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Jet Propulsion Laboratory Lunar Program Guidelines

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Contents

Preface

Continuing changes in launch-vehicle availability and schedule planning have become standard in the national effort for exploration of the Moon. In addition, the inter-relationships of unmanned to manned lunar exploration have not yet been clearly defined, primarily because of more urgent demands in other phases of the program.

Despite the lack of clearly defined inter-relationships, this document is published as a guide for the Jet Propulsion Laboratory Lunar Program.

C. I. Cummings,
Lunar Program Director

I. Lunar Program

A. Program Objectives

The primary objectives of the Jet Propulsion Laboratory Lunar Program are:

(1) To provide maximum assistance as soon as possible to the manned lunar exploration program by:

  (a) Determining key lunar environmental factors.

  (b) Developing pertinent scientific and engineering technologies and directly usable equipment.

(2) To obtain basic scientific information for determining the nature and origin of the Moon and the solar system.

The technical and scientific objectives of the Lunar Program are covered in Sections IB and IC, respectively, of this publication.

B. Technical Objectives

The technical objectives of the Lunar Program are to design, develop, and demonstrate the use of unmanned spacecraft systems capable of performing the required missions and scientific experiments for supporting the manned lunar program and for gathering information about the Moon. The elements of such a system include:

(1) Spacecraft.

(2) Mission package.

(3) Communication link (DSIF).

(4) Command Center (SFOC).

(5) Test equipment and facilities.

(6) Launch vehicles.

(7) Launch equipment and facilities.

(8) Procedures.

(9) Trajectory computation.

(10) Data processing and handling.

(11) Qualified personnel and workable management arrangements.

Specific objectives (not all presently funded) and/or mission package subsystems are to demonstrate:

(1) Hard landing on the Moon with simple operating experiments.

(2) Accurate soft landing on the Moon with advanced experiments.

(3) Soft landing on the Moon with a vehicle capable of moving about the surface with advanced experiments.

(4) Photographing the surface of the Moon from a lunar orbiter.

(5) Placing a radio beacon on the lunar surface for future terminal guidance operations.

(6) Guiding and injecting launch vehicle into an accurate trajectory.

(7) Communicating with and commanding spacecraft en route to Moon.

(8) Controlling spacecraft attitude in pitch, roll, and yaw.

(9) Performing midcourse and terminal correction of trajectory, using chemical rockets.

(10) Communicating with instruments landed on the surface, or placed in orbit about the Moon.

(11) Performing experiments with high reliability in the lunar and space environments.

Specific technical objectives in the communication area are to demonstrate:

(1) Use of minimum power and weight communication equipment and steerable directional antennas in the spacecraft.

(2) Use of a world-wide network of ground tracking stations capable of communicating with a spacecraft through high-gain antenna systems, independent of Earth's rotation.

(3) Development and use of a world-wide data and command communication network to coordinate activities of the ground stations and to command the spacecraft in flight.

Technical objectives required to conduct a spacecraft flight and mission operation include the design, development, and use of a command facility that is capable of receiving information from the spacecraft at a launch site and through the DSIF, and presenting it so the operating personnel can make logical decisions for control of the spacecraft operation.

An important objective of the operation is to demonstrate the ability to rapidly and accurately handle and process the large amounts of data from the spacecraft.

The entire field of trajectory determination must be developed. Important phases of this technology include integrating computers into the system for rapid trajectory computation, and integrating personnel into the system for optimum decision-making capability. Technical procedures for these operations must be developed, refined, be demonstrated.

Methods, procedures, and techniques must be developed to conduct assembly, test, and launch operations on schedule. In particular, the ability to launch on time must be demonstrated.

Techniques must be developed to integrate scientific instruments into the spacecraft system with minimum lead times, with a high order of reliability and accuracy under the expected environmental conditions. In many cases, completely new instruments must be designed and developed.

In all of these efforts, schedule performance is most important because of the urgency of the manned lunar program. The value of the information developed is much greater the earlier it is obtained.

C. Scientific Objectives

1. General

The experiments carried out within the Lunar Program will be based on two fundamental scientific objectives:

(1) Gathering information on those characteristics of the lunar environment which must be known to permit successful operation of subsequent manned and unmanned phases of the lunar exploration program.

(2) Measuring those characteristics of the Moon and its environment which will provide a better understanding of the origin, history, and nature of the Moon and, indirectly, of the entire solar system.

Clearly, some experiments will meet both objectives, particularly in the early phases of the program.

2. Phases

Within the performance capabilities of booster systems and spacecraft, the program of lunar observation will develop through a series of phases. The specific experiments selected for each phase must be considered with reference to the objectives listed above, and within the mandatory engineering restraints.

Ranger *phase.* The *Ranger* class of experiments must produce useful data within the comparatively short observation time available on an impact trajectory, or alternately, must withstand the rough landing environment typical of the *Ranger* 3, 4, and 5 capsule operations. Thus, experiments for the *Ranger* phase include photography, certain spectrographic observations with simple instruments looking at spectral characteristics of sufficient intensity to give a good reading during the available observation time, and simple measurements of the physical characteristics of the surface material at the impact point. Spectral observations may show the characteristics of the lunar surface, and also the radiation environment near the Moon due, for example, to solar activity, which must be measured in preparation for further experiments, including manned flight. Anticipation of soft landings of more complex spacecraft, including manned vehicles, requires determination of surface characteristics. The limited capabilities of the *Ranger* experiments, together with ground-based observations, will be used to the maximum extent possible to satisfy this need.

Surveyor *phase.* The *Surveyor* class of experiments comprises the second phase of lunar exploration. The *Surveyor* spacecraft can carry a number of instruments to a soft landing on the Moon, or into a closely controlled, long-life orbit a few hundred miles above the lunar surface. Detailed analyses of lunar surface chemical and physical characteristics will be made with the *Surveyor* soft-lander, and the orbiter will be capable of detailed optical and spectral observations of large expanses of the lunar surface. Correlation of the results of these two types of measurements will permit the development of highly detailed pictures of the lunar surface—not only the area available to immediate inspection, but also extended areas where characteristics can be deduced from the combination of orbiter and soft-lander measurements. Much as remote stations and aircraft observations continue to be useful as aids to the human observer of Earth geology, so the *Surveyor* type of spacecraft will probably be useful indefinitely in the exploration of the Moon. Their utility will increase when human observers on the Moon are able to program their exact observations.

Experiments concurrent with manned flight. Since the number of man-carrying flights to the Moon will at first be limited by the high risk and cost, it is likely that unmanned logistic and experimental flights using the same large class of launch vehicles will also be made in the 1967–1975 time period. Experiments accompanying these flights can be of three kinds:

(1) Detailed investigations exploiting the *Ranger* and *Surveyor* results, and planned in direct support of the manned flights.

(2) Experiments requiring spacecraft performance greater than that of *Surveyor*.

(3) Development of technology and equipment to permit man to develop survival techniques on the Moon.

3. Types of Scientific Experiments

The early lunar spacecraft carry instruments selected to provide direct information on the chemical nature of the Moon's surface; pictures of surface detail in small segments of area with a resolution two orders of magnitude better than that which can be obtained from Earth; and the nature of any seismic activity on the Moon, and perhaps (if the seismic activity is sufficiently strong), information on the Moon's interior structure.

Chemical analysis. Chemical analysis will be accomplished with a gamma-ray spectrometer sensitive to gamma radiation from the decay of the natural radioactive substance, potassium 40. This gamma-ray instrument is the simplest of a long line of chemical analysis units which will be flown both to the surface and placed in orbit around the Moon. Gamma-radiation monitors are of great value on the Moon because of lack of atmosphere. Unattenuated rays from the surface can be received by an instrument far above the Moon. This means that such devices can be used in lunar orbiters and can measure the abundance of naturally occurring radioactive elements such as potassium 40, uranium, and thorium. It is possible that such techniques can be used to measure the radiation induced by the impact of solar radiation on the surface, and thus extend the analysis to those elements made radioactive by this solar excitation process.

Chemical analysis on the lunar surface can employ more direct techniques, such as X-ray fluorescence and gas chromatography. In all cases, the objective is to identify the relative abundance of elements and molecular species in lunar material for comparison with the material found in the crust of Earth and in meteorites. By such methods, it should be possible to reconstruct the history of the Moon's surface.

Compounds. In addition to the analysis of chemical elements, the presence and abundance of certain organic compounds should also be determined. X-ray diffraction equipment operating on the surface will yield information on the mineralogic structure of the surface material. This technique will permit a comparison between the mineral nature of the Moon and that of Earth and meteorites; it will be of great value in understanding the thermal history of the surface material which resulted in the formation of those minerals.

Organic molecules in the lunar surface material can be identified with instruments such as a gas chromatograph. We do not expect to find actual living organisms on the surface of the Moon. The absence of any atmosphere or liquid water would preclude (as far as we know) the development of any active life form there. Nevertheless, it is possible that certain organic molecules could be present.

Meteorites from disintegrated planets could land on the surface of the Moon and carry with them certain organic carbonaceous compounds and, once on the Moon, they would be free from the contamination to which they are subjected on Earth. Thus, analysis of lunar surface material for organic molecules might reveal those brought to the Moon by meteorites.

Photography. The vidicon telescopes carried on the *Ranger* spacecraft will begin the detailed visual examination of the lunar surface material. Optical observation from Earth is so poor that we could not see an óbject the size of a battleship with current techniques. The *Ranger* vidicon cameras will extend these limits of resolution, first down to the range of a few meters, and finally down to a few decimeters. Since the *Ranger* spacecraft fly an impact trajectory, only a few pictures of a limited area will be available at these high resolutions. Nevertheless, these pictures will probably contain new information on the structure of the lunar surface.

Lava flows should be identifiable, if they exist, as should the breccia resulting from the explosive impact of a meteorite on the surface. If the maria and filled craters are covered with a deep layer of dust, the pictures should show a uniformly smooth, grey surface. Resolutions down to the millimeter range or less would be required before we could be certain that this was a plain of dust and not rather small rocks.

The stationary soft-landers can provide detailed, highly magnified television photographs of the material around the landing site. The orbiting observatories can furnish photo reconnaissance maps similar to those obtained by aircraft flying over the surface of the Earth. This combination of vehicles can produce a detailed examination of a few square miles of the Moon, and then a continuing survey of other sections of the surface for comparison with the detailed examinations. By careful selection of the soft-landing sites, and by close correlation between the photographic observations from the satellite and those from the surface, we can progressively build up a detailed picture of the entire lunar surface.

Structural analysis. Analysis of the lunar structure, both near the surface and deep in the interior, is necessary to complete our understanding of the nature and history of the Moon. The seismometer carried on the first *Ranger* flights is intended to begin this analysis of the Moon's internal structure. Seismic studies of sound waves moving through the solid Earth have revealed not only the presence of a core and mantle but also such information as the presence of the Mohorovicic discontinuity between the mantle and crust, the variation of structures within the crust, the thickness of sediments deposited on the ocean floor, and the depth of ice over the continental mass of Antarctica. These sound waves may be generated naturally by earthquakes, or artificially by explosions set off by seismologists.

One of the first objectives of the seismic exploration of the Moon is to determine the intensity of natural lunar seismic activity. Eventually, artificial explosions can be set off on the Moon's surface for a thorough seismic exploration of the interior. Meanwhile, meteoritic impact is a source of seismic disturbance on the Moon which is absent on Earth. On the Moon, because of the lack of an atmosphere, a small meteorite impact would appear to a seismometer much like an artificial explosion, and could be used to serve a similar purpose. With the help of these "natural explosions," it would be possible to determine, for example, the average thickness of any surface material, such as a dust layer, between the point of the meteorite impact and the location of the seismometer.

Surface probing. Although seismic measurements will provide much information on the large-scale nature of the lunar structure, additional measurements are needed to define the physical characteristics of lunar material on a smaller scale. Thus, for example, it is important to know the bearing strength of the lunar surface, which might be quite low if, indeed, the surface is covered with non-compacted dust. Other characteristics of the surface material must also be measured, such as shear strength and reaction to impact. Such measurements would further our understanding of the nature of lunar material, provide a better picture of the forces which were involved in its origin, and indicate the crucial items of design information necessary before manned landing vehicles and support systems can be designed for operation on the Moon.

The thermal gradient near the surface will indicate the current internal thermal profile and will thus yield evidence on the Moon's internal thermal history. In order to establish this gradient accurately, it is estimated that temperature measurements at depths of several tens of meters will eventually be required, necessitating emplacement of temperature probes in drill holes in the surface. Other devices can be placed in the holes to measure the physical and chemical characteristics of material below the surface; e.g., hardness and density. Material extracted from the hole can be analyzed in the same manner that surface material is analyzed for its chemical and mineral nature.

Earth return. On-the-spot analysis of lunar material will be limited, of course, by the capabilities of the instruments which can be built to withstand rocket launching, coasting in space, landing on the Moon, and operation in the lunar environment. Although, with great ingenuity and the use of considerable payload weight, we could build extremely complex instruments for these tasks, it will in many cases be more efficient to return samples of lunar material to Earth for complete laboratory analysis. Thus, the lunar exploration program will involve sample return.

Detailed observations, both on the surface and in orbit around the Moon, will yield a series of increasingly accurate pictures of our original satellite. However, before our knowledge of the nature and structure of the Moon can approach that of the Earth, human explorers will have to make on-the-spot observations. For this reason, one of the primary objectives of the early phases of lunar exploration will be the gaining of knowledge necessary to enable human explorers to make efficient use of the limited time that they will be able to spend in the hostile lunar environment.

D. Missions

1. Initial Test Flights

General. The primary purpose of the first two *Ranger* flights was to develop certain basic elements of spacecraft technology required for lunar and interplanetary missions:

(a) Spacecraft environment control.

(b) Power.

(c) Attitude control.

(d) Communications.

(e) Instrumentation techniques.

(f) Data handling.

(g) Understanding and solving problems caused by system interactions of all listed elements.

Experiments on these elements of spacecraft technology demanded a weight of several hundred pounds accelerated to escape energy and guided precisely to the injection point. The *Atlas–Agena* B was selected as the first U.S. launch vehicle system expected to meet the requirements with reasonable reliability.

Scientific experiments were an integral part of the planned program. The designation of scientific objectives for each round forced the consideration of system interactions that would not otherwise be apparent, thereby aiding the development of equipment needed in the future. Scientific experiments were carried on a noninterference basis with respect to engineering measurements, but engineering development of scientific instrumentation was considered as important as other engineering development in the spacecraft.

It was decided to fire two simplified spacecraft having only the basic elements of structure, attitude control, power, and communications, plus certain scientific instruments. Following flights would incorporate a more elaborate spacecraft having the above elements with different instrumentation and with the addition of a trajectory error correction system and a lunar capsule.

Mission objectives. The mission objectives of the first two flights were identical: to test the basic features of a spacecraft whose design and operation are somewhat simplified relative to requirements for later missions. The chief simplifications were:

(a) No midcourse maneuver system.

(b) No lunar landing capsule or planet scanner.

(c) Fixed geocentric injection conditions and only moderate firing time constraints, resulting in a fairly wide spread of flight directions in space and no close approach to the Moon.

In addition to preparing for the lunar missions of flights 3 through 5, the first two *Rangers* were to make some tests related to the interplanetary objectives. Trajectories for flights 1 and 2 were selected to yield longer coasting times and greater communication ranges than those that normally occur in flights 3 through 5. Briefly, the objectives of *Rangers* 1 and 2 were:

(a) To test some basic elements of the spacecraft and the Deep Space Instrumentation Facility.

(b) To determine performance and to gain operating experience with the launch vehicles and associated systems.

(c) To test scientific measurement equipment and to measure phenomena of interest along the selected trajectories.

2. Lunar Rough-Landing Attempts

Ranger flights 3, 4, and 5 are planned as repeated attempts at one set of objectives:

(a) To collect gamma-ray data both in flight and in the vicinity of the Moon.

(b) To obtain photographs of the surface of the Moon.

(c) To transmit, after landing, lunar seismic data to the extent practical.

(d) To develop a trajectory error correction technique.

(e) To develop a terminal attitude maneuver technique.

(f) To continue development of basic spacecraft technology.

The spacecraft carries a gamma-ray spectrometer, a TV camera, and a rough-landing retro-capsule subsystem. The capsule is triggered by a radar altimeter (whose signal is telemetered to provide a measure of lunar reflection characteristics) and is launched from the spacecraft as the payload of a spin-stabilized solid rocket. Residual impact energy remaining after the deceleration is absorbed by a thick balsa wood cover on the survival sphere, which contains the seismometer and transmitter.

3. High-Resolution Approach Reconnaissance

General. The primary purpose of *Ranger* flights 6 and following is to obtain high-resolution lunar surface photographs during the terminal phase before impact, and to transmit them by a television subsystem to Earth. To meet this objective, it is intended to exploit the launch vehicle, spacecraft, and ground systems developed in the first five flights, together with a television subsystem using components developed for other programs.

Changes to the basic spacecraft bus will be minimized, as a design objective, relative to the 3, 4, 5 configuration, and the design shall not prohibit the substitution of a rough-landing capsule for the TV subsystem.

In addition to scientific exploitation of the television pictures, numerous other scientific experiments, selected to have a bearing on the problems of manned flights to the Moon, will be carried on a basis of non-interference with the basic TV mission. A radio ranging experiment will be incorporated on a similar basis in flights 8 and 9.

Mission objectives. Flights following *Ranger* 5 are planned as repeated attempts at a single main objective: the obtaining of television pictures of the lunar surface, with definition sufficient to aid in design of manned lunar vehicles, at a date early enough to be effective in that design, and preferably at locations on the Moon near the intended point of manned landing. Other experiments must not divert attention from this primary goal.

4. Scientific Stations

Mission objectives. The primary objectives of the lunar soft-landing missions (*Surveyor* A) are:

(a) To successfully accomplish the soft landing of a number of scientific measurement payloads on the lunar surface, using the *Atlas–Centaur* launch vehicle or its equivalent.

(b) To provide for a minimum of 30 days (90 desired) of scientific observations and measurements on the lunar surface with a modest quantity of reliable and sensitive scientific instruments.

(c) To telemeter the scientific and engineering data to Earth for retrieval, reduction, and timely dissemination to the engineering and scientific communities.

It is intended that these missions achieve and demonstrate general reliability of mission and project-objective accomplishment in excess of 50%.

Scientific objectives. The scientific objectives of the *Surveyor* A missions are to measure the physical properties of the Moon and to analyze the composition of the lunar surface and subsurface in various selected maria regions visible from Earth. The scientific measuring instruments are intended to provide data that will aid in establishing a better understanding of the internal structure and composition of the Moon and its local environment, and to obtain additional data that may assist in determining the origin of the Moon and in understanding the physical phenomena associated with the history of the solar system.

Engineering objectives. Additional objectives of the *Surveyor* A missions are to contribute to the technology required for the successful accomplishment of eventual manned lunar landings and operations, to demonstrate the engineering feasibility of lunar exploration with automated, soft-landing spacecraft systems, and to evaluate the performance of the subsystems in the cislunar environment and during the landing phase.

5. Reconnaissance Orbiter

The lunar orbiter missions (referred to as *Surveyor* B) will seek to obtain information about the Moon which the soft-landing *Surveyor* A cannot provide, and to furnish direct support for the manned lunar-landing operations.

Immediate objectives involve the development of precise lunar orbiting capability; providing an oriented space platform for lunar reconnaissance and mapping; and preliminary site selection in limited and accessible areas of the front face of the Moon for *Surveyor* and, ultimately, manned landings. In addition, the lunar space station will investigate and monitor the lunar radiation environment and other physical parameters, and make selenodetic studies of the size and shape of the Moon and the properties of its gravitational field.

Further objectives are the addition of ancillary instrumentation to equip the lunar satellite as a radio relay station for surface-to-surface communication over the lunar horizon, for communication between the far side of the Moon and Earth, and as a reference for lunar surface navigation.

6. Logistic Support Craft for Manned Lunar Program

The mission objectives of the logistic support craft for the manned lunar exploration program are to provide a lunar soft-landing spacecraft capable of:

(a) Reliable and accurate soft landings on the lunar surface with a variety of payloads.

(b) Short response time to mission requirements.

(c) Relatively inexpensive transportation to the Moon.

(d) Making special required measurements in support of the manned program, which cannot be made with the *Surveyor* spacecraft.

II. Lunar Program Plans

A. Over-all Plans

In further exploitation of the *Ranger* and *Surveyor* vehicle designs in the lunar exploration program, we should concentrate on determining the environmental conditions on the Moon as they will affect the manned flight program. Any later, more advanced spacecraft systems (launched by the larger vehicles) must put first emphasis on developing the technology of travel to, on, and from the Moon, using methods which can be applied in the manned program. Logistic and real-time support for the manned activities on the Moon are also prime requirements. Assuming a relatively successful *Surveyor* Project, the later projects are to have as a secondary objective the further determination of the lunar environment in support of the needs of the manned program.

The specific design for the large spacecraft bus and its various payloads is closely associated with the launch vehicle size, the vehicle availability schedule, and the relative importance of developing and verifying certain key technological features for the manned program.

B. Phasing Schedule

1. Introduction

One of the first and most important tasks in implementing a Program Management and Control System is the establishment and subsequent verification of schedule milestones by levels of responsibility. In order to facilitate assignment of schedule milestones and to obtain uniformity of effort, the Lunar Program Office has designated levels as shown in Figs. 1 and 2, and in the table.

The JPL organization and the nature of the effort to be controlled lend themselves to a level structure that was incorporated earlier in some Navy and Air Force programs. At each level, the responsible organization has the requirement for establishing schedule milestones to support the requirements imposed by the next higher level of authority.

2. Levels of Responsibility

The levels of responsibility are established as follows:

Level	Responsibility	Effort
0	NASA	Total space systems
1	NASA Program Manager	A specific space system program
2	JPL Lunar Program Director	Summary, total JPL Lunar Program
3	Project Manager	Integration of system tasks. (Example: All *Ranger* Project Systems)
4	System Manager (or major subcontractor)	Integration of all major elements (or subsystems) of a particular system, such as *Ranger* RA-1
5	Division Chief (or Manager)	Integration of all components of a major element (or subsystem). (Example: TV subsystem, solar panels, spacecraft assembly).

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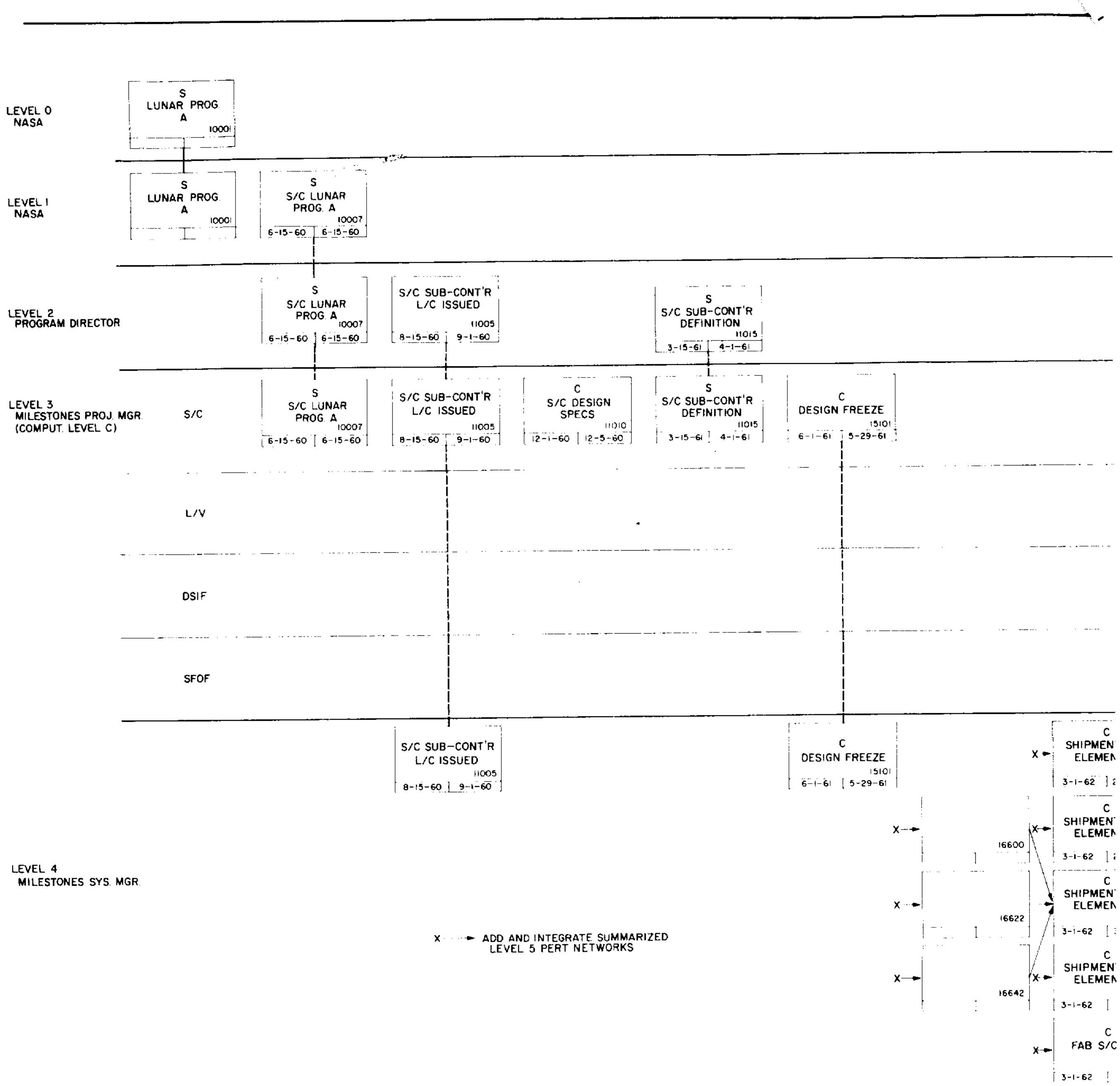
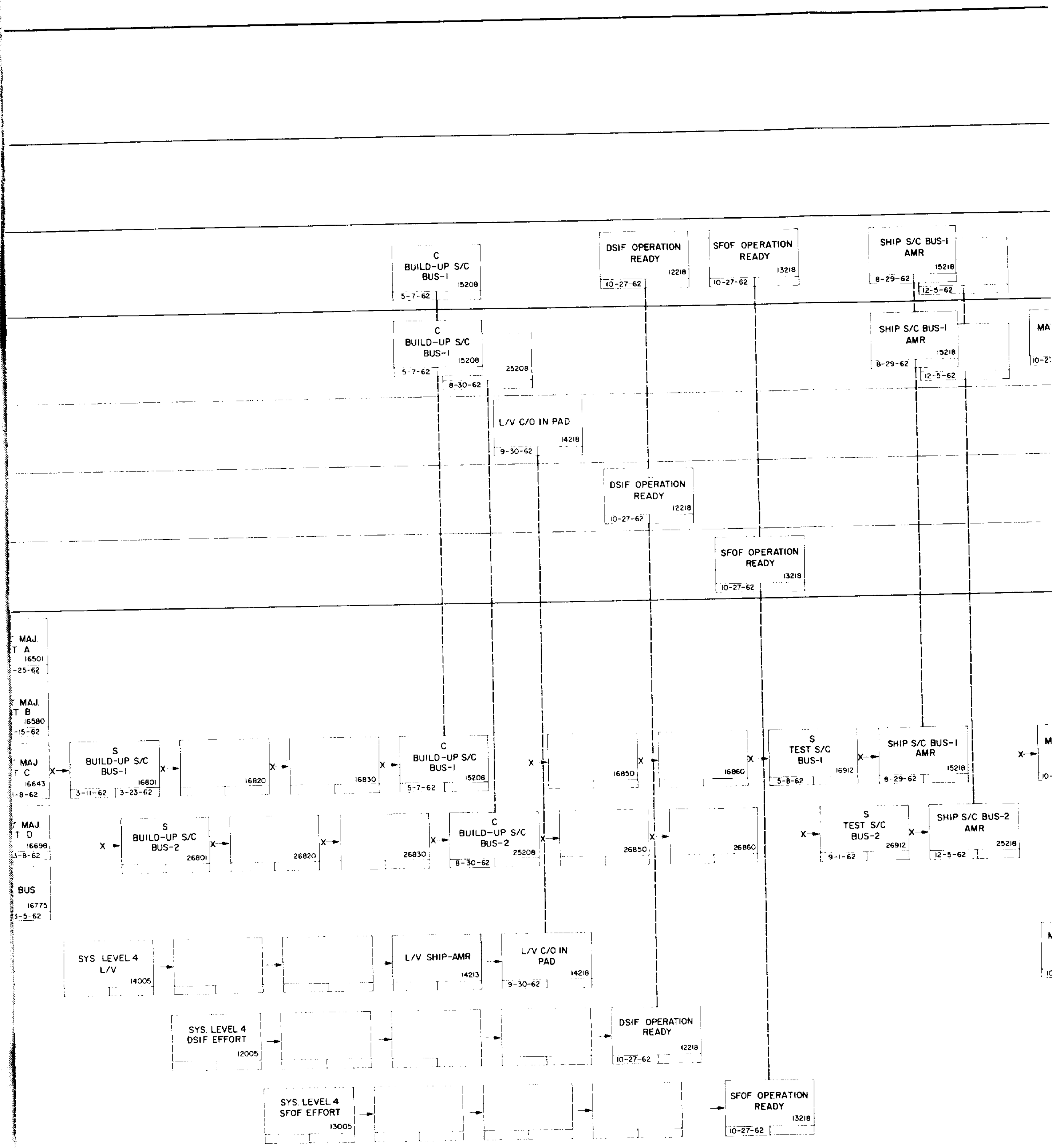


LEVEL 0
NASA
S
LUNAR PROG.
A
10001
LEVEL 1
NASA
S
LUNAR PROG.
A
10001
S
S/C LUNAR
PROG. A
10007
6-15-60
6-15-60
LEVEL 2
PROGRAM DIRECTOR
S
S/C LUNAR
PROG. A
10007
6-15-60
6-15-60
S/C SUB-CONT'R
L/C ISSUED
11005
8-15-60
9-1-60
S
S/C SUB-CONT'R
DEFINITION
11015
3-15-61
4-1-61
LEVEL 3
MILESTONES PROJ. MGR.
(COMPUT. LEVEL C)
S/C
S
S/C LUNAR
PROG. A
10007
6-15-60
6-15-60
S/C SUB-CONT'R
L/C ISSUED
11005
8-15-60
9-1-60
C
S/C DESIGN
SPECS
11010
12-1-60
12-5-60
S
S/C SUB-CONT'R
DEFINITION
11015
3-15-61
4-1-61
C
DESIGN FREEZE
15101
6-1-61
5-29-61
L/V
DSIF
SFOF
S/C SUB-CONT'R
L/C ISSUED
11005
8-15-60
9-1-60
C
DESIGN FREEZE
15101
6-1-61
5-29-61
C
SHIPMEN
ELEMEN
3-1-62
16600
16622
16642
C
FAB S/C
3-1-62
LEVEL 4
MILESTONES SYS. MGR.
X → ADD AND INTEGRATE SUMMARIZED
LEVEL 5 PERT NETWORKS



C BUILD-UP S/C BUS-1 15208 5-7-62
DSIF OPERATION READY 12218 10-27-62
SFOF OPERATION READY 13218 10-27-62
SHIP S/C BUS-1 AMR 15218 8-29-62
12-5-62
C BUILD-UP S/C BUS-1 15208 5-7-62
25208 8-30-62
SHIP S/C BUS-1 AMR 15218 8-29-62
12-5-62
MA
10-2
L/V C/O IN PAD 14218 9-30-62
DSIF OPERATION READY 12218 10-27-62
SFOF OPERATION READY 13218 10-27-62
MAJ. T A 16501 -25-62
MAJ. T B 16580 -15-62
MAJ. T C 16643 -8-62
MAJ. T D 16698 3-8-62
BUS 16775 5-5-62
S BUILD-UP S/C BUS-1 16801 3-11-62 3-23-62
16820
16830
C BUILD-UP S/C BUS-1 15208 5-7-62
16850
16860
S TEST S/C BUS-1 16912 5-8-62
SHIP S/C BUS-1 AMR 15218 8-29-62
S BUILD-UP S/C BUS-2 26801
26820
26830
C BUILD-UP S/C BUS-2 25208 8-30-62
26850
26860
S TEST S/C BUS-2 26912 9-1-62
SHIP S/C BUS-2 AMR 25218 12-5-62
SYS LEVEL 4 L/V 14005
L/V SHIP-AMR 14213
L/V C/O IN PAD 14218 9-30-62
SYS. LEVEL 4 DSIF EFFORT 12005
DSIF OPERATION READY 12218 10-27-62
SYS. LEVEL 4 SFOF EFFORT 13005
SFOF OPERATION READY 13218 10-27-62

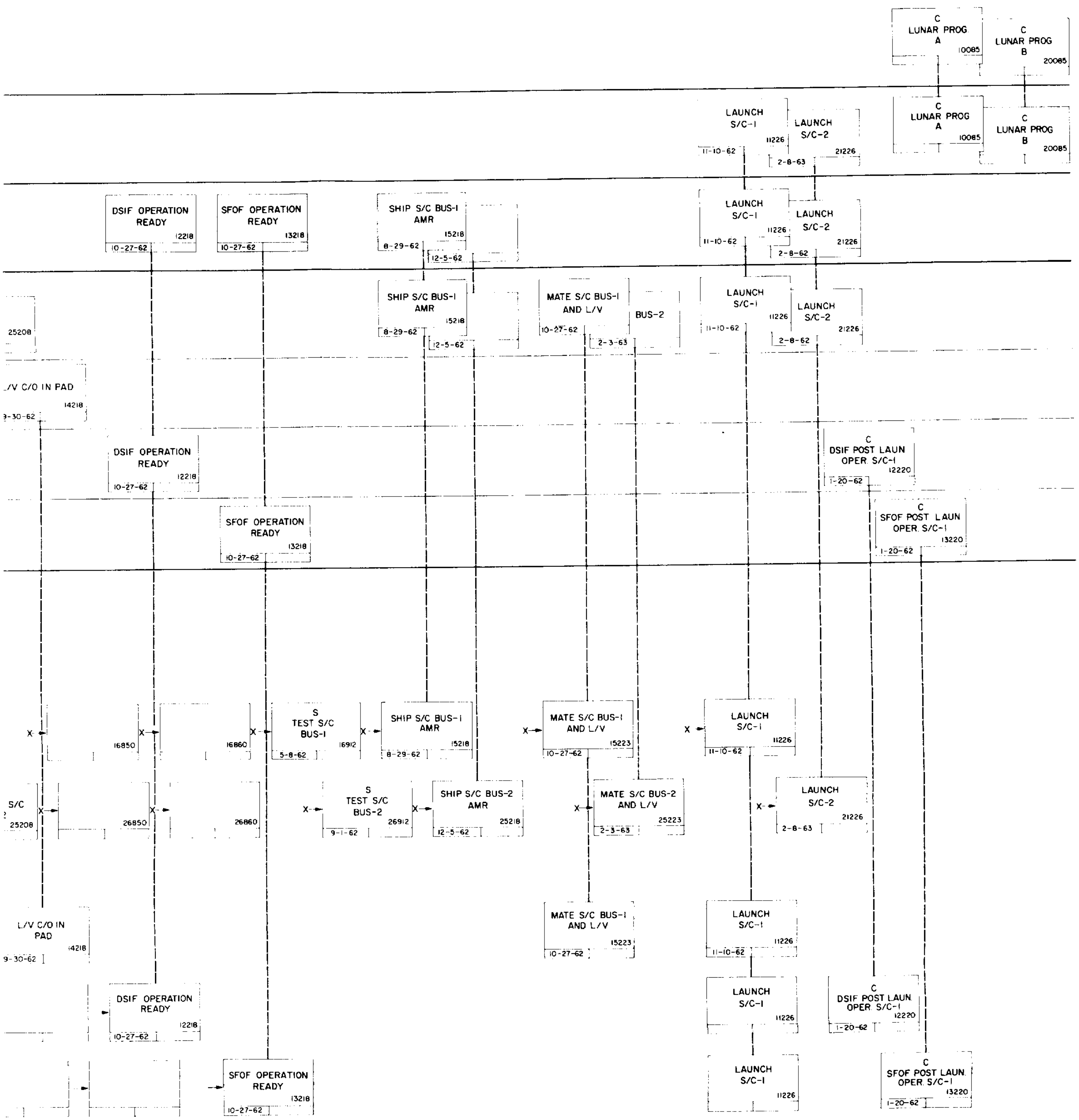


Fig. 1. Lunar Program Levels 1–4 for scheduling, PERT, and control

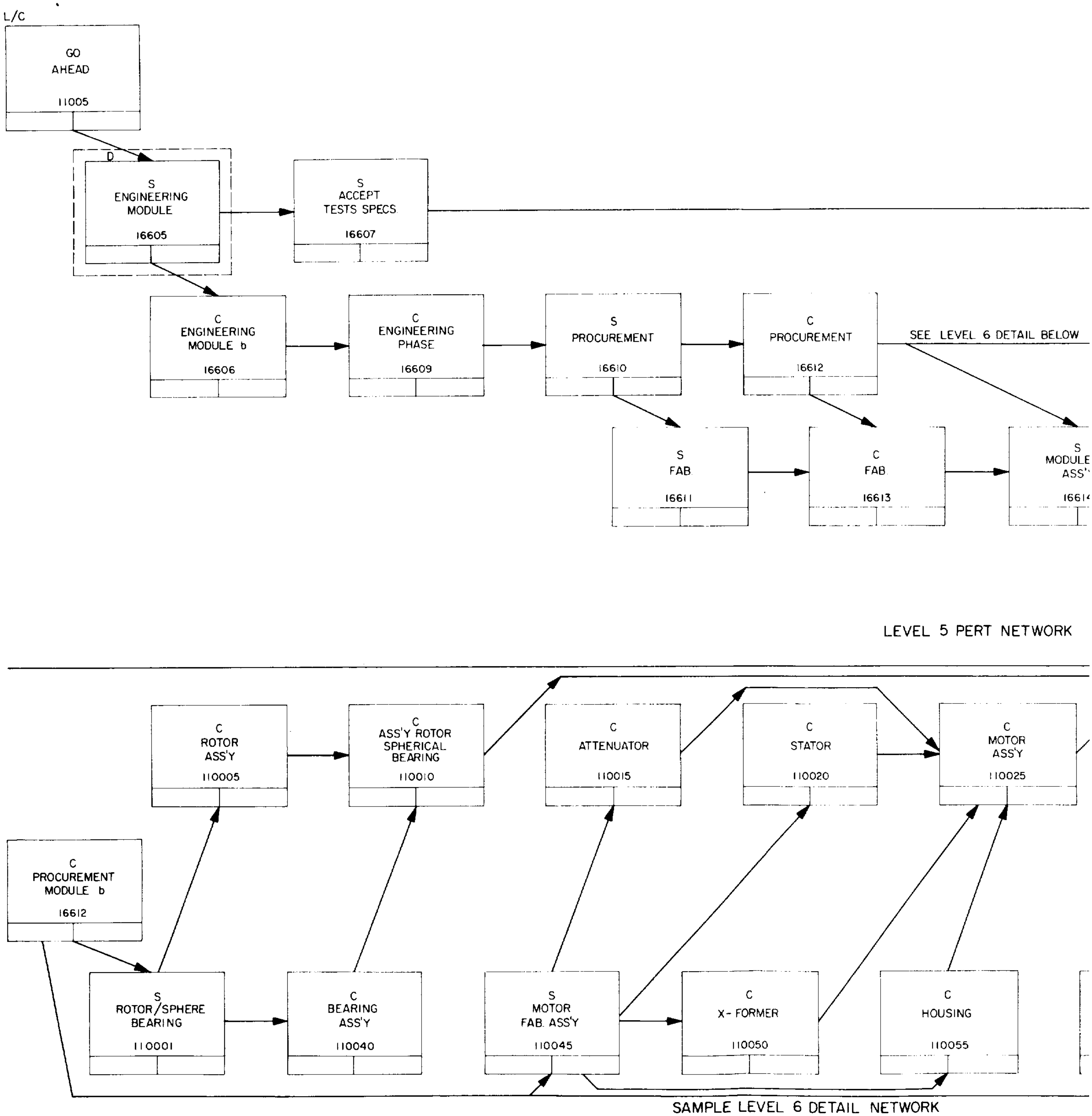
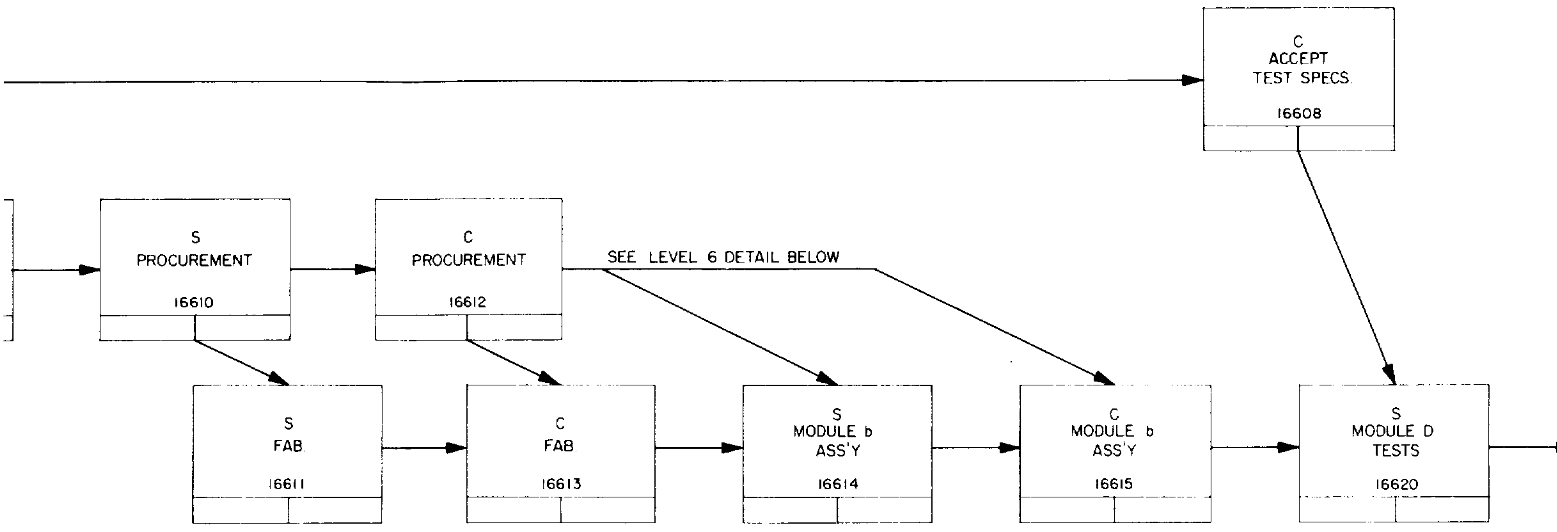
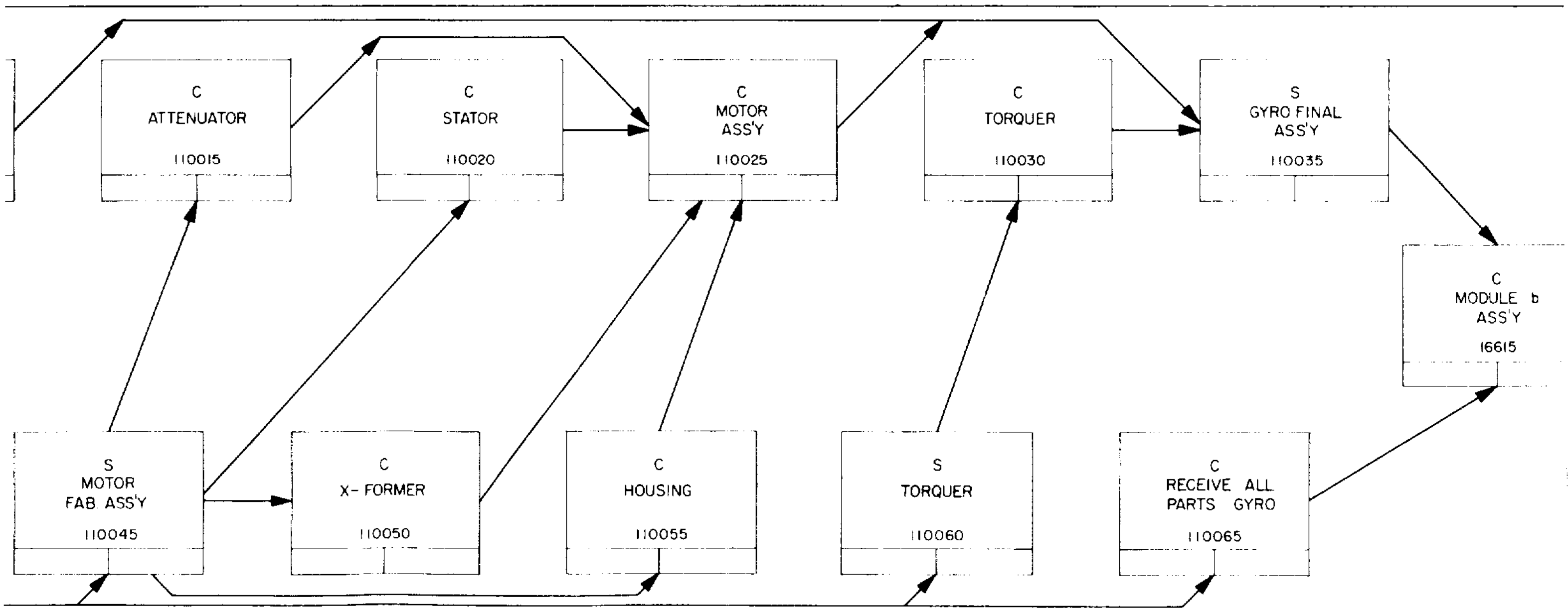


Fig. 2. Lunar Program Levels 5–6 for scheduling, PERT, and control

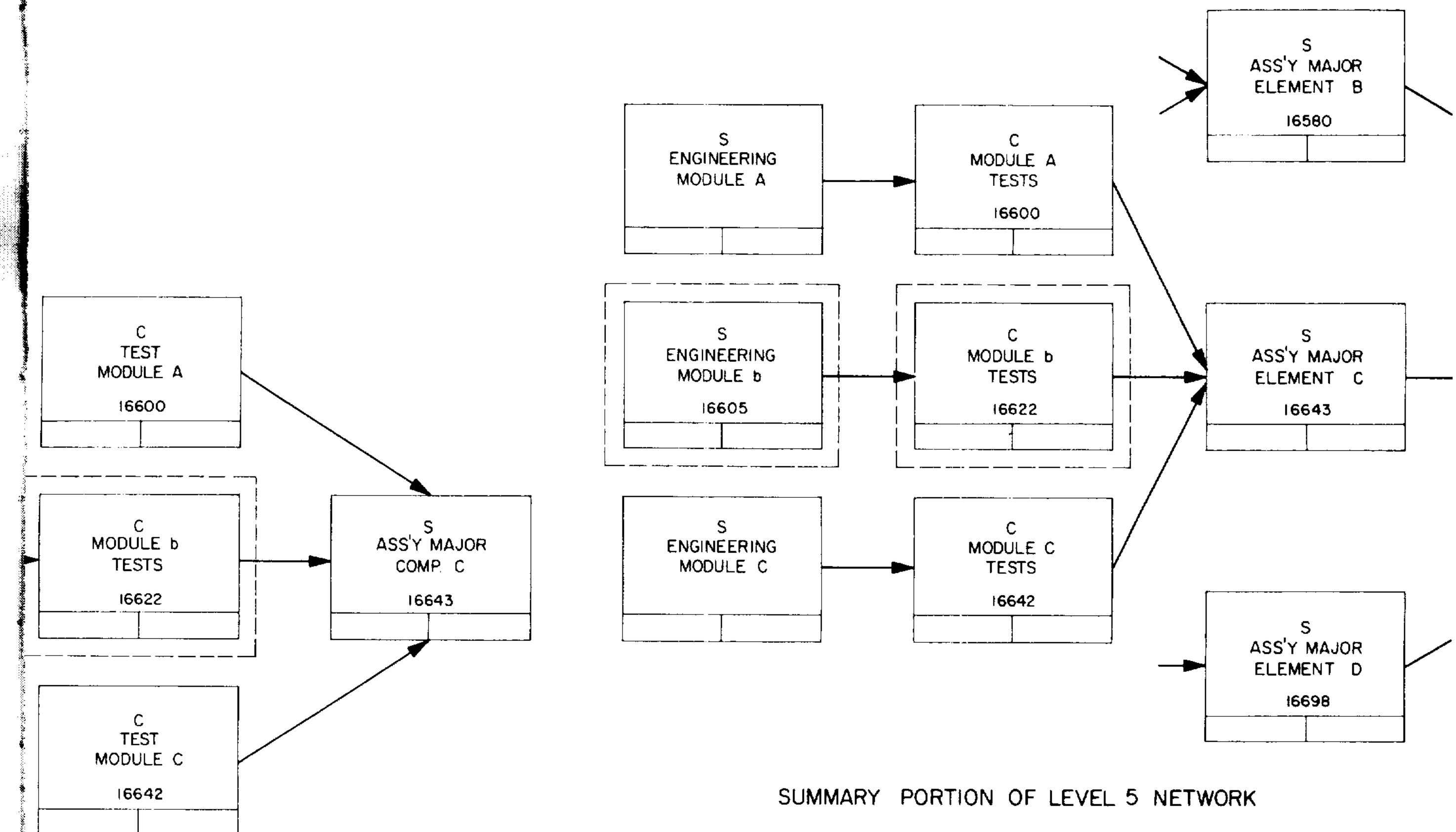


LEVEL 5 PERT NETWORK



SAMPLE LEVEL 6 DETAIL NETWORK

ontrol



SUMMARY PORTION OF LEVEL 5 NETWORK

3. *Milestones*

Milestones to be used for schedules, PERT networks, control, and reporting are established in the following sequence: (1) Level 1 milestones are for the specific space system; (2) Level 2 milestones are established to support the requirements directed by the Level 1 milestones; (3) in turn, Level 3 milestones support Level 2 requirements; and so forth.

4. *Schedule Responsibility*

The schedule responsibility is compatible with the level responsibility and is also shown in Figs. 1 and 2. Schedules are to be prepared using the milestones for those levels. The milestones for the second level will be established to support the milestone requirements previously established at the first level.

The schedule responsibilities follow:

a. Program Requirements (Level 1). NASA establishes the program requirements and Level 1 (Tier 1) milestones.

b. Lunar Program Planning Schedule (Level 2). This schedule shows the start and the completion of the four systems (spacecraft, launch vehicle, DSIF, and SFOF), and the scheduled launch dates for all the missions of the Lunar Projects. It is maintained by the Lunar Program Office and is integrated with the Planetary Program into the JPL Planning Schedule. Any revision requires approval of the Lunar Program Director.

c. Project Office Schedules (Level 3).
Project mission control schedule. This schedule is comprised of the major milestones of the Project. It is a summary of the Systems Division schedules.

Mission phase schedule. A mission schedule is issued and maintained by the Project Office; it depicts the major phases by system for each mission. For the spacecraft, these phases will include but will not be limited to:

(a) Design Specification publication.

(b) Sub-contract award.

(c) Design freeze.

(d) Start and complete assembly of each spacecraft.

(e) Start and complete test of each spacecraft.

(f) Final mating of spacecraft and launch vehicle.

(g) Launch of each spacecraft.

The Project Schedules are prepared and maintained by the Project Office. The Project Manager's approval is necessary for issue and for all changes.

d. Systems Division (or major sub-contractor) Schedules (Level 4). The Systems Division schedules, detailed to the level necessary for effective control, are prepared to support the mission phase schedule established by the Project level schedules. The Level 4 schedules are issued and maintained by the Systems Division. The format of these schedules is the prerogative of the Systems Division, but must be compatible with the Project Office Schedules and approved by the Project Management.

The Systems Division establishes need dates for all major elements required for its specific system. This system schedule must depict the integration of all major elements (an integrated PERT network described later will be prepared and maintained at this level). Any revision of schedule-need dates for a particular system element requires the approval of the System Management Office.

e. Division Chief (or major element supplier) Schedules (Level 5). The Level 5 schedules, detailed to the level necessary to assure delivery of a major element at the specified need date (established at Level 4), are prepared, issued, and maintained by the division or major supplier. It is the requirement of Level 5 management to establish schedule dates (Level 5 milestones) for major elements in such events as the following:

(1) Start and complete engineering.

(2) Start and complete fabrication.

(3) Need dates for the components required in the major element.

(4) Start and complete assembly.

(5) Start tests, not complete.

(6) Complete acceptance tests.

5. *PERT Networking*

Using the merging milestone technique described above, the establishment of different program level PERT networks can be eliminated, provided that the fundamental characteristics of PERT are followed.

During the course of rapid growth of the PERT system in the military, NASA, and industry, many PERT

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fallacies have developed. Three of these which must *not* be permitted to enter the JPL Lunar Program planning are:

(a) That the summarization of the over-all project, or program, can be accomplished through the development of different-level PERT networks.

(b) That the computer should be used only for PERT calculation.

(c) That PERT networking and analysis reporting format cannot be standardized.

This first problem (a) is described by Y. Nakayama, Head, Program Office, Management Plans, Bureau of Naval Weapons, in a paper delivered October 25, 1961, in which he says:

"One of the major obstacles to program summarization of PERT data is the concept, which has somehow developed, that PERT network must have only one end objective event. This concept may have developed because the original computer program available to industry accepted only one end point. This has been interpreted as a basis for progressive program levels of PERT network into which sub-networks feed.

"A PERT network, however, is more likely to have multiple end points. For example, a missile PERT network will have flight-test events as end objectives for missile components as well as for delivery of prototype as milestones. It is true that a network can be drawn but not a PERT network. These milestones would be time-sequenced rather than dependency-sequenced, which is the fundamental characteristic of PERT networks.

"PERT networks exist only at the sub-component or the bottom tier level. It is only through merging of the sub-component networks for the selected milestones that the outlook for the different program levels can be provided."

Note in Figs. 1 and 2 that, in the JPL Lunar Program, PERT networks exist at the subassembly (Level 5) and are merged into the Level 4 milestones. The integration of the Level 5 PERT networks is the responsibility of each System Manager.

The second fallacy is the emphasis on the use of the computer for calculation only. This has deterred the development and use of the graphic capability of the computer for effective and instantaneous management communication of PERT data. The JPL computer program incorporates more imaginative use of the computer and such outputs as a graphic analysis output report (Fig. 3). It can be seen that the milestones for all levels can be verified, monitored, and controlled by PERTing because the milestones are integral events in the PERT net. Because these milestones can be extracted by the computer, there is no requirement to prepare a Project-level or higher PERTing net. A graphic display of the Project, Level 3 milestones, is a necessary management tool and may be prepared as shown in Fig. 1 (Level 3), a bar chart (Fig. 4), or other useful graphic methods. To be meaningful scheduling, PERT networking, and reports must incorporate or be anchored to merging milestones.

6. Integrated Summary Networks

The Project Manager at Level 3 may find it desirable, even necessary, to summarize and integrate the various system PERT networks prepared and maintained at Level 4. A network of this type is time-sequenced rather than dependency-sequenced, as in PERT.

In summarizing any network, only events, probably milestones, existing in the PERT net can be used. Creation of "dummy," fictitious events is not acceptable since it will present information that is not meaningful.

7. Slip Charts

Slip charts (Fig. 4) can be prepared either from information derived from the computer output or from actual history. The chart presents a compact record of the project from start to finish. A presentation of this sort can be used in other ways; i.e., as an aid in keeping track of the behavior of critical events on a PERT network. At JPL, the slip chart is believed to be a useful tool that could well be applied more widely than at present.

C. Organization

The objectives and plans of the JPL Lunar Program required the development of organizational policies and procedures predicated upon a basic Laboratory policy to carry out JPL responsibilities to develop and build spacecraft for lunar exploration through major prime systems contractors, while retaining ultimate responsibility for the over-all mission at JPL, and employing a minimum of Laboratory manpower.

GRAPHIC ANALYSIS OUTPUT REPORT

EVENT NO.	NOMENCLATURE	DATE
10007 A	START LUNAR PROGRAM A S/C	6-15-60 6-15-60 6-15-60
11005 B	S/C SUB-CONTRACTOR L/C ISSUED	8-15-60 9-1-60 9-1-60
15101 C	S/C 1 DESIGN FREEZE	6-1-61 5-29-61 6-1-61
16801 D	S/C 1 START S/C BUILD UP	3-11-62 3-23-62 3-25-62
15208 C	S/C 1 COMPLETE S/C BUILD UP	5-7-62 5-15-62 6-5-62
15218 B	S/C 1 SHIP S/C TO AMR	8-29-62 8-15-62 9-4-62
12218 C	COMPLETE DSIF OPERATION READINESS	10-27-62 10-27-62 10-27-62
13218 C	COMPLETE SFOF OPERATION READINESS	10-27-62 10-27-62 10-27-62
15223 C	COMPLETE FINAL MATING S/C 1 AND LAUNCH VEHICLE	10-22-62 10-26-62 10-27-62
11226 A	LAUNCH S/C 1	11-10-62 11-10-62 11-10-62
25208 C	S/C 2 COMPLETE BUILD UP OF S/C	8-30-62 8-15-62 8-30-62
21226 A	S/C 2 LAUNCH	2-8-63 2-10-63 2-12-63

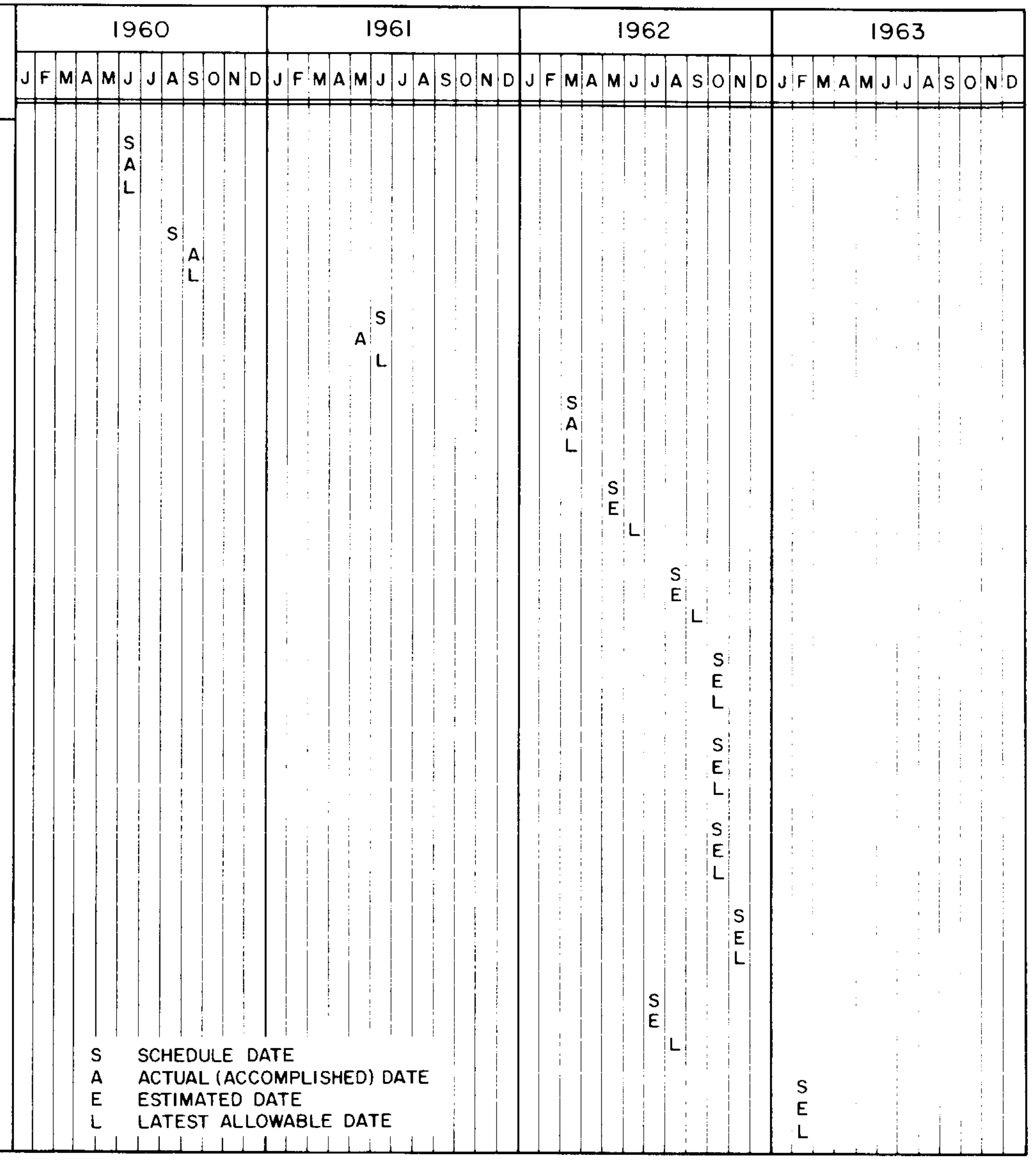

Fig. 3. Lunar Program levels for scheduling, PERT, and control (hypothetical case)

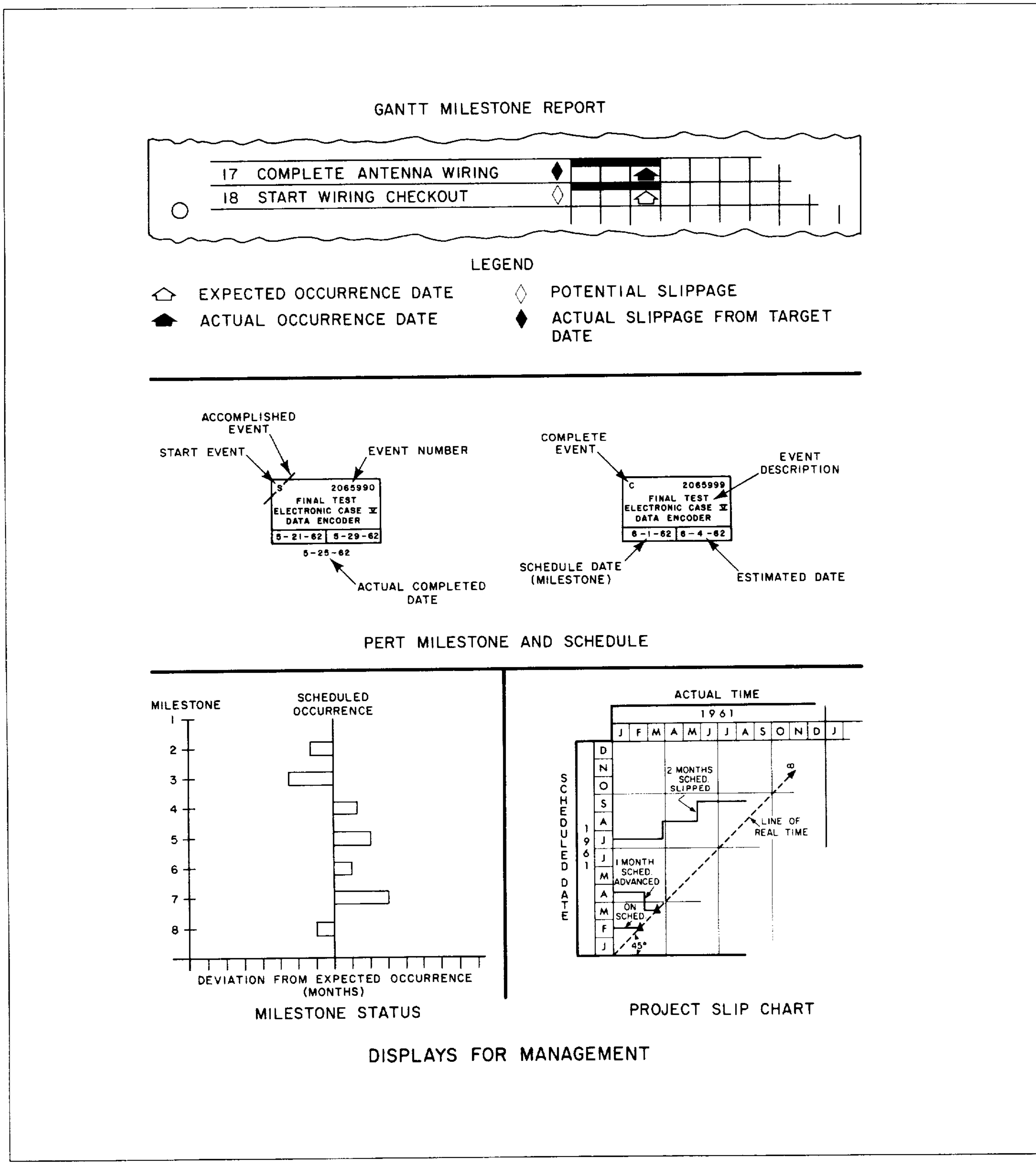

Fig. 4. Proposed computer outputs for top management displays

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This philosophy was embodied in Technical Memorandum 33-32, "Lunar Program Operating Policy, Organization and Functions." This document also included a description of the Lunar Program staff, the functions of the staff members, and their organizational relationship to each other (Fig. 5). Later, this document was revised to reflect a strengthening of the project scheduling, control, and status evaluation functions.

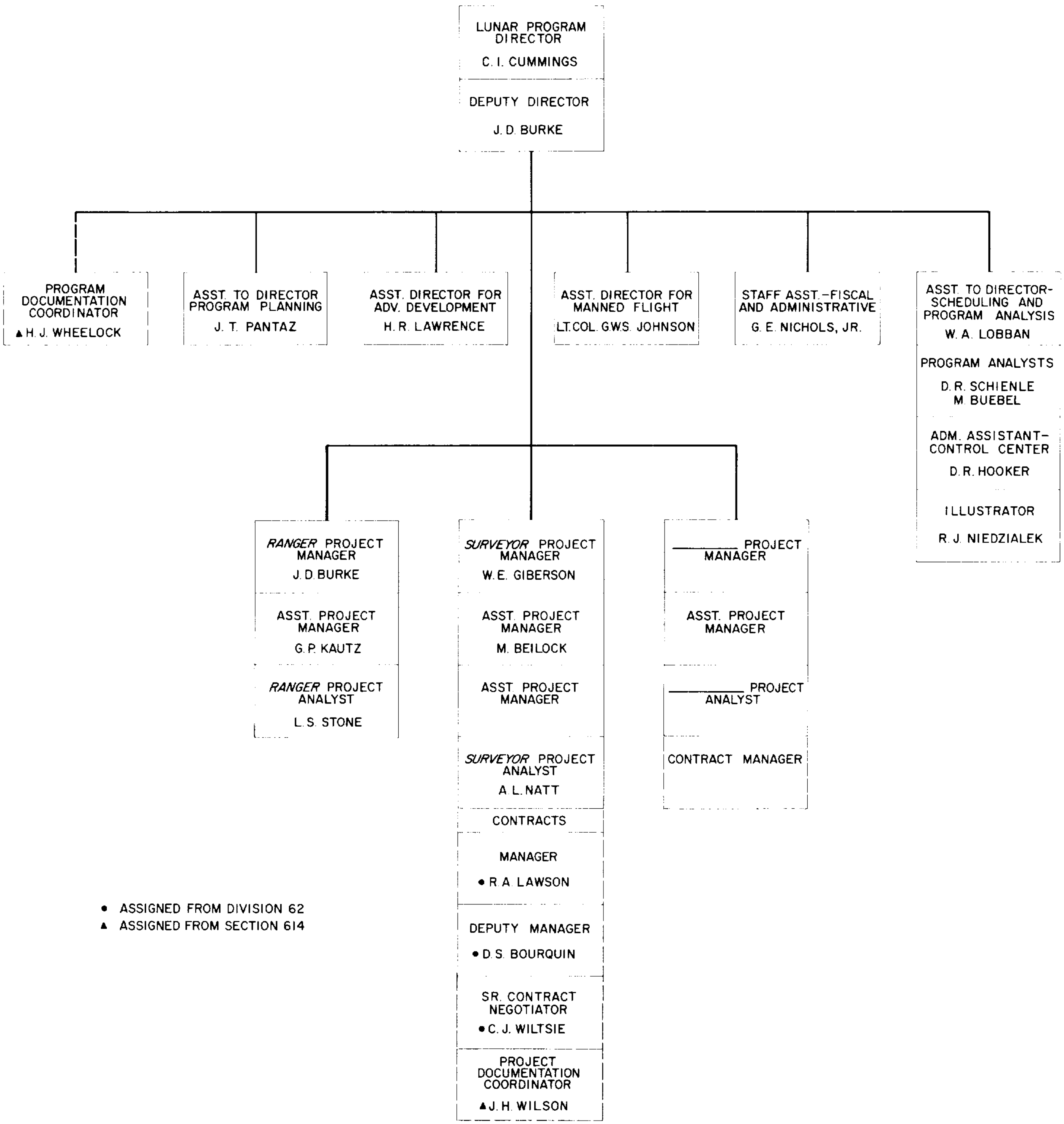

Fig. 5. Lunar Program staff organization

D. Funding

Funding and resource allocation are important factors in implementing Lunar Program objectives and plans. Within the JPL organization, questions involving manpower and facilities are the primary concern of the Laboratory Director and divisional management. However, the Lunar Program Director is responsible for the funds required in support of the various projects constituting the lunar exploration program. Given this responsibility, the various Project Managers are obliged to translate plans into funding requirements, issue budget guidelines, authorize fiscal-year allocations, review expenditures versus progress, reprogram within project totals when necessary, and promote procedures to assure prompt reporting and control data availability.

In projects like *Ranger*, where much of the effort is expended at JPL, this funding control can be implemented through existing Laboratory procedures. For example, long-range planning for future fiscal years helps shape the funding allocation which NASA stipulates for the next fiscal-year period. This allocation, in turn, provides part of the background against which the JPL divisions are requested to detail their funding requirements.

These requirements, after negotiation between the Project Office and the respective divisions, are published in an Operating Plan, which becomes the basis for job number allocations and fiscal control during the year. Monthly budget performance reports for each job which reflect expenditures and commitments in terms of labor, material, sub-contracts, travel, and other costs are furnished within 20 days after the close of the month. In addition, "flash" reports of total project monthly expenditures are reported at the close of the month. This information is presented in graphic display so that project management keeps aware in a timely manner of the gross fiscal status. Any problem areas that appear in the gross scheme are analyzed in detail with the divisions and action is initiated to keep the project within fiscal-year funding bounds.

In the case of projects like *Surveyor*, where substantial effort is accomplished by an outside contractor, more reliance must be placed in contractual implementation of plans, formalized technical and resources review, and mutual adoption of reporting media which realistically represent the contractor's progress, mesh satisfactorily with the contractor's existing reporting mechanism, but which assure project management of the tools which are necessary to make re-programming decisions or resource allocations for the benefit of the over-all project. To this end, new fiscal control schemes are being explored to better mate technical progress to expenditures and commitments. Also, emphasis will be placed on faster reporting, regular management reviews of all facets of project status, including funding, and rapid reprogramming to provide optimum utilization of available resources.

E. Criteria

1. Design

Spacecraft design criteria basically reflect the general project design objectives, the competing characteristics, the defined characteristics, and the experimental philosophy affecting the design techniques.

General design criteria. The general design criteria will vary, depending on the systems state of the art and the past performance of the spacecraft. Availability of "off-the-shelf" hardware components will also influence these criteria, as will the type of launch vehicle and the relative complexity and sophistication of the required engineering and scientific experiments and instrumentation. Attempts will be made to restrain the mission demands to a level below the most complicated that can be proposed at a given date in the belief that such restraints are the only way to achieve useful reliability.

Competing characteristics. The competing characteristics will normally designate reliability as the highest-priority item. Other competing characteristics to be considered for a spacecraft system design are:

(a) Mutual compatibility of subsystems.

(b) Schedule.

(c) Contribution to techniques for follow-on programs.

(d) Operational simplicity.

(e) Cost in funding, manpower, other resources.

Defined characteristics. The defined characteristics include weight allocation, test and sterilization requirements, and the Deep Space Instrumentation Facility restrictions. The experimental philosophy affecting design should consider such conditions as environmental control prior to final mating with the vehicle on the launch pad, operating conditions at launch, in-flight failure detection, and functioning after in-flight failure.

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2. Environmental Testing

The need for highly reliable spacecraft requires the development and design-verification testing of flight hardware in a well-planned testing program and in accurate environmental testing facilities. The major testing categories used on this program may be divided as follows:

Test type	System level
Developmental	Component, assembly, subsystem, system
Type approval	Assembly, subsystem, system
Flight acceptance	Assembly, system

The environmental conditions which are to be simulated include the following:

(a) In-flight dynamic environments, using vibration exciters, shock testers, centrifuges, vacuum chambers, and acoustic test chambers.

(b) Storage and transportation environments, using climatic test chambers and vacuum temperature test chambers.

(c) Spatial environments, using space simulators and vacuum temperature test chambers.

(d) Sterilization techniques environments, using temperature chambers and gas sterilization equipment.

(e) Explosive atmosphere, using an explosive atmosphere test chamber.

Equipment for performing tests with these environments is in existence at JPL; however, deficiencies exist in some environments.

Because of the extensive firing schedule for the Lunar Program, the in-house testing load in the five listed environments will be heavy. Consultation and advice to contractors on JPL testing methods and philosophy will be needed for the contracted portions of the program. The amount of JPL testing support to the contractors cannot be determined readily, but it is likely that some may be required in spatial environment simulation.

The emphasis in this program should concentrate on applying the testing efforts early, at the assembly and subsystem levels, and to introduce the appropriate fixes at these levels to reduce the number of failures and problems occurring at the system level.

3. Assembly and Checkout

a. Test Philosophy.

General. It is imperative that JPL develop consistent methods for demonstrating spacecraft performance as a normal step of the developmental effort, and to ensure mission success. Preference is given to designs that can be analyzed, and testing is resorted to primarily for confirming analysis or resolving system interactions. When subsystem qualification tests are the only method of determining readiness for assembly and flight, the design must, of course, incorporate the necessary test provisions. In general, however, *the objective is to achieve reliability by design rather than by testing.*

Types of tests. The test scheme, projecting the above test philosophy, comprises two basic kinds of tests: type-approval and acceptance. Those acceptance tests which apply to flight articles are flight-acceptance tests; those acceptance tests which apply to nonflight articles, such as GSE, are use-acceptance tests. All flight article subsystem assemblies of the spacecraft, the completely assembled flight spacecraft, and GSE are subjected to acceptance tests only. Prototype models of subsystem assemblies of the spacecraft, as well as a proof test model (PTM) spacecraft, are subjected to type-approval tests.

Test operations. Each flight article is certified for use at the Spacecraft Assembly Facility before being assembled into the spacecraft. This certification is the verification by the cognizant division that its assembly has satisfactorily passed division tests, including type-approval tests of a prototype of the flight article. Analogous procedures will be required when the spacecraft are assembled by a contractor.

Environmental tests. Environmental testing establishes the adequacy of the spacecraft design for operation in the expected environments. The testing is limited to those environments most likely to produce system interaction (i.e., r-f radiation, vibration, or to influence spacecraft temperature adversely).

Space simulator tests. The space simulator tests verify the spacecraft thermal design. Telemetry calibrations are performed utilizing the space environment to observe the operation of the telemetry circuits when a given stimulus is applied to the telemetry system at different spacecraft temperatures.

Vibration tests. Vibration tests of the complete spacecraft verify the ability of the vehicle to perform the

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required operations while subjected to vibration in excess of that produced during launch. A secondary objective is to determine the nature and magnitude of the structural interactions.

Dummy-run tests. Dummy runs simulating operations to be performed during the preflight countdown and through the injection phase of flight are conducted at JPL. These tests evaluate the spacecraft in relation to the launch complex environment, compatibility with the shroud, compatibility with blockhouse and launch complex equipment, effectiveness of test techniques, and verification of the countdown procedures.

Final JPL-Pasadena system test. Upon completion of the dummy-run test, all required subsystem component changes are made. The spacecraft is then commanded through a complete operational sequence from launch countdown through lunar encounter, with monitoring through direct-access electrical connections.

At AMR, the spacecraft is reassembled along with the System Test Complex. The AMR test operations are similar to those conducted in the SAF, except that now the primary objective is to assure flight readiness and compatibility with the launch environment.

4. Sterilization

In conducting the scientific investigation of the lunar surface and substrate by means of landing spacecraft, it is essential that sufficient sterilization and decontamination procedures be employed to preserve the Moon as a possible source of information on the origins of the solar system and of organic life.

Terrestrial organisms would not be expected to survive on or near the lunar surface because of the high temperature and intense ultraviolet radiation known to exist there. However, organisms which were embedded beneath a layer of the lunar crust might be protected well enough to survive in a dormant state for long periods of time. The chief danger is the possibility that contamination might later be detected and mistaken for extraterrestrial life. On this basis, most reputable biologists agree that risks to scientific exploration would not be dangerously high if minimal contamination were confined to small areas of the Moon's surface wherein the probability of subsequent detection would be negligible.

Nevertheless, strict requirements for the decontamination of lunar spacecraft are important for the side benefits. The information and experience obtained from the lunar sterilization program will be of utmost value in the establishment of techniques for later planetary missions. Since the sterilization methods to be employed on planetary spacecraft must be extremely efficient and of the highest reliability, it is doubtful that the planetary objectives could be achieved within the desired time schedule or budget limitations without maximum support from the lunar program. In some cases, it will be expedient to utilize identical launch vehicle systems for lunar and planetary missions. Especially in these applications, it is important that sterilization procedures involving launch vehicle interfaces are designed to satisfy both lunar and planetary mission requirements.

Primary responsibility for the study, development, and application of procedures for decontamination or sterilization of lunar and planetary spacecraft has been delegated to JPL by NASA. In the fulfillment of this responsibility, the Laboratory is required to advise the Director of Office of Space Sciences, NASA, of the procedures to be employed and obtain his approval prior to spacecraft launching.

The basic methods for accomplishing sterilization can be grouped in the following two classifications: (1) methods effective for internal sterilization; and (2) methods which are useful for surface sterilization only because of limited penetrating power. The techniques falling into the first group are heat, gamma radiation, bacteriological filters for liquids and gases, and sterile manufacture by means of sporicidal materials. Of these techniques, heat is by far the simplest and most effective. The second group consists of gas and liquid sterilants and ultraviolet radiation.

For the earliest lunar spacecraft requiring decontamination, the basic approach has been to apply sterilization procedures in three phases: first, internal sterilization of subassemblies by heat or other means; second, the use of liquid sterilants and other techniques to maintain sterilization during assembly and test operations on the spacecraft as a whole; and third, ethylene oxide gas sterilization of all exposed surfaces and maintenance of sterilization within a sealed shroud until the spacecraft is safely above the atmosphere.

Due to the multitude and complexity of the procedures associated with sterile assembly operations, continued emphasis should be placed on the reduction of the number of sterile assembly operations to be performed in the field and utilization of only the most reliable sterilization procedures.

The sterilization criteria can best be met by designing the spacecraft for heat sterilization of the completed assembly as one of the final operations at the launch site. Following heat sterilization, the spacecraft must be enclosed within a sealed envelope and the terminal surface sterilization operation performed. Thereafter, sterile conditions should be maintained until the spacecraft is boosted safely above the atmosphere, where the shroud or special protective enclosure can be deployed.

5. Reliability

Reliability—the prospect of mission success—is an imperfectly developed technique, but one that must remain an ultimate goal for every participant in a program. JPL activities of concept, review, design, analysis, fabrication, evaluation, qualification, inspection, test, and operations are all involved in supporting general and detailed decisions affecting reliability within the Lunar Program. These same activities constitute the primary elements of systems and subsystems engineering development. The choices are vital ingredients of project management.

Reliability attainment in programs involving many responsible personnel and lengthy time increments requires progress information for effective management. Feedback in developmental programs which provides information on the prospect of mission success also contributes to technical and managerial decisions that result in the attainment of reliability in space missions. The closest approach to firm knowledge of space system reliability would be a method whereby well understood equipment and procedures would be used repeatedly under conditions in which detailed mission performance information would be attained and fed back effectively into technical program management.

The challenge of exploration activity within the Lunar Program seriously limits the development of such program characteristics. Different missions are conducted, different exploratory measurements and observations are made, and advances in the state of the art are incorporated in systems for the ultimate increase of mission capability. In recognition of these fundamental characteristics of the Lunar Program, the prudent management of presumed system reliability as a competing characteristic becomes a severe challenge. Such prudent management requires reliability progress information that is truly representative of each system used in the program. These two factors—information and assurance of validity—are the aspects of development engineering which are particularly emphasized in the managed effort to achieve reliability.

It is most important to exploit every bit of experience as it becomes available. Each group of flights provides a measure of the state of the reliability art at that time, and if failure incidence is high, the objectives of the next group should be scaled down to improve the chances of success.

Information bearing on the prospective reliability of an incompletely developed or evaluated system is, of course, peculiar to the system and thus depends in detail on the definition of that system; i.e., on documentation and other means of prototype description. To a degree comparable with the desired level of reliability, the detailed development activity must include sufficient documentation to support the reliability evaluation and assurance activities.

High confidence in mission success is justified only if the item employed is both thoroughly evaluated and closely defined, particularly as we desire to extend the evaluation to items identified as duplicates within a series. Since thorough experimental methods of evaluation—type-approval testing, PTM operations, and actual space flight operations—typically involve wearout or terminal disposition, the requirement for duplication is typical of space systems both as assemblies and as detailed parts.

Assurance of duplication of hardware with respect to documented prototype characteristics is the normal function of quality control activities. Documentation of prototype characteristics typically includes JPL general specifications for control of fabrication and assembly processes. Assurance that these specifications have been complied with is a specific quality control function. Assurance that the handling and testing of space system hardware prior to flight use have not degraded its prospective reliability and performance involves quality control. It requires the disclosure to and through quality control of accidents and other failure-related events affecting flight-type hardware. A close and mutually well-informed relationship between cognizant development engineers and quality control personnel is necessary for effective supply and maintenance of reliable hardware for the Lunar Program.

The imperfections of documentation or other prototype description that can limit reliability information for complex systems or subsystems extend also to component parts. JPL efforts at each of high-reliability electronic parts identification and subassembly qualification are based on the concept that units procured from the same manufacturer to the same model number or specification are identical to the extent necessary for reliability assur-

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ance. Frequently, the reliance placed on such parts in space system design demands a higher order of parts design control and manufacture and application control than is characteristic either of commercial or experimental use of similar parts. Therefore, extension of JPL quality control into supplying activities will be necessary in extreme cases. Selection of components should take into account the disadvantage of such activity and operate in the direction of choosing well-proven parts instead.

Reliability evaluation of complex systems for program management purposes involves repeated attempts to improve on imperfect estimates, beginning with those implicit in conceptual design. Successive refinement of these estimates on the basis of experimental observations is relied on to provide program management guidance as the development progresses. Since the processes of experimental evaluation and data analysis, in the reliability sense, expend significant manpower and elapsed time, these steps themselves should be candidly described and responsibly scheduled as elements of the total development program. These factors of development completion enter into subsystem management as well as program or system management. For reliability evaluation and prudent management of reliability as a competing characteristic, candid presentation of subsystem development progress information, in a form close to raw data as used by cognizant personnel, is desirable. Compromises from this concept for summary presentation should be traceable to raw data sources.

Consistent with organizational assignments within the Laboratory and its major systems contractors, a flow of qualified and certified subsystems to a system assembly and test activity is expected to be characteristic of Lunar Program spacecraft activities. Because some imperfections in the development process and resultant hardware will be expected in programs in which the risk of limited reliability is balanced against risks of excessive cost and program delay, failures of qualified or standardized hardware and procedures will be experienced. Because of the involvement of several units of organization at this stage of a program and because of the short time remaining for management of resulting situations, failure experienced with hardware controlled by flight-approval tests must be reported promptly and systematically. The Lunar Program uses JPL standard failure reporting procedures for this purpose and will secure comparable services from system contractors.

Substantial traffic in advanced design features and in novel operational environments will be generated by Lunar Program spacecraft operations. Particularly for the reliability evaluation aspects of development support, engineering telemetry shall be provided in appropriate relationship to the novelty of each equipment and of operational environment.

Summarily, the various evaluations and controls that are particularly comprised in the reliability aspects of development activity under the Lunar Program shall be so recorded and reported as to support both prudent management of each mission project and accumulated capability of the organizations participating.

6. Reports and Documentation

a. General. The documentation prepared in support of the Lunar Program covers the following phases: planning and study, design and fabrication, schedules, launch-vehicle integration, drawings and drawing lists, specifications and specification lists, tracking and instrumentation, operations, post-flight evaluation, AMR-required documents, and launch-vehicle contractor documents.

b. Planning and Study Documents.

Feasibility Studies. During the early phases of a project, technical feasibility studies are made by JPL.

Project Development Plan. The PDP is a consolidated summary of the guidelines, objectives, background, management structure, resource requirements, and preliminary schedules proposed for a project in order to obtain formal approval and authorization from NASA.

c. Design and Fabrication Documents. This phase begins with the preparation of preliminary design studies and proceeds into the final hardware design and fabrication.

Spacecraft Design Specifications. These documents are prepared during the preliminary design phase and are maintained as a current statement of system design for the spacecraft. The design specification book contains the following principal sections: mission objectives and design criteria, design characteristics and restraints, functional specifications, and such appendices as the inboard profile drawing, reference designations, and packaging criteria for electronic components.

Operational Support Equipment Design Specifications. These specifications are similar to the spacecraft design specifications and perform a similar function for the ground support and launch systems.

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Trajectories. The published trajectories are constrained by the system design, scientific experiment objectives, and interface definitions between spacecraft and launch-vehicle system.

Pre-injection trajectories are the responsibility of MSFC. From them, preliminary post-injection trajectories are calculated for planning purposes. A functional specification is then issued as a summary of the preliminary post-injection trajectories. A set of standard post-injection trajectories is computed about 3 months before launch.

The set of final standard post-injection trajectories is issued 1 month before launch. From these and the pre-injection trajectories, the launch-to-impact nominal trajectory, firing tables, and other data for the mission, are prepared.

d. Schedules. Each cognizant JPL technical division generates and maintains its own internal schedules in sufficient detail to ensure delivery of hardware and documents. Division 31 prepares and maintains a summary schedule from the detailed division schedules on a bi-weekly basis.

The following are the principal schedules prepared for the Lunar Program: (1) Program Management Plans, (2) PERT Networks, (3) Discipline Divisions' Subsystems, (4) Launch, (5) Pad Modifications, (6) Operational Support Equipment, (7) Spacecraft, (8) Space Flight Operations Complex, (9) Documentation, (10) Trajectories, (11) AMR Facilities, (12) Spacecraft Operations, and (13) AMR Launch Base Operations.

e. Launch-Vehicle Integration Documents. These are the design control documents integrating all of the spacecraft interfaces with the rest of the system. The integration design areas for *Ranger* are covered in three documents: (1) Vehicle System Integration Requirements and Restraints, JPL Specification 30331; (2) LMSC–JPL Interface Plan of Operation; and (3) Preliminary NASA–*Agena* Countdown Sequence.

f. Drawings and Drawing Lists. Formal drawings are prepared for flight and ground support equipment to the degree necessary to provide a technical description adequate for a competent engineering group to reproduce the item, subsystem, or system from that documentation. The drawings are completed in time to meet the fabrication and test schedules. Applicable drawing lists, by generation breakdown, are originated and maintained for each dissimilar spacecraft.

g. Detail Specifications and Specification Lists. Formal detail specifications are prepared for all flight and OSE as necessary to supplement drawing information so that these items may be properly designed, fabricated, assembled, tested, and accepted. Drawings and specifications are generated to the degree necessary to guarantee that an exact duplicate of the system, subsystem, or item can be made from them after the original hardware has been expended.

When JPL specifications are supplied to a subcontractor, changes thereto are made only after approval in accordance with normal JPL specification change procedure. When the subcontractor is designing and developing an item for JPL, the contract states the specifications to be written and the format to be used. If JPL format is used, the preparation and approval follows JPL requirements, including technical changes. If the subcontractor format is used, the original and any subsequent technical changes are approved by the cognizant JPL engineer.

h. Tracking and Instrumentation Criteria. This document (formerly known as General Instrumentation Plan) indicates the proposed plans for meeting all tracking and instrumentation requirements from launch to spacecraft injection.

i. Operations Phase Documents.

Assembly and Operations Plan (AOP). The AOP describes the spacecraft systems assembly, starting at the SAF, and the operations plan through launch to injection. This publication, together with the Space Flight Operations Plan, constitutes the complete operational requirements plan. The AOP is also the primary planning document for coordinating and conducting operations and tests at JPL, contractor facilities, and AMR.

Operating Procedures and Check Sheets. These documents provide the detailed operational instructions required to accomplish the assembly, checkout, dummy run, preflight, and flight tests of the system and subsystems of the spacecraft, both at JPL and AMR.

Field Instruction Memorandum (FIM). The FIM defines specific operating instructions for JPL personnel at AMR for assembling and testing the spacecraft and its interfaces with the launch vehicles. It supplements the general plan outlined in the AOP, and specifies operational responsibilities, launch and hold criteria, safety instructions, and other such information.

2

Space Flight Operations Plan (SFOP). The SFOP describes the integrated operations from launch at AMR, through injection, to the completion and evaluation of the mission. It is the primary planning document for coordinating and conducting operations in detail after spacecraft injection. It defines methods, philosophies, and organization for tracking, commanding, data processing, communications, computing, and for evaluating the mission and its experiments.

Tracking Instruction Memorandum (TIM). This document contains the specific operating instructions for the DSIF tracking stations and also includes general background information for the operators.

j. Post-Launch Evaluation Documents. These documents are prepared and published by JPL after the flights. They are concerned with the evaluation of the spacecraft operations at AMR, DSIF, computing, data reduction, communications center, and the SFOC.

Preliminary Spacecraft Operations TWX's. These information bulletins provide a preliminary evaluation of injection parameters, achievement of test objectives, spacecraft performance, and scientific experiments data, following liftoff.

Field Operations Memorandum (FOM). The FOM is a summarized record of the JPL operations from arrival of the spacecraft at AMR to launch.

Tracking Operations Memorandum (TOM). This document summarizes the tracking operations of the DSIF net.

Space Flight Operations Memorandum (SFOM). The SFOM evaluates the space flight operations, spacecraft performance, achievement of mission objectives, and also covers AMR, DSIF, and JPL-Pasadena support operations.

Space Programs Summaries. These formal bimonthly publications report the engineering performance of the spacecraft and support systems, and describe the results of scientific experiments undertaken by lunar missions. These reports also include a condensation of flight results.

k. AMR-Required Documents. JPL either initiates or contributes information to the following range-required documents: Operation Program Estimate, Program Requirements Document, Operations Requirements, Preliminary Countdown Manual, Flight Termination System, Range Safety Report, and Pad Safety Report.

l. Documents for External Distribution. The following documents are prepared by JPL for formal external distribution.

Ranger Annual Report. This formal report is published approximately once each year. It summarizes the technical aspects and over-all results of the project.

Technical Reports. Detailed technical information on specific components, events, and experiments is published in formal Technical Reports when it is considered necessary or desirable to amplify the summary or annual reports.

Technical Papers. Special papers are prepared as appropriate for release in technical symposiums or technical society journals for the further information of the engineering and scientific communities.

Film Reports. Technical progress films are produced quarterly for distribution to NASA agencies.

F. Support Activities

1. Advanced Development

a. General. Programs to explore the Moon and the planets during the immediate future must depend primarily upon vehicle and spacecraft systems currently in development. However, the nation's long-range space exploration capabilities must inevitably equate with the advancement of technologies discretely removed from any specific systems objectives.

Within this philosophy, JPL and NASA must extend the concept of their research and development responsibilities beyond the mere design, development, and procurement of spacecraft systems of the current generation. They must face the equally important task of generating scientific ideas and conceiving technical equipment for the future. Only a planned program of advanced development can ensure that the space technology of 1965 and beyond will evolve in an orderly progression, without the waste and inefficiency of repeated crash efforts.

In general, the current program for advanced development has been inadequate because of the massive and urgent pressures for immediate and spectacular space achievements. But, without significant increase in support for advanced development activities, we face the sobering prospect of continuing dependence upon development of new activities and techniques within the costly area of systems development.

The advanced development activity would permit future spacecraft system development that is faster and less costly in incorporating new and proven advanced techniques and devices. This is one of the principal advantages of pursuing a vigorous, independent program of advanced technology apart from particular systems projects.

Since the risks in terms of money and time are relatively small in an advanced development activity, it is possible to conduct parallel activities to a point where a choice can be made between them. When the gamble is small, as in advanced development, the indicated course is to suspend judgment long enough to gather experimental data on which to base reliable decisions. Only such procedure is likely to provide a basis for the orderly pursuit of advanced technology.

b. Advanced Development Policies. The desirability of utilizing the Advanced Development Program to accomplish the above goals is reflected in the following adopted policies:

(1) The Lunar Advanced Development Program is based squarely on a recognition of R&D as a sequential, knowledge-getting activity. It is to be planned to obtain information as quickly and as cheaply as possible, consistent with functional requirements, and will provide opportunity during the course of the development for maximum exploitation of knowledge obtained.

(2) In initiating outside efforts, the program will seek to give contractors a clear idea of the role of their development activity without, in general, specifying in detail the system configuration and design specifications. Attempts to anticipate the optimum configuration and capability in advance force development to proceed along a predetermined course, thus making it difficult to profit fully from later knowledge.

(3) The program anticipates the frequent necessity to provide for two or more alternatives under development at an early stage. In anticipation that additional information will be required for a decision concerning which major component will be integrated into a final system, this decision can only be based upon initial test data that has provided information about the relative merits of the alternatives.

(4) The Advanced Development Program will make only modest financial commitments to a specific configuration until test results are available to provide a sound basis for determining the potential usefulness of a given device.

(5) It will be a matter of policy to ensure that those in technical charge of the program are quick to take advantage of new information gained during development, wherever possible.

(6) The Advanced Development Program will require that equipment be brought to test as early as possible at each period in the advanced development project, since tests are the only fully reliable source about the technical aspects of these projects.

(7) The test of the suitability for the undertaking of an advanced development project will be based upon establishment of functional requirements.

2. Deep Space Instrumentation Facility (DSIF)

a. General responsibilities. The Deep Space Instrumentation Facility Program Office is responsible for the post-injection tracking, raw data accumulation, and operation of the DSIF in support of the Lunar Program. It shall serve as the DSIF System Management Office with the following broad responsibilities:

(1) Operating and maintaining the basic DSIF as required in support of lunar project testing and mission operations.

(2) Coordinating the design, development, fabrication, installation, and testing and operation of special-purpose ground support equipment added to the basic DSIF by the Spacecraft System Manager.

(3) Undertaking and completing the technical design, development, fabrication, testing, and operation of items of equipment which, while required for the lunar projects, are considered basic to the DSIF.

(4) Providing technical and supporting facilities, as required, for the tracking and raw data accumulation from injection to completion of the mission.

(5) Ensuring that required testing and operations DSIF schedule periods are provided and coordinated with other space missions of JPL and NASA.

b. Specific functions and authorities for system management. The DSIF Program Director, in accordance with his delegated authority to conduct the activities of his Program Office and with recognition of his obligations with respect to JPL's over-all management of lunar projects, shall undertake all technical, procurement, budgetary, and other actions necessary to successful development and operation of the DSIF in support of the Lunar Program.

The DSIF Program Director shall be responsible for requesting the necessary resources from NASA and for notifying the Lunar Project Manager of the results of his actions. Funding for the facilities or equipment required for lunar projects, not currently programmed for the DSIF, shall be determined jointly by the DSIF Program Director and the Project Manager.

The DSIF Lunar System Manager will undertake the following functions:

(1) *System engineering and scheduling.*

(a) Directing all system engineering on the DSIF necessary to meet lunar project requirements.

(b) Deciding interface questions among subsystems within the DSIF.

(c) Requesting other parts of NASA to undertake work with respect to contract monitoring, testing, and reliability studies, or other activities, as appropriate to achieve the technical compatibility of subsystems.

(d) Determining and recommending for Project Manager and NASA approval the detailed DSIF schedule affecting the lunar project.

(e) Ensuring that DSIF schedules for the lunar project are consistent with DSIF commitments to other projects.

(2) *Participation in over-all systems integration.*

(a) The DSIF Program Office shall consider interface decisions and task assignments made by the Project Manager concerning over-all systems integration to be conclusive until (or unless) reversed by higher authority, and providing such actions are compatible with DSIF funding and obligations to other programs.

(b) Task assignments from the Project Manager must be referred for decision by NASA when acceptance would overtax DSIF resources beyond the agreed commitments.

(c) The DSIF Program Office shall participate in reporting, information, advisory, and other procedures designated to provide the Lunar Project Manager with the necessary knowledge of all project systems. These procedures may be either those established in the Project Development Plan, or special requests and procedures made by the Project Manager.

(3) *Technical consultation and advice.*

(a) Establishing and participating in such *ad hoc* advisory and standing bodies as the DSIF requires.

(b) Requesting from appropriate parts of NASA such special technical information as may be required by the DSIF.

(c) Participating in project-initiated committees as required.

(4) *Budget requirements and financial operating plans.*

(a) Developing and recommending to JPL and NASA financial operating plans for the DSIF which are in phase with the over-all lunar project schedules.

(b) Furnishing the Project Manager such financial information on the DSIF as he may request, including a copy of the DSIF Financial Operating Plan.

(5) *Financial management.* Making decisions within approved financial operating plans or other limitations by NASA or JPL, to commit funds and/or to reprogram funds as necessary within allocations for the DSIF to support the Lunar Program.

(6) *Contracting activities.*

(a) Ensuring appropriate technical monitoring over the quality, timing, and costs of DSIF work placed with contractors or other government agencies.

(b) Providing close liaison and coordination with the Spacecraft System Manager in the design, fabrication, test, and operation of special-purpose GSE located at DSIF sites.

(7) *Reports.* Furnishing DSIF system summary reports to NASA, the Project Manager, and other parts of NASA, as required; or furnishing such additional information as may be requested by the Project Manager.

c. Internal organizational assignments. The DSIF Program Director shall retain over-all responsibility for the performance of Lunar Program systems assignments entrusted to his office. He shall assign such of the foregoing functions and responsibilities to an appropriate system management staff as established within the DSIF program.

Requirements placed by the Lunar Project Manager on the facilities, capabilities, and operation of the DSIF shall be submitted to the DSIF Program Director and Systems Manager for concurrence. Agreement by the DSIF Program Director with requirements placed upon the DSIF establishes a commitment to perform the assignment in support of the lunar project.

d. External organizational relationships.

General relationships. Requirements placed by Lunar Systems Managers, contractors, or government agencies on the facilities, capabilities, and operation of the DSIF in support of lunar projects shall be submitted to the appropriate project manager.

Specific relationships.

(1) Figure 6 indicates the DSIF operational relationships for Project *Surveyor,* as typical for the Lunar Program. During missions operations, a Lunar Operations Command Director, to be assigned by the Lunar Project Manager, shall have command authority over the operation of the DSIF within the guidelines of the Space Flight Operations Plan. Responsibility for execution of the DSIF operations shall be vested in the DSIF Systems Manager.

(2) The authority of the Lunar Operations Command Director shall be implemented by the requirements placed upon the DSIF and agreed to by the DSIF

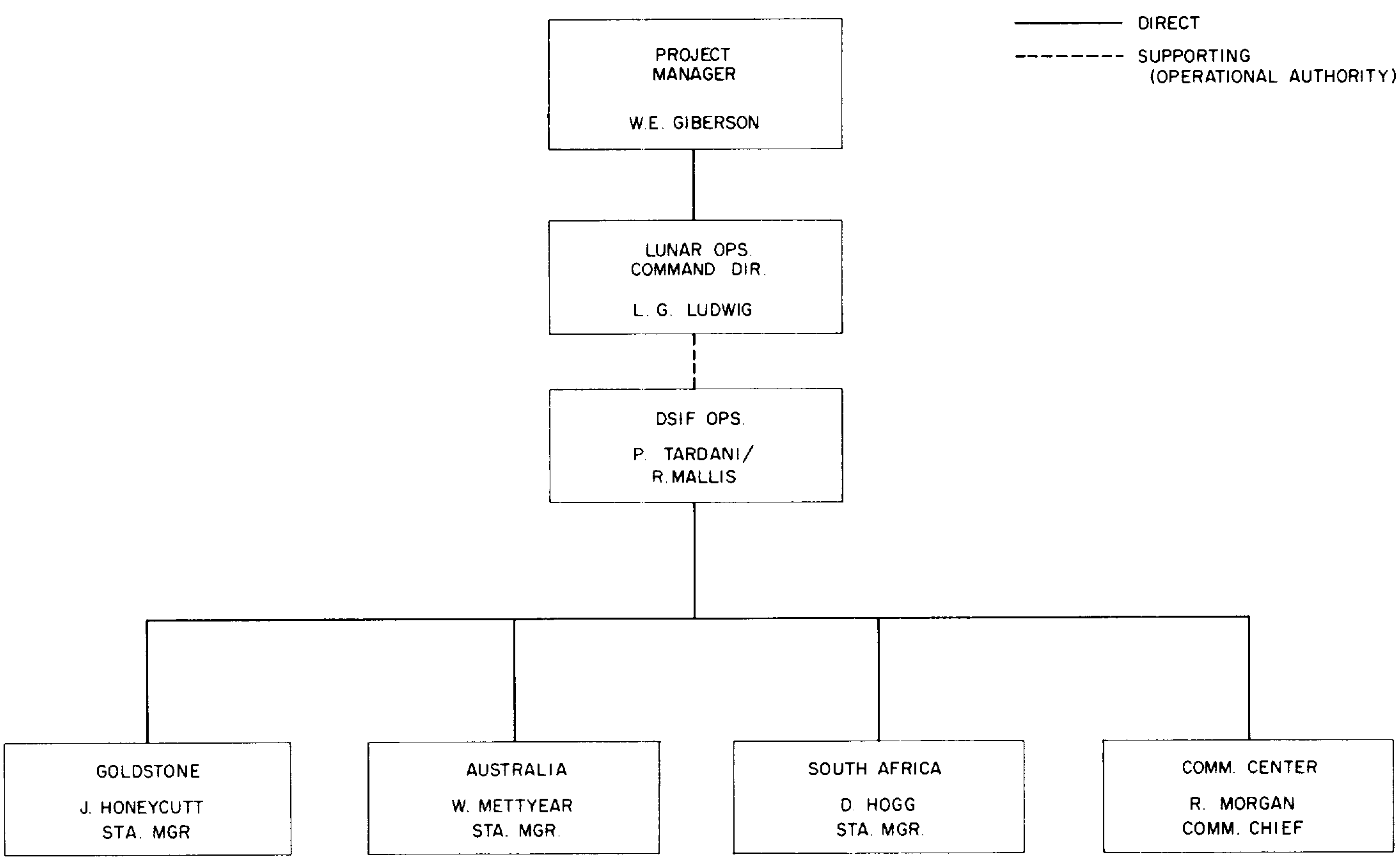

Fig. 6. Surveyor operational structure

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Systems Manager. Normally, during actual flight missions, the Lunar Operations Command Director communicates directly with the executing agency, the DSIF Operations Office (Fig. 7). Conversely, activities within the DSIF are reported by the DSIF Operations Office to the Lunar Operations Command Director.

(3) During missions operations, operating personnel at DSIF stations representing external organizations shall report operationally to the DSIF Station Manager.

(4) At the scheduled completion of a phase or sub-phase of the lunar mission, operational command authority over the DSIF by the Lunar Operations Command Director ceases.

(5) Schedule conflicts regarding DSIF operating time for lunar projects and other projects shall be resolved jointly by the DSIF Program Director and the affected Project Managers or by higher authority.

3. Space Flight Operations

Space flight operations are defined as those operations necessary for the obtaining and processing of spacecraft information, and those commands required by JPL during that portion of flight from launch to the accomplishment of the mission.

Facilities are provided for the transmission to Pasadena of data received from the spacecraft in flight by the DSIF stations; processing, handling, and reduction of the data; computation of predicted flight trajectories, based on the data; and the generation and transmission of trajectory correction commands to the spacecraft. A world-wide communications net is used during flight operations to coordinate the post-injection tracking and command operations with the control center at Pasadena. Figure 8, the

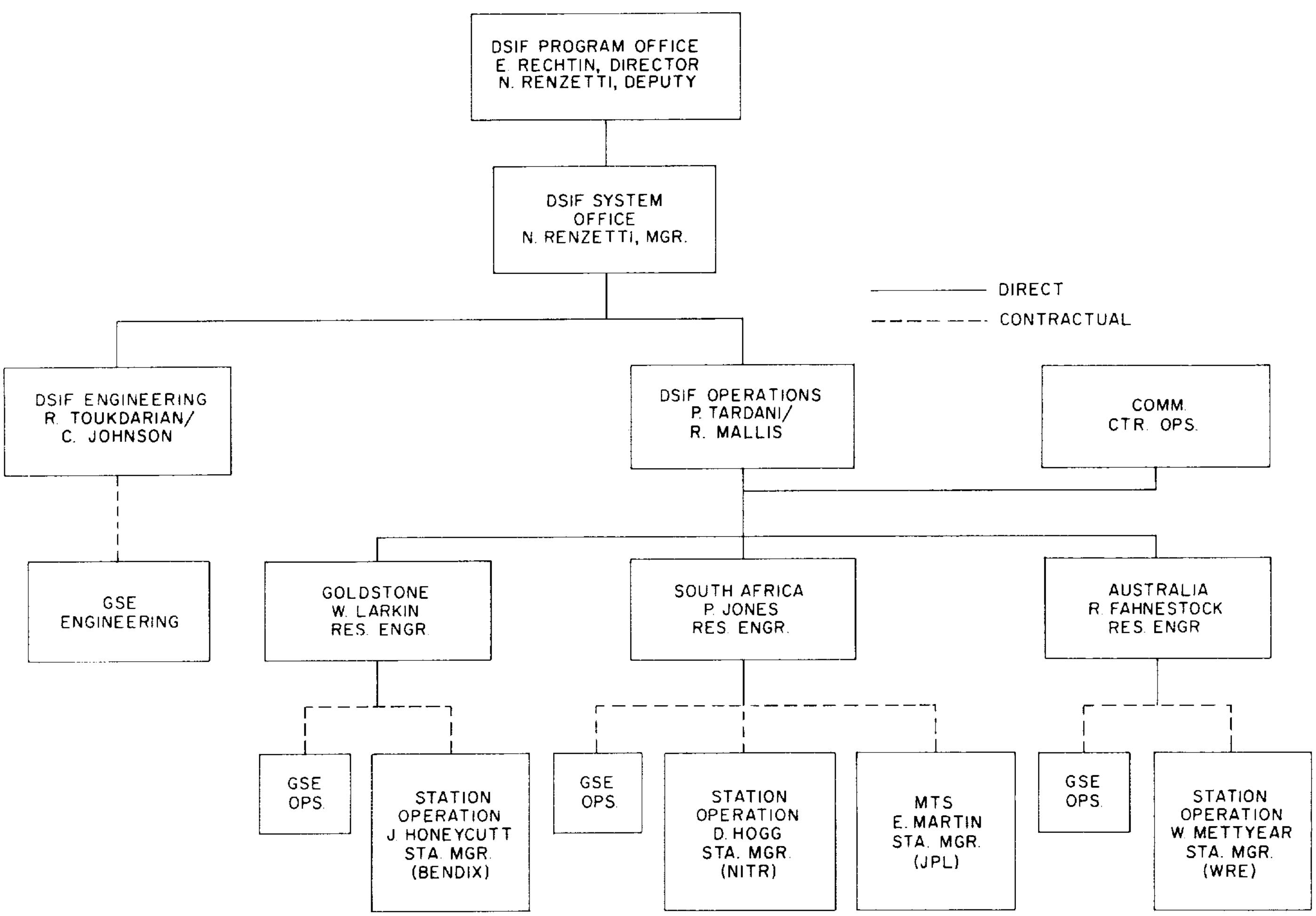
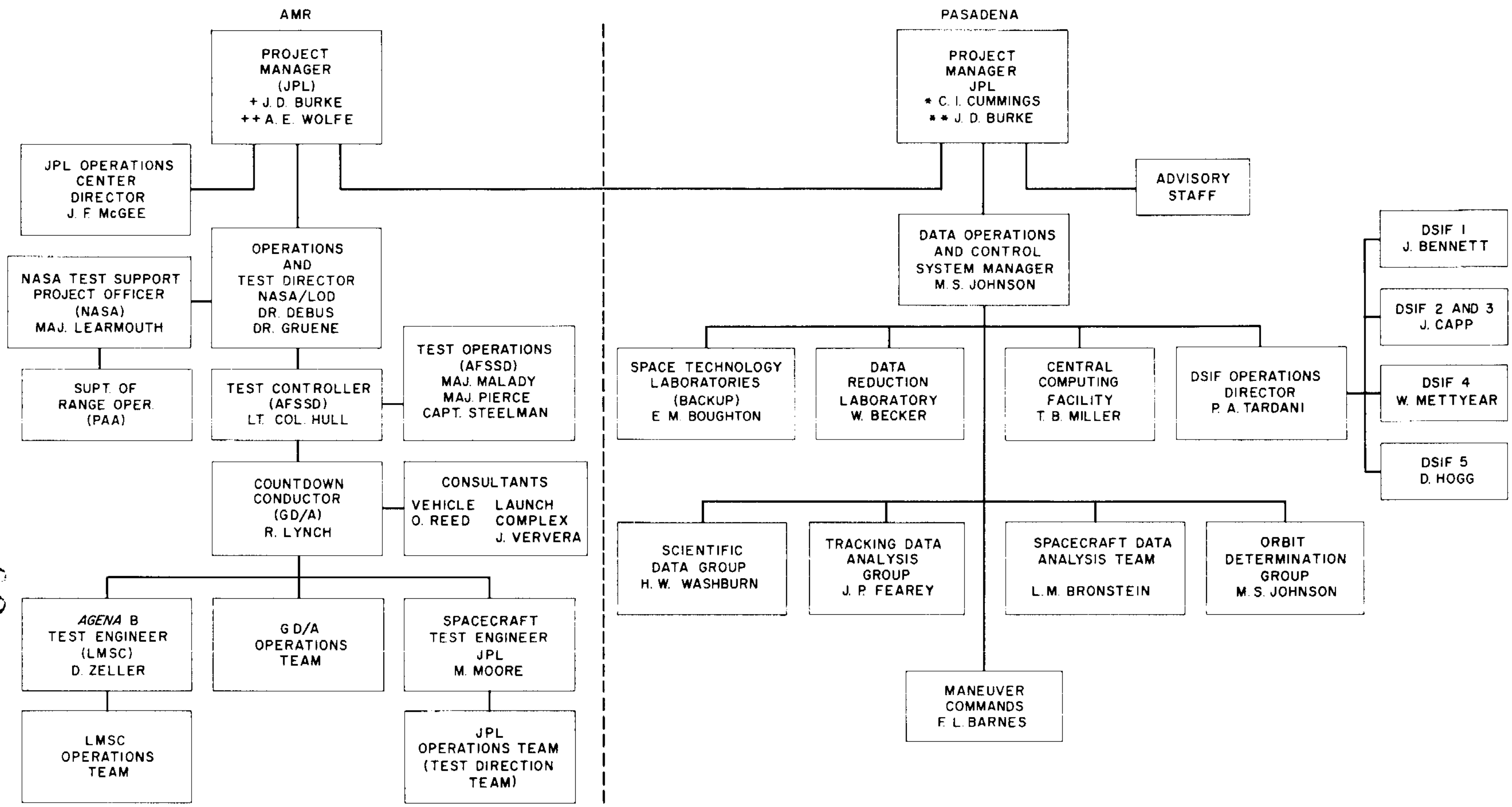


Fig. 7. DSIF operations organization



AFBMD - AIR FORCE BALLISTIC MISSILE DIVISION
AMR - ATLANTIC MISSILE RANGE
CVA - CONVAIR ASTRONAUTICS
JPL - JET PROPULSION LABORATORY
LMSC - LOCKHEED MISSILES AND SPACE COMPANY
LOD - LAUNCH OPERATIONS DIRECTORATE
MSFC - MARSHALL SPACE FLIGHT CENTER
PAA - PAN AMERICAN AIRWAYS

* REPLACED BY J. D. BURKE AFTER LAUNCH PHASE
** AT AMR DURING LAUNCH PHASE; AT JPL THEREAFTER
+ FUNCTIONS AS SPACECRAFT MISSION DIRECTOR DURING LAUNCH OPERATION
++ ACTS FOR PROJECT MANAGER AT AMR IN BURKE'S ABSENCE

Fig. 8. Organization, *Ranger III* mission

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organizational structure for *Ranger III*, is typical of JPL lunar flight operations.

4. Atlantic Missile Range (AMR)

a. Facilities.

General. The basic facilities and ground support equipment used at AMR for direct operational support of the pre-launch and launch activities are: the spacecraft checkout facilities, the Explosive Safe Area, and Launch Complexes 12 and 36. These facilities are used for acceptance tests to verify flight readiness.

Hangar AE. The spacecraft checkout is conducted in Hangar AE, which includes a system test area, the JPL Operations Center, and several laboratories.

Explosive Safe Area. Final preparation of the completed spacecraft, installation of fueled propulsion systems and pyrotechnic devices are accomplished in the Explosive Safe Area. The facility comprises a sterilization and assembly laboratory, a propulsion laboratory, and a capsule laboratory.

Launch Facilities.

(1) *Complexes. Ranger* launch operations are conducted at Launch Complex 12; the *Surveyor* Project will use Launch Complex 36. The complexes include the blockhouse, launch control shelter, umbilical tower, launch complex equipment, launch stand, and gantry. The launch complex equipment is installed in the blockhouse, umbilical tower, and launch control shelter.

b. JPL AMR Operations.

Test philosophy constraints. The JPL test philosophy imposes a launch-complex interface restraint on operations at AMR. In order to attain maximum isolation from the vehicle, the only hard-wire connections to the *Agena* stage, other than special instrumentation lines, will be those connecting the spacecraft to the launch complex and those required to feed the spacecraft telemetry tones to the *Agena* telemetry system. The spacecraft launch complex cables will be routed to the GSE through the umbilical plug provided on the spacecraft–*Agena B* adapter.

JPL lunar launch organization. The JPL Project Manager functions as the Mission Director for the lunar launch operations. He has the over-all responsibility and authority for the execution to completion of the missions and is responsible for mission decisions, for spacecraft preparation, and for defining those criteria necessary for mission attainment. He participates in launch operations and collates inputs from DSIF, communications, the JPL Test Director, and others, to determine total mission readiness for launch. No deviation from the criteria in the countdown manual may be made without his consent.

In addition to the Mission Director, the JPL launch team include a station manager, spacecraft test director, control center coordinator, status coordinator, and communications coordinator. Other JPL personnel are located in the blockhouse and at the Impact Predictor Building during launch.

5. Public Information Policy

The policy governing release of Lunar Program information to the public is established by the Lunar Program Office with the advice of the Jet Propulsion Laboratory Office of Public Education and Information, and in conformance with the policy of the Office of Space Science, NASA.

As a general principle, JPL endorses a policy of information release which recognizes the obligation to report to the public on the use of public money, while protecting the technological advances which might be inherent in a program, and which minimizes the dangers of a publicity buildup which could be harmful to the program. It is recognized, however, that large industrial corporations working with the Laboratory on these projects conduct their information programs under different requirements and rules; these organizations are nonetheless responsible.

To meet these obligations and requirements, JPL originates a public information policy on each project which undertakes to meet these varying requirements so that the rights and interests of NASA, JPL, and industry are equally considered.

In each project, a news release is issued at the time of the assignment of the project to the Laboratory and/or by the Laboratory to an industrial subcontractor. This news release is approved by the NASA Office of Public Information prior to its issuance. Industrial subcontractors associated with the project are allowed to make simultaneous issuance of this news release in their local area.

The initial news release then serves as the basis for all future public information statements concerning that project, and is used by the industrial subcontractor as a guide for preparation of brochures, advertisements, public reports, etc. From time to time, as the project advances, the Project Manager, in consultation with the JPL Office of Public Education and Information, may decide that various milestones in the project should be announced publicly by means of a news release or a news conference. When such milestone releases are made, they become part of the body of releasable information concerning the project.

The JPL Office of Public Education and Information is responsible for developing these news releases and coordinating their approval and release with the NASA Office of Public Information. The JPL OPEI also is responsible for developing the general news release concerning the project which is distributed to news media shortly before the project is completed.

6. Security Classification

Section 304(a) of the National Aeronautics and Space Act of 1958 (42 USC 2455) provides the Administrator of NASA with authority to establish such security requirements as deemed necessary. Executive Order 10501 establishes the general policies and procedures to be followed in safeguarding official information.

Under the above authority, NASA requires the assignment of a security classification to official information when it is determined that disclosure of such information would have a detrimental effect upon:

(a) Scientific or technological programs of vital national importance.

(b) Military or defense plans.

(c) International relations, particularly as they may be affected by or be dependent upon the position of the United States as a leader of aeronautical and space science and technology.

In this connection, JPL is directed by NASA that appropriate information obtained and/or developed as a result of JPL–NASA programs is to be protected in accordance with established classification policy.

Security classification guidance is provided by NASA program classification guides, policy directives, or individual letters. For new projects where classification cannot be determined in advance, JPL is directed to activate interim security requirements check lists for JPL and its subcontractors for each task, in accordance with Executive Order 10501 and existing implementary guidelines. Particular attention is given to those achievements that substantially advance the state of the art in space technology. NASA subsequently reviews each security requirements check list to assure uniformity of classification among programs and modifies such lists if required. Responsibility for the development and coordination of security classifications within JPL and with NASA rests with the Manager, Technical Information Section.

"Security Classification Guide," published January 2, 1961, with four addenda (Engineering Planning Document No. 20), is the official JPL guideline in the area of security classification.

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