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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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The Right Attitude for the Program Manager

by Douglas R. Broome

The NASA experience shows that one can follow all the procedures, rules, suggestions, etc., discussed in a management handbook and still fail to meet program objectives. The practical fact is that there is no cookbook approach or procedure — no specific set of decision rules — that, even if rigorously followed, will ensure program success. The elements most critical to program success are instead found within the individuals serving as the program manager or program scientists. Success does not derive primarily from "what" is done, but rather by the "how" and "why" in the accomplishment. Success, therefore, lies in the individual's personal commitment to leadership and management excellence. It is this commitment that is the key to effectiveness in these positions.

The question of what characteristics and attributes comprise the excellent manager or leader, regardless of the field of endeavor, evokes much emotion and endless opinion; it is the subject of literally hundreds of books. Participation in this debate is not the purpose here. Rather, our primary purpose is to present and briefly discuss the specific characteristics and attributes that the leadership of the Astrophysics Division desires in its program managers and program scientists. We should describe those characteristics and attributes which, when coupled with the appropriate use and application of the methodologies, procedures, aids, and suggestions presented in a handbook, can be expected to maximize the probability of successful accomplishment of the objectives of any program that may be assigned to them.

At first glance, the following discussion and list of attributes may seem to imply that the excellent science program manager, flight program manager, or program scientist must be superhuman. Although outstanding performance is expected, perfection at all times in all things is not really achievable. Instead, what is expected is that degree of perfection necessary at the time to effectively resolve the issues at hand, as they are encountered, without the need to resort to excuses.

Are You "In" or "Ahead of" the Crowd?

It is an unfortunate fact that many people live out their lives within a set of limitations or constraints of their own creation, constraints that unnecessarily but seriously limit their accomplishments in all aspects of life. In one frame of reference, they live "... within their own nine dots;" in another, they "... live lives of quiet desperation." Others, meanwhile, seem intuitively or instinctively to pursue their life goals with a predisposition towards accomplishment and achievement that assures their success at almost anything they try. These latter people seem to possess an attitude, sense or psychology of victory that the former do not. History demonstrates that it is from this latter group that the most successful leaders derive. And it is from this latter group that the Astrophysics Division seeks its science and flight program managers and program scientists.

Should the reader be considering (or holding) a position as a science program manager, flight program manager, or program scientist in this

Division, and after reading this find that he or she is comfortable with the views presented, then the working environment will probably be a friendly, comfortable one. Should the reader find some major disagreement or lack of "gut level" comfort with its content, then his or her talents would probably be better used elsewhere, and his or her mental peace and career potential better served in some other organization.

As a rule, NASA normally has only a handful of major flight programs under way at any given time. These few programs, though, involve a significant portion of the agency's resources and comprise the essence of its reason for existence. The program manager or program scientist positions for these programs are thus coveted. They are positions of high prestige and high visibility; they are also positions that demand measures of commitment, devotion, responsiveness, responsibility, flexibility, courage, leadership, management, and technical skill well above that demanded of most other positions in the agency. Finally, they are positions that involve unusually high levels of pressure, "heat" and career risk. Though the pay is excellent for the government service, the pay cannot be (and normally is not) the reason one serves in either of them. The incumbents must instead derive their primary personal and career satisfaction from the successful attainment of difficult goals in a complex environment by using the best combinations of people, time, dollars, facilities, and interpersonal relationships.

"Trying" Is Not Good Enough

Because of the importance of these flight programs to NASA's mission, the fundamental mindset of the successful program manager or scientist must be on the achievement of excellence, and the most basic personal standard of performance must be the achievement of success. Only to have tried must be considered by the individual to be unacceptable performance. "I tried" cannot be enough for the success-oriented program manager or program scientist. "I sent them a memo," "I wrote a memo for the record," "I left them a message" — this whole approach to satisfaction of their assigned program responsibilities is inacceptable. Instead, the standard must be set on real accomplishment — on having achieved action, met performance, or caused movement, not in having "tried" to. In this line of work, points are not given for second rate or second place performance; there is no second place in program management — only success or failure. The understanding and acceptance of this fact is the key to management excellence!

This point — that "trying," as opposed to succeeding, is not enough — is fundamental to the measurement of success in the Astrophysics Division both in the management of its flight programs and in the management of its science programs. If the Astrophysics science and flight program managers or program scientists accept this and operate accordingly, then their professional lives will be exhilarating and rewarding; they will certainly never be boring. On the other hand, failure in the ongoing, smaller things is not in itself a major problem. In fact, failure is one of the better motivators for "learning that lasts." It is the making of excuses that is unacceptable, for excuses are most often simply the lazy person's rationalizations for not having put out the extra 10 percent that is often necessary to ensure success in any endeavor.

Another major consideration for the prospective member of an Astrophysics program team is this: by virtue of the organizational structure, the science program manager, flight program managers, or program scientists in the Astrophysics Division normally command no one. Instead, they must convince other people to commit the resources of their organizations to the accomplishment of their objectives. To achieve this difficult task, the individuals concerned must exercise great skill in developing and using effective power; that is, in acquiring the voluntary alignment of the goals of the necessary external organizations and people with those of their programs. Again, results, not effort, are the basis upon which performance is measured.

What Part Does "Luck" Play?

One final topic to be considered is "luck." Coupled with the success-related attributes discussed below, one must also possess a large measure of intuitiveness, manifested in what is often referred to as luck. Many people believe that luck is a gift from the gods or an act of nature; others believe that it is a function of the positions of the stars and planets (seven of them, anyway) at birth. The management of this division believes that personal luck is largely a consequence of behavior; that is, luck is in essence "made" by the individual through his or her attitude, beliefs, and lifestyle. Regardless of the field of endeavor, the demonstration of "luck," as with the achievement of "excellence," seems to lie in the mindset of the individual and in what lies in his or her heart. Its mobilizing force seems therefore to originate in the attendant attitude and fundamental approach to life held by the individual. In effect, we are, or become, what we choose to be.

The Necessary Attributes

Specific attributes and characteristics that are desired in the excellent astrophysics science program manager, flight program manager, or scientist follow. While only the rarest of human beings will demonstrate all these attributes at all times, the effective manager or scientist will exhibit the right ones at the right times to solve the problems.

1. **Sense of duty.** Willingness to readily submerge ego to the greater needs of the program, the user community, the agency and the nation; a person to whom the phrase "Duty is the most sublime word in the English language" has real meaning.

2. **Personal integrity.** Possession of a system of ideals and standards consistent with a personal standard of morality beyond which one will not go or upon which one will not compromise; abhorrence of "situational morality."

3. **Maturity of judgment.** Wisdom to know when and when not to speak; to fight; to stand; to judge; to bend or break the "rules" or regulations; and to follow or violate the established chains of command, information flow, and authority.

4. **Moral courage.** Ability to determine when a stand must be taken, without compromise, for the good of the user community, the program, the agency, and one's personal code of honor and standard of conduct; ability to set pride aside and thereby avoid or abandon untenable, unreasonable, or irrational positions rather than exhibit destructive behavior or get into positions that conflict with personal values (see also "Loyalty," below); willingness to choose the unpopular position when convinced that that position is the "right" one.

5. **Mental and (occasionally) physical courage.** Coolness, calmness, steadiness "under fire" or in high-pressure situations.

6. **Enthusiasm.** Supportive of management goals and needs, especially for "quick-turnaround" actions or information transfer; positive in attitude; antithetical to negativism, yet maintaining appropriate objectiveness; antithetical to cynicism; pleasant, especially under stress.

7. **Loyalty (personal and organizational)** Wisdom to understand the innate personal and organizational destructiveness of gossip and disloyalty to one's management chain, supervisor, supervisees, or program objectives, with an ingrained commitment to avoid or discourage such destructive behavior (see "Moral courage," above).

8. **Quick-wittedness.** Ability to respond quickly and positively to unexpected or rapidly changing situations; "quick on your feet."

9. **A "can-do" attitude.** Ability to accept or act on valid management requests for action, however "far out," strange or unreasonable they may seem, in a positive, confidence-inspiring manner, particularly when reaction or response time is short.

10. **Proactive stance.** Possession of an inherent propensity for self-initiated action; a self-starter.

11. **A "nose for problems."** Ability, when all "appears" well, to sense or "feel" intuitively that something is amiss (see also the paragraph above concerning luck and intuition).

12. **Global thinking.** Ability to consider events, plans, alternatives, etc., in both the micro- and macro-view; that is, in planning or in anticipating future actions or possibilities, the ability to identify and assess the potential impacts on the program and initiate the appropriate actions; the ability to develop and maintain a model of the program's political operating environment, identifying both the supportive and the adversarial groups, organizations or institutions, or potential "stop" points or scenarios, or national moods, events or activities that could affect the program — pro or con — and develop appropriate plans or interventions to either minimize adverse impacts or to exploit favorable opportunities for the benefit of the program.

13. **Unwillingness to accept the status quo.** That is, never accepting out-of-hand that "this is the only way it can be done" or "it can't be done."

14. **Tenacity.** Indefatigability; grit; determination; stick-to-it-iveness; unwillingness to accept less than that which will accomplish the objective; willingness to persevere in the face of resistance or peer pressure until satisfied that the findings, conclusions, and corrective actions proposed or taken are in fact sound; appreciative of the difference between "real" action that achieves the desired results, and "apparent" action, represented by the writing of useless or ineffective memos or other such "CYA" documents.

15. **Creativity.** The ability to create order out of chaos; to look at a problem in light of the larger context of what is possible (that is, outside of the narrow focus of the specific details of the problem itself) and to develop unique or non-obvious, straightforward solutions that achieve the supposedly impossible for the overall good of the program.

16. **Innate curiosity/inquisitiveness.** An inherent attitude of "What's this all about?", "How does that work?", "Why do we have to accept that?", "Is that the only way?", "Is that really the right solution?", etc.; constantly looking for problems or alternatives as a normal way of doing business.

17. **Analytical.** Through appropriate "process" questions, ability to determine whether the findings, conclusions, and corrective actions proposed or taken are in fact sound; not intimidated by the assumed "expertness" of others, but instead driven to understand the logic of their recommendations or conclusions.

18. **Practical relevancy.** The ability to identify and isolate the "real" problem from the "apparent" problem; ability to rapidly cut

through the masses of data to get to the relevant information, to separate the "wheat from the chaff," to know when to look at the forest and when to look at the trees; ability to determine what is important to the solution of the real problem while maintaining a continuing sensitivity to any implications of this solution to program and agency objectives and operations.

19. **Open-mindedness.** Openness and willingness to listen to others; willingness, desire, and ability to continue learning; one who finds "not invented here" attitudes unacceptable.

How Do You Measure Up?

The degree to which existing or prospective-program managers or program scientists possess the characteristics and attributes discussed above cannot, of course, be measured objectively. Each person must, therefore, make a rigorously honest, objective self-assessment in terms of the discussions herein and answer the question: "For the position I desire, do I have 'the Right Stuff?" Be thorough in your self-assessment. Your future perception of your personal and professional success, peace of mind, serenity and, in essence, your future happiness are at stake.

Excerpted from "An Introduction to Astrophysics Division Program Management: A Primer on Program Management Practices and Principles Used in the Astrophysics Division, Office of Space Science and Applications (OSSA), NASA" 2nd edition, October 1989. The document was prepared and updated at the request of Dr. C. Pellerin, Director of the Astrophysics Division.

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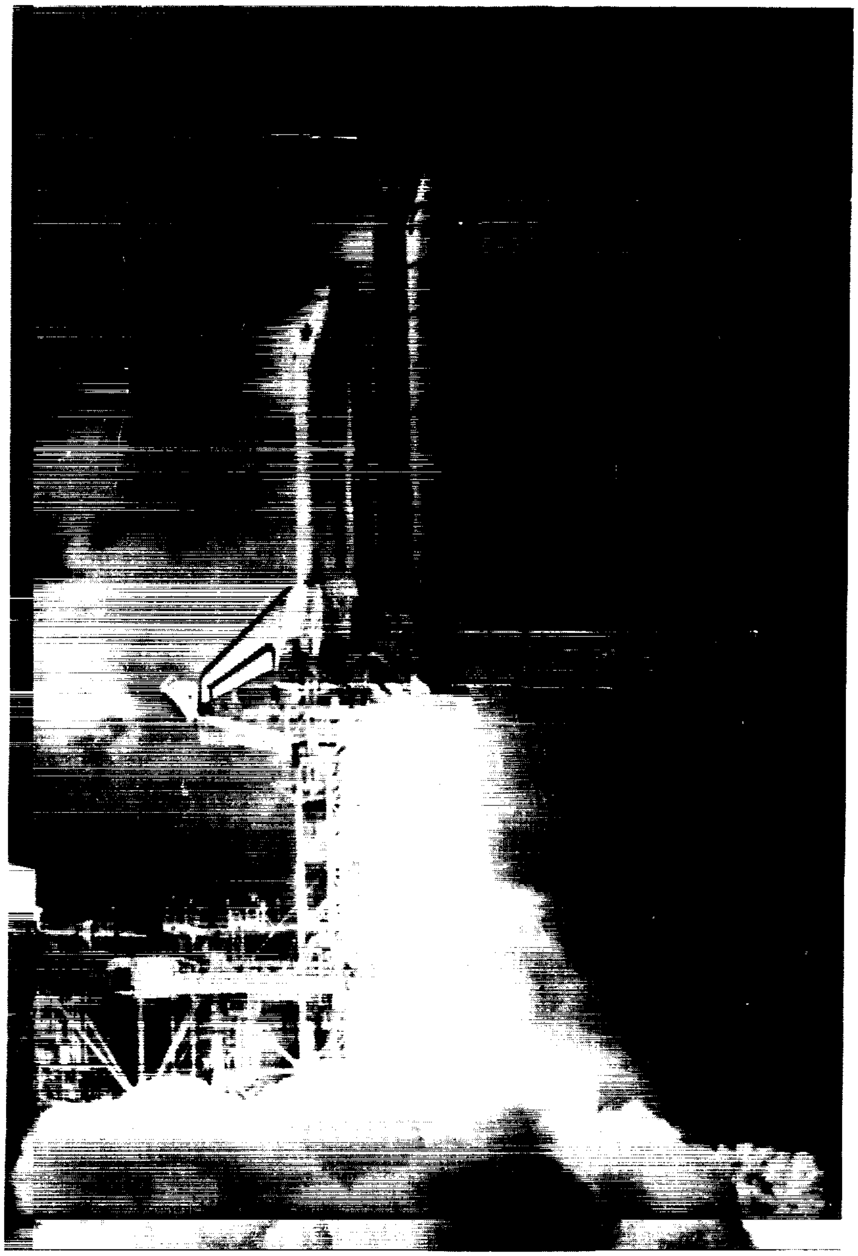

Mission success for the Galileo project will not be determined until December of 1995 when the spacecraft approaches Jupiter. It was launched from Kennedy Space Center in October aboard Space Shuttle Atlantis. Even then, a probe will have to be released to parachute into the Jovian atmosphere before a two-year study of the planet and its moons begins.

Program Control for Mission Success

by G. W. Longanecker

Note: The following represents my contribution to a panel discussion on the subject conducted at the October 4, 1989 session of NASA's Advanced Project Management Course. My fellow panel members were Tom Newman and Bill Sneed.

My first premise is that in order to exercise program control, you must have a controllable program. A controllable program is one that has been properly scoped technically, realistically scheduled, and adequately budgeted.

The first step in scoping a program is obtaining a set of minimum performance requirements to meet the mission objectives. I know that this is a difficult task, because your customer is intent on achieving the maximum possible performance. However, my recommendation is to get an agreement with your customer on the minimum requirements, and then set the specifications to achieve a reasonably increased level of performance. This will allow for possible descoping actions later in the program, should the need arise. Since our programs nearly always involve state-of-the-art technology, and with today's emphasis on resource control, a good descoping plan developed early in the program is important to have in your back pocket.

The other two ingredients of a controllable program are schedule and cost. The two are very much interdependent and must be balanced with the degree of risk deemed appropriate for the program. There has been a lot of rhetoric on the subject of risk, especially in recent years. However, in my 30 years with the agency, I really didn't see much risk-taking, even with the unmanned scientific and applications satellite programs. Risk is extremely difficult to quantify, especially when you're dealing with single satellite programs. How do you explain a risk trade-off to a group of space physicists who are committing possibly half of their professional careers to a single satellite mission?

My consummate goal was always mission success. What this really boils down to is that you need to have adequate schedule slack and budget contingency to solve the inevitable problems that will confront you along the way. Headquarters must hold sufficient reserves to cover any changes in scope. This is important enough to reiterate. The project manager at the field Center budgets and controls reserves for problem solving; the program manager at Headquarters budgets and controls reserves for scope changes. The last line of defense is to descope the program. As I said earlier, if you have set your specifications with some margin over the minimum goals, you should have some room to descope and still meet mission objectives. The real challenge for a manager is that you probably will have to make some descoping decisions during the development phase so that you have some remaining contingency for the test and evaluation phase, mission operations, data collection, and data processing.

Properly scoping a program requires that sufficient studies be performed during the definition phase. As a rule of thumb, four to eight percent of the expected total run-out cost of a program should be spent through phase B. In my experience, NASA is notorious for skimping on definition-phase funding. When you skimp during phase A and phase B, you have an open invitation to performance, schedule, and budget problems during phases C and D. As part of the procurement planning process, you will develop in-house a "should-cost" estimate for the program. Your budget requests will be based on this "should-cost" figure plus contingency. Because of competition, you will most likely negotiate a contract for less than the "should-cost" estimate. The difference should not be considered part of your contingency for problem solving, but rather it represents the additional funds required to realistically perform the prescribed effort without problems. Occasionally a contractor will propose a scheme that should save some money, but again my experience has been that you should pay attention to your "should-cost" estimate.

Beyond the programmatic obstacles to a controllable program, the single biggest hardware obstacle in my experience has been piece parts. I can't remember a single program (and I've launched 21 satellites) where we didn't have problems with piece parts. We'd design a circuit, breadboard it, test it and then find that we couldn't get flight-qualified versions of the parts. We also suffered from being a small-volume user of piece parts since most of our programs involved a single satellite. The only advice I can offer is to use standard parts as much as possible in your designs, order your parts as early as possible in the program, and look for second-source suppliers for your critical parts. Even after doing all of the above, the odds are that you will have piece part delivery problems.

As for program control, there are many good techniques and tools. Everything starts with a good work breakdown structure (WBS). You will have developed one during the definition phase and for the phase C and D procurement package and, subsequent to contract award, will agree to the WBS with your prime contractor. The WBS is the basis for your schedule projection and budget estimate. It must have sufficient granularity to identify the critical elements or building blocks of the program.

Your schedule must have slack identified at critical points in the program. It is not sufficient to carry all the slack in the period just before the launch readiness date. This is especially true when you're dealing with intergovernmental or international partners in a cooperative program. In most cases you'll find that the cooperating agencies have even less flexibility to deal with schedule and budget changes than we do in NASA. Once established, the schedules can be tracked by any number of computer-generated systems. Critical paths are easily identified and tracked. However, I advise you not to rely solely on the automated schedule systems. I've always found it useful to prepare a few charts on critical elements that I could update manually to look for schedule trends. My favorite is one that tracked on a monthly basis, for a few selected milestones, the currently planned date versus the originally scheduled date (Figure 1). I would frequently find that I could apply the slope of the trend for intermediate milestones to forecast the most probable completion date for a downstream event, even though the contractor continued to forecast the original event date. I found it easier to look at my few graphs than to study the computer-generated charts covering the walls of the "war room." You have to keep a perspective on the big picture.

The final element of program control that I wish to discuss is a performance measurement system (PMS). A PMS, or earned value system, allows you to track progress versus expended resources compared to your plan. Es-

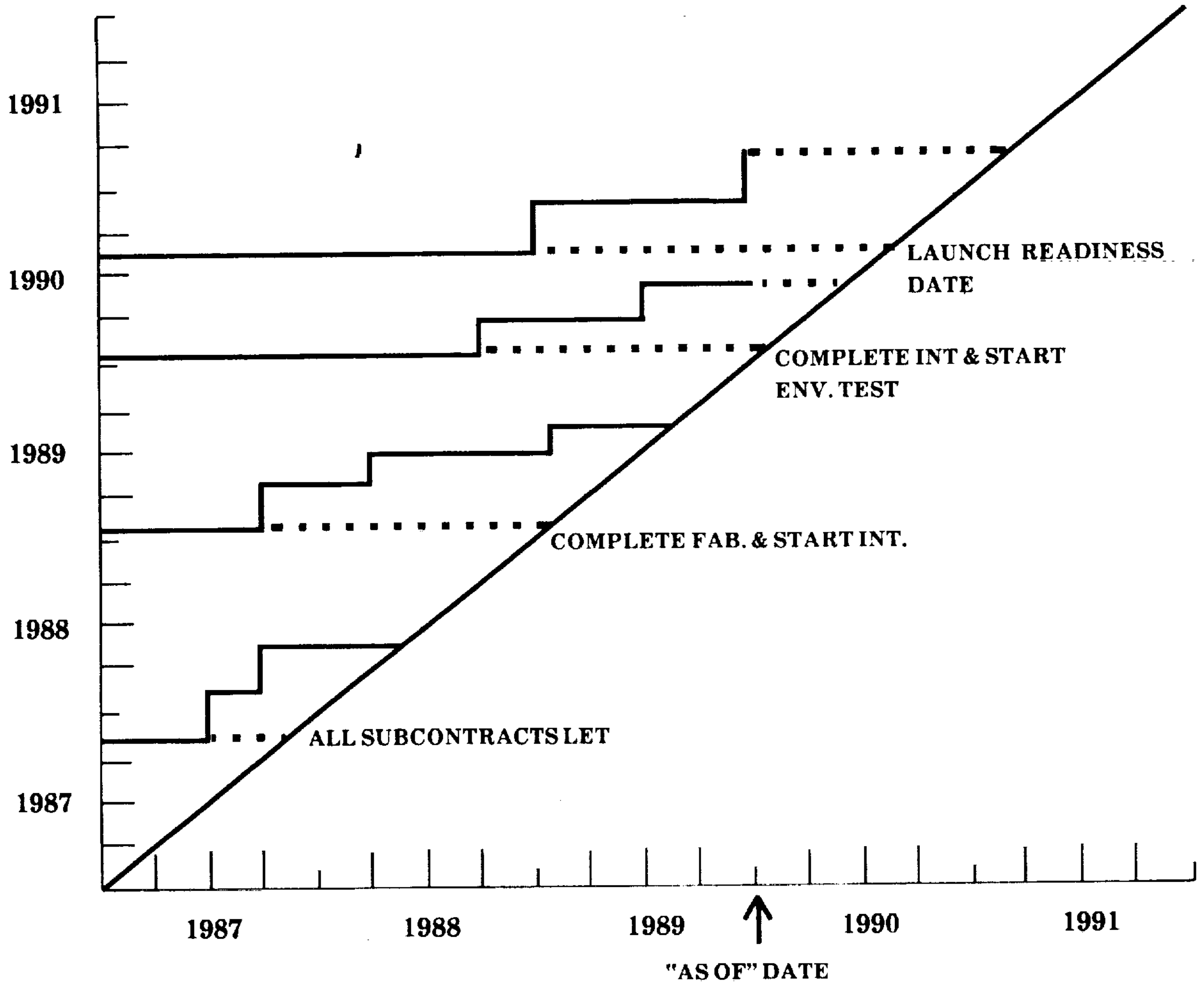

Figure 1. - Sample "Trend" Chart

sentially all major contractors have a PMS that they use for their programs. The key word here is "use." Having a PMS in your contract is a useless exercise if the contractor is not actually using the system to help manage the program. Accordingly, you should adopt the system your contractor is familiar with, rather than insist on a similar but different system. Due to the nature of our business, changes to the program baseline are to be expected. Obviously, such changes should be kept to the absolute minimum, but when it's unavoidable, any significant change must be quickly incorporated into the PMS.

Reporting earned value against an outdated plan is useless at best. It can be worse than useless if someone believes data that is blindly cranked out, based on an outdated plan. If the data is current, a PMS can help you detect the trouble spots sooner and, therefore, direct your problem-solving energies more efficiently.

As is the case with automated scheduling systems, PMS is not a panacea for the managers. You have to keep track of the big picture, and above all, use good old common sense.

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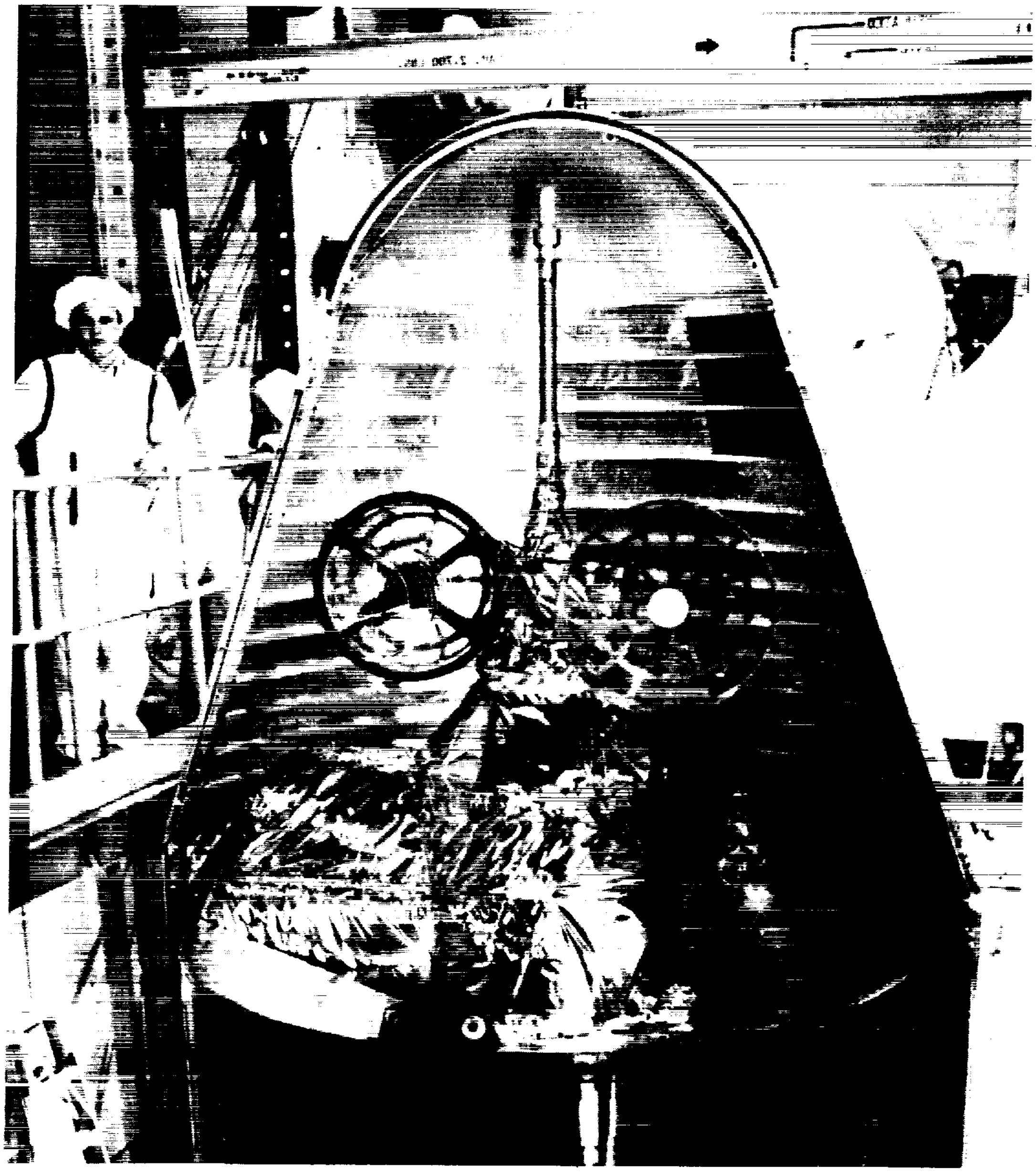


GOES-G, launched on a Delta 178 in 1986, was built for the National Oceanic and Atmospheric Administration. The satellite is an improved version of geostationary meteorological spacecraft providing day and night pictures, plus vertical temperature and moisture data in the atmosphere for weather forecasting. Current GOES projects have PMS requirements that are tested and refined for better program control.

Performance Measurement: A Tool for Program Control

by Nancy Abell

The NASA program and project managers of the 1990s will continue to work in the environment of constrained resources in terms of reduced budgets, limited staffing, and tight schedules. In a speech to the Explorers Club in January 1989, former NASA Administrator James Fletcher stated: "The funds being requested do not permit us the luxury of backups, of alternatives, of programmatic robustness. Virtually every element of the program is being pursued on a success schedule — and we know in advance that there will be unforeseen technical problems to solve and dilemmas to face which will require internal adjustments and constraints." In this environment there are focused efforts to improve program and project management. One potentially powerful tool available to the project manager which has been used successfully in many government agencies is performance measurement.

Performance measurement is a management tool for planning, monitoring, and controlling all aspects of program and project management — cost, schedule, and technical requirements. It is a means (concept and approach) to a desired end (effective program planning and control). To reach the desired end, however, performance measurement must be applied and used appropriately, with full knowledge and recognition of its power and of its limitations — what it can and cannot do for the project manager.

Performance measurement is not a new concept to the government or to the aerospace industry. It has its origins in the Department of Defense (DoD) programs of the 1960s. Interest and application of the performance measurement concept spread to other government agencies in the 1970s and 1980s. Today performance measurement is being applied to major programs of the DoD, National Security Agency, Department of Energy, Federal Aviation Administration, and NASA. Performance measurement is widely endorsed as a valid approach to controlling contract performance.

The Goddard Space Flight Center (GSFC) has been implementing performance measurement system (PMS) requirements since 1983 on major research and development (R&D) contracts with a price of $25 million or more and a period of performance longer than one year. GSFC's PMS policy was established by the Center director to provide for consistent application on all major Center acquisitions. Use of performance measurement is also encouraged on R&D contracts in the $10-25 million range, but applied on a case-by-case basis. GSFC currently has 12 contracts in various project phases that have PMS requirements. With the large number of major independent spacecraft and instrument development contracts at GSFC, such as the various meteorological spacecraft and instruments of the Geostationary Operational Environmental Satellite and Television and Infrared Observational Satellite programs, we have had the opportunity to continually improve our implementation of PMS through a "lessons learned" approach. Many project managers have had the opportunity to test the effectiveness of this management tool. At GSFC, some of the more effective PMS applications have been on the Gamma Ray Observatory and the Tracking

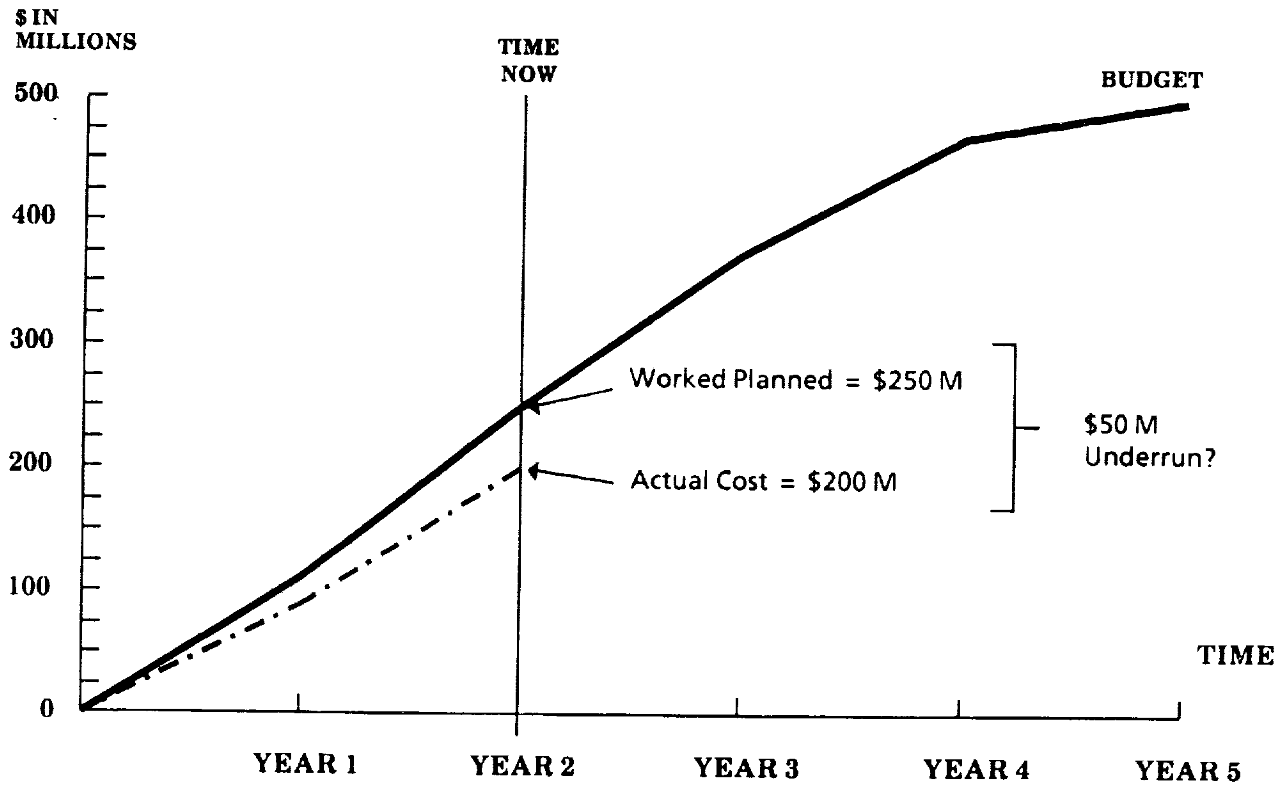


Figure 1. - Traditional Plan vs. Actual Technique

and Data Relay Satellite System spacecraft contracts.

What is the potential of this management tool? What does performance measurement do that a traditional plan vs. actual technique cannot do? Performance measurement provides an improvement over the customary comparison of how much money was spent (actual cost) vs. how much was planned to be spent based on a schedule of activities (work planned). This commonly used plan vs. actual comparison, however, does not allow one to know from the numerical data if the actual cost incurred was for work intended to be done. With performance measurement, actual work progress (work done, also known as earned value) is quantified by an objective measure of how much work has been accomplished on the program. This added dimension of a quantitative assessment of work accomplished allows for comparisons to be made between the value of work that was done vs. the work that was planned to be done (schedule variance). It also allows for a comparison of the actual cost of work that was done vs. the planned value of the work that was done (cost variance). This analysis then provides for early identification and quantification of cost and schedule problems.

A graphic depiction of the data available from the traditional plan vs. actual technique compared to those available from a performance measurement system may serve to more clearly illustrate the concept. A hypothetical spacecraft program is expected to take five years to build at a cost of $500 million. Figure 1 shows the traditional plan vs. actual technique. If "time now" is the completion of year 2, the graph indicates that we had planned to spend $250 million. The actual cost (i.e., time card charges, material expenses, etc.) reported to the government is $200 million.

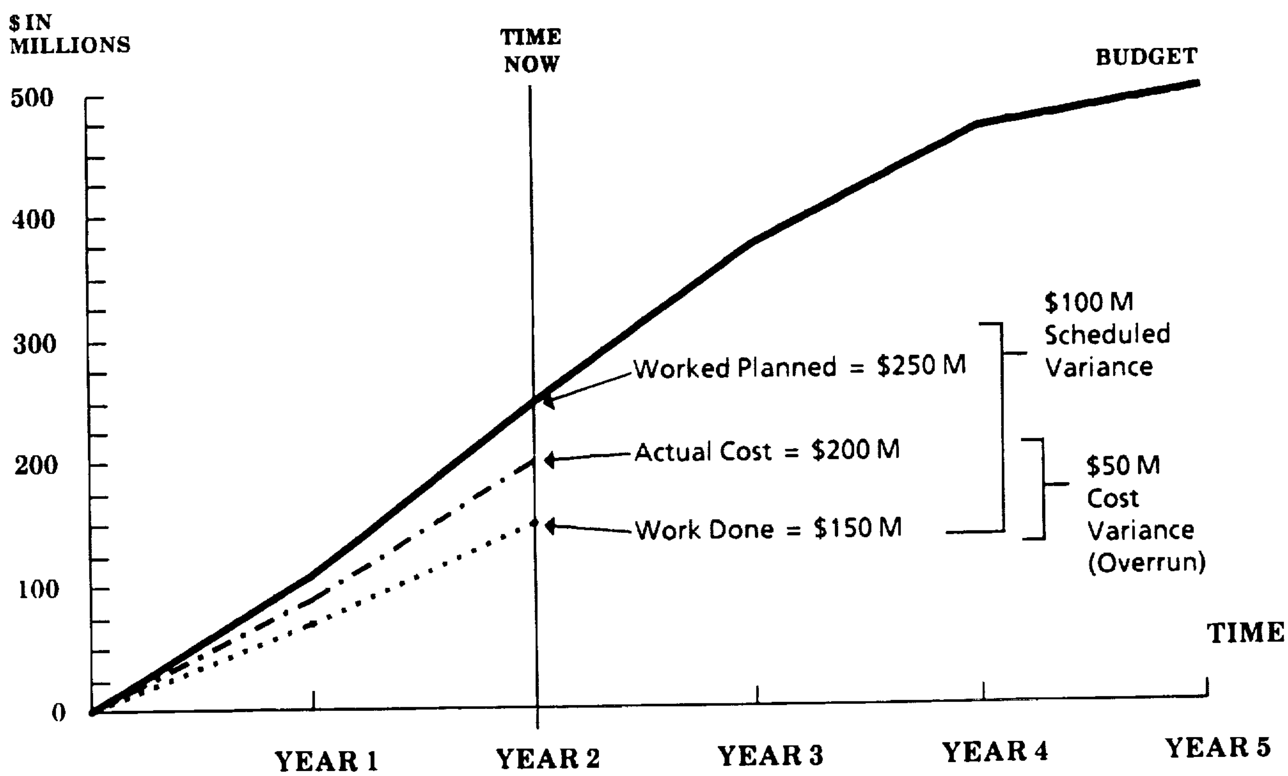


Figure 2. - Performance Measurement Technique

What can a project manager conclude from this information? Is it possible to determine if this program is overrunning or underrunning? With this limited information available, a project manager may assume that the contract is underrunning and would have no basis to question the assumption that this program will underrun at completion. At a minimum it currently appears that the $500 million funding estimate is adquate to complete this effort.

In Figure 2 an additional data point has been added to the same hypothetical spacecraft program. The contractor has assessed the value of the work accomplished (or earned value) to date. This new information reveals that of the $250 million of work planned to be done to date, only $150 million has been done. Some work that was planned to be done has not been done and is reflected as a $100 million scheduled variance. Also the $150 million worth of work done can be compared with the actual cost of $200 million. This comparison shows the planned value of the work vs. the actual cost of that same piece of work. Now the project manager can see that this program is actually overrunning by $50 million to date. We now have enough data to question the validity of the $500 million funding estimate for completion of this effort. We can begin to see that this program is headed for an overrun of costs at completion along with potential schedule slippage.

As a result, the project manager having the PMS data available in Figure 2 is better able to estimate early the total costs and projected period of performance of this program, therefore avoiding being surprised by an overrun much later in the program. If the data yield a "doom and gloom" assessment, there is opportunity to make decisions early to avoid an approach that is too costly or that takes too long.

The basic objective of performance measurement systems is to provide a suitable basis for responsible decision-making by both the contractor and the government management by ensuring that (1) the contractor is using effective internal cost and schedule management control systems and that (2) the government can rely on valid, timely, and auditable data to be produced by those systems to determine program status.

Unfortunately there has not been a consistent experience within the agency regarding PMS implementation. Personnel at various NASA Centers and in the aerospace industry believe that while some NASA applications of PMS have been successful and effective, other attempts to use PMS as a management tool have actually been counterproductive. In some instances, performance measurement systems have not always provided accurate reporting of cost and schedule status, and there are differing opinions about why PMS did not work in these instances. The most prevalent of these is that in the NASA environment and culture, a disciplined approach to program management is not appropriate or applicable. While it is healthy to question the worth and applicability of PMS for NASA programs, it is also beneficial to explore some of the common-sense features of PMS that have proven effective in controlling project costs and schedules in many government agencies for the past 22 years.

Some Basic Principles

Performance measurement can work for you if you apply some basic principles.

1. **Plan the entire contractual effort.** It is essential to plan the work for the entire period of performance. Near-term work is planned in detail while future work can be planned at a summary level. Failure to recognize all of the work to be done makes it impossible to properly allocate resources. Programs could consume too many of the resources on the near-term work and not leave enough to do the work downstream.

2. **Maintain baseline integrity.** The measurement of actual conditions against a disciplined or controlled plan reveals performance trends that can help to predict future conditions and to determine a future course of action.

3. **Determine accomplishment at the level at which the work is performed.** Who can better assess the work that has been done and the work remaining to be done than the manager responsible for performing the work?

4. **Measure accomplishment objectively.** The most valuable status assessment of a piece of work is based on pre-defined milestones as opposed to personal feelings and prejudices lacking reality or substance.

5. **Summarize for higher levels of management.** While accomplishment is assessed at a relatively low level, summary reporting to higher levels of management, where resources are made available, is also essential for control.

6. **Analyze variances and forecast impact.** Variances are simply indications that actual conditions are different from the original assumptions, and variances may indicate the existence of current or potential problems. Analysis of the variances allows management to correct problems or to redirect efforts to avoid potential problems, as well as to project cost at completion.

In summary, the concept of performance measurement is good, common sense program management that NASA project managers have always practiced, but perhaps not in a formal way.

Specifying Customer Requirements

NASA authority for performance measurement is based on the agency requirement specified in NASA Management Instruction 9501.1 "NASA Contractor Financial Management Reporting System" and NASA Handbook 9501.2B Procedures for Contractor Reporting of Correlated Cost and Performance Data. The NASA Form 533P (where "P" represents performance) has been used by contractors to report performance data to NASA, unless the contractor has another format that serves as the equivalent. The 533P is essentially a minimum NASA requirement for data reporting purposes only. It does not require that an identifiable system or set of subsystems support the data. As the contractors are free to generate data in any way they desire, there is the high potential for invalid or misleading data if this is the only requirement placed on a contractor related to performance measurement. Without a system requirement for visibility and control of the baseline, for objectivity in measuring accomplishment, or for discipline in forecasting estimates to completion, then performance measurement may not yield valuable information. While data can be reported on a 533P, a more disciplined approach to the management system is needed to identify some rules for performance measurement systems. These rules are known within the government and aerospace industry as the "criteria."

The performance measurement criteria do not identify a specific management control system to be applied to a program; but rather, they represent a set of standards against which to measure the acceptability of a contractor's cost and schedule control system. There is, in fact, a variety of equally effective ways for contractors to meet the criteria requirements. The criteria allow a company to organize in any way that suits the company's philosophy and style. The criteria also allow a company to develop any desired policies, procedures, or methods that meet the requirements. The criteria address the age-old questions of any project manger: What work is to be done? Who will do it? When is it going to be done? How much will it cost? Where is the program heading? What has changed? The contractors address these questions through their management systems' integrated set of subsystems. These are subsystems that would be required to manage a program whether or not a performance measurement requirement was imposed. Performance measurement criteria simply require that a more disciplined approach be applied to each subsystem. The PMS subsystems are (1) work authorization, (2) budgeting, (3) scheduling, (4) data accumulation, (5) variance analysis and estimate at completion, (6) subcontract and material control and accountability, (7) indirect expense management, and (8) change baseline control. PMS, then, does not address just the accounting system, but rather it addresses the integrated set of subsystems that constitute all elements of program planning and control.

A Good Management System

The key to the power of performance measurement is that performance measurement data are only as valid as the management system that provides them. If a contractor operates a sound internal management system , the customer should be able to extract summary data from that system that reflect project status. To have a valid management system applied to NASA work in contractor plants, several conditions need to be met.

First, a **management commitment** from the top down is required — all levels of management support are essential. It is not enough to have project financial or resources support personnel discussing PMS with the contractor. The involvement of technical personnel is critical. PMS involves all aspects of program management and needs to be viewed in this way by NASA project and functional management personnel to be effective.

Second, management system **discipline** must be stressed and required. While it may be desirable to maintain a spirit of cooperation and non-adversarial relations with our contractors, PMS is not of any value without a disciplined approach to management. Without a requirement for the contractor to maintain a baseline, to apply objective techniques for performance measurement, or to reliably forecast the cost to completion, there can be no confidence in the value of the data that the management system generates and that the contractor reports to NASA on a monthly basis.

Third, use of **data generated by the PMS** is essential. A few simple mathematical formulas and computations yield very revealing information about the project status and potential future of the program. Use of data serves to facilitate communications internally and between NASA and the contractor.

Fourth, **corrective action** needs to be taken when problems are identified. A management system supplies data points, not solutions. It provides visibility into cost, schedule, and technical status. A system, however, does not manage the project, people do. A system cannot eliminate schedule slippages or stop overruns, but it can help the project manager to understand the potential impact if trends are allowed to continue without mid-course correction.

Fifth, an **in-plant review** of the contractor's management system applied to your program and conducted by a NASA team of interested and knowledgeable technical and resources personnel is critical. The NASA personnel gain invaluable knowledge of the policies, methods, and procedures used by the contractor to generate monthly status reports. By understanding the source of the data, we can calibrate the validity of our monthly customer reports and require the contractor to revise procedures that do not produce valid data.

PMS is not intended to replace traditional management tools — it should enhance them. Day-to-day program management is essential. In fact, if managers are relying solely on performance measurement data generated at month-end, they will be learning of problem situations much too late to be effective. Periodic status reviews, "kicking the tires," and routine communication internal to the contractor and between the contractor and government managers are critical in managing a program. PMS may identify a new problem; but, in most cases, it allows quantification of a known problem through all elements of the work breakdown structure and through the functional organizations to provide a basis for improved management decisions.

Cost Effectiveness

In times of constrained resources it is reasonable for managers to question the cost effectiveness of PMS. What are the benefits and associated costs? The question is difficult to answer, however, since both the benefits and costs are nearly impossible to quantify.

PMS results in a better controlled project with improved communication, both internally and with the customer. To quantify the benefits is to ask, "What is the value of good management?" It is not evident how a cost savings (or cost avoidance), a shortened schedule, or improved technical performance through corrective action can be clearly associated with results or a specific cost.

The costs of PMS have also defied quantification for 22 years. The PMS-unique costs on the total contract cannot be separately identified from the management costs that would be incurred in any case. They are not routinely collected by contractors, nor is it considered practical to do so. This was illustrated in a 1987 survey of GSFC contractors who had implemented a PMS requirement. In the survey, some contractors suggested that the costs of PMS beyond the usual management costs may be expressed as a percentage ranging from 2 percent to 6 percent of total contract costs. In each case, however, the contractor could not substantiate the percentage. It was someone's "non-scientific estimate," as stated by one contractor. Surveys conducted by the DoD show that there is no correlation between the cost of PMS and the contract costs.

This is not to say that there cannot be cost associated with PMS requirements. In fact, the cost of implementing PMS is in direct proportion to the quality of the existing management system. The poorer the state of the contractor's system, the greater the need for improvement and the more it will cost to improve. Contractors who maintain discipline in their systems would incur very low cost for implementing PMS on subsequent contracts. If the same contractors did not maintain their systems, over time the cost to implement PMS on future contracts would be greater as the need for improvement becomes greater. Further, if there is not an existing integrated cost and schedule management system, the contractor will certainly incur cost to develop one. GSFC experience, however, has been that contractors awarded major development procurements that contain PMS requirements are contractors who already have operational PMS systems as a result of their dealings with the DoD. Costs of PMS have been minimal compared to the significantly greater value added.

There is one additional factor to consider in a discussion of the costs of PMS. Typical points of contention between the government and industry concerning PMS implementation include the levels of detail identified for management and reporting, and the variance analysis thresholds identified for customer reporting. It is possible to avoid incurring unnecessary cost to the government and frustration for the contractor by not requesting reports that no one reads or uses, or "nice to have" items or analyses.

In summary, with the focus on efforts to improve program and project management, PMS is a potentially valuable tool. Like any tool, however, it is only as valuable as the user chooses to make it. Implemented properly, PMS can ensure the generation of valid cost and schedule performance data to ease the manager's decision-making process and can result in more effective program planning and control.

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

Galileo and its Inertial Upper Stage (IUS) were installed in Atlantis' payload bay at the end of August 1989. Six hours after launch the IUS was ignited, sending Galileo in a planetary trajectory past Venus once and Earth twice before swinging out to explore Jupiter, the Solar System's largest planet. SMR&QA engineers had to identify and analyze potential hazards related to the spacecraft's nuclear power source.

Managing SRM & QA Throughout the Project Life Cycle

by George A. Rodney

Program and project managers often ask me how they can gain maximum benefit from their safety, reliability, maintainability, and quality assurance (SRM&QA) engineering and technical support. My answer is that it is vital to develop a "team" culture within the program or project that includes SRM&QA support. Managers stand to benefit most when their management procedures and techniques are designed to ensure that safety, reliability, maintainability, and quality are built into the design plans of products and services up-front. They benefit least when safety, reliability, maintainability, and quality have to be built into the products and services at a later date, with the associated high costs of inspection and rework as well as the consequent impact on schedule and budget. You cannot "inspect" quality in.

The purpose of this article is to discuss the role of NASA's SRM&QA capability as a valuable resource to assist program and project managers in managing risk throughout the life cycle of their programs and projects and to show the importance of utilizing SRM&QA resources and total quality management (TQM) principles to achieve excellence. The principles embodied in the philosophy of TQM range from proper planning to total involvement of the workforce to assure quality products and services. Therefore, it is important to understand more fully the benefits that SRM&QA support has to offer. TQM principles include the following:

- Creating a "team" culture characterized by quality, innovation, goal-setting, two-way communication, and participation;
- Ensuring top management leadership and involvement in quality;
- Focusing on the customer and customer requirements;
- Pursuing continuous improvement; and
- Working towards prevention instead of correction.

The underlying theme of my discussion is that, because application of TQM principles encourages appropriate consideration of all factors (including SRM&QA-related ones), the end product or service will have safety, reliability, maintainability, and quality designed in, thereby reducing rework. The consequent impact on cost and schedule will show that SRM&QA can help conserve budget and time resources while ensuring safer mission performance.

SRM&QA Support at Agency, Center, and Project Levels

SRM&QA expertise spans a wide range of knowledge, skills, and experience available to the project manager throughout the life cycle. SRM&QA engineering and technical personnel at three levels assist project managers endeavoring to address risk management issues during the design, development, implementation, and evaluation phases of their projects.

At the agency level, the Office of SRM&QA at NASA Headquarters is responsible for developing and implementing firmly defined agency-wide SRM&QA policies. These policies, found in a variety of NASA Management Instructions (NMIs) and NASA Handbooks (NHBs), provide a foundation for project efforts to address risk. The Office of SRM&QA also tracks and analyzes trends and provides independent assessments of major programs. Finally, as NASA's safety and mission assurance advocate, the office acts on behalf of project managers in helping secure resources and scheduling that promotes safety and mission assurance.

At the Center level, each Center's SRM&QA organization develops and implements its SRM&QA policies. It performs trend tracking and analysis and provides independent assessments of programs and projects in a manner similar to the Office of SRM&QA at Headquarters. Also, the Center SRM&QA organization provides project managers with the engineering and technical support to perform the required SRM&QA design, implementation, and evaluation functions.

At the project level, SRM&QA personnel use a variety of tools and techniques, within the framework of agency and Center SRM&QA policies, to assess risk.

SRM&QA Tools and Techniques

Managers should become familiar with the tools and techniques that their SRM&QA support personnel use to assist them in designing and implementing product or service plans. Information concerning these tools and techniques can be gained from discussions with the supporting SRM&QA personnel and by being familiar with the requirements set out by the NHB 5300.4 series and other applicable agency and Center SRM&QA directives. The tools and techniques described in the following paragraphs are some of the principal ones with which managers should be familiar.

Failure Modes and Effects Analysis (FMEA). A FMEA is a systematic analysis performed on each component of a system to identify those components that are critical to the performance and safety of the crew, vehicle, or mission. The analysis includes identifying all system components, determining the potential modes of failure for each component, and recommending corrective actions.

Critical Items List (CIL). Based on a FMEA, a CIL is developed, consisting of a summary of single critical failure points and a summary of redundant elements, the failure of which could cause loss of crew, vehicle, or mission. As such, the CIL contains the same information as the FMEA, except that it includes the rationale justifying retention for redundancy of any critical item not meeting design specifications.

Hazard Analysis (HA). HAs are performed after the FMEA/CIL and are designed to identify, analyze, and categorize safety hazards, and subsequently track them to closure or resolution. Closure or resolution includes elimination of the hazard or control of the hazard through development of acceptable safety measures.

Problem Reporting and Corrective Action (PRACA). PRACA is a system for reporting all problems (failures and unsatisfactory condition reports) and establishing the necessary corrective action.

Electrical, Electronic, and Electromechanical (EEE) Parts and Mechanical Parts Control. These parts control systems are designed to control the selection, reduction in number of types, specification, failure analysis, stocking and handling methods, installation procedures, and reliability requirements of EEE and mechanical parts.

Qualitative Risk Assessment (QRA). QRA is a nonmathematical review of all factors affecting the safety of a system (hardware, software, etc.). It examines actual designs, processes, and parameters against a predetermined set of risk acceptability parameters.

Probabilistic (or Quantitative) Risk Assessment (PRA). PRA, a more rigorous engineering review than QRA, generates numerical probabilities of risk by considering reliability and probability estimates of risk occurrence.

Risk assessment, whether qualitative risk categorization or quantitative risk estimation, must be followed by the evaluation of risk significance. It is important to note that numbers per se are not the most important result from risk assessment. In fact, numbers can sometimes be deceiving. Program and project managers must keep in mind that, in reviewing risk assessment results, the most important result is an increased understanding of the system that leads to the discovery of ways to fix weak spots. Efforts can then be aimed at eliminating hazards where possible through redesign or through controlling hazards, by developing acceptable safety measures, in those cases where elimination is not possible.

Cost, Schedule, Performance, and Risk Management

Sound decision-making for program and project managers requires assessing each decision's impact in three areas: cost, schedule, and performance. Managers face immense pressure to keep cost within budget, schedule according to plan, and performance according to assigned mission objectives. Therefore, much of their time is spent reconciling the three. Since there is an element of risk to budget, schedule, or performance associated with every decision or non-decision, managing risk is a primary component of this process.

Risk, as it relates to performance, is defined as exposure to the chance of loss or injury to personnel, loss or damage to equipment, or loss or delay to the mission. It is a function of the following three factors:

- The frequency with which a hazard occurs;
- The potential severity of the resulting consequences; and
- The probability of those consequences occurring when the hazardous situation exists.

We at NASA have learned all too well that performance failure can mean more than just failure to accomplish a mission objective. It can mean tragic loss of personnel and equipment, sometimes with long-term consequences to cost and schedule.

Risk management is the decision-making process concerned with the balancing of performance-related risk with cost, schedule, and other programmatic considerations. It consists of the following four steps:

- Identifying risk;
- Assessing risk;
- Making decisions regarding the disposition of risk; and
- Tracking the effectiveness of the decisions made.

Safety is defined as the measure of freedom from occurrence or risk of loss or injury during use of a system or equipment through the elimination or control of hazards or the reduction of risk to an acceptable level. For example, SRM&QA engineers for the Galileo program had to identify and analyze the potential hazards related to the vehicle's nuclear power source. These analyses helped planners to eliminate some hazards and develop measures to control others. The effectiveness of these controls is continuously tracked and evaluated and change recommendations are developed, as required.

Reliability is the measure of assurance that a system or equipment will perform as designed by reducing risks of failure. As the life cycle for NASA programs and projects lengthens, increasing emphasis will be placed on the increasing reliability of systems as a method of eliminating or controlling hazards. High reliability in the Apollo and Voyager programs contributed to their success.

Maintainability is the measure of ease and rapidity with which a system or equipment can be restored to operational status following a failure or be maintained as a preventive measure prior to failure. Increased maintainability contributes to managing risk since it helps compensate for reliability shortcomings in current technology. Space Station Freedom, with an expected life of 30 years, will require systems with an increased degree of maintainability since the space station cannot return to Earth for repair. SRM&QA support can assist by performing integrated logistics support and configuration management studies.

Quality assurance is the measure of assurance that a system or equipment is produced or implemented as designed or intended through design review, inspection, and evaluation. High reliability systems are useless if they are not produced to high quality standards. For example, the quality of fasteners is becoming an important quality issue of international proportions. Also, new nondestructive evaluation technology is assisting managers in ensuring the quality fabrication of hardware.

Conclusion—SRM&QA Contributes to Good Management

The principles of TQM provide the foundation for decisions. Successful managers have learned the importance of continuous improvement in providing products and services and are designing in quality to achieve excellence. Less successful ones risk dooming their program or project to struggling to "inspect quality in" and reworking problems in their products and services that could have been resolved during the design process.

From my standpoint, risk management is a decision-making process when the manager balances performance-related risk with cost, schedule, and other programmatic considerations. Stated this way, performance should receive somewhat greater consideration in the decision-making process than do cost and schedule, at least to the extent that acceptable safety and mission assurance standards are met. While no one wants to make decisions that have a negative impact on cost and schedule, cost and schedule decisions cannot result in the kind of loss, in terms of resources and equipment, that performance failures can.

Performance objectives and mission success must come first, as they did in past programs such as Apollo, Voyager, and Viking. SRM&QA expertise is a critical element of the project team's ability to develop solutions to eliminate or control risk, attaining continued objectives and mission successes within budget, on time, and according to specifications.

Quality is planned in, designed in, and built in. Quality is not inspected in. Quality starts before designs are drawn and well before metal is bent. The main message here is that each person and organization in the program must understand and believe in the need for quality performance from the onset of the program. You cannot wait until the hardware is built to decide you want quality and then attempt to "inspect" it in. I have often seen this tried, but never successfully or economically. Quality encompasses more than just the delivered hardware. It includes management, requirements, design, development, testing and documentation.. Simply stated, the quality of every person's output is very important to the outcome of the program. — James B. Odom, "Guiding Principles for the Space Station Program," in Issues in NASA Program and Project Management, NASA SP-6101 (1988).

Advantages of Cost Plus Award Fee Contracts

by William C. Keathley

Personal experiences in the management of projects and shared experiences with colleagues have convinced me that a Cost Plus Award Fee contract is the best procurement vehicle for the high-tech, one-of-a-kind, development projects that constitute most of NASA's projects.

But, like most things, success isn't automatic. It takes work to make it happen, and the successful implementation of award fee contracts is no exception. In fact, the use of this type of contract requires more government and contractor effort than other forms of contracts. But, in my opinion, it's worth every hour spent.

Over the years, I've collected a list of "lessons learned" related to the use of award fee contracts. I'll try to articulate those lessons adequately in the following text. Keep in mind that I'm not speaking from the standpoint of a procurement officer. My observations come from the day-to-day use of these contracts in various positions I've held — project manager, director of flight projects (project manager's supervisor), and fee determination official.

An award fee contract is described as an arrangement whereby the government periodically awards a fee consistent with the cost, schedule, and technical performance achieved by a contractor during a preset period with preset award fee pools.

Rationale

Let me explain why I like award fee contracting. First, it's the only contracting method where both government and contractor goals are closely linked. The government wants cost, schedule, and technical performance; the contractor wants profits. The better the total performance, the better the fees (profits) will be. Compare that with a fixed price contract where the total price (cost plus fee) is fixed. If the cost of a fixed price effort is underestimated, the contractor may sometimes make adustments that impose risks to the technical performance. This protects the contractor's profits but imposes risk on the government's goal for technical performance. Other ways exist for contractors to protect their fees in a fixed price arrangement (all of them bad for the government), but that subject deserves a separate paper.

Second, an award fee contract has a built-in mechanism to conveniently alter and emphasize program events in order to satisfy current external and internal situations — and the government is involved in these adjustments. Prior to each award fee period, the government and contractor project managers review the plan for the upcoming period, agree on the planned events, and place the appropriate emphasis on each event. Should problems arise (and they always do), the plan and the fee emphasis can be adjusted accordingly. This is considered by most project managers to be the most important feature of award fee contracts. And while I'm on adjustments, I'd like to mention the use of "rollovers," in which lost fee from prior periods is used to "sweeten the pot" on future events that have become so critical that additional emphasis is warranted. Rollover is a powerful award fee tool to motivate contractors if used properly.

Third, the award fee process demands good communication between the government and contractor participants. And every project manager knows — or should know — that good communication is a necessary ingredient of every successful project. The meetings required by award fee contracting reinforce the need for clear communication.

Fourth, it has been my experience that contractor performance on award fee contracts is superior to performance by the same contractors on other types of contracts. The quality of the product is certainly superior. The fee earned by those contractors is better than they could have received on other cost type contracts, and it should be. Remember: better performance, which the government wants, results in higher fees, which the contractor wants. I don't have any data on fixed price contracts because there is no government knowledge of final costs of those types of contracts. But I'll bet award fees are close to the profits customarily realized by contractors, even on fixed price development contracts.

The downside to award fee contracting is the additional contractor and government personnel required to implement award fee contracts. It is certainly true that more people are needed to formally assess contractor performance, conduct performance evaluation board meetings, and report findings to the fee determination official. But I maintain that most of that work should be done under any circumstances, and the improved communication is worth the effort. So I'm not sympathetic to those complaints.

Implementation

All the good features discussed above can go down the drain with faulty implementation. I've found the following nine ground rules to be effective in properly implementing the award fee contracts in which I've been involved. I will readily admit that there should be many ways to skin this cat, but frankly, I've found no effective alternatives to the following rules. I've also seen instances where both the government and the contractor failed to reach their objectives as a direct result of deviations from one or more of the following rules.

First, the government project manager must chair the Performance Evaluation Board (PEB). After all, the project manager is the key official selected by NASA to be responsible for the project cost, schedule, and technical performance. The project manager is therefore in the best position to evaluate and judge the importance of the performance during the project evolution and obviously has the most to gain or lose from that performance or lack thereof. If that's not true, the agency should find another project manager. On the other hand, it's crucial that the contractor understand that the government project manager is the most influential government individual for all project activities, and looking elsewhere for project-level influence is unproductive.

Second, the PEB should consist of institutional members who are participating in the project: procurement, business (program control in some Centers), engineering, and product assurance (quality control and safety at some Centers). Depending on the end item or service, science and operations should also be added. It's advisable to keep the PEB membership as small as possible, and it's important to select individuals with experience applicable to the end item or service delivered. In other words, make sure they are capable of understanding what the contract monitors are telling them.

Third, the Fee Determination Official (FDO) should be no higher than one level

above the project manager and, in fact, should be the project manager's line supervisor. The FDO must have more than a passing knowledge of the project's status. This requires frequent interactions with the project manager, which the supervisor's position provides. Deviations from this rule can result in some awfully dumb fee determinations. I might add that if the project manager reports to the Center director, the deputy Center director should be the FDO. Center directors should not be FDOs and should be reserved to resolve institutional or project issues should they arise.

Fourth, use adjectives that can be understood and that properly describe performance levels. I prefer the academic model where "Satisfactory" is used for barely passing performance (a 60 or 70 percent performance rating, depending on your preferences.) Levels below "Satisfactory" can be identified as "Poor" and "Failing." Levels above "Satisfactory" can be called "Good" and "Excellent." It's confusing to everyone when fee curves are set so that the fee letter indicates a contractor got a "Superior" rating but received only 65 percent of the available fee for that period. Don't laugh; that's actually happened.

Fifth, skew the fee curve (fee earned vs. performance rating) so that most of the available fee falls above "Satisfactory," or whatever you've decided to call passing performance. This clearly shows our desire for high performance and motivates the contractor to exceed a mere passing grade.

Sixth, make the award fee periods sufficiently long to allow time to correct deficiencies after a mid-term review by the project managers. I prefer six-month periods. This allows the project managers to assess the performance status three months into the period in order to identify performance problems, and then still provides three months to correct the situation before final evaluation and scoring of that period's performance. Periods of less than four months preclude this important process.

Seventh, offer contractors an opportunity to present self-assessments of their performance to the PEB and the FDO. Some contractors will choose not to do this, but the invitation ought to be given. If the offer is accepted, I believe the PEB should hear the contractor's self-assessment before making the final rating. As an FDO, I definitely preferred hearing the contractor's self-assessment before hearing the PEB's story. Frankly, I've found that the major advantage of contractor self-assessments is that they indicate faulty government-contractor communication — which will kill a successful project more quickly than anything I know.

Eighth, rollovers should be allowed in the award fee plan but never promised. They should be left to the discretion of the FDO and result from recommendations by the PEB. They should be used infrequently and always targeted to specific events that have become crucial to the success of the project. Specific "go/no-go" performance criteria must be established for these events and announced in the fee letter for the period preceding the period in which the selected event falls.

Finally — and most importantly — the contractor project manager and the government project manager <u>must</u> jointly agree on milestones and criteria, and the emphasis to be placed on each, <u>before</u> the beginning of each award fee period. And then <u>everyone must stick to the agreements</u>. This won't eliminate disagreements with the amount of fee awarded, but it does eliminate surprises, which are simply unacceptable. Nothing can kill an award fee process quicker — and demoralize contractors more — than to be "dinged" for something they didn't know.

Fee Determinations

Now let's look at the lessons learned in the awards themselves. The first and most important ground rule is: don't play games. If the contractor earned all of the fee, by all means award it. Don't fall into the trap of telling yourself, "If I give 100 percent, the contractor will start expecting it every time." Or: "The contractor earned 100 percent, but I'll give 80 percent to give some room to improve." Or just as bad: "If I give the contractor the 20 percent really earned, I'll get the project manager fired." Awards that are too high or too low are equally bad. Awards that are too high tell the contractor to underperform and get away with it. Awards that are too low tell the contractor that no matter how hard the work and how much the accomplishment, efforts will be in vain. Both situations are bad and will demoralize the contractor. Stick to the prior agreements and award the fee consistent with the actual performance. If the performance is deficient and your awards are consistently fair, you'll soon see the performance improve. If the performance is good, and the contractor is convinced that fees will be lost by backsliding, the performance will remain high. In case you didn't notice, the operating word is fair. By the way, it's a good idea to keep histograms for the percentage fee earned as the program develops. If the awards have been consistent (fair), you'll see the hills (good times) and valleys (problems) that occur in any development activity.

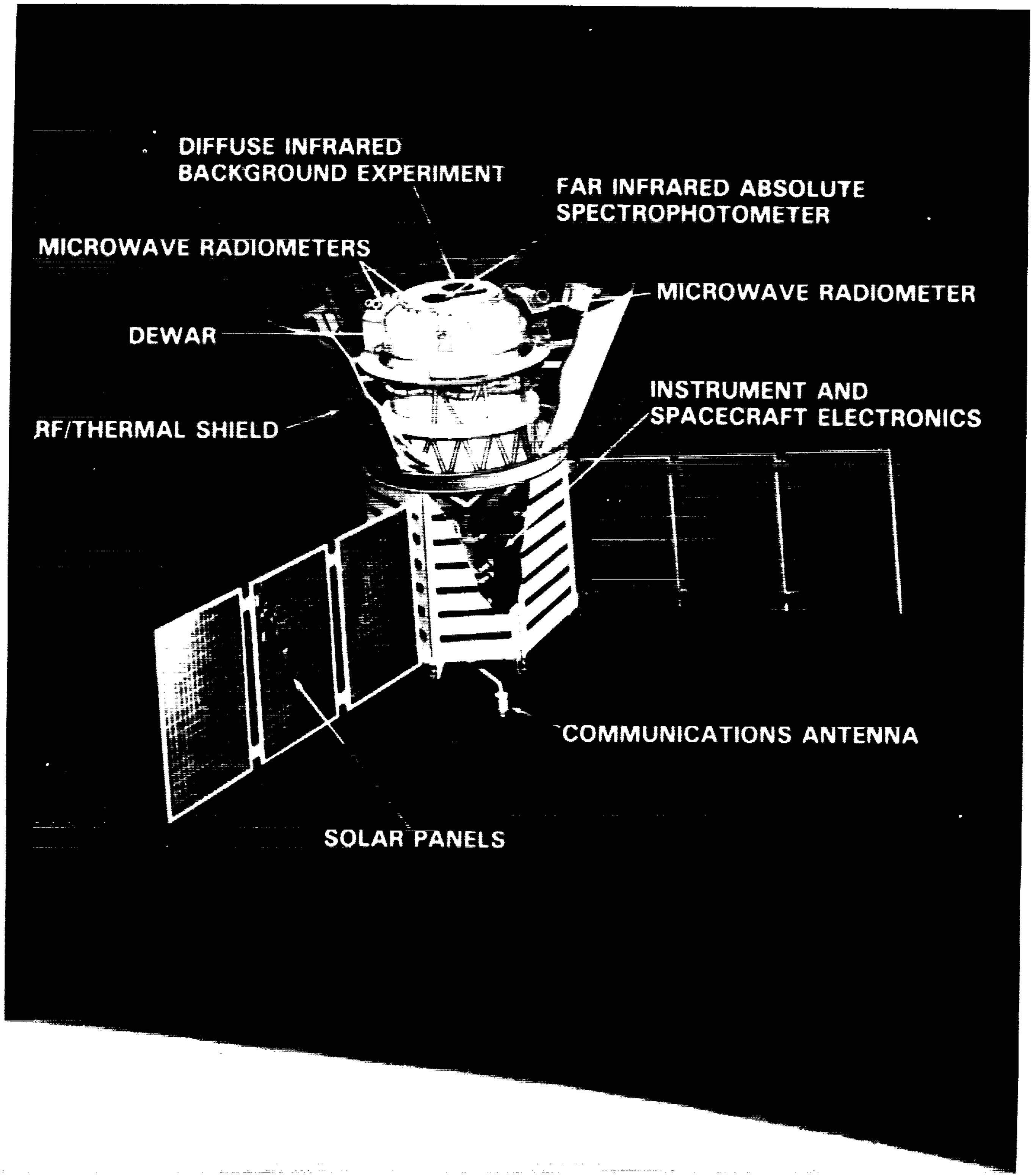
Award Fee Letter

Now for the important fee letter where you tell the contractor about the determination. Believe me, you can ruin a good award fee process and all the work you've done by issuing an award fee letter that no one understands. It would be impossible to overstate the importance of these letters. I've found the letters should have four basic parts. The first paragraph is really a boilerplate paragraph that references the contract title and number, identifies the period for which the award is given, states the percentage of the award earned and the specific dollar amount, and gives the performance adjective rating. The second paragraph should identify the instances of commendable performance. Be specific, even if you have to use bulleted items. Be clear. The contractor must understand which ratings were high so as to pass the accolades along to the working troops. The third paragraph should identify deficiencies. Again, it's extremely important to be specific and clear. I call the final fourth paragraph the "message" paragraph. The content of this paragraph can range from "keep up the good work" to "be advised that continued inferior performance in (a certain area) will have serious effects on future overall fee determinations."

A good contractor general manager will do several things with the fee letter — that is, if it is understood. First, a meeting with the project manager will be held to review the letter. The project manager will be commended for the things done properly (second paragraph), actions will be identified to correct recurrence of the deficiencies (third paragraph), and the message (fourth paragraph) will be discussed and actions (project or institutional) will be identified to respond to the thrust of the message. Next, the good general manager will send a letter to the FDO stating that the award has been reviewed with the project manager, the recognition of the commendable items is appreciated, the deficiencies and message are understood, and appropriate actions have been assigned. In addition, the general manager will now be in a good position to report the profit status on this contract and articulate the details of the award. All of these good things transpire when the contractor understands the fee letter. Otherwise, there is no followup or feedback, the situation cannot be explained to corporate reviewers, and everybody loses.

The understanding of the awarded fee is so important that I added one more step to the process. As an FDO, if a general manager called and verbally complained about certain elements of the award, I would discuss the call with the government project manager and provide verbal feedback to the general manager. If the complaint came in writing, I would reconvene the PEB with instructions to draft a written response to <u>only the specific concerns</u> stated in the general manager's letter, not every element of the award. I would then discuss the recommended government response with the PEB. If I agreed with the PEB position, I would send the written response to the general manager. By the way, I have changed a prior award in the contractor's favor after learning that the PEB used erroneous information. In that case, the general manager was correct and the contractor earned the fee increase. After all, that was the <u>fair</u> thing to do. The contractor response to that small dollar change was tremendous, and performance improved markedly.

So in summation, I believe that award fee contracting is particularly suited to the one-of-a-kind development projects which constitute most of NASA's efforts. I do not believe fixed price contracts or fixed price plus incentive contracts belong in this environment. Perhaps someone else may wish to argue the advantages of the latter types, but my experience suggests that award fee contracting is the better way to go.



COBE's three instruments will be able to observe, map and measure the entire sky twice during its 1 year mission lifetime. COBE, which includes the FIRAS instrument, is 19 ft (6 m) long and 29 ft (9 m) in diameter once the arrays are extended. The instruments measure radiation from a variety of objects in space and the cosmic background radiation of the "Big Bang."

COBE: Lessons Learned from the Management of FIRAS

by Mike Roberto

On November 18, 1989, NASA launched the COsmic Background Explorer (COBE) from Vandenburg Air Force Base in California. COBE's mission is to orbit 559 miles above the Earth for one year to study the origin and dynamics of the universe by measuring diffuse infrared radiation and microwaves, including the cosmic background. COBE will also test the "Big Bang" theory of the origin of the universe, predicated 15 billion years ago.

COBE is carrying three principal instruments to map the sky at 100 microwave and infrared wavelengths. The Differential Microwave Radiometer (DMR) is looking to see whether the original explosion was equally bright in all directions, or whether patchy brightness will unveil the origins of galaxies, clusters of galaxies, and clusters of clusters of galaxies. The Diffuse Infrared Background Experiment (DIRBE) is searching for the light of the oldest stars and galaxies by measuring the collective glow of millions of objects, accounting for all known sources of emissions, and seeing what signals remain. The third instrument is the Far Infrared Absolute Spectrophotometer (FIRAS), which measures the spectrum of the cosmic background radiation from the "Big Bang" and intergalactic dust. A smooth black body spectrum with small deviations is predicted. Any deviation may indicate other powerful energetic events from the period of universal history shortly after the "Big Bang," such as annihilation of antimatter, matter swallowed by black holes, or supermassive exploding objects.

FIRAS was designed, built, and integrated at NASA Goddard Space Flight Center. The entire process was kept in-house, the first time such a complex project had been done this way. While the outcome was successful, the process did not always go smoothly. Following are some of the lessons learned from this experience.

1. Matrix management

Problem: Four divisions and numerous branches of Goddard's Engineering Directorate provided excellent support to FIRAS. However, the support personnel had other concurrent responsibilities and were not under the direct control of the FIRAS management team. Because they were not always available, more flexibility was needed in the schedule.

Solution: With limited personnel resources, there is no easy solution here. There is a trade-off between keeping support personnel in their organizations where they can interface with peers on technical problems and co-locating a team to support the instrument.

2. Breadboarding vs. system modeling

Problem: Too much time was spent developing breadboard subsystems, making the project too much like experimental research. A lot of time was spent varying parameters to arrive at the right recipe for the operation of temperature controllers.

Solution: Have good analytical capability for modeling from the beginning. Then you can run computer simulations, changing parameters and predicting results. Use system modeling extensively in the beginning of the process, before breadboarding. During most of FIRAS integration and testing, we did not have an analysis program to predict the proper temperature controller settings. After the analytical model was developed, establishing settings became routine and quick.

3. Peer level design reviews

Problem: The design reviews were not detailed enough to catch subtle design problems. For example, the mirror transport mechanism (MTM) was a good mechanical design but complex enough that proper assembly was not immediately apparent. If the assembly were not perfect, the mechanism would not work properly. Parts were assembled at ambient temperature and cooled to near absolute zero; components cool at different rates and to different lengths.

Solution: Have experts perform a thorough technology assessment early in the program. Then you can find out early which parts of the program need more emphasis and more work; you can point out potential problem areas which are technology drivers. Reviews should be held at each level of maturity of design, so that problems can be caught early, before the hardware is cut. Peer reviews should be conducted in small groups in a small conference room where the diagrams can be put on a conference table for people to review together. The reviewers are thus more likely to discuss the diagrams and to mark problem spots and indicate solutions. When the review is held in a large conference room with a large group and the diagrams projected on a screen, the atmosphere is less conducive to criticism, discussion, and changes.

4. Comprehensive system level approach to system design

Problem: The responsibility for the various electronic subsystems of FIRAS was divided among different branches and divisions. Some FIRAS circuits required modification late in the program. For example, the MTM is extremely complex. We didn't find out how noisy it was until it was installed on the spacecraft; we then had to modify the electronics design of the shielding and grounding to make it work properly. This including piggybacking a box onto the drive electronics box to eliminate noise and to ensure that the MTM would recover from any scan upsets. Before modification the mechanism would occasionally go to the end of its course for a while, where it drew excessive power. Once the problems were corrected, it performed flawlessly.

Solution: Early in the evolution of the electronic system design, the instrument team needs to have an expert on grounding, noise immunity, electronics components and interfaces, etc., to coordinate the overall system design. This skilled individual should have overall responsibility for all the electronics.

5. Engineering model

Problem: The engineering model was deleted from the program because of time and cost. An engineering model could provide some flight spare components as well as an instrument for testing fixes on the ground before trying to correct an on-orbit problem. The FIRAS team ended up making changes to flight hardware.

Solution: There is no easy solution here. An engineering model of FIRAS would have been more expensive and time-consuming than the modifications made to the flight hardware. However, for an instrument as complex as FIRAS, I believe an engineering model would have been good insurance.

6. Documentation

Problem: With the pressing schedule, the

FIRAS team received hardware without its documentation. The same people who supplied the hardware had to prepare the documentation. To maintain the schedule, testing had to proceed without all supporting documentation.

Solution: Insist that without complete documentation, the hardware is not considered to be delivered.

7. Test requirements and schedule

Problem: In the FIRAS test program, tests were sometimes shortened or deferred to a higher level of integration to maintain the schedule. FIRAS paid a price for trying to maintain the schedule. The problem of the Xcal (external calibrator) not staying in the horn was not discovered until FIRAS was in the flight dewar. The MTM drive electronics required modification on the spacecraft, and then a special electronics box had to be mounted on the drive box (see #4). The lesson here is that the risks of a success-oriented schedule are very real.

Solution: There is no easy solution here either. We're doing Monday morning quarterbacking. The success-oriented schedule had many successes, but going back into the dewar was a big hit (costing us more time in the long run). At times, a more flexible schedule would have helped.

The FIRAS team could have fought harder for additional time at certain critical points in the program.

8. Software support

Problem: FIRAS was severely constrained by having to use the developing mission software system for its instrument integration and testing. The software was periodically modified as it was being developed as a ground support system for the mission. The integration and test team had to use the same software; when the version of the VAX operating system was changed right before a test, the software would not work properly for the integration and test team. The integration and test effort was necessary for launch, but the team felt they were being used as guinea pigs for the new software, rather than having software developed to support their efforts. They had no control; they couldn't prevent the software from being modified as they were preparing to conduct a test.

Solution: Instrument integration and testing needs independent, dedicated software support.

9. Programmed pauses

Problem: A number of times in the FIRAS program, the FIRAS team fell behind schedule. We were trying to prepare for the next item on the schedule while also bringing test procedures, test reports, etc., up to date. We would get into a new test without having a chance to completely evaluate the results of the previous test. It was easier at times to run a test again, rather than to go back and try to process old data.

Solution: At times in a test program, it may be necessary to stop everything and get up to date. This may save time in the long run.

10. Common language

Problem: We tested FIRAS using one version of STOL, a program for commanding the instrument from a computer. The spacecraft has a slightly different version of STOL. The POCC (payload operations control center) has a significantly different version of STOL.

Solution: Use the same test language from the start.

11. Procedure changes

Problem: It was a rare event for a FIRAS test procedure not to go through several iterations.We made considerable extra work for ourselves in developing and reviewing new procedures for early orbit operations and the FIRAS mission.

Solution: Develop procedures from the start with inputs to cover all phases of the program. This would require a lot of coordination in the beginning, with procedures reviewed by subsystem, engineering, science, and operations personnel. However, the overall program would be more efficient and more appropriate.

12. Personnel work hours

Problem: The COBE work has been exciting and demanding. However, a work schedule that runs through holidays, nights, and weekends for extended periods is usually not good for the individual. Health and efficiency may be affected. There should be a way to maintain a steady work pace that allows the individual to keep up with responsibilities outside of work.

Solution: There is no easy solution here. Mandatory time off would mean that the project would take longer and be more expensive. At Goddard, projects are where the action is. One could say that if you can't stand the heat, get out of the kitchen. Some people want to work lots of extra hours. However, since thIs is now a "kinder and gentler nation," project work could be made available for individuals content with working more normal work weeks.

Conclusions

People at Goddard received a lot of training with the COBE project. Goddard benefitted as a whole; it learned that it could handle a large project in-house.

The FIRAS team was to a large extent captive to the overall push to complete COBE. COBE put an extraordinary demand on personnel, money, and facility resources. Better planning might have allowed for more efficient resource utilization. As the magnitude of the job became evident, it would have been helpful to conserve personnel resources by reducing night, weekend, and holiday work. Additional facility (and money) resources would have been required, but there would have been a better overall balance in resource utilization.

In the end, everything came together. We are very excited about how well FIRAS and the other instruments are working. It is hard to argue with success. Thus COBE may reinforce our dependence on extraordinary personal efforts by our people. Any volunteers for COBE 2?

Management of Small Projects: Streetfighting in the NASA System

by William J. Huffstetler

The NASA management system, as it has evolved over the past three decades, is characterized by larger projects. Ambitious plans, bold directives, massive budgets, and tens of thousands of workers characterize the most spectacular achievements of NASA, yet all during the huge Apollo and Shuttle programs, NASA was involved in hundreds of smaller projects, some of them totally unrelated to their much bigger contemporaries, serving the needs and aspirations of American and international science and technology.

NASA counts some 20,000 "spinoffs" or technologies twice used, about half of them related to medical science. Many of these spinoffs are the direct result of NASA's smaller projects. NASA is one agency whose parts are greater than the whole, whose sum yield is higher than the total of projects.

What is a "small project" at NASA? It is defined as any project not supported by a large pipeline of dollars from a major program or project. It can be a minuscule, stand-alone part of a major program, but it usually has a short life cycle, perhaps 18 to 36 months. While it may have a lower priority in a NASA Center's goals or objectives, a small project is not considered extra, optional, or expendable — it is considered a mandatory activity.

Murphy's Laws enable us to understand the real beauty of a small NASA project. The shorter life cycle of a small project goes a long way in protecting us from Murphy's Fourteenth Law: If you fool around with a thing for very long, you will really screw it up. Most of all, a small NASA project provides two immeasurable benefits not ordinarily found in mega-projects: considerable "hands-on," in-house activities, and a marvelous opportunity to have some fun. But to manage a small project at NASA you need to know something about the art of streetfighting.

Like a Real Business

Managing small projects is the closest thing to running a true business you can find inside NASA, or within the government for that matter. Small businesses have to streetfight and most new businesses are knocked out in two years or less. Streetfighting techniques can be applied to small government projects as well.

First of all, the first decision for a private business is selection of a product line. NASA does this every day, examining the needs of the nation and the projects to meet various conflicting and shifting priorities, to the satisfaction of Center goals.

Next comes evaluation of competition. True businesses merely have to study other producers in order to begin planning and market strategy, but competition within NASA can come from many sources. Some are internal (such as other funded projects), and some are external (such as user needs). As the new NASA manager on the block begins to streetfight for a project he or she believes in, things get rough. As Murphy notes, friends come and go, but enemies accumulate.

The common next step for private enterprise is conceptualizing, a process that involves both strategy and credibility. In planning, you don't want to eliminate any idea or concept initially — but then, you do not want to plan by committee, either. Near-term action (two to four years) is easy, but long-term strategy (four to eight years) will require phases for major decision points. The idea is to gain credibility for the project by breaking new ground — in small pieces, not big chunks.

The business world next considers risk assessment. For managers of small projects, technical and programmatic risks should be distinguished. I would assume minimum risk technically and maximum risk programmatically. The turtle moves forward only when its neck is sticking out from its protective shell.

Marketing comes next in small business: selling and convincing people of the concept. For small projects, that means internal selling. Establish a visible "golden cookie" for all those from whom you need support. What's in your project for them? How are the organization's aims and aspirations reflected in this small project? Market yourself as a leader — managers are a dime a dozen, but leaders are worth millions. Convince others that you can handle the project, but remember that major conflicts will come from within.

So a continuing process of reinforcement is required to sustain commitments. Murphy warns, however, that if you try to please everybody, nobody will like it. Commit yourself to the project, and convince others. Lead, don't follow, in the marketing of your small project.

Can you deliver the small project on time, on budget, with the people assigned to you? To be sure, take a chapter from the business book and do some "resource projections."

Think twice about assurances of success until you have the people, dollars, and schedule.

You may be asked to do a "cost-to-benefit" study, as commonly practiced in thebusiness world. While some people claim that if government were a business, it would go out of business, others would say that government is there to take risks in order to push technology and expand the frontiers of science. Even if the numbers look bad, lead — don't follow the numbers. Use the numbers, don't be used by them, for strong leadership is mandatory on small projects.

Acquisition and Implementation

So you sold the project. Now what do you do? Acquisition and implementation is the customary final phase of a typical business plan outlined above, but I want to spend some time on this. Most people would think you put all your energy into design, development, test, and certification. That's the easy part of the project.

The hardest part is requirements.

Developing strong yet flexible requirements can make or break a small project. While it is estimated that one hour of planning can save perhaps three or four hours of execution, Murphy adds that anything you try to fix will take longer and cost more than you could imagine. Changes occur at the blink of an eye. They may come from any direction, friend or foe. But the major syndrome, costing valuable time and money, is: "I forgot."

The key to successful acquisition is control, but such control must be self-imposed, and, more important, self-maintained. Let George do it, and George should have your job. Throw out your plans and strategy, and here comes trouble.

Throughout the implementation of a small project (and most large ones as well), the manager discovers the necessity of a continuing process in justifying the project's existence. Here come budget cuts. Can we still proceed?

Here come new priorities. Can we adapt to them? And where did all the project's advocates go? You left it to George, and George left.

At this point you had better control the risks, for, as Murphy observed, the light at the end of the tunnel is actually the headlamp of an oncoming train.

There is no such thing as an optimum organization. There are only good leaders. And then there are managers. Anyone can manage, but few can really lead.

In practical terms for small projects, this means giving maximum authority to project engineering and project managers. It starts with honesty: you do not and cannot know everything about everything. Develop close relationships with subordinates in a spirit of honesty and trust. Be flexible and adjustable, reducing tensions as much as possible. Above all, develop leaders, not merely more managers.

An organization is strengthened when it becomes an organism, when your team numbers know and feel personally responsible for their work. Authority is delegated to the lowest possible level, and commitment to the project rises to the maximum.

Some managers are continually on the lookout for project visibility. If it's visibility you want, have a failure while all else on the flight is nominal. Maximum visibility, however, does not necessarily result from a totally successful flight project; rather, it is provided by project products that fly.

Visibility in an organization is a tricky concept. Support for projects will appear to be totally nil — or you will be helped to death. Visibility is not always desirable for an organization. A genuine leader will recognize others on the team but will not seek personal recognition.

So, Why Manage Small Projects?

You want to manage small projects because the rewards are so great.

On a small project, rewards are more personal than tangible. Success is sweeter for something over which you have major (though never total) control. And the personal relationships, good and bad, built up over the lifetime of a small project will stay with you for the rest of your life.

Those relationships are based upon building leadership through responsibility and authority delegation. The small project is the perfect mechanism for educating younger personnel by integrating them with oldtimers.

With the Apollo-era engineers and technicians retiring at an alarming rate, their wisdom finds no better place to live on than in the hearts and minds of those working so closely together on a small project.

One venerable oldtimer, now officially retired, is Clarence L. "Kelly" Johnson who created his famous "Skunk Works" at Lockheed in 1943.

The "Kelly Johnson factor" is a true educational experience in both learning and teaching, perfectly suited to the management of small projects. Kelly proved that projects led by small committed project teams could be fun as well as challenging, and some of his precepts are paraphrased and outlined on the next page.

Basically, Kelly Johnson pulled a few good people together, gave them authority from beginning to end, and let them tackle tough problems with the simplest of tools and methods. In a mere 43 days, ten dozen people, in cluding 23 engineers, built the first U.S. fighter plane to fly faster than 500 mph. With unexpected shared authority, this team focused on a single, clear objective and had enormous fun achieving it. Managers of small projects at NASA would do well to reflect upon what Kelly Johnson learned and taught.

Kelly Johnson's

SKUNK WORKS: BASIC OPERATING RULES

1. The manager delegates practically complete control of the program in all aspects; reports go to highest level.
2. The projects office is small, but strong.
3. The number of people having any connection with the project is restricted in an "almost vicious manner."
4. The drawing and drawing release systems are very simple, with great flexibility in making changes.
5. Required reports are at a minimum, but important work must be recorded.
6. Monthly cost reviews cover what has been spent and committed, and projected costs to completion.
7. The contractor must be delegated and must assume more than normal responsibility for good bids on subcontract project work.
8. Existing inspection systems are used, with more basic inspection sent back to subcontractors and vendors. Don't duplicate.
9. The contractor delegates authority to test the final product in flight.
10. Specs applying to hardware must be agreed to in advance of contracting.
11. Funding must be timely.
12. Mutual trust is sustained between project organization and the contractor. Closest cooperation is on a day-to-day basis.
13. Access to the project by outsiders is strictly controlled.
14. Ways must be provided to reward good performance.

— See Chapter 16, "It's No Secret," of Clarence L. "Kelly" Johnson's Kelly: More Than My Share of It All (Washington, D.C.: Smithsonian Press, 1985), reviewed in Issues in NASA Program and Project Management, NASA SP-6101(02).

Age Distribution Among NASA Scientists and Engineers

by Michael L. Ciancone

The loss of technical expertise through attrition in the technical work force is a growing concern throughout NASA and the aerospace industry, and may impact on the way NASA manages projects. An unusual distribution of age groups among scientists and engineers (S&Es) within NASA presents both challenges and opportunities to NASA managers.

This article documents historical age-related S&E information within NASA in general, and the NASA Lewis Research Center (LeRC), Cleveland, Ohio, in particular, for 1968 through 1988, and discusses the implications for NASA managers. Recommendations are made for addressing the age distribution issue to provide a practical approach for avoiding adverse consequences and for allowing us to take advantage of opportunities that may arise.

The reputation of any technical organization is based on the individuals who comprise its work force, including both supervisory and nonsupervisory S&Es. These individuals form the core of the organization's technical and programmatic memory. It is essential to the viability of these organizations that they maintain a critical core of experienced individuals. Equally important is the need to attract, develop, and retain individuals who will comprise the agency work force in the years to come. This is the challenge of balancing short-term needs (i.e., utilizing existing experience to meet current demands) and long-term needs (i.e., developing new talent to meet projected demands).

Early in the U.S. civilian space program, following the formation of NASA in 1958, many S&Es were hired directly out of college by NASA, supplementing those who made the transition from the former NACA and those who were drawn from military programs. These young S&Es acquired invaluable experience as they matured along with NASA through the U.S. civilian manned space programs, including the Mercury, Gemini, and Apollo programs.

In the late 1960s, forces external to NASA (e.g., congressional and administration priorities, and budget constraints) dictated a decrease in the size of the NASA workforce (and a corresponding decrease in the number of S&Es) as the Apollo program drew to a premature close.[1] More recently, an influx of new hires in the early 1980s has helped to bolster the NASA S&E base in support of a revitalized mission, including programs such as Space Station Freedom. As a result, we are faced with a combination of a large number of S&Es nearing retirement age, a shortage of mid-career S&Es, and a large cadre of relatively inexperienced S&Es. Aggravating the situation is an anticipated downturn in the number of S&E graduates who will be available to the agency in the coming years.

If we assume that the S&Es hired in 1958 were recent college graduates with an average age of 22, then these employees will be eligible to retire under the existing Civil Service Retirement System (CSRS) in 1991, i.e., with at least 30 years of service and at 55 years of age. Current personnel statistics reflect an average retirement age among NASA S&Es of 60.[2] The impact produced by the introduction of the Federal Employee Retirement System (FERS), supplanting the "golden handcuffs" of the CSRS, have yet to be fully determined.

The following information was obtained from raw data and annual work force summary reports prepared by the NASA Personnel Evaluation and Analysis Division for the years 1968 through 1988 to determine our current situation in light of relevant historical trends. NASA S&Es are defined by the following position categories: support engineering and related positions, aerospace technology (AST) S&E positions, and life science positions.

Support engineering and related positions include professional physical science, engineering, and mathematics positions in work situations not identified with aerospace technology. AST S&E positions include professional scientific and engineering positions requiring AST qualifications, and professional positions engaged in aerospace research, development, operations, and related work including the development and operation of specialized facilities, and supporting engineering. Life science positions include life science professional positions not requiring AST qualifications, and medical officers and other positions performing professional work in psychology, the biological sciences, and professions that support the science of medicine such as nursing and medical technology.

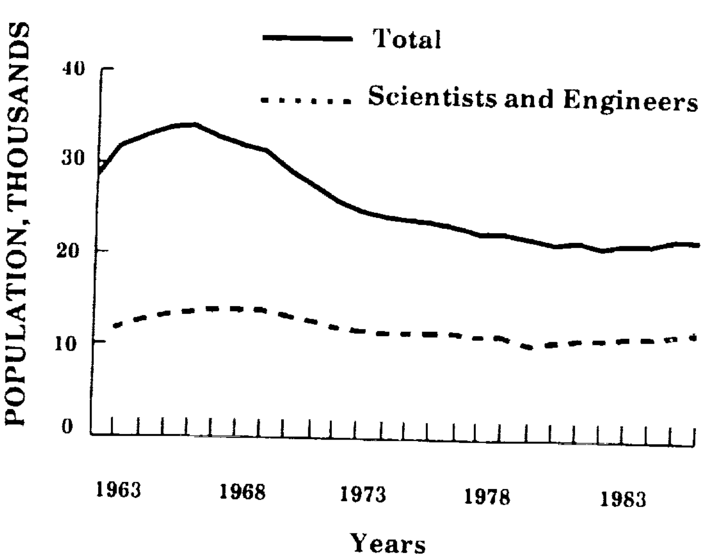


Figure 1. - NASA Civil Service Workforce

Figure 1 shows the general trend in both the total number of NASA civil service workers (CSs) and the number of CS S&Es. However, Table 1 indicates that, throughout the variations in the size of the NASA CS workforce, the percentage of S&Es in the total NASA CS workforce increased — from 36.5 percent in 1963 to 54 percent in 1988. This increase was not unexpected as many former CS, non- S&E

YEAR	TOTAL	S & Es	S & Es as a percent of total
1963	28,358	10,340	36.5
1964	31,285	11,893	38.0
1965	32,697	12,838	39.3
1966	33,538	13,282	39.6
1968	33,677	13,681	40.6
1968	32,471	13,851	42.7
1969	31,733	13,839	43.6
1970	31,223	13,837	44.6
1971	29,478	13,227	44.9
1972	27,428	12,616	46.0
1973	25,955	12,085	46.6
1974	24,854	11,770	47.4
1975	24,333	11,665	47.9
1976	24,039	11,612	48.3
1977	23,569	11,544	49.0
1978	23,169	11,465	49.5
1979	22,633	11,291	49.9
1980	21,613	11,200	49.5
1981	21,844	10,923	50.0
1982	21,186	10,746	50.7
1983	21,505	11,094	51.6
1984	21,050	10,879	51.7
1985	21,423	11,144	52.0
1986	21,228	11,147	52.5
1987	21,831	11,679	53.5
1988	21,991	11,866	54.0

Table 1. - NASA Civil Service Workforce

positions were converted to positions involving activities that could be provided by private industry. Although these mandated conversions contributed to the depletion of in-house talent, a conscious effort was made by NASA management to retain the technical expertise of the S&E workforce as much as possible.

Figure 2 illustrates the changing age distribution among NASA S&Es, at 10-year intervals. Table 2 tabulates the NASA S&E age data for 1968 through 1988. NASA has gone from a "young" agency in 1968 during the height of Apollo, to a somewhat normal age distribution in 1978, to the current bimodal age distribution.

A bimodal age distribution, i.e., with two distinct peaks or modes, may preclude a smooth personnel transition as experienced senior

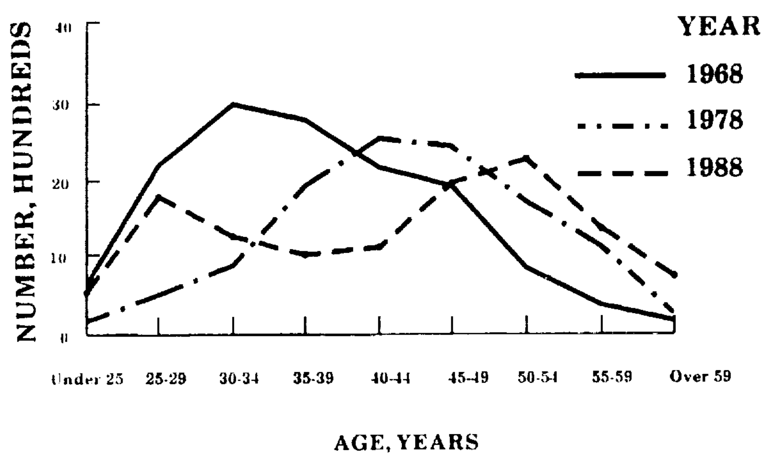


Figure 2. - Age Distribution Among NASA Scientists and Engineers

S&Es are succeeded by available personnel, consisting of a relatively few mid-career S&Es and relatively inexperienced S&Es. Since 1968, 19 to 23 percent of the total S&E popu-

YEAR	AGE RANGE									TOTAL
	‹ 25	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	≥ 60	
1968	633	2,168	2,945	2,767	2,136	1,874	815	347	166	13,851
1969	459	1,946	2,849	2,829	2,150	2,097	900	406	203	13,839
1970	381	1,718	2,658	2,914	2,235	2,167	1,085	472	207	13,837
1971	286	1,396	2,435	2,837	2,243	2,103	1,248	477	202	13,227
1972	135	1,109	2,185	2,746	2,383	1,950	1,452	453	203	12,616
1973	89	801	2,000	2,594	2,517	1,900	1,559	467	158	12,085
1974	108	606	1,769	2,524	2,541	1,888	1,684	486	164	11,770
1975	153	521	1,537	2,408	2,608	1,962	1,701	594	181	11,665
1976	186	468	1,308	2,264	2,662	2,050	1,738	736	200	11,612
1977	167	456	1,063	2,072	2,574	2,314	1,685	974	239	11,544
1978	176	503	874	1,928	2,528	2,406	1,683	1,098	269	11,465
1979	199	503	728	1,744	2,475	2,482	1,671	1,175	314	11,291
1980	349	598	725	1,544	2,379	2,562	1,733	977	333	11,200
1981	317	666	725	1,343	2,212	2,551	1,772	952	385	10,923
1982	328	710	660	1,159	2,060	2,475	1,927	966	461	10,746
1983	602	809	709	958	1,940	2,454	2,049	1,034	539	11,094
1984	557	909	706	842	1,723	2,379	2,091	1,074	598	10,879
1985	636	1,168	781	837	1,508	2,269	2,171	1,137	637	11,144
1986	549	1,375	887	862	1,327	2,120	2,207	1,183	637	11,147
1987	627	1,612	1,055	916	1,229	2,044	2,206	1,307	683	11,679
1988	522	1,755	1,243	993	1,102	1,960	2,253	1,328	710	11,866

Table 2. - Number of NASA Scientists and Engineers

lation has consistently been concentrated in the peak age group. The percentage of S&Es between 30 and 50 years of age has steadily decreased since 1970, while the percentage of S&Es over 50 has steadily increased (although at a slightly lower rate of increase than the rate at which the percentage between 30 and 50 decreased). In addition, the decreasing trend in the percentage of S&Es under 30 was reversed about 1980. As of 1988, 19 percent of NASA S&Es are under 30, and 36 percent are over 50.

The NASA-LeRC data represents a microcosm of NASA's S&E age distribution trends. Figure 3 presents NASA-LeRC S&E data (tabulated in Table 3), comparable to the NASA S&E data presented in Figure 2. During this time period, NASA-LeRC S&Es constituted 10 to 13 percent of NASA's S&E work force.

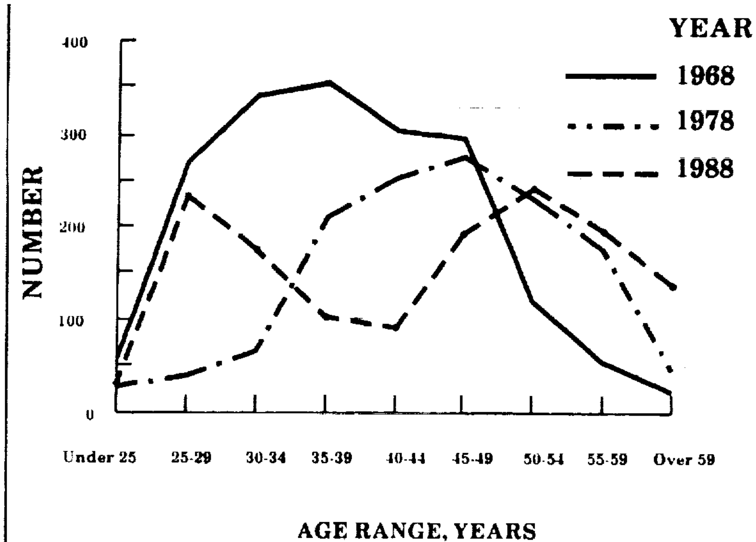


Figure 3. - Age Distribution Among NASA LeRC Scientists and Engineers

Figure 4 illustrates that the average age of NASA's S&Es increased at a rate of 0.65 years/year between 1968 and 1978. NASA's

YEAR	AGE RANGE									TOTAL
	<25	25-29	30-34	35-39	40-44	45-49	50-54	55-59	≥60	
1968	56	271	340	355	301	296	118	53	22	1,812
1969	35	233	321	342	294	326	138	57	32	1,778
[a]1970	27	194	312	331	302	329	170	66	28	1,757
1971	19	154	302	320	309	332	202	75	23	1,736
1972	12	102	271	306	308	287	238	73	31	1,628
1973	6	66	223	265	300	260	249	67	22	1,458
1974	5	43	188	256	286	245	245	73	22	1,363
1975	6	38	153	254	271	265	242	89	25	1,343
1976	18	34	111	244	270	262	250	128	31	1,348
1977	25	36	90	230	260	268	240	158	32	1,339
1978	28	40	64	209	253	276	228	173	43	1,314
1979	29	42	58	177	247	285	220	197	47	1,302
1980	27	50	57	141	251	266	244	155	47	1,238
1981	19	59	52	116	240	253	226	157	61	1,183
1982	33	66	49	96	226	239	212	151	72	1,144
1983	133	98	80	73	213	236	227	148	88	1,296
1984	122	112	79	64	180	240	233	156	91	1,277
1985	114	176	87	74	146	247	226	173	94	1,337
1986	46	218	92	75	122	231	230	161	104	1,279
1987	56	249	127	92	108	228	229	164	120	1,373
1988	32	231	174	101	90	190	242	195	137	1,392

Table 3. - Age Distribution Among NASA LeRC Scientists and Engineers

[a] Figures for 1970 were obtained through interpolation of the data from 1969 and 1970

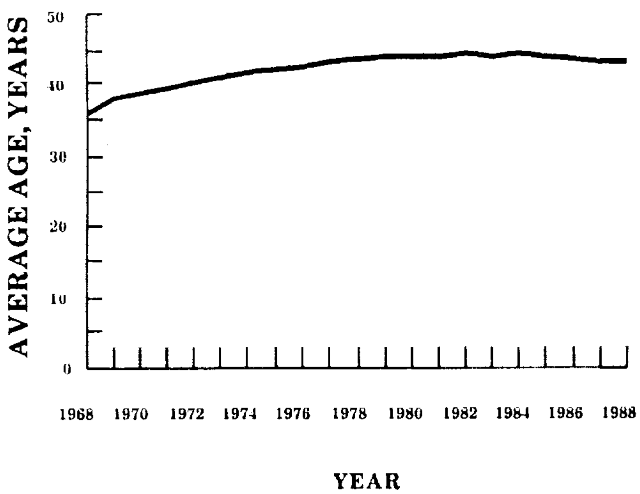


Figure 4. - Average Age of NASA Scientists and Engineers

S&E aging trend, both at LeRC and throughout the agency, has stabilized since 1979, primarily as a result of the infusion of S&E new hires and the inevitable loss of senior S&Es.

Recommendations

The following list of recommendations addresses several facets of a plan of action that will allow us to take advantage of opportunities and successfully face challenges. It includes measures that are extensions of or variations on existing NASA initiatives and is intended to be as practical as possible to facilitate implementation at the lowest possible organizational level without necessitating either an act of Congress or an act of God.

Hire Experienced S&Es

Perhaps the most obvious course of action when faced with a low level of in-house experience is to look outside the organization for available talent. However, it may not be feasible to replenish the pool of experienced personnel by hiring from outside NASA if the bimodal age distribution among NASA S&Es is indicative of the situation in the aerospace industry in general. Discussions with S&Es in the private sector indicate that this seems to be the case.

The size of the available S&E employment pool in the U.S. work force cannot be stated with certainty, but it has been reported that upwards of 50 percent of those earning B.S. degrees in S&E-related fields transfer out of the S&E field.[3,4] This loss of available talent was perhaps most evident during the downturn in aerospace industry employment during the 1970s. More recently, events in eastern Europe have led to speculation that a reduction in the funding of military programs will lead to the greater availability of experienced S&Es from the military side of the aerospace industry. However, this merely represents an additional factor in an already uncertain equation.

The availability of new S&Es is not expected to improve in the near future — forecasts are that there will be an increase in the demand for engineers through the 1990s, while the supply will be decreasing, primarily as a result of the busted baby boom reducing the size of the traditional pool of students entering S&E fields.[5,6] The issue of attracting students to S&E fields, a "pipeline" issue, will not be addressed here.

An additional source of experienced S&Es that should not be overlooked are recent retirees. These experienced retirees can be utilized through support service contractors or as private consultants when comparable, but unavailable, S&Es are needed. The 1989 enactment of Public Law 100-679 (Post Employment Restriction Act) placed restrictions on post-employment activities for former federal procurement officials and resulted in accelerating the retirement of some employees, but any long-term effect on retirement statistics is likely to be negligible. Further complicating this situation was the recent suspension of PL 100-679 by Congress until December 1, 1990.

Although contentious, the use of retirees via support service contracts or as private consultants is particularly appealing when personnel funding (R&PM) is limited, but contracting funds (R&D) are available. Such an effort, however, should not detract from the development of an in-house technical workforce. In essence, it only serves to postpone the inevitable transition of experience.

Regardless of the success of our efforts to hire experienced S&Es from outside NASA, we must ensure that we do not neglect the development of the in-house pool of talent that is already available.

Increase Awareness

One of the easiest ways to deal with an issue is to heighten awareness of the issue among the people most affected. This is possible, for example, through articles (such as this one) in employee newsletters and technical publications, and in briefings to the technical workforce (particularly as part of orientation and retirement seminars). The personnel who comprise the technical work force will determine the future viability of NASA. If the issue is credible and gains grassroots acceptance, then individual actions addressing the issue will become a matter of routine rather than a result of formal policy. For example, the Equal Employment Opportunity (EEO) Office at NASA Goddard Space Flight Center, Greenbelt, MD, has provided first-line supervisors with the opportunity to attend a one-day, in-house training program on "Managing Age Diversity."

Support Employee Development Programs

While we may be limited in our ability to hire additional S&Es, we can and should continue to support programs that provide employees with opportunities to develop greater technical or managerial experience. These programs constitute an investment by the agency in its future that requires commitment at all levels of management. A critical element to the success of these programs is the support of first-line management. These are the managers who are in the trenches and who must balance the long-term developmental needs of their employees (in the interest of the employee and the agency) with the near-term demands of the group activities (in the interest of the tasks at hand).

Most obvious among these programs are the continuing and graduate education programs that enable NASA employees to pursue degrees of higher education during their employment or to enhance their technical education. Less obvious, perhaps, is the "continuing education" that occurs when employees attend professional and technical meetings where information is shared and valuable contacts are made throughout the industry. Such activities may be viewed as a form of "continuing education" for experienced employees, insofar as the activity enhances their ability to succeed on the job.

Other NASA programs provide for non-academic personnel development. NASA's Professional Development Program (PDP), for example, allows selected NASA personnel to participate in a one-year developmental program at NASA Headquarters or a NASA Center. The program is intended to provide the opportunity for individuals to broaden their technical and programmatic experience, as well as to gain an understanding and appreciation of the culture and perspective of other organizational elements within NASA. More emphasis on inter- and intra-Center assignments should also be considered.

Document and Disseminate Information

Valuable information can be lost if adequate and timely documentation of technical and managerial information does not occur.[7] All too often, formal documentation does not occur until a program or project is either cancelled or completed, and "lessons learned" become "lessons lost" as key employees move on to other assignments and personal files are either discarded or sent into storage.[8]

Policies should be established and promoted, particularly by relevant program and project managers, that facilitate the documentation and dissemination of technical and management information. In the case of detailed, technical design data, it will also be necessary to provide updates to the information base as new or revised information becomes available.

In general, this activity will necessarily involve the efficient and widespread storage and dissemination of information via electronic media. On a more immediate level, the mass of documentation associated with major programs, such as Space Station Freedom, is too extensive for any individual to be familiar with the bulk of it.

Establish Deputy Manager Positions

Nothing provides better experience than on-the-job training and experience. One possibility for accelerating the management "education" of inexperienced employees would entail the official or unofficial establishment and promotion of temporary or rotating positions for deputies to first-line managers. These positions would provide management experience for qualified employees, while minimizing the risks associated with placing an untrained individual in an unfamiliar, and perhaps, inappropriate role. The non-permanent nature of the position would avoid the appearance of a demotion when the individuals return to their former position, while maximizing the number of employees who could benefit from the experience. Caution should nonetheless be exercised to ensure that such positions do not generate an undesirable, and possibly unnecessary, layer of bureaucracy.

Establish Chief Engineer/Scientist Positions

Within programs and areas of technical expertise, it is advantageous to the organization to maximize the benefits available through the experience of senior individuals. This organizational need can be balanced by the benefit accrued to the senior employee who has either stagnated on the technical side of the dual-career ladder, or who chooses to relinquish supervisory responsibilities in favor of a more technical, non-supervisory role. Ideally, this is the situation encountered in establishing positions for chief scientists and chief engineers. These positions would enable a greater number of individuals to benefit from experienced, non-supervisory S&Es, while providing highly-valued S&Es with greater visibility and enhanced recognition of their value to both the group and the agency.

Implement Technical Mentor Programs

Although established fresh-out mentoring programs exist at several NASA Centers, there does not appear to be an agency-wide position on mentoring. In some respects, each program must necessarily be tailored to the personality and culture of the particular Center; however, there should be some program characteristics that are common among mentoring programs at all the Centers. An example of a Center initiative is the Interactive Development of Engineers, Administrators, and Scientists (IDEAS) program, at NASA Ames Research Center (ARC), Mountain View, CA, designed to better integrate new hires into the ARC work force through interaction with peers and highly regarded senior employees. Participant feedback has shown that the long-time employees involved in the program claim a feeling of revitalization as a result of their experiences within the program.

It is not enough to place an inexperienced individual in a position of responsibility, particularly on long-term programs, when hardware will not be produced for some time. A pratical understanding of technical principles is necessary if success is to be ensured.

We can serve two purposes by facilitating interactions among experienced, long-time employees, and inexperienced fresh-outs or new-hires — the new employees are more quickly schooled in the culture and history of the organization, and technical insight and knowledge can be passed along; and the long-time employees are presented with fresh, new perspectives that sometimes break with accepted lines of thinking. These interactions could take the form of one-on-one pairings that provide both technical and cultural mentoring, or they could take the form of small, low-cost, low-risk technical projects that provide inexperienced personnel with the opportunity to acquire invaluable hands-on experience.

Conclusions: What the Age Distribution Issue Means to NASA Management

The challenge of balancing short-term needs (i.e., utilizing existing experience to meet current demands) and long-term needs (i.e., developing new talent to meet projected demands) has increased for the NASA manager due to the combination of a large number of experienced S&Es nearing retirement age, a dearth of mid-career S&Es, and a large cadre of relatively inexperienced S&Es.

The character of the agency will certainly change in the near future as the average age and experience levels of our S&Es decrease. As we strive to fulfill the requirements of new and existing missions, we can prepare our less-experienced S&Es to assume greater levels of technical and managerial responsibility at an earlier age. The resources that we have at our disposal will be best directed in areas over which we are able to exert the most control, such as the development of in-house talent.

The future promises both challenges and opportunities for the NASA manager. While we may hope for the best, we should nonetheless plan for the future in order to assure the continuity needed for increasingly complex missions.

Sources

1. Hirsch, Richard, and Joseph John Trento. *The National Aeronautics and Space Administration,* New York, Praeger, 1973.

2. NASA Headquarters Personnel Programs Division. Management Information System (PMIS) reports, 1989.

3. National Academy of Sciences. *The Science and Engineering Talent Pool: Proceedings of the 1984 Joint Meeting of the Scientific Manpower Commission and the Engineering Manpower Commission.* Washington, D.C., National Academy of Sciences, May 15, 1984.

4. Scientific Manpower Commission. *"The Technological Marketplace — Supply and Demand for Scientists and Engineers,"* May 1985.

5. Quayle, Dan, "Space Science Education," *Defense Science,* Sept. 1988, pp. 52-53.

6. Brown, Dr. Robert W., Testimony to U.S. House of Representatives Committee on Science, Space, and Technology, May 1989.

7. Brown, David W., and Nancy Milly. *Retention and Application of Saturn Experiences to Future Programs,* NASA TM X-64574. Washington, D.C.: U.S. Government Printing Office, 1971.

8. Allen, Robert O., "The TDRSS Management Story." *Issues in NASA Program and Project Management,* NASA SP-6101(02). Washington, D.C.: U.S. Government Printing Office, 1989. pp. 1-9.

Resources for NASA Managers

The Program and Project Management Collection

A special collection, The Program and Project Management (PPM) Collection, has been established at the NASA Headquarters Scientific and Technical (S&T) Library. The collection is part of the Program and Project Management Initiative, sponsored by the NASA Office of Human Resources and Organizational Development.

The S&T Library maintains and lends documents from this collection to interested personnel through each of the NASA Center libraries. The collection includes books, seminar proceedings, documents, and videos gathered from Headquarters and the NASA Centers. Some of the materials include:

Books

Project Management: A System Approach to Planning, Scheduling and Controlling by Harold Kerzner, 1984.

Management: Tasks, Responsibilities, Practices by Peter Drucker, 1974.

Computer Models for Operations Management by Owen P. Hill, Jr., 1989.

Beyond the Atmosphere by Homer Newell, 1981.

Issues in NASA Program and Project Management, (NASA SP-6101) 1988 and (NASA SP-6101(02)) 1989.

Documents

Getting on Contract, JPL D-1844, Rev. C October 1987.

Management Directives Relevant to Typical Phase A, Phase B, and Phase C/D Request for Proposals, Marshall Space Flight Center, Revision E, July 1987.

Technical Managers Handbook, Engineering Directorate, Goddard Space Flight Center, May 1989.

Videos

Introduction to Project Management, IEEE, Parts 1- 4, 1982.

Shared Experiences in NASA Projects, Angelo Guastaferro, April 21, 1989.

Project Management at Johnson Space Center, Aaron Cohen, December 7, 1989.

Explorer Satellites Program: Shared Experiences, Gerald Longanecker, September 1989.

Proceedings

NASA Colloquium on Project Management, 1980.

Project Management Institute Seminar/ Symposium, Several years running.

Materials from the PPM Collection are accessIble at each Center Library using the Aerospace Research Information Network (ARIN). ARIN is an online catalog to which all of the NASA libraries contribute on a daily basis. Any book added to a NASA library collection can be located through the use of ARIN. Much like a card catalog, ARIN may be searched by title, author, or subject. The advantage of an online system is its keyword searching capabilities. All of the materials in the PPM Collection have been "tagged" with a special code. Using that special code in a keyword search will display every title in the collection.

For example, to see a list of all the titles from the collection, enter **K=XPMX**. Enter the line-number to see the entire entry. You may want to print the screen if you think the title is of interest. To return to the list of titles, enter the letter **i**.

Because there will be many titles in the entire collection you may want to limit your search by subject:

K=XPMX SYSTEMS ENGINEERING

or you may know when a document was published. Enter:

K=XPMX 198$

An author search may be entered like this:

K=XPMX CLELAND

There are many variations on keyword searching. Ask your librarian for assistance.

The request will be handled quickly if you have a title, author and call number, such as "T56, 8 N37 1989." The request will be forwarded to the NASA Headquarters S&T Library. After identifying the materials you want to borrow, please relate pertinent information to the reference desk at your NASA Center library, which will expedite the request and get the material to your library as soon as possible. You may keep the material for one month. Exceptions will be considered on an individual basis.

Additional questions concerning the collection may be addressed to Char Moss, at FTS-453-, or (202) 453-8545, who welcomes suggestions from users on how to improve the collection and what could be added. Donated materials — books, documents, videos, or proceedings — are always needed. If you have any useful materials that would be of value or interest to NASA management, forward them to the Headquarters S&T Library where they can be processed and made available to others. Out-of-print books on NASA management and historical reports on "lessons learned" from NASA projects are particularly in demand. Keep in mind that this collection is useful not only for current NASA managers but also the next generation of NASA managers as they learn from the past and prepare for the future.

A Crash Course in Defining 'Systems Engineering'

Back on September 27, 1968, a NASA engineer by the name of George S. Trimble wrote to the Chief of the Management Analysis and University Programs Office after the Chief issued a letter to find a universally suitable definition for "systems engineering." The engineer told the manager that the term had no particular meaning at all. "In fact," Trimble claimed, "I may know the guy who thought it up or resurrected it, as the case may be, for modern usage." His seemingly authoritative account follows:

"During the war, new management practices were introduced at a great rate, and one of the functions that came to the fore was the business of writing job descriptions and evaluating them. Certain industrial relations experts fell heir to this function, and there was a tendency for them to write very clear job descriptions for all jobs except their own. It soon became obvious that the value of a job, or, more importantly, the money it paid (or even more importantly, its draft-dodging power), was inversely proportional to the ease with which one could describe it. Industrial relations people were able to describe any engineering job in 25 words or less, whereas an industrial relations function might take two or three pages. Although miserable to begin with, engineering salaries were threatened and so was draft status.

"Of course, everyone knows that engineers are very creative. They could see that the industrial relations boys had a good thing going, so they borrowed the approach and improved on it (typical engineering method).

"Soon it took five pages to describe the most menial engineering task, and the engineers were saved. It was a simple matter to spend three hours explaining to a job analyst from industrial relations why a 'systems engineering' blueprint file was much more complicated to run than a simple old 'engineering' blueprint file, which was, of course, familiar. The guy from industrial relations never did understand it because the guy who explained it, didn't. It takes a lot of words to explain something you don't understand or that isn't there. Try explaining 'zero' sometime.

"A parallel effort with the objective of emphasizing *!!ENGINEERING!!* was carried out with great dispatch by the 'scientists,' all of whom became famous at the close of WWII because a couple of them single-handedly invented and built the A-bomb, all by themselves, with great secrecy. What they were really doing all that time, of course, wasn't science — it was engineering. When this was discovered, a mixed wave of nausea and terror ran through the brotherhood. It was worse than being caught reading a dirty book in church. Most learned scientists knew that engineers were people who ran around with special hats and oil cans and made steam locomotives go, and who, incidentally, made too much money. Being identified as part of the same crowd was too much for the intellect to bear. Scientists had to be working on something more important than 'engineering' which is supervised by a Ph.D. and is therefore high-class and also obvious to those schooled properly, but difficult if not impossible for anybody else to understand.

"Since, as we all know, very few, if any, Ph.Ds understand the meaning of plain, ordinary 'engineering,' it follows that 'systems engineering' has given engineering a bad name, and should be avoided for that reason alone.

"A third group who helped the cause for systems engineering were the pre-war 'handbook' engineers who discovered creative engineering when they joined up with a wartime industrial engineering group to avoid being drafted. They had always thought that 'engineering' was the *choosing* from a catalog of the proper washer for a quarter-inch bolt. It was difficult for them to use the same name for their new discovery, creative engineering (*designing* a washer for a quarter-inch bolt). The term 'systems engineering' suited well, and groups of people were noising it around by then. It sounded nice and, after all, a quarter-inch bolt is a fastening system of high complexity. It consists of a bolt with threads (helical inclined plane), a nut of the proper size, hand and thread configuration (bolt interface problem), external shape (wrench interface problem), one or more washers (structures interface problem), and sometimes even a cotter pin (reliability).

"Moreover, one could dream of performing systems engineering at increased hierarchical levels by considering at one and the same time not only the quarter-inch bolt, but also the half-inch bolt. Advanced systems engineering.

"So much for the history and meaning of systems engineering. You can demonstrate the validity of my story to yourself in several ways. Your letter can be clarified by eliminating the word 'systems.' I believe it appears 10 times. Check the universities for courses in systems engineering and find out what they're really teaching. Note also that the term 'systems engineering' does not yet appear in a an accredited dictionary. This is because Webster can't figure it out either. Good luck."

Well, that was the extent of definition history, according to engineer George Trimble in 1968. But what about today? Is "systems engineering" a set, definable term in the dictionary today? First stop, American Heritage Dictionary — no listing for "systems engineering."

Second stop, a Webster's. Indeed, the granddaddy of all dictionaries has it listed as an "Americanism," a term indigenous to this country. It reads:

> **systems engineering**, a branch of engineering using esp. information theory, computer science, and facts from systems analysis studies to design integrated operational systems for specific complexes.

All well and good, you suppose, but whatexactly is "information theory" following the "esp."? Turn back 722 pages and you find:

> **information theory**, the study of processes of communication and the transmission of messages; specif., the study dealing with the information content of messages and with the probability of signal recognition in the presence of interference, noise, distortion, etc.

The "etc." may be imprecise, but just when you think you are getting a handle on an up-to-date definition of "systems engineering" which has something to do with "information theory," you get thrown off by another term: "signal recognition." Not to worry, right? Because you can always look up that fuzzy term for a clear, concise definition. But guess what: "signal recognition" is not in Webster's (nor is it in American Heritage Dictionary). Mr. Trimble may have been right all along.

BOOK REVIEWS

Project Management Body of Knowledge (PMBOK)

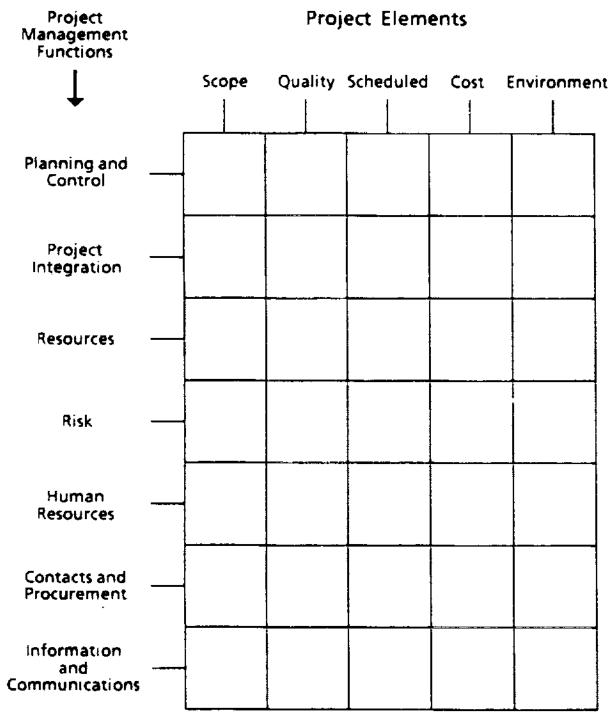
by PMI Standards Committee
(Drexel Hill, PA: Project Management Institute, 1987)

The hundred or so pages of PMBOK covers nine areas of concentration: PM Framework (Philip Nunn), Scope (Richard Cockfield), Quality (William Dixon), Time (Joe R. Beck), Cost (Peter G. Georgas and George Vallance), Risks (David V. Pym), Human Resources (John R. Adams and Linn C. Stuckenbruck), Contract/Procurement (Shakir Zuberi), and Communications Management (Shirl Holingsworth), plus an essay by R. Max Wideman on PMBOK Standards and a glossary.

PMBOK was developed by a PMI Committee in 1983 as an effort to describe and define the knowledge necessary to function adequately as a Project Management Professional. As such, it became the official PMI basis for certification exams and review of graduate programs in September of 1988.

The effort itself was well thought out. Purposes were to organize and classify in PMBOK; to integrate, correlate, store, and retrieve, and "build on what we have." Characteristics of the effort had to be simple, logical, saleable, comprehensive, compatible, systematic, and understandable. As areas were carved out, they were published in the Project Management Quarterly (now Journal).

Stuckenbruck, in an overview section, illustrates the basic project management elements and functions in a matrix model which resembles this:



Project Management Matrix Model

Wideman suggests that a simpler Work Breakdown Structure (WBS), defined as a task-oriented tree of activities, "is too restrictive for purposes of representing the PMBOK," so the matrix model serves as the framework for discussion of the PMI approach to a project management body of knowledge.

Wideman traces the effort to produce a body of knowledge on project management to 1976. The main concerns then were standards, certification, accreditation, and a code of ethics to establish project management as an independent profession. By 1986, the PMI project #121 had settled on a working definition: "A project is any undertaking with a defined starting point and objectives by which completion is identified. In practice, most projects depend on finite or limited resources by which the objectives are to be accomplished."

PMBOK is nicely printed with foldout charts and diagrams in a looseleaf binder. As the discipline or standards of project management change, modified pages can be inserted easily. And as the distinct profession of project management evolves, pages can be added. PMBOK thus represents a strenuous effort on the part of prominent management theorists in the U.S. and Canada to reduce the commonly accepted essentials of project management knowledge into one short, easy-to-read binder with useful glossaries and references at the end of each section.

The Management of Research Institutions: A Look at Government Research Laboratories

by Hans Michael Mark and Arnold Levine
(NASA SP-481. Washington, D.C.:
U.S. Government Printing Office, 1984)

Starting with the assumption that "the greatest strength of the technology development laboratory is in basic and applied research and not (with rare exception) in product development," physicist Hans Mark and social scientist Arnold Levine set out to analyze large research institutions constrained by normal financial limitations. For example, how does a manager do medium- and long-range planning on an annual funding cycle?

Following a brief historical overview from the Lyceum of Aristotle and Plato to the founding of the British Royal Society, the authors focus on the past two decades of NASA, DoD, and the Nuclear Energy Development Center.

The "ultimate reality" for the authors are projects themselves, leading to some "practical" applications of technology development. The use of project methods is nothing new — re-call the six-month construction of the Monitor in 1862, the Manhattan Project, and the Apollo Program. However, "the project approach sometimes entails heavy penalties when it is pushed to the exclusion of other approaches and becomes a brute force effort to achieve a goal, or freezes technology prematurely." No better example serves them than Apollo, with lunar landing as a "dead end." Had NASA selected "earth-orbit rendezvous initially, the lunar landing could still have been achieved and NASA would have had at least a ten-year start on deploying an orbiting space station, rather than waiting until 1982 to let study contracts for its design." The authors contrast the "single-minded" Apollo program with the "open-ended and continuing" Shuttle Program and suggest that the Project Approval Document (PAD) may no longer be possible for NASA in some projects, due to their complexity.

The authors make several assumptions about the management of professional staff in large research institutions. First, "there are no personnel policies which are guaranteed to work across organizational lines." Such policies as continuing education, indefinite or term employment, and rotating work assignments may or may not work, depending on the organizational culture. Rather, they see personnel issues as "synonymous with the organizations goals." They quote Arnold Deutsch to the effect that technical people are best motivated by the challenge of the work itself, as inspired by the institution's environment. The steady decline in large research institutions suggests to the authors that they will change little but also that an older work force will not mean obsolescence if the institution can transform scientists and engineers into managers.

Can they? In a case study, the authors point to NASA in the 1970s. Yes, scientists and engineers can and do make good managers when their loyalties are more to the organization than to their technical discipline. Many are called to internships and supervisory training programs, but few are chosen because of "a narrowly, technical education," these authors conclude.

The Management of Research Institutions is amply illustrated with charts, illustrations, and case studies, ending with an assertion that the most precious of all qualities is the human imagination, which enabled even Andrei Sakharov to withstand stifling. Imagination is best freed in a decentralized system "where decision-making is not monolithic but yet is well enough organized to make the importance of science and technology felt."

Organizing for Project Management

by Dwayne P. Cable and John R. Adams
(Drexel Hill, PA: Project Management Institute, 1986)

This 34-page monograph is described as a "concise yet readable" introduction to or refresher in organizational alternatives. It is not a guidebook or manual, but rather a brief description of standard organizations on a scale of no or low to high project managerial authority: functional, expeditor, coordinator, weak matrix, strong matrix and fully projectized structures. Expeditor and coordinator are described as subsets of functional organization, and the "fully projectized" organization is defined as one in which the project manager has total responsibility, with all the personnel needs assigned to that one project.

The differences in structure and authority are spelled out in a series of organizational charts, including one repeated 10 pages later. Of course, as the authors point out, "few large organizations involved in multiple projects use any single form of organization" in pure form, but selection of the best chart may be "an enormous step from which there may be no return."

While most of the outline and description would be "old hat" to the seasoned or schooled project manager, the authors do list 22 advantages and disadvantages of a matrix organization form. Particularly interesting is a section on "Matrix Pathologies." They include Power Struggles, Anarchy, Groupitis (confusing matrix behavior with group decision making), Collapse During Economic Crunch, Excessive Overhead, Decision Strangulation (caused by too many administrators), Sinking (when matrix structure falls to lower management levels), Layering (matrices within matrices), and Navel Gazing (absorbed with internal operations to the detriment of the world outside the organization).

Team Building for Project Managers

by Linn C. Stuckenbruck and David Marshall
(Drexel Hill, PA: Project Management Institute, 1988)

U.S.C. Professor Stuckenbruck and his research assistant suggest that "team building" is at the very core of project management, perhaps even more important than technical knowledge.

"Even the best projects using the best tools are not immune to failure," they say, claiming that most troubled projects require "team members to work together and provide outstanding group performance."

To accomplish such team building, the authors say "the cookbook approach" to management, a recipe of tools and techniques, won't work for projects, nor for a losing football team. A project is "losing" or sick when there are signs or symptoms of frustration, conflict, and unhealthy competition, unproductive meetings, or lack of confidence in the project manager. An alert manager will turn the situation around by presenting the problem as a challenge, giving regular review and feedback on performance, using a team reward system (such as visibility or recognition), encouraging professional development (papers, workshops, and special training opportunities), encouraging healthy competition, and providing a good environment for a wholesome place to work with all the tools and support necessary to excel. Clear and effective communication are basic in such remedies. That is not to say "team building" is a cure-all. The authors say no amount of teamwork will save a project if the project concept is faulty. Also, the lack of top management support can undermine any efforts towards team building. Finally, no amount of team building will save hopelessly unproductive people nor a hopelessly inept manager.

Nevertheless, the authors insist that "team building can very well be the most important aspect of the project manager's job," and this 50-page booklet is a good start in the process.

Roles and Responsibilities of the Project Manager

by John R. Adams and Bryon W. Campbell
(Drexel Hill, PA: Project Management Institute, 1988)

In a mere 30 pages, the authors attempt to describe the functions of a typical project manager, as well as the education and experience needed for effectiveness. As such, these topics are merely touched upon, making the booklet a very broad overview of a few basic, commonly accepted generalizations.

However, the PMI booklet does contain a few fresh topics on conflict resolution, derived from a 1979 book co-authored by Adams. Conflict over planning, organizing, and controlling occur frequently over the span of a project, and the authors suggest five resolution-strategies. Most common is "confrontation," whereby the two parties face the problem directly and work together toward a workable solution. "Compromise" is a second method, involving give and take. Another important method, they suggest, is "smoothing" where differences are played down and areas of agreement are given the most attention.

Fourth is "forcing" a win-lose agreement, where the project manager exerts power to impose a solution. The least used is "withdrawal" or when one or both parties backs down and gives up the conflict for the sake of the project. The point is: the project manager is expected to manage even conflict situations in one of the five ways as part of the demanding job.

"Experience is irreplacable as a learning tool for managing people in a project, " the authors assert, but formal education in management is also desirable to complement a manager's technical expertise. Typically, such a complement would be an MBA degree, although they also suggest formal education in such areas as psychology, labor relations, and law, plus informal workshops in communication, group dynamics, leadership, and, of course, conflict resolution.

Skill in Communication: A Vital Element in Effective Management

by David D. Acker (Defense Systems Management College, Fort Belvoir, VA: U.S. Government Printing Office, 1985)

David Acker spent two decades with Rockwell 'n the Autonetics Division before becoming a ›rofessor of management at the Defense System Management College. He asserts that good communications are the source of good management, and skill in communications is essential to every other management skill."

Interactive communication is needed in any organization, he says, for task coordination, problem solving, information sharing, and conflict resolution. The manager, before communicating, must have a purpose, know the audiences' needs, select the right channel or medium, and expect a specific kind of feedback. It sounds elementary, but these are useful reminders.

Skills in presentations (public speaking), listening, reading, writing, and conducting meetings are outlined from a managerial point of view. Short chapters on non-verbal communication, communication barriers, and communication theory round out this handy, pocket-size booklet of 86 pages.

While there is no attempt to provide depth, the author does throw up some bewildering terms like "kinesics" (related to something called "movement analysis"), "paralanguage" (not defined), and "noise barrier" (defined mysteriously as "any communication problem that can't be fully explained"). Nevertheless, its brevity is the booklet's strength. This booklet is a storehouse of useful tips to refer to before a manager is called upon to speak, present, read, write, or listen.

One insightful term which keeps popping up in Skill in Communication is "empathy." Acker suggests that the speaker or author "can put yourself in the receiver's place and analyze the message from his viewpoint." A disclaimer in a footnote explains, but does not justify, that the author is using the male adjective as a literary term, in a generic sense. Rhetoricians are saying now that the use of sexist language is inexcusable. A sentence that calls for a personal (male) pronoun is, more often than not, a poorly constructed sentence anyway.

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