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LANGLEY MANAGEMENT OF A NASA RELIABILITY

AND QUALITY ASSURANCE PROGRAM


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# LANGLEY MANAGEMENT OF A NASA RELIABILITY

# AND QUALITY ASSURANCE PROGRAM

By S. P. Leonardy*
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## INTRODUCTION

Successful space missions save money and time; we cannot afford the high cost of failure. NASA and the Langley Research Center insist that every contractor, subcontractor, and vendor should deliberately design and build success into every NASA project.

The nature of NASA programs places inherent limitations upon the program and dictates the methods by which they are accomplished. Industry is accustomed to mass production and the American economy has grown with this concept. On the other hand, NASA projects require small numbers of very reliable, very expensive items. Each item must be individually inspected, and statistical sampling is impossible. Mass-production concepts must be discarded and a new departure in thinking is called for. Many large companies are finding it necessary to become reoriented in their thinking.

Our projects require new thinking, new methods, and companies who are able to contribute heavily to a successful mission.

By the time I have finished this talk, I hope you will understand our motives and our methods for accomplishing this purpose. I will tell you first of our philosophy of missions success. Then I shall discuss how the Langley Research Center expects contractors to eliminate incipient failures during design, during manufacturing and assembly, and during testing. Major tasks that occur within each of these three time phases will be described in detail.

## THE PHILOSOPHY OF MISSION SUCCESS

There is only one way to insure the success of space missions, and that is to carefully schedule all failures so that they occur prior to the launch. How are failures eliminated? Project management has three opportunities during any program to find and correct failures of the mission. The first opportunity comes in the design period when reliability engineers should be giving inputs to the designers in order that critical modes of failures are designed out of the system and redundancy is designed in, to the necessary extent. The second opportunity to eliminate failures is when hardware is being produced and quality assurance personnel determines that the specified materials are being used to manufacture items according to correct design, using

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the prescribed methods of production and inspection procedures. The third and last opportunity to eliminate failure occurs during the period of testing when parts are being qualification tested, and when the flight items are being flight-acceptance tested.

We consider that these programs, which are designed to insure the success of the mission, are interrelated and are, in fact, inseparable.

The extent to which reliability, or quality assurance, or the test program are relied upon is dependent upon the nature of the particular project and the NASA facility managing the project. At Langley Research Center the Project Management is responsible for reliability and quality assurance throughout the project. The reliability and quality engineers serve the manager in a staff function; however, they have access to Langley top management, when required. Other factors that will affect the project management will be the extent of utilization of state-of-the-art items and the amount of research and development work that must be performed in hardware design, material selection, and fabrication. For this reason, the NASA reliability and quality assurance publications are selectively invoked on each contract to the extent determined necessary by the Project Management.

Different Centers of NASA are found to have different philosophies toward project management, and these will also influence the extent of application of the reliability and quality programs. It also goes without saying that the funding and the scheduling of the project are factors in the consideration of project management.

However, success does not come from task performance per se. It comes from people. Each person working on a project must be keenly aware of the importance of his job and must have a strong personal desire to perform in a manner to meet exacting requirements. Each one must be firmly resolute that his work shall not contribute to failure! The project management must institute orientation and training of personnel that will reflect an awareness of these attitudes. Don't forget success depends upon many people, but failure can be caused by just one person! Vehicles don't fail; only people fail!

## PROGRAM PLANNING

At NASA, the quality engineer and the reliability engineer, figuratively, have desks next to each other. Quite often, we find that in industry these are widely separated functions. Since it is impossible to have high reliability without high standards of quality, one NASA engineer is often responsible for both quality and reliability. On our projects, we expect close coordination and communication between the contractor's quality and reliability engineers. We have been told by some companies that our projects have required their quality and reliability engineers to speak to each other and become better acquainted than they have ever done before. We feel that this "togetherness" is necessary and improves our chances of mission success. This philosophy was written into NASA Quality Publication, NPC 200-2, entitled, "Quality

Program Provisions for Space System Contractors." In Section 1 of this publication, we read in paragraph 1.4, "The quality program provisions herein are intended to aid in achieving the required reliability of the complete space system, launch vehicles, spacecraft, and ground support systems involved. Detailed reliability requirements generally will be contained in the contract work statement. Certain requirements herein, such as testing, may be considered common to quality and reliability programs. The contractor's quality program shall be planned and used in a manner to effectively support the contractor's reliability program."

In planning his quality program, the contractor may utilize his existing quality program to the maximum possible extent; however, it may have to be revised so that complete conformance to the requirements of the contract and NPC 200-2 is obtained. The contractor must submit program plans for quality, reliability, and testing. Each program plan should indicate the clear awareness and recognition of all tasks and their accompanying problems. They should demonstrate that there is a well-organized approach to implement, staff, and maintain the program. All requirements must be satisfied throughout all phases of preliminary engineering, engineering design, development, fabrication, processing, assembly, inspection, testing, check-out, packaging, shipping, storage, maintenance, field use, flight preparation, flight operations, and flight analysis.

Although each quality and reliability program is to be organized so that they receive direction from the contractor's project management, they must have clear unimpeded access to the contractor's top management. The tasks called out in the reliability publication, NPC 250-1, may not all be accomplished by the reliability group; however, this group is delegated with the responsibility to monitor the reliability tasks and insure that all are accomplished effectively and in a timely manner. This means, for example, that if a separate group within an organization is responsible for selection of piece parts, the reliability group must monitor this work and still determine that adequate inputs to parts selection are made and that all requirements and tasks of the parts and materials program are accomplished. In like manner, the quality assurance personnel should be certain that all tasks delegated to quality are accomplished. This may include giving certain inputs into design for inspectability of items still on the drawing board. Each program plan should tell how the contractor intends to perform each task within the program, where this task will be performed, and when it will be performed. Remember that the end result of any task is not the generation of a piece of paper. The end result is a vehicle on the launch pad capable of successful mission performance. In planning the various programs, NASA expects that the contractor shall elaborate on how the outputs of the tasks are disseminated, who uses them, what they do with them, and how all of this action finds its way into design, into a production process, and into the vehicle. It seems to be easy for some people to become so involved in how they are trying to do something, that they completely forget what they are trying to do. This is the reason why we should never lose sight of an overall mission success goal, and also why everyone on the project must be completely imbued with a "success complex." Each person must have an intense desire that failure shall not occur and that he will do more than is required. Of course, a workman who realizes that he is working himself out of a job finds it hard to do his best. Management must understand what motivates people and be alert for situations that may hurt the mission. For example, when one workman was congratulated for doing a very good rework job, he replied, "Thanks for what? As soon as I set foot back in the plant, I'm out of a job." Of course, program plans cannot be made to consider all degrading situations, but program managers must be able to recognize them when they exist and react accordingly.

Finally, communications is a continuous prime problem. There should be provisions made so that events occurring at a subcontractor's or vendor's plant many miles away will start a train of events to pinpoint a problem and begin the necessary action to find the solution to that problem.

## DESIGN INPUT

One of the earliest useful tools in the design is the failure mode, effect, and criticality analysis. This analysis is to uncover modes of failure and categorize them relative to effect on the mission success. All mission critical and major modes of failure should be investigated to minimize susceptibility of occurrence. These analyses should be made beginning at the systems level and continuing to the components level. The analysis should, in turn, be used as a basis for trade-off studies and redundancy studies in order to consider alternate possibilities of design. Each analysis should be considered by project management for inclusion into design, and a final disposition should be reported in each case with justification for that decision. It is necessary that adequate consideration be given to all means for elimination of failures and that these analyses will not become buried and unused in a file.

Elimination of human-induced failures can be one of the most serious and yet one of the most nebulous problems of any project. Designers must consider not only the need for assemblying a vehicle correctly, but also for making it almost impossible to assemble incorrectly. It must be impossible to mate incorrect plugs. Tests, checkout and inspection, parts replacement, access, disassembly, and other functions must be considered for ease of accomplishment and for human safety. Ground test equipment must be designed so that in case of failure during checkout it will not in turn cause failure of components within the vehicle. As an illustration of human-induced failure, I call to your attention one payload which consisted of, among other things, many thermocouples distributed over the surface of the payload. These thermocouples contained extremely fine wire and there were many failures during handling, assembly, and inspection. Each time the payload was handled, a few more thermocouples either opened or shorted. It appeared that the payload would never withstand the rigorous environmental stresses of the mission. However, when it was flown, there were no thermocouple failures. The worst environment was caused by being handled by people.

## DESIGN REVIEW

The design review is an important tool throughout the design from the preliminary to the final design and includes changes in design. NASA requires contractors to organize, plan, and present design reviews as indicated in NPC 250-1. The design review will be conducted at all levels of component, subsystems, and system design. These reviews must be well documented with extensive handout sheets or drawings, schematics, and other diagrams for the benefit of the participants. All design aspects of each component and subsystem or system must be thoroughly covered in order to unearth any design deficiency. Prior to the design review, the contractor should submit a description of the design program including practices and procedures, a check list of design aspects to be covered, and a schedule. He must notify the NASA Agency as well as other interested parties well in advance of each review in order that they may participate. A design review report covering the information presented is submitted at the conclusion of the review. Design reviews also serve a very good purpose of bringing together people who are on the outer fringes of the project, in support functions, or who are involved in a small area of the project. Quite often they are able to make substantial contributions to a review. At the Langley Research Center, our in-house design reviews and flight readiness reviews include in the list of participants, experienced people who are independent of the project in order to get this detached, objective view.

At some NASA facilities, including the Langley Research Center, there is a review at the completion of the environmental testing for each spacecraft assembly. This review consists of an inspection of all paper work, test reports, engineering changes, equipment log, failure reporting data, log inspection data, and the spacecraft to determine that all changes have been incorporated as required, and that no open items remain. This is a very thorough review by a team consisting of all cognizant engineers from NASA, the contractor, and major subcontractors.

## CONTRACTOR'S QUALITY ASSURANCE PROGRAM

During fabrication and assembly the contractor is expected to maintain a program for quality control in accordance with NPC 200-2 and NPC 200-3 and necessary supporting documents for all of his in-house manufacturing. He must exercise rigid control over himself, subcontractors, and vendors. Provision should be made for supplying documented criteria for determining performance of all articles and will include standards for judging whether or not the article meets the drawings and specifications requirements. He must also plan and schedule functional tests and inspections conducted during all phases of manufacture, fabrication, and assembly. This will be based on a comprehensive study of the articles, fabrication and processing operations, methods of materials integration, assembly and checkout, and the testing requirements of the end item. Inspections and functional tests require written procedures and specifications. During each inspection or test, the specifications and procedures will be physically located at the particular work station at the time of the inspection or test. Each action shall be traceable to the individual responsible for its accomplishment, and all inspection personnel must be well trained and qualified for the performance of his duties.

Fabrication control shall be imposed to cover production tooling, fabrication equipment, materials, cleanliness of the fabrication and test areas, and process control. Materials and items undergoing fabrication or assembly must maintain a traceable identity throughout the processing. Those items which have definite characteristics of quality degradation due to age or use shall be marked to indicate the date and test time or cycles at which the critical life was initiated or at which the useful life will be expended.

Processes where quality cannot be assured by inspection alone require a defect prevention program by the contractor. Such processes include metallurgical, chemical, material cleaning, bonding, soldering, welding, coating, and plating. Adequate control of inspection processes such as radiography, ultrasonic, liquid penetrant, and magnetic particle shall insure that the results are uniform and accurately indicate true quality. Inspection personnel operating such equipment must be trained and certified for performing these duties. Where special control procedures of processes or environments are required, there must be a special procedure written giving details on the preparation, fabrication, conditions maintained during each phase of process, and the means of verifying the various control parameters. Soldering is an example of a procedure requiring certification of process, equipment, and operators. NASA publication NPC 200-4, dated August 1964, details hand-soldering requirements for NASA projects. It appears that some electronic equipment and component manufacturers feel that solderers are born and not made. There are those who feel that anybody who can hold a soldering iron in one hand and some solder in another is a natural born solderer. Let me assure you that this is not the case. The equipment used in soldering, the man doing the soldering, and the procedure must all be the result of careful planning and continuous surveillance. NASA feels that good soldering is a basic requirement in the manufacture of space electronic equipment, and is not something that should require extra effort. Why should NASA, and the taxpayer, have to pay extra for good soldering from a company that is expected to do good soldering as a normal part of their production requirements? NASA publication NPC 200-4 is available from the Superintendent of Documents in Washington, and should be in the hands of all personnel associated with soldering of NASA space projects.

## PARTS AND MATERIALS

The contractor's parts and materials program is of major importance. Selected materials and parts, including components, must be of adequate quality and well qualified for the mission for which they are intended. The contractor must have a program of application and review of parts and materials to insure that operating stresses, environmental stresses, and operating times and conditions are considered in the selection of parts for the application. The parts and materials group must consider parts on the basis of proven qualification of each part and select them from sources with in-house programs of adequate quality assurance and reliability programs. During the parts selection, a conserted effort must be made to reduce to a minimum, the number of styles and types of each part. Space system contractors should accumulate data on previous usage of parts and materials, failure histories, and current data. A library of parts application data, and supplier's history of performance and quality is a very valuable asset to any NASA contractor.

A definition of the word "qualified" is required. The fact that a part has been qualified for use in one particular mission, does not necessarily imply that it is qualified for any other mission. Each mission has its peculiar requirements of operating conditions, environmental stresses, and times of application to these stresses. The environments of shock, vibration, acceleration, altitude, pressure, and other environmental stresses are peculiar to that vehicle and mission. In addition, a part or component under consideration may operate for a major part of the mission in a standby mode, therefore, information on this mission may not be applicable to the same part selected for another mission in which the part or component is operating in a continuously loaded condition. Therefore, when speaking of a qualified part, it should be remembered that the part is qualified only for performance under a given set of conditions. It is a common error to say that a part is qualified without indicating the particular set of environmental parameters and operating conditions in which it is assumed to be operating.

When past history or current testing proves to be inadequate or invalid for any reason, qualification of parts and materials must be conducted to the mission environment. This also applies to parts or components that have had design changes imposed that will reflect on their qualification status. When considering past history, or planning qualification tests, it is important to be certain that all components are identical with the item to be flown. There have been instances in the past when a contractor procured parts of the same part number at the same time from the same manufacturer, and received parts that were not identical. In one instance, we found a vendor producing four different configurations of ignitors, all with the same part number. A definition of the word "identical" is important. All piece parts that go into flight components should be from the same manufacturer, have the same part number, the same lot number, and be, in all respects, the same as every other corresponding part in other components of the same part number. For example, if we purchased six VCO's, we would expect that a particular resistor in each to be of the same manfacturer, lot, and part number as the corresponding resistor in all like VCO's purchased. Unless components are identical in all respects, past history or qualification data cannot be assumed to apply to all components with the same part number.

## NONCONFORMING MATERIAL

In order to properly provide for control and disposition of nonconforming material, a Material Review Board is established. This Board, or MRB, has decision-making powers and is composed of contractor and NASA Personnel (or NASA delegated representatives). All actions of the Board shall be by unanimous agreement of its members. The Board is not a rubber stamp organization. It must meet with all members around a table in order that problems may be presented, questions asked, and solutions discussed. The practice of routing a paper to each individual member for sign-off defeats the purposes for which the Board was established. Board actions are documented and are also summarized in the periodic technical progress reports. Matters that come before the Material Review Board affecting safety, reliability, durability, performance, interchangeability of parts or assemblies, weight, or function of the components or vehicle require written request for approval of the Contracting Officer at the cognizant NASA installation.

## SUBCONTRACTOR CONTROL

The contractor must assume the responsibility for the adequacy and quality of all purchased articles, materials, and services. He is expected to exercise care and knowledge in selecting procurement sources; he must transmit all design, quality, reliability, and other requirements to subcontracts and purchase orders; he must evaluate the adequacy of procured articles; provide for early and accurate information feedback; analysis and correction of failures and deficiencies; and provide technical assistance and training to suppliers when required. Procurement sources should be selected on the basis of a continuous history of high-quality production of articles, supported by qualitative and quantitative information. If no previous quality records are available, a thorough survey of the supplier's facilities and quality control inspection system will indicate his capability of supplying the necessary articles which meet all quality requirements of the project. Continuing records of the quality history of the various subcontractors and suppliers should be maintained. Subcontracts and purchase orders issued at all levels of procurement must include provisions of the contract that are applicable to each procurement. These provisions will necessarily include basic technical requirements such as drawings, engineering orders, specifications, tests and inspection procedures. Government source inspection requirements are to be included with provision for notification prior to testing and inspection. All purchase documents issued by the contractor must contain provision for Government access to the subcontractor's plant and records in use on the project. Major subcontractors must follow the provisions of NPC 200-2 or as specified in the NASA work statement. Suppliers of materials, parts, and components, including off-the-shelf items are required to follow publication NPC 200-3. Where subcontractors are producing complex assemblies or subassemblies, they are required to follow applicable portions of NPC 200-2, and NPC 200-3. This brings up the question of the definition of a "major subcontractor" or a "major component." The definition of a major subcontractor or supplier should be tied to mission criticality. That is, if a component or subsystem is mission critical, regardless of whether it is off-the-shelf or composed of off-the-shelf items, it should have quality assurance and reliability requirements imposed. The contractor's program plans should indicate major items and the suppliers of each.

Subcontractors are required to maintain a failure and deficiency feedback system that closely ties in with the contractor's system. He must expeditiously perform failure analysis on items returned to him for this purpose.

Subcontractor control is a two-way street. A good contractor will feed success data back to subcontractors and vendors as zealously as he will forward failure data.

## TESTING

There are four general types of tests that are performed during the course of a project. These are development, functional, qualification, and flight-acceptance tests. Each type has a particular purpose at a given time. Development testing is to verify that a proposed design is (or is not) capable of performing its intended function. Qualification testing verifies that the design, hardware, and vehicle are capable of performance to environmental levels in excess of those required for the mission. Flight-acceptance tests verify that the flight vehicle (or vehicles) are flight-ready for the mission environments. Functional tests verify operation before, after, or during the other tests.

Qualification testing is an expensive, but necessary, part of any program. It is difficult to simulate environments, and parts that are used for qualification testing cannot be used for flight. As previously stated, there is a need for historical use data and the contractor who is able to supply this information shows awareness and an alertness that may be a great asset. It is surprising how little some manufacturers know about what has happened to parts and components which they have produced for earlier projects. The more alert manufacturers should attempt to set up a feedback system with his customers whereby he may learn details of tests and program usage of his manufactured articles.

Pyrotechnic items are unique in that after they are environmentally stressed, they cannot be functionally tested without destroying the test items. For this reason, pyrotechnic flight items cannot be flight-acceptance tested, and are not subjected to any testing that will degrade them. Therefore, flight items are never subjected to environments, or checked for minimum all-fire current. We also require that flight items be from the same manufacturer's lot as items that are qualification tested. This assures that the items which are qualified are identical to the articles which are flown. Past history that is utilized in the selection of pyrotechnic items is of no value for qualification purposes because past history is usually based upon earlier manfacturer's lot than the lot of items to be flown. It is important that environments be applied to pyrotechnics in flight sequence and that functional testing should include firing at mission altitude conditions. On one recent project, we were separating the payload by cutting the skin with linear-shaped charge. During testing, everything worked fine up to about 280,000 feet. Then we began to have failures. Our detonators were supposed to be sealed, but they leaked. We selected another manufacturer's product, tested 40 more and had no failures at 320,000 feet. The mission was a success.

Spacecraft qualification testing should be performed whenever possible, with operating prototype vehicles. This vehicle should be identical to the item to be flown in all respects and with similar operational modes.

The sequence of environmental stress application should be flight oriented with higher levels of environmental stress than the flight levels. During vehicle testing and subsystem testing, it is important that instrumentation and test procedures be complete and adequate so that interaction between components and subsystems may be evaluated.

If it is not expedient to manufacture a complete prototype vehicle, then prototype subsystems should be fabricated and tested. It is important that qualification of the vehicle take place at the highest level of assembly in order that interaction of systems may be adequately evaluated.

Flight-acceptance testing is performed on flight components, and on the flight vehicles. Environmental stresses in these tests do not exceed those anticipated in flight and test times are kept to a minimum in order to evaluate the flight readiness without degrading the vehicle. Usually, flight-acceptance testing will involve the application of vibration, altitude, acceleration, and in some instances, shock. If there are special environmental considerations during the mission, these should also be evaluated during FAT. Here again, environmental stresses are in a mission-oriented sequence and the equipment is operated in modes similar to those in flight.

All testing is done in accordance with test specifications and test procedures which are reviewed or approved prior to the beginning of the test, in accordance with the requirements of the contract. After conclusion of each test, a test report will be issued. It will perhaps be helpful to explain the function of test specifications as compared to test procedures. The test specifications will list the objective of the test, define the test item, indicate and explain any differences between the lot tested and the lot flown, and justification for this, the numbers of items to be tested, the environmental requirement, performance conditions, operational modes, test time or cycles, the allowable maintenance, the logging requirements, manner of analyses, disposition of test specimens, retest requirements, and the allowable number of failures per test. The test procedure will describe the step-by-step method to accomplish the test including the cailbration requirements, layout and interconnecting of equipment, and the safety practices to be observed. Flight-acceptance testing and qualification testing are in addition to acceptance tests performed by vendors or subcontractors for the purpose of determining that the items are manufactured in accordance with design requirements.

Testing has brought out bad or marginal design. A marginal explosive bolt was found because bolt number 14 failed in a test of 24. This also shows the need for adequate testing.

## COMMUNICATIONS

Communication is always a problem in all situations of life. If your son came to you and said, "Daddy, dare I go to the movies," unless you lived in central Pennsylvania you could not be sure if he was asking if he could go to the movies or telling you that he had already been. If you did live in central Pennsylvania, then you would understand what he said and you would probably answer, "No, you daresn't."

It is necessary that NASA and the contractor communicate and understand each other many times each day. It is also necessary for them to be able to recognize when they do not understand each other. For this reason, information must be exchanged between the two with the major portion going from the contractor to NASA.

Throughout the project, the contractor must submit communications to NASA for "approval" or "review." A document submitted for approval may not be acted upon until NASA has approved it. Submittal for review also requires NASA approval; however, if disapproval is not disclosed within a specified period, the contractor may assume approval and proceed to implement the document. If within the specified period, NASA indicates that the document is not acceptable, the contractor may not proceed until the discrepancies are rectified and NASA approval is obtained.

As an illustration of the extent of required documentation for reliability and quality assurance on a typical project, your attention is directed to table I. This table reflects minor revisions made to accommodate the particular project for which it was intended. You will see that there are some documents that I do not specifically refer to in this talk. Those documents that I refer to are considered among the more important ones and of greatest use in project management.

Documentation should serve the singular purpose of communication with the end result of a successful mission. If a piece of paper does not accomplish this, it is not necessary. Each document listed in table I is necessary for correct and timely communication regarding work done, or to be done, and all associated detailed information.

A very important document generated by the contractor, subcontractors, and vendors is the equipment log. This log is initiated for each component at the time specified in the contract. For the purpose of Langley Research Center projects, we usually require that the log be initiated at the time of first electrical or mechanical activation of the functionally operating item. This means that the log would begin at the first activation of an item before it is potted. These requirements are also included on all subcontracts. At the time of the component integration into the spacecraft subsystem, the individual component logs are combined into an appropriate subsystems log. The logs will be kept with the equipment at all times and delivered to NASA upon delivery of the spacecraft subsystem. Equipment logs must be kept current and ready for inspection or review at any time. The equipment log will give detailed information on operating times, environmental stresses and times within those stresses, the identity of any tests or inspections and characteristics investigated, the parameter measured, the identification of instrumentation used including serial numbers and calibration dates, any failures observed and a failure report number reference, the accumulated operating time and the accumulated number of duty cycles to date, discrepancies between the item tested and the pertinent specifications or drawings, the record of maintenance and repair, the record of unusual or questionable occurrences involving either the part or equipment, action taken to have quick fixes made, and tests formalized as design changes, and the identity of the individual making each entry. We also frequently combine the narrative end-item report of quality publication NPC 200-2 with the equipment log of NPC 250-1. The narrative end-item report is also expanded to include such things as balance data, rechecks, stability checks, inventory of all installed items, results of checkout of all subsystems and sample records or descriptions of all pertinent measurements for checkout procedures in order to define normal operating conditions. The contractor is required to submit his proposed format for equipment logs for NASA approval prior to letting any subcontracts. This is necessary in order that the equipment logs which are originated at the subcontractors are complete and accurate and contain the same information as all other equipment logs.

The equipment log contains the complete life story of each component, subsystem, and system. It is useful for many purposes including an evaluation of each vehicle to determine which is the best one to launch.

The failure or malfunction report is another important document generated by the project. This report, when properly executed and implemented in a timely manner, causes the analysis and corrective action required for maintaining a high level of reliability. It is necessary that quick followup on failure analysis and corrective action be initiated, so that time is not lost in implementing the design changes necessary. At LRC, we include all failures including human-induced failure, malfunctions, deficiencies, and troubles due to all causes including methods and procedures. This is due to the fact that the reliability of a component, system, or vehicle can easily be degraded by the failure of a piece of test equipment or improper procedure in test or checkout. A typical Langley contract will require that failures at the contractor's plant must have a failure report generated within 24 hours after the failure with a copy forwarded to NASA within 3 days after the failure. For failures occurring at subcontractors, the failure report shall be generated within 24 hours after the failure and a copy forwarded to the contractor within 3 days after the failure, who will forward it to NASA within 6 days after the failure. Failure analysis and correction reports shall be submitted within 30 days after occurrence of the failure. It has been noted that on some projects, there is an inclination to list as a corrective action simply "Workman reinstructed in correct procedures." Since written procedures are required and the contractor must have complete specifications for all processes and materials, it is very soldom that instructing a workman will be sufficient. The procedure may be wrong, or a new process specifications may be required.

After occurrence of a failure, it is extremely important that the failed item be protected from further damage and that the failure analysis be performed expeditiously by people well qualified in this field. I would suggest that the contractor do as much failure analysis as possible before returning it to the vendor. There have been isolated instances when the item returned to the vendor has had the failed part destroyed prior to failure analysis. If the cause of failure is unknown, the failure should be reproduced and analyzed.

Always remember that the most important and often the weakest, links in the chain of communication are people. It is not enough that the person writing a specification know exactly what he means. Another person reading that specification 2 months later must think the same thoughts and have the same mental picture as the writer did when he wrote it. If this does not happen, then communication has broken down and confusion exists.

## CONCLUSION

In conclusion, let me impress upon you that vehicles do not fail; only people fail! People fail to plan adequately, fail to select the correct materials, fail to design properly, fail to manufacture carefully, fail to inspect thoroughly, fail to test meaningfully, fail to communicate clearly, - et cetera, ad infinitum. It is impossible to plan so completely and so clearly that success is assured. In addition to good planning, sincere, conscientious, hard-working people are required to implement and carry out all of the details to place a spacecraft capable of mission success on the launch pad. Management must be cognizant of the motivations of people working on the project, and be sure that all are motivated toward the same goal.

The response that we have had to our peculiar requirements indicates that industry is becoming reoriented to our one-of-a-kind programs.

I am encouraged when I note such titles as "Manager, Reliability and Product Integrity" as the title of a corporation officer. This indicates a transition to the realization that high performance is a rather broad, as well as a deep subject. It is not the goal to perform tasks and produce pieces of paper. It is the goal, rather, to complete required tasks and to incorporate the intelligence and knowledge into materials, processes, components, and a vehicle that is capable of mission success. We cannot afford to focus our attention so minutely that we lose sight of the job that we are trying to perform. It is necessary that each task contribute its share to the success of the vehicle and that no task remains undone or that no action remains unaccomplished.

As the missions of the Langley Research Center become more complex and of longer duration, it will become necessary for us to expect unique performance from contractors. This will involve new departures in thinking for the inspection of new state-of-the-art materials and components. It will require new ways of performing old jobs where accuracies of measurement are presently unknown. Regardless of the demands that are made, we are convinced that American industry will respond in a positive manner.

TABLE I.- EXAMPLE DOCUMENTATION SCHEDULE

| Document | Issued to NASA (calendar days) | NASA action required |
|---|---|---|
| Quality Program plan | 75 days after contract award | Approval |
| Procurement specifications | As generated | Review |
| Inspection and test procedures | As generated but not less than 15 days prior to use | Review |
| End-item test plan | Not less than 30 days prior to use | Approval |
| End-item test and inspection procedures | 30 days prior to use | Approval |
| Process control procedures | 15 days prior to use | Review |
| Storage procedures for end items | 90 days prior to use | Review |
| Quality status report | Separate section of the bi-weekly progress report | Review |
| Quarterly summaries of quality audits | Quarterly | Review |
| Reliability program plan | 30 days after contract award | Approval |
| List of subcontractors and suppliers | First submittal 30 days after contract award | Review |
| Design specifications | As generated | Review |
| Trade-off studies | Summarized as generated | Review |
| Failure mode, effects and criticality analyses | Summarized as generated | Review |
| Design review reports by contractor | Within 15 days after review | Review |
| Design review reports by sub-contractors | Within 15 days after review | Review |
| Failure/malfunction reports | Within 3 days after failure | Information |

TABLE I.- EXAMPLE DOCUMENTATION SCHEDULE - Concluded

| Document | Issued to NASA (calendar days) | NASA action required |
|---|---|---|
| Failure analysis and corrective action reports | As generated each individual report within 30 days after respective failure | Review |
| Parts and materials specifications | As generated | Review |
| Parts and materials qualification status list | First submittal within 90 days after contract award | Approval |
| Parts and materials qualification test specifications | As generated | Review |
| Parts and materials application reviews | Available for NASA review | ----------- |
| Equipment logs | Accompany assemblies | Information |
| Reliability evaluation program reviews | Within 30 days after review | Review |
| Reliability progress reports | As section in bi-weekly progress reports | Review |
| Master test plan | 45 days after contract award | Approval |
| Environmental design and test criteria specifications | 60 days after contract award | Approval |
| Component qualification test specifications and procedures | 90 days after contract award | Approval |
| Component qualification test reports | 21 days after completion of each test | Review |
| Spacecraft FAT specifications and procedures | 90 days after contract award | Approval |
| Spacecraft qualification test specifications and procedures | 90 days after contract award | Approval |
| Spacecraft FAT report | 21 days after completion of tests | Review |
| Functional test specifications and procedures | 90 days after contract award | Approval |
| Functional test report | 15 days after completion of test | Review |