CONTRACT 950137

RANGER TV SUBSYSTEM (BLOCK III) FINAL REPORT

VOLUME I: SUMMARY

Prepared For:

JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
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By The:

ASTRO-ELECTRONICS DIVISION
DEFENSE ELECTRONIC PRODUCTS
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Preface

This report summarizes the Ranger TV Subsystem program. This work was performed by the Radio Corporation of America, under JPL Contract No. 950137, for the Jet Propulsion Laboratory of the California Institute of Technology, Pasadena, California. The period covered by this, the Final Report on the program, extends from July, 1961 through July, 1965. The report is submitted in five volumes:

Volume 1	Summary
Volume 2	Subsystem Analysis
Volume 3	TV Subsystem Design
Volume 4	Manufacturing, Product Assurance, and Test
Volume 5	Evaluation

This volume, Volume 1, contains:

- An Introduction;
- A discussion of the Project Organization;
- A summary of the Contractual History;
- A summary of the TV Subsystem Design;
- A summary of the Operational Support Equipment (OSE) Design;
- A summary of the Ranger VI, VII, VIII, and IX Missions;
- A summary of the Significant Scientific Achievements;
- A listing of special and nonrecurring reports issued by RCA during the program;
- A listing of the RCA specifications prepared for the Ranger TV Subsystem Project.

Acknowledgement

It is impossible to acknowledge the significant contributions of all of the individuals within RCA to the Ranger TV Subsystem Project. A project of this duration and size is, of necessity, a team effort with each member of the team contributing to the whole. The Ranger TV Subsystem team consisted of many groups of individuals from various parts of RCA. The staff of the Ranger Project Management Office at AED provided the basic management skills needed to organize, direct, and control the project within RCA. These personnel furnished the vital day-to-day continuity of cognizance and the long-range planning needed to achieve the project objectives. The members of the various engineering skill centers at AED, who were responsible for the design of the TV Subsystem, and the members of the quality control, manufacturing, assembly, and test groups, who were responsible for reducing these designs to working hardware, must be commended. The support of individuals at the RCA facilities at Camden, N.J.; Burlington, Massachusetts; and Van Nuys, California who functioned as part of teams responsible for the design and production of elements of the TV Subsystem and the operational support equipment was significant. The unique contribution of the Electronic Components and Devices Division, in Lancaster, Pennsylvania, in providing the high-quality vidicons used in the TV cameras was important to the success of the project. It is worthy of note that these personnel from many diverse functional areas and divisions of RCA performed successfully as an integrated project team with the single-minded purpose of achieving the objectives of the Ranger Project.

Special mention should be made of the Astro-Electronics Division Publications Department for their consistent technical reporting effort and, in particular, for their effort in the compilation of this document.

Special acknowledgement is made to the following:

- Dr. S.W. Spaulding, who provided leadership in his role as Project Manager from 1961 to 1963.
- Messrs, J.J. Corr and J.R. Staniszewski, who were the focal points for the direction of the RCA effort during the entire program and who capably directed the RCA participation in space-flight operations and data reduction.
- Mr. O.E. Cole, who supervised the RCA Service Company personnel responsible for operating and maintaining the OSE and the ground support equipment at RCA, JPL, ETR, and the DSIF stations at Goldstone, California.
- Messrs. S. Goldfarb and R. F. Sharp, who were operations directors during the Ranger VII, VIII, and IX missions.

- Messrs, W.W. Conder and S. Dobren, who were the test directors for Ranger VII, VIII and IX.
- Mr. A.J. Vaughan and his staff, in particular, A.I. Pressman, who gave so much of themselves to the assurance of the technical integrity of the Ranger TV Subsystem design.

Acknowledgement is also extended to the Jet Propulsion Laboratory for providing guidance during the critical periods of this project, and for establishing a working relationship that surmounted the barriers to decision-making and to technical exchange that often inhibit complex projects.

BMiller

B.P. Miller
RCA Ranger Project Manager
July 22, 1965

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Section I

Introduction

A. GENERAL

The design, fabrication, and test of the Ranger TV Subsystem and support of field operations for the Ranger Spacecraft were accomplished by the Radio Corporation of America for the Jet Propulsion Laboratory of the California Institute of Technology. The objective of the Ranger program was to obtain high-resolution pictures of the lunar surface through a series of lunar-impacting missions.

Design of the Ranger TV Subsystem was started in July 1961. After carrying out a study contract for the TV Subsystem, RCA embarked upon the hardware phase of the project under a letter contract from JPL (No. 950137) in October 1961. By the end of January 1962, RCA had built and tested a mechanical test model (MTM) which was then shipped to JPL for further tests. At that time, RCA had also built and installed at their facilities the first Operational Support Equipment for the TV Subsystem. Assembly of a thermal control model (TCM) was completed shortly thereafter.

A product assurance control program for the TV Subsystem was developed and formalized in November 1961. This program provided for: (1) A continuing series of reliability studies using an analytical model of the TV Subsystem to evaluate the probability of mission success and to identify potential problem areas; (2) A parts selection, evaluation, and control procedure to ensure that every component used in the TV Subsystem had a proven capability and was spaceworthy; and (3) A procedure for analysis and reporting in order to pinpoint components that might be particularly susceptible to failure.

The TCM completed its tests at the RCA facilities and was shipped to JPL in March 1962. By the end of May 1962, the various test models were in operation and showed satisfactory performance. On the basis of these tests, RCA began the fabrication of flight models. Environmental testing of the Proof Test Model (PTM) which was used for extensive analysis of system performance, was completed at RCA early in August 1962. It was then shipped to JPL for further testing.

The environmental testing of Flight Model 1 was started in September 1962. By October 1962, testing was completed and Flight Model 1 was shipped to JPL. By the end of November 1962, the assembly and initial checkout of the second flight model was completed and Flight Model 2 was awaiting environmental test.

In late 1962 the Ranger Project was rescheduled and additional time was available for a series of Subsystem conceptual and design reviews with JPL. At the direction of JPL, RCA undertook to study alternative configurations of the TV Subsystem. The objective of this study was to evolve a TV Subsystem configuration having an improved capability of obtaining information either during a nonstandard mission or under conditions of partial failure of the TV Subsystem. As a result of this study, RCA proposed a configuration having a maximum degree of redundancy of both the signal and power paths. This design concept, known as the "split-system," was reviewed and accepted by JPL. A reliability study comparing the original design with that of the split system was performed and showed that the split-system configuration was less vulnerable to catastrophic failure and that it had an improved probability of achieving partial mission success under nonstandard operation conditions.

Following the reliability study, a design study was initiated to define the specific electrical and mechanical changes to be made to the

PTM of the Ranger TV Subsystem as the first step in implementing the split-system configuration for the flight models.

The split-system modification of the PTM was authorized early in 1963 and a new test cycle was initiated in the spring. The tests included extensive simulation of various failure effects in addition to normal modes of operation. These tests were completed, the new design was verified, and the unit was shipped to JPL in June for further testing.

The authorization to proceed with the modification of the revised flight models was received in March 1963; the designation of the models was changed to FM III-1 (previously RA-6), FM III-2 (RA-7), FM III-3 (RA-8), and FM III-4 (RA-9). By July, all of the modifications for Flight Model III-1 (Ranger VI) were completed and the unit was shipped to JPL in August 1963. The full test cycle of the integrated spacecraft was then carried out at JPL. On December 28, 1963, the final series of tests commenced at the Eastern Test Range. The last of these tests was completed on January 26, 1964. A total of 69 formal tests were performed on Ranger VI. Of these tests, 11 were made in a simulated space environment and a total of 27 individual tests involving the TV Subsystem were performed on the entire spacecraft. The testing of the Ranger Spacecraft at JPL and ETR confirmed the validity of the design and verified the performance of the TV Subsystem.

The Ranger VI Spacecraft was launched from Cape Kennedy, Florida, at 10:50 a.m. Eastern Standard Time, on January 30, 1964. The primary purpose of this mission was not achieved since pictures of the lunar surface were not received. The investigation which followed this mission established several possible failure modes, the most probable of which attributed the malfunction to arcing in the high-voltage elements of the Subsystem during an inadvertent and premature turn-on during the launch phase of the mission.

As a result of the failure of Ranger VI to fulfill its primary mission objective, the command and control elements of the Subsystem were redesigned to eliminate the possibility of premature turn-on. In addition, all assemblies were reinspected, reworked, and retested as required prior to installation. After reassembly and the incorporation of new designs, the Ranger VII TV Subsystem was delivered to JPL for further testing. Upon completion of an extensive test program that demonstrated satisfactory operation of the redesigned TV Subsystem, the Ranger VII was delivered to ETR and was launched on July 28, 1964. It performed its mission perfectly, returning over 4000 high-resolution close-up photographs of the lunar surface.

Authorization to assemble the TV Subsystems for Rangers VIII and IX was received in August 1964, and the delivery dates for these were changed to October and November 1964. The Subsystems were delivered on time to JPL for integration with their respective JPL Bus to become Rangers VIII and IX. Following testing at the JPL facility, the spacecraft were delivered to the Eastern Test Range (ETR); they were launched on February 17, 1964, and March 21, 1964, and performed their missions perfectly.

B. MAJOR MILESTONES, RANGER TV SUBSYSTEM

JPL Contract 950137 covered the design, development, fabrication, and test of one Proof Test Model, four flight models of the TV Subsystem, and associated operational support equipment. A summary of major contractual milestones is shown in Figure 1.

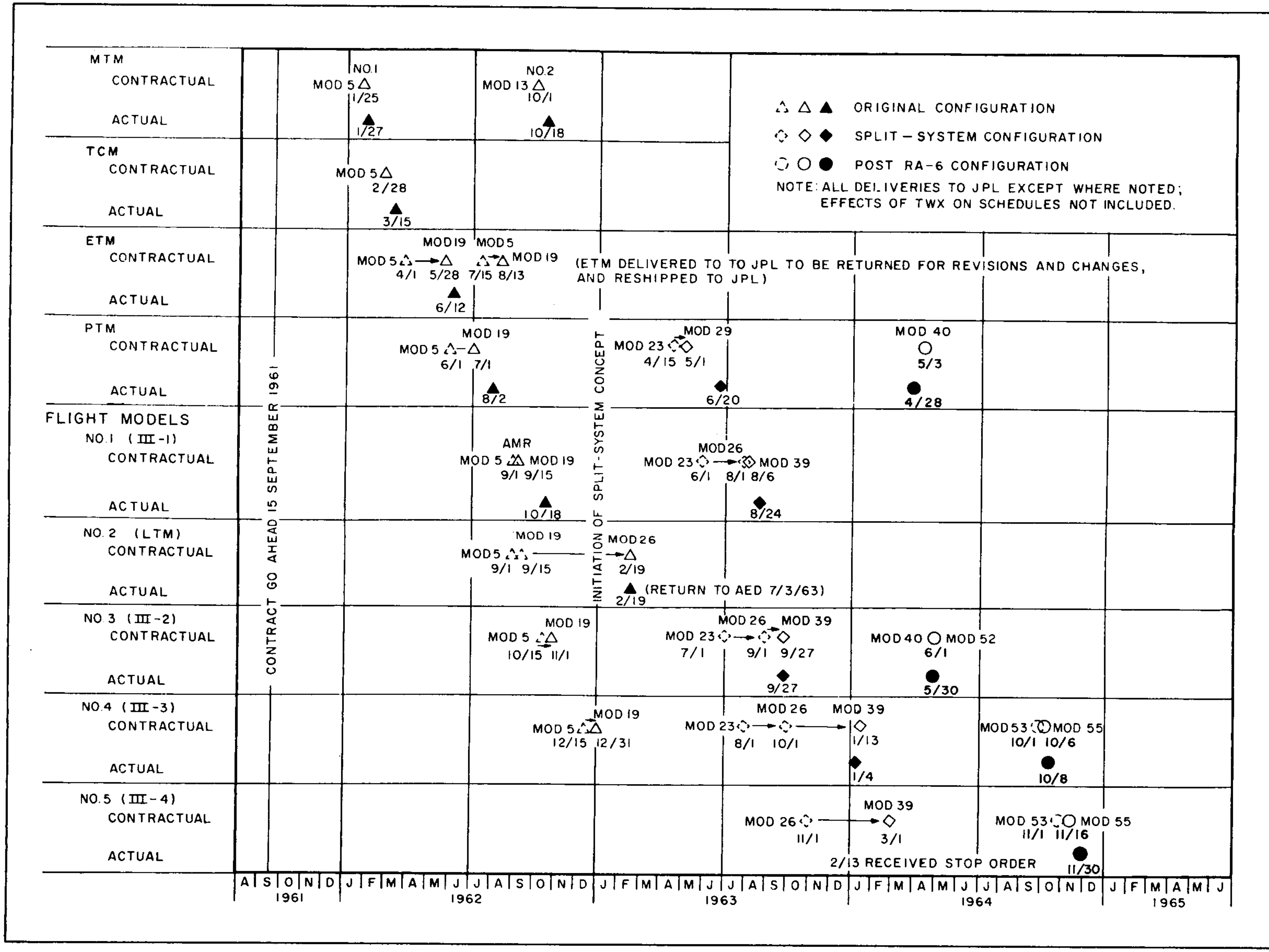


Figure 1. Major Milestones, Ranger TV Subsystem Program

Section II

Ranger TV Subsystem Project Organization

A. RCA MANAGEMENT

The Radio Corporation of America assigned the responsibility for the Ranger TV Subsystem project to the Astro-Electronics Division (AED) at the initiation of the project. To ensure the availability of the full capabilities of RCA, direct contact with other RCA Divisions was maintained through the RCA Defense Electronic Products (DEP) organization (see Figure 2).

B. AED MANAGEMENT

All phases of the TV Subsystem project were managed by the Project Office established within AED as shown in Figure 3. Consistent with the management concepts refined through the successful performance of similar space programs (including Relay, TIROS, and various classified projects), the Project Office included both administrative and technical management skills, as required, not only to monitor and control progress, but also to provide detailed guidance to the participating AED skill centers, to other RCA Divisions, and to the RCA suppliers. The Project Manager, Mr. B. P. Miller, reported directly to Mr. R. E. Hogan, Manager, Systems Programs at AED, who in turn reported directly to Mr. B. Kreuzer, Vice President and General Manager of AED. Mr. Hogan and Mr. Kreuzer provided executive control of project performance and ensured access to all specialized talents and facilities of the RCA corporate structure as required by the project for the successful fulfillment of its objectives.

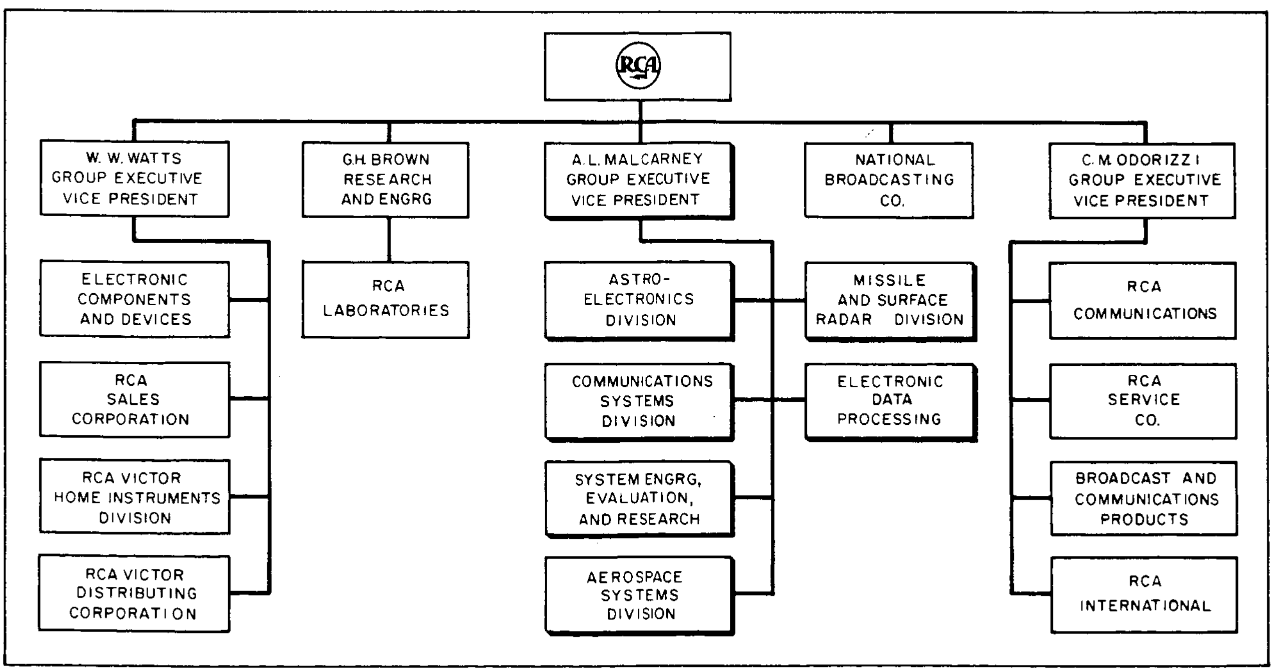


Figure 2. RCA Corporate Structure

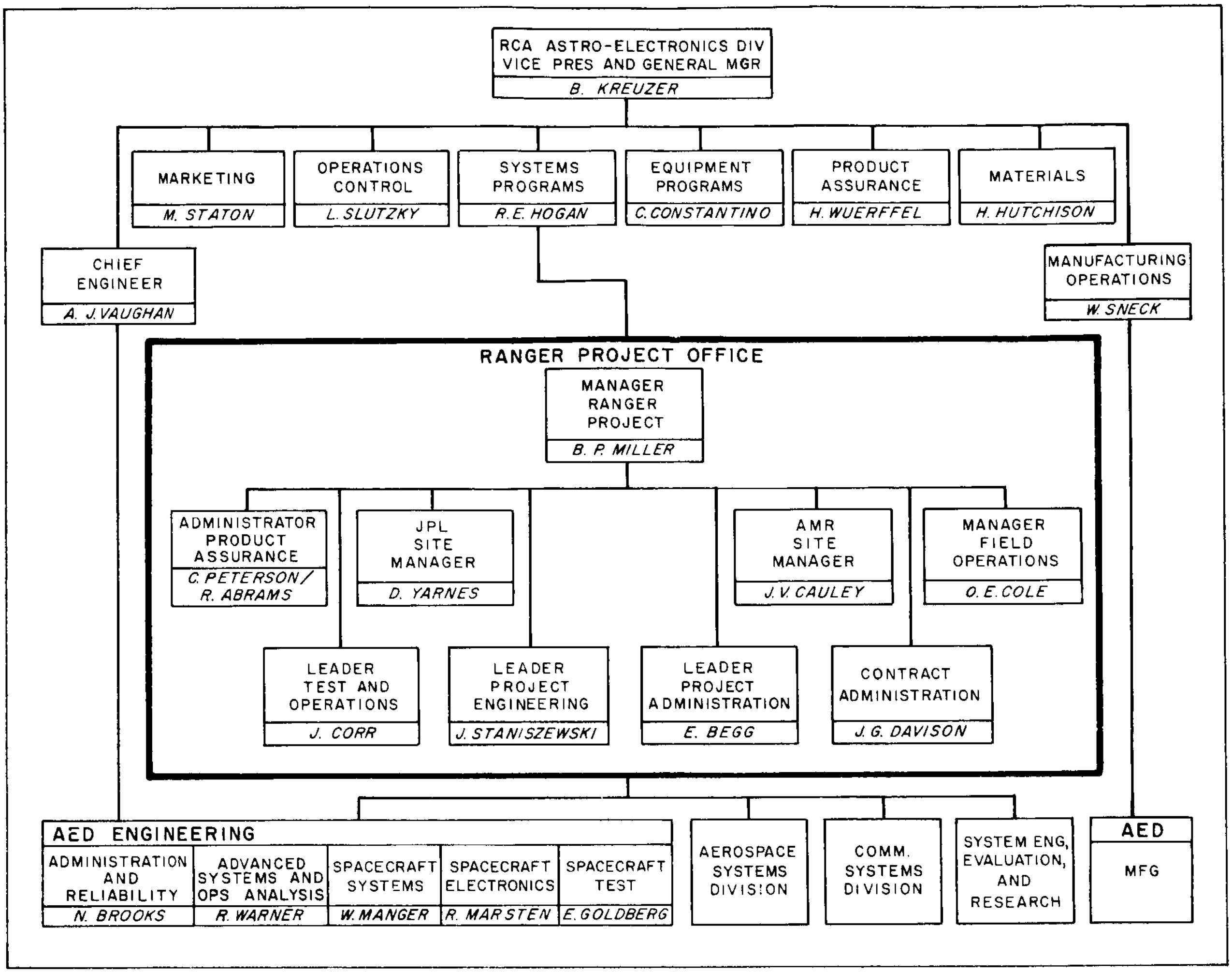


Figure 3. Relationship of Ranger Project Office to AED Organization

C. SUMMARY OF RESPONSIBILITIES FOR RANGER PROJECT OFFICE

The RCA approach to the Ranger project management was to establish a project organization distinct from the line activities supplying the detailed working skills. The Project Office was specifically dedicated to the accomplishment of the goals of the Ranger project.

Full management responsibility and full project authority were vested in a team collectively known as the Project Office. The Project Office provided a single point of customer contact, as well as a single source of internal RCA responsibility, authority, and control. The Project Manager provided the focal point for this responsibility and authority and, in effect, interpreted the customer's (JPL) requests, their requirements, and their viewpoint within RCA.

RCA employed its project office concept as an effective answer to the complex management demands created by the research, development, and production of the Ranger TV Subsystem. By concentrating overall project responsibility and direction within a single task-oriented organization located within AED, efforts of the diverse but interrelated corporate and subcontractor functions were effectively directed toward the common goal of close-up high-resolution pictures of the lunar surface.

This approach permitted technical competence and effective management to be obtained at minimum cost. The major responsibilities of the Project Office included:

- Project planning, and contract administration;
- Technical direction and control;
- Schedule and cost control;
- Production control;
- Product assurance and reliability;
- Customer contact, and postdelivery product support; and
- Coordination of engineering skill center activities, including detailed equipment specifications, detailed test specifications, and technical assistance to subcontractors.

The correlation of these various functions within the Project Office is illustrated in Figure 4.

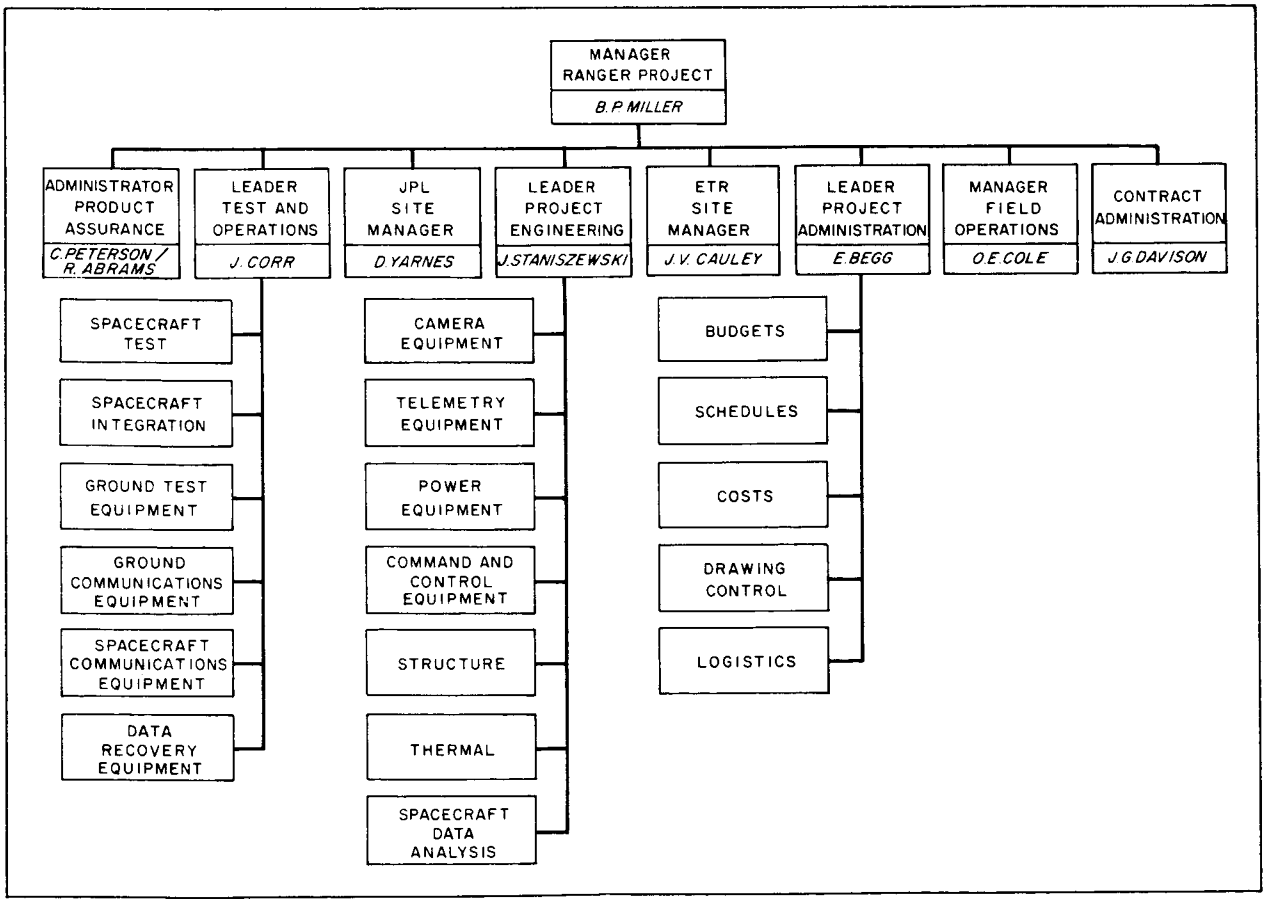


Figure 4. Ranger Project Office Organization

1. Ranger Project Management

Working within the framework established by the Project Office, and under the direct cognizance of the Project Manager, project office personnel consulted with the appropriate engineering and manufacturing activities to define the specific areas of responsibility for each activity. Detailed work statements were jointly agreed upon by project and engineering management, and formed the basis of the shop-order structure. Work statements were then issued by the Project Manager. Where the scope of work to be performed changed, revisions to the individual work statements were issued by the Project Manager; in all cases such directives remained consistent with the requirements of the Project Office to ensure the fulfillment of the mission requirements.

The Project Manager continually evaluated project performance against requirements, and immediate steps were taken whenever necessary. Evaluation was on a daily basis; status reports highlighting existing problems were submitted immediately to the Project Manager. When a problem arose which affected the overall schedule of the program, the Project Manager immediately notified JPL.

The Project Manager conducted weekly status meetings with the project staff. Firsthand information was collected at this meeting, and information on costs, budgets, and schedules were compared with the overall program goals. When problems appeared, the Project Manager took immediate steps to identify the causes and to provide effective solutions. Minutes of these meetings provided specific direction to working groups, and allocations of resources were adjusted as required by the Project Manager.

2. Project Engineering, and Test and Operations

The leaders for project engineering and for test and operations provided the technical direction of the engineering skill centers. These leaders were the focal point in the Project Office for the design and development of the TV Subsystem, for the procurement and production of Subsystem hardware, for the integration and test of assemblies and the Subsystems, and for delivery to the customer. They were the direct-line contact between the Project Manager and the AED skill centers.

The project leaders for engineering, and for test and operations reported directly to the Project Manager. Under their direction, the project engineering staff was responsible for coordinating all RCA activities and for coordinating the RCA efforts with those of the Jet Propulsion Laboratory. Responsibilities at the project engineering level were assigned to specific project engineers within the Project Office, who monitored and controlled the efforts of other participating RCA divisions as well as of the functional activities within AED. The project engineers were the direct-line contacts between the Project Office and the skill centers, providing both day-to-day and long-term task assignments. Technical responsibilities were clearly defined, with individual project engineers responsible for technical performance, costs, and schedules associated with the 17 specific tasks.

To ensure continuity of effort throughout the project, the responsibilities of the project engineers were continued from the start of design through equipment fabrication, test and delivery. Thus, the general structure of the Project Office was preserved throughout the period of performance, and the interfaces between RCA and JPL did not require redefinition.

3. Product Assurance Administration

The product assurance organization was charged with the responsibility of establishing policies and procedures; implementing or assisting in implementing product assurance tasks; and the auditing of engineering, manufacturing, purchasing, marketing, and the project office, to assure that the product complied with all quality and reliability requirements of the contract.

The staff of the Ranger TV Subsystem Project Office included a product assurance administrator. He was responsible to the Project Manager for the organization and direction of the quality assurance and engineering reliability tasks in accordance with the Ranger TV Subsystem program plans in each area.

The product assurance administrator maintained continuous control of the program through the use of monthly status reports, formal product assurance program reviews, and person-to-person contacts. He was the point of contact at RCA for JPL on matters concerning reliability, safety, and quality control.

4. Project Administration

The project administration leader was responsible to the Project Manager for the overall project cost and schedule planning, formal work authorizations, control of project documentation, evaluation of cost estimates, and the planning and implementation of postdelivery equipment support. The project administration function ensured coordinated planning and action among all participating activities. Specifically, the project administration leader had the following responsibilities:

- Plan, monitor, and maintain the project planning charts and schedules;
- Implement the modified PERT and APEX (analysis of performance and expenditure) cost control systems;
- Monitor, and maintain manpower-load charts and budgets;
- Schedule and transmit project documentation;
- Maintain the project library and records;
- Conduct project administration reviews; and
- Prepare presentation material for both customer and Project Manager review.

In addition to a day-by-day review, reviews with the Project Manager of the cumulative costs for each activity and the milestone accomplishments of the overall project budget were performed on a scheduled basis. The project cost analysts, schedule controllers, drawing controllers, and logistics support administrator reported to the project administration leader. When these men reported possible trouble areas, the project administration leader acted as a troubleshooter by investigating these areas and recommending corrective action or policy.

5. Contract Administration

The contract administrator, who reported to the Project Manager, was responsible for the management of all project contract administration functions. He was the legally responsible interface between JPL and the Project Office on all contractual matters, as detailed in the legal and governmental direction (e.g., ASPP/AFPI).

His responsibility included the monitoring of subcontractor negotiations. Through his analysis of program manpower utilization, overtime, and delivery progress, he was able to isolate potential contractual problems and guide the project toward fulfillment of its contractual obligations.

To ensure contract adherence, the contract administrator initiated all RCA action directives whose implementation could involve changes in projected cost or schedules. He was, therefore, responsible to ensure that RCA was responsive only to those customer directions which were received from authorized sources.

6. Field Operations

The field operations manager had overall responsibility for ground station operation, including installation, checkout, modification, and maintenance operations. Specifically, he had the following responsibilities:

- Determine and analyze the field support requirements in liaison with JPL;
- Coordinate planning for spares procurement and spares acquisition;
- Coordinate the maintenance of both the operational and support equipment;
- Select and administer field support personnel at JPL, ETR, and Goldstone (Echo and Pioneer sites);
- Monitor the repair of equipment, when required;
- Provide RCA assistance in the training of ground station personnel; and
- Provide RCA assistance during integration, prelaunch, launch, and postlaunch operations.

7. JPL Site Management

The JPL site manager was responsible for the liaison between JPL and RCA at Pasadena, California. He provided technical groups at JPL with direct access to technical groups at RCA, and facilitated the rapid interchange of technical data throughout the course of the program. The JPL site manager provided the organizational administrative guidance at JPL during the TV Subsystem testing and OSE compatibility verification, and coordinated the activities of the flight model engineering teams (one for each flight model and one for the PTM) at JPL. In addition, the JPL site manager was responsible for the operation of the OSE at JPL.

8. ETR Site Management

The ETR site manager was responsible for the liaison between JPL and RCA at Cape Kennedy, Florida. He provided technical groups at ETR with direct access to technical groups at RCA, and facilitated the rapid interchange of technical data throughout the course of the program. He initiated the Ranger site operations as they applied to the TV Subsystem at ETR, was responsible for site operations of the OSE, and provided the liaison between the RCA Ranger test teams (accompanying each of the flight models) and ETR personnel. The ETR site manager provided all necessary assistance to ETR personnel during the prelaunch, launch, and postlaunch phases of the TV Subsystem mission.

D. DESCRIPTION OF BASIC TASKS

At the inception of the RCA effort on the Ranger TV Subsystem, the Project Office at RCA defined 17 basic tasks which made up the overall effort. This section contains a brief description of these tasks, and some of the items included under each task.

Task 1: Project Engineering

This task included the activity in the Project Office by the staff of the Project Manager. The staff functions were organized into the following general areas, and were monitored under the cognizance of Mr. B. P. Miller.

- Project engineering;
- Project administration;
- Contract administration;
- Test and operations;
- Field operations;
- JPL site management;
- ETR site management; and
- Product assurance.

The various efforts of Task 1 are summarized below:

- Defined the overall TV Subsystem effort on the program at RCA as 17 basic tasks;

- Established and implemented a system of cost-control and shop-order reviews for the TV Subsystem program;
- Coordinated manpower efforts to meet the schedule demands of the Ranger program;
- Assisted in all TV Subsystem program negotiations;
- Provided liaison and technical direction for all participating RCA Divisions and for all TV Subsystem vendors;
- Provided close liaison with JPL personnel, resident and nonresident, on all matters concerning the TV Subsystem program;
- Defined and monitored all interface areas concerned with the TV Subsystem;
- Monitored all power, weight, and volume budgets from an overall TV Subsystem viewpoint;
- Monitored all aspects of the preparation and delivery for all models of the TV Subsystem;
- Assisted and participated in the quarterly design reviews at JPL;
- Monitored the implementation of both RCA and JPL design review recommendations for the TV Subsystem; and
- Redefined and redirected, as required, TV Subsystem technical effort in light of program changes in guidelines or goals.

Task 2: Cameras and Camera Electronics

Task 2 included the effort for the design, fabrication, procurement (where necessary), breadboard, and acceptance testing of the camera subassemblies and camera electronics assemblies.

The following assemblies resulted from the effort expended under this task:

- Shutter;
- Camera housing;
- Vidicons, both partial-scan and full-scan;
- Camera preamplifier;
- Deflection programmer;
- Video amplifier;
- Color wheel (until terminated); and
- Camera erase circuitry.

Task 3: Optics

The activity included under this task was for the design and development of the optical components for the cameras. This activity also included the design and development required for alignment and calibration equipment.

The effort included the following:

- 25-mm, f/0.95 lenses;
- 75-mm, f/2.0 lenses;
- Color-technique study (until terminated);
- Collimators, for use during camera system alignment and calibration; and
- Lunar photometry.

Task 4: Control Programmer and Camera Sequencer, and Sequencer Power Supply

This task included the effort required to design, develop, fabricate, breadboard, and acceptance test a Control Programmer and Camera Sequencer Assembly and the associated power supply. The Control Programmer and Camera Sequencer Assembly generated the various timing and control signals needed by the vidicon-tube networks for the proper functioning of the cameras.

The effort expended under this task included the following:

- Control Programmer and Camera Sequencer;
- Sequencer Power supply;
- Rapid-scan erase circuitry;
- Separation of F- and P-Channel information; and
- Video Combiner.

Task 5: Power Supplies

The effort expended under this task was for the design, development, fabrication, breadboard, and acceptance testing of the TV Subsystem batteries and voltage regulators, and the auxiliary supplies for ground test.

The effort was expended for the following:

- Batteries, Model 202, 22-cell;
- Lightweight Battery, Model 230, 12-cell;
- Lightweight Battery, Model 252, 22-cell;
- High-Current Voltage Regulators; and
- Low-Current Voltage Regulators.

Task 6: Communications (Flight)

Task 6 was directed toward the design, development, fabrication, breadboard, and acceptance testing of the communications equipment for the spacecraft.

The following assemblies resulted from the effort on this task:

- F-Channel Transmitter;
- P-Channel Transmitter;
- Telemetry Assembly;
- 15- and 90-point Commutators;
- Four-Port Hybrid Ring; and
- Dummy Load.

Task 7: Ground Checkout and Data Recovery Equipment

This task was directed toward the design, development, fabrication, breadboard, and testing of the equipment used to conduct tests to verify operation of the TV Subsystem during ground checkout, and equipment used to recover video data at the ground stations.

The effort expended under this task resulted in the following:

- Console;
- Video Amplifier;
- Power-Control Relay;
- Systems Cables; and
- TV Recording and Display Equipment.

Task 8: Structure and Thermal Control

The effort expended under this task was devoted to the design, development, fabrication, breadboard, and acceptance testing of a basic structure with a thermal heat shield on the exterior. The task effort also included the analysis, simulation, testing, and design required to specify the internal arrangement of heat-dissipating electronic elements, surface finishes, both internal and external, heat sinking, special sources of heat when required, and temperature history calculation. Considerable digital computer work was performed to determine the interaction of many elements of the analytical thermal model.

Task 9: Mechanical Integration

The work performed under this task included the design of the mechanical arrangement of assemblies and subassemblies within the structure, the payload-handling equipment, and the shipping containers. A computer program was developed and employed for weight, center-of-gravity, and moment-of-inertia prediction and control. All models were assembled, balanced and weight-controlled, and checked after all dynamic tests. In addition, mechanical integration assistance was rendered at both JPL and ETR for the mating of the TV Subsystem with the basic bus, and the spacecraft with the launch vehicle.

Task 10: Electrical Integration

Task 10 included the design and fabrication of the electrical interconnecting of subassemblies and assemblies, and control of the various tests from an equipment viewpoint. This task included the cable harness and connectors in the payload, the connection of the payload to the checkout and test equipment, the operation of all these elements in test by means of switches, relays, meters, panels and test equipment. The development of test procedures and philosophy, and the supervision of tests were included in this task, as were the operating system tests and the interconnection and testing at JPL. This task also included integration support at JPL, ETR, and Goldstone during the field operation and flight evaluation phases of the program.

Task 11: Environmental Test

This task included the environmental testing of subassemblies and assemblies for qualification or flight acceptance testing of complete payloads for such environmental tests as thermal-vacuum, vibration, shock, temperature-humidity, and the supervision of these tests. Also included were any special instrumentation required for the TV Subsystem and its component parts, and the recording of all necessary test data. It also included the design, development, fabrication, evaluation, and use of any special test fixtures and jigs required, as well as of any special test equipment necessary to evaluate performance. In addition, this task included close liaison with test personnel at JPL and ETR, and assistance and conferences when required.

Task 12: Project Assurance/Quality Control

The overall reliability analyses and product assurance activity associated with the project was accomplished as Task 12. More specifically, the program was divided into two categories: the first dealing with system concepts and control during the design stages and normally referred to as the reliability effort; and the second dealing with the manufacturing aspects of the program, particularly during the fabrication of prototype and flight units, and normally referred to as the quality assurance effort. The reliability effort included an analysis of a system mathematical reliability model, detailed failure mode and effects analysis, parts selection, and evaluation and control of purchased parts and materials. The quality assurance effort included quality control implementation of existing systems throughout RCA and at all vendors, a manual on quality control for use by all participating activities, implementation of in-process inspection both at RCA and at the vendors, and surveillance inspection of all suppliers.

Task 13: Publications and Flight Evaluation

This task consisted of two specific subtasks; the first being the preparation and submission of all technical documentation for the program, and the second being the effort required to analyze and evaluate the data from the flight of the TV Subsystem as part of the Ranger Spacecraft.

The publications effort included both periodic and nonperiodic documents, handbooks and manuals, the color photographs of all flight equipment, and the motion picture coverage of all significant events of the TV Subsystem. It included close liaison with JPL both at RCA, and at JPL and Goldstone. A list of the special and nonrecurring reports issued under this task is given in Table 1. The specifications and test procedures for the Ranger TV Subsystem and for the OSE are listed in Table 2.

The flight-evaluation effort included the activity necessary to analyze and reduce the data received from all four flight models of the Ranger TV Subsystem. This effort took place at RCA, JPL, ETR, and Goldstone.

Task 14: Field Operation

This task included the support of all TV Subsystem and associated operational support equipment (OSE) at various locations including RCA, JPL, ETR, and Goldstone. The activity included system tests on the ground checkout systems; test support of Flight models III-1, III-2, III-3, and III-4 at RCA, JPL, and ETR; launch support for all four flight models; and the maintenance and operation of the OSE at the DSIF site at Goldstone during the mission of all four flight models. This task also included the effort required for the training of all personnel required to operate all OSE associated with the TV Subsystem.

Task 15: Communications, Flight

The spacecraft communications system consisted of the telemetry subsystem, the FM modulators, the power amplifiers, associated power supplies, RF combiners, intermediate power amplifiers, and dummy load antennas. This task included the design, fabrication, procurement, assembly, breadboard, and testing of all the units.

This task also included effort required to tie together the subassemblies and assemblies into a working payload prior to the actual mechanical and electrical integration. This task also included effort to provide vendor liaison with the suppliers of certain major subassemblies and assemblies.

Task 16: Communications, Ground

The ground communications consisted of all the equipment necessary to receive, from the Ranger TV Subsystem, the multiplexed TV and telemetry data, and to process this data into the proper form for the data recording and display equipment. This receiving equipment was contained in each of the ground checkout systems and in the primary ground station at Goldstone where it was attached to the DSIF.

The task included the design, fabrication, procurement, assembly, breadboard, and testing of all ground receiving equipment. The total number of ground receivers consisted of six complete channels; two installed at the DSIF, and one in each of the four ground checkout systems.

This task also included the design and fabrication of an appropriate processing and switching circuitry to complete the interface integration of the ground receivers and the data recording and display equipment. There was one such unit at the DSIF, and one with each of the four ground checkout systems. In addition, there was one tape demodulator in each of the checkout systems and two tape demodulators at the DSIF. This task also provided for a remote test transmitter, a test transmitter, a 960-Mc receiving front end, and a 30-Mc preamplifier. All equipments were supported by spares for maintenance and operation.

Task 17: Recording and Display Equipment

This task specifically included the recording and display equipment which was a major part of the ground equipment in the checkout units and in the Goldstone installation.

The basic purpose of this equipment was to take composite video signal at the IF channel and record it on tape, and to take demodulated composite video for kinescope display and 35-mm film recording. In addition, the equipment was capable of generating its own synthetic composite video for system checking and calibration.

This task included the design, fabrication, assembly, breadboard, and test of the basic set of equipment which was contained in seven racks. A set was included in each of the four checkout units used at RCA, JPL, and ETR. At Goldstone, the equipment complement was increased to provide redundant recording of line signals.

The basic set of equipment included a one-megacycle bandwidth tape recorder, a kinescope display unit with a 35-mm film camera for primary data recording and a Polaroid camera for quick-look-at data, a sync signal separator for each type of composite signal, a video simulator, and associated power supplies and control panels. The Goldstone installation was further implemented with an additional tape recorder and an additional kinescope display unit.

As part of this task, all necessary liaison with JPL personnel was provided at JPL, ETR, and Goldstone.

TABLE 1
LISTING OF SPECIAL REPORTS ON RANGER TV SUBSYSTEM PREPARED BY RCA

Report Title	Publication Date	AED No.
Ranger TV Subsystem Payload, Volumes 1, 2, 3, 4	August 25, 1961	726
Ranger TV Subsystem Product Assurance Program (including Reliability Demonstration Plan)	February 15, 1962	1075
Environmental Test Report for the Proof Test Model of the Ranger TV Subsystem	September 28, 1962	1516
Ranger TV Subsystem Contract Program Summary	November 12, 1962	1405
Brochure of Presentation to JPL on Proposed Bus Program Plan	December 13, 1962	1414
Ranger Follow-on Product Improvement, Volume 2	December 19, 1962	1412
Environmental Test Report for the Flight Model 1 of the Ranger TV Subsystem	December 19, 1962	R-1666
Presentation Brochure	January 16, 1963	5001
Ranger TV Subsystem Reliability Study Report	March 7, 1963	R-1846
Environmental Test Report for the Flight Model 2 of the Ranger TV Subsystem	March 29, 1963	R-1845
Ranger Design Study Report	April 15, 1963	R-1890

TABLE 1
LISTING OF SPECIAL REPORTS ON RANGER TV SUBSYSTEM PREPARED BY RCA (Continued)

Report Title	Publication Date	AED No.
Ranger Design and Environmental Test Plan	May, 1963	R-1910
Environmental Test Report for the Proof Test Model, Block III, of the Ranger TV Subsystem	July 20, 1963	R-1949
Failure Effects Analysis, Ranger TV Subsystem	August 15, 1963	R-2047
Environmental Test Report for the Modified Block III-1 (RA-6) Flight Model of the Ranger TV Subsystem	November 15, 1963	R-3003
Ranger Flight Evaluation Report for RA-6 (III-1)	April 7, 1964	R-2257
Environmental Test Report for the Modified Block III-2 (RA-7) Flight Model of the Ranger TV Subsystem	July 17, 1964	R-2407
Final Report for Ranger Alternate Turn-on Device	September 28, 1964	R-2508
Ranger Flight Evaluation Report for RA-7 (III-2)	October 30, 1964	R-2473
Environmental Test Report for the Block III-3 (RA-8) Flight Model of the Ranger TV Subsystem	February 2, 1965	R-2521
Environmental Test Report for the Block III-4 (RA-9) Flight Model of the Ranger TV Subsystem	February 17, 1965	R-2601
Ranger Flight Evaluation Report for RA-8 (III-3)	May 14, 1965	R-2677
Ranger Flight Evaluation Report for RA-9 (III-4)	June 24, 1965	R-2692

TABLE 2
LIST OF SPECIFICATIONS AND TEST PROCEDURES FOR THE RANGER TV SUBSYSTEM

RCA Specification and Test Procedure Number	Title	Date of Latest Issue
RANGER TV SUBSYSTEM		
RSP-1000A	Specification for Hardware for the Flight Equipment of the Ranger TV Subsystem	June 18, 1964
RSP-1100A	Specification for the Ranger TV Subsystem	August 7, 1964
RTSP-1100A	Test Specification for the Ranger TV Subsystem	April 27, 1964
RTSP-1100A, App. A	Initial Power Application and Checkout Procedure	December 24, 1964
RTSP-1100A, App. B	Subsystem Acceptability Criterion	August 6, 1964
RTSP-1100A, App. C	Component Alignment	March 24, 1964
RTSP-1100A, App. D	SimulatedMission Procedures and Test Data Sheets	August 7, 1964
RTSP-1100A, App. E	Ground Support Equipment Loop Test and Data Sheet	March 26, 1964
RTSP-1100A, App. F	Test Specification for the Ranger TV Subsystem (Block III)	August 6, 1964
RTSP-1100A, App. G	Operational Verification Test	August 6, 1964
RTSP-1100A, App. H	Camera - Array Alignment and Overlap Determination Procedures and Test Data Sheets	November 10, 1964
RTSP-1100A, App. J	Thermal Balance Procedures and Test Data Sheets	August 6, 1964
RTSP-1100A, App. K	Battery Charging and Discharging Procedure	April 17, 1964
RTSP-1100A, App. L	Inspection Testing, Handling, and Pre-flight Preparations	August 7, 1964
RTSP-1100A, App. M	Assembly and Mechanical Procedures	April 7, 1964
RTSP-1100A, App. N	Telemetry Calibration and Test Data Sheets	October 6, 1964

TABLE 2
LIST OF SPECIFICATIONS AND TEST PROCEDURES FOR THE RANGER TV SUBSYSTEM (Continued)

RCA Specification and Test Procedure Number	Title	Date of Latest Issue
RANGER TV SUBSYSTEM (Continued)		
RTSP-1100A, App. O	Voltage and Current Distribution Test Procedure and Test Data Sheets	July 27, 1964
RTSP-1100A, App. P	Command and Control Circuitry Noise Immunity Test Procedure	Not Issued
RTSP-1100A, App. Q	Magnetic Tape Review and Analysis Procedures	April 22, 1964
R	Abbreviated Subsystem Test Procedures and Test Data Sheets	August 10, 1964
RSP/RTSP-1101A	Test Specification for the Environmental Testing of the Block III Flight Models of the Ranger TV Subsystem	March 23, 1964
RSP/RTSP-1101, Apt. A	Detailed Vibration Test Procedure	March 23, 1964
RSP/RTSP-1101, Apt. B	Detailed Thermal-Vacuum Test Procedure	March 23, 1964
CAMERA GROUP		
RSP-1111A	Specification for the F-Type TV camera Subassemblies (A1A5 and A1A6) and Associated Camera Electronics Assemblies (A6 and A7) of the Ranger TV Subsystem	April 3, 1964
RTSP-1111A	Test Specification for the F-Type TV Camera Subassemblies (A1A5 and A1A6) and Associated Camera Electronics Assemblies (A6 and A7) of the Ranger TV Subsystem	April 30, 1965
RSP-1112A	Specification for the P-Type TV Camera Subassemblies (A1A1 through A1A4) and Associated Camera Electronics Assemblies (A2 through A5) of the Ranger TV Subsystem	April 3, 1964

TABLE 2
LIST OF SPECIFICATIONS AND TEST PROCEDURES FOR THE RANGER TV SUBSYSTEM
(Continued)

RCA Specification and Test Procedure Number	Title	Date of Latest Issue
CAMERA GROUP (Continued)		
RTSP-1112A	Test Specification for the P-Type TV Camera Subassemblies (A1A1 through A1A4) and Associated Camers Electronics Assemblies (A2 through A5) of the Ranger TV Subsystem	April 30, 1965
RSP-1120A	Specification for the Camera Sequencer Group (A9, A8, and A28) of the Ranger TV Subsystem	July 31, 1963
RSP-1121A	Specification for the Control Programmer and Camera Sequencer Assembly (A9) of the Ranger TV Subsystem	April 17, 1964
RTSP-1121A/1122A	Test Specification for the Control Programmer and Camera Sequencer Assembly (A9), and Sequencer Power Supply Assembly (A28) of the Ranger TV Subsystem	April 20, 1964
RSP-1123B	Specification for the 504-Series Video Combiner Assembly (A8) of the Ranger TV Subsystem	April 6, 1964
RTSP-1123	Test Specification for the 504-Series Video Combiner Assembly (A8) of the Ranger TV Subsystem	April 14, 1964
RSP-1164	Specification for the Filter Assembly (A38) of the Ranger TV Subsystem	September 16, 1963
RTSP-1164	Test Specification for the Filter Assembly (A38) of the Ranger TV Subsystem	April 7, 1964

TABLE 2
LIST OF SPECIFICATIONS AND TEST PROCEDURES FOR THE RANGER TV SUBSYSTEM
(Continued)

RCA Specification and Test Procedure Number	Title	Date of Latest Issue
POWER GROUP		
RSP-1131B	Specification for the Battery Assemblies, Models 202 and 202M (A10 and A11) of the Ranger TV Subsystem	October 18, 1964
RTSP-1131B	Test Specification for the Battery Assemblies, Model 202 and 202M (A10 and A11) of the Ranger TV Subsystem	June 22, 1964
RSP-1132A	Specification for the Low-Current Voltage Regulator Assembly (A17) and High-Current Voltage Regulator Assemblies (A12 and A37) of the Ranger TV Subsystem	April 6, 1964
RTSP-1132A	Test Specification for the Low-Current Voltage Regulator Assembly (A17) and High-Current Voltage Regulator Assemblies (A12 and A37) of the Ranger TV Subsystem	October 29, 1964
RSP-1133	Specification for the Battery Assemblies Model 252 (A10 and A11) of the Ranger TV Subsystem	October 30, 1963
RTSP-1133	Test Specification for the Battery Assemblies Model 252 (A10 and A11) of the Ranger TV Subsystem	October 25, 1963
TELECOMMUNICATIONS GROUP		
RSP-1140A	Specification for the Telemetry Assembly (A26) of the Ranger TV Subsystem	April 6, 1964
RTSP-1140A	Test Specification for the Telemtry Assembly (A26) of the Ranger TV Subsystem	November 4, 1964

TABLE 2
LIST OF SPECIFICATIONS AND TEST PROCEDURES FOR THE RANGER TV SUBSYSTEM
(Continued)

RCA Specification and Test Procedure Number	Title	Date of Latest Issue
TELECOMMUNICATIONS GROUP (Continued)		
RSP-1141A	Specification for the Temperature Sensor Assembly (A27) of the Ranger TV Subsystem	November 12, 1963
RTSP-1141A	Test Specification for the Temperature Sensor Assembly (A27) of the Ranger TV Subsystem	July 26, 1963
RSP-1150A	Specification for the Communications Equipment (A14, A15, A16, A19, A20, A21, A24, A25, A29 and A30) of the Ranger TV Subsystem	November 2, 1964
RTSP-1150A	Test Specification for the Communications Equipment (A14, A15, A16, A19, A20, A21, A24, A25, A29 and A30) of the Ranger TV Subsystem	November 4, 1964
RTSP-1151	Test Specification for the Stripline, Four-Port Hybrid Assembly (A24)	January 24, 1964
RSP-1166	Specification for the Current Sensing Group (A40, 41, and A42) of the Ranger TV Subsystem (Block III)	September 22, 1964
RTSP-1166	Test Specification for the Current Sensing Group (A40, A41, and A42) of the Ranger TV Subsystems (Block III)	September 22, 1964
CONTROLS GROUP		
RSP-1161	Specification for the Distribution Control Unit (A34) of the Ranger TV Subsystem	April 7, 1964
RTSP-1161	Test Specification for the Distribution Control Unit (A34) of the Ranger TV Subsystem	June 11, 1964

TABLE 2
LIST OF SPECIFICATIONS AND TEST PROCEDURES FOR THE RANGER TV SUBSYSTEM
(Continued)

RCA Specification and Test Procedure Number	Title	Date of Latest Issue
CONTROLS GROUP (Continued)		
RSP-1162	Specification for the Electronic Clock Assembly (A35) of the Ranger TV Subsystem	April 7, 1964
RTSP-1162	Test Specification for the Electronic Clock Assembly (A35) of the Ranger TV Subsystem	April 6, 1964
RSP-1165	Specification for the Command Control Unit of the Ranger TV Subsystem (Block III)	April 9, 1964
RTSP-1165	Test Specification for the Command Control Unit of the Ranger TV Subsystem (Block III)	October 29, 1964
STRUCTURE GROUP		
RSP-1170A	Specification for the Structural and Thermal Design of the Ranger TV Subsystem	April 9, 1964
RSP-1170A, App. A	Handling Procedures	August 10, 1964
RSP-1170A, App. B	Thermal Shroud Mounting and Removal	November 8, 1964
RSP-1170A, App. C	Mounting Hole Transfer Procedure for the Ranger Spare Shroud Assembly	December 2, 1964
RSP/RTSP-1175A	Specification for the Pressure Vessels of the Ranger TV Subsystem	November 22, 1963
GROUND SUPPORT EQUIPMENT		
RSP-1200A	Specification for the Ground Support Equipment for the Ranger TV Subsystem	April 6, 1964

TABLE 2
LIST OF SPECIFICATIONS AND TEST PROCEDURES FOR THE RANGER TV SUBSYSTEM
(Continued)

RCA Specification and Test Procedure Number	Title	Date of Latest Issue
GROUND SUPPORT EQUIPMENT (Continued)		
RTSP-1200A	Test Specification for the Ground Support Equipment for the Ranger TV Subsystem	April 6, 1964
RSP-1220A	Specification for the Ground Communication Equipment for the Ranger TV Subsystem	April 8, 1964
RTSP-1220A	Test Specification for the Ground Communication Equipment for the Ranger TV Subsystem	April 8, 1964
RSP-1230A	Specification for the Ground Power Supply Equipment for the Ranger TV Subsystem	May 19, 1964
RTSP-1230A	Test Specification for the Ground Power Supply Equipment for the Ranger TV Subsystem	May 19, 1964
RSP/RTSP-1231A	Specification for the Ground Power and Control Equipment (AMR Blockhouse and Shelter Areas) for the Ranger TV Subsystem	June 22, 1964
RSP-1240A	Specification for the TV Recording and Display Equipment for the Ranger TV Subsystem	November 15, 1963
RTSP-1240B	Test Specification for the TV Recording and Display Equipment for the Ranger TV Subsystem	November 8, 1963
RSP-1250A	Specification for the System Test Console for the Ranger TV Subsystem	April 7, 1964
RTSP-1250A	Test Specification for the System Test Console for the Ranger TV Subsystem	April 7, 1964

Section III

Summary of Contractual History

A. GENERAL

RCA participated in the Ranger program from July of 1961 through June of 1965. During the course of the program, 55 modifications to the contract were invoked: some to better define the contract; some to incorporate additional and new requirements because of increased insight into possible problem areas (gained as a result of accumulated test data and various analyses and studies); some to authorize funding for specific tasks; and some to provide funding for special studies. Abstracts of the original letter contract and of those modifications which concern technical and schedule requirements are discussed in the following paragraphs of this section. A Milestone Chart Summary of the contract is given in Section I of this volume.

B. ABSTRACTS OF ORIGINAL LETTER CONTRACT AND MODIFICATIONS DEALING WITH TECHNICAL AND SCHEDULE REQUIREMENTS

Original Letter Contract (dated August 25, 1961)

The original letter contract, JPL No. 950137, dated August 25, 1961, authorized RCA to: (1) Conduct a system analysis to provide a definitive and quantitative description of the Subsystem required for the Ranger high-resolution TV camera missions; (2) Design, develop, fabricate, test, and deliver one PTM and four flight models of the TV Subsystem based on the results of the system analysis; and (3) Initiate purchasing to meet the above requirements. No performance dates were specified.

Modification No. 5 (dated April 18, 1962)

This was the modification which became the definitive contract for the original concept of the Ranger TV Subsystem which was to meet the requirements of the Design Specification for Ranger TV Subsystem, JPL Specification No. 30880, and the Design Requirements and Restraints for Ranger TV Subsystem, JPL EPD-40. Under this definitive contract, RCA was to provide the following items.

- Four flight models of the Ranger TV Subsystem: Flight Model 1 (with 1 set of spare plug-in assemblies) to ETR by September 1, 1962; Flight Model 2 (with 1 set of spare plug-in assemblies and 1 spare structure) to JPL by September 1, 1962; Flight Model 3 to JPL by October 15, 1962; Flight Model 4 to JPL by December 15, 1962.
- One DSIF data recovery system to JPL by August 1, 1962.
- Four sets of Subsystem checkout complex: first set to RCA by January 15, 1962; second set to JPL by April 1, 1962; third set to RCA by May 1, 1962, then to ETR by September 1, 1962; and fourth set to JPL by July 1, 1962.
- One mechanical test model (MTM) to JPL by January 25, 1962.
- One thermal control model (TCM) to JPL by February 28, 1962.
- One Proof Test Model (PTM) to JPL by June 1, 1962.
- One engineering test model (ETM) to JPL by April 1, 1962 for use until the PTM was received at JPL, at which time the ETM was to be returned to RCA for revision and changes. The revised ETM was to be delivered to JPL by July 15, 1962 for use until Flight Model 2 was received at JPL, at which time the revised ETM was to be returned to RCA.

Modification No. 7 (dated April 19, 1962)

This modification authorized a 2-month color-technique study program that was to encompass methods of mechanizing objective color techniques for Flight Models 3 and 4, and consider other possible techniques such as fixed-filter techniques and beam-splitting techniques.

Modification No. 13 (dated October 23, 1962)

This modification amended the statement of work of the definitive contract as follows:

- RCA was to deliver two (one additional) MTM's: MTM 1 to JPL by January 25, 1962; MTM 2, incorporating modifications required to accommodate the Ranger IX flight solar panels, to JPL by October 1, 1962.
- RCA was to perform a simulated 66-hour flight mission with the PTM, in accordance with RCA specification No. 1101, dated June 11, 1962.
- RCA was to modify existing collimators to simulate the color-response range of the vidicons.
- RCA was to furnish one additional camera-cover assembly for use on MTM 1.

Modification No. 14 (dated October 25, 1962)

This modification defined the requirement for a lightweight battery power supply for Flight Model 4 and a redesign of the 22-cell parallel battery configuration to achieve a weight reduction of approximately 34 pounds. RCA was to modify MTM 2 to incorporate this battery configuration; this modification work was to be performed at JPL.

Modification No. 16 (dated November 16, 1962)

This modification amended the definitive contract by adding the following work for 5 additional flight models, designated models Block IV-1 through IV-5.

- RCA was to provide five additional flight models as described in JPL Specification No. 30880 plus one spare structure and two sets of spare plug-in assemblies;
- RCA was to conduct camera performance improvement studies for the Ranger TV Subsystem.

Modification No. 19 (dated December 28, 1962)

The scope of work of the definitive contract was amended as follows. RCA was to deliver:

- One ETM to JPL by May 28, 1962 for use until PTM was received at JPL, at which time the ETM was to be returned to AED for revision and changes. The revised ETM was to be delivered to JPL by August 13, 1962 for use until Flight Model 2 was received at JPL, at which time the revised ETM was to be returned to AED;
- One PTM to JPL by July 1, 1962;
- Flight Model 1 to JPL (instead of to ETR) by September 7, 1962;
- Flight Model 2 to JPL by September 15, 1962;
- Flight Model 3 to JPL by November 1, 1962;
- Flight Model 4 to JPL by December 31, 1962.

RCA was to conduct environmental tests on the JPL 2A21 high-gain antenna, 2A20 rotary joint, and 2A15 directional coupler in conjunction with the RCA Subsystem transmitter chain to ensure against arcing in the overall communications link when subjected to a space environment.

Modification No. 20 (dated December 28, 1962)

RCA was to conduct a one-month Subsystem study and reliability analysis prior to the first flight of the Ranger TV Subsystem to culminate in recommendations on the desirability of modifying mission requirements and/or Subsystem configuration to enhance the probability of mission success. (This was a prelude to the split-system configuration.) RCA was to make an oral presentation at JPL during the week of February 4, 1963.

Modification No. 21 (dated January 28, 1963)

This amendment to the statement of work affected the lightweight battery power supply for Flight Model 4 only. RCA was to redesign the present 2-22 cell parallel battery configuration to provide a 2-12 cell series battery configuration with a weight reduction of approximately 38 pounds. RCA was to rework MTM 2 to meet the resultant requirements.

Modification No. 23 (dated January 23, 1963)

This modification amended the statement of work of the definitive contract by adding the following work.

- RCA was to conduct a design study which was to include at least an investigation of two separate and independent redundant video chains, as described in the RCA Ranger TV Subsystem Presentation Brochure, dated January 17, 1963; and an investigation of increased lens capability with regard to extending the field-of-view coverage and light-gathering power. A design study report was to be provided to JPL by March 15, 1963.
- RCA was to modify the PTM, consistent with both the design study and the results of the Subsystem study and reliability analysis. The modified PTM (called the Block III PTM to designate the split-system configuration) was to be tested by RCA under the surveillance of JPL technical personnel. The PTM test plan was to be delivered to JPL March 15, 1963 for review and approval. Also, RCA was to deliver the modified (Block III) PTM to JPL by April 15, 1963.
- RCA was to deliver a design modification plan for Flight Models III-1 through III-4, and supporting spares, to JPL by April 15, 1963.
- RCA was also to deliver Flight Model III-1 (with one set of spare plug-in assemblies) to JPL by June 1, 1963; Flight Model III-2 (with one set of spare plug-in assemblies and one spare structure) to JPL on a date to be specified by JPL; Flight Model III-3 to JPL by July 1, 1963; and Flight Model III-4 to JPL by August 1, 1963.

Modification No. 24 (dated March 20, 1963)

The statement of work was amended as follows:

- RCA was to furnish two MTM's to be tested in accordance with JPL Specification No. 30236A, dated October 20, 1961, as amended by JPL Report No. 315-183, dated April 16, 1962.
- RCA was to conduct environmental tests on the JPL high-gain antenna to be completed by September 1, 1962. The test was to be conducted using an RCA-designed filter capable of rejecting noise at 890.046 Mc. RCA was to provide a test report upon request from JPL.

Modification No. 26 (dated March 26, 1963)

Under this modification to the definitive contract, RCA was to:

- Incorporate the design and system changes required to convert Flight Models 1, 3, and 4 to split-system configurations and become Flight Models III-1, III-2, and III-3. In addition to the design and system changes resulting from the Ranger TV Subsystem reliability and mission probability improvement program, the following new items were to be added to the Flight Models: a dummy-load pressure vessel; a DCU and new HCVR; and a timing mechanism to provide backup for the Subsystem turn-on command.

- Develop a 2-inch lens capability for one F-camera on a noninterference basis.
- Fabricate and test Flight Model III-4 (identical to Flight Models III-1, III-2, and III-3) using spare assemblies where possible.

Except for Flight Model 2 which was still required to be delivered to JPL by February 19, 1963 for use as a life test model (LTM), RCA was to deliver to JPL the following split-system configurations of the Ranger TV Subsystem:

- Flight Model III-1 by August 1, 1963;
- Flight Model III-2 by September 1, 1963;
- Flight Model III-3 (with two sets of spare plug-in assemblies and one spare structure) by October 1, 1963;
- Flight Model III-4 by November 1, 1963.

Modification No. 29 (dated May 10, 1963)

This modification added to the definitive contract the following work.

- The design study for the split-system configuration, and the modification program for the Block III PTM, as defined in Modification No. 23, were reiterated.
- The required delivery date of the modified Block III PTM to JPL was changed from April 15, 1963 to May 1, 1963.
- The required delivery date of the design study report to JPL was changed from March 15, 1963 to April 15, 1963.
- RCA was to evaluate the feasibility, suitability, and/or performance of the split-system design considerations using the MTM's and the TTM which were furnished to JPL. These models were to be made available to RCA by JPL.

Modification No. 35 (dated October 18, 1963)

This modification authorized RCA to:

- Institute a camera performance optimization program on Flight Models III-3 and III-4 (formerly designated as Flight Models 4 and 5);
- Design, fabricate, test, and deliver three flight model handling fixtures (design drawings to be approved by JPL);
- Modify P-Channel Transmitter of the LTM (formerly designated as Flight Model 2) to incorporate Resdel IPA, and perform environmental tests in accordance with JPL Specification No. RCT 50040-ETS. The results were to be reported in the LTM Resdel IPA test report.

RCA was to deliver:

- Flight Model III-1 (formerly Flight Model 3) to JPL by August 6, 1963 (delivered);
- Life test model (formerly Flight Model 2) to JPL by February 19, 1963 (delivered);
- Flight Model III-2 (formerly Flight Model 3) to JPL by September 27, 1963;
- Flight Model III-3 (formerly Flight Model 4) to JPL by January 13, 1964;
- Flight Model III-4 (formerly Flight Model 5) to JPL by March 9, 1964.

Modification No. 37 (dated November 1963)

This modification defined the work to be performed as Block III (Modification No. 26). All work was to be accomplished in accordance with JPL Specification No. EDP-156, Rev. 1, titled TV Subsystem Requirements for Ranger Block III, dated August 14, 1963; and with JPL Specification No. FR 3-4-110A, titled Functional Specification for Ranger Block III Flight Equipment TV Subsystem, dated August 14, 1963.

RCA was to deliver:

- Four flight models (described by JPL Specification No. FR 3-4-110-A);
- One LTM, described by JPL Specification No. 30880 and RL-4-180;
- Two sets of spare plug-in assemblies;
- One spare structure; and
- A design plan and environmental test plan for Block III to JPL by May 20, 1963.

Work on the LTM was to be accomplished as follows:

- The condition of the LTM was to be established by ambient condition testing. All assemblies were then to be removed from the LTM structure and tested to ascertain the effects of all prior testing.
- The following items were to be reworked to flight configuration, bench tested, and returned to the Ranger integration area without being environmentally acceptance tested: Sequencer Power Supply, HCVR, LCVR, and Command Switch. These items were to be used as spares for the PTM to be delivered to JPL by October 1, 1963.
- The following items were to be reworked to flight configuration: F-Channel Transmitter, Transmitter Power Supplies, Structure, and Thermal Shield. The F-Channel Transmitter and Transmitter Power Supplies were to be acceptance tested in accordance with RCA Specification No. 1171807. These items were to be used as spares for the flight models to be delivered to JPL by October 15, 1963.
- All vidicons and yokes were to be removed from camera heads and their applicability for flight use ascertained.

Modification No. 39 (dated January 21, 1964)

This modification defined the camera performance optimization program (Modifications 36 and 37) and partially terminated the Block IV effort. The terminated portions were discussed in the second bimonthly progress report for the Block IV Ranger TV Subsystem which was effectively the final report for the Block IV effort (AED R-2086, dated October 1, 1963). The unterminated portions, which were essentially related to vidicon improvements, were incorporated into the Block III effort.

RCA was to deliver:

- Flight Model III-1 to JPL by August 6, 1963 (delivered);
- LTM to JPL by February 19, 1963 (delivered);
- Flight Model III-2 to JPL by September 27, 1963 (delivered);
- Flight Model III-3 to JPL by January 13, 1964;
- Flight Model III-4 to JPL by March 9, 1964.

Modification No. 40 (dated February 19, 1964)

RCA was to perform the following on the PTM:

- Ship the PTM from JPL to AED;
- Conduct 100-percent inspection of all assemblies;
- Conformally coat all exposed terminals and pot exposed connectors on assemblies that would not require further rework as a result of design changes;
- Conduct pin-retention tests on all assembly and harness connectors.

RCA was to review the design for Flight Models III-2, III-3, and III-4 to:

- Arrive at a final recommended design configuration of a revised command system, supported by breadboard tests;

- Provide final design recommendations for the deletion of unused or unnecessary functions in the umbilical harness;
- Develop techniques for pin-retention tests, 100-percent reinspection of all TV Subsystem assemblies, conformal coating of exposed terminals, and potting of exposed connectors;
- Provide recommendations for desired venting of all TV Subsystem assemblies;
- Review and define modifications to OSE as a result of modifications to the TV Subsystem.

RCA was to conduct on Flight Model III-2 the work originally required by Modification No. 40 on the PTM, upon receiving approval from JPL of the techniques used and results obtained by RCA on the PTM.

Modification No. 41 (dated April 3, 1964)

RCA was to deliver two sets of wavemeters to JPL and AED by February 14, 1964. The AED unit was to be delivered subsequently to JPL with Flight Model III-4. RCA was to design and fabricate three pivot mount fixtures for delivery to JPL, ETR, and RCA by February 28, 1964. The fixture retained at RCA was to be delivered subsequently to JPL with Flight Model III-4.

RCA was to have two sets of spare assemblies available for shipment to JPL-designated locations concurrent with the delivery of Flight Models III-2 and III-3.

Modification No. 42 (dated March 13, 1964)

This modification amended Modification No. 40 to extend the period for execution and the limitation on percentage of work completion of the formal supplemental agreement contemplated by Modification No. 40.

Modification No. 45 (dated May 1, 1964)

- Prepare ten Resdel Intermediate Power Amplifier (IPA) modification kits for use as follows: two for the PTM; two for Flight Model III-3; two for Flight Model III-4; four for flight spares.
- Revise ten transmitter assemblies by incorporating the Resdel IPA modification kits. This rework activity was <u>not</u> to commence until after the flight of Ranger VII Spacecraft <u>and</u> upon written notification by JPL to proceed.
- Revise drawings and specifications as necessary.

RCA was to furnish and deliver the supplies and services in accordance with the following schedules:

- Modification kits: two on or before June 15, 1964; four on or before July 1, 1964; four on or before July 20, 1964.
- Revised transmitter assemblies (based on a July 1, 1964 notification to proceed with the rework effort): two on or before July 30, 1964; four on or before August 15, 1964; four on or before September 1, 1964.
- Revised drawings and specifications on or before July 30, 1964.

Modification No. 52 (dated July 22, 1964)

This modification provided for the following amendments to the effort.

- RCA was to conduct a program of analysis, detail design, fabrication, testing, delivery, installation and checkout, operations, data recovery and reporting related to the Ranger TV Subsystem. All work, except as specified, was to be accomplished in accordance with the requirements of JPL Specifications EPD-156, Rev. 1, <u>TV Subsystem Requirements for Ranger Block III</u>, dated August 14, 1963, as amended by Amendment 1 dated April 22, 1964; FR3-4-110A <u>Functional Specification Ranger Block III Flight</u>

Equipment Television Subsystem dated August 14, 1963; and FR3-4-110B Functional Specification Ranger Block III Flight Equipment Television Subsystem, dated April 22, 1964.

RCA was to deliver items and services as follows:

- Flight equipment: one flight model as described in JPL Specification FR3-4-110A Functional Specification Ranger Block III Flight Equipment Television Subsystem, dated August 14, 1963; three flight models as described in JPL Specification FR3-4-110B Functional Specification Ranger Block III Flight Equipment Television Subsystem, dated April 22, 1964; one flight model, designated the life test model (LTM), as described in JPL Specifications 30880 and RL-4-180; and one spare structure and two sets of spare assemblies, to consist of a minimum of the items (shown in Table 3) necessary to completely maintain the flight-ready condition of flight hardware, except that cameras were to be contained in one set of spares only.
- Ten Resdel Intermediate Power Amplifier (IPA) modification kits for use as follows: two for the PTM; two for Flight Model III-3; two for Flight Model III-4; four for flight spares.
- Revise ten Transmitter Assemblies by incorporating the Resdel IPA modification kits.
- Revise drawings and specifications as necessary.
- Furnish a mechanized offset indenture listing of all TV Subsystem drawings to the part level for Flight Model III-2 only, including a numerical list of drawings and a summary of all parts used on Flight Model III-2 as of June 1, 1964.

A new portion of the program was added. It required RCA to make design and system changes to Ranger TV Subsystems, Flight Models III-2, III-3, III-4 and the PTM, originally designed under this contract. This program was to consist of, but not necessarily be limited to, review of the design, rework implementation and testing. The work to be performed under this portion of the program was described in Addendum 1 under Amendment No. 1, dated April 22, 1964, to JPL Specification EPD-156, Rev. 1, TV Subsystem Requirements for Ranger Block III, dated August 14, 1963.

The delivery schedule was to be as follows:

- Flight equipment: Flight Model III-1 (delivered August 21, 1963); life test model (delivered February 19, 1963); Flight Model III-2 (originally delivered September 27, 1963) as modified, on or before May 1, 1964 (accomplished); Flight Model III-3 (originally delivered January 4, 1964) modified assemblies only, through flight acceptance testing phase on or before July 10, 1964; Flight Model III-4 modified assemblies only, through flight acceptance testing phase on or before June 30, 1964; and two sets of spare assemblies to be available for shipment to JP L-designated locations, one set concurrent with delivery of Flight Model III-2, and one set on or before May 25, 1964 (accomplished).
- Operational support equipment (modified) to support TV Subsystem flight testing, to be available on or before May 12, 1964 (accomplished).
- One PTM (originally delivered June 21, 1963) as modified, on or before April 3, 1964 (accomplished).
- Pivotal mount fixtures: one with the PTM (accomplished); one with Flight Model III-2 (accomplished); and one as directed (available February 28, 1964).
- Wavemeter sets: one on or before February 14, 1964 (accomplished); and one

TABLE 3
CONTENTS OF SPARE SETS

Item	Quantity	
	Spare Set 1	Spare Set 2
Video Combiner	1	1
Control Programmer and Camera Sequencer	1	1
Sequencer Power Supply	1	1
P-Channel Transmitter	1	1
F-Channel Transmitter	1	1
Transmitter Power Supply	1	1
Power Amplifier	1	1
Telemetry Assembly	1	1
Telemetry Processor	1	1
Dummy Load	1	1
4-Port Hybrid	1	1
High-Current Voltage Regulator	2	1
Low-Current Voltage Regulator	1	1
Command Control Unit	1	1
Current Sensing Unit	1	1
Temperature Sensor	1	1
Distribution Control Unit	1	1
Electronic Clock	1	1
Cable Harness	1	none
Filter Box	1	1
Batteries	2	none
Cameras:		
Partial Scan (P)	4 (1 each of P1, P2, P3, P4)	none
Full Scan (F)	2 (1 each of F_a and F_b)	none

with Flight Model No. III-2 (accomplished).

- Resdel IPA: two modification kits on or before June 22, 1964; four modification kits on or before July 7, 1964; and four modification kits on or before July 27, 1964.
- Transmitter Assemblies: two revised Transmitter Assemblies on or before August 6, 1964; four revised Transmitter Assemblies on or before August 17, 1964; and four revised Transmitter Assemblies on or before September 4, 1964.
- Offset indenture listing: indenture drawing listing, twelve copies on or before June 15, 1964 (accomplished); numerical list, twelve copies on or before June 30, 1964; and parts summary, twelve copies on or before June 30, 1964.

Modification No. 53 (dated July 24, 1964)

This modification provided for RCA to integrate, test, and provide field support for the Ranger TV Subsystem Flight Models III-3 and III-4, for which the subassemblies and assemblies were fabricated and tested in accordance with Addendum 1 to JPL Specification EPD-156, Rev. 1, TV Subsystem Requirements for Ranger Block III, dated April 22, 1964, including certain modifications, requalification testing and new equipment not provided in previous effort. RCA was to perform the following:

- Mechanically and electrically integrate Flight Models III-3 and III-4, and perform environmental and system tests in accordance with RCA Specifications RSP 1100A and RTSP 1100A.
- Evaluate two methods for turning on the Ranger TV Subsystem, as alternates for the silicon-controlled rectifier (SCR) based turn-on method currently in effect. The two alternate methods were a transistor-relay circuit (TRC) and an all-relay circuit (ARC). The tasks to be performed were to permit an evaluation and to qualify both methods, the ARC and TRC, for flight acceptance. Work on both the ARC and TRC was to proceed in parallel, with a higher priority given to the ARC. Documentation covering design work and testing on the ARC, which had been accomplished at JPL, was available for contractor's use and was to be utilized wherever feasible.
- Procure and fabricate eight repackaged, space-qualified High-Current Voltage Regulators (HCVR) for the flight units. The HCVR design was such that either the ARC or TRC could be incorporated with minimal modification, since the TRC used all of the ARC circuitry except the arc suppression. Upon incorporation of ARC or TRC in models, the HCVR was to be subjected to acceptance testing per RCA Specification No. 1171807.
- RCA was to conduct a requalification test (vibration and thermal-vacuum only) of the Resdel IPA system level tests. The Resdel IPA was to be subjected to QTM levels per RCA Specification 1171-807 in the x, y, and z axes. There was to be a special sweep in the z axis only between 70 and 90 cps at 11g rms, a sweep 70 to 90 cps in 35 seconds, and 90 to 70 cps in 35 seconds. Upon completion of the special sweep, the thermal-vacuum test was to be rerun.
- RCA was to modify the operational support equipment (OSE) cables from the power control relay assembly to the TV Subsystem battery connectors in order to accommodate the addition of the 30J14 connectors. In addition, RCA was to design, fabricate, assemble, test, conformally coat, and inspect six sets of interface OSE cables.
- RCA was to replace Raytheon 2N320A transistors in the P1 Cameras (for Flight Models III-3, III-4 and spare sets)

with Sperry or National 2N329 transistors. Reworked cameras were to be bench-tested to the applicable RCA test specifications.

- RCA was to fabricate, test, and install an improved synchronization system on four sets of OSE. Circuitry design was to be mutually acceptable to RCA and JPL, prior to fabrication and installation of the improved system.

- RCA was to amend its failure reporting and analysis system procedures to include the following. During field operations at JPL and Cape Kennedy, RCA personnel were to utilize the JPL problem failure report, form No. JPL-1290 (January 1964), to report all problems and/or failures on the TV Subsystem. The form was to be initiated jointly by members of the RCA and JPL teams assigned to specific spacecraft. Both originators were to sign the form and submit copies to their respective failure-reporting groups. It was to be the responsibility of RCA to handle the JPL P/FR form in the same manner as the AED failure analysis form, and to assure proper and expeditious closeout of stated problems and failures. The form was to be reviewed and signed by the RCA project assurance reliability engineer, the RCA Project Manager, and the JPL TV Subsystem project engineer. One copy of each completed form was to be transmitted to JPL, Pasadena, under cover memorandum.

- RCA was to amend field support procedures to provide two groups of payload-oriented field service personnel for the Ranger VIII and IX Spacecraft missions. One group was to provide support to the Ranger VIII TV Subsystem; the other group was to support the PTM effort at JPL until the Ranger IX TV Subsystem was ready for integration, at which time it was to assume support duties for that Subsystem.

- RCA was to conduct torsional mode and vibration (x and y axes) tests on the PTM at JPL.

- RCA was to rework the PTM cable harnesses, after the flight of the Ranger VII Spacecraft, to make them electrically equivalent to those harnesses supplied for Flight Models III-3 and III-4. The rework was to include, but not be limited to, the addition of separate connectors for P- and F-Channel Batteries and provision for incorporation of either the power-relay, or transistor-switch, turn-on device. Upon written request, JPL would furnish two Current Sensing Transformers for use in the harness modification.

RCA was to furnish and deliver the supplies and services in accordance with the following schedules:

- The PTM torsional mode and vibration tests were to be completed on or before July 15, 1964.

- The transistor replacement was to be completed on or before July 15, 1964.

- The Resdel IPA requalification test was to be completed on or before July 30, 1964.

- The modification to the OSE cables was to be completed on or before July 30, 1964.

- The evaluation of an alternative to the SCR: the design, testing, and qualification tasks were to be completed on or before July 31, 1964. If the alternative were adopted, then: (1) the fabrication of flight-qualified HCVR was to be completed on or before August 14, 1964; (2) the weekly summary progress letters were to be submitted by Tuesday of the following week; (3) the drawings and specifications were to be released on or before August 31, 1964; and (4) a final engineering report was to be submitted on or before August 31, 1964.

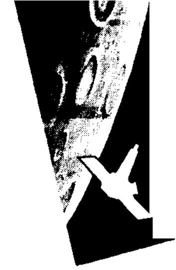
- OSE synchronizing improvement: the circuitry design was to be completed on or before August 1, 1964; and the installation was to be completed on or before September 1, 1964.
- The PTM cable harness rework was to be completed on or before September 1, 1964, based on the availability of the PTM to RCA by August 15, 1964.
- Integrated and tested TV Subsystems: Flight Model III-3 on or before October 1, 1964; and Flight Model III-4 on or before November 1, 1964.

Modification No. 55 (dated October 20, 1962)

This modification provided for RCA, as the Ranger TV Subsystem manager, to conduct a program of analysis, detail design, fabrication, testing, delivery, installation and checkout, operations, data recovery and reporting related to the Ranger TV Subsystem. All work, except as specified hereafter, was to be accomplished in accordance with the requirements of JPL Specifications EPD-156, Rev. 1, TV Subsystem Requirements for Ranger Block III, dated August 14, 1963, as amended by Addendum 1, dated April 22, 1964, and Addendum 2, dated September 20, 1964; FR 3-4-110A Functional Specification Ranger Block III Flight Equipment Television Subsystem, dated August 14, 1963; and FR 3-4-110C Functional Specification Ranger Block III Flight Equipment Television Subsystem, dated July 1, 1964, and the specifications incorporated.

Deliverable items and services were as follows:

- Flight equipment: three flight models as described in JPL Specification FR3-4-110C Functional Specification Ranger Block III Flight Equipment Television Subsystem, dated July 1, 1964.
- Design and system changes: RCA was to make design and system changes to Ranger TV Subsystems, Flight Models III-2, III-3, III-4 and the PTM, designed under this contract. This program was to consist of, but not necessarily be limited to, review of the design, rework implementation and testing. The work to be performed under this portion of the program was described in Addendum 1, dated April 22, 1964, and Addendum 2, dated September 20, 1964, to JPL Specification EPD-156, Rev. 1, TV Subsystem Requirements for Ranger Block III, dated August 14, 1963.
- Flight Equipment was to be delivered according to the following schedule: Flight Model III-1 (delivered August 21, 1963); LTM (delivered February 19, 1963); Flight Model III-2 (originally delivered September 27, 1963) as modified, on or before May 1, 1964 (accomplished); Flight Model III-3 (originally delivered January 4, 1964) as modified, on or before October 6, 1964; Flight Model III-4 as modified, on or before November 16, 1964; two sets of spare assemblies to be available for shipment to JPL-designated locations, one set concurrent with the delivery of Flight Model III-2, and one set on or before May 25, 1964 (accomplished); operational support equipment (modified) to support TV Subsystem flight testing, to be available on or before May 12, 1964 (accomplished).



Section IV

Summary of TV Subsystem Design

A. GENERAL

The TV Subsystem was the means by which the primary data-gathering function of the Ranger mission was performed. This self-contained unit provided the power, control, and communications equipment for collecting, processing, and transmitting the pictorial information of the lunar surface. In a normal mission, the picture-taking sequence was initiated by an earth-generated command, with the first picture taken at an altitude of approximately 2000 kilometers from the lunar surface and continuing uninterrupted until lunar impact. The initial pictures covered a wide area of the moon at resolutions comparable to that obtained by earth-based telescopes.

Area coverage was traded for increasing resolution as the TV Subsystem approached impact at a terminal velocity of 2700 meters per second, until resolutions of 0.5 meter, or better, were achieved in the final picture sequence.

The TV Subsystem contained many elements, such as the six cameras, sequencers, two transmitters, telemetry assembly, two batteries, and power supplies. The TV Subsystem was electrically complete and independent of the spacecraft Bus, with the exception of commands received either from the Bus command system or the CC&S (central computer and sequencer) system and the utilization of the Bus high-gain directional antenna. In addition, in the Ranger VII, VIII, and IX configurations the TV Subsystem turn-on circuitry was locked out by the Bus during the boost phase of flight to prevent any premature turn-on of the TV Subsystem.

The TV Subsystem was separated into two essentially independent channels of operation to ensure a maximum probability of mission success. Channel separation is illustrated in Figure 5. Each channel provided the functional components required to collect, process, and transmit the video information of the lunar surface. The channel separation was a function of the distinction between the two types of cameras employed: full-scan and partial-scan. Both types employ ruggedized 1-inch vidicon television tubes with a highly sensitive photoconductive target as the image transducer. The high sensitivity of these vidicons dictated an image retention characteristic which required that their photoconductive surface be brought to a uniform potential, or the image erased, after a frame readout and prior to a subsequent exposure to prevent a double image. To provide for maximum utilization of the communications equipment, multiple cameras, operating during each other's erase cycles, were used to fill what would otherwise be nonproductive portions of the available transmission time.

B. DESIGN PHILOSOPHY AND IMPLEMENTATION

The philosophy behind the design of the TV Subsystem was to make it as self-sufficient as possible and also to provide for as much redundancy as necessary to ensure meeting the mission objectives.

The basic design of the TV Subsystem was reflected in the camera and communications areas. In considering a television system for the lunar-impacting mission, factors such as lunar luminance and approach velocity and the resulting image smear had a profound effect on the camera design. The RF-channel allocations and the assignment of Goldstone's maser-equipped 85-foot-diameter antenna to the Ranger mission also had their effect on the camera design and on the design of the telecommunications system. The RF allocations

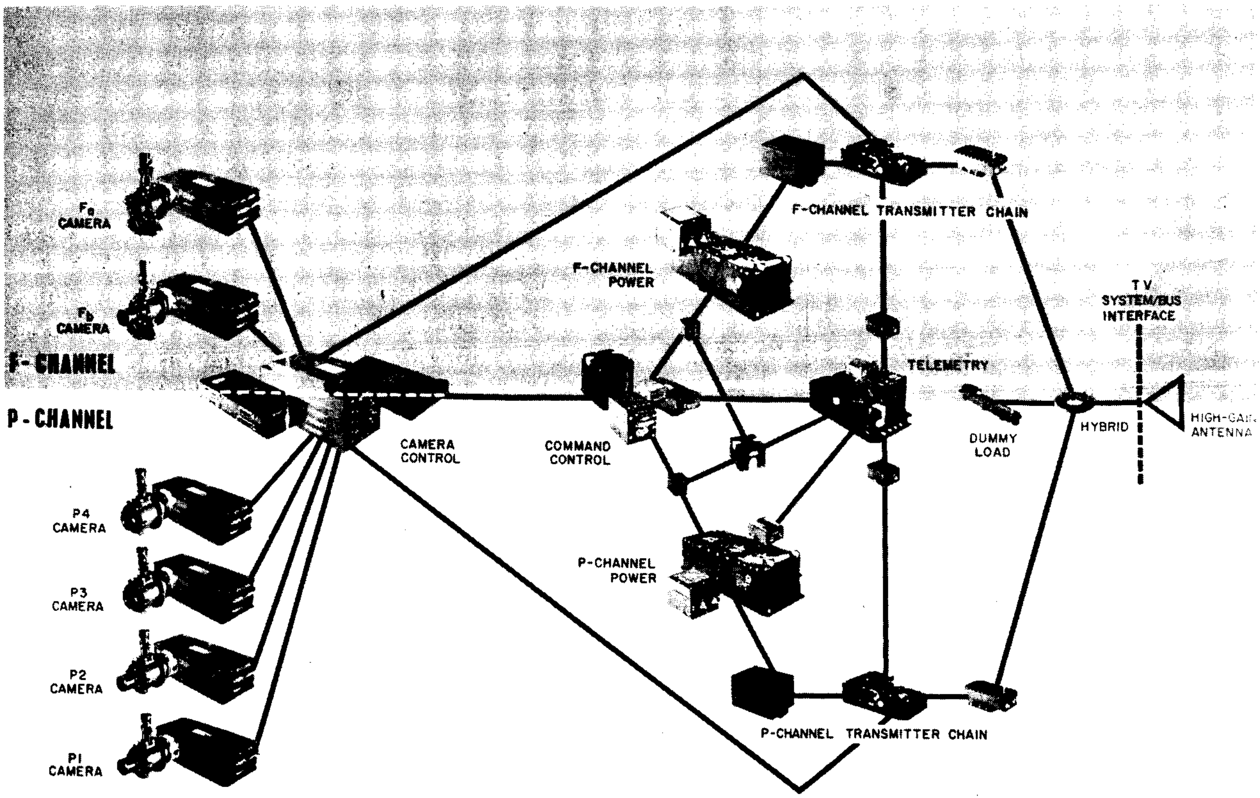


Figure 5. Channel Separation of the Ranger TV Subsystem

provided two separate channels, each with a bandwidth of 900 kc. A review of L-band transmission and modulation systems suggested that a standard FM system would provide overall simplicity in video transmission and retrieval for eventual display and recording. Two conflicting system criteria—that rapid informational gathering requires a large video bandwidth and high signal-to-noise ratios, and that advantageous use of an FM system requires as large a deviation as possible—were traded off to allow a maximum video bandwidth of about 200 kc with a deviation ratio near unity. This was the largest informational channel bandwidth yet made available for space applications; however, it was considerably smaller than standard commercial-television channel allocations. The implications were two-fold: that the television camera would need to be designed using the slow-scan techniques pioneered in earlier space missions by Radio Corporation of America (RCA) and that a reliable transmitter with considerably higher power output than previously used would be required to span the 240,000-mile cislunar distance.

Utilization of this 200-kc bandwidth for camera video was then dependent on the realization of a telecommunications system operating with existing DSIF elements that would provide video signal-to-noise ratios in excess of 30 decibels even at threshold. Parameters available for early consideration, shown in Table 4, indicated that a transmitter power of 15 decibels above one watt would be required for single-channel operation, and that if simultaneous transmissions over both channels were

TABLE 4
SUMMARY OF COMMUNICATIONS PARAMETERS

Item	Value
Losses:	
JPL circuit losses	1.7 db
Spacecraft antenna	-18.1 db
Antenna pointing	0.3 db
Path loss	204.5 db
DSIF antenna	-45.7 db
Receiving circuit	0.4 db
Total	143.1 db
System noise temperature	128.9° K
Noise bandwidth	~800 kc
Receiver noise power	-148.5 db w
Transmitter power	17.8 db
RF combiner and cable losses	3.5 db
Received carrier-to-noise ratio	19.5 db

desired, an additional 3 decibels of power would be required to overcome losses in the RF-combining network. It became clear that the probability of mission success would be best served by simultaneous operation of two transmitting channels. The transmitting channels operated in the following manner. Inputs to the FM modulator were video frequencies from DC to 200 kc and telemetry information in the band of 220 to 230 kc. The modulator consisted of baseband amplifiers, a crystal-stabilized voltage-controlled oscillator (VCO), and a buffer amplifier. The center frequency of the VCO was 1/48 of the final transmitted signal. The VCO operated at about 20 Mc. Both the deviation and center frequency were increased by a factor of 48 through two varactor doublers and a varactor tripler in the X12 stage and a single-stage varactor quadrupler in the X4 stage. The output was 960 Mc at 150 milliwatts. In the Ranger VI and VII configuration, the IPA cavity used an RCA type 7870 tetrode power amplifier to increase the power level to about 6 watts, and the Machlett-type 3CX100A5 was used as the IPA in the Ranger VIII and IX configurations. The final boost to an output power of 60 watts was provided by a Resdel cavity utilizing a Machlett-type ML-7855 triode operating class "C." The power amplifiers and dummy load were pressurized at 15 psi and the Four-Port Hybrid Ring was of a solid-state design to prevent multipactor and RF arcing at this power level.

With the question of the design of transmitters capable of propagating 900 kc of RF bandwidth at the lunar distance firmly answered, the camera design utilizing the full 200-kc bandwidth also moved ahead.

A ruggedized 1-inch-diameter RCA ASOS* vidicon was the key element in the Ranger television camera design. It provided the sensitivity required to capture a latent image during the brief shuttered exposure as the camera platform hurtled toward the Moon at speeds approaching 2700 meters per second. This vidicon effectively stored the latent image while it was converted to an electrical analog signal by operating the camera in a slow-scan mode, and it provided a fine enough scanning aperture to achieve a significant modulation at spatial frequencies of 35 optical line pair per millimeter. These factors weighed heavily in selecting this vidicon as the camera sensor

*Antimony sulfide-oxygen sulfide, a vidicon target material.

Reliable operation with minimum weight and power also imposed significant constraints on the camera design. A scanning system was developed which utilized the vidicon's limiting response of 35 optical line pair per millimeter over an active photoconductor area of 11.4 by 11.4 millimeters. The informational content of the generated video signals could be contained in the allocated 200-kc bandwidth by permitting the entire photoconductive area to be scanned with 1132 scanning lines in 2.56 seconds. It became clear, as a probable terminal sequence (shown in Figure 6) was examined, that a closing speed of about 2700 meters per second would be achieved. At that speed, the final full picture possible would be taken at an altitude of 6500 meters. Optical systems under consideration (such as the Bausch and Lomb 76-millimeter f/2 Super Baltar) at the 35-optical-line-pair-per-millimeter system resolution would result in lunar resolution of about 2.5 meters per optical line pair, an order of magnitude larger than the system expectations. It would be necessary to get

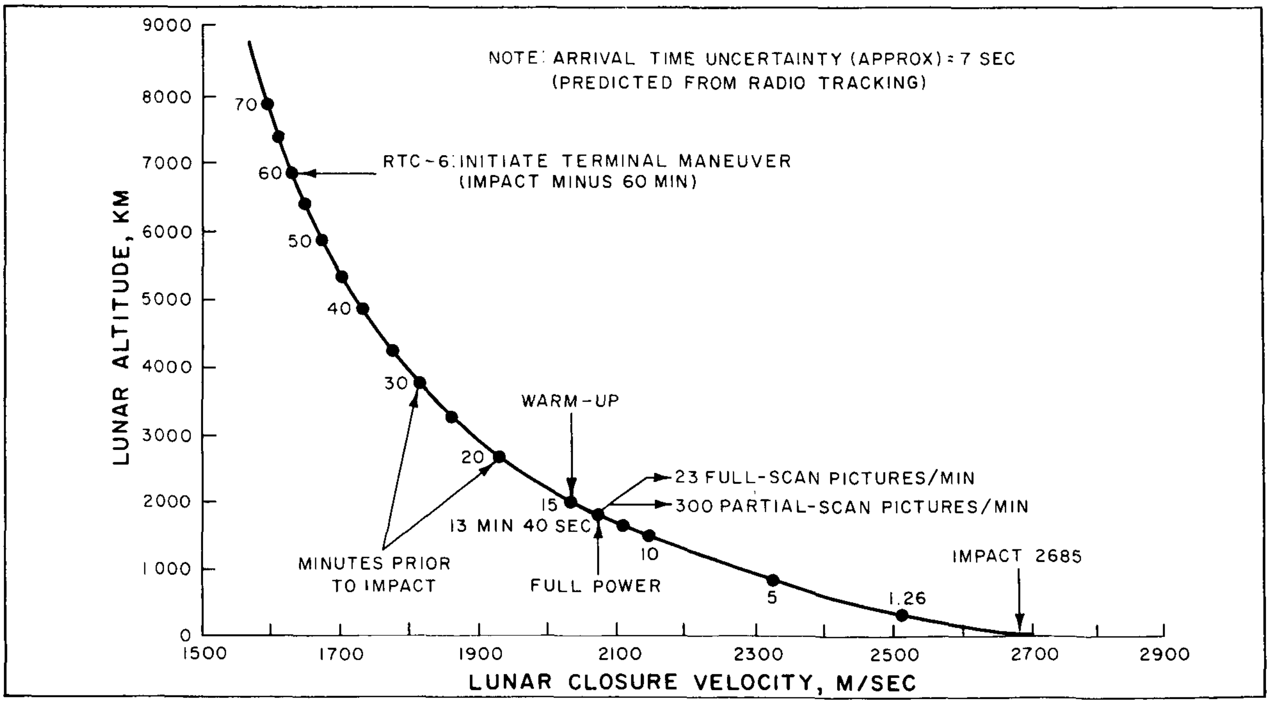


Figure 6. Lunar Closure Velocity

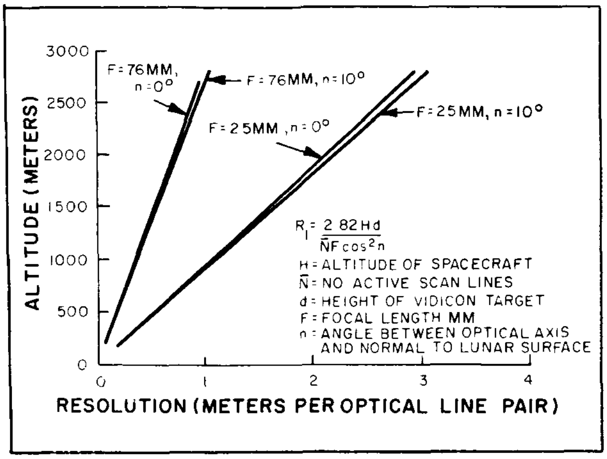


Figure 7. Intrinsic Resolution vs. Lunar Altitude

closer to the Moon to improve on the final lunar detail if this optical system was to be used. As shown in Figure 7, the desired detail would be achieved if the final picture could be taken a fraction of a second before impact. With the 200-kc bandwidth limitation it would be necessary to reduce the informational content in this last picture by a ratio of almost 16 to 1. A partial-scan camera was conceived which used all of the equipment of the 2.56-second-scan full-scan camera but arranged to utilize this informational and scanning density in a 2.8-millimeter-square area on the photoconductor.

The basic difference in the design of the two types of cameras, therefore, was in the area scanned on the vidicon faceplate and, thus, the time required to read out the stored image. Continued refinement of the cameras led to the final designs as outlined in Table 5.

At the 2600-meter-per-second approach velocity image smear would definitely be a constraining item on photographing detail less than a meter per optical pair. A focal-plane shutter capable of a million operations had been developed for the TIROS program. This shutter,

TABLE 5
CAMERA PARAMETERS

	Full-scan		Partial-scan	
	F_a	F_b	P3, P4	P1, P2
Lens	25-mm f/0.95	76-mm f/2	25-mm f/0.95	76-mm f/2
Shutter	5 msec		2 msec	
Line rate	450 cps		1500 cps	
Frame time	2.56 sec		0.2 sec	
No. of active scan lines	1132		290	
Photoconductor area	11.4 mm x 11.4 mm		2.8 mm x 2.8 mm	
Vidicon	RCA ASOS vidicon		RCA ASOS vidicon	
Weight: Camera	7.0 lb		6.5 lb	
Electronics	6.5 lb		6.5 lb	
Power	13 w		12.0 w	

modified to provide a 2-millisecond exposure, was used in the Ranger camera. With this image-immobilization technique, it was possible to reduce translational smear and edge blur to less than the acceptable 0.25 to 0.3 optical line pair for the last or next-to-last picture taken for reasonable trajectories (Figure 8). It became evident that the sensitivity of the RCA manufactured ASOS vidicon would be required to capture the latent lunar image with an exposure of 2 milliseconds. A review of lunar regions of interest indicated that average brightness was to be on the order of 200 to 400 footlamberts for maria regions about 20 degrees from the terminator. This amount of lunar luminance, the exposure required to immobilize the image, the lens aperture ratio, and the integrated illumination of the vidicon's photoconductor are related in the following equation:

$$E\,(ft\text{-}c\text{-}sec) = \frac{B}{4}\,\frac{T\Delta t}{(F/No.)^2}$$

where

B = lunar brightness

T = lens transmission

Δt = exposure time

For the 76-millimeter f/2 lens and a 2-millisecond exposure, the energy on the photoconductor would be about midway on the vidicon transfer curve.

The camera system design now seemed near at hand as the application of this sensitive vidicon in a slow-scan camera was reviewed. It became apparent that the storage capability of the ASOS vidicon would cause residual images on subsequent readouts and that some provision would have to be included in the camera to reduce these residual images remaining from previous exposures. To accomplish this, a ring of erase lamps was located in the camera yoke so that they could flood the photoconductor with light, thus discharging each element of the photoconductor surface after the normal video had been read out (see

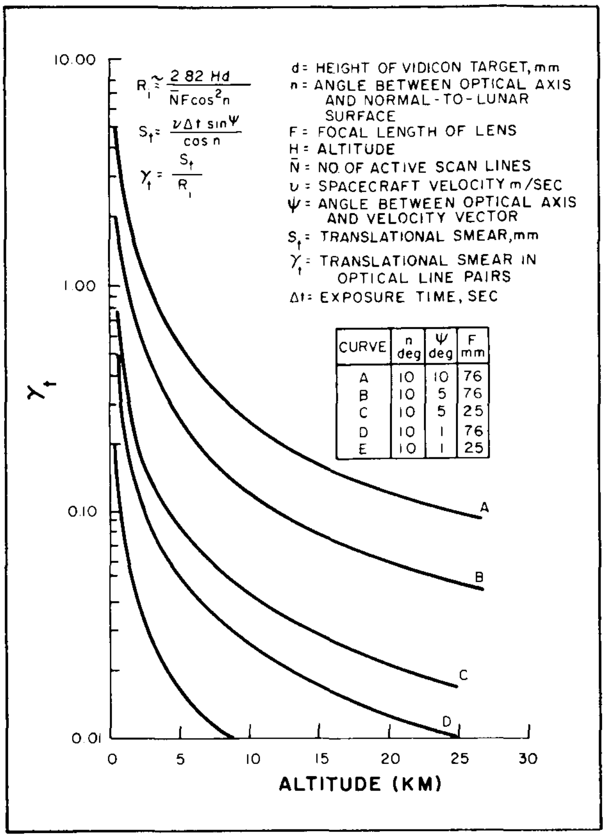


Figure 8. Translational Smear vs. Altitude

Figure 9). To complete this preparation cycle effectively would require an additional 0.6 second. This reduction in the duty cycle per camera would require an additional three cameras to provide maximum utilization of the available channels. Four such partial-scan cameras could then be arranged to provide picture overlap. They would be outfitted with 76-millimeter f/2 Bausch and Lomb and 25-millimeter f/0.95 Kodak Angenieux lenses to provide a dynamic range extending from 30 to 2700 footlamberts, as shown in Figure 10. Four cameras sequencing in exposure and readout would also ensure that the last full picture would be captured at a distance less than 1000 meters from the lunar surface.

The full-scan cameras also suffered from this vidicon lag problem; however, there would be

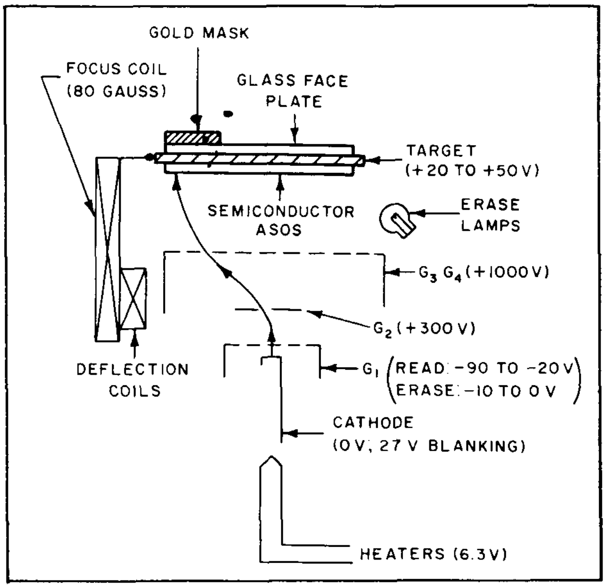


Figure 9. Vidicon Elements

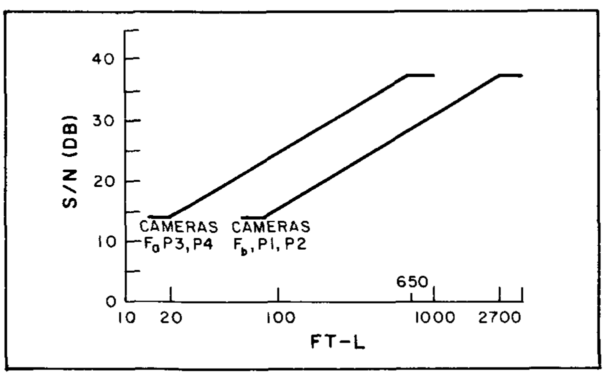


Figure 10. Dynamic Range of Cameras

sufficient time to eliminate these video residuals by sequencing two cameras, one camera being exposed and read out while the other camera was being erased and prepared. A rudimentary sequencing program is shown in Figure 11.

In this manner a camera system was evolved that would satisfy the mission requirements of high-definition lunar images and that would optimally use the channel allocations and satisfy weight and power constraints. Each television camera would be packaged in two parts: the sensing equipment containing the vidicon, the lens, the deflection and focusing yoke, and shutter in the camera head; and the scanning generators and analog-signal-processing equipment in the camera electronics. The type of circuits and equipment required are illustrated in Figure 12, the camera block diagram. These camera operational circuits were primarily analog in nature. The programming of the operational sequence for each camera and for the complement of six was more appropriate for digital-processing circuitry; hence, a digitally derived control programmer and camera sequencer was provided for the above operations.

The design of the Control Programmer and Camera Sequencer requires that the program start with two completely independent 18-kc crystal-controlled clocks and power supplies and would, by binary division, generate a sufficient number of gates to provide the control sequences, enumerated in Table 6.

The sequencer not only arranged sequential exposure and camera readout, but arranged to drive open the appropriate gate of the video combiner, permitting only the signals from the camera being read out to be the input to the modulator while the preparation signals from the cameras being erased were inhibited from this modulator by appropriate closed gates. The unit that provided this function of impedance matching, serialization of camera video, and additional video processing in the form of "preemphasis" was the Video Combiner. A block diagram shown in Figure 13 for the P-Channel Video Combiner illustrates its role in the Subsystem. Similar gating was provided for the F Channel. Preemphasis was added to the video processing to gain a signal-to-noise improvement for video transmission over an FM system. The assembly of each of the items described as essential to the Ranger VII, VIII, and IX missions for high-detail television pictures of the Moon is illustrated in Figure 5.

The Ranger Spacecraft with the TV Subsystem integrated with the Bus is shown in Figure 14.

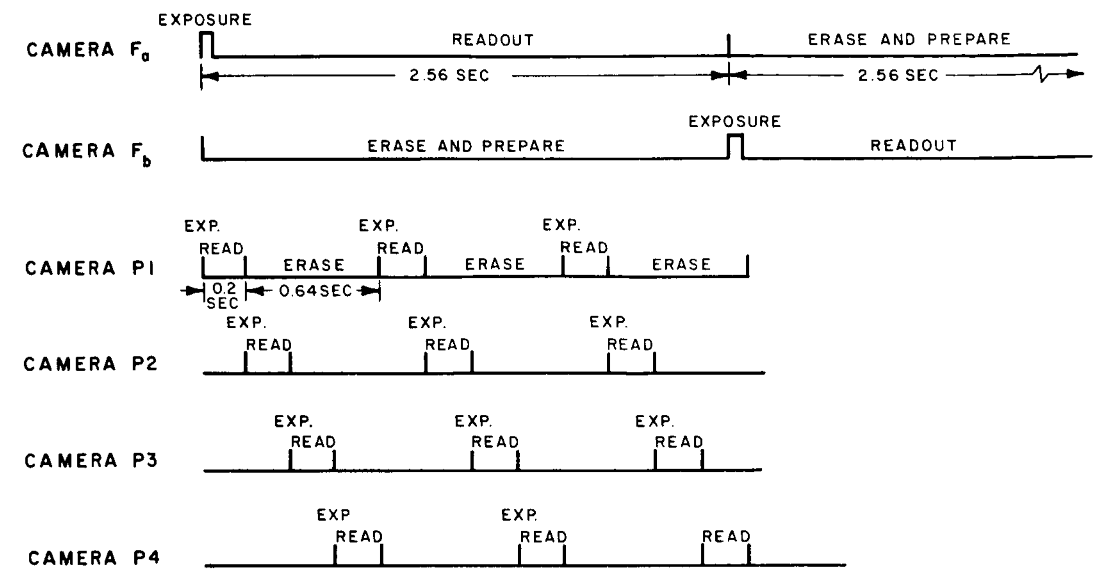


Figure 11. Camera Sequencing Program

TABLE 6
CAMERA CONTROL SEQUENCES

Partial-scan Cameras	Full-scan Cameras
Horizontal sync, 1500 cps	Horizontal sync, 450 cps
Vertical read	Vertical read
Shutter drive	Shutter drive
Erase lamp drive	Erase lamp drive
Vertical blanking	Vertical blanking
Black clamp	Black clamp
Video gates P1, P2, P3, P4	Video gates F_a, F_b

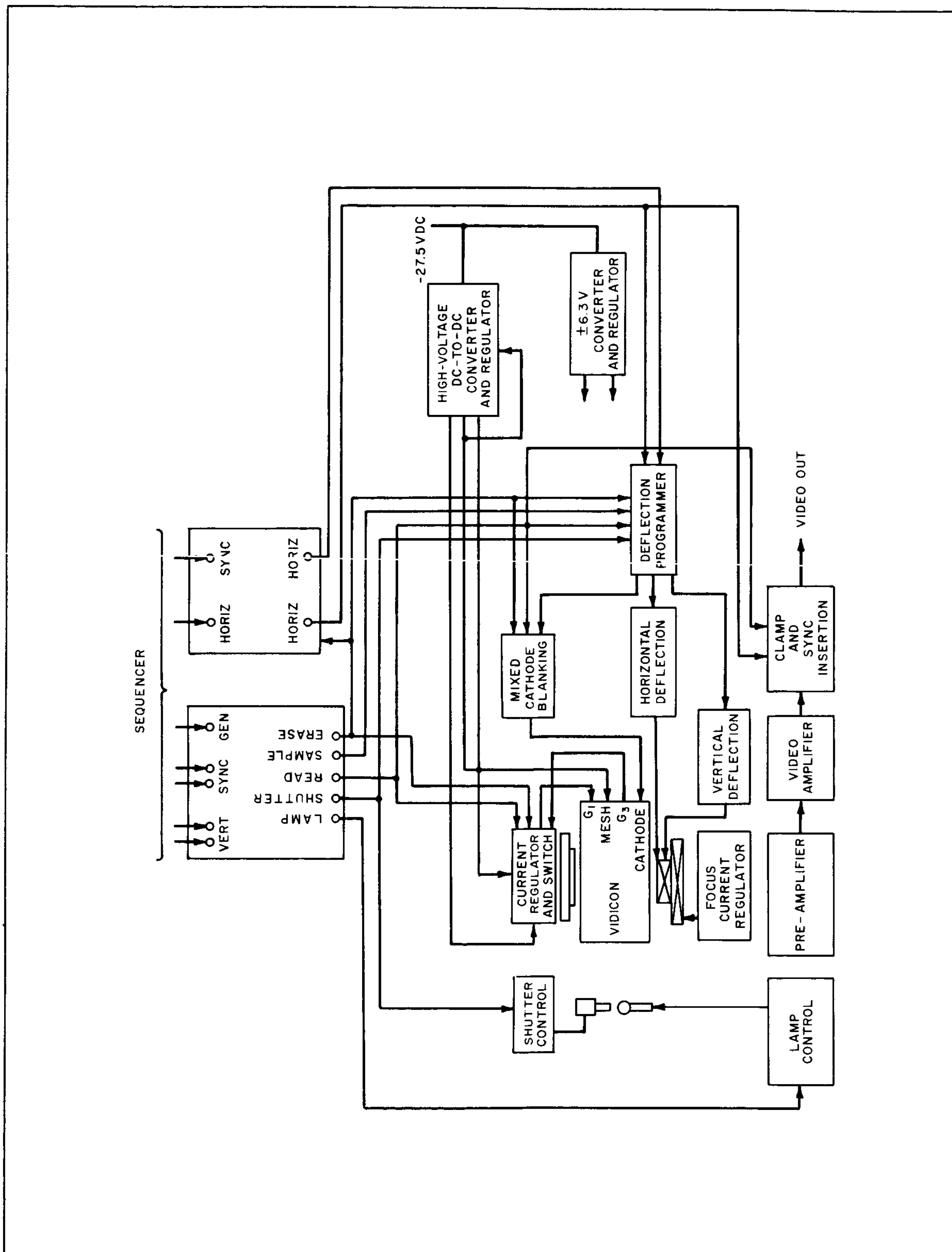


Figure 12. Camera and Camera Electronics Block Diagram

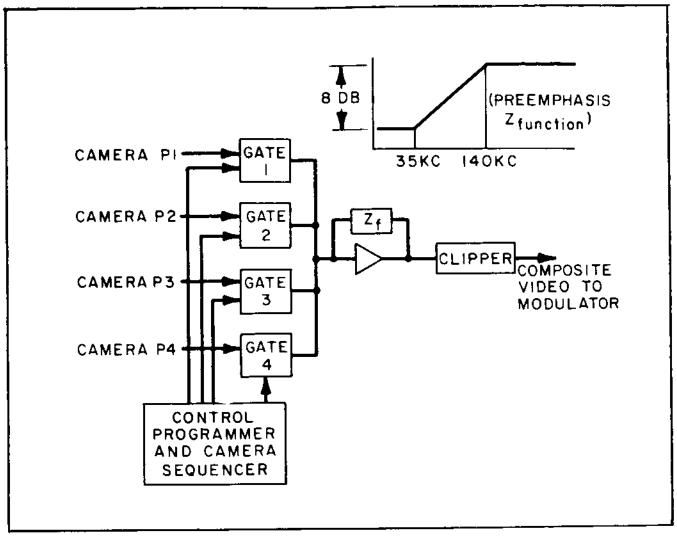


Figure 13. P-Channel Video Combiner

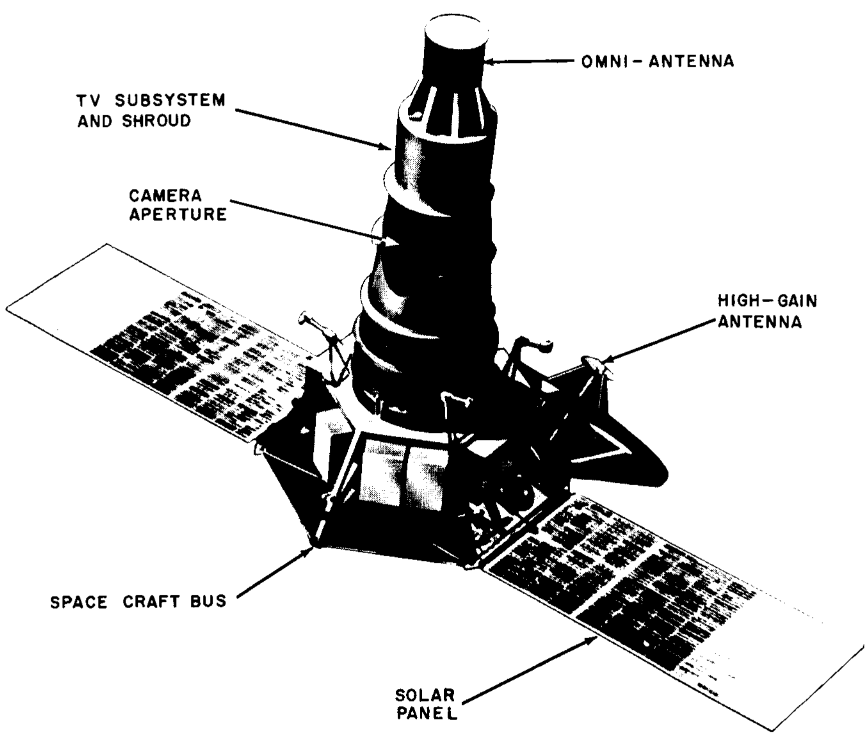


Figure 14. Ranger Spacecraft Configuration

Section V

Summary of Operational Support Equipment Design

A. GENERAL

The signals transmitted from the Ranger Spacecraft must be reconverted from the electromagnetic to the visual domain for use and interpretation by the lunar experimenters. This conversion must be handled with maximum attention to fidelity in visual reproduction of the scene. The design approach to the ground-based receiving and recording equipment (OSE) considered two factors: use of existing, reliable components and redundancy in information storage.

One factor that stood out as having a large effect on the eventual OSE and system design was the selection of the primary data film recorder. It became apparent that the most fruitful film format for a kinescope recording would be provided by a camera featuring rapid film pull-down and sufficient magazine storage to accommodate at least a 15-minute mission. A Flight Research 35-millimeter camera equipped with a data box was chosen. The film would be pulled down in less than 20 milliseconds by a drive pulse derived from the system's vertical sync and be ready for exposure within 46 milliseconds. The camera was equipped with magazines capable of storing 200 feet of film—more than enough for a 15-minute picture-taking mission.

With the basic camera chosen, an optical bench of sufficient mass to reduce vibration effects on film recording was added to provide the optical configuration for the kinescope- and film-recording camera. The signal flow from image sensing, transmission, signal reception, and reproduction and recording is shown in Figure 15. The effect of the kinescope recorder was to introduce additional aperture into the overall system. It became important to select elements in this recording chain that would have minimal depressing effects on the final overall system response. The modulation transfer function is shown in Figure 16 for a kinescope-recording system consisting of a Westinghouse kinescope WX-4877P11, a Canon 100-millimeter f/3.5 lens, and Kodak 5374 film. This curve also indicates the effect of these recording elements on the total system response.

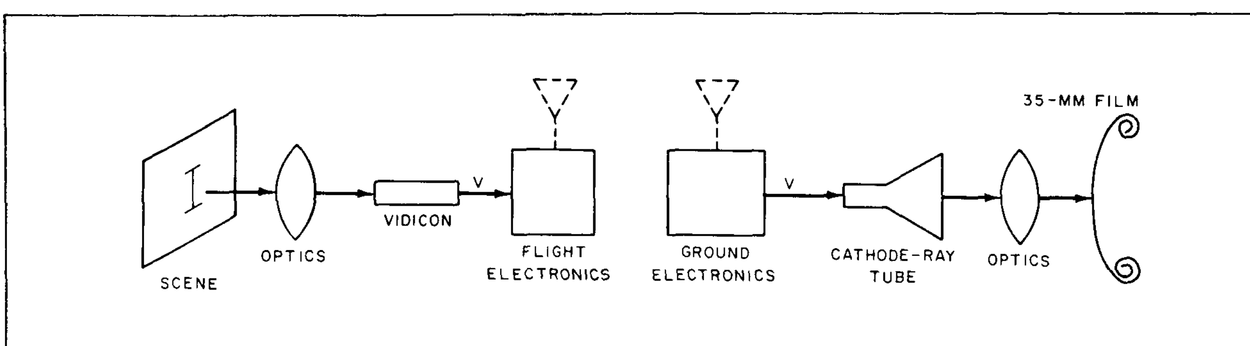


Figure 15. Ranger Image Sensing, Transmission, Reproduction, and Recording Chain

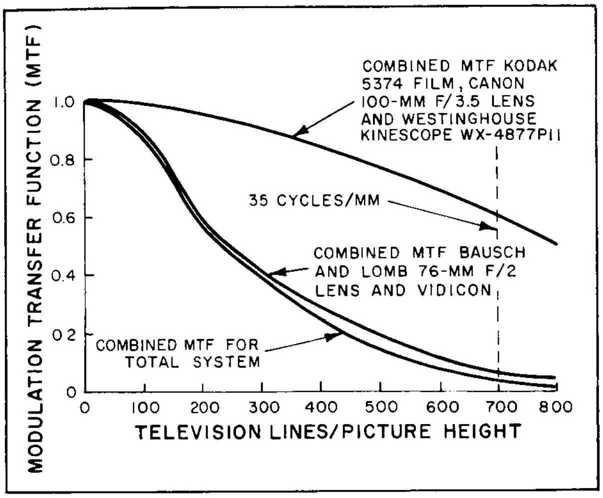


Figure 16. Modulation Transfer Function

B. DESIGN PHILOSOPHY AND IMPLEMENTATION

An important decision in the early design effort of the kinescope-recording system was that it should have provisions of self-checking. To this end, a sync and video simulator was designed that would provide signals simulating the partial- and full-scan camera video. These signals which included grating patterns, resolution bursts, and gray scales at the vidicon gamma, were essential in the alignment and calibration of this part of the system. Another important decision was the implementation of a quick-look capability at the kinescope with a Polaroid camera.

The TV ground recovery system for the reception and recording of the signals from the Ranger Spacecraft was located at the Deep Space Instrumentation Facility (DSIF) tracking station at Goldstone, California. Three tracking stations were located around the world to provide continuous coverage of the spacecraft, although the equipment necessary to recover the video information from the TV subsystem was located only at Goldstone. The Ranger flights were timed so that the lunar encounter occurred while Goldstone was tracking the spacecraft. The purpose of the TV ground recovery system was to receive the RF signal from the spacecraft and convert this into photographic images on 35-millimeter film. The main elements of the system were receivers, tape recorders, telemetry recorders, and film recorders (Figure 17).

For test purposes an L-band transmitter and an RF head unit were also included in the OSE design. These units would provide for overall loop tests. The test transmitter could be modulated by simulated video signals properly preemphasized. The RF head would convert the direct 960-Mc transmission of the TV Subsystem or the test transmitter to a 30-Mc signal. This unit was a crystal-controlled receiver, centered at 960.05 Mc with a gain of 25 decibels and a 2-Mc bandwidth.

Interim storage of predetected received data was accomplished by a multichannel, magnetic-tape recorder. A 0.5-Mc baseband predetected signal was fed to the magnetic-tape recorder from each of the receiver channels. The tape reels contained sufficient tape capacity at a recording speed of 120 inches per second to record a 15-minute mission. The tape output was processed by a tape demodulator, which in turn could be connected to the low-pass filter for video and telemetry distribution. The operational ground-based receiving and recording equipment was designed to be self-checking and capable of independent operation and alignment. Its operation and alignment was to be accomplished without ever being operated with the actual TV Subsystem in test at JPL and the Eastern Test Range (ETR), Cape Kennedy. Final calibrations were to be performed with magnetic tapes of the camera video made during prelaunch tests at ETR.

C. OPERATION

The spacecraft-transmitted RF signal was received by the 85-foot parabolic antenna at the Echo-site Ranger ground station located at the Deep Space Instrumentation Facility (DSIF), at

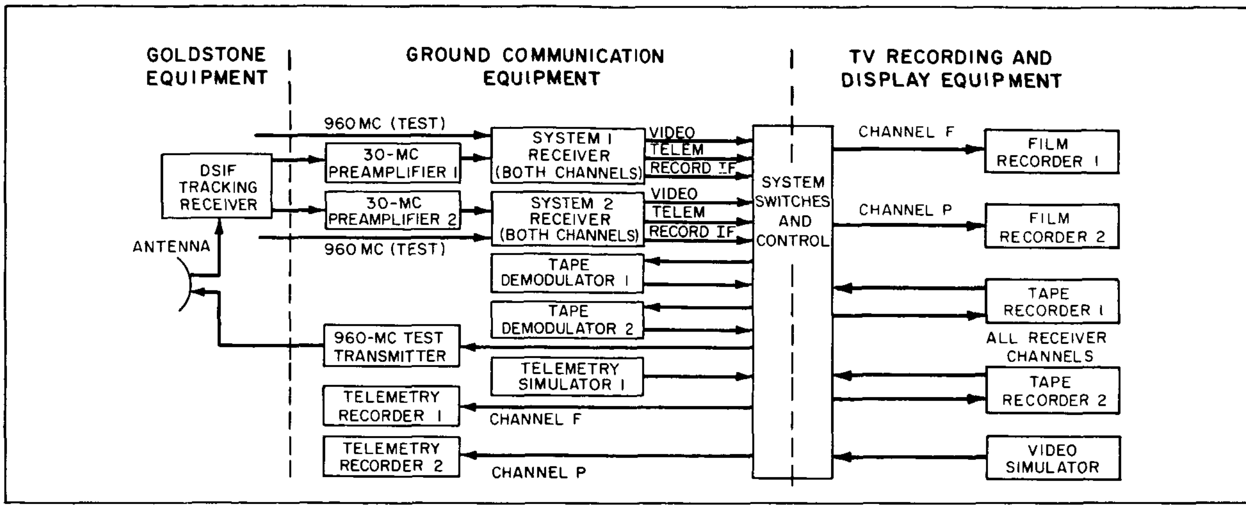


Figure 17. Functional Block Diagram of Ground Receiving and Recording System

Goldstone, California. The antenna receiver system, using a maser front end, converted the 960.06-Mc FM signal to a 30-Mc, dual-channel signal and applied it to the operational support equipment (OSE), through a 30-Mc preamplifier, for processing, recording, and display. A picture of the OSE is shown in Figure 18. The signal was again frequency-converted to the 5-Mc region in the dual-channel limiter amplifier of the OSE receiver, and separated into two individual video channels for further processing. The channel containing the full-scan video signal was centered at 4.47 Mc, and the channel containing the partial-scan video signal at 5.53 Mc. These 4.47- and 5.53-Mc signals were then applied to detector amplifiers and record IF amplifiers.

In the detector amplifiers, the signals were amplified, limited, detected, and deemphasized, and then applied through a low-pass filter to the TV recording and display equipment for on-line, or real-time display and 35-millimeter film recording of the video. The outputs of the detector amplifiers were also applied to a 225-kc discriminator, which rejected all video information from the signal and allowed real-time display of the telemetry data, through a DC-coupling amplifier, on a strip-chart recorder.

The signals applied to each record IF amplifier from the limiter amplifiers were frequency-converted to the 0.5-Mc region and made available to the TV recording and display equipment for the predetection tape recording of the composite video and 225-kc telemetry data.

TV recording and display equipment provided interim storage of predetected IF data, and reduction, display, and archival storage of the transmitted video information. Archival storage of the video data was performed automatically by 35-millimeter film recorders which provided photographic records of the kinescope displays of the F- and P-Channel video. In addition, photographs of selected video displays were taken semiautomatically by means of a Polaroid camera.

In the film-recorder equipment, kinescopes which utilized 5-inch cathode ray tubes (CRT) displayed a full frame of F_a or F_b video (Channel F), or four frames of camera P1, P2, P3, P4 video (Channel P). The kinescope for P-Channel presentation displayed the video frames of Channel P in sequence, divided equally in area and aspect ratio in the four quadrants of the CRT. A 35-millimeter camera

Figure 18. Operational Support Equipment at the Echo-Site Ground Station

then photographed the CRT and a data board, which identified the video display through use of a real-time clock, an indicator light to identify an F_b-Camera display, a frame counter, and a slate board for handwritten information. Additionally, a Polaroid camera was used for single-frame, sampling photographs. The film-recording formats are illustrated in Figure 19.

The tape recording equipment employed for predetection recording of the composite video and 225-kc telemetry signals were seven-channel, wideband, magnetic-tape devices. The recorders operated at a tape speed of 120 inches per second, and an interconnection technique was used whereby each recorder recorded both full- and partial-scan video.

Additional redundancy was provided through the use of two completely separate ground stations including antennas, receiving, processing, and display equipment, one at the Echo site and the other at the Pioneer site of the JPL (Goldstone, California) Deep Space Instrumentation Facility. Both operational-support chains operated simultaneously during the terminal mode of the mission. Maximum probability of successfully satisfying the mission requirements of obtaining high-resolution pictorial data of the lunar surface was achieved by the transmitted signal being received, processed, and recorded with minimum loss of integrity or fidelity. To ensure that the ground-station equipments had the capability of performing this function, a detailed test and calibration program was carried out prior to the spacecraft mission, and also during the mission prior to the terminal mode of operation. This test program provided confidence that the pictures received and recorded were faithful reproductions of the lunar image viewed by the television cameras.

Prior to the Ranger mission, proper operation of the communications equipment was verified by checking all significant operating parameters through the use of a test transmitter,

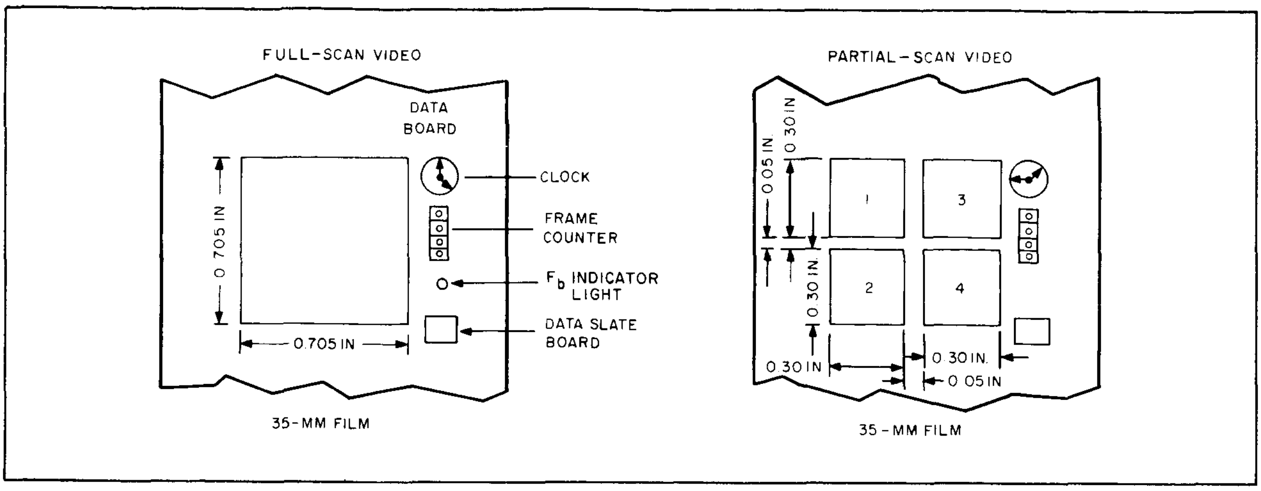


Figure 19. Film Recordings Format

tape demodulator, and standard and special test equipment. The bandwidth, rate response, signal-to-noise ratio, modulation distortion, and linearity were checked for both the F- and P-Channels.

Extensive tests and calibrations of the TV recording and display equipment were performed using electrically generated test standards to ensure that picture detail and photometric characteristics were faithfully reproduced. Magnetic tape recordings of actual video data from various spacecraft tests were used to confirm the operating parameters of the video display equipment and the film recorders. Resolution capabilities, linearity, CRT display characteristics (optical distortion, sizing, etc.), and the integrity of the display were checked. Further tests and calibrations of the entire operational support equipment were carried out up to the time of the terminal-mode operation of the spacecraft when the video signals from the spacecraft were transmitted. Additionally, postflight calibration and check were performed so that proper evaluation of the received data was made, based on the actual performance of the operational support equipment during the mission.

Section VI

Summary of RA-6 Mission

A. MISSION EVENTS

Ranger VI, consisting of the JPL Ranger Spacecraft and the Flight Model III-1 of the RCA Ranger TV Subsystem, was launched from Cape Kennedy, AMR, on an Atlas-D/ Agena-B vehicle. Liftoff occurred at 15: 49:00 GMT, January 30, 1964. The first nonstandard event occurred when the TV Subsystem Channel-8 telemetry inadvertently turned on at 15:51:30.0 GMT and transmitted data until 15:52:36.5 GMT, at which time the transmission ceased. Normal turn-on of the Channel-8 telemetry occurred at a time corresponding to 17 minutes after separation of the Ranger from the Agena (16:36:34 GMT). Except for a brief period during the mid-course maneuver when the JPL telemetry was switched to Mode-II operation, reception of the Channel-8 data continued to be normal until impact.

The first timing pulse from the TV Subsystem Clock was received, via the Channel-8 telemetry, on schedule at 16 hours after separation (08:19:50 GMT, January 31, 1964). Subsequent pulses were received as anticipated at separation plus 32 hours, 48 hours, and 64 hours.

Because of the near-perfect trajectory and orientation of the spacecraft as it approached the Moon, it was decided that a "terminal maneuver" would not be employed. Considering the temperatures and voltages of the Subsystem components, as determined by reducing the 15-point telemetry, it was further decided to allow the Subsystem Clock to time out and to initiate warm-up of the F-Channel of the Subsystem at Impact minus 19 minutes. An RTC-7 command would be sent four minutes later to initiate warm-up of the P-Channel. Each channel was to be activated into full power when the 5-minute accumulators for each channel completed timing. Because the "terminal maneuver" was not performed, the warm-up command and backup full-power command from the JPL CC&S were not used.

The warm-up command to the F-Channel of the TV Subsystem was initiated by the TV Subsystem Clock at separation plus 64-3/4 hours (09:05:42 GMT, February 2, 1964). At this time, a drop in the Channel-8 telemetry point monitoring the F-Battery indicated that a warm-up load had been placed on the F-Battery. The first RTC-7 command was initiated at 09:08:00 GMT and verified by the JPL Spacecraft. The state of the P-Channel warmup was confirmed by both a drop in the P-Channel battery voltage and the presence of the 30-second accumulator pulse on the Channel-8 telemetry. No indications of full power were received from either the F- or the P-Channels after five minutes of warm-up, and no video was received at the Goldstone DSIF ground station. A second RTC-7 command was initiated at 09:15:29 GMT and verified; however, emergency telemetry was not received. The third RTC-7 command was initiated at 09:19:20 GMT and verified. Impact occurred at 09:24:33 GMT. No video, 225-kc telemetry, or emergency telemetry was received from the TV Subsystem.

Subsequent playback of the magnetic tape records, obtained at the Goldstone ground station through narrow-pass filters and processed through a computerized autocorrelation program, failed to produce evidence of data transmission from the TV Subsystem.

B. DESCRIPTION OF THE CHANNEL-8 TELEMETRY RECORDED

The Subsystem operational conditions, as monitored by the Channel-8 telemetry, were investigated. The purpose of this investigation was to interpret the telemetry recorded during several critical time periods and to establish (as nearly as possible) the values of the sensor data using calibration curves for the telemetry points.

Specifically, the critical time periods which were investigated are as follows:

- GMT 030:12:17:01 – Launch minus 128 minutes. Normal prelaunch-pad TV telemetry turn-on.
- GMT 030:15:51:29 – Inadvertent Channel-8 telemetry turn-on. 67 seconds of data.
- GMT 030:16:36:34 – Separation plus 17 minutes. Normal Channel-8 telemetry turn-on. (Woomera recording.)
- GMT 030:16:49:00 to 16:52:00 – Separation plus 30 minutes.
- GMT 033:09:05:42 to 09:24:33 – Terminal data.

The following conclusions were reached:

- There was continuity in the Channel-8 telemetry from the prelaunch readings to the readings at the inadvertent turn-on at launch plus 3 minutes and to the readings at separation plus 17 minutes.
- There was a definite drop in both battery potentials during the inadvertent Channel-8 telemetry turn-on.
- There was a return to almost normal levels of the battery potentials by the time of separation plus 17 minutes.
- There was another definite drop in both battery potentials during the initial phase of the terminal mode.

The detailed analysis of the recorded data and of the significant events is contained in Volume 5 of this report.

C. DISCUSSION OF CHANNEL-8 TELEMETRY

The Channel-8 telemetry stopped between points 2 and 3 at the end of the countdown test and started at point 3 during the inadvertent turn-on. The Channel-8 telemetry was received for a period of 67 seconds and stopped between points 9 and 10. At the normal turn-on time (separation plus 17 minutes), the telemetry started between points 9 and 10 and continued until impact. Thus, it can be concluded that the Channel-8 telemetry was on only during the time that data was received and recorded.

The battery potentials were closely reviewed. The telemetry voltage levels prior to launch were 4.25 volts (equivalent to a battery voltage of 35.2 volts) for the P-Battery and 4.35 volts (36.1 volts) for the F-Battery. The potentials dropped to 4.05 volts (33.6 volts) for both batteries during the inadvertent turn-on. At separation plus 17 minutes, the telemetry reading for the P-Battery had returned to 4.25 volts (35.2 volts) and the F-Battery to 4.30 volts (35.7 volts). This voltage drop, 1.6 volts on the P-Battery and 2.5 volts on the F-Battery, was a normal drop for a turn-on of the Subsystem.

The battery potentials were at normal levels from separation plus 17 minutes until the turn-on of the F-Channel into the warm-up mode by the Clock at GMT 033:09:05:42 when the voltage level of the F-Battery dropped 1.25 volts, a 150-milliunit (Gerber Scale division) drop in telemetry, indicating that a load had been applied to the F-Battery.

The second change in battery potentials occurred at GMT 033:09:08:00 when an RTC-7 command was sent to turn on the P-Channel. At this time, the P-Battery potential dropped 0.8 volt (a 100-milliunit drop in telemetry) indicating that a load had been applied to the P-Battery.

The lowest telemetry readings for both battery potentials occurred between GMT 033:09:08 and 033:09:18, after which both telemetry points indicated that a load had been increased.

The temperatures of the batteries were also closely reviewed. During the inadvertent turn-on, a 2° F rise in temperature was noted from the temperatures before launch. The temperatures of the batteries continued to rise at a rate of 1° F an hour for the first ten hours of the flight. The temperatures remained relatively constant from that point till impact.

A search of the data recorded during the inadvertent turn-on was made to determine if an accumulator pulse had been actuated during that time. No pulse could be found. However, 30 seconds after the first RTC-7 command was received by the spacecraft, a pulse from the 5-minute accumulator in the P-Channel was received as expected. The frame times of the Channel-8 telemetry were also measured during this investigation (See Table 7 for a listing of the various frame times). There appeared to be little or no change in frame time from the prelaunch test to separation plus 17 minutes. From that time until impact, the frame time decreased slightly.

D. POST FLIGHT EVALUATION

With the limited information available for evaluation, the analysis was concentrated on the period of booster-engine separation, at which time four unscheduled frames of channel-8 telemetry were received. The analysis first attempted to determine the most probable failure mode that could have occurred during this period, and then sought to isolate the mechanism that could have caused this failure mode.

This investigation established the probable cause of failure to be the result of an inadvertent turn-on of the TV Subsystem in the partial-pressure environment existing in the range of altitudes corresponding to the Atlas booster engine cut-off and separation. The high-voltage elements of the TV Subsystem communications and cameras were probably destroyed by arcing in the partial-pressure environment, and were not able to operate when commanded on during the period of lunar encounter. Several mechanisms for the unscheduled turn-on and turn-off of the TV Subsystem during the boost phase were advanced and studied. No single simple failure mechanism was conclusively established.

TABLE 7
CHANNEL-8 TELEMETRY FRAME TIME

Pad Test at Launch 30:12:17:00		Inadvertent Turn-on at 30:15:51:30		Turn-on at S+17M 30:16:36:00		Terminal Mode to Impact 33:09:02:00	
Frame No.	Frame Time (Seconds)	Frame No.	Frame Time (Seconds)	Frame No.	Frame Time (Seconds)	Frame No.	Frame Time (Seconds)
1	19.7	1	19.6	1	19.1	1	16.6
3	19.5	2	19.6	5	19.4	15	16.9
6	19.4	3	19.5	45	18.6	30	17.0
						60	17.0
						75	17.1

Section VII

Summary of Ranger 7, 8, 9 Missions

A. RANGER-7 MISSION

1. General

On July 28, 1964, at 16:50:08 GMT, the Ranger VII Spacecraft was launched from Cape Kennedy, Florida. Approximately 68-1/2 hours later, RA-7 impacted on the lunar surface after returning 4316 pictures of the surface of the Moon. This collection of data satisfied the requirements of the Block III Ranger mission as stated in EPD-156. In summary, all aspects of the performance of the TV Subsystem during the flight of RA-7 met or surpassed all mission requirements.

The TV Subsystem of the Ranger VII Spacecraft was composed of six vidicon cameras (2 full-scan, 4 partial-scan); the electronic equipment to control these cameras; the communications chains to transmit the acquired video information back to earth; telemetry components to monitor the operation of the functional components; a completely independent power source (batteries) for the entire TV Subsystem; a structure to house and support all electronic gear; and passive-thermal-control components. The components that make up the various functional groups within the Subsystem were arranged in two completely redundant, electrically separated channels of operation: the F-Channel and P-Channel. Channel separation was characterized by the basic differences that existed between the full-scan and partial-scan cameras. The two camera types differed in the area of the scanned image and, consequently, in the scanning time and frame rate. For this reason, each channel, in addition to the cameras, consists of video-combiner, sequencer, transmitter, control, and power-distribution circuits. This arrangement resulted in two channels which were capable of operating either independently or simultaneously. The TV Subsystem weighed 381 pounds. Besides the two-channel separation, the electronic components of the TV Subsystem were arranged into major functional groups. These groups included:

- Camera Group;
- Telecommunications Group;
- Controls Group;
- Power Group; and
- Thermal Design and Structure Group.

2. Equipment Performance

The reception of 4316 high-quality pictures of the lunar surface from the Ranger VII Spacecraft was indicative of the performance of each group of equipment of the Flight Model III-2 Ranger TV Subsystem. The level of performance of some portions of the TV Subsystem could be evaluated on the basis of specific information received during the mission. This was particularly true in regard to the cameras and their associated electronic equipment, since the pictures themselves were evidence of the performance of this equipment. It was also true, although to a lesser degree, of the telemetry equipment, thermal control equipment, power equipment, telecommunications equipment, and OSE. The performance of the command and control circuitry, however, could only be evaluated in absolute terms; that is, all commands were processed and executed on time and in good order, as expected. The detailed discussion of the flight evaluation is contained in Volume 5 of this report.

By observing the 35-millimeter photographs and the magnetic tapes of the video signals it could be said that the Flight Model III-2 camera equipment met the mission requirements. The last partial-scan picture was a fragment from the P3 Camera which was outfitted with a one-inch, f/0.95 lens. A line selector was used to determine that impact occurred on line 167 approximately 400 μsec after the start of scan.

Exposure for the camera actually occurred about 80 milliseconds before the end of readout for the P1 Camera. The total time before impact then was the sum:

70	milliseconds during P1 readout
6.6	milliseconds of blanking
111	milliseconds of P3 readout
187.6	milliseconds before impact.

A simple geometrical relationship for the 1-inch optical system and for a spacecraft traveling at 2.64 kilometers per second showed that the final picture was taken at an altitude of 500.0 meters from point of impact on the lunar surface and covered an area about 42 meters by 28 meters. Craters could be recognized that occupy 1/50 of picture height, a diameter of 0.8 meter. The bright rim and shadowed rim constituted image elements of 0.4 meter; hence, the mission resolution requirements were easily satisfied.

For the full-scan cameras a fragment of a frame of the F_a Camera was the last to be scanned before impact. Video ceased after 350 microseconds on scan line 1074. The mission requirements of wide-area coverage and picture nesting were also satisfied. Examination of an image produced by the F_a Camera at an altitude of 480 miles from the Moon showed these two requirements satisfied. This image covered a wide area with several well-known features such as the crater Lubiniezky and the Riphaeus Mountains. This image also nested all the remaining sequence of F_a Camera images and recorded the impact point.

The exposures for both the 76-mm, f/2 cameras and the 25-mm, f/0.95 cameras were such as to provide high signal-to-noise ratios. The peak illuminations appeared not to exceed 1800 footlamberts with average illuminations between 250 and 450 footlamberts. The variations in exposure were noted and examined.

Based upon an analysis of the data returned from the flight of the Ranger VII Spacecraft, it was concluded that the flight performance of the RA-7 TV Subsystem (III-2) met or surpassed all design and mission requirements.

Typical results of the data returned are shown in Figures 20 through 29 and the explanatory data for the figures are given in Table 8.

B. RANGER-8 MISSION

1. General

The Ranger VIII Spacecraft was launched from Cape Kennedy, Florida, at 17:05:01 GMT on February 17, 1965. At 09:34:30 GMT on February 20, 1965, video data of the lunar surface was transmitted to Earth. The picture-taking operation continued uninterrupted for 23 minutes and 10 seconds until the Ranger VIII (RA-8) Spacecraft impacted on the Moon at 09:57:37 GMT. A total of 7140 pictures of the lunar surface was obtained by the full-scan and partial-scan cameras of the Flight Model III-3 TV Subsystem. The pictures covered an area extending from Mare Nubium, across the lunar highlands, to Mare Tranquillitatis. The final high-resolution pictures were taken in Mare Tranquillitatis.

The TV Subsystem of the Ranger VIII Spacecraft basically consisted of six vidicon cameras (2 full-scan, 4 partial-scan); the electronic equipment to control these cameras; the communications chains to transmit the acquired video information back to Earth; telemetry components to monitor the operation of the functional components; a completely independent power source (batteries) for the entire TV Subsystem; a structure to house and support all electronic gear; and passive thermal-control components. The electronic equipments that made up the

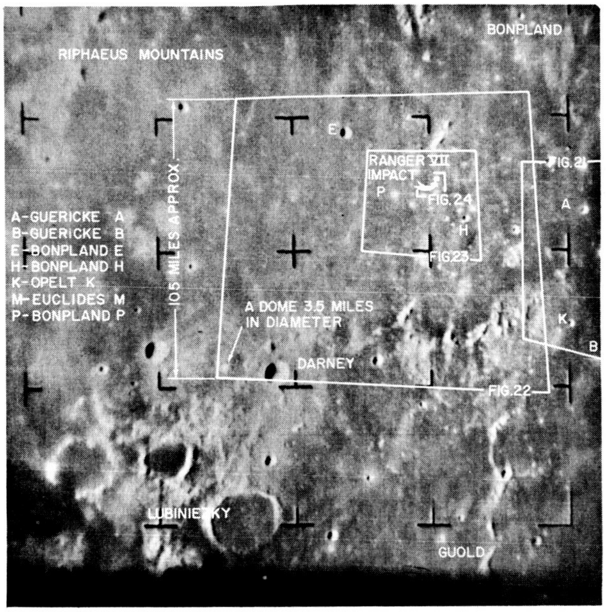


Figure 20. Ranger VII F_a Camera Picture Taken from an Altitude of 480 Miles

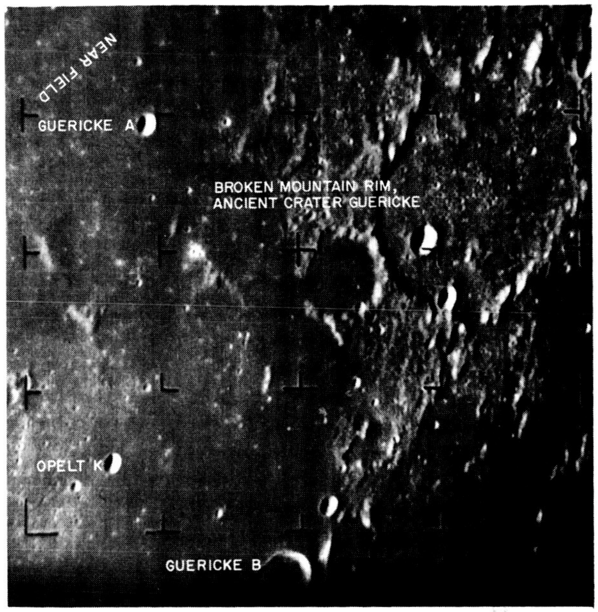


Figure 21. Ranger VII F_b Camera Picture Taken from an Altitude of 470 Miles

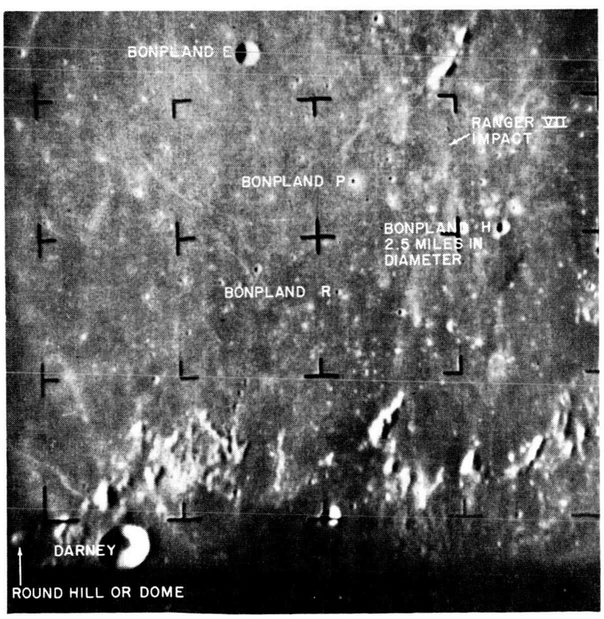


Figure 22. Ranger VII F_a Camera Picture Taken from an Altitude of 235 Miles

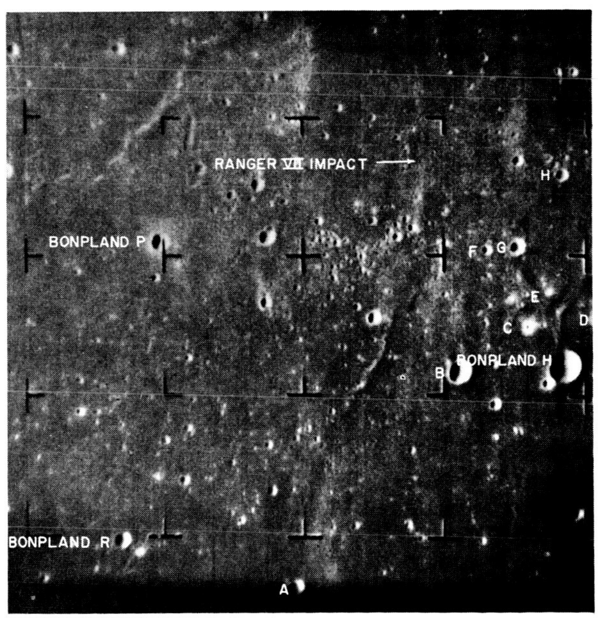


Figure 23. Ranger VII F_a Camera Picture Taken from an Altitude of 85 Miles

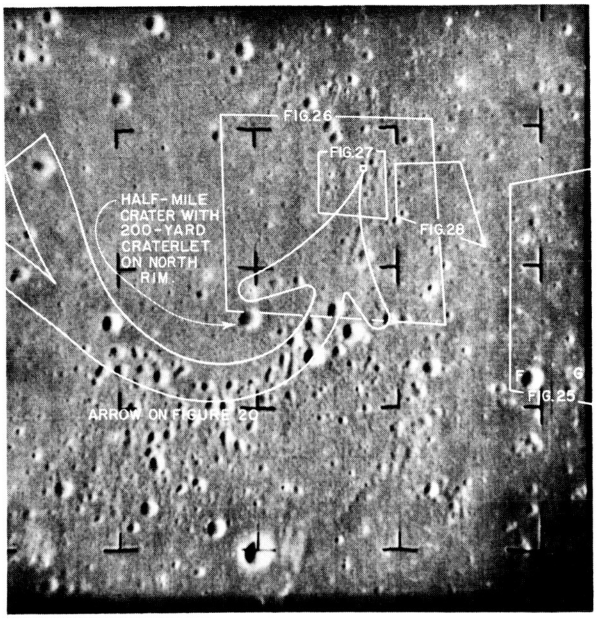


Figure 24. Ranger VII F_a Camera Picture Taken from an Altitude of 35 Miles

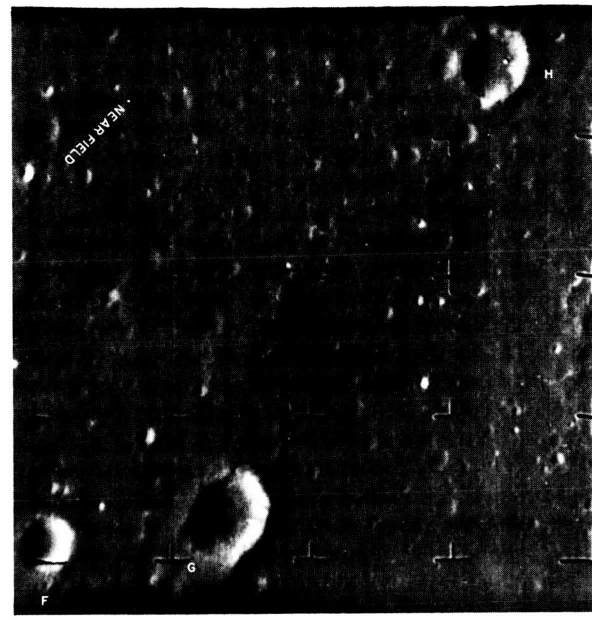


Figure 25. Ranger VII F_a Camera Picture Taken from an Altitude of 25 Miles

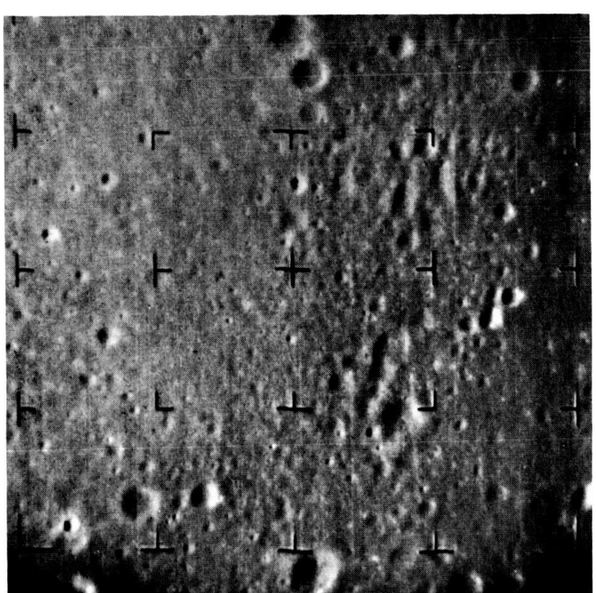


Figure 26. Ranger VII F_a Camera Picture Taken from an Altitude of 11 Miles

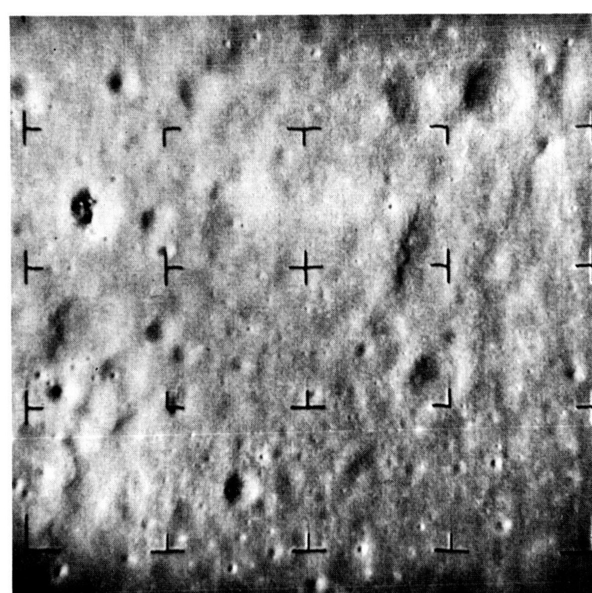


Figure 27. Ranger VII F_a Camera Picture Taken from an Altitude of 3 Miles

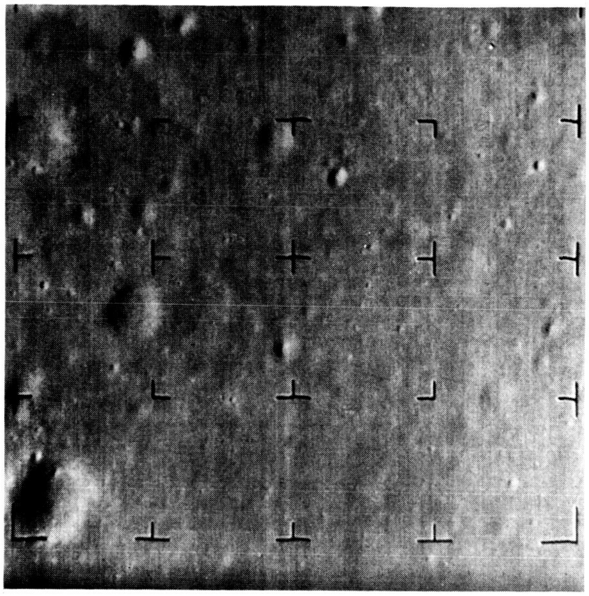


Figure 28. Ranger VII F_b Camera Picture Taken from an Altitude of 14 Miles

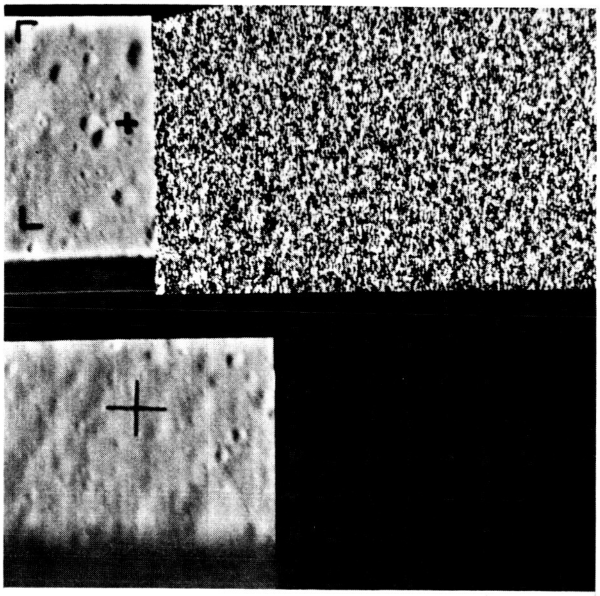


Figure 29. Ranger VII Final P3 Camera Picture Taken from an Altitude of 1000 Feet

TABLE 8
EXPLANATORY DATA FOR TYPICAL RA-7 PICTURES
(Figures 20 through 29)

Figure No.	Explanation
20	Television picture taken by Ranger VII F_a Camera before it impacted on the Moon on July 31, 1964, at 13:25 GMT. Viewed with the three large shallow craters in the lower left corner, North is at the top of the picture. It was taken from an altitude of 480 miles and duplicates closely the resolution obtained in Earth-based photography. The large open dark crater in the lower margin is Lubiniezky. The dusky view of the Riphaeus Mountains, upper left, compared to the brilliance of the hilly areas at the bottom right, confirm the high back-scatter nature of the gross lunar photometry which had previously been inferred by astronomers.
21	Television picture taken by Ranger VII F_b Camera before it impacted on the Moon on July 31, 1964, at 13:25 GMT. Viewed with the largest crater in the upper right corner, North is at the top of the picture. It was taken from an altitude of 470 miles and shows an area of about 800 feet in diameter. The large crater in the upper right corner is Guericke. Numerous small secondary craters, as well as two large conical craters, are shown on its floor. The larger of the two is about four miles in diameter.

TABLE 8 EXPLANATORY DATA FOR TYPICAL RA-7 PICTURES (Figures 20 through 29) (Continued)	
Figure No.	**Explanation**
22	Television picture taken by Ranger VII F_a Camera approximately 2 minutes 46 seconds before it impacted on the Moon on July 31, 1964, at 13:25 GMT. Viewed with the large crater in the lower left corner, North is at the top of the picture. It was taken from an altitude of about 235 miles and shows an area about 113 miles on a side. The eventual impact point of Ranger VII is approximately on the border between the two squares in the upper right corner as defined by the reseau marks. The smallest craters are about 1000 feet in diameter and are shown with a resolution about four times that of Earth-based photography.
23	Television picture taken by Ranger VII F_a Camera before it impacted on the Moon on July 31, 1964, at 13:25 GMT. Viewed with the largest crater on the right, North is at the top of the picture. It was taken from an altitude of 85 miles and covers an area 48 miles on a side and shows craters as small as 500 feet in diameter. The central area shows a cluster of secondary craters in part of an outlying ray of the crater Copernicus. This cluster is shown with greater resolution in Figure 24. The largest craters shown, with prominent shadows, are primary craters of approximately conical shape.
24	Television picture taken by Ranger VII F_a Camera before it impacted on the Moon on July 31, 1964, at 13:25 GMT. Viewed with the largest crater to the left, North is at the top of the picture. It was taken from an altitude of 34 miles and shows an area of 16 miles on a side with craters as small as 150 feet in diameter. The central area is occupied by an outlying ray of the crater Copernicus containing numerous secondary craters.
25	Television picture taken by Ranger VII F_a Camera before it impacted on the Moon on July 31, 1964, at 13:25 GMT. Viewed with the two large craters in the bottom left corner of the picture, North is at the top. It was taken from an altitude of 25 miles and shows an area 4-1/2 miles square with craters down to 50 feet in diameter. Many craters have steep sides and others have shallow sides. An interesting feature is the ridge emanating from a prominent crater. Note also the radial structure on the slope of the largest crater.
26	Television picture taken by Ranger VII F_a Camera before it impacted on the Moon on July 31, 1964, at 13:25 GMT. It was taken from an altitude of 11 miles and shows an area four miles on a side with craters as small as 45 feet in diameter. Note that numerous secondary craters with rounded

TABLE 8
EXPLANATORY DATA FOR TYPICAL RA-7 PICTURES
(Figures 20 through 29) (Continued)

Figure No.	Explanation
26 (Continued)	walls as well as sharp pits down to the smallest size are recognizable. The area shown is a close-up of the region just below and left of center of Figure 24.
27	Television picture taken by Ranger VII F_a Camera some 2.3 seconds before it impacted on the Moon on July 31, 1964, at 13:25 GMT. Viewed with the largest crater in the upper right corner, North is at the top of the picture. It was taken at an altitude of about three miles and shows an area about 1-2/3 miles on a side. The smallest craters shown are approximately 30 feet in diameter and 10 feet deep. There are many craters with rounded shoulders. One rounded crater, at the left and toward the top of the picture, is about 300 feet in diameter and has, in its center, an angular rock mass which might possibly be responsible for its origin.
28	Television picture taken by Ranger VII F_b Camera before it impacted on the Moon on July 31, 1964, at 13:25 GMT. Viewed with the most prominent large crater at the lower left corner of the picture, North is at the top. It was taken from an altitude of 14 miles and shows a region 2.7 miles square with craters of diameters down to 25 feet. Large craters on the left side of the picture show characteristic rounded shoulders of secondary craters at this resolution.
29	Television pictures taken by Ranger VII prior to its impact on the Moon on July 31, 1964, at 13:25 GMT. Viewed with the line of receiver noise at the top, North is at the top in both pictures. The top partial picture was the last taken by the P3 Camera before Ranger VII crashed into the Moon; the Spacecraft was destroyed while transmitting, resulting in the receiver-noise pattern. The picture was taken from about 1000 feet above the lunar surface and is of an area about 100 feet by 60 feet. It has a resolution more than one thousand times better than that of Earth-based observations. The smallest craters are about three feet in diameter and one foot in depth. The lower complete picture showing an area about 100 feet on a side, was taken by the P1 Camera from an altitude of about 3000 feet. Many of the craters shown have rounded shoulders in contrast with most larger lunar craters.

functional groups of the TV Subsystem were separated into two completely redundant, electrically independent channels of operation, designated the F-Channel and P-Channel. Channel separation was characterized by the basic differences of design between the full-scan cameras and the partial-scan cameras. The two camera types differed in the area of the scanned image, and therefore, in the scanning time and frame rate. Consequently, each channel, in addition to the cameras, consisted of video-combiner, sequencer, transmitter, control, and power-distribution circuits, which permitted independent or simultaneous operation of the channels.

In addition to channel separation, the components of the TV Subsystem were arranged into major functional groups. These groups were:

- Camera Group;
- Telecommunications Group;
- Controls Group;
- Power Group; and
- Thermal Design and Structure Group.

2. RA-8 TV Subsystem Modifications

Several modifications were incorporated into the Flight Model III-3 Subsystem which distinguished the RA-8 TV Subsystem from the RA-7 TV Subsystem. These modifications were product-improvement, equipment-refinement, or mission-requirement changes. The changes were based on results of the RA-7 flight, and further design studies, or were directly related to the particular constraints of the RA-8 mission. The modifications to the Camera Group of Flight Model III-3 TV Subsystem were as follows:

- An improved technique for focusing the TV cameras equipped with narrow-angle (76-mm) lenses (P1, P2, and F_b Cameras) was introduced on RA-8. This revised method of focusing provided for optimum optical focus of the cameras in a true space environment by compensating, during the alignment operation, for the displacement of the plane of best focus that occurs between air and vacuum conditions as a result of the pressure dependence of the index of refraction of air. In practice, a 0.0025-inch shim was used to increase the spacing between the lens and the vidicon faceplate, and the camera was subsequently optically focused in air for a maximum electrical response signal. When the shim was removed, the camera was in proper focus for operation in the space environment of an actual mission. The shift in optical focus due to the difference in index of refraction between air and vacuum was computed for the TV cameras with wide-angle (25 mm) lenses (P3, P4, and F_a). The change in focus was not considered sufficient to warrant application of the revised focusing technique to these cameras.

- The gain of the F_b, P1, and P2 Cameras was increased to change the peak-scene-luminance level of these cameras from 2700 footlamberts to a nominal 1500 footlamberts. This change was implemented on the basis of an increased ability to define the anticipated levels of lunar luminance as a result of the actual camera performance during the RA-7 mission.

- The P1 and P4 Cameras were equipped with new vidicon tubes having a higher-density mesh structure. The new mesh structure had 1500 wires per inch rather than the 750 lines per inch of the previous vidicons. The effect of the increased mesh density was to raise the frequency of the mesh scan noise above the system video passband.

- A new type of shutter-shock isolator was fabricated in the form of a castellated pad from polyurethane Solithane 113

(Thiokol formulation 5); and Solithane material instead of Sty-cast was employed to soft-mount the nuvistor in the preamplifier. These changes, along with the preselection of nuvistors for minimum microphonic sensitivity, were incorporated to suppress the effects of camera microphonics.

The modifications to the Telecommunications Group were as follows:

- Modification of the F- and P-Channel Transmitters and Transmitter Power Supplies to incorporate the Resdel (triode) configuration intermediate Power Amplifiers (IPA) to provide improved temperature/frequency stability for the Transmitter chain.

- Replacement of varactor diodes in the X4 multiplier circuits of the F- and P-Channel Transmitters. The new diodes, which had a bonded construction, are more reliable than the pressure-contact units previously employed.

- Installation of a new O ring in the Dummy Load Assembly. The new O ring results in a leak rate that is only 20 percent of the value previously encountered.

- Relocation of the Telemetry Processor Assembly to accommodate the IPA modifications.

- Addition of telemetry points to monitor the cathode currents of the Intermediate Power Amplifiers in the F- and P- Channel Transmitters.

The circuitry of the Current Sensing Unit on Flight Model III-3 was modified to provide greater resolution of cruise-mode currents while maintaining full-power current indications within the normal telemetry range.

The modifications to the Harness Assembly of Flight Model III-3 were as follows:

- A new-design harness was constructed, which eliminated unnecessary splices and rerouted cables:

- New High-Rel Cannon connectors were incorporated in the new harness design:

- Special molds were fabricated for forming potting material on right-angle connectors;

- Stainless-steel, screw-lock assemblies were used with the connectors;

- Novathene wire replaced the Rayolin "N" wire used in the harness of the Ranger VII TV Subsystem; and

- Redundant battery power plugs were provided.

Battery support bars fabricated from stainless steel replaced the aluminum support bars employed on Ranger VII. The use of stainless steel provides increased strength to the support bars.

The solar absorptivity of the thermal-control paints on the fins was reduced by increasing the percentage of white PV-100 in the paint mixture. This reduction in absorptivity was to compensate for the effects of the increased solar constant during the season of the year in which the RA-8 launch was anticipated.

3. Equipment Performance

The receipt of 7140 high-quality television pictures of the lunar surface attests to the overall performance of the Flight Model III-3 TV Subsystem during the Ranger VIII mission, and in particular to the performance of the TV Camera Assemblies. The telemetry data received throughout the RA-8 mission indicated that the thermal-control, power, and telecommunications equipment functioned as predicted from the results of prelaunch system tests. Proper operation of the control circuitry is evidenced by the fact that all commands were processed and executed on time and in good order.

The level of performance of the TV cameras and associated video-processing equipment can be evaluated by a review of the 35-mm film and magnetic-tape recording of the video information obtained. The large bandwidth in the RF channel permitted an accurate determination of all important parameters for the Camera Group. The quality of the pictures, the video signal levels, and signal strength measured during the mission were used to evaluate the performance of the Communications Group. The Thermal-Control and Power Groups were best evaluated from the telemetry received. Proper functioning of all equipment was necessary to achieve the quality and quantity of the pictures obtained.

The four partial-scan and two full-scan TV cameras aboard the RA-8 Spacecraft obtained 7140 pictures during the 23-minute 10-second full-power mode of the mission. All pictures were of good quality with the exception of the pictures obtained by the P2 Camera during the final 5 minutes of terminal-mode operation. The mesh of the vidicon in the P2 Camera became microphonic during this period, and although the microphonic signal was objectionable, there was very little loss of information. The microphonic signal produced a number of horizontal bars across the picture. The amplitude of these bars was less than 20 percent of the dynamic range, so that lunar-surface details were still visible in all frames.

The exposure settings of the cameras with 3-inch focal-length, f/2 lenses (F_b, P1, P2) provided balanced pictures during the entire mission, while the exposure settings of the cameras with 1-inch focal-length, f/0.95 lenses (F_a, P3, P4) provided optimum pictures only during the last 10 minutes of the mission. There was considerable compression of video in the "on-line" kinescope display of the F_a, P3, and P4 pictures during the first thirteen minutes of operation. There was, however, very little saturation in the video signals from the TV cameras. This problem could be corrected by adjusting the drive signal to the OSE kinescope and recording video on 35-mm film from the playback of the magnetic tape.

The Camera Assemblies performed satisfactorily throughout the mission. Examination of film reproduced from magnetic tape playback revealed that impact occurred after 13 percent of a P4-Camera picture had been read out. The preceding picture from the P2 Camera represented an area of approximately 23 by 29 meters. Craters as small as 0.3 meter in diameter would have been visible except that the lack of a terminal maneuver caused approximately 1.3 meters of smear in each of the partial-scan pictures. The last picture from the P1 Camera represented an area of approximately 56 by 70 meters, and would have shown craters as small as 0.75 meter in diameter. Typical results of the data returned are shown in Figures 30 through 36 and the explanatory data for the figures are given in Table 9.

C. RANGER-9 MISSION

1. General

The Ranger IX Spacecraft was launched from Cape Kennedy, Florida, at 21:37:02 GMT on March 21, 1965. At 13:49:34 GMT on March 24, 1965, video data of the lunar surface were transmitted to Earth. The picture-taking operation continued uninterrupted for 18 minutes and 46 seconds until the Ranger IX (RA-9) Spacecraft impacted on the Moon at 14:08:20 GMT. A total of 5866 pictures of the lunar surfact was obtained by the full-scan and partial-scan cameras of the Flight Model III-4 TV Subsystem. The initial pictures covered regions of the central lunar highlands in the vicinity of the Crater Alphonsus; the final high-resolution pictures were of the floor of the Crater Alphonsus.

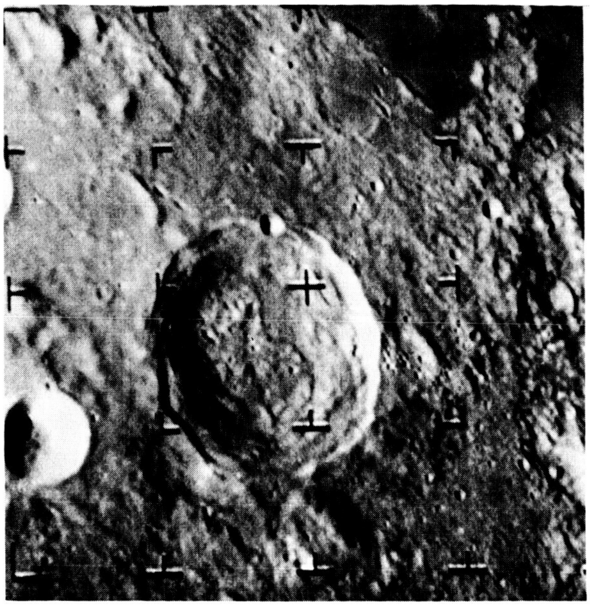


Figure 30. Ranger VIII F_b Camera Picture Taken from an Altitude of 470 Miles

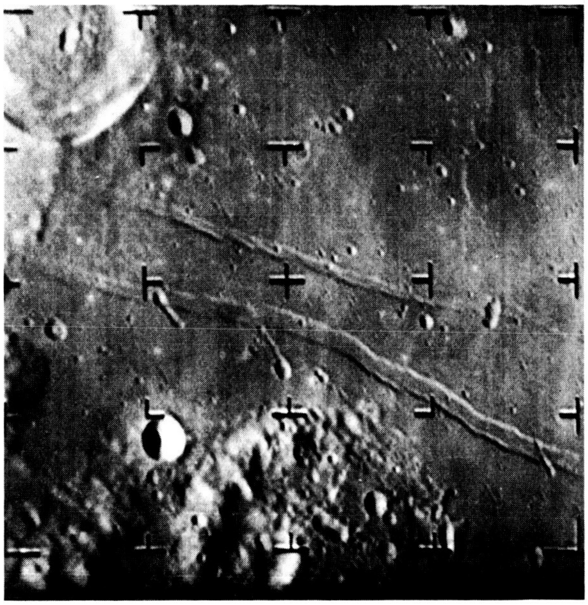


Figure 31. Ranger VIII F_b Camera Picture Taken from an Altitude of 270 Miles

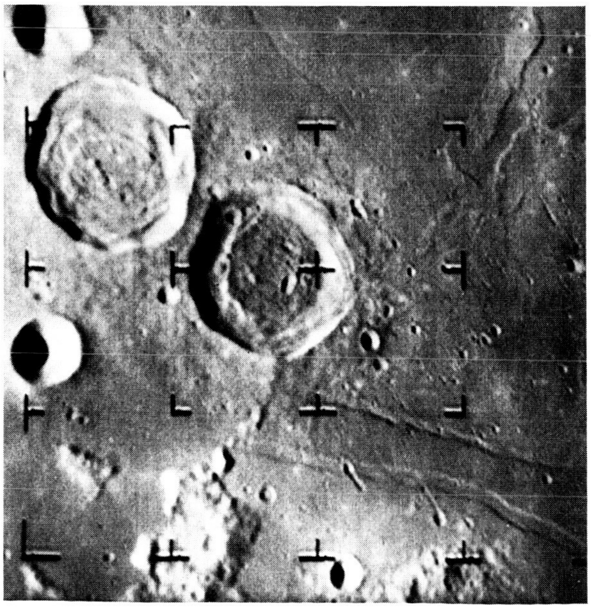


Figure 32. Ranger VIII F_b Camera Picture Taken from an Altitude of 151 Miles

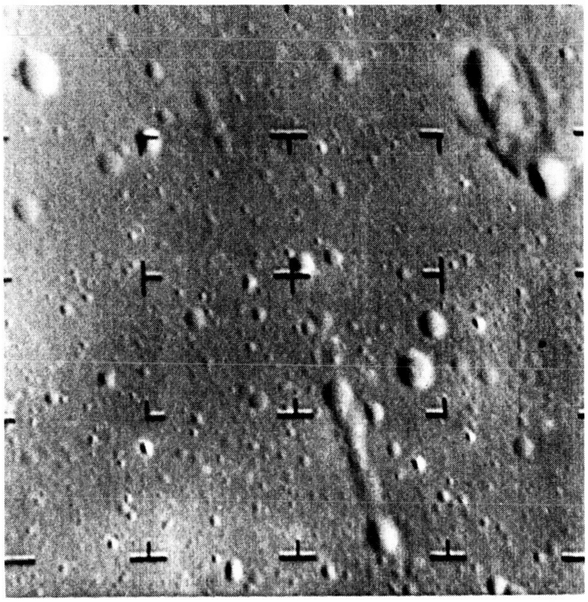


Figure 33. Ranger VIII F_b Camera Picture Taken from an Altitude of 50 Miles

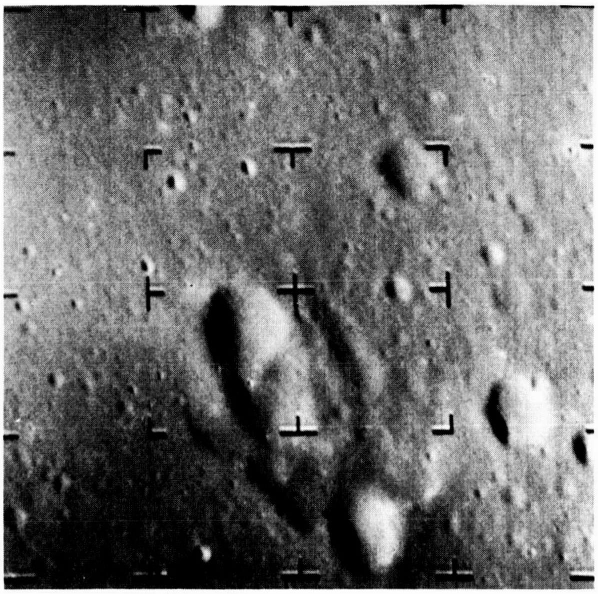


Figure 34. Ranger VIII F_b Camera Picture Taken from an Altitude of 27.5 Miles

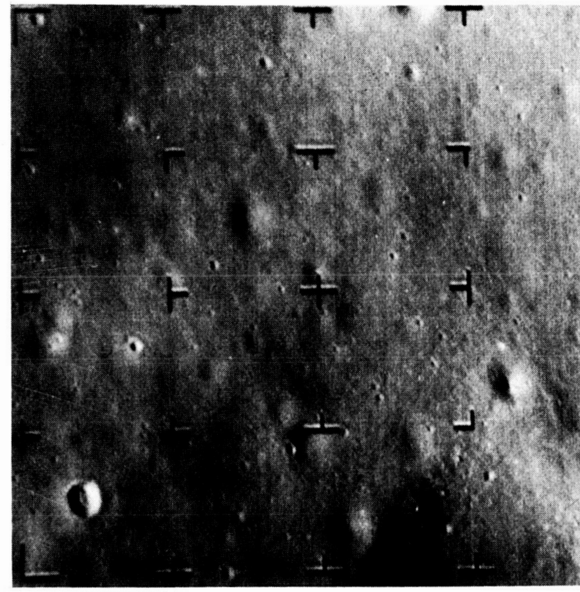


Figure 35. Ranger VIII F_b Camera Picture Taken from an Altitude of 5.1 Miles

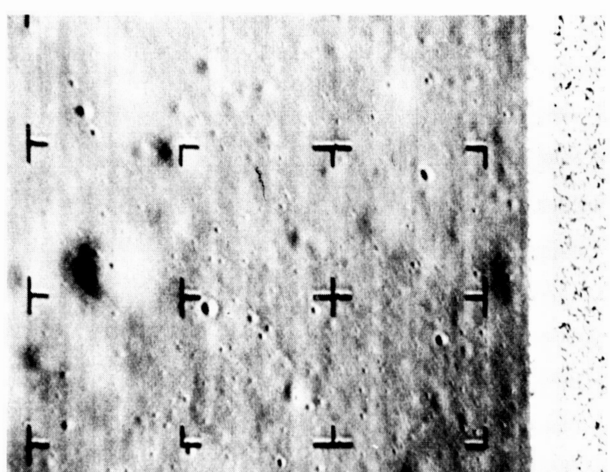


Figure 36. Ranger VIII Final F_a Camera Picture Taken from an Altitude of 12,000 Feet

TABLE 9
EXPLANATORY DATA FOR TYPICAL RA-8 PICTURES
(Figures 30 through 36)

Figure No.	Explanation
30	Television picture taken by Ranger VIII F_b Camera approximately 7 minutes prior to impact on February 20, 1965, at 1:57:36 (PST). Viewed with crater shadows at left, North is at top. This picture is the 81st from last F_b Camera frame, and represents an area of 93 miles by 71.5 miles. Spacecraft altitude above the Moon is 470 miles. The picture shows crater Delambre, 32 miles in diameter, near the center of the picture; a conical crater with flat floor at left margin; and highlands at the right margin.
31	Television picture taken by Ranger VIII F_b Camera 4 minutes prior to impact on February 20, 1965. Viewed with crater shadows at left, North is at top. This picture is the 47th from last F_b Camera frame and represents an area of 58 miles by 43 miles. Spacecraft altitude above Moon is 270 miles. This picture shows the shoreline of the Sea of Tranquility, with Crater Sabine in Northwest corner, and two parallel rills crossing the center portion of the Sea. Several elongated craters are probably due to Crater Theophilus 250 miles to the Southeast.
32	Television picture taken by Ranger VIII F_a Camera 2 minutes 15 seconds prior to impact on February 20, 1965. Viewed with crater shadows at left, North is at top. This picture is the 27th from last F_a Camera frame, and represents an area of 77 miles by 67 miles. Spacecraft altitude above the Moon is 151 miles. This picture shows the Southwest corner of the Sea of Tranquility with flat-bottomed Craters Sabine and Ritter; two cone craters at left; low ridges in upper right; and rills parallel to lower shoreline.
33	Television picture taken by Ranger VIII F_b Camera 45.6 seconds prior to impact on February 20, 1965. Viewed with shadows on left side of craters, North is at the top. This picture is the ninth from last F_b Camera frame, and represents an area of 12 miles by 8.5 miles. Spacecraft altitude above the Moon is 50 miles. Two elongated and one irregular depressions are shown.
34	Television picture taken by Ranger VIII F_b Camera 25.13 seconds prior to impact on February 20, 1965. Viewed with crater shadows at left, North is at top. This picture is the fifth from last F_b Camera frame, and represents an area of 6.5 miles by 4.5 miles. Spacecraft altitude above the Moon is 27.5 miles.

TABLE 9 EXPLANATORY DATA FOR TYPICAL RA-8 PICTURES (Figures 30 through 36) (Continued)	
Figure No.	**Explanation**
35	Television picture taken by Ranger VIII Fb Camera 4.65 seconds prior to impact on February 20, 1965. North is at top when picture is viewed with large crater in lower left corner. This is the last F_b Camera frame and represents an area of 4000 feet by 3000 feet. Spacecraft altitude above the moon is 5.1 miles. Larger crater in Southeast corner shows small craters and rocks on the slope; a dimple-type crater can be seen above it. Crater in the Southwest corner has steep wall and central projection.
36	Television picture taken by the Ranger VIII F_a Camera, 2.09 seconds prior to impact on February 20, 1965. Viewed with the shadows on the left side of craters, North is at top. This is the last F_a Camera frame, and represents an area of 5570 feet by 4460 feet. Spacecraft altitude above the Moon is 12,000 feet.

The TV Subsystem of the Ranger IX Spacecraft basically consisted of six vidicon cameras (2 full-scan, 4 partial-scan), the electronic equipment to control these cameras, the communications chains to transmit the acquired video information back to earth, telemetry components to monitor the operation of the functional components, a completely independent power source (batteries) for the entire TV Subsystem, a structure to house and support all electronic gear, and passive thermal-control components. The electronic equipment that formed the functional groups of the TV Subsystem were separated into two completely redundant, electrically independent channels of operation, designated the F-Channel and P-Channel. Channel separation was characterized by the basic differences of design between the full-scan cameras and the partial-scan cameras. The two camera types differed in the area of the scanned image, and therefore, in the scanning time and frame rate. Consequently, each channel, in addition to the cameras, consisted of video-combiner, sequencer, transmitter, control, and power-distribution circuits, which permitted independent or simultaneous operation of the channels.

In addition to channel separation, the components of the TV Subsystem are arranged into major functional groups. These groups were:

- Camera Group;
- Telecommunications Group;
- Controls Group;
- Power Group; and
- Thermal Design and Structure Group.

2. RA-9 TV Subsystem Modifications

Several modifications incorporated into the Flight Model III-4 Subsystem distinguished the RA-9 TV Subsystem from the RA-7 TV Subsystem. These modifications were product-improvement, equipment-refinement, or mission requirement type changes. The changes were based on results of the RA-7 flight, on further design studies, or were directly related to the particular constraints of the RA-9 mission. All comparisons were made to RA-7 instead of RA-8, because RA-9 was shipped to Cape Kennedy during the RA-8 mission and time did not allow for any modifications as a result of the RA-8 mission.

The modifications to the Camera Group of Flight Model III-4 TV Subsystem were as follows.

- An improved technique, used for the first time on RA-8, was also employed on RA-9 for focusing the three TV cameras equipped with narrow-angle (76-mm) lenses (P1, P2, and F_b Cameras). This revised method provided optimum optical focus of the cameras in a true space environment by compensating, during the alignment operation, for the displacement of the plane of best focus that occurs between air and vacuum conditions as a result of the pressure dependence of the index of refraction of air. In practice, a 0.0025-inch shim was used to increase the spacing between the lens and the vidicon faceplate, and the camera was subsequently optically focused in air for a maximum electrical response signal. When the shim was removed, the camera was in proper focus for operation in the space environment of an actual mission.

The shift in optical focus because of the differences in the air and vacuum indices of refraction was computed for the TV cameras with wide-angle (25-mm) lenses (P3, P4, and F_a). The change in focus was not considered sufficient to warrant application of this technique to these three cameras.

- The gain of the F_b, P1, and P2 Cameras was increased to change the peak-scene-luminance level of these cameras from 2700 footlamberts to a nominal 1500 footlamberts as the result of actual camera performance observed during the RA-7 mission.
- New vidicon tubes with a higher-density mesh structure than previously used were installed in all cameras with the exception of the F_a Camera. The new mesh structure has 1500 instead of 750 wires per inch.
- A new type of shutter-shock isolator was fabricated in the form of a castellated pad from polyurethane Solithane 113 (Thiokol formulation 5), and Solithane material instead of Sty-cast was employed to soft-mount the nuvistor in the preamplifier. These changes, along with the preselection of nuvistors for minimum microphonic sensitivity, were incorporated to suppress the effects of camera microphonics.

The modifications to the Telecommunications Group were as follows:

- Modification of the F- and P-Channel Transmitters and Transmitter Power Supplies to incorporate the Resdel (triode) configuration Intermediate Power Amplifiers (IPA) to provide improved temperature/frequency stability for the Transmitter chain.
- Replacement of varactor diodes in the X4 multiplier circuits of the F- and P-Channel Transmitters. The new diodes, which had a bonded construction, were more reliable than the pressure-contact units previously employed.
- Installation of a new O ring in the Dummy Load Assembly. The new O ring resulted in a leak rate that is only 20 percent of the value previously encountered.
- Relocation of the Telemetry Processor Assembly to accommodate the IPA modifications.

- Addition of telemetry points to monitor the cathode currents of the Intermediate Power Amplifiers in the F- and P-Channel Transmitters.

The circuitry of the Current Sensing Unit on Flight Model III-4 was modified to provide greater resolution of cruise-mode currents while maintaining full-power current indications within the normal telemetry range.

The modifications to the Harness Assembly of Flight Model III-4 were:

- A new design harness was constructed, which eliminated unnecessary splices and rerouted cables;
- New High-Rel Cannon connectors were incorporated in the new harness design;
- Special molds were fabricated for forming potting material on right-angle connectors;
- Stainless-steel, screw-lock assemblies were used with the connectors;
- Novathene wire replaced the Rayolin "N" wire used in the harness of the Ranger VII TV Subsystem; and
- Redundant battery power plugs were provided.

Battery support bars fabricated from stainless steel replaced the aluminum support bars employed on Ranger VII. The use of stainless steel provided increased strength to the support bars.

The solar absorptivity of the thermal control paints for Ranger IX TV Subsystem was reduced by using a greater percentage of white paint in the finish than was used in the RA-7 thermal finishes. This reduction in absorption was to allow for the increased solar constant existing during the anticipated March launch.

3. Equipment Performance

Every aspect of the performance of the Flight Model III-4 TV Subsystem during the Ranger IX mission achieved or exceeded specification requirements. The countdown, launch, and cruise phases of the mission, as evaluated from the 15-point telemetry, very closely followed the predicted levels of operation. The terminal phase of the mission, from the initiation of warm-up until impact, produced results which exceeded all expectations. A terminal maneuver was performed which aligned the common optical axis of the cameras with the spacecraft velocity vector, thereby allowing for excellent picture nesting and almost eliminating image smear. The Electronic Clock was reset by means of an RTC-5 command to allow for the initiation of warm-up of the TV Subsystem by means of a CC&S command at a time which was essentially ideal to provide area identification and also ensure continuing operation until impact.

The performance of the Camera equipment, as well as the transmission link to Earth, can best be adjudged by the evaluation of the mission film and magnetic-tape records. There existed unanimous agreement that the received picture quality far exceeded all expectations.

The mission requirements of high-resolution pictures of the lunar surface and of picture nesting were achieved by the Ranger IX Spacecraft.

The TV Subsystem sent back 5866 pictures during the approximately 19-minute terminal-mode operation: 5422 pictures were taken by the partial-scan cameras, and 444 pictures by the full-scan cameras. Typical results of the data returned are shown in Figures 37 through 44 and the explanatory data for the Figures are given in Table 10.

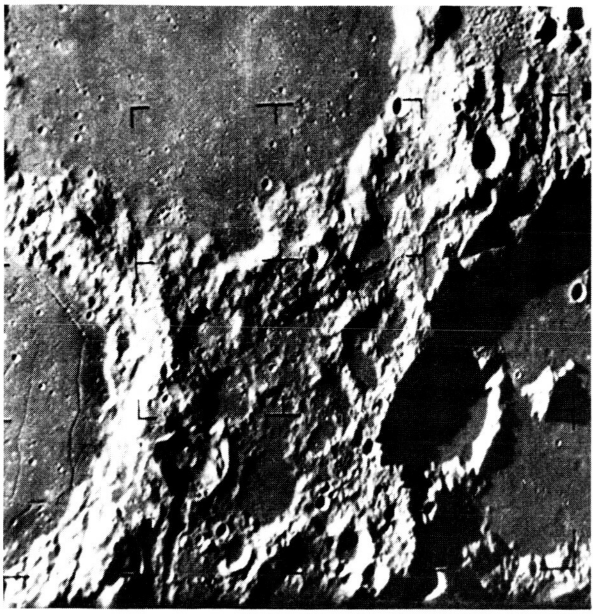


Figure 37. Ranger IX F_b Camera Picture Taken from an Altitude of 775 Miles

Figure 38. Ranger IX F_a Camera Picture Taken from an Altitude of 258 Miles

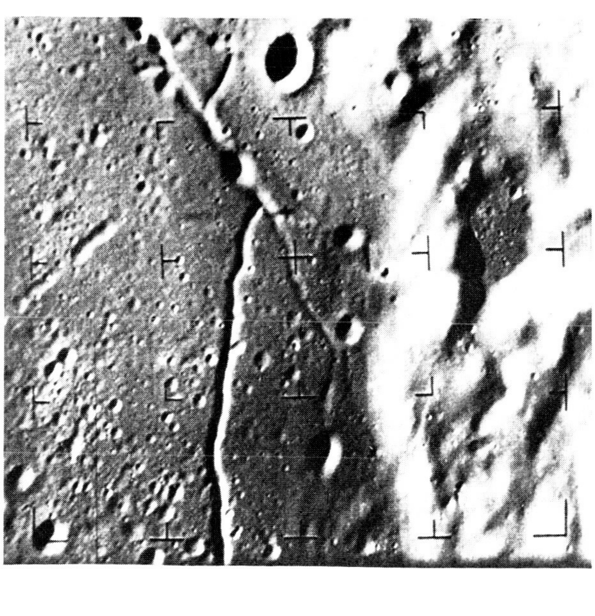


Figure 39. Ranger IX F_b Camera Picture Taken from an Altitude of 115 Miles

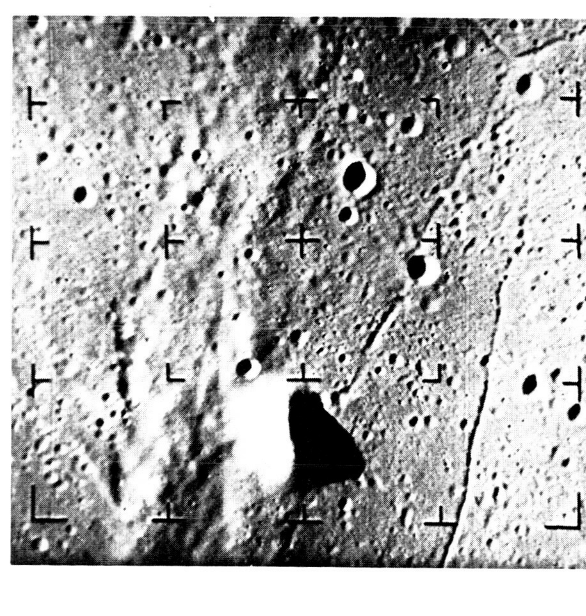


Figure 40. Ranger IX F_a Camera Picture Taken from an Altitude of 58 Miles

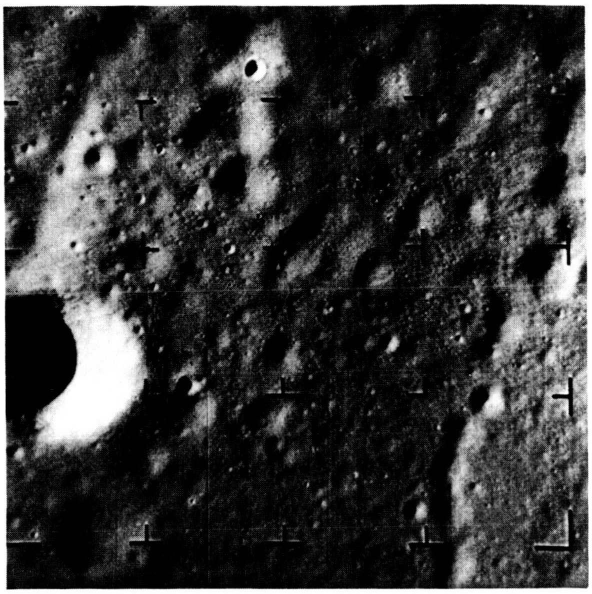


Figure 41. Ranger IX F_a Camera Picture Taken from an Altitude of 12.2 Miles

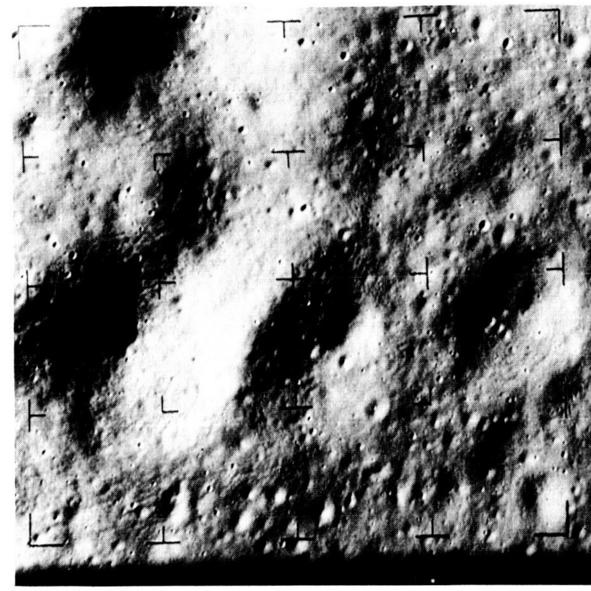


Figure 42. Ranger IX F_b Camera Picture Taken from an Altitude of 8.3 Miles

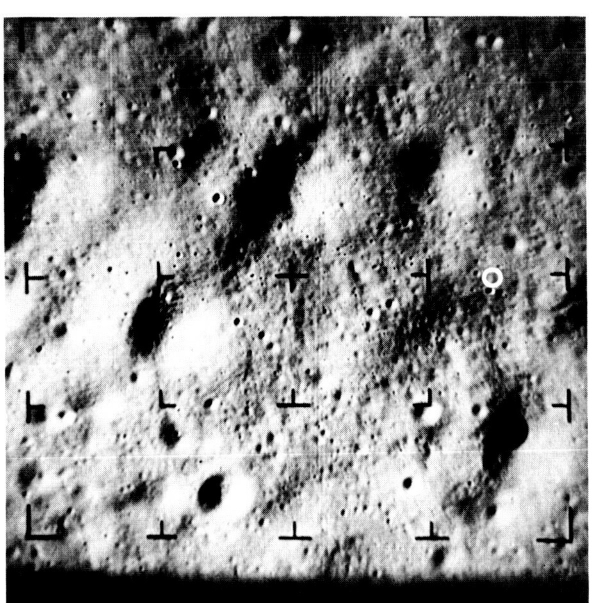


Figure 43. Ranger IX F_a Camera Picture Taken from an Altitude of 4.5 Miles

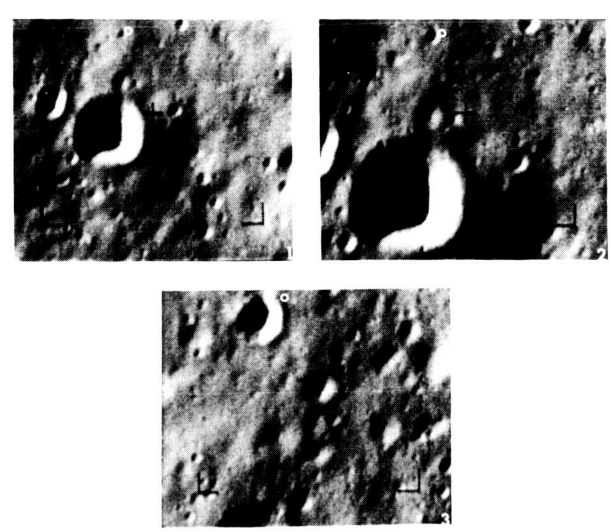


Figure 44. Ranger IX Final Three P1 Camera Pictures Taken from an Altitude of ¾ Miles

TABLE 10
EXPLANATORY DATA FOR TYPICAL RA-9 PICTURES
(Figures 37 through 44)

Figure No.	Explanation
37	Television picture taken by Ranger IX F_b Camera, 9 minutes 18 seconds prior to impact on March 24, 1965, at 06:08:20 PST. Viewed with shadows to left, North is at top. This picture is the 110th from last F_b Camera frame, and represents an area of 147 miles by 123 miles. Spacecraft altitude above the Moon is 775 miles. This picture shows slightly more than half of three major craters. Ptolemaeus at the top without central peak; Alphonsus on the left with rill system and a central peak which rises 3300 feet above floor; and Albategnius with 4500 feet central peak.
38	Television picture taken by Ranger IX F_a Camera, 2 minutes 50 seconds prior to impact on March 24, 1965. Viewed with shadows to left, North is at top. This picture represents an area of 121 miles by 109 miles. Spacecraft altitude above the Moon is 258 miles. Crater Alphonsus is shown in the right half of picture; Crater Alpetragius is near lower left with a broad central mountain; and Crater Davy A is in top left corner. The floor of Crater Alphonsus shows an intricate pattern of ridges and rills. Eight craters with dark patches are seen near the crater wall. The floor of Crater Alphonsus has higher crater density than adjacent Mare Nubium on left.
39	Television picture taken by Ranger IX F_b Camera, 1 minute 17 seconds prior to impact on March 24, 1965. Viewed with shadows to left, North is at top. This picture is the sixteenth-from-last full F_b Camera frame. Spacecraft altitude above the Moon is 115 miles. The picture shows the East edge of Crater Alphonsus floor, with part of surrounding wall in right one-third of the picture. Crater floor is cut by prominent rills which are lined with dark halo-type craters that have covered part of the rill. The crater walls have soft contours and are almost featureless.
40	Television picture taken by Ranger IX F_a Camera, 38.8 seconds prior to impact on March 24, 1965. Viewed with shadows to left, North is at top. This picture is the eighth-from-last F_a Camera frame, and represents an area of 28 miles by 26 miles. Spacecraft altitude above the Moon is 58 miles. The picture shows region of the central peak of Crater Alphonsus with a rill running through its shadow toward upper right. This same rill is shown in next-to-last F_a Camera frame with larger scale.

TABLE 10
EXPLANATORY DATA FOR TYPICAL RA-9 PICTURES
(Figures 37 through 44) (Continued)

Figure No.	Explanation
41	Television picture taken by Ranger IX F_a Camera, 8.09 seconds prior to impact on March 24, 1965. Viewed with shadows to left, North is at top. This is the next-to-last F_a Camera frame. Spacecraft altitude above the Moon is 12.2 miles. This picture represents an area of 5.8 miles by 5.3 miles. The large crater toward left margin is 1.6 miles across and is situated on a shallow rill running upward. A second rill near right margin is resolved as a string of chain craters.
42	Television picture taken by Ranger IX F_b Camera, 5.5 seconds prior to impact on March 24, 1965. Viewed with shadows to left, North is at top. This is the last full F_b Camera frame and represents an area of 1.6 miles by 1.4 miles. Spacecraft altitude above the Moon is 8.3 miles. The picture shows several major shallow depressions with numerous dimple-type craters and fine structure in shadowed area. Smallest craters shown are approximately 30 feet in diameter.
43	Television picture taken by Ranger IX F_a Camera, 2.97 seconds prior to impact on March 24, 1965. Viewed with shadows to left, North is at top. This picture is the last F_a Camera frame, and represents an area of 2.1 miles by 2.0 miles. Spacecraft altitude above the Moon is 4.5 miles. The picture shows several large shallow depressions with "tree-bark" texture in the walls, and many dimple craters near top and left lower margins. Craters to 40 feet in diameter may be seen.
44	These television pictures are the last three P1 Camera frames taken by Ranger IX on March 24, 1965. Viewed with shadows to the left, North is at top. Frame No. 3 was taken 0.453 second before impact and represents an area of 160 feet by 125 feet. Spacecraft altitude above the Moon is 3/4 of a mile. The Ranger IX Spacecraft impacted in the circle shown on the edge of the 25-foot crater near upper margin. The smallest visible crater shown in frame No. 3 is 2.5 feet across.

Section VIII

Technological Achievements

This section of the report contains a summary of the technological advances made during the TV Subsystem program.

A. OVERALL SUBSYSTEM

During the TV Subsystem program, four specific technological advancements were made in the overall Subsystem. These are the split-system concept, passive thermal-control techniques, redundant command provisions, and adaptation of commercially available lenses to the TV camera.

1. Split-System Concept

The TV Subsystem was packaged as a 380-pound payload with two entirely redundant camera and television transmitter chains. Each chain was completely independent of the other and could be operated independently of, or simultaneously with, the other chain. Furthermore, each chain was completely independent of the Bus operation during the terminal portion of the mission.

2. Thermal Control Techniques

Passive thermal-control techniques were used to maintain the TV Subsystem equipment within the desired range of operating temperatures during the in-flight portion of the mission. The use of passive techniques eliminated the necessity for on-board equipment which would have added weight and power-drain to the Subsystem. These techniques successfully maintained the operating temperatures and eliminated a power drain ranging from a few watts, during the in-flight (cruise mode) portion of the mission, to more than 1 kilowatt during the terminal (full-power mode) portion.

3. Redundant Command Provisions

A redundant turn-on capability was provided for the Subsystem by a multiplicity of command paths; these paths consisted of the RTC-7 (real-time radio), the TV-2 (radio-stored) command), and the TV back-up clock. The use of the TV back-up clock with a preset timer plug, and the use of the Spacecraft midcourse maneuver to adjust the time of arrival at the moon (as well as impact location) to correspond to the clock time, are additional examples of the redundant capability incorporated in the Subsystem command equipment.

4. TV Camera Lenses

The two lenses used in the TV Subsystem were 76-mm, f/2.0 and 25-mm, f/1.0. These lenses were small, off-the-shelf lenses which were commercially available. They were adapted to obtain the very high resolution pictures returned by Rangers VII, VIII, and IX.

B. CAMERA GROUP

The Ranger TV camera is a compact vidicon camera which is small in size, low in weight, and low in power drain. The camera, including optics and electronics, weighs 15 pounds, occupies a volume of approximately 0.25 cubic foot, and requires 15 watts of power. This camera is comparable to a commercial television camera that would weigh more than 100 pounds, occupy several cubic feet of space, and use more than one kilowatt of power.

The Ranger TV camera uses 1150 scan lines in a 2.56-second frame time to provide 800 TV lines of resolution over a 200-kc bandwidth. A commercial television camera provides about 350 TV lines of resolution with 525 scan lines in a 3.5-Mc bandwidth. The vidicon is ten times more sensitive than those used in commercial applications.

The Ranger TV camera utilizes all semiconductor circuits with the exception of the vidicon and a nuvistor preamplifier. The Ranger vidicons and nuvistors are ruggedized to survive a rocket launching.

The Ranger TV camera has the capability to stop motion and take pictures at a closing velocity of 6000 miles per hour; this is accomplished with a focal plane shutter which is operated by an electro-mechanical actuation. The exposure provided is 1/500 of a second. The shutter can safely be actuated at least 250,000 operations; more than 1,000,000 operations were demonstrated in the laboratory. (Standard photographic cameras rarely achieve more than 10,000 operations with their shutters).

C. COMMUNICATIONS GROUP

The television transmitters are the highest-power units used in space to date; they radiate 30 watts per channel in the L-frequency band (960 Mc). Special problems (successfully solved) included: (1) the combining of simultaneous radiations of two 900-kc RF bandwidths whose carrier frequencies are separated by only one Mc; and (2) the solution of arcing and multipactor breakdown by pressurizing the power amplifiers and dummy load and by utilizing a solid-state design for the RF-combining network.