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SECOND NASA-WIDE RELIABILITY & QUALITY ASSURANCE MEETING

NASA HEADQUARTERS NOVEMBER 29 - DECEMBER 1, 1966

FOR NASA USE ONLY

PROCEEDINGS

SECOND NASA-WIDE RELIABILITY & QUALITY ASSURANCE MEETING

NASA HEADQUARTERS
NOVEMBER 29 - DECEMBER 1, 1966

National Aeronautics & Space Administration
Office of Reliability & Quality Assurance
Washington, D. C. 20546

PREFACE

The papers presented at the second NASA-Wide Reliability and Quality Assurance Meeting are published to disseminate current experiences and information.

These papers, presented at NASA Headquarters on November 29 - December 1, 1966, are one means of exchanging current NASA reliability and quality assurance knowledge between projects and programs.

This publication has been marked "FOR NASA USE" since it contains management opinions and contract experiences. Publication of papers suitable for wide dissemination in the Government, Industry and University community is expected to be made separately.

John E. Condon

John E. Condon
Director
Reliability & Quality Assurance

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KEYNOTE ADDRESS

Mr. William Rieke
Assistant Administrator for Industry Affairs

It is a pleasure to welcome you to the second NASA-Wide Reliability and Quality Assurance Meeting. This meeting is intended to provide a means of exchanging reliability and quality assurance information and experiences and to provide an opportunity for discussion of current problems. A look at the agenda tells me that we are going to have the active participation of all NASA installations and I hope that each of you will get some real and identifiable benefit from these three days of discussion.

Reliability and quality assurance is one of the most important functional areas in NASA. It wouldn't be too hard to make the case that it is the most important since all our efforts and our money go down the drain when a mission fails. The importance in Manned Flight is even more obvious.

Your role is twofold: Namely, to support NASA's technical and project management people in putting together hardware that will perform successfully at a reasonable cost, and to keep general management informed of the effectiveness of the reliability and quality assurance program at your installation. This twofold role provides both a challenge and an opportunity.

Functional management within NASA has been defined to mean the providing of centralized professional leadership in the area concerned. Thus, in supporting and assisting NASA's technical people, your effectiveness will depend mainly on your ability to exercise leadership in reliability and quality assurance. Effective leadership is a combination of many attributes. Certainly patience, understanding, maturity and professional stature rank high on the list.

You must have patience and understanding. Reliability and quality assurance has reached a state of professional maturity such that there is no question regarding its ability to assist in the successful execution of technical projects, but there are many other technical support disciplines which are also designed to help in the successful execution of projects and programs. Thus, the technical and project management people are pressured from many sides--and in some cases maybe they are "helped to death." The success of your reliability and quality assurance effort will depend upon how well you demonstrate to these people that you can help them to do their job better and that you do recognize and understand the responsibilities of project managers and the many constraints faced by them in doing their job. In most cases you must tailor a reliability and quality assurance program to fit their specific needs and resources.

Your success also depends, to a large degree, on your professional stature with the technical people and your ability to provide them with the reliability and quality assurance leadership that they can respect and recognize as valuable to the effective accomplishment of their responsibilities. Leadership and professional stature cannot be legislated for you. We can provide some opportunity for you to develop and exercise these attributes but the rest is up to you. You might say that your job in supporting technical and project management people is to make them "heroes"--the better you do this the more they will want you to do it.

The second major part of your job is to apprise general management of the effectiveness of reliability and quality assurance programs and to indicate where improvement is necessary. This responsibility to general management and the opportunity you have to participate in general management decisions leads me to a pet subject of mine--management selection and development.

It appears that NASA and other agencies are finding it more and more difficult to obtain the right people for spots in general management. There are several reasons for this; an obvious one of course is the increase in the federal establishment and the creation of new departments and agencies. But there are other reasons. People stay in school longer these days so they are hired at a later age and they are retiring much earlier than they used to. The result is a shorter work span in which to acquire experience and wisdom. I suppose another reason for the shortage is the tendency to specialization. Most of our people are so specialized in their job activities that they do not really develop the capability for general management.

I believe, therefore, that we must look more to professions such as reliability and quality assurance which deal with major programs at all levels, inside and outside of NASA for potential general management candidates. I think that reliability and quality assurance organizations should take it upon themselves to improve their own qualifications and to develop themselves as potential managers. Your work exposes you to many technical and administrative fields and thus provides you with the opportunity to develop the management capabilities within your organizations.

There are a number of things you can do. You can work out informal rotation plans for your own people, you can fill job vacancies with people who have potential and who may be just a little over their heads in going into the job (if they are not over their heads they are not going to get much training), you can keep your own eyes to the outside world, serve on committees, become involved even at the expense of your own time in things outside your particular specialty, but above all be readily available by always making sure that you have a back-up man ready and able to take your place. You aren't going to get moved if you are indispensable where you are.

Perhaps there is another thing that a man can do to enhance his own potential and that is to discipline himself to think about every problem with a general management viewpoint. This means consideration of the responsibilities and viewpoints of other functions, recognition of the impact of reliability and quality assurance decisions on the total success of the agency; it means a mature understanding of the impatience and frustration that engineers experience in dealing with their part of the reliability and quality assurance program; and it suggests thoughtful consideration about how we can learn from other agencies and how we can put to use the knowledge and wisdom existing in the universities.

In some agencies and in some corporations it is considered impolite to get too much involved in other people's business, but we are particularly fortunate in NASA that Mr. Webb encourages everyone in management to think not just about his own speciality, but the operations of other functions. He is continuously urging thoughtful consideration of how advances and experience in one function can serve to advance the capabilities of others.

As you know, Mr. Webb feels there is a lag in the development of administrative competence and perhaps more than anyone in government he is searching for innovation and for ways to improve government administration. In the management milieu created by Mr. Webb there is great opportunity for the man with ideas who wants to think like a general manager even if he has not yet reached the general management level.

Let me now get a little closer to the business of this meeting. I believe NASA has a fine reliability and quality assurance operation and this is indicated in the many successes we have had in our space flight programs. As a team you look good and to my knowledge we are under no criticism.

But like any other field, you have to run to stay ahead and you have many unsolved problems. Many of these problems are generally shared with DoD but we should not wait for DoD to solve them. We should be taking the lead and I hope that this meeting will make significant progress towards this end.

I think that your most significant problems in reliability and quality assurance boil down to one of communication. The need to improve our reliability and quality requirements in all phases of the procurement process and in the delegations we make to DoD appears to be a continuing problem. While we may never obtain the ultimate solution to this, I feel that there is a distinct need for improvement. This subject, more than any other, was a main theme of the CODSIA Report on NASA Quality Requirements. The more we can do to minimize the many misunderstandings and misinterpretations between ourselves and industry which occur after the contract is signed, the more effectively we can accomplish our technical projects within the constraints imposed upon us.

I feel that we can improve the way in which we contract for reliability and quality assurance programs; I have no ready suggestions here but some creativity and innovation might bring significant results. There are other problems which I could single out but these seem to be adequately covered in your agenda.

In conclusion, let me again remind you that much of your success depends upon your ability to develop and exercise a spirit of cooperation, respect, and leadership in dealing with technical and project management people and to avoid petty contests of authority.

My very best wishes for a successful conference.

2nd NASA-WIDE RELIABILITY & QUALITY ASSURANCE MEETING

INTRODUCTORY REMARKS

by

John E. Condon
NASA Headquarters, Code KR

Good morning. It is indeed a pleasure to welcome you to this second NASA-Wide Reliability & Quality Assurance meeting. As you can tell from a glance at the agenda, this is your meeting and it is our intention that you be the primary beneficiary of these three days of discussion and exchange of experiences.

Mr. Rieke, in his keynote remarks, has indeed given us much food for thought and I sincerely hope that each of us will translate his words into positive actions. Mr. Rieke emphasized the need for us to exercise leadership in R&QA and to develop our professional stature. He further stressed the need for us to improve our communications relative to all the engineering, administrative and management people with whom we deal. I would like to expand on these points for a few moments.

The development and improvement of our professional stature in R&QA is important for at least two reasons:

(1) to enhance our value as members of the NASA team and

(2) to earn the respect of the project managers and engineers with whom we must deal.

Maybe each of us should reflect a bit on the following series of questions:

- How many of us are active dues paying members of a professional society?
- How many of us have attended at least 75% of our professional society's local meetings in 1966?
- How many of us are active in the planning and management of a professional society or local chapter thereof?

- How many of us have had an article published in a professional journal during the past year?

While active participation in a professional society is not the only means available to improve our professional stature, it is a good one. It also provides an opportunity for development of one's general management of professional society activities.

With respect to improving our communications with engineering, administrative and management personnel, I might suggest a few "do's" and "don'ts" that should be beneficial to all of us:

- Do recognize the constraints and problems of the other fellow and tailor your solution accordingly.

- Don't stand firmly on past practice or existing prerogatives when the situation calls for innovation and creativity.

- Do try to take a general management view of the situation and thereby contribute to the total success of NASA.

- Do avoid petty contests of authority and concentrate on getting the job done.

- Don't restrict your circle of activities and communication to R&QA people--broaden to include all people who affect and interface with R&QA.

In conclusion, let me encourage each of you to read Mr. Rieke's remarks when they are published. He has described the opportunities and challenges for R&QA very effectively and we can all profit by following his advice.

RECENT EXPERIENCE IN SPACE SCIENCE AND APPLICATIONS PROGRAMS

by

Robert F. Garbarini
Deputy Associate Administrator for
Space Science and Applications
(Engineering)

Although the agenda lists my address as "Reliability and Quality Assurance Experience in Recent Space Science and Applications Programs," I have taken the liberty of broadening it to include all aspects of the developmental phase of projects since you are also vitally affected by other than the reliability and quality assurance areas.

My comments will be associated primarily with my observations over the last two years, but before doing so it is desirable to say a few words of the early environment during which many of today's programs were initiated.

Sputnik was launched in October 1957. In July of 1958, the National Aeronautics and Space Administration was established by law, with the object of rapidly establishing and maintaining a leading position in the exploration of space, and the exploitation of its applications of benefit to mankind. NASA was formed from member of the former NACA laboratories and other Government agencies and personnel recruited from universities and industry.

The Agency had a modest beginning, but had to grow to carry out the task it was assigned. Chart (1) shows the manpower growth of the Goddard Space Flight Center and the Jet Propulsion Laboratory where most of the early unmanned spacecraft projects were carried out.

It is significant to point out, that it was during the early years of NASA, that many small spacecraft were built and flown. During this same period the larger and more complex spacecraft missions were conceived.

* * *

2nd NASA-Wide Reliability & Quality Assurance Meeting
NASA Headquarters, November 29, 1966

MANPOWER GROWTH

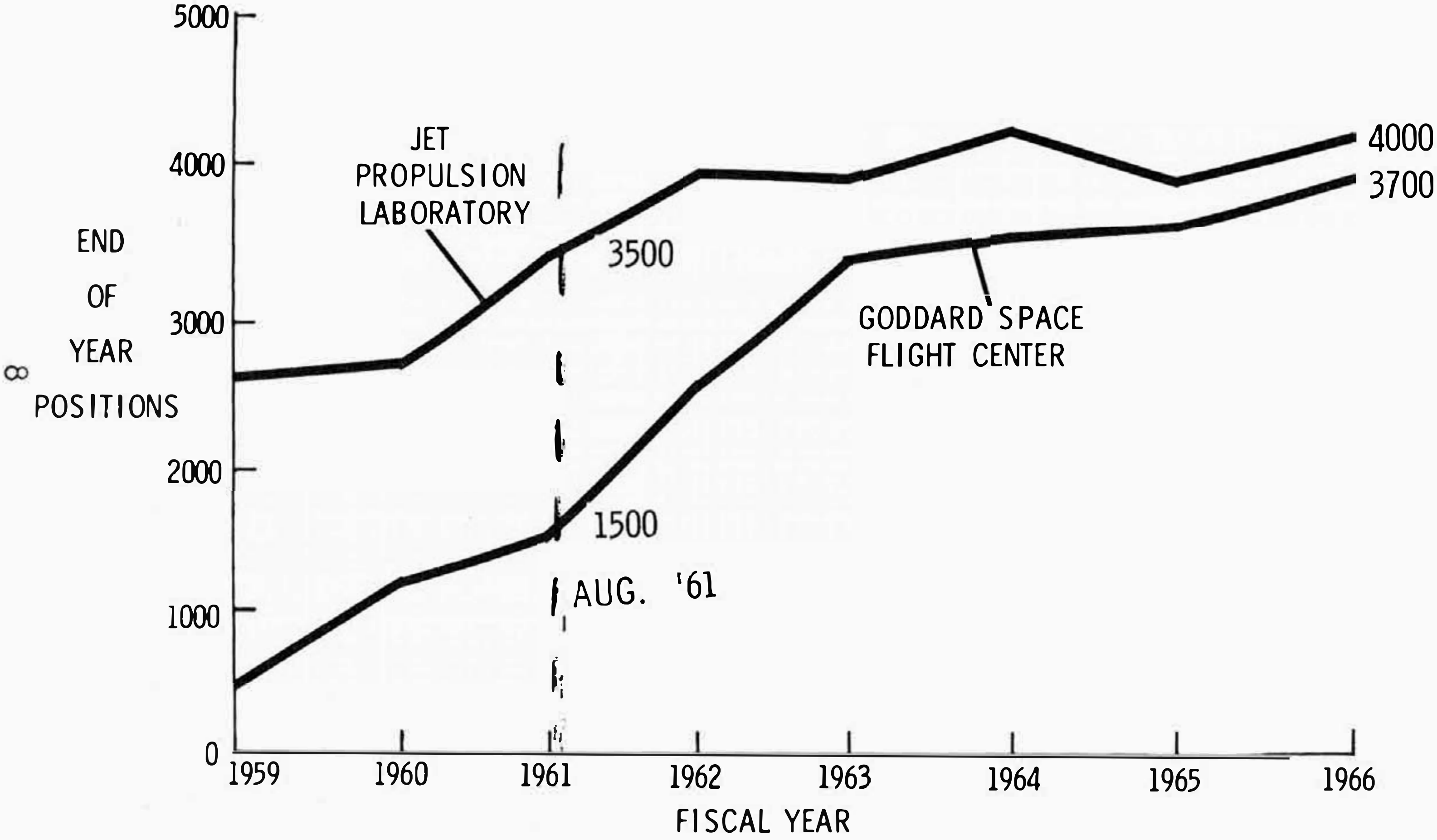

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CHART #1

Chart (2) shows the contract initiation date and first flight date of the major observatory, lunar, and planetary missions. It should be noted that Ranger I-V, OSO, Nimbus, OAO, OGO, Surveyor, Ranger VII-IX, and Mariner-Venus all started on or before August 1961. Only Mariner-Mars and the Lunar Orbiter were started since that time. This was at a time when spacecraft technology was still in its infancy and the number of personnel in government and industry with experience in space technology was small.

Let us examine the performance record of the Agency's unmanned missions. Chart (3) shows the record for the non-observatory missions (generally the smaller, less complex and spin-stabilized spacecraft). It shows the reliability problems of the launch vehicles in the early days of the Agency and their improvement as development problems were solved. The spacecraft, however, had a phenomenal success record. Of the 54 spacecraft that were successfully injected into orbit, 53 were categorized as successful by the Agency.

Chart (4) shows the record for observatory spacecraft. It includes OSO, Nimbus, OGO and the OAO. Of the 9 launches which took place starting in 1962, 8 of the launch vehicles were successes. Of the 8 spacecraft which were successfully injected into orbit, 5 were successful.

Chart (5) shows the record for the lunar and planetary missions. It includes the Rangers, Mariners, Surveyors and Orbiters. Of the 17 launches, which took place starting in 1961, the launch vehicle was successful in 12. Of the 12 spacecraft which were successfully injected into the correct trajectory, 8 spacecraft were successful. The spacecraft performance record for the observatory missions and the lunar and planetary missions are about the same. In any case they are not as high as the record for the non-observatory missions which involved less complex spacecraft. Generally speaking, one might attribute their lower performance record to their greater complexity and to the initiation of many of them early in the space science program. It appears that spacecraft missions that were flown in the later years have benefited from the Agency's experience gained from the earlier missions, for example Rangers VII, VIII, and IX, Mariner IV, and Lunar Orbiters I and II. It is also clear that the performance of launch vehicles starting in 1962 has been remarkably good.

From the above, I believe that it is fair to conclude that the Agency has done outstandingly well in small space-

PROJECT DEVELOPMENT HISTORY

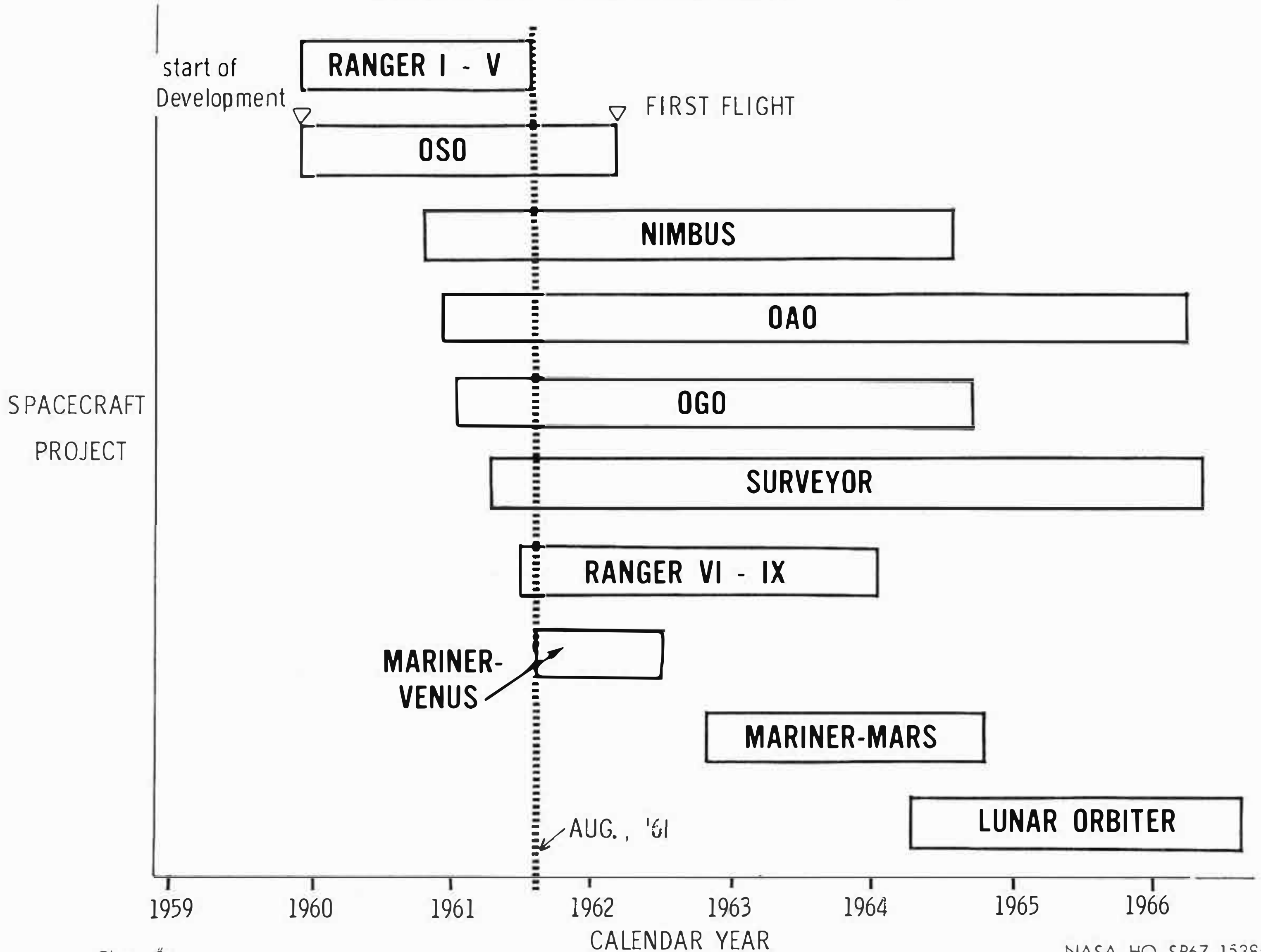

Chart #2

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PERFORMANCE RECORD
NON-OBSERVATORY MISSIONS

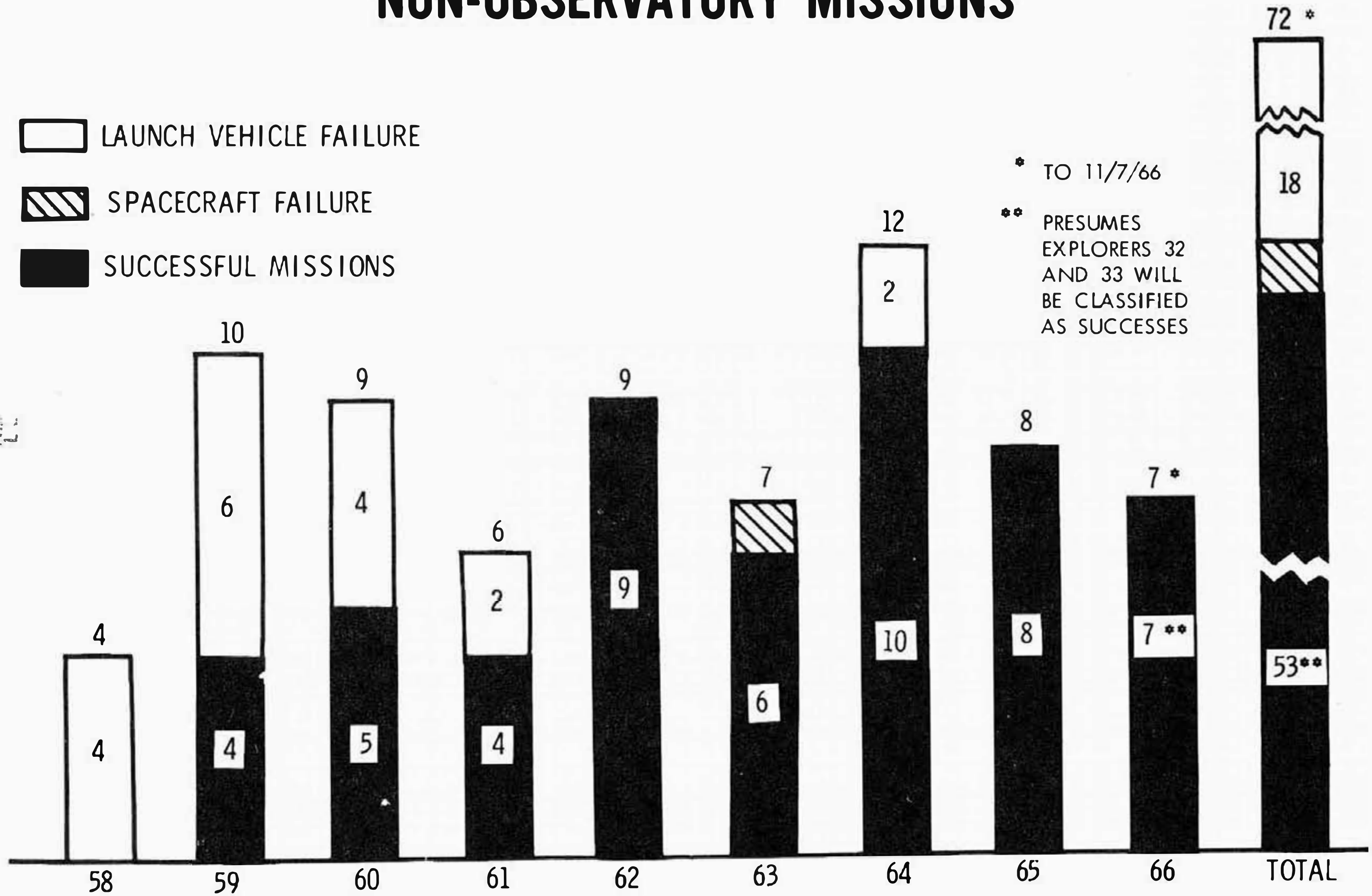

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CHART #3

PERFORMANCE RECORD
OBSERVATORY MISSIONS

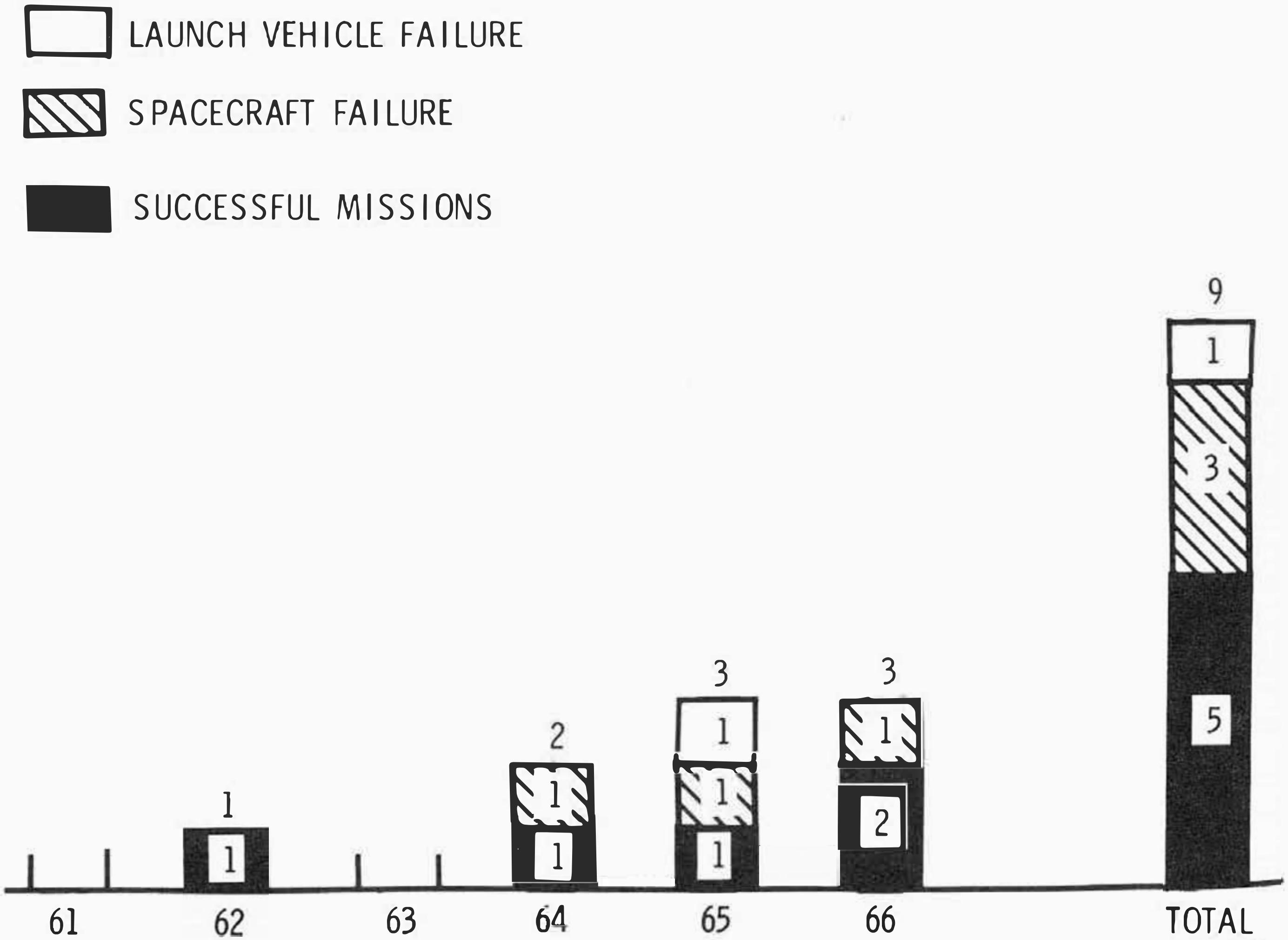

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CHART #4

PERFORMANCE RECORD
LUNAR AND PLANETARY MISSIONS

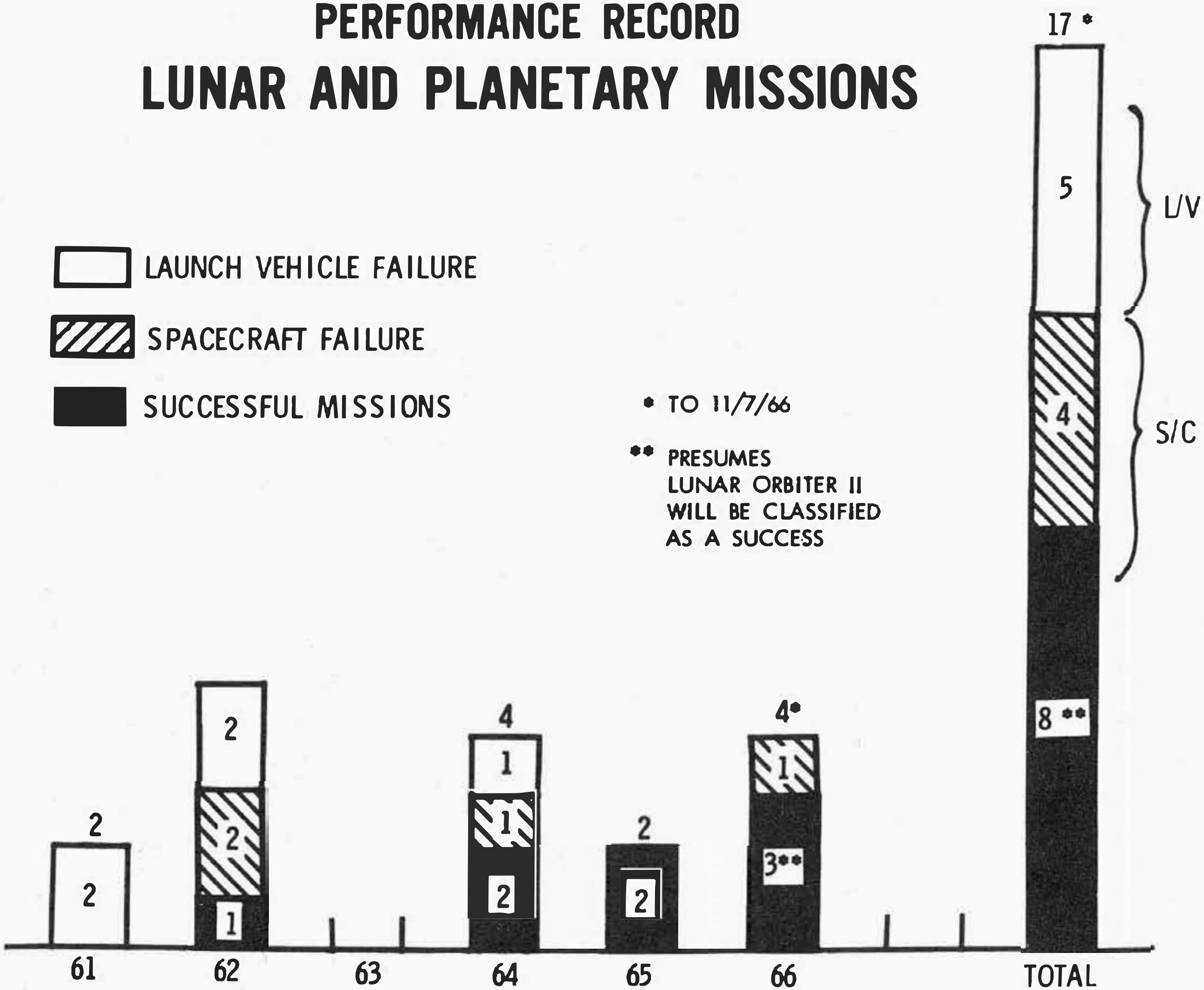

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CHART #5

craft programs, that it has been responsive to the Space Act by the early introduction of the more imaginative and difficult programs such as Rangers, Mariners, Nimbus, OGO, Surveyors and OAO, and that the lessons learned from the experience of failure generally has been successfully introduced into later programs.

I will now make a few comments which are pertinent to the future:

- Our Space Science Congressional Committee has been critical of a number of our large unmanned programs during the last few years.

- Competition with other agencies for funding is becoming more severe.

- Many of our future programs will increase in equipment complexity and consequently cost.

- Many of the current and future missions will require longer orbital life than we can now promise.

It would appear therefore that we must keep our programs scientifically attractive to the groups that influence their support. We must also manage our programs to stay within authorized costs and schedules. Also as important, we must conduct our programs so that they are successful from performance considerations. Chart 6 shows the approximate unit cost of additional observatory, lunar and planetary missions. They vary from $15M to $65M. The cost of a Voyager mission is expected to exceed the larger of these costs by a factor of 8 or 10. One therefore can see the pressures that will be on all of us to make the launches successful. In any case the road ahead will not be easy.

Today we are not necessarily making full use of everything that has been learned. I will point out a few samples illustrating this even though some of them may be due to the programs having started 5 to 6 years ago, or were caused by funding limitations:

- A number of black boxes on space science spacecraft projects do not use conformal coating on exposed terminals.

- Limited environmental tests, e.g., absence of squib firing tests.

ESTIMATED UNIT COSTS

COMPLEX AUTOMATED MISSIONS

	Weight of Spacecraft (Pounds)	Number of Experiments	Estimated Unit, Excluding Development, Costs (Millions of Dollars)		
			Vehicle	Spacecraft	Total
RANGER	675-805	1-8	10.8	15.3	26.1
MARINER '62	450	8	11.6	10.2	21.8
MARINER '64	575	9	11.6	16.8	28.4
SURVEYOR	2,250	2-4	16.6	38.5	55.1
LUNAR ORBITER	850	1	8.5	20.6	29.1
OSO	540	7-9	3.2	12.1	15.3
NIMBUS	1,400	10-12	7.8	45.0	52.8
OGO	1,100	20-23	9.1 (Atlas/AG) 6.6 (Thor/AG)	25.4	34.5 32.0
OAO	4,000	1-4	10.7	53.7	64.4

Chart 6

- Carelessness in mating connectors.

- Burnout of spacecraft elements during special qualification and/or acceptance tests due to inadequate procedures or not carefully following them.

- Non-vigorous use of single point of failure analysis, and its feedback into the design.

- Inadequate redundancy to assure initial success or long life.

- Use of break-out boxes, rather than fixed connectors for the connection of test equipment during integrated and subsequent testing.

- Spacecraft status telemetry is not always provided during the launch phase.

- Some of the failure reporting systems are not as complete as they should be. It is not clear that they are invoked on prime and subsystem contractors to the extent that they should be.

- There are cases where it is not evident that the personnel responsible for design, test, reliability and quality of equipment are working as a coordinated team on each project.

- On some projects the prototype is not updated for each major configuration change in the follow-on mission (usually because of funding limitations).

I would now like to single out for your attention several practices which I believe we should keep in front of us as we continue into the future:

1. Build complex spacecraft in blocks of two (or more), and plan to fly them in order to provide greater assurance that at least one mission of each different configuration is successful.

2. Build prototype and update to each major configuration change for requalification tests and other uses. Maintain configuration until success of flight model is demonstrated in flight.

3. Plan to use launch vehicles with payload capabilities in excess of mission requirements to permit ease of spacecraft design and incorporation of added redundancy.

4. Increase the use of redundancy in spacecraft designs.

5. Initiate early in the design phase the development of test plans and test requirements so that the necessary test provisions can be properly incorporated during design.

6. Initiate early in the design phase the development of the flight operational system requirements so that operational provisions can be designed into the spacecraft.

7. Formalize at outset of the project a thorough failure reporting system which includes reporting, failure analysis, review and closeout. Invoke the same system on prime contractors and subcontractors.

8. Project, test, reliability and quality assurance personnel should work as a team in establishing and implementing the reliability requirements of the project.

9. Look outside your project and Center for additional experience which can be used in your program.

There is nothing new or astounding in the above highlighted practices. However, they appear very important, and yet we are not doing a uniformly good job in all of them.

PROGRAM MANAGER'S

PERSPECTIVE ON R&QA

by

R.L. Body, KSC

In general, the project or program manager has a conservative R&QA perspective; more specifically, an outward support but inward "proceed with caution" perspective. There are probably many intangible as well as tangible reasons why this might be. This paper will highlight some of the more tangible reasons along with recommendations to clear the haze from the program manager's R&QA view. With the strain of compressed schedules, funding restraints and day-to-day hardware problems, the project or program manager has limited time available to devote to R&QA. Therefore, R&QA people should take a close look at where are we now contributing to the problem and where, in the future, we can more greatly contribute to the solution.

The following highlight some of the things that should be closely evaluated:

1. Definitions - of Reliability, Quality Assurance, Quality Control, Product Assurance, Systems Effectiveness, Repairability, Maintainability, Functional Test, Qualification Test, Acceptance Test, Reliability Test.

   Solution - Why not a NASA directory on R&QA definitions.

2. Identify "Acceptable Risk" in Engineering Terminology - Clarify the distinction between risk and uncertainty. Talk in terms of cost,

schedule and reliability risks. Do the basic engineering analyses first before trying to equate the risk in terms of probabilities - don't consider FMEAs, Testing and Test History, Failure Reporting, Failure Analyses, Corrective Action as too mundane an area for reliability. Relate all these one-to-another. Drop numerical assessment at the design freeze. Assure consistent depth of reliability analyses by identifying single point failure potentials in a meaningful, relatable way to their actual probability of occurrence - even if only in a relative manner.

Solution - Why not an NMI on "Engineering Criteria for Determining Acceptable Risk" written for the design engineer rather than the statistician.

3. Supplement 200-2 and 250-1 Contractual Requirements - with specific needs tailored to the contract - e.g., a subsystem design versus a launch operation support contract. Be knowledgeable of the most critical items bugging the program manager from a schedule and cost viewpoint. Look behind these to determine whether lack of definitive R&QA requirements or adequate administration of the R&QA aspects historically placed the items on the critical path - or are keeping them there. **(See also Appendix "A")**

Solution - Why not an NMI on "Instructions on Preparation and Updating of Program Plans." Simultaneously broaden the perspective and upgrade the status of R&QA people.

4. Study Test Plans, Test Specifications - for both components as well as systems. Are all critical test parameters, environments covered - are they gold plated (e.g., testing of valves to -120°F when they only see ambient conditions in Florida).

Solution - Why not issue an NMI on "Instructions for Uniform Preparation of and Determining Conformance to Test Plans."

5. Keep Q.A. Inspectors Knowledgeable - of critical component, subsystems and systems. Provide them a briefing on relatively critical single point failure potentials derived from FMEAs, etc. Instruct them on the most likely failure modes, developing mandatory inspection stations around critical items that can most surely impact mission success. Provide training to plant people on the relative importance of these critical components. Inform vendors of the ultimate critical application of the components and subsystems they are supplying.

Solution - Why not an "Instructions on Selection of Mandatory Inspection Points" in assembly, acceptance, and receiving inspection.

6. Uniform System for Documenting Unsatisfactorily Delivered Hardware - If hardware is consistently delivered in unsatisfactory condition, how can we make it easy to document and report it to higher levels of procurement, R&QA, etc.?

Solution - Why not an NMI on "NASA DD-250 Acceptance Criteria."

7. Management Review and Indexes for R&QA Performance - for example, number of failures or rejects per million manhours.

Solution - Why not a government-industry sponsored council to study common R&QA problems.

8. In summary - Where are we going in the future? Are R&QA areas responding to these forecasted activities in terms of:

a. More sophisticated experiments.

b. Longer duration missions.

c. Large space stations.

d. Complex missions requiring multiple launches and logistics supply.

e. Shorter space vehicle preparation time.

f. High probability of checkout and launching of complex experiments and spacecraft configurations.

g. Capability for long standby with short reaction time-to-launch.

h. Automated checkout, rapid fault isolation with high accuracy in fault prediction and selection of alternate modes of operation.

i. Optimization of the checkout and launch process for real time response to high probability of launch availability.

j. Maximum practical application of computer techniques, data processing and microelectronics.

k. Human factors - improved techniques in assembling, operating, repairing and maintaining hardware.

1. Meaningful ways of displaying status information for management decision making for quick reporting and comprehension of significance of the data.

Solution - Coordinate, and publish yearly, NASA R&QA long range objectives and forecasted goals.

PROGRAM MANAGER'S PERSPECTIVE ON R&QA

1. DEFINITIONS - RELIABILITY, QUALITY ASSURANCE, QUALITY CONTROL . . . .

2. IDENTIFY "ACCEPTABLE RISK" IN ENGINEERING TERMINOLOGY

3. SUPPLEMENT 200-2 AND 250-1 CONTRACTUAL REQUIREMENTS

4. STUDY TEST PLANS, TEST SPECIFICATIONS

5. KEEP Q.A. INSPECTORS KNOWLEDGEABLE

6. UNIFORM SYSTEM FOR DOCUMENTING UNSATISFACTORILY DELIVERED HARDWARE

7. MANAGEMENT REVIEW AND INDEXES FOR R&QA PERFORMANCE

8. IN SUMMARY - WHERE ARE WE GOING IN THE FUTURE?
   ARE R&QA AREAS RESPONDING TO THESE FORECASTED ACTIVITIES?

TABULATION OF FLIGHT CRITICAL COMPONENTS

A. CAN IT BE REPLACED WITHOUT DEMATING?

B. IS IT ACCESSABLE?

C. WHAT ACCESS KITS ARE REQUIRED?

D. ESTIMATED TIMES TO:

(1) REMOVE HATCH AND INSTALL ACCESS KIT

(2) REMOVE AND REPLACE COMPONENT

(3) REMOVE ACCESS KIT AND RECLOSE HATCH

E. WHAT SPECIAL HANDLING EQUIPMENT IS REQUIRED?

F. WHAT SPECIAL TOOLS AND/OR FIXTURES ARE REQUIRED TO REMOVE OR INSTALL THE COMPONENT?

G. HOW MANY PEOPLE ARE REQUIRED?

KSC CLOSED-LOOP SYSTEM TO ASSURE IMPLEMENTATION OF THE

INTEGRATED LAUNCH AVAILABILITY RELIABILITY PROGRAM (ILAR)

1. RELIABILITY PREDICTION

2. FAILURE MODE AND EFFECTS ANALYSIS
(SINGLE POINT FAILURE ANALYSES)

3. CRITICALITY ANALYSIS

4. ALTERNATE MODE OF OPERATIONS

5. INTEGRATED TEST REQUIREMENTS

6. CERTIFICATION TESTING

7. SYSTEMS READINESS ASSESSMENT

8. FAILURE RECURRENCE CONTROL

APPENDIX "A"

KSC RELIABILITY/QUALITY PROVISIONS

FOR STAGE AND SUPPORT CONTRACTS

A. General

The contractor will submit with his proposal a plan that describes how he will apply the provisions of NPC 200-2 and 250-1 as related to launch operations. This section explains the minimum requirements that the contractor must discuss in his plan.

Nothing in this section shall be construed by the contractor as a requirement for duplication of effort. The contractor's operations group may perform the function required to comply with these requirements. Although the tasks may be delegated to operations personnel, the contractor's management will ensure that the requirements are effectively accomplished.

The contractor's plan will identify the operational element assigned the responsibility of performing the required functions.

B. As a minimum, the following requirements will be included:

1. The inspection system to be used during test, checkout and launch operations at KSC, including the flow of rejected material, the inspection of spare parts, and the support documentation used to perform inspections.

2. The inspection system to be devoted specifically to repair or rework purposes.

3. The system to be devoted to acceptance inspection.

4. The system to be used for control and calibration of inspection equipment.

5. Special processes and specialized inspection personnel certification requirements.

6. The system used for recording and reporting time and cycle data on critical equipment to insure life of items in use is not exceeded.

7. The system for maintaining equipment logs and means by which the contractor will assure maximum use of this data in conjunction with his launch site responsibilities.

8. The system for identifying and reporting ALERT problems to KSC. ALERT problems are defined as major or unusual malfunctions, defects or phenomena occurring at KSC which may lead to repetitive failure of mission-related items that may have an impact on KSC or other NASA programs.

9. The system for administering and controlling the reporting, local investigation and corrective action feedback of failures and malfunctions that occur during launch preparation. This system is to be compatible with KSC Apollo Program Directive No. 6, "KSC Apollo Unsatisfactory Condition and Corrective Action Reporting." The following will be reflected in the failure reporting system:

a. Contractor to propose on the basis of using KSC Form 14-14 for failure reporting at the launch site.

b. KSC to issue overall failure report blocks of numbers.

c. Contractor to code failure reports for automatic data storage in accordance with KSC coding tables.

d. KSC or MSFC to take corrective action on items for which the contractor does not have design responsibility.

e. Contractor to supply and distribute 15 copies of validated reports within 72 hours of the malfunction of failure to KSC.

f. Contractor to provide expeditious corrective action or failure analysis feedback within a time frame commensurate with the criticality of the malfunction or failure.

g. Contractor to maintain and keep current trouble case history information on multiple or repetitive problems encountered during prelaunch checkout and testing operations.

h. A system for maintaining and relating failure history to current failure occurrence.

i. Contractor to maintain current records on priority I, II and III problems that occur during operations.

j. The system for developing and maintaining a list of items that failed during pre-launch activities that require closeout and disposition by the cognizant design organization prior to launch.

k. The system for determining where non-critical failed items or problems have priority applications and alerting the cognizant design organizations to the need for appropriate investigation and analysis prior to launch.

l. The system for storage and disposition of failed items, as related to failure analysis disposition.

m. The system for determining whether field failures invalidate present spare stockage levels.

10. The system for identifying and verifying whether redundancy on priority items has been independently checked and validated during pre-launch operations.

11. The system for developing and maintaining a list of items mandatory to be operational for support of checkout activities and launch.

12. The system for developing and maintaining recycle times in event of failure of a mandatory item.

13. The system for developing a list of pre-planned solutions (work arounds/alternate modes, etc.) in event of failure of a mandatory item.

14. The system for analysis and reliability review of checkout procedures to optimize mission success including the system for identifying potential human factor single point failures in pre-launch operations by review of checkout procedures.

15. The system for maintaining a list of all unqualified items.

QUALITY ASSURANCE ON THE TIROS OPERATIONAL SATELLITE (TOS) SYSTEM

by

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The purpose of this paper is to present and discuss the major factors involved in the formulation, implementation, and management of a quality assurance program for the TIROS Operational Satellite System. This system is known as TOS, or the ESSA series. TOS is a quantity produced satellite and is the first of a new concept of meteorological spacecraft which evolved from the initial TIROS research and development satellites. TOS' mission is to provide weather observations on a continuous, systematic, daily, world-wide scale.

TOS was designed, developed, and is being built by the Radio Corporation of America/Astro Electronics Division for the National Environmental Satellite Center. Management and technical direction is provided by Goddard Space Flight Center through an agreement with the Department of Commerce.

TOS is a cylindrical shaped spacecraft (see Figure 1), 22.5 inches high and 42 inches in diameter. Two camera systems, both redundant, are mounted 180 degrees apart around the perimeter of the spacecraft. The fully operational system employs two types of satellites in orbit to achieve required global and local weather coverage. One satellite carries an automatic picture transmission (APT) system. This system continuously transmits pictures to local receivers along the orbital path. The other satellite employs an advanced vidicon camera system (AVCS). This system provides stored "on-board" pictures for delayed transmission to centralized data processing stations.

At this time I would like to point out the major differences in the TIROS and TOS Programs from a quality assurance and manufacturing viewpoint:

TIROS did not employ a formal, documented quality program. I am not inferring that the quality assurance aspects were totally ignored on TIROS. The program was remarkably successful. TIROS' satellites were essentially fabricated, one at a time, in an engineering model shop environment with assembly and testing performed by small, skilled engineering groups. A special engineering integration team closely followed each phase of work from fabrication through assembly, integration, test and launch. Other features included design reviews, parts derating, 100 percent parts preconditioning, use of preferred parts, failure reporting and corrective action, and an extensive environmental test program, both at the black box and spacecraft levels.

Conversely, production of TOS satellites is a manufacturing operation involving coordination among many functions of the contractor's organization. This type of operation, of course, increased in magnitude the problems relative to interdepartmental communications and the close collaboration of many diverse skills. To effect control over the many potential problem areas and to achieve continuity throughout the contractor's effort, Goddard project management required that a formal quality program be established by the contractor based on requirements of NPC 200-2, "Quality Program Provisions for Space Systems Contractors."

At GSFC, the ultimate responsibility for project equipment quality rests with project management. The quality engineer for TOS serves the project manager in a staff function. As such, this function--pertaining to quality requirements--was initially to advise the manager to the extent of application of NASA quality assurance system requirements relative to achieving the goals set forth by the project.

It goes without saying that it is best to get in on the program as early as possible so that proper basic requirements are imposed. In the case of TOS, the quality engineer was a little late in arriving on the program, after initial quality requirements were already a part of the TOS RFP. Fortunately, because of relatively close proximity to the contractor's facility, the quality engineer was able to communicate and work closely with contractor quality assurance personnel in resolving differences and developing a comprehensive quality program plan.

The TOS quality assurance requirements are in general agreement with the intent of NPC 200-2. The basic aim of project management was to get the contractor to establish a formal documented quality program, to exercise control of major areas of operation. It was understood by the contractor that some of the past practices in conduct of the earlier TIROS Program were acceptable and merely needed to be formalized; also, that the existing quality system could be used to the maximum possible extent to satisfy other requirements.

Everyone at this meeting, I assume, is familiar with the details of quality programs which are normal to NPC 200-2 requirements and which do not need explanation. However, of special interest to you may be the quality program features referenced in Figure 3. These features are considered unique to TOS and extend beyond what is the usual NPC 200-2 quality program.

A Product Assurance Administrator was assigned to the contractor's project management staff to provide direction to the various Quality Control Groups and Engineering Reliability. The administrator is responsible for conduct of the quality program in all respects and to prevent duplication of quality and reliability tasks. He also assures that the quality program provides effective support to the reliability program. Areas of responsibility for the Product Assurance Administrator are shown in Figure 2.

The TOS Project was not free of problem areas. We had significant problems with subcontractors supplying hardware which failed in test, or was rejected because of poor workmanship. These problems were usually traceable to the supplier not working to his quality plan, basic design, or to a supplier loss of his process control. Corrective actions in some of these cases ranged from simply "cleaning up" quality operations, 100 percent monitoring, redesign, change in process controls, additional part screening, or dropping the supplier when corrective action could not be achieved. In-house prime contractor problems basically concerned workmanship and inadequate specifications where better planning and coordination among the contractor's organization could probably have reduced the effects of these situations.

We feel that our quality program is flexible enough to recognize and cope with our particular problems and achieve our purpose--assurance that the end-item is of the quality and reliability to perform TOS' intended mission.

In summary, to date, two TOS satellites were launched that were produced under the auspices of this quality program. The first satellite exceeded its designed mission life in orbit and is continuing to transmit excellent weather pictures. The second satellite reached the halfway mark in its mission life with no degradation in performance. We believe success of this kind can be greatly attributed to implementing a realistic quality program in accordance with NPC 200-2, and by continuous monitoring and auditing to assure conformance to that overall quality effort documented in a NPC 200-2 program plan.

TOS SATELLITE

(VuGraph)

Figure 1

ORGANIZATION CHART

TOS PRODUCT ASSURANCE

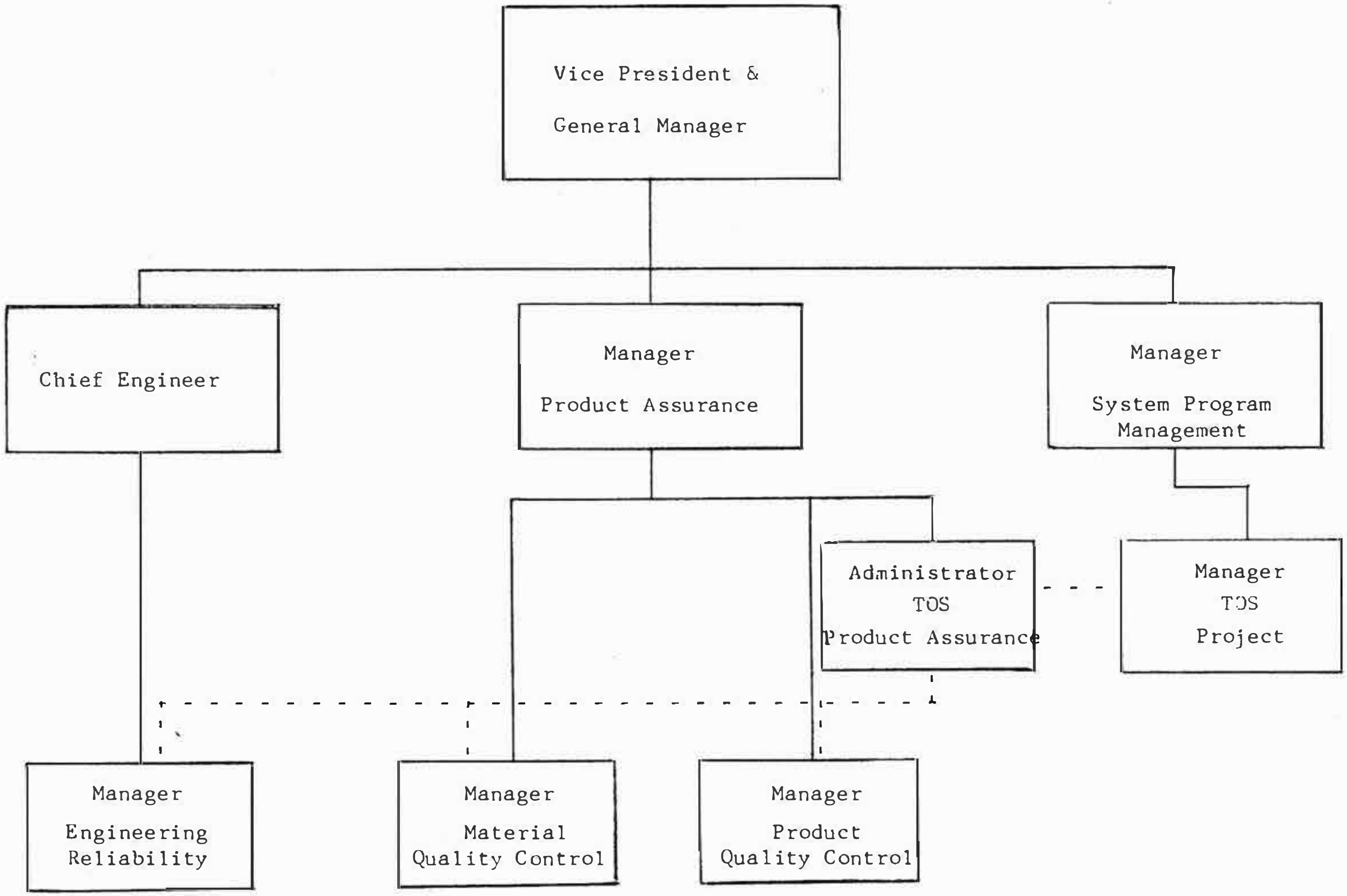


Figure 2

TOS UNIQUE QUALITY PROGRAM FEATURES

* Flight Hardware Identified
* Sealing for Subsystem and Spacecraft Integrity
* Subsystem Documentation Folder
* Spacecraft Logs and QC Data Package
* TOS Test Review Board
* Pre-Environmental Test Reviews
* Environmental Test Committee
* Contractor and Government QA Responsibility

Figure 3

R&QA EXPERIENCES IN A SMALL FLIGHT PROJECT

Frank E. Mershon, LaRC

The purpose of this paper is to illustrate a technique for supplementing written specifications with visual aids. The technique was used in the manufacture of the Pageos satellite, a small flight project managed at the Langley Research Center (see Figure 1). This project is typical of some "one of a kind" small flight projects at Langley where the flight article cannot be tested, yet confidence of its integrity is mandatory. The flight satellite was not inflated on the ground for inspection, so extraordinary care was required in its manufacture.

As a continuation of the NASA effort in support of the National Geodetic Satellite Program, an Echo I type satellite was launched into a near polar orbit between 4,000 and 4,500 kilometers in altitude on June 24, 1966. The 100-foot diameter, aluminum-coated, spherical satellite is being observed from the ground as a point source of light while it reflects the incident sunlight. Simultaneous photographs of this light source taken against the star background by two or more widely separated ground based cameras will enable geodesists to determine the spatial coordinates of each camera position. An interconnected series of camera positions will be established that will cover the entire surface of the earth, thereby permitting geometric determination of each camera position within a single reference system. The use of this satellite for geodetic purposes will continue for a five-year minimum period.

The sphere is constructed from 0.5 mil thick plastic film (polyethylene terephthalate) with a vapor deposited aluminum-coating (approximately 2200 $\overset{o}{A}$) on the outside surface. The aluminum-coating presents a highly reflective surface to the incident sunlight and also protects the plastic film from damaging ultraviolet radiation. The position of the sun's image on the mirrorlike surface of the satellite will only coincide with the center of the sphere, as viewed by an observer, when the sun is directly behind the observer. When the sun is not behind the observer, a correction is necessary, and the accuracy of this correction is dependent on the sphericity of the satellite. Manufacturing a highly spherical satellite with a mirrorlike surface requires close attention to quality assurance procedures.

The inflatable sphere was built by the G. T. Schjeldahl Company, who also built Echo I. It was determined early in the contract that specialized training for the company personnel would be required, if the goals for sphericity and surface smoothness were to be met, and a school was conducted at the Langley Research Center for this purpose. Comprehensive manufacturing procedures and specifications were also defined. But these specifications did not provide the effective communications desired because of the inherent difficulty of describing the many types of flaws possible in this type construction. It was later decided to supplement them with "visual specifications" in the form of sample boards. Some typical sample boards are illustrated in Figures 2 through 8.

Figure 2 shows a sample board which illustrates a typical material defect. In this case, it is stretch marks. In this discussion, material defects are those defects of the plastic film which are not discarded in the surplus material when the gore is cut. Fabrication defects are those defects which occur during fabrication of the satellite seams. Figures 3 and 4 show some fabrication defects which occur when the gore is cut. Figure 3 is the legend from the sample board in Figure 4.

Figures 5 and 6 show one fabrication defect which may occur in the bonding of the seam. Figures 7 and 8 show a sample board illustrating an acceptable seam. Listed are the reasons the seam is acceptable. This technique of using visual examples to train manufacturing and quality control personnel was effective, as can be shown by Figure 8. Note the dramatic decrease in material defects in the second column, and in manufacturing defects in the third column, after the sample boards were introduced in the manufacture of the third satellite.

The results of these procedures are also illustrated by a comparison of Figures 1 through 10, showing Pageos and Echo I. Note the greater smoothness of the Pageos by comparing the reflected images in both spheres.

In summary, the quality of space components can be greatly improved by personnel training and by the use of visual aids in the communication of the specified requirements.

PAGEOS

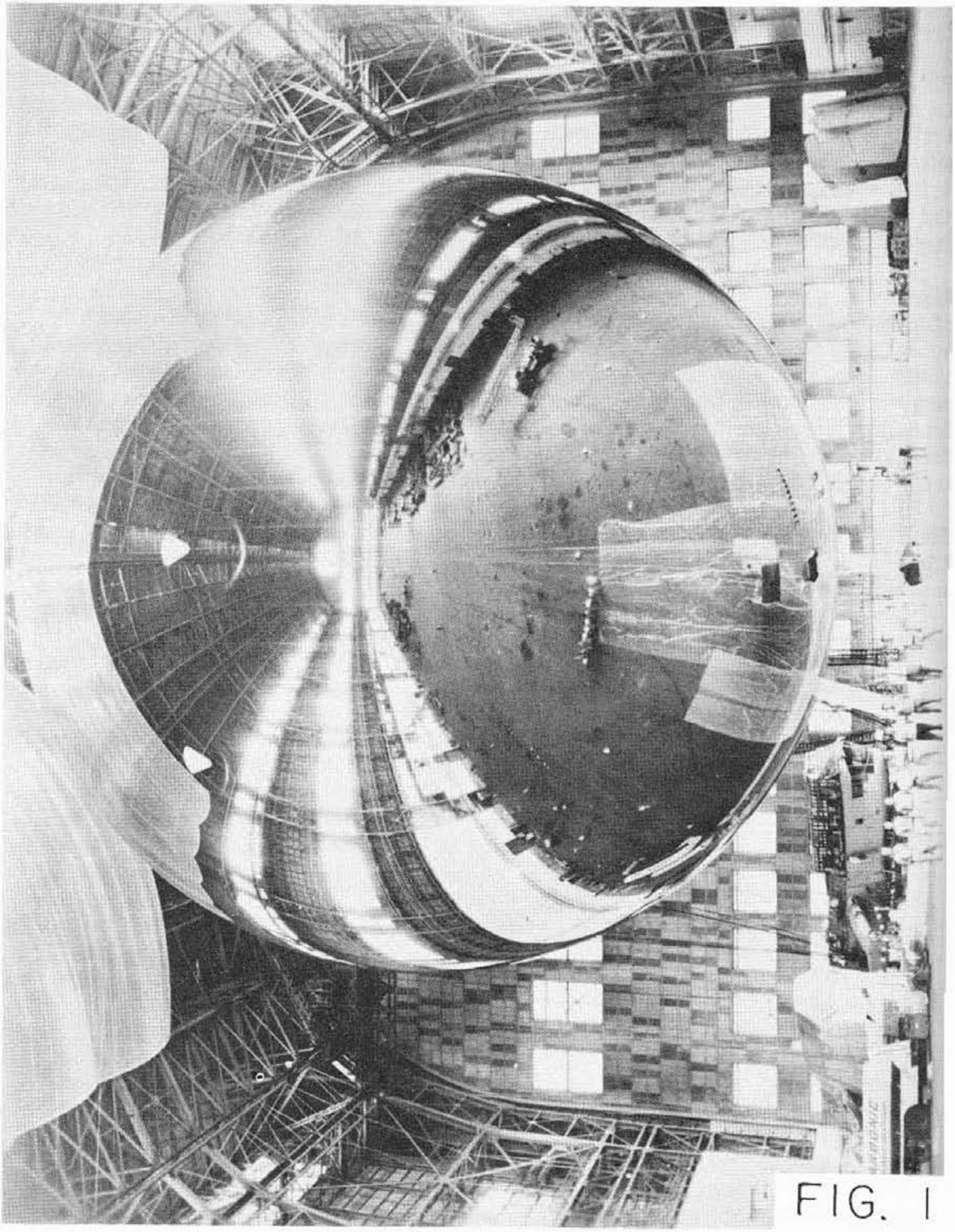
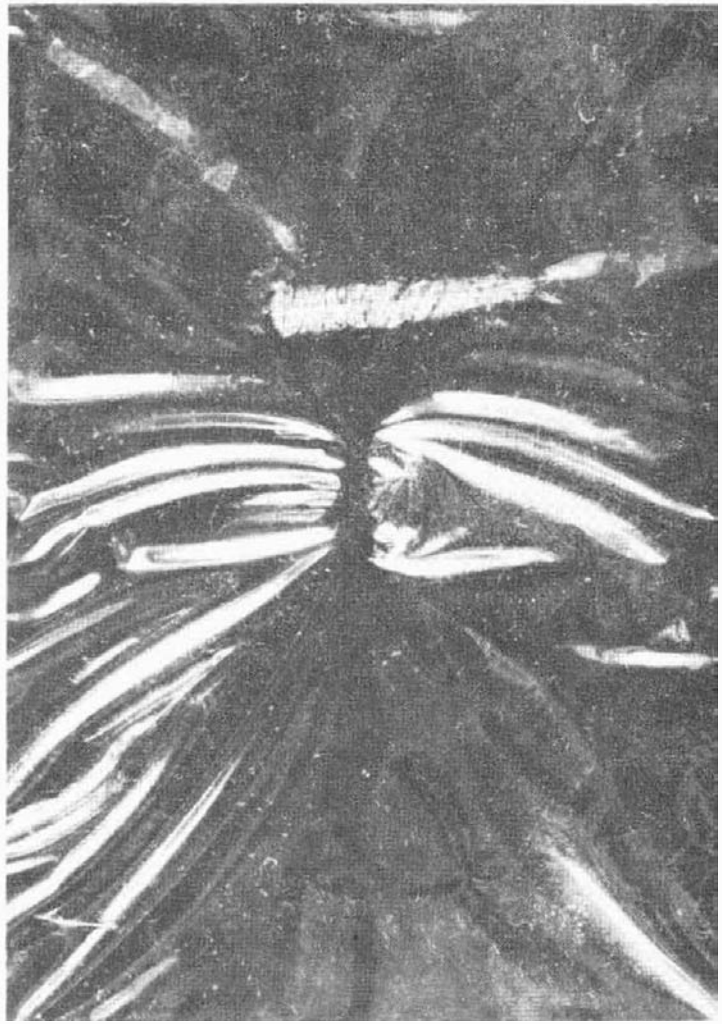


FIG. 1

TYPICAL MATERIAL DEFECT



STRETCH MARKS

FIG. 2

FIGURE 3

RAIL CUTTING SAMPLES

1. CUT NO. 1 IS AN ACCEPTABLE CUT. IT IS STRAIGHT AND SMOOTH AND INCLUDES THE INCREMENT MARK.

2. CUT NO. 2 IS A REJECT CUT. IT HAS THE FOLLOWING DEFECTS:

   a. OVERHANG

   b. INCREMENT MARK THAT HAS SHARPLY CREASED MATERIAL BEHIND IT - INCREMENT MARKER SLIPPED OVER THE EDGE OF THE RAIL

   c. CUT IN THE MATERIAL

   d. A PIN HOLE WITHIN 2 INCHES OF THE GORE EDGE

SAMPLE BOARD FOR GORE CUTTING

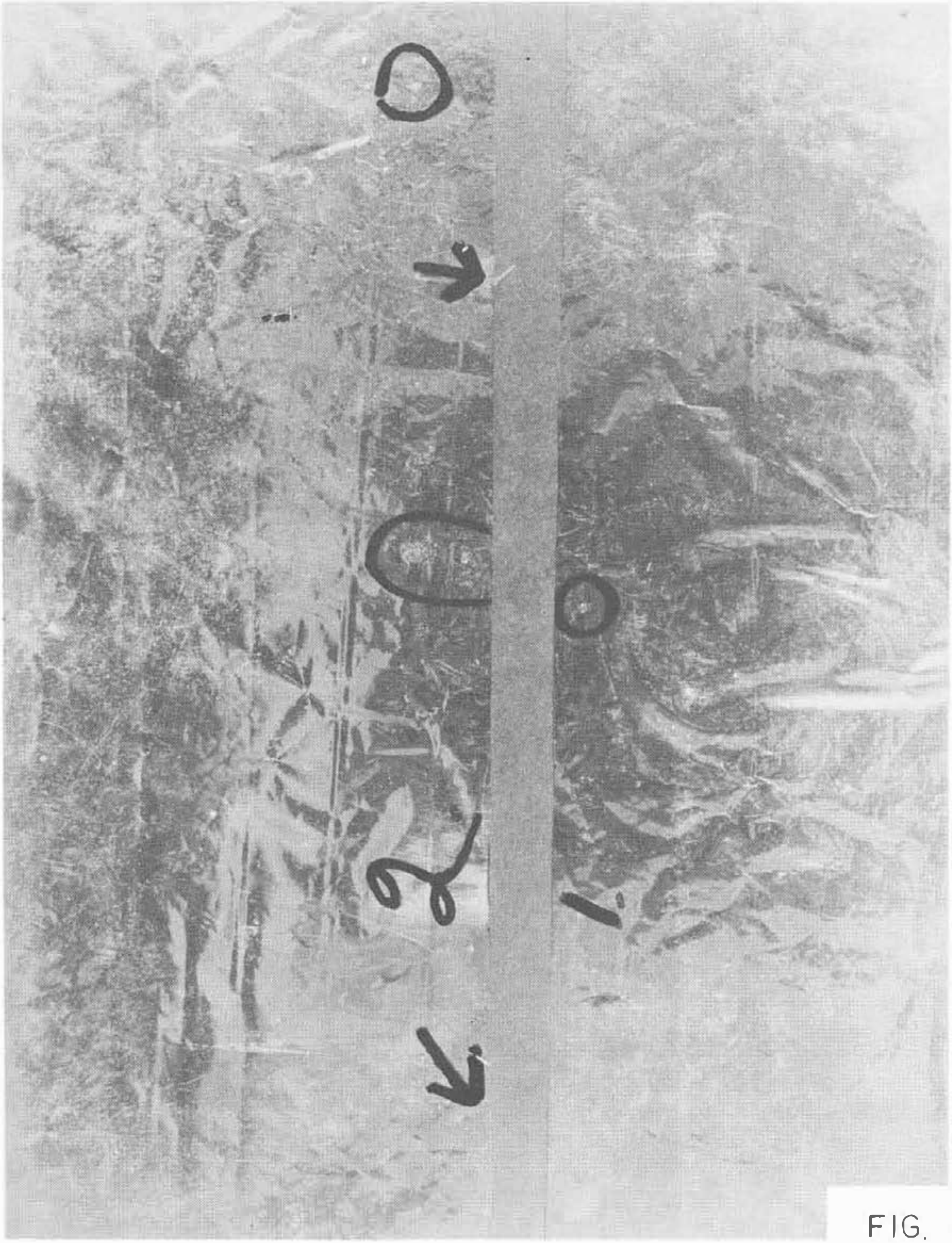


FIG. 4

PLEATS

REJECT - BECAUSE OF THE WEAKENED AREAS OF THE PLEATED MATERIAL THIS SEAL IS REJECTABLE.

FIGURE 5

SAMPLE BOARD SHOWING FAULTY SEAM

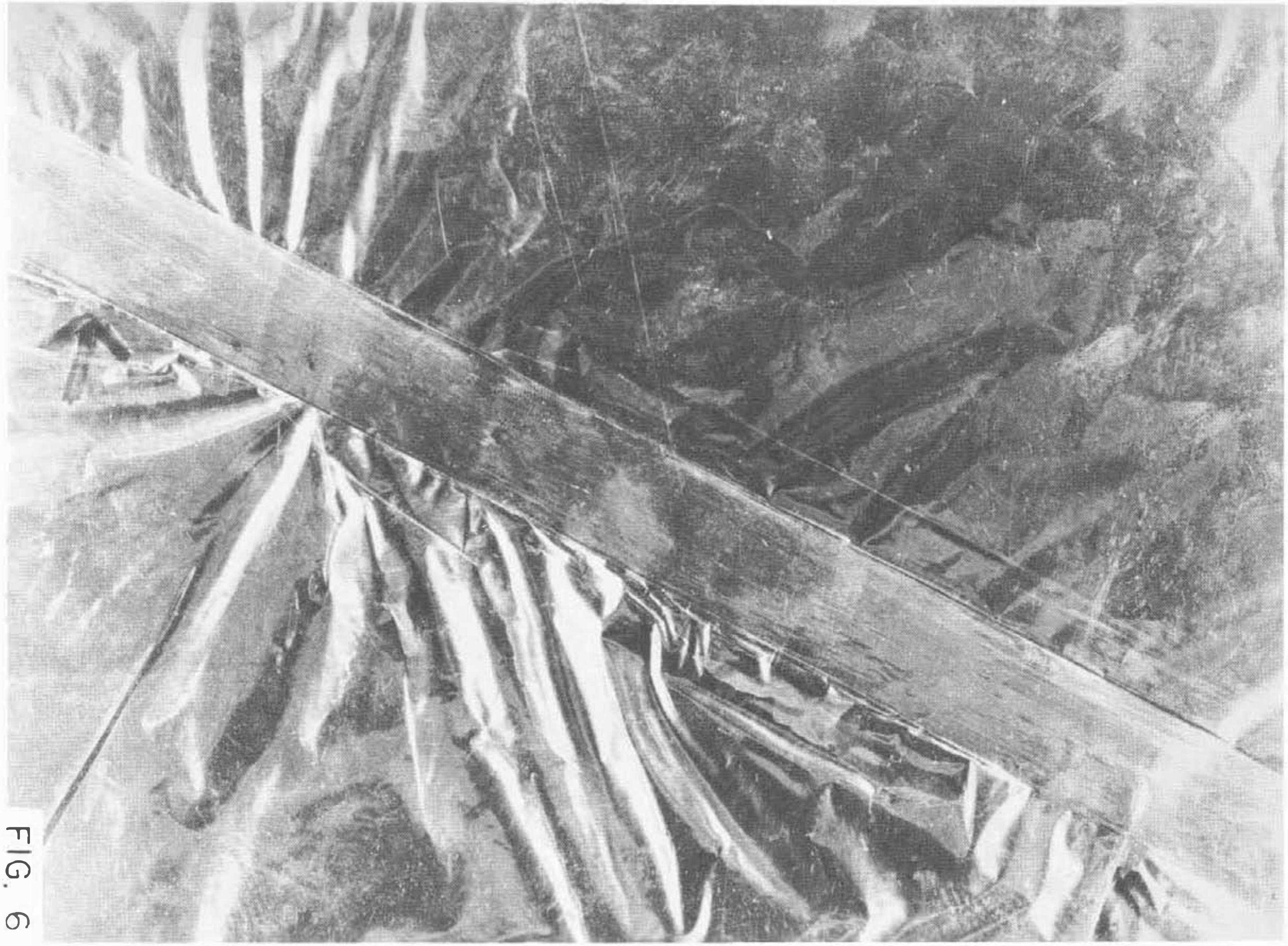


FIG. 6

ACCEPTABLE SEAL

REASON:
1. SEAM HALF WIDTH IS AT LEAST 0.40 INCH.
2. NO BLOCKING.
3. NO SEAM GAP.
4. NO MATERIAL OVERLAP.
5. INCREMENT MARKS ARE WITHIN ± 1/16 INCH.
6. NO MATERIAL FOLDOVER OR PLEATS.
7. NO TAPE FOLDOVER.

FIGURE 7

SAMPLE BOARD SHOWING AN ACCEPTABLE SEAM

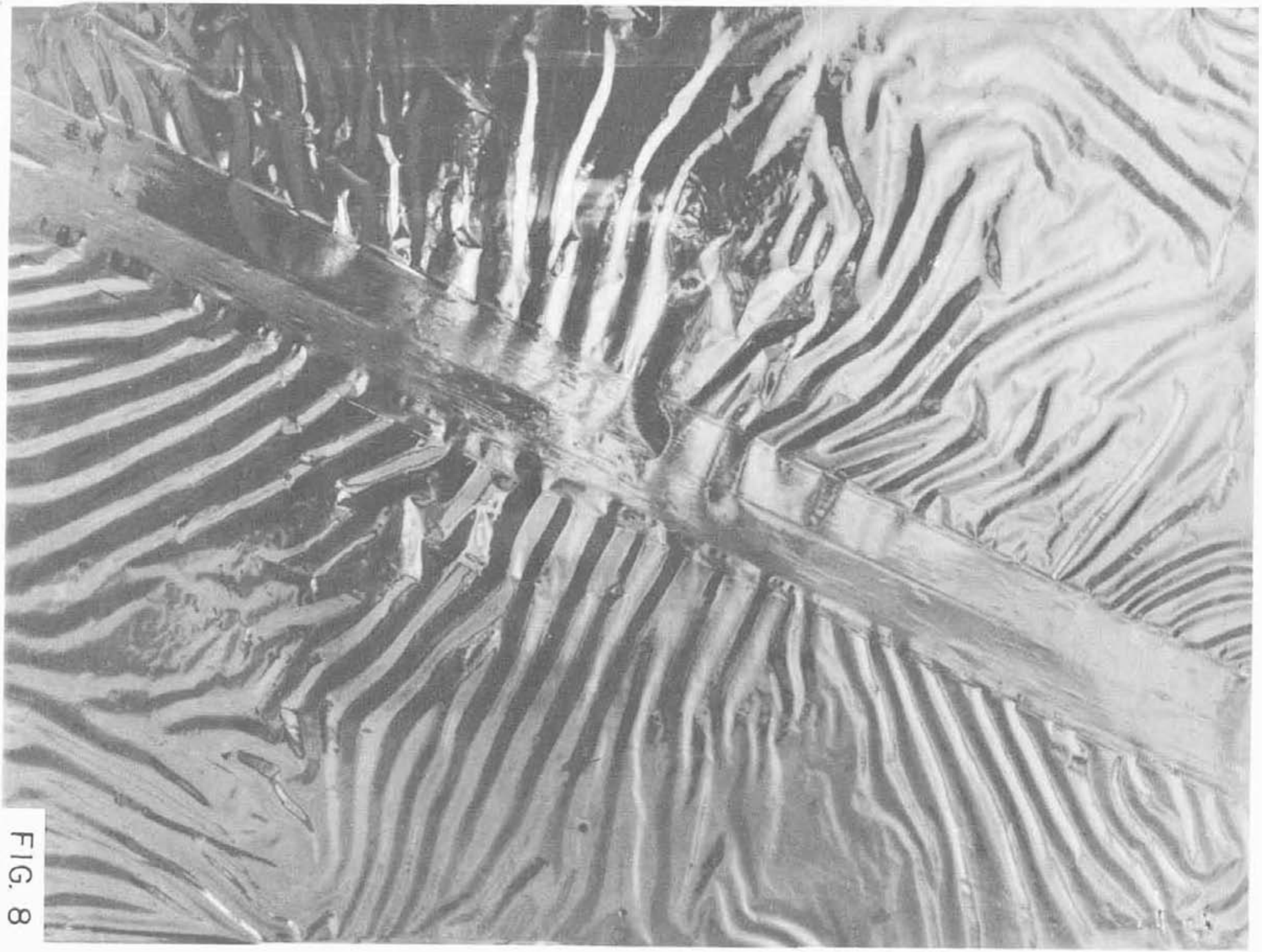


FIG. 8

DEFECT HISTORY

SATELLITE NO.	MATERIAL DEFECTS (IN FABRICATED SATELLITE)	FABRICATION DEFECTS
1	32	26
2	25	123
3*	4	1
4	7	0
5	5	2
6	8	1

*SAMPLE BOARDS INCORPORATED ON THIS SATELLITE.

FIGURE 9

ECHO I

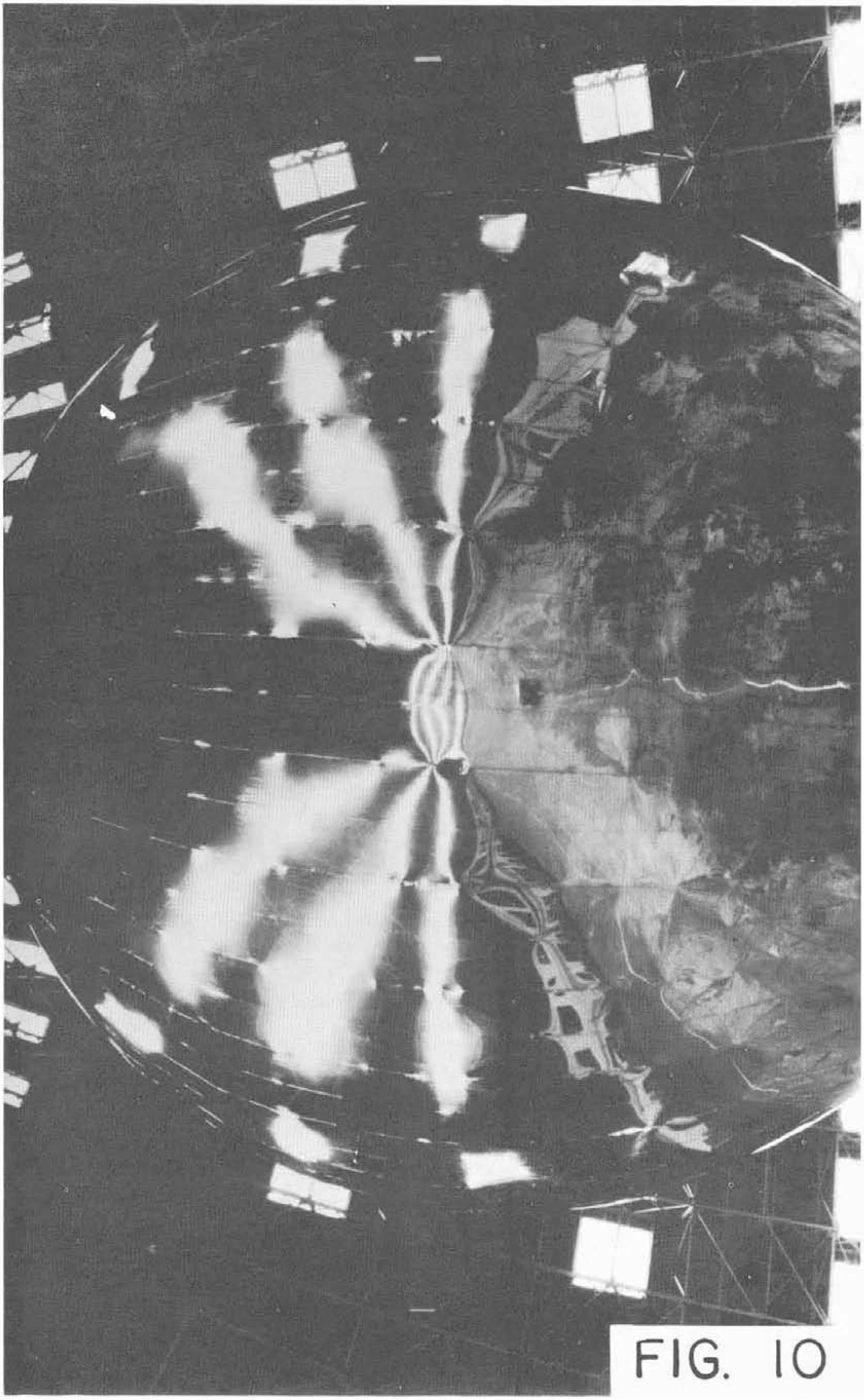


FIG. 10

TITLE: SURVEYOR SPACECRAFT QUALITY ASSURANCE ACTIONS

By C. J. Brewer
Jet Propulsion Laboratory

Since May, 1963, JPL Quality Assurance has performed a vital role in assisting the project on all matters pertaining to quality. The scope of operation covers the general quality areas of Quality Management, Systems and Procedures, Fabrication and Test, Supplier control, and launch operations. The overall quality activities as aligned to project needs are fairly standard in nature. Though specific actions may vary in method of approach or application, the type and amount of coverage are dictated to a great extent by the complexity of the product required to accomplish the assigned task or set of objectives. The quality problems and experiences, with the results of specific actions undertaken by Quality, will be covered in some detail.

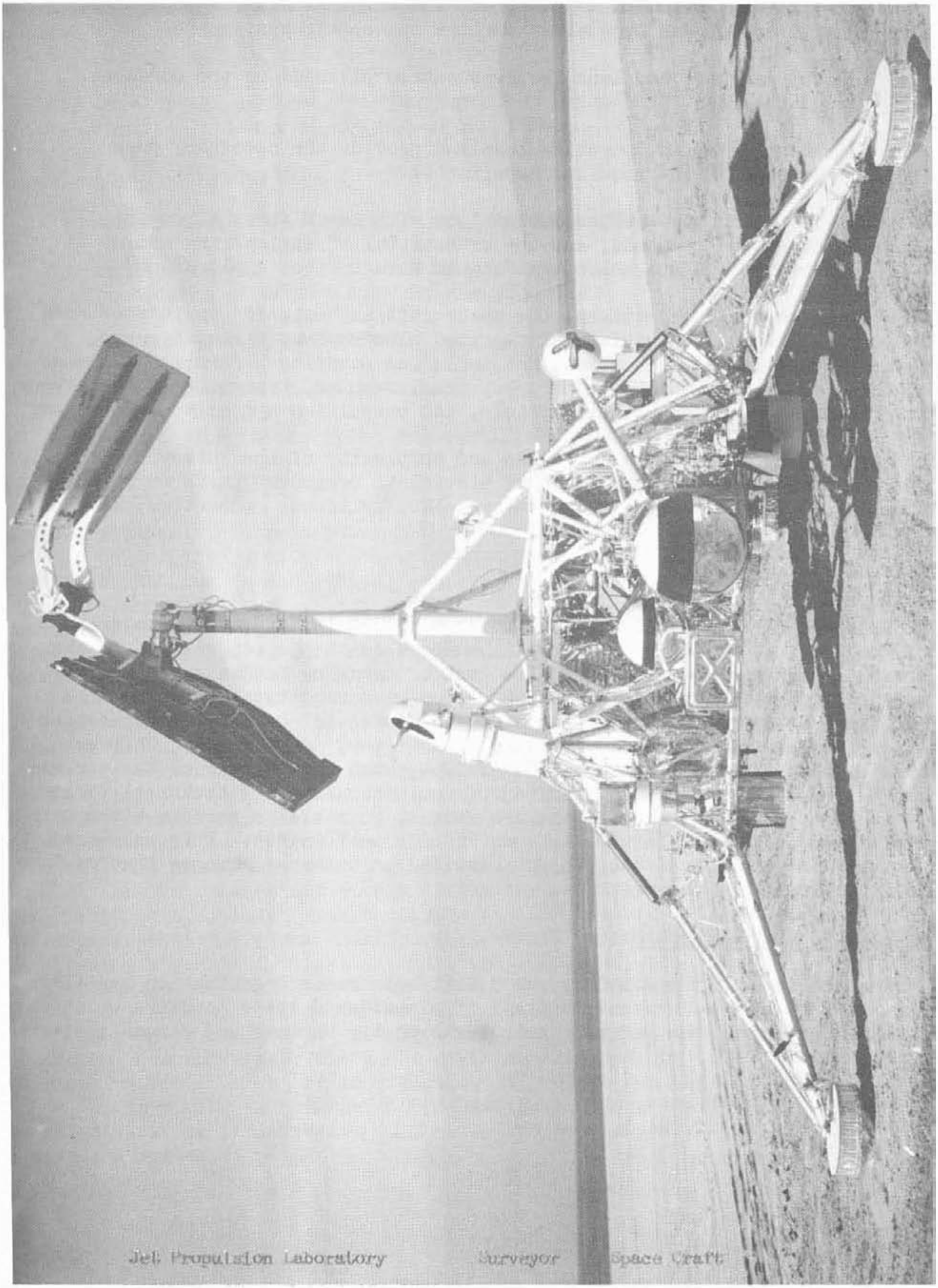
PROJECT HISTORY

To touch briefly on Surveyor history, its mission objectives, and product complexity, at this point, will set the stage for the Quality activities involved in this task.

The Surveyor Project had its beginning when the National Aeronautics and Space Administration (NASA), through its office of Space Science and Applications (OSSA), assigned to the Jet Propulsion Laboratory (JPL) the project management responsibility for the Project.

The Surveyor task which encompasses the development, fabrication, testing, and operations associated with the spacecraft system, was initiated on March 1, 1961, when NASA designated the aerospace firm chosen to be the Spacecraft System Contractor for the Surveyor spacecraft. The project's first five years were plagued with major technical problems which virtually staggered its existence. The changes that evolved affecting weight, scientific payload, quantities and configuration of spacecraft, trajectories and midcourse correction capabilities, took its toll in time and resources to impede the project. What, then, had started out to be a program of eight 2500 pound spacecraft having 340 pounds of scientific payload, and a midcourse capability of 30 m/sec with first launch in 1963, finally settled down to a program of seven engineering test flight spacecraft of 2250 pounds with limited payload on selected flights, and a midcourse capability of 50 m/sec with first launch completed in May, 1966, two and a half years later than predicted on the original schedule.

Primary causes for this rocky beginning stems from deficiencies in hardware design, subsystem/system integration, test methods, and program management coupled with inadequate implementation of quality plans and procedures.


Jet Propulsion Laboratory
Surveyor
Space Craft

Even with the many problems encountered, the original mission objectives were unaffected. These objectives for the spacecraft system are:

a) To transport and land instrumentation payloads on the surface of the moon.

b) To serve as an operating base and provide the necessary power to perform the required experiments.

c) To provide two-way communications with earth for the receipt of ground commands, and the transmittal of engineering and scientific data which will aid in future space exploration.

To accomplish these objectives, the spacecraft as designed consists of some 140 control items of associated integrated electronics, wiring harness, thermal controls and mechanisms, not including mounting hardware. A number of these control items are major subsystems, such as, transmitters, receivers, television, landing gear, solar panels, and propulsion system to name a few.

To give you a feel for the magnitude and complexity of the Surveyor spacecraft system, the population of electronic component parts is in the order of 29,000 pieces excluding solar cells, switches, connectors, and the like.

PROJECT MANAGEMENT

Since the contractor had the system design responsibility, the management of the project, by JPL, was accomplished by a small project staff. As the system design problems increased the task of managing became exceedingly more difficult. With manpower being a premium commodity at the time, the additional support required by Surveyor to assist in the resolving the technical problem was limited, due to other Laboratory commitments. This condition existed until about the middle of 1964, when the phasing of Mariner and Ranger permitted additional staffing of administrative and technical personnel on the project. This shot in the arm made it possible to perform a thorough evaluation and assessment of the contractor's performance. This increased activity on the part of the project resulted in numerous changes that assisted in stabilizing the program.

QUALITY ASSURANCE PROGRAM

During this phase, the JPL Surveyor Quality Assurance organization was also strengthened by the increase in staff of experienced space hardware oriented Quality personnel, who had cut their teeth on the Mariner and Ranger projects.

The Quality representation, as established by project management, is charged with the responsibility for those activities controlling the quality of the project. These include such activities as:

1) Develop and implement QA program in accordance with the applicable tasks of NPC 200-1A and 200-2.

2) Audit and approve contractor QA program and documentation plans.

3) Assess adequacy of systems and subsystem quality.

4) Monitor inspection, parts selection/application, and packaging procedures of contractor and subcontractors.

5) Monitor system and subsystem tests.

6) Participate in QA review boards.

7) Participate in accepting and certifying flight hardware and spacecraft.

QUALITY ASSURANCE ACTIONS

In the discharge of this responsibility, the JPL Quality actions undertaken resulted in the detection of quality system deficiencies with "out of control" conditions existing in many areas, and the discovery of a number of workmanship and acceptability practices considered to be detrimental to product quality. A review of the major quality problems encountered, and corrective measures initiated, will serve to outline the JPL Quality Assurance actions on the Surveyor Project.

A. Requirements: The application of project standards was a major problem, generated primarily from the lack of controlled and defined interrelationship between the various divisions of the contractor; some divisions having design responsibility, a separate division doing the manufacturing, part of another division performing inspection, and other divisions doing subcontract work; all of which were performing functions in compliance with their respective standards, and not necessarily to the standards developed by the project. Parallel to this, the establishment of quality requirements, and their application within this division, was receiving similar treatment. Due to the nature of the program, the Project Quality requirements periodically require modification to stay abreast of changing conditions. However, the problem is encountered in the perturbation caused when these modify or change existing divisional quality requirements or procedures. JPL has encountered several instances where the project quality requirements are not reflected into the divisional procedures, and conversely where the division initiates procedure changes for a common function, which are in violation of project quality requirements. JPL QA, by approving all changes to project quality requirements, and reviewing all divisional implementing documents, has to a great extent closed these gaps in the system.

B. Fabrication Control: The results of a Quality system and hardware audit identified workmanship as a major problem. The workmanship standards as developed by the project were not being utilized in the fabrication of hardware. In fact, the majority of the working level personnel were not aware of the approved Surveyor workmanship standards. It was further discovered that Quality does not establish nor review workmanship standards. The philosophy of the contractor's quality organization is, "Engineering establishes the workmanship, Quality only inspects." Based on these findings, which permits the application of non-uniform standards across the board, JPL QA implemented Mandatory Product Control (MPC) and established mandatory inspection points in the fabrication cycles to identify and correct poor workmanship practices. This operation further substantiated our previous findings regarding workmanship. Equipment coming off the lines was being reworked to extinction prior to delivery to inspection. Overall condition of the equipment with respect to soldering, wiring, and assembly was very poor. Obvious problems on hardware then in production made a "tear down" inspection of the previously assembled SC-1 spacecraft to verify the level of workmanship and hardware integrity a necessity. This inspection resulted in the replacement of a number of major control items for workmanship.

Conditions noted in the MPC operation resulted in a number of operational and hardware changes. Significant among them were the following:

1) Excessive wear in the spacecraft cabling due to the extended testing. Cables were found to be worn to the point of breakage through work handling of strands. Corrective action included extensive reinspection and replacement or repair, and ultimately included a redesign of a number of cables.

2) Damaged hardware due to rough handling by personnel brought about immediate pressure applied in all areas and on all levels. Training classes were initiated with attendance required by all personnel involved.

3) Assembly handling fixtures were not utilized during critical assembly phases. Due to the physical design of many of the systems, the cable harnesses frequently act as hinges, being flexed each time the unit was handled. Various means, including issuance of stop orders against the hardware, brought about the development of fixtures to maintain the integrity of the hardware.

4) Cleanliness problems involving metal fragments and loose bits of solder in flight hardware. Cleaning methods were haphazard and inadequate. Air hoses were used to blow off debris and this method drove particles into the equipment as often as not. Corrective action included initiation of vacuum cleaning methods, preparation and enforcement of housekeeping rules, and movement of certain hardware to properly controlled areas.

5) Backside solder problems experienced on the lines indicated that the contractor was unaware of the behavior of molten solder in a confined space, especially with respect to solder extrusion from the backside of a plated through hole circuit board with a sealed underside. When solder is molten, heat expansion causes beads of solder to form off the pads, frequently resulting in short circuits on closely spaced circuit lines. This is a condition which JPL became aware of through bitter experience in the subsystem development phase on the Ranger Program. Pressure on the contractor has resulted in scrapping a number of boards and major rebuild of many others. New assembly techniques have been devised to compensate for the problem.

6) Tooling Control. Investigation revealed that controls on tooling used to position the spaceframe during assembly were not then under calibration or dimensional control. This resulted in some radical problems in vehicle assembly and test. Had this not been caught, weight, balance and alignment would have been placed in jeopardy.

7) Spaceframes had never been subjected to a dimensional inspection, and had been assembled on the unproved tooling previously noted. It developed that the contractor did not have the capacity to perform this activity. Action produced the following results:

   a) All tooling involved was returned for reinspection and modification.

   b) Spaceframes were submitted for dimensional inspection.

   c) Formal tooling control was established.

8) Optical alignment capability was identified as a potential problem. Attitude control and midcourse capabilities of the spacecraft are predicated on precise positioning of the various thrust motors. This positioning is entirely dependent on optical alignment. Investigation revealed that this capability did not then exist at the contractor. No trained personnel were available, procedures were lacking, the optical dock had not been calibrated, optical tooling had not been proofed or calibrated, and no plans existed that would develop a capability in this direction. Six months of concentrated effort by JPL Quality Assurance in conjunction with JPL Engineering eliminated the problem.

9) Dimensional Error in Spacecraft Cabling was detected as a result of harnesses of the wrong configuration being delivered to the spaceframe which required extensive rework to install. Pressure

produced a design review which developed a number of engineering changes, and the development of a number of new harness assembly boards. Problem occurred as a result of building three dimensional cables on 1 and 2 dimensional assembly boards.

10. Removal and elimination of In-Line Splices from Cables was another JPL QA action taken to increase reliability. In-line splices are a notoriously weak means of joining two wires, being prone to work hardening breakage when flexed in a cable. Several failures on this score have been experienced on cables where it was once a recommended means. This method has long since been barred from use.

To summarize, the more significant problems identified during the course of JPL Quality activities in the fabrication areas were: Improper contamination requirements, improper spacecraft assembly and control techniques, poor wire practices, and general workmanship, inadequate optical alignment techniques, improper splicing techniques, tooling deficiencies, and poor multi-circuit board soldering techniques. The detection of these problems brings to mind an old phrase sometimes used by us Quality cats, "You can't inspect quality into the hardware." Generally, this is true, but when the necessary criteria is not defined, the "inspection and rejection" method by the customer to achieve improved workmanship is a difficult but effective tool. This "inspection and rejection" method has been the prime tool applied by JPL Quality to alleviate these conditions, and to improve hardware integrity. In addition, we have utilized other tools such as participation in design reviews, and requests for engineering and Quality requirement changes. However, since basic designs and quantities of hardware have been built, this route has been slower and less effective.

C. Subcontractor Controls: To establish an initial level of confidence JPL QA conducted audits of each critical supplier. Analysis of the twenty-eight audits performed indicated there were three major common deficiencies:

1) Inadequate QA contractual requirements.
2) Inadequate application of existing Quality requirements.
3) Ineffective contractor source personnel.

Subsequent actions resulted in a complete rewrite of the controlling supplier QA plan, and the initiation of training for the source personnel, in the control requirements and uniform enforcement. Follow-up audits began to show a definite improvement, taking place in the majority of suppliers. Source personnel had responded, and the suppliers had begun to show signs of toeing the mark. However, there were exceptions, and these were handled by JPL imposing MPC at the supplier to ensure compliance.

QUALITY REPORTING

Reporting, particularly in this program, plays an important role in being able to gauge the performance in monitoring and assuring that the contractor has a timely and effective Quality Assurance system, and that non-conforming material is identified, dispositioned, and corrective action initiated.

The Quality reporting system as established provides a means for written communication with project management, engineering, and the contractor on matters pertaining to results of inspections performed, trends of contractor performance, identification of quality problems, and material review actions.

The following is a description of the reporting methods utilized:

1) Discrepancy Reports: The methods utilized for identifying hardware and system discrepancies, and for obtaining corrective action, are handled in the following manner:

   a) Hardware discrepancies are recorded on the appropriate contractor quality documentation. Customer squawks identified in this manner require customer buy-off of action taken before the item is cleared.

   b) Repetitive hardware or quality system problems are listed on a Discrepancy Notice (DN). The DN, which identifies a problem and requests corrective action, is utilized to notify the cognizant Contractor Quality Supervisor of action required. The contractor's response is reviewed for concurrence, and those requiring lapse time implementation have a follow-up card initiated to ensure that adequate corrective measures are taken and maintained.

   c) Corrective Action Request: The CAR serves the same purpose as the DN, except that it is reserved for the more critical problems. The CAR is issued by the QA Manager through contractual channels to the contractor QA Manager to focus management attention on particular problems.

2) Inspection Summary Sheets: This report is a score sheet of inspections performed by Quality Representatives at MPC points in the assembly, test, and acceptance cycle of flight hardware. Analysis of these reports identifies areas of weakness or strength in the contractor's fabrication control, and further serves as a prime source of information utilized for computing statistical data.

3) Unit History Logs: Log books are maintained by Quality representatives as a means of tracking the history of each spacecraft through assembly, system test, and launch operations.

4) Activity Reports: This report, prepared weekly by Quality Supervisors, is a summary of Quality activities for areas covered. The intent of this report is to appraise management and engineering of the day-to-day activities and problems encountered. Secondary function is to provide cross-pollinization of knowledge and information between the various elements of the Quality organization.

5) Quality Status Report: This report, issued monthly, provides visibility of current hardware quality and trends. The report includes statistical data comprising precent defect trends for hardware presented to the customer; defect characteristics by distinct hardware categories, significant problems requiring attention by project organizations; summary of outstanding deficiency notices; and material review board summaries by hardware and type of defect, including recurrence rates.

CONCLUSION

The preceding examples serve to demonstrate the quality actions that have been applied on the Surveyor Project. Significant amongst these is the utilization of microscopic and inline/inseries inspections. On projects of this nature, the tollgate inspection compensates for the short production run which doesn't afford the luxury of the cut and try method in obtaining confidence in the end results of a formalized Quality System.

The application of this type of inspection, coupled with the concentrated efforts by Quality in all other areas, has brought about a measurable improvement in the integrity of the hardware by upgrading the level of workmanship and the quality system as the project has progressed.

There are two points to be touched on; one, which has proven to be useful on this project, is customer support of the contractor's quality organization. As there are occasions when quality people need backing in order to stand up and be counted. The customer can provide this support and thereby assists in uplifting the stature of quality, within the contractor.

The other, based on Surveyor experiences, is that new projects can be helped immensely by the inclusion of the applicable quality disciplines early in the technical planning phases. This action will help prevent the impact that could result downstream due to major quality type problems through lack of appropriate planning.

ENCLOSURES

The attached photographs of the accomplishments of Surveyor I are included to visually display the potential landing sites (Figure 1), earth-moon trajectory (Figure 2), terminal descent phase (Figure 3), landing location on the moon (Figure 4), and two moon photos, one (Figure 5) is a mosaic of narrow-angle pictures of the moon forming a panoramic view of lunar terrain, and the other (Figure 6) is the imprint of one of the three landing feet on the lunar surface.

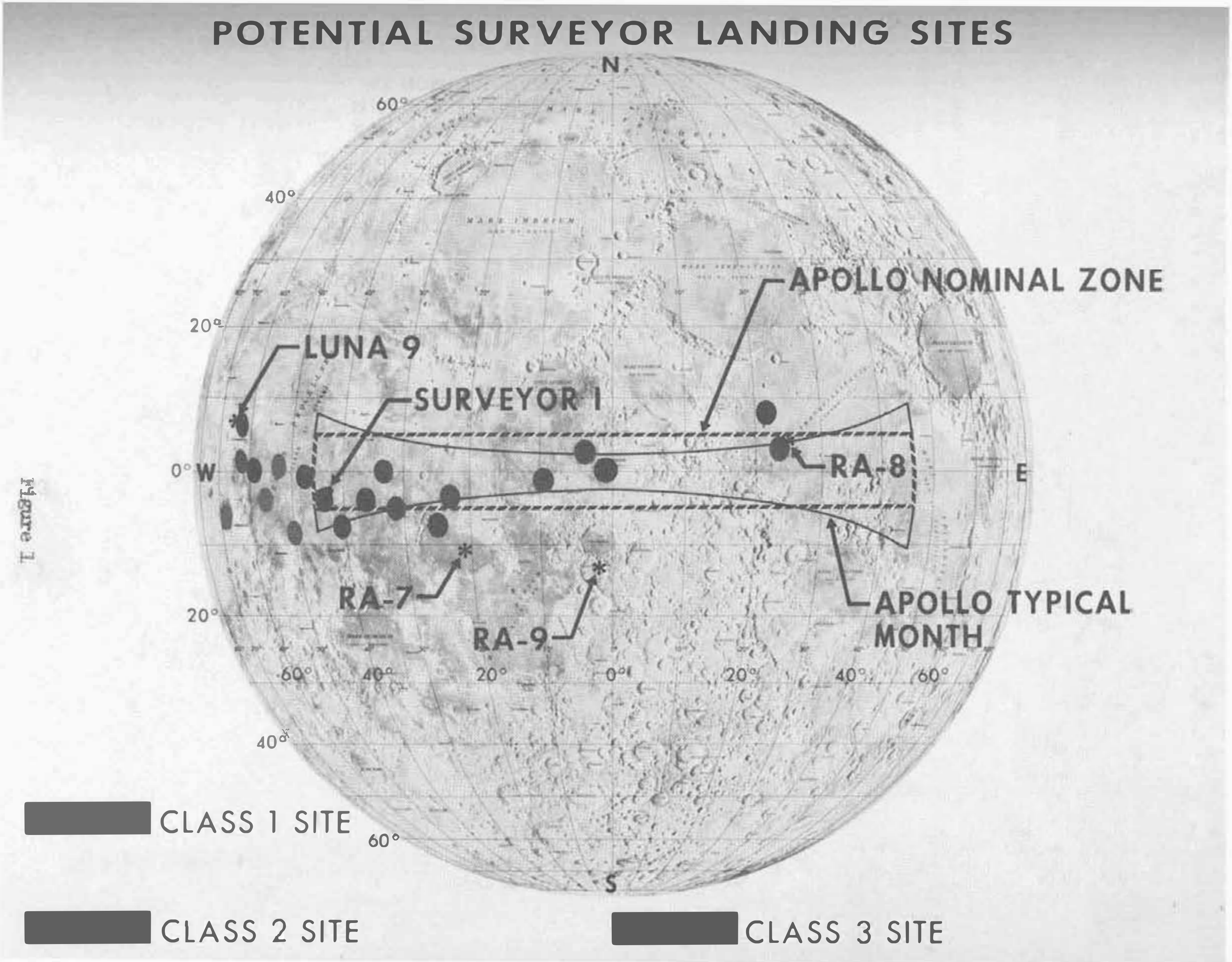
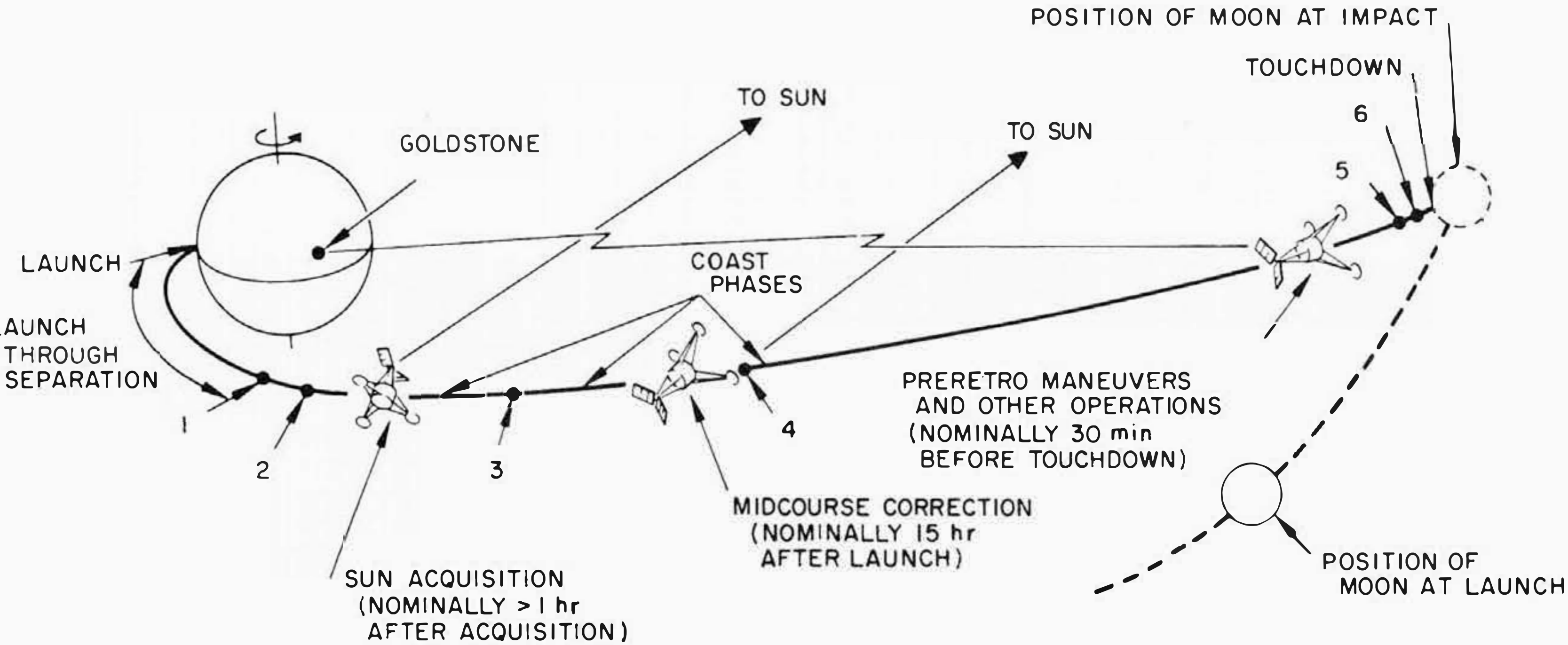

POTENTIAL SURVEYOR LANDING SITES
N
S
W
E
LUNA 9
SURVEYOR I
APOLLO NOMINAL ZONE
RA-8
RA-7
RA-9
APOLLO TYPICAL MONTH
60°
40°
20°
0°
20°
40°
60°
60°
40°
20°
0°
20°
40°
60°
CLASS 1 SITE
CLASS 2 SITE
CLASS 3 SITE

Figure 1

EARTH-MOON TRAJECTORY AND NOMINAL EVENTS



1 INJECTION AND SEPARATION
2 INITIAL DSIF ACQUISITION
3 STAR ACQUISITION AND VERIFICATION (NOMINALLY 15 hr AFTER LAUNCH)
4 REACQUISITION OF SUN AND STAR (IMMEDIATELY AFTER MIDCOURSE CORRECTION)
5 RETRO PHASE (INITIATED AT NOMINAL RANGE OF 60 mi FROM MOON)
6 VERNIER DESCENT (NOMINALLY LAST 35,000 ft OF FLIGHT)

Figure 2

TERMINAL DESCENT NOMINAL EVENTS

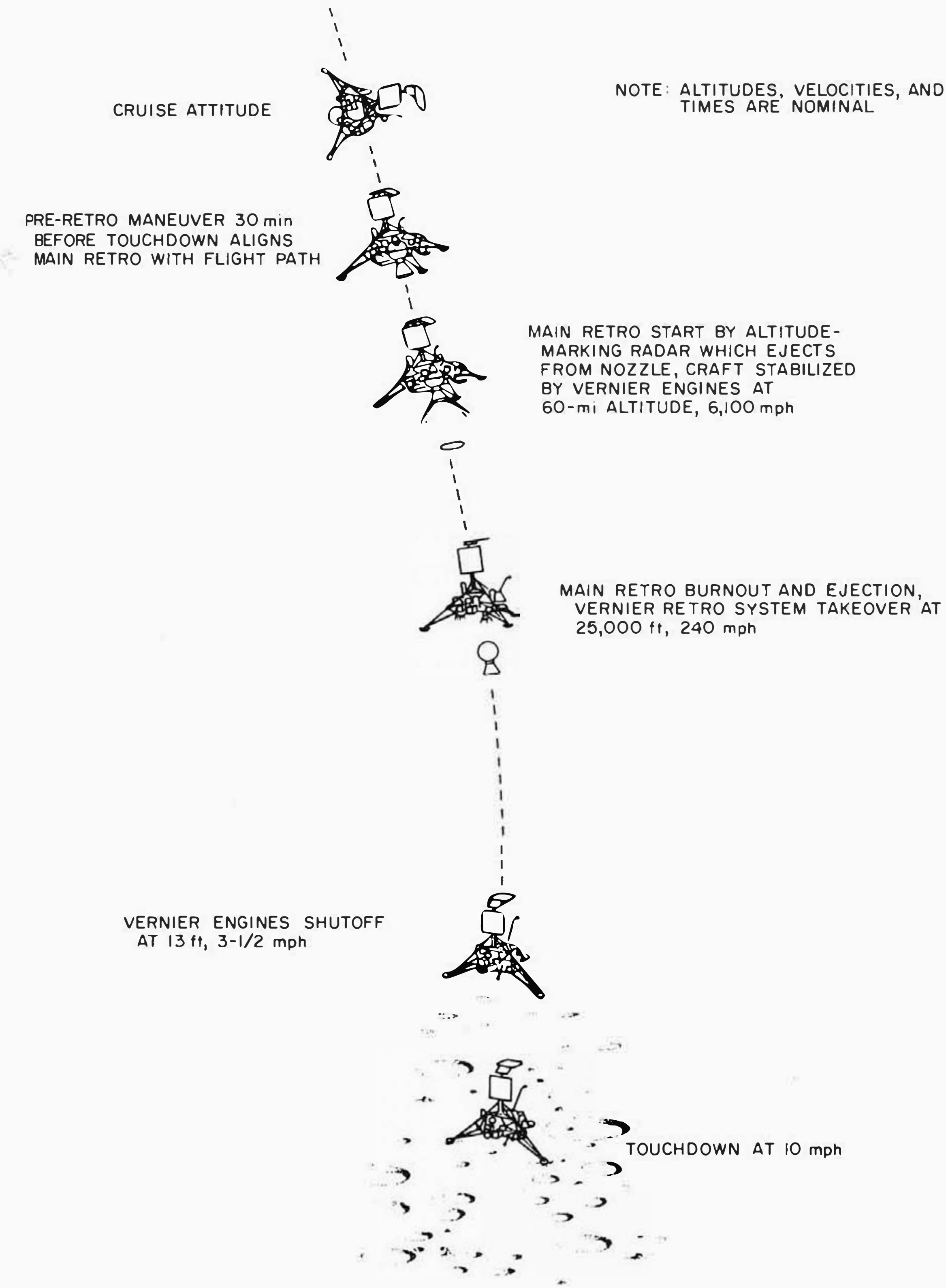
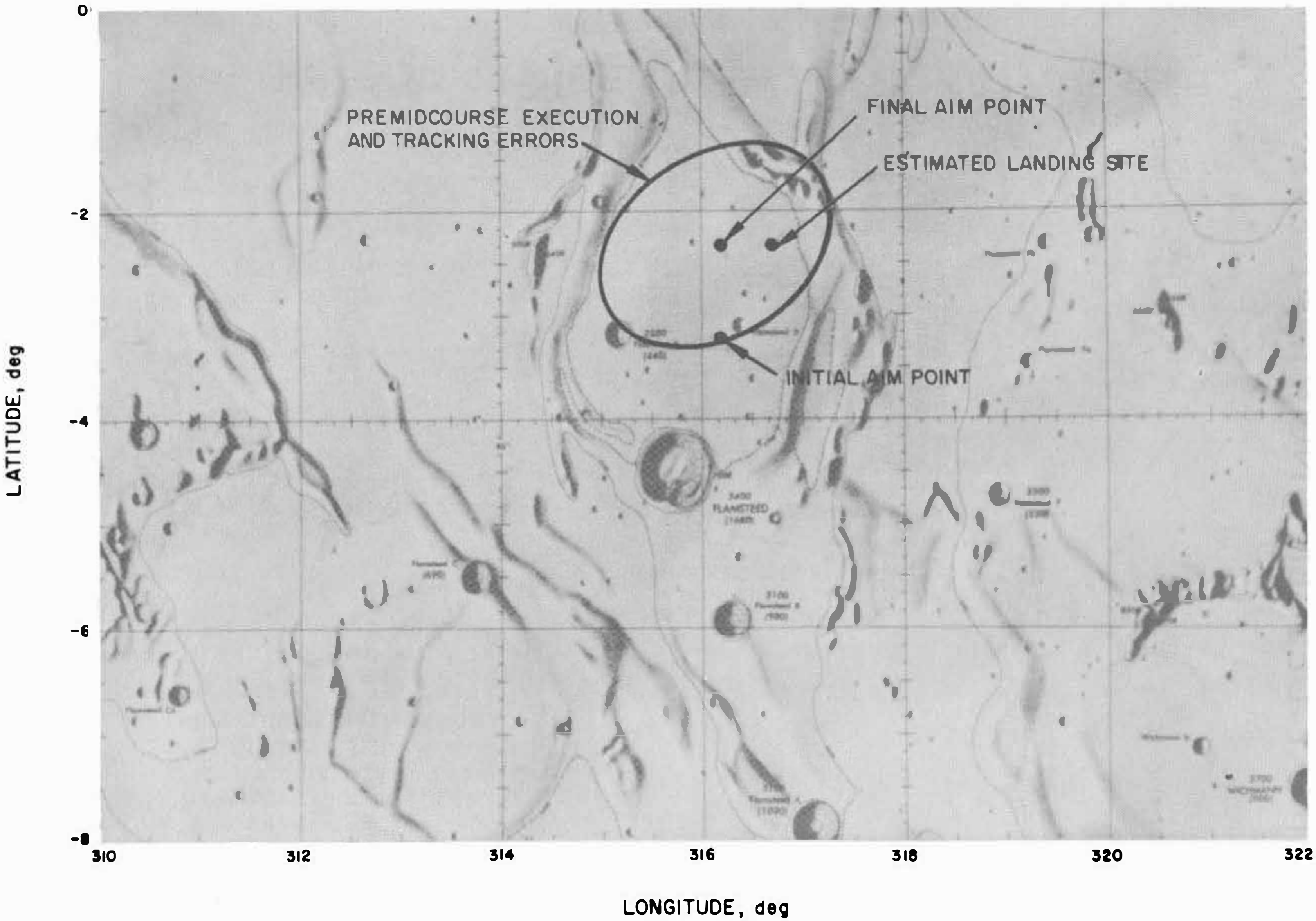


 Figure 3



SURVEYOR I LANDING LOCATION

Figure 4

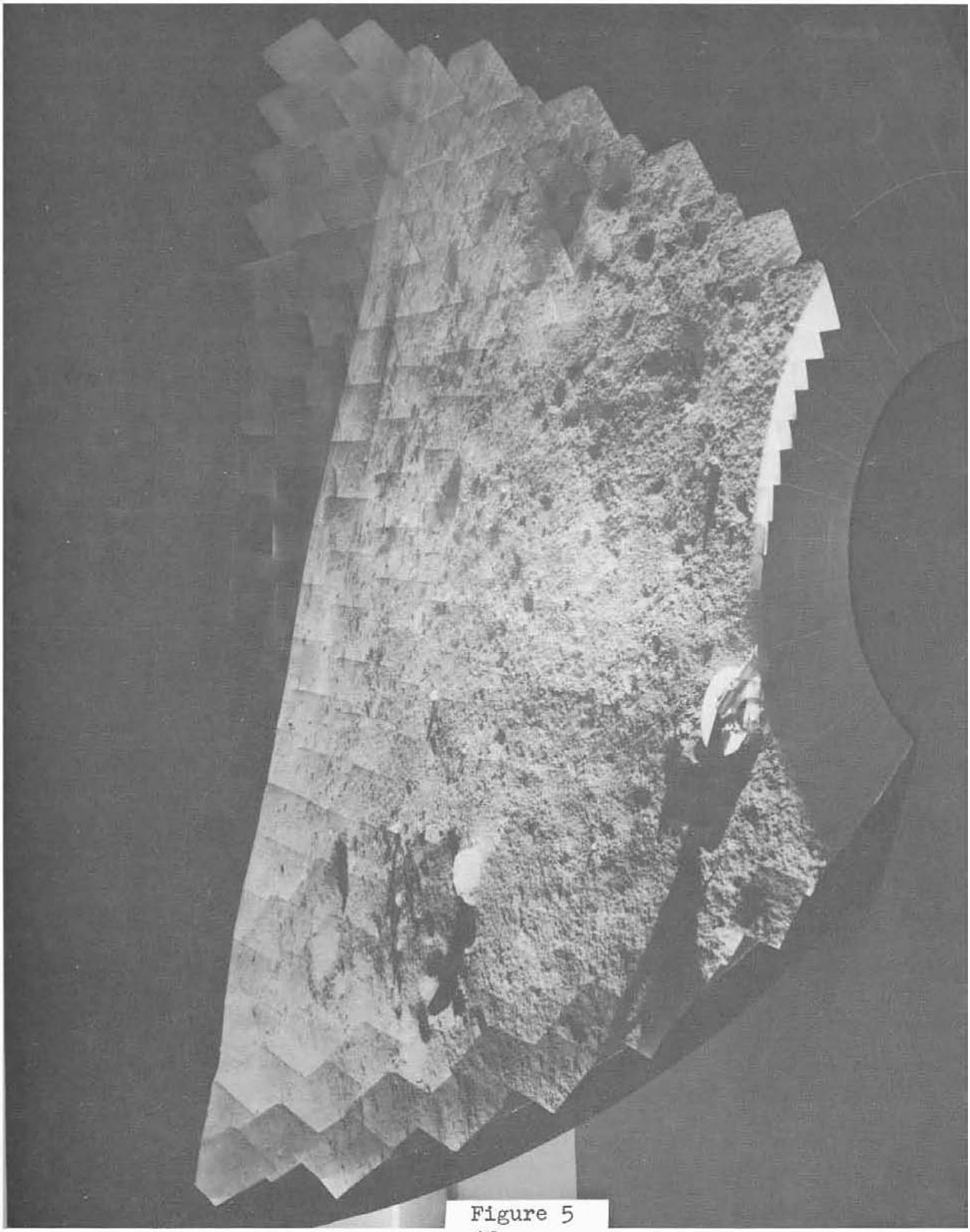


Figure 5

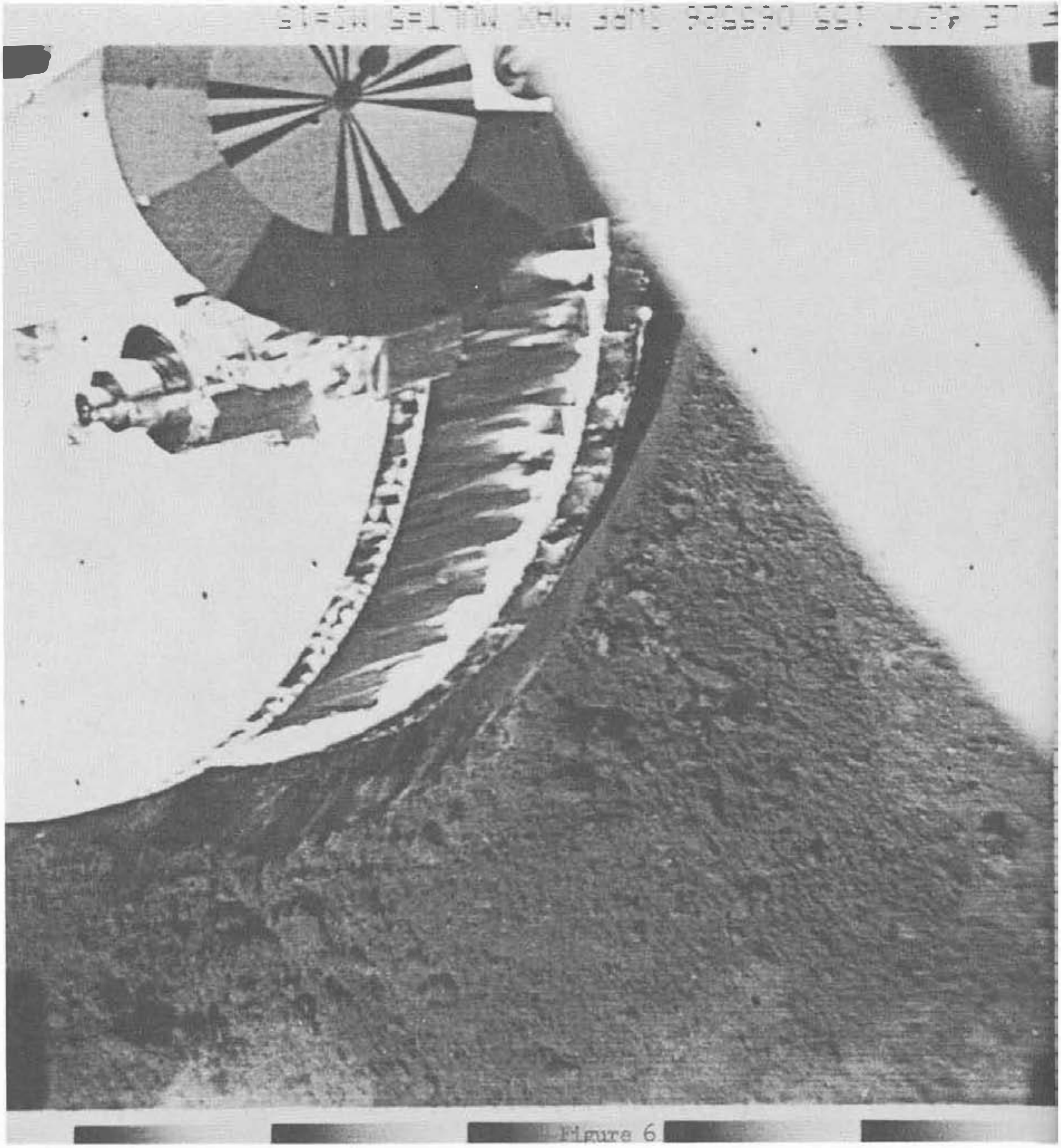


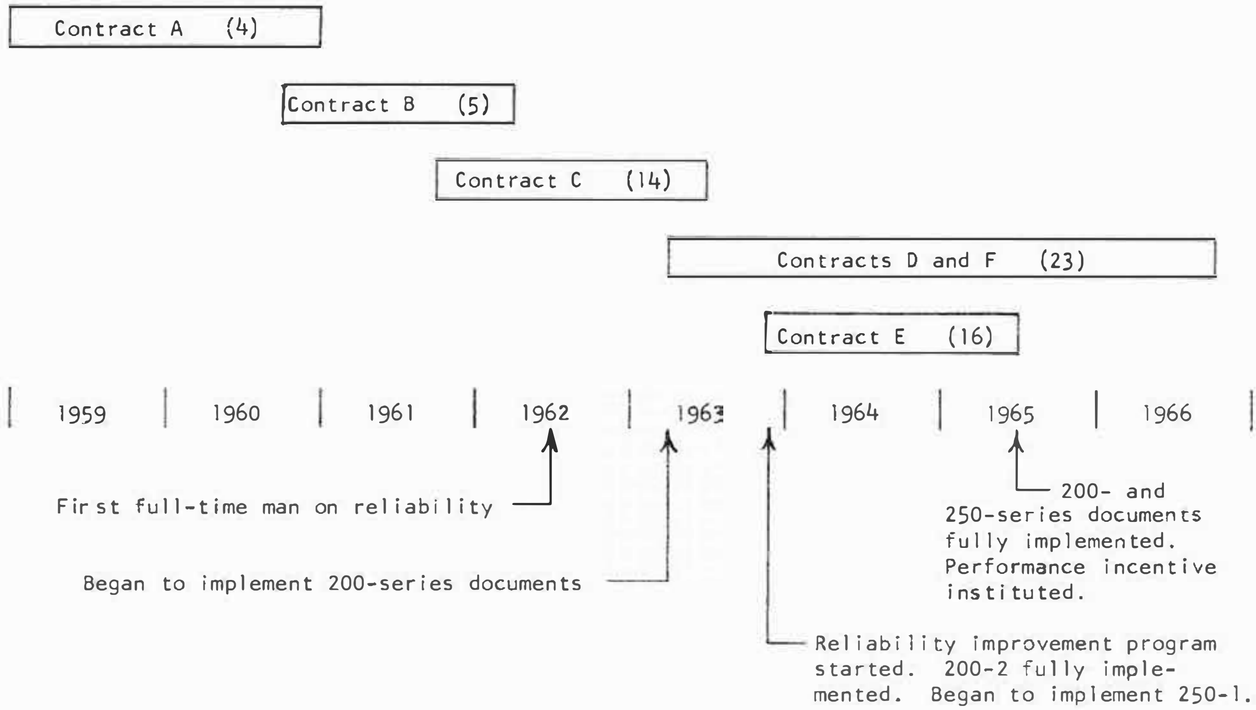
Figure 6

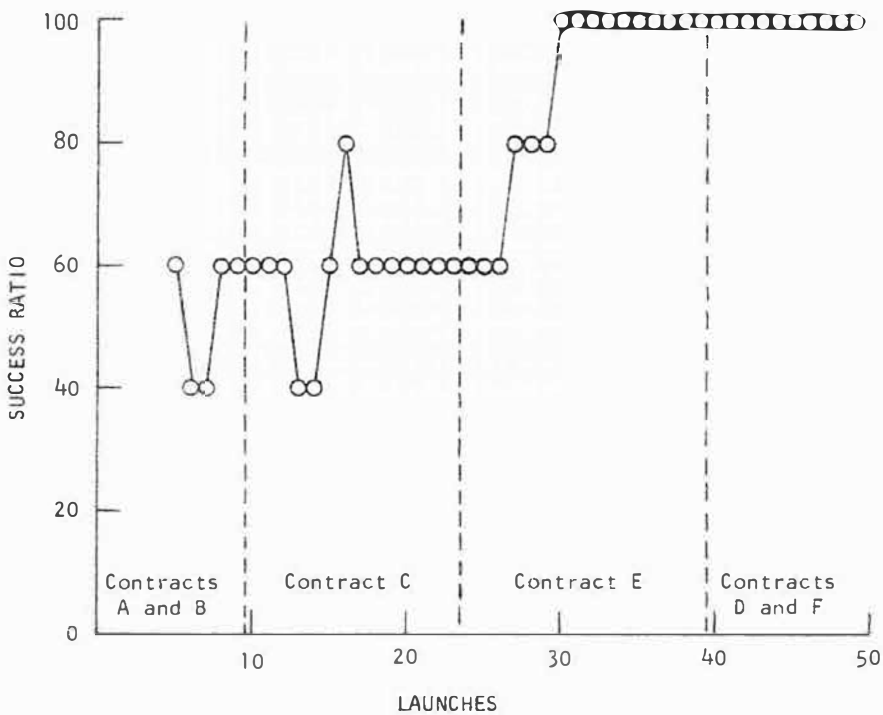
SCOUT RELIABILITY AND QUALITY ASSURANCE

R. D. English, LaRC

At several recent symposiums on reliability and quality assurance, presentations have been made in which it was noted that remarkable progress has been made in these areas during the last decade. But, unfortunately, it was concluded that progress has largely been limited to technology; the same advances have not been made in the area of communication and motivation. In those presentations the discussion was concerned with motivation of the reliability specialist and the management to which he reported, only. I believe the concern should be extended a step further, and I propose to examine the experience on the Scout Project in the areas of reliability and quality assurance with this thought in mind.

We may begin the examination by looking at a history of the fabrication and certification of Scout vehicles, together with some of the milestones in the reliability and quality assurance program as they relate to this history. These are shown on the first slide. Depicted here are the various contracts under which vehicles were procured as a function of the time period over which the contracts extended. The numbers in parentheses designate the number of vehicles delivered under a particular contract. Along the time scale are indicators showing the dates on which certain milestones associated with reliability and quality assurance occurred. The first milestone is the assignment of a man whose sole responsibility was reliability. Prior to this time the reliability and quality assurance program had been administered by several people, each in a particular technical area - for instance, the mechanical systems engineer was responsible for the reliability of mechanical systems, the electrical systems engineer was responsible for the reliability


Contract A (4)
Contract B (5)
Contract C (14)
Contracts D and F (23)
Contract E (16)
1959
1960
1961
1962
1963
1964
1965
1966
First full-time man on reliability
Began to implement 200-series documents
200- and 250-series documents fully implemented. Performance incentive instituted.
Reliability improvement program started. 200-2 fully implemented. Began to implement 250-1.


100
80
60
40
20
0
SUCCESS RATIO
Contracts A and B
Contract C
Contract E
Contracts D and F
10
20
30
40
50
LAUNCHES

of electrical systems, etc. Subsequently, we've always had people whose only responsibility was reliability and quality assurance. Next is the implementation of the NPC 200- and 250-series documents which was begun in early 1963 and continued as the documents became available and it was practical to incorporate their provisions. More or less full implementation was completed in mid-1965. Then there is the reliability improvement program which was initiated in December 1963. This program was started because at that time we were not happy with the flight success ratio. We felt that the inherent reliability of the vehicle had not been realized and this program consisted of several steps designed to improve the situation. Finally, there is the institution of performance-incentive provisions in the middle of 1965. Taken individually, with the possible exception of the reliability improvement program, these milestones probably do not have a lot of significance. All together, however, they constitute a steadily increasing emphasis on the importance of reliability and quality assurance on the Scout program, beginning in the middle of 1962.

Next, by way of examining history, I'd like to take a look at the Scout flight success record, as shown on slide two. Shown here is a plot of percent flight success for sliding groups of five vehicles as a function of the total number of launches. The number five was selected arbitrarily; any other number would show the same trend, namely, that somewhere between the twentieth and thirtieth vehicle there is a remarkable change in the flight success ratio. Up to this point, except for a few brief excursions, it had run about 60 percent. Subsequently, it climbed to 80 percent briefly, then to a hundred percent where it has remained since.

Now let's look at slides 1 and 2 simultaneously. We note that the vehicles for which we experienced the lower flight success ratio came mostly from the first three contracts and that these contracts were all initiated before the beginning of the increased emphasis on reliability and quality assurance. As a matter of fact, the overall success ratio for the vehicles from the first three contracts is 56 percent; for those from the last three contracts, it is 97 percent. It is doubtful that you will see a more striking example of the beneficial results from emphasizing the importance of reliability.

We were naturally interested in determining just how the emphasis on reliability improvement contributed to the increase in flight success ratio, and this question has been given a great deal of thought in the Scout Project Office. In this case, as probably in all cases, we feel that there were two general categories into which the beneficial results fall. These are direct benefits and indirect benefits as defined on the next slide. By direct benefits we mean those which involve detectable improvement in hardware or processes. I can give an example. Recently, in the processing of vehicles, a problem was discovered which involved cracking of terminals on a circuit board. It appeared that the cracking occurred subsequent to fabrication because it was not discovered during inspection. Investigation showed that the cracking was caused by the method of attachment of the terminals to the board. These boards had been built prior to the implementation of NPC 200-4, and had the terminals been attached in accordance with the requirements of NPC 200-4 the problem would not have occurred. This is a direct benefit. Indirect benefits are not so easily defined because the results are not easily identified. Basically, indirect benefits are those that accrue from a change in the attitude and interest, displayed by the people associated

1. DIRECT BENEFITS

BENEFITS WHICH INVOLVE IMPROVEMENT TO HARDWARE

2. INDIRECT BENEFITS

BENEFITS WHICH INVOLVE IMPROVEMENT IN ATTITUDE TOWARD RELIABILITY AND QUALITY ASSURANCE with a program, toward reliability practices. I think, referring back to the introduction of this talk, that direct benefits correspond roughly to an improvement in technology and indirect benefits to an improvement in motivation. Now, since we know of no method of determining what part of the improvement in flight success ratio resulted from direct benefits and what part from indirect benefits, any conclusion in this regard is necessarily largely subjective. Nevertheless, we have drawn such a conclusion. It is the consensus of the people closest to the Scout Project that the indirect benefits far exceeded the direct benefits. I'd like to give the reasons for this feeling. Looking first at direct benefits, we noted that prior to the implementation of the NPC documents, our contracts required a reliability and quality assurance program in accordance with the then-current mil. specs. Now, there is no question that the NPC documents brought about improvements. I mentioned the case of the terminals on the circuit board, and I could give other examples. But the differences between the mil. specs. which we were using and the NPC documents just aren't so extensive that they would account for an increase in flight success ratio from 56 percent to 97 percent or even a large fraction of it. Similarly, the reliability improvement program resulted in some direct improvement. One of the elements of this program was the refurbishment and recertification of vehicles that had been delivered earlier than they were needed and had been stored for several months. In certain components deleterious effects of age were discovered and corrected, resulting in hardware improvement. But again such improvements were not numerous enough, we believe, to account for a major part of the increase in flight success ratio. On the other hand, let's consider the evidence of indirect benefits. There is reason to believe that during the period of emphasis there was a notable improvement in the concern of the technical personnel on the Scout program for reliability and quality assurance considerations. An example that comes to mind is the attitude toward change control. In a continuing program like Scout, a true production status is never reached. Some development is always necessary just to maintain the capability to meet mission requirements. A previous project manager felt, however, that changes were not being kept to the necessary minimum and that when necessary changes were made, they were not given the proper design review and testing and qualification before incorporation. To correct this situation, he created a change control board consisting of five members, all of whom had to approve a change in design before it was accepted. All of the five members were supervisory personnel with full authority to make their decisions stand. Still the results were not satisfactory. Now, four years later, we have very effective change control; and we don't even require a change control board. The personnel on the project police themselves; and the results are satisfactory. The difference, we have concluded, is that during those four years the emphasis on reliability and quality assurance programs had a by-product, a vast improvement in the motivation of personnel; and it is this improvement that accounts for the major part of the increase in success ratio.

The Scout Project Office is probably not unique with regard to the attitudes of its personnel toward reliability. Upon reflection, I think you will agree that most engineers and technicians are hardware-oriented. They are accustomed to dealing with things that can be described in exact terms or defined more or less precisely. There are many elements of a reliability program that fit this category. There is one concept, however, that does not lend itself to precise definition. That concept is the collective awareness, attitude and approach, of the personnel responsible for a program, toward reliability and quality assurance. That concept is of the utmost importance; because, though we may have the most advanced technology and the best documents in the world, it is the people who administer them that determine whether success will be achieved. But because this concept does not lend itself to precise definition, and because it has not been emphasized, I believe it gets little consideration from the large majority of technical personnel.

To summarize briefly, from an examination of the history of the Scout program as it relates to reliability and quality assurance, we have reached several conclusions which are shown on the last slide. The first conclusion is that emphasis on reliability and quality assurance resulted in a striking increase in flight success ratio (from about 56 percent to about 97 percent). Secondly, we conclude that the increase in success ratio was due much more to indirect benefits than to direct benefits, indirect benefits being those associated with an improvement in motivation. The last conclusion is that there is a need to improve the motivation of technical personnel on flight projects.

1. EMPHASIS ON RELIABILITY AND QUALITY ASSURANCE PROGRAMS RESULTED IN A STRIKING INCREASE IN FLIGHT SUCCESS RATIO.

2. THE INCREASE IN SUCCESS WAS DUE MUCH MORE TO INDIRECT THAN TO DIRECT BENEFITS.

3. THERE IS A NEED FOR IMPROVEMENT IN THE MOTIVATION OF TECHNICAL PERSONNEL ON FLIGHT PROJECTS TOWARD RELIABILITY AND QUALITY ASSURANCE.

R&QA EXPERIENCE WITH A UNIVERSITY RESEARCH LABORATORY

J. D. Rosenberg, Space Applications Programs
Office of Space Science and Applications

This paper will discuss the experience had with the development and fabrication of GEOS-A (Explorer XXIX) by a university-based research laboratory.

GEOS-A is the principal active spacecraft of the National Geodetic Satellite Program (NGSP) -- a cooperative effort of the Department of Defense, the Department of Commerce and NASA. The research objectives of the NGSP are to refine the description of the Earth's gravity field and to develop a worldwide reference system in which major control points are located to within ± 10 meters in earth-centered coordinates.

Launched on November 6, 1965, GEOS-A is now being operated for some 112 ground observation stations. Over 105 stations have been observing GEOS-A on a daily basis since it became fully operational in January of this year. GEOS-A is a 385 lb., state-of-the-art, gravity-gradient stabilized spacecraft -- the first flown by NASA -- containing 5 geodetic laser corner-cube reflectors, a Goddard range and range rate transponder, Navy doppler beacons and an Army range transponder. Timing of optical beacon flashes during a five (5) or seven (7) flash sequence is accurately controlled by an on-board memory system which is programmed by ground command once each day. The other systems, except for the passive laser reflectors, are scheduled by the Geodetic Operations Control Center at Goddard which issues the required system ground commands.

From this brief description it may be apparent that GEOS-A is neither fish nor fowl. That is, it is not an R&D spacecraft since it does not carry space experiments. And it is not an operational spacecraft, since the data taken by the ground stations are used to support research programs rather than operational programs. However, in view of the extensive ground facilities and personnel which are deployed to obtain the observations and which rely on the spacecraft, GEOS-A more nearly meets the requirements of an operational spacecraft than of an R&D spacecraft.

As you know, an important and fundamental difference between an operational and R&D spacecraft lies in the area of reliability and quality assurance. The operational spacecraft must have a planned finite life to effectively provide the support and the outputs needed to complete operational requirements. Thus, the implementation of a sound reliability and quality assurance program is essential to the success of the project. For an R&D spacecraft, however, it may suffice to merely prove out a principle or technique in space wherein a foreshortened spacecraft life is acceptable and the R&QA effort may be minimal.

The discussion that follows evolved largely from the GEOS Project's experience with the laboratory that made GEOS-A. We believe, however, that it represents a rather general situation that exists within the quasi-academic atmosphere in which such laboratories function. The Applied Physics Laboratory of the John Hopkins University made GEOS-A and will serve as a case study from which we will attempt to derive a measure of insight into the procedures and problems of such groups in the space program.

Before starting our discussion, however, it is mandatory that we point out the philosophical basis of such a laboratory. The primary concern of the R&D university laboratory is the advancement of the state-of-the-art or technology in science. The development of hardware thus becomes but a means to an end and not the end in itself. The success of the development is measured by the achievements in science rather than by the quantity or quality of data that is accumulated for other investigative or program purposes. Therefore the approach is one of deriving satisfaction from the scientific achievements rather than from a successful contribution to the overall program which is not under the control of the laboratory. As a corollary to this, the dominant drive of the university laboratory is for technological excellence and originality rather than for the minimization of risk in the accumulation of data by the application of accepted technology.

Another factor that should be noted at this point is the general approach of a scientific laboratory to the development of scientific instrumentation (i.e. hardware development) in contrast to that of an industrial organization. In the R&D environment the personnel responsible for the hardware development are highly qualified and equally capable of conducting the scientific investigations and the scientific analyses associated with the hardware. Because of this and their emotional commitment to the total job,the individual responsible for a system or sub-system assumes full responsibility for every aspect of the development including the design conception, fabrication, testing and final checkout. The motivation is an honest one and understandable -- the individual's and the laboratory's dedication to science and scientific achievement.

The consequences of this attitude are readily recognized. First, documentation of the hardware development is considered unnecessary, a waste of time. The responsible engineer knows what is required and what is being done and sees no reason why he should slow down the development to prepare reports. Of course, papers for the technical journals and technical meetings are not to be neglected.

Another consequence is that the individual designer is held responsible not only for the performance of the system (or sub-system) but for its reliability as well. The argument for this is that (1) he knows the system best, since he designed it, (2) this permits the fullest utilization of all his talents and interest, and (3) since his reputation is involved, he should have authority over the total system and the responsibility for its performance, on the ground and in-orbit.

Still another consequence is that although the developments are completed on schedule, most milestones between start and completion are slipped because they are considered unimportant.

It is believed that the APL R&QA organization was established only to supplement and complement the individual's authority and responsibility, never to threaten it. The entire R&QA effort appeared to be directed at general process control and piece-part selection and specification. There was no extension of the responsibility of the R&QA organization above this level except as requested by the responsible designer. In these two areas QA was good, but even here the designer could select a component from outside the "preferred" list should his system require it.

Turning to industry and its motivation, we find significant differences. The personnel in industry although equally capable at equal levels, perform under an important restraint. Not only should the job be technically challenging so that the development group can be motivated to perform properly, but, in addition, the job must show a profit. With this in view the development group must meet other objectives besides its own scientific satisfaction.

The development objectives must meet the customer's requirements, needs and specifications as spelled out in the contract. Industry is restrained to fulfill the obligation to supply an operational capability as it is specified in, and funded by, the contract. The industrial contractor, therefore, imposes on himself a strong R&QA effort directed towards providing the specified operating life so that the contract commitment is fulfilled.

This paper will not dwell on the fast footwork that contractors display to meet profit goals. However, it has been the experience of the GEOS project that in the development of the initial spacecraft by an R&D laboratory, the strong individualistic "scientific" approach left much to be desired from the project and program point of view. As stated earlier, the GEOS project required a virtually operational spacecraft to provide outputs for many investigators over a fairly extensive period of time. The success of the program was dependent upon its life in orbit. At launch the project had little reason to be confident that this objective would be met. In the period immediately after launch there was considerable concern regarding the continued operation of GEOS-A due to a number of serious spacecraft difficulties. These were:

1) Internally generated noise upsets some digital circuits -- the Laboratory blamed the noise on arcing caused by part degradation during abnormal orientation after launch, but there is a possibility that this problem might have been detected during ground testing if a more comprehensive spacecraft test had been performed prior to launch.

2) Severe degradation of the output of the Solar Aspect Detectors within several days of launch - although the Laboratory had successfully flown the sensors and the quartz filters previously, the cement holding the filter on the sensor darkened when exposed to sunlight.

3) A converter began generating noise shortly after launch, and its parallel component has been used since - this noise first occurred during ground tests and was cured by adding more capacitance to the circuit without any attempt to analyze the possibility of part degradation.

4) In addition to these problems, the Laboratory volunteered information at a post-launch meeting on two others that they knew about prior to launch - knowledge of at least one of these would almost certainly have resulted in a launch delay.

It should be noted that although GEOS-A lost some of its redundancy early in its life, it was fully operational for more than one year. Thousands of data passes were obtained and the hundreds of ground observation stations satisfied.

In view of the problems encountered early in the life of GEOS-A and the dependence of the success of the national program on the spacecraft success, the GEOS Project evaluated the approach taken in the development of the spacecraft. It ascertained that the approach had disadvantages. (1) The assumption of full responsibility by the design engineer for all aspects of his system development did not permit adequate visibility for evaluation and control by the project staff to assure that the desired operational lifetime would be achieved. (It is also believed that the Laboratory management itself did not have as much visibility as it required to control the overall development.) (2) The lack of adequate documentation to and communication with the project did not permit an adequate evaluation to be performed to assure that the necessary reliability and testing efforts were expended by the Laboratory. (3) It was also difficult to determine the condition of the spacecraft or its readiness for launch.

In order to relieve these concerns and fears for the next geodetic satellite, GEOS-B, a new R&QA approach has been negotiated with the Laboratory. The requirements of this approach are not intended to impose a fundamental change in the organization structure of the Laboratory nor to inhibit the technical competence of the group assigned to each system development. They are only intended to insure that full visibility and control are provided to the project to assure the mission requirements will be met by GEOS-B.

The negotiated R&QA approach is based on the preparation by the Laboratory of a Reliability Program Plan, a Quality Assurance Plan and an Integrated Test Plan, all based on NASA R&QA documents.

The Reliability Program Plan, in this case, is the most important of the three since it lays the groundwork for this approach. In this plan, visibility into the development is assured by the project attending and participating in all systems and sub-system design reviews. In addition, the laboratory will cooperate in a series of major design reviews with GEOS-B Design Review Committee from the Goddard Space Flight Center. The GEOS project maintains responsibility for the spacecraft development, however, the presence of the review committee provides an invaluable base for decision.

Under the negotiated approach the laboratory will submit for project acceptance a specification document for each system and sub-system, once the design is frozen. These documents will be the basis for the configuration control system. There will be a R&QA sign-off for each proposed change to these specifications. In this manner, the Laboratory R&QA group (augmented by two personnel assigned to this spacecraft) will have an increased role to play for they will be assuming appreciable responsibility for the spacecraft.

The Laboratory has agreed to brief and/or provide documentation to the project on every significant change to these specification documents. In addition, the project will be invited to attend and participate in all discussions of the proposed changes.

The director of the division in the Laboratory that is developing GEOS-B will sign each month's milestone report so that he becomes cognizant of schedule slips that might occur.

In all of the above, the GEOS project is attempting to (1) increase visibility, (2) become more intimately involved in the details of the development, (3) persuade the Laboratory to bring additional personnel into the R&QA group to assume more responsibility for the spacecraft, (4) intimately involve the Laboratory management in the development, and to (5) convince the design engineer that the additional difficulties and burdens being placed on him will, in fact, improve his product, safeguard his reputation, and share responsibility for failure.

The GEOS project hopes that as the R&D Laboratory personnel absorb these procedures which are usual to industry, the best of both the University and Industrial worlds will be reflected in the successful performance of GEOS-B in-orbit.

QUALITY EXPERIENCE ON NASA'S LARGEST PRECISION INSTRUMENT (210 FOOT ANTENNA)

J. P. Frey, Jet Propulsion Laboratory

ABSTRACT

To meet the requirements for improved tracking and command communication with deep space vehicles traveling not only to Mars and Venus but to the outer reaches of the solar system, NASA's Office of Tracking and Data Acquisition, working with JPL, defined the requirements for an Advanced Antenna System that would meet the demands of new, more sophisticated, spacecraft. This paper defines the 210 foot antenna and the Quality Program maintained during fabrication, erection and final acceptance testing.

INTRODUCTION

The completion of the first 210 foot diameter antenna has extended NASA's deep space communications and tracking capabilities to the limits of our solar system. The new NASA facility is under the systems management and technical direction of the Jet Propulsion Laboratory. The 210 foot antenna will soon join the Deep Space Network which includes 85 foot and 30 foot antennas located at Cape Kennedy; Goldstone, California; South Africa; Australia; Spain; and Ascension Island. The command and control center for the Deep Space Network is known as the Space Flight Operation Facility located at the Jet Propulsion Laboratory in Pasadena, California. The Space Flight Operation Facility is connected to all stations through the Ground Communication System which connects all parts of the Deep Space Network by telephone and radio-teletype.

210 FOOT DISH ANTENNA AT GOLDSTONE TRACKING STATION

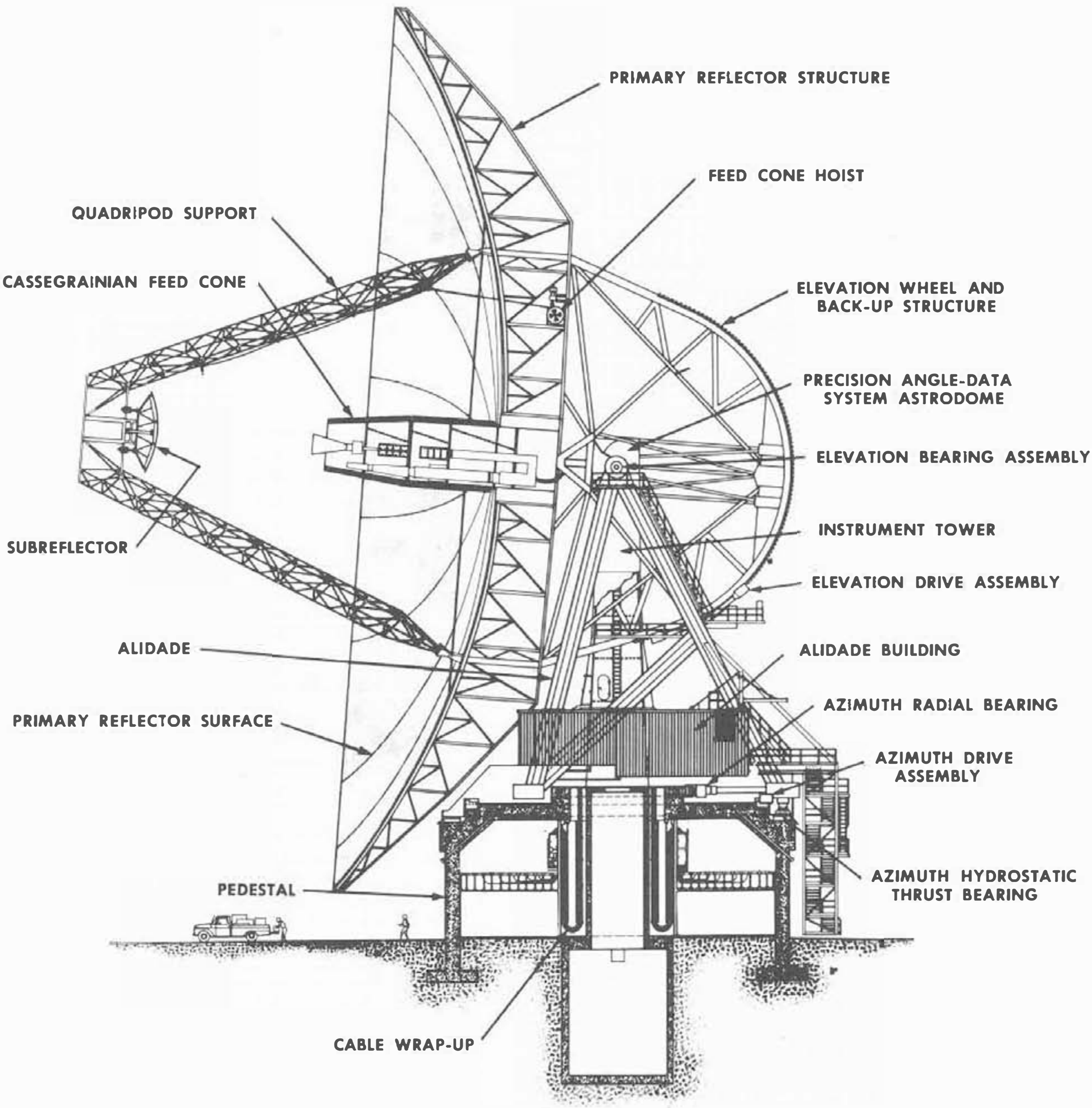


FIGURE I

In June of 1962, the Rohr Corporation, Chula Vista, California, won a competitive fixed-price contract for the detailed design, fabrication and erection of the structural-mechanical assembly of the antenna, including the Servo and Control System. The antenna was formally dedicated by Congressman Eugene Miller on April 29, 1966.

DESCRIPTION OF ANTENNA SYSTEMS

The antenna has a 210 foot diameter paraboloidal reflector, a sub-reflector and uses a Cassegrain Cone System. The entire antenna structure stands 234 feet high and weighs 16 million pounds. The pedestal is constructed of high strength, reinforced concrete with 4,000 psi compression strength and a modulus of elasticity of 5,000,000 psi. The pedestal wall is 42 inches thick, 34 feet high and 80 feet in diameter. (Figure I).

A high strength reinforced concrete instrument tower, within and completely isolated from the pedestal, provides a vibration-free reference platform for reading out antenna pointing data by means of the master equatorial unit, having an accuracy better than .002 degrees.

The azimuth rotation of the antenna is accomplished by means of the Hydrostatic Bearing and the hydraulic drives. The moveable portion of the antenna structure is connected to three steel pads, 40 x 60 x 22 inches, equally spaced under the structure. The three pads ride on the Hydrostatic Bearing runner. (Figure II).

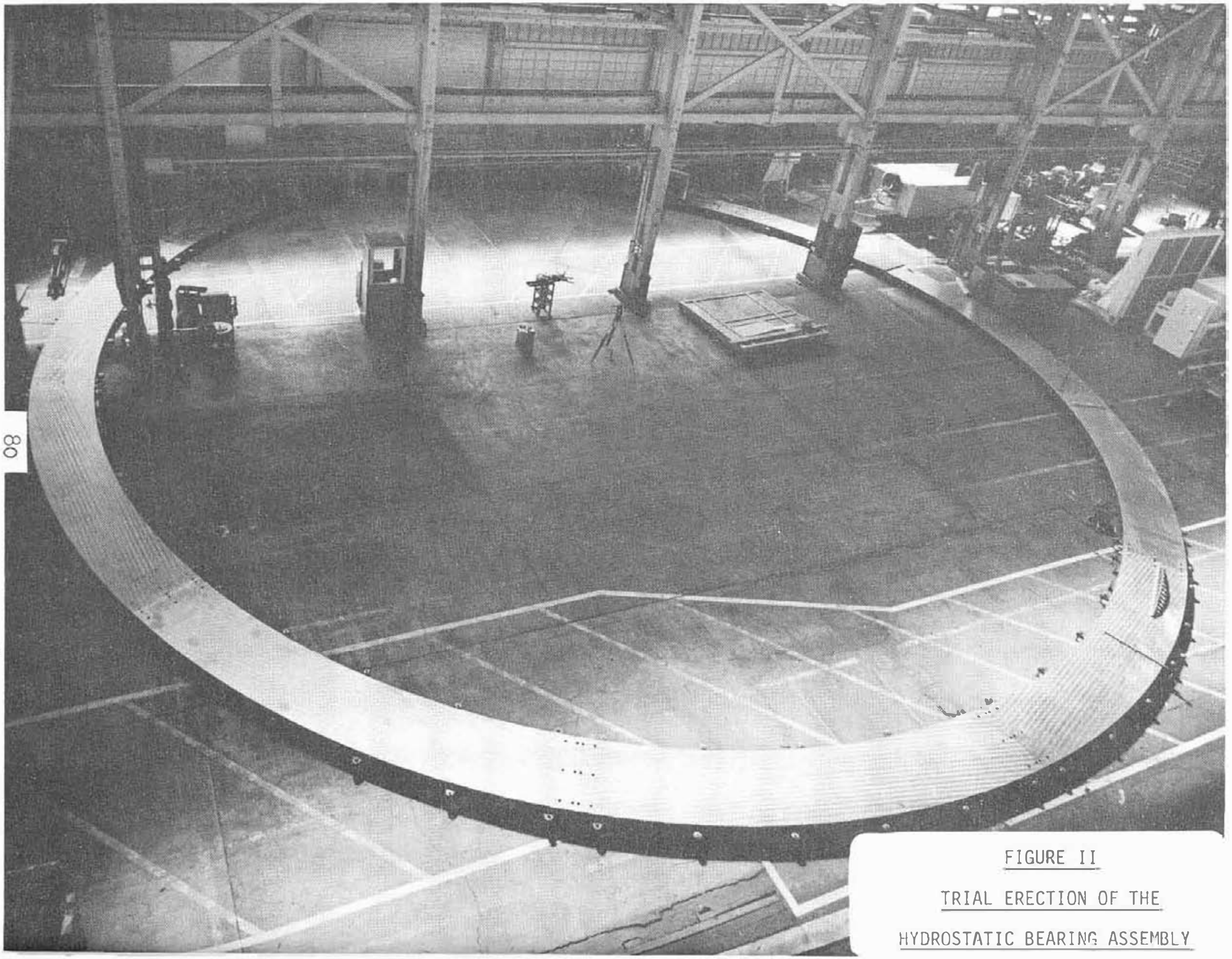


FIGURE II

TRIAL ERECTION OF THE HYDROSTATIC BEARING ASSEMBLY

The runner consists of a steel ring 78 feet in diameter, 44 inches wide and 5 inches thick. Pressurized oil flows from the underside of the pad, lifting the antenna .008 inch, and creates an oil bearing for the rotating part of the antenna.

The Azimuth Radial Bearing consists of three adjustable truck assemblies which are equally spaced and attached to the main rotating part of the structure. The truck assemblies each have two large rollers 36 inches in diameter and bear on the Azimuth Radial Bearing Runner. The Runner is a cylindrical steel ring 30 feet in diameter, 20 inches high and 4 inches thick. This Runner is attached to the center collar of the concrete pedestal. The truck assemblies are adjusted to exert a 300,000 psi load on the Radial Bearing Runner. This controls the rotating part of the antenna about its true center.

The Azimuth Bull Gear Assembly is part of the gear drive which rotates the antenna in azimuth. It is 70 feet in diameter and the face of the gear is 9 inches wide. The assembly is attached to a heavy steel sole plate, held in place by bolts embedded in the pedestal concrete. (Figure III).

The Elevation Bull Gear and Elevation Wheel Assemblies are part of the drive system for the tilting part of the antenna. The two Bull Gear and Wheel Assemblies are attached to the Tie Truss, one on each side of the Instrument Tower. Counterweights are built into the Elevation Wheel Assemblies as counterbalance for the reflector and structure located above the elevation axis.

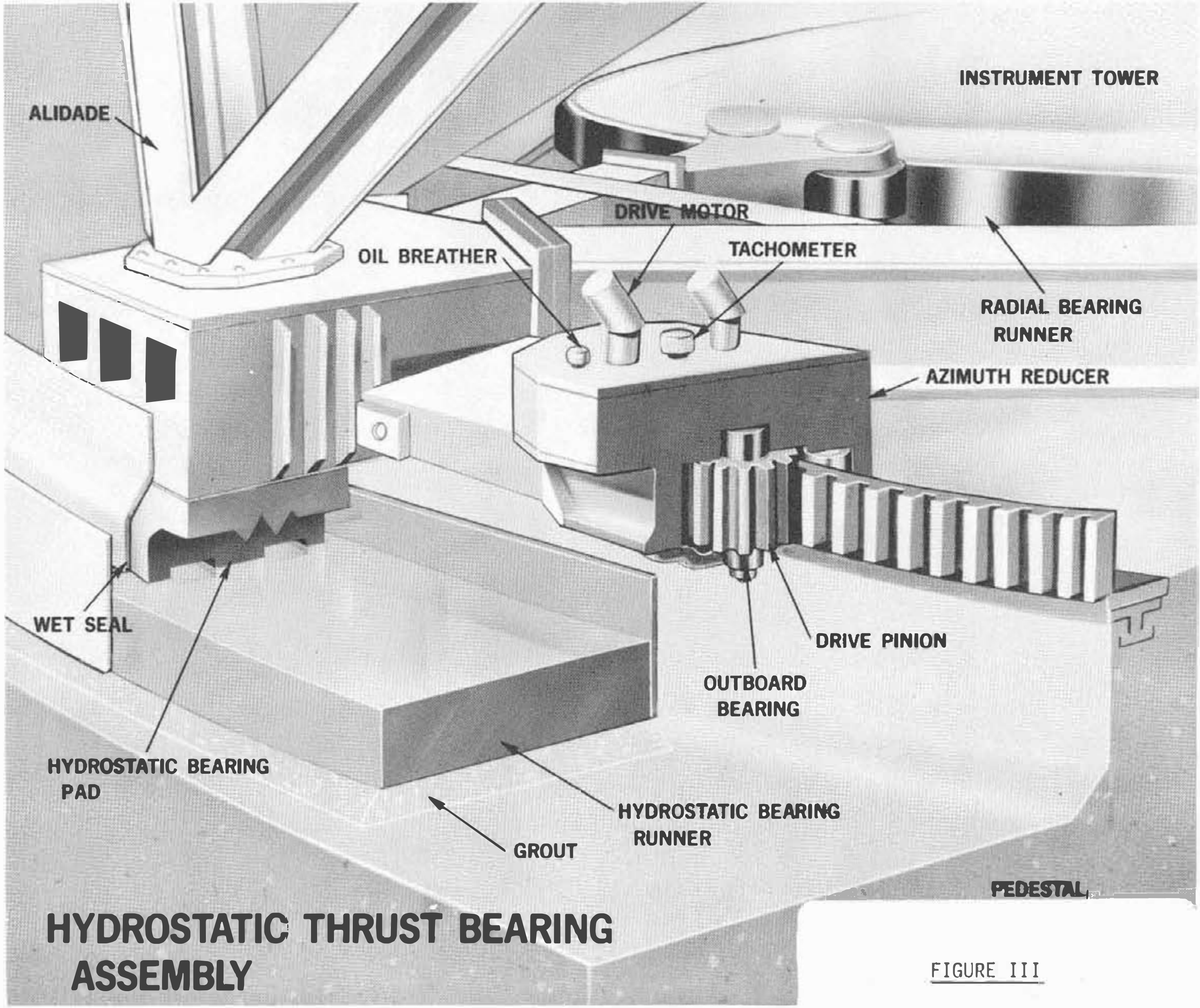

INSTRUMENT TOWER
ALIDADE
DRIVE MOTOR
OIL BREATHER
TACHOMETER
RADIAL BEARING RUNNER
AZIMUTH REDUCER
WET SEAL
DRIVE PINION
OUTBOARD BEARING
HYDROSTATIC BEARING PAD
HYDROSTATIC BEARING RUNNER
GROUT
PEDESTAL
HYDROSTATIC THRUST BEARING ASSEMBLY

FIGURE III

The structure extends 85 feet above the Hydrostatic Bearing and supports the two elevation bearings. The elevation motion is carried on four self-aligning roller bearings. Motion is continuous from 5 degrees above horizon to zenith. The elevation bearings support the 2.5 million pounds reflector assembly. (Figure IV).

The primary reflector surface consists of 554 adjustable panels coated with a high reflectivity paint that is used for thermal control. The outer 50% of the panels are perforated to reduce horizontal wind loading and torque. (Figure V).

The Precision Angle Data System is the primary pointing reference for the antenna. It is mounted in an environmental controlled room on top of the instrument tower. The azimuth and elevation motions of the antenna are operated by servo controlled hydraulic drives attached to four gear boxes on each axis having a combined torque capacity of 20,000,000 foot pounds. The measured peak tracking error of the Servo and Control System is .002 degrees. The overall pointing accuracy of the antenna is approximately 0.016 degrees.

QUALITY ASSURANCE PROGRAM

In order to meet the difficult specification requirements, it was deemed necessary to establish a thorough Quality Program throughout all phases of this contract to assure the design goals were met.

The quality requirements of the contract specified that the contractor shall submit a detailed Quality Plan within forty-five days after award of contract. The design being incomplete, the Quality Plan submitted was a general plan used on previous, less critical programs. Since this was a fixed-price contract, the contractor was reluctant to increase the scope of the Quality Program. After extensive negotiations, the contractor agreed to rewrite and implement a Q.C. Plan specifically written for this contract that would satisfy the JPL requirements. Throughout the program, constant surveillance by JPL was necessary to assure full implementation of the agreed upon program. This same problem existed with many of the subcontractors, particularly steel fabricators whose Quality Program is minimal. To solve this problem, it was necessary to aid the subcontractor in establishing adequate material, processes, and configuration control programs.

Early in the fabrication phase, welding defects were found on the heavier weldments. This included cracking, excessive warping and porosity. Investigation disclosed the need for detailed welding schedules that included the proper sequencing of all welding, preheating to 300°F, method of supporting members during welding, and post-heating. These requirements were mandatory throughout the remainder of the contract. 100% visual inspection and 75% magnetic particle or dye penetrant was performed on all welds.

554 primary reflector aluminum panels were fabricated to aircraft assembly techniques. In process inspection was maintained throughout the fabrication cycle. The compound curvature of the individual panels were

checked with an automatic print-out data machine. Reduction of the 55,000 readings recorded, indicated an error of .035 inches; specification requirement is .060 inches.

QUALITY EFFORT DURING ERECTION

The contractor and JPL's quality representatives maintained a continuous surveillance on all phases of the site work from the excavation to the final acceptance test.

Soil compaction tests were taken to verify compliance. Sampling tests were performed on the 2,500 cubic yards of concrete poured for the pedestal and instrument tower. Slump tests, compression tests and modulus of elasticity tests were performed.

All work performed at the site was inspected for workmanship and compliance to erection drawings.

Alignment and Final Acceptance Procedures for each major subsystem established the testing to be accomplished and the acceptance criteria. All testing was witnessed by the quality engineer and detailed data recorded.

All structural members were bolted, using approximately 25,000 high strength bolts. In order to maintain the integrity of the bolted joints of the antenna, a "Turn of the Nut" tensioning procedure was used to assure stable structural joints. Due to friction type joints in the structure, bolt tension had to be maintained at 15 per cent below the yield point of the bolts. Sampling inspection was performed to assure compliance with the approved procedure.

To determine joint movement due to excessive dynamic loads or seismic shocks, a monitoring system has been devised to periodically measure joint movement sensitive to 0.001 inch. Periodic measurements show no joint movement to date.

To determine accuracy of the primary and secondary reflector surfaces, 2,788 optical readings were taken on the targets installed on the panels, using a precision theodolite. Reduction of the data revealed a system accuracy of 0.190 inches. The required accuracy is 0.250 inches.

A Discrepancy-Corrective Active Procedure was used throughout all phases of the contract. Evaluation, disposition and corrective action of each discrepancy was made by a joint contractor-JPL Material Review Board. This program also included discrepancies of the subcontractor. A Discrepancy Summary Report was issued at a weekly discrepancy meeting between the contractor and JPL to resolve outstanding problems.

SUMMARY

Final results of the acceptance and performance tests showed the antenna systems satisified all specification requirements, and the program was completed within the original budget. The antenna system will formally join the Deep Space Network as fully operational by June 1967.

The antenna system, to date, has been used primarily for communications with the Surveyor spacecraft during touchdown and with the Pioneer VI and Mariner IV spacecraft. Mariner IV was tracked at ranges in excess of 200 Million miles. The 210' antenna was used to contact Surveyor I after six lunar days on the moon. Even with the greatly reduced signal from the spacecraft, the 210' antenna was able to receive and tape significant data from the Surveyor #1.

The overall Quality Program was a cooperative joint effort by the contractor, his subcontractors and by Jet Propulsion Laboratory, Quality Assurance Engineering Group. This program was instrumental in insuring compliance with the contract requirements.

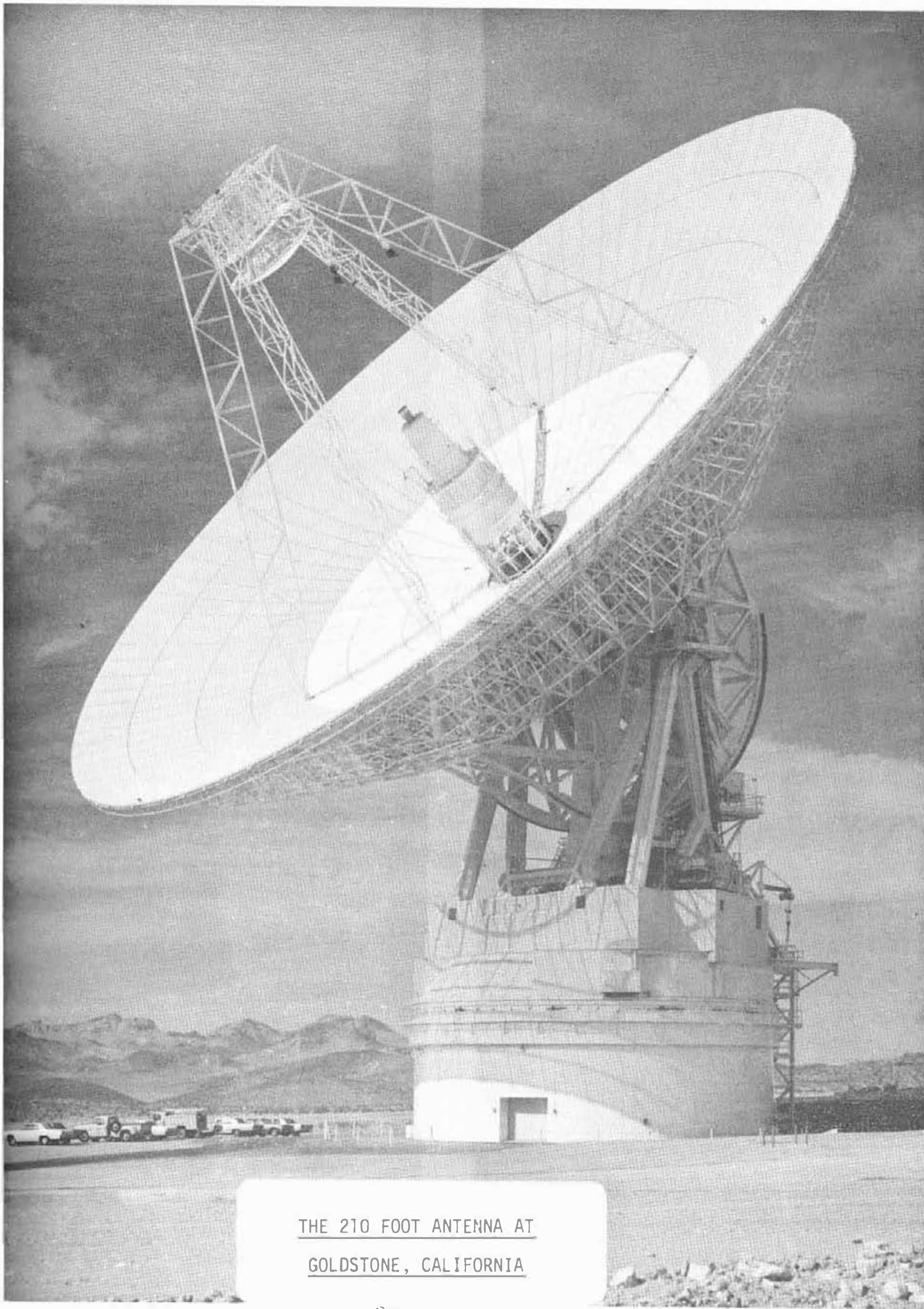
T E C H N I C A L   D A T A

ANTENNA DIMENSIONS

Diameter	210 feet
Focal length	88.941 feet
Focal length/diameter ratio	0.4235
Surface area	37,491 square feet (0.85 acre)
Depth of paraboloid	31 feet
Pedestal wall thickness	3.5 feet
Outside diameter of pedestal	83 feet
Overall height of instrument tower	139 feet
Total concrete	2500 cubic yards

ANTENNA WEIGHTS, lb

On elevation bearings	2,530,000
On azimuth bearings (including bearings)	5,000,000
On soil	16,000,000
Total rotating	5,000,000
Total tipping	2,500,000
Component	
Hyperboloid	4,100
Feed cone and equipment	62,000
Quadripod	39,000
Primary reflector surface	58,000
Reflector assembly (including reflector, wheels, and elevation counterweight)	2,370,000
Alidade and buildings	2,200,000
Azimuth bearings	400,000
Pedestal and foundation	10,000,000
Instrument tower (including wind shield)	
Steel	96,000
Concrete	1,151.000
Overall	16,000,000



THE 210 FOOT ANTENNA AT GOLDSTONE, CALIFORNIA

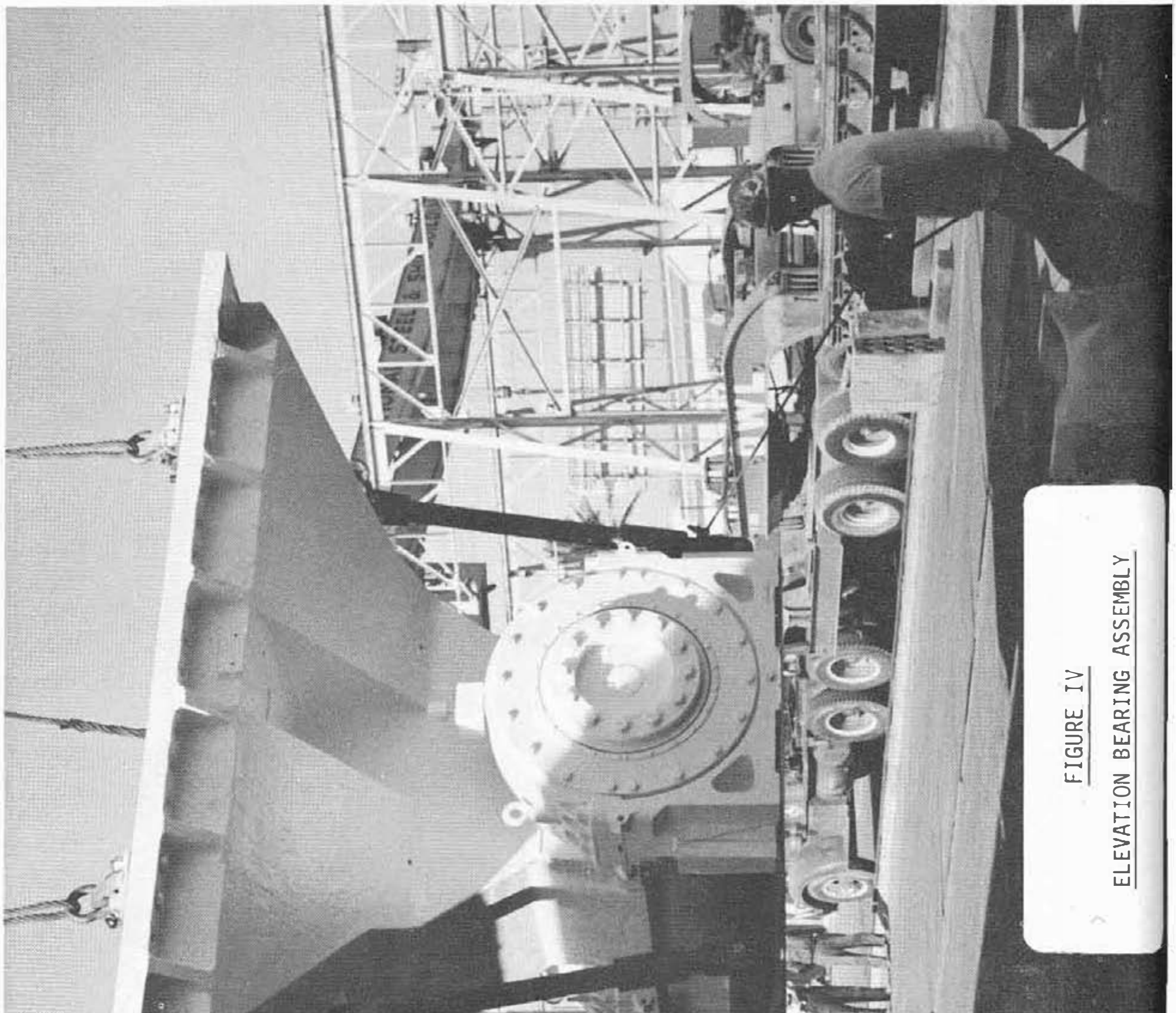


FIGURE IV

ELEVATION BEARING ASSEMBLY

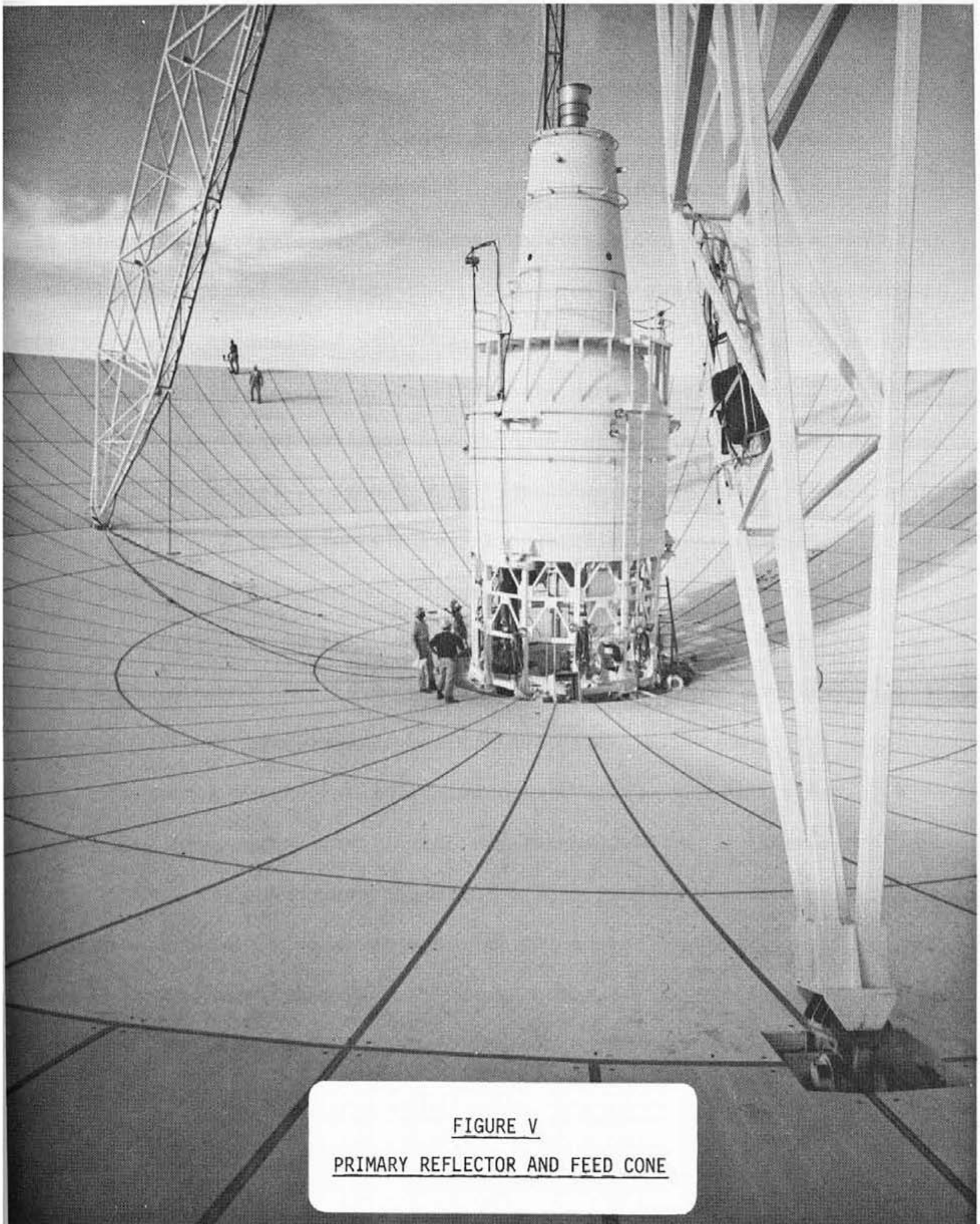


FIGURE V

PRIMARY REFLECTOR AND FEED CONE

EXPERIENCES IN APPLYING NPC 200-2 IN THE NERVA PROGRAM

By James W. Dutli (SNPO-Cleveland)

Nearly four years ago when we were formulating our first Quality Programs with our prime engine contractor and our major nuclear reactor subcontractor, we were faced with two different attitudes on the parts of managements of those contractors. The former said, "agree to anything as long as they are willing to pay for it," whereas, the latter maintained, "I'll not have quality control in my laboratory." The main reason for such diverse attitudes was the lack of experience in applying a disciplined and comprehensive Quality Program, such as one provided for by NPC 200-2, to a large technology program such as the NERVA Program. It took considerable and often very tedious negotiations to prepare our basic Quality Assurance Program Plans. One of the main concerns of the contractors was that quality control would interfere with meeting hardware test milestones and hamstring the various task engineers in accomplishing their experiments. However, we insisted that one must know the quality and integrity of experimental hardware in order to fully evaluate the success or failure of an experimental test and establish the adequacy of specifications, inspections and other quality requirements imposed. After all, the end product of a technology program is not hardware but is the complete documentation, including drawings, specifications, inspections, manufacturing methods, test data, design methods, structural analysis, etc., which describe the hardware. With this philosophy and a lot of perseverence and patience, we eventually formulated quality programs which essentially included all of the provisions of NPC 200-2.

The next problem was implementation of the agreed upon program. Since most of the contractor's engineers and scientists were used to "free-wheeling," so to speak, in their previous experiences in experimental programs it took considerable time and effort to educate them in the quality program requirements. Because of this many things fell through the cracks in the early days of our program. However, in due time we were able to pick up most of the pieces and educate all concerned the quality discipline they must function under.

Poorly prepared procurement packages were also a problem in the early days. For a period of eighteen months my staff reviewed hundreds of our contractor's procurement packages for quality requirements. At the beginning of these reviews in depth, we found fault with approximately eighty per cent. By diligently pointing out to the contractors the errors and inadequacies of the packages and by withholding approval of the procurement actions until corrective action was taken, improvements were realized over the eighteen month period to the point where very few faults were found. Typical problems were: no quality requirements, obsolete specifications, improper or inadequate nondestructive testing, lack of traceability, no material certifications, and no process certifications. The reasons for such poor procurement packages were that quality engineering was by-passed in some cases or the quality engineers did a poor job in reviewing the procurements. Similar problems existed on in-house work fabrication orders.

This brings us to another implementation problem. A good Quality Program Plan is ineffective and, in fact, can be deleterious if the quality engineering staff is of poor caliber. We have continually made close observation of the contractor's quality engineering staff and pointed out weaknesses to management. This has resulted in a gradual but gratifying upgrading in the competency and technical know-how of the quality engineers on our program.

The quality control people in SNPO-C put great emphasis on the use and value of nondestructive testing. It has been our observation that the space industries, in general, lagged in recognizing and establishing extensive use of nondestructive testing as it has been for many years in various nuclear programs, in the aircraft industries, and in pressure vessel and heat-exchanger manufacturing. It is gratifying to note, however, that in the past few years there has been a great increase in the recognition and application of nondestructive testing in space programs. We encourage and support our contractors in the development of new techniques and methods and in extending the applications of the classical methods. This requires initiative and creative thinking backed by sound engineering and scientific knowledge on the part of quality engineers. The fuel elements for the NERVA reactor are an example of critical items. We require extensive processing and quality control of fuel elements involving rather sophisticated nondestructive testing methods and are continually seeking better ones. Forty per cent of the cost of finished fuel elements is due to quality control, much of which is nondestructive testing. Wherever repetitive or incremental types of nondestructive testing data are taken, we encourage automation backed by computer processing of data.

In the broad field of quality control, we have experienced many problems and solutions too numerous to dwell on here. We believe we have established disciplined quality programs based on the provisions of NPC 200-2 not only for the development of NERVA engine technology but also for ground support equipment and test facilities. The successful implementation of the programs have resulted from technical direction in depth of our contractor's activities.

The SNPO-C quality control staff has been fortunate in that it has had full support and understanding by the Chief of SNPO-C, Mr. R. W. Schroeder. Without this support, our quality programs would suffer considerably and be doomed to mediocracy at best.

KSC EXPERIENCES IN APPLYING
NPC 200-3
TO NEW PROCUREMENTS

by

Thomas J. Griffin, Jr.
Plans and Policy Office
Quality Assurance Directorate
KSC

I think it is interesting to note that the First NASA-Wide Reliability and Quality Assurance Meeting, held in February, 1965, brought out many common criticisms and statements concerning the NASA Reliability and Quality Assurance documents, our relationships with Contractors and Government Agencies, and our own internal Reliability and Quality Assurance methods. To refresh your memory, I would like to quote some typical comments from the published proceedings of that meeting:

"One of our in-house difficulties has been in explaining the document to our project management people. Primarily, this concerns what the requirements can and cannot do for the project." (Thornton - Langley)

"The words in the requirements must convey the same message to both parties. This may require adding more definite details." (Thornton - Langley)

"Maybe it's time to start massaging hard the human factors, doing more missionary work, especially with top management involving challenges in leadership, face-to-face communications, and motivation to Reliability and Quality Assurance people, and in practical applications of Quality Assurance documents to promote the usefulness of Reliability and Quality Assurance people in the project effort." (Kromka - WOO)

"We must take the necessary time to adequately and thoroughly document our requirements so that they are clearly understood by our contractors." (George Friedl, Jr. - Headquarters)

"I see this communication problem between NASA and its industrial partners as one which requires continual and increasing attention by all of us within NASA." (George Friedl, Jr. - Headquarters)

"There is a great deal to be done to improve our effectiveness with the DoD and to assure that we get the services we are paying for...make sure that they really understand what it is we are striving for, as we have a somewhat different job than the DoD." (Dr. Robert Seamans, Jr. - Headquarters)

"DoD responsive, but lacks manpower." (Young - WOO)

"Another problem is education...it is still evident the knowledge of NASA quality requirements is lacking, or the requirements are not understood." (Depew - MSFC)

"The Contractor's approach as defined in his plan frequently is in variance with those of the customer." (Mulkern - GSFC)

"This kind of status report (vague and general) is not an isolated case, but is quite prevalent, especially among itinerant inspectors." (Collins - Downey)

Remember, Gentlemen, all of these statements are quoted from the First NASA-Wide Reliability and Quality Assurance Meeting which took place nearly two years ago. I hope you have noticed, as I have, that the majority of these problems, which existed then, are still with us. We have, admittedly, made some strides forward; such as, the current revision efforts on NPC 200-2, 200-3, and 200-4; and the publication of NASA Handbook 5330.7. Still, I think the following problems will continue to plague NASA Reliability and Quality Assurance for a long time to come: (Refer to Figure 1).

Through meetings such as this one, through continuous evaluation of our own in-house organizational structures and procedures, and through individual and concerted efforts to constantly upgrade and improve our documents, we at KSC and NASA-wide are making progress.

I would like to discuss with you some of KSC's experiences in applying NPC 200-3 to new procurements. Please note as I go along how some of the problems we have experienced over the last two years are identical to those expressed by Reliability and Quality Assurance personnel at our last meeting nearly two years ago.

Several significant events have occurred at Kennedy Space Center which have aided our work tremendously. These were: (Refer to Figure 2).

Dec. '64 Publication of the KSC Apollo Reliability and Quality Assurance Plan, K-AMP-5.

This document served to get across to the different organizations the services and functions of the Reliability and Quality Assurance groups at KSC.

CONTINUOUS PROBLEMS

1. ACCEPTANCE OF RELIABILITY AND QUALITY ASSURANCE AS ENGINEERING DISCIPLINES BY PROJECT AND DESIGN PEOPLE.

2. CONTINUOUS UP-GRADING AND TRAINING OF OUR OWN AND DCAS PERSONNEL.

3. INTERPRETATIONS OF NASA QUALITY AND RELIABILITY REQUIREMENTS FOR BOTH THE CONTRACTORS AND DCAS.

4. ADEQUATE AND QUALIFIED MANPOWER COVERAGE FROM DCAS.

5. PLANS, BOTH CONTRACTOR AND DCAS, WHICH ARE SPECIFIC AND ENCOMPASSING ENOUGH TO BE THE CONTRACTUAL DOCUMENT WITHOUT HAVING TO RELY ON THE NPC'S.

6. COMMUNICATIONS...."MISSIONARY WORK"...."PEOPLE PROBLEMS".

Figure 1

KSC SIGNIFICANT EVENTS

DEC. 1964: PUBLICATION OF "KSC APOLLO RELIABILITY AND QUALITY ASSURANCE PLAN", K-AMP-5.

MAR. 1965: INTERNAL QUALITY ASSURANCE DIVISION REORGANIZATION.

AUG. 1965: PUBLICATION OF "APOLLO/SATURN RELIABILITY AND QUALITY ASSURANCE REQUIREMENTS FOR KSC PROCUREMENTS", K-AM-050/3.

SEP. 1965: DIRECTORATE OF QUALITY ASSURANCE AND SAFETY ESTABLISHED.

NOV. 1965: INTERNAL REORGANIZATION OF QUALITY ASSURANCE DIVISION.

APR. 1966: KSC REORGANIZATION BEGAN.

JUL. 1966: IMPLEMENTATION OF THE DIRECTORATE OF QUALITY ASSURANCE BEGAN.

Figure 2

Mar. '65 Internal Quality Assurance Division reorganization

This reorganization assigned quality engineers to cover specific KSC divisions in order for these engineers to better perform their work of analyzing procurements and technical documents for adequate quality requirements. The Quality Assurance Field Representatives were assigned to cover specific DCAS regions at this same time.

Aug. '65 Publication of "Apollo/Saturn Reliability and Quality Assurance Requirements for KSC Procurements", K-AM-050/3.

This publication specified "who, what, when, and where" as back-up to the Procurement Regulations.

Sep. '65 Official KMI established the Directorate of Quality Assurance and Safety.

The first real recognition by KSC higher management of the importance of quality assurance.

Nov. '65 Internal reorganization of the Quality Assurance Division.

Mainly of the Quality Engineering Branch, which amounted to a better realignment of their functions.

Apr. '66 KSC reorganization

Under the new management concept, Dr. Debus initiated what amounted to a complete realignment of KSC functions and responsibilities. This included establishment of the Quality Assurance Directorate.

Jul. '66 KSC implementation of the Directorate of Quality Assurance began.

Additional recognition by higher management of the importance of quality assurance. KSC Reliability was also included as a part of the new directorate's responsibility.

There is no doubt in my mind that the most significant of these events was the establishment of the Quality Assurance Directorate. KSC is an operations center, and because of this, the Quality efforts carried on are decentralized.

QUALITY ASSURANCE INTERORGANIZATION RELATIONSHIP

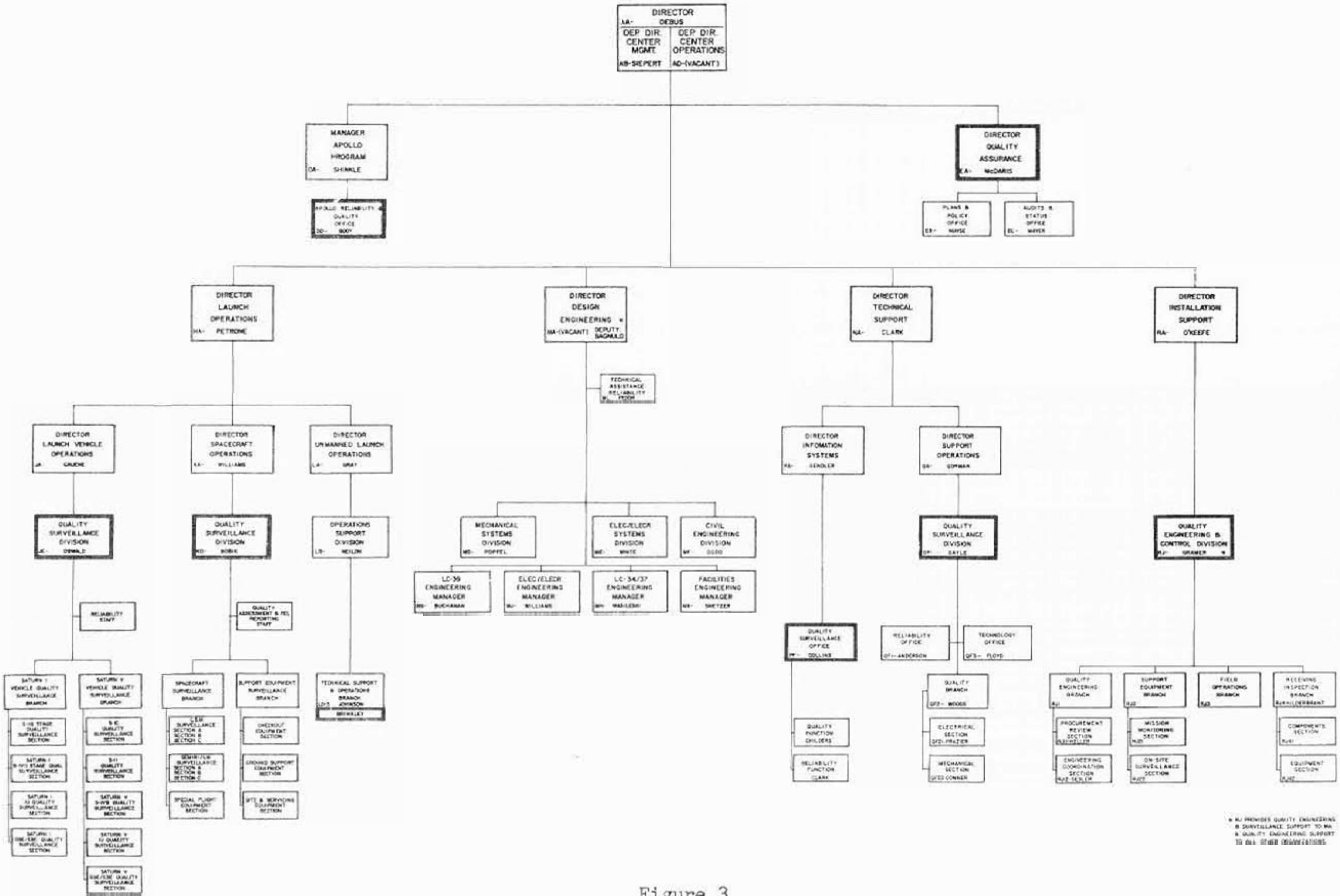
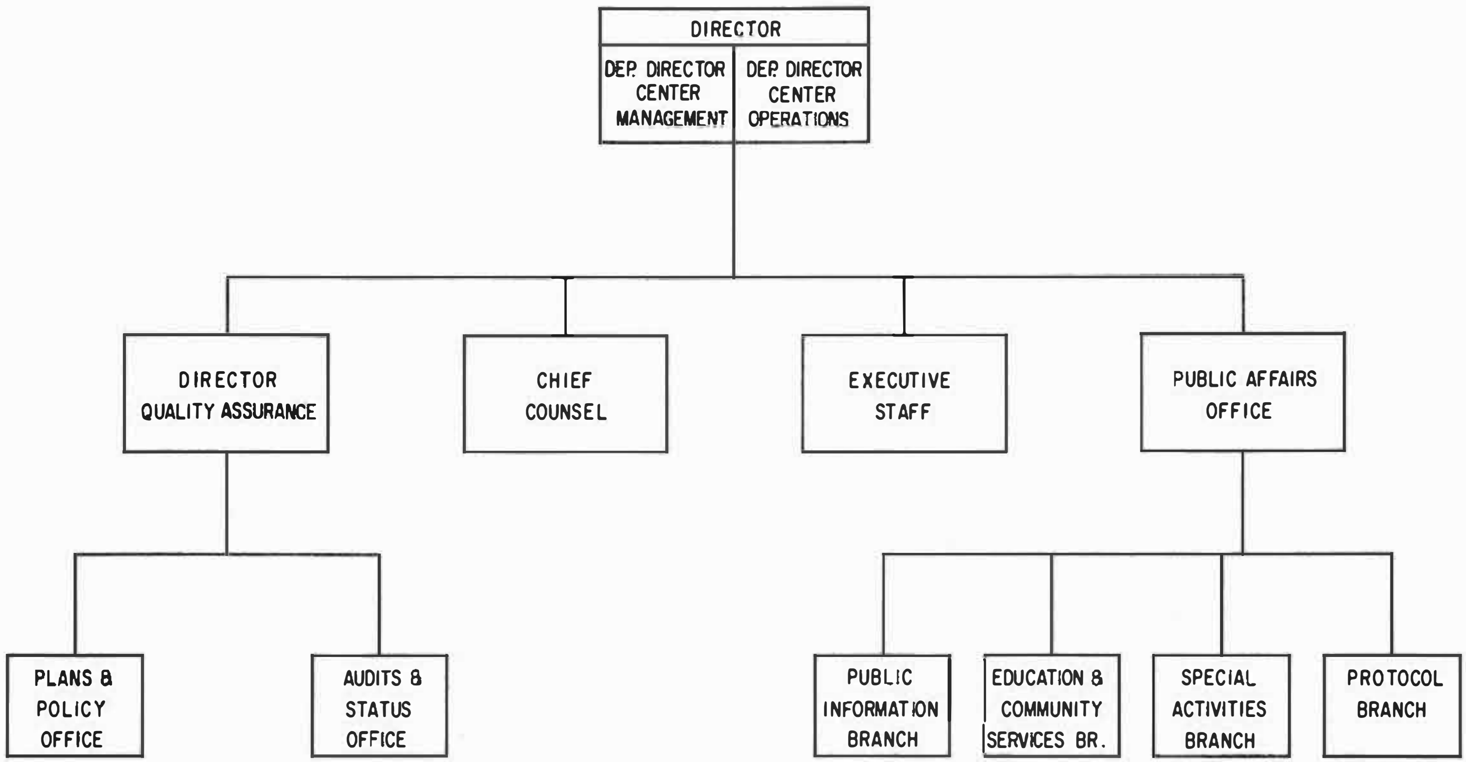


Figure 3

JOHN F. KENNEDY SPACE CENTER, NASA
IMMEDIATE OFFICE



APPROVED: Kurt H. Debus
KURT H. DEBUS
DIRECTOR, KSC

DATE: Sept. 29, 1966

Figure 4

(Refer to Figure 3) Each line operations directorate has a Quality Surveillance Division or group, as noted by the heavier lined blocks. The Center Director holds each line director responsible for the quality and reliability of his operations. This responsibility is specifically noted in each Director's functional statement. The only exception to this decentralized operation is Quality Engineering and Receiving Inspection, which remain centralized functions serving all groups from the Director of Installation Support's Quality Engineering and Control Division. They also provide quality surveillance services to the Director, Design Engineering.

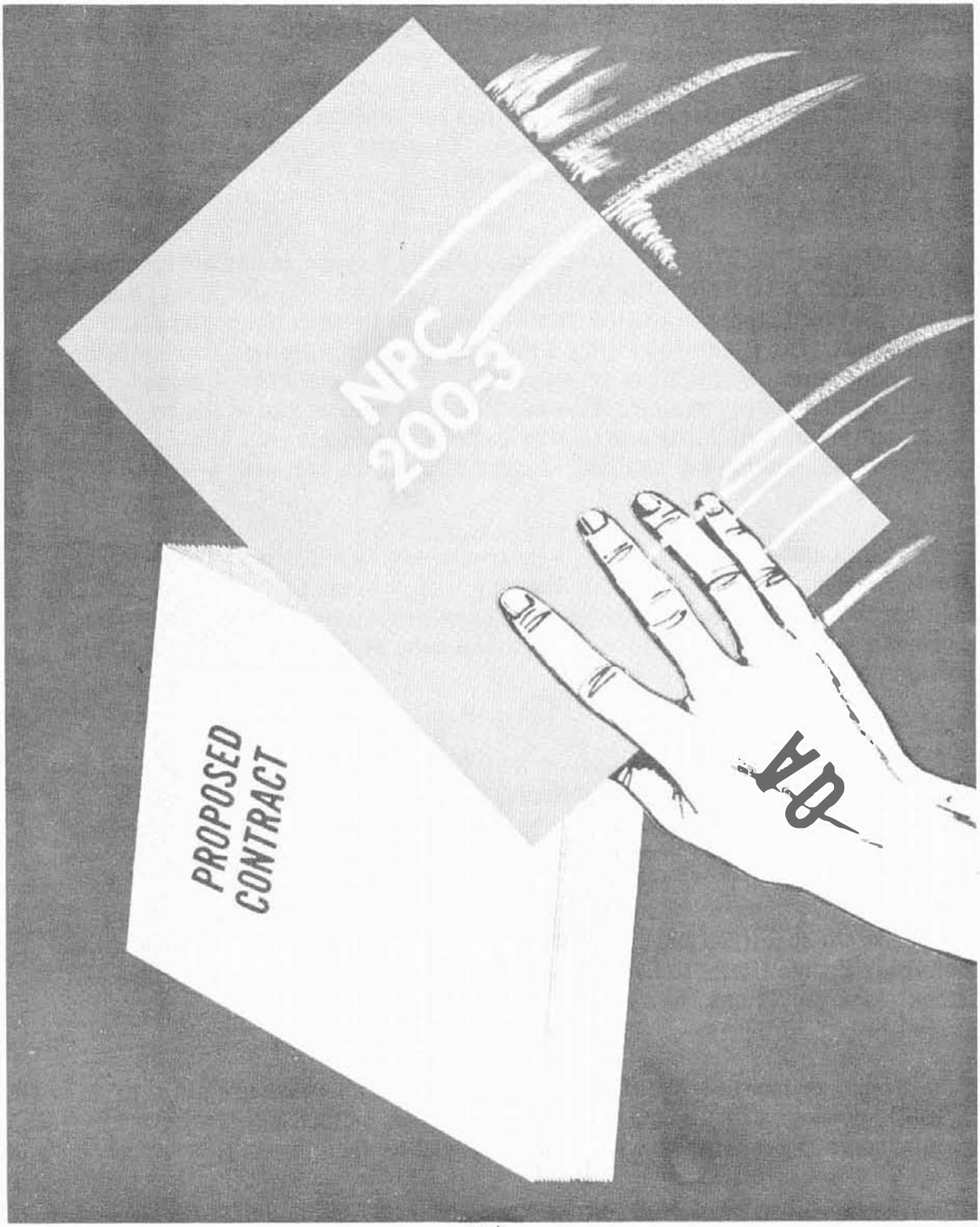
(Refer to Figure 4) The Directorate, Quality Assurance has the responsibility of formulating KSC Reliability and Quality Assurance policy and plans, and is to assure, through proper evaluation techniques, that these policies and plans are carried out. The Plans and Policy Office of the Directorate is now developing KSC Management Instructions covering the many vital elements of a good reliability and quality system. Program Plans, Surveys, Status Reports, and Incorporation of Reliability and Quality Assurance requirements into KSC procurements, are typical subjects of some of these Management Instructions.

As an inherent part of our plans for proper implementation of Reliability and Quality Assurance at KSC, we are taking effective steps to improve communications, perform "missionary" work, and resolve "people problems", including gaining acceptance of quality assurance as an engineering discipline by the project and design personnel.

(Refer to Figure 5) I think we at KSC have learned, just as all of you, that quality requirements in the form of the NPC documents just can't arbitrarily be slapped on a proposed contract...

(Refer to Figure 6) Instead, we have learned that we must carefully study the technical specifications, the end-item use, and the environmental conditions before we decide (Refer to Figure 7) whether the procurement warrants "out of stock" NPC provisions, or a tailored treatment.

(Refer to Figure 8) We find we have situations where we use all of NPC 200-3, portions of it, and tailored versions which include technical quality requirements in combination with commercial quality requirements.


NPC 200-3
PROPOSED CONTRACT

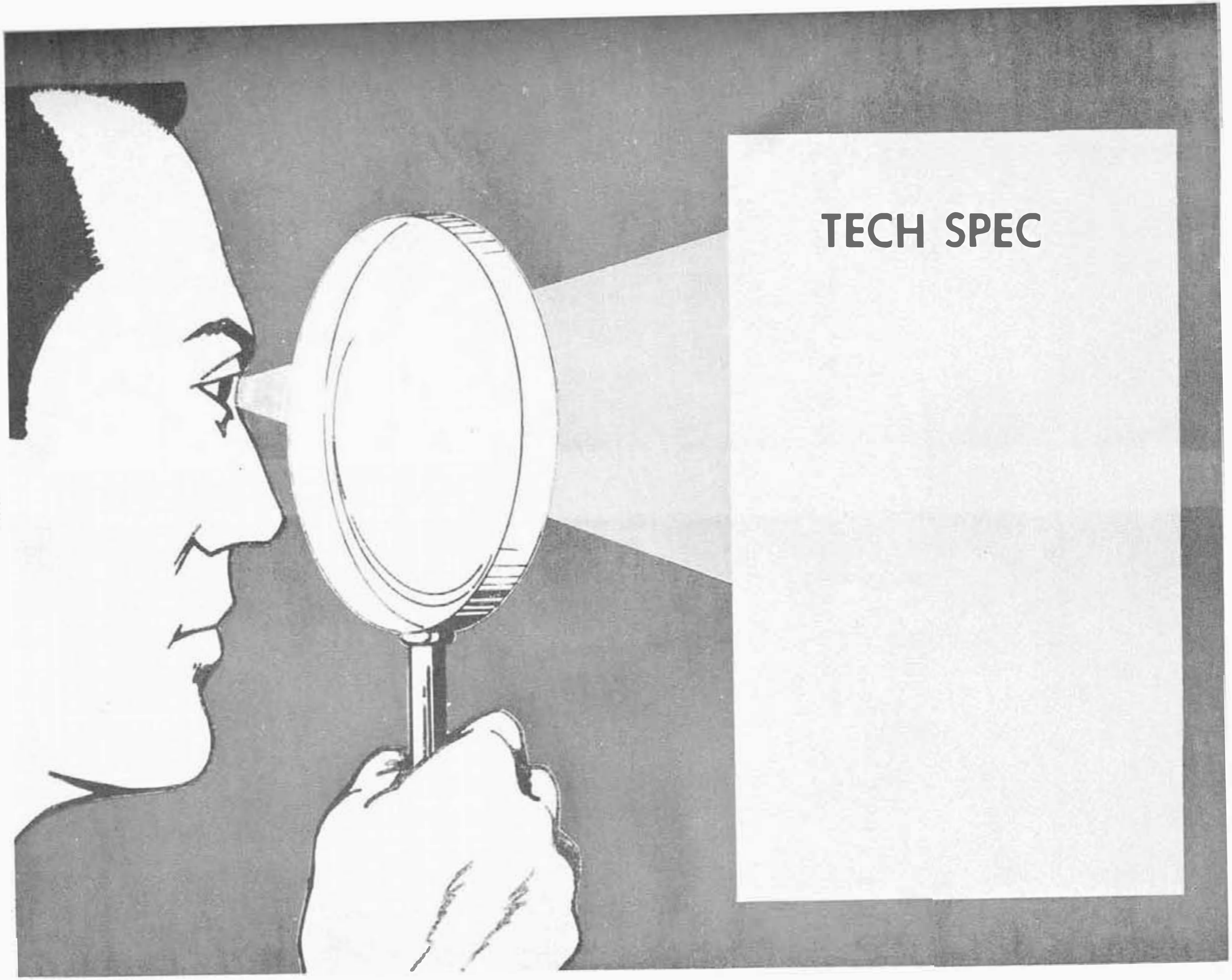


Figure 6

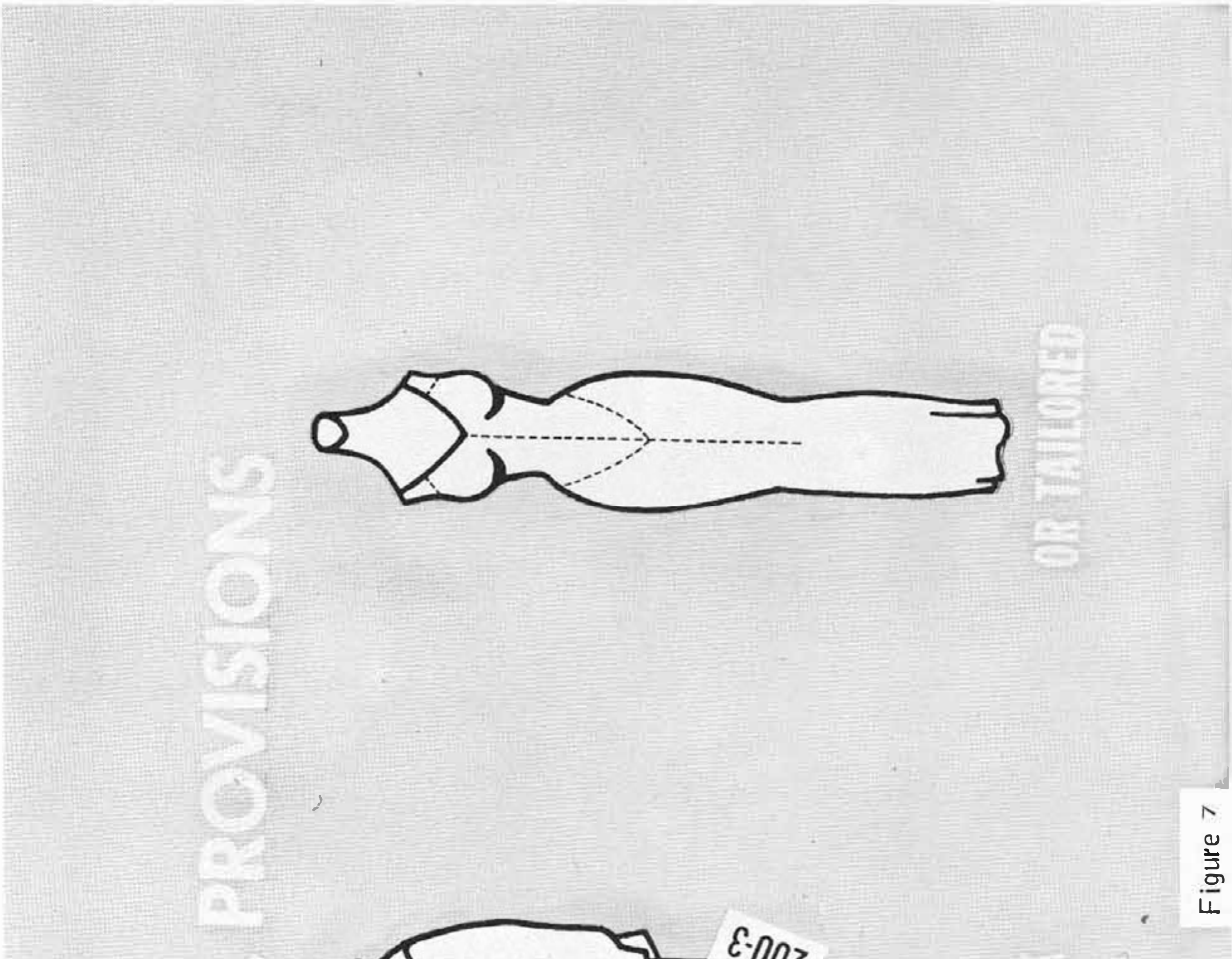


Figure 7

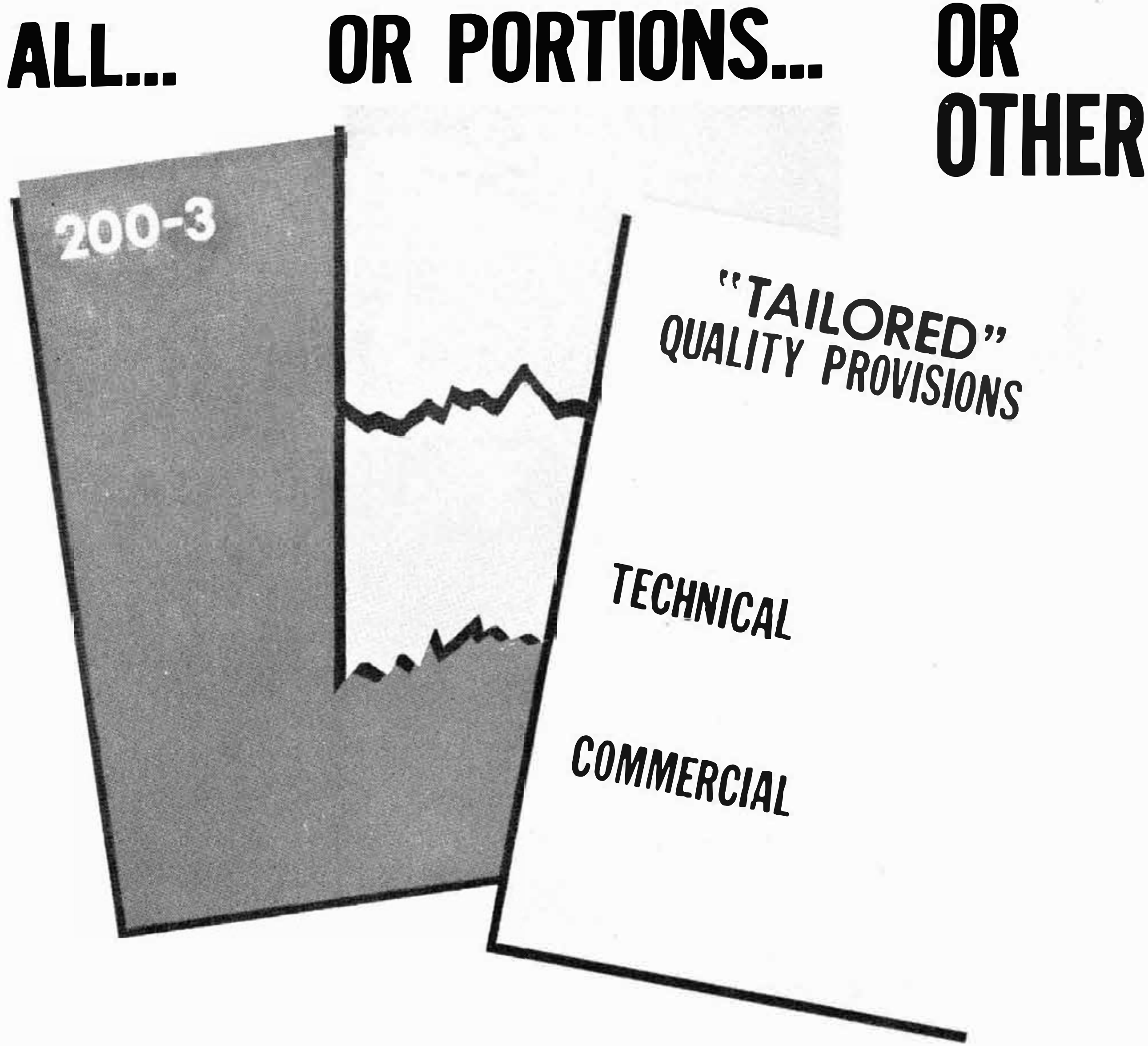

ALL...
OR PORTIONS...
OR OTHER
200-3
"TAILORED" QUALITY PROVISIONS
TECHNICAL
COMMERCIAL

Figure 8

CONTRACTORS

1. NPC 200-4 WORKMANSHIP CRITERIA
2. NONCONFORMING MATERIAL
3. PLANS
4. IN-HOUSE SPECIFICATIONS

DCAS

1. ADMINISTRATION OF THE DELEGATION
2. ADEQUATE COVERAGE
3. RESPONSIBILITY
4. STATUS REPORTS
5. PLANS

Figure 9

Rather than relate to you the successes we have had in invoking NPC 200-3 into our procurements, I would like to cover some of our recurring problems, starting first with problems with contractors: (Refer to Figure 9)

CONTRACTORS

1. Workmanship Criteria. (NPC 200-4)

One of our biggest problems has been the lack of clear-cut, definitive descriptions which both the contractor and the Government inspector understand: the contractors' and Government inspectors have many differences of opinion as to judging what is acceptable.

For example: What is insufficient or excessive solder?

What is a solder point (peak)?

What is a cold-solder connection?

What is de-wetting?

We have had legal suits involving interpretations of just such items. We have high hopes that the revised NPC 200-4, along with additional training and experience, will clarify these nebulous areas. We at KSC are trying to increase the frequency of our planning conferences with both the contractors and the Government inspectors and it is here that we can get across to both our definitions of these judgement items.

2. Nonconforming Material.

NPC 200-3 does not provide for MRB action. Although the Procurement Regulations permit MRB action based upon Category of Procurement, the environment of Fixed Price contracting generally keeps us from substituting the MRB language contained in NPC 200-2. We must, however, recognize that minor nonconformances do occur which cause schedule delays. Rapid disposition of such nonconformances does extend benefits to the Government. For this reason, our Procurement personnel, working with the Quality Engineering and Control Division, have developed a procedure for dispositioning minor nonconformances quickly through DCASR and allowing negotiations for cost adjustments to take place later.

3. Plans.

Even on plans for NPC 200-3 work, we have had the usual troubles all of you have experienced. After the contract award, we were still sending comments back and forth through the mail, attempting to get the details we needed. Often, due to the fact that most of our procurements are of short lead times and schedules, the product was finished before the plan was satisfactory. Now we explain in greater detail in the RFP what we want the plan to contain. We also require a preliminary plan with the proposal. This preliminary plan serves many purposes: it helps us to evaluate the bidders' capabilities, it serves as a baseline for pre-award surveys, and most important, we can evaluate it and prepare comments for its revision prior to the contract negotiations. In many cases the preliminary plan has been approved without any changes at the time of contract award.

4. In-house Specifications.

Another area where we are beginning to have some success is in allowing the supplier or contractor to use his own in-house specifications and standards in lieu of our NASA specifications and documents. This can only be done by carefully evaluating these documents before approval. We approach this by first using a clause in the RFP which allows the bidder to submit with his proposal those standards, specifications, and procedures, in addition to those cited in the RFP and technical Scope of Work, which he proposes to use in procuring, fabricating, inspecting, and testing the items to be supplied under terms of the contract to be awarded. After the contractor's existing procedures are evaluated and approved, they are invoked in the contract by titles, revision numbers, and dates.

DCAS

1. Administration of the Delegation.

Our contracts people are still experiencing difficulties in this area. The delegation is considered a reimbursement contract between NASA and DoD for a service, yet we still suffer from delays and improper identification (reimbursement information). We have, for example, just recently received billing for work performed 18 months ago. We also find continuous over-running of obligated monies for services without prior notification to us so we may adjust the funding. We feel that the change in procedure by billing direct to NASA Headquarters will not alleviate these problems, it could make the situation worse.

I would like to mention that the NASA/DCAS representatives in the regions have been an immeasurable aid to KSC in assisting us in resolving some of the problems we have experienced with DCAS coverage of our contracts.

2. Adequate Coverage.

DCAS regions are instructed to accept NASA delegations regardless of existing backlog of DoD business and the technical capability of their local personnel. We would rather be told at the onset that manpower is short than to sit back and find out downstream that our contracts are not being properly covered.

DCAS Quality Assurance coverage of NASA contracts is a multimillion dollar business between the two agencies. I wonder: how will the increasing manhour requirements to cover defense and war products for the Viet Nam conflict affect DCAS services to NASA?

3. Responsibility.

The following is a problem we are actively seeking a solution to: KSC is directed to delegate to DCAS. DCAS is directed to accept the delegation. KSC, however, may not delegate the responsibility to DCAS. We cannot hold DCAS legally responsible for any discrepant material or equipment shipped to KSC; yet, the contractor does hold the Government (to him, NASA and DCAS) responsible as having inspected the equipment during fabrication. How can we at KSC reject it and expect the contractor to repair or make it good?

4. Status Reports.

We are now receiving most of these in good time. We put in the letter of delegation a statement that monthly status reports should be submitted starting the first day of the month after receipt of the letter of delegation. Some DCAS regions are sending the first report at their convenience...as much as two months late.

Due to DCAS internal routing up the management chain, we were receiving reports as much as six weeks late. Receipt of the monthly report is now required no later than the tenth day of the following month.

KSC is still getting status reports that are vague and general. The NPC 200-1A section on status reports is copied verbatim with negative comments. We have had to spend time by letter, phone, or in person, detailing our reporting requirements. We are now more specific in our letters of delegation on this subject.

5. Plans.

These are being written in violation of the Defense Supply Agency Manual 8200.1, which states that plans in support of NASA contracts should apply the procedures of NPC 200-1A, where the procedures contained in DSAM 8200.1 are in conflict with the directed NASA procedures. Regardless of this, we still receive plans written to the DSAM instead of NPC 200-1A. In a lot of cases, we have had to accept these due to schedules.

Let me hasten to add that our relationships with DCAS at all levels is definitely improving. We have found in dealing with both contractors and Government agencies that face-to-face communications is the key to the solution of most of our problems.

COMMERCIAL OFF-THE-SHELF EQUIPMENT

We have lived with and gained experiences in using the NPC 200 series documents for over four years now. As a result, the task team is now revising NPC 200-2 and 3, updating and improving them. There remains, however, one gray area in quality assurance that we need to take a close look at sometime in the near future. (Refer to Figure 10)

We at KSC are beginning to look closely at commercial off-the-shelf equipment procurements and the necessity for quality requirements. Keep in mind that KSC is unique among the Centers, in that we are an operations center... we don't design equipment and systems which require NPC 200-2 very often; most of our procurements are either NPC 200-3, portions thereof, or are of commercial gear. Many, many times the procurement of commercial gear is critical to us, in that the equipment is usually required on short schedules and is tied into a critical system or subsystem.

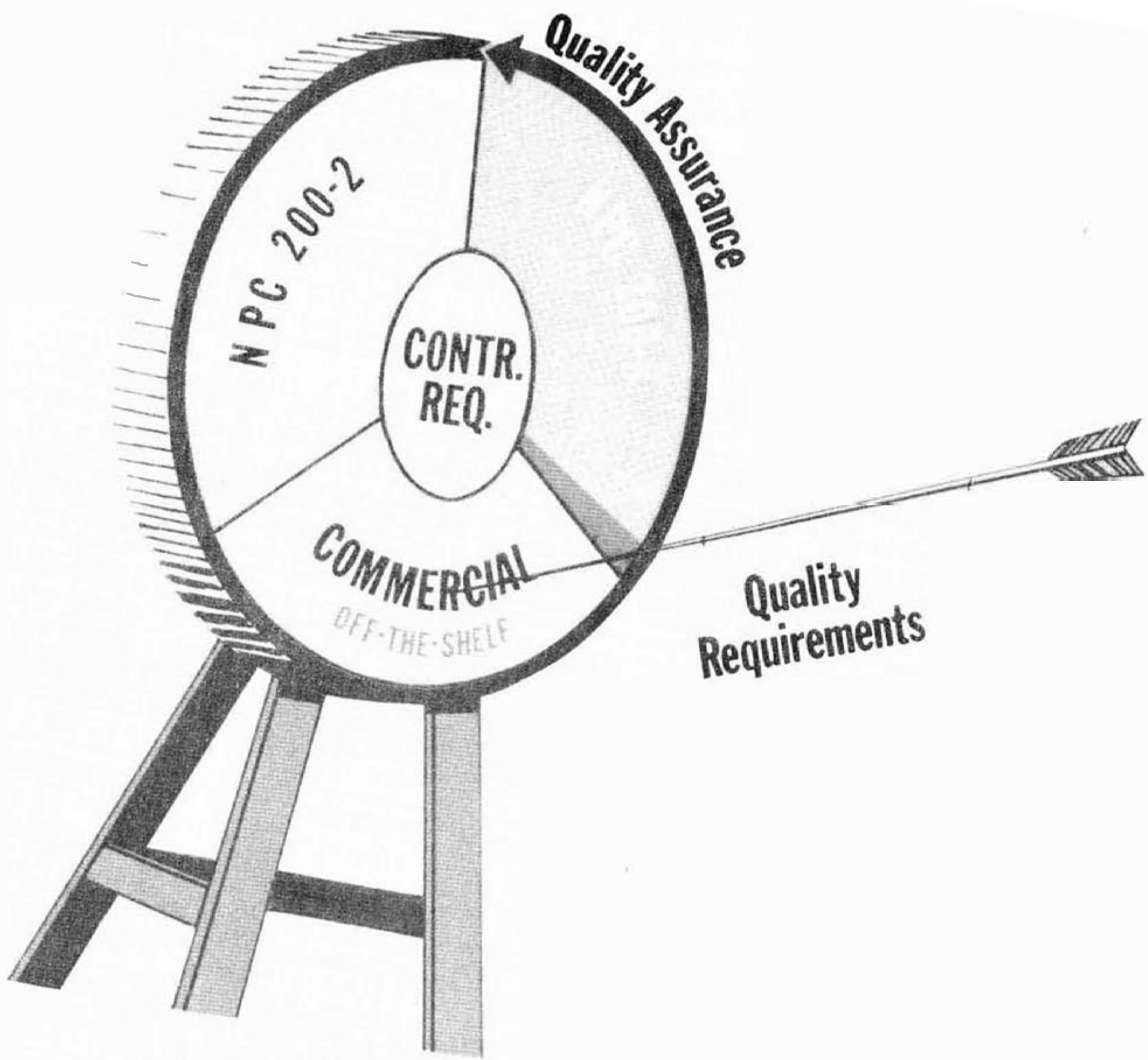

Quality Assurance
N P C 200-2
CONTR. REQ.
COMMERCIAL
OFF-THE-SHELF
Quality Requirements

Figure 10

If a piece of commercial equipment comes into KSC and is rejected by either Receiving Inspection or the user, we don't have time to go through a rejection cycle that involves arguing with the supplier over definitions of "commercial quality." We also find that our engineers are using more and more commercial gear as part of a subsystem or system, where definitive quality requirements are invoked on part of the system and not on the commercial gear. Here we find we must specify to the bidders our definition of just what is commercial off-the-shelf equipment, and what the acceptance criteria are in the areas of soldering, lacing, testing, control of nonconforming material, printed circuit board fabrication, etc.

Because of our use of commercial gear at KSC, Quality Assurance has developed a procedure for incorporating certain quality clauses into these type procurements. We do this by first carefully defining to the bidders what we consider commercial off-the-shelf gear to be. We then list the acceptance criteria for workmanship in soldering, etc. If we have Government inspection at source, our letters of delegation specify monitoring of the supplier's inspection system, and does not list mandatory characteristics involving the commercial equipment. We still have a lot of ground work to do in this area. If our commercial criteria list gets too lengthy, we might propose publication of a document on "Quality Requirements for Commercial Off-the-Shelf Equipment." We could then refer to this document in the RFPs. Your comments on this whole area of commercial quality requirements is solicited and will be appreciated.

In conclusion, let me state that KSC is rapidly making progress in overcoming our difficulties. I feel that we have advanced twice as fast in the past year than we have in the preceding three; and I am confident that this coming year will result in even greater advances at Kennedy Space Center and NASA-wide.

Thank You

A PROFILE OF PRESENT AND FUTURE GSFC SUPPLIER SURVEY ACTIVITIES

by

Patrick W. Cooke
Quality Assurance Branch, Test & Evaluation Division
Goddard Space Flight Center

Beginning in March, 1964 through November of this year, members of the GSFC Quality Engineering Section, in one of its prime support missions as a service organization to GSFC Project Offices, Technical Officers (including experimenters), and Contracting Officers, have conducted a total of 127 on-site quality assurance surveys.

Chart no. 1 (Vugraph #1) summarizes the results of these evaluations for each of the three years by survey outcome for each of the various types of survey evaluations performed.

These survey evaluations are performed by experienced members of the Quality Engineering Section to evaluate and investigate in depth all elements as well as those interrelated disciplines that make up a supplier's quality program with respect to GSFC's application of the NASA Quality Publications NPC 200 Series to a specific or anticipated contractual agreement. Also, this diagnostic procedure of on-site investigation results in a measure of the individual supplier's degree of conformance to the intent of the proposed quality requirements (pre-award surveys) or contractual quality assurance obligation (if post-award).

As you may have observed from reading any of our survey reports, the GSFC survey procedures call for the surveyor — (and that's just what it means in most cases — surveyor) to make a final determination as to the individual supplier's "capability to comply." This judgment is usually limited to NPC 200-3 type evaluations and takes into account the nature and collective influences of the various surveyed elements on the effectiveness of the quality system with respect to the supplier's product line and mode of operation. Of course, such a serious judgment factor as this requires that all quality engineers sent into the field on surveys be fully trained and indoctrinated in supplier relationships, survey techniques, and diplomacy. To some of the smaller companies, the friendly, all-knowing, benevolent, one- or two-day "visitor" from Goddard is an expert in all phases of NASA activities. We help this situation by leaving a copy of the booklet "Selling To NASA," April 1964, with the company management. New survey personnel are exposed to at least three on-site surveys before going off on their own, and four of our engineers have attended the "Training Seminar for Quality Program Surveyors" under the auspices of the Apollo Support Department, General Electric Company.

Chart no. 2 (Vugraph #2) is a compilation by year and type of discrepancy for all survey and related functions evaluated for the three-year period. For purposes of this analysis, each survey weakness, whether a major discrepancy or less serious area of concern, have been treated equally. The data from this tabulation indicate that of the 871 total deficient observations, 67 percent (or 584) were the result of weaknesses found in the 39 percent (or 50) noncompliant companies. Also the average number of discrepancies per company for the noncompliant companies is 12; while that for the compliant companies is 4. The range of discrepancies for a company is from 2 to 18 for noncompliant companies and 0 (3 times) to 10 for those companies found compliant.

With few exceptions, the majority of our survey results—and they must be formally requested in writing by a valid "user" element at the Center with substantiating data provided— have been of the NPC 200-3 pre-award, post-award, or "suspect supplier" type. The category "suspect supplier" falls more closely in the "post-award" classification, but is distinguishable due to a suspected shift in quality or performance at the supplier's plant and these evaluations could more specifically be called "product or process audits." For these visits, product specialists from the Failure Analysis Section of the Quality Assurance Branch also participate. All evaluations of the 200-3 variety are performed within the standardized guidelines of an established GSFC Reliability and Quality Assurance Survey Procedure (No. RQA-154), although it must be admitted that each individual survey situation is unique within itself and must be handled accordingly. These situations range from those of a serious nature, e.g., those semiconductor manufacturers whose very sophisticated initial processing of photolithography, mask-making, and diffusion as well as other areas are 'off limits' because of 'security' and 'industrial piracy' reasons, to the lighter side such as the poor Quality Manager of one company in a popular part of the country who could not accommodate our survey visit because he had already been surveyed three times that month and was booked up solid for the next two months. And of course those major contractors all had or kept changing the requirements and never sent detailed reports except sometimes a letter of acknowledgment — so he never knew who was on first base.

Which leads to the subject of survey reports. Upon completion of each Goddard survey visit, a formal report to objectively reflect all survey findings, conclusions, and recommendations is distributed as an individually numbered Quality Assurance Survey Report (QASR). The report is primarily addressed to a Goddard user audience; however, a copy is formally sent to the supplier involved and the cognizant DCASR activity. This practice of supplying a copy to the supplier is contrary to DCAS policy. Distribution within NASA, except for pre-award surveys which are withheld until after award is made, is accomplished via the INQUIRE (INterchange of QUality Information REports) Program, which Goddard introduced in 1964 and which I am sure you are all by now familiar with. This listing apparently needs updating, (#3) so that we have active contacts at each of the Centers' QA organizations. This program, I might observe, should be strengthened and participated in continuously by all concerned. We have received and interchanged survey reports and other related information with MSC and Ames, but not too much response has been received from the other Centers.

We have found that tape recording survey proceedings is appealing, since it will confirm any possible future misinterpretations. The tape has substantiated our position in delicate situations twice in the past.

Twice yearly, in February and August, our Branch compiles and issues a Semiannual Tabulation of Quality Assurance Survey Evaluations on record for the most recent two-year period. Again, this listing, which also includes those reports sent to us by the other Centers, includes a "Yes - No" or report caption as to each listed company's capability at the time of the evaluation.

Other factors significant in the analysis of our survey results are as follows:

	Non-Compliant	Compliant
Company size (up to 100 employees)	46%	18% passed
No prior NASA business (direct or indirect)	93% of companies	
No or inadequate DCASR coverage	70% of companies	

Future GSFC Survey Activities and Suggested Improvements

1. Strengthen and develop specific survey check lists and reporting techniques for evaluating supplier process controls from an engineering standpoint.

2. In the current revision of NPC 200-3, I would suggest that major contractors be required to submit results of first tier survey results to the cognizant installation's INQUIRE Representative.

3. Utilize the VSMF (Visual Search Microfilm File) listing known as Vendor Selector. This file contains specific information on personnel, quality control and testing, and facility information on some 12,000 suppliers and subcontractors. The file is updated twice yearly.

4. Incorporate survey results in a meaningful vendor quality rating system.

5. Develop a self-audit questionnaire which can be mailed to prospective suppliers to perform their own evaluation with the results to be validated and/or certified by DCAS or the regional NASA Field Representative.

YEARLY SURVEY RESULTS FOR ALL QUALITY ASSURANCE SURVEYS
CONDUCTED 1964-65-66

	SURVEY OUTCOME BY TYPE OF SURVEY								
	1964		1965		1966		3 YEAR TOTALS		
TYPE OF SURVEY:	COMP	N/C	COMP	N/C	COMP	N/C	COMP	N/C	OVERALL TOTAL
NPC 200-3 Pre-Award	1	5	6	3	-	2	7	10	17
" " Post-Award	2	4	1	3	1	1	4	8	12
" " Resurvey	5	2	6	-	2	1	13	3	16
" " Suspect Supplier	10	15	31	10	4	3	45	28	73
NPC 200-2 Pre-Award	-	1	1	-	1	-	2	1	3
" " Program Plan	-	-	5	-	1	-	6	-	6
Totals - By Outcome	18	27	50	16	9	7	77	50	-
- By Year	45		66		16		127		127
Percent - By Outcome	40%	60%	76%	24%	56%	44%	61%	39%	100%

FREQUENCY OF SURVEY DISCREPANCIES

Area/Function	Non-Compliant Companies CY 64 No.	CY 65 No.	CY 66 No.	Total No.	%	Compliant Companies CY 64 No.	CY 65 No.	CY 66 No.	Total No.	%
1. Functional Operating Procedures	22	16	7	45	7.7	5	17	5	27	9.4
2. Drawing & Change Control	16	11	5	32	5.5	4	14	4	22	7.7
3. Procurement Control	22	13	5	40	6.8	2	12	1	15	5.2
4. Incoming Material Control	18	11	5	34	5.8	2	10	4	16	5.6
5. Control of GFP	5	1	0	6	1.0	1	0	0	1	0.3
6. In-Process Test & Inspection	18	14	4	36	6.2	2	2	3	7	2.4
7. End-Item Test & Final Inspection	7	9	5	21	3.6	1	1	0	2	0.7
8. Special Process Controls	20	13	5	38	6.5	3	18	1	22	7.7
9. Fabrication Controls	20	12	4	36	6.2	2	2	1	5	1.7
10. Non-Conforming Material Control	10	12	6	28	4.8	1	8	4	13	4.5
11. Calibration Control	23	14	7	44	7.5	11	37	3	51	17.8
12. Inspection Stamp System	14	9	2	25	4.3	2	12	2	16	5.6
13. Preservation, Packaging, Storage	23	13	5	41	7.0	9	30	5	44	15.3
14. Data Reporting & Corrective Action	16	14	5	35	6.0	1	13	3	17	5.9
15. Records of Inspection & Test	16	12	5	33	5.7	1	4	1	6	2.1
16. Training of Personnel	10	4	1	15	2.6	1	3	2	6	2.1
17. Reliability (If Evaluated)	1	1	0	2	0.3	0	3	0	3	1.0
18. Quality Management/Organization	17	8	3	28	4.8	0	3	1	4	1.4
19. Attitudes	7	2	3	12	2.1	0	0	1	1	0.3
20. Facility Housekeeping	19	9	5	33	5.7	7	10	2	19	6.6
Totals -	304	198	82	584	100.0	55	199	43	287	100.0
Companies (Chart No. 1)	27	16	7	50		18	50	9	77	
Average Discrepancies/Company	18	13	12	12		3	4	5	4	
Most Discrepancies for a Company				18					10	
Least Discrepancies for a Company				2					0	(3 times)

Chart No. 2

INQUIRE DISTRIBUTION LIST
November 1966

NASA Ames Research Center
Moffett Field, California 94035
Attention: Mr. George DeYoung

NASA Electronic Research Center
575 Technology Square
Cambridge, Massachusetts 02139
Attention: Mr. Paul McDonald

NASA Headquarters
Washington, D.C. 20546
Attention: Mr. Howard Weiss

NASA Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, California 91103
Attention: Mr. Paul E. Ross
Mr. Clifford H. Rumin

NASA John F. Kennedy Space Center
Kennedy Space Center, Florida 32899
Attention: Mr. Charles R. Caro

NASA Langley Research Center
Langley Station
Hampton, Virginia 23365
Attention: Mr. Eugene H. Britt

NASA Lewis Research Center
21000 Brookpark Road
Cleveland, Ohio 44135
Attention: Mr. Walter R. Schumm

NASA Manned Spacecraft Center
Houston, Texas 77058
Attention: Mr. Karl P. Sperber
Mr. L. S. Menear

Chart No. 3

NASA George C. Marshall Space Flight Center
Huntsville, Alabama 35812
Attention: Mr. Arthur Carr

NASA Michoud Operations
P.O. Box 29300
New Orleans, Louisiana 70129
Attention: Mr. A. C. Taylor

NASA Western Support Office
150 Pico Boulevard
Santa Monica, California 90406
Attention: Mr. Donald W. Porter

Chart No. 3

QUALITY IMPROVEMENTS THROUGH THE APPLICATION OF GSFC INCOMING INSPECTION RESULTS

by

William P. Corbin
Quality Assurance Branch, Test & Evaluation Division
Goddard Space Flight Center

It is a pleasure to have an opportunity to discuss Goddard's Incoming Inspection Program with representatives from various NASA Centers. During this presentation I will attempt to detail the advantages which have been realized as a result of the utilization of the inspection data. These advantages are summarized in the first view graph. Before discussing these advantages in any detail, I would like to discuss for a moment the function of an incoming inspection organization.

An incoming inspection function provides the primary source of quality data by which other management and control decisions are made. It is one of the most important elements in the establishment of an effective and decisive quality assurance organization. Such a program provides the first indication of quality problems and if effectively administered should help eliminate defective units from being used in space flight and mission essential applications. A receiving inspection program also supports such functions as the control of incoming material and the establishment of concise and realistic specifications and standards. In addition to these functions, a NASA Center inspection and testing program provides data necessary to set up a vendor quality evaluation system and provides the facts necessary to evaluate the inspection performance of both industry and the Department of Defense.

To set the stage for the quality improvements realized at Goddard, it would appear worthwhile to examine the quality level of semiconductors bought by Goddard during the spring of 1964.

Audit results of inspected semiconductors obtained from the GSFC storeroom in April 1964 indicated the possibility that 50 percent or greater of the devices delivered to Goddard did not comply with the requirements of the referenced specifications. To quote one local distributor house when asked if the part being furnished was in compliance with the stated requirements, the distributor stated, "We always bid on every order from Goddard, they (GSFC) take anything we ship and besides if it doesn't work, they'll ship it back."

A. IMPROVED QUALITY OF ELECTRONIC COMPONENTS,

B. ELIMINATION OF DISTRIBUTORS AND SUPPLIERS WITH POOR PERFORMANCE RECORDS FROM BEING AWARDED GODDARD CONTRACTS,

C. AVAILABILITY OF STATISTICAL DATA ON LOT QUALITY, AND

D. BASIS FOR MORE CONCISE RELIABILITY AND QUALITY ASSURANCE PROVISIONS.

Some of you in the audience may recall the counterfeit problems encountered at Goddard during this same period. In an article which appeared in the Electronic News dated March 8, 1965, Motorola stated, "We first became aware of counterfeit devices about a year ago when NASA complained about some transistors failing." Motorola was referring in their statement to an order of 2N1132 transistors inspected at Goddard. The counterfeiting was confirmed on these devices when a Motorola representative explained that the square-shaped M appearing on the 2N1132 devices was not identical with the bat-shaped M always used by Motorola.

Initiation of Goddard Inspection Program

On May 27, 1964, the Goddard Incoming Inspection Program was formally initiated. At first the program covered only semiconductors bought for the GSFC storeroom. At present resistors, capacitors, relays, and integrated circuits are also inspected as requested by Goddard Project Offices. All parts delivered to the Inspection Area receive 100 percent inspection of salient electrical performance characteristics prior to acceptance. Visual inspections are performed on a sampling basis. Parts purchased to NASA, military specifications, or tighter, (Hi Rel) requirements are identified with the color green when accepted; and parts purchased to commercial/Electronic Industries Association (EIA) or similar specifications are identified with the color yellow when accepted. Rejected devices are identified with a red marking and then returned to the respective supplier or manufacturer.

Quality Improvement

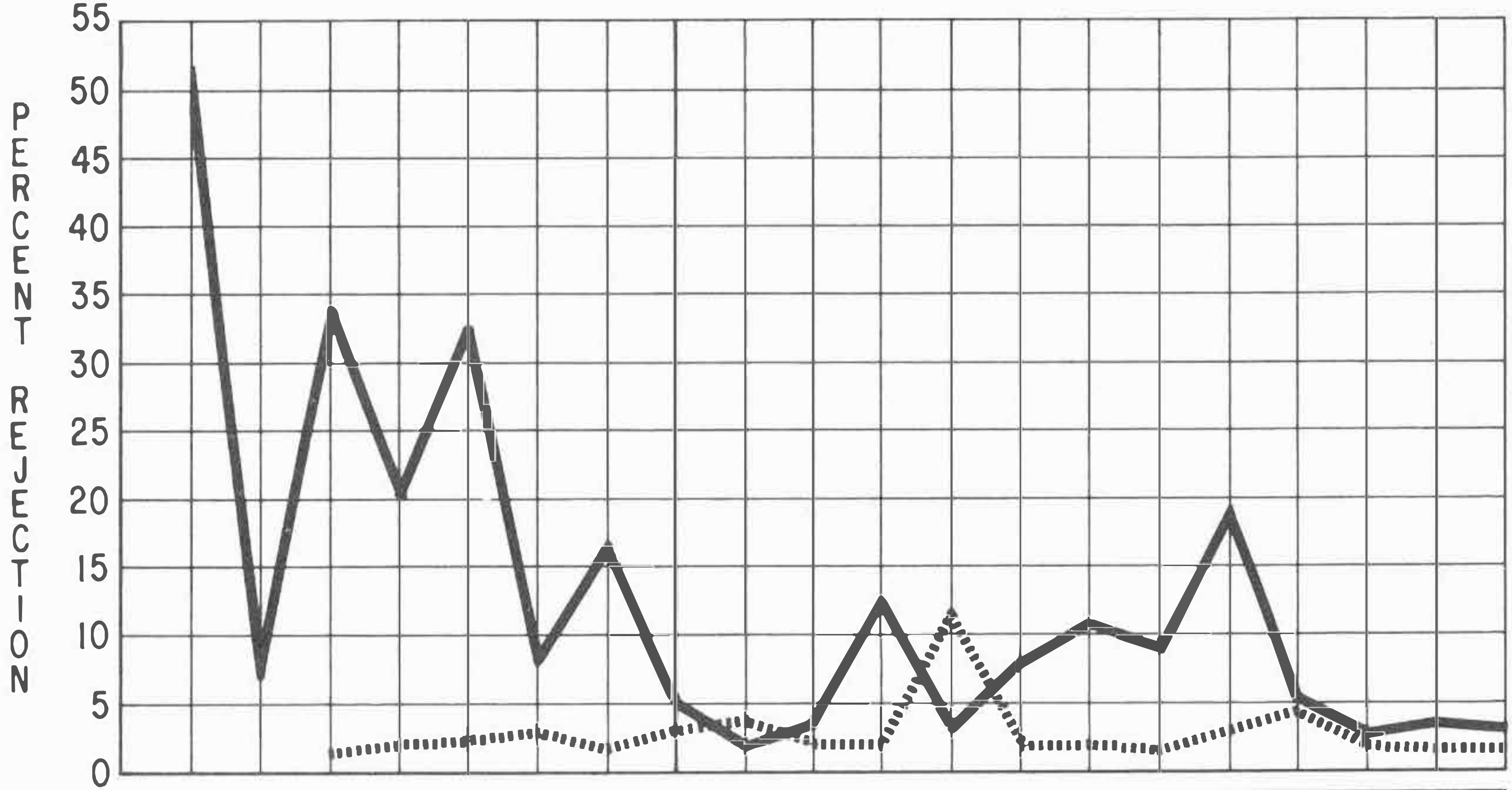
As you know, an incoming inspection program, by its nature, is a conglomeration of statistical data which I feel would bore this audience, and for that matter most any audience. I have no intention of repeating the detailed test results obtained during 1966. This data is available in a Goddard publication QER 66-112, entitled "Summary of Inspection Results For the First Three Quarters of Calendar Year 1966."

Chart I, "Quality Assurance Performance Chart for Semiconductors Procured for the GSFC Stockroom" during 1964 and 1965, is a reflection of the quality improvement realized during the first two years of the program. The rejection rate was reduced during this period from approximately 50 percent to less than 5 percent, regardless of the method of procurement, (either commercial/EIA or military). The possible reasons for this improvement are listed below:

CHART I

QUALITY ASSURANCE PERFORMANCE CHART

(SEMICONDUCTORS PROCURED FOR GSFC STOCKROOM)



		CY-1964								CY-1965											
SPECIFICATION		MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
EIA COMMERCIAL (solid line)	QUANT.	6380	3886	10442	6106	5394	6672	4082	4849	3957	5247	7182	2784	2830	9067	4977	1322	3323	5492	12001	8974
MILITARY (dotted line)	QUANT.	0	0	305	2590	1897	400	2443	7417	19801	11570	20122	4956	7534	5745	8845	3414	24869	7731	3248	7350

1. Inspection data was forwarded to Procurement Division semiconductor buyers and contract personnel to aid them in their selection of responsible suppliers.

2. Increased procurements to Military Specifications.

3. General awareness of Goddard inspection program.

4. More clearly defined R&QA requirements.

Charts similar to the one shown have been placed throughout Goddard in an attempt to motivate other Center organizations to work toward quality improvement. In fact, one Branch Head from the Procurement Division has made it a practice to contact the Quality Assurance Branch if the chart is not kept up to date.

Chart II which covers Calendar Years 1965 and 1966 is similar to Chart I and points out the continual improvements which may be expected by procuring to military specifications. Commercial specification rejections outnumbered military specification rejections during this period by a ratio greater than three to one.

It is interesting to note that during CY 1966, 81,624 semiconductors were purchased and inspected to EIA/commercial specifications, and 4,406 devices or 5.4% were rejected. During the same period 64,392 semiconductors were inspected to military specifications and only 1.3% or 856 devices were rejected. These results clearly indicate the advantages of procuring semiconductors to military specifications in lieu of commercial specifications.

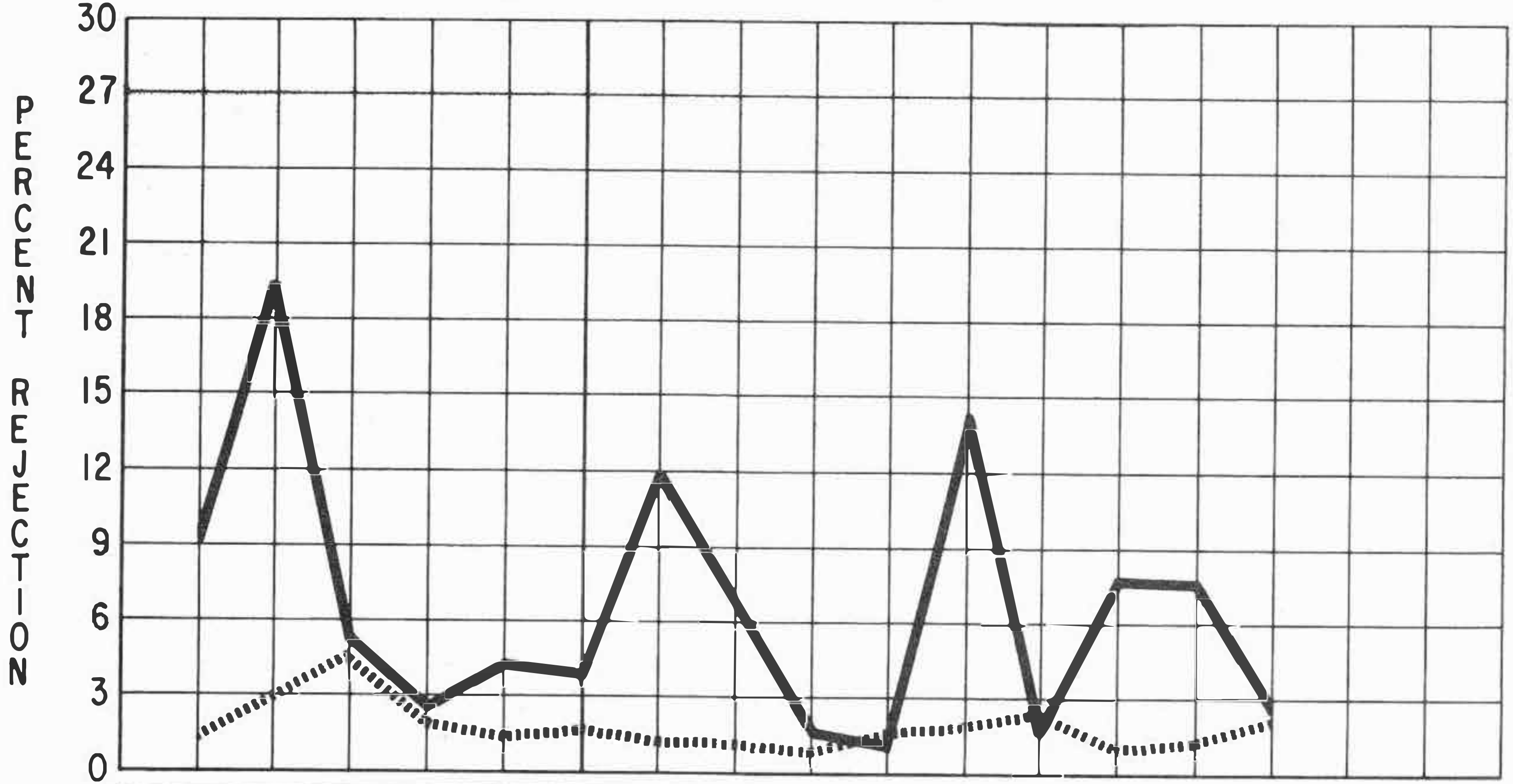
It is realized that occasionally a required device type may only be available to a commercial specification, and there may also be instances when a commercial "Hi Rel" specification is judged the best to use for a particular application. These cases are considered exceptions to the guiding principle of procuring to at least military specifications.

During the first three quarters of 1966, 211,714 devices were inspected by the Quality Assurance Branch with 10,201 devices or 4.8% being rejected. The detailed listing of device types inspected and corresponding rejection percentages are shown in Table I.

CHART II

QUALITY ASSURANCE PERFORMANCE CHART

(SEMICONDUCTORS)



SPECIFICATION		CY-1965 JUL	AUG	SEP	OCT	NOV	DEC	CY-1966 JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
EIA COMMERCIAL (solid line)	QUANT.	4977	1322	3823	5492	12001	8974	8847	5999	11382	11621	5539	10689	5034	16152	5058			
MILITARY (dotted line)	QUANT.	8845	3413	24869	7731	3248	7350	9256	3938	6215	3211	16510	4270	16525	2642	3006			

TABLE I

QUALITY ASSURANCE INSPECTION SUMMARY

FIRST THREE QUARTERS 1966

PART CATEGORY	FIRST & SECOND QUARTERS			THIRD QUARTER			TOTAL		
	QTY.	# REJECT	% REJECT	QTY.	# REJECT	% REJECT	QTY.	# REJECT	% REJECT
DIODES	50078	1487	3.0	30869	1146	3.7	80947	2633	3.3
TRANSISTORS	48388	1806	3.7	16681	823	4.9	65069	2629	4.0
RESISTORS	41681	4045	9.7	15675	740	4.7	57356	4785	8.3
INTEGRATED CIRCUITS	503	8	1.6	—	—	—	503	8	1.6
CAPACITORS	36	0	0.0	7760	144	1.9	7796	144	1.8
RELAYS	18	2	11.1	20	0	0.0	38	2	5.3
SWITCHES	5	0	0.0	—	—	—	5	0	0.0
TOTAL	140709	7348	5.2	71005	2853	4.0	211714	10201	4.8

What Can be Done to Eliminate Distributors and Manufacturers with Poor Performance Records?

The Goddard inspection program has provided the data necessary to rate various vendors based on their quality history. The data is presented in GSFC quarterly inspection reports and they have proven quite useful in strengthening vendor performance. Goddard has found that when a reputable supplier is apprised of a poor quality history, he makes every effort to improve his standing or reputation.

Goddard decided, in October 1965, to take a definite course of action on those distributors and manufacturers who had demonstrated a poor record of performance. It was decided that suppliers with a rejection rate greater than 5 percent could be considered nonresponsive for GSFC RFP's and IFP's, for the calendar quarter immediately following the Quality Assurance quarterly reporting period. The decision of nonresponsiveness is based on the type of device supplied per manufacturer. It is felt that manufacturer/distributor awareness of Goddard's approach is a significant reason for the overall reduction of the semiconductor rejection rate experienced by Goddard.

Vendor Performance Records

During the third quarter of 1966 (as shown in Table II), 10 of 28 manufacturers experienced overall rejection rates of less than 1.0 percent. On the other hand, nine manufacturers' rejection rates were greater than 5.0 percent. Table III compares supplier performance records, and it is encouraging to see that 23 of 30 suppliers had a rejection rate less than 5.0 percent.

As an example of the interest shown by manufacturers and distributors in the Goddard rating program, one manufacturer has even directed its authorized distributor to send any orders destined for Goddard back through the manufacturer's facility to insure proper inspection prior to delivery.

We have discussed the improved quality of semiconductors received at Goddard and the use of inspection data to establish a vendor performance record. There is still an area which has caused Goddard considerable concern. What can be done to eliminate poor suppliers, not previously supplying poor quality devices, who do not have the capability to provide acceptable devices?

TABLE II

QUALITY ASSURANCE INSPECTION SUMMARY

THIRD QUARTER, 1966

MANUFACTURER	INSPECTED	REJECTED	% OF REJECTS	MANUFACTURER	INSPECTED	REJECTED	% OF REJECTS
BENDIX CORPORATION	1	0	0.0	MOTOROLA SEMICONDUCTOR	4550	52	1.1
WESTINGHOUSE ELECTRIC CORP.	3	0	0.0	GENERAL INSTRUMENT	12059	157	1.3
POTTER AND BRUMFIELD	20	0	0.0	GULTON INDUSTRIES	2064	34	1.7
UNITRODE TRANSISTOR	25	0	0.0	INTERNATIONAL TELEPHONE AND TELEGRAPH	1400	28	2.0
SYLVANIA	60	0	0.0	FAIRCHILD SEMICONDUCTOR	4237	100	2.4
R C A	304	0	0.0	NATIONAL SEMICONDUCTOR	2315	64	2.8
MEPCO INCORP	2053	0	0.0	TEXAS INSTRUMENTS	3141	106	3.4
CONTINENTAL DEVICE	1100	5	0.5	RAYTHEON	52	2	3.9
CRYSTALONICS	204	1	0.5				
ERIE TECHNOLOGICAL	1700	14	0.8	GENERAL ELECTRIC	14224	993	7.0
SPRAGUE	16476	180	1.1	SOLITRON	1040	98	9.4

TABLE II (Contd.)

QUALITY ASSURANCE INSPECTION SUMMARY

THIRD QUARTER, 1966

MANUFACTURER	INSPECTED	REJECTED	% OF REJECTS
LANSDALE TRANSISTOR	200	22	11.0
KEMET COMPANY	200	29	14.5
TRANSITRON ELECTRONICS	5	1	20.0
TRI-KING INDUSTRIES	2457	641	26.1
ELECTRONIC TRANSISTOR	670	184	27.5
INTERNATIONAL RECTIFIER	400	118	29.5
INDUSTRO TRANSISTOR	45	24	53.3
TOTAL	71005	2853	4.0

TABLE III

QUALITY ASSURANCE INSPECTION SUMMARY

THIRD QUARTER, 1966

SUPPLIER	IN-SPECTED	RE-JECTED	% OF REJECTS	SUPPLIER	IN-SPECTED	RE-JECTED	% OF REJECTS
DEFENSE ELECTRONIC	19	0	0.0	MOTOROLA	4358	48	1.1
TECHNICO INC.	25	0	0.0	POWELL ELECTRONICS	241	3	1.2
STOREROOM	400	1	0.3	ALLIED RADIO	314	4	1.3
RADIO ELECTRIC SERVICE	1160	5	0.4	V P COMPANY	73	1	1.4
SCHWEBER ELECTRONICS	2520	19	0.8	SILBERNE	3520	57	1.7
GENERAL INSTRUMENTS	11100	85	0.8	ELECTRONIC WHOLESALERS	1203	22	1.8
WHOLESALE RADIO PARTS	12785	113	0.9	FAIRCHILD SEMICONDUCTOR	2396	54	2.3
SPRAGUE	1308	12	0.9	PROJECT	3799	97	2.6
TEXAS INSTRUMENTS	550	5	0.9	D & H DISTRIBUTING	67	2	3.0
SHERIDAN SALES COMPANY	100	1	1.0	NATIONAL SEMICONDUCTOR	2016	64	3.1
				PIONEER STANDARD	2300	81	3.5

TABLE III (Contd.)

QUALITY ASSURANCE INSPECTION SUMMARY

THIRD QUARTER, 1966

SUPPLIER	INSPECTED	REJECTED	% OF REJECTS
SANBORN DIVISION OF HEWLETT-PACKARD	104	4	3.9
MILGRAY/WASHINGTON	2409	107	4.4
MILO ELECTRONICS	65	4	6.2
GENERAL ELECTRIC	13513	987	7.3
SOLITRON DEVICES	1000	97	9.7
EMPIRE ELECTRONIC	78	12	15.4
TRI-KING INDUSTRIES	2457	641	26.1
RADIO DISTRIBUTING	1070	302	28.2
VALLEY ELECTRONICS	55	25	45.5
TOTAL	71005	2853	4.0

The high rejection rate associated with the initial orders received from these unauthorized distributors and unqualified manufacturers has plagued Goddard for some time. In an effort to more concisely specify Goddard requirements, it was decided, in June 1966, to impose the following clause on all semiconductor suppliers:

"GSFC TRACEABILITY CLAUSE FOR PROCUREMENT OF SEMICONDUCTORS"

"Semiconductor suppliers shall comply with the following traceability requirements for all semiconductors provided under this contract:

A. Device Manufacturer

All devices and documentation must contain the original manufacturer's name, symbol or trademark which positively identifies the manufacturer of the device. Bidders/Offerors shall identify the manufacturer/manufacturers of each device they intend to supply. in their bid/offer.

B. Component Identification

Each semiconductor shall be marked with the original manufacturer's name, symbol or trademark. Semiconductors which have been branded, rebranded, redated or otherwise remarked by other than the original manufacturer are not acceptable. All semiconductors shall be date coded by the original manufacturer in accordance with the latest issue of the EIA Source Code and Date Code Booklet" or the applicable military specification. In the case of diodes, lot number identification will be acceptable in lieu of the date code, if the supplier provides copies of the original manufacturer's certified documentation which relates the lot number to the date of manufacture. Marking shall be placed on the body or case of the device, except where device size precludes such markings. In these instances, marking shall be placed on the lead tag, holding strip or the individual package. Semiconductors must be delivered in the original manufacturer's package which contains the required markings.

C. Documentation Requirements

Semiconductor suppliers shall furnish documentation with each shipment which will permit GSFC to establish direct and positive traceability of the device from the supplier to the original manufacturer. This documentation shall consist of invoices or shipping documents, including subcontractor documents which contain the name of the manufacturer, the device number, the lot code number or the date code traceable to the original manufacturer.

All information on the documents must be entered by the originator of the invoice or shipping documentation. When lot code identification is used in lieu of date coding, the manufacturer's documentation must contain date code identification to relate the lot code to the date of manufacture. If the required documentation is not provided the devices will be rejected.

D. Device Description

All devices supplied under this procurement shall be new, shall be manufactured no longer than 12 months prior to shipment to GSFC, and shall not be culls, rejects from other contracts, or from sources unknown. Evidence on the leads, cases, or packages that indicate prior use will be cause for rejection."

Results to date reveal that several unauthorized distributor types have ceased bidding on Goddard semiconductor contracts where the traceability clause has been incorporated. The clause presents little if any problems to authorized distributors, but it has caused considerable concern to those distributors whose stockrooms are "half filled with questionable semiconductors obtained in auction sales in Canada."

Distribution Analysis

A valuable tool used at Goddard to analyze incoming inspection results is the Frequency Distribution Computer Printout. This printout provides statistical data to aid engineers in matching particular parameter characteristics. The Goddard computer program is a basic frequency distribution printout which provides a measure of the process variation of a particular manufactured lot. Additional statistical information such as: standard deviation, process average, and the upper and lower specification control limits are included in the printout. An example of a complete Goddard program has been made available for review by the conference attendees who might desire to examine it more closely. (Chart III.)

The information provided by the printout has been useful in detecting: the possible delivery of counterfeit devices (Figure 1), the degree of inspection performed by industry or DOD (Figure 2), a lot where a supplier has culled out the more stable devices for a previous order (Figure 3), or finally, a lot where part of the production output was produced under one set of conditions and part under another (Figure 4).

It is hoped that Goddard's experiences in utilizing incoming inspection data will prove worthwhile and beneficial to the attendees from the other NASA Installations.

TABLE III

TEST PARAMETER - ICBO FINAL

QUANTITY ANALYZED 59

PERCENT OF TOTAL (0 20 40 60)

COUNT	RANGE
	.000000002500
33	
	.000000009450
8	
	.000000016400
6	
	.000000023350
0	
	.000000030300
0	
	.000000037250
1	
	.000000044200
1	
	.000000051150
0	
	.000000058100
0	
	.000000065050
2	
	.000000072000
0	

51 ON GRAPH
0 OFF LOW SIDE
8 OFF HIGH SIDE

GRAPH LOW LIMIT 2.500-9

GRAPH HIGH LIMIT 72.000-9

QUANTITY ANALYZED 295

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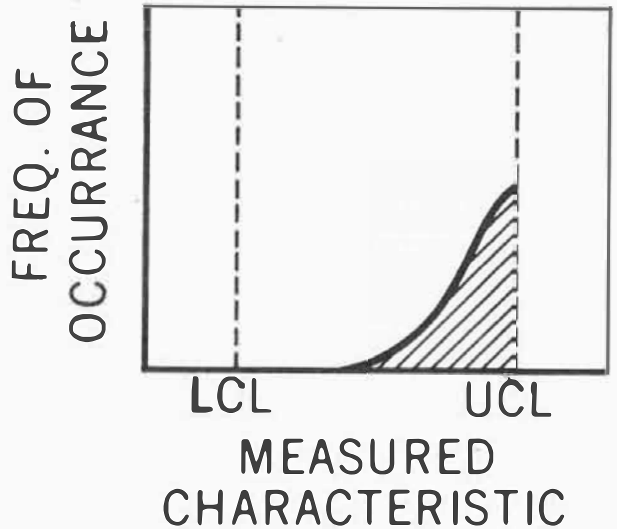
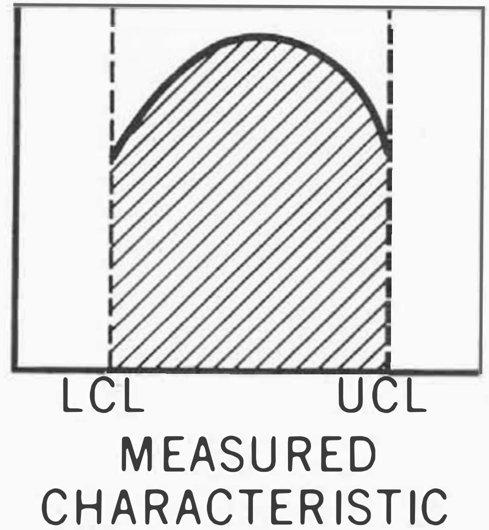
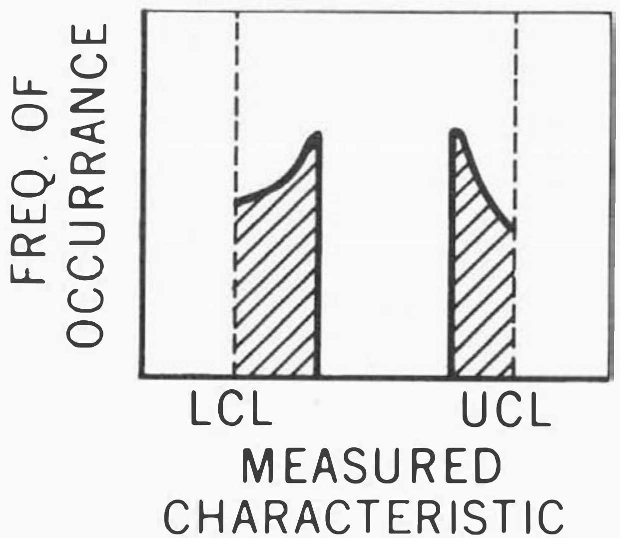


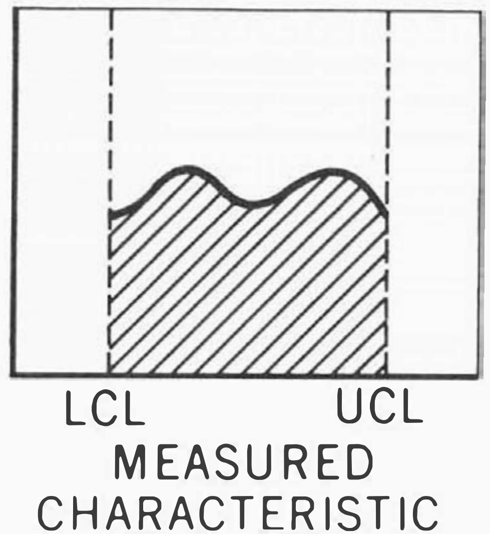
(FIGURE 1)



(FIGURE 2)



(FIGURE 3)



(FIGURE 4)

NASA QUALITY ASSURANCE POLICY & PROCEDURE STATUS

Howard M. Weiss
NASA Headquarters (KR)

Current and near future activity in NMI's on quality assurance are summarized as follows:

NMI 5330.1: Basic Quality Assurance Policy

This is expected to be combined with NMI 5320.1 (Basic Reliability Policy). However, the draft revision circulated earlier this year will be replaced by a broader document. Based on another look at the proper focus of total R&QA activity, KR expects to have a new version early in 1967 which will:

- Provide authority for and describe general R&QA requirements in projects.
- Define and describe specific R&QA functions to be performed in-house and by contractors.
- Define responsibilities of central R&QA organizations.

NMI 5330.2: Quality Status Stamps

Revision is underway to accommodate partial conformance indication, which was suggested by MSFC. Coordination draft expected to be circulated in December.

NMI 5330.3: Hand Soldering Requirements

Revision to be circulated with coordination draft of NPC 200-4A will be consonant with latter and companion Technology Utilization Publication on soldering process details. Involves both hand and machine soldering.

NMI 5330.4A: NASA Training & Certification - Hand Soldering

Revision effective October 12, 1966 discontinued formal training and certification of contractor and delegated Government agency personnel. Provided for seminars for new Government agency personnel, experimenters and suppliers. In-house personnel to be trained by installation courses given on an as-needed basis with inter-installation collaboration.

NMI 5330.5: Training & Certification-Fabrication & Inspection Processes

To be revised after completion of NPC 200-4A to delete reference to soldering as the "pattern" for Case II process control. Expected to be consonant with joint NASA-DoD action on Government training and certification.

Activity in quality assurance procedures are:

NPC 200-4A: Soldering Requirements

September coordination draft resulted in sufficient comments and changes so that it will again be circulated for approval--about December. Since this will be the third time, a short approval cycle is contemplated. Will cover hand and machine soldering.

Soldering Technology Publication

Under preparation by Headquarters Technology Utilization Office with KR in approval role. Will contain "how to" details from all Centers. Expected to be published about the same time as NPC 200-4A.

NPC 200-2A & 200-3A (Revision)

Task team of installation members under KR chairmanship has been busy on this. Study topics were reviewed in September and November. Writing of each section assigned to a team member and is underway. Expected to be ready for coordination in April, 1967.

NPC 200-X (Application of 200-2A & 200-3A by NASA and Contractors)

Writing deferred until draft of 200-2A and 200-3A is completed. Material being collected by task team during writing of 200-2A and 200-3A.

Revision of PR 1.50 (Quality Requirements in Procurement)

An interim NPD is being prepared to obtain early application of non-controversial improvements generated by the 200-2A and 200-3A task and from recent Center evaluations. Expected to be coordinated about December. A complete revision to PR 1.50 is expected to be coordinated at the same time as 200-X.

Other quality assurance events are:

NHB 5330.7 (Management of Government Quality Assurance at Supplier Operations)

Published effective July 1, 1966. Recent problem experiences indicate this is good source that should be implemented more widely. Therefore, it is mentioned here.

NASA-DCAS Coordinated Quality Assurance Training

This course was developed jointly by NASA and DCAS in May under KR leadership. 17 DCAS instructors were trained at MSFC during June and July. Will result in field training of about 1100 DCAS personnel on NASA quality requirements, with special reference to differences between NPC 200-1A and DSAM 8200.1. Will result in estimated savings of $700K and completion of training in one year with minimum student travel. Course will be open to other DoD field quality assurance personnel. It is expected to reveal need for specific improvements in both NPC 200-1A and DSAM 8200.1.

ASSESSING EFFECTIVENESS OF R&QA ACTIVITY IN PROCUREMENT

Daniel E. Negola
NASA Headquarters (Code KR)

Headquarters, Reliability and Quality Assurance Office, Code KR, in accordance with its functional management responsibilities (NMI 1136.5 dated August 17, 1965), is conducting evaluations of the effectiveness of the reliability and quality assurance (R&QA) functions relative to the Headquarters and Installation procurement process. These evaluations are designed to provide functional management assistance to program and project office and installation R&QA elements.

The objectives, methods, and techniques of conducting the evaluations are contained in Code KR draft publication "Management Reliability & Quality Assurance Evaluation Program," dated October 1966. These evaluations utilize the new approach of an "exchange of information technique" in lieu of surveys which solely indicate compliance with prescribed regulations and procedures. In addition, the evaluations provide an insight as to the practicability and effectiveness of Headquarters policies, procedures, and regulations.

Evaluations will be conducted at each NASA installation on a periodic basis at the rate of approximately one installation every two months. Team visits will be coordinated with installation contact points designated by Installation Directors.

The evaluation teams are under the chairmanship of the Headquarters Reliability & Quality Assurance Office and are supplemented by R&QA specialists from Headquarters Program Offices and field installations (other than the installation being evaluated). Each NASA installation, and other installation personnel to serve as team members, will be appropriately advised 60 days in advance of a planned evaluation.

Objectives: This evaluation program has the following objectives:

- To review, evaluate, and assess the effectiveness of the implementation of NASA-Wide R&QA policies, procedures and requirements.

- To determine the need for improvement of NASA-Wide R&QA policies and procedures.

- To promote an interchange of R&QA knowledge, experience, and practices between NASA installations and program offices.

- To provide for the establishment of effective communication channels between NASA and DoD support elements performing delegated R&QA functions.

- To achieve uniformity in those areas where commonality exists.

- To enhance and improve NASA's R&QA image with industry.

The management R&QA evaluations conducted under this program have three essential characteristics:

- They are conducted by R&QA personnel who have extensive previous experience and demonstrated skill in R&QA operations.

- The criteria for review, evaluation and assessment is common for all installations.

- The results of each evaluation are contained in a report to Headquarter's Institutional and Installation Directors. The report clearly and accurately reflects the effectiveness of the R&QA organization and contains recommendations for implementation of any required improvements.

These evaluations are designed to provide NASA Headquarters and installation management visibility into the maximum utilization and effectiveness of NASA resources available to plan, manage and direct the implementation of Headquarters R&QA policies and procedures to assure overall reliability of space hardware.

Cost reduction, uniformity when commonality exists, value engineering, and motivation principles and concepts will be fully considered in the total evaluation and assessment program. Improvement in the team concept of total R&QA will be encouraged.

The schedule for FY-67 is:

	Installation	Dates
1.	ARC FRC	Oct. 17-21, 1966 (completed) Oct. 24-28, 1966 (completed)
2.	LeRC SNPO	Dec. 5-13, 1966 Dec. 14-16, 1966
3.	LaRC	Feb. 6-14, 1967
4.	Wallops	Mar. 13-17, 1967
5.	MSC	April 3-14, 1967
6.	GSFC	June 5-16, 1967

Advance Planning

Well in advance of the scheduled team visit, the manager of the R&QA Evaluation Program will contact the appropriate program office to discuss the requirements for the forthcoming evaluation and to extend an invitation for their participation. These discussions include the following:

- Special R&QA problem areas of particular interest concerning the installation to be evaluated. These discussions will be directed toward extent and importance of problems, facts and circumstances surrounding problems, existing NASA policy concerning the problems, and program office guidance or instructions previously forwarded to the installation.

- Status of incomplete actions resulting from prior evaluations. Determination of follow-up actions considered necessary by the program office.

- Responsiveness of installation R&QA personnel to program office direction and requests for action. Consider such aspects as the timeliness and responsiveness of R&QA reports, of questionnaires and information queries, of submissions for Headquarters approvals, and of submissions of data for Headquarters information. Obtain Program Office comments on adequacy of installation procurement plans and contracts submitted for Headquarters review and approval. Determine what type of R&QA reports are required of R&QA installation elements.

- Determine the program office requirements or emphasis placed on R&QA requirements for RFP's (or IFB's), such as off-the-shelf equipment procurements, experiments, fabrication support contracts for in-house programs, major R&D equipment contracts (over $1,000,000), and smaller R&D equipment contracts ($50,000 to $1,000,000).

- Solicit comments from the program offices on responsiveness and effectiveness of installations' R&QA elements in meeting program requirements.

The team leader will request from the installation to be evaluated, one copy of all implementing documents for all R&QA activity, specifically including those documents issued based on NASA policy directives contained in NHB's, NMI's, and PR's. A cross-section of delegated letters issued by the installation to DoD activities or letters of delegation for specific selected programs will be requested. Detail arrangement or requirements for the team will be discussed with the installation contact point.

Conducting The Evaluation

Pre-Evaluation Orientation and Briefing of Team Members-- The team leader will schedule a meeting of the team in the morning prior to the opening interview. Major items to be discussed include:

- Assignments of the team members and assure understanding of their responsibility for preparing the report.

- Evaluation procedures and clarification of any questions.

- The working schedule, explaining that all will participate in the initial and final meetings with the representatives of the installation.

- The administrative procedures, that is, how the team will work with the organization's liaison representative, how interviews will be arranged, how contracts and purchase orders, R&QA plans, etc. will be obtained and returned to files, and schedules of team meetings.

- New areas of significance, for example, the current emphasis on greater use of incentive clauses for R&QA.

Other areas requiring special attention could include:

- Unique methods of including R&QA concepts in the procurement process.

- Introduction of R&QA requirements in Project Phases.

- Cost reduction efforts.

- Value engineering.

- Teamwork between reliability and quality assurance personnel.

<u>Opening Interview</u>

The team leader will introduce the members of his team, outline the objectives of the evaluation and explain how it will be conducted. The objective of the teams approach is an evaluation of the total R&QA system; the team is not interested in isolated trouble spots or bad examples. It is our desire to have the evaluations render a useful service. The team is made up of R&QA specialists who will be more than willing to make constructive suggestions for a better R&QA operation wherever they can.

A (1 - 1½ hour) presentation by the installation quality and reliability organizations will be given. This will include areas such as:

- Installation organization

- Relationship of R&QA to the overall organization--Procurement, etc.

- Workload--Programs and Projects--present and future.

- Contract support utilization.

- List of personnel and specific assignments relative to the mission included within installation and field assignments.

- What are the recognized problems of R&QA and the proposed recommendations.

- Other R&QA elements and the relationship with the central focal R&QA organization.

Review of Procurement Practices

The review of individual contracts, purchase orders, R&QA plans, and letters of delegation is a most important evaluation technique. These documents are a primary source for determining the effectiveness of the R&QA organization. But the evaluation of these documents is not an end in itself, nor will this method unfailingly supply the right answers. The documents that are reviewed will disclose the pattern of the organization's thinking. The teams preliminary evaluation of the soundness of this thinking will be confirmed or modified by interviews with the R&QA organization personnel.

Documents will be reviewed based upon a sampling procedure influenced by information acquired prior to the evaluation. Some of the factors to be considered in determining the documents to be reviewed are:

- Dollar value
- Type of contract
- Type of procurement
- Type of delegation

Review of Policies, Directives, and Procedures

Each installation is expected to implement the NASA PR as provided in NASA NPC 400, paragraph 1.108 to provide operating personnel with comprehensive, step-by-step guidance. The team will review the policies, directives and procedures that guide and regulate the R&QA organization's actions. The following areas are considered appropriate:

- Location within Installation of Headquarters R&QA policies.
- Installation R&QA policies and procedures relative to Headquarters R&QA policy (clarity, availability, control, distribution, use, etc.)
- Other directives from Headquarters Program Offices concerning R&QA.
- Installation R&QA policy for which no Headquarters policy exists.

- Statement of functions and authority for the R&QA group. Review organizational relationships for interface between project managers, other organizational elements, and the R&QA organization. (Refer NMI 5320.1, 5330.1, and NHB 5330.7, par. 102).

- Installation comments on adequacy or inadequacy of Headquarters R&QA policy with specific recommendations, if applicable.

Closing Interview

The purpose of the closing interview is to present the team findings and recommendations to installation management and to provide for discussion of major problem areas. The interview provides a good opportunity for the exchange of information and to focus management attention on needed improvements.

Report

A preliminary draft of the evaluation report will be sent to the installation for information and comment prior to the final report. The report will summarize recommendations of the team and its findings. Final report will be sent to the installation Director within 5 weeks of evaluation completion, requesting specific comments and proposed action upon the team findings and recommendations.

Post Evaluation Activities

Post evaluation visits to the installation will be made to determine the effect of the action taken by the installation and to obtain the maximum of the potential improvement measures. Based on the evaluations and post evaluation visits, KR will improve or modify NASA-Wide policies and procedures as necessary.

G.W. Brewer, LaRC
Reliability and Quality Assurance

Talk on "Experiences in Reliability and Quality Assurance Programming in the Lunar Orbiter Incentive Contract"

Some time around last August it was suggested to me that it would be of interest to go back through the Lunar Orbiter experience and see what could be said about the impact of the incentive on the R and QA effort. I soon realized that I might have a problem. The problem that I had then and still have now is this:

First: I have always felt strongly that R and QA should not be affected by whatever type of contract is in effect.

Second: I could not find any obvious or convincing examples of the impact of the incentive.

However, the fact of the matter is that Lunar Orbiter has operated under a cost incentive, delivery penalty, and performance award type contract and we have gone the route from contract start to a first flight in 29 months and a second flight 3 months later (November 6). There are a few observations to offer based upon this activity.

To set the stage for some concluding remarks, a brief project description is in order.

In a nutshell:

1. The RFP was released August 15, 1963
2. Contract negotiated March 1964, signed May 7, 1964
3. Design frozen January 1965
4. Component testing started February 1965.

5. Ground spacecraft testing began October 1965

6. Spacecraft delivered June 1966

7. Spacecraft flown August 1966

The Langley Research Center has had project management responsibility under OSSA and the many organizations laced together for this 225 million dollar effort to include five Lunar Orbiter flights is shown in:

Vugraph 1 - Lunar Orbiter Project Organization

As you can see, a wide variety of organizations are supporting this effort.

The spacecraft is 850 pound minimum structured assembly of 35 components consisting of about 20, 000 parts.

Vugraph 2 - Lunar Orbiter Spacecraft

The spacevihicle is Atlas-Agena, basically the same system as employed by Ranger and Mariner and countless other payloads of similar weight range. The actual space vehicle lift-off from Pad 13 on August 10, 1966 is shown on

Vugraph 3 - Lunar Orbiter Launch

The operational mission flight profile is shown in:

Vugraph 4 - Typical Flight Sequence of Events

and is a very familiar pattern approaching the moon but an original and exacting procedure for the orbiting phase.

The photographic mission is to obtain vast coverage of terrain down to a 1 meter resolution of possible Apollo sites. The first-flight primary sites were dispersed as shown in:

Vugraph 5 - Lunar Orbiter Photographic Coverage

The second flight had a similar flight plan but covered a more northerly photographic site band.

The Contract incentives are described in

Vugraph 6 - Lunar Orbiter Contract Incentives

Now at this point, I want to emphasize that the entire Contract management approach of Lunar Orbiter was to emphasize speed of delivery and obtain a first flight success. This required the use of space proven hardware, whereever possible, and the expediting of all aspects of procurement to meet a 2-year delivery objective. Unfortunately most all of our problems stemmed from having to modify almost everything that had been space proven. I suspect this is the fate of most new space projects.

The next few vugraphs cover some key aspects of the implementation of the R and QA program.

The overall considerations of Reliability were generated through this all-encompassing process listed in:

Vugraph 7 - Steps to Reliability as stepping stones to system capability and readiness for flight.

The achievement of Reliability is through the careful management of engineering progress and human factors by means of the tasks listed in:

Vugraph 8 - Reliability Engineering - which are some of the major areas of NPC 250-1.

It is always of interest to look the challenge of a project square-on and I do not know of a more sobering way than by absorbing the significant prediction of:

Vugraph 9 - Measure of Success ? - which is an estimate based on judgment and experience of some measure of success (or failure) expected for the particular conditions of design and use.

Lunar Orbiter worried a great deal about implication represented by these curves and decided to go all the way and place NPC 250-1 as well as the NPC 200 series documents into the contract as requirements. We are one of the first, if not the first NASA incentive contract to do this. We felt that a space project could do no less than place particular emphasis on the R and QA requirement to strive for first flight success. This action proved a dynamic (and traumatic) experience for the

Contractor and not a few grey hairs were lost on our part as we molded the requirements into a workable pattern of R and QA activity for the prime and his subs and vendors.

This was done in part by some very key documentation provided by the Contractor shown in:

Vugraph 10 - Lunar Orbiter Reliability Documents

The most influential of these, from a program control viewpoint, are the first and last. The first tells the customer what will be done to satisfy the contract requirement, and the last is the basis for instructing the subs and vendors as to their responsibility for their part in the effort to achieve "First Flight Success".

Likewise the QA area was controlled through key documentation as noted in:

Vugraph 11 - Lunar Orbiter Quality Control Documents

which single out three of the principal requirements which have a powerful effect on the end item.

In the QA area, it should be noted that we nogotiated with the DOD Plant representatives through AFPRO Boeing Seattle for Quality coverage all over the country where Lunar Orbiter hardware was being manufactured, tested, and inspected. This proved an important contribution, despite shortcomings and the periodic breakdown of understanding of assignments which seems inherent for human beings thrice removed.

The remainder of this discussion will be devoted to some random, but carefully selected, remarks in the form of observations from experience. You will have to draw your own conclusion as to whether or not the incentive contract played a dominant part.

1. A very heavy effort was made by the Contractor and the Project (NASA-LRC/LOPO) in the Contract negotiation period, and for 3 months into the Contract, to detail the scope of R and QA tasks. Without this base-line the road would have been slippery and rough, and the end item possibly suspect.

2. The most important single value of having NPC 250-1 in the Contract (by the Contractor's own evaluation) was the requirement of reliability programs from all suppliers. The same held true for quality programs under NPC 200-2, but these are not in quite the same category, due to the greater commonality of this area through-out the industry.

3. We have no records that show the Contractor formally claimed government interference in the R and QA area of the Contract although in a few instances near the spacecraft delivery period there were mutterings in this direction. We were able to mutually agree on

a "right way" from a R and QA viewpoint technically, even though the solution sometimes was by granting a waiver here and there (after a great deal of study on the matter.)

4. The prime contractor had a great problem implementing the R and QA requirements to all vendors. In fact we (LOPO) played a very powerful role in this by reviewing the contents of his "bible" and practically rewrote his "book" to bring Lunar Orbiter requirements into proper perspective - out of the boiler-plate treatment of his typical procurement; I cannot overstress the importance of this point.

5. The Contractor and his suppliers under-estimated the impact of Lunar Orbiter R and QA requirements. The result was either a steady pressure of waivers and deviations (the NPC 200-Y document as example) or in some few cases out-right breakdown of discipline leading to poor quality product (lack of configuration control).

6. We paid the price of letting the Contractor rush out his procurement specs before design was frozen and thereby "firmed-up" contracts with "preliminary agreements." By the time final requirements were documented these had to be negotiated like changes - very difficult and unsuccessful under incentive or any schedule sensitive contract.

7. Despite an excellent configuration management plan developed in conjunction with LOPO, the Contractor had severe diffucilties in

some areas with lack of identicality caused by inconsistent configuration control. The problem here is the lack of contact by the prime with his supplier at critical points of progress. Every instance which came to our attention we forced a review and action in the name of reliability. A constant policing action is necessary, if any semblance of configuration control is to be achieved.

8. Process controls and parts screening was a challenge for all parties concerned. The industry has yet to recover from our dogged insistence on excellence of the parts program. This was one area where we tangled seriously with the Contractor on several occasions, some of which came close to claims of schedule delay and program interference. My experience has been that the technical "troops" always "wanted" to do "all the way" for space program reliability, but management pressure often pinched the "soft spots" and eliminated the "extras" often desired.

9. Perhaps one of the most significant contributions by the incentive was that it certainly kept the government constrained from making major changes in scope of the task agreed upon. Certainly there have been changes (both in and out of scope) particularly of recent months due to the lack of definition in the original statement of work of flight operations areas, but consistent management resistance to changes has been exercised by both parties. I had a hard time bending under my Project Manager's policy of "Let the incentive work;

Don't interfere with the Contract; Clarify, demand excellence, but don't tell him what to do". I'm still struggling to honor this management objective without appearing to be telling him how to do it better. (This policy is a good one; if there is discretion by all concerned, but such discretion in any contract seems hard to cultivate.)

10. The Contractor placed a heavy emphasis on schedule, then performance, and finally cost, in that order in evaluating his trade-offs on project management decisions.

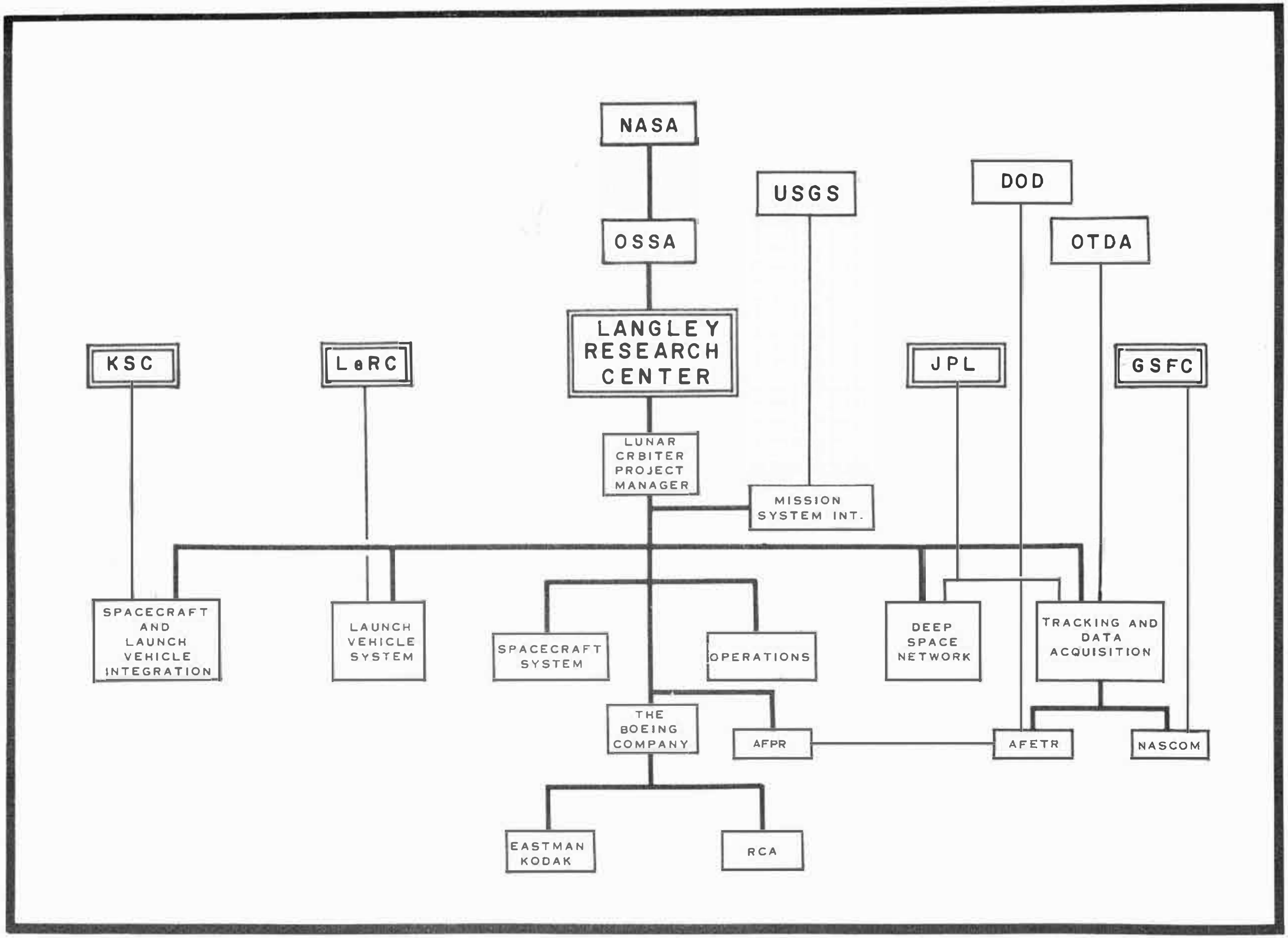
11. Reliability is a constant contest between engineering judgment versus management's estimate of the risk of failure. We, (LOPO) fought many a battle against the Contractor's claim of "inherent capability through Design Margin" particularly when accompanied by a minimum test phase. The flaw in this simple concept of Reliability through design is that successful operation of the end item is not solely the produce of "Reliability" but is in fact, the combination of "R and QA". I have long since concluded that reliability is not only an exacting engineering specialty, but reliability has to be recognized by management as everybody's business, or else the job does not get done - either well or on time.

12. In connection with this last comment, it should be stressed that both R and QA functions must be carefully planned and implemented beyond hardware development and delivery, into all testing phases, and particularly disciplined through-

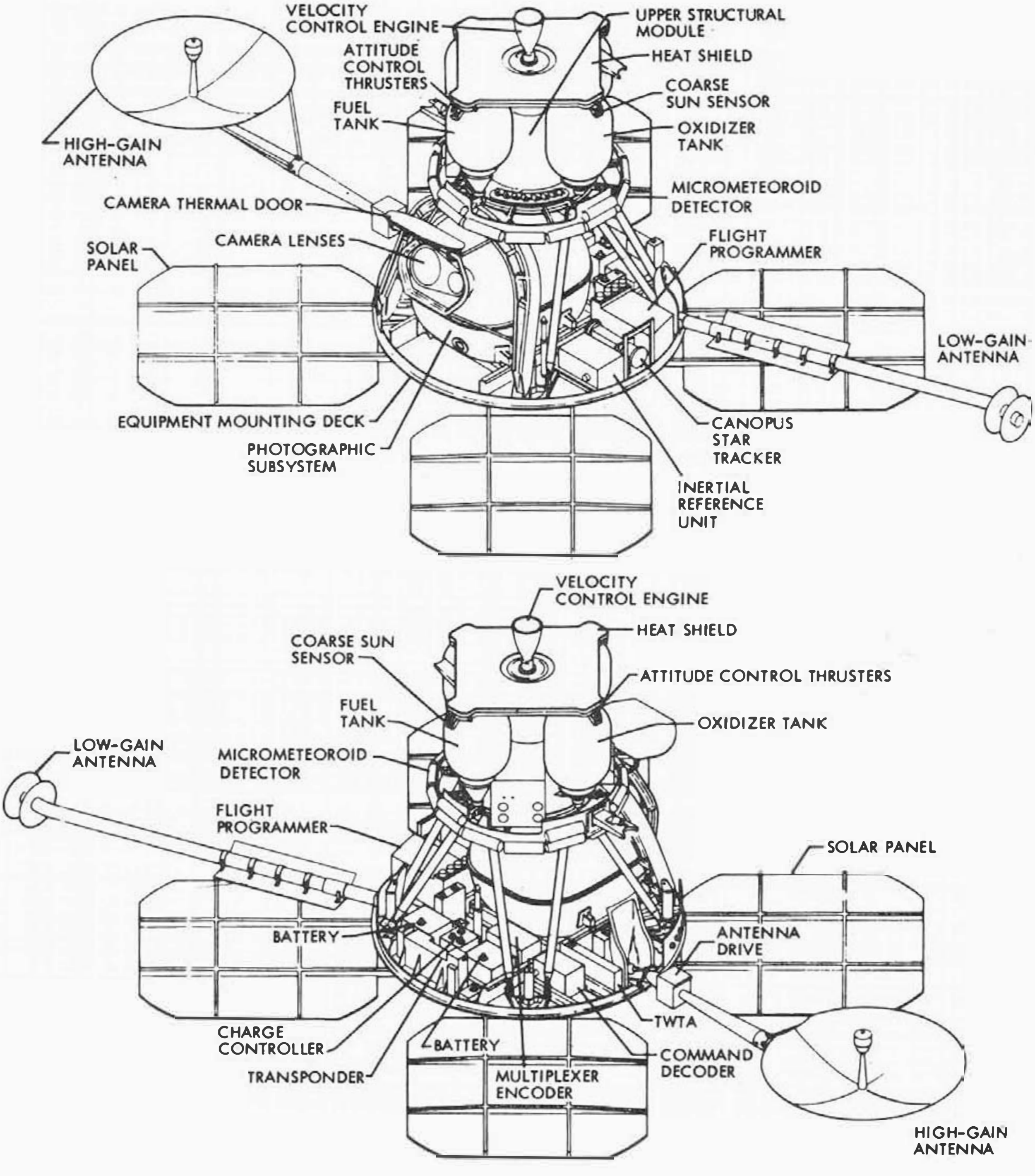
out readiness for flight - and all throughout the flight itself. In the final analysis, no matter how perfect the status of spacecraft going into a flight, operator response during "normal" flight control periods or during stressful off-nominal activity has a significant bearing on the ultimate success of a given mission. The level of success achieved on Lunar Orbiter I flight is a living testimony to this point - we did concern outselves on such matters prior to flight and it paid off with dividends. A conclusion can be drawn - those who plan and engage in space flight programs should give more emphasis to implementing certain of the NPC 250-1 reliability requirements into the operations phases more completely than has been done to date.

13. Lastly, we have spent about millions on R and QA on the Lunar Orbiter spacecraft contract totaling about 150 million to date. Judging from flight results thus far, this may have been almost enough.

GWBrewer. pr 11-10-66

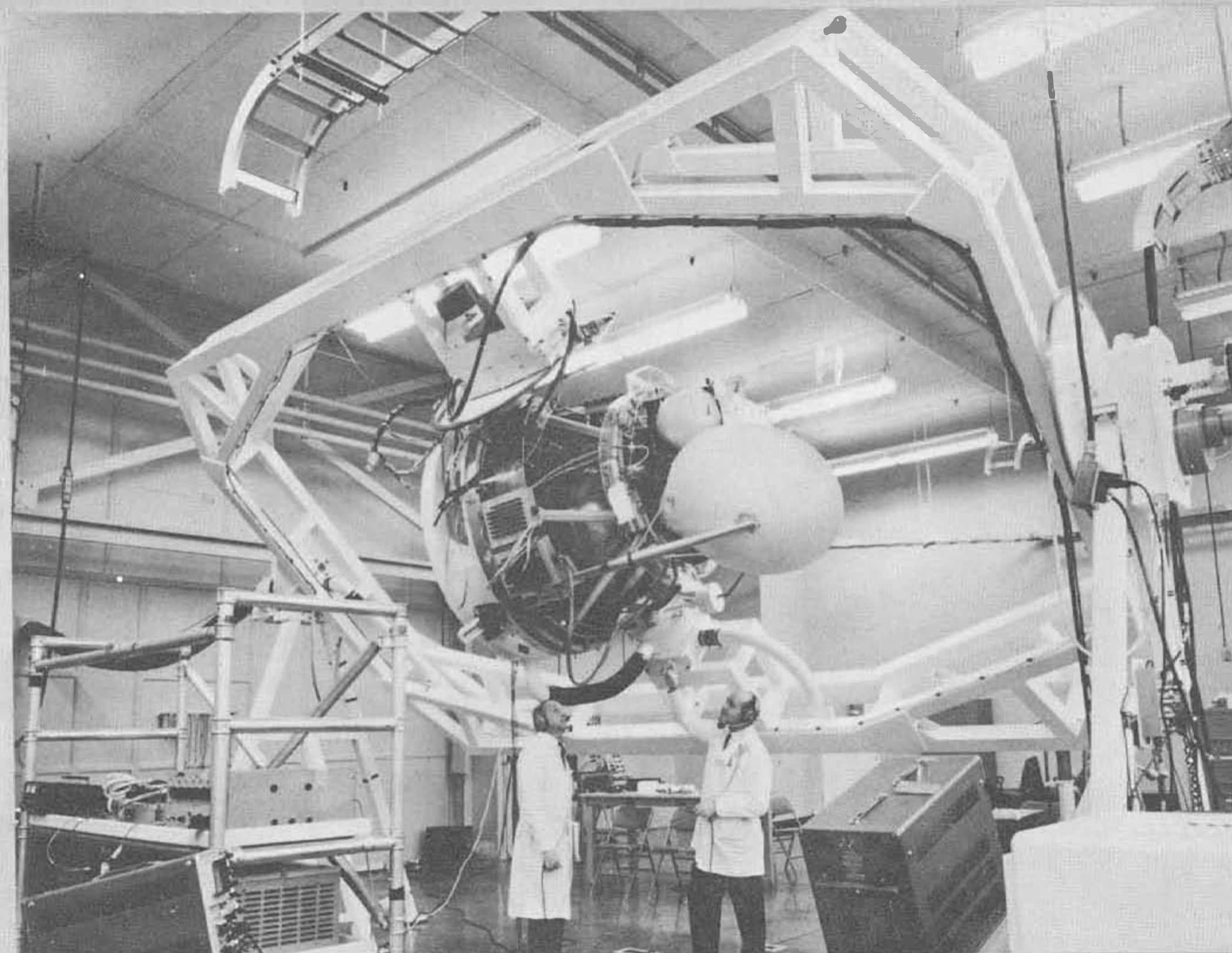


LUNAR ORBITER PROJECT ORGANIZATION



LUNAR ORBITER SPACECRAFT

LUNAR ORBITER MISSION SIMULATION PROTOTYPE



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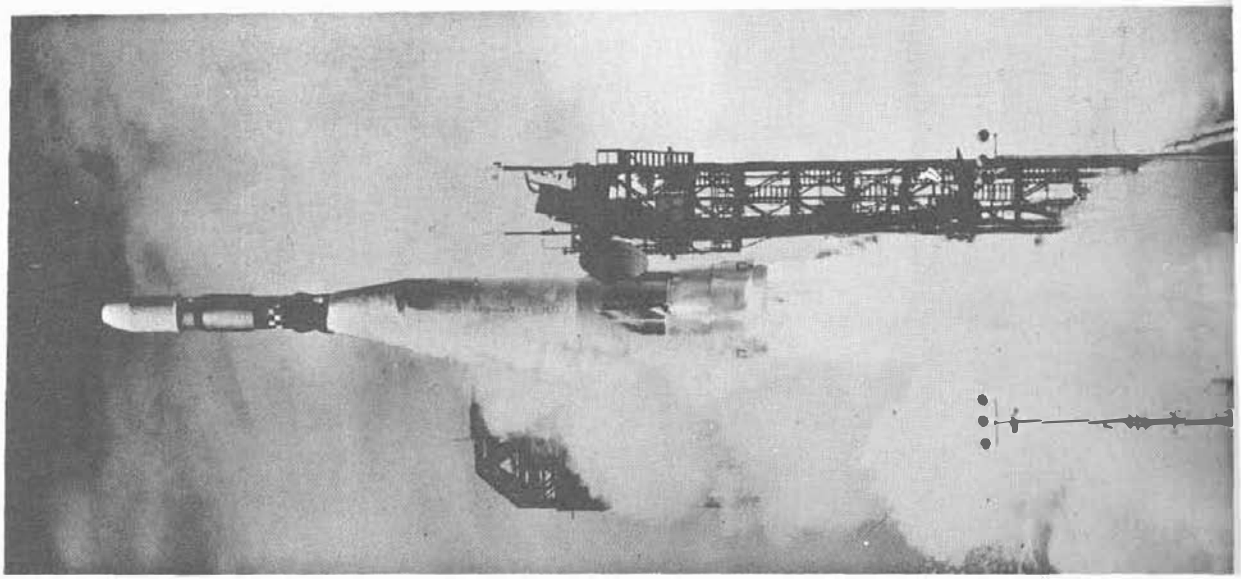
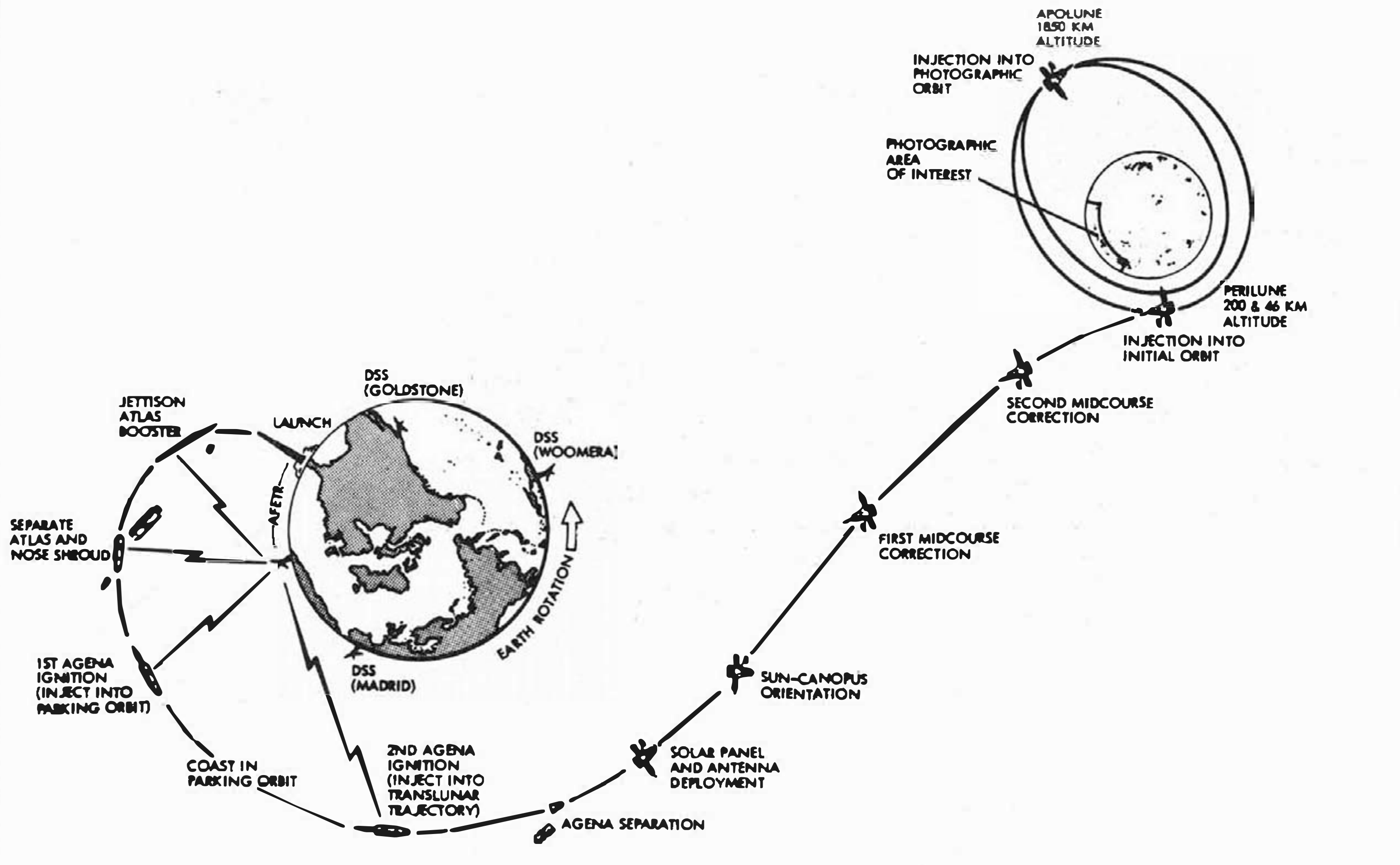
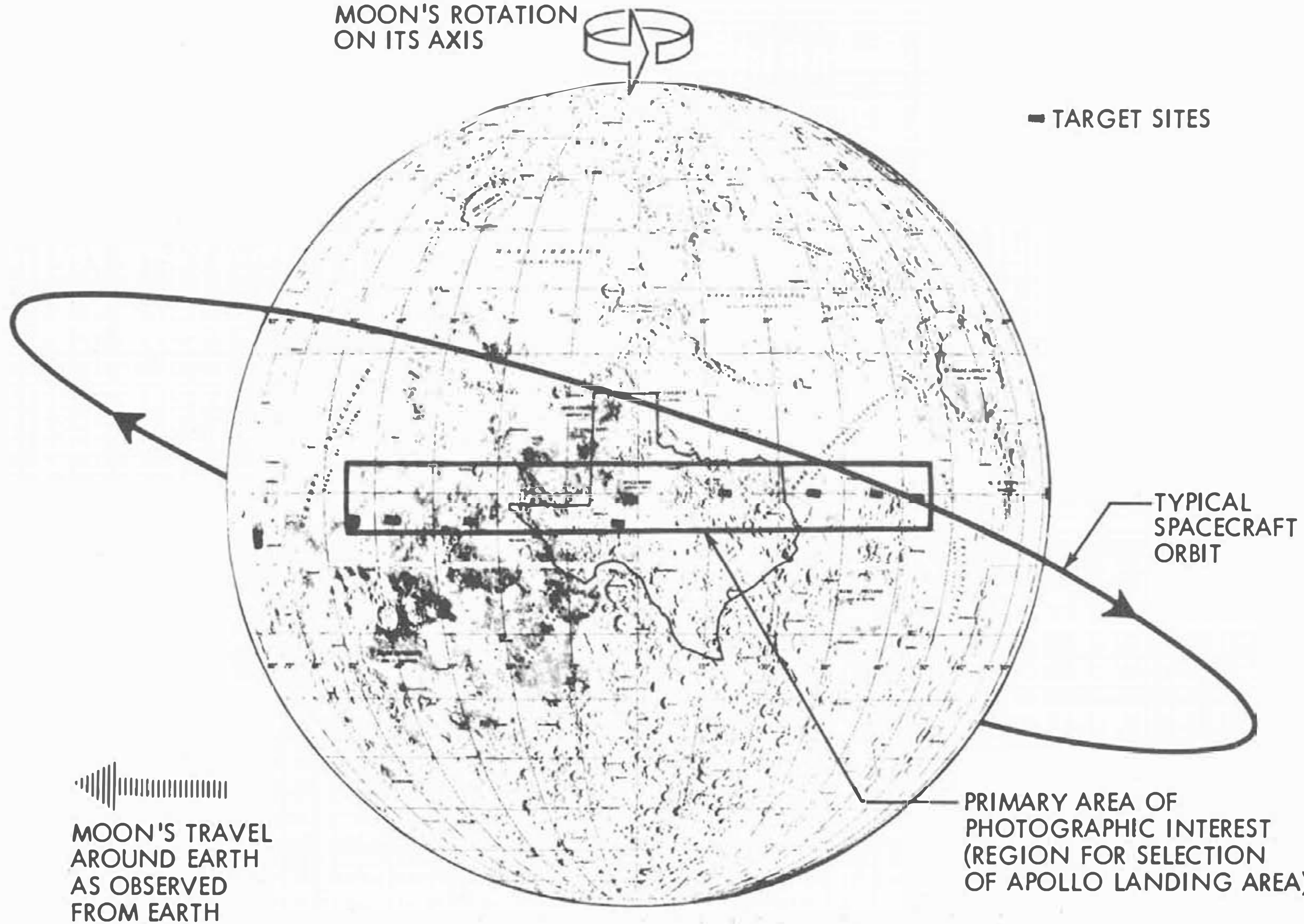


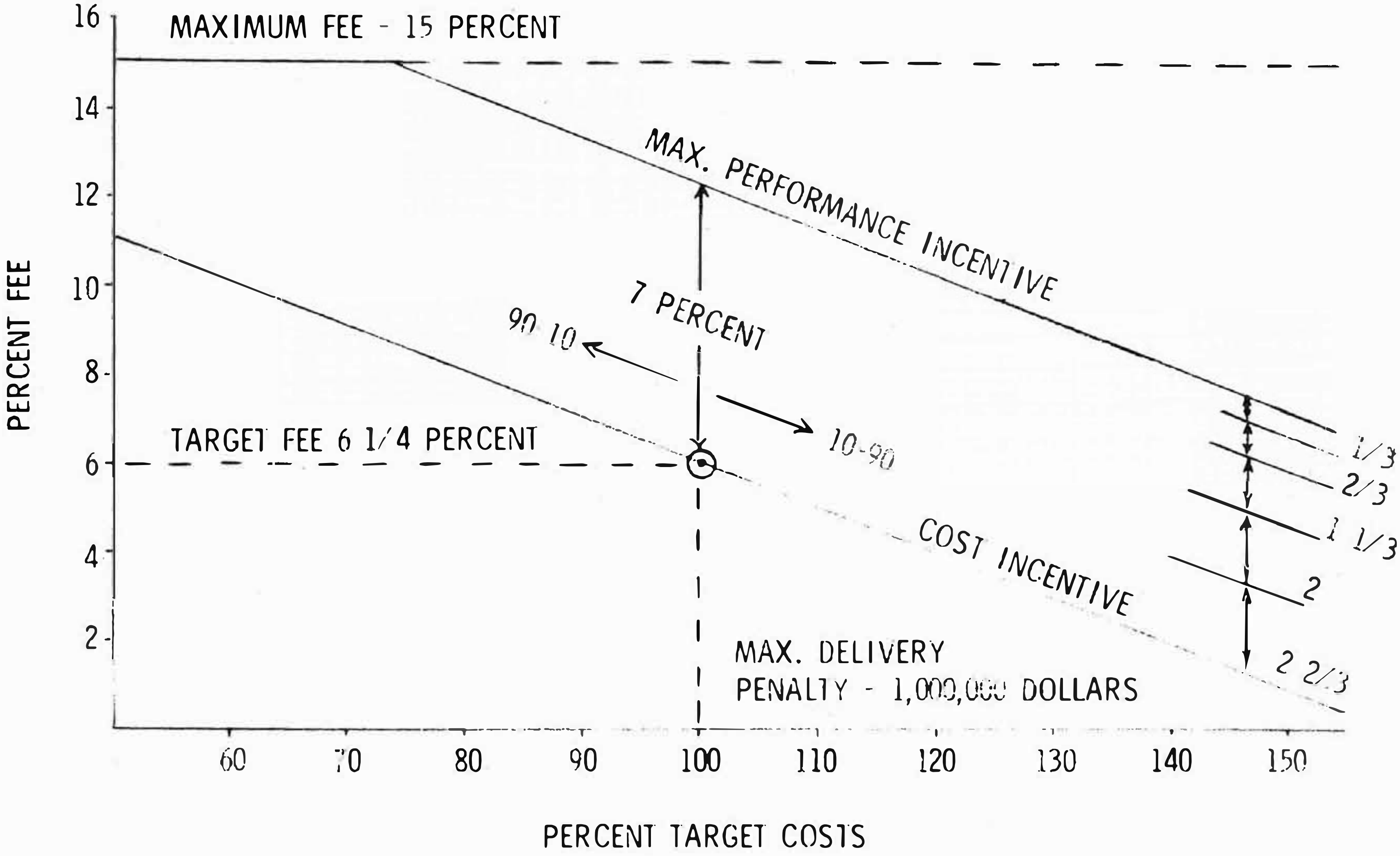


TYPICAL FLIGHT SEQUENCE OF EVENTS



LUNAR SURFACE PHOTOGRAPHIC COVERAGE

LUNAR ORBITER CONTRACT INCENTIVES



STEPS TO RELIABILITY

TECHNICAL EXCELLENCE

DESIGN OF INHERENT RELIABILITY

CONTROLLED RELIABILITY GROWTH

PROOF TESTING

DEMONSTRATED FLIGHT CONTROL CAPABILITY

RELIABILITY ENGINEERING

PLANS FOR RELIABILITY, QUALITY ASSURANCE, AND TESTING

SPECIFICATIONS FOR RELIABILITY, QUALITY ASSURANCE AND TESTING

MONITORING

REVIEWS

RELIABILITY ANALYSIS

HUMAN FACTORS

FAILURE REPORTING

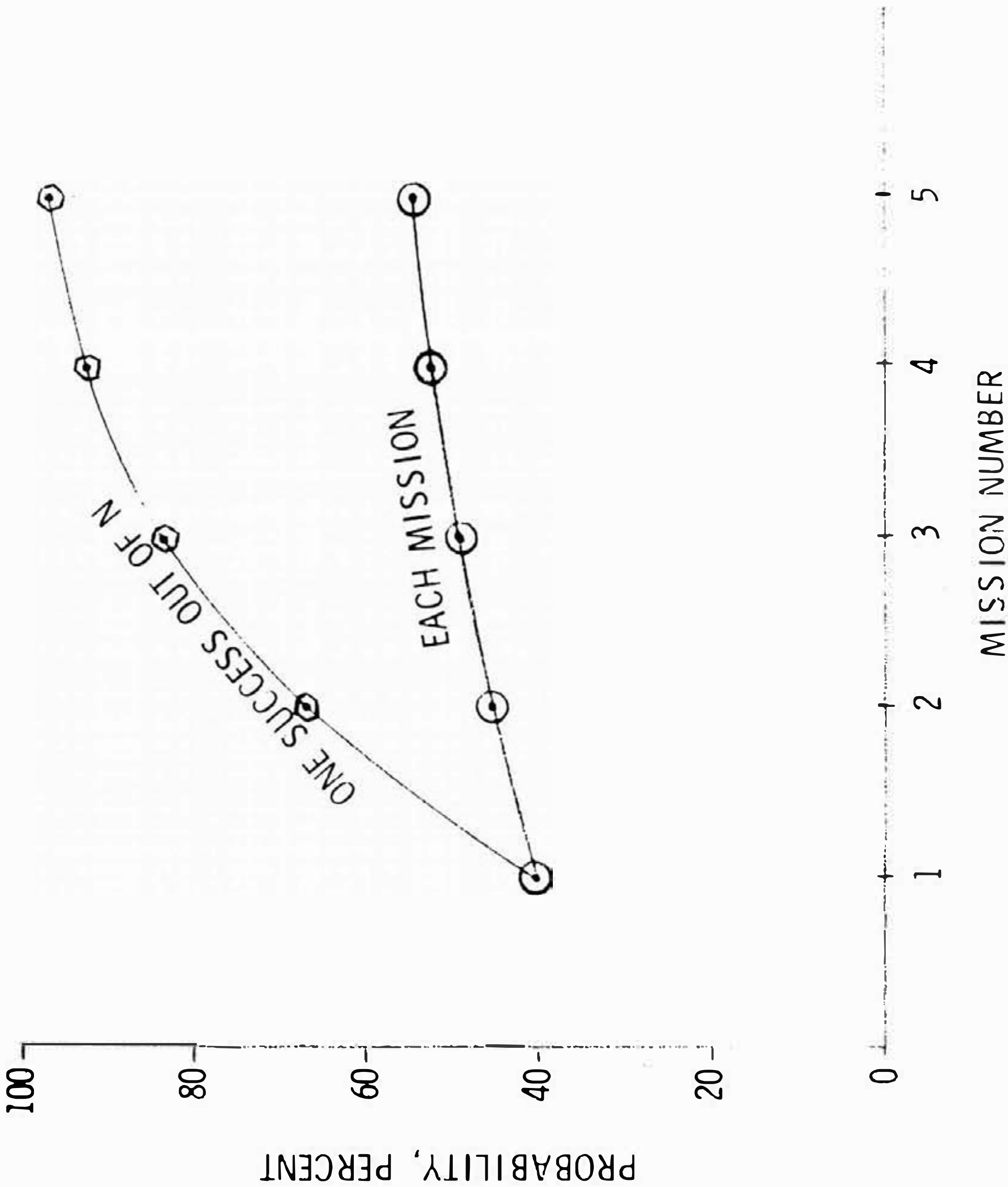
PROCEEDURE CONTROLS

PARTS, MATERIALS, AND COMPONENT PROGRAM

QUALITY CONTROL

TESTING

DOCUMENTATION



ONE SUCCESS OUT OF N
EACH MISSION
PROBABILITY, PERCENT
100
80
60
40
20
0
1
2
3
4
5
MISSION NUMBER

LUNAR ORBITER RELIABILITY DOCUMENTS

D2-100151	RELIABILITY PROGRAM PLAN
D2-100201	PARTS, COMPONENTS, MATERIALS, PROCESSES PLAN
D2-100102	APPROVED PARTS, COMPONENTS, AND MATERIALS
D2-100173	PARTS QUALIFICATION STATUS LIST
D2-100173-1	COMPONENTS QUALIFICATION STATUS LIST
D2-100224	PARTS SCREENING REQUIREMENTS
D2-100255	RELIABILITY ANALYSIS
D2-100259	FAILURE MODE AND CRITICALITY ANALYSIS
D2-100177	RELIABILITY ALLOCATIONS
D2-100269	TIME-CYCLE REQUIREMENTS
D2-100263	FAILURE REPORT SYSTEM
D2-100261	NPC 250-1 PROVISIONS FOR SUBS AND SUPPLIERS
D2-100081	GENERAL REQUIREMENTS SUPPLEMENT FOR PROCUREMENT SPECIFICATIONS

LUNAR ORBITER QUALITY CONTROL DOCUMENTS

D2-100150	QUALITY PROGRAM PLAN
D2-100174	CONFIGURATION MANAGEMENT PLAN
--	INSPECTION AND TEST PROCEDURES
--	PROCESS CONTROL PROCEDURES
--	SAMPLING PLANS
--	QUALITY STATUS REPORTS
--	SPACECRAFT SUMMARY LOGS
D2-100389	SPACECRAFT COMPLIANCE REVIEW REPORTS

THE EFFECT OF INCENTIVE FEE ON RELIABILITY
DEMONSTRATION OF LIQUID ROCKET ENGINES

By A. R. Torruella and A. Steinberg, MSFC

Introduction

When Marshall Space Flight Center (MSFC) began to convert from CPFF to CPIF contracts, we studied our quality control (QC) and reliability requirements to determine what, if anything, could be incentivized. The considerations of any such incentive were:

a. Data must be available to monitor the incentive characteristic.

b. The data system on the incentive characteristic must be free of bias during the incentive phase.

c. The incentive must buy something of value that might not be obtained without the added fee.

We found no existing program QC element that qualified. Data on scrap rates, non-conformances, unsatisfactory conditions, inspection hours, or amount of material inspected could be biased for higher incentive fee by changing the method of counting. Variables data might be used as an incentive by rewarding for values closer to $\bar{x}$ or for smaller sigma, but there are few monitorable QC characteristics that meet the three incentive considerations.

In fact, we look upon QC as an attribute; either quality is or is not under control. Inspection criteria must be met and the acceptance tests passed.

Reliability program elements, with one exception, were even less adaptable to incentive. The number of design reviews, higher "predicted" reliabilities, the amount of reports, and the size of the data bank provide no measurable quantity suitable for award.

The reliability element we found suitable for incentive is that of reliability demonstration tests. The engine hot firings had been subject to a reliability demonstration since 1962. Rules for counting, classifying, and record keeping had been negotiated and were providing a relatively unbiased statistic. Therefore, we modified the contracts to provide added fee for accrued sequential successes (or, conversely, for no accrued failures)beyond a baseline reliability level.

The F-1 program has provided a significant amount of reliability experience. The pre-incentive phase which required the demonstration of minimum reliability goals was started October 1965, and completed February 1966. The second phase, which consisted of the sustained reliability incentive, then started in February 1966 and was successfully completed August 1966, and just prior to the completion of the engine qualification test series.

For purposes of this paper and discussion, the F-1 engine reliability program has been selected as a model for incentive development and accomplishment.

Reliability Demonstration Procedure

Liquid rocket engine programs are unique in that an abundance of ground systems tests are conducted (Figure 1). These include development, acceptance, and special firings such as qualification. All tests representing a reasonably similar configuration, hot fired to near flight performance conditions, are eligible to be counted for reliability demonstration. Reliability estimates can be obtained by introducing special controls over all tests conducted regardless of test objectives. Tests need not be conducted solely for reliability demonstration.

The elements of scorekeeping are based on the concepts of Chapter 16, "Reliability: Management, Methods, and Mathematics," by Lloyd and Lipow. They include these conditions:

a. A pre-run declaration must be filed prior to the test, indicating whether the test is applicable for reliability.

b. To count as a success, specified conditions of specific impulse, thrust, mixture ratio, and duration must be met.

c. A success of less than full duration is weighed as less than one success in accordance with a mortality curve of a priori data.

d. Failure due to conditions external to the engine, e.g., facility malfunctions, are not classified as failures.

MSFC monitors the assessment and must agree with the contractor's success/failure classifications prior to incentive fee award.

Special Incentive Provisions

To qualify for incentive fee on reliability, a minimum reliability level was established as a baseline. This level was, as per prior contract requirements, a demonstration of .99 reliability at 50% confidence. For this requirement, a block of at least 69 successive declared engine equivalent full duration tests is selected for closer review prior to the completion of a given program milestone.

After completion of this baseline demonstration, the number of tests that might be available for reliability demonstration during the incentive phase was estimated. Available funds for reliability demonstration incentive were then amortized to cover a finite block of these tests. Figure 2 shows various incentive structures now in effect for reliability demonstration for four engine programs by number of tests and incentive fee per test.

The relationship of the reliability incentive to other incentives can be seen in Figure 3. This shows the structure of the F-1 first phase R&D contract incentive. The F-1 program office deserves credit for having structured their contract to reward for characteristics important at the time of negotiation.

Current contracts have reduced incentives for earlier engine delivery. This schedule characteristic is no longer a prime factor. Instead, we added penalties for launch delay caused by engine maintenance during pre-launch checkout.

The incentive reliability contract work statement may be simple, specifying the incentive per test, sample size, and maximum total fee (see Figure 4, J-2 Contract NAS8-19). It may be described statistically as per Figure 5, if the preferred monitoring procedure is by confidence level. The concept governing the latter approach is that the true engine reliability is a constant. Hence, continuing reliability demonstration lends only increased confidence in the demonstrated reliability.

In order for NASA to derive more than a counting benefit from the incentive, a failure mode elimination clause was added. This states that, should a failure occur, if the cause of failure is determined, corrective action initiated, and subsequent tests prove the failure mode has been eliminated, the failure may be discounted. The incentive fee will continue to accrue only after NASA is satisfied that a similar failure cannot recur. The impact of this provision is to make almost the entire reliability incentive a reward for quick reaction to failure mode elimination. This, we believe, is the greatest return to NASA from the reliability incentive.

Controls for Program Implementation

Once the contract requirements are defined for the reliability incentive, the following controls are exercised:

1. The contractor issues a letter of intent to start the demonstration series. The letter identifies the engine configuration and applicable engineering changes.

2. Test declaration forms are submitted to the government prior to each test (Figure 6).

3. Test results are submitted to NASA for review. NASA acceptance or disapproval is mandatory within ten days.

4. Weekly meetings are held between NASA and the contractor to discuss test results. Minutes of these meetings are published. Meetings are also held to discuss action on failure mode elimination.

5. The contractor periodically submits a list of tests for incentive payment approval.

6. Close followup on failure mode elimination action is maintained until closed out.

7. The contractor maintains a data bank of all pertinent test information, unsatisfactory condition reports (UCR's) and failure analysis reports (FAR's). These data are presented for review by NASA.

8. Any deviations from the approved configuration are reported.

In addition, the QC monthly status report, the configuration monthly, and the engine logbooks are used for backup data in monitoring incentive provisions. Special reports are issued on failure analysis and on tests confirming failure mode elimination.

The NASA resident reliability engineer acts in behalf of the NASA program managers in reviewing the reliability demonstration tests and monitoring the reliability incentive provisions. He assures NASA that:

1. A valid pre-run declaration is available

2. The performance envelope and duration criteria have been met.

3. The engine configuration is as required.

4. Weighing factors have been applied.

5. When failure occurs, a failure analysis is conducted.

6. A failure mode elimination test plan for proposed corrective action is adequate.

Experience to date

Most of the reliability demonstration failures are associated with a premature test cutoff, id est, failure to meet pre-declared run duration. High correlation exists between engine reliability and the premature cutoff rate. Figure 7 shows the trend of F-1 premature cutoffs since January 1965. Note that the rate has dropped in half and is still decreasing. It is of interest to note that no engine oriented premature cutoffs have occurred on production (deliverable) engines since October 1965, the beginning of the reliability incentive baseline test series.

Since Figure 7 includes all tests, not just those pre-declared for reliability, the data is not the demonstrated reliability.

Figure 8 shows the test rate of the F-1 since January 1965, and the number of reliability tests, or yield of homogeneous engines and tests.

The first incentive reliability demonstration phase has been completed on the F-1 program. Three of the tests were initially classified "failures." The failure modes were identified, corrective action initiated, and verification tests for the corrective action completed. The maximum fee for this incentive was earned. Contractor response to failure mode elimination was quick and satisfactory. Hence, we believe that the incentive fee did buy improved reliability. Figure 9 shows the problem and action on the three failures.

Additional Controls

If the incentive structure is well founded, more than target fee can be obtained only by exceeding basic requirements. However, the incentive characteristic should not be so challenging as to discourage the contractor from trying to attain maximum fee.

To date, the contractor has worked strenuously on the F-1 schedule and reliability incentives but may attain little of the cost or performance incentives.

Though not directly related to the reliability incentive, another NASA/contractor review is held to support our reliability approach. This is to examine the unsatisfactory conditions (UCR's) on deliverable engines prior to government acceptance of the engines. These UCR's originate prior to, during, and after hot fire acceptance tests. They may or may not be associated with reliability demonstration test failures. However, we require evidence of failure analysis and corrective action on these UCR's before we accept the engine for the government.

Figure 10 is an example of the "Pre-delivery UCR Review." Figure 11 shows how manufacturing reliability has been improving. The first group of five delivered F-1 engines averaged over 40 UCR's per engine. Currently the average is less than 10 UCR's per engine.

Summary

It should be noted that the logic for construction of engine incentive contract provisions was to provide NASA an immediate benefit. We initially avoided warranty type clauses whereby the incentive is contingent on successful flights. Our aim was to detect and eliminate unreliable hardware or procedure prior to flight missions.

In conclusion, the reliability incentive story is as follows:

1. The reliability demonstration program is incentivized. Incentive is based on accruing successes in static firing tests.

2. First phases of reliability incentives on the H-1 and F-1 programs are completed. Contractor management has strengthened his response to resolving engineering problems in order to qualify for the reliability incentive.

3. The primary benefit to NASA from the reliability incentive is the contractor response to "failure mode elimination".

4. The contractor has reduced his response time in the closeout of unsatisfactory conditions.

5. Management attention to any incident associated with the reliability tests has increased. This management attitude has filtered down to all work levels.

6. The yield of tests available for reliability demonstration has increased.

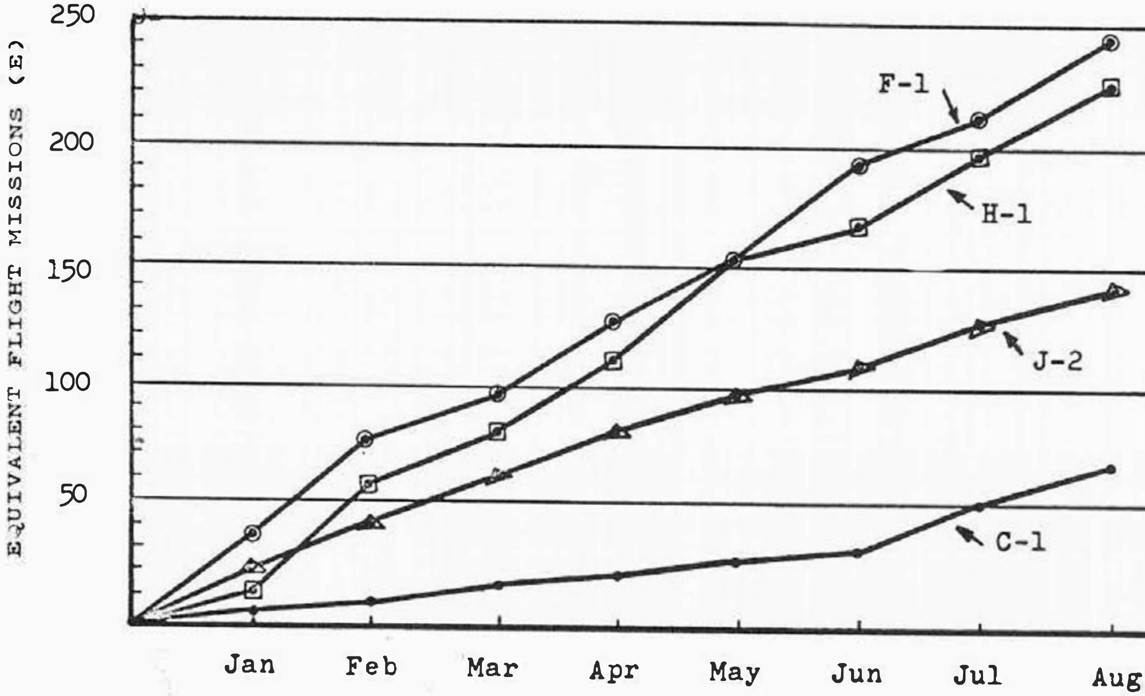
7. Reliability goals are met in a timely manner.

8. Less number of unsatisfactory condition reports (UCR's) are being issued since less engine failures are experienced.

9. Engine premature test terminations have been reduced; none are currently experienced on deliverable production engines.

FIGURE I: CUMULATIVE NUMBER OF TESTS IN 1966

BASED ON TEST TIME/ FLIGHT MISSION TIME



F-1	T	5,712	11,703	16,259	20,863	25,079	31,264	34,802	40,167
	E	34.6	70.5	98.5	126.4	152.0	189.5	210.9	243.4
H-1	T	1,732	8,622	11,897	16,667	22,749	25,169	29,479	33,346
	E	11.5	57.5	79.3	111.0	151.7	167.8	196.5	222.3
J-2	T	9,920	20,819	29,227	39,162	48,212	53,780	62,558	70,143
	E	19.8	41.7	58.4	78.3	96.4	107.5	125.1	140.3
C-1	T	1,441	3,716	10,511	14,422	20,469	27,665	52,864	62,643
	E	1.4	3.7	10.5	14.4	20,4	27.6	52.8	62.6

T: CUMULATIVE TEST TIME, Seconds

E: EQUIVALENT FLIGHT MISSIONS; T/ Flight Time

Flight times:
F-1: 165 sec
H-1: 150 sec
J-2: 500 sec
C-1: 1,000 sec

Figure 2 : ENGINE INCENTIVE CONTRACT STRUCTURE,

RELIABILITY DEMONSTRATION

PROGRAM	No. of Baseline tests	No. of Incentive tests*	Approximate Incentive per test	Total allocated reliability fee
C-1	69	24	$ 4,205	$ 100,920
H-1	69	69	$ 1,884	$ 130,000
J-2	69	60	$ 3,900	$ 234,000
F-1 (1st)	69	69	$ 5,072	$ 349,968
F-1 (2nd)	138	161	$ 3,674 (1st 92 tests) $4,899 (next 69 tests)	$ 676,000

* In addition to Baseline tests

Figure 3: F-1 ENGINE PROGRAM R & D INCENTIVE STRUCTURE, Contract NAS w 16

EFFECT	CONDITION	MAX. INCENTIVE	% OF INCENTIVE	MAX. PENALTY
Cost		$ 450,000	18.7%	$1,940,400*
Schedule	Test rate	$ 584,136	48.0%	$ 548,797
	Stability tests	$ 99,990		$ 255,085
	Qualification	$ 468,000		$ 108,480
Performance	Specific Impulse	$ 450,000	18.7%	-
	Reliability	$ 349,968	14.6%	-
Totals		$2,402,094	100%	$1,940,400

*The entire penalty may be applied toward cost or toward a combination of cost and schedule.

Incentives and penalties range from the target fee.

Figure 4: J-2 Contract NAS8-19

Sustained Reliability Demonstration

The fee shall be increased by $3900 for each successful declared performance test conducted on the last sixty (60) production engines as set forth in the contract. These performance tests will be declared during the acceptance test series, in accordance with pages 13.2 and 13.4 through 13.8 of Report R-5406-2, dated January 31, 1966. This incentive is limited to one test on each engine, and a success may not be counted on any engine which has experienced a failure of a declared test. The fee shall not be increased by more than $234,000 as a result of this incentive provision. The Contractor will notify the Contracting Officer in writing as to the date and test which is considered to have fulfilled each demonstration.

Figure 5: F-1 Contract NAS8-18734

Sustained Reliability Incentive

Using 99% reliability at a confidence level of 75% as a base, the fee shall be increased for demonstration of confidence levels higher than the base. The method used for computing Equivalent Full Duration Tests (EFDT) and the basis for demonstration shall be as specified in the "Reliability Assessment Procedure for the F-1 Engine." Both production support and deliverable engine tests shall be used for the purposes of this incentive demonstration.

Confidence levels associated with 99% reliability shall be determined using the following equation:

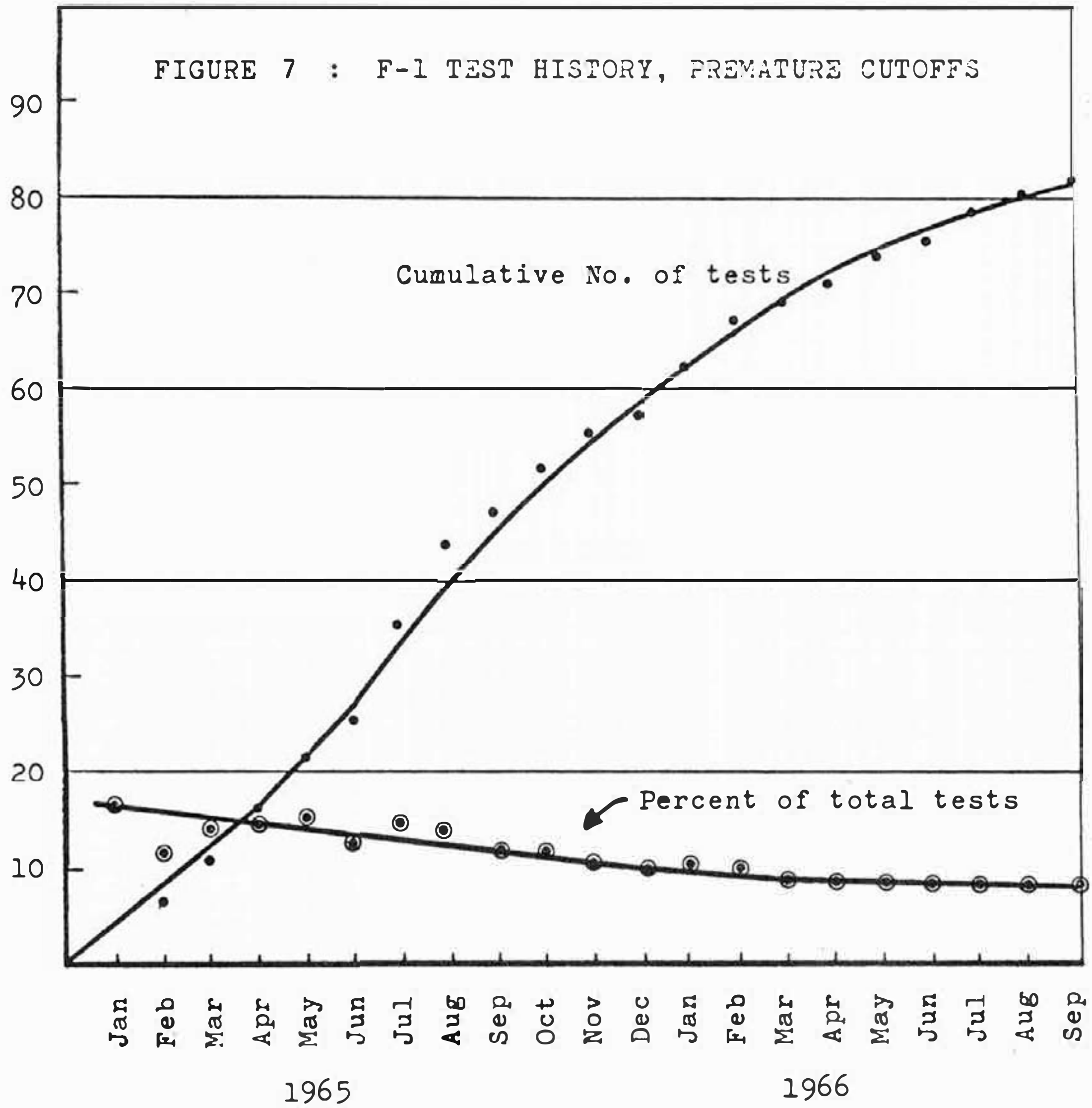
$$1 - C = \sum_{x=s}^{N} C_x^N R^x (1-R)^{N-x}$$

Where s is the number of successful equivalent full duration tests (to the nearest integer), R is the reliability for which the confidence limit is to be determined and equal to 0.99, N is the total number of equivalent full duration tests (to the nearest integer), C_x^n is the binominal coefficient, and C is the confidence.

This equation was obtained from the "Tables of the Cumulative Binominal Probability Distribution," Harvard University Press, 1966.

The fee shall be increased by $2,250 for each one tenth of one percent increase in the confidence level at 99% reliability until the confidence level has been increased to 90%.

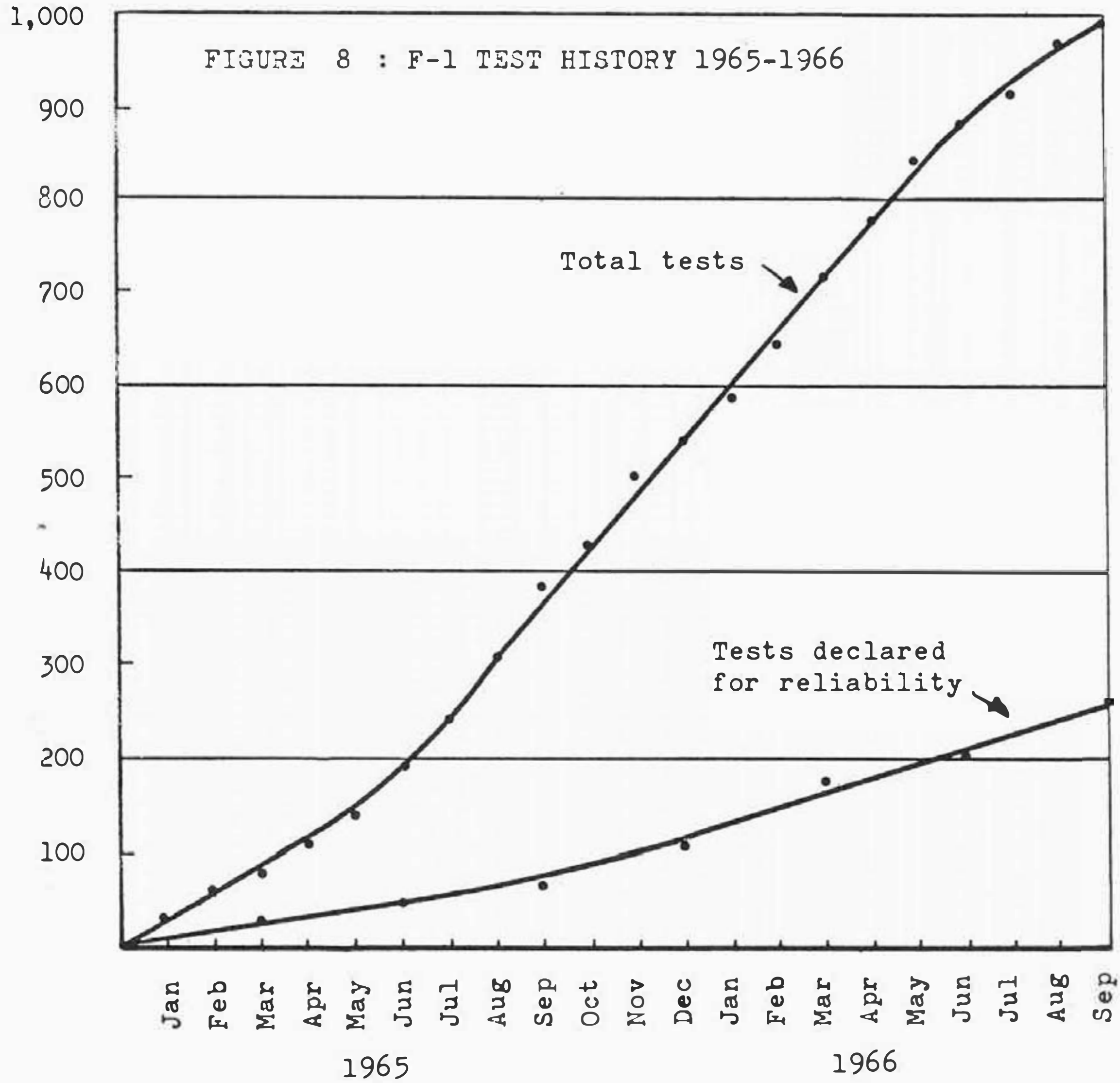
The fee shall be further increased by $6,770 for each additional one tenth of one percent increase in the confidence level at 99% reliability until the confidence level has been increased five percent above that level demonstrated under the paragraph above. Provided, however, the cumulative fee increase shall not exceed $676,000 by reason of this Sustained Reliability Incentive Provision.



Month	# tests cutoff*	% tests cutoff
Jan '65	4	16.7%
Feb	6	11.7%
Mar	11	14.1%
Apr	17	15.4%
May	22	15.7%
Jun	26	13.2%
Jul	36	15.1%
Aug	45	14.8%
Sep	48	12.3%
Oct	53	12.2%
Nov	56	11.1%
Dec	58	10.8%

Month	# tests cutoff*	% tests cutoff
Jan '66	64	10.8%
Feb	68	10.5%
Mar	70	9.7%
Apr	72	9.2%
May	75	8.9%
Jun	76	8.5%
Jul	79	8.6%
Aug	81	8.3%
Sep	82	8.3%

*Cumulative from Jan '65



Month	# tests*	# Rel. tests*
Jan '65	24	
Feb	51	
Mar	78	29
Apr	110	
May	140	
Jun	197	48
Jul	239	
Aug	304	
Sep	389	68
Oct	435	
Nov	505	
Dec	537	115

Month	# tests*	#Rel. tests
Jan '66	590	
Feb	649	
Mar	719	179
Apr	782	
May	843	
Jun	891	206
Jul	919	
Aug	972	
Sept	992	267

*Cumulative from Jan '65

FIGURE 9: F-1 RELIABILITY TEST FAILURES, INCENTIVE SERIES, February-August 1966

Problem I — A fire occurred at the thrust chamber due to external tube wall rupture. A material defect was found due to a combination of oxides and other foreign materials in the parent metal.

Action — Ultrasonic inspection of tubes was instituted. Tubes already assembled into chamber stacks were radiographically inspected. Ultrasonic inspection is being accomplished on untapered, uniform tubes at the mill. Any defect greater than 0.002" in depth is rejected.

Problem II — Heat exchanger LOX coils failed approximately 5 seconds into mainstage due to excess pressure buildup. This ruptured the LOX coils causing a fire. This was a human error where test stand personnel did not remove a cap after pressure testing the GOX line. Leak test procedure covers removal of vent system plug.

Action — Test procedures were reviewed in order to improve and clarify the affected section. Test stand personnel were instructed on the steps to be followed during and after pressure testing.

Problem III — A fuel leak occurred from a crack in the #1 fuel high pressure duct on the radius of the gimbal boss.

Action — Review of engine support equipment disclosed that a stage contractor designed gimbal supply line was installed between the boss on the high pressure duct and the gimbal filter package. A series of engine tests were designed and conducted to determine the failure source. Lines were instrumented to measure the vibration levels imposed on the high pressure duct. After reviewing the test results, it was proven that the stage designed supply line caused the duct rupture due to excessive vibration loads. NASA directed the stage contractor to redesign the supply line.

Engine Pre-Delivery Review

UCR – FAR STATUS

Engine s/n F 6048

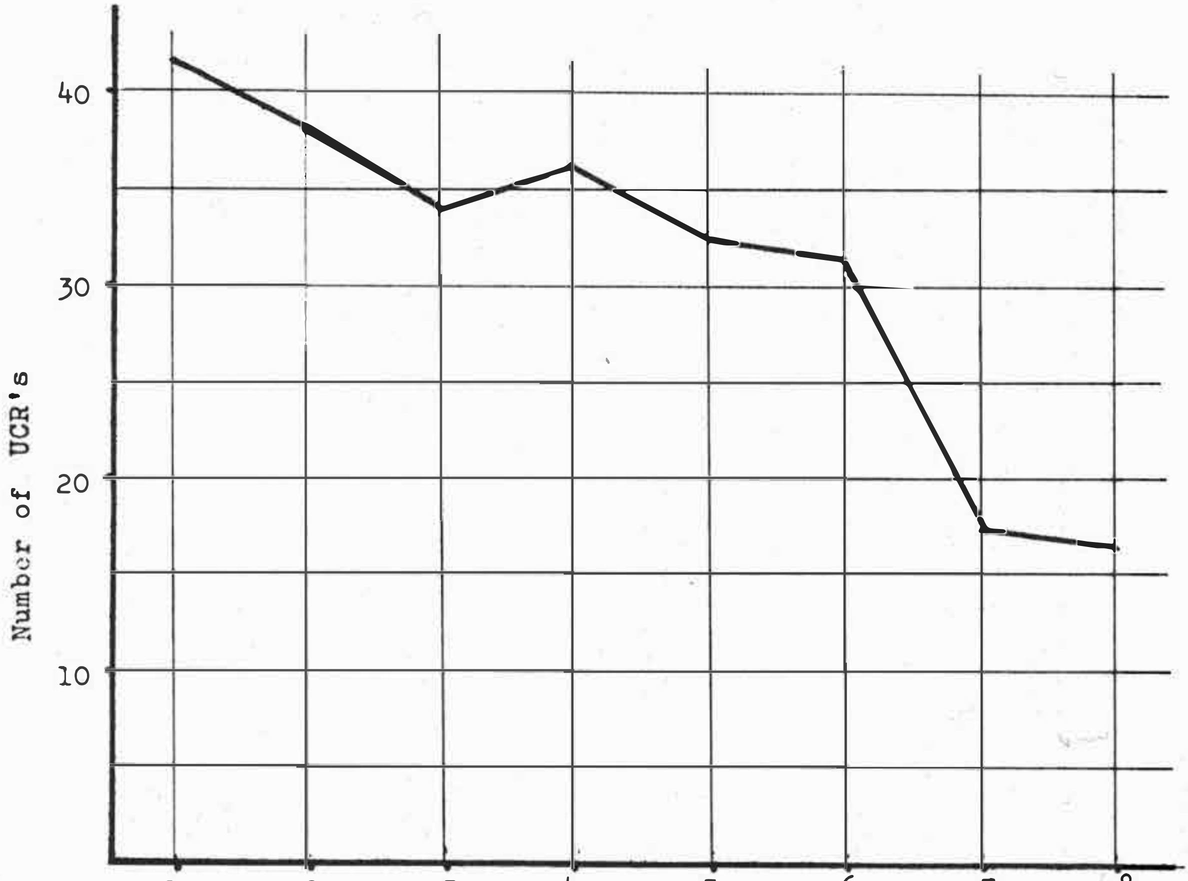
Review Date 10/26/66 JFJ

Assignment

U.C.R. No.	F/I Part Number F/I Name	F/I Serial Disc. Dur.	F.E.A. Sys. Item No.	Previous U.C.R's	Reported Problem Description	F.A.R. Date	Status of Corrective Action and Effectivity
25929	NAS-260079T2-1 Disconnect Assy.	11702 Test 436-058		2	Inner locking seal flange expanded, will not allow installation of drain hose adapter Removed and replaced	9/15/66	Manufacturing supervision and inspection supervision in build area have been informed damage resulted from over torque. They shall take steps to prevent this from happening again.
25998	NAS-26881 Lox Seal Purge Wrap-Around	027 Test 436-058		4	Line will not lay in the cradle of the 602063 support without pre load. Use as is and reworked 410088-9 at Canoga	9/15/66	410088-9 fitting did not fit alignment fixture. Quality analysis will maintain surveillance of manufacturing area.
25910	NAS-28183 Pr Sw #2	25499A Test 436-058		> 10	Sw produced an erratic signal on oscillograph Removed and replaced.	9/16/66	Further testing by Rocketdyne Engineering to determine the adequacy of the present electrical coupling design and possible relationship to reported Pr Sw intermittent electrical signal.
25999	NAS-27412T1 Flt transducer	3047 Test 436-058		> 10	During the valid data interval, the transducer at tap TG5c, varied 3.9 psi lower than the comparable facility transducer reading.		FAR not issued 10/26/66. Pending.

FIGURE 10

FIGURE 11 : F-1 PRODUCTION ENGINE UNSATISFACTORY CONDITIONS (UCR's)



Group	1	2	3	4	5	6	7	8
Engine Serial Number	1001	2003	2011	2017	2022	2027	2032	2037
	1002	2007	2013	2018	2023	2028	2033	2038
	2006	2009	2015	2019	2024	2029	2034	2039
	2008	2010	2014	2020	2025	2030	2035	2040
	2005	2012	2016	2021	2026	2031	2036	2041
Malf.*	41.6	38.4	34.2	36.4	32.6	31.6	17.4	15.8

*Average number of UCR's per engine in each group, Prior to delivery to the government.

F-1 RELIABILITY DECLARATION FORM

1. ENGINE MODEL	2. ENGINE SERIAL NO.	3. TEST NO.
F-1	30-1	423-108-086

4. TEST APPLICABLE FOR RELIABILITY DEMONSTRATION (REF. SPEC RA0615-029)

[X] YES

- [X] HARDWARE AND PERFORMANCE
- [ ] HARDWARE ONLY

VALID DATA AT STANDARD DATA SLICE ON PREVIOUS TEST

- [ ] WITHIN FLIGHT ENVELOPE
- [ ] OUTSIDE FLIGHT ENVELOPE
- [ ] NO

CRITICAL HARDWARE CHANGE

- [ ] YES
- [X] NO

OPERATING BAND DECLARED

- [ ] YES
- [X] NO

[ ] NO

- [ ] CHECKOUT TEST
- [ ] EXCESSIVE INAPPLICABLE HARDWARE
- [ ] MALFUNCTION TEST
- [ ] LIMITS TEST
- [ ] INAPPLICABLE CONFIGURATION
- [ ] JUDGEMENT EXCLUSION

5. TYPE OF TEST

- [X] R&D
- [ ] PRODUCTION
- [ ] PFRT
- [ ] FRT
- [ ] QUAL

6. INTENDED DURATION

75 SEC

7. EXCLUDED HARDWARE

	1.	2.	3.	4.	5.
PART NAME	LOX PUMP	No. 1 FUEL HI. PR. DUCT	HEAT EXCH.	AIR OP. [illegible] LINE	
PART NUMBER	*	408668 [illegible]	[illegible]	[illegible]	
PART SERIAL		[illegible]	[illegible]		
REASON FOR EXCLUSION: NOT INSTALLED	[ ]	[ ]	[ ]	[ ]	[ ]
EXPERIMENTAL PROCEDURE	[ ]	[X]	[ ]	[ ]	[ ]
EXPERIMENTAL HARDWARE	[X]	[ ]	[ ]	[X]	[ ]
OBSOLETE	[ ]	[ ]	[ ]	[ ]	[ ]
OVERAGE	[ ]	[ ]	[X]	[ ]	[ ]
DAMAGED	[ ]	[ ]	[ ]	[ ]	[ ]

8. COMMENTS (ANY ADDITIONAL INFORMATION OR CLARIFICATION OF PRECEDING ITEMS 1-7)

* IL 515F-355

9. RESPONSIBLE ENGINEERS SIGNATURE: [signature]

10. TO BE COMPLETED BY ROCKETDYNE DESIGNATED RELIABILITY AGENT:

TIME RECEIVED	DATE RECEIVED	RECEIVING AGENT (INITIALS)	
0840	8/15/66	[initials]	TEST CONDUCTED 8/15/66 @ 11,10 DURATION 76.67 SECONDS

Form 612-Y-19, New 9-65

FIGURE 6

THE BALANCING OF NORMAL INCENTIVES WITH INCENTIVISED R&QA TASKS

by Fred F. DeMuth, Ames Research Center

I would like to start by telling you what I am not going to do for you today. I am not going to present any detailed analysis of incentive formulas, nor am I going to provide you with any constructive criticism of actual cases where the incentive approach has been successful or unsuccessful. Rather, I wish to provide you with some thoughts, or philosophies, which deserve your continued consideration and which will increase the effectiveness of some of the items which we R&QA people feel are not only beneficial but necessary for the success of NASA aeronautical and space programs.

The basic ingredient in any incentive program is money--not cost dollars, but profit dollars. This comes easily from "my" definition of a business--a perpetual entity for profit. I use "my" in quotes here to signify that this definition, in one form or another, has probably been used by many others. It does apply to the aerospace industry which is just like any other business. The aerospace industry does not exist because management is overly patriotic, or because they like President Johnson, or because they like Mr. Webb or because they are the adventurous or pioneering type. I do not wish to imply that any business is necessarily against these things, or that there are no fringe benefits, such as public image, or low cost research and development, which are connected only indirectly with profit. I just wish to emphasize that any business is vitally concerned with profit. Thus, we have a tool to work with. A tool, by the way, which is not always easy to handle.

We have utilized this tool, in general, to reward the contractor for satisfactory results within the areas of the famous triangle; performance, schedule, and cost. However, performance is normally defined as the end product technical performance, schedule is the end item delivery schedule, and cost is the total cost. This, at first glance, seems quite reasonable. Also, since NASA does not want junk delivered on time and within cost, nor top technical performance delivered late but within budget, nor top technical performance delivered on time at a budget that is way out of sight, a great deal of effort is put into balancing the incentives associated with these items. There are some rather complex treatments of this type of balancing. And indeed it is necessary, since, I assure you, the contractor very closely examines this area to provide the road to the largest overall profit.

There is an area which is a little more subtle than the normal interpretation of performance, schedule and cost. This is the area of R&QA. There are many R&QA functions which are indirect in their effect on all three normal incentive aspects of a program. These functions are of the type which, if effectively employed in a timely fashion, will greatly enhance the probability of desirable technical performance, schedule, and cost. Some of these are: design reviews, failure analysis, failure reporting, reliability prediction, drawing release, life tests, qualification tests, failure mode effect and criticality analysis (FMECA).

Having a critical design review after initiation of fabrication of flight hardware is not effective. Nor is a design review effective if the "package" is incomplete or delivered at the time of the meeting. A "fix" rather than a failure analysis is a costly practice. Late or non-existent failure reporting hides many problems. A reliability prediction model or failure mode effect or criticality analysis made during fabrication of flight hardware is of questionable effectiveness. Drawings and drawing changes released informally are dangerous practices. Life tests which do not reasonably simulate flight conditions or configuration or are initiated during last stages of a program are not accomplishing their objectives. Qualification tests completed after acceptance tests or during missions are also of questionable value.

From the above one can see possibilities of utilizing the incentive tool in a little different manner. For example, the schedule incentive which normally is keyed to end item delivery dates should be balanced by incentivising events which are keyed to each other. This can be implemented by establishing an incentivised schedule so that the preliminary design review (PDR) will be conducted prior to the initiation of detailed design and the critical design review (CDR) will be conducted at end of detailed design but prior to release for manufacture. Similarly, incentivised schedules could be provided to insure that qualification will be complete prior to acceptance testing, and the reliability prediction model and failure mode effect and criticality analysis will be completed and up-dated prior to the CDR.

Another task that could be incentivised under this concept is the design review. Here incentivised schedules could insure that design review packages will be delivered sufficiently in advance to provide for effective preparation on the part of the participants. The purely technical performance incentive may be balanced by insuring, through incentives, that design reviews contain all the elements of reliability and quality assurance such as approved parts lists, parts application and qualification data, reliability predictions, and failure mode effect and criticality analysis.

In the area of cost incentives, the problem gets a bit more difficult. It is common practice to include in a proposal or contract substantial R&QA costs, or even excessive costs because it is a "good" thing to do. After all, no one can really argue against R&QA. However, after a contract is in effect, program managers are prone to utilize these funds for other purposes. Sometimes this is a legitimate trade off, but all too often it is not. Incentivising R&QA costs may present implementation problems but should be given serious consideration.

In all these areas, or in the whole incentive concept for that matter, I do not feel we should forget the potential effectiveness of negative incentives. Taking something back is many times more of an incentive than giving a reward.

In closing, I wish to call to your attention again that the R&QA area does contain tasks, which if effectively employed in a timely fashion, can contribute to the success of NASA programs. To insure their proper implementation, and to prevent their being overshadowed by normal incentives, it is necessary that the R&QA tasks also be incentivised. If you really believe that R&QA does contribute to success, I suggest you closely examine this concept and tailor it to your problems and your programs.

For presentation at Second NASA-Wide
Reliability & Quality Assurance Meeting
NASA Headquarters, 11/29 through 12/1/66

PROBLEMS AND EXPERIENCES IN QUALITY ASSURANCE ON SATURN V S-II STAGE

Presented by
Harold O. Goetz, MSFC *

ORGANIZATION

FIGURE 1 - November 1965

Organization as it existed at the time of the General Phillips' survey.

FIGURE 2 - November 1966

Significant Points

1. Program directors have assumed proportionately greater control of the resources effecting their program. Saturn S-II was 9% of the Q&RA organization in December 1965 and was 16% in October of 1966.

2. All systems activity consolidated into one group. Audit activity placed in same department and both groups established at Chief level. This implies greater emphasis being placed on these functions.

SYSTEMS

S&ID Q&RA has devoted a substantial effort to the development and improvement of basic Quality Assurance systems. One of the foremost of these is the development of the Daily Inspection Record (DIR) system to accumulate and process basic quality information emanating from the inspection process.

FIGURE 3 - DIR Form

This form is used to collect quality information from inspection activities at S&ID production operations in Downey and Tulsa.

FIGURE 4 - L.E.A.D./Wall Chart

In addition to being used for Quality Engineering purposes, this data is furnished to Manufacturing supervision at all levels down to and including the leadman. In addition, wall charts have been developed and are displayed in all production areas to make production personnel aware of their performance in terms of standard quality measures.

* QA Rep. at NAA

FIGURE 5 - Management Chart Room

Quality data, quality cost data, NASA nonconformance data, and other significant management information is maintained in the Q&RA Chart Room. The Q&RA Management Staff Meeting is held periodically in this chart room and each department head explains trends on those charts representing his operation. Each department head holds periodic meetings with his subordinates in the Chart Room for the same purpose.

FIGURE 6 - Report Card

In addition to maintaining performance information on hardware and quality trends, Q&RA has developed a system to measure general management performance. This system deals with tangible and measurable performance factors and results, monthly, in the presentation of a "Report Card" to each manager. Standings are published in the Management Chart Room and the low man receives a trophy which he keeps for the following month. This trophy has come to be known as the "Dirty Bird." This system has been very effective in creating an atmosphere of friendly competition while greatly upgrading general management performance.

FIGURE 7 - Quality Assurance Management Report

Q&RA is developing and will publish this month (December for the month of November) for the first time a Management Report based on selected Chart Room data. This report will be furnished to Corporate and Divisional executives as well as NASA management at S&ID.

FIGURE 8 - S&ID Corrective Action System

Another significant development has been the creation of a uniform Corrective Action system. This system has been designed to serve the corrective action needs of Material Review, Procurement, Quality Engineering, etc., in house. This system merges corrective actions from all of these areas into a single system and greatly enhances the ability of Q&RA to manage the Corrective Action process.

RESULTS

The results of these and other actions can be seen by referring to several trends.

FIGURE 9 - Quality Trends

1. Defects per 1000 Manufacturing direct labor hours.
2. Material Review Dispositions per 1000 Manufacturing direct labor hours.
3. NASA-O reported Nonconformances per 1000 NASA-O Inspection hours.

PROJECTS IN WORK

Among the most significant projects in work at S&ID is a formal project aimed at improving the procedural system.

FIGURE 10 - Procedures

In early June a formal project was initiated to simplify the procedural manual. Substantial superfluous material which had been maintained in the procedures manual and which had been a source on confusion to contractor and NASA personnel alike was removed. As a result, the contents of the procedures manual in late September was found to be reduced 42.5% by weight without the elimination of any procedural material. NASA and contractor personnel alike agree that this first step constitutes substantial improvement. Other work in process will result in the relocation of Operating Instructions to locate them adjacent to the procedures that they amplify and provide other similar improvements which will make the manual more usable.

FIGURE 11 - Systems Analysis

While work continues on the procedures manual, work is also commencing on a formal system analysis project. Systems analysis as used here is defined as:

> A formal process of defining the objectives of and establishing the criteria for the system and objectively reviewing its procedures for structural soundness, necessary and sufficient requirements, and relationship to other procedures.

This will be a formal and continuous program to evaluate each system, improve its necessary interfaces with other systems, and improve the procedures that define it.

FIGURE 12 - Audit System

In parallel with the system analysis function, an activity is underway to improve the contractor's audit system. The contractor has had a vigorous audit activity for a period of time; however, this project is aimed at improving the relationship of the audit activity to the contractor's defined Quality Assurance systems. It is intended that the results of audits will be identifiable to the contractor's Quality Assurance system, will provide a quantified measure of conformance to system requirements, and will be formally communicated to appropriate management in a manner that maximizes the probability of effective and appropriate corrective action.

FIGURE 13 - Audit Functions

The contractor's audit group is organizationally and functionally divided into three activities. The first is charged with the responsibility for assuring that the contractor's Q&RA personnel are in fact conforming to the requirements of the systems and procedures incumbent upon them. The second, the Systems Audit activity, is responsible for measuring the output of quality influences on activities of organizations other than Q&RA, for example, the audit of Engineering Change Orders, blueprints, and specifications. The final group, Configuration Audit, is responsible for assuring that the process which produces the configuration documentation is in fact operating with closed loops at each of the information transfer points.

CONCLUSION

The contractor's actions discussed here are not exhaustive, but rather are representative of the kinds of areas in which significant effort is being placed. Neither does this imply that the contractor has no problems remaining to be solved, but it does demonstrate his ability to identify and solve significant problems.

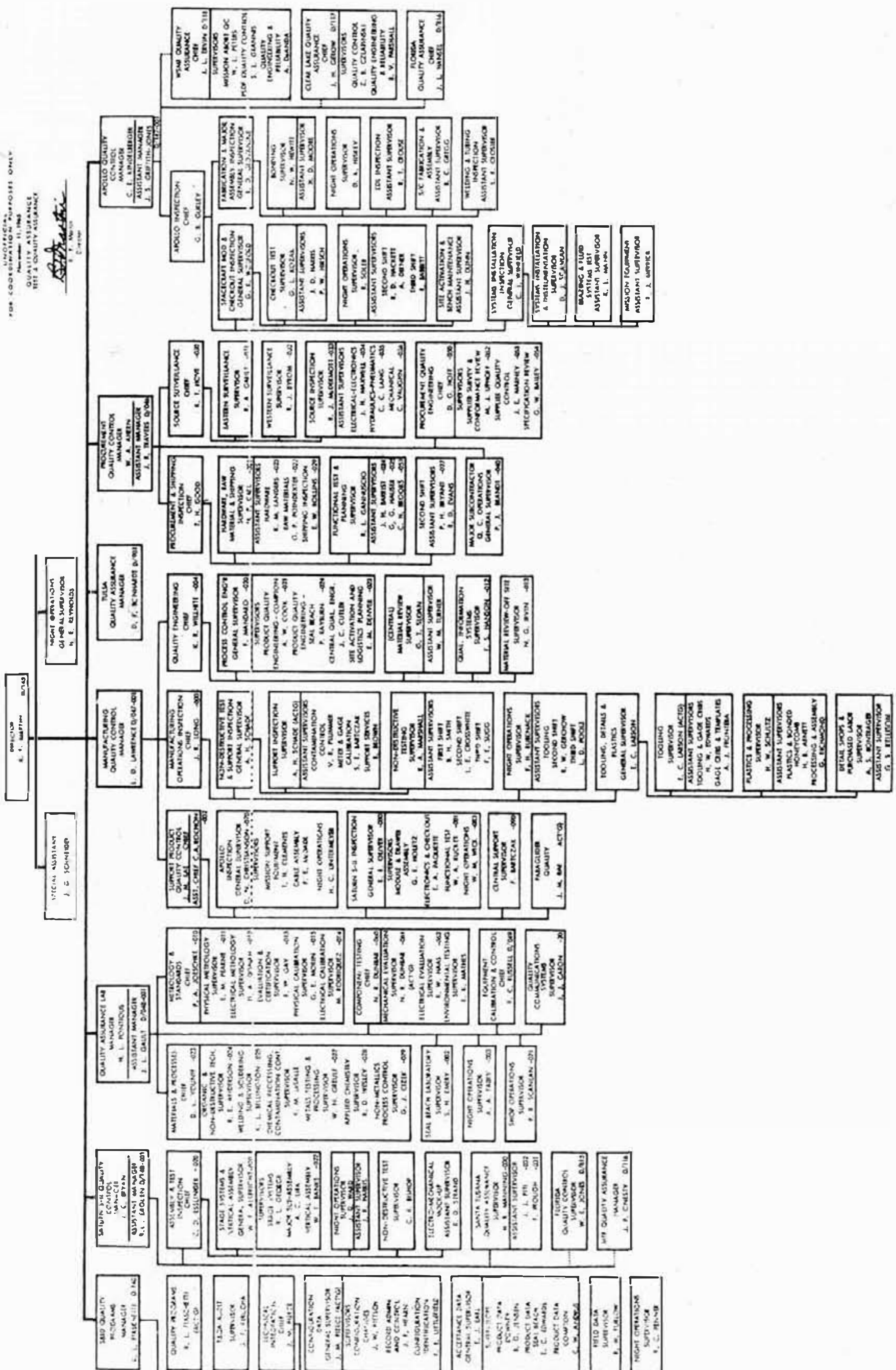


FIG 1

SPACE and INFORMATION SYSTEMS DIVISION
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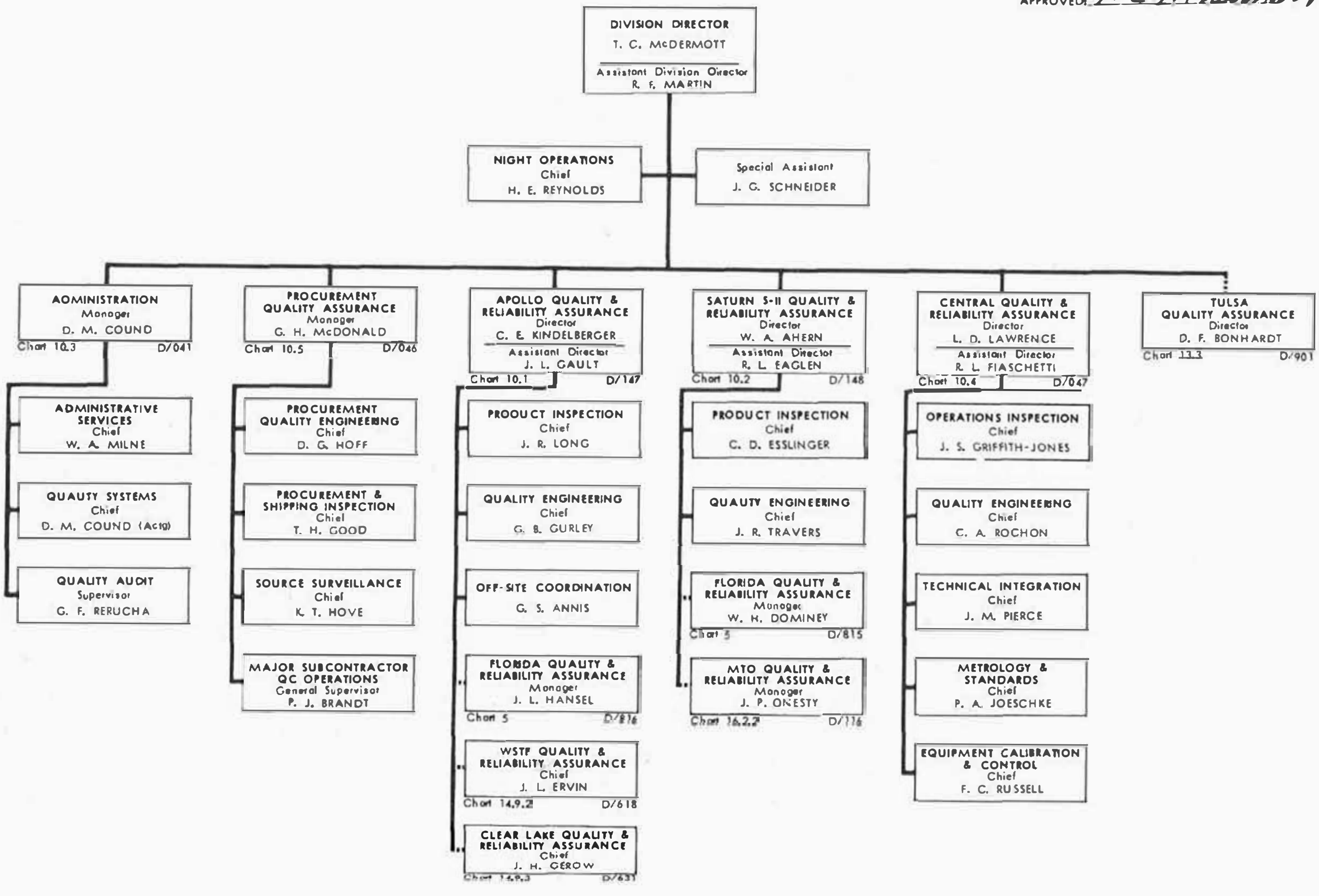
QUALITY & RELIABILITY ASSURANCE
August 5, 1966

APPROVED: T. C. McDermott



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NORTH AMERICAN AVIATION, INC.
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DAILY INSPECTION RECORD

1. INSPECTOR'S NO. ☐☐☐ 2. INSPECTOR'S STAMP ______ 3. INSPECTION DEPT. ☐☐☐ 4. SHIFT ______ DATE 5. MO. ☐☐ DAY ☐☐ YR. ☐ 6. MFG. DEPT. ☐☐☐

7. PROG. CODE	8. PART NUMBER	9. PROC. CODE	10. MODEL NO.	11. SERIAL NO.	12. MFG. STA. NO.	13. L/M 'P' NO.	14. TYPE OF INSP. CODE	QUANTITY OF PARTS 15. INSPECTED	16. DEFECTIVE	17. COND. CODE	18. DEFECT. QUANT.	19. RESP. CODE	20. DISP. CODE

FORM 2923-M REV. 4-66

NOTE: Codes 7, 9, 14, 19, and 20 on back of this sheet. Condition Code 17 on separate sheet.

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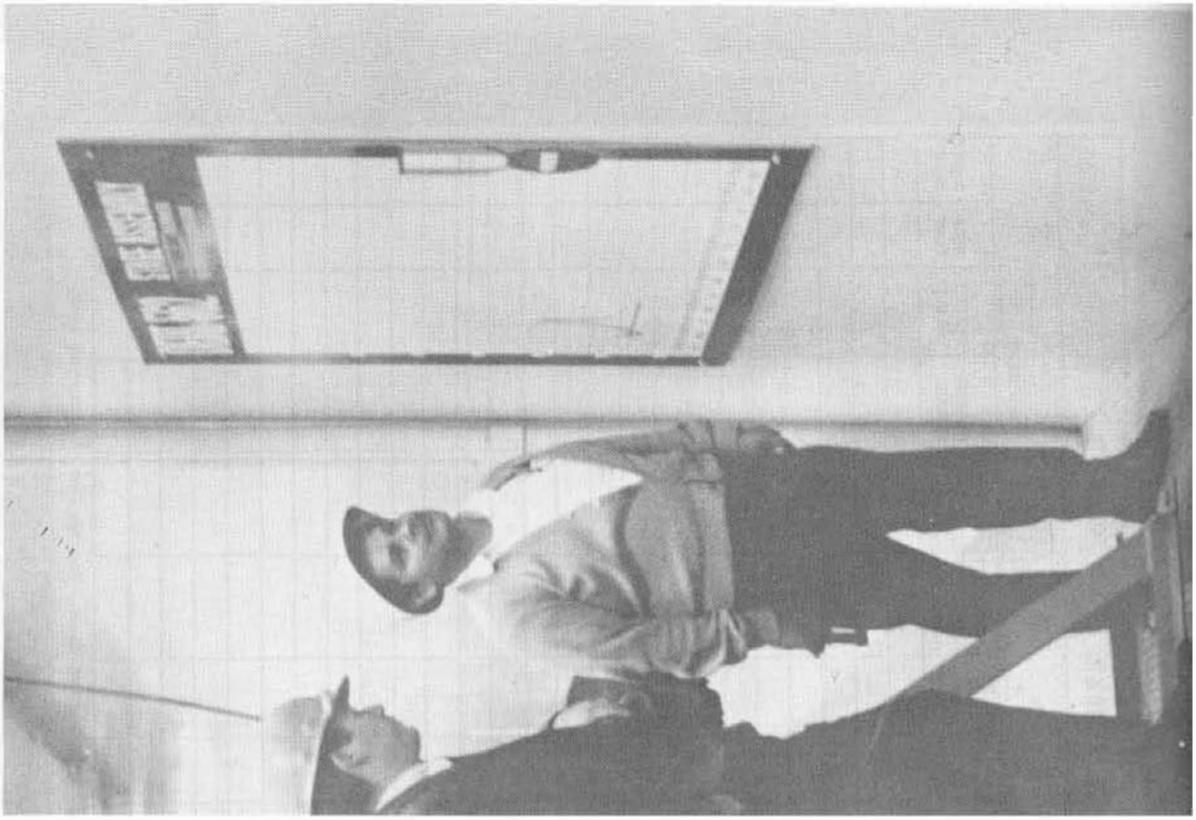
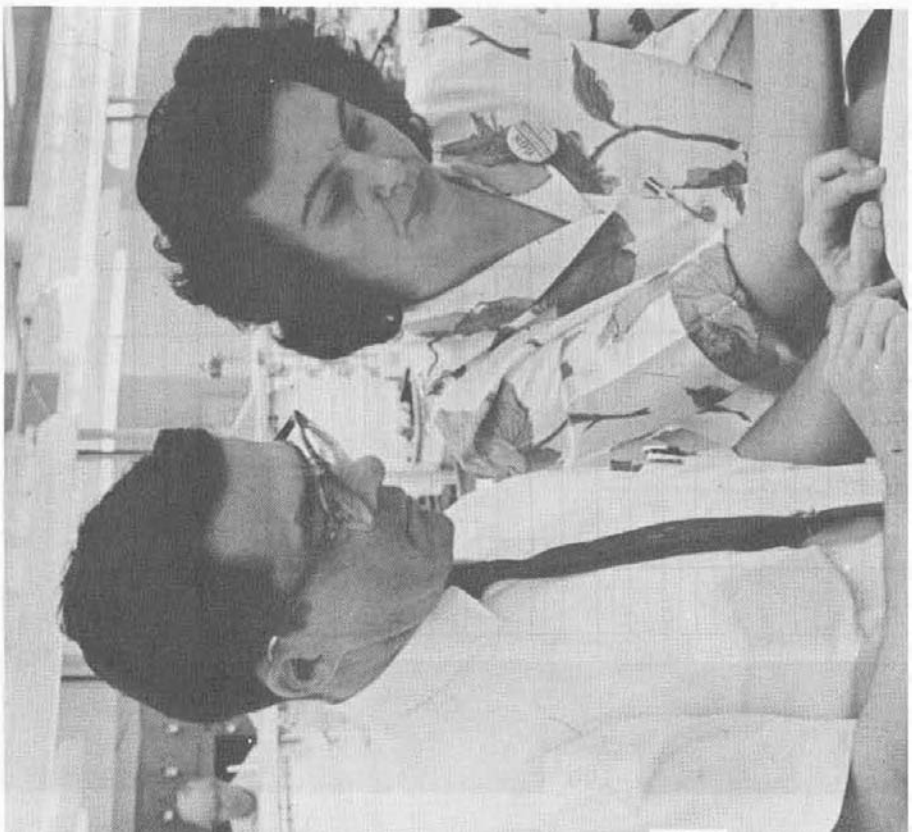
FIG 3





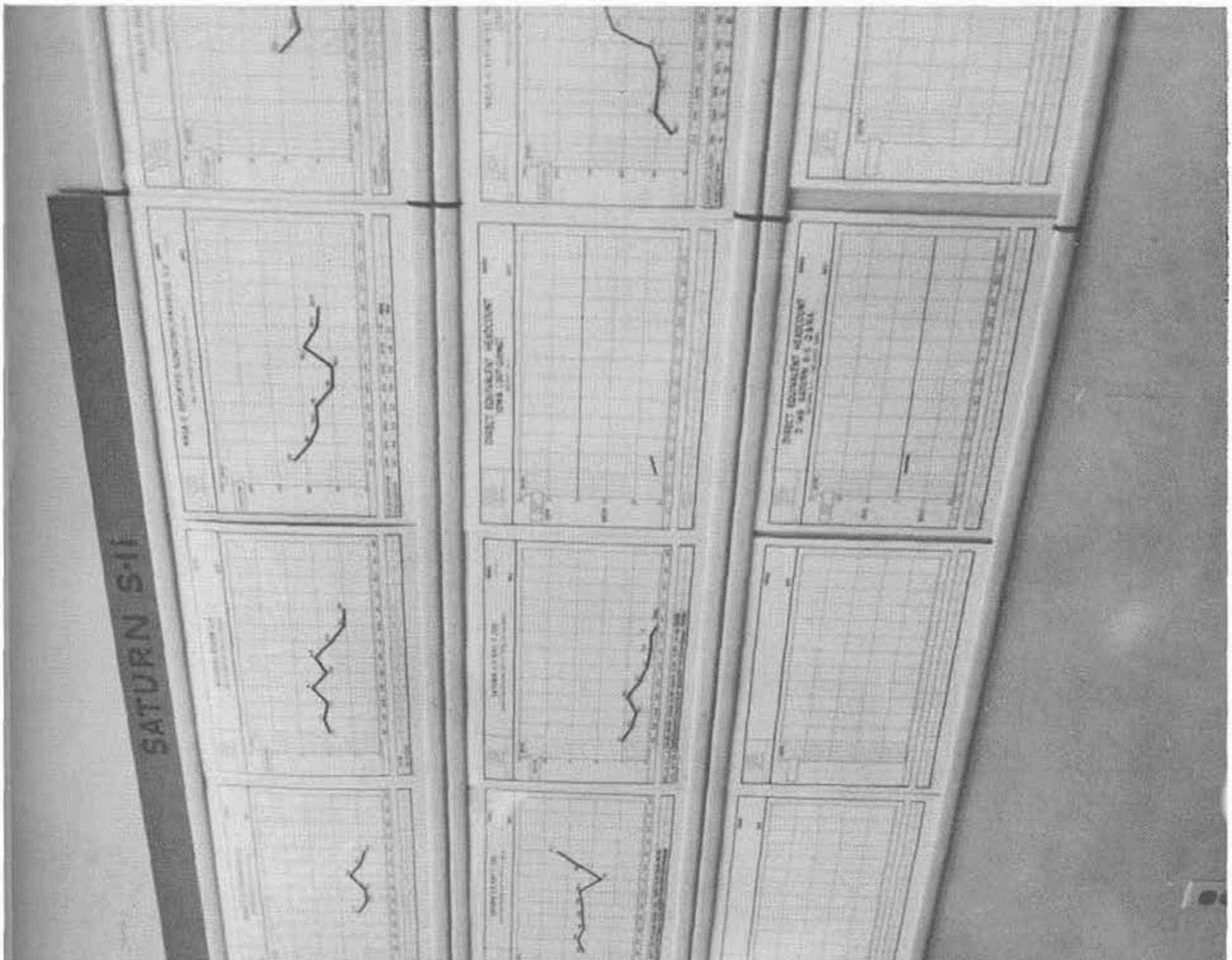
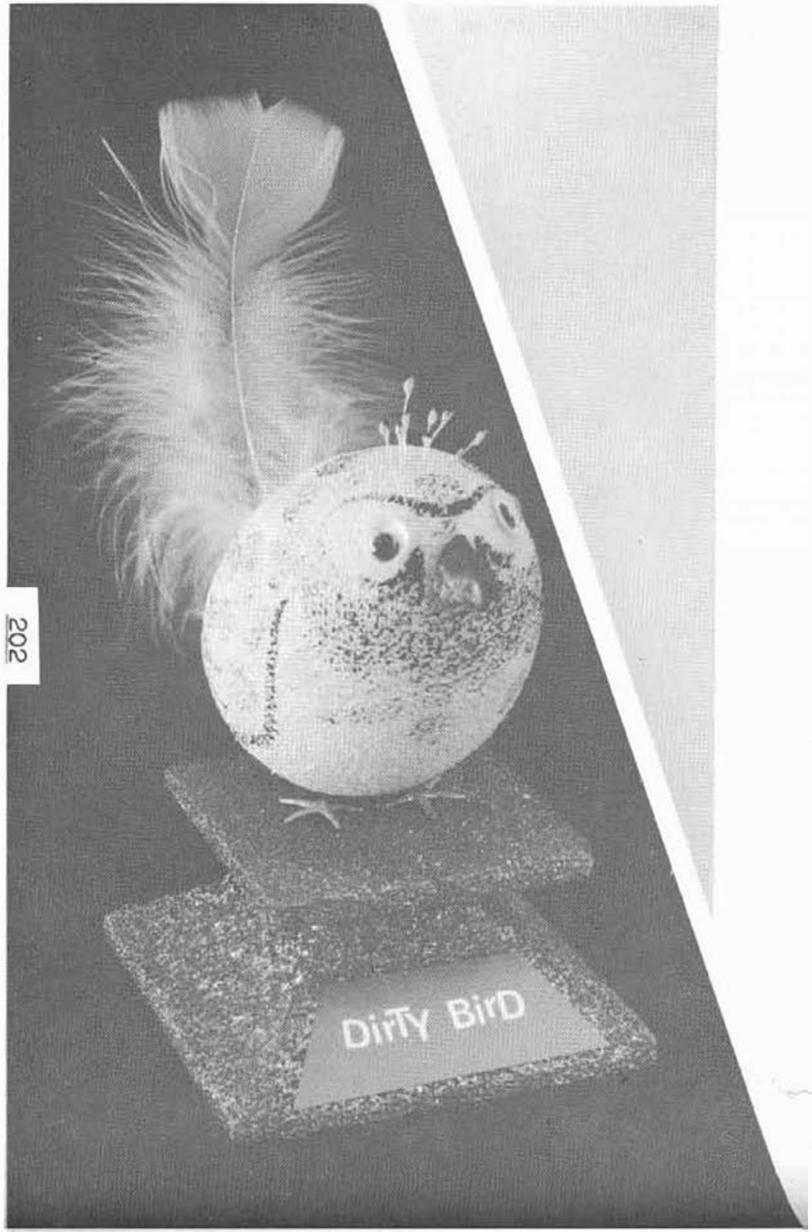

SATURN S-II
APOLLO
DIRECT EQUIPMENT HEADCOUNT
DIRECT EQUIPMENT HEADCOUNT

FIG. 5



NORTH AMERICAN AVIATION, INC.
SPACE and INFORMATION SYSTEMS DIVISION
QUALITY & RELIABILITY ASSURANCE
DEPARTMENT REPORT CARD

DEPARTMENT NO. ________ NAME ____________________

PERFORMANCE FACTORS				PENALTY
1. Salaries & Wages Budgets Direct Indirect	Budgeted $ E/H	Actual $ E/H	% Over	
2. Overtime Administration Direct Indirect	Authorized	Actual	% Over	
3. CAR (NASA) Responses	Delinquencies	Days Late		
4. Customer Letter Responses	Delinquencies	Days Late		
5. Security	No. of Infractions			
6. Procedure Coordination	Delinquencies	Days Late		
7. Operations Improvement Savings Participation	Goal	Actual	% Sub Std.	
8. Technical Utilization	Goal	Actual	% Sub Std.	
9. Travel Expense Reports	Delinquencies	Days Late		
10. Housekeeping	S&ID Inspection Score			

Total Penalty ______

Performance Score 100 - Penalty [ ]

Q&RA 659 Void 10-15-66

FIG E

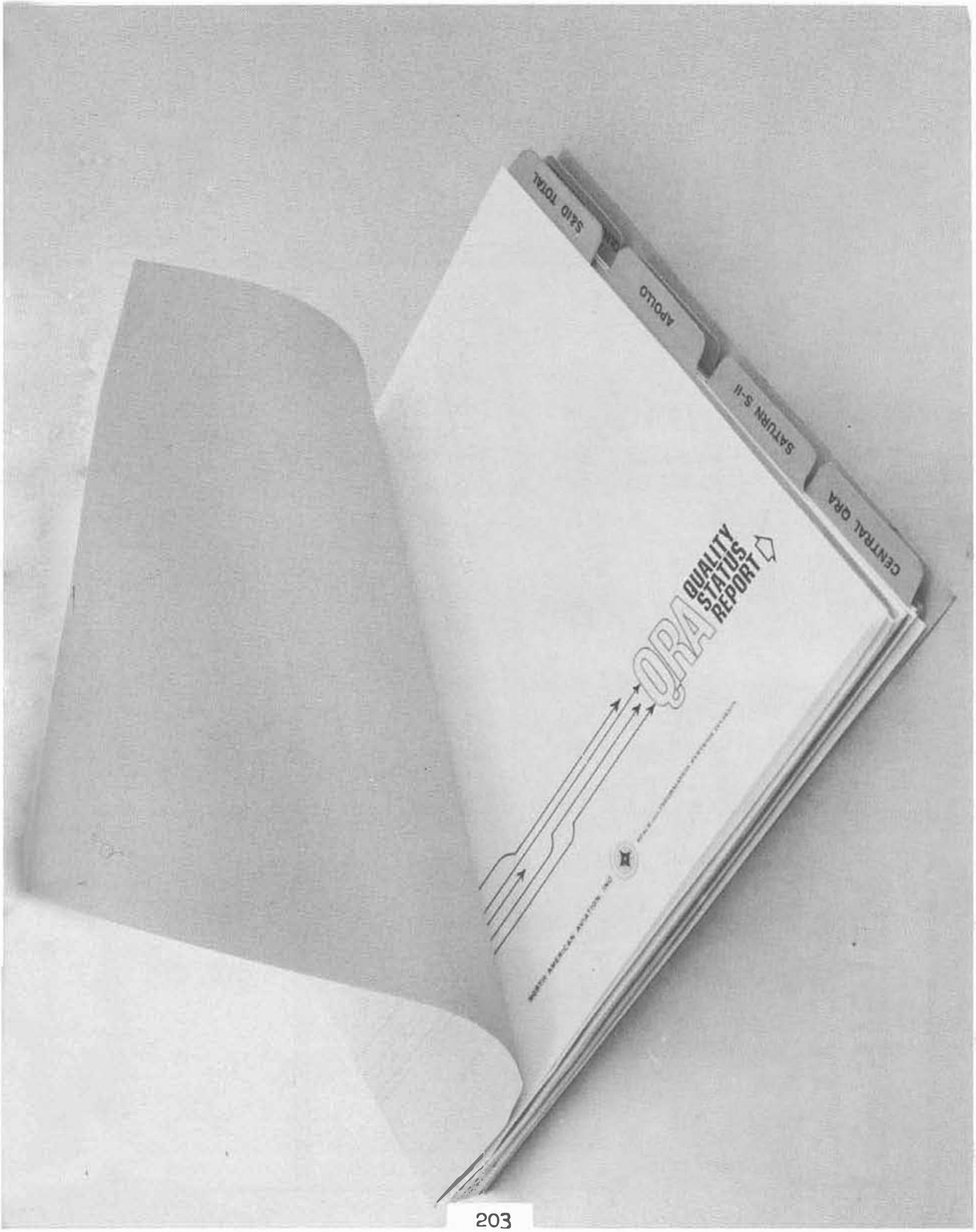
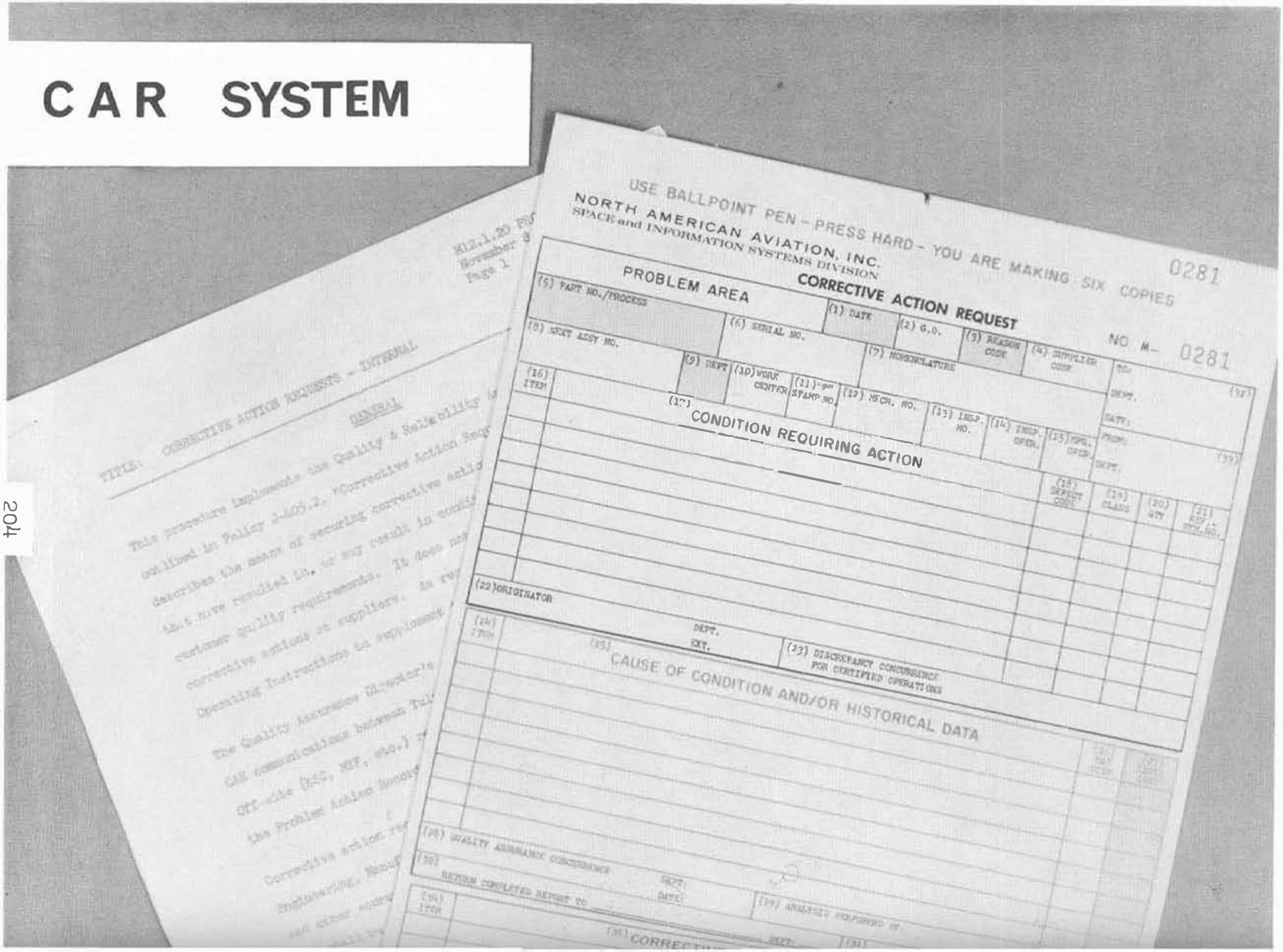

S&ID TOTAL
APOLLO
SATURN S-II
CENTRAL QRA
QRA
QUALITY
STATUS
REPORT
NORTH AMERICAN AVIATION, INC

FIG 7

CAR SYSTEM

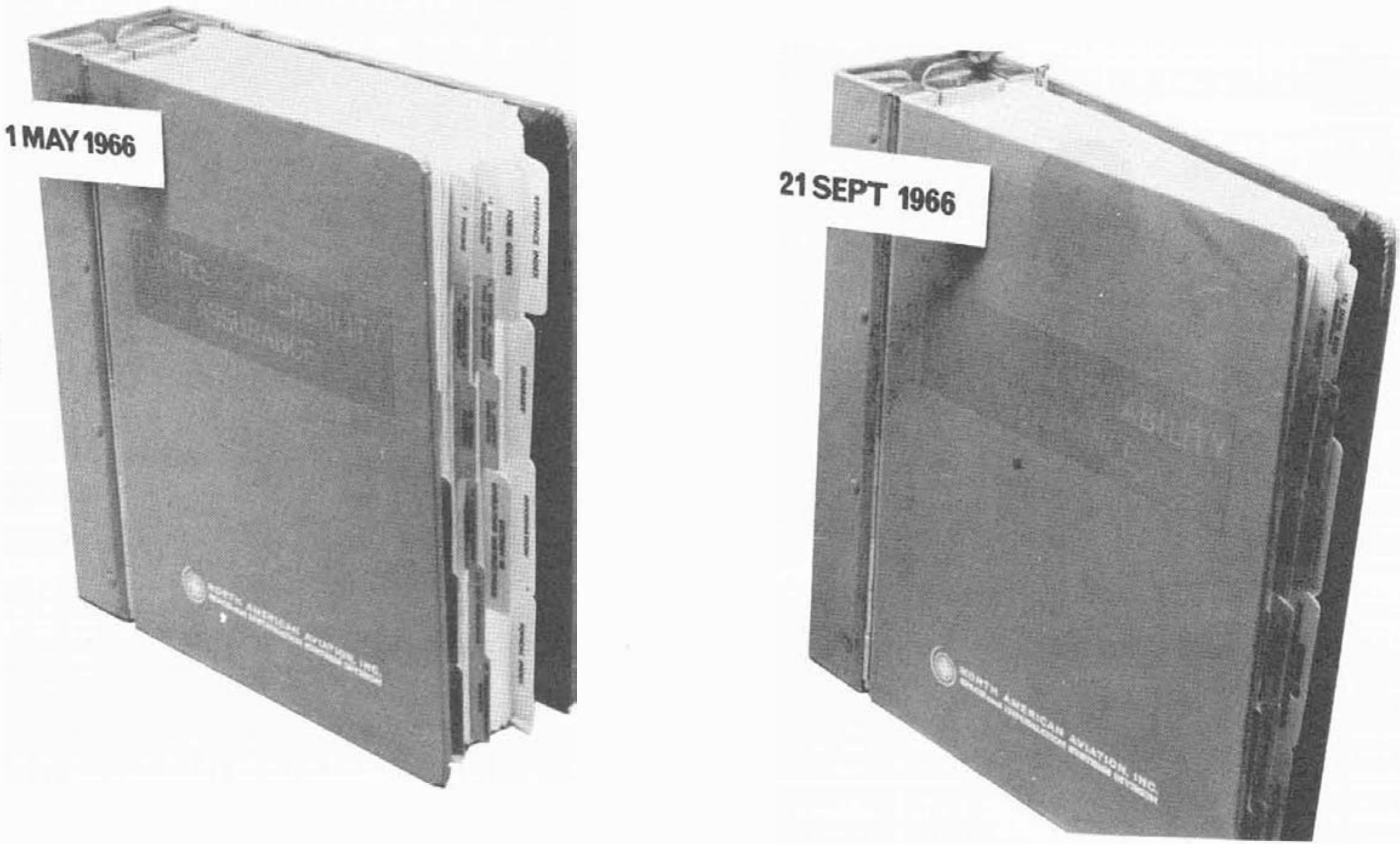

USE BALLPOINT PEN - PRESS HARD - YOU ARE MAKING SIX COPIES
NORTH AMERICAN AVIATION, INC.
SPACE and INFORMATION SYSTEMS DIVISION
CORRECTIVE ACTION REQUEST
PROBLEM AREA
NO. M- 0281
0281
CONDITION REQUIRING ACTION
(22) ORIGINATOR
DEPT.
EXT.
(23) DISCREPANCY CONCURRENCE FOR CERTIFIED OPERATIONS
CAUSE OF CONDITION AND/OR HISTORICAL DATA
(28) QUALITY ASSURANCE CONCURRENCE
RETURN COMPLETED REPORT TO
(29) ANALYSIS PERFORMED BY
CORRECTIVE ACTION REQUESTS - INTERNAL
GENERAL

S-II QUALITY TREND

	APRIL	OCTOBER	IMPROVEMENT
DISCREPANCIES/ 1000 D/L HRS	12.3	8.5	30.9%
MR ACTIONS/ 1000 D/L HRS	4.7	2.7	42.6%
NASA-O REPORTED NONCONFORMANCES/ 1000 INSP HRS	122 *	42.3	65.3%

FIG 9

PROCEDURES MANUAL



42.5% REDUCTION BY WT

FIG 10

SYSTEMS ANALYSIS

- DEFINE OBJECTIVES
- ESTABLISH CRITERIA
- REVIEW PROCEDURES

    STRUCTURE

    REQUIREMENTS

    RELATIONSHIPS

FIG 11

DEVELOPMENT OF AUDIT SYSTEM

AUDIT – SYSTEM VS ACTIVITY

AUDIT COUPLED WITH SYS. ANALYSIS

IDENTIFY

QUANTIFY

COMMUNICATE

AUDIT

- **CONFIGURATION**

  "MEASURES CONFORMANCE OF HARDWARE TO DESIGNED CONFIGURATION"

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- **CONFORMANCE**

  "MEASURES CONFORMANCE OF QRA FUNCTIONS TO PROCEDURAL REQUIREMENTS"

- **QUALITY SYSTEMS**

  "MEASURES OUTPUT OF QUALITY INFLUENCING SYSTEMS OPERATED BY OTHER DEPARTMENTS"

FIG 13

CONFIGURATION AUDIT

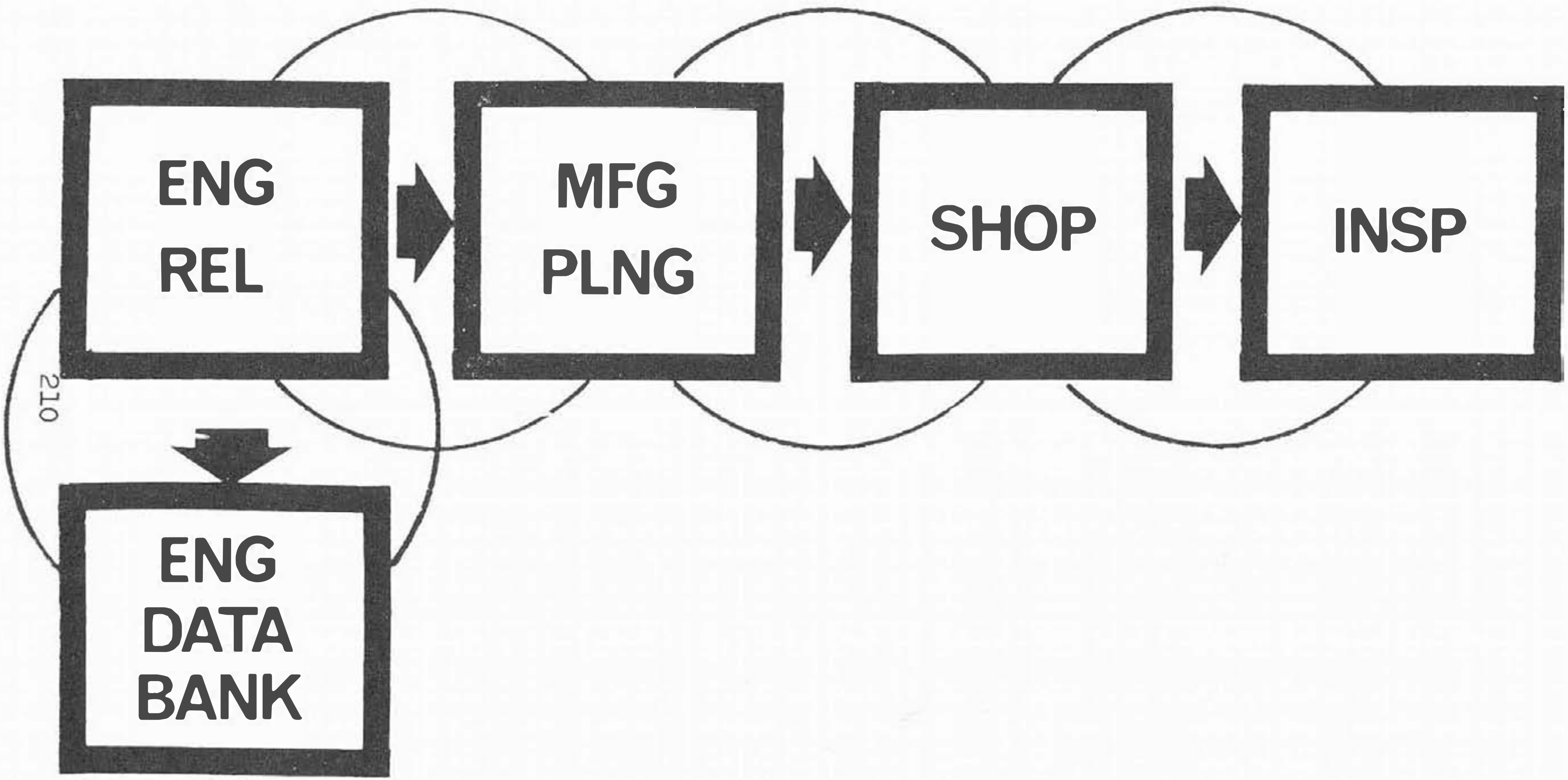

FIG 14

AGENCY QUALITY ASSURANCE PLANS AND QUALITY STATUS REPORTS

By R. V. Gerace
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Greenbelt, Maryland

This paper presents a discussion of the rationale for NASA requiring the submission of agency quality assurance plans and quality status reports. The points noted are based on the writer's experiences at the Goddard Space Flight Center, including frequent contacts with agency personnel throughout the country. Statistics relative to the number of plans submitted versus the number of plans rejected and reasons for rejection are not mentioned in this paper. This type of data was adequately covered in several papers presented at the First NASA-Wide Reliability and Quality Assurance Meeting, and Goddard's experience has not been different.

The requirement for preparation of agency quality assurance plans can be appreciated when we recognize certain basic differences in the type of hardware procured by the Department of Defense versus the type procured by NASA. Typical military hardware procurements usually consist of identical or similar articles produced in accordance with well-defined specifications and drawings. In this catagory, we can find mass-produced articles such as rifles, tanks, aircraft, ICBM's, etc. Since a large portion of the military budget involves procurement of mass-produced hardware, the DOD has established guidelines for resident Government inspectors which are compatible with contractor mass-production techniques. These guidelines are defined in the Defense Supply Agency Manual DSAM 8200.1. This manual establishes a system for monitoring contractor performance on a plant-wide basis rather than on a contract by contract basis. It also emphasizes the contractor's responsibility for controlling product quality and minimizes product inspection by the Government. The agency inspections are usually performed on a random basis as a means of verifying that the contractor has effective control of product quality. Only under certain defined circumstances are in-process agency inspections performed on a 100 percent basis.

By contrast, NASA frequently procures unique articles which are produced in small quantities in accordance with a performance specification rather than detailed drawings. These items are usually procured from the same contractors who are suppliers of military hardware. In recognition of the unique requirements for space flight hardware, the contractor will usually separate NASA work from the military product line and establish a project team to work exclusively on the NASA contract. In this same plant, the resident Government agency has the usual plant surveillance monitoring system with a minimum of product inspection. It is under these circumstances that it becomes desirable to modify the agency monitoring system. To divert the agency from a plant-wide surveillance system to a project-oriented inspection system, NPC 200-1A directs the agency to prepare a detailed plan which parallels the contractor's quality assurance plan.

To be meaningful, the agency plan must show a direct relationship with the product under fabrication and provide detailed information which demonstrates an understanding of the product requirements. Usually product-oriented information can be found in these essential elements of the agency plan:

1. A product flow chart identifying proposed agency inspection stations.
2. A brief narrative description of functions performed at each of these stations, including a listing of the articles involved; inspection and test documents involved; and the type, extent, degree and frequency of inspection and test.
3. A time-phased schedule for proposed manpower.

If the plan does not contain detailed information relative to these essential elements, then the plan cannot possible be considered adequate. Too often, submitted agency plans consist of nothing more than file copies of standard operating procedures for plant-wide monitoring. It is possible for the agency to describe in great detail their method of verifying quality elements and contractor quality decisions without even knowing what the product is. The plan must show how these elements are related to the specific product being fabricated.

General statements which parrot requirements in NPC 200-1A are equally unacceptable. It is not enough to say "Government source inspection will be requested in accordance with the criteria in NPC 200-1A." A positive decision must be made as to which specific subcontracted items warrant Government source inspection. It is not enough to say "mandatory characteristics will be selected as required." The plan must show what items will be inspected, when they will be inspected, what specific characteristics will be inspected, and how the inspection will be accomplished.

This lack of contract-related information has been the prime reason for Goddard Space Flight Center rejection of agency plans. To correct this situation, several documents have been released recently by DOD and NASA. On 30 December 1965, the Defense Supply Agency issued Quality and Reliability Bulletin No. 7. The purpose of the Bulletin is to provide the resident DCAS QAR with a copy of the check list that NASA uses in reviewing agency plans. The Bulletin also recommends that the QAR use the check list as a guide to form a self-appraisal of his plan to assure inclusion of essential and required criteria. Also, in August 1966, NASA issued a NASA/DCAS coordinated Quality Assurance Training Program Manual. This manual is being used to train DCAS personnel in NASA quality assurance requirements and includes guidance in preparing detailed agency plans. It is too early to fully evaluate the impact of these documents, but it is anticipated that fewer plans will be returned due to insufficient information.

Of course, even detailed plans may need revisions as the program progresses and problem areas develop. When a change in the agency plan is requested by NASA, some consideration must be given to the impact of the change and certain human factors involved in getting the change implemented. Whether or not the desired change gets implemented depends significantly upon the type of change involved and how the change is requested. When we ask for a change which is contrary to the normal DCAS method of operation, we are also asking an established organization to break from its existing routine. We may be asking DCAS to monitor a contract in a manner that is radically different from any other contract in the plant. We must be sure the requested change is necessary and justifiable. The need for the change must be clearly established; otherwise, we may find that the agency has reluctently changed the plan but has not really implemented the change.

When requesting a plan change, we must also consider the natural human traits of resistance to change and resentment of criticism. Bear in mind that these plans were originally generated by people who are trying to do a job as they see it. To overcome the resistance to change, we must encourage agency personnel to develop their own ideas as to how the established procedures can be modified to implement the requested change. We can expect a better response when agency personnel feel that they have participated in changing the plan rather than copying a change dictated by NASA.

The requested change must also be presented with a clear understanding to all concerned that the proposed change does not involve criticism of existing or past methods. The agency should be made aware of the unique requirements of NASA hardware which necessitates unique monitoring methods. The agency should also be encouraged to constantly review their plan and propose changes themselves which could result in concrete savings or increased efficiency.

After plan changes are incorporated to everyone's satisfaction, we must next concentrate on the actual implementation of the agency plan. Our experiences have shown that agency support is more effective when the plan is implemented by an agency representative who is familiar with NASA hardware requirements, and he is given full responsibility for assuring all agency functions are accomplished. Depending upon the scope of the contract, the responsible agency representative could act in a lead capacity directing the efforts of other agency personnel or, on a small contract, monitor the contract on a part-time basis. In either case, the responsible agency representative should review all documentation related to the product to become thoroughly familiar with product requirements. He must become the local expert in all quality related contract requirements. He would personally direct or perform all mandatory inspections as specified in the plan. He would be the primary point of contact for contractor quality assurance personnel and NASA project personnel. He would perform all delegated functions which are related to the specific product being procured. This type of specialized service could not be provided for all NASA contracts nor is it always desirable. But when the contractor establishes a project team to work under the NASA contract then the resident Government agency must also take a project-oriented approach in monitoring the contractor's performance.

When we have succeeded in getting adequate agency plans and have responsible and knowledgeable agency representatives assigned to critical NASA programs, we must follow up on our initial efforts to be sure we are getting adequate support throughout the entire period of contract performance. NPC 200-1A provides for a feed-back mechanism which helps NASA personnel to evaluate the level of support provided by the agency. This publication directs the agency to submit a monthly status report which summarizes agency actions during the past month. The reported agency actions should be related to the functions described in the agency plan and show how these functions were implemented from the time material is ordered and received to the time the end-item is shipped from the plant. It should be possible to check off articles in the plan which are designated for mandatory inspections based on the summary of articles inspected as indicated in the monthly status report.

Guidance for additional follow-up actions can be found in NASA Handbook NHB 5330.7. The Handbook directs NASA personnel to perform certain functions which have a direct bearing on agency performance and encourages NASA to communicate frequently with agency personnel. If all NASA Centers follow the guidance in the Handbook, both NASA and the agencies would benefit through a better understanding of mutual problems.

From this general discussion, a number of points were covered. The following are among the more significant ones:

1. Agency personnel have not fully recognized the unique nature of NASA hardware.
2. Agency plans frequently lack detailed information which is directly related to NASA hardware requirements.
3. Various documents have been issued and training programs established to improve agency understanding of NASA requirements.
4. Full implementation of agency plans depends upon the qualifications of the agency representative assigned to the program.

Despite current problems, we can see there have been several steps taken to improve agency performance. We must continue to press for further improvements. Probably the most fruitful area to effect improvements is through regular communication with resident agency personnel when there is evidence of inadequate support. There is enough guidance in current documents relative to getting better agency plans. NPC 200-1A has sufficient guidelines as to the type of information which should be in agency plans. Agency personnel are being trained in how to prepare suitable plans. A check list is available to verify the contents of the plan. If inadequate plans and revisions are continuously submitted, the handbook recommends several courses of action in getting better support. Guidelines for improved agency support are clearly established. It is the responsibility of each Center to assure that they are fully utilized.

The basis for all agency actions is the unique features of NASA hardware. It is essential that the agency plan be directly related to the hardware requirements; that responsible agency personnel are fully qualified to monitor the fabrication of NASA hardware; and that status reports verify the full implementation of the agreed upon agency plan. There is a strong interrelationship between NASA hardware requirements and agency documentation. When we succeed in getting adequate documentation, we are well on our way to getting adequate support.

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NPC 200-1A, "Quality Assurance Provisions for Government Agencies", June 1964 Edition

DSAM 8200.1, "Procurement Quality Assurance Manual for Contract Administration Services", November 1964

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NASA/DCAS Coordinated Quality Assurance Training Program, August 1, 1966

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SOME EXPERIENCES IN QUALITY AT MICHOUD ASSEMBLY FACILITY

by
Harry W. Fowler, Jr.
MSFC/MAF

In 1961, a team of people representing a variety of occupations from the Marshall Space Flight Center at Huntsville made a survey of Government owned manufacturing facilities in the United States. Their purpose--to find a facility that could be activated to produce the Saturn I and the Saturn V first stages. They selected the Michoud Facility in New Orleans, Louisiana. This facility contained 43 acres of air conditioned building, and was close to water for barge transport of stages. We began activating this facility, which was completely empty, in the fall of 1961.

After much hard labor, sweat, and tears on the part of the contractors, the resident MSFC group, and MSFC-Huntsville, we achieved a facility and a team capable of producing stages that takes a back seat to none. By that I mean the stage contractors, CCSD and Boeing, and MSFC have learned to work together as a team--confiding in each other about our problems so that we are able to bring them to light and to resolve them as a team.

And we had our problems. We began with an empty facility. We were new organizations; and although from the same parent organization, for the most part we had never worked altogether as a team. We had problems in concepts for facilities such as clean rooms, surface treatment, and checkout facilities. We, MSFC, found out that there were two ways to accomplish a job, or maybe I should say three ways--Boeing's, CCSD's, and MSFC's. This has helped us resident types at Michoud. We have learned to recognize that you can do a job several ways and the same goal can be achieved.

To give a chronological listing of events at Michoud, we began activating in late 1961. In spring and summer 1962, we signed contracts with CCSD and Boeing. In both we imposed NPC 200-2 for the first time with a major contractor. We immediately began to have problems with interpretation of 200-2. Records of calibration, MRB members, traceability, data reporting, manufacturing records, inspection procedures and records, reviews and approvals, NASA inspections, and others. We had a unique experience at Michoud. We started new, without a system of doing business. We, the contractors, and MSFC learned and were able to implement some of our pet ideas.

Some of the things we in Michoud Quality accomplished were:

a. A system for review of contractor procurement and implementation of Government Source Inspection (GSI).

b. Control over procedures the contractors use to implement their Quality programs.

c. A system for reviewing and certifying manufacturing procedures, processes, and personnel.

d. The establishment of a contractor group within Quality that reviewed engineering drawings and specifications for quality requirements before they were released for use.

e. A group that reviewed facility requirements for the interest of Quality.

To implement the MSFC Quality requirements, we organized the Michoud Quality organization into three groups (see Chart I); the Quality Engineering Office with 40-50 people, the Product Control Engineering Office with 90-110 people, and the Reliability Office with 6-10 people. The basic functions for these offices are as follows:

a. Quality Engineering - Establishes quality requirements for both contractors and other elements of Michoud Quality. Reviews, approves, and audits procedures (including manufacturing and functional test procedures), processes, and techniques used to implement the Quality Assurance Program. Establishes requirements for Government Source Inspection.

b. Quality Control Engineering Office - Assures that contractor implements procedures and that product meets requirements. Acts on Material Review Board. Evaluates contractor and vehicle performance in pre-static and post-static checkout for performance and incentive contract fee.

c. Reliability Office - Establishes reliability requirements and assures the contractor implements requirements. Approves reliability test procedures and final test reports. Responsible for contractors' implementing Manned Awareness Program.

Our education in setting up a program began as soon as a handful of contractors arrived at Michoud. We recognized that the plant layout and the equipment and facilities installed would have an effect on the quality and cost of items produced. We worked out methods of working with other elements of Michoud and the contractors in the establishment of equipment and facilities. In some areas the contract was completely void of specification which could have made our job easier. One in particular was environmental control requirements. We knew we had to have clean rooms due to processing LOX and fuel cleaned components; however, we did not have a clear answer as to what kind of an environment is required to maintain this cleanliness level. We had quite a few meetings to discuss environmental requirements for welding and soldering.

With CCSD, we finally built a clean room. After it had been operating for a couple of months, we established the limits based on what the room was capable of meeting, the requirements on the hardware, and some understanding of what was involved. The CCSD clean rooms have a total area of 26,000 square feet and can maintain a particle count below 100 microns at 70° temperature and 40% relative humidity. They are some of the finest in the country.

Some of our other problems involved surface treatment facilities. These are rather common facilities and in most places should not be any problem. At Michoud, CCSD decided to place their tanks in a pit so their tops would be at near the plant floor level. Two feet beneath the floor we struck water, and it was quite a job to dig a hole 20 feet deep and 80 feet long, pour concrete and place plumbing and tanks in it. Boeing built their surface treatment tanks above the floor level. However, Boeing was faced with the problem of having to have extremely large surface treatment tanks. Both have had excellent use of their facilities.

We reviewed the possibility of common facilities for both CCSD and Boeing and based on problems involved discarded most. We do have common computer service operated by LTV in Slidell, common reproduction, facility maintenance, protection, hospital, and a large part of our calibration standards. Boeing calibrates CCSD standards.

At about the same time that we began our facility problems, we got involved with procurement problems. How should we participate in the contractors' vendor activities? There are several basic things that we wanted to be sure of:

a. That the contractor placed adequate quality requirements on the vendor.

b. That the contractor placed his source inspection on the item if required.

c. That we place Government Source Inspection on the item if required.

d. That the vendor met his requirements.

e. That if there were any problems (with either the GSI, the vendor, or the contractor), we were aware of them.

To implement this we first made sure that the contractor had his quality organization review purchase orders. We placed personnel in this group and they reviewed purchase orders to determine if Government Source was required. We contacted the GSI agency and after a period of tiem, we got to know (by phone) the men in most of the vendor facilities. If the vendor had problems, we either found out about it from our people sitting in the contractors' quality groups or from the GSI. We established a requirement for copies of all nonconforming material reports written at Receiving Inspection to be sent to the Source Control Section of the Quality Engineering Office; and we forwarded these, either for information or corrective action, to the GSI agency.

Since we are for the most part an assembly facility, vendors have caused us and the contractors our biggest headache. Our experience has shown that there are two big reasons for this: (1) buying sole source proprietary items and (2) not fully explaining to the vendor what you want, how it is to operate, and how you plan to inspect and test it. The problem with most GSI, where you receive it and still get a defective item, is because of number 2 above.

The Michoud contractors have taken steps to eliminate both of the above. Prior to doing business with a new source or having a new item made by an old source, they send a team to the vendor to make sure that the vendor understands the requirements and can meet them. If a vendor has problems, they send a team out to resolve them. On proprietary items they work to resolve the problem by informing the vendor of the problem. In most cases the vendor will work to either correct the problem or offer some other item to fulfill the requirement.

Based on vendor performance, contractor performance, ability to demonstrate performance of item, and use of item, we have been reducing GSI. During the past 12 months, we have dropped GSI on about 10 percent of our vendors. We plan to further reduce GSI. We are now under an incentive contract and while we still may stand to lose a lot more than the contractors, we are taking a hard, cold look at all Government Source Inspection and I expect it to be further reduced within the next 6 months. We are striving to place the responsibility on the primes where it belongs. I feel that you must operate on the assumption that private industry wants to do a good job and that they are honest. If you explain the job to be done and they understand what is expected, you will get a good product.

The prime contractors have been paid many millions of dollars to establish and maintain a quality system which will result in the delivery of a stage of the highest quality level.

An important part of this system pertains to procurement of stage hardware, and the controls necessary to insure that it is of the necessary quality level. There has been a tendency, not necessarily recognized, for the Government to perform the contractors' work in the field by over emphasizing GSI requirements. If the prime contractor and his vendors have properly established a quality control system, perform inspection, and can adequately demonstrate this, why should the Government duplicate this effort? I don't believe we must or should. There is no doubt in my mind that the prime contractor desires and welcomes Government Source Inspection. This I have confirmed. Through a properly organized and administered field program, we, the Government, can remove ourselves from the position of working for the contractor and yet assure ourselves that he and his suppliers are satisfying their quality obligation and will accordingly deliver acceptable hardware.

More emphasis should be placed on utilizing DOD and NASA field personnel to monitor the supplier and prime, rather than on detailed hardware inspection. Leave the day-in and day-out inspection function up to the people paid to do the job, the contractors. Our job will be to see that they do this job.

We have instituted a program of auditing Boeing and Chrysler vendors. Normally these visits are to resolve problems; however, on all of these we evaluate how well the GSI and the contractor's field representative are performing. We ask ourselves, "Are we getting what we paid for on GSI? Is the GSI doing the work of the contractor or the vendor? Is the contractor's field representative doing his job? Does the vendor have a good quality system and is he living to it?" Based on answers received we may either cancel GSI or take action with the prime to beef up his operation. We think we have a good vendor program, but we know improvements can be made and we are working to see that improvements are made.

We found out that to inspect to a specification is only one small part of a program. The only way to achieve quality, assuming the design is correct, is to control manufacturing processes. By manufacturing processes I mean everything a worker does to fabricate and assembly an item. This would include metal cutting, forming, welding, soldering, surface treating, cleaning, heat treating, potting and molding, encapsulating, hole drilling, riveting, and assembling. If you control manufacturing processes, quality is pretty well automatic.

We found that too many times we as NASA Quality could not get the job done by dealing solely with the contractors' Quality organizations. We found that problems were resolved much quicker when we delt with either Manufacturing Production or Manufacturing Engineering personnel at the same time we delt with the contractors' Quality organizations. We established a program for the review of the contractors' Manufacturing Engineering Procedures and their process specifications. Working with the Manufacturing and Quality organizations, we established programs for training of personnel and the certification of personnel, processes, and equipment.

In the Quality Engineering Office we hired engineers and specialist with manufacturing and material and processes background and even though they were in a Quality organization they delt more with the contractors' Manufacturing and Design organizations than they did with the Quality organizations. One of the major problems we had was with welding. We make bulkheads out of hydraulic formed segments of 2219 aluminum. We had serious problems with the gore to gore weld. We had tenting, mismatch, and porosity. Two bulkheads could not be used. After many frustrating hours on the floor, we finally arrived at the solution. Get all the supervision and quality experts out of the way and let the welder practice his art. That is, let him be an artist within an established set of limits.

We found that we had been trying to automate too much, to inspect quality into it, make it foolproof by obtaining too many approvals to weld, and waiting too long after the gore had been cleaned to weld. We now have produced many feet of defect free weld. In fact, we built two complete bulkheads without having to repair a single weld defect detected by X-ray. We are now averaging less than 2 defects per 100 inches of weld. This includes all welding, even hand and spot welding.

One of the hardest problems to resolve was in the area of soldering. For quite sometime we had continuous meetings trying to resolve this. We revised training, we changed supervisors, and we did 100 percent inspection behind the contractors. Still, when the distributors reached the Cape, we would get "Squawks" written up on them. MSFC-Huntsville and KSC sent people into Michoud to look at soldering. We got several different opinions of what was or was not a good distributor. We finally decided that our problem was caused by lack of uniform standards. We worked with both Chrysler and Boeing Manufacturing and Quality to develop process procedures and inspection criteria that better defined the operation. Since this has been accomplished, our problems in this area have been greatly reduced.

To date we have launched 5 Michoud assembled stages, static fired 11, fabricated 8 sets of Ground Support Equipment, and fabricated over 20,000 cables, including several hundred for General Electric and Grumman. Each day we are learning new techniques for doing the job cheaper and better. To sum it up, we, both the contractors and MSFC resident groups, have had quite an education. What are some of the lessons learned:

a. The reasons we should have a resident group are (1) to help the contractor do his job and (2) to assure that he has done his job.

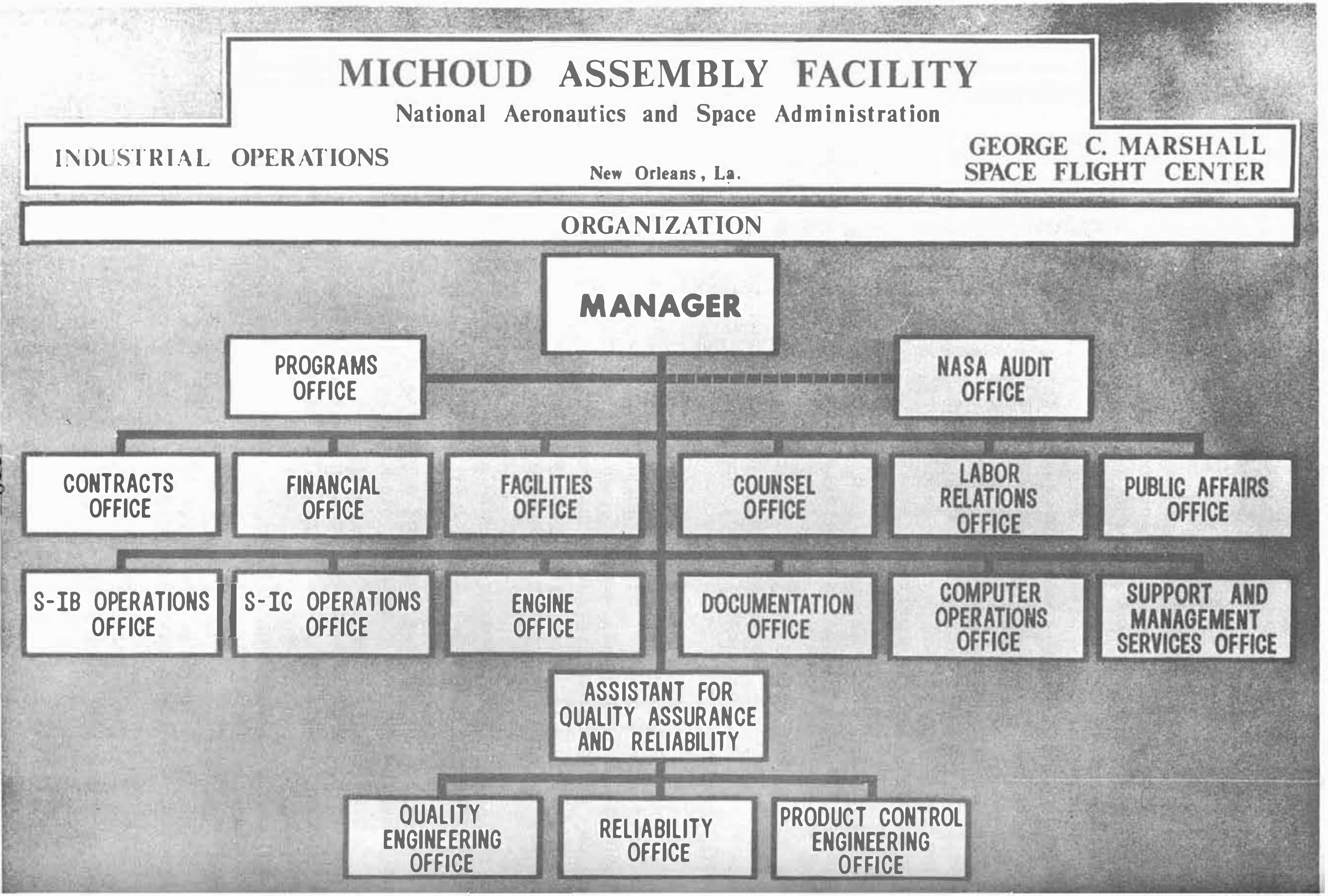
b. At the beginning of a program, wrap the contractors up with help. As the program develops, plan to reduce your coverage.

c. NASA should have their Quality Engineering and Manufacturing Engineering organized into one group at major contractor facilities.

d. A resident group must have competent personnel with the authority to make decisions.

e. The overall philosophy on the use of Government Source Inspection should be reviewed.

f. The method by which a contractor controls his vendors can make or break a program like ours.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New Orleans, La.
GEORGE C. MARSHALL SPACE FLIGHT CENTER
ORGANIZATION
MANAGER
PROGRAMS OFFICE
NASA AUDIT OFFICE
CONTRACTS OFFICE
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PUBLIC AFFAIRS OFFICE
S-IB OPERATIONS OFFICE
S-IC OPERATIONS OFFICE
ENGINE OFFICE
DOCUMENTATION OFFICE
COMPUTER OPERATIONS OFFICE
SUPPORT AND MANAGEMENT SERVICES OFFICE
ASSISTANT FOR QUALITY ASSURANCE AND RELIABILITY
QUALITY ENGINEERING OFFICE
RELIABILITY OFFICE
PRODUCT CONTROL ENGINEERING OFFICE

CHART I

RESIDENT REPRESENTATIVE'S REVIEW OF R&QA REQUIREMENTS ON THE RL-10 ENGINE PROGRAM

Jack H. Cohen, LeRC*

TO CONQUER SPACE, WE MUST FIRST DEVELOP AND PRODUCE RELIABLE HARDWARE DOWN HERE ON EARTH. THERE IS NOTHING MORE DOWN TO EARTH THAN A NASA RESIDENT R&QA REPRESENTATIVE IN A PRIME CONTRACTOR'S PLANT. ASK ONE SOMETIME!!! HE MAY TELL YOU THAT HE IS A TRIFLE BELOW THE EARTH, IN AN INFERNO. HE IS THE LAST BLOCK ON ANY GOVERNMENT ORGANIZATION CHART - SOMETIMES HE DOESN'T MAKE THE CHART AT ALL. NEVERTHELESS, HE IS FULLY RESPONSIBLE FOR THE OVERALL IMPLEMENTATION OF HEADQUARTER'S AND CENTER POLICY WHERE IT REALLY COUNTS, WHERE THE HARDWARE IS DESIGNED, DEVELOPED, MANUFACTURED AND ACCEPTED FOR THE END ITEM - THE SPACE VEHICLE. HE MUST FUNCTION EFFECTIVELY IN DYNAMIC ENVIRONMENT AS AN INTEGRAL PART OF A NASA RESIDENT TEAM. AT TIMES HE PERFORMS FUNCTIONS TOTALLY UNRELATED TO RELIABILITY OR QUALITY ASSURANCE. THERE ARE ALSO TIMES WHEN HE MUST STAND ALONE, PLANT BOTH FEET UPON THE GROUND AND SAY "NO" TO THE CONTRACTOR, AND SOMETIMES TO THE PROGRAM MANAGER, TO ASSURE THAT HIGH

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RELIABILITY NECESSARY FOR SUCCESS IS NOT LEFT TO CHANCE. HE MUST MAKE MANY DECISIONS IN THE "GRAY AREA" ON HARDWARE WHICH ARE EXTREMELY COSTLY TO THE GOVERNMENT, AND WHERE THERE ARE NO PRECEDENTS. THE KEY TO SUCCESS (IF IT COULD BE MEASURED AT ALL IN THIS ENVIRONMENT), IS THE CONTINUOUS ASSURANCE THAT THE CONTRACTOR HAS A WELL DEFINED R&QA PROGRAM AND THIS PROGRAM IS EFFECTIVELY IMPLEMENTED TO THE LAST TIER SUB-CONTRACTOR. IMPLEMENTATION OF THE R&QA REQUIREMENTS ARE NEVER LEFT TO CHANCE - NOT EVEN FOR A CONTRACTOR WHO HAS A PROVEN RECORD OF DELIVERING DEPENDABLE AIRCRAFT ENGINES FOR 38 YEARS. THE STAKES ARE TOO HIGH IN THE SPACE PROGRAM.

AN INTRODUCTION TO PRATT & WHITNEY'S FLORIDA RESEARCH & DEVELOPMENT CENTER, A HISTORY OF THE RL10 PROGRAM, AND THE RESULTS ACCOMPLISHED BY IMPLEMENTING THE NASA R&QA REQUIREMENTS IN A PLANT WHOSE PRIMARY ASSIGNED FUNCTIONS ARE R&D, ARE PRESENTED IN SEQUENCE. A SUMMARY AND GENERAL COMMENTS WHICH MAY PROVE USEFUL TO OTHER NASA CENTERS IS ALSO PRESENTED AT THE CONCLUSION.

I. THE FLORIDA RESEARCH AND DEVELOPMENT CENTER, PRATT & WHITNEY

AIRCRAFT, DIVISION OF UNITED AIRCRAFT CORPORATION, IS LOCATED 20 MILES NORTHWEST OF PALM BEACH, FLORIDA IN THE EVERGLADES (FIGURE 1). THE NASA/LeRC P&WA RESIDENT OFFICE IS LOCATED IN THE MAIN MANUFACTURING BUILDING (FIGURE 2). GENERAL INFORMATION REGARDING THE PLANT AND THE FACILITIES IS PRESENTED IN FIGURE 3. AN AERIAL VIEW OF THE NINE RL10 ROCKET ENGINE R&D AND FLIGHT FULL SCALE TEST FACILITIES IS PRESENTED IN FIGURE 4. THIS MAY BE BETTER ILLUSTRATED BY FIGURE 5. FIGURE 6 IS A PHOTOGRAPH OF THE TEST FACILITY USED TO SIMULATE ADVANCE CENTAUR VEHICLE CONFIGURATION ENVIRONMENTS FOR RESOLVING DEVELOPMENT, INTERFACE, AND FLIGHT VEHICLE PROBLEMS. PRATT & WHITNEY AIRCRAFT EMPLOYS APPROXIMATELY 5,500 PERSONNEL. ABOUT 1/3 WORK IN ROCKET ENGINE RESEARCH AND DEVELOPMENT, INCLUDING THE RL10. NASA HAS 16 CONTRACTS, TOTALLING A LITTLE OVER 56 MILLION DOLLARS, ASSIGNED TO THIS PLANT.

II. RL10 PROGRAM HISTORY

THE RL10 PROGRAM IS QUITE UNIQUE. IT STARTED BACK IN 1958, ABOUT THE SAME TIME THAT NASA WAS FORMED. THE FIRST LIQUID HYDROGEN ROCKET ENGINE CONTRACT WAS NEGOTIATED WITH PRATT & WHITNEY AIRCRAFT

BY THE AIR FORCE IN OCTOBER, 1958, FOR A FEASIBILITY STUDY LEADING TO THE DEVELOPMENT OF AN R&D ENGINE. NINE MONTHS LATER, IN JULY, 1959, A LIQUID HYDROGEN ENGINE WAS SUCCESSFULLY FIRED FOR THE FIRST TIME. THE PRESENT CONFIGURATION OF THE RL10, SHOWN IN FIGURE 7, AND PERFORMANCE CHARACTERISTICS IN FIGURE 8, HAVE EVOLVED FROM TWO ENGINES - THE LR 115 (15K), AND THE LR 119 (17.5K) ENGINES FOR THE CENTAUR AND SATURN I VEHICLES (FIGURE 9). THE ADVANTAGES OF LIQUID HYDROGEN OVER CONVENTIONAL CHEMICAL LIQUID ROCKET ENGINES WERE WELL KNOWN IN 1958, BUT HAD NEVER BEEN PROVEN IN A ROCKET ENGINE. HYDROGEN, BY VIRTUE OF ITS ATOMIC WEIGHT AND COMBINING ENERGY, IS NATURE'S MOST ENERGY-PACKED SUBSTANCE PER UNIT WEIGHT, "THE ULTIMATE KNOWN CHEMICAL ROCKET FUEL SUITED FOR A SPACEBORN OR NUCLEAR ROCKET ENGINE."

THE RL10 ENGINE PROGRAM HAS CONTRIBUTED SIGNIFICANTLY TO SEVERAL TECHNOLOGY "BREAK-THROUGHS". THE ROCKET ENGINE GAS GENERATOR WAS ELIMINATED BY THE RL10 "BOOT STRAP" CYCLE, WHICH USES THE HYDROGEN FUEL TO ACCOMPLISH WORK TO DRIVE THE TURBOPUMP PRIOR TO IGNITION, AS WELL AS COOLING THE EXIT NOZZLE THRUST CHAMBER WALL. ALL COMPONENTS

OPERATE DRY IN A CRYOGENIC ENVIRONMENT WITHOUT LUBRICANTS, THUS AVOIDING A HIGH TEMPERATURE GRADIENT REQUIRED FOR WARM OILS AND -423° FOR LIQUID HYDROGEN. GEARS, BEARINGS, AND SEALS WERE DEVELOPED ESPECIALLY FOR THESE COOL ENVIRONMENTS UP TO -423°F. THE TURBOPUMP ACCELERATES FROM 0 - 30,000 RPM IN 1.4 SECONDS.

THE RL10A-3 ENGINE (FIGURE 10) IS A 15,000 POUND VACUUM THRUST UPPER STAGE LIQUID ROCKET ENGINE CAPABLE OF MAKING 3 OR MORE MULTIPLE STARTS AFTER LONG COAST PERIODS IN SPACE. LIQUID HYDROGEN AND LIQUID OXYGEN ARE USED AS PROPELLANTS IN THE ENGINE, AND GASEOUS HELIUM IS USED TO ACTUATE VALVES FOR STARTING AND STOPPING THE ENGINE. THE ENGINE HAS A SPECIFIC IMPULSE OF 444 NOMINAL (BASED ON A 3-SIGMA DISPERSION OF $\pm$ 5 SECONDS), THE HIGHEST KNOWN FOR A LIQUID HYDROGEN ROCKET ENGINE. THE RL10 ENGINE HAS A TOTAL OF 6,627 INDIVIDUAL PARTS AND WEIGHS 290 POUNDS. THE ENGINE CONSISTS OF THE THRUST CHAMBER, PROPELLANT INJECTOR, (WELDED TO THE INLET OF THE THRUST CHAMBER), THE TURBOPUMP ASSEMBLY, (CONSISTING OF THE PROPELLANT PUMPS AND DRIVE TURBINE), FUEL INLET SHUTOFF VALVE, OXIDIZER INLET SHUTOFF VALVE, OXIDIZER FLOW

CONTROL VALVE, OXIDIZER PRESTART, FUEL PRESTART AND START SOLENOID VALVES, IGNITER OXIDIZER SUPPLY VALVE, ENGINE GIMBAL ASSEMBLY, ENGINE PROPELLANT AND CONTROL TUBING, AND AN IGNITION SYSTEM. THE IGNITION SYSTEM IS A PRESSURIZED, SEALED UNIT CONSISTING OF AN EXCITER AND ONE SPARK IGNITER. THE EXCITER IS ATTACHED TO THE ENGINE GIMBAL MOUNT. THE REGENERATIVELY COOLED THRUST CHAMBER IS MADE UP OF 180 FULL-LENGTH DOUBLE-TAPERED TUBES, 180 SHORT SINGLE-TAPERED TUBES, FUEL DISTRIBUTION MANIFOLDS, EXTERNAL STIFFENERS, AND THE PROPELLANT INJECTOR. FUEL (LIQUID HYDROGEN) FLOWS REARWARD FROM THE INLET MANIFOLD THROUGH THE SHORT TUBES, INTO THE TURN-AROUND MANIFOLD, AND THROUGH THE FULL-LENGTH TUBES TO THE EXIT MANIFOLD. THE FUEL ACTS AS A COOLANT TO REDUCE CHAMBER TUBE WALL TEMPERATURES AND THE ABSORBED HEAT ENERGY DRIVES THE TURBINE AND PROPELLANT PUMPS. CONTROL OF ENGINE THRUST IS EFFECTED BY REGULATING COMBUSTION CHAMBER PRESSURE TO A PREDETERMINED VALUE. IF THE COMBUSTION CHAMBER PRESSURE INCREASES OR DECREASES FROM THIS PREDETERMINED VALUE, THE THRUST CONTROL INCREASES OR DECREASES THE TURBINE BYPASS AREA, THUS CHANGING THE AMOUNT OF FUEL FLOW THROUGH THE TURBINE. THE INSTANTANEOUS CHANGE OF FLOW THROUGH THE TURBINE,

CALLED FOR BY THE BYPASS VALVE, ALTERS THE AMOUNT OF TURBINE TORQUE AVAILABLE AND, ACCELERATES OR DECELERATES THE TURBOPUMP SYSTEM. THE FUEL AND OXIDIZER VALVES ARE HELIUM ACTUATED AND CONTROLLED BY ELECTRICAL SIGNALS APPLIED TO SOLENOID CONTROL VALVES. OPERATION OF THE PRESTART AND START CYCLES OF THE ENGINE IS INDICATED THROUGH HELIUM PRESSURE SWITCHES THAT ACTUATE REMOTE INDICATING INSTRUMENTATION.

THE ENGINE HAS ACHIEVED REMARKABLE RELIABILITY AND PERFORMANCE GROWTHS AS SHOWN IN FIGURES 11 AND 12. FIFTY-TWO OUT OF FIFTY-TWO ENGINES HAVE BEEN SUCCESSFULLY FIRED IN THEIR ENVIRONMENTS ON CENTAUR AND SATURN FLIGHT VEHICLES. THE LATEST AC-9 CENTAUR FLIGHT, IN OCTOBER, 1966, DEMONSTRATED THE RELIGHT CAPABILITY IN SPACE AFTER A COAST PERIOD. THIS WAS A MILESTONE FOR THE LIQUID HYDROGEN RL10 ENGINE, THE CENTAUR VEHICLE, AND THE SPACE PROGRAM IN GENERAL. I'M SURE YOU'RE ALL FAMILIAR WITH THE CENTAUR AC-10 VEHICLE WHICH SENT SURVEYOR TO THE MOON. FIGURE 13, "RL10 DEVELOPMENT HISTORY", REPRESENTS AN ACHIEVED MILESTONE CHART WHICH MAY BE USED FOR COMPARING THE IMPLEMENTATION OF NASA RELIABILITY AND QUALITY ASSURANCE REQUIREMENTS WITH THE DOCUMENTED ACCOMPLISHMENTS

OF THE PROGRAM. THE NATION'S FIRST NASA QUALITY ASSURANCE REQUIREMENTS IN A PRIME CONTRACT OF THIS MAGNITUDE, (NASA-MSFC QEB NO. 2), WERE NEGOTIATED (IN FEBRUARY, 1962) INTO THE RL10 CONTRACT. THREE SHORT PAGES OF RELIABILITY REQUIREMENTS WERE ALSO INCLUDED IN THE STATEMENT OF WORK.

YOU MAY OBSERVE THE SLOPE OF THIS CURVE (FIGURE 13) AFTER THE IMPLEMENTATION OF NPC 200-2 AND NPC 250-1 IN 1962. OUR EXPERIENCE HAS SHOWN THAT IT TAKES APPROXIMATELY ONE YEAR FROM THE NEGOTIATION DATE TO FULLY DEVELOP AND IMPLEMENT NASA R&QA REQUIREMENTS AT THE PLANT LEVEL. THE RL10 QUALITY AND RELIABILITY PROGRAM PLANS EACH REQUIRED ONE YEAR OF CONTINUOUS EFFORT BY THE GOVERNMENT AND THE CONTRACTOR TO ARRIVE AT A POINT WHERE THE PLANS COULD BE ACCEPTED BY NASA. THE ORIGINAL RL10 CONTRACT CONTAINED THE FOLLOWING STATEMENT UNDER QUALITY ASSURANCE "TO BE NEGOTIATED AT A LATER DATE." THE FIRST DEFINITIVE QUALITY REQUIREMENTS (MIL-Q-9858, AIR FORCE BULLETINS 515, 520) WERE NEGOTIATED IN JANUARY, 1961. FIGURE 14, "RL10 ENGINE PROGRAM RELIABILITY AND QUALITY ASSURANCE CONTRACT REQUIREMENT HISTORY" PORTRAYS THE EVOLUTION OF RL10 R&QA CONTRACT REQUIREMENTS. NOTE THAT APPROXIMATELY ONE AND ONE-HALF

YEARS OF TIME HAD ELAPSED AFTER THE FIRST WORKING MODEL OF A LIQUID HYDROGEN ENGINE WAS SUCCESSFULLY FIRED UNTIL THE FIRST DEFINITIVE R&QA REQUIREMENTS APPEARED IN THIS MULTI-MILLION DOLLAR CONTRACT. THE AIR FORCE BEGAN STAFFING THE RESIDENT QUALITY ASSURANCE OFFICE FROM FEBRUARY, 1961, UNTIL IT WAS COMPLETELY STAFFED WITH 12 PERSONNEL IN NOVEMBER, 1961. THE NASA MARSHALL SPACE FLIGHT CENTER ASSUMED CONTRACT ADMINISTRATION FOR THE RL10 PROGRAM IN NOVEMBER, 1961. DURING 1961, TEAMS OF AIR FORCE AND NASA PERSONNEL VISITED THE FLORIDA RESEARCH AND DEVELOPMENT CENTER, SOME FOR SHORT PERIODS, OTHERS FROM THREE TO SIX MONTH INTERVALS. THREE SERIES OF TEST STAND EXPLOSIONS, FROM NOVEMBER, 1960 TO JANUARY, 1961, CREATED A "PANIC APPROACH" WHICH COULD HAVE BEEN AVOIDED (20-20 R&QA HIND-SIGHT) IF DEFINITIVE QUALITY AND RELIABILITY REQUIREMENTS HAD BEEN DEVELOPED DURING THE R&D CONTRACT PHASE OF THE RL10 PROGRAM. FIGURE 15 PRESENTS THE GOVERNMENT R&QA PERSONNEL STAFFING HISTORY. THE DATA COLLECTED BY THE GOVERNMENT DURING 1961 AND 1962 REVEALED SIGNIFICANT DEFICIENCIES IN THE CONTRACTOR'S RL10 RELIABILITY AND QUALITY ASSURANCE PROGRAMS AS WELL AS THE ENGINE HARDWARE. <u>HARDWARE</u>

DEFICIENCIES WERE GROUPED INTO THE FOUR CATEGORIES (PARETOIZED) WHICH CONTRIBUTED TO THE VAST MAJORITY OF THE PROBLEMS.

1. ASSEMBLY OF LONG AND SHORT THRUST CHAMBER TUBES - TUBES WOULD NOT ASSEMBLE AND MAINTAIN THE REQUIRED FLOW AND AREA RATIO IN THE THRUST CHAMBER FINAL ASSEMBLY. THE PROBLEM, ONCE DEFINED, WAS CORRECTED BY THE DEVELOPMENT OF A STATISTICAL TECHNIQUE AND IBM PROCEDURE WHICH SELECTED AND SORTED TUBES FOR A PARTICULAR COMBINATION OF THRUST CHAMBER AREA RATIO AND FLOW CHARACTERISTICS.

2. ENGINE, INTERNAL & EXTERNAL CRYOGENIC LEAKAGES - QUALITY STANDARDS WERE DEVELOPED, FORMALIZED AND IMPLEMENTED TO PREVENT LEAKAGES. HANDLING PROCEDURES WERE WRITTEN AND IMPLEMENTED.

3. THRUST CHAMBER BRAZING - THRUST CHAMBERS WERE INCOMPLETELY BRAZED WITH IRREPARABLE VOIDS. MANY LEAKED AND WERE SCRAPPED. A DESIGN REVIEW, INITIATED BY NASA RELIABILITY AND QUALITY, INSISTED UPON CONTRACTOR REMEDIAL ACTION TO IMPROVE THE PROCESS QUALITY LEVEL OF THIS HIGH VALUE ITEM. THRUST CHAMBERS HAD PREVIOUSLY BEEN BRAZED BY "EXPERIENCE" AND "JUDGMENT". A COMPLETE AND DETAILED STEP-BY-STEP BRAZING

PROCEDURE WAS WRITTEN AND IMPLEMENTED. IN ADDITION, CLEAN ROOM STANDARDS WERE DEVELOPED AND ALL CRYOGENIC COMPONENTS WERE PLACED UNDER RIGID CONTROL. THE PROCESS QUALITY LEVEL IMMEDIATELY INCREASED TO AN ACCEPTABLE LEVEL. THRUST CHAMBERS REJECTED FOR FLIGHT QUALITY WERE REPAIRED AND USED ON R&D PROGRAM CHAMBERS.

4. MAJOR ENGINE COMPONENTS WERE TESTED, RETESTED, REWORKED, AND RECYCLED AS MANY AS THIRTEEN TIMES PRIOR TO ACCEPTANCE. NASA COLLECTED THE CONTRACTOR'S DATA, SUMMARIZED THIS DATA IN A PARETOIZED DISTRIBUTION AND PRESENTED IT TO THE CONTRACTOR FOR CORRECTIVE ACTION. THE CONTRACTOR, IMMEDIATELY RECOGNIZING THE VALUE, BEGAN SUMMARIZING AND ANALYZING HIS OWN DATA. AN IMMEDIATE REDUCTION IN TESTING AND AN IMPROVEMENT IN COMPONENT QUALITY LEVEL RESULTED. COMPONENT TEST PROCEDURES WERE DEVELOPED, PUBLISHED AND IMPLEMENTED IN-HOUSE AND AT THE SUB-TIER SUPPLIER'S PLANTS.

HARDWARE QUALITY DEFICIENCIES, WHEN POINTED OUT, WERE CORRECTED; HOWEVER, SEVERAL BASIC FUNDAMENTAL SYSTEM DEFICIENCIES REMAINED PREVALENT UNTIL THE NASA 200 SERIES REQUIREMENTS WERE NEGOTIATED INTO THE RL10

CONTRACT. THESE DEFICIENCIES WERE BASIC. SUB-TIER SUPPLIERS WERE NOT REQUIRED TO MEET A MINIMUM QUALITY CONTROL SYSTEM REQUIREMENT ON RL10 PURCHASE ORDERS. THE CONTRACTOR'S TOOL, GAGE AND MEASUREMENT SYSTEMS WERE COMPLETELY INADEQUATE. NUMEROUS TOOLS AND GAGES WERE FOUND, BY THE NASA QUALITY REPRESENTATIVES, WHICH WERE WORN BEYOND THE BLUE PRINT LIMITS. THE RESPONSIBILITY FOR CONTROLLING TOOLS, GAGES AND MEASUREMENT EQUIPMENT WAS DIVIDED, I.E., EVERYONE WAS RESPONSIBLE. TRACEABILITY TO NATIONAL BUREAU OF STANDARDS WAS VERY QUESTIONABLE. IMPLEMENTATION OF NPC 200-2 REQUIREMENTS CORRECTED THIS CONDITION. NASA INTERPRETED THE REQUIREMENTS TO FIX THE RESPONSIBILITY FOR THIS FUNCTION TO THE CONTRACTOR'S "QUALITY ASSURANCE" ORGANIZATION. THESE REQUIREMENTS AND CONTROLS ARE PRESENTLY PASSED DOWN TO THE SUB-TIER SUPPLIER ON THE PURCHASE ORDER QUALITY SYSTEM REQUIREMENT. AN AUTOMATIC IBM CALL-IN SYSTEM WAS DEVELOPED AND IMPLEMENTED FOR ALL MEASUREMENT EQUIPMENT. CALIBRATION IS TRACEABLE TO N.B.S. FOR ALL MEASUREMENT EQUIPMENT IN ACTIVE USE.

FIELD IMPLEMENTATION OF NPC 200-2 AND NPC 250-1 REQUIREMENTS

THE CONTRACTOR FELT THAT NPC 200-2 AND NPC 250-1 WERE TOO GENERAL TO BE INCLUDED AS CONTRACTUAL REQUIREMENTS. HIS PRIMARY CONCERN WAS THE WIDE INTERPRETATION OF THE 200 SERIES CONTRACT REQUIREMENTS BY VARIOUS NASA AND GOVERNMENT PERSONNEL, AND THERE WERE MANY INTERPRETATIONS MADE FOR THE SAME REQUIREMENTS. NASA, YOU SEE, WAS ALSO LEARNING. THE CONTRACTOR FORMULATED TWO PLANS, AN RL10 RELIABILITY PROGRAM PLAN, AND AN RL10 QUALITY PROGRAM PLAN. THESE PLANS HAVE REPLACED NPC 200-2 AND NPC 250-1 IN THE RL10 CONTRACTS. TO ASSURE THAT THE CONTRACTOR'S PLANS MET THE ESSENTIAL ELEMENTS OF THE 200 SERIES REQUIREMENTS, THE R&QA PLANT REPRESENTATIVE REQUIRED TWO COMPLETE CROSS-REFERENCE INDICES. ONE RELATING THE PARAGRAPHS IN NPC 200-2 WITH PARAGRAPHS IN THE CONTRACTOR PLANS. THE OTHER RELATING THE PARAGRAPHS OF THE CONTRACTOR'S PLANS TO THE ACTUAL IMPLEMENTED CONTRACTOR PROCEDURES. THE INDICES PROVIDED NASA WITH AN EASY REFERENCE AND MEANS TO DETERMINE WHICH NASA REQUIREMENTS WERE OMITTED. WE HAVE PROGRESSED STEADILY IN THE AREAS OF RELIABILITY AND QUALITY ASSURANCE ON THE RL10 PROGRAM, BUT WE ARE CONTINUOUSLY STRIVING

TO FIND A "BETTER WAY" TO IMPLEMENT NASA REQUIREMENTS AT THE LOWEST POSSIBLE COST TO THE GOVERNMENT.

THE FOLLOWING NOTED IMPROVEMENTS RESULTED FROM THE IMPLEMENTATION OF NPC 200-2 AND NPC 250-1 REQUIREMENTS INTO THE RL10 CONTRACTS:

THE CONTRACTOR'S SYSTEM FOR CONTROLLING TOOLS, GAGES, AND INSPECTION EQUIPMENT WAS PLACED UNDER THE DIRECT RESPONSIBILITY OF CHIEF OF QUALITY ASSURANCE. PRIOR TO NPC 200-2, THIS WAS A DIVIDED RESPONSIBILITY. INSPECTION GAGES WERE CONTROLLED BY THE QUALITY ASSURANCE ORGANIZATION, AND THE PRODUCTION GAGES WERE CONTROLLED BY THE PRODUCTION DEPARTMENT.

AN AUTOMATIC CALL-IN SYSTEM WAS ESTABLISHED TO CONTROL THE ACCURACY OF TOOLS, GAGES, AND MEASUREMENT EQUIPMENT BASED UPON ACTUAL USAGE (MEASURED WEAR RATES). THIS SYSTEM HAS PROVED SO BENEFICIAL TO THE CONTRACTOR THAT IT WAS ADOPTED THROUGHOUT THE UNITED AIRCRAFT CORPORATION FOR USE IN ALL DIVISIONS ON ALL CONTRACTS, COMMERCIAL AND GOVERNMENT.

FOR THE FIRST TIME IN CORPORATE HISTORY, QUALITY ASSURANCE

SYSTEM REQUIREMENTS WERE PLACED ON THE PURCHASE ORDER TO THE SUB-TIER SUPPLIERS. TWO QUALITY DOCUMENTS WERE FORMULATED, ONE FOR PRIME P&WA CONTRACTOR DESIGNED ARTICLES, AND THE OTHER FOR SUB-TIER SUPPLIER DESIGNED ARTICLES. THESE DOCUMENTS HAVE BEEN ACCEPTED AS CORPORATE-WIDE POLICY, AND ARE PRESENTLY IN USE ON ALL CONTRACTOR (GOVERNMENT AND COMMERCIAL) PROGRAMS. THE SUB-CONTRACTORS ARE CONTINUOUSLY ASSESSED BY VENDOR QUALITY CONTROL REPRESENTATIVES AND ARE AUDITED AT LEAST ONCE PER YEAR FOR COMPLIANCE WITH QA REQUIREMENTS.

PERFORMANCE ACCEPTANCE CRITERIA IS PRESENTLY BASED UPON A VALID STATISTICAL MONTE CARLO PROCEDURE FOR TRIMMING THE ENGINE WITH A 0.20 PERCENT BETA (NASA) RISK OF ACCEPTING AN ENGINE TRIMMED TO THE SPECIFICATION LIMIT. THE METHOD IS FULLY EXPLAINED IN P&WA REPORT FR-457, "A MONTE CARLO ANALYSIS OF RL10 TRIM REQUIREMENTS".

A FORMAL RL10 ROCKET ENGINE QUALITY PROGRAM PLAN WAS FORMULATED AND PUBLISHED FOR THE FIRST TIME IN SEPTEMBER, 1962. THIS DOCUMENT HAS STEADILY IMPROVED THROUGH CONTINUOUS NEGOTIATIONS WITH THE CONTRACTOR. THE LATEST REVISION WAS WRITTEN OCTOBER 28, 1966, AND SUBMITTED WITH THE

PROPOSAL FOR ADVANCED CENTAUR VEHICLE RL10 ENGINES. THIS PLAN WAS SPECIFICALLY WRITTEN FOR THE RL10 PROGRAM. FORMER PRACTICE WAS TO REFER THE P&WA QUALITY CONTROL MANUAL, IN THE CONTRACT, WHICH WAS A VOLUMINOUS DOCUMENT DATING BACK TO THE FIRST AIRCRAFT ENGINE MODEL. TWO SUB-TIER SUPPLIER QUALITY CONTROL SYSTEM DOCUMENTS WERE FORMULATED, PUBLISHED, AND ACCOMPANY EACH RL10 PURCHASE ORDER TO SUB-TIER SUPPLIERS.

A FORMAL RELIABILITY PROGRAM PLAN WAS FORMULATED AND SUCCESSFULLY IMPLEMENTED. THE RELIABILITY PROGRAM REQUIREMENT CREATED A NEWLY FORMED GROUP WHICH BECAME RESPONSIBLE FOR RELIABILITY ASSURANCE DISCIPLINES. A FORMAL RELIABILITY REPORT IS ISSUED EACH MONTH, SUMMARIZING THE TESTING AND PERFORMANCE RESULTS FOR THE RL10 PROGRAM FOR THE CURRENT MONTH. A TYPICAL REPORT SUBMITTED TO NASA IS CONTAINED IN REFERENCE I. REFERENCE II IS A LIST OF FORMAL STATISTICAL TECHNICAL REPORTS WHICH WERE PUBLISHED AS THE DIRECT RESULT OF THE RL10 ENGINE PROGRAM RELIABILITY REQUIREMENTS. A LIMITED QUANTITY OF THESE REPORTS ARE AVAILABLE FOR DISTRIBUTION TO OTHER NASA CENTERS.

I WOULD LIKE TO EMPHASIZE THAT IT IS GOOD MANAGEMENT PRACTICE, FROM A STANDPOINT OF RELIABILITY AND QUALITY ASSURANCE AS WELL AS

ECONOMICS, TO ASSIGN GOVERNMENT RELIABILITY AND QUALITY ASSURANCE ENGINEERING REPRESENTATIVES TO A PRIME PROGRAM, EARLY IN THE DEVELOPMENT STAGE, TO ASSURE THAT PROPER RELIABILITY AND QUALITY SPECIFICATIONS ARE PHASED INTO THE BEGINNING OF A FLIGHT PRODUCTION CYCLE. THIS ACCOMPLISHES THREE SIGNIFICANT FUNCTIONS:

1. ASSURES COMPLETE DOCUMENTATION OF DEVELOPMENT HARDWARE WHICH IS USED TO ESTABLISH PERFORMANCE PARAMETERS FOR FLIGHT HARDWARE

2. ELIMINATES MUCH DUPLICATION OF COSTS AND EFFORT IN REPEATING DEVELOPMENT TESTING BECAUSE OF PROBLEMS ASSOCIATED WITH UNKNOWN CONFIGURATIONS, NON-CONFORMANCES AND SKETCHY DATA WHICH OFTEN PREVAIL DURING THE R&D PHASE

3. ALLOWS THE NASA R&QA PLANT REPRESENTATIVE TO ACCOMPLISH TIMELY AND REALISTIC ADVANCED PLANNING PRIOR TO THE PRODUCTION PHASE. PLANNING FOR THE PROPER TYPE OF DELEGATION, R&QA CONTRACT REQUIREMENTS AND SKILLS REQUIRED FOR THE SUCCESSFUL IMPLEMENTATION OF A NASA R&QA PROGRAM.

SUGGESTIONS FOR ASSURING SUCCESSFUL FIELD IMPLEMENTATION OF NPC 200-2 AND NPC 250-1 REQUIREMENTS

EARLY LONG RANGE PROGRAM PLANNING BY NASA SHOULD INCLUDE DIRECT CONTRIBUTIONS AND FORMAL INPUT BY R&QA PLANT PERSONNEL WHO ARE HARDWARE ORIENTED AS WELL AS PROCEDURAL ORIENTED.

ADVANCED NASA PLANNING FOR DOD DELEGATIONS SHOULD INCLUDE FEEDBACK INPUTS FROM EXPERIENCED R&QA PLANT PERSONNEL FROM NASA AND DOD. THIS ALLOWS ADVANCED PLANNING FOR REALISTIC STAFFING OF RESIDENT R&QA OFFICES. THE QUALITY AND BACKGROUND OF ASSIGNED GOVERNMENT PERSONNEL SHOULD BE GIVEN PRIMARY CONSIDERATION ON NASA PROGRAMS, AND THE QUANTITY SECONDARY CONSIDERATION. ENGINEERS SHOULD BE GIVEN PRIMARY CONSIDERATION FOR NASA RELIABILITY AND QUALITY PLANT REPRESENTATIVE POSITIONS IN AN R&D PLANT AND/OR DELEGATED DOD QUALITY ASSURANCE POSITIONS. A CEILING SHOULD BE PLACED ON STAFFING QUANTITIES IN THE LETTER OF DELEGATION.

CONTRACTOR PREPARED MODEL SPECIFICATIONS SHOULD BE REVIEWED BY NASA R&QA PLANT PERSONNEL PRIOR TO NEGOTIATION INTO NASA CONTRACTS. EXPERIENCED R&QA PERSONNEL HAVE MADE SIGNIFICANT CONTRIBUTIONS TO THESE DOCUMENTS ON THE RL10 PROGRAM. THIS ASSURES A REALISTIC, WORKABLE

SPECIFICATION WITH A MINIMUM AMOUNT OF PERTURBATIONS IN THE FLIGHT PRODUCTION PHASE. IN ADDITION, ANY CONFLICTS BETWEEN THE "MODEL SPECIFICATION" AND THE R&QA REQUIREMENTS COULD BE PREVENTED BEFORE THE CONTRACT IS NEGOTIATED.

MONTHLY QUALITY AND RELIABILITY STATUS REPORTING REQUIRED BY NPC 200-2/250-1 SHOULD INCLUDE SAMPLE FORMATS. THE RL10 PROGRAM HAS EXPERIENCED NUMEROUS INTERPRETATIONS AS TO WHAT CONSTITUTES A GOOD "STATUS REPORT" FROM ALL NASA LEVELS AND DOD LEVELS, RANGING FROM ONE PAGE TO TEN POUNDS.

ESTABLISH A CROSS-REFERENCE INDEX BETWEEN NPC 200 SERIES REQUIREMENTS AND THE CONTRACTOR'S PROCEDURES WHICH IMPLEMENT THESE REQUIREMENTS.

WEIGH THE ESSENTIAL R&QA ELEMENTS AGAINST THE "NICETIES" WHEN TRADE OFFS ARE REQUIRED BY PROGRAM MANAGEMENT. TRADE OFF THE "NICETIES"!! DON'T REQUIRE R&QA REPORTS WHICH ARE NOT READ AND NOT USEFUL. NASA RECEIVES NO BENEFIT, THE TAXPAYER RECEIVES NO BENEFIT, AND EVENTUALLY THE PROGRAM SUFFERS.

REFERENCE I

SIGNIFICANT CONTRACTOR PREPARED DOCUMENTS RESULTING FROM NPC 200-3/250-1 IMPLEMENTATION ON THE RL10 PROGRAM

PRATT & WHITNEY AIRCRAFT FR NUMBER	TITLE
705	RL10 ROCKET ENGINE RELIABILITY PROGRAM
694	RL10 ROCKET ENGINE QUALITY PROGRAM PLAN
2100	RL10 ROCKET ENGINE MONTHLY TECHNICAL REPORT SECTION V "RELIABILITY ASSESSMENT & FIRING SUMMARY FOR RL10 ENGINES."
NO NUMBER	RL10 MONTHLY QUALITY STATUS REPORT
NO NUMBER	RL10 QUARTERLY SUMMARY OF AUDIT
597	RL10 END ITEM TEST & INSPECTION PROCEDURE
497	RL10 END ITEM TEST PLAN
QA6064	SUPPLIER QUALITY CONTROL REQUIREMENTS FOR P&WA DESIGNED PRODUCT ARTICLES
QA6068	QUALITY CONTROL REQUIREMENTS FOR VENDOR FURNISHED INFORMATION PARTS

REFERENCE II

STATISTICAL PUBLICATIONS

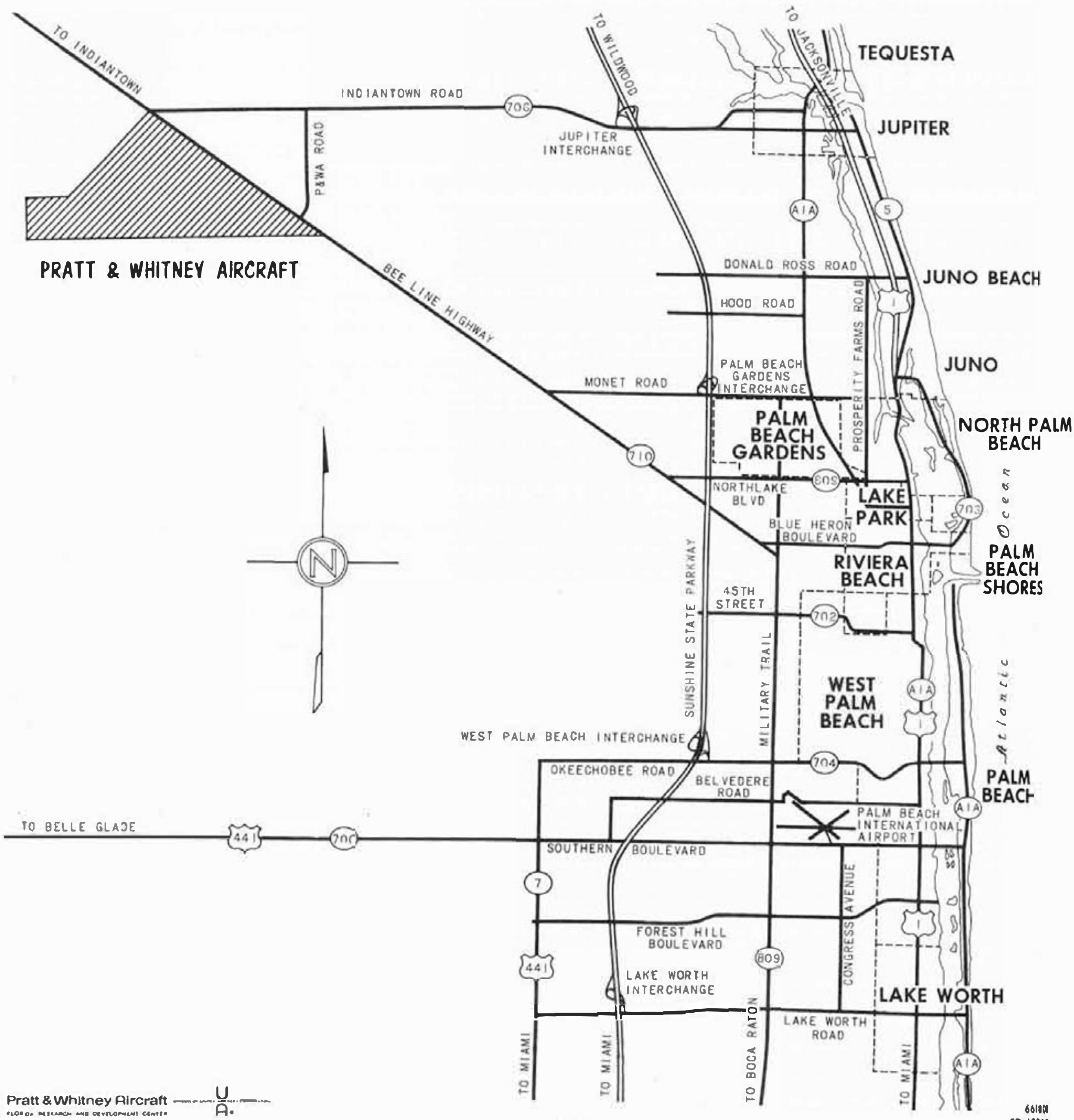
RESULTING FROM THE RL10 ENGINE PROGRAM

P&WA NO.	TITLE	AUTHOR	DATE
FR-413	Prediction of LH Storage Requirements	Harrison	5-18-62
FR-457	Monte Carlo Analysis of RL10 Engine Trim Requirements	Harrison	5-10-62
FR-479A	Parallel vs. Series Redundancy Effects on the Reliability of Rocket Propulsion Systems	Abernethy & Nickle	8-14-62
FR-578A	RL10A-3 Engine Inherent Reliability and Failure Mode and Effect Analysis	Abernethy	8-12-63
FR-743	Precision of RL10 Monthly Reliability	Abernethy	7-8-63
FR-764	RL10 Reliability for a Two-Start Mission	Abernethy	8-9-63
FR-781	One-Sided Statistical Tolerance Factors	Nickle	8-26-63
FR-799	Precision of Reliability Based on Small Sample Sizes	Harrison	
FR-1896A	A Novel Application of Least Squares to Improve Precision	Colbert	5-20-66
FR-1993	Use of Partial Derivatives in Variation Analysis	Colbert	8-1-66

REFERENCE III

FIGURE 1

LOCATION OF PRATT & WHITNEY AIRCRAFT
FLORIDA RESEARCH & DEVELOPMENT CENTER
NASA/LeRC P&WA RESIDENT MANAGEMENT OFFICE



Pratt & Whitney Aircraft
FLORIDA RESEARCH AND DEVELOPMENT CENTER

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FIGURE 2

FLORIDA RESEARCH & DEVELOPMENT CENTER
MANUFACTURING BUILDING

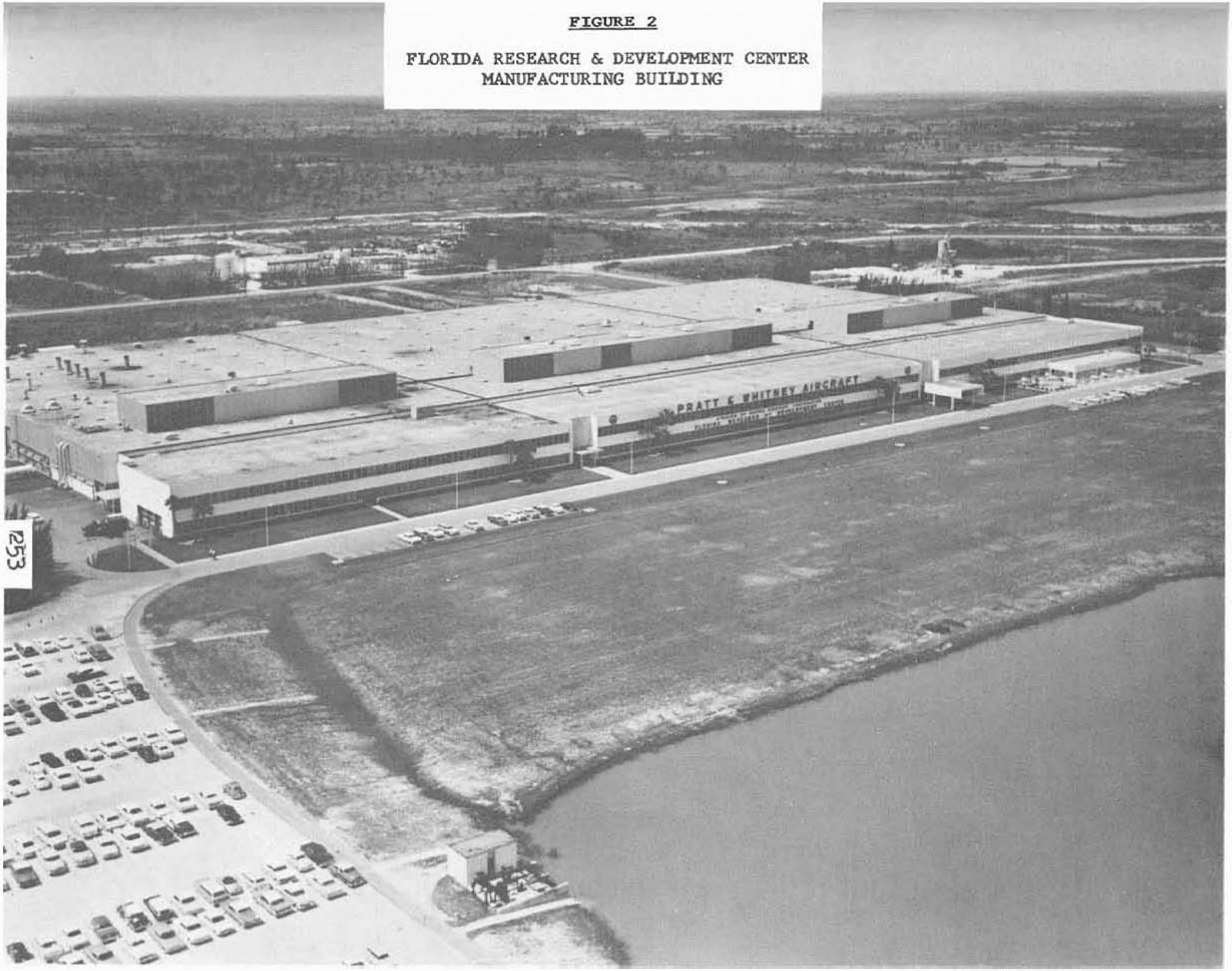


FIGURE 3

Florida Research and Development Center Facilties

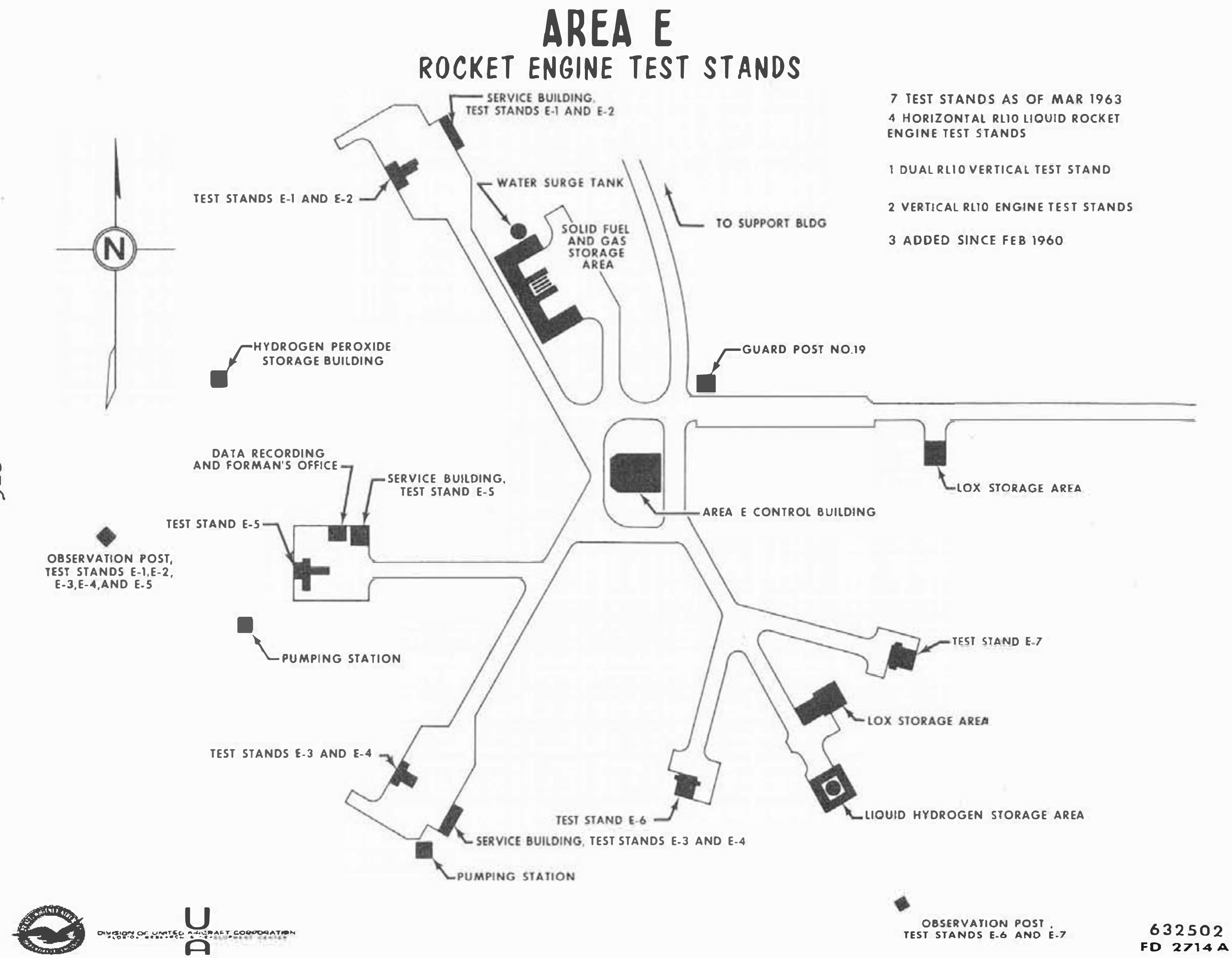
Manufacturing Floor Space - sq ft	506,000
Office Area - sq ft	211,000
Test Floor Area - sq ft	330,000
Total Floor Area - sq ft	1,047,000

Test Stands	Engine	Component
Turbojet	9	38
Rocket	9	53

FIGURE 4

AERIAL VIEW OF RL10 ROCKET ENGINE
FULL SCALE TEST FACILITIES

FIGURE 5


AREA E
ROCKET ENGINE TEST STANDS
7 TEST STANDS AS OF MAR 1963
4 HORIZONTAL RL10 LIQUID ROCKET ENGINE TEST STANDS
1 DUAL RL10 VERTICAL TEST STAND
2 VERTICAL RL10 ENGINE TEST STANDS
3 ADDED SINCE FEB 1960
SERVICE BUILDING, TEST STANDS E-1 AND E-2
TEST STANDS E-1 AND E-2
WATER SURGE TANK
SOLID FUEL AND GAS STORAGE AREA
TO SUPPORT BLDG
N
HYDROGEN PEROXIDE STORAGE BUILDING
GUARD POST NO.19
DATA RECORDING AND FORMAN'S OFFICE
SERVICE BUILDING, TEST STAND E-5
LOX STORAGE AREA
AREA E CONTROL BUILDING
TEST STAND E-5
OBSERVATION POST, TEST STANDS E-1, E-2, E-3, E-4, AND E-5
PUMPING STATION
TEST STAND E-7
LOX STORAGE AREA
TEST STANDS E-3 AND E-4
TEST STAND E-6
LIQUID HYDROGEN STORAGE AREA
SERVICE BUILDING, TEST STANDS E-3 AND E-4
PUMPING STATION
OBSERVATION POST, TEST STANDS E-6 AND E-7
DIVISION OF UNITED AIRCRAFT CORPORATION
632502
FD 2714 A

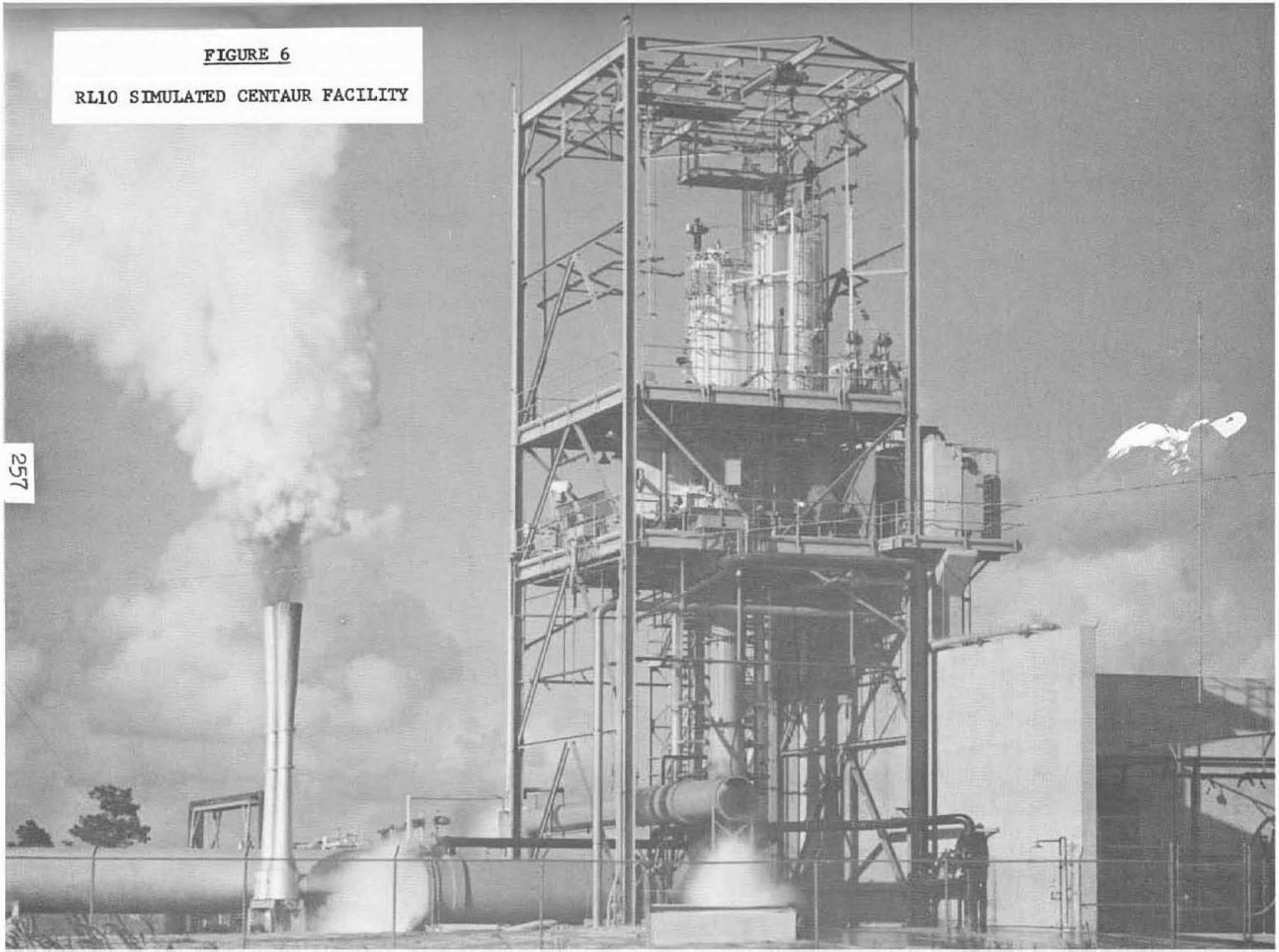


FIGURE 6

RL10 SIMULATED CENTAUR FACILITY

FIGURE 7

PHOTOGRAPH OF RL10A-3-3 ENGINE

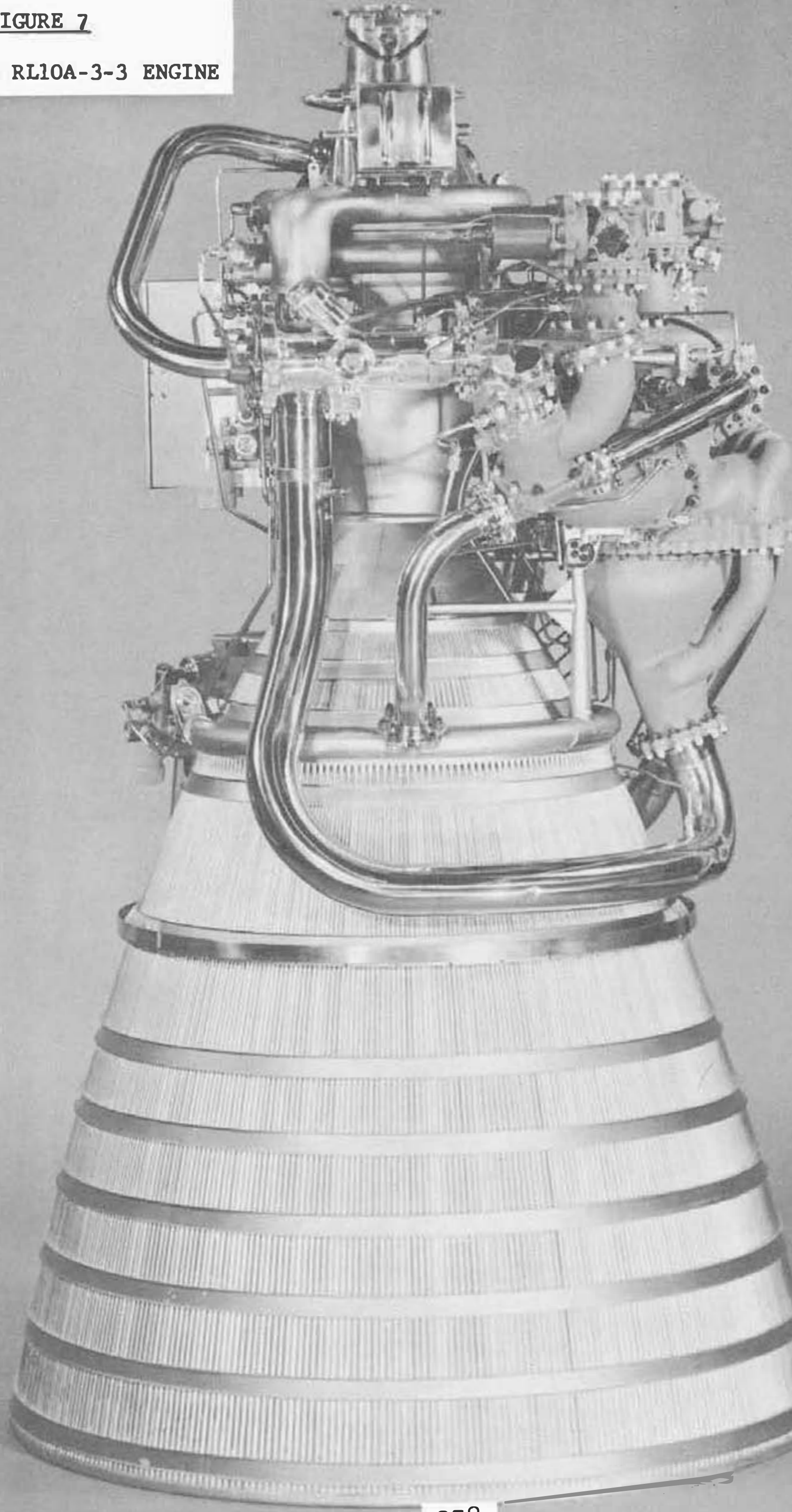
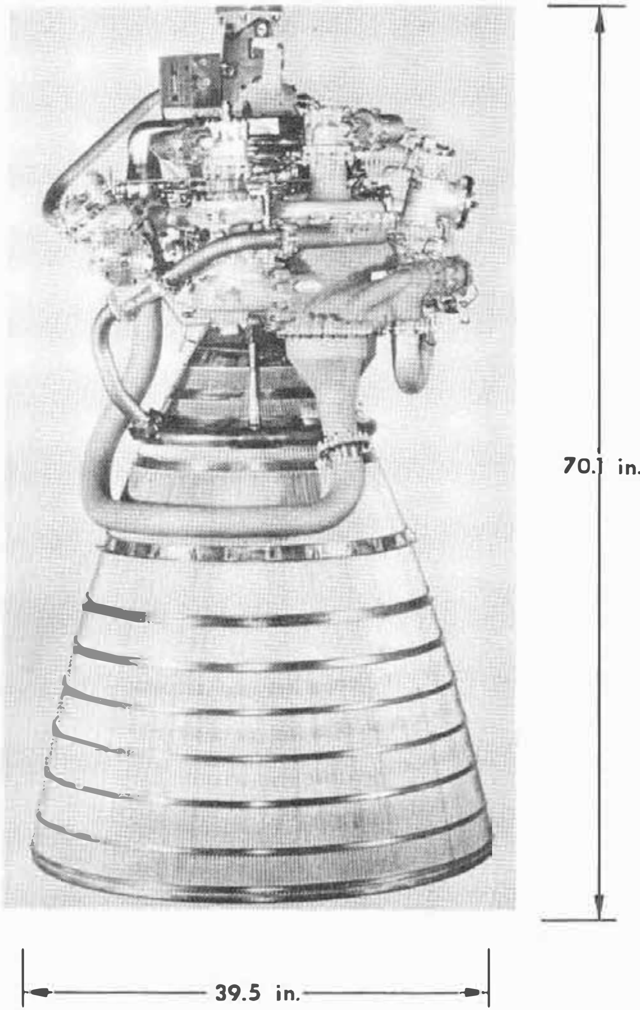


FIGURE 8

RL10A-3-3 PERFORMANCE CHARACTERISTICS

RL10A-3-3 Performance Characteristics



Vacuum Thrust, lb	15,000
Nominal Vacuum Specific Impulse, sec	444
Expansion Ratio	57
Thrust to Weight Ratio	52
Mixture Ratio	5
Restarts	Minimum 3
Weight, lb	290
Service Life, sec	4,000

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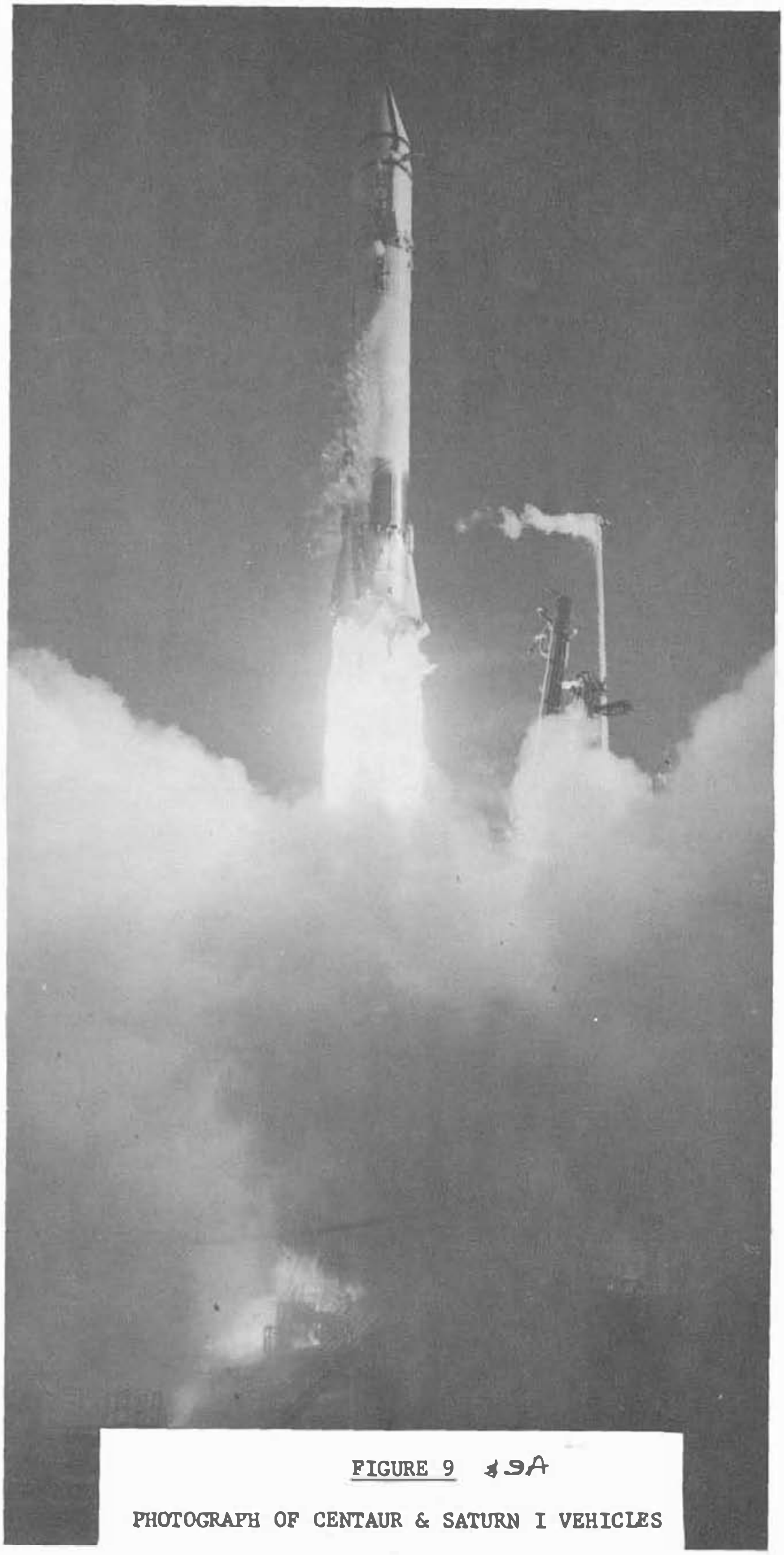

FIGURE 9 ~~1~~9A

PHOTOGRAPH OF CENTAUR & SATURN I VEHICLES

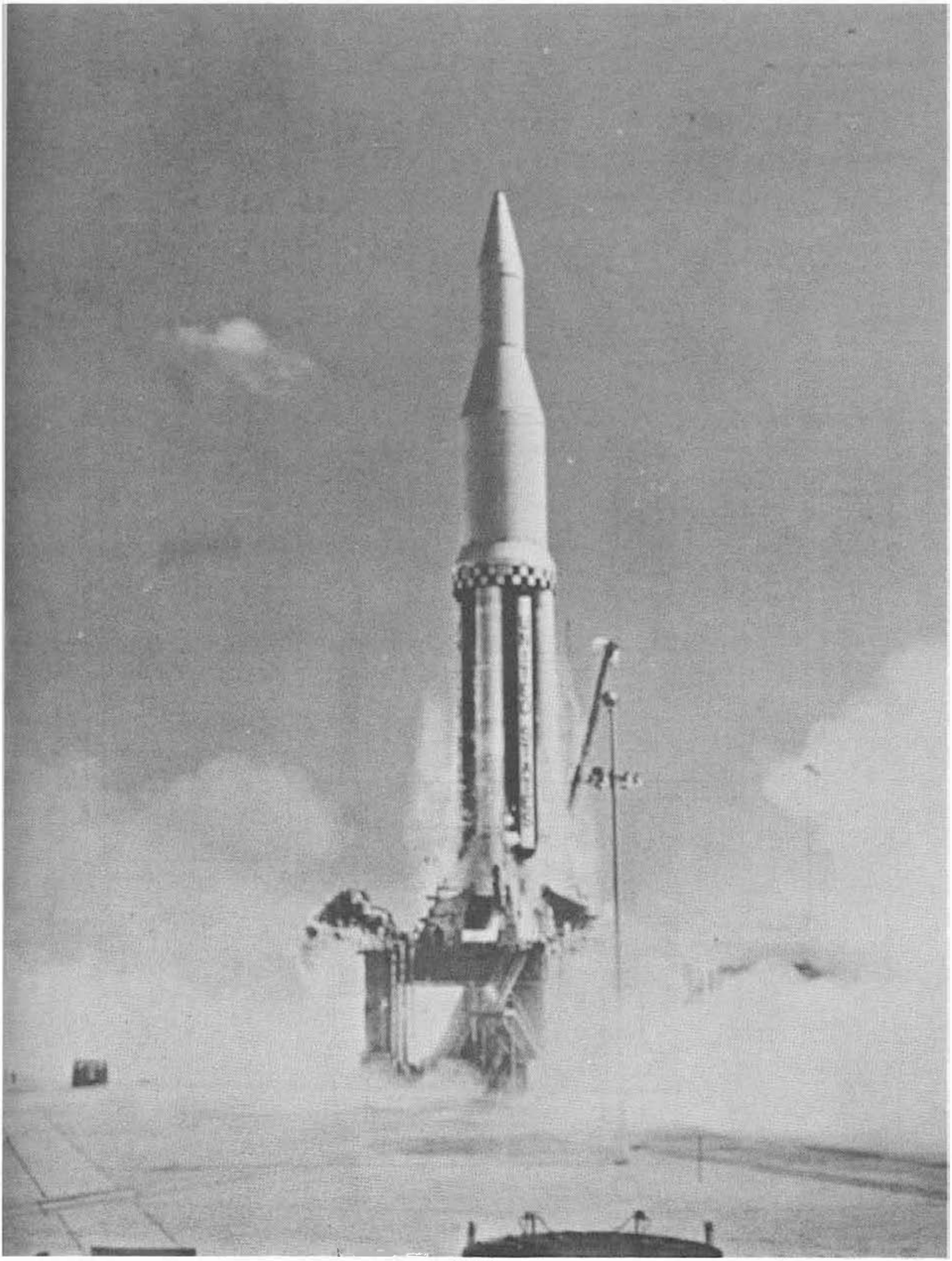

FIGURE 10

RL10 FLOW SCHEMATIC

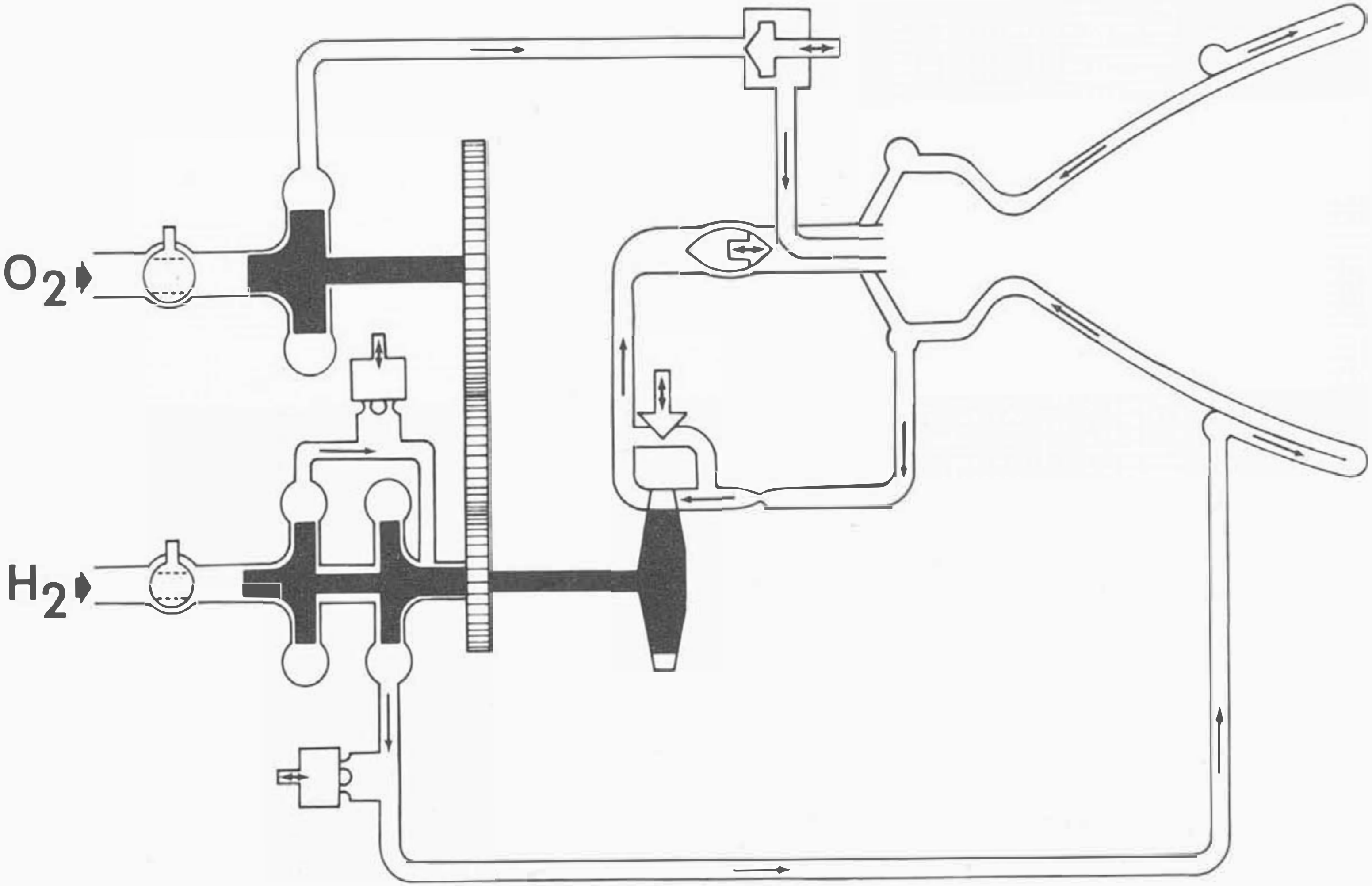

FIGURE 11

RL10 PERFORMANCE HISTORY

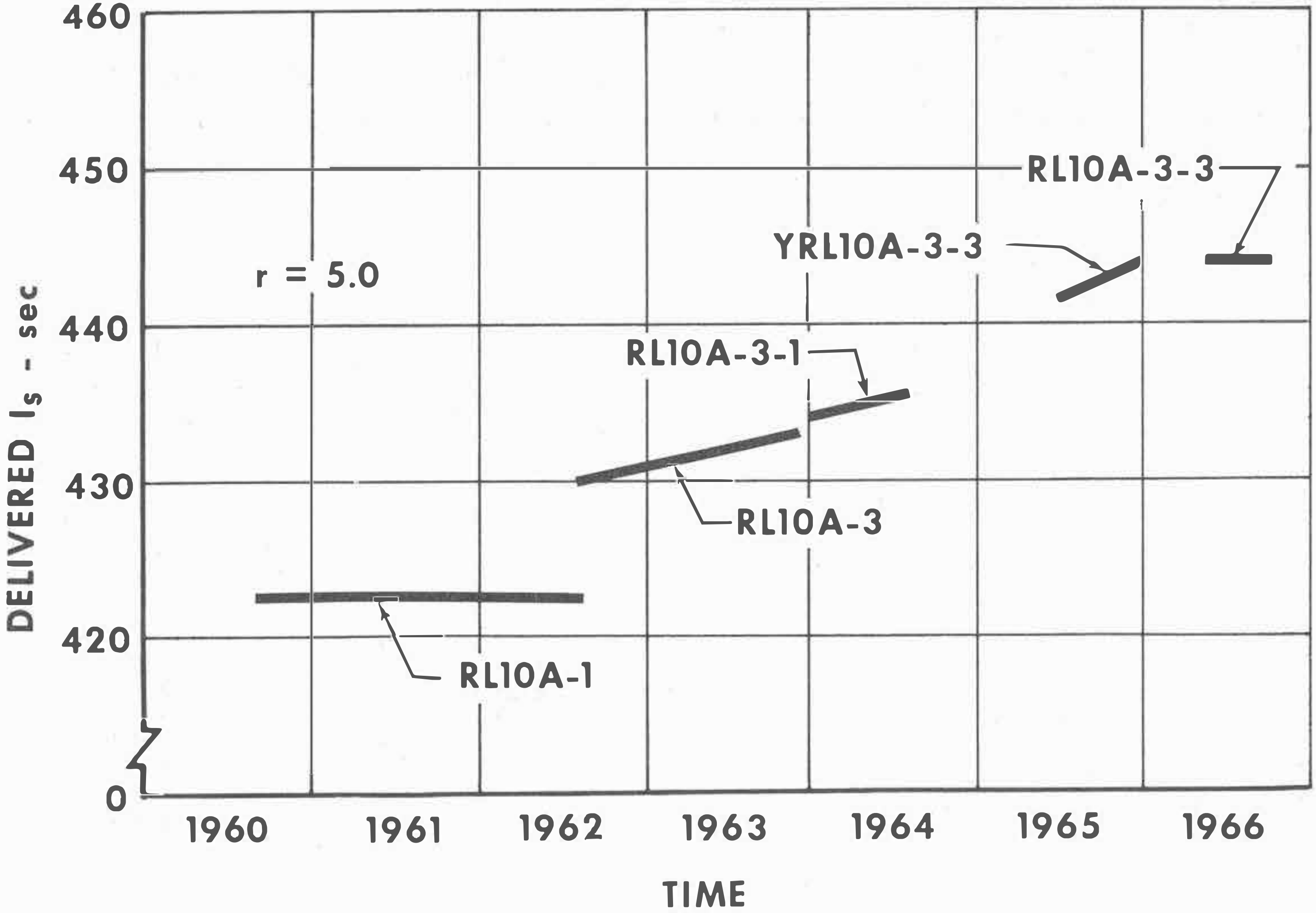

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FIGURE 12

RL10 RELIABILITY ESTIMATES

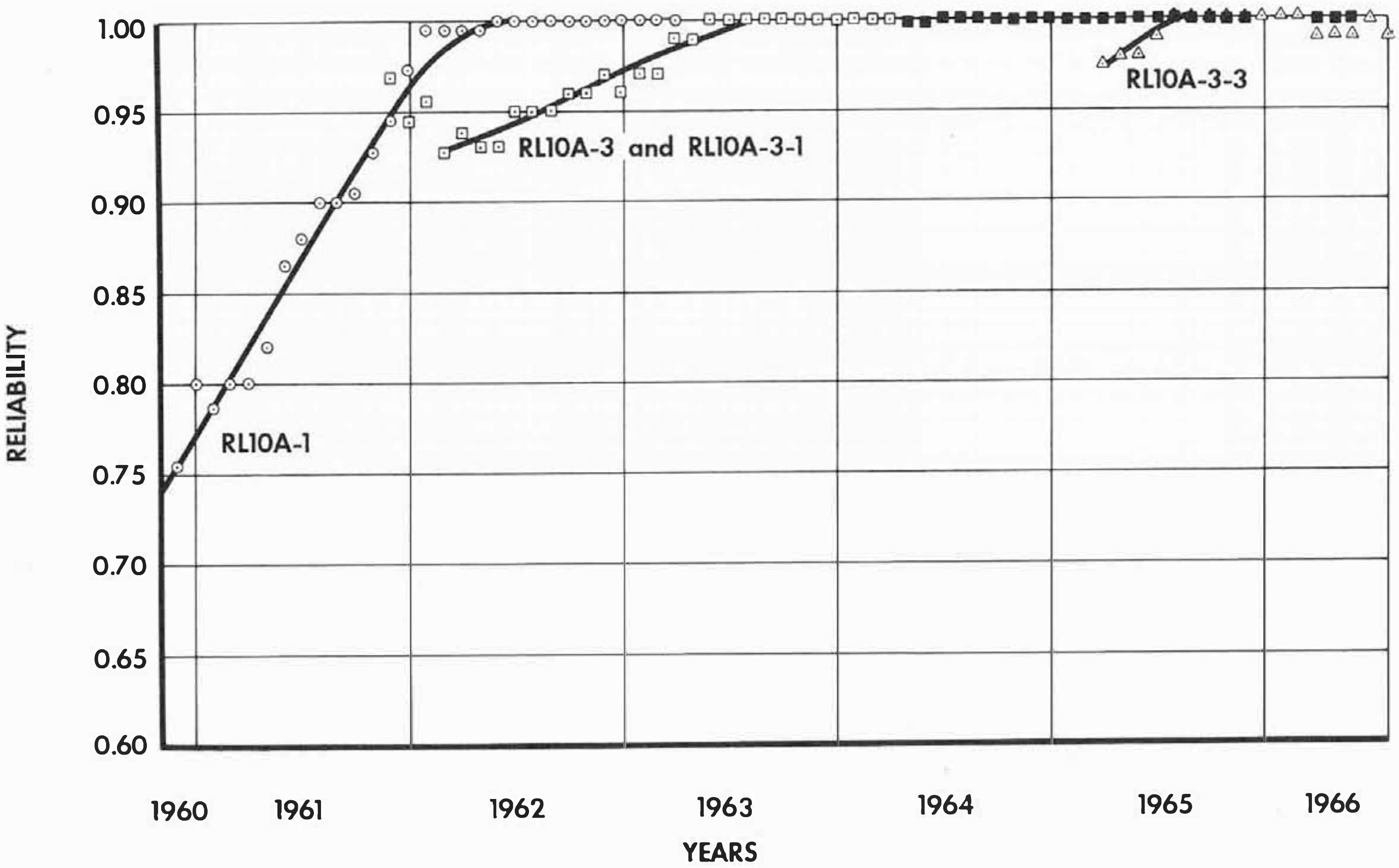

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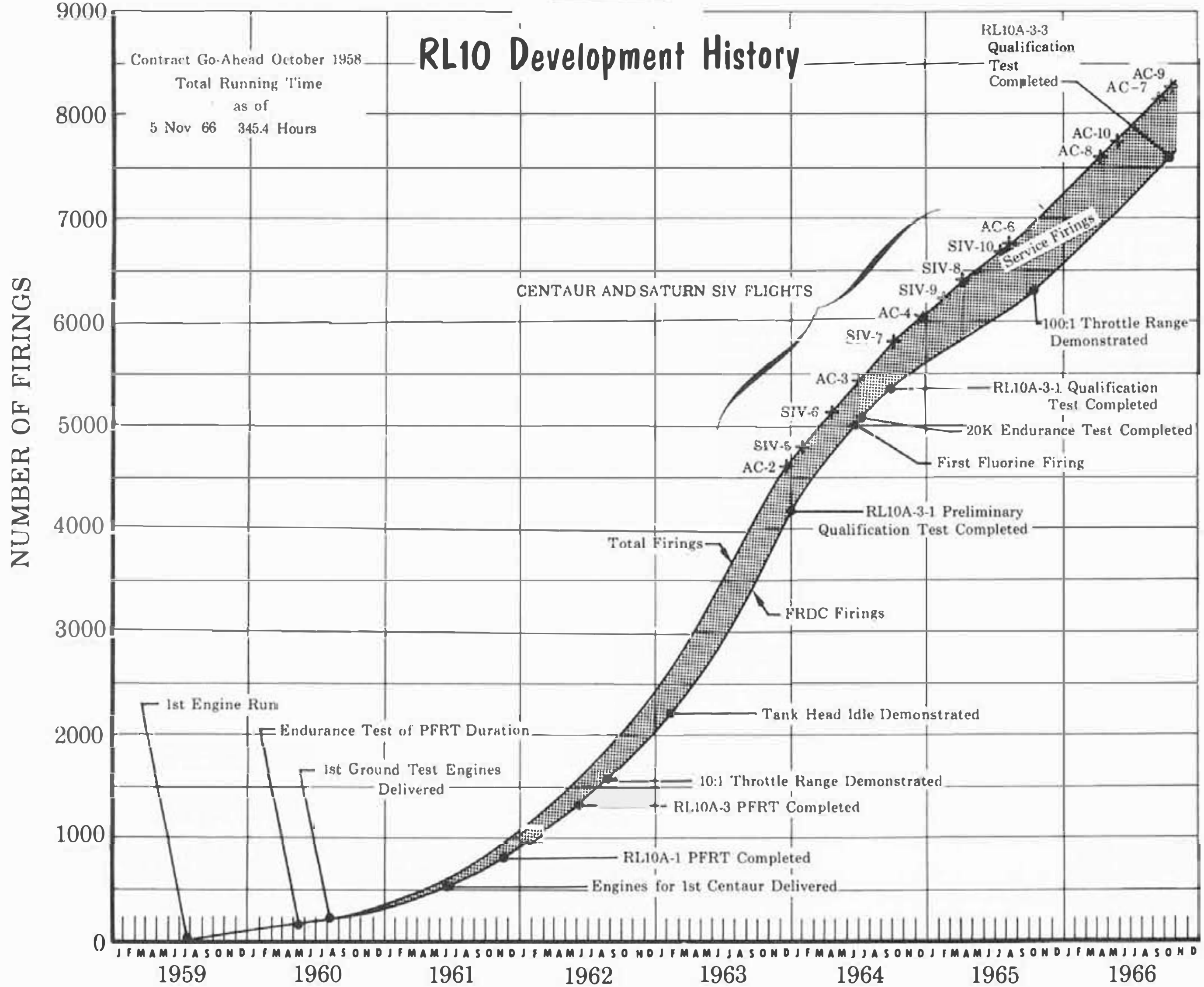
FIGURE 13



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FLORIDA RESEARCH AND DEVELOPMENT CENTER

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FIGURE 14

RL ENGINE PROGRAM RELIABILITY AND QUALITY ASSURANCE CONTRACT REQUIREMENT HISTORY

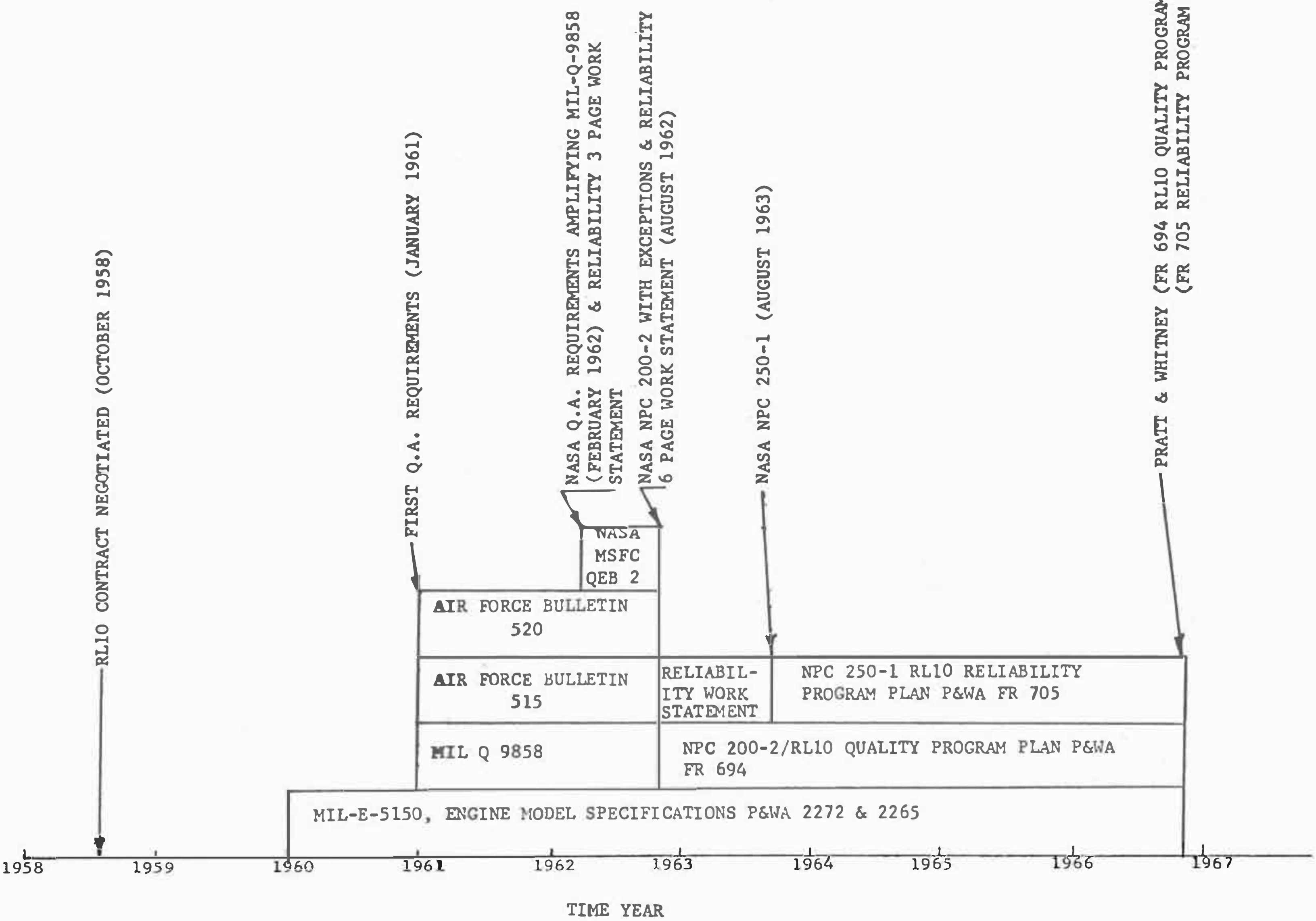
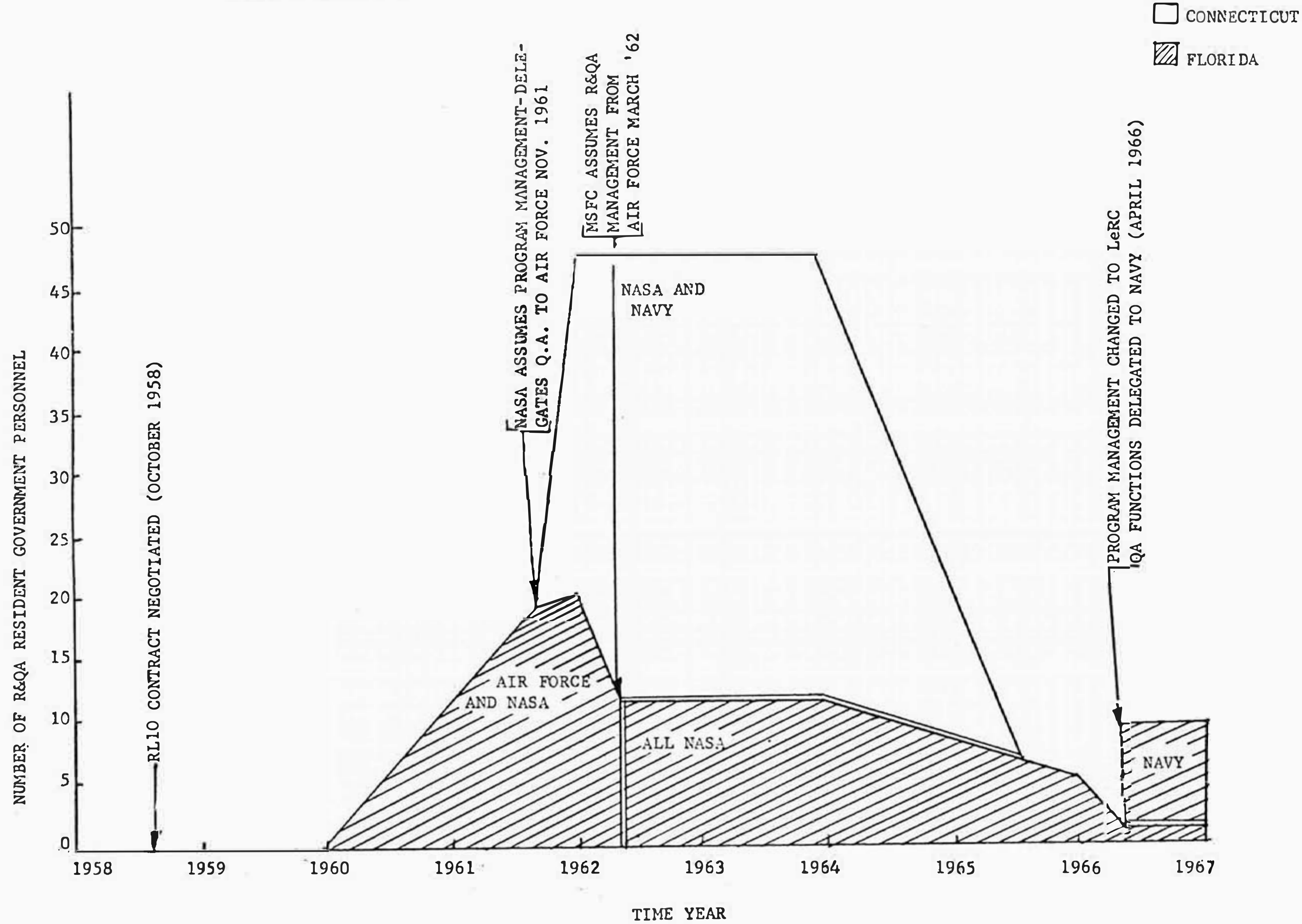


FIGURE 15
RL10 ENGINE PROGRAM R&QA RESIDENT PERSONNEL STAFFING
PRATT & WHITNEY FLORIDA AND CONNECTICUT OPERATIONS



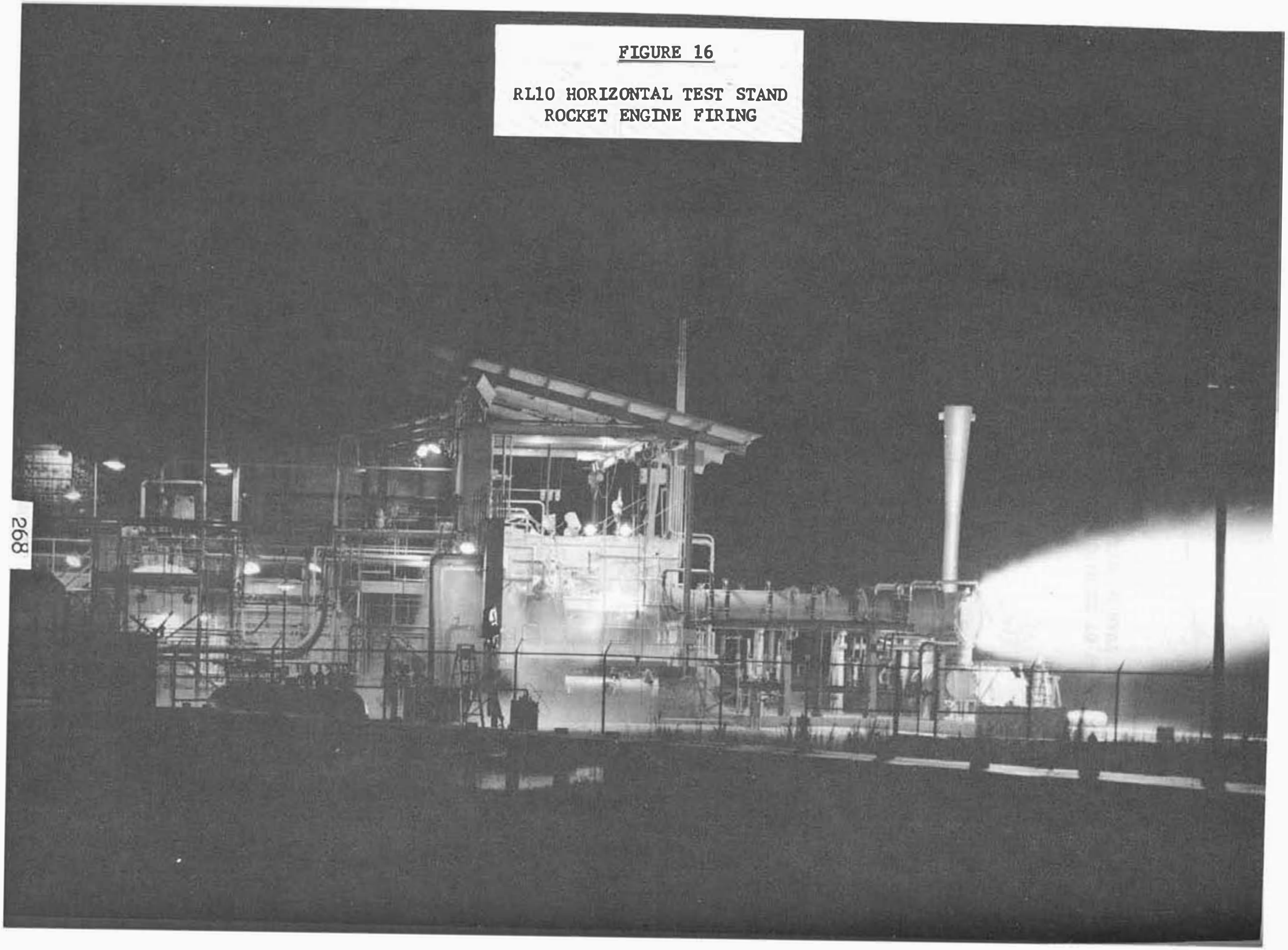
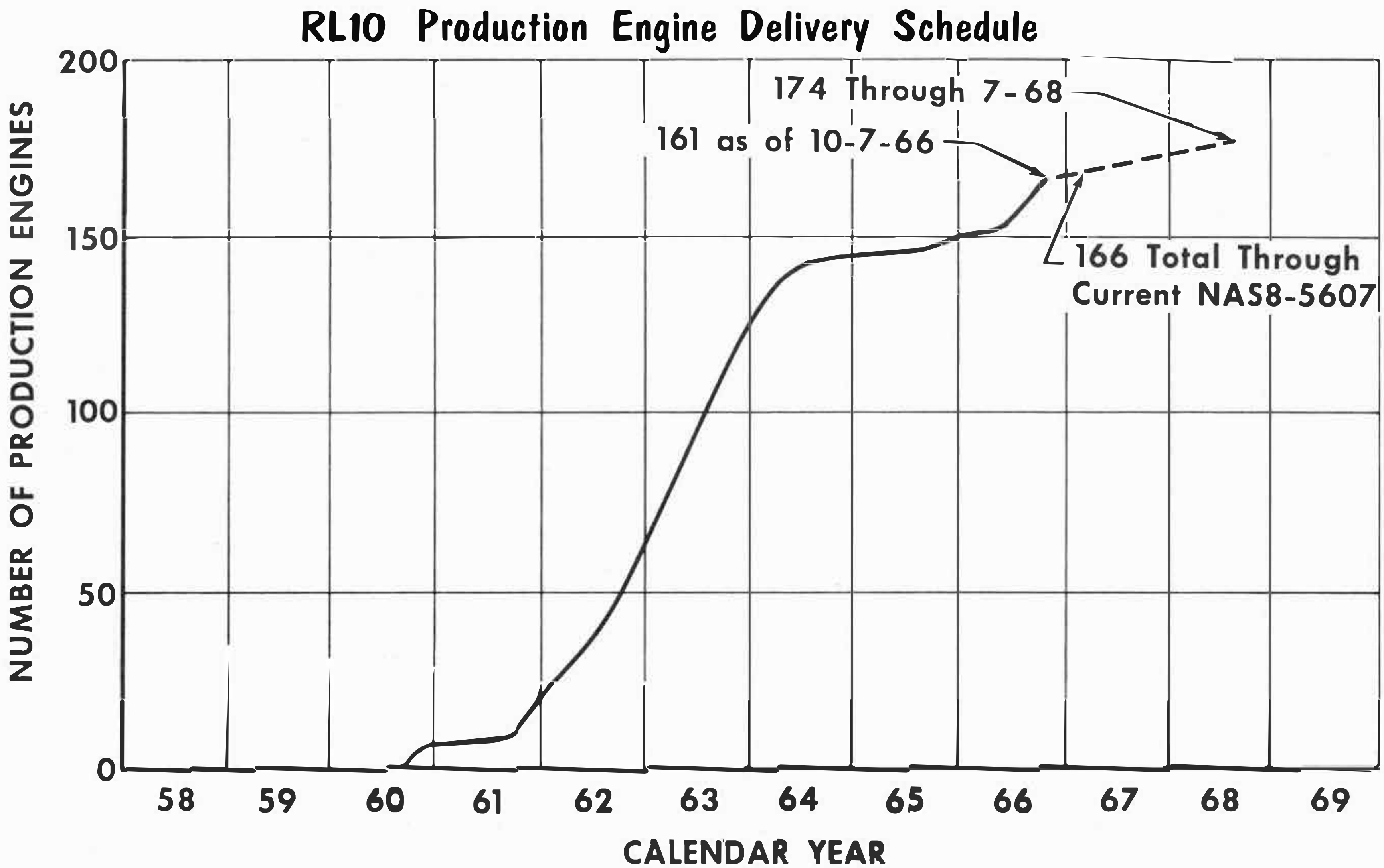


FIGURE 16

RL10 HORIZONTAL TEST STAND
ROCKET ENGINE FIRING

FIGURE 17



Pratt & Whitney Aircraft DIVISION OF UNITED AIRCRAFT CORPORATION
FLORIDA RESEARCH AND DEVELOPMENT CENTER

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GS 2662 A

FIGURE 18

RL10 THRUST CHAMBER

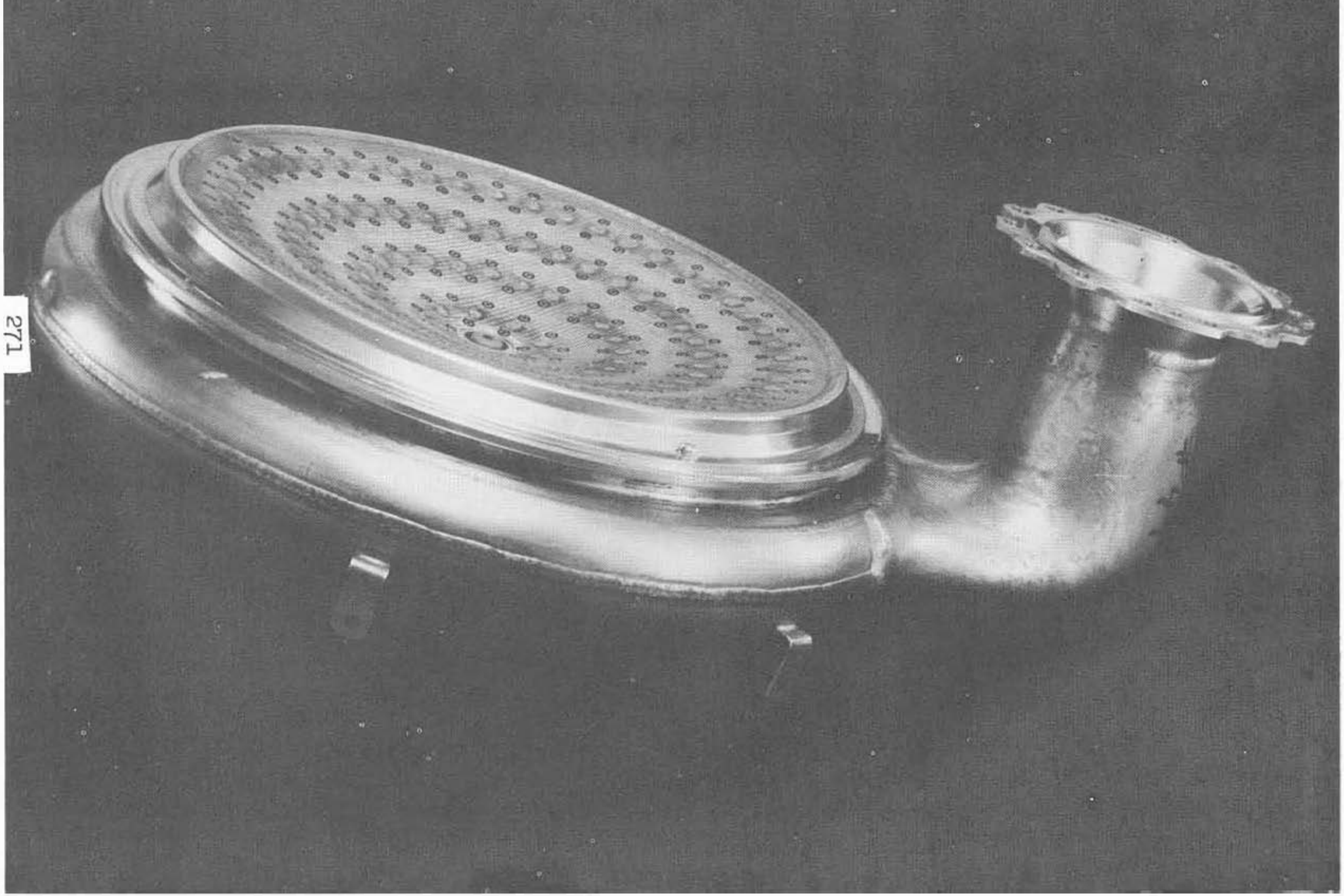


FIGURE 19

RL10 INJECTOR

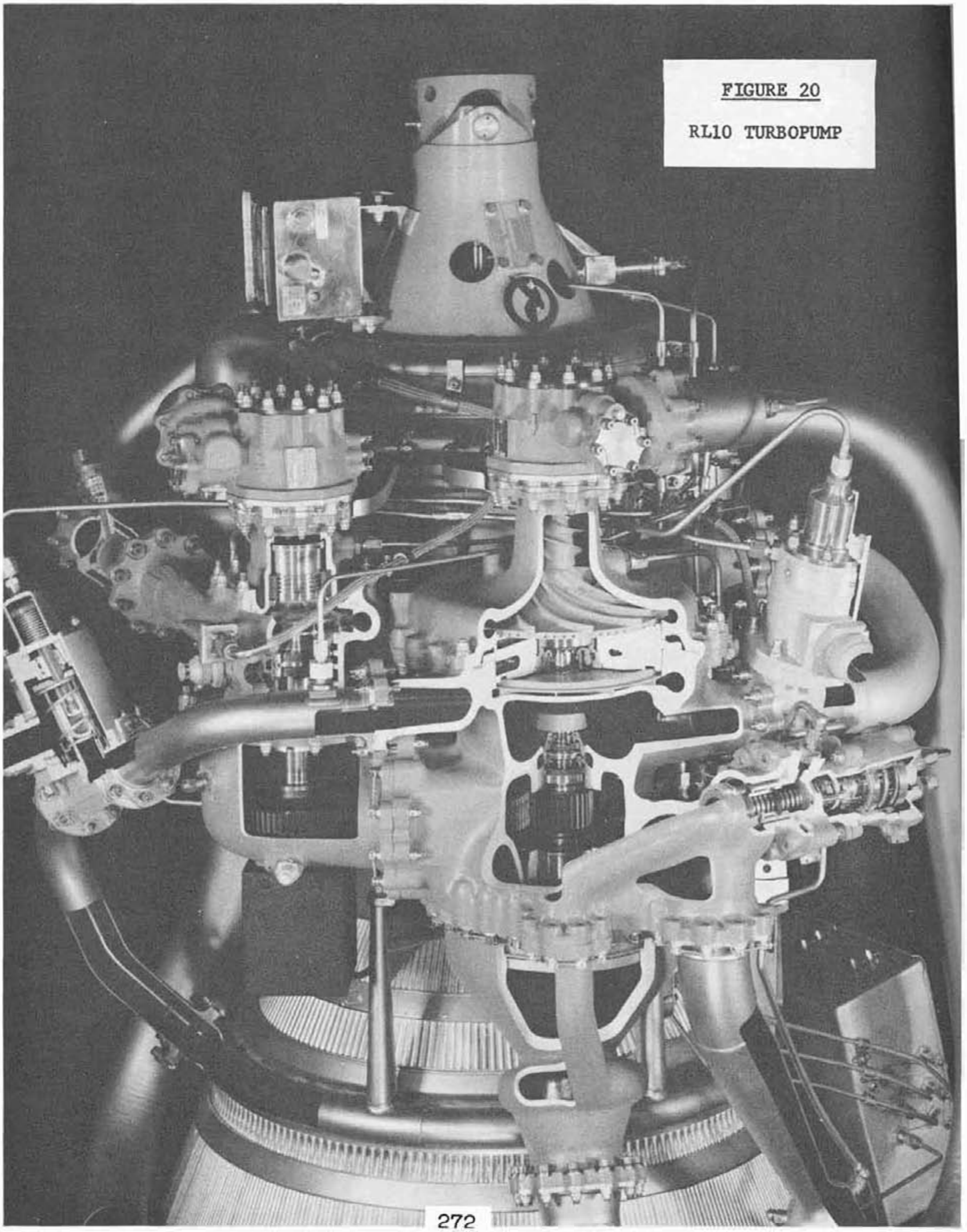


FIGURE 20

RL10 TURBOPUMP

LYLE CURRAN
NASA-O, Downey,
Calif.

UTILIZATION OF NASA-O QUALITY DATA

In July 1964 the NASA Office, Downey, implemented a Quality Data System to identify quality problems by type and organizational location. Although the system proved valuable in identifying quality problems and assisting in the management of resources, it's full value was not realized until January 1966 when the data derived from the system was used as a basis for a joint contractor/NASA quality assessment activity in identified problem areas. Today I will describe those points of our data system which contribute to the quality assessment activity. Then I will cover in detail the procedures used and the results attained by the assessment group, as you may also find this device a helpful supplement to a normal corrective action program.

The Quality Data System is based on a series of codes that identify inspection control points (ICP's) by program, organizational element, manufacturing area, and activity, including the use of standard defect characteristics.

Flow charts identified to the flow of hardware are prepared to cover all phases of the contractor's activity (Figure 1). This chart is typical for the electrical and GSE activity on the Apollo Command and Service Module Program. Nonconformances which are discovered are identified by defect code against the individual inspection control point. For example, nonconformances discovered in the area engaged in wire harness assemblies would be written up against Inspection Control Point AE 1.5. Information derived from the quality assurance inspections is collected daily, processed by computer, and analyzed on a monthly basis. Problem areas are identified by characteristic and by location.

One breakdown of nonconformances identifies the characteristics causing the problems (Figure 2). Documentation nonconformances accounted for 17.3% of the total nonconformances written by our Apollo Quality Assurance Division during one month, with installation and fit a close second with 15.9%. As you can see, most of these were written in the AE Branch which covers Flight Electronics and GSE Assembly & Test. Also note that 653 out of the total of 990 nonconformances of the Division were also written within this Branch.

Another breakdown of the quality data (Figure 3) indicates 31.7% of the total nonconformances were written within one of the inspection control points of the Branch, AE 5.8. Notice that most of these non-conformances are hardware oriented. The data reflected in this chart was used as the basis for the first Quality Assessment Team effort which I will describe this afternoon.

Although our Quality Data System provided a basis for corrective action from inception, it's effectiveness was restricted because of the lack of contractor acceptance of the data and the consequent lack of corrective action. However, in late 1965 the Office of Manned Space Flight headed an MSC/MSFC installation survey of the contractor's activities. Quality data from our system was utilized by this team to reflect their dissatisfaction with the contractor's quality program to the top management. Needless to say, from that point on, we had the contractor's attention. As a result of several subsequent changes in the contractor's Quality organization, they became interested in the data produced by our Quality Data System and were very concerned over the high number of nonconformances which were written every month by the Government. I would like to stress that before you undertake an effort of this type -- obtain the support of the contractor's top management.

The contractor agreed to participate in a joint assessment activity in an area or activity designated as having the most NASA nonconformances for the month. Representation on the committee was to consist of a Government Quality Assurance Representative, a contractor's Quality Assurance Representative, and a representative of the contractor's manufacturing and engineering departments. It was soon discovered that the manufacturing and engineering representatives contributed the most to the assessment committee -- they were in a position to take immediate action to eliminate the causes of nonconformances. Manufacturing and engineering personnel should definitely be a part of any assessment team.

The assessment team was given instructions to examine in detail each of the nonconformances written by the Government and contractor's inspection personnel in the designated area during the preceding thirty day period. They were asked to "call the shots as they saw them", that is, if the Government squawks appeared to be nitpicking, they were told to identify them as such. The manufacturing and engineering personnel were also instructed to raise their voices over any inequities in the nonconformances written up by contractor's Quality Control during this period. The review disclosed that 409 nonconformances were written in the area covered by ICP AE 5.8 for the preceding thirty day period.

The next chart (Figure 4) shows the breakdown of these nonconformances. Out of the total of 409, 305 nonconformances were written against hardware.

I am sure you have all heard it said many times that most Government squawks or nonconformances are directed toward paper-type defects. This was not the case in this instance as you will observe that 84% of the Government squawks were written against hardware. Less than 10% of both the contractor and Government nonconformances were identified as software problems during this particular period.

The combined Company and Government distribution of nonconformances by characteristic is shown on the next chart (Figure 5). You can see that over 50% of the total squawks were concerned with wire harness installations and identification. Detailed review of these nonconformances resulted in a determination of the cause and assignment of quality assessment actions which are reflected on the next chart (Figure 6).

A large number of nonconformances attributable to identification were found to result from a material and processing problem. Changes were made in the specification and new sleeving material was purchased.

It was determined that additional visual aids or quality standards were required to give everyone a better understanding of the requirements for wire harness installation and visual evidence of electrical, mechanical and soldering practices. These aids were provided in manuals for distribution to each supervisor and lead man and to the S&ID inspectors and the Government inspectors. Enlarged individual reproductions of these standards were displayed in the work area.

In addition, large discrepancy trend charts were displayed at the end of each work bench showing the trend of S&ID and NASA nonconformances for each position. These discrepant trend charts were identified to manufacturing lead men.

Finally, Quality Robber Bulletins listing two or three squawks requiring immediate attention were posted throughout the area.

At the beginning of calendar year 1966 there were over 200 nonconformances written by Government in the ICP area which was covered by the assessment team. As a result of the actions taken by this team, there has been a continuous downward trend in nonconformances, reaching a low of 26 during the month of September 1966 (Figure 7).

The next chart (Figure 8) shows a reduction in the number of squawks on very complex harnesses which are fabricated in the area. It is interesting to note that during the period when the squawks or nonconformances were being reduced for very complex harnesses, there was also a tremendous reduction in the manufacturing effort which went from a total of 69,000 hours on one of the early compartment harnesses, down to a total of 11,000 hours on the most recent harness assemblies fabricated. This indicates that the learning curve can be very sharp at the same time the quality is being upgraded.

The actions taken by the assessment team are not restricted to the particular area under survey. Matrixes are prepared and action is taken by the contractor on a plant-wide basis in any area where a particular defect might recur.

As a result, corresponding reductions in defects occurred throughout all departments supporting the Apollo Command & Service Module Program (Figure 9). I am confident that the assessment activity played a major role in this improvement in hardware quality.

Many of you probably share my usual opinion of a committee being formed to get results -- in most cases the end result turns out to be the legendary definition of a camel--a horse designed by a committee. Experience in this instance has shown the committee approach to be effective. Why? .....Because it allowed joint participation on an equal basis by Government and contractor. It also gave manufacturing and engineering an opportunity to be heard, and be a part of quality improvement.

Activity of this type should not take the place of normal day-to-day corrective actions. It should supplement the normal corrective action program in identifiable hardware problem areas with benefits applied across-the-board.

ELECTRICAL & GSE BRANCH

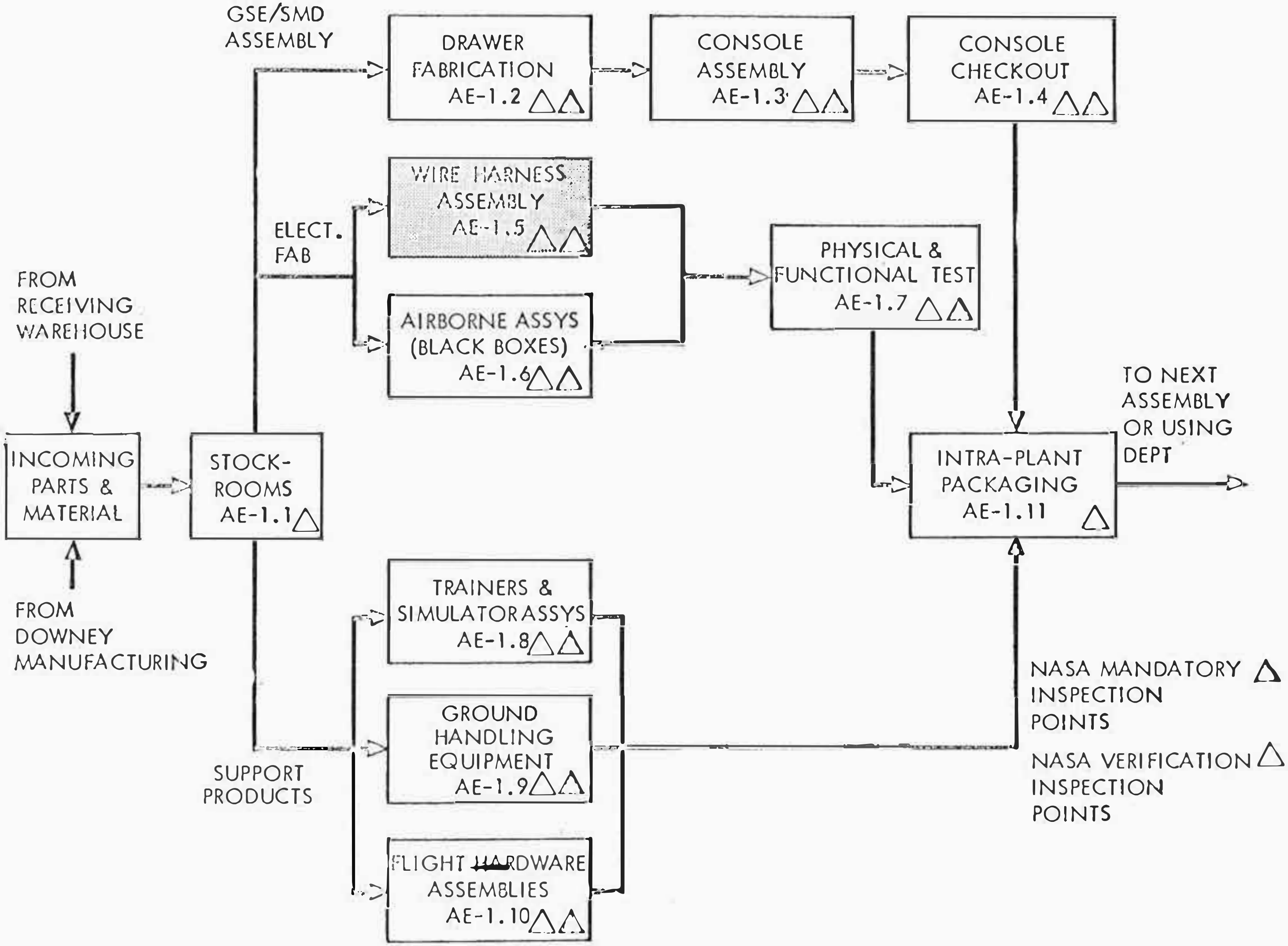


FIGURE 1

APOLLO
DISTRIBUTION OF NONCONFORMANCES

NOVEMBER 1965

NO.	CHARACTERISTIC	BRANCH AE	AS	AT	TOTAL	% OF TOTAL
1	DOCUMENTATION	107	17	48	172	17.3
19	INSTALLATION & FIT	122	1	34	157	15.9
3	IDENTIFICATION	76	7	17	100	10.1
13	SOLDERING	83	-	3	86	8.7
20	FUNCTIONAL TEST	25	1	39	65	6.6
2	CONFIGURATION	53	5	6	64	6.6
6	CRIMPING	45	1	6	52	5.2
11	DAMAGE	36	7	6	49	4.9
25	ELECTRICAL	25	-	23	48	4.9
12	BONDING	10	27	-	37	3.7
5	DIMENSIONS	18	4	5	27	2.7
	ALL OTHERS	53	34	46	133	13.4
	TOTAL	653	104	233	990	100.0

FIGURE 2

APOLLO
NONCONFORMANCES BY ICP

NOVEMBER 1965

FIVE AREAS WITH HIGHEST NUMBER OF NONCONFORMANCES

ICP NO.	AREA	NO. NONCONF	% OF TOTAL NONCONF	CHARACTERISTICS	
AE-5.8	FLIGHT HARNESS FOR SPACECRAFT D/668	207	31.7	INSTALL & FIT	(49)
				CRIMPING	(39)
				IDENTIFICATION	(36)
				SOLDERING	(16)
				DIMENSIONS	(14)
AE-5.4	ASSY, MECHANICAL	143	21,8	DOCUMENTATION	(35)
				SOLDERING	(19)
				INSTALL & FIT	(18)
				IDENTIFICATION	(17)
				CONFIGURATION	(16)
AE-5.7	SPACECRAFT ELECTRONICS ASSY PHYSICAL	120	18.3	INSTALL & FIT	(39)
				DOCUMENTATION	(19)
				SOLDERING	(19)
				CONFIGURATION	(15)
AE-5.6	SPACECRAFT.ELECTRONICS SUB-ASSY FAB	81	12.4	SOLDERING	(23)
				DOCUMENTATION	(20)
				INSTALL & FIT	(9)
AE-5.9	CABLES, SPACECRAFT	33	5.2	DOCUMENTATION	(12)
				INSTALL & FIT	(4)
				CONFIGURATION	(3)
	TOTAL	584	89.4		

FIGURE 3

QUALITY ASSESMENT
AE-5.8 NONCONFORMANCES BY TYPE

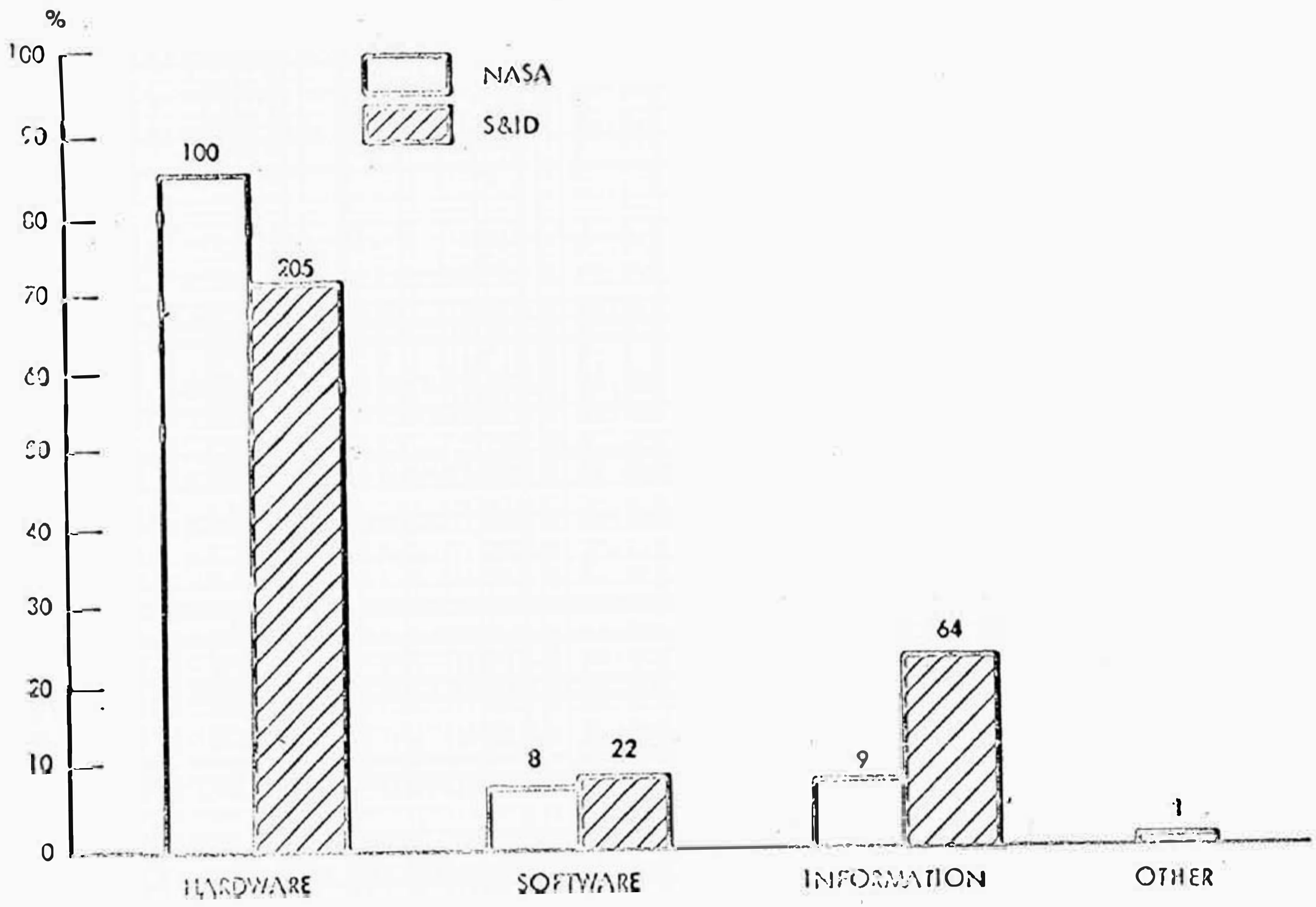


FIGURE 4

COMBINED COMPANY AND CUSTOMER
AE-5.8 DISTRIBUTION OF NONCONFORMANCES

CHARACTERISTIC	NUMBER NON-CONF	% OF TOTAL
IDENTIFICATION	104	34.1
WIRE/HARNESS INSTALL	63	22.3
ELEC COMPONENT	42	13.8
SOLDERING	31	10.2
MECH COMPONENT	19	6.2
CRIMPING	16	5.3
NOT READY FOR INSP	13	4.2
POTTING	7	2.3
TYING	5	1.6
TOTAL	305	100.0

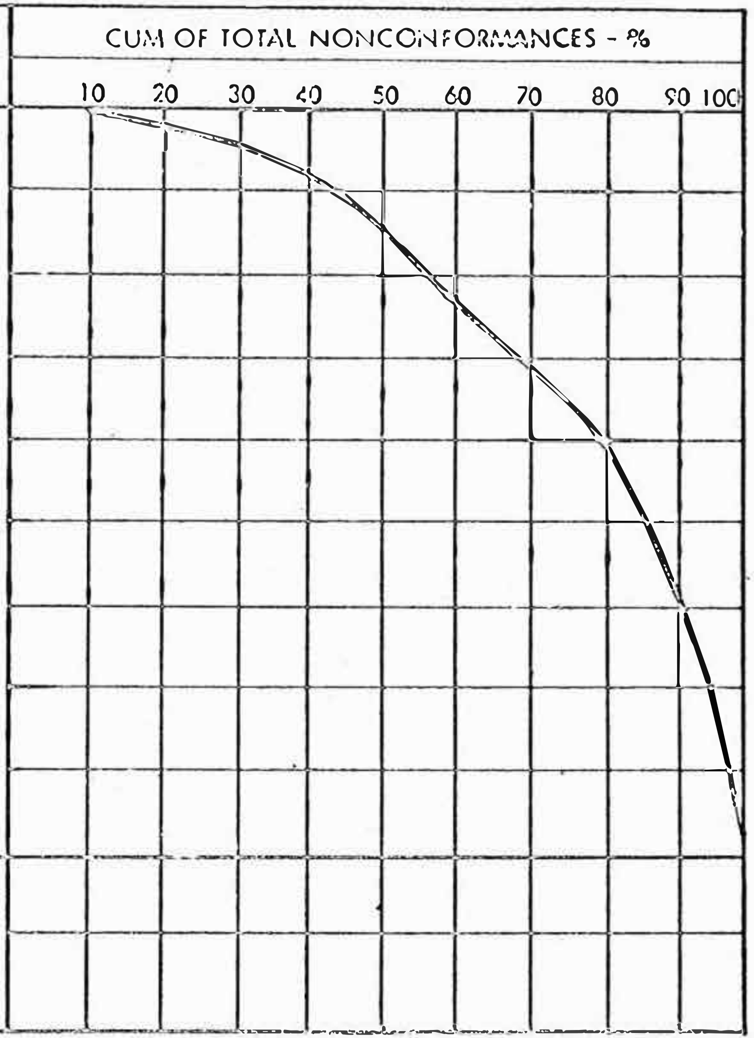


FIGURE 5

QUALITY ASSESSMENT ACTIONS

D/668

- MATERIAL & PROCESS ENGINEERING REVIEWED MATERIALS, METHODS & SPECIFICATIONS USED IN SLEEVING & IDENTIFICATION. SPECIFICATIONS WERE CHANGED. NEW SLEEVING MATERIAL WAS PURCHASED.

- S&ID QUALITY STANDARDS MANUALS WERE PROVIDED EACH SUPERVISOR & LEADMAN, S&ID INSPECTORS & NASA-O INSPECTORS.

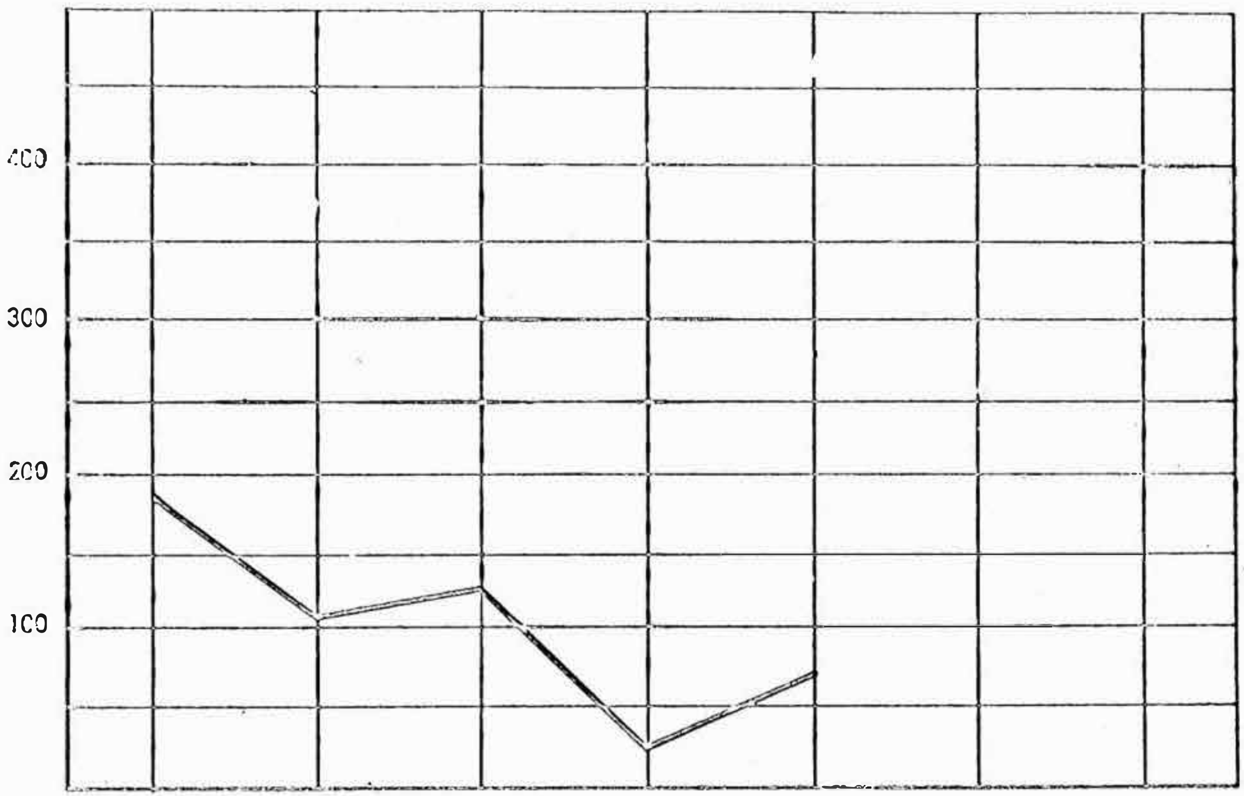
- ENLARGED INDIVIDUAL REPRODUCTIONS OF QUALITY STANDARDS WERE DISPLAYED IN WORK AREA.

- LARGE DISCREPANCY TREND CHARTS WERE DISPLAYED AT END OF EACH WORK BENCH & AT FINAL INSPECTION POSITION SHOWING TREND OF S&ID & NASA NONCONFORMANCES FOR EACH POSITION.

- QUALITY ROBBER BULLETINS LISTING TWO OR THREE SQUAWKS REQUIRING IMMEDIATE ATTENTION WERE POSTED THROUGHOUT AREA.

FIGURE 6

AE-5.8 NONCONFORMANCES FOLLOWING QUALITY ASSESSMENT ACTIONS



	JUN	JUL	AUG	SEP	OCT		
NONCONFORMANCES	186	105	135	26	73		

FIGURE 7

MAIN CREW COMPARTMENT HARNESSES

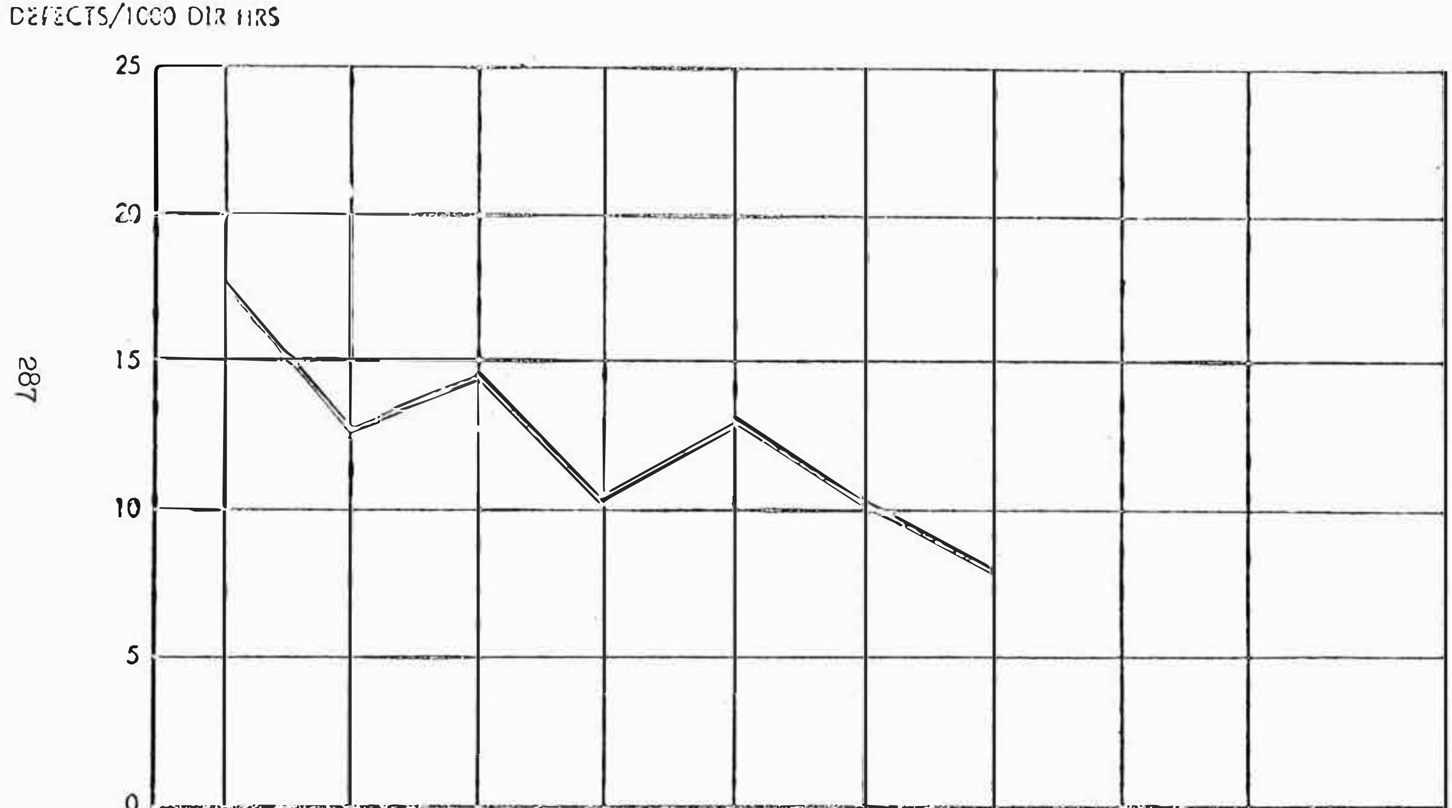
S/C	DATE	NO. OF WIRES	NO. OF CONNECTORS	MFG HRS	NASA SQUAWKS
011	JUL 65	5235	239	69,000	135
008	OCT 65	8553	315	70,000	106
012	NOV 65	6720	236	64,000	64
014	DEC 65	6720	236	43,000	71
017	FEB 66	7588	243	37,000	77
020	MAR 66	7588	243	23,000	33
2TV-1	JUN 66	6360	357	15,533	78
101	JUL 66	8090	407	16,661	65
102	AUG 66	7514	357	13,023	41
103	OCT 66	7487	360	11,761	44

FIGURE 8

APOLLO 600 SERIES DEPTS
QUALITY TRENDS TOTALS

SOURCE
DIR SYSTEM

DATE 1966



MONTH	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
DEFECTS/ 1000 HRS	17.6	12.8	14.5	10.1	13.3	10.6	7.5			

FIGURE 9

IMPROVEMENTS IN FAILURE REPORTING, ANALYSIS AND CORRECTIVE ACTION AT KSC (APOLLO)

R.L. Body, KSC

Perhaps no-where within NASA is the urgent need for, and the lack of uniformity in failure reporting and timely corrective action felt, as at KSC.

Ever since we became the launch operations center for NASA, we have been wrestling with the intercenter and intercontractor failure reporting and corrective action systems. Our experience indicates inconsistency in failure reporting data exchange and communications resulting from a lack of pre-planning as to just what the failure reporting document should do after the equipment is delivered to the launch site. The failure reporting form has been expected to serve as the media for:

1. Rejecting equipment after acceptance.

2. Repair, rework, maintenance, spares requisitioning and failure analysis of equipment.

3. Documenting test anomalies and procedural problems.

4. Documenting and resolving launch constraints.

5. Real-time paperwork for determining remedial action.

The lack of pre-planning is evidenced by the absence of program and NASA administrative systems designed to adequately cope with these problems. This is most evidenced by the lack of information and detail that is desired from the failure reporting and corrective action system. It is impossible for the launch site to anticipate all of the needs of the failure reporting form itself and the failure reporting management outputs desired.

To partially resolve this, we have recently revised and updated our Apollo Program failure reporting and corrective action requirements at KSC. This program directive places uniform format and data requirements on the KSC organizations working on Apollo Program and in turn to the appropriate contractors. However, since most KSC Apollo prime contractors working at KSC were contractually obligated years ago, the impact of improved failure reporting, corrective action and data reporting will be minimal.

The Apollo Program experience has highlighted that NASA should be working toward uniform failure reporting requirements in terms of what do they want out of the failure reporting area and what purposes they want it to serve. Also there is a need for definitions of failure, unsatisfactory condition, discrepancy, defect, material review action, etc., and whether or not NASA wants one form or numerous to fulfill reporting requirements and to what end objectives. A NASA-wide criteria document concerning what is to be reported and for what purpose would be helpful.

In summary, failure reporting and correction action system must be pre-planned on a NASA-wide basis with latitude for program or project flexibility. A requirement should be placed on the program or project to pre-plan the system from inception of the hardware through the entire life cycle of the equipment. The system must recognize that saving a few dollars by buying the contractor's in-plant system at the beginning may, in the end, be the most costly.

FAILURE REPORTING AND CORRECTIVE ACTION

Thomas J. Edwards

Manned Spacecraft Center

We still have two hundred and twenty thousand miles to go, but we also have come a long way down the yellow brick road to the moon. Twisting and turning, as it is, even reversing direction on occasion, but anyone who has been on the Apollo Program for any length of time has seen milestones approach and pass and knows progress has been made.

Today, I'd like to discuss Failure Reporting and Corrective Action, not the system per se, but the results of the system and the problems associated with the system. We have imposed the requirement on all of our contractors that a closed loop system must be implemented. The guy that determines a failure has occurred must be notified that an appropriate corrective action has been incorporated before that failure can be considered closed.

The reason we have a failure reporting system at all is to track progress, flag any problems, and at least get an intuitive feeling about the reliability of the equipment. With the size, complexity, and lengthy mission durations, obviously the number of failures is large. Daily the amount of hardware on test, in inspection and checkout increases and regardless of the system, the forest could easily be lost in the trees. It is very possible that the system could be so overloaded that information pertinent to the program could be lost. This becomes an even greater problem when we have more than one contractor on the job.

The very first step requires a definition of a reportable failure that is understood and accepted mutually by NASA and the contractors. At MSC a failure is defined as the inability of a system, subsystem, component, or part to perform its required function within specified limits under specified conditions for a specified duration. Thus we have eliminated such failures to meet specifications as, inverted name plates, scratches or incorrect shades of paint. These discrepancies do not go unnoticed by any matter but they are not handled through the Failure Reporting System.

There are many failures that occur that fit into the above definition which, if included in our Failure Reporting System, would add little or nothing to the program and therefore should be excluded, for instance, in the early design stages, feasibility studies. Such studies are conducted with available parts to prove out an idea. They will never be flown and are not intended for spacecraft use; a failure analysis might be of interest to someone, but not necessarily to a spacecraft program. We have imposed a starting time when failures as per the definition must be reported in the Failure Reporting System. This "cut-in" time is the commencing of Design Verification Testing (DVT). DVT is a qualification test on non-qualifiable hardware. Let me explain the test sequence a bit. We want some sort of assurance that an equipment is ready for qualification test and also the equipment to be qualified must be production hardware. When a contractor or subcontractor feels his design is ready for production and qualification testing, he demonstrates this by DVT. A prototype piece of gear, similar to the future production item, but not identical, is subjected to the qualification test requirements. If it passes, the go-ahead is given to produce gear. Production items are then taken from the line and put through acceptance tests. Acceptance test is the same as will be imposed on all equipment for Government buy-off. Successful completion of acceptance testing allows the contractor or subcontractor to proceed with qualification testing. Only failures occurring after the start of DVT are reportable failures into the Failure Reporting System.

We have another breed of cats in the Bench Maintenance Equipment (BME) and Ground Support Equipment (GSE). In many cases the maintenance and checkout equipment are pieces of commercial, off-the-shelf equipment. They are high grade, the best you can buy, but they still are commercial gear. A failure in an oscilloscope is not going to require a redesign of that instrument. Again, we do not throw this failure information away. It is used to compute MTBF's, which in turn, are used in the estimate for operational readiness.

In the GSE world we do have Mission Essential Equipment (MEE). This is equipment used in the final countdown, which on the Apollo Program is arbitrarily defined as the final seventy-two hours. Equipment used in this final phase could cause a miss of the launch window. For this reason, a failure in MEE is treated exactly the same as a failure in flight hardware. The report is filed, a failure analysis is conducted, and a corrective action is determined and implemented.

A major problem is tracking these failure reports and corrective actions. Remember in Apollo we have two complex spacecraft so it shouldn't seem unreasonable to say we have about 25,000 reported failures to date. Such an amount must be handled by an automatic data processing system. The Manned Spacecraft Center has such a system which was ably described at the 12th Annual Symposium on Reliability in San Francisco in January 1966. This excellent paper was prepared jointly by Mr. Hesson of the Manned Spacecraft Center and Mr. Carter of the General Electric Company, Apollo Support Department.

The Apollo prime contractors are required to submit to MSC, on magnetic tape, all reportable failures. These failure tapes are updated on a weekly basis and contain such information as the failed item identification, symptoms, failure analysis and corrective action.

With such an automated system, the printout capability is almost unlimited. There are however some obviously invaluable printouts useful in tracking failures. Each week the failure status is run off by subsystems. At MSC we have a subsystem manager for each subsystem on each Spacecraft, Command and Service Module and the Lunar Module. These printouts are type-two documents. It is the responsibility of the subsystem manager to review the tape for various aspects. He notes the failures that have received a failure analysis and corrective action. Since this is a type-two document, he can accept these by not commenting. He also has the perogative of challenging these, which in most cases is merely a request for data, or he may reject them completely and reopen the closed failure. In actual practice, the subsystem manager works in close contact with his counterpart at the contractors' plant. He is usually well aware of what has been done.

Summary sheets are printed giving the number of open failures and the length of time, over 30, 60, or 90 days, they have been open. The subsystem manager receives this data and it is also distributed to other division and the program office. The subsystem manager may be called on at anytime to give a status report and defend the fact that he has open failures associated with his subsystem that have been in the open status for a considerable length of time.

At MSC we have reliability end-item engineers. Their job is to follow a specific end-item, such as Spacecraft 012, from fabrication through test, checkout, launch and recovery. These men live with that specific end-item and are well aware of any failures that occur during its lifetime. However, we have configuration tapes which when played against the failure tapes will printout not only the failures associated with that end-item, but also failures on components or assemblies that are on test and identical to a component or assembly in the specific end-item. This way the end-item engineer cuts across the subsystem managers and performs a valuable check and double look at any failure in an equipment that will eventually fly.

Even with a computerized system, it would be impossible for the top management that is represented on the review boards, such as the CARR or FRR to assimilate this information. For this reason a system of summaries was devised. These are called APS's (Apollo Problem Summaries). The APS's are the documents that are presented at the top level reviews. These APS's are compiled from outstanding failures that have been experienced. An APS can reference one or many failures. If a failure has a serious impact on schedule or if it could abort a mission, it's an outstanding failure. Frankly, these are easy to spot if they occur. Almost equally important is repeated failures at the part or component level. The failure tape can printout all failures associated with a given component. From such a printout, problem areas become obvious and an APS is prepared. This enables a concentrated effort be put on many failures at one time. The APS has an open and closed status, the same as a failure report. The failure report remains open even when an APS has been prepared; however, when an APS is closed out then all failure reports referenced are also closed out.

There is another category for an APS, that is an "explained" category. If we understand a failure, feel sure it will not reoccur and it does not affect crew safety, it is placed in an "explained" category. These explained APS's are presented to the CARR and FRR Boards. At the CARR Board some APS's may be presented that are still open, but a plan of action to close or explain the problem must also be presented. At the time of the FRR all APS's must be closed or explained. It is then up to the board to accept the explanation or give direction as to the course of action.

Sometimes an Apollo Problem Summary is written on a closed failure if that failure is considered "famous." For example, the failure printout is checked against the list of single point failures which has been derived from the Failure Mode and Effects Analysis (FMEA). This, of course, is a list of hypothetical failures, but if a failure has actually occurred that falls in t Single Point Class, it automatically is a "famous" failure. The analysis may be complete and the corrective action implemented still it is a candidate for discussion at a CARR or FRR Board presentation.

To aid in the problem of tracking a weekly Problem Tracking List is prepared. This lists all the primary open problems in the criticality I and II categories. Category 1 being problems that affect crew safety and Category II, problems that could abort the mission. Perhaps this could be considered a summary of summaries, but we have found it a convenient tracking mechanism. For instance, at the time of this writing the total open problems on this list are 43 for the Command and Service Module, 25 on the

Lunar Module and 21 on the Guidance and Control Subsystem. Granted, these are major problems, but they are in quantities sufficiently small in size to be comprehensible by those interested in the overall program.

Keeping on top of the situation and devising means to get a jump on anything detrimental to the program has been a prime aim. MSC has imposed on all contractors the requirement of a 24-hour failure notification. This is not a Failure Report, it merely says something has happened. It makes no attempt to explain why or what should be done. It does give MSC an alert and forewarned is forearmed. Twenty-four hour failure notifications are required on any occurrence that fits the failure definition and occurs: 1. during qualification testing, or 2. on flight hardware, or 3. has serious program impact. The first two are easy to identify but the third requires some amount of subjective judgement, because that could even be on development hardware. A prime example of this is the inadvertent firings of rocket engines even in the development state. Quite frankly, program impact failures have been easy to spot and although defining them may be a problem, spotting them when they occur has not caused either NASA or the contractors any trouble.

To paraphrase a great oriental, let me say a picture is worth a thousand failure reports. For this reason we have some eleven graphs that are updated weekly and on display. For instance, there is a trend chart showing the total failures, the total open failures, and the open APS's by spacecraft. I'd like to point out that there can be an open APS against a spacecraft even though that spacecraft has not experienced a failure of that type. A failure may have occurred on a different spacecraft that has identical components. There is an open APS against Spacecraft 012 because of the tank failure on 017.

At MSC we feel the Failure Reporting and Corrective Action System must be more than just what the title implies. We must have insight into the problem, we must have a manageable system so that we can keep track of the vast number of failures expected on a program of the magnitude that we handle and any jump ahead we can get, such as the failure notification, helps placing an emphasis where it will be most beneficial.

The road to hell is paved with good intentions, but the road to the moon is paved with closed out failure reports.

AN UNSATISFACTORY CONDITION REPORTING SYSTEM FOR MULTI-PROJECT OPERATIONS

W. David Brown, MSFC

Introduction

Before we get into the presentation, I would like to explain some of the history behind the development of the MSFC Unsatisfactory Condition Reporting System for the control of multi-project operations. On the initial Saturn I vehicles most of the work was performed in house and the UCR or failure reporting program on these vehicles was relatively easy to control. However, with the phase over to contractor support effort and the development of multi-stage vehicles, it became evident that something more was needed to control the various programs involved.

In view of this, the Quality and Reliability Assurance Laboratory was assigned the responsibility of developing, implementing, and operating an overall unsatisfactory condition reporting system. The objectives of this program were:

1. Assure implementation of effective corrective action on all Saturn failures.

2. Provide a system for cross feed of Saturn information in assuring that problems involving similar hardware or situations are eliminated from all systems and stages.

3. Measure the effectiveness of existing quality control programs such as reviewing the adequacy of a vendor's program based on a failure trend detected during one of our checkout operations.

4. Determine the adequacy of test programs not only in terms of increasing testing for a given subsystem but also in identifying areas where testing can be reduced.

5. Establish the basis for reliability assessment studies in determining failure trends and isolating problem areas.

In our discussion of the system which was developed to satisfy these objectives we will first present the requirements and operation of the system, and then secondly, how the information obtained from the system is utilized.

Section I

System Requirements

I. Definitions: (Figure 1)

We have developed or standardized on several definitions to be used in conjunction with the MSFC UCR system.

(a) First an unsatisfactory condition being any failure or discrepancy discovered in connection with flight hardware or launch configuration ground support equipment beginning with post manufacturing checkout and extending through launch checkout.

(b) Here we define post manufacturing checkout as beginning with the first power-on application to the stage during subsystem level testing and after overall inspection and acceptance of the stage by Quality Control from the manufacturing area. This would not include verification testing performed at this time such as electrical-mechanical status and stage continuity checks. Excluded also are reports written to remove hardware from the stage as part of a normal refurbishment operation and reports written to document failures and discrepancies discovered in connection with assembly operations that are performed during a checkout phase. This data has been eliminated in an effort to limit the UCR system to the more significant problems or those occurring after the hardware has been installed and accepted from the manufacturing area. UCR's written against GSE would be included if the failure or discrepancy is discovered during or related to an actual stage checkout operation.

(c) An Unsatisfactory Condition Report or UCR is any report submitted by a government or contractor organization documenting unsatisfactory conditions as described above.

Then in terms of corrective action we have two distinct areas of close out.

(a) Remedial action as the immediate action taken to insure that an unsatisfactory condition has been corrected for the particular vehicle or associated support equipment against which it was reported, i.e..., hardware replaced or rework to specifications.

(b) Recurrence control action as the action taken to prevent an unsatisfactory condition from recurring on subsequent launch vehicles or associated support equipment i.e., an engineering order issued for a design change.

II. Failure Mode Classifications: (Figure 2)

We have also developed standard definitions or criteria for classification of failure modes with respect to hardware criticality.

We have three hardware classifications for both flight and GSE hardware which are in accordance with the criteria established in the Apollo Test Requirements document NPC 500-10. Category I being hardware failure of which results in loss of life of any crew member. Category II - hardware failure of which results in abort of mission and Category III - all other hardware.

Then in classifying the UCR's written against the various categories of hardware we have established failure mode or severity classifications. This classification is necessary in distinguishing between critical problems involving a complete malfunction and minor defects such as dents and scratches.

(a) Critical - Being any unsatisfactory condition that would result in loss of life of any crew member.

(b) Major - An unsatisfactory condition that would result in abort of mission or complete stage/vehicle loss but does not cause loss of life and conditions that can cause a definite launch scrub.

(c) Minor - An unsatisfactory condition that does not affect critical or major classification criteria. This classification would also include unsatisfactory conditions that would result in information loss when no significant effect on mission operation is concerned and conditions that would cause a short launch delay.

(d) Defect - Any unsatisfactory conditions other than the above (i.e., documentation errors, dents, scratches, and minor discrepancies).

Then for Category II and III hardware we have the same failure mode classification with the exception that we cannot have a critical condition involving loss of life on Category II hardware, and we cannot have either a critical or major condition involving abort of mission on Category III hardware.

The codes shown here 1 through 9 are simply reference numbers for entering the classification information into the automatic data storage system.

III. Stage Contractor Requirements: (Figure 3)

The reporting requirements that have been implemented with all of the Saturn IB and Saturn V stage contractors are:

(a) Type of information required - All unsatisfactory condition, remedial action, failure analysis and recurrence control action information.

(b) On all flight stages and launch configuration ground support equipment.

(c) Beginning with post manufacturing checkout and extending through launch checkout.

(d) The unsatisfactory condition and remedial action information to be forwarded to MSFC within 10 days after discovery. Then later the failure analysis and recurrence control action information, or a status report when failure analysis is still underway, to be forwarded within 30 days of the initial report.

(e) All of this information to be transmitted to MSFC by magnetic tape or punch cards in accordance with MSFC automatic data format requirements.

However, transmittal of data through an automated program was not established with the various GSE contractors due to the volume of data involved. Copies of the UCR's from these areas are entered into the automatic data processing system by R-QUAL.

IV. Reporting System Flow Chart: (Figure 4)

This chart reflects the overall flow of UCR information from the various test and checkout areas (contractor, MSFC and KSC) into MSFC Central Control.

(a) UCR's written at the contractor's facility or MTF are forwarded to contractor central control where the data is reviewed, converted to punched card or magnetic tape format and forwarded to MSFC Central Control. At the same time this information and any rejected hardware is submitted for vendor or contractor investigation with subsequent failure analysis and recurrence control action information being fed back through contractor central control and the automated system as an update to the original entry on the MSFC computer tape. This operation being performed under the surveillance of resident Quality and Reliability Assurance Laboratory and government agency personnel.

(b) At MSFC all failures and discrepancies are documented on the MSFC UCR form and submitted to the Quality and Reliability Assurance Laboratory for accomplishment of failure analysis and establishment of recurrence control action with the MSFC design laboratories.

(c) UCR's written during launch checkout on MSFC furnished hardware (i.e., RCA 110A computer) are documented on the KSC UCR form by KSC or the operating contractor and forwarded through the KSC R&QA Office to R-QUAL Central Control and the applicable Saturn IB or V R&QA Office.

(d) UCR's written on MSFC contractor responsible hardware (i.e., S-IVB stage) are documented on the contractors' failure reporting form and forwarded to the contractors' resident office where copies are distributed to the KSC R&QA Office, IO Program Office, R-QUAL Central Control for immediate flight readiness review and the contractors' central control organization. Here necessary failure analysis is performed, recurrence control action established, and as before the data submitted through the ADP System to MSFC Central Control - again with the time frame of 10 days for initial notification and 30 days for follow-up action.

(e) Failure reporting at KSC and the contractors' facility is accomplished under the surveillance of a MSFC resident office who immediately notifies both R-QUAL and the program office of critical failures or priority action requiring immediate attention.

These arrows (from UCR Central Control) reflect the feedback of information from central control to KSC, MSFC Resident Office at KSC, MSFC Resident Office at the contractor's facility or MTF and the contractor's on their respective stages. Then our overall reporting to the Industrial Operations Stage Offices and R&QA Offices.

V. MSFC Central Control Analysis: (Figure 5)

As the MSFC Central Control Group, the Quality and Reliability Assurance Laboratory reviews all UCR's.

Here again we have information submitted on the MSFC UCR Form or the KSC UCR Form and the cycle of evaluation and processing this information into the automatic data processing system. On contractor data, again information from KSC and the contractors' facility thru the automated system and a review of the resulting computer printout. First of all an evaluation of the initial failure report to ensure that remedial action has been taken, a determination as to previous occurrences of the same failure mode, and criticality classification. Then later receipt and review of the recurrence control action initiated with followup as necessary with the originating activity.

We also interface continuously with the R&DO Labs, including other Divisions within R-QUAL, in accomplishing the following:

(a) Detailed investigation of significant problems and corrective action taken.

(b) Performance of routine failure analysis on MSFC design responsible hardware and when required special failure analysis on contractor hardware.

(c) Determination of failure trends and isolation of problem areas.

(d) Review and optimization of test requirements.

(e) Preparation of corrective action recommendations, such as required design changes.

SECTION II

DATA UTILIZATION AND MANAGEMENT REPORTS

(FIGURE 6)

The requirements and collection of information that we have been discussing are utilized to prepare a variety of reports for distribution at the working level and to all levels of management.

I. Computer Printouts: (Figure 7)

One of the major outputs of the systems is, of course, our computer printouts which are periodically provided to Resident Office personnel, government agencies, and the contractors on their respective stages. These printouts reflect for each UCR entry:

(a) Identification information, i.e., the functional system code (Control Pressure System), found during code (static test), stage and vehicle (S-IB-204), nomenclature (part number/name), and the test in progress when the failure occurred (Test Procedure).

(b) A description of the unsatisfactory condition (vent valve) assembly which failed to give a closed indication).

(c) Disposition or remedial action initiated (valve replaced).

(d) The MSFC evaluation of this information. Here we show the remedial action okay, no previous occurrences during checkout or static test, a criticality code 3 assigned, the date our review was made, and the overall entry marked okay with the initials of the engineer that evaluated the action.

(e) Then later upon receipt of the recurrence control action established, the final review and close out action.

II. Checkout Completion Report: (Figures 8 and 9)

As a summary of UCR activity, a report is prepared at the completion of each test or checkout operation. This report, which is utilized by the stage offices in preparation for the preflight review includes:

(a) First a summary of the total UCR's reported for a given checkout operation by subsystem, the number of remedial actions completed, the number of UCR's on which we have experienced previous occurrences, classification of each UCR as to criticality, and the number of UCR's on which recurrence control action has been completed.

(b) The second part of this report consists of a list of the significant UCR's reported or those involving critical and major failure modes with a brief summary of the unsatisfactory conditions and the corrective action initiated.

III. Apollo-Saturn Program Failure Summary and Trend Report: (Figure 10)

Another report which is prepared to reflect UCR status on a monthly basis is the Apollo-Saturn Program Failure Summary and Trend Report. This report provides an accumulative statistical summary of all UCR's for each active vehicle including a description of the significant UCR's as previously shown in the checkout completion report. This report is submitted to center management personnel and the Apollo Reliability and Quality Office (NASA Headquarters) for comparative analysis and overall program review.

These charts reflect a summary of information by:

(a) Post Manufacturing Checkout - with additional charts for

(1) Pre-static Checkout

(2) Static Test

(3) Post Static Checkout

(4) Pre-launch Checkout

(5) Launch (Flight)

(b) Again we show the total UCR's reported by stage and subsystem, the number of remedial actions completed, number on which there were previous occurrences in the same failure mode, criticality codes established, and the number of UCR's on which recurrence control action has been completed.

IV. Part/Material Application Problem Disposition Report: (Figure 11)

In addition to establishing cross feed of information within the MSFC programs, on problems involving similar hardware or situations, we also participate in the NASA ALERT System or issuance of Part/Material Application Problem Disposition Reports. Each NASA Center and Saturn stage contractor has a contact point for receipt and dissemination of these reports and is responsible for the submittal of Part/Material Application information.

This report isolates the problem at the piece part level. Here we have a rectifier within a power supply built by Transistron Electronic Corporation, which failed to operate during static firing of S-I-9 with a previous failure on SA-5 that resulted in the loss of flight data. (1) Probable cause - Inadequacy of silver paste bonding material, (2) Remedial action - Replaced with different type using gold perform bonding, (3) Problem Solution - Retrofit with rectifiers using gold perform bonding, (4) Recommendation - Discontinue use of this rectifier in space applications with a reference to the complete failure analysis report.

V.. Benefits of MSFC UCR System: (Figure 12)

We feel the most important aspects of the MSFC UCR system are:

(a) That each UCR written on Saturn stages and GSE, beginning with Post Manufacturing Checkout, is reported and evaluated to a standard set of criteria, which is most essential in analyzing statistics and establishing uniform criticality classifications. These elements also establish a basis for the uniform reporting of data in that the statistics reported for the S-IB Stage are in consonance with the data reported on the S-IVB Stage.

(b) That remedial action is formally completed in the evaluation and assurance of vehicle flight readiness and that adequate recurrence control action is established in the elimination of similar problems on future flights.

(c) All data is maintained within a centralized automatic data processing system with the capability of providing information on short notice without having to contact many different organizations. The centralized data system provides for the extraction of data in a wide variety of forms, i.e., all UCR's in part number sequence, all actuator problems, all welding or leakage defects for a given piece of hardware or subsystem and almost any combination of 22 different codes which are entered into the automatic data processing system for each UCR.

(d) That a basis is provided for program analysis in:

(1) Measuring the effectiveness of our existing Quality Control Programs and the development of corrective action recommendations, such as increased screening of hardware during receiving inspection, the establishment of new procurement sources, and required changes in process controls and the application of workmanship specifications.

(2) In the optimization of test programs and the evaluation of failure rates in determining areas where testing needs to be increased or if no UCR's are now being written then a further evaluation as to the possibility of deleting the checkout all together. These evaluations go all the way from deletion of certain subassembly test to complete deletion of all static test requirements.

(3) In the performance of reliability assessment studies such as the complete review and assessment of all critical and major modes of failure on Category 1 and 2 hardware and in the overall review of problems by defect such as the evaluation of an excessive number of leakage problems within a given subsystem.

(4) In the elimination of similar problems and situations not only within the Saturn Program, but through our NASA ALERT System on a NASA-wide basis.

Summary

In conclusion, I would like to say that the MSFC UCR system was primarily designed as a management tool in assuring successful completion of our individual flight missions and as a system by which we can assure that necessary action is initiated to increase the reliability of future flights.

However, we also feel that the cost savings resulting from this program in times of data utilization for reliability studies and evaluation of checkout requirements will far outweigh the cost of implementation and operation of the program.

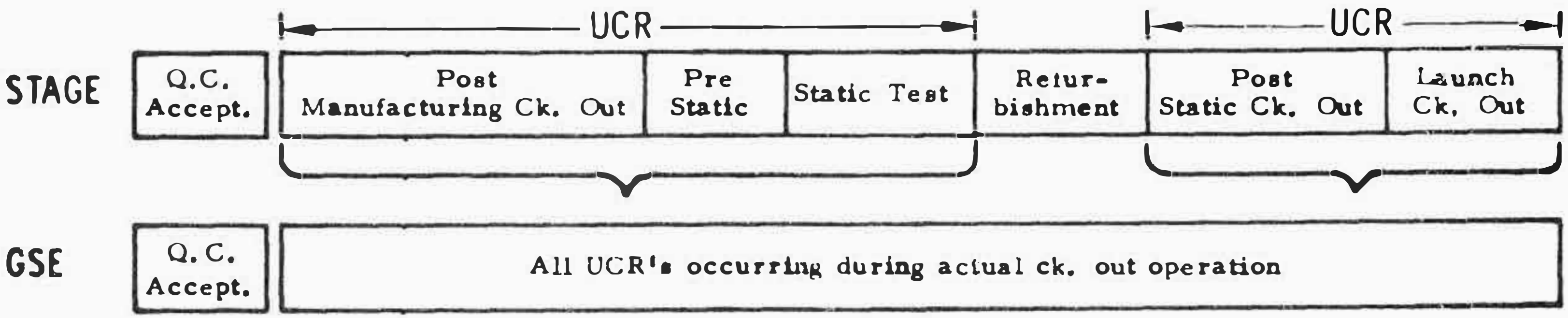
UNSATISFACTORY CONDITION REPORTING SYSTEM
OBJECTIVES

- Assure implementation of effective corrective action
- Provide cross feed of information on similar problems
- Measure the effectiveness of quality control programs
- Determine the adequacy of test programs
- Establish the basis for reliability assessment studies

OCP-AV-33

DEFINITIONS

- UNSATISFACTORY CONDITION - ANY FAILURE OR DISCREPANCY DISCOVERED IN CONNECTION WITH FLIGHT HARDWARE OR ASSOCIATED GROUND SUPPORT EQUIPMENT DURING THE TIME PERIOD BEGINNING WITH POST MANUFACTURING CHECKOUT AND EXTENDING THROUGH LAUNCH CHECKOUT.



- UNSATISFACTORY CONDITION REPORT - any report submitted by a Government or contractor organization documenting unsatisfactory conditions described above.

- REMEDIAL ACTION - immediate action taken to insure that an unsatisfactory condition has been corrected for the particular vehicle or associated support equipment against which it was reported.

- RECURRENCE CONTROL ACTION - action taken to prevent an unsatisfactory condition from recurring on subsequent launch vehicles or their associated support equipment.

Figure 1

MSFC UNSATISFACTORY CONDITION REPORTING SYSTEM
FLIGHT AND GSE HARDWARE FAILURE MODE DEFINITIONS

HARDWARE CRITICALITY CATEGORIES (Ref. NPC 500-10) FLIGHT HARDWARE CATEGORIES 1, 2, AND 3 / GROUND SUPPORT EQUIPMENT CATEGORIES A, B, AND C	FAILURE MODE CLASSIFICATIONS ADPS CODE	DEFINITIONS	
CATEGORY 1 or A Hardware, failure of which results in loss of life of any crew member. This includes normally passive systems, i.e. Emergency Detection System, Launch Escape System, etc. (Category A also includes loss of life of any ground crew member).	1	CRITICAL	- An unsatisfactory condition that would result in loss of life of any crew member.
	2	MAJOR	- An unsatisfactory condition that would result in abort of mission or complete stage/vehicle loss but does not cause loss of life. This includes conditions that can cause a definite launch scrub.
	3	MINOR	- An unsatisfactory condition that does not affect critical or major classifications criteria. This classification includes unsatisfactory conditions that would result in information loss when no significant effect on mission operation is concerned and conditions that would cause a short launch delay.
	4	DEFECT	- Any unsatisfactory conditions other than the above, (i.e., documentation errors, dents, scratches).
CATEGORY 2 or B Hardware, failure of which results in abort of mission but does not cause loss of life.	5	MAJOR	- An unsatisfactory condition that would result in abort of mission. This includes conditions that can cause a definite launch scrub.
	6	MINOR	- An unsatisfactory condition that does not significantly affect mission success. This classification includes unsatisfactory conditions that would result in information loss when no significant effect on mission operation is concerned and conditions that would cause a short launch delay.
	7	DEFECT	- Any unsatisfactory condition other than major and minor classifications.
CATEGORY 3 or C Hardware, failure of which will not result in abort of mission nor cause loss of life.	8	MINOR	- An unsatisfactory condition that does not significantly affect mission success. This classification includes unsatisfactory conditions that would result in information loss when no significant effect on mission operation is concerned and conditions that would cause a short launch delay.
	9	DEFECT	- Any unsatisfactory condition other than the above.

Figure 2

MSFC STAGE CONTRACTOR

UNSATISFACTORY CONDITION REPORTING REQUIREMENTS

- **TYPE OF INFORMATION REQUIRED-** ALL UNSATISFACTORY CONDITION & REMEDIAL ACTION INFORMATION, RELATED FAILURE ANALYSIS INFORMATION, AND RECURRENCE CONTROL ACTION INFORMATION.

- **APPLICABILITY-** INCLUDES ALL FLIGHT STAGES AND LAUNCH CONFIGURATION GROUND SUPPORT EQUIPMENT.

- **TIME PHASE-** ENCOMPASSING THE TIME PERIOD BEGINNING WITH POST MANUFACTURING CHECKOUT AND EXTENDING THROUGH LAUNCH CHECKOUT.

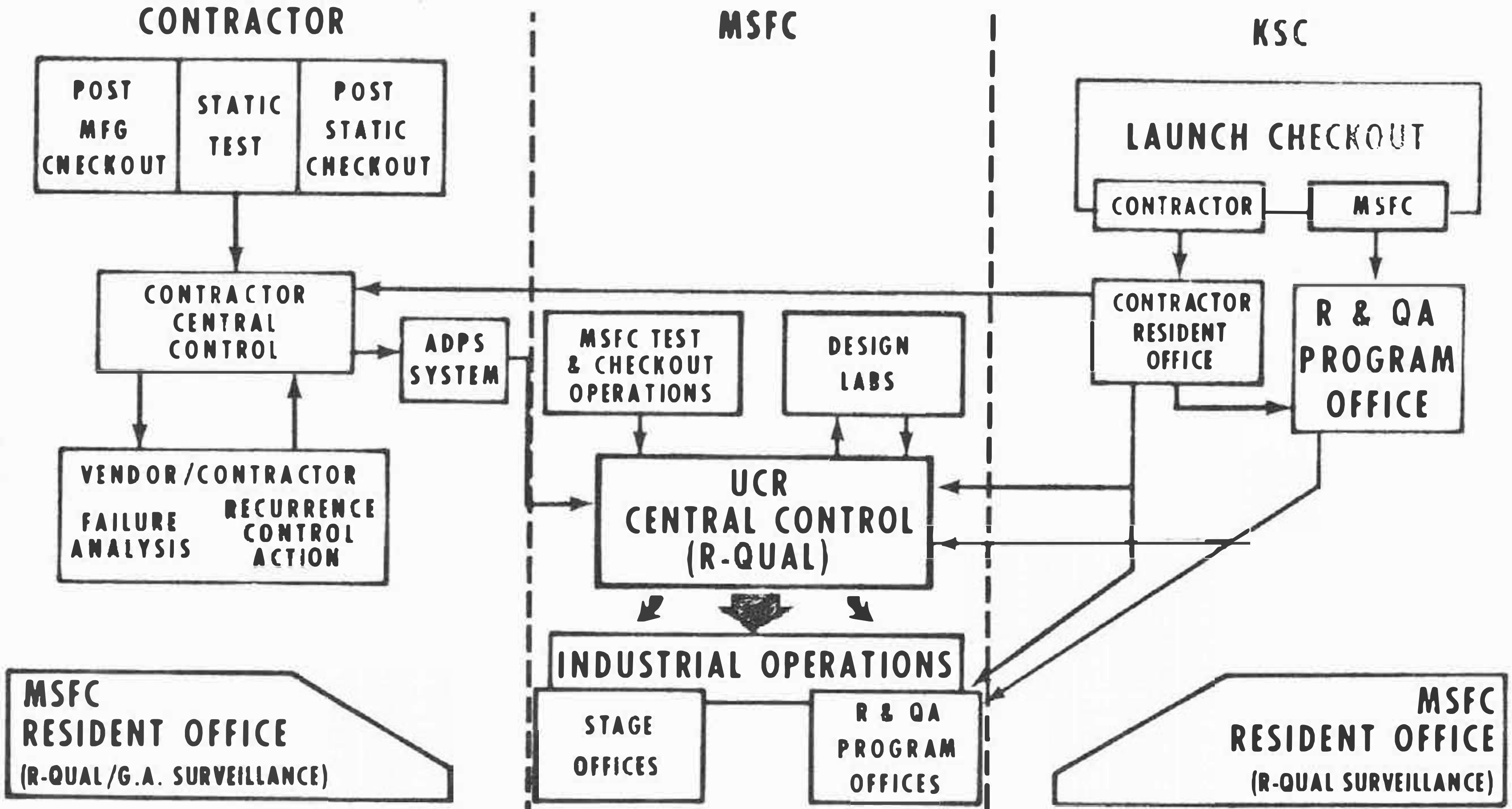
- **WHEN REQUIRED-** ALL UNSATISFACTORY CONDITION & REMEDIAL ACTION INFORMATION TO BE FORWARDED TO MSFC WITHIN 10 DAYS AFTER DISCOVERY OF THE DEFICIENCY OR FAILURE. THE FAILURE ANALYSIS AND RECURRENCE CONTROL ACTION INFORMATION TO BE FORWARDED TO MSFC WITHIN 30 DAYS AFTER THE INITIAL REPORTING OF THE FAILURE OR DISCREPANCY.

- **FORMAT-** UNSATISFACTORY CONDITION INFORMATION SHALL BE TRANSMITTED TO MSFC EITHER BY MAGNETIC TAPE OR PUNCHED CARDS IN ACCORDANCE WITH MSFC FORMAT REQUIREMENTS.

OCA AV-11C

Figure 3

MSFC UNSATISFACTORY CONDITION REPORTING SYSTEM



- NOTIFICATION OF FAILURE OR DISCREPANCY WITHIN 10 DAYS AFTER DISCOVERY
- NOTIFICATION OF FAILURE ANALYSIS AND RECURRENCE CONTROL ACTION WITHIN 30 DAYS AFTER INITIAL REPORT

- NOTIFICATION OF FAILURE OR DISCREPANCY WITHIN 2 DAYS AFTER DISCOVERY
- NOTIFICATION OF FAILURE ANALYSIS AND RECURRENCE CONTROL ACTION WITHIN 10 DAYS AFTER INITIAL REPORT

- NOTIFICATION OF FAILURE OR DISCREPANCY WITHIN 5 DAYS AFTER DISCOVERY
- IMMEDIATE NOTIFICATION OF PRIORITY ACTIONS

MSFC CENTRAL CONTROL ANALYSIS

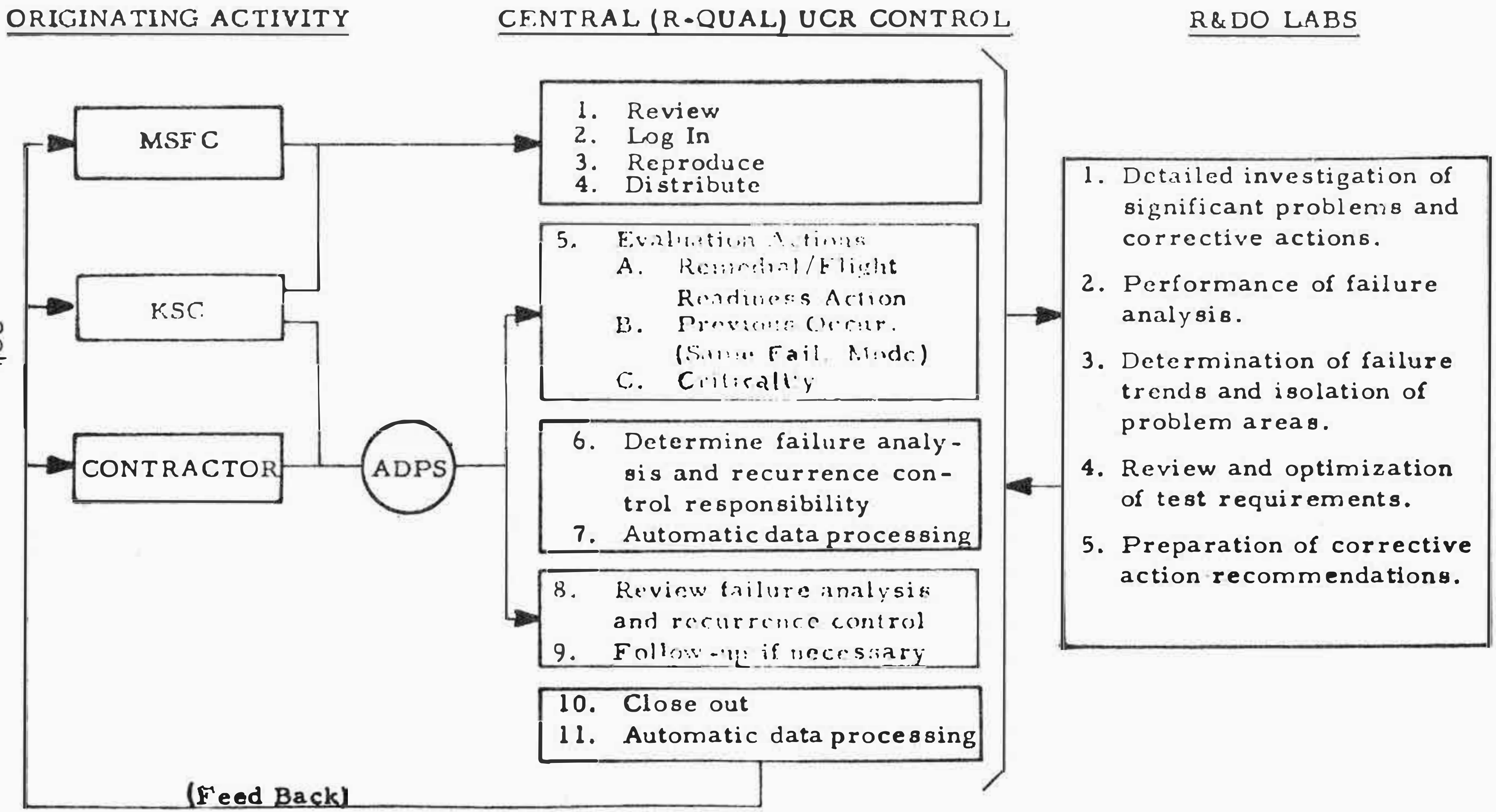


Figure 5

DATA UTILIZATION
AND
MANAGEMENT REPORTS

I. COMPUTER PRINTOUTS

II. CHECKOUT COMPLETION REPORT

III. APOLLO-SATURN PROGRAM FAILURE SUMMARY AND TREND REPORT

IV. PART/MATERIAL APPLICATION PROBLEM DISPOSITION REPORT

Figure 6

UNSATISFACTORY CONDITION REPORT

U.C.R. NR.	DA SYS	MO	YR FOUND	MAJ. VEH.	ITEM ORG	PART SERIAL	NR DEF	CD	REV NR	DEF	PART NAME MEAS NR	OTC	OP	TIME	CA	MANUFACTURER FA	TEST PROC	PROJECT CRITICAL
MC00002940	17 210	01	66 17	780 81204	STE	20M30460 0015		22	1 0001	4	INCH VENT VALVE ASSY UNK				11	Y	7CHS1B603C	SB 3

DURING THE SHORT DURATION FIRING, SA-32, THE 4-INCH LOX RELIEF VENT VALVE ASSEMBLY FAILED TO GIVE A CLOSED INDICATION. THE VALVE WAS VISUALLY VERIFIED TO BE CLOSED AND THE LOX TANKS PRESSURIZED TO OPERATING PRESSURE FOR THE TEST. THE PROBABLE CAUSE IS A MALFUNCTION OF THE POSITION INDICATOR SWITCH.

REMARKS - THE 4-INCH LOX VANT VALVE S/N 0015 WAS REPLACED BY A SIMILAR ITEM S/N 0016. IT IS RECOMMENDED THAT A FAILURE ANALYSIS BE PERFORMED ON THE VENT VALVE ASSEMBLY.

MSFC QUALITY REVIEW DATE 01-02-66 CA

REMEDIAL ACTION	OK
PREVIOUS OCCURENCE	NONE
CRITICALITY	3
REMARKS	FLIGHT CRITICAL ITEM. INDICATOR FAILURE WOULD CAUSE SHORT LAUNCH DELAY OR LOSS OF INFORMATION WITH NO SIGNIFICANT EFFECT ON MISSION.

INVESTIGATION BY CCSD, MICHOUD.
THE MAGNETIC REED SWITCH IN SUBJECT VALVE FAILED TO INDICATE VALVE CLOSED DUE TO THERMAL CONTRACTION DIFFERENCES WITHIN THE VALVE. SUBJECT VALVE HAS BEEN REPLACED ON S-IB-3 AND SUBSEQUENT STAGES WITH A NEW VALVE, 60C31004-1.

MSFC QUALITY REVIEW DATE 31-03-66 CA

CLOSED

Figure 7

STAGE CHECKOUT / TEST
UCR SUMMARY

IU-202 POST MANUFACTURING CHECKOUT

SUBSYSTEM	TOTAL UCR's REPORTED	REMEDIAL ACTIONS COMPLETED	PREVIOUS OCCURENCES	HARDWARE CRITICALITY CATEGORY 1 — FAILURE CLASSIFICATION: CRITICAL (1)	1: MAJOR (2)	1: MINOR (3)	1: DEFECT (4)	2: MAJOR (5)	2: MINOR (6)	2: DEFECT (7)	3: MINOR (8)	3: DEFECT (9)	RECURRENCE CONTROL ACTIONS COMPLETED
STRUCTURAL	3	2	1				1					2	1
ENVIRONMENTAL CONTROL	8	8	3			2		5				1	7
FLIGHT CONTROL	4	4	3				1	1	1		1		2
INSTRUMENTATION	27	26	20						9	3	15		24
ELECTRICAL	9	8	4			2	1		5			1	8
TOTAL	51	48	31			4	3	6	15	3	16	4	42

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SIGNIFICANT UNSATISFACTORY CONDITION REPORTS

IU-202 POST MANUFACTURING CHECKOUT

UCR NUMBER	PART NAME/NUMBER	SUBSYSTEM	FAILURE/DISCREPANCY	CRIT	CORRECTIVE ACTION STATUS
IBM 00102	Power Transfer Switch 40M37219	Electrical	Will not function to extreme position - could result in launch scrub.	5	Caused by error in test procedure. Procedure corrected and responsible personnel notified.
IBM 00124	Launch Vehicle Data Adapter 50M35011	Guidance & Control	Functional test unsatisfactory - may result in inability to issue sequencing commands.	2	Defective unit replaced. Investigation continuing.
IBM 00128	GN_2 Fill Valve 20M30380	Environmental Control (Gas Bearing Supply)	GN_2 leak - loss of GN_2 pressure could result in ST-124 platform malfunction.	5	Valve replaced. New valve design incorporated, effective IU-204.
IBM 00131	Low Pressure Switch 20M42131-1	Environmental Control (Gas Bearing Supply)	Switch deactivates at wrong pressure (1950 PSIG; 1500 PSIG normal pressure) - could cause ST-124 platform malfunction.	5	Switch replaced on IU-202. New switch design to be used, effective IU-204.
IBM 00157	Flowmeter 50M12340	Environmental Control	GN_2 leak - possible ST-124 platform malfunction	5	Flowmeter not defective. Water System Test Procedure modified.
IBM 00177	EDS Distributor 40M37218-001	Electrical	Thrust Relay Malfunction - can result in inability of EDS to operate at a critical time.	5	E. O. initiated to modify circuitry.
IBM 00202	Relay (E. D. S.) 40M37496-1	Electrical	Inductive Voltage Spikes (EMI) - could activate E. D. S. during normal vehicle operations	2	Engr Change Req. No. EAA-105 prepared to provide separate contacts to eliminate EMI source.
QUAL 20734	High/Low Pressure Switches (Gas Bearing Supply). 20M42130 / 20M42131	Environmental Control	Improper Cleaning Spec. (164): incompatible with gas input to ST-124 (cleaned to gas bearing spec.) - particles can impede flow, possibly causing ST-124 platform damage.	2	Gas input to ST-124 checked and certified clean. New switch design effective on IU-204.

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Figure 9

UNSATISFACTORY CONDITION REPORT SUMMARY

STAGE AND SUB-SYSTEM		SA-202 STATIC TEST												
		TOTAL UCR's REPORTED	REMEDIAL ACTIONS COMPLETED	PREVIOUS OCCURENCES	CRITICALITY 1				CRITICALITY 2			CRITICALITY 3		RECURRENCE CONTROL COMPLETE
					(1) Critical	(2) Major	(3) Minor	(4) Defect	(5) Major	(6) Minor	(7) Defect	(8) Minor	(9) Defect	
S-IB	STRUCTURES	5	5	0			2					1	2	5
	PROP. & MECH.	23	23	11		2	2		5	1		7	6	21
	FLIGHT CONTROL	0												
	INSTRUMENTATION	45	45	24						7	12	16	10	45
	ELECTRICAL	5	5	0					2				3	5
	ENVIR. CONTROL	0												
	TOTAL	78	78	35		2	4		7	8	12	24	21	76
S-IVB	STRUCTURES	13	13	2				4				5	4	11
	PROP. & MECH.	18	18	1		1		1		1		15		14
	FLIGHT CONTROL	13	13	4		2	1	2		1		7		9
	INSTRUMENTATION	40	40	12			1	1				36	2	30
	ELECTRICAL	13	13	0		1						11	1	1
	ENVIR. CONTROL	1	1	0									1	
	TOTAL	98	98	19		4	2	8		2		74	8	65
S-IU	STRUCTURES	NOT APPLICABLE												
	FLIGHT CONTROL													
	INSTRUMENTATION													
	ELECTRICAL													
	ENVIR. CONTROL													
	TOTAL													
GSE	MSE	16	16	2								15	1	7
	ESE	9	9	0								9		5
	TOTAL	25	25	2								24	1	12
GRAND TOTAL		201	201	56		6	6	8	7	10	12	122	30	153

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

PART/MATERIAL APPLICATION PROBLEM DISPOSITION REPORT 1-64

INSTRUCTIONS

To be completed after follow-up action by the contact point of the responsible center, and copies distributed to the contact point at each center, the system contractor, and the item manufacturer. Please complete by typewriter.

1. ORIGINATING NASA CENTER MSFC, Huntsville, Ala.	2. DATE May 27, 1964

3. REFERENCE

TWX DATED: April 30, 1964 SIGNED BY: H. K. Weidner

4. LOCATION OF PROBLEM SITUATION Power Supply	5. PROJECT Saturn I

6. PART OR MATERIAL IDENTITY

Rectifier

7. NAME OF MANUFACTURER Transitron Electronic Corp.	8. CATALOG NO. TK21	9. DATE PROCURED 6th wk. 1962

10. [illegible] NO. None	11. MANUFACTURER'S LOT NO. OR DATE CODE 6206
12. SOURCE OF PROCUREMENT Transitron Electronic Corp.	13. [illegible] NO.

14. SPECIAL REQUIREMENTS

None

Figure 11

15. PROBLEM SITUATION

Three measuring rack power supplies failed to operate during static firing of S-I-9. During flight of SA-5, a power supply identical to the supplies in question failed, resulting in the loss of valuable flight data.

16. PROBLEM(S) OR CAUSE(S)

Failures on S-I-9 were found to be caused by type TK21 rectifier. The Silicon pellet broke loose from the header due to inadequacy of silver paste bonding material. Also, metallic balls were present inside the rectifier.

NASA FORM 863 JUL 63 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE.

17. REMEDIAL ACTIONS TAKEN

TK 21 rectifiers replaced with type IN3190 manufactured by Texas Instruments using gold preform bonding technique.

18. PROPOSED SOLUTION

Replace all Type TK21 rectifiers with type IN3190 rectifiers which have been manufactured using gold preform bonding technique.

. RECOMMENDATIONS FOR FURTHER ACTION

Discontinue use of TK21 rectifiers in space vehicle applications, as they are not suitable for use in areas where vibration and shock may occur.

Complete failure analysis contained in MSFC report IN-R-QUAL-64-37.

20. DATE	21. TYPED NAME, TITLE AND CODE	22. SIGNATURE
May 27, 1964	Nancy Milly, R-QUAL-QVA	Nancy J. Milly

GPO 870-745

BENEFITS OF MSFC UCR SYSTEM

- STANDARD REPORTING REQUIREMENTS
- UNIFORM EVALUATION OF DATA
- ASSURANCE OF CORRECTIVE ACTION
- CENTRALIZED MAINTENANCE OF DATA
- PROGRAM ANALYSIS
  1. Evaluation of quality control systems
  2. Optimization of test programs
  3. Performance of reliability assessment studies
  4. Elimination of similar problem situations

OCP-AV-33

Figure 12

Customer Involvement in Failure Review
by
Fred F. DeMuth, Ames Research Center

Since we are to discuss one aspect of failures, that is, customer involvement in failure review, perhaps we should define failure.

Some people think of a failure as something catastrophic. In the aerospace business, this would be a capacitor or diode shorting, a bearing "freezing," or a wire breaking. Most others, including myself, think of a failure as a lack of performance, or a failure to perform as required. Thus, a leaky capacitor which provides an output of 0.95 volts instead of a required 1.00 volts is a failure. A bearing which causes sufficient drag to reduce the output speed to 59.5 RPM instead of a required 60 RPM is a failure. A pinched wire which causes a current leak through the insulation is also a failure.

In general, I class a failure as any non-conformance to established procedures, specification, or drawings. These cover the normal situations of the form, fit and function categories. However, in early fabrication and subsequent inspection prior to parts becoming a recognizable or serialized component, the form and fit failures, normally designated as non-conformances, are weeded out and handled by a "floor" MRB or by a normal MRB. This leaves the class of failures to which I am directing my attention. These are those non-conformances to established procedures (particularly test procedures), specifications and drawings which show up in the area of function or performance. I will hasten to add that any failure in function or performance may be due to a heretofore undiscovered form or fit problem. Basically these failures are discovered during manufacturer's pre-acceptance, acceptance pre-qualification and qualification testing. While there are certain problems which arise from the definition of a failure, the major problem associated with today's topic is the general stigma which surrounds a failure.

First of all, it is considered by most people, customer and supplier alike, as a dirty word. Herein lies a major source of trouble whenever the subject arises. I think as normal human beings, none of us likes to be associated with the word failure. It tends to proclaim, loud and clear, that there is a definitive inadequateness in what we are doing. It tends to brand us as incapable in one form or another. It tends to make the participant guilty and secretive, and tends to make the observer critical and suspicious. So you see we start out discussing failures in a rather uncomfortable atmosphere. To compound this effect we have with us a consistent and seemingly ever increasing pressure from the contractor to keep the customer out of the picture. The contractor wants to handle the program as he sees fit and he accomplishes this by supplying as little information as possible to the customer. In the case of failures, which take the form of non-performance by the contractor, he is even more reticent.

You might ask, why the fuss about failures? Well, I firmly believe there is no single factor which more clearly defines the health of a program than its failure history. The number, type, and disposition of failures have a very significant impact on cost, schedule, interfaces and, of course, technical performance. Customer involvement in failure review provides the opportunity to contribute to failure solution, and more importantly, to utilize the information as a critical input to the management task. I do not wish to imply that the customer is endowed with extensive technical ability. However, in addition to their fair share of technical competence, the customer many times has had the benefit of multi-program experiences and he may be able to provide desirable information conducive to the solution of a failure problem. Also, and possibly more important, there are facets of the program, unknown to the contractor, which could be seriously affected by a failure problem and its solution. Of prime importance is the involvement from the management viewpoint. Being on top of the failures provides the customer with a major step for being on top of the program. Since the basic function of NASA is to manage programs, I feel customer involvement in failure review is significantly important.

As a point of clarification, when I say failure review, I do not mean failure solution. I mean a systematic review of the failure, its cause, its solution, the implementation of corrective action and verification of the adequateness of the corrective action. Thus, the normal requirement of notification of the customer of any failure within the usual 24 or 48 hours does not fulfill the failure review requirement.

At Ames we have had some interesting and constructive experience in the area of failure review. I believe a brief discussion of this experience would be of value to you and hopefully provide you with some encouragement as to the workability of customer involvement in failure review.

At Ames we have two major spacecraft programs and in each program there is some form of failure review in which the customer, NASA/ARC, is involved. Neither program had any provision for this function in the RFP or in the resultant contract. In both programs the failure reporting system used by the two contractors is fairly standard. There are good and bad details and, of course, the normal problems of conforming to the procedures. Each, by similar means, provides for a form of failure analysis corrective action, and failure closeout. However, there is a definitive difference in attitude between the two contractors as to closing and reviewing failures. The philosophy with respect to review and with respect to customer involvement is as far apart as the two contractors' plants, the east coast and the west coast. On one hand the contractor attempts to restrict the customer's knowledge and depend upon the "system" to take care of things. On the other hand, the second contractor provides essentially complete visibility to the customer and he also has a method of review which provides significant insurance that a failure is completely and properly closed. In the area of initiation of failure reports, a companion topic, there is a significant difference between contractors which is indicative of the two basic philosophies and which for one contractor contributes greatly to the problem of establishing a failure review system which includes the customer.

The rather reticent contractor conducts a component bench test after manufacture and prior to acceptance test. If a failure occurs in the component, a non-conformance report (NCR) is written, but it is not classed as a failure but as a manufacturing error and is returned to manufacturing for correction, with no analysis performed by reliability. Oddly enough, if the bench test is successful, the operating time is counted from a reliability evaluation viewpoint. The same philosophy was utilized for the first tests of a system. We have, however, convinced the contractor that at least in the latter case, these are failures. As further background the man in charge of reliability stated that it sounded as if we were trying to absolutely prevent a failure from reoccurring. He thought it was not necessary because if it did occur again, their system would catch it. The other contractor treats all operating non-conformances formally as failures. If an individual module, not yet a black box, fails during a manufacturing test, it is classed as a failure and a report written and dispositioned in the normal manner as a failure. You can see there is a bit of a difference between contractors.

With this background in mind, I would like to point out some of the progress we have made in the area and how Ames gets involved in failure review.

The more cooperative contractor initiates ARC involvement in the normal manner of written notification of each failure within 48 hours. This is in the form of TWX sent to the Ames Project Manager with copy to the Ames Reliability and Quality Assurance Manager. A copy is also supplied to the Ames in-plant representative. In addition, in critical cases, a phone call is made to the Ames Reliability and Quality Assurance Manager by the contractor Reliability or Quality Assurance Manager within a few minutes of failure occurrence. Continuous customer visibility in the failure area is maintained since the contractor Reliability Manager calls the Ames Reliability and Quality Assurance Manager each Friday and provides a verbal report on all open failures and action items. In some cases, when the list is long, only the more critical items are discussed. The failures are closed by the contractor in an orderly process during which there is free exchange of information between the contractor's reliability and quality assurance and technical personnel and Ames reliability and quality assurance and technical personnel.

A Failure Report Review Board (FRRB) was established to review, on a monthly basis, all module, unit, subsystem, and system test failures. The function of the Board is to review all failures to ensure that: proper failure analysis has been conducted, corrective action has been established, corrective action has been implemented and proper disposition of failed items has been made. The Board is chaired by the contractor Project Reliability Manager who is supported by one other reliability staff member. Other members are representatives of Quality Assurance, Fabrication, and the Ames Reliability and Quality Assurance Manager. The Board has the responsibility and authority to close failures, reopen failures and assign action items.

The Board is assisted on an invitation basis, by representatives from the test area, parts application and, of course, the responsible engineers. Normally the Ames Spacecraft Manager and/or other Ames technical people are present. Even an independent reliability contractor has a standing invitation. The Board is a working body and observers are not welcome since the theme is participation, not presentation.

The basic working document of the Board is the Failure Report Summary issued no later than the 10th of each month. The summary provides pertinent information such as complete part identification, description of failure, cause of failure, corrective action and responsible engineer. All failures occurring during the interval between the issuance of the summary and the Board meeting are covered during the meeting by using copies of the failure reports. The discussions are supported by hardware, drawings and other documentation deemed necessary to provide a clear insight to the problem. Minutes of the meeting including any assigned action items are distributed within a few days after the meeting.

This method of failure review was not implemented without some pain and effort on the part of Ames. However, the contractor is to be complimented and given full credit for the basic concept of the Failure Report Review Board. The customer participation in the failure review function has provided Ames with two very desirable rewards: an excellent and timely visibility in the failure area, and a degree of confidence in the contractor not normally experienced.

The more reticent contractor also brings Ames into the failure review cycle by notification to the Ames in-plant personnel within 24 hours of failure occurrence. The in-plant people in turn provide copies of the information to the Ames Reliability and Quality Assurance Manager and the Ames Project Office. In this case, however, the customer notification is not by the contractor Reliability and Quality Assurance Manager but by other members of the Project Office. No early communication between the contractor Reliability and Quality Managers and the Ames Reliability and Quality Assurance Manager was permitted by the contractor Project Office. Attempts to initiate a weekly phone call between the contractor Reliability Manager and the Ames Reliability and Quality Assurance Manager were unsuccessful. The contractor finally agreed to the phone call but insisted upon other members of the Project Office being on the line and Ames' having to prepare a written report on the conversation and then submitting this report to the contractor for review and authentication. Aside from being rather ridiculous, this did not work because it was not possible to get the required contractor personnel at the phone at the same time. This effort was dropped.

Efforts were made to provide for an Ames input during the contractor failure closeout. This approach met with substantial resistance and resulted in the contractor closing failures according to his system and Ames independently closing the same failures. The major difference centered around the extent to which the corrective action was followed. The failure was closed by the contractor when the corrective action was recommended or established. Closure by Ames occurred when proper corrective action had been implemented. The need for the Ames approach was demonstrated several times when a physical check was made and it was found that even though the corrective action was reported to have been taken, it was embarrassingly obvious that it had not been taken.

Due to continued pressure on the part of Ames a reasonably adequate system of failure review evolved for major and critical failures. After the contractor closes out a failure, the contractor reliability personnel gathers information verifying the corrective action or disposition has been implemented. At that time the information is submitted to the Ames Reliability and Quality Assurance personnel for review and Ames closeout. Ames reviews the information and a meeting between the contractor reliability personnel and Ames Reliability and Quality Assurance personnel is scheduled.

In some cases, the Ames Reliability and Quality Assurance personnel are supported by Ames technical personnel. This is particularly true if there is a serious question as to the adequacy of the solution to the failure. Normally the Ames position is established prior to the meeting and either the failure is promptly closed or discussions bring out additional information supporting the closure. Sometimes, but not very often, the contractor will bring in his technical people to support the closure. Upon Ames closeout, a written notification is provided to the contractor.

In the case of minor failures, there is a 10% audit made by Ames following the same plan as outlined above for major and critical failures.

A Status of Failures Report issued monthly and up-dated continuously provides "score card" type information on closeouts by Ames and the contractor.

The contractor also issues, for general information, a monthly Failure Summary Report which provides component identification, failure description, failure investigation and corrective action as well as responsible personnel.

While the Ames involvement and contractor treatment of failure review is not completely satisfactory, very significant progress has been made. The contractor is fully aware of the importance Ames attaches to proper failure closeout and there is a gradual movement toward understanding, on the part of the contractor, of the Ames position in this matter. There is a little less resistance to the Ames demands for adequate closeout. In several cases the contractor has taken significant steps, upon Ames insistence, to rectify an inadequate failure closeout. However, the contractor is very adept in scheduling and rescheduling meetings and submission of data. As a result the review is sometimes rather spasmodic. Also, since minor failures are treated as an audit basis, failure classification has to be carefully watched.

While in the case of this contractor the degree of confidence is still considerably below that of contractor previously discussed, it is the hope of Ames to eventually bring about a completely satisfactory failure review system.

Because of the confidence in the Failure Report Review Board system and its customer involvement, it is the intent of Ames to include this function as a requirement in future contracts.

NEED FOR VISUAL INSPECTION

by

Edward F. Thomas
Quality Assurance Branch, Test & Evaluation Division
Goddard Space Flight Center

Workmanship defects resulting from lax manufacturing quality control procedures rank high on the list of failure causing mechanisms. GSFC procured parts, because of their use in space applications, must be free from all possible failure inducing defects. Fortunately, in the case of glass encased diodes it is possible to screen out many of these defects by the proper use of internal visual examination. However, because of the extra handling operations introduced into the manufacturer's production schedule, the cost of a 100 percent visual inspection requirement can become appreciable.

It was the purpose of this evaluation to ascertain (a) whether routinely procured, MIL-qualified parts met the minimum workmanship requirements set by GSFC, or (b) whether these parts could be effectively screened to a GSFC specification so that acceptable units could be obtained. The MIL-S-19500 specification governs case and lead dimensions, electrical measurements, environmental tests and device markings, but does not include the 100 percent internal visual inspection.

For this evaluation, sample lots of fifteen units each were procured from fourteen different MIL-approved manufacturers. Several device types were selected to cover a broad spectrum of diode design. This resulted in a total of twenty-two diode manufacturer/type combinations. The diode types, manufacturers and specific procurement specifications, are listed in Table I.

Upon receipt the units were checked for electrical performance characteristics and all conformed to the appropriate military specification. The units were then subjected to the inspection criteria of S-323-P-3 which includes examination of the diode leads, external body, and internal construction under 20x magnification. A magnification of 30x was used to resolve questionable defects. An examination of the leads and external body of all the devices found them to be fully acceptable under S-323-P-3.

TYPE	SAMPLE SIZE	MANUFACTURERS	MIL-SPEC
1N270	15	Transitron, National Transistor, Hughes	MIL-S-19500/200
1N277	15	Sylvania, Ohmite, General Instrument	MIL-S-19500/201
1N483	15	Raytheon	MIL-S-19500/118A
1N485B	15	Raytheon, Fairchild	MIL-S-19500/118A
1N486B	15	General Instrument, Texas Instrument, Continental Device Corporation	MIL-S-19500/118A
1N649	15	General Electric, General Instrument	MIL-S-19500/240A
1N658	15	General Instrument, Sylvania	MIL-S-19500/257
1N746A	15	Texas Instrument, Western, Hughes	MIL-S-19500/127B
1N748A	15	Hoffman	MIL-S-19500/127B
1N749A	15	Continental Device Corporation, Motorola	MIL-S-19500/127B

TABLE I

List of Diodes Examined to S-323-P-3

Prior to the internal examination, the paint was removed from the cases of the diodes. The internal examination uncovered several prominent defects among the units. These defects are listed in Table II along with the rejection criteria of S-323-P-3. Examples of these defects are presented in Figures 1 and 2.

Of the twenty-two diode manufacturer/type combinations examined, only three met the additional workmanship requirements of S-323-P-3. The three device types that met these requirements were from different manufacturers indicating that only 20 percent of the manufacturers examined produced MIL-level diodes acceptable for GSFC applications, relative to the visual inspection criteria, without requiring additional screening.

Since the examination of the MIL-qualified diodes showed them to have various workmanship defects, all of which could be easily screened out by using S-323-P-3, a number of manufacturers were asked to comment on this document and its effect on device cost. Of the thirty-one manufacturers contacted, fourteen submitted comments. All but one of the replies stated that the extra screening step could be easily incorporated into the production schedule. The price increase, due to the extra handling and inspection, ranged from $.05 to $1.00 per unit, the latter figure being based on small lot sizes of 1 to 50 units.

The examination of a number of diode types from several manufacturers and all procured to the appropriate military specification has shown these devices to contain various workmanship defects. By invoking GSFC's visual inspection criteria, S-323-P-3, it would be possible to screen out units containing the type of defects described in this report. Manufacturers have replied that although there would be a slight cost increase due to the additional screening, S-323-P-3 could be easily incorporated into their production schedules.

Based on the above information, it is recommended that the visual inspection criteria, GSFC S-323-P-3, be added to all GSFC procurements of MIL-qualified glass encased diodes intended for space flight applications.

	WORKMANSHIP DEFECTS	PERCENTAGE OF UNITS EXHIBITING DEFECT	GSFC-S-323-P-3 REJECTION CRITERIA
1	Foreign material inside glass case	40%	Unnecessary material either loose or attached, exceeding 0.001 inch in its greatest dimension. See Figures 1a, b, and c.
2	Misaligned internal construction	16%	Any element tilted, shifted, or twisted greater than 10 degrees from normal. See Figure 1d.
3	Poor contact between ribbon and anode post	4.2%	Any welded or soldered connection exhibiting less than 50% fusion or adhesion.
4	Poor contact between wafer and cathode post	2.2%	Any welded or soldered connection exhibiting less than 50% fusion or adhesion. See Figure 2b.
5	Solder balls inside glass case	1.9%	Unnecessary material either loose or attached, exceeding 0.001 inch in its greater dimension. See Figure 2c.
6	Bent or twisted ribbon	1%	Any element tilted, shifted, or twisted greater than 10 degrees from normal. See Figure 2d.
7	Chipped or broken wafer	0.7%	Wafer exhibiting cracks, chips, nicks, or other deformities in excess of 25% of wafer thickness.
8	Poor anode weld	0.3%	Any welded or soldered connection exhibiting less than 50% fusion or adhesion.

TABLE II

Results of an Examination of MIL-Qualified Diodes to GSFC's S-323-P-3

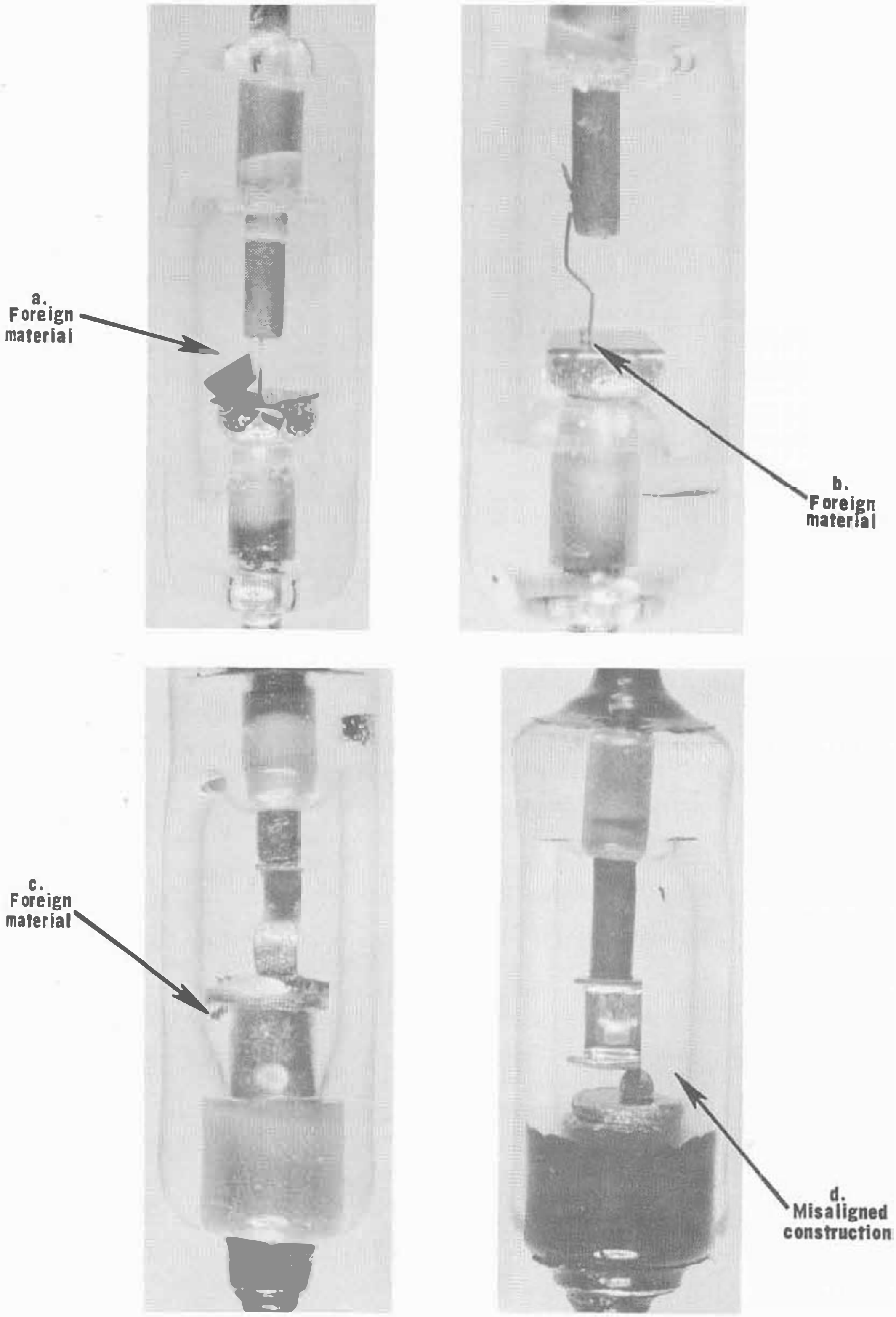

Figure 1. Workmanship defects.

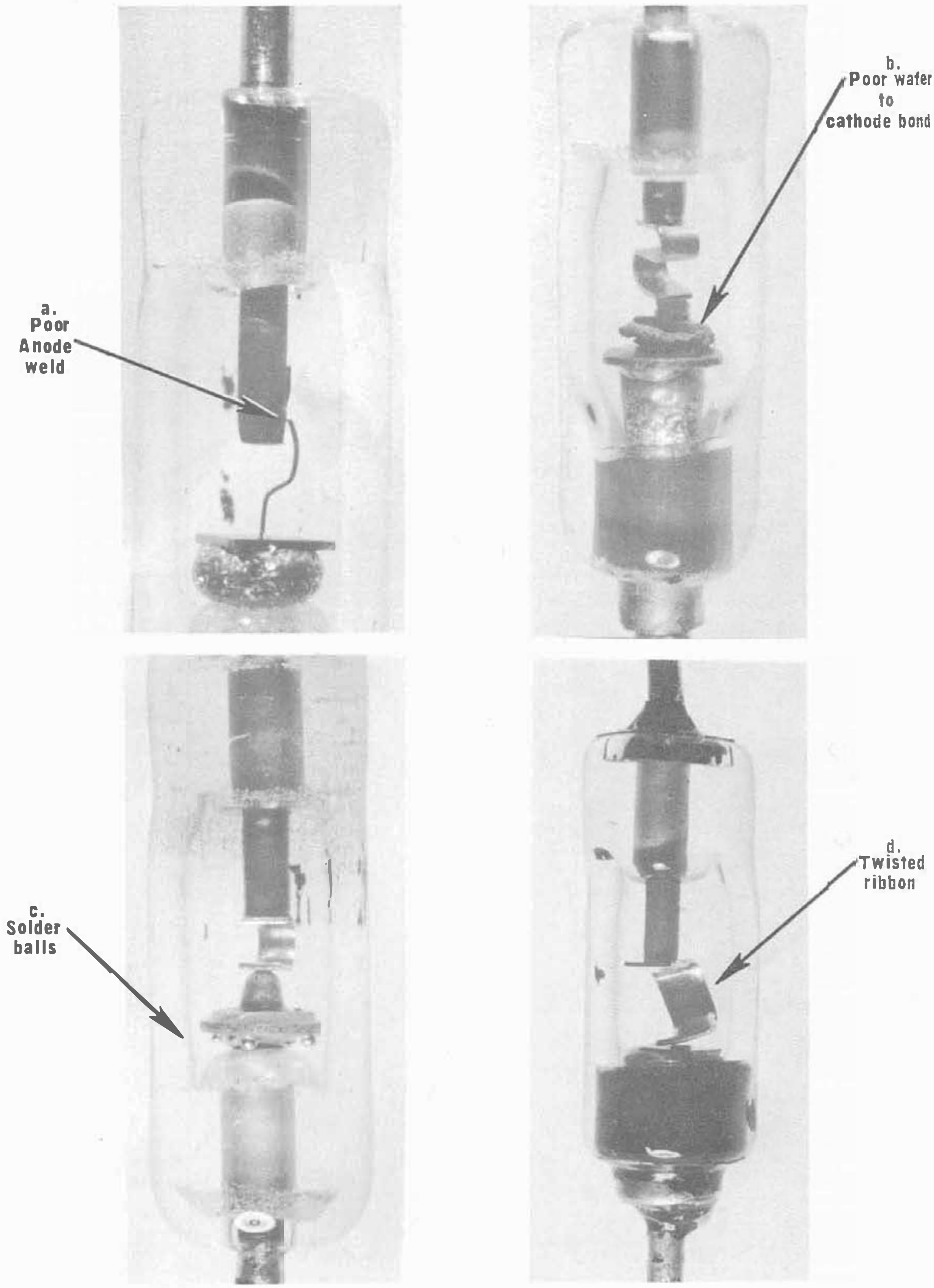

Figure 2. Workmanship defects.

Human Factors Bearing on Plant Personnel Motivation

by

John C. New
Goddard Space Flight Center

Improving the quality of unmanned spacecraft components through a close attention to the human factors which affect both quality and reliability is an area in which the Goddard Space Flight Center has been extremely interested. This paper will concern itself with a review of two studies recently completed at Goddard and suggest an approach for NASA to take in the future to help motivate industry toward providing reliable hardware for space flight.

Previous Studies

Since 1943, and particularly during the past century, extensive research has been directed toward the nature of human motivation. A great deal of this effort has been aimed at determining the degree to which man's basic needs are met. The following chart is adapted from A. H. Maslow's[1] theory on the "hierarchy of human needs." As illustrated in the chart, man's needs may be arranged in a hierarchy form such that needs higher up the hierarchy do not become capable of influencing behavior until lower more basic needs are satisfied to some degree.

As illustrated, man's needs may be divided into five categories: physiological, safety, social, ego, and self-actualization. The physiological level of needs concerns various basic needs, such as, food, clothing, and shelter. The second category level concerns safety needs, such as, freedom from the fear of job security. Both the physiological and safety levels may be considered as basic attitude foundation factors. The absence of these factors will preclude the adequate establishment of fully motivated individuals,

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1. A. H. Maslow, Motivation and Personality. New York: Harper, 1954. An expansion of a paper originally published in 1943, entitled, A Theory of Motivation.

THE HIERARCHY OF MAN'S NEEDS

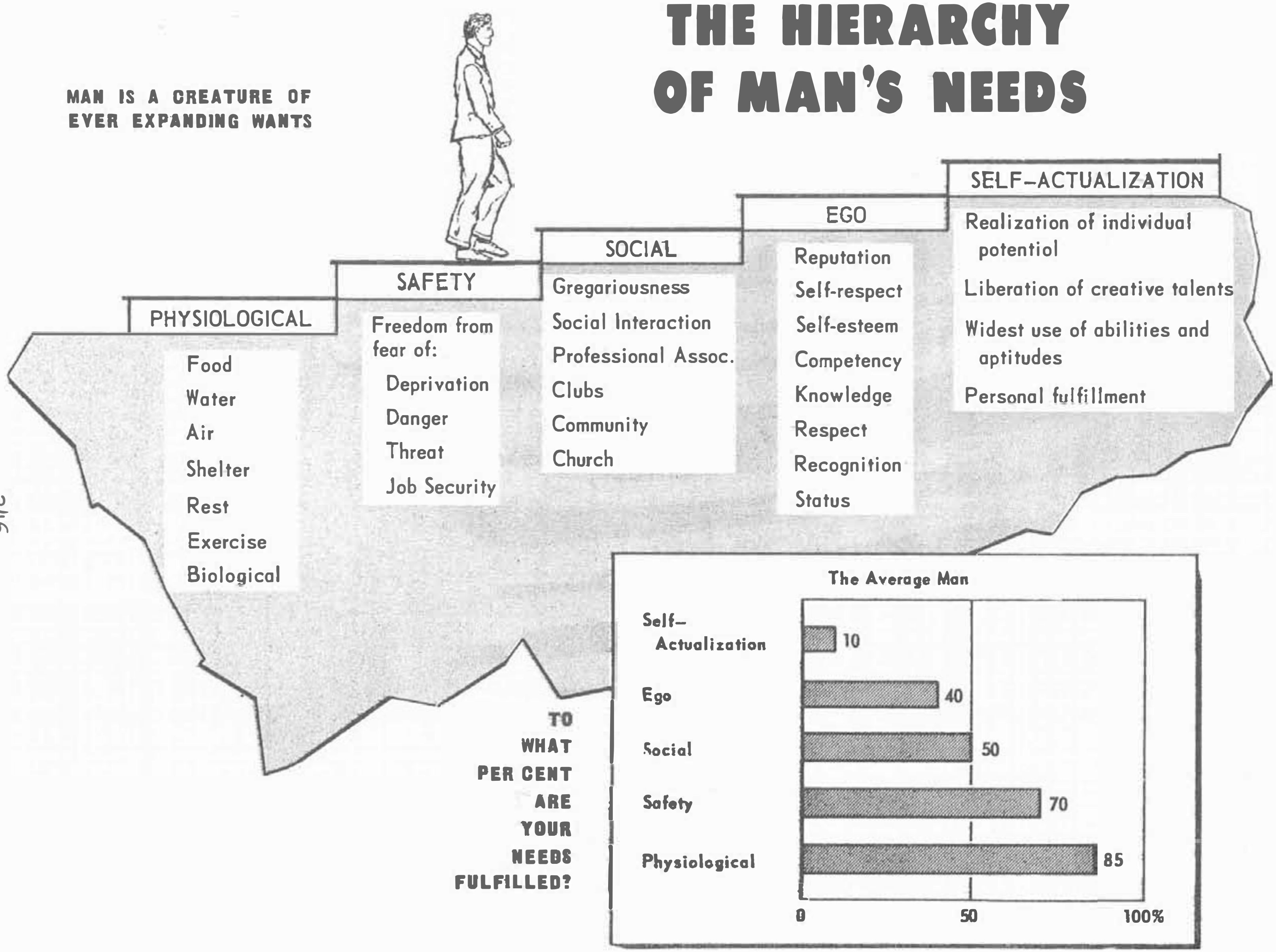

Chart 1

COMPARISON OF MOTIVATORS AND
DISSATISFIER FACTORS

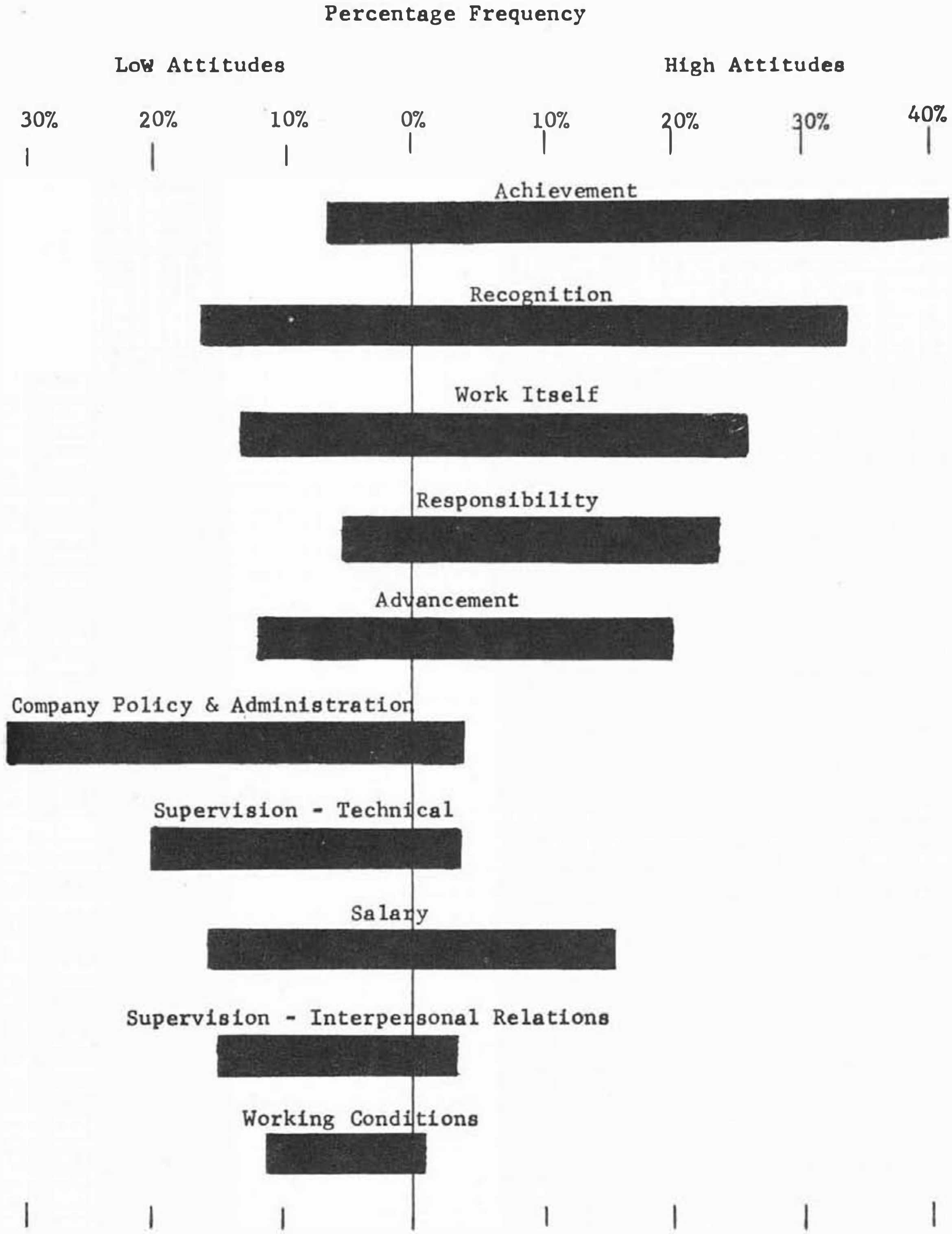

Chart 2

but their presence will not guarantee permanent motivation.

Studies conducted in 1959 by Dr. Frederick Herzberg[2] and his colleagues at the University of Pittsburgh point out that the needs shown in Maslow's top three levels are the real motivators. When man has satisfied his sociological needs, he may move up to the more permanent motivators associated with egoistic and self-actualization.

The Herzberg study highlights that jobs satisfiers, such as achievements, recognition, responsibility, and advancement, were usually present in satisfactory job situations. Chart 2 compares the percentage frequency for the principle motivators and dissatisfiers mentioned by the workers in the Herzberg study. The Herzberg comparison indicates that low attitude job situations usually develop from such dissatisfiers as (inadequate) supervision, (poor) company policies, administration's (unfair) criticisims, and (poor) working conditions.

The factors which influence human motivation are indeed complex. To further understand the complete picture, we might examine the maturity cycle of the organization within which a human functions.

The following chart (3) presents typical cycles through which an organization passes as it acquires a position of maturity.

Similar needs associated with individuals may also be applicable to organizations. For example, a new company is primarily concerned with a pioneering-type effort. Such items as recruitment, facilities, etc. are prime motivators. At a later date, further up the scale, when the organization has become more secure, efforts are usually directed toward

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2. Frederick Herzberg, Motivation to Work. Bernard Mousner, Barbara Bloch Snyderman. John Wiley and Sons, Inc., 1965.

MATURITY CYCLES FOR ORGANIZATIONS

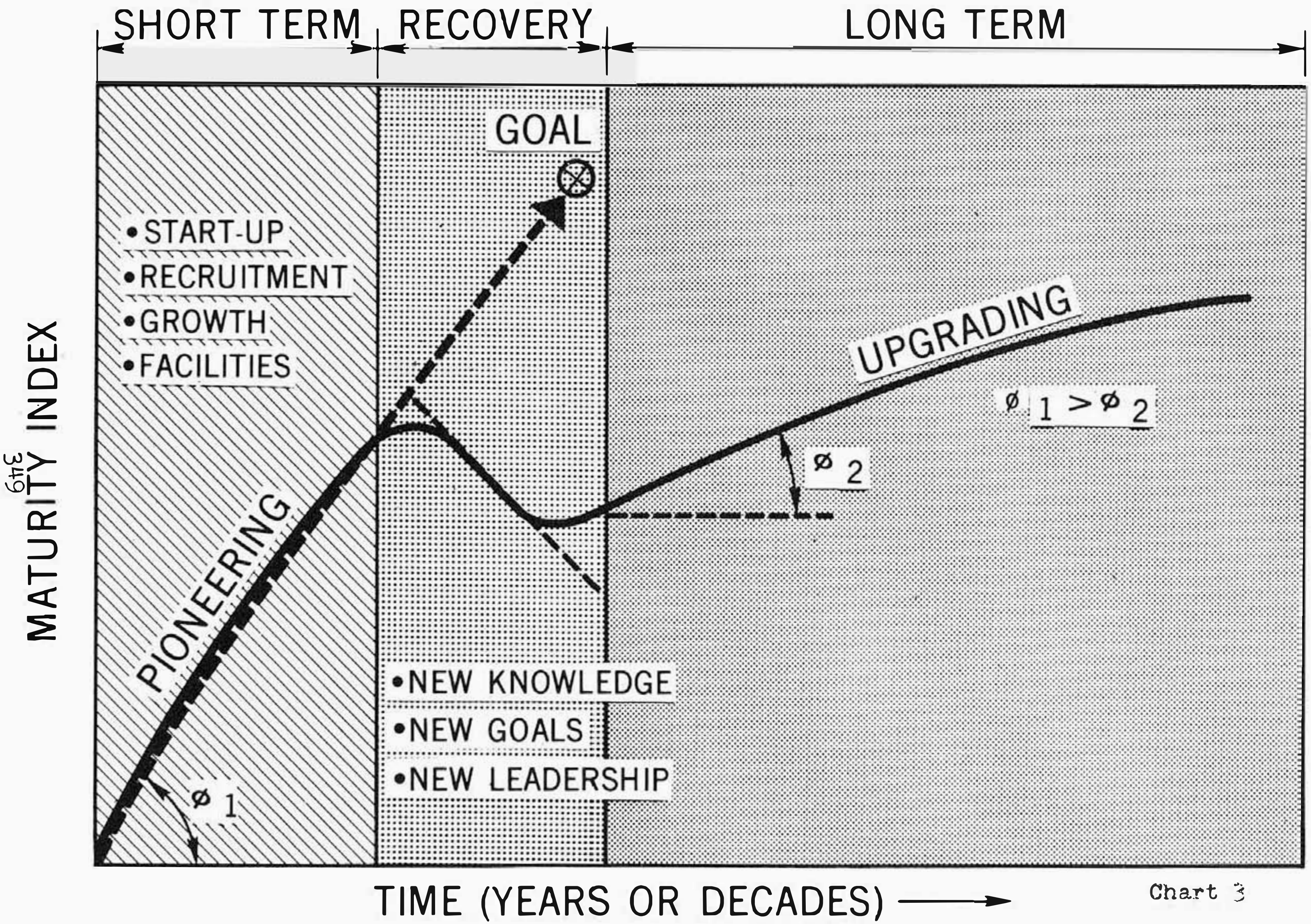

Chart 3

acquiring new knowledge, goals, and leadership. A knowledge of the particular position of an organization along the maturity scale would prove worthwhile in determining basic organization motivators and dissatisfiers, and would ultimately result in a clearer understanding of the individual workers. It is the writer's observation over some 20 years that organizations follow a hierarchy of needs much the same as individuals. Since the goals of the individual and the goals of the organization must be compatible for effective performance, it is essential to understand each set of goals if one is to predict or influence effectiveness.

GEORGE WASHINGTON STUDY 1964 - 1965

Goddard's interest in human factors resulted in a contract with the Center for Behavioral Sciences, George Washington University (GW) which was awarded in September, 1964. The purpose of the contract was to isolate, identify and analyze human factors which affect the management of quality and reliability programs. The GW Study[3] presented two basic propositions concerning human performance. The first was that man's performance is a function of his ability and motivation. The following equation illustrates this relationship:

Performance (P) is a function (f) of Ability (A) and Motivation (M)

$$P = f\ (A, M)$$

As stated by Mr. Victor H. Vroom in his book, Motivation In Management,[4] the interaction between ability and motivation suggests the fairly obvious point that motivation is not the sole factor influencing a person's level of performance and also that the consequences of a given degree of each factor is dependent on the pre-existing value of the other.

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3. Dr. Regis Walther, Study on Human Factors Related to Quality and Reliability of Unmanned Spacecraft Components. George Washington University under a GSFC contract, 1964/65.

4. Victor H. Vroom, Motivation In Management. An American Foundation for Management Research Study Effort, 1965.

The second proposition was that production can be achieved through three performance levels depending on the complexity of the task. These performance levels are:

Individual

Supervisor

Executive

The Study highlighted several basic behavior concepts required for effective performance at each of these levels.

One of the most thought provoking conclusions of the GW Study was the emphasis which was placed on communications. Dr. Walther pointed out that, at each level of performance, communication carries out a vital function. An individual's best performance is improved by the communication of both production expectations and the supervisor's interest and respect. As individuals, supervisors also respond to the quality of communication from their supervisors. Finally, an executive's ability, his capacity to assemble and maintain systems serving the overall goal, is singularly dependent on the quality of his communications. A major thought expressed by GW was that the quality of communication which flows through an organization depends on whether its personnel are interrelated through cycles of trust or fragmented cycles of mistrust. Chart 4 presents these cycles:

A cycle of trust will result in cooperative activity toward shared goals. On the other hand, a cycle of mistrust results in an employee setting standards of self-protection rather than production goals.

SCHLEH STUDY, MARCH through AUGUST 1966

Goddard's interest in human factors and their effect on quality and reliability continued in 1966 with the award of a contract to Schleh Associates, Inc. to perform "A Study of Human Factors Affecting Quality and Reliability in Unmanned Spacecraft Components."[5]

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5. Schleh Associates, Inc., A Study of Human Factors Affecting Quality and Reliability in Unmanned Spacecraft Components. Prepared under NASA Contract NAS 5-8783 for Goddard Space Flight Center, NASA. July 1966.

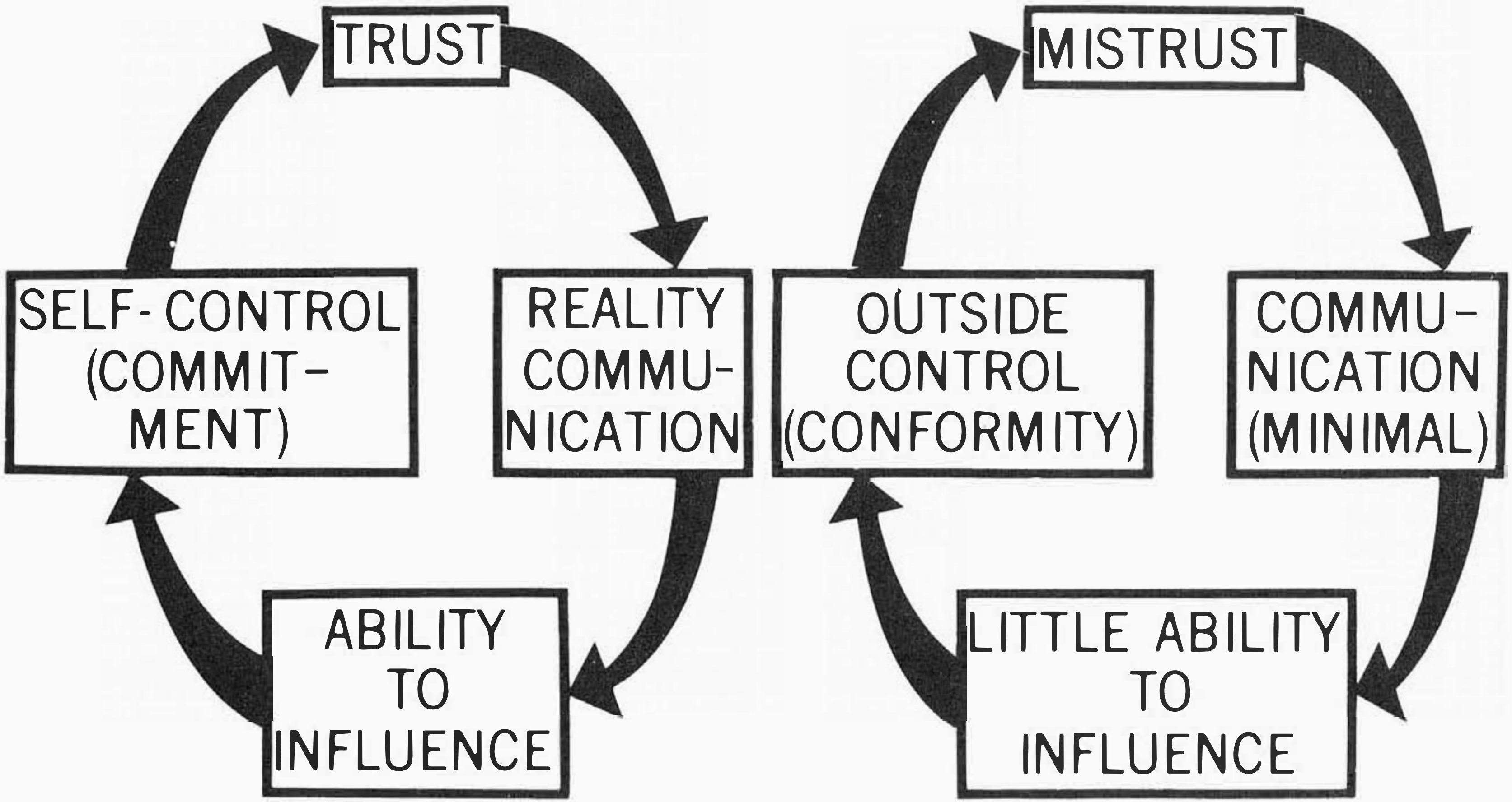
TRUST
REALITY COMMU-NICATION
ABILITY TO INFLUENCE
SELF-CONTROL (COMMIT-MENT)
MISTRUST
COMMU-NICATION (MINIMAL)
LITTLE ABILITY TO INFLUENCE
OUTSIDE CONTROL (CONFORMITY)

Chart 4

The study contract involved the evaluation of four different companies as shown below:

Companies Studied

Company	Location	Product Supplied
A	Texas	Components
B	California	Sub-Assembly
C	New York	Scientific Instrumentation
D	Colorado	Spacecraft

Note: All companies had more than one GSFC contract with dollar value from 200K to several M's.

The percentage of interviews conducted at the respective companies by Schleh were distributed in the following areas:

Distribution of Interviews

1.	Production	30%
2.	Quality and Reliability	30%
3.	Administration	20%
4.	Engineering	10%
5.	Divisional and Corporate Management	10%

The Schleh Study concerned itself with the following questions:

Study Questions

1. What are some of the various management approaches that increase operator commitment for Quality Work?

2. How is Operator Training related to Quality?

3. What is the effect of Multiple Quality Standards on Quality Performance?

4. Who should be held accountable for Quality?

5. Is a Balanced Approach Needed to Obtain Optimum Quality?

6. Should a critical area approach be stressed to gain Quality results?

7. Can Quality Accountability be improved by Organizational Design?

8. Should the Quality function be Enforcement or Improvement?

9. What are effects of Company Growth on Quality?

These questions are discussed in detail in the Schleh Study. The study conclusions which evolved from the companies examined were as follows:

<u>Study Conclusions</u>

1. Where individuals are not accountable for the way their efforts affect quality, Quality performance suffers.

2. When one function or result is overemphasized, the total Quality effectiveness may be lessened.

3. When excessive detailed control is imposed, there is an adverse effect on individual operator commitment for Quality performance.

4. When people must work to several quality standards, one or the other, or both, are sacrificed.

5. When the improvement role of quality is used in conjunction with enforcement, line-staff relationships are improved and better quality results can be expected.

6. When the business has grown rapidly, special attention must be given to training problems, tie-in accountability, and staff accountability, or quality may suffer.

7. When the training setup of operators does not provide for (1) accountability for results of training, (2) training on "How to Train," and (3) follow-up, poorer Quality can be expected.

8. When critical areas in the production process are identified and special provision is made to cover those areas, better quality results are possible.

MOTIVATION OF INDUSTRY - A challenge to NASA!

How can NASA motivate contractors to more fully achieve desired performance?

The relationship between NASA and Industry is similar to the contract relationship which exists between a manager and his employee. Acceptance of a contract by industry involves the acceptance of a form of external control in exchange for money and other rewards. Since this arrangement goes against the grain of many individuals (and companies) the relationship sets the stage for conflicts and wastes the potentialities of both industry and NASA.

As expressed by Mr. Douglas McGregor, in his book, The Human Side of Enterprise, "The manager (NASA) is in a position very much like navigating a small boat amidst powerful currents. The trick is to adapt itself to those currents rather than buck them."[6]

In the case of NASA/Industry relationships, the "steering" of the small business-type purchase order through the "currents" of negotiations takes on additional difficulties. As if someone deliberately damaged the steering mechanism, NASA personnel find themselves attempting in most cases to motivate companies where there are little or no incentives.

A check of Goddard procurement actions during FY 1966

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6. Douglas McGregor, The Human Side of Enterprise. New York: McGraw-Hill Book Co., Inc., 1960.

reveals the following data:

Procurement Placement	No. Actions	% Total	K's
Small Business	22,770	43.0	52,194
Large Business	14,817	28.0	288,225
Intragovernmental	13,926	26.3	91,331
Universities	1,027	1.9	19,613
Other Non-Profit Institution	172	.3	2,305
Grants	33	.1	1,198
Miscellaneous	14	---	4,780
Outside USA	193	.4	18,930

As shown in the above table, 43% of Goddard's procurement actions during FY 1966 were with small businesses while only 28% were with large companies. Actually the small business % is considered larger than 43% since a fairly large portion of the intragovernmental actions finally end up in small business procurements.

A question that comes out of this comparison is, what can be done, therefore, to motivate small businesses? Although these companies received over 40% of Goddard's procurement actions, they only received 10% of the dollars. Recent discussions with several small distributors and manufacturers of Goddard components have been most enlightening. Two companies, one a distributor on the West Coast and the other, a distributor in Washington, D.C., both confirmed that they were not motivated to do business with Goddard because of the dollar value involved but rather because of the value of the prestige associated with participating in the NASA program.

A side comment made by the West Coast firm was that he thought his workers would be highly motivated if the NASA astronauts would pay a personal visit. This is a fine idea which I am sure has already caused our Astronauts to travel a great deal through the USA. In a similar manner, occasional visits by Center personnel to smaller businesses would also prove a stimulus which would improve communications and quality motivation. As stated by one Washington distributor after a recent visit by a GSFC Quality Assurance Representative, "The fact a NASA representative would bother to visit distributors to attempt to explain the reasons behind Quality Assurance requirements can only result in improved performance. My employees appear to be clearly motivated by this visit."

The principal reward that NASA has to offer industry is the opportunity to capitalize on the fact that industry's product has been used in a NASA program—and should therefore be "the best quality available."

For example, you only have to glance at any current weekly magazine to see the advantage that industry is already taking of this aspect. In a recent issue of Business Week the following picture took up a 3/4 page ad. The caption under the picture went as follows: "To find his way through space, an astronaut depends on a gyro-guidance system lubricated by less than one drop of a special oil. We developed it for industry, not for Space. As one of our premium industrial oils, it was remarkably well suited for the critical gyro bearings. It works so well, in fact, that aerospace researchers have never permitted any substitution. Now the Government is reserving it all for special aerospace applications."[7]

This article is a masterpiece of advertising and points out (in addition to the amount of mileage one drop of oil can see) the extent to which industry will go in order to achieve a benefit from NASA contracts. This action is considered only natural. The company has capitalized on the NASA "Seal of Excellence." Why doesn't NASA? The "Seal of Excellence" is the one commodity that NASA has to offer industry which is a marketable commodity.

I suggest that NASA begin to take advantage of this selling point to motivate suppliers toward providing higher quality hardware. For example, consider taking the trouble to award small firms who have obtained outstanding performance records, a NASA "Seal of Excellence." The reaction of such an award will be gratifying to industry as long as the award is one which small businesses can understand and appreciate.

By permitting industry to share in the rewards associated with outstanding performance, NASA will begin to see an even greater reduction in rejection rates and there will be a positive improvement in the quality of NASA procured parts and components.

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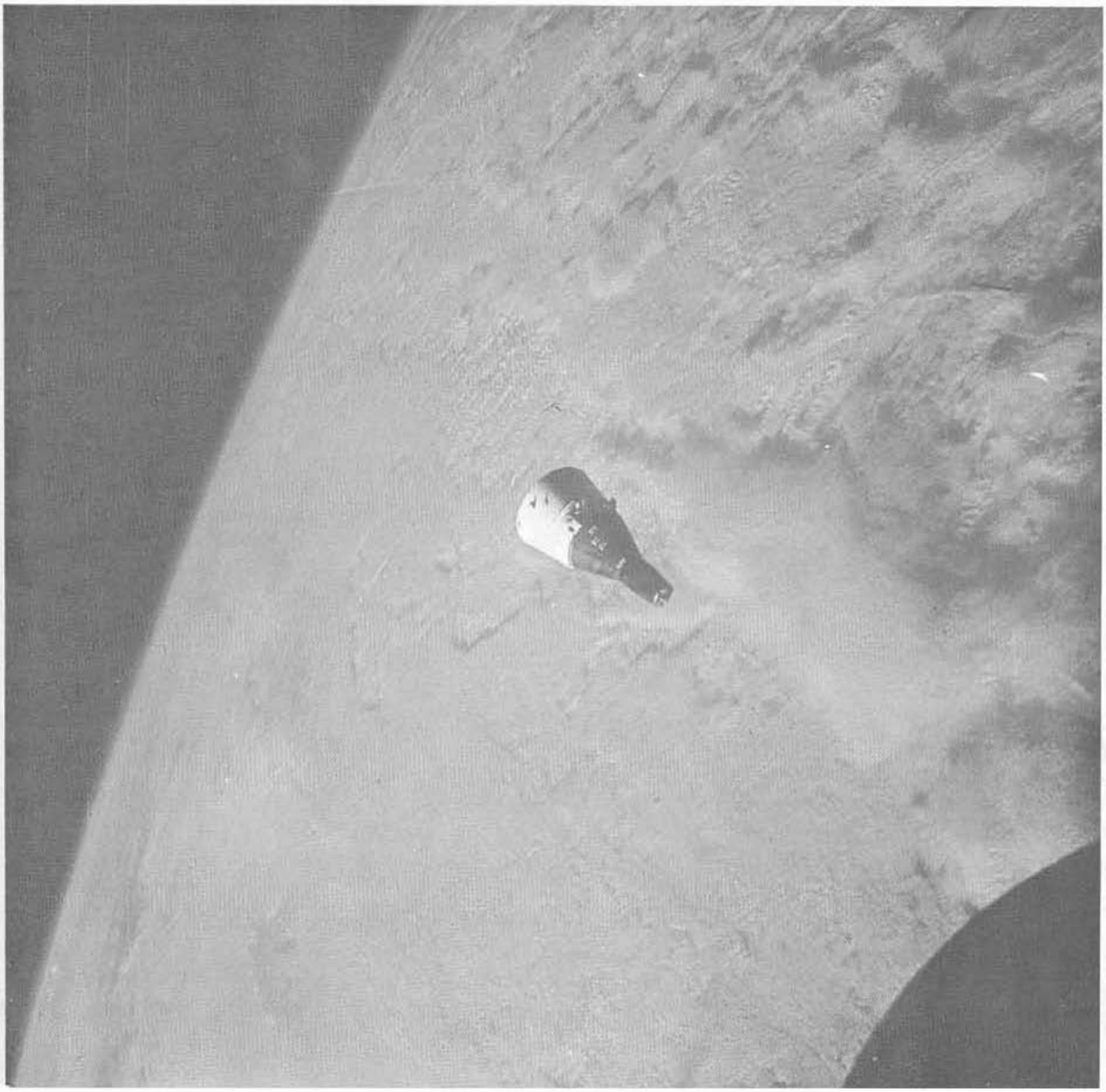
7. Business Week, November 26, 1966, Article on page 128.

By way of conclusion, it is noted that quality is an attribute of hardware influenced by design, materials, processes and people. Historically, quality control has given emphasis to many non-personal factors such as materials and process control. In space hardware the role of the individual becomes very important because of the limited production and criticality of each part. Thus, understanding the individual and his motivations within his particular organizational structure may have much more impact on quality than other conventional approaches.

It appears that the first level of supervision is the key place for improvement and that promoting improved communications by establishing an atmosphere of trust is essential. PEOPLE COMMUNICATE; PAPER RECORDS INFORMATION.

Finally, organizations have a hierarchy of needs much as do individuals. While profit is the prime motivator of industry, prestige of space work may be equally important to many producers. NASA might exploit this concept in rewarding quality conscious companies with a "Seal of Excellence" award.



NASA G-66- 4797

THERE GOES A DROP OF OIL YOU CAN'T BUY

Chart 5

APOLLO MANNED FLIGHT AWARENESS PROGRAM

Presented by

Morris K. Dyer and Preston T. Farish, MSFC

Mr. Dyer

It was recognized in the early days of NASA (1961 to be exact) that special quality and reliability requirements were needed to help ensure success of NASA programs. The result, of course, was the NPC 200 series quality documents and NPC 250-1. It was also recognized that regardless of the excellence of NASA documents, they would not serve their purpose unless the people who were to use them were willing to put forth the extra effort needed to meet these requirements - and not only that, but meet them by doing the job right the first time. This extra effort, experience has shown, will only be effectively put forth by people who are not only qualified to do their job but who understand what they are to do, why they are to do it, and recognize the importance of their contribution to the program.

Here are some quotes from NPC 250-1 which are directed toward the area we are discussing (Figure 2). NPC-200-1A also highlights the effort required of government agency personnel on NASA programs (Figure 3).

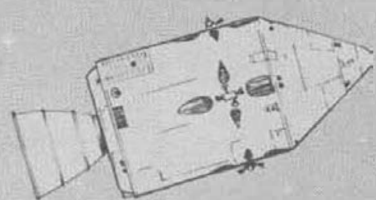
Recognition of this human factor resulted in a number of NASA Quality and Reliability people talking to many individuals and groups across these United States, stressing the what and the why, as well as the need for attention to detail and a return to craftsmanship. This has been and continues to be an effort to develop what might be termed an "extra effort - do it right the first time" state-of-mind.

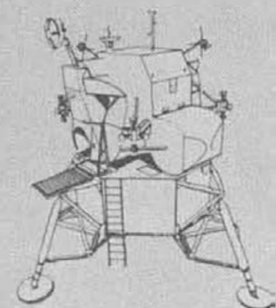
Of course, people with Quality and Reliability titles were not the only ones who had recognized the need for developing this state-of-mind. Other people concerned with crew safety and success of manned space flight missions sought ways to do this when the Mercury project began. They moved in the direction of specially identifying Mercury hardware and also identifying the workers with the program. This effort has evolved into the Apollo Manned Flight Awareness Program which is being discussed today.

Up until the early part of this year, MSFC Manned Flight Awareness people and Quality and Reliability Assurance people (who are organizationally separated) had worked independently of each other to a great degree. Both groups, however, were striving for the same end and stressing the same points

MANNED FLIGHT AWARENESS

PRODUCT RELIABILITY THROUGH CONSCIENTIOUS CRAFTSMEN





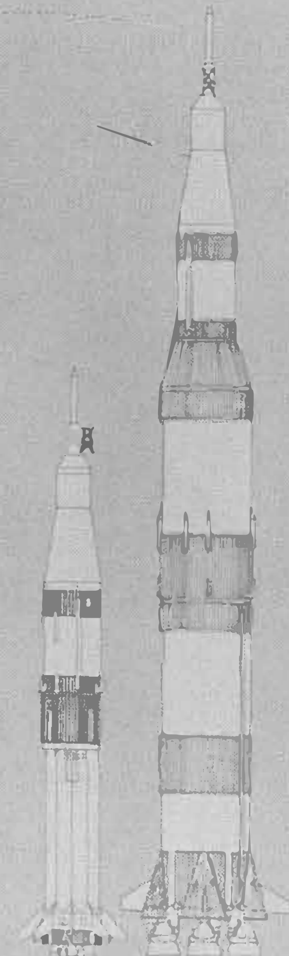


CHART #1

MANNED FLIGHT AWARENESS AND **NPC250-1**

- **RELIABILITY CAN ONLY BE ACHIEVED BY AN INTENSE AWARENESS**, vigilance and attention to detail by every member of the project team; and

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- a thorough **PROGRAM OF MONITORSHIP** and **CONTINUOUS RELIABILITY STATUS INDICATION** is necessary to sharpen this awareness and highlight areas of weakness for timely corrective action

CHART #2

MANNED FLIGHT AWARENESS AND NPC200-1A

NASA SPACE EXPLORATION PROGRAMS REQUIRE —

- ALL PRACTICABLE ACTIONS BY GOVERNMENT AGENCIES TO ENSURE MISSION ACCOMPLISHMENT
- THOROUGH UNDERSTANDING OF NASA CONCEPTS
- CAREFUL ATTENTION TO DETAIL
- TECHNICAL KNOWLEDGE CONCERNING ARTICLES OR SERVICES PROCURED

CHART #3

MANNED FLIGHT AWARENESS . . . GOALS

ASTRONAUT SAFETY
AND
MISSION SUCCESS

BONUSES

- COST SAVINGS
- FIRM SCHEDULES
- INCREASED QUALITY AND MORE RELIABILITY

CHART #4

(i.e., attention to detail, craftsmanship, knowledge of the product and its usage, etc.). (Figure 4). This past spring each looked at what the other was doing and mutually decided that more could be accomplished by joining ranks much closer than in the past.

A major joint venture since that time has been bringing DCAS personnel into the MFA picture. Until April of this year, MFA effort had been directed principally toward contractors. This approach, however, actually missed a large number of key Apollo team members. The events which have taken place thus far in this direction will be discussed by Dr. Farish.

MSFC Quality and Reliability people feel that an organized approach toward motivation of individuals and organizations such as is evidenced in the Apollo Manned Flight Awareness Program has brought and will continue to bring significant returns in quality and reliability achievement. We are attempting to support the program in every way. We encourage Quality and Reliability people at other installations to do likewise. The benefits of this effort can certainly extend to unmanned programs too, even though the man is now the primary Manned Flight Awareness focal point. In fact, Manned Flight Awareness people are already stressing the tremendous importance of unmanned missions in the total space program.

Dr. Farish will describe the Apollo Manned Flight Awareness Program, its background, some of the techniques used, and some of the results.

Dr. Farish

Figure 5. The Manned Flight Awareness program has its antecedents in a series of employee motivation programs that goes back to the Mercury Awareness program in 1959. While this program did not have the scope and depth of the present MFA program, it was effective and resulted in giving us perfect boosters for our first two manned spacecraft flights of the Mercury program. Following this program there were others as you see here. They developed in pace with the expanding national space program.

Figure 6. Earlier in this year the MFA program received an added boost when Dr. Mueller reemphasized it both within NASA and to the Congress. He mentioned the program and its purpose in his hearings with the House Committee on Science and Astronautics, and he sent letters to field centers that resulted in the appointment of MFA coordinators at MSC and KSC.

Figure 7. Now let us look a little closer at what Dr. Mueller did say to Congress, because it is important. Notice he stressed the objective by restating it in reliability terms and he also gave the purposes for the program.

Figure 8. Here we have the MFA structure in NASA and its functions. On this first slide you see the three field centers of MSF and the individuals responsible for the program at each center. Notice also the number of major contractors each Center has designated for MFA purposes. The program is monitored at Headquarters by the Reliability and Quality Assurance office for the Apollo program.

APOLLO NASA

MANNED FLIGHT AWARENESS

BACKGROUND. . .

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- MERCURY REDSTONE - MERCURY AWARENESS PROGRAM OF 1959

- MERCURY ATLAS - GENERAL DYNAMICS/ASTRONAUTICS "DO GOOD WORK" PROGRAM

- TITAN GEMINI - MARTIN COMPANY ZERO DEFECTS

- NASA MANAGEMENT COUNCIL MEETING 1963 - EXTENSION OF EMPLOYEE MOTIVATION PHILOSOPHY TO CONTRACTOR PROGRAMS

CHART #5

MANNED FLIGHT AWARENESS

PROGRAM RE-EMPHASIS

- DR. MUELLER'S TESTIMONY TO THE COMMITTEE ON SCIENCE AND ASTRONAUTICS - FEB 1966

- LETTERS FROM DR. MUELLER TO MSF FIELD CENTERS - APRIL 1966

CHART #6

MANNED FLIGHT
AWARENESS

CONGRESSIONAL RECORD ENTRY

(BY DR. MUELLER IN FEB 66/NASA MC66-5382)

MANNED FLIGHT AWARENESS

✱ OBJECTIVES

- PRODUCTION OF DEPENDABLE EQUIPMENT

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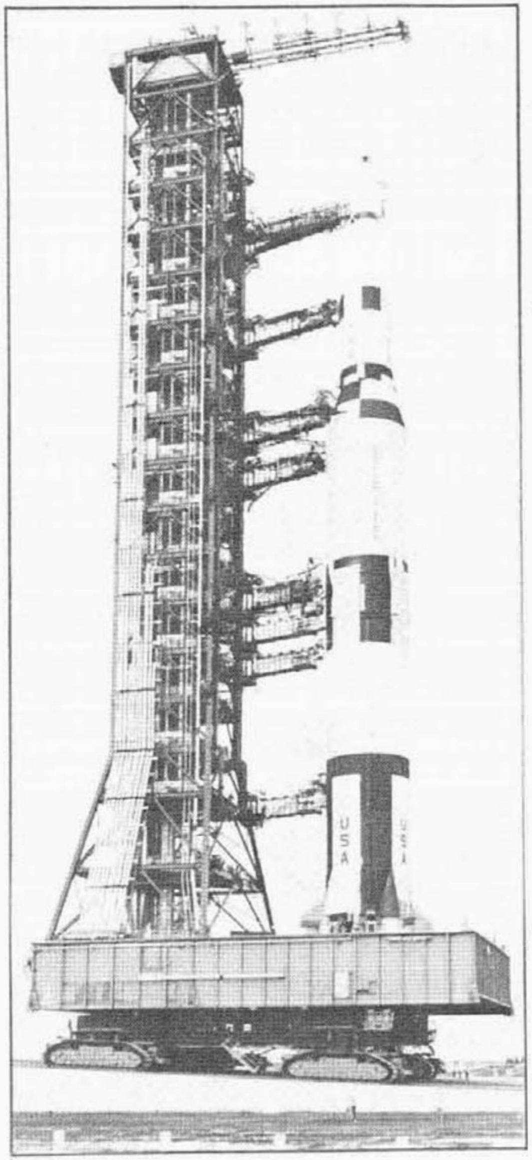
✱ PURPOSE

- CREATE EMPLOYEE AWARENESS TO PUT FORTH BEST POSSIBLE EFFORT

- DEVELOP INTIMATE SENSE OF PARTICIPATION AND INDIVIDUAL RESPONSIBILITY FOR PROGRAM SUCCESS

CHART #7



MSC

MANNED FLIGHT AWARENESS

(5 PRIME CONTRACTORS)

●

HORTON

MSFC

MANNED FLIGHT AWARENESS

(7 PRIME CONTRACTORS)

●

FARISH

KSC

MANNED FLIGHT AWARENESS

(9 PRIME CONTRACTORS)

●

SIEBENEICHEN

CHART #8

Figure 9. Here we have the channel of communication for MFA between MSFC and the contractors for its Saturn 1B. You see that each prime contractor has a designated individual who heads up a company-sponsored employee motivation program of the Zero Defects type. Our MFA messages and other program features are fed into the company program through these individuals. Notice the IBM Corp. calls its program Manned Flight Awareness. Since the company did not have a program, it adopted ours in name.

Figure 10. The Saturn 5 MFA set up parallels that of the Saturn 1B. As you can see the third stage and instrument units are the same as those for the Saturn 1B. The same is true for the engines. I might mention here that all of these company coordinators have access to each other and are urged to communicate with others on matters of MFA.

Figure 11. The MFA personnel at our major contractors extend the chain on down to the subcontractor and supplier level, thus adding considerable depth to the MFA program. A typical example of the way this feature of the program operates is shown here, using IBM as an example. These various suppliers have access to NASA MFA program material through IBM. I might add that IBM's supplier awareness program is one of our most active ones.

Figure 12. When NASA entered into an agreement with the DCAS to perform quality inspection at contractor facilities, the procedure gave us a new channel of communications to suppliers as shown here. It also provided a valuable interface with DOD's Zero Defects program, since each DCAS regional office has a ZD administrator on the staff. We work through this individual when dealing with suppliers.

Figure 13. Our activity in presenting MFA to DCAS has been great during the year. As you can see from this slide, we have met with DCAS at every level from the top to the working inspector and told them all what MFA is and how DCAS can participate. We have also prepared a special instructional kit for use within DCAS so that their own personnel can spread the MFA word within the organization.

Figure 14. Let me show you quickly some of the material we provided DCAS to acquaint them with our NASA products so they will know the hardware and relate it to the products being produced in the plants in which they work. We stress to these people that they are just as much a part of the MFA team as NASA employees, including the astronauts, or NASA prime contractors. The DCAS people are an integral link in our quality chain.

Figure 15. During the year we have had a particularly active MFA Program. As you can see from this slide there is a variety of activity. Let me briefly update it for you. Under visits to the Cape, we can add the launch of AS 202 in which we had about 70 visitors. We are now inviting through our prime contractors suppliers as well as prime contractor personnel to observe Saturn launches. The Craftsmanship van is winding up its west coast tour and will be back in Huntsville for refitting this month. We are going to add more material to it to give a wider range to its MFA message. MSC is supplying us with some Apollo hardware for this purpose. Our displays continue to be so popular that they are literally wearing out faster than we can repair or replace them.

MANNED FLIGHT AWARENESS

SATURN IB CONTRACTORS

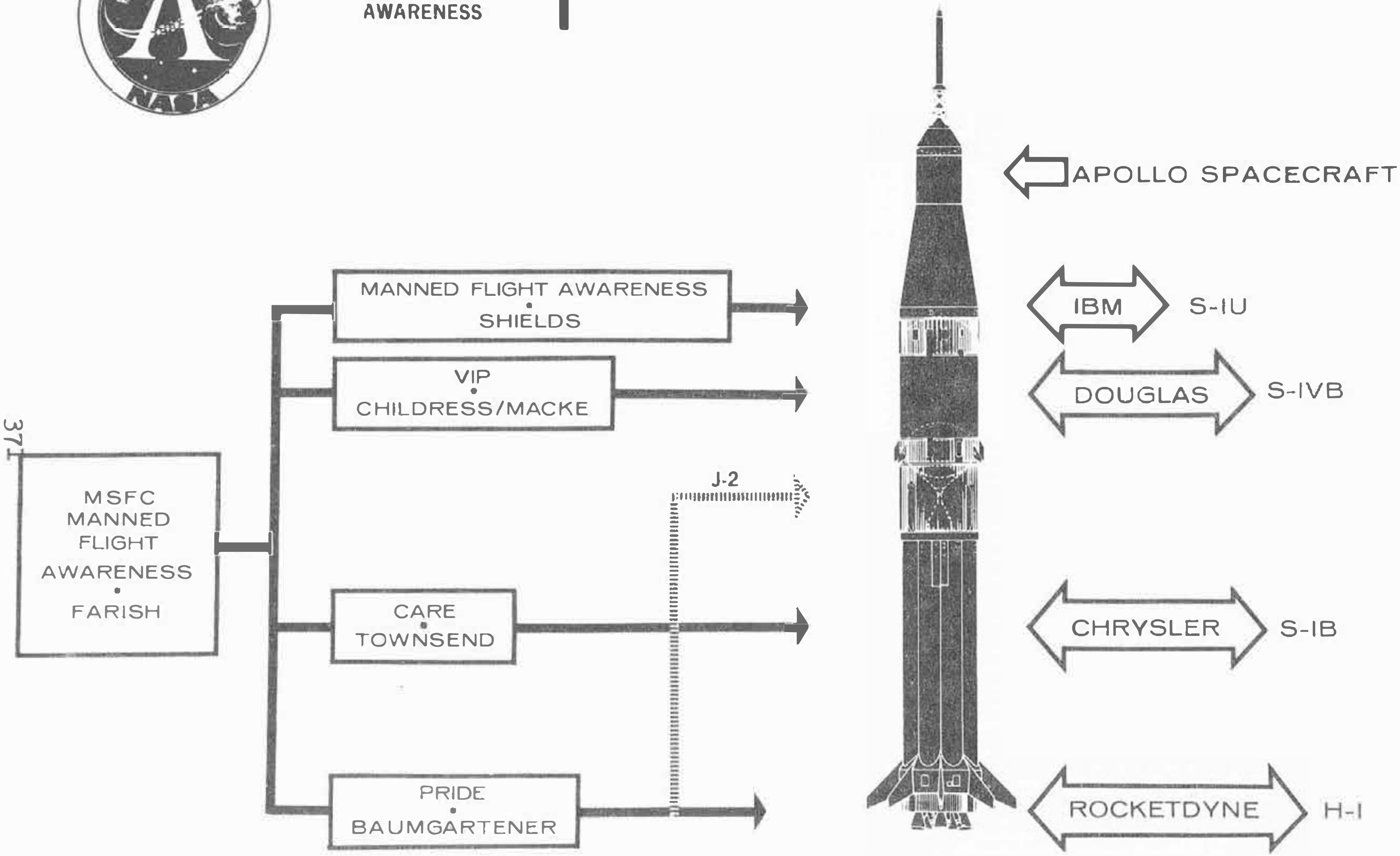


CHART #9

MANNED FLIGHT
AWARENESS

SATURN V CONTRACTORS

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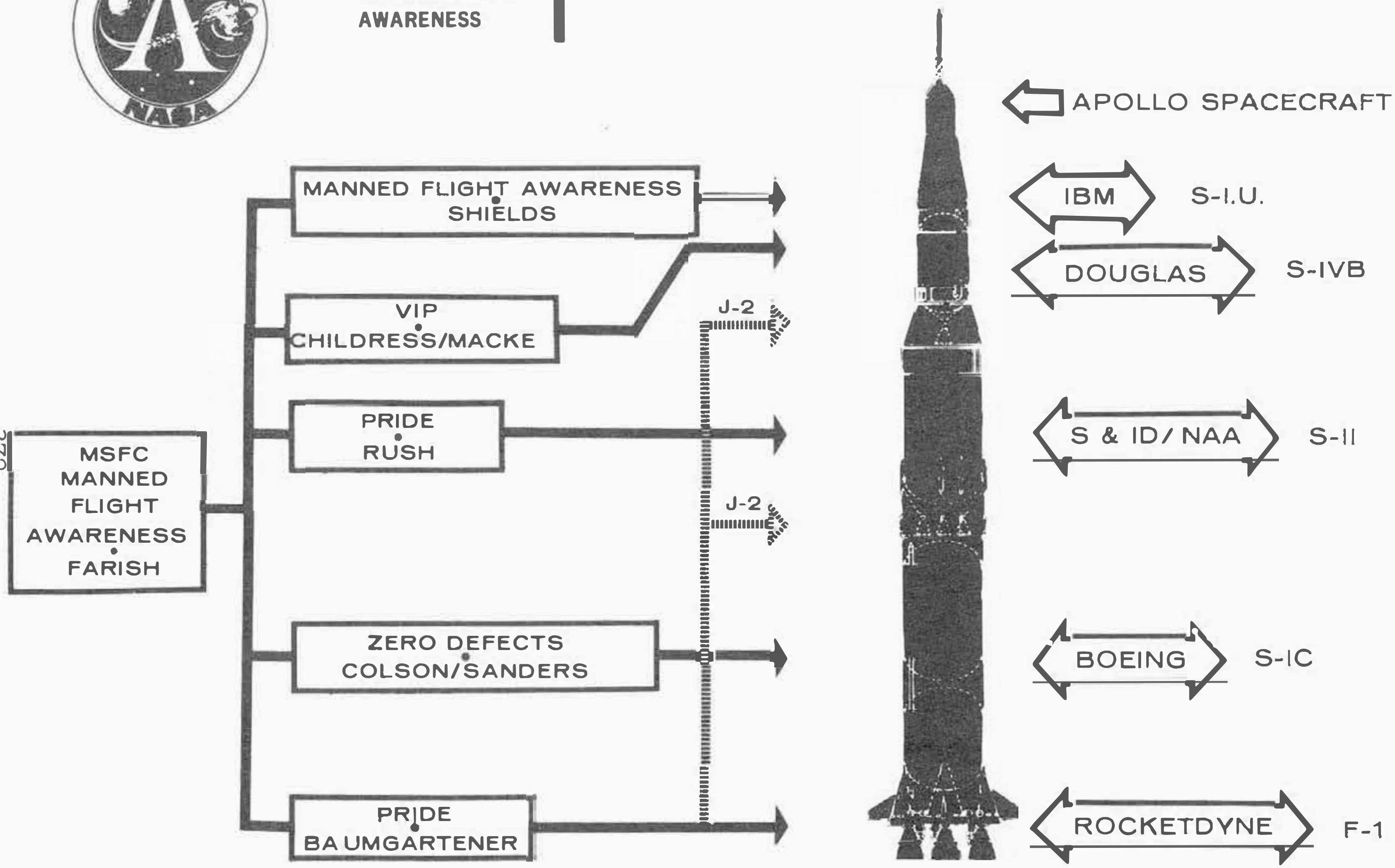


CHART #10

MANNED FLIGHT AWARENESS

SUBCONTRACTORS

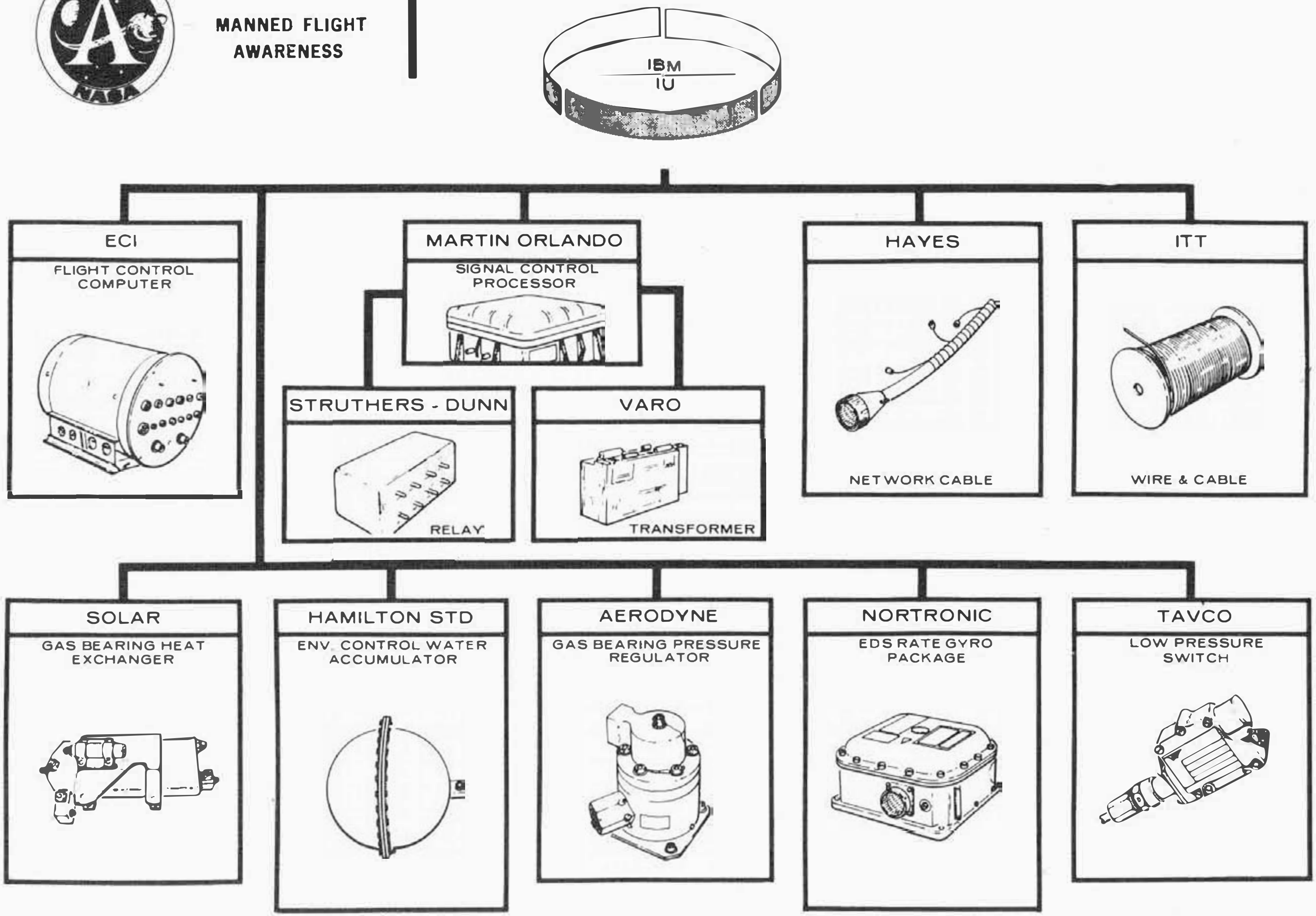


CHART #11

MANNED FLIGHT AWARENESS COORDINATION CHANNELS

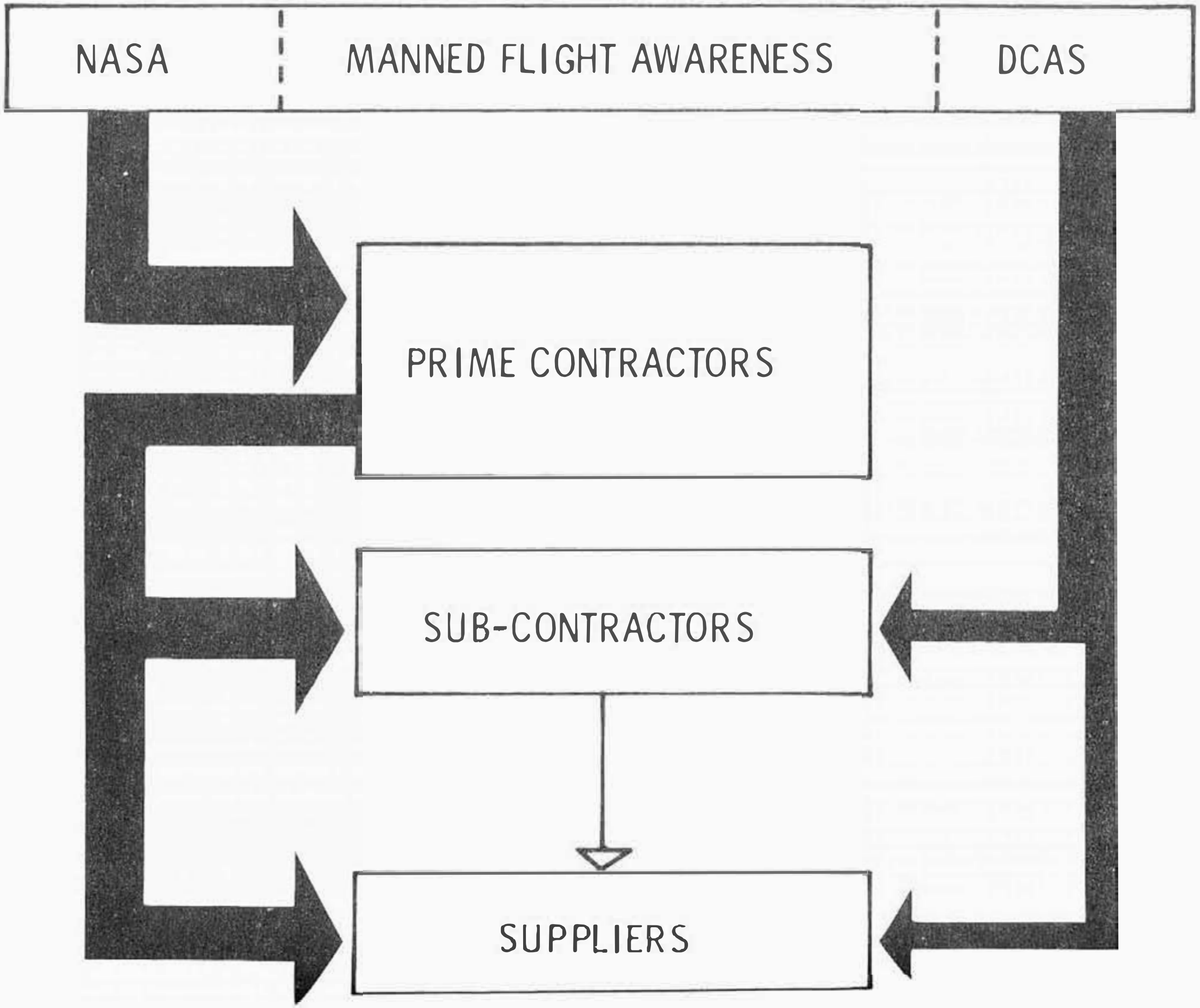


CHART #12

MANNED FLIGHT AWARENESS

DCAS BRIEFINGS AND COORDINATION FY 66

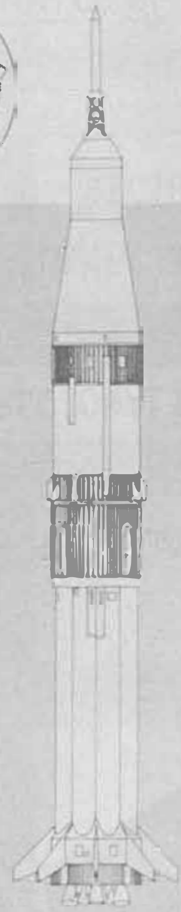
BRIEFINGS

- APRIL 27 - HEADQUARTERS, CAMERON STATION
- MAY 19 - REGIONAL ZD ADMINISTRATORS, BUFFALO, NEW YORK
- MAY 31 - REGIONAL QUALITY DIRECTORS, NEW YORK, N. Y.
- JUNE 6 - NASA/DCAS REGIONAL REPRESENTATIVES, CAMERON STATION
- JULY 12 - ATLANTA REGION
- (SEPTEMBER) - REGIONAL DIRECTORS MEETING, CHICAGO

ASSISTANCE

- PREPARATION OF SLIDES AND TEXT FOR DCAS USE IN-HOUSE
- PARTICIPATION IN MSFC-DCAS QUALITY INSTRUCTORS SEMINAR, JUNE 24, HUNTSVILLE

CHART #13



UPRATED SATURN I/ VEHICLE CHARACTERISTICS

LAUNCH VEHICLE

LENGTH	142 FT
WEIGHT AT LIFTOFF	1,297,000 LBS
APOLLO PAYLOAD	38,100LBS

STAGES

S-IB

SIZE	21.5X 80 FT
THRUST	1,640,000 LBS
ENGINES	8 H-1
PROPELLANT	LOX & RP-1

INSTRUMENT UNIT

SIZE	22X 3 FT
GUIDANCE SYSTEM	INERTIAL

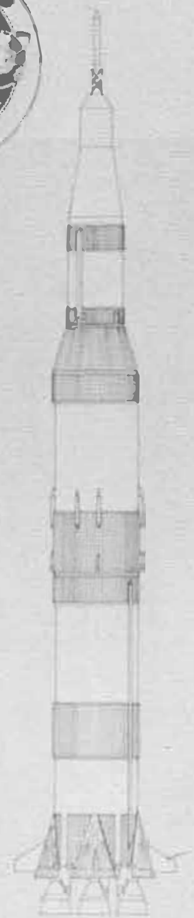
S-IVB

SIZE	22 X59 FT
THRUST	200,000 LBS
ENGINE	1 J-2
PROPELLANT	LOX & LH_2

TOTAL LENGTH

(INCLUDING SPACECRAFT & LES)224 FT

CHART #14-A



SATURN V/ VEHICLE CHARACTERISTICS

LAUNCH VEHICLE

LENGTH ______ 281 FT

LENGTH VEHICLE, SPACECRAFT, LES ______ 365 FT

WEIGHT AT LIFTOFF ______ 6,200,000 LBS

PAYLOAD CAPABILITY APPROXIMATE

TRANSLUNAR TRAJECTORY ______ 95,000 LBS

EARTH ORBIT ______ 250,000 LBS

STAGES

S-IC

SIZE ______ 33 X 138 FT

THRUST ______ 7,500,000 LBS

ENGINES ______ 5 F-1

PROPELLANTS ______ LOX & RP-1

S-II

SIZE ______ 33 X 81 FT

THRUST ______ 1,000,000 LBS

ENGINES ______ 5 J-2

PROPELLANTS ______ LOX & LH_2

S-IVB

SIZE ______ 22 X 59 FT

THRUST ______ 200,000 LBS

ENGINES ______ 1 J-2

PROPELLANTS ______ LOX & LH_2

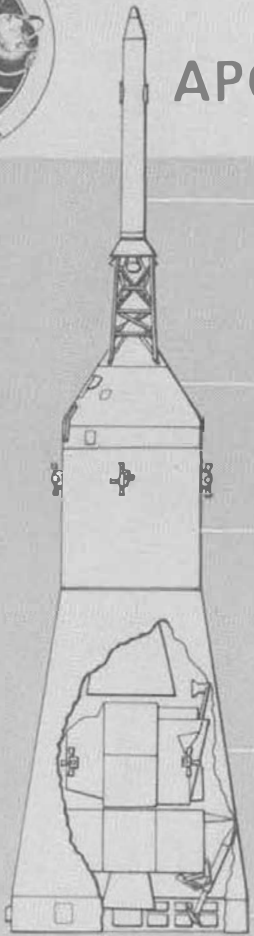
INSTRUMENT UNIT

SIZE ______ 22 X 3 FT

GUIDANCE SYSTEM ______ INERTIAL

CHART #14-B

APOLLO SPACECRAFT / VEHICLE CHARACTERISTICS



	WT. (GROSS)	THRUST (LBS)	PROPEL-LANT	BURN TIME	SIZE (FT)
LAUNCH ESCAPE SYS.	6,600	150,000	SOLID	3 SEC	2.2×29.6
COMMAND MOD (NAA)	10,000	NONE	NONE	NONE	12.8×11.7
SERVICE MOD (NAA)	46,000	22,000	HYPER-GOL	680 SEC	12.8×12.9
LEM (GRUMMAN)	30,000	{ 10,000 3,000	HYPER-GOL	{ 365 SEC 135 SEC	21.7 to 12.8 ×29.2
VEH. INSTR. UNIT (IBM)	3,500	NONE	NONE	NONE	21.7×58.7

CHART #14-C

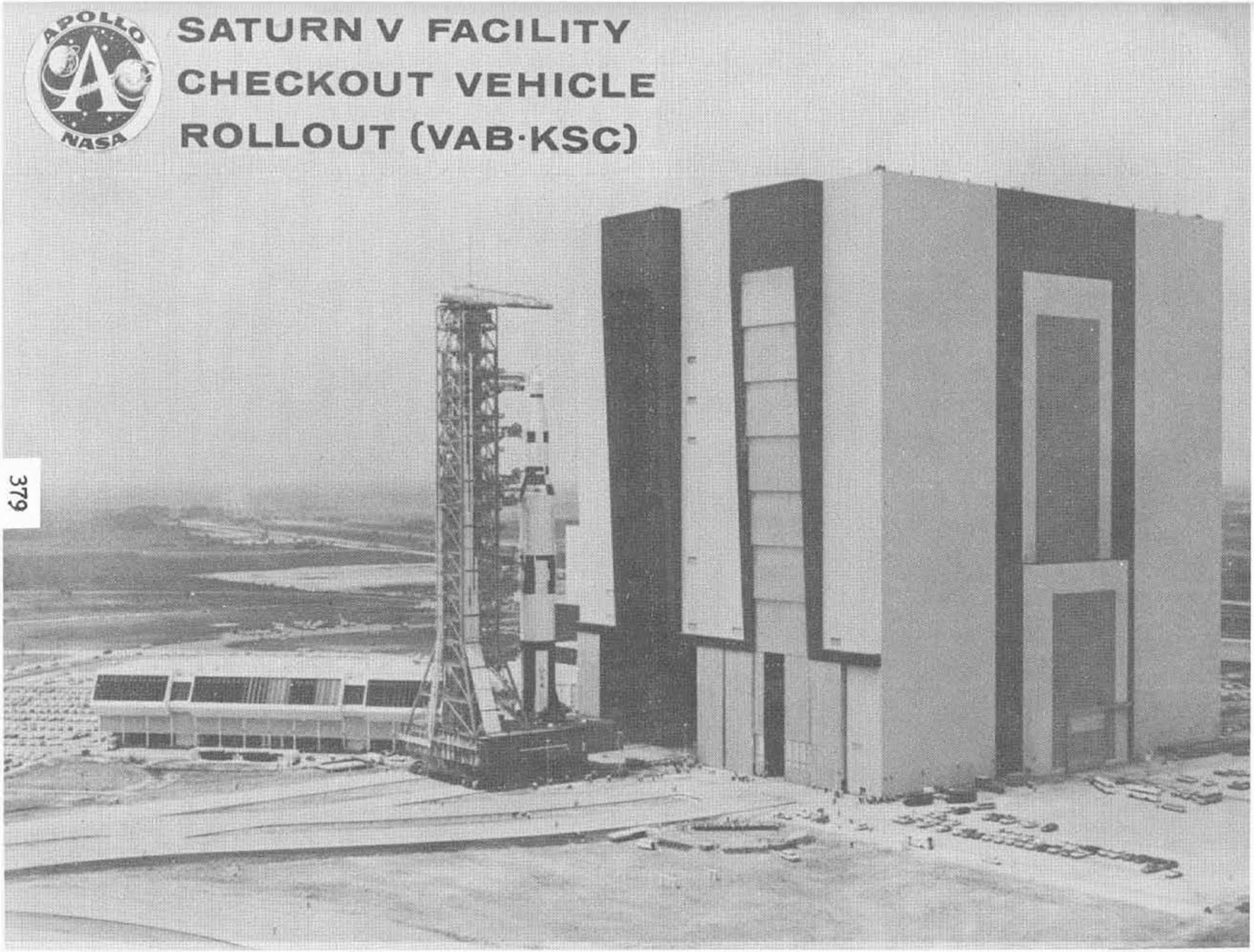

APOLLO
NASA
SATURN V FACILITY
CHECKOUT VEHICLE
ROLLOUT (VAB·KSC)

CHART #14-D

MANNED FLIGHT AWARENESS

EMPLOYEE MOTIVATION ACTIVITY FY 66

VIP VISITS TO CAPE KENNEDY
- AS201 - 10
- AS203 - 12

CRAFTSMAN SHIP TOUR
- EAST COAST (KSC AND MSFC VENDORS) 49,320 VISITORS
- DOUGLAS AIRCRAFT AND 33 VENDORS - 30,000 VISITORS
- NORTH AMERICAN AVIATION AND 10 VENDORS - 60,000 VISITORS

DISPLAYS
- 39 BOOKINGS

FILMS
- THE ESSENTIAL COMPONENT - 1,254 BOOKINGS

ASTRONAUT PARTICIPATION

SCHWEICKERT - KSC, FEBRUARY; NAA, ANAHEIM, MAY
SCHIRRA - IBM, HUNTSVILLE, APRIL
SHEPARD - NAA, ANAHEIM, MAY
WHITE, NAA, ANAHEIM, MAY
CHAFFEE - NAA, SEAL BEACH, JUNE; ANAHEIM, MAY
CERNAN - ROCKETDYNE, APRIL
LOUSMA - MTF, JUNE

CHART #15

Recently we printed a catalog of our exhibits and have it available in quantity. Under the films, I would like to say that "The Essential Component" won an award in this year's annual Industrial Management Society film competition. I would also like to mention that we have just released our second MFA film: "The Million Dollar Eraser." It is designed primarily for Saturn IB contractors and suppliers, but it is a valuable tool in any employee motivation program. The astronaut visit is certainly our most popular feature since it impresses upon the individual worker that his efforts are going to mean the difference between success and failure, life and death, for another human being. We would like to expand this portion of the program, but there just are not enough astronauts to go around.

Figure 16. Let us have a quick look at some of the highlights of our MFA program in action. Here we have the group of MFA VIPs who visited the Cape to observe the launch of AS 202. You can see that they got to meet the prime crew for AS 204 and each of them got a copy of this picture. In addition to a tour of the Cape and its facilities, each member received an autographed picture of an astronaut and a certificate of appreciation signed by an astronaut and the Center director. The selection of these people is left solely to the company. We ask only that the company not send middle or top level management personnel, who can legitimately visit the Cape for business reasons.

Figure 17. Here is our popular Craftsman Ship van during its current tour of the west coast. As you can see the van can be set up indoors, as it is here in Tulsa, Okla., or outdoors. We let a prime contractor sponsor the visit of the van among his many suppliers and subcontractors. Space inside the van is available to the local company to exhibit his own product and thus relate it to the overall Saturn/Apollo program.

Figure 18. Here we see a selection of the various displays available to contractors through the MFA program. Most of these are rugged and easily assembled, needing only to be plugged into a 110 volt line. Thus they can be used anywhere. We furnish special MFA literature to go with them.

Figure 19. Certainly our most popular MFA program feature is a visit from an astronaut. Here Capt. Jack Lousma, one of our newest astronauts, visits MTF. Notice that the visit puts the astronaut into personal contact with as many personnel as possible. He mingles with people rather than making pep talks to assembled crowds. He also is available for pictures, TV tapes, etc.

Figure 20. In closing, let me cite just three typical results we have realized in the MFA program. You see them here on this slide. Similar results are reported from our other contractors.

CHART #16


NASA
SATURN - APOLLO MANNED FLIGHT
GEORGE C. MARSHALL SPACE FLIGHT CENTER - HUNTSVILLE, ALABAMA
AWARENESS-CRAFTSMANSHIP
BY
IMPORTANT PEOPLE

CHART #17

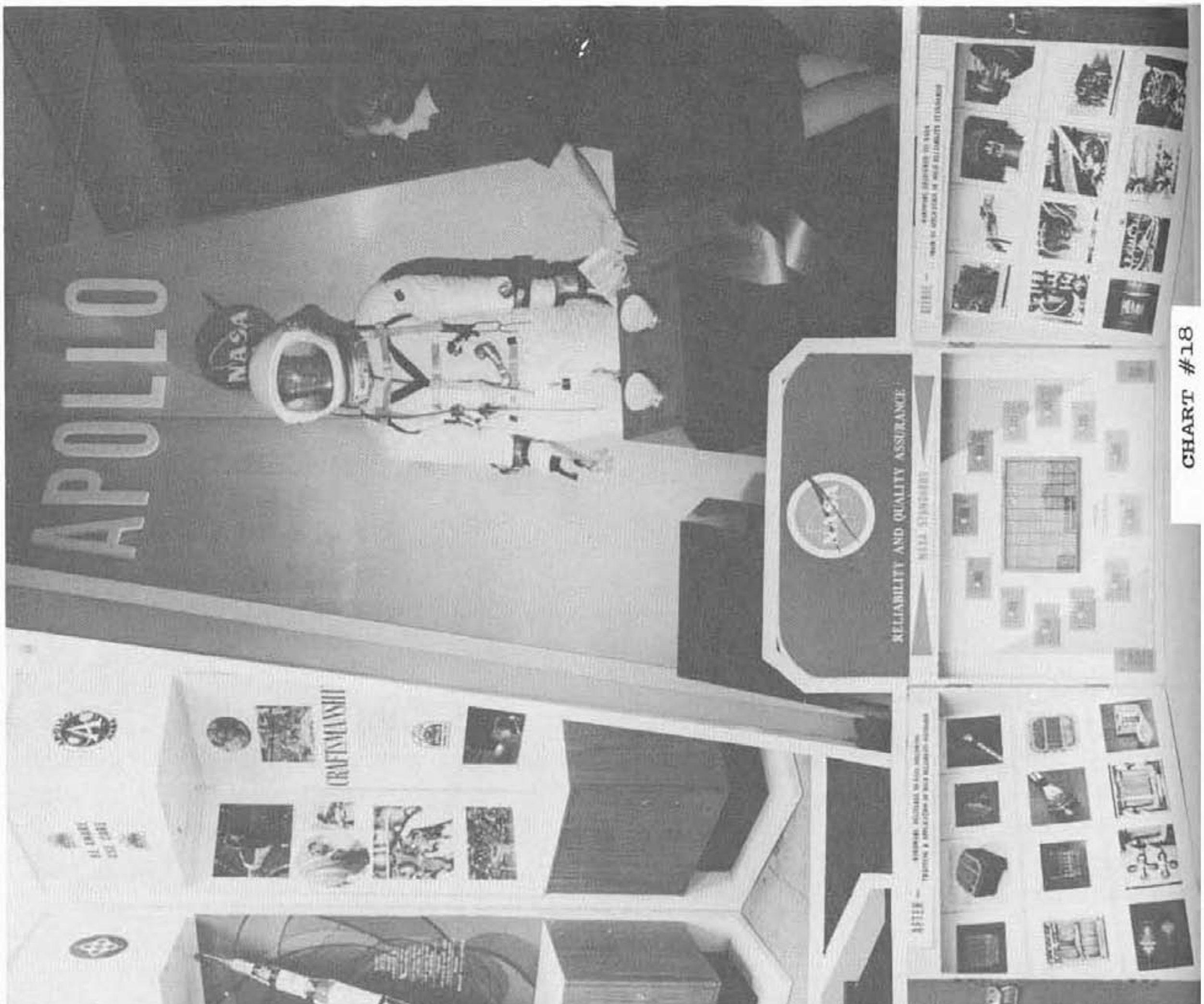

APOLLO
NASA
SATURN V
SATURN IB
CRAFTSMANSHIP
GEORGE C. MARSHALL SPACE FLIGHT CENTER
RELIABILITY AND QUALITY ASSURANCE

CHART #18

CHART #19

MANNED FLIGHT
AWARENESS

TYPICAL RESULTS

ROCKETDYNE / 23% CUMULATIVE IMPROVEMENT IN DEFECTIVE PART RATE SINCE JAN 66 AND TREND IS IMPROVING

IBM / WITHIN ONE DEPARTMENT IN 5-MONTH PERIOD ERRORS REDUCED FROM A LEVEL OF 4.5% TO LESS THAN 2% AFTER MANNED FLIGHT AWARENESS PROGRAM WAS INSTITUTED

BOEING / ON 'F' VEHICLE, WORKERS DRILLED 1146 HOLES AND INSTALLED FASTNERS IN S-IC THRUST STRUCTURE WITH ZERO DEFECTS AFTER COMPANY ADOPTED MANNED FLIGHT AWARENESS TECHNIQUES

CHART #20

UTILIZATION OF THE DOD FOR R&QA SUPPORT IN CONTRACTOR'S PLANTS

E.H. Britt, LaRC

INTRODUCTION

NEARLY TWO YEARS AGO THE LANGLEY PHILOSOPHY AND APPROACH TO MAKE EFFECTIVE USE OF THE DEPARTMENT OF DEFENSE PERSONNEL FOR MONITORING CONTRACTS WAS PRESENTED AT THE FIRST NASA-WIDE RELIABILITY AND QUALITY ASSURANCE MEETING. SINCE THAT TIME, A GENERAL PROCEDURE FOR ORGANIZING TO USE THE DOD HAS BEEN DEVELOPED AND EFFECTIVELY USED ON OUR PROJECTS.

PHILOSOPHY OF ORGANIZATION EFFORT

THE FIRST SLIDE SUMMARIZES SOME OF THE FACTORS PREVIOUSLY PRESENTED THAT ARE INCLUDED IN OUR APPROACH FOR ORGANIZING THE DOD RELIABILITY AND QUALITY ASSURANCE SUPPORT AT CONTRACTOR'S PLANTS. (1) SHARE DEFINITION OF THE MISSION OBJECTIVE, SHCEDULE, TECHNICAL DIFFICULTY, AND THE ROLE WHICH LANGLEY IS DEPENDING UPON THE DOD TO PERFORM AT THE EARLIEST POSSIBLE TIME. (2) DEFINE TASK REQUIREMENTS REALISTICALLY IN TERMS OF CAPABILITIES OF PERSONNEL AND THE SUPPORTING EFFORT REQUIRED AT THE CONTRACTOR'S PLANT. (3) SHOW AN APPRECIATION OF THE IMPORTANCE OF THE DOD EFFORT TO THE PROJECT AND THE CONTRIBUTION THAT THEY MUST MAKE IF NASA IS TO ACHIEVE SUCCESS. (4) BUILD A "UNIFIED" GOVERNMENT TEAM FOR THE PROJECT. ENCOURAGE AND ESTABLISH FREEDOM OF ORAL COMMUNICATIONS BETWEEN LANGLEY PROJECT AND DOD PLANT REPRESENTATIVE PERSONNEL IN CORRESPONDING DISCIPLINES AND MOTIVATE THE DOD WITH THE SAME ENTHUSIASM AND PRIDE THAT THE NASA PROJECT PERSONNEL HAVE ABOUT THEIR TASKS.

TIMING IS A MOST IMPORTANT FACTOR IN ORGANIZING A GOVERNMENT TEAM WHICH IS EFFECTIVE FOR A NASA PROJECT. INITIAL CONTACT IS MADE BY OUR CONTRACT ADMINISTRATOR WITH THE DOD, EITHER THROUGH THE NASA LIAISON REPRESENTATIVE

OF DCAS OR THE ADMINISTRATIVE OFFICER OF THE DOD REGIONAL OR PLANT OFFICE. THIS ACTION IS TAKEN DURING FINAL NEGOTIATION STAGES WITH THE CONTRACTOR AND PRIOR TO ACTUAL AWARD OF THE CONTRACT.

LANGLEY INDOCTRINATION TEAM

A LANGLEY PROJECT TEAM IS ASSEMBLED FOR THE TASK OF INDOCTRINATION OF THE DOD FOR EACH PROJECT. THIS TEAM NORMALLY CONSISTS OF THE CENTER RELIABILITY AND QUALITY ASSURANCE OFFICER, THE PROJECT MANAGER OR THE PROJECT TECHNICAL REPRESENTATIVE, THE PROCUREMENT ADMINISTRATOR, RELIABILITY SUBSYSTEM MANAGER, AND THE QUALITY SUBSYSTEM MANAGER.

INDOCTRINATION AGENDA

THE PRIMARY PURPOSE OF THIS TEAM IS INDOCTRINATION OF THE DOD BY A BRIEFING GENERALLY HELD AT THE DOD FACILITIES. A TYPICAL AGENDA WOULD INCLUDE THE PRESENTATION OF THE FOLLOWING ITEMS: (1) A DESCRIPTION OF THE LANGLEY RESEARCH CENTER, INCLUDING SOME HISTROY AND DEVELOPMENT OF THE ORGANIZATION, THE LINE ORGANIZATION AS IT EXISTS, THE CENTER MISSION, THE GENERAL TYPES OF PERSONNEL AND CAPABILITIES, THE KIND OF FACILITIES AVAILABLE AT THE CENTER, AND THE GENERAL RELATIONSHIP OF PROJECT TO CENTER MANAGEMENT. (2) A GENERAL DISCUSSION OF THE FUNDAMENTAL DIFFERENCE OF APPROACH OF NASA IN DEVELOPING A "FEW OF A KIND" RATHER THAN THE USUAL DEPARTMENT OF DEFENSE PROCEDURE OF PROCURING DEVELOPMENT HARDWARE WHICH MAY LATER BE MODIFIED FOR A PRODUCTION RUN. WE HAVE FOUND THAT OPEN DISCUSSION OF THIS CONCEPT IMPARTS A CLEARER UNDERSTANDING OF THE NASA APPROACH AND GENERALLY UPGRADES THE HARDWARE OBTAINED WITH DOD SUPPORT ON NASA PROGRAMS. (3) A GENERAL DESCRIPTION OF THIS NASA PROGRAM IS PRESENTED, SPECIFICALLY THAT PART WHICH IS TO BE UNDER CONTRACT AT THIS PARTICULAR PLANT. THE PURPOSE, OBJECTIVES, AN

ABBREVIATED MILESTONE DESCRIPTION AND THE PLAN FOR ACCOMPLISHING PROJECT REQUIREMENTS IS ALSO INCLUDED AT THIS TIME. (4) DEFINITION AND DESCRIPTION OF THE HARDWARE TO BE DEVELOPED AT THIS PLANT IS PRESENTED. (5) THE ROLE OF THIS PARTICULAR CONTRACTOR IN THE OVERALL PROJECT MISSION IS STATED. (6) CRITICALITY OF COST AND SCHEDULE IN THIS PARTICULAR PROJECT ARE DEFINED. (7) THE TECHNICAL AREAS BEING CONSIDERED FOR DELEGATION AND THE DEPTH OF SUPPORT REQUIRED OF THE DOD IS MADE KNOWN

DEFINITION OF DOD SUPPORT

EACH MEMBER OF THE NASA INDOCTRINATION TEAM DISCUSSES IN GENERAL TERMS, ELEMENTS OF THE DISCIPLINES WHICH THEY REPRESENT. THE LANGLEY CENTER RELIABILITY AND QUALITY ASSURANCE OFFICER GIVES A BRIEFING OF THE WORKING AGREEMENTS BETWEEN NASA AND THE DOD AT HEAD OF THE AGENCY LEVEL, WHICH ENABLES THE ASSEMBLY OF THIS NASA/DOD GOVERNMENT TEAM, AND THE ADMINISTRATIVE PROCEDURES, COMMITTEES AND ROUTES OF APPEAL THAT ARE AVAILABLE TO OBTAIN RELIEF IN SPECIFIC MANAGEMENT PROBLEMS. FOR EXAMPLE, SOME CASES MAY BE DISCUSSED CITING THE DIFFICULTY OF THE DOD IN A PARTICULAR REGION TO OBTAIN POSITIONS FOR SUPPORT OF NASA PROJECTS ON THE TIME SCHEDULE REQUIRED. SOME CASE HISTORIES AND STEPS THAT LANGLEY HAS TAKEN TO CAUSE CORRECTIVE ACTION TO SOLVE A PROBLEM CREATES A BETTER UNDERSTANDING OF THE NASA/DOD WORKING RELATIONSHIP. THIS ALSO MAKES THE DOD AWARE THAT WE ARE ACTIVELY INTERESTED IN CORRECTING ADMINISTRATIVE AS WELL AS TECHNICAL MANAGEMENT PROBLEMS WITHIN OUR CAPABILITIES. IT IS TO OUR MUTUAL ADVANTAGE TO USE ALL THE MANAGEMENT TOOLS THAT HAVE BEEN PROVIDED NASA TO ESTABLISH SUPPORT FROM THE DOD. INTERAGENCY AGREEMENTS BETWEEN NASA AND DOD ENABLE THE USE OF DOD PERSONNEL FOR NASA CONTRACTS. A RELIABILITY AND QUALITY ASSURANCE NASA/DOD COMMITTEE HAS BEEN ESTABLISHED FOR COORDINATION OF THESE ACTIVITIES.

PROVISION HAS BEEN MADE TO EXCHANGE FUNDS FOR SERVICES RENDERED. PERSONNEL ASSIGNMENTS TO NASA PROJECTS MAY BE INDEPENDENT OF NORMAL DOD PERSONNEL COMPLEMENT ALLOTMENTS. REVIEW OF THESE MANAGEMENT TOOLS THAT HAVE BEEN PROVIDED, FREQUENTLY SERVES TO BE INSTRUCTIVE TO OUR OWN PROJECT PEOPLE AS WELL AS THE DOD, PARTICULARLY WHEN THESE ARE INITIAL ASSIGNMENTS FOR THE PROJECT MANAGEMENT NASA PERSONNEL. THE LANGLEY CONTRACT ADMINISTRATOR FOR THE PROJECT THEN DEFINES IN GENERAL TERMS THOSE ELEMENTS OF CONTRACT ADMINISTRATION BEING CONSIDERED FOR DELEGATION, CITING ANY SPECIFIC PROBLEMS OF GENERAL INTEREST PERTAINING TO THIS PROJECT. DEVELOPMENT ENGINEERING OR OTHER SPECIAL TECHNICAL ASSISTANCE UNDER CONSIDERATION FOR DELEGATION IS GENERALLY DISCUSSED BY THE PROJECT MANAGER. THE RELIABILITY SUBSYSTEM MANAGER FOR THE PROJECT THEN DESCRIBES THE RELIABILITY PROGRAM IN GENERAL TERMS AS RELATED TO THE ENTIRE PROJECT AND IN SPECIFIC TERMS AS RELATED TO THE PROPOSED CONTRACT. A DISCUSSION OF THE QUALITY ASSURANCE EFFORT REQUIRED IN GENERAL TERMS AND PROJECT PECULIAR REQUIREMENTS ARE THEN DISCUSSED BY THE QUALITY ASSURANCE SUBSYSTEMS MANAGER FOR THE PROJECT. EMPHASIS IS PLACED ON THE FACT THAT WE ARE MORE INTERESTED IN THE PRODUCT OF THIS "FEW OF A KIND" TYPE OF DEVELOPMENT THAN THE RIGIDITY OF PAPER FUNCTION SIGN-OFF. IT IS GENERALLY SUGGESTED AT THIS POINT THAT SEPARATE SESSIONS BE HELD BETWEEN THE PERSONNEL OF THE DISCIPLINES JUST COVERED, FOR MORE SPECIFIC COVERAGE OF DEPTH, APPROACH AND RELATIONSHIP OF THE NASA AND DOD. AFTER THESE SEPARATE DISCUSSIONS, THE MAIN INDOCTRINATION MEETING IS AGAIN ESTABLISHED AND A BRIEF SUMMARY OF THE UNDERSTANDING IS MADE BY BOTH NASA AND THE DOD. AT THE TERMINATION OF THIS MEETING THE NASA PROJECT PERSONNEL HAVE A BETTER APPRECIATION OF THE CAPABILITIES OF SUPPORT READILY AVAILABLE FROM THE DOD, THEIR PERSONNEL PROBLEMS, THEIR

ADMINISTRATIVE PROBLEMS, SCHEDULING AND AN APPRAISAL OF THE DEVELOPMENT UPGRADING POTENTIAL FOR DOD SUPPORT THAT CAN BE EXPECTED AS THE PROJECT PROGRESSES. ON THE OTHER HAND, DOD HAVE A BETTER APPRECIATION OF THE KIND OF ORGANIZATION THEY ARE WORKING WITH IN LANGLEY; THE KIND OF SUPPORT THAT IS AVAILABLE TO THEM FOR ADMINISTRATIVE AS WELL AS TECHNICAL PROBLEMS; THE IDENTITY OF NASA PERSONNEL WITH WHOM THEY CAN DEAL DIRECTLY, ORALLY, AND INFORMALLY; AND A BETTER APPRECIATION OF THE CONCEPT OF THE NASA'S "ONE OF A KIND" SUPPORT THAT IS MANDATORY FOR PROJECT SUCCESS. IT IS IMPERATIVE THAT THESE DISCUSSIONS EMPHASIZE DIFFERENCES OF APPROACH OF NASA AND THE DOD, ALONG WITH THE DEFINITION OF THE TYPE OF SUPPORT, MAGNITUDE OF EFFORT, SCHEDULE CONSTRAINT, AND ASSOCIATED COST OF THE PROJECT. THE TYPE OF SUPPORT REQUIRED INCLUDES NOT JUST PAPER SIGN-OFF, BUT REVIEW AND CONTROL OF THE HARDWARE AND PROCESSES EMPLOYED TO PRODUCE ACCEPTABLE NASA FLIGHT HARDWARE.

DURING THE PERIOD, BETWEEN THE INDOCTRINATION MEETING AND THE ACTUAL CONTRACT AWARD, SPECIAL TRAINING AND DIRECT CONTACT BETWEEN MORE PROJECT AND DOD PERSONNEL WHO ARE COUNTERPARTS IN THE PROJECT SHOULD BE ESTABLISHED. IT IS FREQUENTLY DESIRABLE TO BRING SOME KEY DOD PERSONNEL TO LANGLEY FOR SPECIAL TRAINING IN PARTICULAR DISCIPLINES, SUCH AS PLASTICS, PYROTECHNICS, INFLATABLE STRUCTURES, ETC. SPECIAL INSTRUCTIONS IN PROCESSES PECULIAR TO A SPECIFIC PROJECT OR INDOCTRINATION IN SPECIAL CONTROL PROCEDURES CAN ALSO FREQUENTLY BE HANDLED BY TEMPORARY RESIDENCE OF KEY DOD PERSONNEL AT LANGLEY DURING THIS PERIOD. IN GENERAL, HOWEVER, THE DOD ARE EXPECTED TO PROVIDE PERSONNEL OF PROPER CAPABILITIES AND TRAINING TO SUPPORT THE DELEGATION WITHOUT THE SPECIAL CONSIDERATION. WITHIN A FEW WEEKS AFTER THIS MEETING, THE CONTRACT IS OFFICIALLY AWARDED AND THE DOD CAN PROCEED

TO DEVELOP A RELIABILITY AND QUALITY ASSURANCE PLAN, ALONG WITH THAT OF THE CONTRACTOR. IN ADDITION, THE CONTRACT ADMINISTRATION SUPPORT CAN BE IMPLEMENTED IMMEDIATELY AND THUS THE DOD CAN ASSUME THEIR SHARE OF THE LOAD IN THE PROJECT TEAM. THE PROJECT MANAGER HAS ARRANGED FOR DIRECT CONTACT BETWEEN THE COUNTERPARTS OF THE DOD AND NASA, WHO WILL WORK TOGETHER IN THE PROJECT AND THE DELEGATION IS REACHING MATURITY. IT SHOULD AGAIN BE EMPHASIZED THAT ORAL COMMUNICATION IS MANDATORY IN ADDITION TO DOCUMENTATION IF THE TEAM IS TO OPERATE SMOOTHLY WITH THE RESPONSE NORMALLY REQUIRED TO MEET THE PROJECT SCHEDULE.

MAINTAINING DOD SUPPORT EFFECTIVENESS

SUBSEQUENT TO DELEGATION AND THE ESTABLISHMENT OF DOD SUPPORT, LANGLEY MANAGEMENT PERIODICALLY REVIEWS AND EVALUATES THE EFFECTIVENESS OF THE DOD PROJECT PROGRAM. REVIEWS ARE CONDUCTED ON A SAMPLING BASIS AT VARIOUS LEVELS OF MANAGEMENT AND BY VARIOUS MEANS. THE LANGLEY RELIABILITY AND QUALITY ASSURANCE OFFICER NORMALLY CONTACTS THE PROJECT ORGANIZATION AT LANGLEY FOR COMMENT AND EVALUATION OF THE DOD PERFORMANCE DURING THE PROJECT LIFE. CONTACT IS ALSO MADE WITH THE PLANT REPRESENTATIVE DOD DURING THE LIFE OF THE RPOJECT TO RECEIVE THEIR APPRAISAL AS TO THE ACTUAL WORKING ARRANGEMENT OF THE DELEGATION. IN ANY DYNAMIC INTERRELATION THERE ARE BOUND TO BE HONEST DIFFERENCES OF APPROACH IN ACCOMPLISHING A GIVEN TASK. OPEN DISCUSSION OF THE COMMENTS RECEIVED CAN BE USED TO RESOLVE DIFFERENCES AND ENHANCE THE SUPPORTING EFFORT IN THE NASA/DOD TEAM. THE RELIABILITY AND QUALITY ASSURANCE EXECUTIVE MANAGEMENT COMMITTEE ALSO RECEIVES OCCASIONAL BRIEFINGS TO EVALUATE EFFECTIVENESS OF THE DOD IN SUPPORT OF LANGLEY PROGRAMS. OCCASIONAL TRIPS FOR A FIRST HAND LOOK AT FIELD OPERATIONS

ARE MADE BY CENTER MANAGEMENT PERSONNEL AT VARIOUS LEVELS. THIS PROVIDES DIRECT KNOWLEDGE OF THE OPERATION AND INDEPENDENT EVALUATION OF THE PROGRAM EFFECTIVENESS.

DOD CONTRIBUTION TO LANGLEY PROGRAMS

WE BELIEVE THAT THE SOUNDNESS OF OUR APPROACH TO ATTAIN RELIABILITY AND QUALITY ASSURANCE SUPPORT FROM THE DOD HAS BEEN DEMONSTRATED BY CONTRIBUTION MADE IN THE LUNAR ORBITER PROGRAM, THE SCANNER PROGRAM, PAGEOS, LIFE SUPPORT AND THE PLANETARY ENTRY PARACHUTE PROJECT AND REENTRY F PROGRAMS. THE LUNAR ORBITER PROGRAM IS THE LARGEST SINGLE PROGRAM THAT HAS BEEN TREATED AND ORGANIZED AS DESCRIBED PREVIOUSLY. THE PRIME OBJECTIVE OF THE LUNAR ORBITER PROJECT IS TO SECURE TOPOGRAPHIC DATA OF THE LUNAR SURFACE IN SUFFICIENT DETAIL TO EVALUATE THE SURFACE CHARACTERISTICS OF AREAS UNDER CONSIDERATION FOR APOLLO LANDING SITES. IT WAS REQUIRED THAT A NUMBER OF COMPLEX MANEUVERS BE PERFORMED BY A SPACECRAFT TO ORBIT THE MOON. THE SURFACE OF THE MOON WAS THEN TO BE PHOTOGRAPHED AT SELECTED SITES, PICTURES DEVELOPED AND RETRANSMITTED, ELECTRONICALLY, BACK TO EARTH. AN EXTREMELY SHORT SCHEDULE, A LITTLE OVER TWO YEARS, SEVERE WEIGHT LIMITATIONS, AND SPACECRAFT DESIGN AND SYSTEM RELIABILITY REQUIRING THE HIGHEST OF ENGINEERING AND MANUFACTURING EXCELLENCE WAS REQUIRED TO ACHIEVE SUCCESS. THE RESULTING SPACECRAFT HAS APPROXIMATELY 20,000 PARTS.

THE PRIME CONTRACT WAS WITH THE BOEING COMPANY, HAVING TWO MAJOR SUBCONTRACTS, ONE WITH EASTMAN KODAK AND ONE WITH RADIO CORPORATION OF AMERICA. THESE SUBCONTRACTS WERE OF ALMOST EQUAL TECHNICAL EFFORT. THE DELEGATION FOR ENGINEERING AND QUALITY ASSURANCE WORK WAS GIVEN TO THE AIR FORCE PLANT REPRESENTATIVE AT THE BOEING COMPANY, WITH POWER OF

REDELEGATION TO OTHER DOD ORGANIZATIONS. THIS MADE THE AFPRO BOEING COMPANY EFFECTIVELY A PRIME DOD SUPPORTING GOVERNMENT AGENT, PARALLELING THE ORGANIZATION LINES OF THE BOEING COMPANY WITH ITS SUBCONTRACTORS. LANGLEY PARTICIPATED IN MAJOR REDELEGATIONS. DURING THIS CONTRACT, APPROXIMATELY 43,000 MANHOURS OF ENGINEERING SUPPORT WERE RECEIVED FROM THE DOD, AND A 101,000 MANHOURS OF QUALITY ASSURANCE AND INSPECTION WERE PROVIDED IN A PERIOD OF APPROXIMATELY 27 MONTHS. THIS IS AN AVERAGE OF OVER 30 PERSONNEL IN SUPPORT OF PROJECT THROUGHOUT ITS CONTRACT LIFE. THE AIR FORCE PLANT REPRESENTATIVE OF THE BOEING COMPANY ISSUED 62 REDELEGATIONS IN BEHALF OF THE LUNAR ORBITER PROJECT AND REQUESTED QUALITY ASSURANCE SUPPORT ON ALL OF THESE. ELEVEN OF THESE REDELEGATIONS REQUIRED SUPPORT IN EITHER THE AREA OF QUALITY ENGINEERING OR DEVELOPMENT ENGINEERING. THE EXCELLENCE OF THIS SUPPORT CAN BE MEASURED TO A GREAT EXTENT BY THE SUCCESS OF THE OPERATION OF THE FIRST TWO SPACECRAFT.

SUMMARY

USE OF THE DOD FOR RELIABILITY AND QUALITY ASSURANCE SUPPORT AT CONTRACTOR'S PLANTS POSES A MAJOR COMMUNICATIONS PROBLEM. THIS IS AGGRAVATED BY THE FACT THAT MANY OF THE LRC PROJECTS ARE OF SHORT SCHEDULE AND AFFORD LITTLE TIME TO FULLY PLAN AND ASSEMBLE A TEAM OF NASA/DOD PERSONNEL. IF A CONSCIENTIOUS EFFORT IS MADE TO APPRECIATE THE INHERENT COMMUNICATION DIFFICULTY AND STEPS ARE TAKEN TO ESTABLISH THE UNIFIED GOVERNMENT TEAM, DOD SUPPORT CAN BE VERY REWARDING. THE KEY POINT IN USING THE DOD FOR R&QA SUPPORT HAS DEVELOPED TO BE EARLY INDOCTRINATION OF THE DOD WITH AS MUCH KNOWLEDGE OF THE PROJECT AS WE CAN IMPART ON A SHORT TERM BASIS. A SECOND POINT IS THE ACCEPTANCE OF THESE DOD PERSONNEL AS FELLOW MEMBERS

OF ONE GOVERNMENT TEAM OF ALMOST EQUAL IMPORTANCE IS AN EVALUATION TECHNIQUE FOR CONTINUALLY ASSESSING THE EFFECTIVENESS OF DOD IN THE PROGRAM WITH UPGRADING OR REVISING THE DELEGATION, AS APPROPRIATE. THE IMPORTANCE OF THE DOD ROLE MUST BE RECOGNIZED AND PLACED IN PROPER PERSPECTIVE BY THE NASA PERSONNEL IF THE GOVERNMENT TEAM IS TO BE EFFECTIVE. NASA HAS BEEN GIVEN ADEQUATE MANAGEMENT CONTROL OF THE DOD THROUGH DELEGATION AUTHORITY TO EFFECTIVELY ACHIEVE RELIABILITY AND QUALITY ASSURANCE SUPPORT FOR NASA AT CONTRACTOR'S PLANTS. WE FEEL WE HAVE DEMONSTRATED TO OURSELVES - - WE HOPE TO OTHERS - - THAT WITH SOME INGENUITY, THE USE OF DOD IN SUPPORT OF NASA PROJECTS IS FEASIBLE, GRATIFYING, AND REWARDING.

PHILOSOPHY OF ORGANIZATION EFFORT

1. PROGRAM OBJECTIVES
2. TASK DEFINITION
3. DOD ROLE
4. "UNIFIED" GOVERNMENT TEAM

LANGLEY INDOCTRINATION TEAM

1. LANGLEY CENTER REPRESENTATION
2. PROJECT REPRESENTATION

   PROJECT MANAGER

   TECHNICAL REPRESENTATIVE

   PROCUREMENT ADMINISTRATOR

   RELIABILITY SUBSYSTEM MANAGER

   QUALITY SUBSYSTEM MANAGER

INDOCTRINATION AGENDA

1. LANGLEY RESEARCH CENTER ORGANIZATION
2. EMPHASIS OF NASA "FEW OF A KIND" APPROACH
3. PROGRAM AND PROJECT DESCRIPTION
4. PROGRAM HARDWARE DEFINITION
5. ROLE OF CONTRACTOR
6. SCHEDULE AND COST CRITICALITY
7. DOD SUPPORT FOR CONTRACT

DEFINITION OF DOD SUPPORT

1. CONTRACT ADMINISTRATION
2. DEVELOPMENT ENGINEERING
3. RELIABILITY PROGRAMMING
4. QUALITY ASSURANCE EFFORT
5. SPECIAL MANAGEMENT PROBLEMS

MAINTAINING DOD SUPPORT EFFECTIVENESS

1) EVALUATION - REVIEW BY CENTER MANAGEMENT OF EFFECTIVITY OF DOD SUPPORT

   a) PROJECT VIEWPOINT

   b) DOD ANALYSIS OF RELATIONSHIP

   c) FIELD TRIPS FOR "LOOK SEE"

DOD CONTRIBUTION TO LANGLEY PROGRAMS

1. CURRENT PROGRAM SUPPORT
2. LUNAR ORBITER CONTRIBUTION
   - A) PRIME DELEGATION
   - B) MAJOR REDELEGATIONS
   - C) ENGINEERING
   - D) QUALITY ASSURANCE

SUMMARY

1) COMMUNICATION

2) INDOCTRINATION

3) "UNIFIED" GOVERNMENT TEAM

4) ASSESSMENT OF EFFECTIVITY

5) RECOGNITION OF DOD ROLE

MSC EXPERIENCES IN CONTAIMINATION CONTROL

Quintin T. Ussery, MSC

MSC has been experiencing cleanliness problems during delivery of GFE, such as space suits, experimental hardware, and various types of extravehicular equipment. These problems were difficult to resolve, primarily because of the inconsistent cleaning requirements and lack of standards in the manufacturers' specifications.

This condition became even more serious with the Apollo Command/Service Module and the Lunar Module, where cleanliness conditions and requirements should be the same or very close. We had two prime contractors with different programs and different requirements which were difficult if not impossible to correlate.

This matter was further complicated by having numerous other contractors with little uniformity in contamination control, delivering material which would ultimately interface with S/C systems or would be used in the cabin interior.

Faced with such a situation, the MSC Flight Safety Office established an MSC contamination coordinator within the Quality Assurance Branch to coordinate contamination matters, develop specifications and standards, and to generally organize an MSC contamination program.

A quick look at our contamination activities in-house revealed a lack of coordination and uniformity of methods and standards. More specifically standardized procedures were lacking for methods of identifying clean rooms, facility monitoring, clothing, cleaning, cleanliness verification, packaging, and protection, etc.

To effectively standardize procedures, we first had to standardize requirements and also to insure that the people involved understood those requirements.

Our first order of business then was the development and standardization of requirements for on site operations. This was accomplished by issuance of Quality Assurance Procedures based on selected specifications and standards such as Federal Standard 209 and industry or MSFC specifications, modified to fit our specific requirements. This was considered the most expedient means to continue operations until we could develop standards and specifications.

The requirements we are concerned with here are normally supplied via specifications and we found a variety of these in use - MSFC, prime contractor, military, society of automotive engineers, ASTM, and others. Many of these specifications unfortunately are concerned with large systems such as the Saturn and are not too satisfactory for cleaning the small valves and orifices found in the spacecraft systems. Too many conflicted in their requirements and it was difficult to relate cleanliness levels between specifications, one clean room specification with another, or with spacecraft systems.

To date we have developed and have in use 18 MSC Standards and Specifications tailored to fit our unique requirements. These are shown here.

Slide 1

Note that we have a standard for definitions and one for clean rooms and work stations. The clean room standard is based on Fed. STD-209, but contains more operational details such as furniture and lighting requirements. Perhaps its most important feature is that it provides a use table of controlled environment areas versus equipment critical surface cleanliness levels. Due to many differences of opinion regarding clean room garments, we have written a garment specification that ties down garment features and decontamination requirements. Another establishes decal requirements--these decals are intended for application to the outside of inner clean bags to indicate class equipment is cleaned for; e.g., LOX service, etc. Also we have written a packaging specification, MSC-SPEC-C-12. Specifications are available for fluid sampling and fluid analysis--these relate specifically to spacecraft fluids.

Slide 2

The most significant of these are the Apollo Spacecraft Cleanliness Specification - MSC-SPEC-C-5, MSC-SPEC-C-6 Fluid Cleanliness and MSC-SPEC-C-7 Fluid System Surface Cleanliness.

The Apollo Spacecraft Specification establishes and standardizes cleanliness requirements in manufacturers' final assembly and checkout areas, environmental test chambers, and at launch site test and checkout areas.

This specification has been placed on the Apollo Command/Service contractor, the Lunar Module contractor, and KSC has been requested to implement it during checkout and launch operations. Present plans call for invoking 8 of the other MSC specifications on the prime contractors and requesting implementation at KSC as well. These specifications cover Apollo S/C fluid and surface cleanliness, and fluids; specifically potable water, high purity water, and water glycol.

Also we have in use a specification for spacecraft on-board equipment cleanliness--this covers equipment that is carried on board and interfaces with a spacecraft system or is used in the cabin environment. We have a cleanliness specification for the pressure garments and accessories; one for control of systems contamination during repair or maintenance, and one for cleanliness of non-airborne systems--this is for manned chambers and facilities piping.

As we reviewed existing specifications or standards we kept coming up with the thought that specification standardization among the three Centers would be a major achievement and would certainly be a major source of cost savings. Informal discussions with MSFC, KSC, and NASA Headquarters (KR personnel) resulted in the forming of a NASA Contamination Panel made up of KSC-MSC-MSFC personnel. The panel membership is shown here by slide.

Slide 3

This panel has been meeting at regular intervals since its establishment in May of this year and has been instrumental in accomplishing two significant undertakings:

1. Development of an agreement for inter-Center coordination and joint use of SPEC's and standards. About a dozen specifications are in coordination at this time.

2. Issuance of two contracts to Sandia Corporation, Alburquerque, New Mexico for development of two NASA Handbooks.

The first of these, "Principles of Contamination Control," will become available early in 1967--this is being funded by the Office of Technical Utilization. This is a general approach for operations and management personnel. The second Handbook, "Contamination Control Guidelines for Designers and Manufacturing Engineers" will be available some time in the next fiscal year--this is being funded by MSFC. We expect this handbook to provide the design engineer sound parameters and methods for designing equipments that can be cleaned to acceptable levels without exceeding the state of the art. The panel has agreed to act as advisors on both of these contracts and to provide final review and coordination within each Center.

I would like to conclude this presentation with these thoughts and recommendations. It is recommended that contamination be recognized and treated as a significant quality process with emphasis on obtaining and maintaining high technical standards. Supplier or contractor personnel should be trained and certified by in-house programs, with training and certification subject to the review and disapproval by NASA or the delegated agency. Certification is a must if we are ever to achieve a standard approach to contamination control. I also propose that NASA review and approve supplier or contractor developed contamination specifications and standards. Further NASA installations should be authorized to provide brief seminars in contamination to indoctrinate suppliers and contractors in NASA contamination requirements and special techniques. This would do much to reduce costs. Literally thousands of manhours are being wasted in the space industry because of a lack of standardization and training. Insofar as training is concerned MSFC has a program for contamination training—here is a ready made opportunity for offering training as necessary to indoctrinate other Centers and contractors.

Substantially the entire space industry recognizes the desirability of a NASA wide contamination program--one that would tie the Centers, suppliers and prime contractors together. But so far no one to my knowledge within NASA has taken the initiative to develop a coordinated program. Initially what is needed is a group or an office which could take existing specifications or standards and obtain coordination across the OMSF Centers; i.e., MSC-MSFC-KSC. The next and final step would then be to expand to include all NASA Centers. The Apollo metrology program is a good example of how this effort could be handled. MAR-Q here at NASA Headquarters has established and is operating a coordinated metrology program. Contamination could be handled in the same manner. In fact the basic organization is already in operation--the NASA contamination panel discussed earlier all that is needed is a Headquarters Sponsor.

Slide 1

DEFINITIONS

MSC-STD-C-1	Definitions for Contamination Programs

GARMENTS

MSC-SPEC-C-2A	Clean Room Garments, Specification for

DECALS

MSC-SPEC-C-3	Decals, Certification of Cleanliness, Specification for

CLEAN ROOMS

MSC-STD-C-4	Clean Room and Work Stations

PACKAGING

MSC-SPEC-C-12	Precision Clean Packaging, Specification for

FLUID SAMPLING AND ANALYSIS

MSC-SPEC-C-13	Fluid Sampling, Specification for
MSC-SPEC-C-14	Spacecraft Fluid Analysis, Specification for

Slide 2

SPACECRAFT CLEANLINESS

MSC-SPEC-5A	Apollo Spacecraft Cleanliness, Specification for

EQUIPMENT SYSTEM CLEANLINESS

MSC-SPEC-C-6	Apollo Spacecraft Fluid Cleanliness, Specification for
MSC-SPEC-C-7	Apollo Spacecraft, Fluid Systems Surface Cleanliness, Specification for
MSC-SPEC-C-8	Spacecraft On-Board Equipment Cleanliness, Specification for
MSC-SPEC-C-9	Cleanliness of Non-Airborne Breathing Systems, Specification for
MSC-SPEC-C-10	Systems Contamination Control During Repair, Replacement or Maintenance, Specification for
MSC-SPEC-C-15	Pressure Garment Assembly, Specification for

FLUIDS

MSC-SPEC-C-20	Water, High Purity, Specification for
MSC-SPEC-C-21	Water, Potable, Specification for
MSC-SPEC-C-22	Ethylene Glycol-Water, Specification for

Slide 3

NASA CONTAMINATION PANEL

MSFC		KSC		MSC	
F. Beyerlee	Co-Chairman	Dr. J. B. Gayle	Co-Chairman	Q. T. Ussery	Co-Chairman
M. Picard	Alternate	C. E. Whisenant	Alternate		

A. J. Rzeszotarski Secretary - GE/ASD

INTEGRATED CIRCUIT PROBLEMS

by

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Since the first failure analysis at the Goddard Space Flight Center in early 1965, 90 microcircuits have been submitted to analysis. One-half of these failures were attributed to device defects and 80 percent of these defects were the result of human error or other manufacturing deficiencies. During the past two and one-half years, an additional 800 devices have been evaluated or examined and many were found to have defects similar to those producing failure, thus injecting a low confidence in those circuits procured for flight projects. Overall, the microcircuits of seven different major manufacturers (14 percent of the total number of microelectronic companies in this country) were represented. Eighty percent of all devices involved were procured to high reliability specifications.

There were numerous failures not analyzed and, in general, high microcircuit failure rates were encountered.[1] While it is recognized that the science of microelectronics has made great strides, the engineering technology has evidently not progressed as well. Here is an industry which has the sophistication to perform exacting physical processes in which geometries are controlled to ten-thousandths of an inch and impurities to a few parts per million, yet it has trouble putting a good package together. Product quality has suffered because of the industry's growing pains, according to one report.[2] The largest single factor today creating poor microcircuit reliability is human error, according to other sources.[3,4]

Admittedly, not all the problems were those associated with production. The other half of the 90 microcircuits analyzed failed due to mishandling, electrical overstress, external contamination, and some unexplainable reasons. These types of failures, however, were mainly existent during the earlier stages of microcircuit use at GSFC and were reduced considerably through instructional notices and personal communication.

What, then, are the immediate steps necessary to insure the procurement of quality microcircuits? A more thorough and stronger procurement document is needed. In order for the document to be a quality guideline, the type of manufacturing deficiencies commonly causing failures and defects must be understood and thoroughly attacked in the specifications. No amount of detail, however, will make the document strong. It must be implemented by knowledgeable source inspection. You can't rely solely upon the manufacturer to carry out your instructions. After all, he is out to make a profit.

One step has already been taken at GSFC, in that a new general procurement specification, S-323-P-7, has been generated. Heavily taken into account were those failure mechanisms observed in our own Failure Analysis Laboratory, deficiencies observed in production line surveys, and failure reports from other NASA Centers. As a result of these observations, the specification places the most emphasis on handling and visual inspection procedures, in an attempt to hold rein on apparently the weakest parts of the entire microcircuit fabrication technology.

Insight as to why handling and visual inspection have been deficient may be had by taking a look at what we were up against with the devices received at GSFC. Two general types of device defects were observed, viz., extrinsic or intrinsic.[2] Extrinsic defects are readily measurable or observable defects on or within the semiconductor material or package. They include such things as (a) internal contamination, (b) cracks in the silicon, (c) labelling errors, (d) scratches in the metallization, (e) hermetic leakage, (f) photolithographic masking faults, (g) semiconductor crystal defects, etc. The intrinsic defects are latent defects associated with any of the materials forming the microcircuit. They may or may not be readily measurable or observable. Included in this category are (a) surface inversion, (b) degraded thermo-compression bonds, (c) diffused junction degradation, (d) corrosion, (e) package degradation, etc. The ratio of extrinsic to intrinsic defects was roughly 4 to 1.

In an analysis of 3,000 failed semiconductor microcircuits under the sponsorship of the Rome Air Development Center, it was found that high electrical stress tests produced an extrinsic-to-intrinsic failure ratio of 3.5 to 1.[2]

The strangest part of all of this is that the intrinsic problems, which are fewer in number, are mainly tied in with the most difficult and exacting stage of manufacturing, while the extrinsic deficiencies are associated with the less difficult. The entire microcircuit production operation is divided into three major stages (see Figure 1). These are pre-packaging, packaging, and post-packaging. Silicon slice preparation in the pre-packaging stage requires more rigid environmental control and is where most of the intrinsic defects are produced. Photolithography, however, creates many extrinsic defects. The greatest headache is the large number of extrinsic defects produced in the packaging stage. Here, poor handling is the defect generator and inadequate visual inspection allows their passage. One doesn't have to make a production line survey to reach this conclusion. Just look at the products received. Evidently quality took a holiday when Goddard's circuits were being made.

There is no thoroughly proficient set of electrical and stress screening procedures for measuring or finding the defects that have been previously described. This area, like intrinsic problems, needs more investigation in the laboratory. In S-323-P-7, the screening specifications for the packaging stage were not very different from those of the previous procurement document. In order to arrange an in-production evaluation of the circuits to Goddard's needs, however, the sequence of tests have been altered somewhat and visual inspection has been beefed up.

In the final analysis, what good is this document? There is not much, really, because there appears to be an inertia on the part of the manufacturers to perform wholeheartedly to quality specifications. Then NASA must accordingly implement quality procurements with stronger source inspection to insure the delivery of quality microcircuits when needed. The type of source inspection used presently is weak. Inspectors must do more than look at documented evidence of electrical tests or visual inspections. All of the quality control records in the world do not show how well the job was done. The task is to look at the quality, not read about it. Imposition of this type of inspection will require individuals who understand the fabrication technology.

What has been briefly proposed is a first step out of the microcircuit quandary. It is comforting to note that a NASA-wide effort toward strengthening the microcircuit quality program has been in progress and that there is a unanimity of feeling toward the same ideas expressed in this paper.

REFERENCES

[1] "Microelectronics Used on Various Goddard Space Flight Projects," R. VanAllen, GSFC, Sept. 1966, A Survey.

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[3] "Reliability of Integrated Circuits--Analysis of a Survey," W. R. Rodriques de Miranda, Aeronautical Division, Honeywell, Inc., St. Petersburg, Florida.

[4] First Research Report, Sept. 1966, ECRC Research Center, Battelle Memorial Institute, Columbus, Ohio.

MICROELECTRONIC CIRCUIT MANUFACTURING OPERATIONS

PRE-PACKAGING

A. MATERIALS PREPARATION

B. SILICON SLICE PREPARATION

1. LAPPING & POLISHING
2. PHOTOLITHOGRAPHY
3. DIFFUSION & OXIDATION
4. ETCHING & CLEANING

PACKAGING

A. SILICON PIECE PART ENCAPSULATION

1. ELECTRICAL INSPECTION
2. PIECE PART FORMATION
3. PIECE PART MOUNTING
4. LEAD BONDING
5. CLEANING
6. SEALING

POST-PACKAGING

A. PACKAGE SCREENING

1. ELECTRICAL TESTS
2. STRESS ENVIRONMENT TESTS
3. LEAK TESTS
4. BURN-IN
5. LEAD-SHEARING

B. PACKAGE MARKING

FIG. 1

MICROELECTRONICS ON ATS

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Power and weight limitations on the ATS spacecraft called for maximum used of microelectronics in the EME encoder by the Aerospace Division of Westinghouse Electric Company, the spacecraft integration contractor. Texas Instruments series 51 flat-pack circuits were selected for use after study of qualified sources. Up to 110 submodules are used in each ATS spacecraft, with up to 16 flat-packs per submodule. Good mechanical security and excellent heat dissipation are achieved by mounting the submodules on a fluidized aluminum "cookie sheet" split panel with the submodule leads extending through precisely positioned holes for all electrical connections on the underside of the sheet. A relatively high rate of integrated circuit failure during initial electrical inspection over a -20^{o} C to $+80^{o}$ C temperature range was completely eliminated in later devices by using gold-gold ball bonds in place of the original aluminum-gold bonds. However, reliability has been good during qualification tests of all four presently completed EME encoders, three of which use circuits with the aluminum-gold bonds.

INTRODUCTION

The Environmental Measurements Experiment (EME) is the scientific experimental package schedules to fly on each of the three major variations of the Applications Technology Satellite (ATS). These three satellite types are: (1) A synchronous-altitude spin-stabilized satellite, (2) a 6000 mile gravity-gradient stabilized satellite and (3) a synchronous-altitude gravity-gradient stabilized satellite. Each EME package consists of seven or eight different scientific experiments supplied by universities, NASA, and private contractors. The individual experiments have been chosen to measure the spacecraft environment systematically for damaging effects from radiation and energetic particles, and additional scientific information about magnetic and electric fields. On the gravity-gradient stabilized satellite it is planned to take advantage of the 130-foot booms as antennae for a radio astronomy experiment.

The individual experiments in each EME contain certain microelectronics. However, the greatest number by far are found in the PFM telemetry encoder used to handle information from the various scientific experiments in the EME package. Encoder specifications are presented in Appendix A.

This paper describes the reliability aspects, method of handling, packaging, and general comments concerning the use of Texas Instruments series 51 integrated circuits in the EME packages.

BACKGROUND

The Aerospace Division of Westinghouse Electric Co in Baltimore, Maryland, was awarded a contract to integrate the various scientific experiments in the EME package and to support the spacecraft contractor in the integration of EME into the ATS spacecraft. In addition, Westinghouse was given the responsibility to design the EME structure, telemetry encoder, power supplies, and the command control interfaces between the spacecraft command receiver and the individual experiments. Figure 1 shows the configuration of the EME package to be flown on the first ATS mission in a synchronous orbit aboard a spinning spacecraft.

The package mounts cantilevered from the thrust tube. Its overall dimensions are approximately 18 by 10 by 13 inches. All the experiments which must be exposed to the outside of the spacecraft are grouped to view through an aperture 8 by 12 inches to minimize the loss in solar cells which encase the spacecraft. The telemetry encoder, shown in the expanded view in Figure 2, is fabricated in a single sheet to simplify interconnections and to eliminate all connectors except those required as interfaces external to the encoder. Because of severe weight and power limitations, the design specification called for the maximum use of microelectronics.

The design study got underway in October 1964, with a close scrutiny of the qualified sources of integrated circuits available at that time.

Minor considerations such as delivery schedule and the number of nodes per package made the final choice in favor of Texas Instruments series 51 integrated circuits over Fairchild milliwatt micrologic. After much discussion and specification manipulation Westinghouse, to insure a tight delivery schedule, was forced to use the existing GSFC specification NAS-51, which was then in use at Texas Instruments.

The chief elements of this specification were a lowpower (X40) visual inspection, centrifuge, variables data recorded before and after a 300 hour burn-in, x-ray, and leak tests. It was felt that a more rigorous specification should be imposed, to include features such as monitored vibration, closer visual inspections, serialization, etc. However, this could not be realized until some time later, when the new GSFC General Micro-Electronics Spec S-711-P1 was issued.

DESCRIPTION

The single "cookie sheet" encoder is fabricated from 0.030 inch sheet aluminum with a wrap-around frame. Holes are drilled in the base plate to pass the pins from the submodules through to a welded-wire interconnection matrix on the reverse side. Figure 3 shows the technique with which the pins are connected to the welded-wire matrix. The pins are purposely left long so that, in the event of rework, the module may be cut out and returned several times without extending the submodule or matrix leads. Insulation is provided to the aluminum base plate by first an anodizing coat and then a fluidized epoxy dip approximately 0.01 inch thick. This coating tends to fill all the holes in the plate, necessitating a redrilling with an undersized drill. Indexing is kept to a close tolerance of ±0.001 inch by drilling with a tape programmed drilling machine.

The close mounting of each integrated circuit submodule to the aluminum base plate, plus the number of pins through the plate, provides an excellent heat sink. Although the series 51 devices do not dissipate much heat, the reliability is improved by keeping the temperature as low as possible. This technique should prove valuable in other applications, especially where submodules are more densely packed and where heat dissipation is higher in the individual integrated circuits than in the series 51 circuits.

FLAT PACK SUBMODULE

The integrated circuits (flat-packs) are mounted in 24 different types of digital submodules with a maximum of 16 flat-pack submodule. In a single encoder, as many as 71 flat-pack submodules are used along with 39 cordwood sub-modules of discrete components for a total of 110 submodules in ATS-A and a total of 89 in ATS-B.

Assembly of the flat-pack submodules is shown in Figures 4, 5, and 6. The individual flat packs are cemented to the spacers with acrylic cement. Spacers and base are made of black phenolic type MFH. Unused connectors in the spacers and flat-packs are cut off and leads are twisted to meet the wiring run before assembly and welding. The spacers, with attached flat-packs, are cemented in place in the submodule base so that the three leads in the spacers form the pin field of the submodule. After welding, but before potting, the entire submodule is mechanically strong enough for easy handling and testing. In fact, the leads of the submodule are usually inserted directly into a test connector for all submodule tests.

Included in each flat-pack submodule is one 0.1 mfd filter capacitor for the power bus. This capacitor bypasses noise pulses within each submodule to reduce cross talk between submodules and to provide a distributed filter for the entire network.

Where additional diodes or resistors are required, they are cemented to the top of the submodule assembly, dipped in acrylic resin, and the entire submodule foamed with polyurethane.

The individual submodules are mounted on the main frame as shown in Figure 7. The smaller rectangular modules are the flat-packs and the larger square modules are cordwood group of discrete components. There is no evidence of crowding since the distribution is determined by the welded wire interconnection matrix on the reverse side. For ease and speed of fabrication, the "cookie sheet" is made in two parts which are brought together in the final assembly operation. The interconnections between halves can be seen in Figure 8.

INTEGRATED CIRCUIT TEST RESULTS

When the integrated circuits were received at Westinghouse, they were given only visual inspection and a leak test. Data are not included here on devices rejected because of incoming visual inspection. However, all other reject data are included in Table 1.

Table 1.

Series 51 Integrated Circuit Failures as of August 1, 1966

System	Qty.	Leak Failures	Submodule Electrical Failures Prefoam	Submodule Electrical Failures Post Foam	System Electrical Failures
Proto. 1	626	7	6	2	1
Flt. 1	626	9	3	1	1
Proto. 2	799	10	5	2	1
(Gold-Gold Bonding Introduced)					
Flt. 2	799	5	6	1	0
Spares	480	2	3	1	0
Totals	*3330	33	23	7	3

* 864 manufactured using gold-gold interconnections.

It is significant that the highest incident of failures occurs at the first electrical test. This does not imply that the devices were all bad when first turned on. Some devices failed at one of the three different test temperatures, $-20^{o}C$, $+25^{o}C$ and $+80^{o}C$, imposed during each test phase. Failure analysis on all failed devices to date has diagnosed the causes of failure as follows:

Cracked silicon bar	6
Oxide puncture	5
Mislabeled	5
Defective ball bonds	11
Unknown	6
Total............	33

Although bad ball-bonds represented the highest single cause of failure in the aluminum-gold devices used in the EME encoder, there was a much more severe problem on another GSFC in-house project at about the same time. This project was plagued with intermittent problems caused by defective ball-bonds in Texas Instruments aluminum-gold series 51 flat-packs manufactured to the NAS-51 specification.

The high ball-bond failure rate occurred in the Optical Aspect Computer for IMP-D (Reference 1), which used 300 flat-packs per system. In this application one characteristic differed uniquely from the EME encoder: an interruption of power to the flat-pack logic system at a rate of up to 20 times per minute. This was done to achieve a net power saving, since most of the logic was not in use a good portion of the time. Unfortunately, the semiconductor power switch was an efficient source of intermittent behavior in flat-pack ball-bonds of the aluminum-gold type. In this one system of 300 flat-packs, more defective ball-bonds were experienced than in the entire EME, which used over twice as many.

Communications were established with Autonetics in Anaheim, California, and with the personnel who were involved in the isolation of a similar problem on the Minuteman II program (Reference 2). Study of the problem and subsequent failure analysis by Texas Instruments, Inc. confirmed that, in at least four cases of intermittents, the trouble was caused by aluminum-gold ball-bonds. The failure analysis cited evidence of the same problem investigated by Autonetics in Reference 2.

It is still not clearly understood just why the power switch produced a higher incident of intermittent ball-bonds. However, as soon as devices manufactured with the gold-gold interconnections were introduced, this symptom promptly disappeared. Significantly, the 11 ball-bond failures in EME occurred only when aluminum-gold devices were used.

SUMMARY

As of this writing, four complete encoders have been fabricated for EME of which three have been given qualification or acceptance tests. The total microelectronic device time totals more than 1,800,000 flat-pack hours.

Three of the systems were fabricated using flat-packs with aluminum-gold interconnections. Most of the fourth system and spares were fabricated with devices having gold-gold bonds. It is interesting to note that, although the process was changed, the failure rate remained essentially the same.

In each encoder there are approximately three flat-packs used for each transistor. However, in the entire EME package (including the power supply and command interface) transistors are used in nearly the same ratio as flat packs. Interestingly, since the outset of this project there has been approximately the same continuing failure rate in transistors and in flat-packs: in each case about 1 percent. Up to the present time there have been no transistor failures in any tests on the complete encoders. However, three flat packs have failed after submodules were assembled into a complete system. These three failures occurred during the encoder preacceptance tests. No failures have occurred during spacecraft qualification or acceptance testing.

To further substantiate the failure rates of microelectronics used in flight programs a survey was made of all projects at Goddard Space Flight Center. Results of this survey are tabulated in Appendix B. In some cases accurate failure records had been maintained but in many cases the number or percent of failures had to be estimated because complete failure reports were not available throughout all phases of tests. Only data obtained during testing of flight systems was considered which in most cases included an engineering test unit, prototype, flight units and spares.

The large number of devices in active spacecraft following the launch of ESSA-3(TOS-A) are giving an impressive record of flight experience. It is estimated that during the month of October 1966 that approximately 2,000,000 device-hours was accumulated in orbit.

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APPENDIX A

General EME Telemetry Encoder Specifications

	ATS-A	ATS-B
Type	PFM	PFM
No. channels/frame	16	32
No. frames/sequence	16	16
Analog (0-5 volt) data inputs	16	8
Digital data inputs	28	24
Performance parameters		
Analog	9	19
Digital	5	7
Sample rate, channels/sec.	50	100
Frame rate, frames/sec.	3.1	3.1
Flat-pack power supply	-3.85v$\pm$5%	-3.85v$\pm$5%
Power consumption	5.0 watts	4.8 watts
Weight	4.9 lbs.	4.0 lbs.
Integrated circuits	799	626
Transistors	279	252
Environmental requirements:		
Temperature	($+80^{o}$C (-20^{o}C	$+80^{o}$C -20^{o}C
Maximum vibration 250-400 cps	55g	55g
Vacuum	10^{-5}Torr	10^{-5}Torr

APPENDIX B

MICROELECTRONICS USED ON VARIOUS GSFC FLIGHT PROJECTS
AS OF 9/1/66

Spacecraft & System	I.C. Type	Total Devices Used	% Failures	Preflight Device-hrs.	Useful Device-hrs. in Orbit
IMP-A Optical Aspect	Series 51, T.I.				120,000
IMP-B Opt. Asp.	" " "	300	< 1%	≈ 150,000	179,000
IMP-C Opt. Asp.	" " "				550,000
IMP-D&E Opt. Asp.	" " "	3,500	> 1%	≈ 700,000	*924,000
IMP-D&E T/M Encoder	MOSFETs, GME	3,535	.06%	16,000,000	1,300,000
TOS/ESSA Programmer	Series 51, T.I.	3,360	> 1%	≈ 3,360,000	1,920,000
Nimbus II MRIR	" " "	500	<< 1%	≈ 300,000	1,300,000
OGO-A Particle Exp.	" " "	600	?	?	1,500,000
OGO-B None	-	-	-	-	-
OGO-C Airglow Exp.	" " "	250	> 1%	100,000	260,000
IMP Life Test Encoder	MOSFETs, GME	330	None	5,000,000	-
IMP-F Encoder (MK II)	" "	700	None	420,000	-
IMP-F Opt. Asp.	Series 51, T.I.	100	< 1%	7,000	-
" " "	Sprague	200	4%	14,000	-
" Statistics Computer	Series 51, T.I.	400	< 1%	80,000	-
" Encoder (MK III)	MOSFETs, GME	3,000	-	-	-

Spacecraft & System	I.C. Type	Total Devices Used	Failures	Preflight Device-hrs.	Useful Device-hrs. in Orbit
OAO-Programmer	Series 51, T.I.	885	< 1%	≈ 420,000	-
ATS- A&B T/M Encoder	" " "	3,330	1%	1,800,000	-
Experiments	" " "	1,500	< 1%	≈ 750,000	-
NIMBUS-B MRIR	" " "	500	<< 1%	≈ 200,000	-
" " IRLS	Series 51,52, 53, T.I.	1,520	<< 1%	≈ 921,000	-
" " T/M Encoder	Series 51,52, 53, T.I. Sprague I.C. Westinghouse Radiation Inc.	2,832	None	≈ 140,000	-
NIMBUS-D MRIR	Series 51, T.I.	800	Breadboard	≈ 40,000	-
" " IRLS	Planned similar to Nimbus-B				
Encoder	" " " " "				
RAE - T/M Encoder	Series 51,T.I.	1,896	Not past breadboard		
TOTALS.......		30,038	-	29,973,000	8,053,000

*Only system with gold-gold interconnections (250 pieces)

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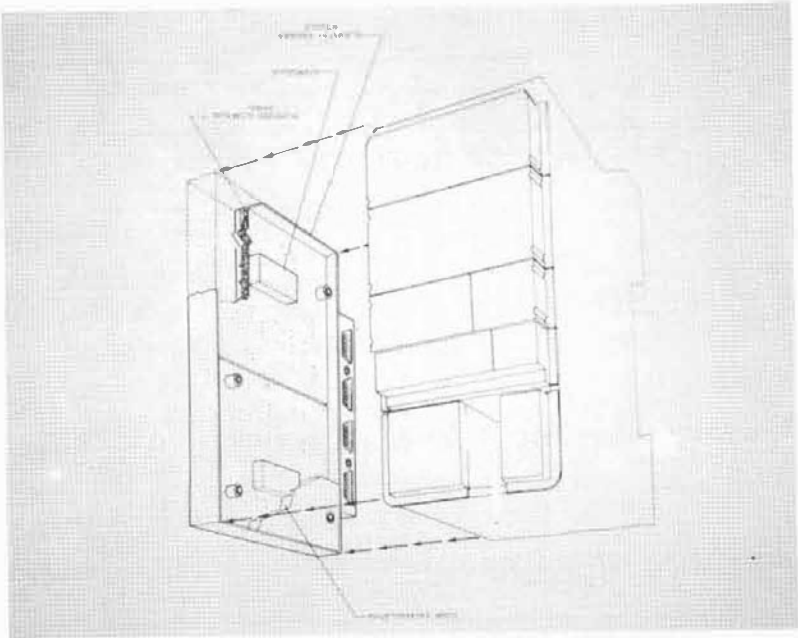

Fig 2

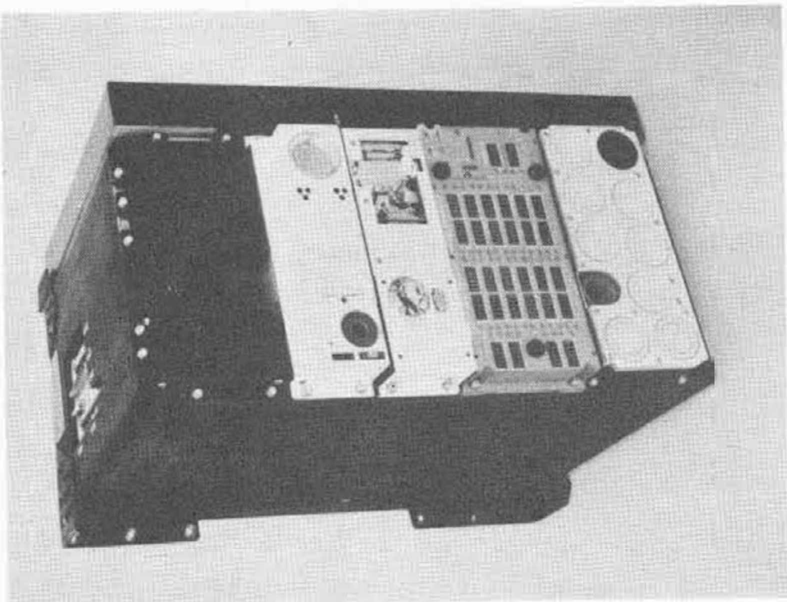

Fig 1

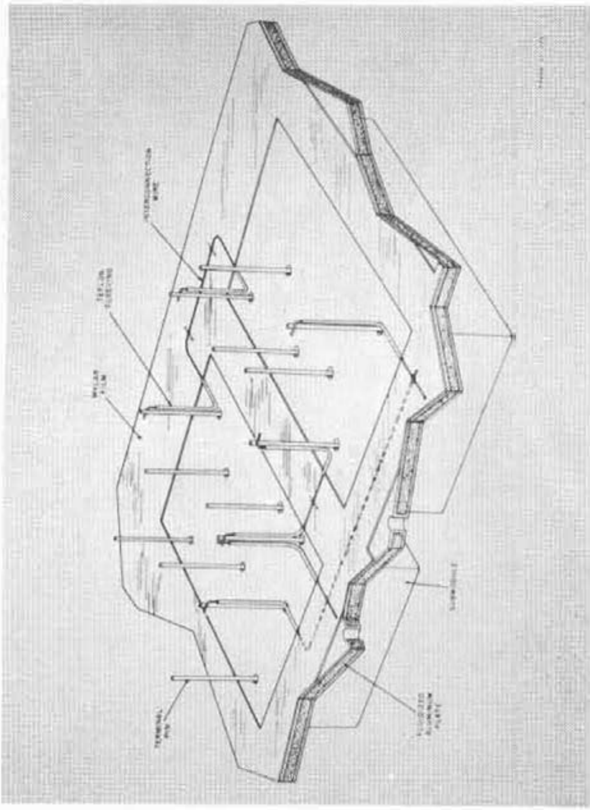

FIG. 3

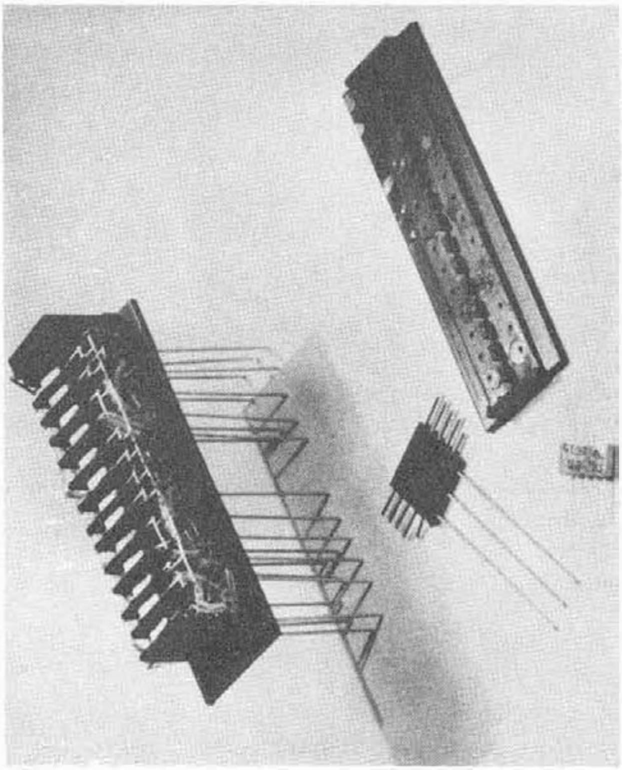

FIG. 4

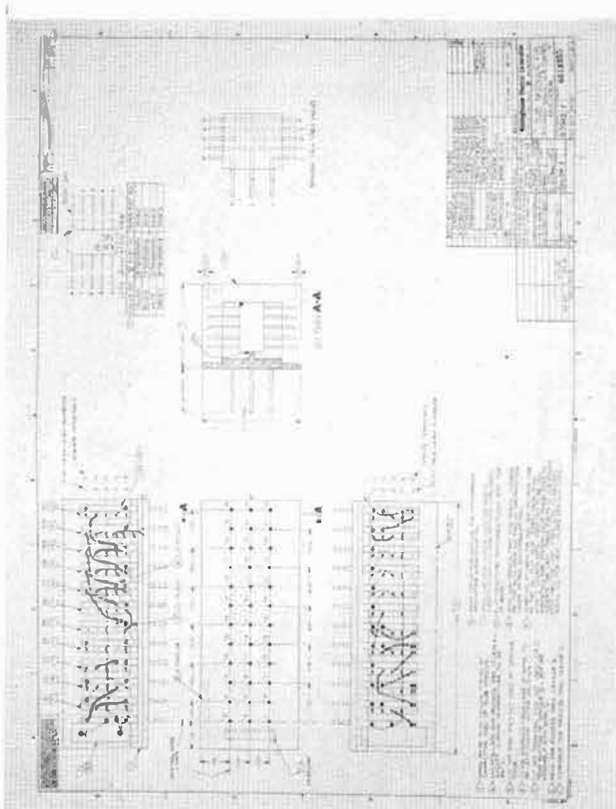

FIG. 5

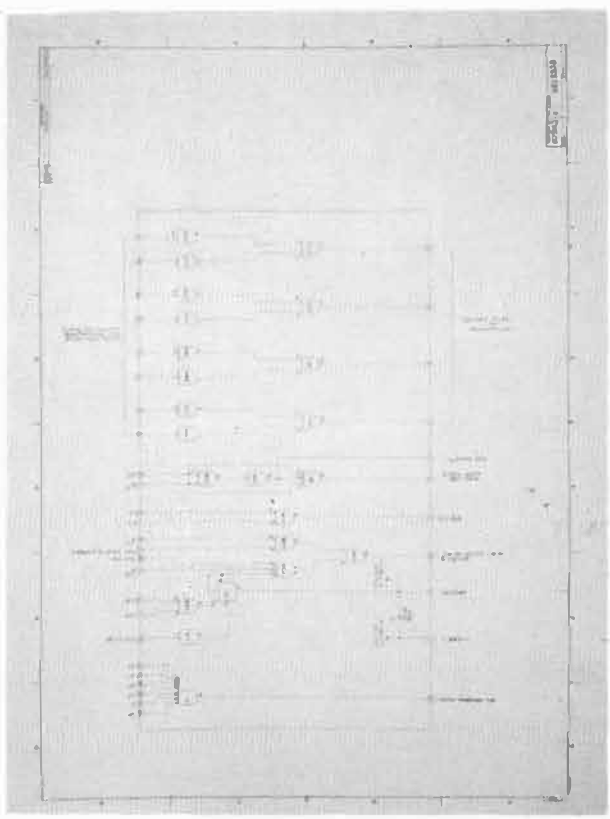

FIG. 6

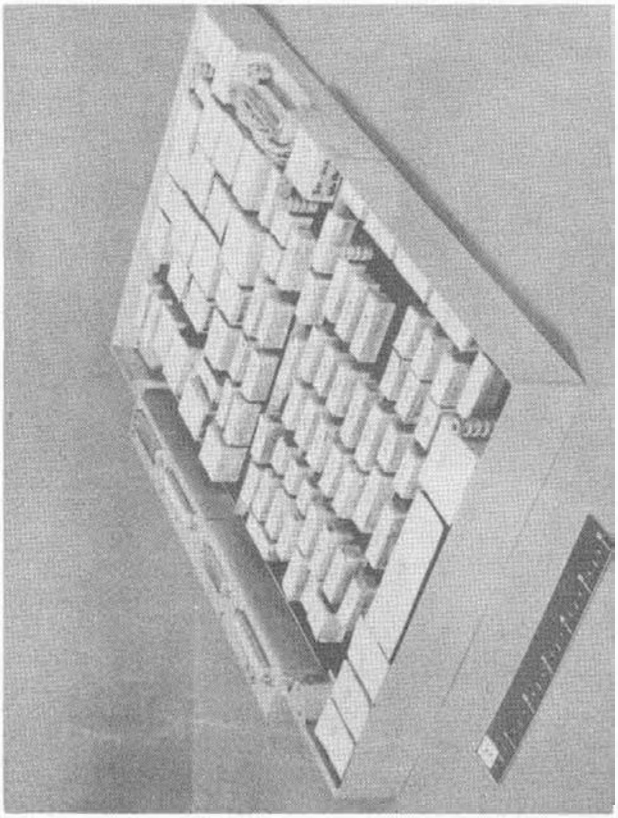

FIG. 7

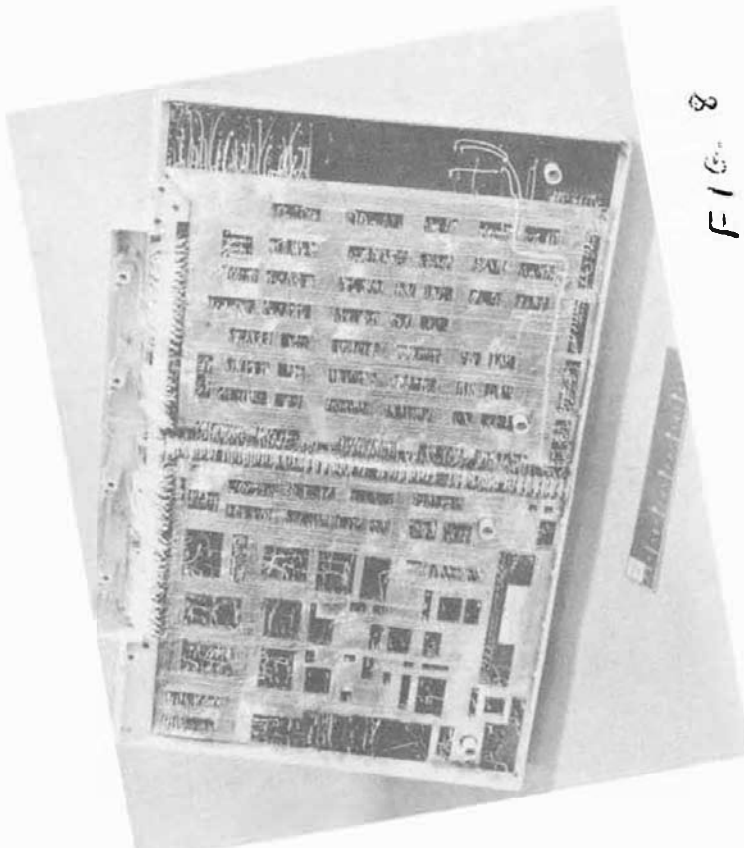

FIG. 8