

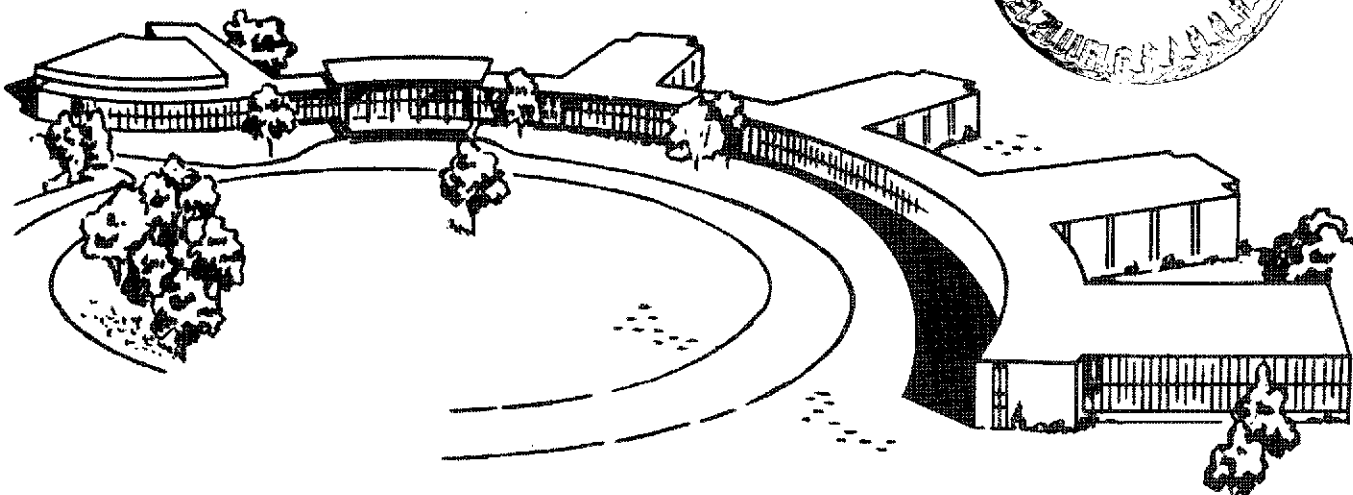
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Tullahoma, Tennessee

MANAGEMENT OF NASA'S MAJOR PROJECTS

By

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ABSTRACT

The intent of this report is to provide practical assistance to NASA project managers, especially the newly appointed project manager. It contains ready challenges and prompting in all areas of project work. Even though it is written from the point of view of a major project manager in NASA, this report can be used with small adjustment by any government manager of a major project.

The research was performed under NASA Grant No. 43-001-116. It consisted of investigating methods and procedures involved in the management of major NASA projects. The approaches used to manage these projects were studied and existing documents on NASA management were reviewed. The principal investigator, Professor Lee B. James, The University of Tennessee Space Institute, Tullahoma, Tennessee, was able to apply first hand knowledge to this research. He previously had been a NASA manager in NASA Headquarters and at a NASA Center.

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PREFACE

The educational world has long lamented and discussed the shortage of research in the management field. Coupled with this is a natural lack of depth in many management areas. As pointed out by Dr. Sayles in *Business Horizons*, the "Behavioral Approach" to management as a result of lavish inducements by the Ford Foundation, is the only concept with adequate field work and publications. Part of this problem is the fault of the researchers. Little has been added to the usefulness of various management approaches since management has become formalized by such writers as Taylor and Weber back in the early 1900's.

Besides the behavioral approach with hygienic needs, satisfiers, theory X, managerial grid, etc., we now have numerous case studies. However, most of the case studies are remarkably related to behavior. We can also fall back on management studies under the traditional standard headings of organization, planning, measuring, controlling, and decision-making. In fact, most of the recent writers with exotic titles such as "A Systems Approach to Management" have these same headings for chapter titles. ^{1, 2}*

This leaves us with the mathematical or quantitative approaches. Although these studies have their place, anyone who observes complex organizations knows that little resemblance exists between formal models of decision-making and the real system of interaction. There are, however, in addition to operations research and math models, related

*Superscript numerals are used for text references.

business area subjects such as finance, PERT, etc., which are quite useful to a manager. These of course are very specialized and do not help him enough with an overall approach.

Not enough research is available on the practical, "every day" management process and its relationship to the working organizations we are using. There has been too little concern with other than the behavioral aspects of leadership. Present writings on control and communication have too little meaning in a dynamic, changing project. Budgeting and management by objective teachings are based on firm plans and historical data. Busy project managers are often forced to develop their own new and updated approaches to needs as management information systems. No one deals sufficiently with changing objectives, unstable technology, one-of-a-kind outputs, relationships of numerous professional specialists and the effect of outside pressures. This may be too severely stated, but the hard working project manager really needs more than background in order to start out right. Yes, the project manager's job is among the more demanding social inventions of our time. There are a number of good training courses available to project managers, but they may not have the time to undertake such courses.

NASA Headquarters, specifically the Policy and University Affairs Office, has recognized the need for some practical assistance to the project manager. They have issued an initial grant to the University of Tennessee to take a step. In making the grant, they expressed interest in treating a small number of management system decisions that must be made by the project manager and write a report that could be used as a reference for government project managers.

It is hoped that this report will be a practical step toward aiding the harassed project manager, from whom so much is expected and so little given. One of the failings of this report is that it will try to treat more of the subject than time and effort allows. However, any new project manager should benefit from studying this report before he starts his

project. It is intended that this report also serve the other managers such as those reporting to the project manager even though they may not require all of the subjects discussed here.

INTRODUCTION

This report is written from the point of view of a major project manager in NASA. With a small adjustment, it can be used by any government manager of a major project. In fact, industry project managers should find the report useful, as should government managers at other levels. It must be emphasized that it was necessary to focus on some level, and the project manager was chosen. This does not mean that he is the only important manager to talk about or the only one who can use this handbook. It simply means he was the focus. Subsystem, line, staff, center, industry, and other managers are just as applicable. All headings may not fit each one, but most items discussed will apply to all managers.

In writing the report, it is recognized that a very large percentage of managers of major projects are engineers who come directly from engineering activities. Usually by the time upper management recognizes the aptitude of these engineers for a senior management role, there is not time for any formal training. Recognizing the need for the new project manager, the skill he has demonstrated in related jobs and the fact that he has probably observed other projects, he is generally congratulated and started rather suddenly. Since he is intelligent and a good engineer, he can do this job. He can do it more effectively if he has some guidelines to follow. There are many features of management, such as budgeting, planning, project decision-making, etc., for which he may not have any training. Some areas he may not even like, i.e., engineers and budgets are not always homogeneous.

What is disliked, though, is often that which is not understood. If a project manager becomes a budget expert, he will probably begin to like the budgeting process. In a report prepared for NASA by the National Academy of Public Administration, it was noted that NASA senior managers who were engineers, particularly disliked budgeting, reporting, and fire fighting.³ This is natural and they are not the types of jobs an engineer has been taught to do. More difficulty was found in planning and policy making. It was also noted that three times as many skills are needed in management positions as in average engineering positions. The importance of these skills showed that engineering managers rated operating within the organizational system and with diverse people, together with decision-making, as most important. "Achieving" more in management was the feature that satisfied most engineers.

When you consider what has been studied and written about management, as discussed in the Preface, and when you realize that most managers are engineers with little management training, there appears to be a lot of subject matter that should be introduced. One report such as this cannot hope to attack the whole problem. So what needs doing most? This report will attempt an overview of practically all of the subjects with which a NASA project manager will be confronted. These subjects will be coupled with numerous suggestions as to some of the things that ought to be done with each subject. Lastly, the subjects and suggestions will be interwoven with a philosophy that will be carried steadily through the report.

It is recognized that this report will be read by gifted project managers who will take issue with many of the suggestions or even the philosophy. This is accepted. What can this report tell a project manager who was once a subsystem manager about managing subsystems? Probably nothing! In fact, project management is an individual thing. No two will go about it in the same way. There could be no set of rules which would satisfy everyone. However, if your imagination on each subject is stimulated to agree or disagree

so you make some suitable decision or take some action, then the author is more than satisfied.

Let us discuss the overall philosophy first. In a nutshell, it is that you cannot "passively" be the manager of any major project. You must be aggressive; you must be on top of all facets of the project. To do this, you must seize the initiative at the beginning, with everyone connected with the project. You are the expert on that project as a whole, and you prove that by leading, not following, the project. It can be comforting to sit in your office all day and have the day filled with others bringing decisions for you to make. But, remember, they are then determining what you do and are recommending you do each thing their way. That is why they came to you. Probably the biggest mistake in big projects which is made by the manager is "never catching up with his project". His organization keeps him busy bringing the project to him instead of him determining what is important. You should decide what is acted upon and in what manner. This does not mean you should not take advice. Using key advice properly will be the key to your success. It means you should make clear who is manager, where central project direction comes from, and that you know what you are doing.

If you believe this, then the question is how do you seize the initiative at the beginning? That is what this report is about. It is believed that if you have the confidence to be convinced you are not overlooking important features of your job and that you are asking the right questions, in time, then that confidence will carry through your project. Therefore, instead of trying to discuss your problems in some chronological order, they will more or less be discussed all at once. There are several reasons for this. First, if you look at the initiation of action on each subject, discipline, or subsystem, some action is required almost as soon as the project begins. Also, some projects by their

nature will emphasize some areas sooner than others. Then, too, the nature of the project manager may change the emphasis. Therefore, the project will be discussed without trying for a particular order.

A new project manager should read all of this report and then select some subjects and some areas where he initiates actions. After these actions are initiated, he should check for the next area he wants emphasized. Remember, you are to retain the initiative so do not ask ten questions of your engineering group and none of your test group, because you are starting engineering and not testing. Also, ask that parts of the test plan you do not understand be explained, or have parts you do not like redone. Otherwise, your test group is idle and may begin to think you do not believe that testing is important. They will then bring recommendations to you that you have not had a chance to study or think about. It will take a major effort to become aggressive again in the test area. Your initiative will stimulate not only your organization but the appropriate segments of industry as well. This same approach should be applied to all organizations of NASA, who are involved in your project-not just your organization. Take the initiative with the center engineering organization, with other centers, with working groups involved with your project, etc. This will have a further advantage. It will change the attitude of you and your own organization from one where outsiders are meddling with your project to one where they are supporting you, like an enlargement of your organization.

Each project manager is capable of starting effort on his project in each part of his and other related organizations. However, he is always a busy man! For one thing, he can find ready challenges and prompting in this report in all areas of project work. For another thing, he will find considerable experience collected here. Where he does not have a good reason to depart from the suggestions made, he should pause and give these ideas some thought.

Remember this report is aimed primarily at the manager of large projects. For small projects several centers have provided excellent guidance, such as Lewis Research Center's "The Management Control System for Small Contracts" or Langley's "Overview of Langley R & D Program Management Principles and Procedures" and several others.^{4,5} There are several publications applying to large projects, too. However, recognizing the scope of these projects and the differences required in approaches, these documents are generally related to the policy and procedures applying to these projects. As such, they are recommended and can be found in NASA Headquarters and most of the centers. Typical of these is a project handbook put out by Goddard Space Flight Center.⁶

In managing large NASA projects, it must be noted that NASA has many types of large projects, and there are different approaches by different centers. A project on a scout vehicle managed by Goddard which manages many such projects will differ from a large engine development by Lewis, or a voyager by Langley or a manned program by JSC or MSFC. Approaches must vary! For some, launching is an integral part of the project. For others it is contracted. Man rating is a useless term in many projects. Center organizations handle such things as procurement, quality, etc., in many different ways. This report attempts to recognize this to the extent practical for continuity. However, some adjustment must be made for center policy and type of project. In fact, although the project manager's initiative is emphasized here, some of the things discussed here, for him to do, will instead be done sometimes by the center.

If, as you go through this report, you make notes of what should be initiated, you may get the impression that there are more things to start than you can possibly handle. Do not get discouraged. Remember, there are very few early items that you have to spend a great amount of time on personally. Make your notes concerning questions to which your organization, or others, should provide you answers.

CHAPTER I

THE PROJECT MANAGER'S ROLE

There are many definitions of project management. One by General Sam C. Phillips, Apollo Program Manager is: "Management of a Research and Development Program is the integration of people into an organized relationship with one another, and providing them the environment, processes, means, disciplines and guidance to attain a specific objective".⁷ The challenge is to orient such a complex structure into singleness of purpose or objective so that such diversities as facilities, equipment, procedures, training, testing, and so on are brought together properly. Technical know-how is essential. Projects flounder or fail if the right technical know-how is not brought to bear in a timely fashion.

A project manager must sell his project in many ways. He must create his market by keeping his superiors, subordinates, and the outside world satisfied that his project is progressing properly toward worthwhile objectives. It has been said that management is accomplishing what you said you were going to accomplish and management is judged on whether the objectives were achieved within the constraints of time allowed or money allocated.

Capable people must be given every chance for success by providing them a structured environment in which to work. Structured does not mean rigid, cast in concrete. It must be flexible with only the objectives remaining rigid. However,

a perfect organizational structure without the initiative and leadership of the project manager is not a structured environment. This is another reason why training would be so useful to a Project Manager. Since Management often does not train the right people in time, an expectant Project Manager should seek concentrated training. A course such as Goddard's Research Engineering Management Exercise (**GREMEX**) takes less than two weeks.⁸ Back to organization, the structure must be vibrant so that the system engineers can identify the way in which hardware, software, facilities, people, and procedures will be put together to achieve the objective. They also define the technical requirements of the pieces. Alternate processes and approaches must be studied. Once an approach is adopted, detailed performance and design requirements must be generated. Quality, test, reliability, maintainability, and other features must be stipulated. Spares and logistics must be planned. It is only after these many features are thought out and a detailed definition of the system obtained, that design, manufacture, test and reviews can be firmly started. To thus get a complex organizational structure started properly is a difficult task. The way this is accomplished is by developing a detailed plan of approach, usually the project plan. Then the elements of that plan are assigned to all of your people and to other organizations having the required know-how, to prepare the plan in detail for your approval. Attention to detail is maintained throughout so that problems can be identified early and timely action initiated. Then, a disciplined approach is developed for measuring progress and making changes when necessary. As can be seen by the above initial actions, much of the early part of the overall task will fall to the systems engineering group. Everyone should participate in the details.

In discussing the overall project manager's role, the above provides one frame of thought. A 1967 NASA Headquarters publication describing Apollo management, identifies the five elements of the management system as requirements definition, requirements implementation, management information and communication,

management decision process, and management review.⁹ The first of these establishes objectives, plans, schedules, resources, costs, procurement and performance baselines against which you can measure. The second translates these papers-or baselines-into actions. The third insures that the right people get all the needed information at the right time. The decision process includes assessing the information, making decisions and then implementing action. The reviews let you assess your own effectiveness and make adjustments and modifications. One might recognize these five NASA categories as analogous to the academic categories of planning, organizing, controlling, directing, and assessing.

Requirements definitions, the first element of the management system, is initiated by program documents from NASA Headquarters. NASA general management generally requires three key Headquarters documents. The Project Approval Document (PAD), the Project Plan (PP), and the Program Operating Plan (POP).^{10,11,12} These and the Work Authorization Document (WAD) are a delegation of authority to the project manager. These approval documents then permit you to write your own baseline of your project, such as your project plan. This plan will be further discussed as it is a very important document. Even if you are not inclined to "paper work", you will find that the effort put into this document is well spent. Whatever title is given your requirements documents, they should detail your management requirements, your technical requirements and for most NASA requirements, your mission requirements.

The Headquarters PAD defines the scope of the project and summarizes objectives, the technical plan, the management plan, the reporting requirements, procurement arrangements, and schedules and quantity requirements. The NASA Administrative Processes Handbook supplements the PAD, particularly in the budget area.¹² One requirement in this handbook is for the POP which is the internal source document for budget estimates used eventually for the Bureau of the Budget, Congress, etc. Lastly, the Project Plan is the basic plan for the execution of the project defined in the PAD. The Project Plan is both

a requirement documentation and an implementation plan. It is the single authoritative summary of the management technical execution and the mission operations of the project. It is written by you and will be the document of prime interest to you in writing your own requirements documents. It will initiate the project baseline in such areas as project schedules, hardware planning, change control, key project milestones, development tests, deliveries, ground support equipment requirements, facility readiness data, software requirements, the Work Breakdown Structure (WBS), Government In-House versus Out-of-House requirements, contract requirements, and so on. The technical and mission requirements can be in great detail. Since NASA Headquarters starts the project when you do, it will not pay you to wait for the Project Plan, PAD, and POP before starting on your requirements documents. You should use previous Project Plans, PADs, and POPs as a guide and anticipate the requirements with as much prompt work as possible. Positive effort on your part will influence these Headquarters documents considerably. In fact, good effort from the field will probably be welcomed, by the somewhat isolated Headquarters staff offices. This is a step in initiative. Also, if you feel strongly on the approach in any of the above areas, you will need to exert your influence early.

When you start your own project requirements definition, which is usually your own project plan, ask yourself and your staff these questions: Who is responsible? Is the organization complete and understood? What are the objectives? This means what are the technical requirements, usually contained in a uniform set of specifications and supporting data given by a configuration management approach. These specifications and the configuration control probably will require many other steps such as baselining all interfaces, writing specifications for major subsystems, writing work statements for prime contractors, preparing Contract End Item (CEI) specifications, etc. When must it be accomplished? Have the schedule milestones from Headquarters been broken down sufficiently to assure your control?

Do you have and understand a Management Information System (MIS) that alerts you promptly to a schedule deviation? What is the estimated cost? Do you have a complete schedule of funding? Do you have funding control?

The second element of the management system in the NASA Headquarters Apollo document, Requirements Implementation, should make you think of your organization. It is the process of converting requirements into assignments which direct people to act. The first part of implementation is the NASA Headquarters Issuance System of key documents.¹³ This is a policy document for all types of written communications which of course are the heart of putting requirements into action. These include policy directives, management instructions, notices, handbooks, manuals, and directives. The next part of implementation is the contract, to include letters of technical direction. These start the contractor on the requirements. The third is the action item list. These may come from all upper levels of management. The fourth is formal direction which provides each management level the authorization for change or amplification of requirements. Letters, memos, or teletypes may be used to implement changes or amplify work. When properly authorized, standard operating procedures and working group action items may implement requirements. The implementation by project directive will be discussed in more detail later.

The third element in the NASA Headquarters system, Management Information and Communication, provides the visibility necessary to measure project progress against the baseline. Visibility demands effective communication and close working relationships. These in turn require logical reporting and a good management information system. (Choices of information systems will be discussed in detail in Chapter IV.) Early in the project, you should decide on the depth, manner and frequency of reporting you desire from your subordinates. There are now a number of techniques for flushing out potential problems in technical performance, schedules, and cost. A good communication and information system should keep management informed, isolate problems, provide early warning of

problems, establish criteria for work around plans, disseminate information, and promote disciplines and teamwork. Currently, full use of the Work Breakdown Structure is management's most effective tool. It is a major part of all present day information systems. Communication is enhanced also by the management reviews at all levels. There are literally hundreds of reports that become a part of the communication system. Here let us list only the types so that you can determine you have coverage in each area. These types include project management schedules, procurement, contract, data management, configuration management, logistics, facilities, manning, financial, technical and system descriptions, reliability, quality, safety, test, site activation, mission operations, project planning, configuration management, and engineering data (weight, action items, etc.). Now, you may have several reports per heading; you may combine some headings into one report; or you may just have some headings presented as displays.

The fourth element is the NASA Management Decision Process. Of course, decisions are made from the beginning; however, requirements, implementation, and communications make decisions vital. The foregoing is of no value unless assessment is made and management acts. NASA has described the decision process for its APOLLO Project as assessment, review, and evaluation action, feedback, and follow-up. A key part of this process is the review cycle. You will have a prescribed series of management reviews. You will also require a system of technical reviews to which you must give considerable thought. The technical reviews will include some or all of the following formal reviews to serve as checkpoints: Preliminary Design Review (PDR), Critical Design Reviews (CDR), First Article Configuration Inspection (FACI), Certification of Flight Worthiness (COFW), Design Certification Reviews (DCR), and Flight Readiness Reviews (FRR). The first four of these are for selected end items.

The last two encompass the total project. NASA publications such as the ATR (Apollo Test Requirements), the NHB series and the remaining NPC series contain requirements for test, reliability, and quality reviews.^{13,14} Other technical reviews you prescribe probably will be more periodic in nature and will search for and solve problems and will validate the compatibility of specs and hardware as set forth in NASA requirements documents. Another closely related activity to these reviews and a part of the decision process is the configuration management system to approve and control changes. This is a particularly active area during testing. This system with the direction of assigned project personnel will suitably document change decisions. Other decisions that you make should have a means of documentation and dissemination, such as by project directives. A particular feature of good management is contact - personal conversations, closed door sessions, hot line discussions, etc. Don't forget that many people need to know the decisions you make in this manner, too. Decisions involving schedules and cost are vital and will take much of a project manager's time.

The last management element, Review and Evaluation of Management Effectiveness, is necessary, but it is less kin to the overall management process than the other elements. To measure contractor effectiveness is probably required by the award or incentive features in the contract. In measuring its own effectiveness, NASA is maintaining viability and is insuring the nation that its trust is well founded. One center cannot be compared directly with another, or one contractor directly with another, on an absolute basis, because of differences in degree of difficulty, type of contract, etc. However, the accomplishment of completing the technical challenge on time and within cost restraints can be measured center to center, contractor to contractor, on a relative basis. Different means of such evaluations have been devised, such as incentive evaluation profiles, PERT and cost correlation techniques; cost, value, and schedule profiles; and contractor critical reviews. For the immediate future, modern Management Information Systems using the Work

Breakdown Structure will be essential in measuring effectiveness. You should study the chapter on these systems with some care. The key checkpoint reviews, PDR, CDR, COFW, etc., are key technical reviews for assessing progress.

We have looked at an approach to the project manager's role as suggested by General Phillips and at one covered in a NASA Headquarters' publication. Let us look at it again from a different direction as a major contracting activity. This is consistent even if a major portion of the job is done in-house. In most large projects, the bulk will be done with industry. Any in-house portion can be considered as an in-house contract. In contract management, there are two key figures who exercise authority--the project manager and the contracting officer. Any delegation starts with these two figures. The project manager today is without question THE key figure in a large research and development project. However, each has spheres of authority in watching for the interests of the government. In this case, instead of direction from the project manager, the project manager should help develop a teamwork approach. Although the goals of the two officials may appear to vary at times, the contracting officer is really a check and balance for the project management. He is vital and is needed. Therefore, teamwork will bring out the best use of his skill and experience.

In looking at project management as contract management, we can describe the project management cycle as Phased Project Planning (PPP), though now somewhat modified.¹⁵ These are four phases A, B, C, and D which in actual application are allowed to vary greatly. A, B, and C are generally Preliminary Analysis, Definition, and Design. D is Development and Operation. Relating these phases to contracting, you must first prepare the project plan previously mentioned. This will include such major features as the technical plan, the management plan, the procurement arrangements and the funding requirements. One important feature of the technical plan is the Statement of Work (SOW). After the project plan is approved, the

statement of work will become key in the Request for Proposal (RFP). It will behoove you to review it carefully with your technical people for content and with your contracting officer to see if it requires what you want it to. The contracting officer is particularly helpful in determining whether you have told the contractor HOW to do this job. This determines the control over him that you desire. The statement of work covers all aspects of the project, such as design, fabrication, spares, reports, and many others. It is here that you form your special instructions to the contractor for such items as use of configuration management, prescribed use of facilities, use of developed components, etc. After considering the RFP, you must plan the procurement and select or recommend the contract type. Then, you conduct the solicitation, negotiation, and award phases. Following this is contract management where many of the features we have discussed such as controlling, measuring, etc., occur.

One can see that the foregoing requires teamwork. While on one hand, a project manager does such things as: determine how project work will be done, plan work, and break work into manageable pieces, analyze work versus resources, assign responsibility for project elements, serve as a focal point, review, participate in negotiation to assure common understanding, solve management and technical problems, make final decisions within contract scope, give guidance and direction, indoctrinate and monitor contractor performance, etc. On the other side, the contracting officer administers the contract, coordinates specialists during negotiations, monitors delays and cost changes in reports, receives all contractor reports and documents, issues change orders and contract modifications, helps delegate inspection and audit to DOD and other agencies, approves fee payments, and delegates function to on-site representatives. Since these two sets of activities are so intermeshed, they must be worked upon together. It will reward the project manager to have his team and the

contracting team meet, formally discuss, and set up the whole ladder of contracts.

To insure that the project manager understands the contracting requirements, he should familiarize himself with a number of Headquarters documents, such as "Procedures for Contractor Reporting of Correlated Cost and Performance Data".¹⁶ His contracting officer should have or have access to such pertinent documents.

Thus far, in this chapter, we have discussed several approaches to describing the overall project manager's role. Certainly, his role is difficult, challenging, and diverse. The scope defies imagination. For instance, the overall manager of APOLLO now goes down in history as having successfully managed the largest R & D project the world has ever known. To successfully manage one of these large projects, you must immediately demonstrate leadership and that takes us quickly back to aggressiveness not passiveness. You must establish yourself. You have full time jobs in the management world, technical world, and the human behavioral world. As such, your big problem will be your own time. You will work long hours and bring work home. That is expected, but it is not enough. What you do with your time is what counts. An early step you should take is to budget your time. This will take considerable initiative on your part. Probably the biggest consumer of a project manager's time is meetings. For a major project, where many organizations are looking for a time that does not overlap with other meetings, usually the entire day is filled with meetings concerning your project. For most project managers anxious to stay on top of their project, a feeling develops that they cannot afford to miss meetings concerning their projects. In reality, you probably cannot afford to attend them. There are some things that must be done each day. If they come after all meetings, they won't get done. You will have a certain amount of mail. YOU should determine how much you want to see and how the rest of

it is to be handled. You must respond to the behavioral world and see and talk to people. You can set up your own method. It is suggested you do this by having one of the line or staff offices or offices not a direct part of your own organization see you at a stated time each day to respond to some particular questions you have asked. This lets you see all key people, makes the time productive, and lets you retain the initiative. Another thing you must do is plan. During a portion of every day you should get together with a few of your key members and devote time to planning. This helps lead you to directing. The meetings, planning, contacting, and the suggestions in this report will cause a need for directives to be issued. This takes time. Allow yourself time to apply your own method of getting the job done. This should have some degree of formality however, so everyone knows what he is to do and so others know who is doing a particular task. Since direction results from mail, phone calls, etc., a standard memo record of your actions with a set distribution is a good way to distribute information without too much effort on your part. One method of planning and of keeping up with your project is to have a set time--thirty or more minutes--at the start of each day for what is known as "The Breakfast Club". You can do some planning and hear of major issues and problems. Although not entirely suitable, since many are involved, this can be enlarged to be your contact meeting. Be sure you have asked written questions at a rate of more than one a day and let your project control officer schedule the questions for answering one each day. Remember that of course the unforeseen will occur--travel, major problems, requirements of your superiors, etc., which will encroach on your time. Therefore, you must allow more than ample time for non-emergencies since some will last. This takes us back to meetings. It is a good thing to have a project deputy and it is good to develop him as an "alter ego" but to have each of you attend the same meetings is a nicety you can not

afford. You must brief each other. A suggested approach on meetings is to have your deputy attend more than you do. You are busier than he is. He can often be used for meetings of higher authority where project management should attend. If you set a pattern and stick to it, people will adjust to your pattern--aggressiveness. It is suggested you announce you will attend one major meeting a day, preferably at a stated time. For other meetings that are considered important, it is suggested you send your deputy. It is suggested that you also develop an assistant who helps you in meetings. Pick someone you have confidence in and let it be known that he attends for you. He will of course have personal bias in his briefings and recommendations to you so this must be done with care. However, such an approach is superior to either attending all meetings yourself or to handling meetings in some random manner.

It will take considerable personal effort to budget your time. Everything that occurs will seem more important than what you are trying to establish as a routine. A work of caution, however, a few "flaps" that can break up necessary project routine are not likely to cause an overall project to fail. On the other hand, if a project manager does not organize his project properly, a thing that he along can do, the project may fail. A project manager must budget his time to take care of what is at times, relatively unattractive portions of his job.

Having discussed the project manager overall role and the allocation of time to that role, it remains to discuss the many pieces, in some detail, that fit into that role. Chapters II, III, IV, and V will devote themselves to some important major elements that are worthy of separate treatment. Chapter VI will treat the subsystem and subelements of project management. Chapter VII will deal with a series of other major decision activities that every project manager confronts in his job. Finally, one must devote considerable effort to doing the project at the lowest possible cost.

CHAPTER II

REQUEST FOR PROPOSAL (RFP)

This subject is taken up separately because it is important, it occurs very early in the life of a project and because it is vital that the project manager become directly involved with the RFP. The RFP should be put in perspective. It is one of a series of related steps in developing the project contract. However, it is a most important step from the point of view of project management. The procurement steps include:

1. The process of Project approval
2. Determination of type of contract
3. Developing the procurement plan
4. RFP
5. SEB activities and contractor selection

If possible, the project manager should chair the Source Evaluation Board (SEB) or at least be a key member on the Board. If so, the RFP will be fundamental to the work of the SEB. The RFP is the first and a very important step in the determination of the project contract. You will have to live with that contract for years. Anything you can do to build the contract properly is worth doing. It has been said that the NASA aerospace experience has developed a philosophy which recognizes the benefits to NASA and to the industrial company of an unambiguous definitive contract work statement. The work statement clearly states objectives and acceptance criteria for all elements of the project, from overall goals to details affecting the work in the shop, to forthright recognition of the integrity of the profit motive. Real motivation is established

by the contract for those goals most important to NASA. Of course, the government interest in the contract is equally high. It will establish your contractor working relationship as well as the subcontractor arrangements. Any oversight committed must later be purchased or done without. Your ability to further define the project, review the progress, measure the work done, correct the problems and direct the correction of deficiencies are all dependent on the contract.

Formally, much of the effort in this state of the project is accomplished by the contracting officer. However, the project manager is responsible for and should want to decide on the special provisions in the contract, the reporting categories, the requirements schedule and financial information, the statement of work, and many other features.

Most of the centers have collected pertinent procurement information just for the purpose of assisting managers developing a procurement package. You should become generally familiar with this information. This guidance generally includes a list of points of information to be considered for inclusion in the RFP. This is a particularly helpful checklist since it is designed for your own center.

All of these, including the selection of the type of contract, are worthy of project management attention. There is no one right answer to the procurement and contract activities. There is instead a best answer for the nature, peculiarities and timing of your particular project. It needs study and expert advice. The project plan, generally required before the process of obtaining project approval is started, should be written so as to be the basis for the RFP. It follows then that the project manager should be on board during project approval. Because this commits a key man before approval is known, for large projects, he is often selected later and must catch up during the RFP. This is avoided where he is also the study manager.

It is NASA policy to give all qualified sources equal opportunity to participate in procurements. The RFP then, which includes the statement of work, describes the work to be performed and the terms and conditions under which the government is willing to enter into a contract. Thus, the quality of the RFP will determine directly whether comparable and pertinent information is received from competing offerers. The RFP also has the objectives of obtaining from the offerer as much data for review and evaluation as are reasonably available and necessary. In order that the proposal can be evaluated and costs controlled, care must be taken not to ask for unnecessary information. The procedures for and the handling of RFP's and responses, by the SEB, is a subject by itself. If you are unfortunate enough to chair an SEB before you have served on an SEB, exercise great care. You will require many briefings, and considerable reading.

This care with respect to RFP's is one reason why lead times are so very long. Even after completion of the technical and management packages and through contract award many months are required. You must plan for this in your scheduling.

The RFP is generally prepared with major assistance from the cognizant procurement branch and guidance from the project office. It is generally written so as to require a response in two major parts, a management plan and a technical plan. It also includes qualification criteria so unqualified sources will not bid. It includes evaluation criteria described as to their relative importance. It also includes such things as preproposal conference details.

The project manager is most concerned with the management and technical plan. The statement of work must be written so clearly that both government and contractor will understand the expected results and the items the

government intends to buy within technical and quality specifications. The SOW must be individually tailored to suit all peculiarities of the work to be performed. It must also take into account the type of contract to be issued. A good SOW will enable the project manager to evaluate the performance of the contractor. Such evaluations will be vital to you throughout the life of the contract, to insure satisfactory performance by the contractor. When special fee evaluations are required, the award or incentive fee criteria for these evaluations must be established in the SOW.

Statements of work may cover the contractor for a variety of work and thus the work done on the statement of work will affect directly all contract phases. From a government point of view, one must always remember you cannot change the contract as advantageously after it has been negotiated as you can just include the item in the first place while it is under competition. The SOW may cover analysis, feasibility studies, supporting research, study tasks within project phases, hardware development, production of limited quantity hardware, modification of a limited quantity of standard hardware, special test equipment, ground support equipment, launch or flight services, management and engineering services, and so on.

Thus, the requirements or tasks for the SOW may vary widely; however, many elements are common for all statements of work. The SOW will be separated clearly into tasks. If a level of effort service is to be provided this must be specified. If it is a cost reimbursement type of contract, your technical direction must permit trade offs, alternate choices, etc., within the contract scope. You are permitted to direct, generally, the contractor counterpart organization to provide team performance with the government at least cost. The SOW is your opportunity to do this. The basic elements of the SOW:

- a. describe the work to be done,
- b. any special instructions to how the work is to be done,
- c. information to help understand the SOW,
- d. various appendices to amplify any parts desired.

In another area, the SOW includes background, objectives, scope of work and specific tasks. In some cases, background and objective statements are also added.

The scope of the work covers what is to be done by the contractor to meet the objective. It is a summary of requirements stating what is to be furnished by the contractors, the class of effort involved and the extent of the work to be performed by the contractor. This scope is general and should not include any specific tasks which are priced. The items to be furnished by the contractor may include personnel, facilities, materials, services, equipment, etc. The effort by the contractor may include study, analysis, design, evaluation, fabrications, instrumentation, examination after testing, preparation, shipment, etc. The extent of the work is described by specifications; therefore, design and performance specs must be written with care.

It is the specific tasks that delineate what work is to be performed and priced. These tasks provide the details of what the contractor is to do. All work which is priced must be in this section. This is the section the contractor's engineers and price analysts will work with in making a proposal. The negotiated price of this section with any work added later will determine the price of your project. If you omit major work, or estimate poorly the price of these tasks or fail to describe them adequately so that the contractor can not be held accountable for the proposal, an overrun will be imminent. A list of typical tasks that could be included in the statement of work are:

- a. Management (project management, schedule, coordination, configuration management, cost control, reporting, etc.)
- b. Development of components, subsystems, and systems
- c. Study and analysis
- d. Design and design maintenance
- e. Fabrication and assembly
- f. Inspection
- g. Conceptual design
- h. Documentation
- i. Test plans and testing
- j. Design review
- k. Building prototypes, mark-ups, and special test equipment
- l. Instrumentation
- m. Providing spare parts
- n. Design, fabrication and maintenance of special equipment, tools, and fixtures
- o. Design, fabrication and testing of ground support equipment
- p. Preparing for delivery
- q. Providing Reliability and Quality Assurance (R&QA)
- r. Reporting
- s. Special Tasks such as value analysis

Reliability and quality assurance are usually established in a special section where the NHB series is tailored to your project. However, any special provisions such as inspection you may desire are included in this section. Some voluminous tasks, such as reporting, are sometimes placed in the appendix.

Performance specification should be given some thought. These specs can be a number, a variable or a range, in order to express physical characteristics. They should be firm, but they may have to be goals, or minimum levels. Uncertainty

in state-of-the-art in large projects cause goals with minimum acceptable levels to be used, i.e., a material to maintain a certain tensile strength at temperatures where the goal is 2500°F and where 2000°F is a minimum acceptable level. If you require the goal you must in some way incentivize the contractor to achieve it. This is a cost element. Of course, the remainder of your design remains uncertain until you know at what temperatures you can operate. Therefore, if possible be specific on performance.

The purpose of special instruction in the RFP is to establish the ground rules you use for the previous specific tasks. They are not cost items but they affect cost. A specific configuration management technique is a special instruction. Also, areas specifying use of equipment, components, and hardware previously qualified can state that the contractor will use certain existing facilities and resources. You may want him to refrain from providing services during times of duplication with government or other agencies, such as during part of the flight.

In preparing the SOW, the project manager should identify the end items required, a clear definition of the objectives, the specificness or flexibility of the SOW, the contracting approach, and the work breakdown structure. It is suggested that you break down the package for writing and become the devil's advocate. Review each package from both the government and contractor point of view and critique each portion with the writer. It is suggested you set up a checklist under major headings. For the technical specifications, is all performance considered; are both design and performance covered; are variables and ranges specified; are test points adequate; are all test specs included; are materials specified; are drawings and specs covered; etc.? For performance management are reporting requirements indicated; are major schedule points defined; are decision or

technical approval points indicated; can point of compliance with SOW be established; are inspection and acceptance points sufficient; are performance features susceptible to incentives, etc.?

For clarity and form, are specs and reporting requirements clear; is the government's response to submissions clear; are there conflicting statements; are tasks separately labeled; is the sequence logical; are cross references accurate, etc.? Office of Manned Space Flight (OMSF), Lewis, Goddard, and others have published good information on specifically how to prepare the RFP and SOW step by step. The NASA Management Instructions (NMI's) can help you, too.

If you will organize the entire RFP in this way, develop checklists, and critique the various packages, you will develop a good clear RFP. The effort spent here will serve you well in the coming years, if you and the contractor both know from the beginning exactly what the RFP requires. The work involved will interface you with all parts of the project and with the technical areas, contracting areas, and your own organization. This being early in the project, it allows you to demonstrate your initiative and control and learn your project.

CHAPTER III

THE PROJECT PLAN (PP)

The prime foundation of any project is its own complete description and its goals. The Project Plan is given separate coverage because, after you have completed contractor selection, your planning or the project plan is the Bible or the basis of your future. The Project Plan is originally written before contractor selection, so much of the work, has been done. Once a contract is underway, the Project Plan is seldom sufficient without some modification. It isn't suggested that now is the time for many contract changes. Instead, you will have learned of new checkpoints and above all you will be able to pinpoint responsibilities. This is the time then to amplify, expand, and define your plan in detail. The first planning action you take is to define what is going to be done and record it in a project plan. This establishes requirements and serves as a baseline against which you can judge progress as the project progresses. Your plan is the WHAT, the objectives and requirements, the WHEN is the list of checkpoints all through the project, and the WHO tells you who is responsible for each and every part of the project. A major mechanism for doing all of this is the work breakdown structure you have already established. This permits clear assignments without overlap. The cost planning features of the work breakdown structure must be worked out in detail.

Now at this point, you may well be a little confused. What is this new big plan suddenly? It sounds very much like the Requirements Plan we discussed at the beginning. Or, at least, it sounds like the Management Plan, the Technical Plan, and

the Statement of Work. The truth is, it is highly related to these previous steps. In fact, if you have done your previous work well, the Project Plan will not be a difficult step. The Project Plan, Procurement Plan and Project Approval Document are the basis for your project and the first documents prepared. The contractors response to the RFP deepens these documents. All we are talking about now that those documents are approved is an updating of your plan, deepening it for internal use and making clear the "what, who and when" for the project duration.

One way you can plan is to think of each major element of the project and assign it for execution or planning to a segment of your own office. Then have each of your offices write project element plans. Since these assignments would fall more to staff offices, you will probably have some hardware development offices which are in the position to carry out these plans. If so, you must coordinate carefully. Such an approach might look like this:

<u>Project Element</u>	<u>Responsible Office</u>
Management Plan	Project Control Office
Schedule System Plan	Project Control Office
Procurement Contracts	Project Control & Contracts
Documentation Plan	Project Control/Data Management
Equipment Management	Systems Engineering & GSE
Logistics Support	Systems Engineering
Facilities Plan	Project Control Office
Manning Requirements	Project Control Office
Financial Plan	Project Control Office
Technical Requirements	Systems Engineering
Rel. & Qual. Assurance Plan	Quality Office
Master Test Plan	Test Office
Launch & Mission Operations	Operations Office
Data Interchange Plan	Project Control Office
Growth Potential Plan	Systems Engineering

Of course, there could be others; and there will be some care required in preparing and monitoring these plans.

Another approach to planning and one more normally used

is to prepare an overall Project Plan. This approach might not involve the staff offices as directly, and assigned responsibility might not be as clear among the staff offices. It would have several advantages, however. The coverage should be more complete and the plan should present a more unified approach. Also, it would offer a better opportunity to have more offices--to include some not in the project office, directly involved in assignment, as opposed to a single office per task. We think of the Project Plan as reflecting the project manager's understanding of the execution of the project, as it is accomplished, mostly by the contractor. It is however, also the reflection of the agreement between the center and the NASA Headquarters Program Office. The funding, its rate of availability and exactly for what the funding is to be spent, must be understood among all NASA offices concerned. Present practices to lengthen the project definition phase, sometimes with additional studies, should further this understanding.

Since a Project Plan is now available for most projects, a good way to start preparing such a plan is to pick a project similar to yours and study its plan. If you hurriedly follow another plan through, you will neither improve on it nor afford it the understanding it deserves. Developing such a plan is another opportunity for you to assert yourself aggressively. The vital work on the Work Breakdown Structure will assist you with your Management Information System.

Completeness is a key note of the plan. Although each plan should vary, listed below will be a typical table of contents for a rather complete Project Plan of a large project, as a checklist:

- a. the summary includes objectives manpower, funds, justification, history and related work;
- b. the technical plan includes approach, problem areas, design considerations, man rating of applicable projects, systems engineering, reliability, human engineering;

compatibility, standardization, transportation, logistics, producibility, mission description, vehicle description, description of each major hardware element (to include structure, propulsion, electrical, instrumentation, flight control systems, mechanical systems, ordnance and ground support systems), Configuration Management (CM), organization, CM Identification, CM Control, CM Accounting, master test plan, ground tests, and flight tests;

c. the reliability and quality assurance includes organizational responsibilities, general requirements, numerical requirements, project requirements, NASA Headquarters requirements, R & QA Plans, R & QA disciplines;

d. the management plans cover the requirements of higher management, the duties and relationships of various offices (to include other centers), the center technical or laboratory areas, the project manager's office, the administrative office, resident offices, project control, test, operations, systems engineering, reliability and quality assurance, and hardware offices. It also describes the contractor relationships. Finally, it gives a baseline definition against which progress will be monitored. The subelements in this baseline resemble the planning elements previously described in this chapter. This baseline will also have descriptions of performance measurement and analysis, management reporting, project control and project directives;

e. the Project Plan will also include various management reporting methods, such as contractor to project, project reporting, financial reporting, reporting to NASA Headquarters, Management Information Systems reporting, periodic reports, film reports, and data management;

f. the procurement arrangements include organization, procurement plans, contract award cycle, negotiations, contract modifications, and a description of the major contracts in the project;

g. the schedule section describes the scope, major milestones and schedule control by the management information system;

h. resource requirements describe the approach, identification, justification, authorization, design, construction, operations, maintenance, management, descriptions of all major facilities used in the project, ground support instrumentation, project support requirements, instrumentation requirements (to include meteorological tracking, communications, telemetry, and photography), transportation requirements for all facets of the project, project funding, planned obligation and expending of appropriated funds, manpower control funding, manpower forecasts, and budget reporting;

i. the section on operating plans is mostly concerned with coordination. There is contractor responsibility, inter-center coordination and intra-center coordination;

j. lastly, the logistic section covers logistics support planning, logistic support requirements, concepts, maintenance, maintenance support, maintainability, maintenance evaluation, spares, supplies, provisioning, maintenance instructions, field support and training.

You can see the Project Plan is intended to plan for every phase of the project. If you plan well, you will find it is much easier to adjust from a well ordered plan than to scramble to cover items which have been overlooked. It is not expected that a busy project manager will write the project plan. You should not or other things will be slighted, but if you decide what is in the plan and review it systematically, your initiative will be felt.

CHAPTER IV

MANAGEMENT INFORMATION SYSTEM (MIS)

Many portions of the project manager's job are relatively obvious, i.e., planning. Regardless of whether your planning is complete or timely, there is little doubt you would be aware of the early need for some planning and that you would do some planning. On the other hand, quite often project managers let the requirement for the establishment of a Management Information System (MIS) slip by them until the planning must be rushed. Of course, a requirement for a MIS is a contractual requirement. It should be covered in the initial contract negotiation, if at all possible, but could be added contractually at a later date. It is generally NASA's practice to specify the WBS levels and make-up and to specify certain areas of compatibility but not to specify the exact MIS that the contractor will use. Actually, it is not necessary to specify the contractor's system in order for you to use any type of system you desire, but it is usually desirable for you to use the same system. Specifying the WBS in some detail and certain features for compatibility will give you flexibility. It is necessary that you specify at an early date that the contractor use some system compatible with the system you require for yourself. Hopefully, you can do this without changing his system. By doing these things early you will insure that the contractor information flows to you as soon as the project begins and that you will have the system to absorb, analyze, and control the project from the beginning.

Actually, the selection, development, and use of a

management information system is a fairly sophisticated process. There may be a decided advantage in changing the type of scheduling system, for instance, for different phases of the contractor's development program, particularly if it fits the contractor's system better if you do change. These systems have progressed to where they range from fairly simple approaches to complicated, state-of-the-art approaches. You must realize, however, that some projects today are quite complex and push the state-of-the-art. It is virtually impossible for a project manager to oversee and direct such projects without some sophisticated help. If you have a large complex project you should study today's MIS and consider one suitable to you and your project. It is preferable that you and your contractor use the same system, if it satisfies your purpose and his. Though you do not want to dictate the system he uses sometimes he has enough leeway that you can agree on a single system. Sometimes you can not. The following may help you sort out the choices and take the necessary steps should you have to embark on a separate system.

Management Information Systems began to reach a sophistication commensurate with the technology level of the projects in the late 1950's. One of the first such systems was PERT (Program Evaluation and Review Technique) which was the basis of management of the complex POLARIS project. PERT could still be used more today. It was invented on POLARIS, was learned thoroughly by everyone from Admiral Raborn on down, and it generated considerable enthusiasm on the project. If it does not work as well today, it is partly due to technology change, but mostly due to the fact that PERT is taken for granted, assumed to be understood by all individuals, and yet, is not really understood by all. For a MIS to work, all must thoroughly understand it and believe in it. You, as project manager, are the only one who can cause that to occur. Without your leadership, enthusiasm, and involvement, any MIS

will fall to specialists and the treatment will become mechanical - and fail. You cannot leave your MIS to specialists. The driving force must be you. One of the main problems with the many systems developed recently is that they are developed by specialists for use by specialists. Many studies have been funded by NASA to further the MIS technology but little involvement by project managers has occurred; therefore, the systems are somewhat sterile.

For completeness and for your consideration some of the more advanced systems will be listed here. After PERT came the Air Force's C/SPCS (Cost/Schedule Planning and Control Specification). The C/SPCS, as do most modern systems, utilizes the WBS, and stresses having the sum of the internal budgets equal contract costs. Here the Air Force, and contractor use the same system. The Air Force has developed this system by using it on several major projects. A major disadvantage, as with most new systems, is that it is not easily understood by project management. The Air Force has taken the time and effort to insure that their managers do understand C/SPCS and make it effective.

Another system is MSF/DPS (Manned Space Flight/Data Processing System). This system is a fairly complex software emphasis system where a user rapidly assembles tailor made application to assist in decisions. A system which preceded MSF/DPS was AMIRS (Apollo Management Information and Retrieval System). A second phase of AMIRS was MAIDS (Management Automated Information Display System). AMIRS and MAIDS were then combined into one system known as MINE (Management Information Network Extension). AMIRS was a means of querying, abstracting, and summarizing files of data. MAIDS was an on-line visual display system. Together, as MINE, they were a complete computer software system, but complex. Another system of this period was MIRADS (Marshall Information Retrieval and Data System). This, too, is a software package using a computer to generate reports from a data base. This could be described as the period of the

specialist where specialist developed system after sophisticated system using some form of processing programs and control tables as well as software language such as Fortran, Cobol, Assembly, etc. Models of these systems were placed on managers' desks and impressive data punched up for him. However, managers did not understand the systems and were unwilling to turn this much of their management over to specialists. Before this fact was accepted, however, systems advanced until they could include these characteristics:

- a. a tutor assistance program
- b. a quick look capability
- c. resource analysis
- d. mathematical analysis capability
- e. file management capability
- f. random access
- g. direct access of fields
- h. formulated outputs
- i. on-line and remote capability
- j. retrieval and up-date capability
- k. user defined formatting
- l. transferability
- m. multi-file capability
- n. independent source language
- o. conversational language capability
- p. immediate access devices
- q. micro language for use in files
- r. regenerative files capacity
- s. optimal usage capability to filed level
- t. text editing
- u. data integrity and access right
- v. flexibility

It is apparent that the computer and software experts have pushed the MIS state-of-the-art, but the complexity

and the flexibility to do everything overwhelm most managers. This situation has caused "User Manuals" to be developed in depth. However, these must be written for specialists because the usage is complex.

The points made above are typical of most modern computer-software MIS. Some of the other existing systems are Burroughs Corporation's FORGE, U. S. Army's RAPID, Overbach Corporation's DM-1, Computer Science Corporation's TDMS, Scientific Data Systems Corporation's 9 SERIES MANAGE, General Electric Company's IDS, Information Incorporated's MARK IV, International Business Machines Corporation's GIS, The National Military Command System Support Center's NIPS, and DOD's SAIMS. These are general systems intended to have access to any User's data base. In addition, most large companies, North American Rockwell, McDonnell Douglas, Boeing, etc., have specialized systems intended for their own internal management and available if you want to accept their systems as is. Unfortunately, there is little usage of such systems by the managers of large projects.

We might pause here and draw a few conclusions regarding MIS:

- a. We do not need to advance the state-of-the-art in MIS.
- b. MIS will not succeed in a large project unless actively used and understood by the managers.
- c. The project manager does not need all of the MIS capability nor all levels of information available for his own use.
- d. The project MIS should reflect the manager's mode of operating.
- e. Effort should be expended to make the computer display a live thing, easy to manipulate, instead of a cold complex cathode ray tube.
- f. Usage and user's manuals should be built for both the manager's level and the staff level.

Unless you are a computer expert or have the time and talent to delve into modern systems these features will be a necessity.

The foregoing might appear to paint a bleak picture and cause you to want to do without a MIS. Do not draw that conclusion too quickly. A good MIS may be a necessity in today's complex projects. True there are some false starts you can take, but this has been recognized in some parts of NASA. The lack of usage of sophisticated systems has been noticed. NASA has let contracts with General Electric and others to produce a usable system. The WBS is still considered vital. The other steps have been not to overcomputerize, to develop methods of measuring performance against both the planned and actual by WBS, and to push the visibility of such a system forward by relating budget and schedule to performance. One system for doing all this is called PMS (Performance Measurement Specification). Unfortunately, no program funds were allocated so that NASA did not complete development of a general use PMS System, but they were on the right track since credibility of performance measurement, has always been a disruptive problem. Relating performance--or problems--to schedule and cost data is another necessity. These things can be done without over-computerizing the system. However, the system, to provide the data you need, will still be complex. It seems to work best when the MIS is engineered in two parts, a top down version for you and a bottoms up version for the staff levels. These parts must be compatible, but each of you will then have a part where complexity and detail suit your requirements. You can each learn your systems in detail and the checking of one against the other will stimulate general use. This is a better way than just using the top charts of one overall system where the overall complexity must be understood by all.

Now how do you get there? It is possible that by the time you read this NASA will have developed a good general

purpose MIS for project managers. This is doubtful, however, both because of the austere nature of today's budgets and because of the different and individual natures of project managers. If your project is small and sparsely funded, you will have to adopt some existing system, PERT or the Control Room technique. You will be somewhat handicapped, however. If you can fund two or three manyears of effort and your project is complex, you can obtain an experienced contractor and adapt a system to your own use. A good way to go at this would be to inform the contractor, telling him what you want by RFP or other suitable approaches. Then, tell him the time scale and what you are willing to pay for implementation. Have the contractor come back in about three weeks and generalize the options available to you. Choose one of these and have him adapt it to your project.

The above approach can be carried out rather quickly. The need for an MIS occurs early so that your people are involved with many other aspects of the project . In addition, it is unlikely that you have a sufficient number of specialists to develop a system, but they can at least do the initial conceptual work. It is for this reason that modest contracting is in order. The keys are to know what you want, select a capable contractor and do not let the contractor get lost in advancing the MIS state-of-the-art. You probably should ask for some internal briefings first so that you form your desires and understanding. This will also get your own and center people involved and develop enthusiasm, so necessary for a successful MIS. You must initiate the action. If you do not, someone will note that you have no such system and make some proposal.

It is recognized that this chapter has emphasized Management Information Systems. At least, it is hoped that it has portrayed some of the history and problems. If you have a large complex project, you will need a system in order to track and measure progress. If your contractor does not have a suitable system you must understand how

you want to proceed. It is always preferable to use his system, but his system will be adapted to his needs, not yours, and will be complex. Since you will not start with equal knowledge, there is doubt at least that you will ever learn his system to the extent necessary.

CHAPTER V

PROJECT ORGANIZATIONAL THINKING

It has been said that a project manager's environment is a "veritable sea of information, coupled with a myriad of constraints, and a constant need for decisions and actions". In this apparent confusion you are expected to insure proper emphasis among technical performance, cost, and schedule so that you achieve total success and stay within your constraints. We have discussed some early necessities to the project, the overall look, the contract award, the project plan, and its information system. Before we discuss subelements of the project, let us assess where you are. The initial rush is over, and we are barely underway. To get here you had to have an organization and do some project and organizational thinking. However, some events have now occurred.

Your project has a slightly different nature now and you want to be sure your own organization is still right for it. Procurement procedures should now be understood. The project is now defined and "sold" so there is less emphasis on trade offs and analyses. You have a plan and you must now adapt to it and execute it. Another event is that you have had time to assess your organization and your people. You understand better how they function, what you may expect and what you cannot count on. Lastly, you have had a chance to look at yourself. It is difficult to make yourself realize the effect that you have on your project, particularly if the project is coming to you instead of your leading the

project. The personality of any manager, good or bad, has a major effect on any project. Also, if it appears to you that this is not so, that anyone could have sat in your meetings today and nodded "yes" at the end, then look again at your aggressiveness. The project is not getting all it can out of you. The decisive steps, remarks, memos, telephone calls, reluctance if necessary, and direction that comes from you and you only will be discussed in the halls and offices. They will set a tone and direction for the project. They can cause a buoyance and an esprit to exist. These things are necessary. Although it is hard to prove, such approaches recall the saying, "A decision, though wrong, made decisively and in a timely manner is better than no decision at all".

Yes, it is the right moment to reassess your organization and some of the thinking that goes with it. The above discussion of what has now passed may seem to indicate you are less busy. Of course, this is not so. You are never less busy. Nevertheless, some time spent looking at the organization may be very worthwhile. As usual, you should initiate some action and not try to do the work yourself. Then, you must take time to assess the result. By this chapter and by your own observations you can no doubt list some questions regarding your organization that have entered your mind. List them and have your staff coordinate them and bring you some recommendations. There are a number of areas worth thinking about again.

One difficult thing for any manager or executive to do is any step that borders on ruthlessness, particularly with his own people. Few managers are capable of removing a man who is not doing his job. However, the project probably has several more years to run and the need to have the right people in the job is obvious. The same features apply to changes in structure because this affects people. Again these changes may be necessary. By having parts of your

organization involved in the organization relook you will help achieve the momentum to carry out the changes that are needed.

First, take a look at all of your interfaces. Some which are particularly susceptible to problems are those with other centers, those with primary investigators for on-board experiments, those with technical working groups and panels, those with the procurement organization, those with center staff, those with the center technical organization, those with center R & QA and Safety offices, and those with NASA Headquarters offices. Inside your own organization, you should look at the organization between line and staff elements, at the relationship that any of your assistants have with other parts of the organization, at the administrative and personnel relations, and at any non-cooperative single elements. If you identify friction or problems, either in structure or people, they should be fixed, not lived with throughout the project. There is too much to do to take time for continuous patching.

You should also take a look at your organization from the point of view of the job to be done, as opposed to whether problems exist. For instance, do you have a hardware office where the components are so far along you can combine it with other offices? Do you have such things as administration and personnel separated, where the work is now routine and could be combined? Do you have staff offices, such as on systems analysis, that could be combined or abolished? These anti-empire building decisions are the hallmark of a center executive and a source of vital spaces for other needs.

Another separate question is the relationship of your line organization, your staff, and the center technical organization. In order to get underway have you given them all the same authority in some areas? Often all of these organizations come to feel responsible for the same total subsystems or disciplines. To have more than one organization

working on a problem is sometimes desirable. To have total overlap of two or three organizations can bring about some clash, particularly with the contractor, and you probably cannot afford the luxury. An example might be where there is an R&QA staff function in the Center technical organization, and you have an R&QA staff function. Further, if you have a hardware line office developing a specific piece of hardware, then that office chief or one of his people is directing the contractor on R&QA activities. Is it then clear what each of these activities is doing with reference to R&QA? Are they all talking R&QA with the contractor? Is each of these offices capable of initiating an action which can result in a change order or work authorization? If so, you have a little organizational arranging to do. It doesn't necessarily mean abolishing an office or keeping people out of the project. It simply means that you must make clear what each is to do, and how.

Another area that bears checking is the amount of centralization or decentralization that you have. There is no right answer to how much decentralization is enough. General Motors and the Ford Motor Company bear witness to how different approaches may be right. What you should do is examine the status you have and decide if it needs changing. You can note if all decisions seem to come to you and then decide if you now have subordinates who could make some of these decisions. Or perhaps, you have given out so much authority that practically all decisions are made at staff or hardware office levels and these decisions are not showing unity of purpose. In either case, this is a good time to make some adjustments. A likely alternative is that you believe you are decentralized too much or too little and do not recall particularly directing that way of working. In this case, examine your procedure and yourself. To get this back under control quickly is to be the aggressive project manager you are expected to be.

An organizational area that really should be thought out at the beginning and bears checking now is the area of your offices which are separated from the home office. These

resident offices, test groups, launch groups or other separated groups are always potential trouble spots. Do they have a home office in your organization where they can expect support and assistance? If you are the sole contact for any of these offices do you make the necessary time available to be the contact or line of authority? Should you consider a different reporting arrangement or a separate contact for assistance? If these offices have personnel from other offices such as procurement, R & QA or test personnel from center organizations, are the authorities clearly understood? Are the duties overlapping or conflicting? Are the arrangements with the contractor satisfactory in areas where more than one organization is involved? Lastly, what is the arrangement between your home office and the separated offices? Where these offices have a total mission, is this properly integrated into your home organization? Where these offices are supporting parts of the home organization, is support really provided? Is the arrangement properly understood? Is the contact and authority from the home office through these offices to the contractor properly spelled out? Does your office visit, call, or write the contractor without keeping these outer offices informed? Lastly, this separation can feel like isolation. What steps do you take to make these offices feel they are a part of the home team?

When pausing to look at organizational aspects, one should think of a related behavioral item-motivation. Behavioral scientists have afforded more study to motivation than any other subject. Textbooks study motivation in conjunction with leadership. Managerial decisions have been categorized as either planning or motivational. The latter implies that behavioral responses must be obtained from organizational participants. The former simply implies that decisions come from responsibilities planned organizationally. More and more organizational and management studies are concentrating on the human aspects of the job. Whether you

believe in the teachings of the psychologist or not, the human problems are getting more attention each day. Whenever one tries to treat the human problem, he must treat motivation. We do not want to get into textbook approaches too far, but some appeals should be noted. Pay, prestige, titles, publicity, and status symbols (rugs, paneling, etc.) are motivators to some degree and should not be overlooked. Some of this class of item can be slipped easily into a class called "dissatisfiers" meaning something that is expected, something to "gripe about" if its missing. Examples would be a good working environment, good hours, etc. All of these types of things have their place and should be remembered by you. However, there is a higher type of motivation that reaches talented and trained personnel of the type you have in your organization. You should give serious thought to how to improve this motivation. It will improve your project and satisfy your people. These motivators are man's desire to achieve something worthwhile, man's desire to use his intellectual capacity. These mean several things to you. You must organize and delegate carefully to get the most from your people. You must create the proper overall environment. This is not just physical environment but total environment. You must let people achieve and advance. Most of all, you must be a leader that makes them realize their efforts are worthwhile. You must reward progress with responsibility. You more than anyone, with encouraging words, proper rewards, your own deduction, and some imagination can be the major motivational force that brings your people to new heights of accomplishments.

The last organizational subjects to check are related to motivation. You should observe your administrative and personnel office to be sure their objectives serve the Center, yourself and your people. It is easy for such an office to lose its balance. You should also watch your development and training programs. These cannot just happen. When a training course or a promotion becomes available, do not

let an assistant place John Doe's name on the list. Instead have your office work out a plan for awarding these items to the most deserving. Get several people involved in these important decisions. These morale items or motivators must be handled as if they are important. They are!!

CHAPTER VI

MANAGEMENT DISCIPLINES

The remainder of this report will be devoted to discussing many of the problems and decisions that occur in individual subelements of the project. This chapter will consider management disciplines and Chapter VII will consider other individual decision areas. It is not expected that all possible subelements will be discussed for your particular project or that every decision you may be confronted with will be taken up. It is expected that coverage of almost all areas of project management is included here and that the many problems and decisions presented represent probable areas of interest to you and a reasonable coverage of each subject. Careful study of each subject and the suggestions presented are sure to assist you in the areas covered and trigger your thinking in related areas.

1. Project Control

As the first item under Management Disciplines, Project Control may not seem to fit the title. Is it a discipline, or an organizational element, or a collection of elements or disciplines? I start with it under disciplines because, accomplished properly, it is a difficult and necessary discipline. If it is broader than that, it is just further enhanced. It is listed first because it is the heart or basis for so much of your effort. For instance, such a group may be the means of initiating any actions you require as a result of this handbook.

For the purpose of definition, I will assume you have taken this discipline and made an organizational staff element of it. You may call it something else, but somewhere you need a group of specialists who take care of many things. Unlike test, or quality, or engineering offices whose duties are evident from the title, Project Control duties are only partly evident by the title. They do execute project control-type of functions such as scheduling, budgeting, etc., but the duties should be much broader. Somewhere you need a personal staff which in some cases takes care of problems that just do not fall clearly to other elements. In other instances, they take care of sudden or unexpected problems, or problems that cut across more than one area.

As an example of such unstructured areas that must be accounted for, one could think of your suspense and action item system. If you think of this as purely a personal problem, you may have your secretary watch such items. However, remember you have grown, you have a project now, and your thinking needs to grow with the project. Other people need to know what items are now suspense items. You should feel free to have action items in great abundance--from administrative to technical. By keeping action items assigned to all elements you are keeping the project viable and alert.

Also, you are involving many people without an intolerable effort on your part. It is vital that this system with suspense dates be kept accurately, fairly, and visibly. It requires the effort of some personal staff and is therefore a logical assignment for your Project Control Office.

If you are now convinced you need some control and personal staff, called Project Control or possibly by another name, what assignments might it have? First, in broad areas early in the project, you will need help in establishing management philosophy, responsibility and authority, project management systems, management communication, organizational and contractor relationships, project requirements, policies, procedures, goals, objectives, project reviews, and of course, project control. In your project plan, this office may write the chapters or subelements on the management plan, schedule control system plan, procurement plan, data management plan, configuration management plan, facilities plan, manning plan, financial plan, data interchange plan, and others. The main thought behind the above listings is to cause you to realize that there are many requirements that could be assigned many ways. It is usually better to organize a highly qualified well-led office, capable of handling the unforeseen than to assign items to one office one time and to some other office for the next item.

Of course, if you use a group called Project Control as suggested, one large part of their responsibility will be concerned with helping you with control of the project. Timewise, control might be thought of as occurring in five stages:

1. Establishing a baseline definition,
2. Measuring and analyzing performance,
3. Resolving problems,
4. Establishing and monitoring a reporting system, and
5. Maintaining a status system such as a Management Information System or Control Room.

Although elements of control are assigned elsewhere (i.e., technical performance), the balancing of performance, cost, and schedule must be established separately. Action item displays, configuration management displays, schedules, cost status and performance require more than just display in depth. In fact nothing is worse than having voluminous data presented to you while everyone waits for your brilliant analysis. This data must be analyzed and digested to some extent before you see it. This is not to say that you should only see conclusions, but the alternatives you have should be studied. This requires a talented, well-led group, if the choices are to be meaningful.

A good Project Control Office can take a lot of work from your shoulders. The problem resolution system, the various schedules, budget changes, etc., create a need for analysis. If your Project Control automatically analyzes the various problems which you must face, considerable improvement in your decision making process can be expected. Your reviews will not just happen-properly. Thought must go into agendas, speakers, problems, approach, etc. Also, your presentations to higher management, even though the individual pieces come from different organizational elements, must be organized, redone, followed-up, and analyzed. Your time is too valuable to get into the stream of preparation. It is vital that these activities be handled for you. Obviously, what we have discussed is vital to the project and the items are ones you are personally involved in. If you have to do the work over, little is saved. Pick your Project Control **personnel** with care.

This discussion has treated the discipline or organizational element of Project Control as a whole. Many of the disciplines discussed under subsequent headings will be a more complete discussion of elements which you may assign to your Project Control organization.

2. Project Planning

Any new Major Development Project of NASA's becomes subject to the requirements for planning and approval as provided by NASA Policy Directives.¹⁷ Project Planning is the formal NASA system that prescribes agency wide policies and guidelines for planning approval and conduct of major development projects.

A NASA policy stated, "It is NASA policy to undertake the implementation of major development projects only on the basis of plans and analysis that clearly define the work to be done, its programmatic, managerial, resources, and schedule implications and the assurance that the required technology can be made available."¹⁸ Project Planning is the means of implementing this policy. It requires the participation of senior NASA management at predetermined "decision points". Formal phased planning required each major NASA project be planned and carried out by a formal plan. The word phases as opposed to separate plans is emphasized. Each of the phases was preceded by an initiating decision by the Administrator and other senior management. Thus, each phase should provide the information necessary at the end of the phase to enable management to decide on proceeding. Although NASA has departed from this rigid phased process, the thoughts are worth reviewing.

Formerly, the first three phases, A, B, and C, involved planning and definition of the project. This included problems, objectives, technical approaches, state-of-the-art, etc. Phase D was concerned with development and use of the actual hardware systems. Sometimes different Centers combined or expanded the phases.

Since these phases are still useful in planning, to be more specific on the phases, Phase A is preliminary analysis and involves the feasibility analyses of several alternatives. This phase should not be ended until the overall feasibility can be evaluated and management can select the best approach. Phase A should be performed largely in-house, possibly drawing on Supporting Research and Technology (SRT) or contracted tasks.

Phase B is the definition phase, consisting of further investigation of hardware approaches. It involves detailed study, comparative analysis, conduct of Supporting Research and Technology and preliminary design. It should result in analytical reports and recommendations for finalizing the approach which best meets requirements. This is mostly a contracted effort with considerable in-house analysis and SRT. Therefore, contractor selection will be a major effort during Phase B.

The actual design accomplished during Phase C should define in detail the project approach selected. This is then detailed definition. This phase should permit a completely defined statement of work for finalizing the hardware. It includes system design, breadboard work, backup system requirements and any other assurance that the technical milestones can be met. Some Centers rebid the effort after Phase C.

Phase D includes developing, fabricating, and testing a prototype. This includes all special tooling and equipment oriented for any production required. It also includes building all hardware items and providing engineering, technical services, etc., required for the duration of the project.

Project Planning is the only NASA means of having a major development project approved. It requires preparation of a Project Plan in depth and a Project Approval Document.

It is useful to review what NASA has in mind in Project Planning. Some of the features are:

- a. To phase the project work so it meets the project needs.
- b. To minimize major costs and delays by insuring that the technology is in hand.
- c. To maximize use of competition for both the government and the contractors.
- d. To insure early preparatory effort by requiring complete project definition.
- e. To emphasize the need for sound planning in depth for highly advanced technology systems.

Therefore, it can be seen that although it is not NASA's intent to hold NASA managers to the rigidity of phased planning in four specific phases, the usefulness of what these phases can do for the project is still real and still in line with the above desired features. One should keep these steps in mind but shape the planning to fit the needs of the project. The highly structured phases insured against risk by a rigid process of checking technology status. This structure can in turn cause high costs from delays. NASA now, while still recognizing the need for phased and orderly plans, allows the manager to exercise judgment to minimize costs. NASA then depends on the reviews of project planning in lieu of a rigid process. Project Planning Methods will change but NASA's objectives for planning - to control costs, be sure of technology, etc., won't change. You should plan with these in mind.

3. Manning

There is usually very little documented on the subject of project manning. Possibly it is not required since most project managers seem to be keenly aware of their need for top talent in large numbers. It is not the purpose of this discussion to get you to overstaff your project. Too many people in the project office are as bad as too few.

On the other hand, it seems to be a fact of life that a new project starts with an uncertain future and Center management has to carve the project resources, primarily manning, out of existing organizations. The uncertain start, the always-present hope for more efficiency and the difficulty of obtaining each space generally leads to a lesser project strength than was anticipated. Possibly more serious is the fact that your project must have superior lead personnel. No where is the quality of people felt more than when a project first starts. Your project leaders must be experienced, motivated, and self-starters.

Just being aware that this perennial problem exists probably won't solve it. What can you do? How can you solve the problem? The best start is to have an accurate assessment of your requirements. It is worthwhile to go over a checklist such as this book and mark your project manpower requirements on each function where you will require effort. If for instance you are assigning safety to your systems engineering group and do not believe it will require additional manpower you cross out that requirement. If you have arranged for a Center logistics office to do the bulk of your logistics work you may need only one man as interface to the contractor or contact point, and for project assessment. With a carefully prepared assessment of your needs you are in the best position to sit with Center management and judge which personnel and how many personnel will be assigned to your project. If your needs are greater than the resources, you are then prepared to negotiate Center assistance in functional areas

where a direct assignment to your project is not accomplished.

It is recognized that personnel needs are always greater than the available resources. It is also recognized that it is difficult to assign the full strength of a project office all at one time. However, the other side is that the greatest needs for a project office are at the beginning when everything is starting at once. Another problem that adds to the issue is that once you accept a block of people with a view to increasing the number later, you will find the increases hard to accomplish. The availability will never improve. You will have your project underway and will apparently be doing a good job. No one can see why your needs should increase since you start at the peak. In fact, if one waits a while the project requirements should lessen. Lastly, you will have appointed all managers so that late arrivals can only work at lower levels.

It is for reasons like this, logical reasons, that many projects never get started right. So many things must be done to start a project right, that if these aren't done, you will have major difficulties later.

Therefore, you are urged to take the following steps as soon as you are named to the project:

- a. Study your personnel requirements as discussed above.
- b. Understand your key personnel and your organization so you can apply personnel logically.
- c. Negotiate with Center Management your total personnel plan. If it means you cannot have everyone at the beginning, negotiate the assignment date of each increment.
- d. Think out and negotiate the selection of key personnel with care and persuasiveness. The loss of two or three key persons for whom you have great need can have a major effect on the success of your project.
- e. If possible, have an understanding of all of the above before you start.

4. Financial Accounting and Control

So far most of the things we have talked in detail about have been technical in nature. Some previous subjects could be emphasized administratively as well as technically, i.e., configuration management. Let us mix in one or two pure management subjects, if no other reason, to show that these subjects range in importance as high as the technical subjects. Also, there is no real separation of the management world, for instance into the "financial" and the technical world. One depends on the other.

Financial reporting is a continuous activity between NASA and the contractors, and through the management levels of NASA. It includes such things as use of work packages, trend analysis, contingency funds, and many disciplines. Cost accumulation and reporting must be done precisely. As we will discuss throughout this section, budget estimating and planning are most difficult processes. Excellent guidance in these areas is available in the NASA NHB or "Procedures for Contractor Reporting of Correlated Cost and Performance Data."¹⁶ Basic contract budget requirements are negotiated with the contractor based on Part I of the CEI specification. The contract value is then broken out by fiscal years, this constituting an agreement with the contractor on fiscal year requirements. You must also account for the fact that as the project progresses, you will have to amend the contract to include changes which must be authorized, negotiated, and executed. Troublesome also is the fact that many changes are of an urgent nature which necessitate authorization to the contractor to incorporate the change based on a preliminary budget estimate, negotiating later the exact value of the change. Estimated variances in the work in the contract, whether overruns or underruns, must also be contemplated. A major cause of variances is schedule changes, usually slippages. Such changes tend to decrease early fiscal year requirements while increasing later year requirements and normally result in an overall increase in runout costs.

During the preparation of your budget, contract changes must be anticipated and estimated for the coming year and for the life of the contract. Some changes can be anticipated, for instance additional later hardware buys, and these should be included in the budget. Other unanticipated changes, such as to correct flight anomalies, must be anticipated and estimated. These estimates require judgment based on experience with test programs, launch activities, mission changes, etc. Past programs as well as experience provide a basis for calculating this part of the budget. All of these pieces put together then make up your total budget. You can see it is difficult to estimate (we'll comment on that again later), and it is even more difficult to administer.

Once NASA and the contractor agree and a dollar amount is negotiated to match a schedule and CEI specification, planned monthly cost rates are plotted for the current fiscal year for each major contract. Using inputs from the contractors 533 reports and work breakdown structure reports and any other means available, you must carefully compare and analyze monthly expenditures against the planned monthly cost rate.¹⁶ Any apparent overrun or underrun must be considered along with all current activity in the budget. For instance, if a contractor makes an adjustment in overhead rates for the previous year, you might appear to have an underrun whereas actually you do not.

You must also budget and fund many activities which are not a part of the prime contracts. These activities include in-house work, facility contracts, support contracts, transportation costs, propellant usage, DOD costs, outside fabrication, experiment development, special tests, etc. As you plan and execute these many budget activities, the contractor is managing his budget, too, trying hard to uncover anything new about the budget by any management means available.

Having discussed the makeup of the budget, before going into problems and budget control, let us amplify further on the overall budget call and budget system. The government's fiscal year budgets are formally initiated twenty months or

almost two calendar years earlier. The Centers initiate budgets at the same time, thus having overlapping budget activity. These activities are reflected in the Program Plan which is submitted to Headquarters as many as four times each year. Headquarters or the Office of Management and Budget (indirectly) may modify or cause modification to the POP at any time. The POP, or program operating plan, compares both obligations, accrued costs, and commitments with the budget plan. In Centers having several dozen projects and hundreds of research tasks, there may be one or two thousand research and development budgets prepared each year. These must be carefully planned and executed. Usually the Center reviews are exhaustive in this area, as they should be. Also, Center and Headquarters receive many detailed budget reports. Whereas you must make continuous or daily budget decisions, the Headquarters and Center approaches are to more detailed analysis, taken in conjunction with other known budgetary influences, such as changes to indirect costs. These analyses can be quite useful to you and since they are generally computerized can often go beyond your capability or effort available.

In considering the overall budget, one area is worth mentioning separately. This is the area of cost estimating. Such estimating includes initial project estimates, the independent estimates of higher authority, the estimates in support of change requests, and also those used with cost effectiveness studies. This is such an important area it deserves special thought and possibly some sophistication. Of course, no estimating is good without your project engineers or systems engineers being directly involved. They know the project, the hardware, the extent of changes, etc. However, costing and estimating is a science and an art. It requires people with experience and with some skill. It requires use of ever advancing techniques. It is not easy to combine these features. Engineers and budget experts are not easily combined. If the budget experts belong to the Center or one of your staff offices separated from the line functions, the problem is

compounded. If the budgets are all prepared at your level and the experts are on your staff there should be no problem. If the budgets are prepared at a lower hardware level, and the experts are at a higher level, you must be careful not to usurp the prerogatives of the responsible level. You must find ways around it, such as loaning the experts to the responsible level. Lastly, estimating is more than skill, particularly when first estimating a proposed new project or a change you want to make. To suggest that anyone deliberately underestimates a cost would be a severe charge. This probably does not occur. On the other hand, for Government agencies to continually misestimate costs, nearly always on the low side, gives rise to questions. That does occur. Are our estimating techniques this poor? No. The problem generally is enthusiasm. With a strong desire to do a project that high costs would kill, we become optimistic that we, for the first time, can make every crossroad turn out favorably. We think we have better people, better techniques, better management, better contractors and are suddenly going to do it differently. A word of caution. It is good to have a challenging project and a Project Manager should be optimistic, but if optimism surpasses judgment, be careful. You are judged on balancing performance, costs and schedules. The problem of schedule generally turns into a problem of cost. Managers today will probably succeed on technical performance, but are likely to fail on costs. When you discuss embarking on a new project at the bottom cost estimate, think about it.

Once a project starts, a project approval document or PAD is written. This is signed at the Administrators level and is a contract from that level outlining resources, dollars and manpower which NASA assigns to accomplish a project. It also assigns Center responsibility and is thus required before a project can begin. The POP cycle then is the Centers request for the funds to execute the approved project. You will be concerned with the R&D budget and the construction of facilities budget which are separate. Your project will be line

items in these two types of appropriations and as such is finally approved by Congress. Everyone today is concerned with expenditures. You have an obligation after your budget is formulated to set up the kind of controls that cause you to meet your commitment.

Because there is no one cost system known today that can solve the contractor's and NASA's problems, it is the general policy not to specify a particular system for implementation by the contractor. The RFP usually specifies some general requirements, some reporting requirements, and has provisions for fee enhancement for a well-managed project. One of the recent standard provisions is that the contractor's system be based on the work breakdown structure. In such a difficult areas as cost, remember the profit motive (fee, expanding base of corporation, paying the overhead of a particular plant, etc.) is the basis of the contractor's activities, you probably cannot spell out the details any more closely in the RFP than is done now. However, the fact that you are unable to specify a precise cost control system and the fact that some leeway is left to the contractor is the beginning of the difficulties you will have with cost control. For this reason, more than in any other area, you should not rely on any one system. You need checks and cross checks. You should use the 533 data.¹⁶ It is fairly good, but not as a cost report standing alone. You should use the cost portions of your management information system. These are improving. They not only cost each discrete package so that you can investigate exactly where the problem is, the ability to plot the planned value of the work scheduled against the actual value of the work accomplished also assists your analysis. You should also check your management cost reviews against known problems to see that you are getting to the bottom of current issues. Reviews are very useful if you don't allow them to become stereotyped. Very little is learned from a general cost presentation by the contractor since it covers so much area. Your staff should be able to provide areas to penetrate where recent problems have

occurred, where schedules have slipped, where tests have been held up, where manpower has been added, where materials have been scrapped and so on. Cost reviews can be deadly boring or extremely active. You should also use any other cost control method that is required or that serves a distinct purpose. In costing it is usually the cross checking of different approaches that will really afford you an understanding. If costs get out of hand, you should not hesitate to take a combined technical, schedule and cost team to the contractor's plant and go through the projects costs in depth.

Since cost accounting is difficult, you should do all you can to make the road easier to travel. Negotiations in depth, closely followed by you and your offices, will go far in insuring that you and your contractor have the same understanding of project costs. Also, even though you do not specifically want to specify the contractors financial and control systems, you can state some of the properties his system should possess, such as:

- a. Be based on a specified work breakdown structure.
- b. Have a capability to permit the measurement of the planned value of work accomplished and resources consumed to date and to compare the planned values with actual costs so that a variance can be established.
- c. Can extract data from the system which permits analysis of the planned value of work accomplished to date, and actual costs to date for hardware items in terms of cost elements such as direct labor hours, dollars, material dollars, overhead, etc.
- d. Have a capability of summarization and reporting of planned, actual and forecasted cost and schedule status so as to achieve data from the lowest levels of the work breakdown structure up to and including the total contract cost.

One of the earliest information systems was PERT/Cost. After advancement of the computer and the work breakdown structure, many Centers advanced the state of the art on these latter systems and have developed very usable approaches to

cost control. Other Centers have retained PERT and have combined it with the work breakdown structure. The PERT fragments with their schedule arrangements are ideally suited to combination with the WBS. As stated previously, any combination of systems will work if you take an interest in it, use it and manage it.

As you know, the budget area is one of the most difficult of all for the engineer to work. It is difficult for you to understand and work with your own budget group. It is difficult for the Center engineering offices to develop an appreciation for budget problems. It is the area where it is most difficult to work with your own budget. It is the stumbling block for everyone for accomplishing technical performance. You must listen to their methods since you need all approaches. You must establish a working relationship with your contractor. This doesn't mean you want to establish a cozy relationship on cost. It means you must understand how you are working with the contractor. Can verbal commitments be understood and relied on until covered in writing? (It is agreed that verbal commitments should be avoided ordinarily.) Do you have a game going where each tries to outguess and outplay the other? This is not recommended since your assets are not sufficient and the stakes are too high. You must develop an honest relationship with the contractor.

It is suggested that once your cost plan has been implemented, you give it enough attention to set a proper pattern. Ask your staff for ideas on how to control costs. Implement the better suggestions and let the contractor know of the importance you place on costs. After an initial cost problem, schedule a special meeting with your contractor and ask for his reviews and approaches. Schedule a thorough premeeting with your staff, and possibly with Center and Headquarters personnel. Go over the problem. Determine if it could have been avoided. Determine if there are solutions to the problem. Prepare questions for use at the contractor meeting. At the meeting, penetrate the problem with probing questions. After the

meeting, have a small meeting with top contractor personnel. If you are satisfied with the general meeting, say so, and let it be known you will probe cost problems as necessary. If you do not think the problem should have occurred, tell the contractor how it could have been avoided. If you think it can now be corrected better than was presented, say so and tell him how. More important, let it be known you are interested in seeing the results of what has been agreed to. You want to understand now how good commitments are. Go over the commitments again and set a time to check on results. Insist he not hide anticipated or recent cost problems from you while he is working on a solution to present.

5. Project Scheduling

After a discussion on budget management and management information systems, there is less to say about scheduling. Budget and schedule go hand in hand and the basis of MIS is to tie the two together. The most critical time in scheduling is before the project starts. Two initial facts affect schedules; everyone wants the developed project as soon as possible, and the longer a project is stretched out, the more it will cost. These facts cause an optimism in "selling" a project. In fact, it seems at times that unless you are very optimistic you can't get a project started. This causes problems. After the project is started, if it can't stay on schedule there is only one reason. You did not manage the project properly. Also, there is nothing worse in the eyes of Center and Headquarter management than for the Project Manager to realize his schedule is too tight and to announce, right after the project has started, that the schedule is too tight and thus he needs more money. Today's environment complicates your problem also. When Apollo was started, the Administrator was able to announce that to accomplish the mission in the decade would cost 20 to 40 billion. Success is probable under these circumstances. When Manned Space Flight started the Shuttle, a project of comparable complexity, every ounce of schedule and budget was squeezed from the project, making it difficult to achieve. However, you must not want your project so badly that you accept it under nonrealistic terms.

Once you have a realistic overall schedule, you need to develop a project schedule plan. It is not sufficient for a major project to just use the schedule information that falls out of MIS. You need a schedule plan. Some features of the plan should be that everyone is using the same scheduling and reporting format. You should then take the major schedule events listed in the PAD and POP and expand these into many major milestones affecting all parts of the hardware program, the R&QA program, and so on. Then lower level schedules are

built to the same format and based on the same control milestones. It is suggested that on each lower level schedule you list a person, right on the schedule, responsible to you for that schedule. This will usually be a key person in the discipline or hardware involved. Such a system will assist you in quickly knowing of problems coming from the bottom up in that particularly lower level schedule. It will help the person shown plan for schedule changes coming from the top down in his area. The overall system permits evaluation, analysis and monitoring of the project. To make sure your scheduling information is accurate and timely you may need more than one concurrent system feeding a single format. You use an MIS, control room display, PERT, Schedule Analysis and Review Procedure (SARP) and others. When PERT data is used for scheduling major projects, it is usually converted to bar graph form. A good technique for displaying schedule information to upper management is the Schedule Outlook Trend Charts. These can be useful to you, too. They help detect difficulties in early milestones affecting the one date they usually cover, first launch. Trend charts are useful to you also in noting a continuous trend to slippages in one of your level schedules. If you have a slippage and a plausible reason for it, but are also showing continuous slippages you have a problem. You will find it takes a major effort to turn around a continuous slippage, more than correcting a problem for each event.

As in budgets you must have a suitable working relationship with your own offices and with your contractor. Your superiors should be able to expect the same from you. As in budgets, there is a tendency from a proud office to fix a problem before talking about it. Your contractor may plan to work around the clock in order to make up a "blown" test schedule and then inform you he has had a little problem which he has fixed. This must not be tolerated. All such events do not "fix" easily and may drag on. You may be counting on the schedule in question. Worse still it is a break in the discipline of the system. If you can use this method here, why not use it on late deliveries, etc.? Instead of depending on a telephone call between the

proper people for small problems, use a system of flash reports, say between project control offices.

For your routine schedule activity, you should watch closely for any signs of a schedule problem having different indications from different sources, (you will want to know why one system didn't work) a cost problem developing, technical problems, test difficulties, etc. When some such a sign is truly indicated, you will want to pursue the schedule concerned with all resources. Visits to the contractor, premeetings with your own staff, management meetings with the contractors, etc., as in budget, are in order.

A difficult management problem with schedules is that almost any scheduling problem can be solved by a change order adding cost to the project. You are sure to be offered this solution as soon as a scheduling problem appears. There are times when this solution will be necessary. On the other hand, if a scheduling problem is solved with additional funds when this solution is really not required or when one doesn't take time to establish responsibility for these funds, a precedent will have been set. This is particularly noteworthy when more than one organization is involved in the interface where the scheduling problem occurred. It is necessary to settle the scheduling relationships at an early date. Too often in the haste of solving a scheduling issue, the necessary visits to the contractor plant and the necessary contracting steps are slighted in order to stay on schedule. Early in the project it is unlikely that a missed milestone will affect end dates. It is better to stop right then, report a missed schedule to higher management, and take time to solve the problem properly.

6. Configuration Management

Configuration Management was ushered into NASA in the 1960's when it became apparent that projects were becoming so big and complex that the original baseline and subsequent changes were impossible to track without assistance. To get underway, NASA borrowed the term and the system from the Air Force. In the Air Force, configuration management is described in USAF appropriate documentation.¹⁹ In NASA, the adaptation is described by the suitable NASA NHB document.²⁰ Almost all Centers handling large projects prescribe that configuration management will be used on these projects. It is too expensive in the long run to do without it. However, because it is also expensive to use, each such Center has published policy covering its implementation at that Center. In these policy documents, you can find a number of references which permit you to go deep into the subject.

Configuration Management is primarily concerned with three types of activities: configuration identification, configuration control, and configuration accounting. Sometimes systematic technical evaluation and approval of changes of hardware items to the black box level, with software probably to the subroutine level, are also a part of the process. Center policy and instructions include such items as requirements for Configuration Control Boards (CCB), requirements for configuration baseline dates, and requirements for submitting changes to higher authority.

The system is a necessity, but you must decide the depth you wish to have in your projects. You should ask your configuration management group to give you the options you have in implementing the system with rough price estimates for each. Identification and control will not have as much range in their options as accounting. Accounting is also one of the more expensive portions in the system.

You will need certain project documentation in order to implement the system for your project. Some of the documentation requirements may be alleviated by Center policy. One way or another you need such things as:

- a. A project configuration management plan,
- b. A configuration procedural manual to instruct all project personnel,
- c. A minimum requirements document for each project contract. These must be contractually implemented.

The above special documents are in addition to a number of standard documents used in implementing the system.

You must of course name an office which is responsible for configuration management. Any hardware offices you have will be involved in implementing and operating the system with the contractors. In addition you need a single staff office responsible for configuration planning, documentation, procedures, and to act as secretary for the configuration control board at your level (probably level II). Technical personnel will be highly involved with changes, with specifications, with interfaces, and with baseline reviews.

The control boards operate at several levels. In a large project usually level I is in NASA Headquarters; level II is at your level; level III is for the hardware managers in your office; level IV is for your resident managers at the contractor site (usually restricted to spec determination, use or scrap decisions, etc.) and level V is the contractor's board. Complex rules have been written to govern the authority of each board, but roughly the procedure is that a board can make decisions within its own authority, so long as it does not violate the cost, schedule, or technical authority of the next higher level. For more typically sized projects, one or two change board levels of the government and contractor are usually sufficient.

The decisions made by the change boards are the most challenging ones in the project. For that matter, they are

the most exciting, awarding, and interesting ones you will probably have. For this reason, it is easy for a technically oriented manager to get wrapped up in the technical problems at the expense of other management issues. Because configuration management requires so many decisions, it is often listed under the project management decision process. It involves decisions in the three areas of project balance-- cost, schedules and technical excellence. It is one of the most formal decision processes you have. It prescribes certain features of the decision making process which are worth noting. It presents decisions which must be made. It documents the decisions so that everyone has the same understanding. It has a formal notification pattern which results in thorough coordination. Lastly, at your level, it makes it clear that the decision is yours and yours alone, not a voting process.

In order for you to fully understand the process, a word should be said here concerning each configuration activity and what it is for.

a. Identification is the technical documentation (specifications, drawings, test data, etc.) defining the approved configuration. Without this baseline, control of your contract, award, or penalty on contract fees, and the understanding of your project financial plan would be impossible.

b. Control is the systematic evaluation, coordination, and approval or disapproval of proposed changes to the baseline. The system is complete enough to let you know that all proposed changes are properly considered and that you see the ones you should see.

c. Accounting is the reporting and documentation of changes made to systems and equipment subsequent to establishment of the baseline configuration. The procedures, requirements, and responsibilities must all be spelled out. These records are of course necessary. A more pertinent question might be: How fast must you be able to call up

status? How much must your timing and format be like your contractor's? These questions lead to whether you computerize the system, etc. These factors set the costs.

Configuration management identifies the baseline design and all of the engineering change proposals identified and/or approved which can change the baseline. This identification includes part I of the specification which is the requirement portion to include such requirements as testing. It also includes part II which is the design portion of the specification. The control portions thus allow you a fairly complete analysis of the impact for any engineering change described by the engineering change proposal. You should always have this impact presented at the change control board meeting. This lets everyone hear the stated impact and it also sometimes brings out impacts not otherwise uncovered. The accounting or recording gives you the complete status of configuration items to varying depths and with varying availability. It also covers spares, contract status, and modification status. These pieces of information are vital in judging approvals and in administering the contract.

In some instances components of a configuration item are considered critical from a design or logistic point of view. This, then, requires a detailed specification to provide the visibility needed at this lower level and gives you special control over such critical components. You should have an initial identification of critical items accomplished when the specification is written.

Typical contractor implementation of the above requirements might read something like this. "The contractor shall provide a configuration management system which will define configuration of hardware and software at any point in time throughout the performance of the program. The system is required to provide for identification of configuration baseline, the control of changes to these baselines, the maintenance of current accountability, of the status of those

baselines, and a progressive verification that the 'as built' configuration agrees with the current configuration baseline or that the differences are identified. The configuration management system will also maintain a cost-per-flight and schedule impact evaluation. Inherent in these activities is the identification of all management and technical interfaces." After such an introduction, details are provided on visibility, detail, meetings, logistic details, GSE, etc.

7. Change Control

In discussing configuration management previously, we discussed the system configuration that must be controlled to a baseline. There is really more to this process, however, than structure. Here, we will attempt to get at the thinking and philosophy concerned in making changes. This must be a disciplined process. It affects how you work with a contractor; more important, how you work with a contractor will probably affect your change control. When you participate closely in contractor activities, you are subject to being a part of any changes. If you cannot hold him responsible for changes to the baseline, the program will be extremely expensive. A quote from Air Force Policy under the Total Package Procurement Concept brings this out, "Acceptance of Part II of the specification is recognition that this is the product configuration baseline for engineering change proposals control procedures. Final acceptance of the item is not made until satisfactory demonstration and proof that the item has met all of the specification requirements. In summary, participation by the Air Force in any of the actions under configuration management cognizance are to be of such a nature as not to negate the contractor's responsibility for any correction of deficiencies because the Air Force had been a party to decisions or actions having an influence on such a deficiency."²¹

There are two sides to the government approval of engineering change proposals, and, as a representative of the government, the place where you draw the line between these two forces is very important. It is suggested that you meet with the contractor at an early date and state your position as follows. You will support the approval of changes to the project baseline when the changes are clearly required. If the changes are government initiated and clearly outside of the specifications, thus adding work for the sole benefit of the government, you will support an increased fee and a modification to the contract. (You must recognize in making such changes the job may turn out to require more effort than estimated;

hence, have more cost even if the contract is of the type to cause the fee to remain fixed.) However, you should make it evident that changes within scope of the Statement of Work which are required to achieve specified levels of performance, must be made by the contractor in response to (contractual) technical direction. Some contracts do not have a technical direction clause with an increase in fee. This statement does not preclude the contractor from charging legitimate costs under a cost-type contract. On the other hand, if the contractual specification must be changed, a contractual modification (including a change order) will be issued for the potentially fee-bearing work.

Technical excellence is a goal of most innovative engineers. Most of the engineers in each discipline, be they contractor or government, can soon find a way to do something better, or can achieve a line of reasoning of why something may not work under certain conditions. It may not; it may have to be changed; it may not have to be changed. Quite innocently, you may find yourself developing new parts for the next project to be approved. As chairman of the level II board and the person solely responsible for its decisions, you will set the pattern for this board and all change boards at a lower level.

You cannot be an expert in every field. As chairman of the change board, you will have experts present for each change whose knowledge will exceed yours on individual subjects. You may hear that a component failed under a certain vibration level and thus must be changed. It is a flat statement, given by experts and may cause you to hastily approve the item. You should not. You should develop a procedure for change meetings and a confidence in your ability as a project level systems engineer. Assuming your own engineering organization is responsible for handling configuration management and that an individual is responsible for overseeing each change presented, you can have a very simple premeeting, just you and that individual if necessary. He should have ideas and convictions

on the change that you should hear. Also, he represents a good place to sound out your own questions on the change. If he can't answer your questions, he has not prepared the change properly for presentation. This two-way discussion will lead you to other lines of reasoning.

It is then in the change board itself that you "earn your pay." You should develop a line of questioning that goes to the heart of the change. Some suggestions may help. In the first place, never accept first answers in any area but probe deeper. Ask what the requirements are that the part is supposed to fulfill. Is this a book requirement or a proven requirement? What is the tolerance this provides over and above the flight condition? Is this much tolerance needed? What caused the failure? How do you know that was the cause? How do you know it wasn't fatigue? Could you have had a defective part? Etc.? A feature that will help with this type of in-depth probing is for you to assume an air of the uninformed who doesn't really know much about the component. In the process of getting you informed, you will be surprised at the number of relevant things that are not known by any one expert there, even by all the experts together. Once your probing has uncovered a clear reason why an "obvious" change should not be made, your confidence will grow; you will then have the respect of the board which will promote some future caution; and all of the lower boards will function more carefully before sending items up for approval.

Changes that need to be made often lead to new problems, new failures, higher costs and delays. Changes that do not have to be made should not be allowed to expose you to these hazards. As a responsible government executive, you should not approve a single change that is not required. However, keep in mind that if the change is necessary, for the project to succeed, it must be made. Separating the two requires the keenest action on your part. You should be able to probe until everyone is convinced.

In preparing yourself for these reviews, stop and realize the preparation that has occurred to bring a certain position to you. One or more lower board levels have already treated the change. A recognized fact is the acceptance of the profit motive in industry. The outcome of these boards affect that motive. You know then that the contractor treats changes carefully. Typically, a contractor change board meets three times a week and is attended by the contractor project director, and top staff. In a program like Apollo, one of the prime contracts might treat more than 2000 changes of all types during the program life. Usually contractor-initiated changes are sent to a change analysis board before going to a change board. This board also helps determine if the solution requires formal contract change and hence, a change order. Also a senior management action board meets for large projects. Among other things, it reviews contractor change board actions. Also related is the fact most contractors have a senior financial management review. By the time you see a proposed change, it has acquired considerable momentum toward approval. In spite of this, some Project Managers turn down half of the proposed changes and are correct in their decisions.

One question you should always ask in a change board is "What other areas are affected?" In spite of your training your office to pinpoint these other areas, more often than not later changes will be brought about that were not anticipated when the change was made. It is rare that you can make a major hardware change without affecting other areas.

A further comment on making changes is a caution concerning interfaces. If other level II boards operate on your project, any changes you make which affect that board's activities must be coordinated with that board. If you are treating a change proposed to you by a level III board, be sure no other level III boards are affected, or coordinate the change.

8. Interface Control

Like many other project management subjects interface control is greatly involved with many other subjects we are discussing, but it is also worthy of separate discussion. One type of interface discussion is organizational in nature. Here we will slant the discussion more to technical interfaces; although this immediately involves the organizational divisions also. The interfaces in a project are probably the most troublesome of all the project technical areas. In the first place, each project of large size has an astounding number of interfaces. If you have carefully assigned responsibility for all subsystem disciplines of each major hardware end item to some individual you have made a good start. For each hardware system then you may have subsystem managers for such things as structures, propulsion, electrical, instrumentation, flight control, guidance, environmental control, GSE and possibly several others. You probably also have individual managers for special disciplines too, such as testing, R&QA, systems engineering, flight operations, etc. These can give you a feeling for the many interfaces.

To treat interfaces quite formally there are a number of things you can do. First, you can divide them by category. The level where your project is assigned in the Center may have an associated project at the same level, say where another Center has part of the project such as the launch vehicle, and you have the space project. These are usually recognizable by the fact that more than one level II configuration control board is operating. These are sometimes designated category A interfaces. Next, are the interfaces within your project among various hardware end items. For instance, you may have a propulsive kick stage and an instrument stage. These interfaces may be designated as category B interfaces. Although a formal designation seldom exists below these two levels, your major hardware managers have interfaces of a similar pattern.

The next thing you can do after designation is write

formal ICD's (interface control documents) for every category A&B interface you can identify. The number may surprise you. There possibly will be hundreds depending on the project. The time it takes to identify and formalize all interfaces will surprise you, too. New interfaces are discovered for some time after the search is started. The formal ICD's are complete descriptions of the interface and also spell out responsibility on both sides.

The next thing possible is to bring all of these ICD's under configuration management control. This will place this troublesome area under formal control. It will ensure that any change treated on one side of the interface is also considered on the other side. For a large project this formal approach is necessary.

If the project is large and the interfaces particularly difficult you can do more. You can establish task forces just to work these problems. For category A interfaces these task forces are usually called interface panels or intercenter panels. For the category B they are often called working groups or Center working groups. Both are discipline oriented and typical headings are safety, electrical, instrumentation communications, flight mechanics, flight evaluation, mechanical, launch operations, flight operations, etc. You can see that these disciplines cut across the various interfaces and, hence, test the interface for sufficiency. The duties of these panels and working groups could be to:

- a. Initiate actions regarding design, analysis, study, test, and operations.
- b. Identify and generate ICD's within project requirements.
- c. Recommend solutions to problems outside the panel or working group.

One other advantage of formally organizing the interface area, using such devices as panels and working groups, is that you get additional people working on your project and you often improve working relationships of many involved organizations.

It is useful for you to test the working of your interfaces as often as you can. Are problems showing up at the contractor's plant that your organization does not detect, or vice versa? Have problems occurred that are not corrected across the interface? Once you make everyone conscious of the ICD's and the interface problem, your organization will work the problem better.

9. Systems Engineering (SE)

A great deal of stress has been given in recent years to systems management or systems engineering or systems theory. These approaches can mean different things. In some schools of thought they are only terms related to computer approaches and engineering modeling. Here we will think of a system as a sum of parts to some complex - in this case, your project, and systems engineering as a means of tying it all together. It's the big picture. It's making everything work and work together. Systems Engineering is simply a comprehensive way of thinking. You might ask, if it is all of that, why didn't we take it up first. Perhaps, we should have. By starting with some other complex items, having uncertain interfaces, some appreciation for SE is gained, however.

How do you separate a subject like systems engineering from all the other project activities? In a sense, it can't be separated. It includes many things. The work breakdown structure is a form of systems engineering - so is your management information system, or your development plan, the configuration management system, or the organization itself, or the final systems test, or mission planning. What systems engineering requires is that you set someone aside, an engineer with a staff of good engineers, to use all of the above things and many other pieces and put it all together. How do you pick the man for this job? A NASA Associate Administrator once said that the average Center doesn't have over two or three systems engineers. He may be right, but we are back to definitions and in some pure sense there are a few. What we are seeking is a good engineer with mechanical, electrical, flight mechanics and mission understanding who can see the whole problem. The average person gets lost in the many troublesome pieces and loses his perspective. Lastly, he has drive. This is a lot to ask. You pick the best you have, (after some thought it may be a talented less senior man) and you give him all the help you can.

Your systems engineering organization must start at the beginning - back with concepts and trade offs. They must be deeply involved in the work statement, the project plan, and most subsequent activities. They are one of the organizational discipline groups, and they are your engineering staff. A truly outstanding and gifted systems engineering group is hard to find, but to some extent such a group can be trained. It is a place for the advancing, thinking, innovating young engineer.

The project requirements definition process relies heavily on an effective systems engineering process for the development of achievable technical concepts. In concert with the objectives of the project as expressed in the project plan, the objectives of your systems organization might be to prescribe the structure and implement a process which will:

- a. Identify, organize, and establish all necessary systems engineering requirements to define and control the total project.
- b. Identify and establish technical documentation requirements, in conjunction with the data management group, for the total project.
- c. Establish an effective everyday management control process.
- d. Continuously execute the systems integration function in an organized and effective manner.
- e. Continuously provide overall systems assessment of proposed changes or mission alterations.
- f. Analyze concepts and trade offs on a continuing basis.

The systems engineering process will provide you with essential data in the following areas:

- a. Analysis, to include: expected performance, recommended problem solution, mission planning effects, operations analysis, cost effectiveness studies, logistic analyses, maintenance analyses, and potential systems performance analyses.
- b. Requirements and integration constraints such as: structures, propulsion, ground support equipment, flight control, guidance and navigation, instrumentation and communications.

Systems engineering and systems analysis techniques should be used to insure that the project and all of its components, including GSE, are of the optimum configuration. This is accomplished by conducting a systematic analysis of prelaunch, launch and flight operations and determining the function that each system element must perform. The element is then evaluated for its capability to perform the functions, which provides a means for selecting between component designs and for detecting design deficiencies. The analysis is also used to insure that the various systems components are compatible with each other and with the launch site. This analysis will continue after the configuration is selected. Design and development testing problems will require that continuous trade offs be made.

Since systems engineering is one of the hard-to-understand areas one might read the above and say, "I still don't know what my systems office is supposed to do exactly." To give a closer feel of the subject for those who desire it, the remainder of this section will be comprised of a more detailed approach to systems management and systems engineering. There is more than one approach to this subject, but this one view may let you decide how you want your systems group to approach it.

The process of systems engineering should be looked at as a tool for designing the project on a total basis so that design will reflect considerations of requirements for equipment, facilities, technical orders, and personnel in an integrated fashion. It serves as this tool by systematically producing systems engineering documentation which provides the source of the development of specifications and the backup data required to define, contract, design, develop, produce, install, checkout, and test the system.

To achieve this the systems engineering process is started by identifying system requirements in basic functional terms. These functions and associated criteria are then analyzed and translated into design requirements. These requirements are

for everything to include design constraints that have a bearing on the functions being analyzed. System and design engineering studies are performed concurrently to:

a. Determine the selection of alternate functions and functions sequence.

b. Determine the requirements for design imposed by the functions.

c. Select the best design approach for integrating the design requirements into end items. Utilizing the design approach determined from these studies, design requirements are integrated into end items.

The systems engineering management documentation provides many of the elements for the other project management activities. For example, the identification and definition of end items provide the source for the specification tree, for cost/schedule planning, for control work, for the work breakdown structure used in procurement action, and for the basis of test planning. The systems engineering process does not make decisions itself, but it does provide a basis for the decisions and provides a discipline for engineering across the various contractors and across the end items. This discipline is achieved through the systems engineering plan and control, through project directive or, through contract instruments. The cycle is completed by reviews and documentation.

The systems engineering process is an integrated process which specifies the hardware, computer programs, facilities, personnel, training and procedural data required to meet system mission objectives. The basic concept of the systems engineering process is to force a logical, systematic, comprehensive consideration of all aspects of the system requirements during its early design, development and test phase. Systems engineering encompasses the early identification of systems objectives, the "design to" requirements necessary to meet these objectives, the "build to" requirements which prescribe the ultimate configuration of the system to be delivered and the requirements for training, personnel, for procedural data, and for logistic

support. As such, systems engineering is essentially concerned with deriving a coherent total system to achieve stated mission objectives. The cycle of the systems engineering office activities might consist of:

- a. Functional analysis.
- b. Functional requirements allocation.
- c. Systems synthesis.
- d. Requirements integration.

Functional analysis is the translation of mission requirements into operations, maintenance, test, and activation functions which must be performed by the various systems elements, i.e., hardware, computer programs, facilities, personnel, and procedural data. The next item, functional requirements allocation consists of analyzing and translating the developed functions into requirements for designs, facilities, etc., and to list all known constraints. The third, systems synthesis, involves the performance of system/design engineering studies to analyze all known requirements and constraints, to create alternate design solutions which can satisfy the performance and functional requirements, to evaluate alternate design solutions, and to select the optimum approach. The final step, requirements integration, integrates the system element requirements developed in the preceding steps, into CEI's, skills, training courses, and procedural publications. It is important to note that this systems process is an iterative one within the various functions required to design the system.

By control, through documentation and review, all pertinent details of an end item design can be traced back to a system requirement. The fundamental systems engineering documents that are delivered to you are the systems specification and the CEI specification. Other supporting documentation covering functional, design, maintenance and support analysis, trade studies, and systems effectiveness are only required on a selective basis. "In process" reviews are used to the fullest extent possible to minimize requirement for formal published reports.

If you desire to go into any of these areas further there is considerable data published within NASA on systems engineering. However, the most voluminous and most detailed data on the subject can be found in the Air Force publications. These are referenced in the Air Force Management Policy documents. ²²

It may be interesting to note that the "Shuttle" statement of work divided the systems engineering task into two parts:

a. Systems management, to include performance management, configuration management, information management, logistic management, Government Furnished Equipment (GFE) management, and procurement management.

b. Systems integration to include data requirements, analysis requirements, general systems requirements, mission requirements, and Shuttle vehicle analysis.

This is a sound systems approach for the contractor. The NASA offices would have certain systems responsibilities in addition to those contracted.

10. Software

Software is a complex technical subdivision. Everyone knows what it is and that it is important. Almost everyone knows that software has a long lead time, that it is probably used in both countdown and in flight modes, and that its configuration must be controlled like hardware. In spite of this, there appears to be only a few places in NASA where there is total software accountability. A recent search of management documents, Project Plans and Requests for Proposals found software listed only two times. This is not meant to imply that software is overlooked the remaining times. Experienced managers no doubt pick it up under configuration management or other headings. It does say, however, that if you are relying on past documentation you may miss the significance of this subarea. Software is expensive and critical to each project. It is associated with portions of the overall project which must be developed late in the program. It can easily be a time and cost bottleneck.

The above obviously says you should initiate software development early. Not only that, you should baseline it early and place it under configuration control. If your software change traffic could be heavy, you probably will want to divide software changes into class I and class II changes. Class I changes would require full government configuration control board approval in the same manner as hardware. These could be defined to include those affecting:

- a. Contract specifications, price, fee, weight, delivery, or tests.
- b. Contract reliability.
- c. Performance.
- d. Interchangeability.
- e. Safety.
- f. Electrical interference.
- g. GSE.
- h. Facilities.
- i. Operational computer programs.

The class II changes would be those not covered above. They should be coordinated between the government and the contractor but would not require change board action. They would be changes such as make-work changes having a software effect only and not causing a cost or schedule impact. These are generally given automatic approval after the government technical organization has had time to examine them.

Flight program software control and verification require careful control. A program verification plan should be written, extensive ground testing accomplished, and tight control imposed. Remember, a misplaced hyphen can destroy your whole flight.

11. Data Management

The data management subsystem is sometimes called documentation management and sometimes information data management. In any case, we are referring to all of the management and technical reports which are requirements of the project. These usually are listed on Data Requirement Lists (DRL's) and Data Requirement Descriptions (DRD's). We are not covering here either flight data or computer data, per se. These are often handled differently. Data recording and data reporting is one of the most expensive aspects of the project. Obviously, it is required. Management at the project level needs data to adequately measure performance. Requests for contractor data, however, are subject to gross misuse. You must determine what kind of data meets your needs and how it should be displayed graphically so as to communicate to management. It is easy to get widely overlapping reports, reports that are not needed or used, and reports that are not timely. It is natural for each organizational element and each discipline to want their private report which covers what they desire and can be used to influence the project in their area. This makes it apparent that data management must be organized and not allowed to grow indiscriminately. It usually requires a specialist in the field early in the project. He can earn his salary many times.

Since so many items are needed at the beginning of a project, it is customary to slight data management. If it is considered, it is usually an additional duty for some busy person. The approach then is to put out a paper asking what reports are needed. Later in the project someone is given the job of reducing the number of reports in the project. This is not the way to conduct data management.

At the beginning of the project a data manager should

set the objectives of the project data management and then draft a list of the reports, documents, etc., necessary to accomplish these objectives. Your objectives for data might be to:

- a. Keep management informed on a day-to-day basis of cost, performance, and schedule status.
- b. Isolate management problems in cost, schedule, and performance.
- c. Provide early warning of potential problems.
- d. Establish criteria for work around plans.
- e. Provide for exchange of management information.
- f. Promote management discipline and teamwork.

Once you write out your objectives, it is not clear that you need the dozens of different reports that easily become attached to each project. A lesser number of reports, properly organized can meet your goals. Remember the number and size of your reports determine cost regardless of repetition within a report, or ease of publication. Also, remember there are many sources of data--working groups, meetings, letters, TWX's, etc.

So much project information is now computerized that you should give thought to how much information can be picked off and displayed in real time by your own organization. Where this is possible you do not need detailed reports at a later date. For record, you can combine the summary information from several areas into one report.

It is hoped that you have been impressed with the fact that data is needed. Not only that, data is vital to the project, but it can easily get out of hand. For the remainder of the discussion on data management, a list of data used at one time or another on one project will be listed. This list does not include many reports which were not formally placed on DRL's, nor does it include reports, the requirements

for which existed for only a brief time span. The purpose of this list is threefold. It will display for you how many reports you can easily procure for one project if you do not plan carefully and desire a lesser number. It will show you the many areas of overlap. Lastly, it will help you manage the other side of the problem-obtaining the reports that are needed, in time, and in a useful manner. By studying this list you should be able to give guidance to your data manager that will allow your project to optimize the data it has and uses-in time to be included in the contract.

PROJECT PERIODIC REPORTS

Management

- Weekly status reports
- Monthly status reports
- Spacecraft management report
- Launch vehicle weekly reports
- Launch operations weekly reports

Schedule

- Monthly status report
- Monthly schedule outlook
- PERT/SARP schedule report
- Project schedule outlook
- PERT status report
- Monthly PERT report
- Official flight schedule
- Hq. Schedules, SARP edition
- PERT launch status

Procurement/Contracts

- Monthly change order and status report
- Procurement milestone status report
- State of contracts and grants

Data Management

- Input report
- Magnetic tape

Configuration Management

- Identification index and modification status report
- Management report

Logistics

- Monthly spares status
- Management report

Facilities

- Preliminary engineering facility report
- Preliminary engineering reports by Centers

Manning and Financial

- Project authorization
- Project allotment authorization
- Status of contracts and operation of installation
- Financial status of project, obligations, commitments and costs
- Object class reports

Technical Description and Systems Engineering

- Quarterly weight and performance report
- Weight and performance summary
- Safety report
- Safety management report
- Safety problems report
- Maintainability report
- GFE status report

Reliability and Quality Assurance

- Quarterly status report
- Failure report
- Management report
- Quality assurance report
- Quality problems report

Testing

- Flight readiness reviews
- FRR summary data books
- Post launch reports
- 3 day evaluation reports
- 10 day reports
- Final flight reports
- 3 and 10 day flight result TWX's
- Launch vehicle flight report
- GSE launch report
- Reports of all major hardware tests

Site Activation Reports

Flight Mission Operations

- Pre-launch report
- Post-launch report
- Failures and anomalies listing report
- 24 hour flash report
- 30 day failure and anomaly report
- Preliminary and reference trajectory report
- Predicted operational trajectory report
- Revised trajectory documentation plan report
- GSE evaluation report

Project Planning (Current)

- Planning and alternate schedules report
- Control milestone schedule report
- Working launch schedule report
- Software flight development report
- Updated launch vehicle working schedules
- Spacecraft and launch vehicle major tests working schedules
- Launch vehicle assessment summary
- Launch operations report
- Spacecraft deliveries report
- Spacecraft working plans
- Spacecraft working schedules
- Project schedule effectiveness report
- Performance index report
- Mission selection status report

Configuration Management Control

- Launch vehicles configuration differences report
- Spacecraft configuration differences report
- CCB open changes report
- Accident review board findings

Engineering

- Weight changes and weight data report
- Weight and performance mission report
- FRR open items report
- Action item status reports
- Major problems report
- Major open items report

Manufacturing

- Failure trends report
- Management status report

Resources Report

Remember this list does not include onetime reports, flash reports, any of the planning reports in the Project Plan, etc. In a larger measure, it does not include the many technical reports intended for the technical organizations below your level. These then are the reports you are expected to see or at least to cope with. Individually each serves a purpose. It should be clear that data management requires considerable constructive and early planning. It requires some dedicated guidance and managing. It will require some difficult decisions.

Data management cuts across all functional areas and overlays a set of disciplines which govern and control the preparation and delivery of contractor data. It does not in itself generate or produce data. Rather it is a standard "way of doing business." Data requirements should result from, and be subservient to, related tasks in the statement of work.

As in most areas the overall system should be controlled from a project data plan. If a Center plan is not sufficient, it should be prepared by the Project Data Manager. It should describe the system used in the project to include the responsibility in staff and line elements for carrying out the plan. It should describe the use of the data requirement list, the data requirement description, the request for data, and the Document Information Record (DIR). It should insure compliance with the requirements of higher headquarters. It should insure control of the key documents. It should provide for continuous review of data requirements, since initial requirements should decrease as the project progresses. It will help keep the problem before the eyes of all key people. Some Centers have the instructions for procuring data laid out in great detail in Management Manuals. These describe all of the steps, the abbreviations, the procurement process, and the kinds of data you may desire, in great detail. They are not always the full answer in data control, but will be helpful wherever they are available.

12. Reliability and Quality Assurance (R&QA)

In general, the R&QA activities are pretty well organized throughout NASA. Further, you seldom find a NASA management document or project document that doesn't have separate R&QA sections. Much has been written on the subject so the above-mentioned documents are also usually complete with references. The problem with R&QA usually is not where can you go to find something about the subject, but rather how do you boil the R&QA subject down to something you can understand and how do you integrate R&QA into your project?

Even though reliability and quality are well treated in NASA, the approaches to these subjects in their detailed procedures are less stable than many recognized disciplines. Much of this is because NASA's one-of-a-kind requirement departs from production techniques previously understood. Also, R&QA organizations from the top down are under constant review since they are related to all other hardware efforts regardless of discipline. Every center has specialized groups to assist the Project Manager in this important area. The projects at Centers which previously just relied on proven concepts have grown in size and complexity, so these Centers now have taken up formal approaches to R&QA. Most Centers have a Center policy group and then another group concerned with data and procedures which is in the technical organization. In addition, it is NASA policy to make maximum use of DOD quality control offices in contractor plants. These three organizational areas will be of considerable help to you in accomplishing the total tasks.

The objectives of NASA's R&QA program are to achieve 100 percent success in space flight missions. Though this seems obvious, it is relatively new. In other types of programs, to accept some failures is economically a better approach. In NASA, it is not. This attention to quality and reliability has increased NASA's flight successes from around 52 percent in NASA's early flight years to over 95 percent in recent years.

The responsibility for quality and reliability in your project is yours. Headquarters and Center reliability and quality offices just guide and assist you. Their services may include assistance in preparing R&QA sections of the work statement and contracts, helping to establish environmental test levels, participation in testing, numerical reliability assessments, maintenance of qualified parts lists, reliability reviews, failure reporting, engineering design support, instrumentation support for testing and flight, problem assessment, overall program evaluation, and mission evaluation. In accomplishing these general tasks there are a number of specific task areas where they can be of major assistance. These include preparation of FMEA's (Failure Modes and Effects Analysis), establishing single point failures, preparing limited life lists, preparing status and waivers lists, preparing qualified parts lists, checking pressure vessel histories, overseeing critical process procedures, overseeing subcontracting procedures, reviewing design specs, in-process inspecting, controlling fabrication, and auditing. One can see that this is a major source of assistance that one cannot afford to do without. One can also see that these areas overlap or cut across all engineering, manufacturing, and test disciplines. Since R&QA offices will exist in your organization, as well as in other government organizations and, also, in the contractor organization, there is a potential source for friction and major misunderstandings concerning responsibilities. A somewhat normal way of handling such responsibilities is to have your own R&QA office work out the various interfaces. A word of caution here. You are interfacing many proud and senior offices. Your own office will naturally want to retain a position of influence and you may get off to a bad start. You or your deputy may want to assist with this organizing - or one of you may want to be designated permanently a senior contract in R & QA matters.

The NHB 5300 series is, of course, the BIBLE for the

R&QA. Actually, these are excellent documents and, as with most documents, are subject to interpretation. They have been invoked enough times now that neither the government nor the contractor should claim problems of interpretation. Cost may preclude buying everything in the series, however, so both the government and the contractor should be clear on which parts are purchased and which parts are omitted. Besides the overall documents in the series, there are specific documents such as NHB 5300.4(3A), the special quality requirement for hand soldering.²³

Anyone with project experience soon realizes it is the seemingly simple change or improvement that causes failures later. An apparently straight forward improvement often invalidates the entire test program. Where innovation and new ideas are the theme in advancing the state-of-the-art, you may well improve your reliability by staying with a proven design or a proven part unless it proves faulty under test or unless the gain in performance or cost, if a change is made, is indeed large. Considerable information is available on the joint NASA-DOD parts program. These programs are labeled Interservice Data Exchange Program (IDEP) and Failure Rate Data Exchange Program (FARADA). Coupled with the thoughts on using proven parts for reliability is a similar trade off on redundancy. To a reasonable point, redundancy can greatly improve reliability.

Since in the early portion of a project you are literally overwhelmed by the statement of work, contract negotiations, etc., it is easy to become completely absorbed with the prime contractor. In such cases it is easy to overlook the hardware designed or manufactured in-house. Further, since you have a definitive contract with the prime contractor, it is sometimes easier to specify what you desire on the outside than from the inside. Since all government furnished flight items must stand the same flight rigors as contractor items, it is necessary they be built, inspected and tested to the same standards. You must insist that your Center R&QA

offices exact the same requirement from in-house flight items as from the contractor. If a reliability or quality contractor, separate from the prime contract, is used, it may be even more difficult to balance these programs where parts are derived from many sources, to include in-house and out-of-house. In such cases, the R&QA reporting program and the review program (always important) become fundamental. One way to insure that you utilize the many organizations involved, the many sources of parts, and the many disciplines is to organize key R&QA people in a matrix organization so that a key person handles a functional area for each key piece of hardware. Such functional areas might include R&QA planning, reliability, quality assurance, component qualification, reliability assessment, reliability modeling, and failure reporting. There are many breakouts which could be utilized to include in-house and contractor parts equally.

It is apparent that R&QA is broad and diverse. It is a source of many potential problems throughout the life of the project. Besides careful organization to get people properly involved with the many technical areas, the best step you can take with R&QA is to insure proper in-depth planning. The quality area should include:

- a. Review of contracts and procurement requests to insure quality provisions,
- b. Surveying contractor plants to insure capability,
- c. Inspecting hardware at various stages,
- d. Maintaining control of the configuration,
- e. Arranging for failure analysis work,
- f. Handling malfunction and corrective actions,
- g. Participation in design reviews,
- h. Training,
- i. Assessment,
- j. Establishing loads and testing,
- k. Maintenance of parts lists (qualified, etc.), and
- l. Quality reviews.

The reliability areas of the plan should include:

- a. Design reliability goals and assessments,
- b. Failure mode analysis,
- c. Need for design documentation,
- d. Requirements for preferred parts,
- e. Workmanship standards,
- f. Test program scope and plan,
- g. Malfunction reporting plan and procedures,
- h. Applicable documentation required,
- i. The system of reviews,
- j. Soldering requirements,
- k. Special requirements (pressure vessel, pyrotechnics, etc.),
- l. Special requirements for analysis, and
- m. Test requirements.

These, and other subjects you know to be applicable to your project, should insure a complete plan. A complete plan, well staffed, will assist in the understanding of interfaces and responsibilities.

13. Testing and Test Management

Because NASA's space flights utilize hardware that is not only "one-shot", but usually one-of-a-kind also, the statistical approach to testing which has been developed for mass production items and weapons is not applicable. Actually, testing is an essential ingredient of the successful flight programs that NASA has conducted. NASA has shown great initiative, simulating practically every condition that the hardware sees during flight.

Testing is performed to insure that all systems are working properly and that the systems satisfy the requirements against which they were designed. These tests, amplification of NASA's test requirements, are designed to detect and correct actual or potential failures and establish functional capabilities of hardware systems and equipment that will be required to operate in space. Acceptance tests, such as functional, vibration, shock, and strain tests are required at proper points during the manufacturing cycle. Testing of the completed major systems is usually performed, at several government and contractor sites. These sequential tests, usually participated in by NASA, are designed to determine the readiness of space hardware. The requirement is to successfully complete these tests before you accept the hardware. This is aided by the fact that each level of hardware test and check-out requirement must be amplified to serve as a check on all possible prior activities.

The testing function in a major project is a very broad one. Headquarters guidance outlines the general policy, philosophy, and responsibility. The appropriate NHB series, for instance, NHB 8080.1A, sets general policy, and among other things requires that you write a detailed project test plan.¹⁴ Since testing includes development testing, quality testing, compatibility testing, reliability testing, environmental testing, acceptance testing, systems testing, and

several other categories, you must plan well to avoid duplication and yet to insure your testing is complete. Thorough testing is a vital part of project development. It must be done well by you and the contractor. You need to have talented people in your test office and you will need to devote considerable time to this area also. A good way to get the most from your personnel and the contractor's personnel is to make some goals and objectives of your testing quite clear. A suggested list of goals you can consider is to:

- a. verify that systems, subsystems, and components meet design requirements.
- b. verify that hardware samples meet performance requirements.
- c. eliminate defects in design, material, and workmanship.
- d. discover unexpected interactions between sub-assemblies, particularly when exposed to environmental conditions.
- e. demonstrate that GSE and data processing equipment are compatible.
- f. train appropriate personnel.
- g. evaluate logistics capability.
- h. completely evaluate coordination.

There are a number of test issues that can arise and that you should watch for. One of these is the logic of the test sequence. Some technical personnel will have features of a test program which they have learned should be emphasized such as low frequency vibration tests. Also, some personnel will be stronger than others and cause emphasis to be given to black box testing, or mechanical testing, or other parts of the program. These types of items can easily unbalance your project. You should utilize your project test plan as the means of analyzing your test program for logic, completeness and sequence. This requires careful analysis.

Another potential problem is component testing. It is difficult to write a contract dictating when component testing will be completed. You are then stating when many designs will be completed, when many pieces of hardware can be built, and when component testing can be successful. As a result, the contractor has considerable freedom in component testing schedules. He does not have this freedom with major flight and test hardware deliveries. The result is that there is considerable demand for the initial deliveries of flight type components. If the components go into assemblies instead of testing, you will undergo high costs in changes which must be retrofitted. You must see that component development testing is emphasized and supplied with sufficient hardware.

Often the peculiarities of your project eventually require certain tests that were not recognized early in the project. When these tests are rushed late in the project, you will not only have higher costs, but you are subject to mistakes from hasty planning. Examples of such tests would be a dynamic test to cover a launch condition, or a major structural test where a failure has occurred, the structural data previously being built up by analysis from a number of structural component tests. All possible effort should be expended early in order to foresee these difficulties.

Another testing problem is overlooking environmental conditions. Environmental tests have become somewhat stereotyped. We step through vibration, fungus, etc., according to existing plans. Particularly, in larger elements, tested for certain features, we do not realize it may be necessary to consider all conditions the hardware sees. For instance, in structurally testing honeycomb bonded to the skin, we may be testing at ambient and find the skin heats and weakens during flight.

Another problem, potentially, is that of organizational interfaces at a test site. When a number of organizations are utilized at a test site, it is worth being careful when tests

are scheduled. Often these problems can be circumvented by stepping through the test months ahead of actual testing. Where the government and contractor both have responsibilities, great care must be utilized to see that responsibilities and duties are understood by each. It is very difficult to understand failures when responsibilities are mixed, i.e., the government builds a test stand and the contractor conducts the test.

When a contractor is graded on the test program, i.e., part of his fee is attributed to points earned during the test program, you can expect difficulty in awarding these points. For instance, if development tests are graded one must expect certain failures during such testing, but if overruns are incurred or schedules not met because of development tests, you must have prior study and understanding of where dividing lines fall.

During contract negotiation, a clear understanding of test levels must be delineated. Since you have not experienced flight testing, if you state that testing should be accomplished to the levels experienced in flight, then you are leaving it to someone to guess what those levels are. It is better if the government organization, together with the contractor if possible, set these levels according to the best judgement available, and differently according to the test levels expected for each portion of the spacecraft. Also, in vibration for instance, if you expect 2 g's at certain frequencies in an area of the spacecraft, do you test to that level for a black-box mounted on the skin? It may be that is the level going into the skin and there may be further amplification by the skin. Therefore, a complete test analysis, box by box, must be accomplished in time to negotiate it into the contract. If it is impractical to have these analyses completed prior to negotiations, then the Government should specify the range(s) expected, therefore precluding unnecessary contract modifications at a later date.

You must also take into account the effect of your test program on other activities and the effect of these activities on your test program. For quality or reliability, when these are run as separate programs there is usually an in-depth test program connected with one or both. It would be improper to conduct quality testing under one program and development testing under another without coordination of objectives, facilities, and tests. Wherever possible ALL programs should funnel in separate requirements and then only one set of tests per type be conducted. In doing this do not forget periphery programs such as value engineering.

14. Safety

The need for safety is obvious, but with the advent of manned flights the launch hazards of sophisticated vehicles, safety has received renewed emphasis. All Centers have safety offices, but they are involved in flight projects to different degrees. Of course, the manned space flight Centers stress safety more because of manned flight.

Safety, per se, is hard to treat since it is not a new and different discipline. It begins with design, proceeds throughout the test program, is reflected in the reliability and quality standard applied to the equipment and culminates in the meticulous checkout of the vehicle and the rehearsals of the mission prior to flight. Safety offices are responsible for such items as safety policies, standards, criteria and procedures and for maintaining a high level of safety awareness and visibility. The safety office jurisdiction includes hardware, software, tests, flight tests, investigation boards, reviewing plans, review checkout documents, total development analysis, participation in reviews, review of facility plans, and other aspects of the project.

You can see that safety can involve every aspect of the project. This leads to some do's and don'ts. Your Headquarters and Center Safety personnel can be a big help to you. They are not involved in daily management of the project and yet they participate in almost every aspect. They will have an insight that you do not have. They can be additional manpower that will assist in seeing something you missed.

On the other hand, a group such as a safety office usually is more effective if it is small and operates as a detached view of the development. If an unsafe act occurs and alarms everyone, you should be careful of overreacting. For instance, asking a contractor to develop a safety plan and thus giving him an opportunity to employ a large number of people in all project disciplines and restate the development plan under a safety cover is not generally useful. Funds spent on safety

ought to be for redesigns, or replanning, where a concrete deficiency exists. Also to hire a large number of support personnel so that a safety office can have personnel in its many areas of jurisdiction is usually not the best use of a large expenditure. A small, top level crew moving from phase to phase will see the changes that are needed better than having a safety man stay with each group.

The playing down of large expenditures for safety does not mean, however, that you should play down safety. You should cultivate the Headquarters and Center safety offices. If they are not directly involved in your project you should attempt to get them involved. You can help by making arrangements for them to be allowed in closed tests or to participate in design reviews. Better still, give them suggestions where you are concerned but have not had time to check and let them be your other eyes and ears. Good rapport on safety will pay.

15. Logistics

One of the biggest problems with Logistics is that more often than not it is overlooked. It has been pointed out in earlier chapters that there are very few publications that assist a Project Manager in other than policy areas. The few that do exist and the policy manuals generally have in common the fact that they do not discuss logistics. One logical reason for this is that the military application of this term stresses support in the field after R&D and when the system is under procurement in quantity.

In the military also, however, logistics covers support on a broader front. In R&D, a broad definition would be everything needed to support the R&D effort and the personnel involved. A more practical approach would be to say everything not covered by other distinct organizational areas. For instance, personnel, data, computer support, etc., could be construed as logistics, but if they are covered by your organization or the Center, there is no need in also having a logistic group cover them. There is a need to have someone particularly watch out for areas not otherwise covered by the organization. This does not necessarily mean you have to have a logistics office reporting to you. It does mean you should designate someone in your project office or your engineering office to cover logistic areas which are otherwise not clearly assigned. A short study could determine the areas needing coverage.

This would lead us quite naturally to want to know what things might be logistic in nature and might not be covered by other parts of the organization. Just to list some of the possibilities we can include: maintenance, spare parts provisioning, supply support, maintenance spares, operations and maintenance instructions, launch and test site engineering, and training. There may be others not covered and some of these may already be covered by your particular organization.

Too often in the development of a difficult project, one becomes concerned with the design objectives at the expense

of logistic needs. Looking at life cycle costs causes system planners and engineers to consider the testing and launch costs and problems. In the launch mode, the function of maintenance becomes one of the strongest factors in determining the need for personnel, facilities, supplies and transportation. The cost of maintenance is directly related to complexity, reliability and ease of maintenance. One of the largest cost elements is the training and retraining to a required high skill level. To consider these features, logistics thinking must be integrated with design thinking. In many major contractor approaches the logistic thinking is either listed generally under resource requirements or is covered by the entity concerned, i.e., test operation, launch operations, etc. As such it is difficult to ascertain that a trade off is really being made to balance design with later logistic requirements. This can result in more effort and cost during operational phases than you had planned on.

Sometimes, when it is apparent the operational phase will be critical the logistics may be well covered. A good example is the Space Shuttle RFP, since the Shuttle is being designed to operate for a number of years. The Shuttle RFP gives the requirement this coverage: "The Contractor shall implement, operate and maintain a logistic management system for support of the vehicle and ground activity. This effort shall, as a minimum, include spares management, analysis of support requirements, training, inventory management, repair and overhaul, propellants and gases, identification and utilization management, warehousing and storage, transportation, and support activities. The contractor shall recommend procedures for and participate in a NASA integrated logistics management system. Low cost per flight should be uppermost, consistent with safety and reliability."²⁴ Such a start will at least ensure logistic consideration at the proper time.

Most large projects, particularly if several launchings are involved, should prepare a logistic support plan. Then you will have an orderly approach and avoid gaps and overlap.

It will help you identify and utilize your resources. It will help you systematically develop requirements based on needs. It will assist in controlling configuration and interfaces. It will save costs through preplanned maintenance and maintenance consideration during design. It will ensure spares, field support, manuals and training when needed. If you have several pieces of hardware at the level below you, possibly each with its own manager reporting to you, a logistics support plan will ensure the uniformity you must have.

Maintenance planning should give consideration to scheduling of maintenance, to failures occurring during scheduled activities, to performing analysis to identify maintenance functions and levels, to accessibility, to malfunction detection, to fault isolation time goals and to spares requirements. Maintenance requirements must also consider all GSE. In addition to maintenance, spares provisioning is a separate subject. There are many considerations here. Spares are usually considered as maintenance spares (those installed on flight articles, etc., on-site), repair parts (to bring a part back to serviceable condition), and standard parts (off-the-shelf). These require different considerations. Obviously, standard spares have a shorter lead time than special items. It will take a careful maintenance analysis to determine how many special spares must be procured, and when. You must consider failure rate, quantity of item used, maintainability characteristics, procurement lead times, turn around time, criticality, and cost. Over supply of spares can be very costly; undersupply can be disastrous. You should publish your decisions on spares in a provisioning document so that everyone understands the situation and so that you have uniformity. This will also assist you in keeping up with changes to your spares list brought about by changes to end items and by experience during tests.

The Operating and Maintenance (O&M) instruction manuals are organized sets of procedures that specify the method of operating and maintaining the equipment. These documents should indicate skill level requirements, show the time restraints, prescribe

the limitations of design specifications and configuration changes and ensure performance. If more than one piece of hardware is involved for your project, particularly if the project is launched by a single launch team, the O&M manuals will be of great assistance in standardizing procedures for a uniform approach. They also provide the means of integrating maintenance with standard configuration management procedures.

Training is an integral part of logistics. This is not optional training but technical training to provide the necessary trained personnel for proper system operation and maintenance during assembly, checkout, test, and launch activities. The program results from an analysis relating tasks, operation, skills and procedures to requirements.

A caution! If you are using your prime contractor to develop your logistics plan, do not forget your GFE items. GFE must be subjected to the same analyses and spares provisioning as flight items. Particularly if these items are designed or procured by in-house laboratories and there is no logistics plan, it is very easy to overlook the costs associated with GFE logistics.

Another thought that should be applied early in the project is to think of maintainability as a part of logistics. Maintainability is a characteristic of design and installation which can be expressed as a probability that an item will be retained in or restored to a usable condition in a period of time, when the maintenance is performed in accordance with prescribed procedures and resources. The purpose of planning maintainability ahead of time is to reduce development time, reduce maintenance costs, cause design personnel to realize its importance and to be able to predict maintainability for later project stages.

Particularly the quantitative nature of maintenance, predicting the life of a part, the number of spares needed, etc., is very relatable to quality and reliability. Good coordination should ensure that your staff offices do not require two similar outputs under different headings.

16. Facilities

Facilities can refer to the facilities required to develop, produce or test the project or portions thereof. It can also include equipment acquisition, modernization and maintenance. Further, it can include facilities planning, design, layout, procurement, construction, installation and reporting. The time, therefore, to give emphasis to facilities is during the preparation of the RFP. Additional facilities are always the means for a contractor or government organization to expand its base. Such expansion is not always desirable, however. Unless specifically controlled, you can expect an organization to expand its facilities. Some expansion may be required and intended. However, the RFP must require that all facility planning be spelled out. The RFP is the time to specify the use of government owned facilities if that is the approach. It is also the time to specify any use of existing contractor owned facilities. Otherwise you may find these committed to another project when you thought they were available. A good approach is to specify in the RFP the facilities you want utilized and request a plan in the response for all other requirements that will be needed. This gives you an opportunity to change after you see the total problem. It also requires the contractor to think out the total problem ahead of time. Starting at the time of the RFP and continuing through contractor response, your office should start testing all facilities for every requirement, major increment of project work, and major project milestones. This should indicate their scheduled availability and/or lead times. This permits you to be sure of coverage. Also, where you know of tight spots in the project, it will prevent your having planning which is too large. You should make this assignment early in the project.

Both NASA Centers and the Aerospace contractors tend to centralize their facility organizations. In the case of the contractor, usually a matrix type organization exists where the chief of facilities reports to management and a lower level

individual is concerned with project facilities. The only caution here is recognize that this organization is oriented to the company. You will probably have facility coverage, but you may not have the most economical coverage that can be considered. In Center facility offices, you usually have capable well-oriented people who know the facility portion well enough. They cannot know the project well enough to obtain an optimum. There are two good solutions to this. One is to appoint someone in your office to interface the facilities offices. The other is to get the facilities office to appoint a man to your office who is responsible to you. You will probably get good design and construction in any case, but only with someone responsible to you, can you ensure that the project milestones are met, that existing facilities are fully considered, that project peculiar requirements are utilized, etc. If the facility concerned is a separate test or manufacturing facility, etc., it will have a separate contractor and/or government facility manager. This must be considered in cohesive planning. Also, there are many considerations and standards which only you can determine. Do you need to retain a capability to expand? What quality control conditions such as clean room, contamination control, etc., need to be imposed. Can you dispose of facilities when they are no longer needed or do they remain charged to the project?

Of course, major facilities are usually charged under the Construction of Facilities appropriation. This means two main things to you. Such appropriations are subject to a four-phase programming cycle with approval to initiate each successive phase based on the results of the preceding phase. These phases are concept, preliminary design, final design and execution. Therefore, lead times for the whole project are incredibly long. Also since this is a line item appropriation to the Congress, you cannot reprogram when your needs change. These features mean that any new facility proposals will require extensive review at NASA Headquarters and Congress. It is vital that your construction requirements be determined

early and correctly. The procedures in detail are set forth in NASA Procurement Regulations.²⁵ One consideration in these regulations is that they state facilities are to be provided a contractor only in those cases where such provision is necessary to assure the performance of the production or schedules. This will cause contractors to propose company owned facilities be built and amortized over a short period of time. Although this arrangement is not generally advantageous to the government financially, it may be required.

Since new facilities tend to expand and since R&D facilities have a tendency to be one of a kind, there is sometimes a desire to disapprove these new facility proposals if at all possible. There are some things you can do. You can make your survey of existing facilities as thorough as possible so as to leave no doubt as to need. You can also design the facility so that it is not so specialized - has a capability and need for continued use.

Once a facility is approved, if it is major and its timing vital, you should develop a facility activation plan and have someone specifically in charge of it. If the facility is complicated you may want to have PERT control or some other visual means of control. Only by this approach can you ensure that the complex final steps of the contractor mesh with your early activation steps. Remember your organization will provide conceptual design; then an architectural and engineering contractor will provide detailed facility drawings and a different, competitively selected contractor will be awarded the construction. Unless you were thorough with the concept design, at the time of beneficial occupancy you may not even recognize all of the final facility.

17. Maintainability and Producibility

This is a subject under logistics also, so not too much more need be said. However, as with other subjects treated here it is worthy of a separate heading so you will consider it in your initial planning. Maintainability and Producibility not considered early will not be worth considering.

First, you should be sure these items are a part of your RFP. Words like "They should be considered in the design" may be good enough, but it will probably take stronger language, such as possibly considering the subjects in incentive contracts. The contractor should at least have to describe his plans. We must always remember that the success of U.S. industry is built under the profit motive. Industry must treat first those things affecting profit. Left to its own devices, ease of maintaining and producing are not first order considerations.

There are a number of other things you should do. Most of these are addressed to maintenance, but they facilitate producibility. You should ensure that the levels of maintenance are thought-out and set up. This dictates what is repaired on site and what is replaced. It tells you where your skill levels must be. With no thought you will probably establish skilled maintenance at too many levels - or possibly too few. Maintenance levels are an aide to scheduling maintenance by time and serviceability.

Once the prime contractors are selected and you have your staff thinking in terms of levels and echelons of maintenance, it is time to stop and have a thorough maintenance and producibility analysis made in detail. This should be accomplished so as to uncover problems in preliminary design. It will identify bottleneck support requirements, new equipment needed, and show unusual spares requirements. Such analyses will identify design trade off while there is still time to judge if costs of producing or maintaining warrants a change. These analyses should consider production methods, tooling requirements man-hours required, accessibility, malfunction detection, fault isolation time goals, spares requirements, GSE requirements,

and training requirements.

These are not very glamorous studies while you are involved in early design. They probably should be performed by your prime contractor unless you have an unusual in-house capability available. However, you will need to have one of your staff watch this effort from the beginning to ensure it accomplishes your purposes. You should end up with parts that are easily produced without undue cost or time for any portion. Your maintenance analysis should end up with a set of operating and maintenance manuals.

Some of the features you should accomplish in the above program will include:

- a. Reducing development and production times.
- b. Increasing the project effectiveness.
- c. Reduce producing and operating costs.
- d. Keeping people aware of the importance of this area.
- e. Improve your reliability predictions.
- f. Avoid serious problems late in the project life.

If you think of maintainability as design, done in such a manner that the system can be maintained or produced within the allowable time and at an acceptable cost, this will let you do your analysis with some goals in mind. Your analysis can be more like trade studies where design, requirements, flow, etc., can be analyzed against time and money.

It is not expected that this discussion will surprise you by the features discussed. It is only intended to refresh your mind on these subjects so that you will have a few sub-elements to prompt them with. You probably cannot spend a great amount of time on these elements but someone must.

18. Specialists

Project management has become more and more technical and more and more complex. One natural outcome of this is the acquiring of specialists. These specialists may be highly involved directly in the activities of a particular project and in such cases are generally assigned in the project office. They may cut across the activities of several such projects and thus may be assigned to the Center staff or to the laboratories or engineering organization. In any case you should survey your project or have such a survey made, to determine how many specialists you have involved with your project or how many you should have.

You can look at specialists in two ways. One, they are additional manpower that through their discipline see your project in a different light and thus contribute to the progress of the project. Two, they are a drain to the resources of your project. They may cause a manpower drain, and they are almost sure to cause a financial drain to some degree.

You should, after listing the involved specialists, set policy for their use. This is somewhat like contributing to a number of welfare agencies, particularly before consolidation. There is some overlap, a few you don't believe in, but in general it is a good cause so you determine what you can afford and how you want to prorate that total. It is generally not good enough to let this subject drift and face up to each specialization as it occurs. A strong specialist may spend more project funds than his specialty deserves. Others, which are important may be weakly represented or not at all. By not checking the total you may underestimate and not be financially covered. This brings up an organizational point. If the Center is not covered in a particular specialty, you may need to devote a specialist to the job, if it is important to the project. If most of these specialists do exist somewhere in the Center, you will probably want to appoint contact and commitment points in your own organization so that the activities remain balanced in the project.

Many of the specialists are so important to your project that they have been given independent coverage here. Even quality, reliability, and testing could be considered such specialist activities. A little less obvious would be safety, logistics, data management, and software. In any case, a number of areas such as these have been treated separately and are not repeated here. This section intends to point out the significance of a number of less obvious areas and bring them to your attention for your action. These can include, but are not limited to: Value Engineering (VE), Technology Utilization, Human Engineering (flight items or GSE), Standardization, Compatibility, System Security, Man Rating (if manned), Packaging, Transportation and others. It can include a different class of items such as Independent Research and Development (IR&D). Their classification is not as important as is their recognition of involvement with the project and hence use of project funds. To this end they should all be assigned and accounted for.

A number of the specialties must be treated in the contract of the prime. Some of those treated separately may warrant considerable coverage in the RFP, i.e., software, quality, etc. Some may be covered by standard clauses in the RFP, just to be sure they are considered and included. These could include clauses on materials for compatibility, loads, handling fixtures, divisions of responsibility under transportation, approved parts lists, references under standardization, and so on. It is not intended in this section to go into each one of these specialty items since they are so numerous and varied. Instead, one such item will be discussed in a little further detail as an example of the considerations which must be planned and assigned. For this example, Value Engineering has been chosen.

Value Engineering may be approached in two different ways, for any given item, depending on the status and nature of the project. One way is to provide value engineering techniques to products which have already been engineered. Usually more

profitable changes can be determined at this stage. The second method pertains to projects under design which have not been fully engineered. This is the most economical time to apply Value Engineering. Value Engineering is generally covered in the contract of the prime, either under an incentive approach in order to encourage it or as a mandatory requirement with incentive as an added attraction. Delay means a decrease in savings so contract provisions must call for prompt evaluation of design and Engineering Change Proposals (ECP's). The real cost and hence real savings is more than the production costs. If research is prompted to verify a VE principle, cost of this research will have to be determined as separately required or required for the VE purpose.

Since a Value Engineering study is primarily to contribute to reducing cost of an item without jeopardizing performance, quality, maintainability, standardization, or interchangeability, significant savings can be accrued. High caliber engineers are trained to see savings in design configuration, the manufacturing process, and the production tooling. Personnel involved should have specialty training and show adaptation to the project. You must weigh the benefits and costs - to your project and decide. You must determine if you desire value engineering in your project, and if so, how deep in the project it should be organized. In any case, you should not let it be accepted by some personnel in your project, without thought or pattern.

19. Procurement

Procurement is a broad subject. Of course, many of its features were discussed under the RFP chapter and other elements are touched upon elsewhere. However, the subject is so important and has so many important aspects, it should be covered separately also.

One thing peculiar to Procurement is that, on one hand, it is just another element of project management, on the other hand, its importance and good business requirements often cause it to be largely administered outside of the project organization. This is all the more reason why this subject must be understood. To start with, considerable procurement policy has been written. Briefly, the top level documents include the NASA Procurement Regulations, the NASA Procurement Policies, the Associate Administrator Offices Instructions, and Field Center Policies.^{25,26,27} These cover regulations, plans, noncompetitive justification, SEB's, impersonal services policies, deviations, mods, waivers, incentive contract guides, Cost Plus Fixed Fee (CPFF) guides, development plannings, letter contracts, milestones for procurement, change orders, and other areas you need to know. Even though procurement has some differences from other areas, it is still a vital and active area in the Project Manager's role. He leads in contract and contract change negotiations, in preparing and understanding the statement of work and specifications, in technical management and in administrative functions. He plays a major if not lead role in the negotiations. His role in procurement is a major order of business.

This is a very complex area. You need an approach. You cannot be expected to keep up with all of these regulations. No one in your organization that you appoint can keep up. Therefore, the usual answer is that the Center Procurement Organization will help serve your procurement needs. From a technical point of view, this is sufficient. However, under the theory that a project manager needs to have control of all aspects of his project, you cannot afford to lose control in the procurement

area. The Center organization is interested in seeing that procurement is done properly and follows all regulations closely. You are also interested in these features and further interested in seeing that your project is accomplished as described. These aims can conflict. Two solutions are: either to appoint someone to interface the procurement organization (for instance a section in your Project Control Organization), or you can have the Procurement Organization detail to you a small number of specialists who would be sufficiently under your control so as to emphasize your requirements. Either way you go, you should have that group go back over all pertinent regulations to determine the items that particularly apply to your project and your circumstances, and then brief you. Also, they should plot all key procurement milestones for your project so you can plan for these key dates. They should also watch for project needs in the procurement area. A particular requirement which should not be accomplished by an outside organization is the preparation of a project procurement plan. Your organization should prepare this plan. It is needed in detail, and early in the project. This will bring you face to face with the issues: type of contract, any noncompetitive procurements, time scheduling, letter contract requirements, etc. You must control these procurement activities.

When coordinating procurement matters, remember that every level is interested and involved. You will have to coordinate Headquarters Procurement Plans, justification for noncompetitive procurement plan, determinations and findings, deviations and waivers, contracts, advance approval of incentives, and letter contracts. Be sure you initiate these items in time to accomplish the needed coordination. You need to understand how many of your procurements exceed your approval authority and what approval levels are involved. You also need to know how many procurement plans will have to be prepared, and their time scales. It would be good for you to refresh yourself on the three funding levels, the various levels of responsibilities for procurement plans (about eight or nine levels total), the

levels for justification of noncompetitive procurement, and the levels for contract modifications of different dollar amounts. It is possible also for your project to be involved in procurement outside of the above negotiated procurements. These include such things as standard issues (electrical parts, chemicals, etc., procured through the Center property stores), consultant services through temporary civil service appointments or otherwise, and various supporting contracts.

As you can see, your procurement activity is large and varied. Even so, a contracting officer is the final signatory authority on all contractual documents issued by a Center and is the only person authorized to contractually bind the agency. Many constraints are placed on that authority so that the contracting officer has limitations in doing what you want done. He has a major coordination constraint which takes valuable time. NASA Headquarters is concerned with shortening procurement administrative lead time. Even so, dozens of offices are involved, and it can take a painfully long time. You can do much to shorten this time!

- a. Familiarize yourself with procurement in general and your procurement activities in particular.
- b. Insure that procurement packages are complete.
- c. Be active personally in technical evaluations within your project.
- d. Schedule your requirements realistically and use emergency procurement action when necessary.
- e. Promote coordination among your office personnel, technical representatives, the financial analyst, and the procurement personnel.

There are various quick reaction methods to get some work done when quick coverage is needed. These differ from Center to Center but they may include:

- a. Off site engineering design services.
- b. Technical writing services.
- c. Off site fabrication services.
- d. Computer programming services.

Most Centers have guidance on modifying existing contracts. For instance, Goddard Space Flight Center's GHB 5104.2A describes the procedure for modifying contract specifications, and it defines changes under the categories of mandatory, highly desirable, and optional and tells how to implement each.²⁸ This handbook also gives details on providing technical direction for a course of action within the scope of the contract. Since small contracts have so much involvement with the procurement activity, handbooks such as Lewis Research Center's "The Management Control System for Small Contracts" are very useful.⁴

It is interesting to note that some Center publications point out that a Project Manager could spend three-fourths of his total time on functions including or related to procurement, or monitoring contractor effort. It shows the extent and importance of procurement, and it shows the demand on the Project Manager's time. As had been pointed out, cost information, abiding by the regulations, etc., are primarily the duty of the Contracting organization, but you are primarily responsible for all such items, particularly for the specifications and statement of work and for monitoring contractor efforts to be sure these requirements are met. You must be involved with the whole process even though you can think of NASA procurement organizations as performance management and contract administration oriented. These two functions are interrelated and each affects the other.

In summary, you are primarily responsible for the total performance management of your contract, including cost, schedules, and contractor performance. You must establish the lines of communication, formal and informal, with your contractor to carry out this function, to include reviews, and feedback. You must act to avoid contract cost overruns by monitoring analysis and action. You must act promptly on change submissions. You must adhere to the configuration management system specified. You and the contracting officer must insure that reliability and quality practices are carried out. Your job is made harder by the fact the end item is seldom

precisely defined. NASA is usually pushing the state-of-the-art. This makes a policy for handling the contract even more important.

You should use all of the contract standards possible, however, and utilize changes as little as possible. You may use all of the following for performance measurement standards.

- a. Tasks in the statement of work
- b. Design specification
- c. Performance specifications
- d. Process specifications
- e. Material specifications
- f. Project Plan
- g. Test Plan
- h. Manufacturing Plan
- i. R&QA Plan
- j. Configuration Management Plan
- l. Performance schedule
- m. Award Fee Criteria
- n. Delivery
- o. Use of the key personnel

Measurements in some of the above areas will be subjective. Other areas of this report will discuss the analysis of progress which you must now make.

20. Project Records

In addition to data management as a subject, you need to think about your record keeping. Of course, that is not a subject requiring many pages of thought, but it is set aside so you will apply some systematic approach to it. Like everything else it needs to be planned early.

You can think of data management as the means of identifying and acquiring the minimum data to effectively manage the project. The project records are those periodic reports, special reports, film reports, plans and other forms of data which should be set aside for particular purposes. These purposes can include:

- a. Historical records.
- b. Data banks for current and future programs.
- c. Training materials.
- d. To assist other Centers.
- e. To assist in problem solving.

It may sound like, from the above, that you should save everything, and if you don't plan it you will fill many safes making it difficult to convert to systematic retention. The best way is to start at the beginning and compile a list of reasons for retaining project information. Your list will look something like the above. You will notice that although you can separate your objectives the material saved cannot be subdivided so many ways. The historical data, data banks data, training data, and data of interest to other Centers will overlap. Therefore, for your purposes you may want this filed under one overall heading by some type of subject listing. The problem solving data is technical in nature and may be listed separately.

It is useful after you have gone this far to take one more step. List under the above two categories the types of data that should be saved, i.e., under the first category: unique management approaches, state-of-the-art problems, technical breakthroughs, lessons learned, unusual approaches, and probably

many others of interest to you. Under the technical problems you will probably want to retain data that may assist you in later problems, i.e., even if you have completed manufacturing, the number of inches of repaired welds in a cryogenic tank will be of interest until the last such vehicle has completed its mission. For the same reason, you will be interested in traceability of most critical materials.

Once you have set such a pattern as this it probably will not be too hard to administratively carry out the actual retention. Possibly you can get assistance from such offices as the Center Historical Office. In any event, you will probably want to organize your office to this end. A simple way is to designate two or three secretaries who are in the flow of such records and instruct them on the type of material to be retained. A central filing location should be designated for all such material. In order to prevent this effort from growing out of proportion, it is helpful if the filing location is just part of some other central files that you require for other reasons. Lastly, designate someone to whom the above secretaries can look for decision in any areas of doubt.

This may seem overdone for such a minor area. Perhaps it is. However, such files are eventually required for each project. They are either planned from the beginning, established later with an undo amount of effort, or the Project Manager must "beg off" the requested assistance or problem solving because the effort and tools simply aren't available.

21. Experiments

Those who have had a project carrying a significant number of independent experiments know that this is one of the most troublesome areas in NASA R&D. Those who have not been directly connected to independently developed experiments may not realize or properly prepare for the potential problems in this area. Early planning for experiments will save much time and effort later.

If you have the capability to carry experiments, it is axiomatic that you will have some and will have to set up some criteria for rating the experiments so that you can choose the best ones and eliminate the others. This is usually a rating based on overall worth and weight. You also may need to select categories of experiments since the experiments proposed may be scientific, engineering, or biomed (manned flight). In many projects this may be obvious, i.e., an astronomy satellite may not accept experiments that are not connected to astronomy. The selection process for experiments carried could cover a separate chapter.

For those who have handled individually developed experiments you know that after selection of experiments the problem has just begun. Besides the diverse nature of the experiments, you will have many diverse requirements. They may have power, telemetry, cooling, weight, size, contamination, environmental, etc., requirements. They may impact the spacecraft access, the mission profile, the system tests, etc.

In addition to having experiments developed at separate locations all over the country, it is to be expected that those who are inventing or developing are not project oriented. It is natural that they will be more concerned with the quality and success of the experiment than with schedules, funding, or impact on other areas of the project: These remain primarily your concern.

We have then described a systems problem. With all the impacts on various parts of the project and with potential

individual problems, you need to go at it two ways, and you need to get at it early. The "system" must be analyzed for requirements in power, telemetry, etc., and a reserve carefully managed. In addition, each experiment must be carefully monitored and tracked by an individual in your office. The purpose of this, primarily, is to understand the experiment and its progress and thus be able to anticipate delays, cost increases, new requirements for power, etc. The purpose is not to have the project monitor placed in charge of the experiment. Therefore, the selection of these individuals must be done with care.

The engineers from your office, who could be called experiment integration engineers, should provide assurance that the experiment and your project are technically compatible. They should be responsible for detecting any incompatibilities that may exist and to assist in resolving them. Specifically, they could be assigned duties such as:

a. Conduct a thorough review of the experiment to project ICD for technical incompatibilities or omissions.

b. Insure that the experiment integration procedures, interface definitions, criteria, etc., are complete and consistent.

c. Review all waivers for technical accuracy, possible impact across the experiment interface, and for adequate coordination.

d. Review all RID's (Review Item Discrepancies) for technical accuracy and adequate coordination, assuring that all of the integration has been successfully closed and that they are satisfactorily resolved.

e. Review the design flight plan for compatibility time lines and design requirements such as voltages, temperatures, etc.

f. Review other system studies that involve experiments, such as safety analyses, sneak circuit analyses, etc.

g. Review the requirements for scientific data. Negotiate data requirements with the Principal Investigator, to include

policies, data release, data reduction, analysis, and reporting mission results.

h. Keep everyone, particularly Center technical personnel, informed of the status and potential problems.

Most of the NASA R&D projects, as a whole, are engineering projects. You, for instance, are probably an engineer. Many of the experiments are scientific in nature and generally conceived and built under the direction of a scientist. In general, a scientist outside of your organization will interface better with a scientist in your organization than with the project engineers. He will feel such a person speaks his language and is interested in more than just producing something to fly on time. If you can obtain, full or part time, the services of a project scientist, it can help establish the cooperation needed to achieve the overall goals. Some managers who have carried major experiments consider the requirement for a project scientist as mandatory.

In order to treat all of your experiments as a system, there are a number of characteristics of each experiment which should be cataloged at the beginning. Although these requirements will change, you can use the catalog as a control device. A checklist for this catalog might be as follows:

- a. Average power requirements in watts.
- b. Peak power requirements and duration.
- c. Voltage requirements.
- d. Noise and transient limitations on the power system.
- e. Experiment data requirements to include films, magnetic tape, specimens, telemetry, video, etc.
- f. Communication requirements to include frequency, modulation, bandwidths, antenna, time of transmittal, etc.
- g. Environmental requirements to include temperature, gas, relative humidity, vibration, acoustics, acceleration, pressure, etc., as well as the variations during different flight phases.
- h. Effects of the experiments themselves on the environment.
- i. Time requirements on ground (or flight) crews.

j. Physical requirements such as weight, volume, location, etc.

k. Spacecraft orientation requirements or special viewing requirements.

l. Computer requirements.

m. Magnetic requirements.

n. Contamination requirements.

o. Any other special requirements (i.e., 0 "g" environment, hard vacuum, synoptic orbital requirement or any other).

As you can see the world of independent experiments is a complete problem of its own. Couple this with NASA's policy of preserving the integrity of each investigation, encouraging the participation of the best qualified scientists, and making the results of investigations available to the scientific community at the earliest practicable time (see NASA Policy Directive 8030.3) and you have an endeavor that will require a major effort from you.²⁹ You should start this work with good people, well placed in your organization. You also need to look into the many and varied interfaces to be sure they are all open and working.

CHAPTER VII

OTHER IMPORTANT DECISIONS

1. Human Relations

In discussing problems and decisions that a NASA manager is likely to be confronted with, it may seem unusual to start with a subject like Human Relations. However, it is here for two main reasons. One, since you as a manager must work through people, it becomes necessary to start thinking in terms of people. Two, since formal management instruction emphasizes behavioral approaches more and more, you are even more likely to be exposed to a need for understanding these methods.

First a word about behavioral management. You should at least be familiar with the terms and the approaches. Since that cannot be covered here, it would be worthwhile to take a short course, glance through a text or read one of the articles now appearing in the engineering journals. Suffice it to say here that it is a management science dealing with human behavior and particularly stressed by the psychologists, sociologists, and anthropologists. It stresses such areas as perception, motivation, stress, learning, and decision making.

A human relations area closer to you at the moment is your getting the best effort from those closely involved with your project. It is worth some time to think of how you want to work with your people and also those at all organizational interfaces. The approach one should take is an individual thing, depending on your own personality and techniques. The important thing is that you develop an approach to handling people and implement it. Don't be passive.

If you are authoritarian - a strict disciplinarian and a stickler for seeing that your instructions are carried out, you can make that approach work - with fairness, reasonableness, and a successful project. If your concern is for people you can have a very successful project by motivating everyone to extra effort. The important thing is to have an approach and work at it. Don't depend on just having a personality which somehow takes over.

It is suggested you think out how much time you want to spend with different levels of personnel. You should consider ahead of time how you want to handle mistakes. Have you planned for the administration and environment of your employees?

Behavioral scientists are working intently on some of the essentials of management - communication, innovation, leadership, feedback and involvement. It is evident that we will feel the effects of these efforts in management, and more so every year. A man's need to belong and the rise of group activity in unions and elsewhere will make this approach continue to progress. Today, however, it is not likely that you need to revolutionize your approach to management just because participative methods are on the rise. You do need to recognize that the days of the entrepreneur and the iron fist rule are becoming less and less. A little awareness of this and a little thought on how to make your organization feel involved is more and more worthwhile. The least you need to do is find a way of getting a personal understanding of the feelings of people at all levels.

2. Project Contractor Relations

While we are on the general subject of relationships, one should think of what sort of relationship is desirable between a NASA project office and a prime contractor. Again, it is a subject you should not let "just happen." Your relationship should be deliberate and planned - thought-out by you to make the project run according to your own style. What then are the issues that you should consider?

For one thing, the project cannot depend on formal communications alone. The project cannot survive if you deal with the contractors only through the contract, through contractual letters and through reports. You must also have meetings, face-to-face discussions and other informal ways of penetrating the project. You have to dig beneath the surface to find out what really goes on. This would say you really need to see him in one way or another every few days. This alone is no doubt a true statement, but there is also another side of the problem.

Can you interface with the contractor too frequently? The answer is probably "yes." For one thing you must certainly consider ethical problems - either actual or implied. Ethics is concerned with the world of values in human conduct and the right or wrong is highly subjective. You must answer if it is truth and fair and beneficial to all. No standards of conduct will be proposed here. But remember, as leader of your project, your example is closely watched and easily misconstrued. You should think out the example you want to set in relations with your own employees, with NASA management, and with your contractors. In so doing, remember too that you have acquired power. Power and ethics are not by nature homogeneous.

Back to relations with the contractor. If you spend too much time together you will at least face having your professional accountancy questioned. If its above reproach you can survive that. More important, however, is what actually occurs. Since you are frequently called on to defend your budget, your schedules, and the adequacy of your project to higher headquarters, you will find additional "cushion" in this area a comforting thing. This causes your aims and goals to be remarkably similar to that of the contractor. There is at least a danger here. It is the experience of this writer that when this situation couples with a too frequent interface, it tends to be most difficult to maintain a separate perspective. Although a close working relationship with your contractor is

desirable, it is neither to your advantage nor the contractors to have you identified to a higher authority merely as a spokesman of the contractor. Many project managers have been so identified in the past.

How does one maintain both optimums? This is a fair question because you can have too close and too loose a relationship. Of course, you must watch closely the social side. Even if you stay within guidelines, if any, this is easily overdone. Try not to socialize alone, but let dinners and parties be mixed affairs, if possible representing several offices. As to the business side, try to stay in a reviewer status. Otherwise, if you have a dirty hands all night working session with your contractor, for instance, your spirit is to be commended, but some objectivity will be lost. Possibly, your staff or even line managers should do the contact work and you review it. Also, if your project has several pieces of hardware with different line managers for each, stress your interface with your own managers and interface somewhat less with the contractor involved.

Having been negative enough to provide the above cautions, it is necessary to again stress the need for a close working arrangement. You should have frequent reviews where you and your staff hears the contractor's viewpoint directly. You should visit his plant and he your Center for reviews. He should be invited to appropriate reviews even if he is not directly participating. This relationship is a personal and undefined science. Think out ahead how you want your relationship to work and how you want it to look.

3. Problem Resolution System

This is closely related to your Configuration Control System. In fact, if you have gone so far as to implement a configuration management system, such as NHB 8040.2, it may seem you have covered the method of resolving problems.²⁰ In general, you have. Such systems are built around technical

changes. Since these relate directly to cost and schedule most of the decisions you are concerned with should come to you via the change boards.

One potential problem here is that you become so "wrapped up" in change boards as THE problem area that you may overlook the fact that other problems may exist. Have you thought about how you want to handle problems which do not come before the change control boards? Have you thought about what kind of problems you want to see and how you want the ones you don't see handled? Invariably, if you just let this situation happen you will be making lower level decisions in one area and possibly none in another. Without guidance your secretary and your staff may not approach it the way you desire. In fact, normally, they will see if you make certain decisions in some area and then, if you do, send you all such decisions. This may perpetuate a bad thing. As in most areas you do not need to do the staff work personally, leading to a decision. Have your staff list all of the decision areas they can with a recommendation as to the decision level for each item.

This again is an area you need to think out ahead of time. You need some kind of system. Presumably, from the earlier chapters, you have thought about decentralization as well as line and staff arrangements. You ought to be in a position to know what level of decision you want your line and staff to make. Because there are always exceptions and implications, it is sometimes difficult to put such rules in an administrative procedures manual. Although rules on decision levels can seldom be fully understood when written, the "first cut" should be in writing. It will then be necessary to discuss decisions making in a staff meeting. After examples and questions, your organization should begin to understand what you have in mind even though it is a most difficult area to describe .

Now how do you want to go about having everyone understand your approach to organizational decision making in the same way? It is suggested that you construct, or have constructed, a decision hierarchy, with yourself at the top, your deputies

or direct assistants next, and then your line and staff organizations as appropriate. To give everyone a feel, list examples of typical decisions for each level. For instance, in the area of personnel you might decide that one of your offices could reassign someone within their own office by merely coordinating with your administrative office. If they want to trade a man for another, within your project office, where everyone agrees, you may want your deputy to agree. You may want your deputy to be informed and approve any transfers in or out of your organizations. For technical approaches, you may just want a note telling you that your line organization is taking an approach which someone in the technical organization of the Center disagrees with. Whereas, if the Laboratory Chief disagrees you may want the approach coordinated with you before it is implemented.

If a little time is taken to list the approaches to several diverse areas, your organization will certainly understand your approach. It is vital that everyone does understand and work to the same system. If you are unsure how you want the decisions made in certain areas, you can of course inform everyone that the approach is tentative. You can also arrange to have your secretary keep a list of decisions made elsewhere so you can check for a while to see if you are satisfied. In the midst of the Apollo Program, the Program Director once delegated a large amount of signature authority, hence decision authority, to his deputy. He satisfied himself on the actions taken merely by glancing over a list of items signed in his name. If he felt the need to modify any action taken, he was thus informed in such a timely manner that modifications were not disruptive if they were ever required. Where a number of people have signature authority, as in the Pentagon, often each keeps a log so that anyone can check what has been signed.

4. Control vs Innovation

Those of you who have been exposed to university or other

prepared courses certainly recognize control as one of the management functions and have probably been exposed to concepts of innovation. More and more formal instruction has tended to stress innovation. Control implies restraint. Innovation is the generation and acceptance of new ideas, processes, etc. It, therefore, implies the capacity to change or adapt. The two considerations are not entirely homogeneous and hint of some conflict. Since the days of Henri Fayol in the early 1900's, it has been recognized that management, particularly project management, must have measurable control. Recently, particularly with our rapidly advancing technology, the need to innovate has become apparent. Can you do both?

Yes, one can control and innovate. Since both embody an attitude, it is not easy for an organization to carry opposing views to all levels - but possible. You are the key. You have to wear the two hats conspicuously. Perhaps one should think of this dilemma in terms of the organization. When one thinks of control, one thinks of a tight or bureaucratic organization. Most project organizations fits this to a degree. When one thinks of an innovative organization one thinks of a loose, participative type organization where everyone freely expresses various views. It is not easy for you to have both in one.

The following suggestions may help. Usually each organization has an element through which it monitors the control function. For instance, if you have a Project Control Office that tracks funds and schedules and also has the configuration management function, this is no doubt your control organization. Your interface to that organization has to be one of control emphasis. It is here you emphasize tight control, restricted budgets and closely held schedules. The direction through your organization to the contractor will also emphasize control. Changes to the technical approach, new ways to advance the state-of-the-art, new ways to achieve the goals of the project are not compatible with this tight control. You have to wear this control hat, however, to succeed in your project.

There is another side, however, particularly for high technology projects. Are we sufficiently abreast of the state-of-the-art to warrant the NASA development we are embarked on? The objections of Center Management, at times, to Project Management is that it must become so involved with control that it doesn't see the future, doesn't look at the big picture, doesn't properly utilize the Center's technical organization. You must be prepared for innovation. You may need to innovate at any time, so you should lay some groundwork.

There is no way you can do a good job of Project Management and not stay largely control oriented. Therefore, to cover the innovative view, you may have to take some steps just for that purpose. Some suggestions might include: encourage a segment of your engineering organization to make innovative approaches and suggestions even if few of them can be adopted; even if funds are insufficient for backup hardware approaches. Using a small amount of funds, encourage backup preliminary designs; meet with the Center engineering organization occasionally to "hear out" innovative approaches; reward by publicity or NASA awards the better and more innovative approaches; encourage innovation in other than technical areas throughout your project office. Have one or more offices that you particularly push for innovation, such as a Systems Engineering Office.

You must wear both hats so they do not conflict.

5. In-House Control

Not all of you will have this problem and there will be various degrees of control required. In fact, some of you may be seeking in-house involvement instead of worrying about control. This is obviously addressed to those who already have major in-house participation. Since it is the normal pattern of NASA Centers to play an active Center role in major projects under their cognizance, these comments should apply to the majority of cases.

In the first place, if control connotes to you a need to

suppress or stifle in-house activity, it is not so intended. A good Project Manager will welcome all of the help he can get. Ordinarily it is not possible to put in the project office all of the people needed to do the job. You have essentially three ways you can go. You can use the people you have and make the best judgment possible on each decision. You can rely more heavily on the prime contractor, or you can muster a major in-house effort to give depth to your decisions. The first two methods are generally used by the Department of Defense, with a few exceptions. NASA utilizes the third method frequently. Nothing is more comforting to a harrassed project manager than to have available the depth needed in procurement, legal matters, administration, or technical problems. It is your duty - and responsibility - to see that you have your Center depth committed to your project, in the amount you need. You can accomplish this by Center agreements, by matrix organizations, by working groups, by established contact points, by a subsystem engineering approach, by specialized assignments, by task forces, or by charisma. In any case, you must see that you have this suport as you need it.

Why then do we head the topic In-House Control? It is assumed you will find the way to get the help you need. All of NASA is dedicated to that approach. You then need to think of keeping that help in perspective. Legal and administrative assistance is seldom a control problem. Procurement help may or may not be. So much of the management of a prime contractor is procurement connected that you should give that area some thought. It is important that you obtain all of the help in that important area that you can. The locations of various procurement offices may be widely dispersed and hence require more trained personnel than you would expect to have. Unlike technical matters the procurement recommendations are usually things you can agree with provided they fit your general policy. Therefore, the main thing is to have the necessary elements of control. Either by co-location or by organizational assignments you can expect to influence procurement matters. Procurement

is one of the essential elements of Project Management; you should not be expected to manage without it.

The most difficult area of in-house control is probably technical control. This area is so widespread you cannot expect to have all involved technical people assigned to you. You should not even expect all such personnel to be subject to your direction. You are looking to them for technical integrity and you are seeking responsiveness to you. You will have more differences here than anywhere for several good reasons. One, all Center Directors are technical men and expect the project to achieve its technical goals. They will take personal interest in the technical progress and naturally will want to hear from all elements of the Center. You will exercise project control more in the technical area than any other because of the effects on costs and schedules. Such controls are repressive to someone trying to improve the project. After one is turned down a number of times, it is natural to try any channel for the changes one believes in. Also, the in-house technical organizations, getting involved more and more, and with no more people, will tend to cut corners where a contractor may not. This affects the formal drawings, the documentation, the quality control of government furnished items, and so on.

Therefore, in the technical areas you must watch for, and control, many things done in-house. You will be concerned with Center approval of technical proposals that you have turned down only because of insufficient funds. You will find strong support to add tests that will disturb your schedules. You will find a tendency to short cut in-house drawings, reports and quality. This must not happen. The Contractor and the Center organization must be treated alike - have the same type of responsibility.

How do you do this? Put yourself in the place of Center personnel trying to do their job. First, don't call them project "support" personnel. Take the necessary steps to "make them belong." Take time to hear their side. Occasionally invest a little, even if you don't see the need. You must have their

help to know when a contractor proposed change is necessary. Spend a little time and money then in protecting your investment. Review in-house work in the same manner as contractor work.

6. Subcontractor Control

A reason for mentioning subcontracts at all is that there is so little coverage of the subject anywhere in NASA documentation. If one is concerned about a related subject, control of government furnished equipment, there are procedures set up for controlling these items. For instance, 533 M, Q & P (Monthly, Quarterly and Performance) forms are set up for contracts from \$100,000 to \$500,000 and most Centers have procedures to assist in setting up such control. If you are concerned with a prime contractor's handling of subcontracts, however, very little has been written. RFP's for instance, usually just point out that subcontracting is the responsibility of the prime contractor and that make-or-buy plans involved are subject to later approval or revision by the government. At least one Center has drafted criteria for subcontracting, but since this is one layer from the prime contract, it is difficult to attempt to control.

This apparently says that NASA management has fully delegated subcontractor management to the prime contractor. In a sense, of course, this is your intent. Certainly, you want the prime contractor to feel responsible for his own subcontracts. However, as you know, a high percentage of technical, schedule and budget problems take place in subcontracts. More quality, reliability and test problems probably result from products obtained by subcontracts than by the work done directly by the primes. You cannot be just an observer on subcontracted parts. A great part of your total time eventually will be spent in this area. It is not logical to leave the subcontract area alone until it is in trouble and then become wholly involved.

What then is the right answer? First, it is a proper start to write the RFP so that the prime contractors are responsible for their subcontracts. However, it is suggested that the RFP

either contain some policy guidelines or refer to such a policy document. This is often done but usually not to a sufficient extent. Some Centers have documents concerning subcontracting which can be very useful.

The real answer, if you start it in sufficient time so as to have it ready, is to have your organization produce a planning document on subcontracting. In it you should cover all of the disciplines interested in subcontracting and state your plan for how you desire to have subcontracting handled. Recognizing it is still the prime contractor's job you are interested in, stating minimum and in some cases, maximum boundary conditions. For instance, for which items do you want certain engineering safeguards, such as specifications that would not ordinarily be covered, by having certain items produced on government or prime contractor drawing format, etc.? For quality, are there items where you need to have a government or prime contractor quality man cover the subcontractor's plant? Do you want subcontractor traceability or use of high-reliable parts specified anywhere? Concerning tests, are acceptance tests sufficient to prevent holdup of major tests later on or do you need to specify certain development or quality tests?

It is not possible to give all of the subcontracted parts the consideration described above, nor should you. However, if you describe areas where these special features must be considered, you will have taken a major step. Such considerations could cover where the state-of-the-art is being advanced significantly, where vibration or acoustic conditions are severe or where past experience gives cause for concern.

One obvious feature of this effort is that you will draw the prime contractor's attention to subcontracting - at an early phase in the project. This alone may be worth the effort. However, in addition, some real attention to detail here, by your staff, should catch some major potential problems. No major space project yet has flown without an inordinate amount of time spent trying to sort out some feature of subcontracting. This is usually made more difficult by the fact that trace-

ability or inspection, or whatever the problem, was done differently for the various subcontracted parts.

If you want to go a little further here are some features you can consider. During negotiations, review the contractor's internal procurement system against his system description and against some of the following criteria. Does he provide a focal point for planning and managing the procurement system? Does he define individuals and interfaces for his system? Is there a clear relationship of procurement with project management? Is there an identified procurement interface with other company divisions and subsidiaries? Are there procedures for initiating and following up procurement awards? Are there procedures to insure competitive awards? Is surveillance established for awarded contracts? Are subcontractors measured in areas of costs, schedules and performance? Is there a procedure for resolving problems and making changes? Are the data requirements described? Even though you may not want to prescribe criteria in all areas, a look at such criteria and some probing questions are in order.

7. Specifications

Specifications are a major concern to you and a major cost item. It is easy to say that you should give specifications early attention, but it is difficult to say just what you should do. Specifications are somewhat like documentation, but are more difficult. In both cases all of the specialists want to have as much as possible in their particular area.

The usual situation for specifications is that too many are imposed. The contractor will have engineers go over all of the specifications you list and study them. This takes funding. He will also implement all of them. This takes funding too. In both cases the amount probably could have been reduced.

There are three major reasons why the number of specifications imposed on contracts are excessive. One is that they are so discipline-oriented that specialists are permitted to impose

them in each area. Two, they are so numerous and unwieldy that they are not "combed" often enough to see if they can be reduced. And three, too often when a specification is imposed because some part of it is desired, the whole specification is listed instead of just the part desired.

Near the end of the Apollo program, the major aerospace contractors of that program were surveyed to see how costs of future space programs could be reduced. Although they were contacted individually each one listed excessive specifications as a major cost item where major reductions could be made. Although the treatment of specifications was not uniform most of the aerospace contractors studied the specifications in depth and imposed them thoroughly and carefully.

The best way to restudy the status of specifications is at the Center level. Specifications usually represent Center policy, they are applied to all Center projects and their study is time consuming and involves many people. Of course, it is better if you restudy the specifications before you negotiate a contract, but it is not too late even if the contract is under way. Therefore, if the specifications used by the Center have not been reviewed recently, perhaps you can persuade the Center to make such a study. Another method is to ask the contractor to suggest all specifications he considers too costly and perhaps unnecessary and then have your office or Center personnel review just that list. Another approach is to appoint a small task force to study the specifications in a few of the disciplines to see if there is a problem. Lastly, of course, you can ask your own discipline oriented staff to review the specifications in their own area; however, this approach is generally less satisfactory.

As in most areas, the fact that you are interested in this subject will have a rewarding effect. Government and industry personnel will then take an interest in the project specifications and surface some of the problems. This discussion has been oriented to the situation where the specifications imposed are too numerous. In general, this is the case. Hopefully,

however, any review will uncover important omissions also.

8. Make-or-Buy Criteria

The make-or-buy planning is mentioned here in order to bring it to your attention early. The standard RFP "boilerplate" will require that the contractor submit his make-or-buy plan to the government, and it will also inform him that the government may require revisions to his plan. Often that is all that is said on the subject and generally you will be so busy that you won't even think of make-or-buy considerations until much later.

In general, after insuring that the contractor uses standard GFE items wherever possible, the breakdown of "make-or-buy" is left to the contractor. However, there are considerations which may cause government interest in the plan. Sometimes, the lack of early consideration of the make-or-buy plan causes problems later. You may be concerned about the contractor's ability in some area and desire that he have certain work done out-of-house. You may be concerned about the percentage of work that he does in-house. Small business considerations may cause you to want to increase the efforts in those areas. You may have critical parts that you want the prime contractor to design and build himself. The prime contractor may be improving the corporation role by placing major work in other corporate locations by Interdepartmental Work Authorization (IDWA) when you are concerned over their ability to produce. You may have any number of other special considerations which will affect how the make-or-buy plan is constructed.

There are any number of ways you can explore, or have explored for you, the make-or-buy considerations for your project. Assuming it is not the sort of thing you want to put a great deal of time on, a suggested approach is a short brain-storming session. You can lead, or you can have led, a session with a small select group of personnel from your office or throughout the Center. You are simply interested in any items that affect

the make-or-buy plans for your project.

It may help you in assessing "make-or-buy" to review briefly how the contractor approaches the subject. The make-or-buy plan includes major components, assemblies, items adding up to a large dollar value, data, or services. To the contractor it is divided into two parts - the plan required by the contract to be submitted to the government and a plan for all other items required. The contractor realizes the customer is interested in using standard GFE, using existing sources, maintaining true source competition and having a broad distribution of procurement. He, in addition, is interested in his competitive position, in maintaining a labor base, in preserving technical skills and in balancing his capital investment program.

Ahead of time he will have a general preplan, broken down by such headings as: solar arrays, batteries, inverters, regulators, cabling, computing and sequencing, auto pilot, inertial reference, and so on through all possible subsystems. These will be listed as "make" or "buy" or possibly "to develop a capability." Unless some of the considerations in the above paragraph prevail, he knows in general what he should make or buy. However, since a company's viability and future growth are strongly influenced by its capability to design and produce internally those elements which represent the bulk of its sales, you should expect a strong interest in doing work in-house.

9. Costs Not Directly Related to the Project

All revenue sources for the Center, such as your project, are subject to outside "taxes" or at least requests for support. These include such items as TU (Technology Utilization), support of advertising activities of the Public Affairs Office, furnishing Project hardware to museums, etc., and Center basic and supporting research programs. One should not automatically subscribe to all of these items nor should one adopt the atti-

tude that all such requests are unreasonable since your project is underfunded anyway.

Probably the wrong way to handle such items is to just let them happen and settle each as it occurs. If you just had a budget review you would probably turn down any item requested that day, and if you had a good test you might approve the next request. One good approach is to develop your own basic policy to all such items and then appoint someone in your office, part time, to handle all such items within the policy. This works best when the person designated is from your immediate office, such as an "assistant to" or "executive assistant." He should list at the beginning how many such items you expect to affect your project and then treat each one within your policy. This should result in recommendations back to you which will permit planning early in the life of the project. It should also cause all offices affected to realize that they were treated fairly compared to others and within a planned policy.

A related item, somewhat in reverse, is the contractor's use of IR&D funds. Do you have advanced state-of-the-art developments in your project where he might be persuaded to apply his IR&D funds? This could apply in particular to portions of your project where the contracts are not yet determined or negotiated.

10. Parts Lists

There are a number of parts lists involved in NASA developments. These include "Hi-Rel" (High Reliability) parts, qualified parts lists, standardized parts lists, previously developed parts list, and even previously proven subsystems. You should think out your approach to these various lists. Some, like the "Hi-Rel," can be expensive to use if we over specify such parts for all uses. Most of the other lists have been compiled with a cost savings in mind. It is good business to utilize qualified parts, where possible, instead of redesigning and requalifying new parts of each requirement. The usual comment by design

engineers is that "such and such" an approach would be better. This is usually true. However, in these days of less funding and greater experience, you must ask yourself if the better approach is necessary. Considerable savings can be realized by restricting "hi-rel" parts use, and by using all qualified parts (or subsystems) which will satisfy your requirements - even if they aren't the best. Many parts are selected because of the requirements in the reliability section of the performance specification, so whatever you do starts there.

Probably you will want to establish your own policy first. Most Centers have policies in these areas, so these need to be checked first. Once you have an overall policy you will need to make your contractor aware of it. Since costs are affected this should really be done in the RFP and part I of the specifications. This is particularly true if your approach is a significant departure from the approach the contractor would be expected to take. For any refinements after the RFP, it is a good approach to give the contractor your views in a letter, telling him why you have taken this approach and suggest it to him without directing it. This general approach to contractor direction is recommended in many areas and can save money on directed changes. With an official letter he must give the suggestion serious thought.

The last thing you have to insure is that your own project office and the Center engineering, quality, etc., groups understand the approach on parts. These groups not only may be working in a different direction, they have considerable influence at various contractor levels. Certainly the contractor should not feel the influence of more than one policy.

Most of the contractors have complete guidelines for parts programs and for preparing preferred parts lists since NASA projects are all low-volume, high-reliability projects. They can go as far as your reliability and performance specifications dictate. Since electrical parts alone on a large project will number over a hundred thousand parts, you must go far enough, and not too far. The contractors will impose controls

on design, incoming parts, fabrication, and subcontracting. A good program trades off schedules, mission profiles, environmental conditions, and cost of implementing and maintaining the program. They must consider such items as preferred parts lists, parts specification, quality assurance, parts surveillance inspection, failure analyses, handling, stocking, vendor monitoring, and screening. You will want to be sure that once you have set all of that machinery in motion, it is to the proper depth.

The Air Force encourages use of a QPL (qualified parts list) by eliminating many requirements for identification, for FACI, for test reports, and for other reports. This program is successful and their qualified parts are used to avoid new development. In March 1964 NASA studied the problem with a view to centralizing these activities, standardizing terminology and participating with other agencies. The DOD-NASA programs which resulted from this included IDEP on data exchange and FARADA on failure rates. Electronic Component Research Center (ECRC), Batelle's electronic parts program was also studied by NASA. These show the need and NASA interest in improving NASA's use of parts lists, but these efforts were too bulky, time consuming and hard to keep up to date to impose in contracts. NASA continued to recognize the need to utilize proven parts for expected conditions.

One last related item is commonality. This is a simple word, but it can involve everything from using the same transistors throughout the project to using the same booster for related projects. The advantages of a commonality program range beyond development cost savings. They include reduced stock of spare parts, less training required, simpler maintenance, fewer interfaces, etc. It is worthy of your consideration.

11. Packaging and Transporting

Obviously this is not as large an item as some we have discussed. It was an item of greater impact in the Armed Forces

where large quantities of items were packed, preserved, shipped long distance and subjected to a difficult environment. Because NASA has a lesser problem, we sometimes fail to give it sufficient thought.

You need to think out ahead of time the major transportation routes of the larger items to be shipped. If accomplished early much can be done. You can arrange rerouting. You can ship before some part is assembled if it causes removal of poles, lines, etc. You can sometimes make some redesign if your present design doesn't fit the better form of transportation, i.e., the Guppy, truck vans, railcars, etc. Sometimes a little different arrangement in what is to be assembled at the test or launch site can cause major savings in shipping requirements.

Packaging can present a similar situation. If not pre-planned the status of the project hardware can require elaborate containers having shock conditioning, temperature and humidity control, pressurization capability and so on. In some cases the whole transporter, such as the Guppy, may have to have these severe environmental capabilities.

The essence of the above is that the criticality of the design of your project and the limitations on time can easily force you into situations where you pay an excessive price for shipping. One feature that sometimes complicates this situation is the contract itself. From a sheer manpower point of view most design considerations are initiated by the contractor. Many NASA contracts are written so that the government has major transportation responsibilities. These situations make it particularly incumbent upon you to initiate the proper action in a timely manner.

There are many ways you can initiate a proper action. One good way would be to have your staff office which is concerned with logistics, initiate a survey of the entire transportation area. To be effective this must be accomplished in time to influence the contractor's preliminary design. Along with the survey you should require your logistics office to develop a transportation plan. Thus they would study the project, obtain

a preliminary feel for size, weight and environmental conditions and begin to develop a plan for the best way to transport the necessary items. If this is started in time proper trade offs between design and transportation can be made as the design progresses. Your staff would have to involve the contractor's, thus getting them to think about the problems at an early date.

12. What Level to Track and Control

The next several subheadings involve control. Much of your job as a manager involves control. It is a subject that all management textbook writers devote considerable attention to. As portrayed there you write a good plan and you control to the plan. This is true. There are some other features of control that should be mentioned, however.

As described in formal instruction, a good plan stimulates good control. Also, a good management information system, as discussed in Chapter IV, contributes greatly to proper control. One of the things that occurs if the above items are not handled carefully is uneven tracking and control. You will find sometimes that you are tracking one piece of hardware to a lower level than another or that you are tracking quality tests lower than development test or other such inequities. More aggressive staff or line managers can further contribute to unbalanced tracking and control.

There are other features that help determine the depth of tracking and control. The type of contract and the responsibility given to the contractor have a great deal to do with the depth of tracking and control. How you are organized and backed up by the Center organization affects your approach. You do not want more information to see or controls to manage than you have organization to apply to it.

Another consideration is what is critical to your particular project. It is quite possible that you know at the beginning that schedules or a piece of hardware or a particular test will have problems and you want your depth there to be in more detail than elsewhere.

All of this must be satisfied by your method of control. Sayles and Chandler in their "Managing Large Systems" which is a text based on their observations of NASA management, state the following, "Control systems designed to encourage excellence of performance are a key management tool." "What kind of excellence-inducing control system does the multiorganization want to develop? What should be the major sources of control over organizations participating in the program." "One thing is certain, the managerial control solution cannot be a simple one." "A top manager of a large-scale system is continuously seeking a means of identifying problems as they first arise. To achieve this goal a pressure system must be devised that will correct significant errors and prevent major distortions from arising." ³⁰

This view from one text was stated here so as to emphasize both the importance of control and the importance of controlling properly. Few managers can accomplish all features of management properly, but the work should be done so that the control function operates by itself - or enough so - that you, the manager, can focus on other forward looking aspects of the task. This includes many things. It means your management information system must function, and we will come back to that. It means your change control must be thorough and smooth. It means your organization must run smoothly, as a team and with esprit. It also means your relations with your contractor must be on a sound basis.

If the above exists, and partly to help it exist, you must think about your controls early. How much control is mechanized and how much is by people? How deep do you want to control and where do you want to control deeper? What system of reviews must check the control you desire? How do you want status and variation reported? One suggestion; insofar as you feel you are well organized, do not have your controls set too deep. Don't have you and your staff inundated with paper and reports. Give the contractor and your staff room to operate. On the other hand, by either personal means or a well designed manage-

ment information system, occasionally explore an item in great depth. This lets you understand organizations and the status of your project in some detail. It also keeps all organizations "on their toes" if they know you, the manager, may pursue any problem or activity in fine detail.

13. Weight, Performance and Schedule Control

The items listed in this subject probably don't even have to be mentioned. They are the heart of any NASA project. Except for costs which will be discussed later, if weight, performance and schedule are under control, the project is probably under control. The purpose of listing these now is to let you think of these items collectively for a moment and be sure that they are all considered and in context. A good way to maintain the monitoring of these items is by trend analysis.

Weight and performance tend to work against each other. To increase your performance you will probably need more weight. To take weight out of your project you will find it difficult to do without affecting the performance. The sequel to this comment is that if you have a weight problem, but no problem with performance, or vice versa, you had better think of both variables from the beginning. If one of them is in trouble, it is probable that the other eventually will be affected.

In measuring overall performance today, we tend to use the Work Breakdown Structure. With the whole project divided into small measurable tasks, it is easy to lose sight of a weight problem or a performance problem as we use it here. Concerning performance, if you are building something like a rocket engine the resultant performance is so much a part of the end product that it is obvious what you are measuring. If you are building a launch vehicle, or a communications satellite, or an earth resources satellite, or some other advancement to the state-of-the-art, it is true you will have

specifications expressing minimum or target requirements for such things as range, accuracy, capacity, etc. Invariably, however, the need for greater and greater performance increases as the development progresses. This can be very disruptive to a project in late stages. Also, it will be costly to increase performance or decrease weight if they are not accounted for in the original contract.

You should examine your project early, preferably before the RFP to see if you believe there is any possibility of a problem or an increased requirement in these areas. If there is, you need to have weight and performance controls. You will probably need to combine these with incentive features in the contract. These areas should be reported on and tracked carefully even before there is a problem.

Schedules also are accounted for in the Work Breakdown Structure. Usually there is a very complete treatment of schedules. Since schedules are a red flag alert to all kinds of problems, they are of particular interest to you. If you now track weight and performance specifically and separately, you must be sure your schedule tracking alerts you to problems or potential problems in these areas. If these new items do modify your WBS, it is probably that you also need to add certain schedules to your master schedule list.

14. Computer Control

This is a somewhat different type of control to discuss right after items that are made part of a plan, to track and control. The type of control we have in mind here will no doubt require tracking, but the control is more in the sense of not letting an essential element of a project get out of hand.

Computers are here to stay, and properly utilized are vital to the project. A difficulty with computers is that it is an item handled by specialists. As such it is difficult for a manager, talking through layers of people to fully understand the requirement for computers. Also, there is a natural in-

clination of the specialist to need the latest generation of computers and to need computers of large size and in large numbers. In addition, a prime contractor may have a tendency to a very large computer capacity. If you are tightly controlling his manpower and not controlling his computer capacity, he can, to a degree, trade manpower for computer time. Both in-house and at a contractor plant, each new project can serve as a requirement for new computers.

You do not want to sell yourself short on computers, but you need to know what your contract says about computer time, preferably before it is written. You need to know what in-house capacity you are supporting. You need to know how much computer time you really need and what type computers you need time on. Used indiscriminately computers are very expensive.

It is suggested that you have one of your staff develop a computer usage plan which answers the above questions. Unless you are a computer expert it is suggested you ask for a comparison of computer usage for projects similar to yours. As before, an early interest and a few correct early steps taken by you will cause everyone to realize you are interested in running this aspect of the project in a businesslike manner.

15. Communications Control

Unlike some of the previous discussions this particular subject is probably as concerned with too little as too much. In fact, you are more likely to underplan your communications than to overplan them. In this discussion we are not talking of the communications links that may be connected with your project after launch. We are discussing the communications you require with your contractors, with your own remote offices, with your supervisors, and with any others connected with your project.

Usually the types of communications we are discussing are not planned. Occasionally when they are, they include several telephone lines, TWX circuits, hot line circuits, even televi-

sion links - to the extent that they can be overdone and prohibitively expensive. This is not usually the case. Usually a little more thought on improving project communications is money well spent. Good communications are a key to a good project. From the Office of the President of the United States on down there is constant concern that everyone who needs to be informed, is informed. Because any communications you install may appear to be an added luxury item, there is a tendency to consistently underplan project communications. Also since telephones and review meetings already exist there is a feeling that nothing else is really needed.

Good communications should be a feature of your good management. It is not enough to simply have a means of communicating if the need arises. The need is constant and one needs to have means that facilitate usage. One should not only consider communications to your key government and contractor people but also should insure that information flows to the many levels concerned, that horizontal communications exists, that it flows up as well as down. This takes some planning.

You should have a layout of all who need to have direction from you and of the flow onward from each of them. If special telephones or TWX's are needed, and the project can possibly afford them, then they should be provided. You should determine what it takes to facilitate information flow. It seldom happens by itself. You should consider what means other than mechanized means can assist your communications. These can include reports, meeting, oral presentations, verbal direction, etc. Do not add means of communications that you do not intend to use. However, if you use it - so more information flows - it is probably worth the cost.

16. Failure Investigations

The next several subheadings will mention a number of items which generally are concerned with the time frame after development and during testing. They can be brief and serve only as reminders. The first of these is failure investigations. The need here is to have a system ready. Usually there isn't time after a failure to do all of the investigation planning properly if you have not considered it beforehand.

Your Center or the launch or test site may have procedures already in being for major failures. If so, all you will have to do is be familiar with them so that you can determine ahead of time how your organization may be involved. However, such procedures may not exist. In any case, there will be a level below which you will want investigations conducted where no plans exist. This is particularly true for moderate cost items still under contractor control.

The simplest procedure is to preappoint an investigative board, with alternates, and write enough procedures to state what they are to do, how to report, etc. If you prefer you can just write procedures and enlarge on them enough to cover the appointment of the board also. In any case, if you become pressed for time you will be glad to have a way to proceed all ready when the need arises - for all types of accidents or failures.

17. Amount of Flight Data

Again, it would not seem that you would be surprised at considering this item. Decisions on the amount of flight data are a normal part of Project Management. Let this just remind you to make these determinations in an orderly way. Often a stab is taken at just how much flight (or test) data is required when early project design is underway. As time goes on this is broken down by the system to be used (FM-FM telemetry, etc.) and finally continuous and multiplexed channels are determined. What is available then is divided among

those requesting data. Considering this problem as a system problem at the beginning often can help the decision making in this area. Is project development telemetry to be traded off with project data transmission? Are there new development systems that will require more data than other areas? Do you have enough telemetry throughout the flight hardware to have a good chance of determining a failure in any area? Are you transmitting large amounts of data in some areas out of habit when the data could be reduced?

Nothing is worse than having to add to your data system at the last minute in order to solve urgent requirements. Major rearrangement is nearly as bad. Early system planning for data use can do much to solve these problems.

18. Tracking and Data Acquisition

Related to the amount of data transmitted is the requirement for tracking and data acquisition. There are five major test ranges in the United States and documents are available for each describing facilities, procedures, and tracking equipment. Fitting your project to the range involved can simplify your development. If per chance you are not familiar with the test range you will be using, you should visit it enough to be thoroughly familiar with it. Also, all NASA satellite tracking is the responsibility of Goddard Space Flight Center and the deep space network is the responsibility of The Jet Propulsion Laboratory. Knowing their capabilities and requirements is vital. NASA's Office of Tracking and Data Acquisition has overall responsibility in these areas. One thing you can conclude from these comments is that if you have very extensive tracking data requirements you will be involved with a number of interfaces and some different planning and requirements documents.

Three of the most pertinent comments you can consider in these areas are: Thoroughly familiarize yourself with the people and equipment concerned with your test sites or ranges.

Insofar as possible, design your project to fit the equipment at the test site or range, since the sponsor of new requirements will bear heavy costs. Keep your requirements only to those needed, since activating tracking areas or ranges is a high cost item.

19. Planning for Flight Hardware

You will have put a lot of effort into your flight hardware. Be sure you protect your investment while the flight hardware is being transported and while it is at a launch site. It has been mentioned earlier that there are major savings possible in designing to the best means of transportation. There are savings too in taking care of the completed hardware.

Some of the obvious concerns are the provision of safeguards for the environment, i.e., shock, pressure, temperature, humidity, etc. These items must be provided for in transit and while in storage or preparation at the launch or test site. As in most things, if these provisions are provided hastily when needed they are costly and makeshift. Incomplete preparations for any aspect of environmental protection can produce serious consequences.

An even greater hazard to flight hardware may be the numerous interfaces the hardware may encounter. When hardware moves it encounters many new interfaces - changes in government or contractor organizations for transportation, new receiving personnel, new storage personnel, new engineering and quality organizations, new test and checkout personnel, etc. This at least requires careful planning. If you have a complex project and it experiences environmental and interface problems of any magnitude, during this period, one suggestion is worth considering. It may be worthwhile to assign a project engineer to each piece of flight hardware to travel with it. So many unforeseen problems can occur that this precaution may save time and dollars.

20. Launch Vehicle

The launch vehicle can have many relationships to the development project, from where it is an integral part of a project, such as in Apollo, to where it is mass produced by a different organization and even launched by an outside agency. When it is highly involved with the project, no further comments are required. It will be a major part of your total development effort. When it is furnished as a standard, proven item, don't take too much for granted.

Each launch vehicle presents its own gambit of problems. You will no doubt have considered its own peculiar environmental conditions during launch. It will also have some mechanical and electrical interface requirements for the spacecraft which must be preplanned. Sometimes a launch vehicle imposes restriction on checkout such as on radiation of certain frequencies, launch direction, accessibility, gantry availability, control center requirements, and so on. One of the biggest considerations is that the launch vehicle will determine the exact launch area. You will have to adapt to the launch pad and control area that fits the particular launch vehicle.

Many projects set up a launch operation or operations staff office. There are so many things such as this and the other previous items which they can watch out for, that this may be worthwhile. In any event there is planning for someone to do.

21. Contractor Organizational Phasing

This series of decision making topics can also be covered briefly. These topics are administrative or organizational in nature. The first item to consider is the organizational phasing of your contractor. The same thoughts probably could apply to your own office, but since your personnel are not a major contract cost item we will address the contractor personnel.

There are several facts one can start with. The heaviest requirement for contractor personnel is early in the project so

the contractor organization at the beginning will be complex and the staffing heavy. Later in the project schedule, the organization should be simplified and the staffing reduced. Most contracts rely heavily on cost control, by incentives or other methods, and thus depend on costs to reduce manpower as required. Manpower is by far the most expensive item in your project.

Contractor manpower phasing may work very well if left to incentives and cost control, but it may not. It may not be convenient for a contractor to lay off a large percentage of his work force at a particular time for reasons which are peculiar to his own situation. For instance, if he is expecting the award of a new project which will require in six months the manpower now on your project, it may be better business for him to retain these personnel on your project, even if some incentive fee is lost. This situation may or may not be to your best interest or to the government's best interest.

As in each instance you must think of your early planning in this area. However, there are a few thoughts worthy of consideration on this subject. It is necessary that you track manpower very closely and that you understand even the smallest deviations from plan. For instance, a small upturn in manpower may be explained to you as just the coincidence of many of the contractor personnel returning from vacation at one time - or the effect of a five week month. If such is the case - fine, but be sure. One, the contractor planning is usually too good to miss coincidences such as these and, two, if this is not the case your problem will be out of hand by the time you get another periodic manpower report.

Another thought is to be aware of the environment affecting your contractor. Is he bidding on several new projects? Is his "other business" financially sound now? Is he subject to having a project terminated which could dump a number of people? A final thought is that you should try to develop the relationship with your contractor where perturbations like this, without warning, do not occur. It is seldom company policy to

keep you in the dark. His only reason for not telling you things is his concern that you might stop him from doing what he thinks he has to do. If you develop a relationship with him that insures fair treatment both ways, you both usually profit by avoiding surprises. Frankly, also, if you make an honest attempt at such a relationship and if you make it clear you will not tolerate such situations you are in a position, after one surprise, to see that it doesn't happen again.

22. Contractor Key Personnel

An item closely related to the previous item is the understanding you have with the contractor on changes to his key personnel. It is inevitable that there will be a number of changes in contractor personnel who are critical to your project, during the life of the project. You have to be concerned with the extent and timing of these changes.

The best possible answer is to have proposed changes presented for your agreement prior to implementation. Then proposed changes can be negotiated into the contract as prepriced options which may be experienced by the government at a later date. Unless this is specifically required by the contract, it is seldom done. The solution usually tried by a government project manager, after a surprise or two, is to achieve a relationship with his industry counterpart which prevents surprises. This is worth doing, but since everyone knows the situation, it is easily circumvented by the company surprising your industry counterpart, too.

Both government and industry have requirements on key personnel which sometimes conflict. You require that sufficient, capable engineers and managers remain with your project until it is properly and economically developed on time. The contractor must see that his assets are assigned most effectively to the tasks he has to do. However, he does have additional responsibility regarding existing projects which are working satisfactorily.

You both need to recognize each others problems. In your case you should not be overly demanding in your requirements of him. For instance, it would not be proper to insist on knowing of every personnel change he makes or every shift of personnel. One good approach would be to select, say four or five persons who you consider vital to the project and request that you be notified prior to any planned reassignment. You might do the same for any shift of personnel more than some set amount. For other changes you could ask to be notified as they are accomplished.

You note that the above wording said "request." Direction is probably not required. Since it is a request it should be done in writing, possibly by a contract letter. This will permit forwarding it to proper company officials. Also as a request no one should take issue with it. On the other hand, it does not help a company's record and files to ignore it. Experience has shown that it will be honored.

23. Committees

Any text will tell you that the use of committees is both good and bad. Committees are an organizational concept, such as line and staff organizations. They can be permanent or temporary. The principal advantage of a committee is that it permits an interchange of ideas and a judicious deliberation on problems too broad or too difficult or too important for any one individual. The disadvantages include the diffusion of responsibility, the fact the decision process is common to all members and, hence, maybe not the best, and the fact committees can delay and suppress any action.

If committees are used to avoid making a personal decision, obviously they are not an asset. If one recognizes their strong point and limitations and utilizes them properly they can be very useful. If not managed they are a costly approach; however they permit you to control use of other organizations. They let you combine government and contractor thinking. They permit bringing great expertise to bear on a problem. An outgrowth of

the committee is a task force. It usually has the advantage of being time limited.

It is suggested that your use of committees is a good thing - if you take precautions. Write out what it is supposed to accomplish. Pick the chairman and members carefully. Instruct the chairman as to what you want done. State how the conclusions and recommendations are to be presented. If necessary, put boundaries on the conclusions to be reached. State the time duration of committee operation .

24. Project Design Reviews

Reviews, like reports discussed previously, can be overwhelming. Much of what was given on reports control could apply to reviews control. Yet reviews are vital. They are the way to stay current. They are the means of applying your personal touch. They are the means of probing in depth as required. You should not just let reviews accumulate indiscriminately. Look over the possibilities and decide from the beginning what reviews you desire.

Some of the types of reviews now used by NASA include:

- Administrator Reviews
- Associate Administrator Reviews
- Center Project Reviews
- Project Plan Reviews
- Work Statement and Specification Reviews
- Preliminary Design Review
- Critical Design Review
- First Article Configuration Inspection
- Final Systems Review
- Prelaunch and Postlaunch Review
- Flight Readiness Review
- PERT Review
- SARP Review
- Coordination Committee Review
- Monthly or Bimonthly Contractor Review

Customer Acceptance Readiness Review
Design Certification Review
Delta Reviews
Operations Reviews
Specific Problem Reviews
Management Reviews
Periodic Technical Reviews
Subcontractor Reviews
Configuration Reviews
Periodic Project Reviews
R&QA Review
Safety Review

There are other reviews, but the above cross section shows that many reviews can exist and that they must be laid out carefully to accomplish your particular needs. Preparation of and conducting reviews is expensive, but usually money well spent. They should be carefully thought out in two respects. You should decide just what reviews you want to have and you should decide just what material should be presented in each type of review so that you have coverage without repetition. There are other decisions. Which reviews will be held at the contractors' plant? What level of speakers do you desire? Which reviews should just precede your briefings of higher headquarters so as to provide material? What attendance do you desire for each review, particularly where travel is required? Should you invite upper levels of management to reviews at your level?

25. Visits to Contractors

A seemingly minor item that has at times been trouble is visits to contractors' plants. A number of people have a need to see the hardware and contractor personnel firsthand. These usually are various levels of government personnel and other contractors involved in the project at a similar level. A good way to accomplish this is to conduct some reviews at the plant so that these visits can be made at a few controlled times.

It may not be necessary to totally control visits to the contractor's plant but if uncontrolled visits are overdone there are a number of effects. One is that certain key government personnel can "tie up" a number of contractor personnel who are obligated to meet their requests. This on any scale can be expensive and delay your project. Another problem is the effect of the visit of a number of technical personnel. It is true that all changes must go through a change control board and that technical design is accomplished by the contractor, but government technical personnel can perturb this process in a variety of ways if you allow it. Another problem is nontechnical policy and direction. You should be the only source of direction. If various levels of government management are in the hallway of the plant, it is inevitable that there will be confusion on just what certain policy or direction is.

26. Travel and Overtime

Items such as travel and overtime are often treated as purely administrative, but are in fact considerably more important than that. For one thing if travel and particularly overtime are consistently running at a high rate the items are expensive. Also if they run consistently higher than planned, there is something wrong with the project or the contract. The contractor did not bid on the contract on the basis of doing it on overtime. If this is the case you will want to find out why and no doubt stop it. The same thing applies to any in-house government work that you may be supporting for your project. In fact the in-house work often requires more control on these items than the contractor.

You should expect a reasonable amount of travel both in-house and by the contractor. Also it is seldom worthwhile initially at least to control travel to too low a level. However, it is suggested you establish policies by department; engineering, manufacturing, etc., according to your own situation. You may, for instance, desire that engineering not

average over five percent overtime in any quarter. Additional overtime beyond that policy may require some particular approval. Then you should have overtime and travel tracked, just in the context of your policy. The figure given may not be the right one for your project, but a consistently high figure usually requires some action.

27. Unsolicited Proposals

This is a small but interesting item. One usually thinks of proposals as being for major new projects. They can be. They can be for add-ons to your project and they can be for changes to your project. You are aware that these proposals can be a product of the projects engineering organizations or they can be a new projects group charged directly to your project. As such the proposals coming from these organizations may result in appreciable cost.

The other side of the question, however, is whether you desire such proposals or whether you do not. Some circumstances lend themselves to one approach or the other. For instance, if your project is the type that an advanced follow-on version is a natural thing you may desire to have someone working on it. If you are having difficulty with some advanced aspect of your project, such as the discrimination by earth resources equipment, you may want someone working on better approaches. On the other hand, for instance, if the technical group you have evaluating such proposals is working too closely with the contractor group making the proposal you may want to discourage submission of proposals. It is probably sufficient to be aware of the possibilities, observe your own situation, and act if required.

28. Ethics

The engineer is oriented to a world where facts are facts until proven otherwise. Ethics is concerned with the world of values and principles of human conduct. The practice of ethics

is one of the social responsibilities of managers. It is a problem of universal concern. Unethical conduct is highly publicized wherever it is found. Yet it is a problem which is very difficult to get hold of because there is not yet a science of ethics having generally accepted principles.

The question of what is right and what is wrong is subjective at best. The answers are not scientific but are based on good intent. There are relationships of ethics to morals, but they are not the same. Therefore, no one yet has written out successfully a set of ethical codes for NASA or any other agency. Boundaries are somewhat understood but you must set your own approach.

The President of Rotary International suggested four guides. Ask yourself:

Is it truth?

Is it fair to all concerned?

Will it build good will?

Will it be beneficial to all concerned?

Using whatever approach you like you must consider your professional life, the public, your employers, fellow engineers, and your contractors. It is suggested you set some maximums and let them be known to your office. Is dinner with your contractor all right? Every week? Can you accept a commemorative metal depicting your project? Made of gold? Remember this is important also because you are showing the way to those who work for you.

CHAPTER VIII

LOW COST APPROACH

This is the final chapter, and it seems appropriate to discuss doing NASA projects for less. Costs were discussed in Chapter VI, but that was in the context of cost control and cost accounting. Here we are looking at the history of rising costs, the history of some overruns and the stabilized or somewhat lower NASA budget and asking ourselves how we can contribute toward doing projects at a lower overall cost.

This general subject is of sufficient concern to NASA that a Low Cost Evaluation Project was set up by the NASA Administrator in May of 1972. The NASA Deputy Administrator has repeatedly sought to reduce the cost of NASA projects and has stated, "If we don't do something about the high cost of doing business in space, and do it soon, our nations space program is in deep trouble. If we don't find a way to do more for our money, we may lose our hard-won worldwide leadership in space." This warning is well timed and we should all heed it. Perhaps the best way to start is to list the eleven cost principles given by the NASA Deputy Administrator:

1. Don't reinvent the wheel. Use the best that is available from other programs.
2. Standardize - Including parts, components, modules, to subsystems and entire systems.
3. Design for low cost. Involves production engineering in the earliest stages of design.
4. Design to minimize testing and paperwork. Take advantage of reduced weight and volume constraints and use standard parts, larger margins and larger safety factors.

5. Recognize that different systems can accept differing degrees of risk. Where possible, the cost of a system should reflect the acceptance of risk.
6. Know your costs. Accurate cost estimating must be developed.
7. Trade features for cost. Consider requirements as goals.
8. Pay particular attention to the few very high cost items.
9. Know your costs before you start. The most fundamental of all requirements.
10. Set firm cost targets. Desire for the lowest possible cost is not a good approach.
11. Meet the established cost targets. Find ways to meet targets, no matter what happens.

These are excellent principles, subtle in places, and well thought out. If you understand and implement these eleven principles alone, you will be taking major strides toward low cost.

The efforts of the Low Cost Evaluation Project, referred to above, will not affect current projects such as Shuttle as much as they are expected to affect payloads for Shuttle and other later projects. Reducing these costs will be a necessity if NASA is to fly the number of payloads it will have the capability of handling. The principal product of the low cost project thus far is possibly two things: First, a determination to sacrifice some performance and utilize the Shuttle payload capacity or design approaches necessary to avoid tight margins. Second, to issue a catalog of standardized subsystems for future spacecraft housekeeping functions. These subsystems then would reduce new developments and emphasize reliability. This catalog will emphasize subsystems such as in power, communications, propulsion, guidance, navigation, telemetry, attitude control, data processing, environmental control, etc. These approaches are fundamental and should effect cost savings. It will be necessary to do much more if NASA is to move on as it should. The cost project has studied a number of other approaches.

Low cost projects are somewhat the result of various individual approaches by cost conscious managers. It's an awareness, an attitude and a drive. Possibly everything that

works for one will not work for another. However, if you consider enough approaches used by others, some may appeal to you and, hence, may help. The most useful one of all is to make clear your intent and policy. If your decisions overlook cost, everyone will notice and you cannot expect an effort to reduce costs by others. If you are truly intent on making your project a low cost one, then in addition to the comments above by the Deputy NASA Administrator it will be useful to list for you some low cost ideas that have derived from studies by the Low Cost Evaluation Project and some others developed by industry. These suggestions do not necessarily have status, but are some of the products of the efforts of these groups.

Some of the work done by the Low Cost Evaluation Project was intended for management levels above yours. However, in all cases it is useful to know the actions suggested for those levels and in most cases you can play an active part in helping to realize these objectives. Some items that fall into that category include:

1. Establish realistic program plans for the agency.
2. Assure that each program is well defined and accurately estimated before Phase C or even Phase B.
3. Set realistic flight dates.
4. Insist on a low cost approach.
5. Require a risk analysis before Phase C.
6. When budgets are cut eliminate line items instead of deoptimizing all programs.
7. Push parts standardization.
8. Push for more NASA participation in overhead negotiations.
9. Establish a policy for trading risk and cost.
10. Assign resources to the low cost programs.
11. Minimize interfaces in assigning missions for each program.
12. Make firm budgets a policy - cut programs to fit budgets.
13. Avoid dead end projects.
14. Establish minimum requirements for data.
15. Resist changes.
16. Establish and pursue an employee cost consciousness program.

17. Improve cost estimating and risk assessment techniques.
18. Develop a program which prepares engineers for project management to include a cost management capability.
19. Insure that low costs and realistic estimates are emphasized in the contractor selection process.
20. Insure that standarization and off the shelf utilization is a requirement for Phase B.
21. Insure that cost improvement and risk analysis are requirements for Phase B.
22. Insist on a policy of effective management tools to control cost and risk.
23. Perform studies and initiate programs on uses of standardized parts.
24. Consider the use of value engineering and other existing assurance programs.
25. Provide training which will contribute to cost effective projects.

As you can see, many of the things that upper management can consider are also within your pervue. Attempting not to repeat too many items there are also some items that more specifically fall just to your own consideration:

1. Use risk, cost, performance analyses on important trade off studies.
2. Assure that everyone in your project understands that you want lowest cost at an acceptable risk.
3. Have acceptable risk defined for each system and subsystem.
4. Be sure your test programs consider already qualified parts.
5. Minimize and simplify all project interfaces - both people and hardware.
6. Use extra weight or space where possible to simplify testing or design.
7. Minimize nonflight hardware and standardize it where possible.
8. Ship test hardware where possible to reduce number of sets.
9. Have crews travel with hardware where possible and avoid multiple shifts, for continuity.

10. Reduce presentations, meeting, etc.
11. Make an experimenter more responsible for the performance of his equipment.
12. Don't assume the contractors responsibility at first trouble.
13. Negotiate a contract where small changes are in the base price to avoid paperwork.
14. Use incentives and awards for low cost approaches.
15. Eliminate new technology where possible.
16. Provide leadership and motivate participants to low cost.
17. Find ways to utilize the Work Breakdown Structure as a tool to control costs.
18. Validate the contractors approach before any trouble occurs.
19. Know your requirements.
20. Understand your costs in detail.

Again, many of the items listed above apply to the contractor as much as they do to you, or the Center, or NASA Headquarters. There are some items the contractor should specifically consider, however:

1. Identify problems early and surface them for all to see.
2. Shorten communication lines.
3. Utilize existing inventories, GSE, facilities, etc.
4. Restrict changes to make-work.
5. Concentrate on improving cost estimates and related management practices.
6. Keep layers of management to as few as possible.
7. Continuously review requirements for validity and effectiveness.
8. Select proven vendors.
9. Use a simple but complete drawing release system.
10. Be willing to chance some understaffing.
11. Discuss requirements causing heavy staffing.
12. Be willing to staff down.

There are of course many other suggestions which will fit all or some layers of project management. If these suggestions get you to thinking how you can be cost conscious they will have served their purpose. When one thinks about how to reduce costs, responsible suggestions do not differ that much in approach. It

is the execution that is different. To show the similarity, just different phrasing, listed below is a set of suggestions on cost savings developed by a prime contractor:

Management

1. Use small co-located project teams.
2. Shorten project schedule as much as practical.
3. Stay on schedule.
4. Optimize funding curve for project.
5. Control changes.
6. Keep same customer and contractor key people throughout project life.
7. Reduce layers of management.
8. Perform good planning.
9. Make detailed cost assessments.
10. Make all personnel aware of cost savings need.
11. Make the managers combined business and technical managers.
12. Use Value Engineering and profit sharing to motivate contractors.
13. Standardize management and cost reporting systems.

Technical

1. Use off-the-shelf designs.
2. Use higher design margins and less testing.
3. Eliminate engineering models by using standard electronic packaging.
4. Refurbish qualification parts for use as spares where appropriate.
5. Plan, schedule, and require only one set of GSE.
6. Minimize nonflight hardware.
7. Use model shops for short runs of advanced hardware.

The Department of Defense guidelines are direct and to the point:

1. Reduce concurrency.
2. Design to cost.
3. Use the prototypes.
4. Complete the hardware.
5. Reduce industry design teams.
6. Minimize detailed requirements.
7. Increase test and evaluation prior to procurement decision.

Department of Defense, as others, is also recognizing the need to state a policy of permissible risks and to accept more and more risks. Also, more and more the government is looking for the best possible job at a fixed cost. This requires DOD, NASA and others to become more used to assembling space projects than developing them. Commercial practices for new products should be adopted where possible.

A low cost development project is the most difficult project of any you can undertake. It requires small but strong project offices, teamwork, responsible contractors and vendors, constant cost checking, clear requirements, a cost ceiling attitude, visibility, ability to trade performance for cost, and dogged determination. Since such a task requires such an organized and disciplined approach, many will argue that the low cost approach, to be successful, requires greater use of the assurance technologies; value engineering, reliability assurance, quality assurance and configuration management. It can be shown that such disciplined programs, properly implemented and managed, pay for themselves many times. The discipline alone is conducive to low costs. Countless charts exist to show the savings these programs have produced. The key to such savings is management support and understanding.

Perhaps for completeness we should pause and consider two of the largest cost drivers in R&D. These are related and can be considered major unresolved problems. Complete solution is beyond your scope, but a short discussion here, hence knowing where the real problems are, does help your own cost effectiveness program and help in putting project costs in perspective. These problems are our present methods of competitive source selection and the related situation of out-of-scope changes added to the contract. The competitive source selection is required by law for several good reasons. However, the fact that the selection is competitive, and costly, does add to your problems of developing at low cost. If you have a normal R&D project, presumably several contractors have spent a large amount of money and used top talent to bid on the contract.

Although NASA is departing from source selection by the lowest bid, it is still very important and the contractor is considered to be developing to the total cost he described. Also NASA is doing a much better job of describing the requirements before proceeding. In fact, from a technical point of view the projects are now sufficiently described before any projects are initiated. Only the strongest and most competent government management can control these costs in today's situation. Since the bidding was cost competitive and since the NASA budget is restricted also, the best possible situation would be to build the item described if nothing went wrong and if no changes occurred.

Now let us briefly look at the control of all changes. There is no easy way to turn a government in-house capability loose and not find a myriad of other management and technical changes that really need to be made, i.e., the vibration test conditions have a new input, or a schedule change, or a new report is required. The contractors know this. To them it is both a way to take care of any cost omissions in the project from the bidding and it is also a government input too large to absorb as it exists today. The contractor therefore insists on out-of-scope changes as well as in-scope changes, resulting in a tremendous amount of traceability documentation for hundreds and thousands of changes per project. This overall situation is perhaps the most costly thing in the development project and can be solved only by new legislation or by you.

It is hoped that innovative new legislation will improve the above situation. Until then, however, you are the only control element in the loop. You cannot alter too much the contractor selection process and the resulting situation it causes. However, you can hold down changes. The technical personnel naturally will want to improve a project. It takes real leadership to keep the Center's technical personnel interested and a part of the project to assess proposed changes, etc., and yet to turn them down on most of the changes they

consider necessary. Yet, this is what is required. To keep morale high and everyone involved in a project that is not being improved is not easy.

In summary, the task of accomplishing a low cost project is very difficult, like "swimming up stream." A project organization is a "high morale" group. Everyone is dedicated to driving on and accomplishing a difficult technical job on time. For one to interpose rigid cost control methods is to appear to be out of step. It is not a popular position, except with top management or financial groups. All other Center, project, and contractor personnel may feel restricted by cost savings. It is not an easy task. Every other feature of the project - performance, risk, schedules, etc. - demands higher costs. Therefore, for you to set your goals on a low cost project and achieve it, you will have to be dedicated and skillful. However, it can be done. It requires your own brand of innovation. One example; have you ever considered when your Center technical personnel find a vibration test that is really insufficient, NOT writing a change order? Instead, writing a contract letter to the contractor saying it is the opinion of the government that the vibration tests are insufficient, but that the contractor must finally decide. A contractor would find such a letter hard to ignore; yet you have not increased the ceiling of the project. This suggestion is only to let us realize there are other ways of doing business. You must find the ways that fit you best.

APPENDIX A

ACRONYMS AND ABBREVIATIONS

AMIRS	Apollo Management Information and Retrieval System
ATR	Apollo Test Requirements
CCB	Configuration Control Board (Change Board)
CDR	Critical Design Review
CEI	Contract End Item
CM	Configuration Management
COFW	Certification of Flight Worthiness
CPFF	Cost Plus Fixed Fee
C/SPCS	Cost/Schedule Planning and Control Specification
DCR	Design Certification Review
DIR	Document Information Record
DOD	Department of Defense
DRD	Data Requirement Description
DRL	Data Requirement List
ECP	Engineering Change Proposal
ECRC	Electronic Component Research Center
FACI	First Article Configuration Inspection
FARADA	Failure Rate Data (Exchange Program)
FM	Frequency Modulation
FMEA	Failure Mode and Effect Analysis
FRR	Flight Readiness Review
g's	Gravity
GFE	Government Furnished Equipment
GREMEX	Goddard Research Engineering Management Exercise
GSE	Ground Support Equipment
HI-REL	High Reliability
ICD	Interface Control Document
IDEP	Interservice Data Exchange Program
IDWA	Interdepartmental Work Authorization
IR&D	Independent Research and Development
JSC	Johnson Space Center

MAIDS	Management Automated Information Display System
MINE	Management Information Network Extension
MIS	Management Information System
MIRADS	Marshall Information Retrieval and Data System
mods	Modifications
MQ&P	Monthly, Quarterly, and Performance (Financial Reports)
MSFC	Marshall Space Flight Center
MSF/DPS	Manned Space Flight/Data Processing System
NASA	National Aeronautics and Space Administration
NHB	NASA Handbook
NMI	NASA Management Instruction
NPC	NASA Publication Control
O&M	Operating and Maintenance
OMSF	Office of Manned Space Flight
PAD	Project Approval Document
PDR	Preliminary Design Review
PERT	Performance Evaluation and Review Technique
PMS	Performance Measurement Specification
POP	Program Operating Plan
PP	Project Plan
PPP	Phased Project Planning
QPL	Qualified Parts List
R&D	Research and Development
R&QA	Reliability and Quality Assurance
RFP	Request for Proposal
RID	Review Item Discrepancy
SARP	Schedule Analysis and Review Procedure
SE	Systems Engineering
SEB	Source Evaluation Board
SOW	Statement of Work
specs	Specifications
SRT	Supporting Research and Technology
TU	Technology Utilization
VE	Value Engineering
WAD	Work Authorization Document
WBS	Work Breakdown Structure

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