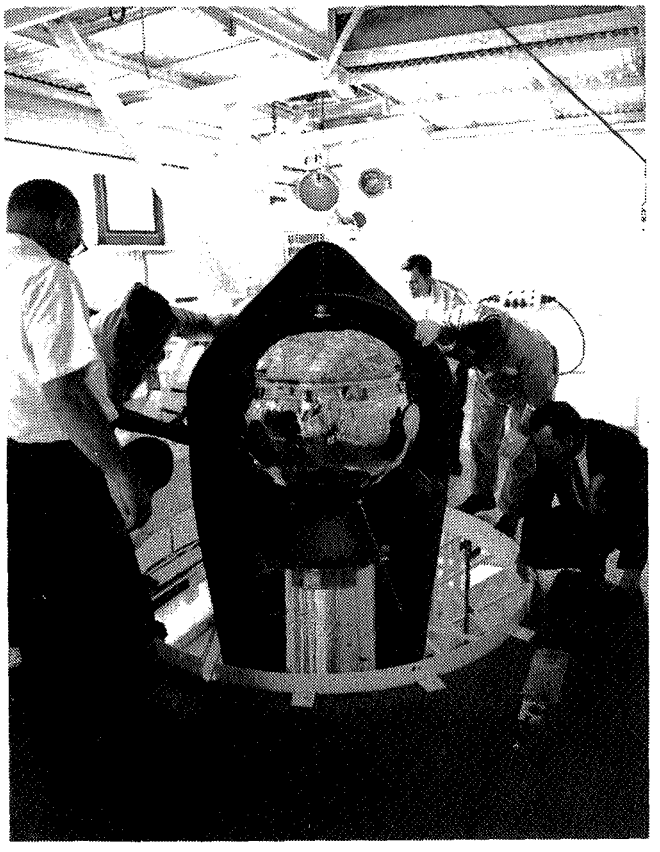
- Be willing to work as part of a NASA/contractor team rather than at arm's length.
- Be extremely cost conscious.
- Be technically aware as well as competent.

For Project Managers:

- Get good people on the project team and make sure they talk to each other.
- Be obsessed with cost and schedule — count things.
- Motivate your staff with similar feeling, and instill in them the conviction that success can be achieved.
- Keep encouraging and pushing your people.
- Maintain an information net that alerts you to difficulties within one day.
- Take the calculated risk.

For Field Center Managers:

- Ensure that the project leader has effective control of project personnel.
- Ensure there is continuity of assignment of people to the project team.



Engineers at Kennedy Space Center place a nose fairing around NASA's Atmosphere Explorer-B prototype spacecraft in 1966 at Complex 17B.

- Encourage the approaches described above.
- Provide the in-house manpower to support the project.

For Headquarters Program Managers:

- Back your project manager.
- Compete with other projects for scarce resources.
- Convince center management that headquarters supports the project and project manager.

Mariner/Venus/Mercury 73 Project Jet Propulsion Laboratory

Gene Giberson, Manager

The project consisted of a single spacecraft launch to the planets Venus and Mercury during the 1973 launch opportunity. The mission plan's primary objective specified a flyby of the planet Venus with a continuing trajectory toward a flyby of Mercury. Subsequent post-Mercury planning allowed for return encounters of the spacecraft with Mercury. The program had a firm not-to-exceed budget of $98 million with the stipulation that a spacecraft system contractor was to be used for the design, fabrication, and test of the flight spacecraft and test articles.

The experiments and the participation of science teams were also limited to a fixed budget included in the $98 million ceiling. The project experienced excellent cost control throughout and underran the contract effort. The Jet Propulsion Laboratory in-house effort — consisting primarily of mission operations, tracking, data acquisition and science management — also experienced an appreciable underrun. Mr. Giberson elaborated on the following guidelines used by his team during the management of the Mariner/Venus/Mercury Project:

- Establish firm in-house mission specifications and strongly resist any deviation from them.
- Establish firm science mission requirements, including all science interfaces prior to spacecraft design.
- Establish firm cost estimates with principal investigators, and instill within the science team the not-to-exceed philosophy of the project.
- Establish a design carry-over attitude for the subsystem managers and resist any state-of-the-art improvements.

A major point touched on during the discussion was the trade-off between the spacecraft implementation phasing alternatives available and the spacecraft systems contractor. One plan had the contractor work force building up rapidly, with the contractor buying all parts, completing all design effort and subsystem fabrication early before retrenching into a one-year slack period prior to a second manpower build-up for final assembly, test and launch operations. This plan had the obvious advantage of staying ahead of the inflation spiral by completing all costly procurements early in the program. The second plan involved delaying contractor start as late as possible, building up fast, reaching a peak level of effort just prior to final checkout and

launch, and then terminating the project activities in a short period of time. The latter plan, adopted by the project, was cost- and success-oriented, but assumed considerable risk. It was recognized that this plan might not be the best approach for a program involving major new developments.

Mr. Giberson submitted the following activities related to project success:

Pre-Project Mission Design

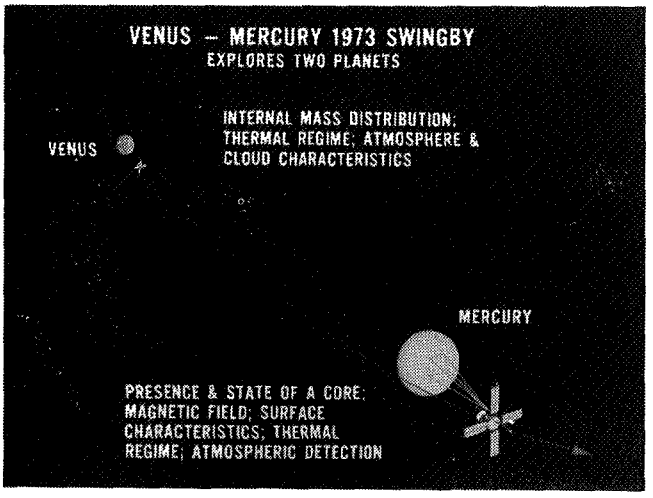
- Establish mission objectives.
- Use science steering group.
- On science/mission/spacecraft design interaction:
  - —Establish technical requirements/ performance trades. Develop preliminary cost estimates.
- Emphasize design carry over approach.
- Establish "baseline" mission trajectory.
- Emphasize cost trade-off analysis:
  - —Implementation models.
  - —Hardware quantities, design inheritance.
- Select "baseline" system configuration.
- Establish target cost.

Project Definition and Planning

- Restrain staff size.
- Expand "baseline" system designs and interfaces.
- Develop detailed cost estimates for implementation alternatives.
- Establish project guidelines and constraints.
- Conduct scheduling/cost trades:
  - —Maximize cost predictability and control.
- Establish operating budget.
- Budget planning:
  - —Use fixed-cost/variable-scope approach.
  - —Emphasize cost-at-completion.
  - —Use no-year funds approach.
  - —Assure compatibility of scope and resources.
  - —Stress candor on plans, allocations, and status.
- Prepare detailed implementation plans:
  - —Make specific and detailed request for proposals.
  - —Make careful make/buy trade-off assessments.
  - —Use existing documents and administration systems.
  - —Select fee approach.
- Indoctrinate personnel:
  - —Raise cost consciousness.
  - —Make cost goal believable.
  - —Foster an understanding of cost control plans and system.

Project Implementation

- Define contracts prior to start of work.
- Establish organization impedance matching and communications for:
  - —Intense technology transfer.
  - —Cognizant engineer concept.
  - —Work package approach.
  - —Frequent face-to-face meetings.
  - —Timely problem identification and resolution.



— Periodic status/performance reviews.

- Maintain current implementation and budget plans.
- Do only essential work.
- On-load and off-load manpower in timely fashion.
- Use "tiger team" problem solving.
- Tailor test activities.

Recommendations

(1) Plan early and in detail.

(2) "Start" late.

(3) Use existing designs where practicable.

(4) Established cost-at-completion budgeting and control.

(5) Communicate often.

(6) Do only what's essential.

SPHINX Project
Lewis Research Center
Robert Lovell, Manager

SPHINX was the smallest spacecraft discussed during the workshop. The objectives of the project were to obtain engineering data on the interaction between a high-voltage surface and space plasma. Although a launch vehicle failure terminated the operational phase of the satellite, SPHINX was considered successful from the standpoint of cost control and schedule performance. From its inception, the project was considered to be a high-risk, low-cost effort (approximately $1 million), with no redundancy in the spacecraft.

An engineering model and a protoflight model spacecraft were designed, fabricated, and tested in-house. The experiment, a technically difficult, high-voltage instrument package, was designed and fabricated under contract.

Many problems were encountered during the design, fabrication, and test phase of the contractual effort: technical difficulties in developing the high voltage instruments, lack of adequate center engineering support during the early part of the program, unavailability of parts, and the use of research and development contractor personnel for spacecraft support.

Recommendations for future projects of this type were:

(1) Establish a realistic schedule early in the program.

(2) Apply sufficient in-house engineering design effort during the preliminary design phase.

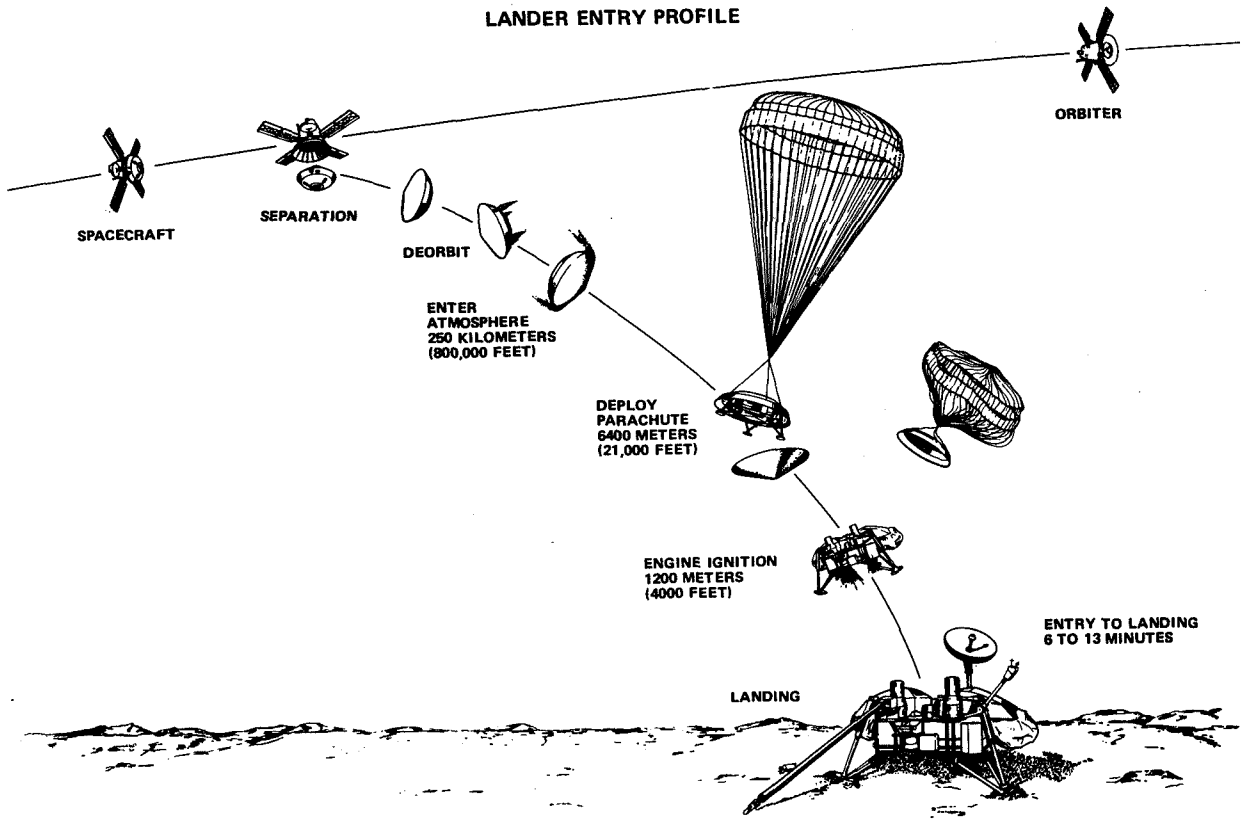
(3) Obtain a complete parts inventory as early as possible.

(4) If all parts are not available, make the design compatible with the parts that are obtainable.

(5) Insist on project, not research, personnel from the contractor and use an experimental shop approach.

Viking Project
Langley Research Center
Angelo Guastaferro, Assistant Manager

The Viking Project was a two-spacecraft mission to Mars, both scheduled for launch in the summer of 1975. The payload was launched on a Titan/Centaur



launch vehicle. Each spacecraft included an orbiter and a lander capable of soft-landing on the Martian surface and conducting a series of meteorological, biological, and planetological experiments. Viking experienced a considerable cost growth, from $364 million estimated in 1968, to $930 million projected in 1975.

Factors contributing to the early cost growth included:

- Lack of understanding of the magnitude of the project.
- Use of cost estimates scaled up from the previous Lunar Orbiter project.
- Poor appreciation of the effects of inflation.
- No reasonable industry cost estimates.
- Lack of ability to pinpoint critical technological areas requiring state-of-the-art improvement.

During the discussion, the following points were made:

- It was not clear that additional money during the early phases of the project would have been used to the best advantage because the real problems were not well identified.
- Insufficient in-house engineering during the early phases contributed greatly to later problems.
- State-of-the-art improvements need special attention as early as possible.
- The role of the scientist/principal investigator in all projects should be re-examined. The principal investigator on Viking had no direct responsibility for schedule and cost, and limited responsibility for the performance of the experiment hardware. A consensus was that the scientist should be given the total job, including responsibility for cost, schedule, and performance.
- There needs to be more emphasis on in-house engineering.

The deputy project manager provided the following observations and recommendations:

(1) Realistic costs are difficult to estimate using limited parametric studies.

(2) Realistic cost estimates must be developed prior to large expenditures of project funds.

(3) Science definition and scientist participation in instrument development should be managed firmly.

(4) Beware of "state-of-the-art" pitfalls.

(5) Invest significant early money in hardware development and testing.

(6) Assign well-trained contractor management teams to major, critical subcontractors early.

(7) Beware of contractor estimates for:

— Subcontractors.

— Changes.

— Estimates to complete.

(8) Maintain a dollar-reserve posture equal to the degree of uncertainty.

(9) Have a continuous cost-offset/cost-concern program.

(10) Use an aggressive management and flexible staff concept:

— Assign "tiger teams."

— Get outside help.

— Use incremental reviews.

— Keep organization dynamic (matched to phase of project).

(11) Establish cost, including indirect cost management techniques for control, monitoring, evaluating, statusing, and reporting early.

(12) Assign technical/schedule/cost responsibilities for each area of work to a technical manager.

Delta Project
Goddard Space Flight Center

William Schindler, Manager

The Delta launch vehicle project was not involved in a new design effort but rather in an adaptation of an inherited or modified design. The vehicles were built in a limited mass production operation. The project management was primarily concerned with providing to its customers a high reliability launch system at a reasonable cost. A major concern of the project was determining the proper balance between achieving greater reliability and performance, and maintaining a competitive price.

In selecting reliability goals for launch vehicles, consideration must be given to launch vehicle and spacecraft costs. In general, for non-redundant vehicles, reliability levels greater than 90 percent are achievable only at considerable costs, and for reliability goals above 95 percent, the cost may well become prohibitive. The project manager felt that in attempting to assess launch vehicle cost versus reliability, the ratio of the spacecraft cost must be considered; that is, a higher spacecraft cost justifies more effort on launch vehicle reliability. The Delta launch vehicle failures have been determined to be about equally divided among electrical, mechanical, structural, and ordinance (including solids) subsystems.

The project manager felt there was a large quantity of data on projects that varied greatly in their approach to reliability, from "low-cost" projects such as Delta, Scout, and Explorers, to "high-cost" projects such as Saturn, Apollo, and Viking. He suggested a study to determine whether a quantitative relationship could be established between dollars invested and achieved reliability.

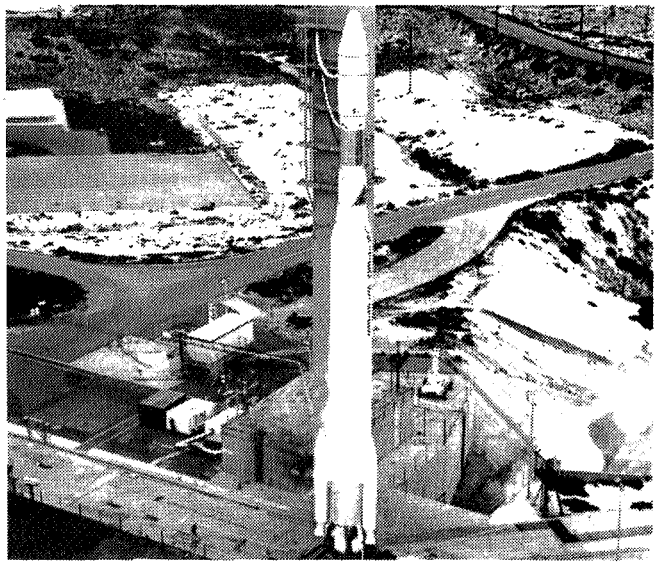
The project manager identified the following cost drivers:

- During development of major configuration change:

  — Component qualifications.

  — Systems integration and compatibility testing.

  — Formal system qualification.



Prelaunch view of Delta rocket in 1973, about to take a new weather satellite into orbit from NASA's western test range in Lompoc, CA.

- During the operational phase:
  - — Component production acceptance testing.
  - — Requalification requirements.
  - — Systems acceptance testing.
  - — Amount of field rework/modification permitted.
  - — Method of effective governmental acceptance/approval of contractor activity.
  - — Flight readiness review process.

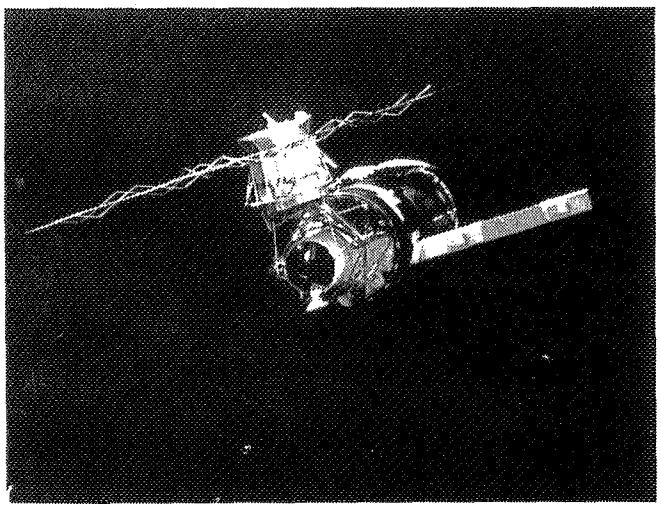
Skylab Project
Marshall Space Flight Center

Leland Belew, Project Manager

Skylab, this nation's first space station, made maximum use of existing launch vehicles, spacecraft, hardware, facilities, and equipment. The management experience from past programs and the ongoing Apollo Program was fully utilized. Skylab, with the Apollo spacecraft attached, was 118 feet long, weighed approximately 100 tons, and cost approximately $2.5 billion. Skylab was equipped with solar telescopes, earth sensors, and equipment for space manufacturing. Skylab was launched on a Saturn V launch vehicle and the Apollo spacecraft on a Saturn 1B launch vehicle. Program emphasis was on obtaining biomedical, earth applications, and scientific data. The program had a comprehensive involvement with a large number of scientists and principal investigators. (More than 100 different experiments were conducted.)

Comments by the project manager and other panel members regarding the project are as follows:

- A firm, comprehensive program plan was established in early 1969.
- A principal project guideline was to use existing proven hardware and facilities, allowing only mandatory changes.
- The design, development, test and checkout, launch and mission operations were carried out using essentially the same team (the team flowed with the hardware). For instance, the principal investigators, the scientists, and the crew (astronauts) actively participated in all the above activities.
- A strong in-house systems engineering and integration activity prevailed throughout the program, including a relatively small percentage of representative hardware activity (such as the Apollo Telescope Mount systems and one ATM experiment).
- Interface control documentation was jointly established and controlled between the design and operational centers and contractors early in the program. A control board primarily involving MSFC, JSC, and KSC was established.
- Program cost drivers were the following: (1) Skylab was coupled to Apollo. Apollo supported the basic program relative to common hardware. Skylab launches were in series after Apollo. (2) Crew safety and mission objectives and requirements dictated a design with considerable redundancy. (3) Skylab was a manned, one-of-a-kind, national commitment.
- A deliberate matching of management skills is recommended when the working relationship involves multiple centers.



- Hardware procurements should first consider available items. The most cost-effective path is to use an existing component or system.

Recommendations for future projects are:

(1) Make authority delegations known throughout the project organization.

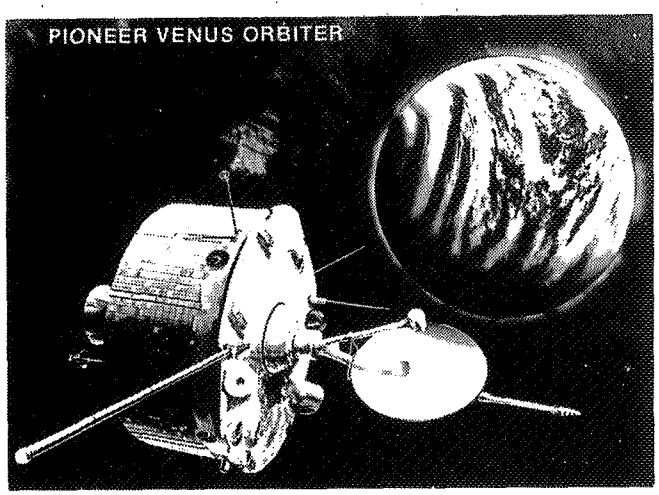
(2) If cost is to be the controlling factor, establish it early in project planning.

Pioneer-Venus Project
Ames Research Center
Skip Nunamaker, Manager

The Pioneer-Venus Project consisted of two launches to the planet Venus scheduled for 1978. The orbiter was to be launched first, followed by the probe launch. The Venus encounter was planned to occur in December 1978, for both the orbiter and probe. The probe was designed to enter the Venusian atmosphere and transmit atmospheric data until impact with the surface.

The Pioneer-Venus budget was $173 million for a six-year period covering fiscal years 1975-1980.

Hughes Aircraft Company was the spacecraft systems contractor for both orbiter and probe. The decision to change launch vehicles from Thor/Delta to Atlas/Centaur allowed much more flexibility in the spacecraft/probe design, and contributed to containing costs. Also, the contractor was instructed to



The Pioneer Venus orbiter is depicted as it approaches Venus in order to study the planet's atmosphere and weather.

plan spare or vacant time in the schedule following each major test. This permitted resolution of test anomalies without impacting other scheduled activities.

Recommendations:

(1) Keep mission objectives specific.

(2) All mission and spacecraft specifications should be prepared in-house and given to the contractor, not the other way around.

(3) Spend time studying and engineering the proposed mission prior to project start. This will pay big dividends later, especially in cost estimating.

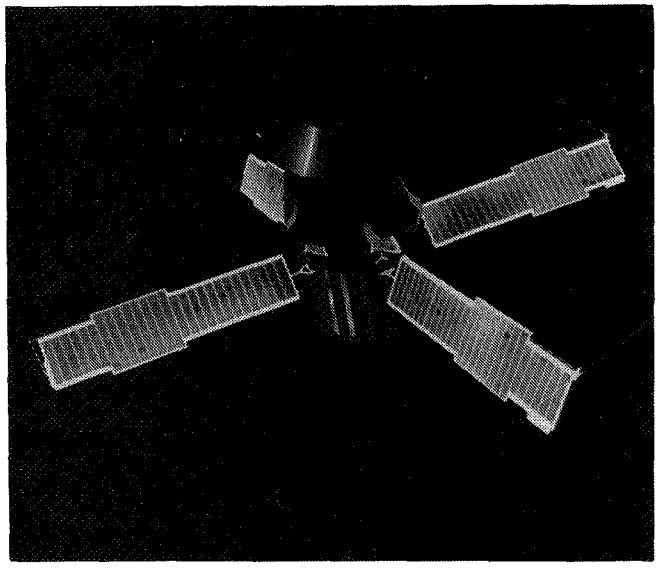
(4) Provide pre-project approval funds for ordering parts. Parts availability and long lead times are big cost items and are difficult to control.

HEAO Project
Marshall Space Flight Center
Fred Speer, Manager

High Energy Astrophysics Observatory (HEAO) consists of three, low-Earth orbit missions whose objectives were X-ray, gamma ray, and cosmic ray-astronomy. The spacecraft was built by Thompson-Ramo-Woolridge (TRW).

The project manager emphasized the thoroughness of definition that preceded the hardware phase and the participation of MSFC engineering in all essential design features. A very high percentage of components and subsystems represented off-the-shelf designs, obviating the need for full qualification testing. Major cost savings were accomplished by accepting the protoflight concept on all instruments and the spacecraft. All HEAO instruments were constrained to allow for substantial initial design margins in weight, power, and volume. Early cost ceilings were established on all instruments, and descoping was performed on those that exceeded ceilings.

There was considerable discussion by the panel on whether or not an existing spacecraft design could have been adapted or modified to satisfy the HEAO requirement. Mr. Speer reported that the HEAO payload originally contracted with TRW was much larger than any existing spacecraft would support. Following the program restructuring in 1973, other spacecraft were considered and found less cost-effective than permitting TRW to scale down its initial HEAO design.



NASA's High Energy Astronomy Observatory project set out to study some of the most intriguing mysteries of the universe, including pulsars, black holes, neutron stars, quasars and supernovas. High-energy celestial gamma and cosmic rays are obscured for ground-based observatories of our atmosphere.

One of the cost-benefit practices implemented by HEAO involved the common electronic piece parts suppliers for both the spacecraft and science experiments. Obtaining piece parts is a major problem for all programs, but especially for experimenters.

Recommendations for controlling costs:

(1) Refine and reduce programmatic requirements.

(2) Concentrate on specific technical requirements.

(3) Use value engineering (contractor shares in savings from proposed cost reductions).

(4) Establish firm budget ceilings for each program element.

(5) Adopt modular payload mode with options to be deleted.

(6) Ensure that experiments are manufactured by qualified hardware contractors.

(7) Encourage commonality and standardization.

(8) Use a design-to-cost approach.

(9) Establish adequate contingency funds.

Sounding Rockets Project Goddard Space Flight Center

John Busse, Manager

The sounding rockets presentation concentrated on the launch vehicle aspect of project management and did not cover payload or spacecraft. Sounding rockets are low in cost and take a different management approach to cost control and cost benefit analyses.

Sounding rocket launches differ from other unmanned scientific or applications missions in that a large portion of the launch vehicle and payload hardware is recoverable and can be refurbished and reflown. The refly option reduces cost to the point where total reliability is not the concern it would be for a larger, more expensive mission. When failures

occur, they are handled in a less formal atmosphere, and the resulting change in hardware or procedures is minimal compared to satellite launches. Mr. Busse emphasized, however, that a rocket launch is never allowed to proceed with a known defect in either rocket or payload. If a repair or design change is judged to be essential, it is accommodated before launch.

Recommendations:

(1) Establish better flight program definition.

(2) Improve the procurement process for standard hardware by lessening time and eliminating paperwork.

(3) Improve cost accounting and compare predicted versus actual costs (both manpower and dollars).

(4) Establish methods of evaluating scientific value of flight against cost to support.

This concluded the first workshop. A second workshop was scheduled for June 1975. The second part of this article will cover the recommendations from six more NASA projects, an overall summary, and a discussion of the recommendations forwarded to the Deputy Administrator.

Space Science: What's Wrong at NASA

by Robert Bless

In December 1989, after long years of development and delays, the Hubble Space Telescope (HST) is scheduled to be carried into orbit by the space shuttle *Discovery*. The telescope is the most ambitious — and expensive — scientific satellite ever constructed by the National Aeronautics and Space Administration (NASA). Its 2.4-meter-diameter mirror is the world's most nearly perfect astronomical mirror. Above the blurring effect of Earth's atmosphere, the HST will be able to detect celestial objects five times farther away than can be observed by the most powerful ground-based telescopes, and will produce images that are roughly 10 times more detailed than conventional images. In the words of Charles Pellerin, NASA's director of astrophysics, "It's going to blow people's socks off."

Despite the expected rewards, however, the story of the HST is also the story of what's wrong with how NASA conducts space science. Experience with the project has revealed three particular policy areas that render scientific programs less effective and more costly than they ought to be. These are overreliance on the Space Shuttle, a predilection for big projects, and poor management.

The nation is now debating long-term goals for the U.S. space program. Should we send a manned mission to Mars or establish a manned base on the moon? Should we build a space station, and if so, how big should it be and what should it be used for? These are important issues — the government needs a well-planned, coherent strategy to guide future ventures in space. But the problems created for space science by current NASA policies can be addressed immediately, and solving them will do much to advance research even without spending more money.

Getting Off the Bus

Since the *Challenger* accident in January 1986, most people have come to accept what some members of the space science community had been saying all along: that NASA committed a major mistake in making the shuttle the only launch vehicle in its stable. The shuttle can never be a space "bus," as the agency advertised, with the reliability and low cost this implies. Nor is it prudent to risk the lives of astronauts in order to launch satellites that can just as well be lofted into space by unmanned rockets. The recent resumption of shuttle flights should not blind us to these realities.

With the shuttle as the main avenue to space, scientific missions have had to be tailored to its requirements and capabilities. Science has often proved the loser. For one thing, the orbiters can't fly very high, which limits a satellite's altitude. The HST will orbit about 370 miles above the Earth. This is nearly twice as high as most shuttle flights, but our planet still blocks about half of the sky from the telescope's field of vision. Coupled with other operational constraints, this means the telescope can gather data only about one-third of the time — no better than ground-based telescopes. By

comparison, the smaller International Ultraviolet Explorer satellite, boosted by a Delta rocket into geosynchronous orbit some 22,000 miles above the Earth, can observe the heavens 85 to 90 percent of the time.

A smaller satellite in a geosynchronous orbit is also likely to require simpler operational systems, since the satellite is directly visible to a single ground station 24 hours a day. This makes control far easier, especially for real-time operations. By contrast, NASA now intends for messages to be relayed to and from satellites in low orbit via the Tracking and Data Relay Satellite System (TDRSS), which has two communications satellites in geosynchronous orbits. In some cases this will work fine, but TDRSS is a very limited resource. The HST and other scientific satellites that must send large amounts of data can expect access to the system only about 15 to 20 percent of the time. This means that real-time operations will be possible only rarely, and that some kinds of celestial observations requiring high data rates will be made more complicated or even compromised. In addition, the Defense Department now has priority for the use of TDRSS, and this may reduce its regular availability to civilian programs.

NASA has tried to make some of the shuttle's capabilities seem like advantages. For example, the agency touted the opportunity to be able to repair or refurbish satellites, either in orbit or by bringing them back to Earth. As it turns out, though, this capability may prove of dubious benefit for the HST, and probably for most other spacecraft as well.

The HST was planned to be the first of a new breed of scientific satellites, with a lifetime of about 15 years, far longer than usual. It was to be built largely of "black boxes" — independently mounted, easily replaceable modules containing equipment that performed individual functions. Every 2 or 3 years the telescope would be brought into the shuttle's cargo bay, where astronauts would replace any ailing boxes, and every 5 years or so astronauts would haul it aboard for a trip back home. After about 6 months of maintenance, the HST would return to orbit via the Shuttle. The HST's longevity, made possible by such regular attention, justified its great cost, estimated in the project's early days to be about $500 million. Or so NASA argued to Congress.

However, when agency engineers took a closer look at plans for refurbishment — which didn't happen until several years into the project — they found that returning the satellite to Earth was prohibitively expensive. Shuttle launches would be more expensive, by roughly a factor of 10, than estimated. It would be necessary to maintain extensive maintenance facilities and a large inventory of electronic, mechanical, and thermal components. And it would take much longer than 6 months to do the job. When it became apparent that the cost of ground-return refurbishment would approach the cost of building a second telescope — and not about $10 million as NASA had told Congress — the idea was abandoned.

Only refurbishment in orbit is now planned, but this won't be as useful or affordable as claimed, either. The HST's original design called for more than 100 replaceable boxes. However, the refurbishment budget fell victim to several raids when the overall program encountered financial difficulties. The number of boxes once dropped to about a dozen, but it has

since increased to about 30. These boxes — along with thousands of other items, including spare parts, test equipment, technical drawings, and manufacturing and test records — must be cataloged and stored, and manufacturers must be kept under contract to maintain their knowledge of the subsystems in case they are ever needed.

If a box fails that is critical for the HST's survival — for example, the solar arrays, batteries, or communications receivers — NASA says it will take about a year to be able to mount an emergency shuttle mission to repair the satellite. Failures that reduce the observational capability of the telescope but don't threaten its life will have to wait for a scheduled maintenance flight. NASA now plans such flights every 5 years, though the agency has "reserved" a contingency shuttle flight during the first 5-year period. Of course, most of the support people needed to operate the HST must be kept on the program even when the satellite is inoperative or working at limited capacity.

During refurbishment flights, scheduled or emergency, the shuttle will have to carry enough fuel for two attempts in order to maximize the probability of a successful rendezvous with the telescope. That extra weight, combined with the bulky complement of replacement boxes, will likely mean that no other payload can be carried.

Thus, all of the launch and operational costs should effectively be charged against the HST. Using a conservative price tag of $250 million per shuttle flight, two or three launches would about equal the price of building a second telescope. However, NASA's Office of Space Science and Applications (OSSA), the agency's science arm, has traditionally been little concerned with launch costs. Since the shuttles are handled by another part of the agency, and hence paid for from a different budget, OSSA seems to consider them as essentially "free."

Not to be overlooked, either, is the chance of damage to the telescope during refurbishment. At roughly 12 tons and 15 by 43 feet in size, it is almost as big as the shuttle's cargo bay. Working in space is no easy matter, and docking the satellite in the shuttle will be a complicated and risky endeavor. In mock deployments of the HST at NASA's Johnson Space Center, astronaut Steve Hawley has reported that he achieved "a comfortable amount of clearance between the telescope and the orbiter. When I say comfortable, I mean a few feet or so."

Big Projects, Big Problems

NASA favors large projects for a number of reasons. They are seen to represent a natural evolution in the maturity of a particular scientific field or in the development of technical capability; such arguments were used to justify the shuttle and the space station. Large projects also afford vivid public relations opportunities, and many observers note that the agency usually can sell Congress a billion-dollar project about as easily as a $300 million project.

The HST is undoubtedly a big project. Planning began in earnest in 1971, and construction contracts were awarded in 1977, after Congress finally approved funding. Launch was originally intended for late 1983, but it kept slipping. The date had been set for October 1986 when the *Challenger* exploded. However, the accident probably did not appreciably affect the HST's ultimate launch, since many project participants agree that the telescope was

unlikely to have been ready as scheduled. When the HST finally reaches orbit, the project will have cost a little over $2 billion, not including launch costs.

One drawback of large projects is that they generally take longer from conception to the delivery of spacecraft to orbit. This means the technology becomes outdated. Sometimes this isn't a problem: for example, many types of power supplies built 15 years ago are still perfectly adequate. But in areas of rapid technological development, such as computers, the consequences can be great. The two primary computers on the HST are based on technology now considered obsolete — indeed, they are not as powerful as today's low-priced personal computers. The limited computer memory in which to store commands will create significant problems in operating the satellite. Obviously, no spacecraft has ever been launched replete with the very latest technological marvels, but shorter lead times provide the best chance for flying the best equipment.

Long-term projects may also sacrifice scientific flexibility. Science changes rapidly, and the nature of questions that drove the design of a particular instrument might have changed by the time a satellite is ready to launch. Often, payloads can be made sufficiently versatile to avoid such problems. Indeed, this is likely to be true for the HST. But there is little question that some capabilities not now present would be designed into the telescope if it were being built today.

A long development period results in considerable turnover in personnel. Wondering if launch will ever occur, people become discouraged and leave, or are wooed away to more promising programs, or finally retire. This is true at all levels of the project. For example, since 1977 there have been four HST project managers at NASA's Goddard Space Flight Center and five at Marshall Space Flight Center, which developed the HST. NASA's Headquarters has seen about half a dozen HST program managers come and go. Maintaining continuity and project "memories" — vital factors in ensuring smooth, coordinated progress — is difficult under such circumstances.

Long projects are particularly difficult for researchers in universities. Graduate students are able to participate only in small bits of the program, and rarely have the satisfaction of seeing it come to fruition. Young professors, who have only 5 or 6 years to establish their credentials for tenure, are understandably wary of becoming involved in something that promises no scientific return for a decade or more. Even senior professors must ask themselves whether a lengthy and time-consuming commitment as an actively participating investigator is compatible with their responsibilities to teaching, to students, and to departmental and university affairs, not to mention research.

If university faculty and students are to remain involved in space science projects, the environment must be made more attractive. Otherwise, future space scientists may well receive all of their training at NASA Centers or in industry, which will deprive the field of much of the diversity and innovation that nurtures it.

The scientific disciplines served by large projects may also suffer because of long dry spells in data collection. Once a large project has begun, NASA usually feels, not unreasonably, that it cannot afford to put additional money into that branch of astron-

omy. For example, the HST will carry instruments that analyze ultraviolet light. Therefore, NASA has not committed any other substantial funding to research in this area. Only because of the remarkably long life of the International Ultraviolet Explorer, launched in 1978 and still working, have astronomers had a continuing flow of spectrographic data. By pouring resources into large projects, prospects for the immediate future are mortgaged against ambitious hopes. The gamble may pay off — but it could also jeopardize the health of the science.

Who's in Charge?

NASA once had a reputation for sound management. But if this were ever really true, it is true no more. Indeed, the Rogers Commission identified a host of serious management flaws during its investigation of the *Challenger* disaster. In the case of the HST, a variety of management problems plagued the project from its inception, and contributed to making the satellite cost perhaps two or three times more than originally estimated.

For one thing, the project regularly found itself short of funds toward the end of the fiscal year, which meant that the solution of various problems or the construction of certain equipment had to be delayed. This produced a huge "bow wave" of deferred problems. As a project advances, the options narrow and the right people may no longer be available, and it is almost a fact of scientific life that the longer problems are put off, the more they cost to fix.

Perhaps the greatest management problem, however, arose from the project's organization. In an unusual move, NASA gave two space flight centers — Marshall and Goddard — major management roles. Marshall had overall responsibility and was to oversee construction of the telescope and the spacecraft. The Perkin-Elmer Corporation would build the telescope, and the Lockheed Corporation would build the satellite as a well as assemble all the components into a working observatory and carry out an extensive testing program.

Goddard, reporting to Marshall, was to be responsible for construction of the scientific instruments and the ground system for operating the HST. Goddard contracted work on the ground system to TRW. The center also contracted with a consortium called the Associated Universities for Research in Astronomy (AURA) to form the Space Telescope Science Institute, which would manage the observatory's science programs and serve as the interface between the HST and the international astronomical community. Some of the satellite's equipment was to be built by the European Space Agency, which would be guaranteed at least 15 percent of the telescope's viewing time.

On paper, such fragmented organization may have seemed a reasonable approach, given the project's size and complexity.

But in fact it proved cumbersome and led to significant difficulties. Differences in institutional styles between Goddard and Marshall quickly became apparent. For example, they effectively adopted different approaches to verifying that work was done properly — Goddard usually wanted to conduct performance tests, whereas Marshall was more willing to accept a "paper audit" as evidence — which often left project participants confused when it came to planning their work.

The two centers also engaged in turf battles, and an "us against them" attitude developed that reduced project efficiency even further. For example, Goddard officials tried to make all communications between the groups working on scientific instruments and groups in other parts of the program flow through Goddard, even though its HST staff lacked the manpower or capability to serve as a pipeline.

Because management was so diffuse, the responsibility for systems engineering — that is, making sure that all the HST's components performed together smoothly — was never clear. Not until it became apparent to everyone that the HST project wasn't making serious progress toward completion, and in fact was in jeopardy, did NASA Administrators begin to pay serious attention. In 1983, NASA finally assembled a group of engineers at the agency's headquarters and made them responsible for directing the development program and resolving critical problems. They were also given power of the purse, so the group had real clout.

Communication difficulties contributed to the project's slow progress, especially during the first half-dozen years. Fragmented management and the fortress mentality that developed helped create this problem, but more subtle and pervasive factors made communication across groups and organizations even harder. For example, messengers with bad news were definitely not welcome, particularly at Marshall, and anyone reporting problems was often held responsible for having caused them.

Thus, quarterly reviews presented by project participants to Center Directors and officials from NASA Headquarters were often designed to give the impression that everything was going well, that any problems were well understood and being solved, and that schedules were being met. However, conversations among participants in the hallway or over a beer often revealed drastically different pictures. Not having accurate knowledge about where the project actually stood and what areas needed attention prevented NASA Administrators from intelligently making tradeoffs in allocating development dollars.

Learning from Experience

After the HST reaches orbit and begins sending back exciting new images of the universe, it may be tempting to put aside the problems encountered along the way. That would be a mistake, for only if NASA recognizes the problems caused by its current policies will space science regain its lost vigor. The 20 percent of NASA's budget that historically has gone into space science — now about $4 billion a year — should be sufficient to carry out an exciting program, if it is planned well and carefully executed.

First, the shuttle must be reserved for those missions that absolutely require manned operations. Otherwise, expendable launch vehicles, selected to meet the orbital requirements of the satellite as closely as possible, should be used. NASA does in fact plan to launch some satellites using expendables, but it remains to be seen how vigorously this option will be pursued. For example, the Advanced X-ray Astronomy Facility, a large telescope scheduled for the mid-1990s, is still slated to be launched by shuttle and refurbished in orbit.

NASA should explore ways by which the lifetimes of scientific satellites can be maximized without resorting to extensive orbit-

al refurbishment. There may be a few cases in which simple maintenance by shuttle-borne astronauts would be worthwhile. (Note that this does not mean the satellites themselves should be launched by shuttle.) For example, an instrument with infrared detectors cooled by liquid helium might run out of coolant long before the end of a satellite's useful life. It might be possible to develop a method for replacing the coolant reservoir. Of course, this benefit must be balanced against the orbital limitations imposed upon the satellite by the requirement of a shuttle rendezvous.

A more realistic and generally applicable strategy for adding years to scientific missions is to build a second spacecraft that would be launched when the first one failed. Since it costs less to build two satellites at the same time than it does to build them separately, this could well prove a viable alternative to shuttle refurbishment.

A variation on this approach would have NASA return to its early practice of building a prototype satellite to test before building the final spacecraft. When needed, the prototype could be modified as required and sent on its way.

NASA should also begin to think smaller. Huge space-science projects are justified if they are the only way to obtain crucial scientific data. On the HST, for example, several of the instruments do not actually require the sophistication of the telescope's large mirror in order to fulfill most of their goals, yet their presence has added to its size, complexity, and cost. Launching a series of more modest satellites carrying specialized instruments might well have provided greater rewards. The steady activity would also have kept engineers and scientists productively busy.

Only one NASA space flight center should be given responsibility for the development of any scientific project. (Indeed, one way of judging whether a project is too big is if it requires more than one Center for its development.) Clear lines of authority and responsibility must be established from the start in order to prevent organizational confusion. Systems engineering groups — staffed by engineers and the ultimate users, scientists — must also be organized from the program's outset. Managers must be aggressive in their efforts to learn what is going on in their groups. And officials in NASA headquarters must actively pursue their oversight role in order to better understand budgetary matters as well as to prod the project most effectively.

In planning its scientific project, NASA must assess the real costs of each venture. This means including vehicle and launch costs. In this regard, the agency should begin a long-term effort to reduce costs by developing better ways of building spacecraft, instruments, and ground systems. Too often, practices have continued simply because "that's the way we have always worked."

People with new ideas must be encouraged and rewarded. This is difficult under the best of circumstances. But NASA, like many other federal agencies, has suffered steady manpower reductions, which have forced the agency to farm out more of the construction of instruments and spacecraft to private companies. Not only is this economically questionable; it also means that the expertise developed as a consequence of the job may not be available to NASA in

the future. This problem is magnified by the fact that government salary scales have not kept up with the private sector, and the agency is facing increasing difficulty in attracting the most talented and experienced people.

But perhaps the most fundamental issue to be faced is the question of whether NASA should have a space science program at all. Would science be better served if an independent organization took over most of the functions of the agency's Office of Space Science and Applications?

For some space scientists, the answer is yes. An independent space science agency could contract for launch vehicles with NASA or one of the private companies now emerging, and could even arrange with NASA for manned support on the relatively rare occasions that it is needed.

From its earliest days, NASA has been oriented not toward science but toward huge engineering projects, usually involving human activities in space. Its three largest projects — the Apollo program, the shuttle, and now the space station — were undertaken for technological or political reasons, not for their scientific potential. But in selling the shuttle as an all-purpose launch vehicle, NASA forced all space science missions to use it and there is a real danger that the same thing will happen with the space station.

Just this point was made in a report on the space station by the National Academy of Sciences in 1987: "It is important that space science not be conformed, made hostage if you will, to the space station and the shuttle." Indeed, the Academy's Space Science Board concluded in a 1983 report that there would be no scientific need for the space station for at least the next 20 years.

Critics of an independent space science agency often argue that space science would never be funded on its own behalf, and that it exists only because it is a small part of NASA's mission. But this isn't totally convincing. Indeed, it may be that just the reverse is true — that in the minds of many laypeople and perhaps even in the halls of government, science to a considerable degree justifies the larger program. For example, polls conducted during the recent presidential election indicate that space science was of significant interest to a large majority of citizens. In any case, however, a public discussion of the role that space science plays — or should play — in NASA would likely prove useful.

The U.S. space program, now emerging from a period of relative inactivity, is poised for a fresh start. Coupled with the beginning of a new administration, this is an opportune time to reshape NASA's policies. If we proceed with business as usual, we will lose a golden opportunity to inject renewed vitality into the space sciences.

Recommended Reading

Walter A. McDougall, . . .*the Heavens and the Earth: A Political History of the Space Age.* New York: Basic Books, 1985.

National Commission on Space, *Pioneering the Space Frontier: The Report of the National Commission on Space.* New York: Bantam Books, 1986.

National Research Council, *Report of the Committee on the Space Station of the NRC.* Washington, D.C.: National Academy Press, September 1987.

Robert Smith, *Shaping the Space Telescope: The Interpenetration of Science, Technology, and Politics.* New York: Cambridge University Press, 1989.

National Research Council, "Assessment of the Scientific Value of a Space Station." Report of the Space Science Board, National Academy of Sciences, Washington, D.C., 1983.

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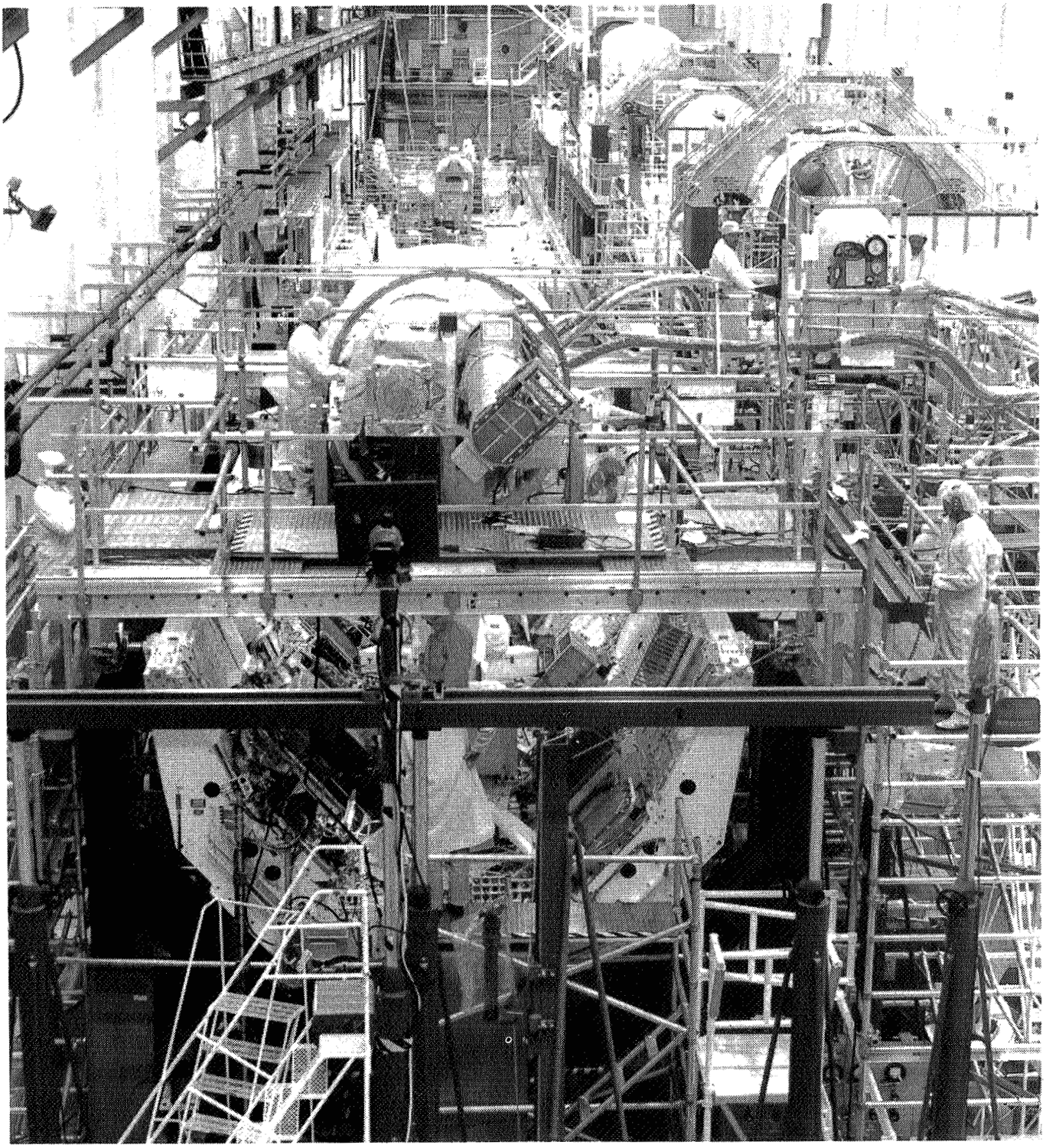

Engineers and scientists are shown working in a clean environment on Spacelab-2 during the Mission Sequence Test in the Operations and Checkout Building at Kennedy Space Center in July of 1984. Specialized instruments can be seen on the cruciform structure for the 13 experiments on-board a subsequent Shuttle launch.

Resources for NASA Managers

by William M. Lawbaugh

Book Reviews

Liftoff: The Story of America's Adventure in Space
by Michael Collins
(New York: Grove Press, 1988)

Michael Collins, best known as the guy who stayed above in the Apollo 11 command module while Neil Armstrong and Buzz Aldrin became the first to walk on the moon, was asked to write "the" story of America's space flight experiences. He agreed, but only if he could do it independently. The result is "a" story of manned space flight, but a compelling one.

His successful *Carrying the Fire* was more personal and revealing, and the ingredients which worked so well for his autobiography are the strengths of this more technical and historical volume. It is ably illustrated by form NASA art director James Dean, who worked with Collins when they were curator and director of Smithsonian National Air and Space Museum.

While *Liftoff* covers much the same territory as other surveys of space flight, Collins' viewpoints and firsthand observations make it interesting. For example, more space is devoted to Gemini (he flew on Gemini X) than Shuttle, and more space on Gemini X than all the other 11 missions, and the book opens with a wonderful account of Apollo 11.

Collins clearly set up his heroes and his adversaries, and he spends an inordinate amount of space on recent events reflected by past experiences. "I cannot imagine von Braun sitting on a problem like the O-rings," he says in his analysis of the Challenger disaster. And "Jim Webb would have known about the O-ring problem," he claims. "He might not have known the difference between a tang and a clevis, but he would have known that one of his contractors was out there waving a distress flag. His people would have told him." In 1988, two years after Challenger, he laments a NASA in which "the magic is missing."

In contrast, he points to George Low's Configuration Control Board which considered 1,697 changes and approved 1,341 of them in the two years following the 1967 Apollo disaster, a fire on board that took the lives of Grissom, White and Chaffee. He quotes Low as saying: "Arguments sometimes got pretty hot ... In the end I would decide usually on the spot, always explaining my decision openly and in front of those who liked it the least," including the astronauts, Collins' most important people.

In a concluding chapter, "Ad Inexplorata," Collins endorses the Paine Commission report starting with a permanent space station and culminating in a mission to Mars. For the near future, he predicted, "The Hubble's successful launch will, I feel, be the most important piece of work NASA has done in recent years, and one that I hope will herald the agency's return to the forefront of science and exploration."

Ethics in Engineering 2nd edition
by Mike W. Martin and
Roland Schinzinger
(New York: McGraw-Hill, 1989)

The authors, professors of philosophy and electrical engineering from the University of California, Irvine, do a credible job of offering an ethical system for engineers, applying it consistently to some of the engineering dilemmas of our time: Chernobyl, Three-Mile Island, Bhopal, Love Canal, the Pinto, all-terrain vehicles and asbestos.

While the authors list and explain each of the major ethical approaches in Western philosophy, their main approach is synthesis. They start with the psychological theories of moral development of Piaget-Kohlberg and modify it with insights from Kohlberg's student and colleague, Carol Gilligan. Piaget and Kohlberg perceived three levels of moral development: preconventional (self-interest), conventional (obedience to authority) and postconventional (autonomy). Few reach this "highest" level of isolated, individual, altruistic morality. Yet, Gilligan suggests a synthesis of second and third levels, balancing one's own needs with the needs of others "toward an ethic of caring."

Likewise, a synthesis is sought between actions and people, or personal and professional life, through Aristotle's Golden Mean. In other words, the authors favor an ethic based upon virtues, particularly those of trustworthiness (honesty in action and word, competence, diligence, loyalty and discretion) and benevolence (gentleness, compassion, and generosity). These virtues are particularly important for responsible and responsive engineers, and they incorporate Gilligan's theory of moral development. Rarely do we choose an action for one reason alone. An engineer may do engineering for money and fulfillment (self-interest), to serve the family and company or institution (social convention) and to serve humanity and one's destiny (postconventional morality), not just one or the other.

With that ethical framework, the authors explore the duties and the rights of engineers on the job. As the engineer attempts to provide creative solutions to practical problems, there is always an element of risk. The authors even define engineering as "experimentation" stressing "learning from the past." The overriding duty of the engineer is to balance the demands of risks and safety. They suggest that top officers at Morton Thiokol decided not to convey the vigorous, unanimous warnings of the 14 O-ring engineers to NASA officials who had to make the decision to launch the Challenger in 1986. The moral dilemma seems to be in the reporting system, the authors suggest.

The rights of engineers include whistle-blowing as a practical moral necessity of last resort, but the authors go beyond that to suggest that there is a better method: to remove the need for whistle-blowing with "greater freedom and openness of communication within the organization." Engineer rights also include the right of self-determination through enlightened unionism, and the elimination of sexism and racism in an institution. Balance and Aristotle's Golden Mean are considerations here between the duties of management and the rights of individuals, the rights of management and the duties of individuals. Collaboration and compromise are paramount concerns.

In a final section of *Ethics in Engineering*, the authors consider global issues such as environmental concerns and computer ethics, and then wax poetic on "the existential pleasures of engineering" as a vocation, suggesting that engineering attracts the best and the brightest of creative, yet practical, people. The medical profession may dispute this claim, but the authors quote Herbert Hoover, an engineer who said the engineer, at least, "cannot bury his mistakes in the grave like the doctors." The book concludes with codes of ethics from ABET, AAES, NSPE and IEEE, plus an extensive bibliography.

Influence Without Authority
by Allan R. Cohen and David L. Bradford
(New York: John Wiley & Sons, 1990)

How do you get people (bosses, peers, subordinates) to do what you want? According to the authors: "We have discovered that it is the process of give and take that governs influence. Making exchanges is the way to gain influence; and that process leads to cooperation rather than retaliation or refusal to engage. People cooperate because they see something of value that they will gain in return."

While this rather simple but often overlooked prescription seems like manipulation, the authors go to great length to insist that lies and deceptions will be uncovered sooner or later, and all gains of influence will thus be jeopardized. Nor is "influence" merely directed at the other's self-interest, or "what's in it for me?" More often, it is directed at doing what is right, pursuing excellence, realizing the organization's goals and doing challenging work. Also at great lengths, the authors fill more than half this 319-page book with hypotheticals, little and long dramatizations of the principles in case study format.

The idea of this book is to "replace the crutch of authority with the engine of influence." Even in hostile situations, where hardball strategy is required for the obstinant or nasty superior, the authors stress the self-interest of the ally, accentuating the negative. For example, the influential subordinate will want to show the possible consequences or ramifications of not cooperating. This sounds like a threat, but the authors suggest "breathing room options," including putting your job on the line. In the hypothetical, the boss appreciated the candor and spunk of a harsh memo-writer.

Influence without authority, raised to the highest level, is to become a partner with your boss. The authors point to three typical attitudes toward authority (dependence, counterdependence, and independence) and suggest that a higher ideal is interdependence. What manager wouldn't want "subordinate partners who own the unit's problems, carry out their responsibilities, ask for help when they need it, are loyal with them enough to prevent mistakes rather than letting them slip by as long as someone else's (usually the boss') head will roll, and make sure that important issues are raised at the right time"?

This is a book for subordinates, not bosses, though. Few bosses are "enlightened" enough to share power and responsibility. For those bosses, the authors recommend their previous book, *Managing for Excellence* (New York: Wiley, 1984), where they claim that "managers can no longer be effective by heroically trying to be responsible for everything; they must make heroes out of their subordinates by sharing responsibility."

Quality Circle Management: The Human Side of Quality
by Harry Katzman, Jr.
(Blue Ridge Summit, PA: Tab Books, 1989)

This small, 150-page book is more of a handbook of suggestions than a text or study of quality circles, defined as "a small group of workers who meet regularly on a voluntary basis to analyze problems and recommend solutions to management." Described as a quality control discipline originating in Japanese manufacturing, quality circles can be instituted in any organization to spot problems and to manage solutions.

The author covers quality circle principles, methods and strategic planning, with supplementary material on automation, group decision-making and human relations in a clear, understandable way, but sacrificing depth and examples.

One interesting tool he discusses and illustrates is the Johari Window, named after originators Joe Luft and Harry Ingham. The four "panes" of the window are labeled Open Area (information known to all), Blind Area (known to workers), Hidden Area (known to managers) and Unknown Area (information not known to any). The fourth quadrant can lead to new opportunities for greater productivity. Quality circles should enlarge the Open Area and shrink the other three through feedback, communication and joint exploration, respectively.

The New Realities
by Peter F. Drucker
(New York: Harper & Row, 1989)

When Peter Drucker talks, managers listen, but there is little on management in his latest book, *The New Realities*. Here, Drucker claims that 1973 marked the end of New Deal ideology and the beginning of confusion in economics, politics and society. That was the year of the Arab oil embargo following the end of the gold standard.

However, in a single chapter on management in this new age, Drucker asserts it is not "a bundle of tools like those taught in business schools." Rather, it is about human beings, "deeply imbedded in culture." Management is, or should be, common goals and shared values in an organization. The real job of management is to enable people to grow as needs and opportunities change, not just the "bottom line" or quantity of output. Most importantly, "results exist only on the outside," in a satisfied user or customer.

"Large organizations will have little choice but to become information based," he concludes. Typical of his cryptic style, Drucker defines his terms in ways that send readers into thought: "Information is data endowed with relevance and purpose."

Managing Projects in Organizations
by J. Davidson Frame
(San Francisco: Jossey-Bass Publishers, 1989)

J. Davidson Frame is professor of management science at George Washington University, a computer system expert, and a specialist in international economics. Observing that instructional materials abound for project managers in defense and construction industries (where "deliverables" are concrete), Frame says little can be found for smaller, information-age projects resulting in software or intangibles. His 240-page book fills that void in a very readable way.

Two key lessons he emphasizes in the nine chapters are: avoiding pitfalls, and making things happen. After definitions and overview, Frame discusses and illustrates resources, team structure, end-user needs, defining requirements (like "trying to nail jelly to a wall"), tasks and techniques for planning control (WBS, Gantt charts, PERT/CPM, etc.), and rudimentary principles for achieving results.

Perhaps his best chapter is "Capable People: The Heart of Every Project." Frame notes how management rediscovered the people ingredient in the early 1980s though such best-sellers as *In Search of Excellence* (1982), *The One Minute Manager* (1982), *Theory Z* (1981) and Tracy Kidder's *The Soul of a New Machine* (1981). Frame approvingly quotes one executive who always looks for the busiest people in forming a project. "I stayed away from those people who were readily available." The rest of this fine chapter is devoted to the Myers-Briggs Type Indicator in selecting staff, reducing conflict and improving staff relations.

While this book, subtitled "How to Make the Best Use of Time, Techniques, and People," covers the basics of project management on a beginner's level, it does deal with three planning and control tools not often discussed: the earned value approach, gap analysis and the bureaucratic milestone review technique.

The earned value technique is attributed to DoD, DoE and NASA for very large projects, but Frame suggests it is useful for small projects as well. He uses Gantt charts of the budgeted cost of work scheduled (BCWS) and the actual cost of work performed (ACWP) of each subtask or work package to determine the budgeted cost of work performed (BCWP), which shows the earned value. Schedule variance is determined in monetary terms by subtracting the BCWS from the BCWP. Thus, while most of the work may be completed ahead of schedule, the earned value may be less or more than raw figures may show. For example, a pyramid may be 90 percent complete but the last pieces will take more time and cost to cut, lift and place. Earned value shows that.

Gap analysis is useful for planning of multiple projects that are co-managed, such as a data processing department or an R&D department which works on many projects simultaneously. Allocations of time and money, investment and output, are charted along with a projected budget and a current budget. The gap between the two budgets is the focus for analysis: "What should the project portfolio look like in order to fill the gap?"

The bureaucratic milestone review technique, as described by Frame, was developed by the U.S. Navy project managers who had seen their projects defunded, not on the basis of technical merit but simply due to missing deadlines for funding. "Technical people often pay little attention to bureaucratic milestones," Frame asserts. So he suggests a three-tier set of deadlines, starting with the technical or performance level design document, reviewed by the project management level, and submitted on time to the organizational level. What makes this milestone technique work is the advice and consent of workers at the performance level. Frame ends with common sense reminders, including: "Be as flexible as possible; don't get sucked into unnecessary rigidity and formality."

The Leader-Manager: Guidelines for Action
by William D. Hilt
(Columbus: Battelle Press, 1988)

The Director of Manager Development at Battelle Memorial Institute likes to think this book is third in a trilogy. James McGregor Burns developed a seminal theory of political leadership in *Leadership* (1978), distinguishing transactional leadership (reward and punishment, carrot and stick, bribes and threats) and transforming leadership (recognizing needs and demands, and "lifting people into their better selves"). Second is Bennis and Nanus' *Leaders* (1985), extending that theory to organizational leadership ("Managers do things right while leaders do the right thing," with vision). *The Leader-Manager* tries to translate such theory into practice.

Hilt's leader-manager is a dreamer and a doer: a pragmatic idealist. Ultimately, such a leader is a "change agent," one who views change as growth, self-development and higher levels of achievement. Change is viewed as "a friend:" leaders will see change itself as inevitable, as the norm; others yearn for "things to return to normal." The central question of *The Leader-Manager* is: What should I do to become an effective leader? Hilt answers that question in a chapter entitled "Empowering,"which is really a chapter on motivation. First he points out the limitations of the transactional leadership model by noting that the image evoked by this carrot-and-stick approach is that of a jackass. The transformational leadership model, on the other hand, empowers workers to operate on seven or eight cylinders instead of the typical four.

Such a theory of empowering others as a leader is based upon Abraham Maslow's hierarchy of needs. Hilt offers 25 specific guidelines to move from theory to practice, five each for Maslow's five steps to self-actualization. The focus, of course, is not on product or profit, but rather people. Practical tips, such as making sure people take vacations, equitable pay, joint goal setting and planning, recognition, and good personal coaching, are listed and explained.

"High tech without high touch is sterile," he concludes. But that is not to suggest that the "nice-guy" leader-manager is without competence and vision, for "high touch without high tech is blind." Such a synthesis points to the main strength of this 268-page book. Hilt constantly refers to and quotes the leaders in the field of management, suggesting that "nothing is so practical as good theory." This book will pull together and place in context some of the major management theories of the day, such as Tom Peters' MBWA and Peter Drucker's customer responsiveness. A Leadership Assessment Inventory and a case study in the appendix enable the reader to review the material and apply it to self.

Keeping the Dream Alive: Managing the Space Station Program, 1982-1986
by Thomas J. Levine and V.K. Narayanan
(Washington, D.C.: NASA Contractor Report 4272, 1990)

The authors, professors at University of Kansas and Rutgers, respectively, trace the history of internal management of the space station program from program approval to the decision to locate program management in Reston, Virginia. This methodology con-

sisted of archival research and interviews conducted between December 1987 and July 1988. Their 185 pages of text and notes were prepared for the NASA History Office under contract and do not necessarily represent the views of NASA.

The main problem with the content is chronology. Instead of a gradual unfolding of the story or developing a theme, the authors go back and forth, often and needlessly repeating basic information and even duplicating identical quotations. The table of contents suggests chronology — leading up to and the reversal of the "lead center" management approach — but rarely does one chapter lead into or follow another. Such may be the peril of dual authorship.

The title comes from a quotation of James M. Beggs, NASA's sixth Administrator from 1981 to 1985, who hoped that his epitaph would read: "He tried to keep the dream alive." Even before his confirmation hearings, Beggs, along with his designated Deputy Administrator Hans Mark, knew what kind of management would work best for the nation's first permanent presence in space: "One that is well decentralized, where the guy who has to do the work has the resources and the responsibility and the authority to get the job done."

His first job was to establish the Space Station Task Force to reflect what the professors call his "crescive" style of leadership, which, they explain, encourages "intraprenuership" (innovation in large organizations). Whatever the theory, the Task Force, due to its "participative, open culture,. . . brought the entire Agency together and involved all the Centers in the definition of the space station program,. . . [and] established the planning guidelines for the station for both management and engineering," the authors assert. Later, however, "with the gearing up of the program office it became apparent that the change in management style, although successful in the Task Force, was not to become a NASA standard."

Instead, the space station program became the battleground for internecine turf battles among the Centers. The authors suggest that "over the years NASA had evolved into a decentralized organization, and the field centers had become more or less autonomous." Thus, the lead center concept won out, for awhile, with Johnson Space Center effectively in control. However, the other center directors are quoted as telling the Phillips study group under acting Administrator Graham, "you can't have centers telling other centers what to do. It won't work."

Ultimately, Administrator Fletcher decided to abandon the lead center management concept, and the space station program was reorganized, very much as it is today. The authors do point out that a "skunk works" group formed in Houston during the interim period "did not take advantage of the concepts developed by the Space Station Task Force," nor did Phase B study groups. Also at this time, NASA lost its Administrator, Deputy Administrator, Associate Administrator for space station, the lead center director and the Level B program manager, not to mention problems with the Space Shuttle and then scrutiny of the Rogers Commission into all NASA management processes.

The underlying theme of this book — decision and reversal — roughly parallels the configuration studies of the station, from power tower to dual keel to single boom. While the authors seem to lament the passing of the early days, when the space sta-

tion concept was hatched and then approved by President Reagan, the main text does end on a hopeful note with another quotation from Jim Beggs: "Oh, well, I think NASA will come back strong," because NASA "puts a halo over all of science and technology."

The upbeat ending may compensate for all the flaws of this slim volume. In a biographical profile, for example, the authors have Beggs working at Westinghouse for 13 years between 1974 and 1981. Chapters have more footnotes than footnote numbers. And one candidate for space station manager is first described as "NASA's finest program manager" and then a page later as not having had any program experience.

Keeping the Dream Alive is hardly the last word on the subject, but, as the authors point out, a history of space station constituency building by Howard McCurdy is due out soon, along with a book by John Logsdon. The shortcomings of this book may inspire others to take up the pen before this chapter of corporate memory is lost forever.

Augustine's Laws
by Norman R. Augustine
(New York: Penguin, 1987)

Norm Augustine, president and CEO of Martin Marietta Corporation, has written one book — several times — and each subsequent version is more readable and richer. First published by the AIAA a decade ago, *The Compleat Augustine's Laws* took off like a rocket, leading to a "revised and enlarged" second edition by AIAA in 1983, followed by a more complete Viking Penguin edition in 1986 and Penguin Books in 1987. The 1983 edition was subtitled "And Major System Development Programs," containing only 45 "laws" instead of the current 52, "one for every week of the year." Originally written for the manager of large aerospace engineering projects, it has become a favorite among program and project mangers in government and private industry.

Nearly all of the 52 "laws" are derogatory of current management practices. At times, they sound like the proverbial Murphy: "Most projects start out slowly — and then sort of taper off"; "The optimum committee has no members"; "Hiring consultants to conduct studies can be an excellent means of turning problems into gold — your problems into their gold." Augustine is down on not only committees ("a powerful technique for avoiding responsibilities, deferring difficult decisions, and averting blame while at the same time maintaining a semblance of action"), but meetings in general, acronyms ("a powerful means of increasing confusion"), lawyers, briefings, management reorganizations, most marketing techniques, most financial prognostications and even some how-to books. He does like Quality Circles, a management tool used by Martin Marietta on certain projects.

The key to Augustine's thinking on management has more to do with his approach rather than the content. In every chapter, the author counts, calculates and extrapolates figures. Whether they concern the tenure of football coaches, government spending or footnotes per author in the AIAA Journal (Augustine was once president of AIAA), he reduces every topic to percentages, ratios or figures on a chart. At one point, he counts (erroneously) the number of words in Lincoln's Gettysburg Address. At times, his analysis of data is pointed *ad absurdum*: "Modest extrapola-

tion of the College Board scores in Figure 25 reveals that, if the trend of the late 1960s and 1970s prevails, in just 142 years there will be no perceptible intelligence left whatsoever." While humor, such as ridicule of "bean counters," lightens the image, the picture that emerges is one of a manager who takes Augustine's favored MBO principles to the extremes and reduces every management issue to numerical equivalents, often involving people.

Augustine mentions NASA about a dozen times, usually to illustrate some managerial problem, such as "the perversity of software" (Mariner 1), "precise guesses" (chances of injury from a falling spacecraft) or "the perversity of nature" (a destroyed NASA wind tunnel). The military, however, after Augustine had served as Undersecretary of the Army, receives the bulk of his scorn and criticism. He quotes approvingly from Dr. Bob Frosch (against bureaucratic engineers) and Kelly Johnson (against aircraft design by committee).

If the book sounds cynical of government, it is criticism of the system, not the civil service employees. In fact, he dedicates the book to them and speaks glowingly of certain government employees — as individuals, not as part of "the system." In an epilogue, he mentions "people" as the first lesson to be learned in the book:

> People are the key to success in most any undertaking, including business. The foremost distinguishing feature of effective managers seems to be their ability to recognize talent and to surround themselves with able colleagues. Once such colleagues are found, it is the ultimate in sound management to reward them generously to assure that they are not lost.

He follows "people" with other qualities such as teamwork, recognition, delegation, customer satisfaction, quality and integrity, trying to boil them all down to one trait: self-discipline.

Discipline, laws and mathematical calculations do not, on the surface, add up to a warm, wholesome work environment, but Augustine demonstrates a hearty sense of humor throughout the book which seems to flavor the bitter medicine. His prescriptions, all bunched and explained in the epilogue, are self-evident, but the epilogue seems tacked on, as an afterthought. Nevertheless, *Augustine's Laws* is insightful, clever and fun if not rigidly organized and fully developed. The fourth edition might be better coordinated.

The Silent War: Inside the Global Business Battles Shaping America's Future
by Ira C. Magaziner and Mark Patinkin
(New York: Random House, 1989)

Ira Magaziner is an international business consultant who has teamed up with a journalist to prove that the Europeans and the Japanese are beating America as economic and industrial world leaders through strategic planning in high tech development.

While "decline of the U.S." books are common, this one is based upon firsthand observation and analysis. Most such books catalog the dire warnings: a scary federal budget deficit, the U.S. as the world's biggest debtor nation, a lingering trade imbalance, and sharp decline in research and development — all created in the past decade.

Magaziner does not merely list these woes. Rather, he talks with CEOs and workers

alike, offering perspective and commentary. An extensive, hundred-page notes section carries the boring analysis and statistics to make the text readable. In brief, he asserts: "If a nation is to prosper, it has to succeed at world trade. And ninety percent of world trade is goods, not services." If indeed the U.S. economy is increasingly service-oriented, his warnings are poignant.

The authors structure the book around competition with low-wage and developed nations, and competition in future technologies, including aerospace. While most U.S. companies relocate to developing nations to escape unions and high wages, such "sourcing" eventually becomes real competition. Thus, the short-term gains of cheap labor eventually come back to haunt those companies which exploit the poor in low-wage countries as the latter gradually develop competing industries. Magaziner claims that "many of these products we source from them could be made competitively in the U.S." if only U.S. plants would modernize, automate and market for export.

Competing with developed nations, however, is different. Japanese, West German and Swedish workers earn 20 to 30 percent more than U.S. workers, and yet their products (especially autos, electronics and steel) are of higher quality and sell better than U.S. products, in the U.S. as well as the world market. How come? "Industrial policy," the authors claim. Fully developed countries, except the U.S., tend to erect trade barriers to protect their targeted industries, pump them full of subsidies and low-cost loans, and encourage them to export to the U.S. and elsewhere. While Magaziner does not suggest formation of an American version of Japan's Ministry of International Trade and Industry (MITI), a government-industry planning consort, he does suggest that "with the proper investment strategies, we could have positive trade balances in these products."

Advanced Project Management
2nd edition
by F.L. Harrison
(Gower: Hants U.K., 1987)

Frederick Harrison has combined a 30-year career in project management with teaching in a business school and working for Britian's National Coal Board, and earlier Imperial Oil of Canada. When his first edition of *Advanced Project Management* came out 1981, it was virtually ignored. It was not even listed in a 300-plus item bibliography of project management recently published in the United States, for example. Perhaps this omission is due to Harrison's obscurity as director of operations in the largest public sector, direct labor organization in Western Europe. As Harrison notes, "effective project planning is difficult to carry out and puts much more emphasis on a manager's conceptual skills, than does the normal day-to-day management of operations."

Harrison stresses the value and importance of planning at appropriate detail for both project launch and control. Large projects will have a hierarchy of plans — less detail for reporting to top management, greater detail for supervisors — and he even presents a major section on "Planning the Planning Process."

This second edition of *Advanced Project Management* contains separate chapters on small and large projects and one on the use of computer-based systems. In his chapter

on planning the smaller project, Harrison lists "the line of balance technique" (LOB), not even mentioned in other project management books. The LOB is a method, developed by the U.S. Navy in the early 1950s, to plan and control repetitive activities, such as modular home-building. Diagonal lines are drawn down a Gantt chart to show the number of identical units or subassemblies accomplished simultaneously.

Larger projects will require the project manager to use other, more sophisticated planning and control tools such as work breakdown structure (WBS), hierarchical planning ("rolling waves" of plans for each level of activity), performance analysis of meaningful data, and systematic change control systems, each amply illustrated. A final chapter deals with the "people system," engineers as managers, and conflict resolution.

Harrison's 370-page book is described as a guide for managers and others concerned with project planning and control, and as a college-level textbook for those students of project or construction management. Most of the illustrations suggest construction management, but the book does serve as a handy compendium of tools and techniques from a European point of view.

NASA Video Reviews

Note: These and other videotapes, each about 50 minutes long, may be borrowed through Center or Headquarters librarians or directly from the NASA Program/Project Management Initiative, Code NHD.

"NASA Experiences in Program and Project Management"
with Frank Cepollina

The story of the Multi-Mission Module Spacecraft (MMMS) begins in the mid-1970s at Goddard Space Flight Center. Cepollina and his team were challenged to "fly more science at less cost," due to inflationary pressures. In his design and cost study of 150-180 spacecraft, he came to these conclusions: there was no significant commonality in manufacture; but there was common equipment for payloads; one-third to 60 percent of program cost was in the integration and test phase; and performance was mixed. He settled on a single, standard spacecraft that could be used for four or five different space science missions, could be launched on any vehicle (Delta, Atlas or the upcoming Shuttle), that incorporated manageable risk, and could be serviced on orbit with common, modular components. The concept of a standard spacecraft was then first used on Solar Max.

The camera shifts to NASA Headquarters where Dr. Noel Hinners, Associate Deputy Administrator, and Dr. Anthony Calio, the former Associate Administrator for OSSA, recalled the lessons learned from the approval of Solar Max. Calio said the MMMS was a good concept to start with and praised Cepollina's "tenacious persistence."Hinners agrees, adding that such a project had a salesman to build support across a series of program offices, and that Goddard management had encouraged innovation by giving Cepollina plenty of leeway.

The camera switches back to Goddard with a discussion of the February 14, 1980 launch of Solar Max and to explore "the tragedy and the triumph" of the failure of

fine pointing equipment. In 1984, because of its modular design, the Solar Max was repaired on orbit and worked fine subsequently. Cepollina shows some components returned and refurbished for the next flight.

Cepollina concludes by noting that inflationary pressures are even greater today but advises, "Don't be afraid to grab the cutting edge of technology" and try to inspire staff and business people to follow the lead with three P's: Persistence, Patience and People-dedication.

"Shared Experiences in NASA Projects"
with Angelo Guastaferro

"Gus" Guastaferro, a former NASA official now with Lockheed, calls project formulation "the most critical part of any program." He explains how the Space Station Freedom Program, in its earliest phase, was a textbook example of how the project formulation team accomplished careful, flexible planning in conjunction with industry and the academic community. The Space Infrared Telescope Facility, however, peaked too early, lacked flexibility and was still on the drawing boards after 17 years. Project formulation failure may mean "delay" in NASA, he notes, but in private industry it is more decisive — go or no go.

His next topic is accountability, as opposed to responsibility or authority. Accountability suggests getting a commitment ("as if you were running your own business") with all three legs of the stool in place: cost, schedule and technical performance. The project manager needs quantifiable, measurable, objective standards, he advises. In industry, the bottom line for staying in business is critical; in NASA it is synthetic, with performance first.

Forming a project team is also critical. Recalling his eight years on the Viking project, Guastaferro noted: "Jim Martin cared about my personal growth." The successful project manager in NASA treated people right, provided ample opportunities for personal and professional growth, and "the payback was tremendous." He notes that industry is more apt to use rather than develop human resources.

On the management side, flexibility and tradeoffs are essential. "Make sure you don't die of hardening of the categories," he warns. Furthermore, he cautions that with the emergence of the personal computer as a management tool, managers may tend to fall in love with their electronic PC and hole up in an office. Guastaferro recommends "management by walking around" and sees MBWA as an emerging trend.

He closes with nine personal "lessons learned" (reprinted in *Issues in NASA Program and Project Management,* Vol. 1 - SP-6101). The capstone of these valuable lessons is communication: "A good manager is a good communicator," he writes. A brief question and answer period follows.

"Project Management from a Scientific Perspective"
with Dr. Frank McDonald

"The future has never been brighter," says this 30-year veteran of NASA. At the time of taping (May 1989), McDonald was Associate Director and Chief Scientist at Goddard Space Flight Center. Despite the set backs from the Challenger disaster, "18 operating satellites carried us through the past three years." And EOS is described as

"the largest pre-sold program NASA has ever put through."

McDonald focuses on key issues for the future. First is to build a space infrastructure to increase our access to space, particularly ELVs. He is impressed with NASA's new engineers and scientists, and recalls no conflict when they work one-on-one with other scientists and engineers in other Centers. However, pointing to the Hearth and Phillips reports, he sees big problems when work is carved up among several Centers on big projects. Finally, he sees more and more international involvement in NASA programs. Not only is international cooperation beneficial, but overseas competition stimulates more support for programs at home.

In terms of long-range issues, McDonald alludes to the Paine and Ride reports and concludes: "Mars is the next logical step." Some argue that NASA needs a tightly focused program, but McDonald disagrees. "NASA needs a highly diversified program to keep it strong." A mission to Mars or the moon will require a variety of disciplines and skills.

In a question and answer period from several Centers, McDonald noted that first and second tier universities are now in a position to attract NASA scientists and engineers with better pay. At the same time, the pool of good fresh-outs from top universities is shrinking.

"Shared Experiences in NASA Projects"
with A. Thomas Young

This interactive video teleconference linked the former Director of Goddard Space Flight Center, now President and Chief of Martin Marietta, to NASA Headquarters and various Centers on April 11, 1990.

"Project management is the best job in aerospace," Tom Young says, "and NASA is the absolute best in the field." He added that project management is where the action is, where an individual can make a difference.

Young outlined four areas of importance in project management. First: people above all else. Select those scientists and engineers who have technical competence, good interpersonal skills, and the commitment to regard the project not as "uh job" but rather as "a cause."

The goal is to create a work environment where average people overachieve, realizing there will be fringes of over- and underachievers. Then, listen. He quotes Yogi Berra: "It's amazing what you can hear when you listen."

Secondly, attention to detail. "Failure is usually caused by a small problem," he notes, "but success is the integration of thousands of small details." In terms of cost, an excess of operating funds can cause bad habits, but too much of a squeeze can cause "the Three-Mile Island syndrome" of too many variances. "Even the smallest variance is significant," he says.

Thirdly, the customer; one component rarely discussed. Yet, he says, "success is determined by the customer," and quality, too — his fourth point. Quality is not inspection but rather an attitude: "Doing it right the first time." Such an attitude is the project's best hope for meeting cost and schedule. In response to questions from the Centers, Young stressed the need for genuine Total Quality Management (TQM) principles as

opposed to sloganeering, and his preference for participative management over authoritarian structures. He encouraged more women and minorities in the management career path, noting that "cultural diversity makes for better decisions."

"Experience in Managing Award Fee Contracts"
with William Keathley

"I don't believe in firm, fixed-price contracts for high-tech, one-of-a-kind development projects" declares the Associate Director for Programs at Goddard Space Flight Center. Keathley also doesn't think much of the fixed-price incentive contract, the cost-plus incentive contract or cost-reimbursable contract. In a well organized presentation, he lists all the pros and cons of the cost-plus award fee contract.

He describes the award fee contract as "win-win" for contractor and government in terms of profit and performance motives. At project milestones, such a contract has the flexibility to change emphasis on the project, to adjust to such realities as a shifting launch schedule. "The award fee contract will promote — no, demand — good government-industry communications," he notes, so essential for mutual understanding of each other's needs. The award fee report card "guarantees periodic attention from contractors," and the award fees are nearly as high as fixed-priced profits, but with less risk involved.

On the downside, the award fee contract demands more civil service employees to meet, monitor and review the project. However, the additional personnel may be worth it, he says. Then there are those who say there is a tendency to be more lenient in the scoring of contractors since civil service workers are scored, too.

As for the ground rules to implement an award fee contract, Keathley insists that the government project manager chair the performance evaluation board and that contractors recognize his or her importance. Before every performance period, the milestones and criteria must be agreed upon in advance. "Surprises are unacceptable."

In the fee determination itself, "Be fair . . . don't play games." Appeals to the determined fee can be mitigated by a clear, factual award fee letter. A verbal appeal calls for a verbal explanation; a letter appeal calls for a written response, directed only to the disputed areas of concern. A lively discussion period follows his presentation, including amplification of "rollover" whereby the fee determination officer may take an unearned portion of the fee and apply it later in the project to a crucial milestone.

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