CONTRACT 950137

RANGER TV SUBSYSTEM (BLOCK III) FINAL REPORT

VOLUME 4a: MANUFACTURING, PRODUCT ASSURANCE, AND TEST

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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 4, is divided into two parts. Part a contains:

- A description of the special manufacturing techniques employed on the Ranger TV Subsystem project,
- A description of the reliability methods employed on the Ranger TV Subsystem project,
- A description of the Quality Control methods employed on the Ranger TV Subsystem project, and
- A history of the Ranger TV Subsystem test program.

Part b of this volume contains the appendices to part a.

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Section I

Manufacturing Engineering

A. INTRODUCTION

1. Ranger Requirements

The Ranger program imposed new and greater responsibilities on the engineering support facilities. To achieve the Ranger mission objectives, a new concept of reliability in manufacture (surpassing that of preceding space programs) was required. Stringent requirements had been placed on the selection and qualification of electronic components. More explicit delineation and control of processes was required. Precautionary measures were needed to insure that materials and processes of manufacture would not degrade the built-in reliability of qualified materials and components.

2. Existing RCA Capability

In meeting these high reliability requirements and the stringent Ranger schedule, RCA was able to apply its experience in space technology gained on Score, Echo, TIROS, Relay, and similar programs. Thus, a great many of the required Ranger techniques were already in existence, having been proved by testing and by successful space flight.

Existing production equipment and facilities were broadly arrayed in support of engineering requirements for models, prototypes, and short-run flight programs rather than high-production runs. The machining and metal-working equipment was of excellent precision quality, and the operators were qualified as expert mechanics and toolmakers. Proficient personnel were available for turning, boring, milling, drilling, and welding of aluminum, stainless steels, carbon steels, and magnesium. Forming, bending, and blanking of sheet materials were confined to the lighter gauges.

Printed-circuit facilities had been established to provide a quick-reaction, short-order capability for producing high-quality printed-circuit boards. The equipment and techniques used were those acceptable for highly reliable military and commercial production.

Conformal coating, bonding, and potting capability was established as an engineering rather than a production operation. Essentially all applied materials were compounded, applied, and tested as part of a development or product qualification program.

3. New Manufacturing-Engineering Programs

The intensified requirements for additional reliability of manufacture prompted the implementation of manufacturing-engineering programs for exacting control of manufacturing and testing of products. Detailed manufacturing and testing procedures were developed for production operations. The recording and documentation of manufacturing and test results were established and maintained to ensure the identification and traceability of material and processes at all times. The development of new processes and techniques was keyed to the need for reliable and safe joining of high-reliability components without degrading component performance or life. These efforts led to the increased use of high-reliability transistors and diodes, the development of new soldering and welding techniques, and the employment of high-quality weldments and castings, machined to precision requirements.

The significant aspects of manufacturing and testing are discussed herein in relation to the higher reliability and improved uniformity which they produced on the Ranger program.

B. FABRICATION TECHNIQUES

1. Fabrication of Camera-Shutter Solenoid Coil

To obtain a solenoid plunger with low mass, the coil was made the moving element of the camera-shutter solenoid and rode on the magnetic core which was stationary. The unique construction of the coil necessitated the development of a special coil-forming machine and a process to implement the design. A cutaway view of the Camera Shutter Assembly is shown in Figure 1.

The body of the coil was formed from epoxy-impregnated glass-cloth tape. In fabricating the coil, the glass-cloth tape was passed through an epoxy bath and wound onto a steel-mandrel. The epoxy-glass tube thus formed was placed in an oven to cure the epoxy. After curing, the tube was machined, and magnet wire, passing through an epoxy bath, was wound onto the tube. This operation was followed by winding another layer of epoxy-impregnated glass cloth onto the coil. The new layer was then cured and machined, after which the steel mandrel was pressed from the coil.

The major problem in manufacturing the shutter solenoid coil was the prevention of air entrapment. Air trapped in the epoxy or between the glass tape layers would cause bubbles in the epoxy-glass material when the coil was exposed to a vacuum environment. These bubbles would deform the coil sufficiently to cause binding between the moving coil and the magnetic core, since the clearance between the two was only 0.0005 of an inch.

The problem was overcome by directing a jet of hot air onto the epoxy-impregnated glass cloth during winding to prevent hardening of the epoxy before all entrapped air was forced out by the pressure of the winding.

Another problem was encountered in maintaining the very smooth finish in the bore of the coil when removing it from the steel mandrel. Various mold-release agents were investigated for coating the mandrel prior to forming the coil. These included polishing wax and teflon coating which did not give the desired results. Ultimately, the problem was solved by the use of a high-temperature silicone grease.

2. Fluorescent Coating for Electrical Conductors

A unique insulating material was developed for the conformal coating of exposed terminals and conductors. The material is a thixotropic polyurethane resin which contains a trace of fluorescent material. When exposed to ultraviolet radiation, the material fluoresces so that pinholes or uncoated areas are readily disclosed. Coated areas with a film thickness of less than 5 mils do not react to the ultraviolet light and are, therefore, easily detected.

Processes were developed for the preparation, storage, application and curing of the coating material. The material was applied on all TV Subsystem subassemblies, and each subassembly was rigorously inspected under the ultraviolet light to ensure complete encapsulation of the conductors. The use of this material and inspection technique has become the standard on all company programs.

3. Energy-Damping Materials

A number of cured urethane resin compounds were developed for use as energy-damping materials. These materials were employed in the fabrication of isolators which were used to eliminate or minimize microphonics induced by the operation of the camera shutters. The materials exhibited high energy-absorption characteristics, good tear strength,

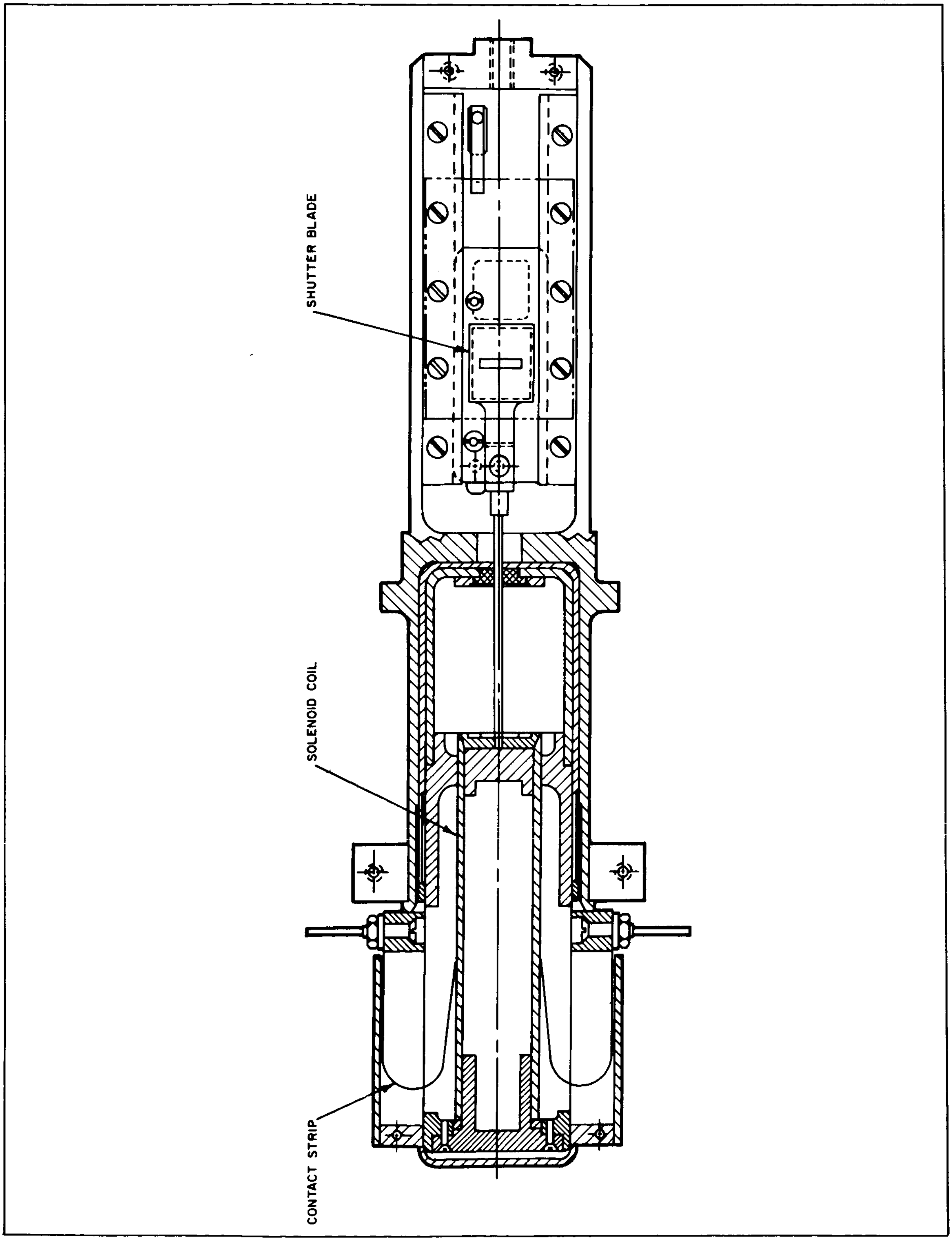


Figure 1. Cutaway View of the Camera Shutter Assembly

and low outgassing in a thermal-vacuum environment.

C. ASSEMBLY TECHNIQUES

Assembly methods and soldering techniques in use at the start of the Ranger program conformed to high-reliability military production standards. Nevertheless, the superior reliability required for a successful Ranger Mission engendered a program of continuing improvement of assembly techniques.

1. Soldering of Coaxial Cables

Improved methods were developed for soldering connectors on RF coaxial cables. These methods included ultrasonic cleaning of connectors just prior to soldering, pull tests, and x-ray of connector center-pins to insure that at least 95 percent of the center-pin cavity was filled with solder. These techniques have been adopted as standard production practice.

2. Cable-Lacing

"Tack-Stitch", a new unique method for lacing cables, was developed during the Ranger program. The standard method is to lace the harness wire into a circular bundle. With the new lacing method, the harness wiring can be formed into an oval or a flat shape for passing through decks and making tight bends. The flatter harness configuration can also be utilized within assemblies to permit smaller overall dimensions of the completed unit. This technique was particularly advantageous in the TV Subsystem because of the close structural tolerances and compact design. Moreover, the "Tack-Stitch" is a more secure and faster method of lacing. It is now the company standard for all spacecraft and spacecraft assemblies.

3. Conformal Coating

Conformal coating of circuits was utilized, instead of potting techniques, to allow nondestructive rework and modifications. Methods were developed to remove conformal coatings from assemblies during repair or modification without damage to unaffected components. Special spatulas were designed for this task.

4. Low-Temperature Soldering

Specially shaped soldering irons with controlled heat were developed for removal and installation of components. Experimental work was done to evaluate the amount of heat which could be tolerated on printed circuits. It was found that a low-temperature soldering iron, applied for a relatively long period of time, would not damage the circuit boards; whereas, a high-temperature iron would tend to cause damage even when applied for a short interval of time. Consequently, special low-temperature soldering irons were obtained.

5. Assembly Fixtures

Various holding fixtures were employed to expedite assembly and to protect the equipment during handling. These fixtures were generally attached to the assembly, and, for maximum protection, were not removed until the assembly was integrated with the TV Subsystem.

A set of special fixtures was developed to facilitate assembly of the Camera Shutter Assemblies. The fixtures are shown in Figure 2. The large fixture in Figure 2 was used to hold the camera shutter during assembly. The magnetic core guide was used to align the magnetic core to ensure proper clearance for the solenoid coil which was the moving element of the solenoid. The coil positioner was used to hold the solenoid coil in the proper position within the solenoid housing during soldering of the contact strips to the coil. The contact-strip fixtures were used

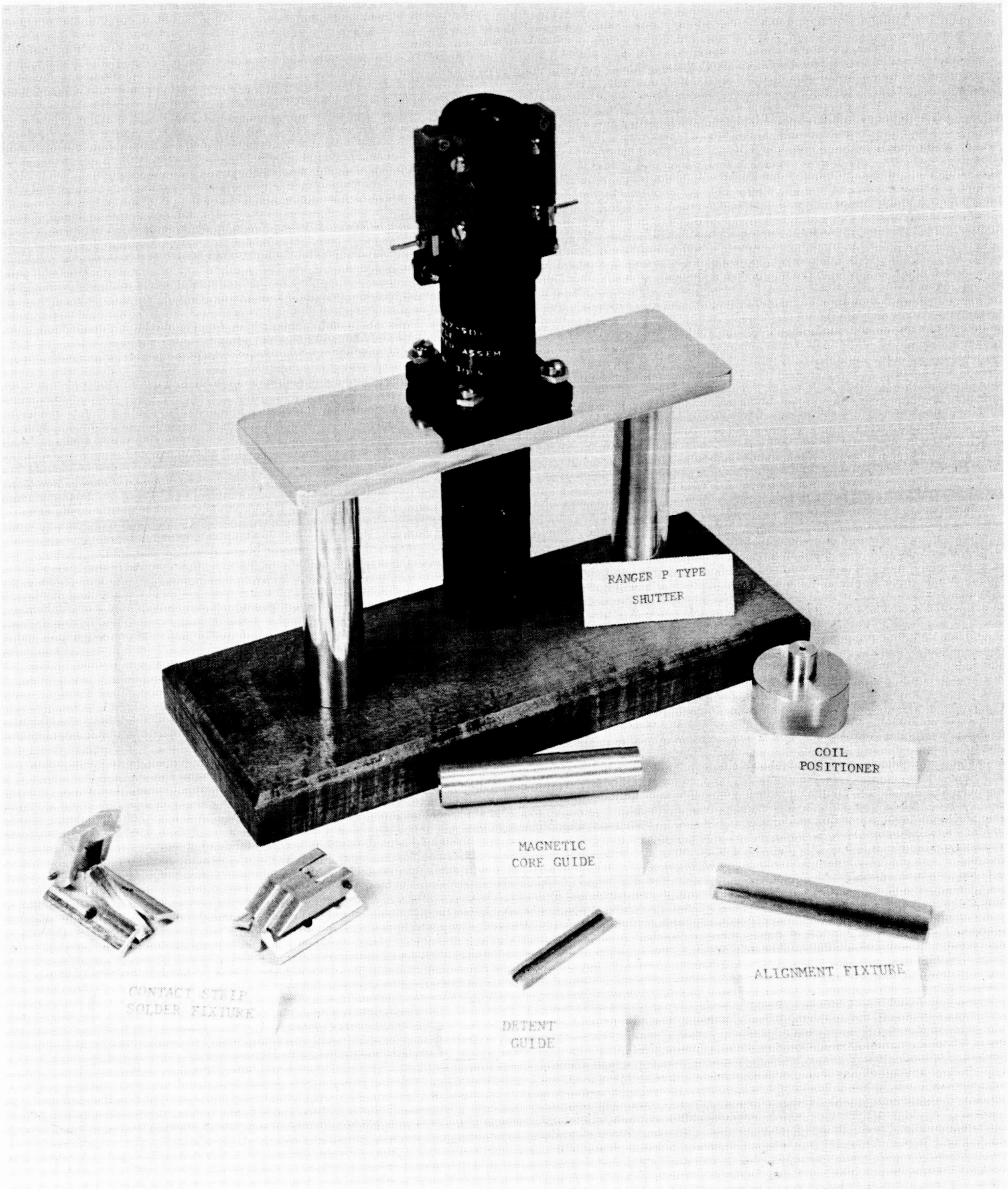


Figure 2. Set of Special Fixtures Developed to Facilitate Manufacture of Camera-Shutter Assemblies

to hold the contact strips in proper alignment for soldering. These fixtures also served as heat sinks during soldering. The guide-alignment fixture was used to align the shutter guides and to set the distance between them. The detent guide was used to align the detent springs with the shutter-blade detents.

6. Assembly Status Board

Because of the urgency of the program, a special material-routing plan was implemented and maintained. Every assembly in the TV Subsystem was listed on a tally board. A complete minute-by-minute status could be obtained from the tally board, including location of the assembly, the specific operation being performed on it, and the next step in assembly. Material coordinators assigned to the program maintained a smooth flow of material from one operation to the next. By reference to the tally board, the material coordinators could determine what units required expediting and could then establish operational priorities.

7. Look-Alike Assembly

Photographs of the assemblies were used as a reference to ensure uniformity of wire dress, component placement, and conformal coating. This "look-alike" technique was not a contractual requirement, but was employed to ensure identical operation of all assemblies of the same type. It also simplified the detection of any irregularity which may have occurred in an assembly. An 8x10 inch color photograph was made of the first unit assembled. The photograph served as a guide for the assembly of subsequent units. This technique has become a standard company practice and photographs, now a part of all documented manufacturing procedures, are the primary medium for conveying information to the manufacturing operators.

8. Harness Assembly Board

The first harness for the PTM was fabricated on a plastic structure. In order to comply with the JPL specification that all Cannon Golden "D" and Bendix "pygmy" connectors be potted, a potting procedure was devised by materials engineering. The potting was specified to be performed with the connectors mated, in order to assure proper pin alignment. The potting was used to provide both strain relief and protection for the solder connections. It was necessary to mount the harness on a special board to allow the connectors to lie in the proper position for potting. The PTM harness which was formed and fabricated on the plastic structure could not be laid on a flat potting board without experiencing considerable deformation. It was decided to fabricate future harnesses on a flat board rather than a mock-up structure to avoid this deformation.

Manufacturing engineering, in cooperation with design engineering, developed a board which permitted the fabrication of the harness to the contour of the TV Subsystem structure.

D. TEST PROGRAM

The manufacturing test program in effect at the start of the Ranger project was designed to allow uniform testing by the use of standard techniques and equipment, and to relieve engineering personnel of repetitive testing. The severe reliability requirements of the Ranger program necessitated a sharp increase in the complexity and multiplicity of tests. Individual manufacturing test procedures were prepared for all assemblies of the TV Subsystem and for the TV Subsystem itself. These procedures were designed to uncover faults in workmanship and components, and to reveal possible design problems. Special test equipment was developed to implement the procedures. The equipment consisted of component-level test sets, equipment-group test sets, and a TV-Subsystem-integration test set. The special equipment and procedures are described in the following paragraphs.

1. Six-Camera Bench Test

A six-camera bench test was developed to test the six TV cameras simultaneously. The purpose of the test was to eliminate camera interface faults and to optimize operation of the cameras prior to integration with the TV Subsystem.

The six-camera bench-test equipment simulated the TV Subsystem electrical and mounting interface for the cameras. It was a self-contained test set which included all required power, synchronizing signals, control circuits, and measurement facilities. The only external requirements were a 115-volt, 60-cps source and optical collimators.

2. Camera-Group Test Rack

A Camera-Group test rack was developed specifically for the troubleshooting and alignment of the TV Subsystem Cameras, Camera Electronics, Video Combiners, Camera Sequencers and Shutter Assemblies. The unit was mobile to permit easy transport to the environmental-test area and to permit its use as support equipment at the launch site.

The test rack included provisions for a functional check of the individual circuit boards of the flight-model Camera Electronics Assemblies. A system of cabling permitted any circuit board in the test-rack Camera Electronics to be substituted for a flight-model circuit board of the same type. Actual operating conditions were simulated to provide meaningful test results.

The test rack incorporated protective circuitry to safeguard TV Subsystem components under test. A vidicon protective circuit constantly monitored the deflection and filament voltages of the vidicon. In the event of failure of one or both of these voltages, the high accelerating potential applied to the vidicon would be interrupted immediately. Appropriate lamps on the test-rack control panel visually indicated the operational status of the vidicon. All input power lines were filtered and fused to protect components under test from external transients and overloading.

3. Moment-of-Inertia and Center-of-Gravity Measurements

Special equipment and procedures were developed to measure the moment-of-inertia and center-of-gravity of the TV Subsystem. The test rig was essentially a bifilar pendulum from which the TV Subsystem was hung. A collimated light source and a photoelectric cell connected to an electronic counter were used in conjunction with a mirror attached to the test rig to determine the period of oscillation. A test bar with a known moment-of-inertia was used to check the accuracy of the test setup. The test rig with the test bar attached is shown in Figure 3. The test setup for measurement of the TV Subsystem moment-of-inertia about the z-axis is shown in Figure 4. The setup for measurement of moments-of-inertia about the x- and y-axes is shown in Figure 5.

A protective cage was designed to safeguard the TV Subsystem during setup of moment-of-inertia tests. This case facilitated the manipulation of the TV Subsystem to any position without imposing any undue stress on the shroud or structure. The protective cage, containing the TV Subsystem in the inverted position, is shown in Figure 6.

4. Connector-Pin Retention

A pull-test was developed to determine if the individual female terminals were exerting a sufficient gripping force on the connector pins. A method was also developed for repairing the female terminals without removing the connector or disconnecting the wiring. In this method, a hardened copper sleeve was installed over the female terminal to restore

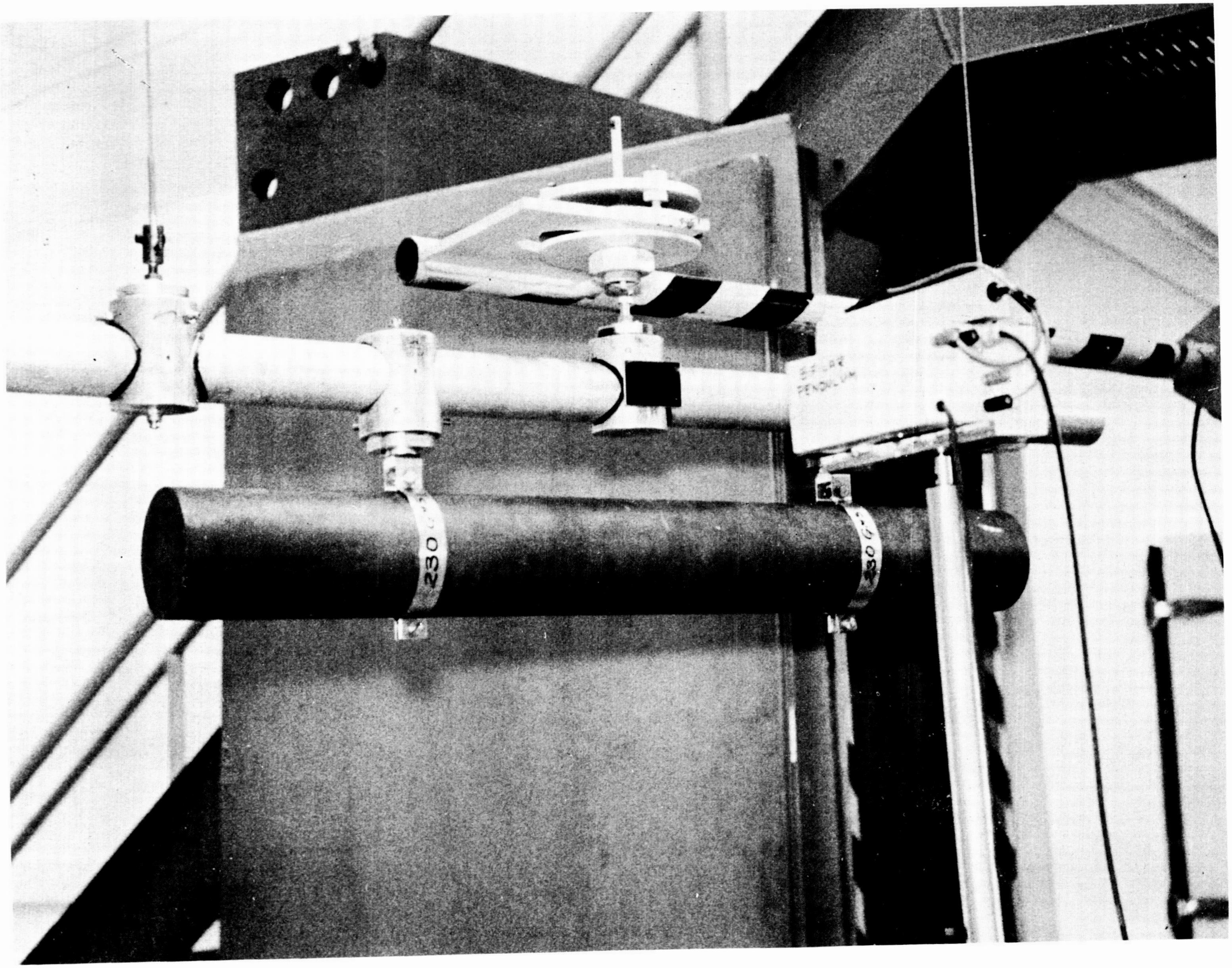


Figure 3. Moment-of-Inertia Test Rig with Test Bar

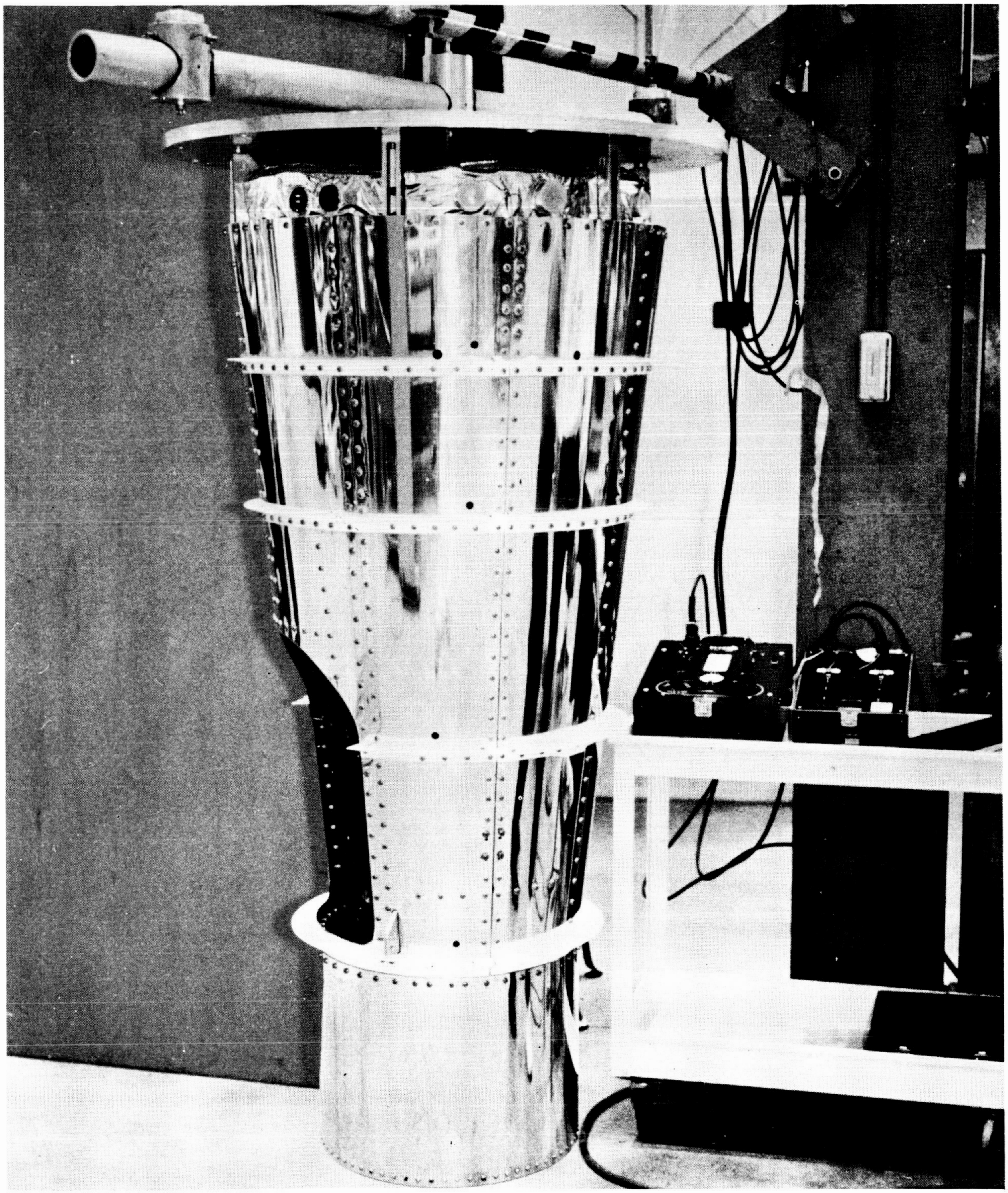


Figure 4. Test Setup for Measurement of Moment-of-Inertia about the Z-Axis

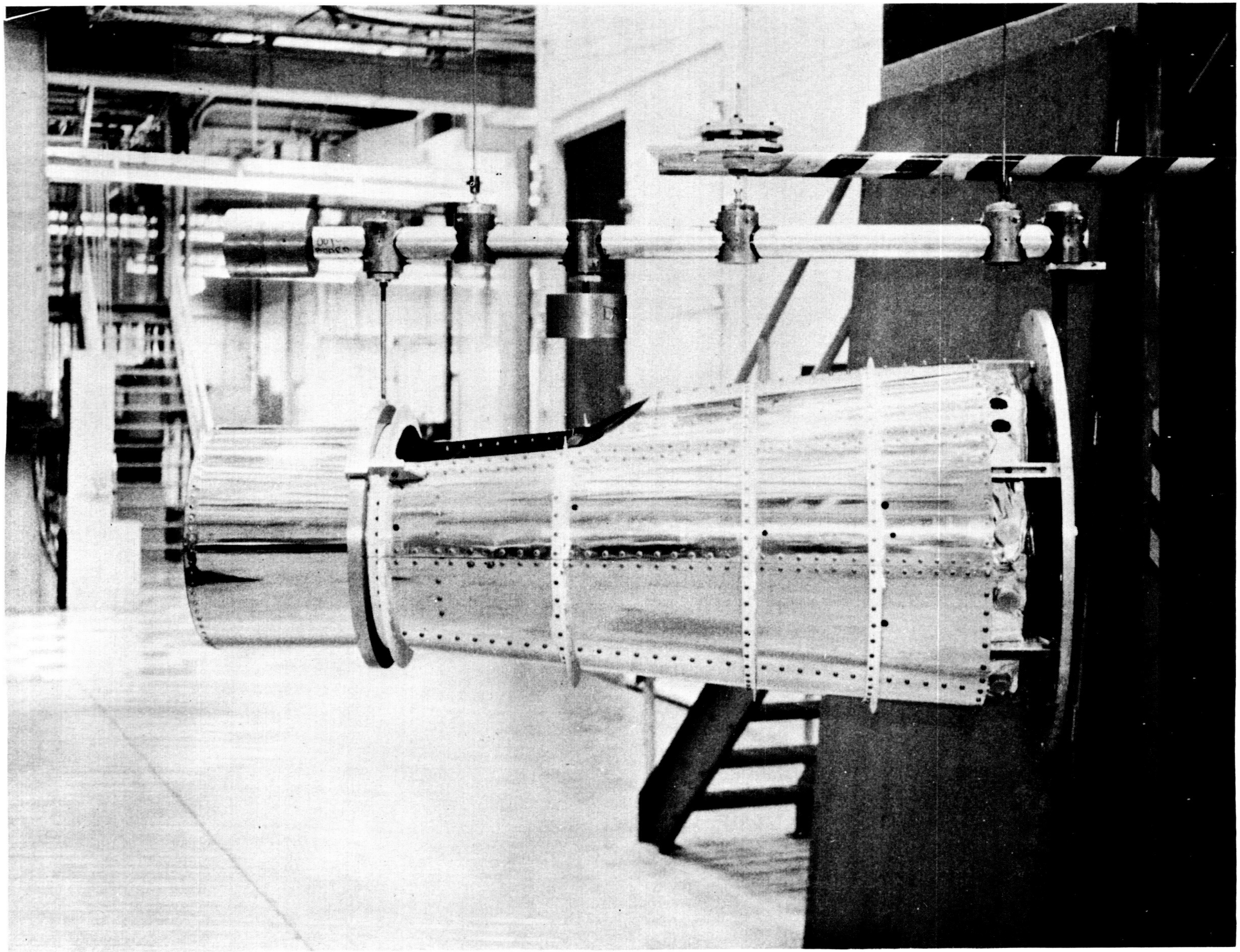


Figure 5. Test Setup for Measurement of Moment-of-Inertia about the X-and-Y-Axes

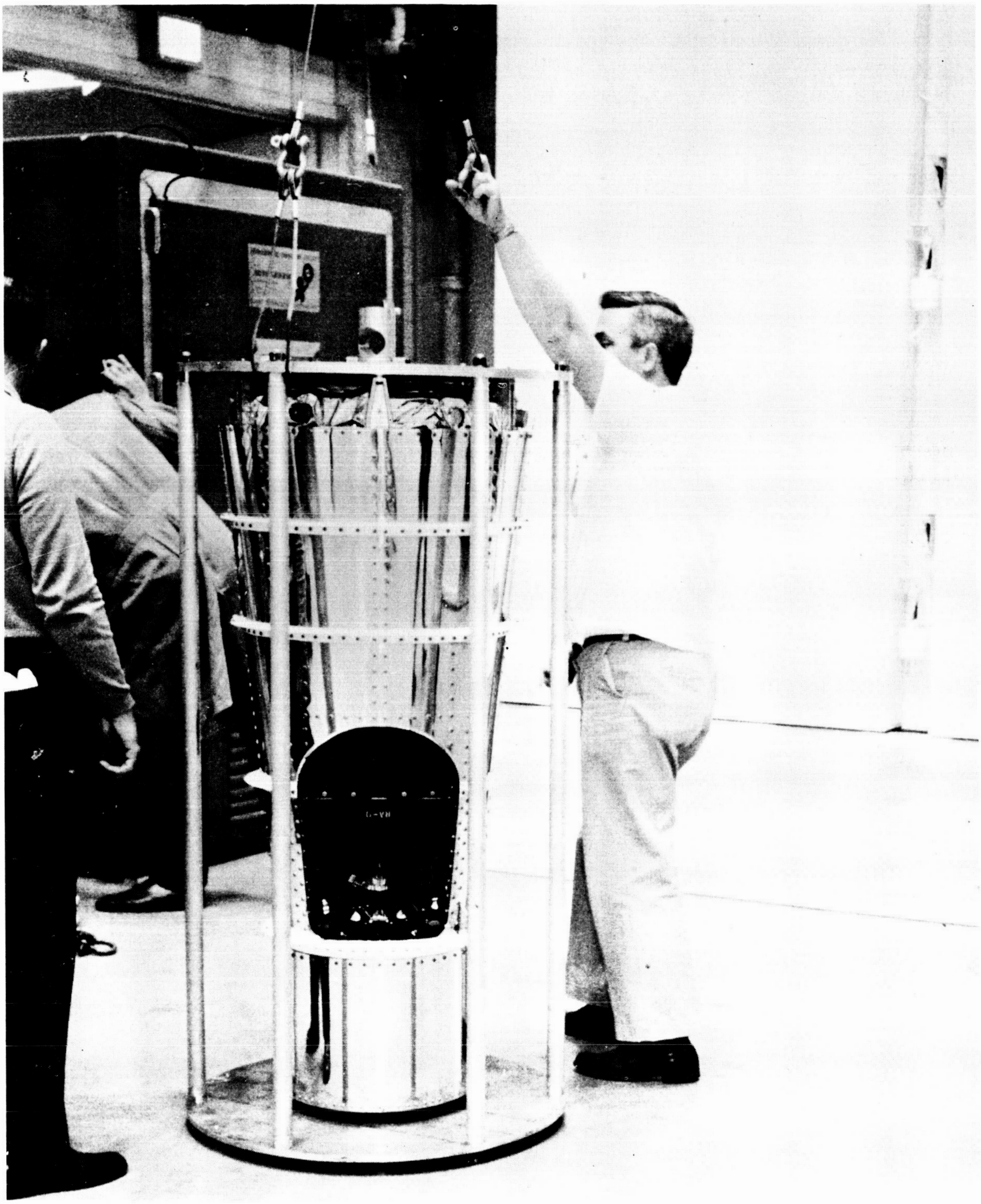


Figure 6. TV Subsystem in Inverted Position in the Protective Cage

the proper tension. A kit of special tools was developed to form the sleeves and to insert them in the connectors. A container of methyl-ethyl-ketone and an applicator brush were included for cleaning the connectors. The kit is shown in Figure 7. The tool used to form the sleeves from flat stock is shown in Figure 8. Insertion of the sleeve into a female connector is shown in Figure 9. The pin-retention test and the repair technique have become a standard procedure on all company programs.

E. SPECIAL HANDLING PROCEDURES

Comprehensive procedures were developed for handling material for the Ranger program from the receipt of individual parts to the shipment of the completed TV Subsystem. The primary aims of these procedures were to ensure cleanliness of the equipment and safeguard it from damage.

1. Material Identification and Storage

A color-coding system was used to identify the date on which each item was received. The rule was to process parts on the day of arrival. Any parts left over were processed first on the following day. Parts were routed from the receiving room to Purchased Material Inspection Quality Control and then to the Controlled Stores Room. Here the parts were packaged in clear plastic zipper bags or plastic boxes and placed in drawers. The Quality-Control approval ticket and an item-control serial number were kept with the stored material to permit tracing of the items to a particular shipment. A section of the Controlled Stores drawers displaying the packaged items and their control-numbered tags is shown in Figure 10.

Kits were prepared, as needed, from the parts stored in the Controlled Stores Room. All parts used in a particular assembly were placed in white Royalite tote boxes with clear plastic lids (Figure 11). Parts-traceability identification and kit identification were included in the boxes. Also stored in the boxes were a flow chart, an outline of the manufacturing procedures, and a logbook. As each step of assembly or cleaning was performed, it was entered in the logbook.

2. Assembly and Transport Dollies

A special dolly (Figure 12) was used in the fabrication of the TV Subsystem wiring harness described in subsection C8. The harness board could be tilted to any angle by a simple adjustment of the dolly to permit easy access to any part of the harness.

Specially designed carrying cases were used to transport the TV Subsystem wiring harnesses into and out of conformal coating, testing, and other operations.

A pivoting dolly (Figure 13) was developed to meet the transportation and handling requirements of the TV Subsystem.

The dolly served as an in-plant transportation device for the TV Subsystem and as a functional work fixture during assembly. It had provisions for positioning the Subsystem at various angles to facilitate assembly operations and the replacement of the batteries at the bottom.

An optical alignment dolly (Figure 14) was also developed. It was primarily a precision fixture for aligning the TV Subsystem cameras with an optical target during testing. It was also used to transport the TV Subsystem to other test locations.

3. Shipping Container

A reusable shipping container was developed for transporting the completed TV Subsystem to Jet Propulsion Laboratory for integration with the Ranger Spacecraft. The container was designed to control shock and vibration that would otherwise be transmitted to the TV Subsystem during shipment. The internal atmosphere could be controlled by pressurizing the container with an inert gas.

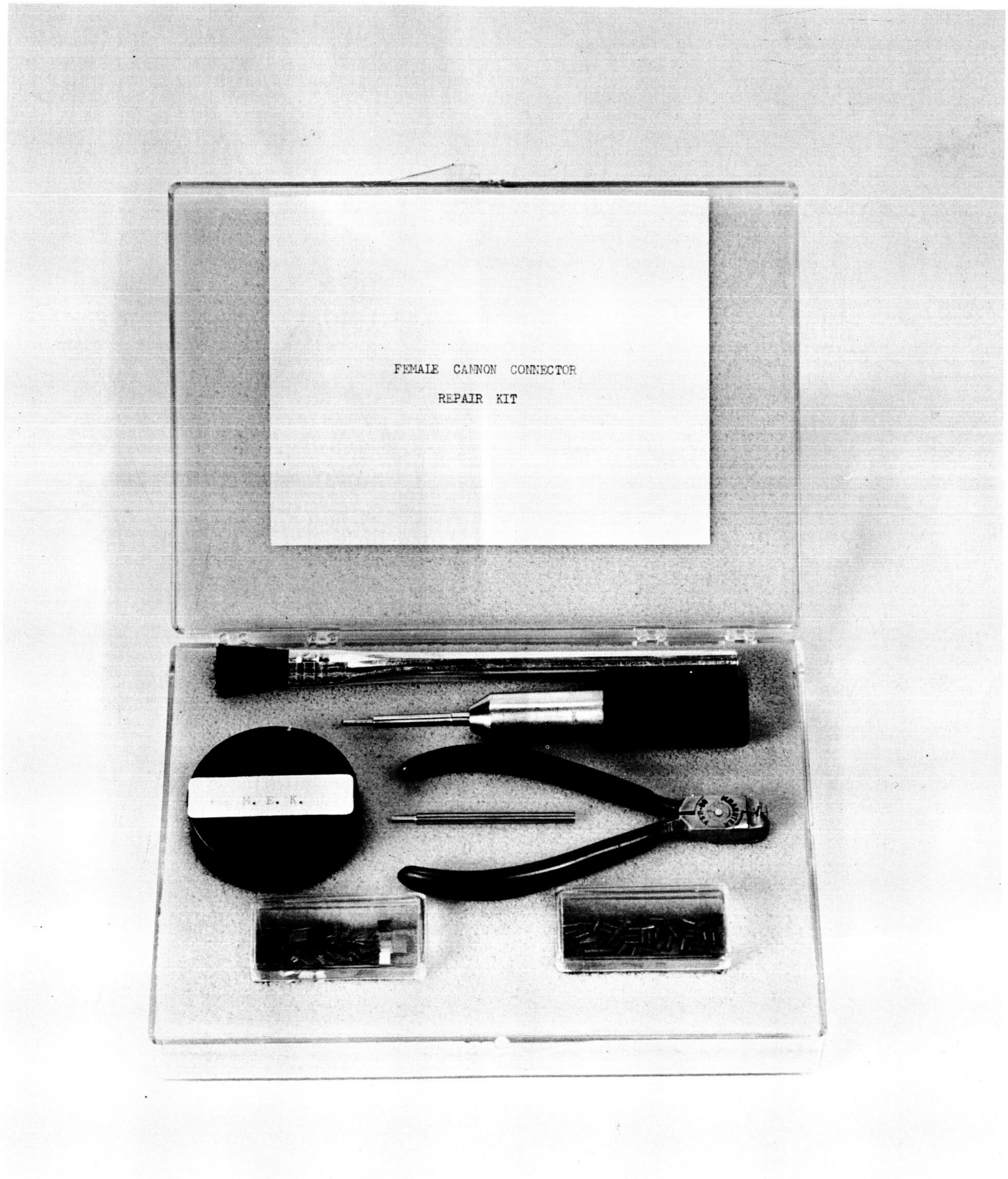


Figure 7. Female-Connector Repair Kit

Figure 8. Sleeve-Forming Tool with Flat Stock and Completed Sleeves

Figure 9. Installing Sleeve on Female Terminal

Figure 10. Method of Storing Parts in the Controlled Stores Room

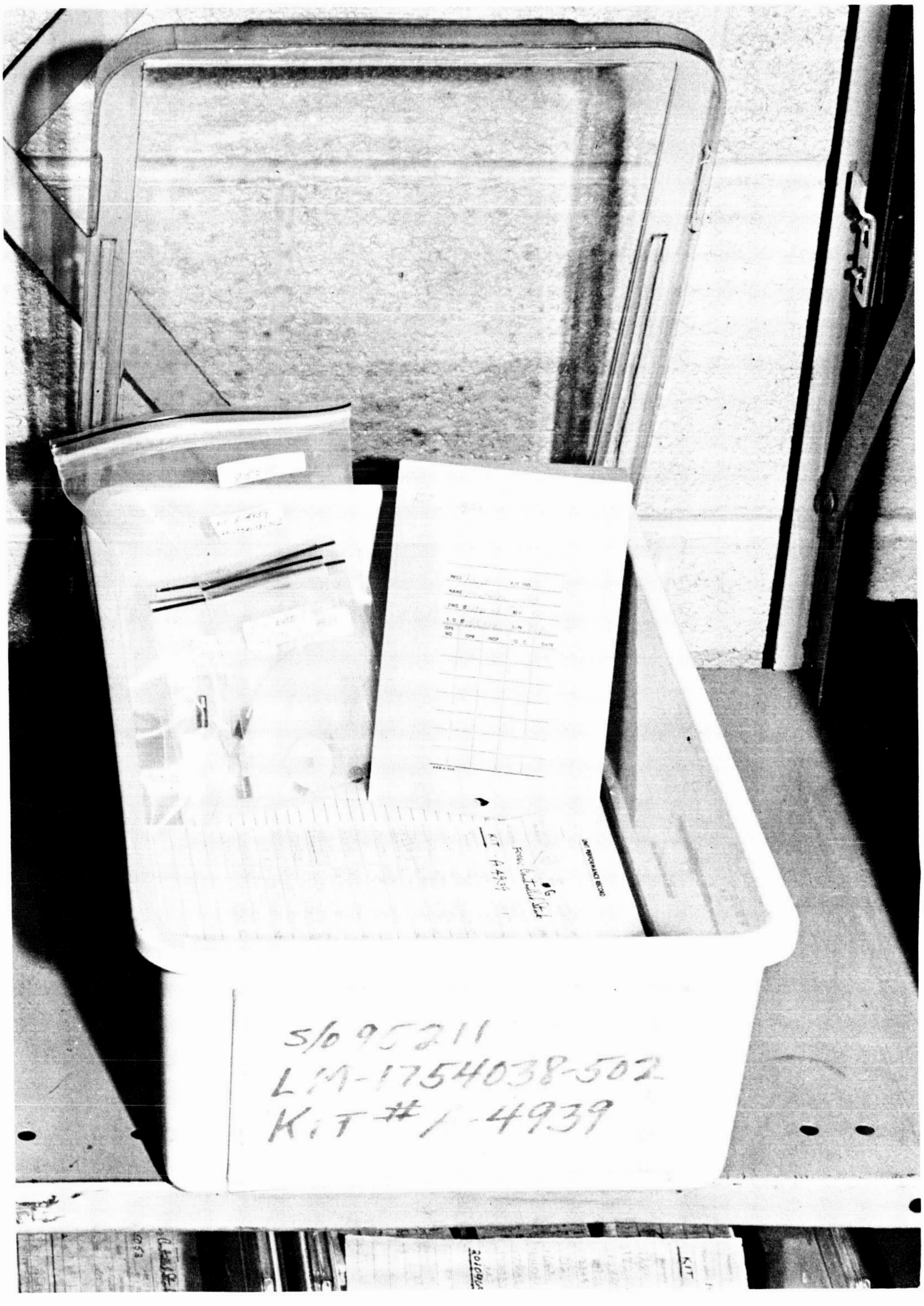


Figure 11. Tote Box for Transporting Parts

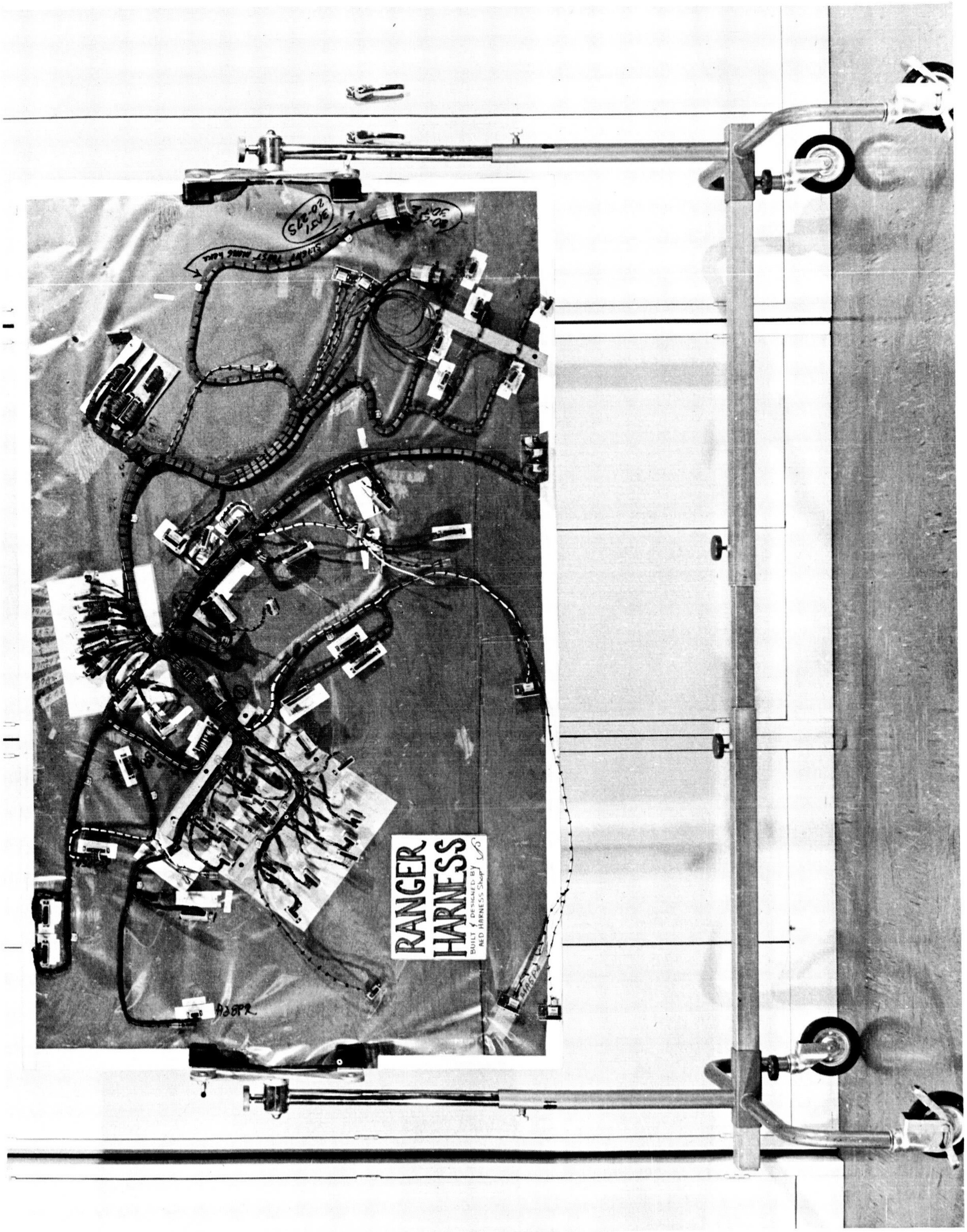


Figure 12. Wiring Harness Dolly

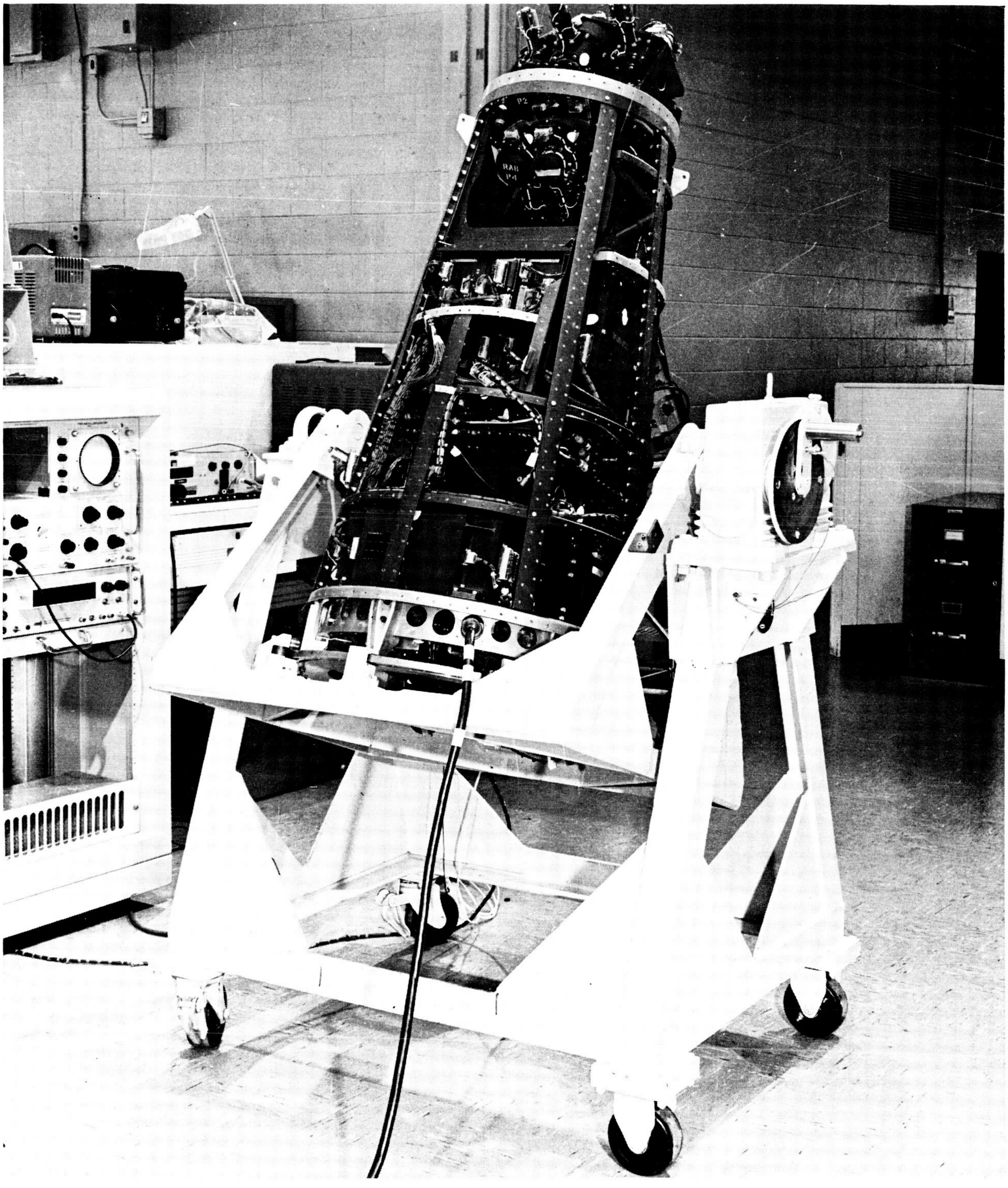


Figure 13. Pivoting Dolly for TV Subsystem

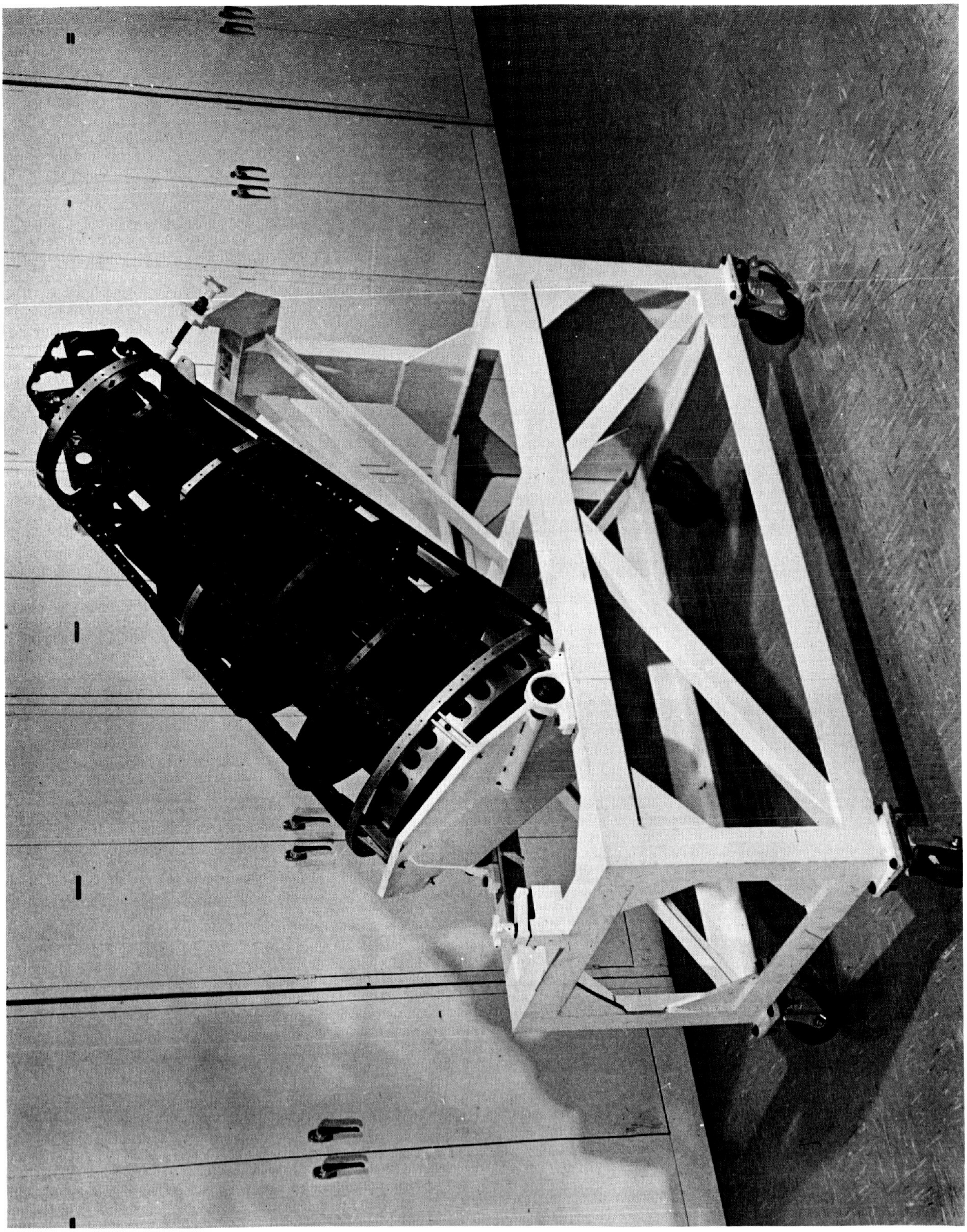


Figure 14. Optical Alignment Dolly for TV Subsystem

Section II

Reliability

The reliability program for the Ranger TV Subsystem was implemented in accordance with the Ranger Product Assurance Plan of February 15, 1962. This section describes the program established by that plan and its effects on the Ranger missions which followed. Six principal program tasks are considered: (1) reliability requirements study; (2) reliability analysis and prediction; (3) parts selection, evaluation, and control; (4) design reviews; (5) failure reporting and analysis; and (6) demonstration testing. To the extent applicable, each is treated in reference to the changing requirements of the initial system, the split-system, and the post-Ranger VI TV Subsystem.

A. RELIABILITY REQUIREMENTS STUDY

The first task of the reliability program was a requirements study of the initial system to determine the necessary reliability level. This study included preparation of the mission profile, development of a mathematical model, determination of redundancy requirements, and definition of mission successes. This study was updated as necessary for the split-system and the post-Ranger VI TV Subsystem.

1. Mission Profile

The mission profile of TV Subsystem operation is outlined in Table 1. The mission profile summarizes the events of a mission to the Moon to obtain high-resolution TV pictures and to transmit them back to Earth. Equipment operation is compared for each of the three Subsystem configurations.

a. INITIAL SUBSYSTEM CONFIGURATION

In the initial configuration, the operational period of the TV Subsystem was limited to the cruise and the terminal modes. During the cruise mode, the 15-point telemetry and the battery heaters were the only units of the TV Subsystem that were to operate. The terminal mode consisted of a Turn On command, which placed the Cameras, Sequencer, and Transmitters in the operational mode. The Sequencer was scheduled to time out a five-minute warm-up delay and then switch the Transmitters to full-power. Both F- and P-Camera video data were to be transmitted for the next eight minutes. After the elapse of this eight-minute period, the F-Camera video was to be switched from the Transmitter, and in the final minutes of the mission, P-video data was scheduled to be transmitted over both output Transmitters.

b. SPLIT-SYSTEM CONFIGURATION

In the split-system configuration, portions of newly added equipment were made operable during the cruise mode. These consisted of (1) the Electronic Clock, (2) the Power Control Unit, and (3) portions of the Distribution Control Unit. The two video channels operated independently of each other. Switchover from F-video to P-video during the last minute of operation was deleted.

c. POST RA-6 CONFIGURATION

In the post RA-6 configuration, TV Subsystem equipment operation was modified to permit transmission of telemetry data continuously from end of countdown (T) minus 15 minutes until impact (I). This included activation at T-15 of the LCVR, Temperature Sensor, 15-point commutator, Telemetry Power Supply, 3-kc VCO, and parts of the Command Control Unit. At injection, the Electronic Clock and part of the Distribution Control Unit were activated as in the split-system configuration.

TABLE 1
MISSION PROFILE

Events	Initial	Split-System	Post-RA-6
Launch and Parking Orbit	---------------	------------------	LCVR, Temp Sensor, AC Ampl, 15-pt Commutator, T/M Power Supply, 3-kc VCO, parts of Command Control Unit (T-15)
Injection	LCVR, AC Ampl, Temp Sensor, 15-pt Commutator, T/M Power Supply, 3-kc VCO, part of Command Switch	LCVR, AC Ampl, Temp Sensor, 15-pt Commutator, T/M power Supply, 3-kc VCO, Clock and part of Command Switch, Power Control Unit, Distribution Control Unit, and Electronic Clock	Same as (T-15) plus Clock, and part of Distribution Control Unit
Cruise	Same as injection	Same as injection	Same as injection
Midcourse	Same as injection	Same as injection	Same as injection
Terminal	Complete TV Subsystem ON	Complete TV Subsystem ON	Complete TV Subsystem ON

d. SUBASSEMBLY QUALIFICATION

Using the mission profiles as the basis of required equipment operation, anticipated environmental conditions were determined. The environmental conditions, used in qualification testing, are tabulated in Table 2. To ensure proper performance of the TV Subsystem, qualification environmental requirements were made more severe than those anticipated during the actual launch, parking orbit, cruise, and terminal mode.

2. Mathematical Models

The second phase of the reliability requirements study was the development of the reliability mathematical model.

A complete reliability mathematical model provides the probability of operation for each assumed a priori condition (system state). By use of system-state probabilities, the probability for attaining a specific degree of mission success can be computed.

Three separate mathematical models were prepared: (1) a model for the initial Subsystem configuration, prepared early in the program; (2) a revised model for the initial Subsystem configuration prepared in conjunction with a model for the split-system configuration; and (3) a model for the split-system configuration. Post-RA-6 configuration changes did not warrant the preparation of additional mathematical models.

a. INITIAL SUBSYSTEM CONFIGURATION MODEL

(1) Scope

Four major items were considered in the initial model:

- F-Cameras, A and B plus transmission;
- P-Cameras, P1, P2, P3 and P4 plus transmission;
- 90-point telemetry; and
- 15-point telemetry.

(2) Approach

The mathematical model was based on the reliability function block diagram shown in Figure 15. Initially, two profiles were used: Profile I, a 15-minute mission; and Profile II, a 40-minute mission consisting of a 15-minute mission plus five 5-minute prelaunch turn-ons.

Cruise-mode telemetry was considered operational upon turn-on at launch plus 16 hours; it was further assumed, that in the worst case, the overall mission could extend to 64 hours (including a one-hour terminal phase) requiring the telemetry to remain on for a possible 47-hour period before initiation of TV turn-on.

Probability of success (P_S) symbols were defined for each unit treated. Table 3 lists these symbols to the component level. Subscripts are used to denote the unit or function (For example, P_A represents the probability of success of F-Camera A and its camera electronics). These probabilities are based on the exponential distribution.

$$P_S = e^{-\lambda t} = 1 - Q$$

where

λ = failures per hour;

t = mission time in hours; and

Q = probability of failure.

(3) F-Cameras, A and B, plus Transmission Probabilities

The F Cameras, A and B, and Camera Electronics were considered redundant. The F-Channel consisted of the Sequencer, Video Combiner, Transmitter, Power Amplifier, RF power output combiner, command and control

TABLE 2
QUALIFICATION TESTS

Test	Initial	Split-System	Post-RA-6
1. Temperature Sterilization and Storage			
All assemblies except batteries and vidicon)			
High Temperature	36 hours at +125° C, 36 hours at +63° C } nonoperating	72 hours at +63° C, nonoperating	Waived
Low Temperature	72 hours at -7° C, nonoperating	Same as original	Waived
Batteries			
High Temperature	78 hours at +54° C	Same as original	Same as original
Low Temperature	78 hours at +10° C	Same as original	Same as original
Vidicons	Not subject to this test	Not subject to this test	Not subject to this test
2. Ethylene Oxide Compatibility	Nonoperating assembly exposed to controlled sterilization-gas environment. Ethylene oxide concentration: 450 mg/liter Environment: 12% ethylene oxide, 87% Freon 12 Exposure duration: 24 hours Gas temperature: 30 ±10° C Relative humidity: 35 to 90%	Waived	Waived

TABLE 2
QUALIFICATION TESTS (Continued)

Test	Initial	Split-System	Post-RA-6
3. Static Acceleration	All assemblies 14g in both directions of each of three mutually perpendicular axis. Run Duration: 5 min. (one assembly axis parallel to thrust axis) Acceleration developed c. g. Acceleration gradient across assembly surface $< \pm 1.5$g nonoperating	Same as initial system	Same as initial system. All assemblies nonoperating except DCU, CSU, CTU, CCU, HCVR, LCVR, Telemetry Unit, Batteries, and Temperature Sensors. Cruise Mode circuits of these assemblies operate during this test.
4. Vibration	All assemblies. White gaussian noise (band limited between 15 cps to 1500 cps) combined with sinusoidal Duration: 5 sweeps, each 2 minutes, 10 minutes total Planes: 3 mutually perpendicular axes, one axis parallel to direction of thrust G-levels: White gaussian: 12.0g rms Sinusoidal: 5.0g rms Total: 13.0 rms All equipment nonoperating	All assemblies same as original except frequency extended to 2000 cps. Equipment nonoperating. Equipment operational during midcourse maneuver to be subjected to the following. Planes: Same as initial system. White gaussian noise (band limited 15 cps to 2000 cps) for a minimum of 135 seconds. G-level: 0.75g rms Equipment operating.	Same as split-system except g-levels increased to: White gaussian noise: 14.0g rms Sinusoidal: 5.0g rms Total: 14.9g rms Following equipment to operate: HCVR, LCVR, DCU, CCU, Telemetry, CSU, CTU, Temperature Sensor, and Batteries. Same as split-system except minimum duration increased to 180 seconds and maximum to 360 seconds. Electronic Clock only.

TABLE 2
QUALIFICATION TESTS (Continued)

Test	Initial	Split-System	Post-RA-6
5. Shock	All assemblies nonoperating during test. 6 blows total, 2 directions in each of 3 mutually perpendicular axes, one axis parallel to direction of thrust. Level: 100g terminal peak sawtooth Duration: > 0.5 milliseconds <6.0 milliseconds.	Same as initial system except those equipments required to operate after Agena separation operate during the exposure to the shock pulse. All other assemblies nonoperating.	Same as split-system operating equipment defined as: HCVR, LCVR, DCU, CCU, CSU, CTU, Telemetry, Temperature Sensor, and Batteries in the Cruise Mode.
6. Temperature & Humidity	All assemblies (except batteries, camera heads and electronics.)		All assemblies -
Low Temperature	0° C, 95% R.H. After stabilization, operate for 15 minutes	Same as initial system	Temperature: Stabilize at 21° C.
High Temperature	+65° C, 95% R.H. After stabilization, operate for 15 minutes	Same as initial system	Humidity: Increase to 95%, Temperature: Increase to 38° C, and stabilize. Operation: 1/2 hour. Humidity: Reduce to as low as possible at the 38° C chamber temperature. Test: Return to room ambient and test.

TABLE 2
QUALIFICATION TESTS (Continued)

Test	Initial	Split-System	Post-RA-6
6. Temperature & Humidity (Continued)			
Batteries	Same as assemblies above except stabilization at +10° C and +54° C	Same as initial system	
Camera Head & Electronics	Same as assemblies above except stabilization at +40° C	Same as initial system	
Four-Port Hybrid	Same as all assemblies above	Same as initial system except R.H. between 60 and 70%	
7. Explosive Atmosphere	All assemblies Chamber: Per MIL-C-9435 Chamber Temperature: +20° C to 50° C Fuel Mixtures: lean, intermediate rich Full Grade: MIL-C-5572B grade 100/130 or commercial butane. Test Pressures: Sea level and 10,000 feet Equipment operating during test.	N/A	Telemetry assembly only Same as initial

TABLE 2
QUALIFICATION TESTS (Continued)

Test	Initial	Split-System	Post-RA-6
8. Thermal Vacuum	All assemblies (except batteries, cameras and camera electronics) (1) Vacuum: 1 x 10^{-4} Torr or less (2) Temperature: Stabilize at -10° C (3) Operation: 1 hour (4) Temperature: Stabilize at +65° C (5) Operation: 1 hour	Cruise Mode assemblies (except telemetry) (1) Vacuum: 1 x 10^{-4} Torr or less. (2) Temperature: Stabilize at -10° C, Equipment to operate 4 hrs. (3) Temperature: Stabilize at + 65° C, equipment to operate 71 hrs.	Same as Cruise Mode assemblies of split-system except equipments (LCVR, Temperature Sensor, Electronic Clock) operate during temperature changes and the upper temperature operation (3) is extended to 116 hours.
	Terminal Mode Assemblies turned off (1) Temperature: in accordance with equipment detail specifications	Telemetry: Same as above except high temperature limited to + 45° C.	15 - point Telemetry: Same as above except upper temperature is limited to + 55° C.
	Batteries: Same as above except upper and lower temperatures shall be +40° C.	Batteries: Same as above except high and low temperature shall be + 54° C and + 10° C respectively. In addition: (1) Low temperature operation: 3 hrs 25 min in cruise mode; 5 min of warm-up; and 30 min of full-power operation.	Batteries: Same as above except high and low temperatures are + 54° C and + 10° C, respectively. (1) Low temperature operation: 3 hrs 25 minutes in cruise mode; 82 seconds in warm-up; and 30 minutes full power.

TABLE 2
QUALIFICATION TESTS (Continued)

Test	Initial	Split-System	Post-RA-6
8. Thermal Vacuum (Continued)		Terminal Mode assemblies (except camera and camera electronics, telemetry and communication assembly) (1) Vacuum: 1×10^{4} Torr or less (2) Temperature: Stabilized at -10° C (3) Operation: 6 one-hour periods. (4) Temperature: Stabilized at +65° C (5) Operation: 6 one-hour periods. Camera and Camera Electronics. Same as for Terminal Mode assemblies except upper temperature is limited to +40° C. Telemetry: Same as for Terminal Mode assemblies except upper temperature is limited to +45° C.	(2) High temperature operation: 70 hrs 25 minutes in cruise mode; 82 seconds in warm-up; 30 minutes in full power. Electronic Clock not to operate during transient conditions of temperature or pressure. DCU, CCU, CSU, CTU. Shall see the temperature and time conditions of Cruise Mode assemblies above but will operate the last hour of the Low Temperature condition in the cruise mode and will operate 6 one-hour periods during the high temperature condition. All Terminal Mode assemblies (except the Cameras, Camera Electronics, 90-point Telemetry chassis, Communications equipment,

TABLE 2
QUALIFICATION TESTS (Continued)

Test	Initial	Split-System	Post-RA-6
8. Thermal Vacuum (Continued)		Communications: (1) Vacuum: 1×10^{-4} Torr or less. (2) Temperature: Stabilized at -10° C. (3) Operation: six 20-minute periods consisting of 5 minutes warm-up, 15 minutes full power. (4) Temperature: Stabilized at 6 +55° C. (5) Operation: 20-minute periods consisting of 5 minutes warm-up, 15 min full power. (6) Temperature: Stabilized at +10° C. (7) Operation: 5 minutes warm-up, 1 hour of full power.	Batteries, DCU, CCU, CSU, CTU and HCVR. (1) Vacuum: 1×10^{-4} Torr or less. (2) Temperature: Stabilized at -10° C. (3) Operation: 6 one-hour periods. (4) Temperature: Stabilized at 65° C. (5) Operate: 6 one-hour periods. Camera and Camera electronics: Same as for Terminal Mode assemblies above except high temperature limited to +50° C. Operate 1 hour after temperature stabilizes. Drop temperature to +40° C and verify performance to specification.

TABLE 2
QUALIFICATION TESTS (Continued)

Test	Initial	Split-System	Post-RA-6
8. Thermal Vacuum (Continued)			90-Point Telemetry Chassis: Same as for Terminal Mode assemblies above except operation at low temperature is 1 cycle for 1-1/2 hours and at high temperature 2-1/2 hours. Drop temperature to +45° C and verify performance to specification. Telecommunications Equipment: Transmitter Power Supply, Power Amplifier, Telemetry Processor, Four-Port Hybrid (Stripline), Dummy Load; same as for Camera and Camera Electronics for split-system.

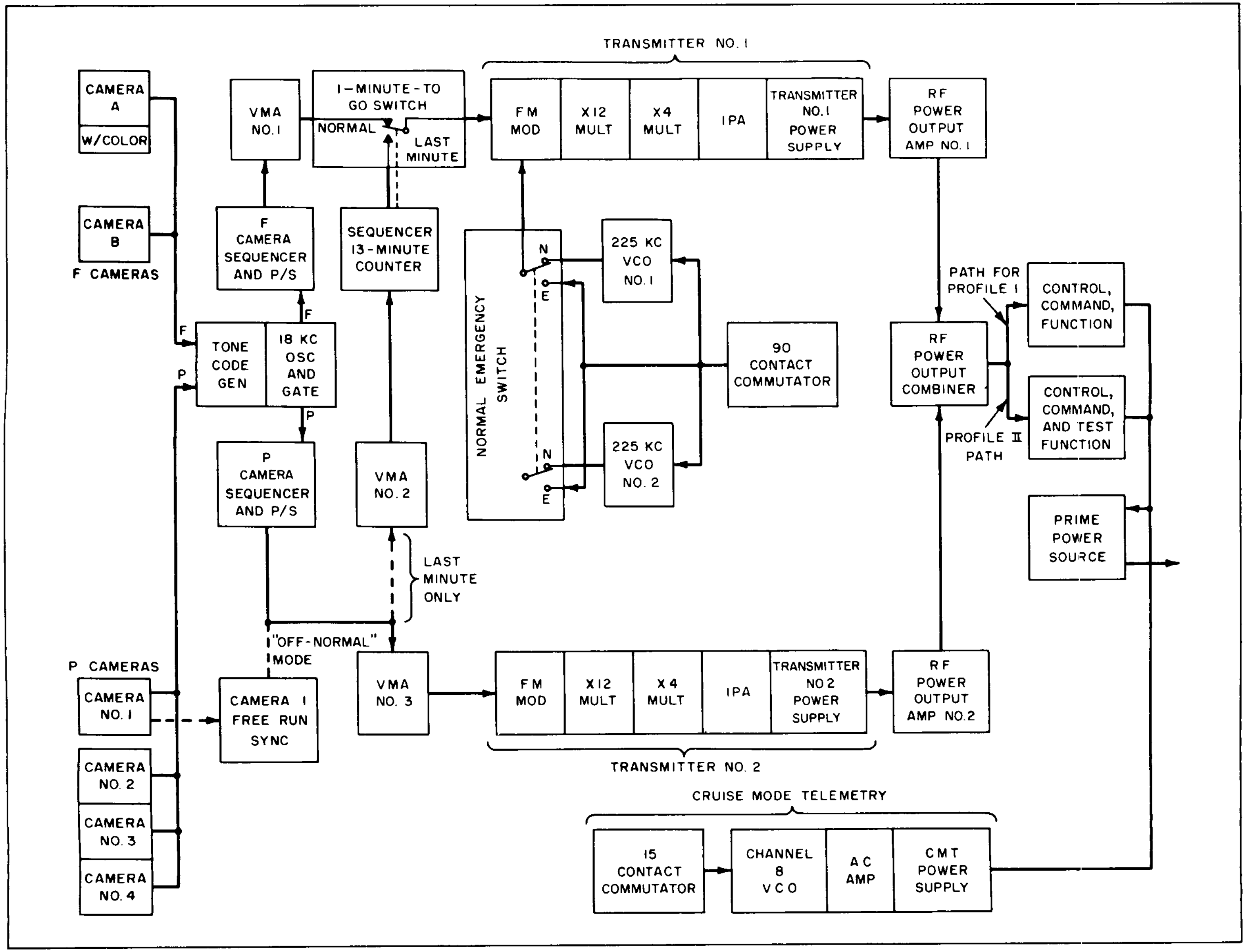


Figure 15. Reliability Functional Block Diagram of Ranger TV Subsystem

TABLE 3
PROBABILITIES-OF-SUCCESS SYMBOLS OF COMPONENTS

Equipment	Symbol Used
TV Cameras and Electronics:	
Camera A (including color)	P_A
Camera B	P_B
VMA Nos. 1, 2, or 3	P_m
Camera 1, Free Running Sync.	P_n
Camera 1, 2, 3, or 4	P_1, P_2, P_3, or P_4
Time Code Generator	P_p
1 Minute-to-go Switch	P_q
Test and Control Function:	
Test Mode Switch	P_r
Command Switch and Drive Amp.	P_s
Prime Power Source:	
Regulator and Batteries	P_t
Communications:	
Transmitter 1 (or Transmitter 2)	P_a
Power Amplifier 1 (or Power Amplifier 2)	P_b
Transmitters 1 and 2, Associated Telemetry:	
90-Point Commutator	P_d
225-kc VCO Nos. 1 or 2	P_e
Cruise Mode Telemetry	P_f
RF Combiner	P_g
Normal Emergency Switch	P_o
Control Programmer & Sequencer:	
18-kc Oscillators and "OR" Gate	P_h
Camera A, B, Sequencer and P/S	P_l
Camera 1, 2, 3, 4 Sequencer and P/S	P_j
Counter Circuits	P_k

functions, and the prime power source. Probability of success of the complete F-Channel as shown in Figure 16 was denoted by the Symbol P_X.

$$P_X = P_p P_h P_i P_m P_q P_a P_b P_g P_r P_s P_t$$

The combined probabilities of success of the F Cameras, camera electronics, and transmission P_X were thus stated as:

$P_A P_X$ = Probability Camera A will transmit video

$P_B P_X$ = Probability Camera B will transmit video

$P_A P_B P_X$ = Probability Cameras A and B will transmit video

$(P_A + P_B - P_A P_B) P_X$ = Probability at least one F-Camera will transmit video*

(4) P-Cameras P_1, P_2, P_3, and P_4 Plus Transmission Probability

(a) GENERAL

The four P Cameras were considered to be redundant and to consist of the equipment illustrated in Figure 17. From Table 3 it is seen that cameras 1, 2, 3, and 4 were denoted by the symbols P_1, P_2, P_3, and P_4 respectively.

The mathematical model for these four P-Cameras utilized the probability theory concept of "subsets of a set", that is N items taken k at a time, written $\binom{N}{k}$.** These quantities are called binomial coefficients because of the role they play in the binomial theorem, which states that for any two real numbers P and Q and any positive integer N :

$$(P+Q)^N = \sum_{k=0}^{N} \binom{N}{k} P^{N-k} Q^k$$

In this case a set N of 4 items, where k had values varying from 0 to 4 was used. These values substituted in the binomial expression and expanded produced the following probability equation:

$$(P+Q)^4 = P^4 + 4P^3Q + 6P^2Q^2 + 4PQ^3 + Q^4$$

This equation is interpreted as follows:

P^4 = Probability that all 4 cameras work; this can occur in 1 way.

$4P^3Q$ = Probability that only 3 cameras work; this can occur in 4 ways.

$6P^2Q^2$ = Probability that only 2 cameras work; this can occur in 6 ways.

$4PQ^3$ = Probability that only 1 camera works; this can occur in 4 ways.

Q^4 = Probability that no cameras work; this can occur in 1 way.

(b) P-CAMERA PROBABILITY PRIOR TO LAST MINUTE

All elements of the P-Channel prior to the last minute were denoted by P_w:

$$P_w = P_p P_h P_i P_m P_a P_b P_g P_r P_s P_t$$

(see Figure 18)

Thus, the following expressions depicted the reliability of the P cameras prior to the last minute:

$P^4 P_w$ = Probability that at least 4 P Cameras will transmit.

---

*The expression $(P_A + P_B - P_A P_B)$ was derived from the equation:

$$P_{total} = 1 - (1 - P_A)(1 - P_B)$$

which governs redundant components.

**"Modern Probability Theory and Its Applications" E. Parzen.

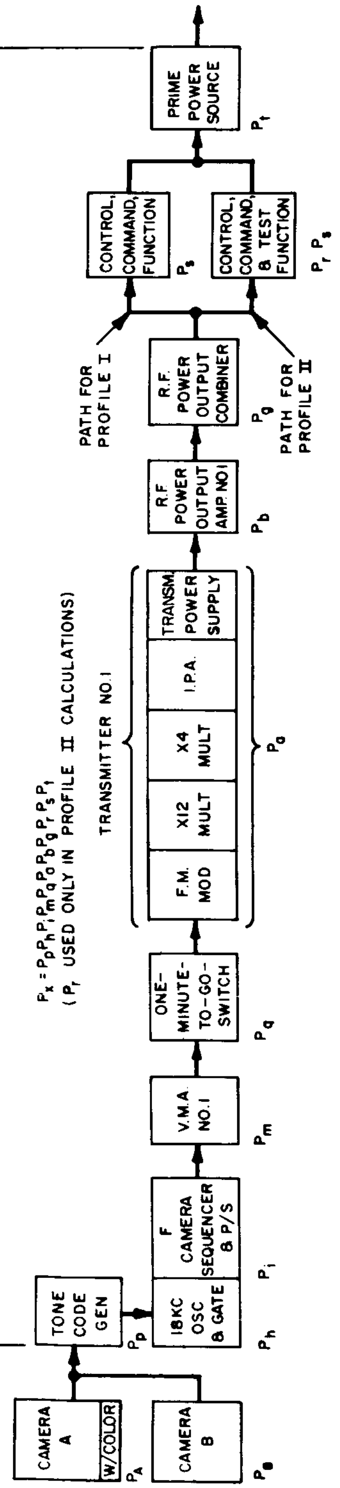


Figure 16. Diagram of Reliability Mathematical Model of F-Camera Path

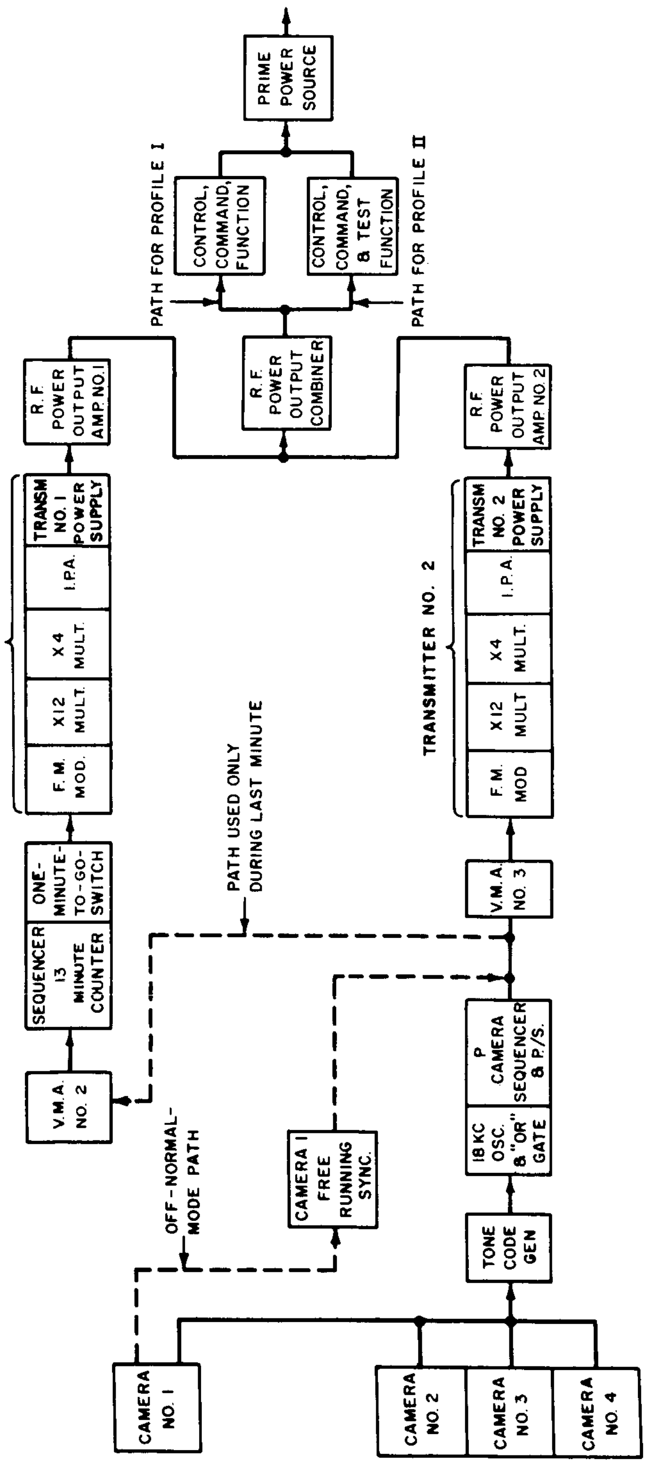


Figure 17. Reliability Diagram of Equipment Included in P-Camera Path

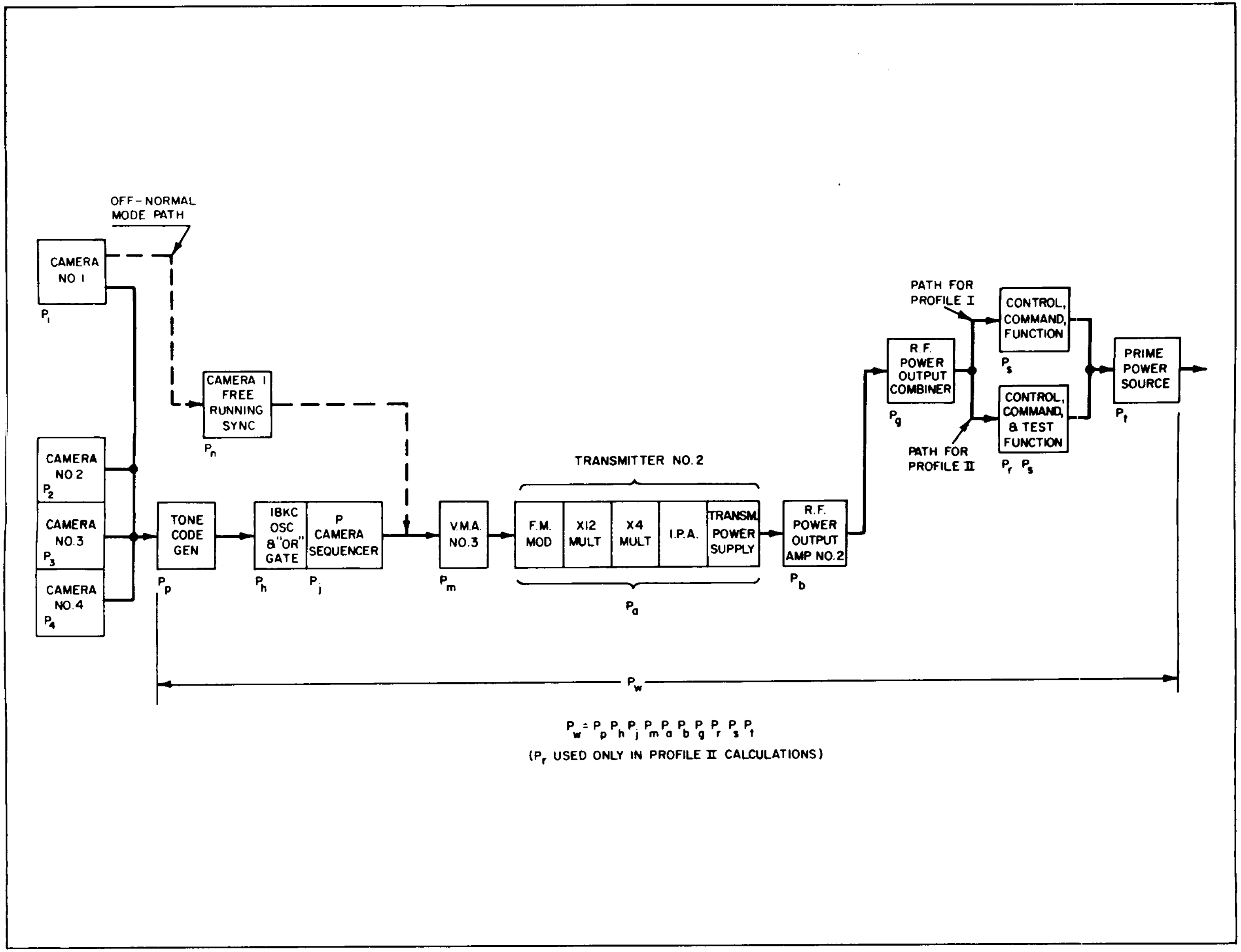


Figure 18. Diagram of Reliability Model of P-Camera Path (Prior to Last-Minute Operation)

$(P^4 + 4P^3Q)\, P_w =$ Probability that at least 3 P Cameras will transmit.

$(P^4 + 4P^3Q + 6P^2Q^2)\, P_w =$ Probability that at least 2 P Cameras will transmit.

$(P^4 + 4P^3Q + 6P^2Q^2 + 4PQ^3)\, P_w =$ Probability that at least 1 P Camera will transmit.

(c) P-CAMERA PROBABILITY FOR LAST MINUTE

In the last-minute of operation, the F-video transmitter was switched to provide a redundant transmitting facility for the P Cameras. (See Figure 19).

P_z and P_y were used to define the redundant links of the transmitting channels. P_R was the probability of redundant transmitters 1 and 2.

$$P_z = P_m\, P_k\, P_g\, P_a\, P_b$$

$$P_y = P_m\, P_a\, P_b$$

$$P_R = 1 - (1 - P_z)(1 - P_y)$$

P_v was the overall transmission capability for P-last-minute video using redundant transmitters.

Thus, the possible probabilities of receiving P video during the last minute were as follows:

$P^4 P_v =$ Probability of at least 4 P Cameras transmitting.

$(P^4 + 4P^3)\, P_v =$ Probability of at least 3 P Cameras transmitting.

$(P^4 + 4P^3Q + 6P^2Q^2)\, P_v =$ Probability of at least 2 P Cameras transmitting.

$(P^4 + 4P^3Q + 6P^2Q^2 + 4PQ)\, P_v =$ Probability of at least 1 P Camera transmitting.

(d) P-CAMERA PROBABILITY IN FREE-RUN MODE

The final aspect of P-Cameras operation considered was the free-run mode of operation of the P1 Camera and its camera electronics should a failure occur in the camera sequencer. Both the probability of entering this mode and the probability of success were examined.

The probability of entering the free-run mode was clearly the probability of failure in the loop, $P_p\, P_h\, P_J$. (See Figure 18). If the probability of success of this loop were defined as $P_N = P_p\, P_h\, P_J$. Then the probability of failure would be:

$$Q_N = 1 - P_N = 1 - (P_p\, P_h\, P_J)$$

This was the probability of entering this mode of operation. Once in this mode, there was a probability, for the time period prior to the last minute, for video transmission of P1, as follows:

$$P_1 = P_1\, P_n\, P_m\, P_a\, P_b\, P_g\, P_r\, P_s\, P_t$$

If the failure in the sequencer which resulted in the P1 Camera free-run mode of operation also disabled the 13-minute timer, there would not be a switchover and the previous equation would define the probability of successful P1 video transmission up to impact.

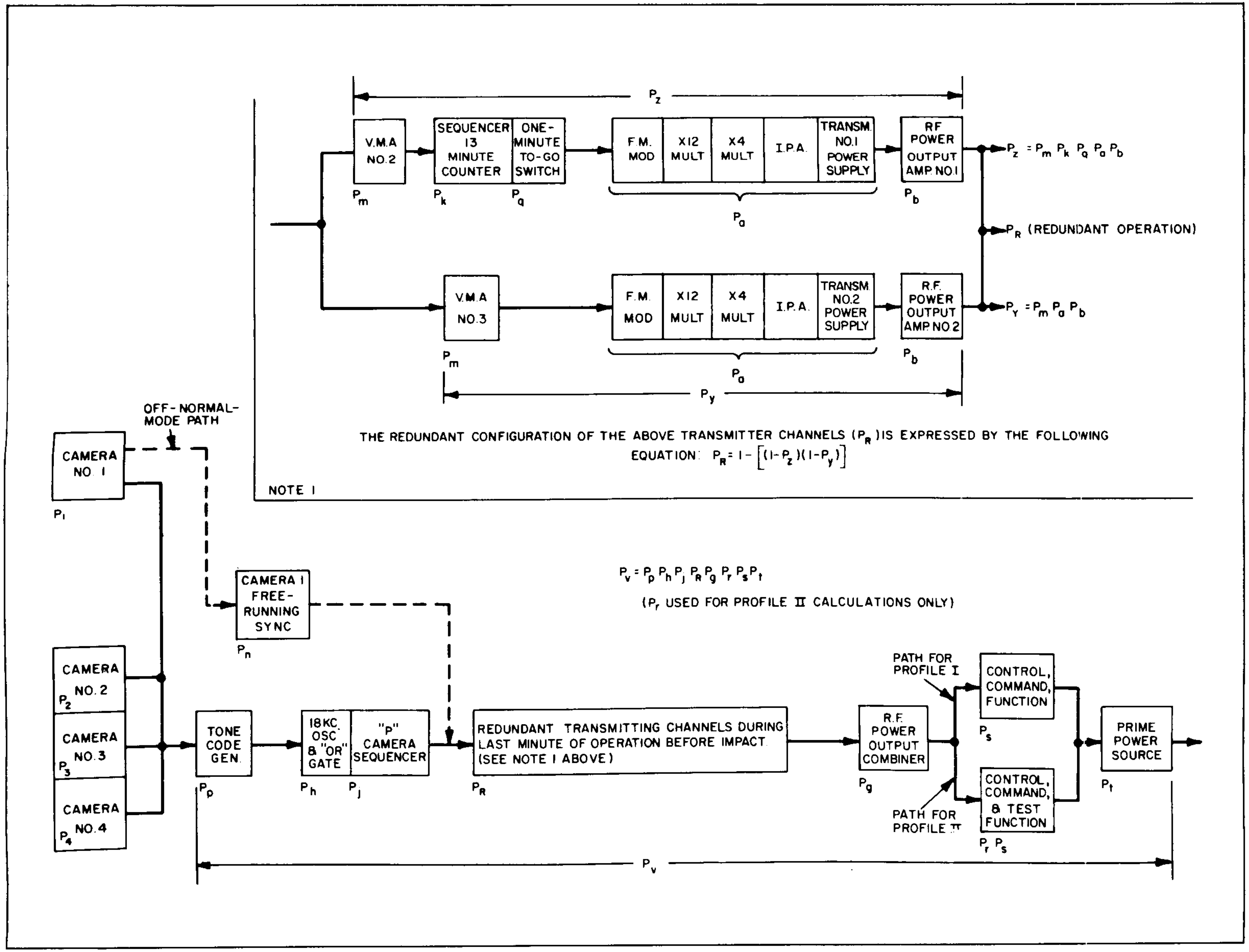


Figure 19. Diagram of Reliability of P-Camera Path (Redundant Transmitter Channels in Final Minute)

If the sequencer failure did not affect the 13-minute counter, then switch over would occur and result in P1 video transmission over redundant transmission channels for the last minute of operation. This probability of success was defined as follows:

$$P_1 = P_1 P_n P_R P_g P_r P_s P_t$$

(5) 90-Point Telemetry Probability

The 90-point telemetry equipment is shown in Figure 20. In its normal mode, P_{T_1} and P_{T_2} were used as redundant transmitters fed from separate Voltage Controlled Oscillators (VCO). A single 90-point commutator supplied the input for the VCO (See Figure 21). The probability of success was defined by:

$$P_{T_1} = P_{T_2} = P_e P_o P_a P_b$$

which for redundant transmission was stated as follows:

$$P_{TR} = 1 - (1 - P_{T_1})(1 - P_{T_2})$$
$$= 1 - (1 - P_{T_1})^2$$

The complete 90-point telemetry transmission was given as follows:

$$P_i = P_d P_{TR} P_g P_r P_s P_t$$

In the emergency mode, the VCO was deleted from the circuit and the P_e term dropped from the P_{T_1} and P_{T_2} equations.

(6) 15-Point Telemetry Probability

The last item considered was the 15-point commutator and its associated telemetry. This telemetry was for the cruise mode which went into operation 16 hours after launch. The cruise-mode telemetry operation (See Figure 22) was defined as:

$$P_{CMT} = P_f P_t$$

b. INITIAL SUBSYSTEM CONFIGURATION REVISED MODEL

At the time of generation of the mathematical model for the split-system configuration, a revised model for the initial Subsystem configuration was prepared to permit comparison of the two Subsystems. This revised model is presented here; the split-system follows in paragraph c.

The functional diagram of the initial Subsystem configuration (Figure 23) was used as the basis of the revised model. Of a total of 60 possible Subsystem states, 15 are described in detail in the following paragraphs. These 15 states represent the possible failure-success combination of the four P Cameras and two F Cameras, and assume no loss of telemetry. The remaining 45 states were not considered in detail because they are essentially identical to the original 15 states and differ from these states only as a function of the success-failure combinations of the two telemetry systems. As depicted in Figure 24, State (1) is the condition of complete data return; that is the condition in which both F cameras, the four P cameras, and the 15-point and 90-point telemetry systems remain operative throughout the entire mission. Mathematically, State (1) can be expressed as follows:

State (1) = Probability of complete success (i.e., probability of having 2 F cameras, 4 P cameras, and both telemetry systems operating satisfactorily)

$$= \Big(P_{\text{Battery pack}} \bullet P_{\text{4P cameras}} \bullet P_{\text{2F cameras}} \bullet P_{\text{High-current voltage regulator}} \bullet P_{\text{P video combiner}} \bullet P_{\text{F video combiner}} \bullet P_{\text{Command switch}} \bullet P_{\text{Hybrid}} \bullet P_{\text{Dummy load}} \bullet P_{\text{Low-current voltage regulator}} \bullet P_{\text{15-point T/M and VCO}} \bullet P_{\text{90-point T/M and VCO}} \bullet P_{\text{F transmitter chain}} \bullet P_{\text{P transmitter chain}} \bullet P_{\text{Control programmer, sequencer and power supply}}\Big)$$

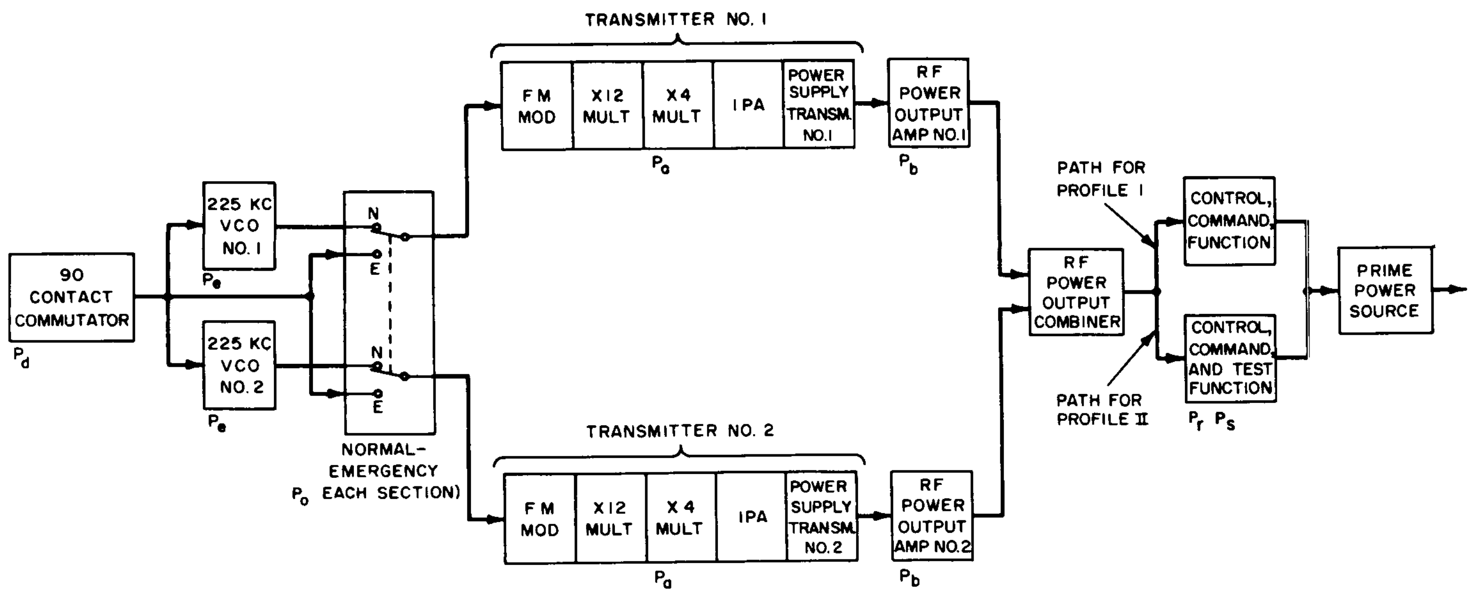


Figure 20. Reliability Diagram of Equipments Included in 90-Point Commutator Telemetry Operation

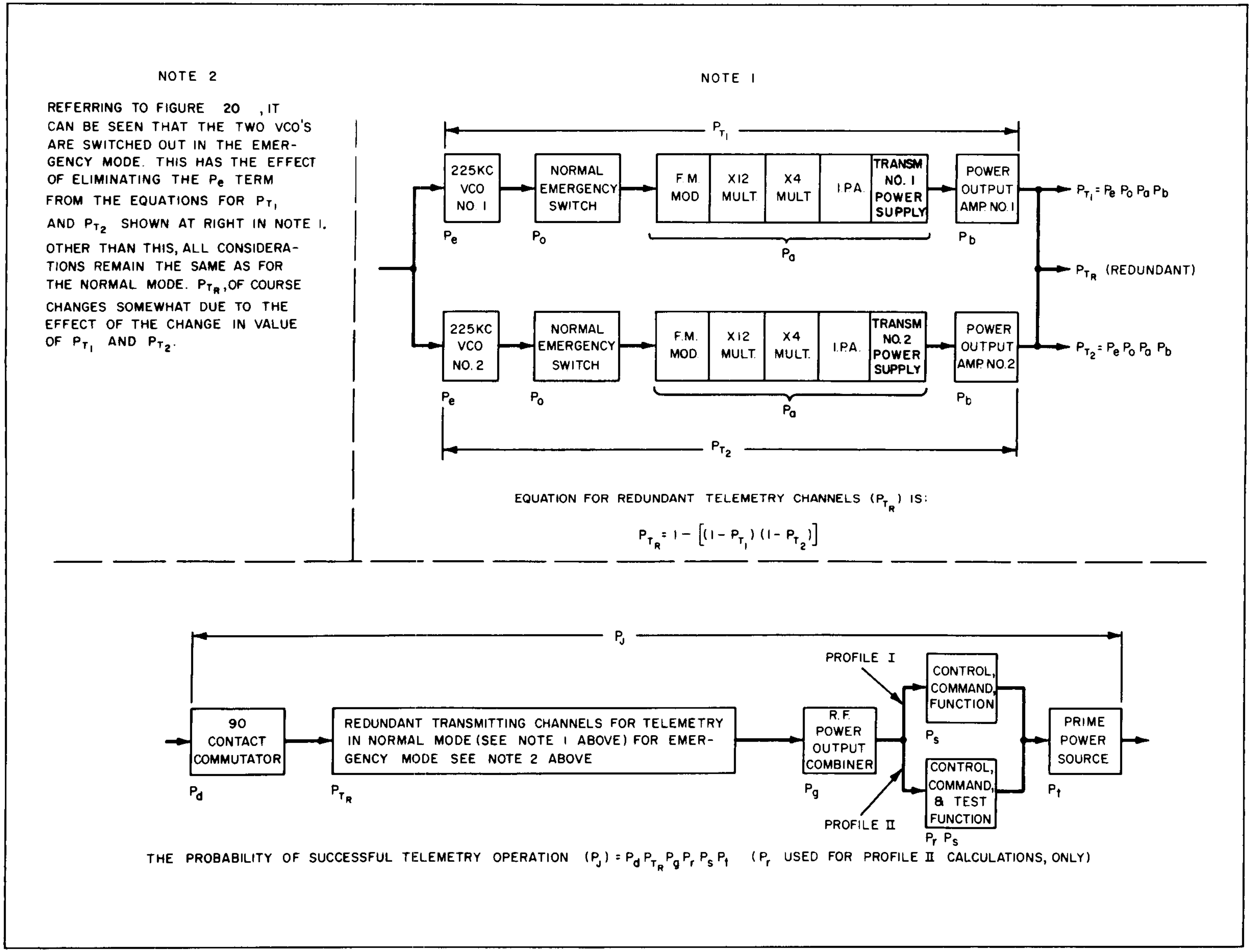


Figure 21. Diagram of Reliability Mathematical Model of the 90-Point Commutator Telemetry in Normal Mode

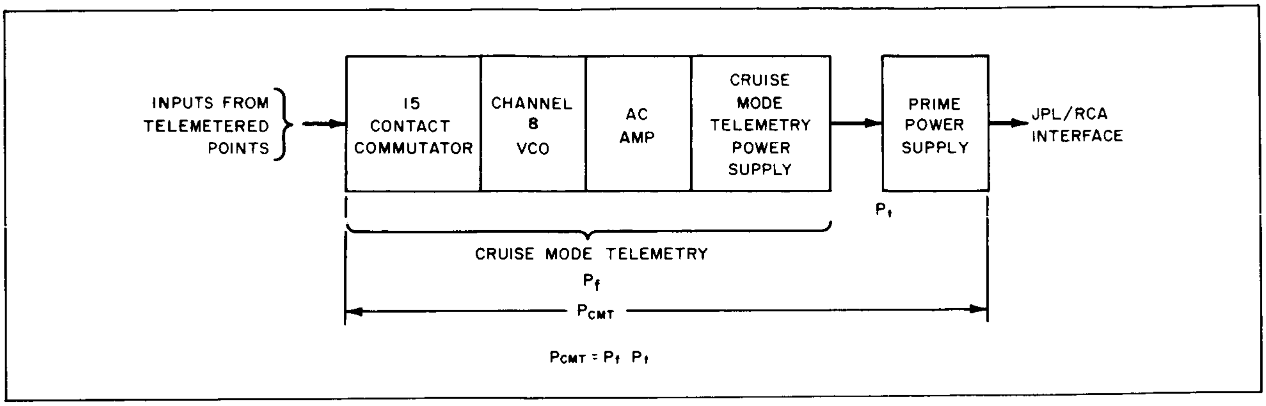


Figure 22. Diagram of Reliability Mathematical Model of Cruise-Mode Telemetry Operation

States (2), (3), and (4) are essentially the same as State (1) and differ only as a function of the number of P cameras that remain in operation. State (5) is also essentially the same as State (1). However, it is assumed that there are no P-camera returns. The probability equation for State (5)* must be expanded as follows:

State (5) = Exact probability of having 2 F cameras, 0 P cameras, 15-point T/M, and 90-point T/M operating satisfactorily

= Same as State (1), except $P_{4\ P\ camera}$ is replaced by

$$\Big\{\Big[\left(\bar{P}_{P\ camera\ 1} \bullet \bar{P}_{P\ camera\ 2} \bullet \bar{P}_{P\ camera\ 3} \bullet \bar{P}_{P\ camera\ 4}\right)(P_A)\Big]$$

$$+\Big[\left(P_{P\ camera\ 1} \bullet P_{P\ camera\ 2} \bullet P_{P\ camera\ 2} \bullet P_{P\ camera\ 4}\right)\left(P_{\substack{Control\\Programmer\\seq.\ \&\ P.S.}} + \bar{P}_{\substack{Control\\Programmer\\seq.\ \&\ P.S.}}\right) P_B\Big] + \Big[\bar{P}_{P\ camera\ 1} \bullet P_C \bullet P_A\Big]\Big\}$$

where:

$$P_A = \Bigg[\left(P_{\substack{Control\\Programmer\\seq.\ \&\ P.S.}} \bullet P_{\substack{P\ Video\\Combiner}} \bullet P_{\substack{P\ Transmitter\\Channel}}\right)$$

$$+\left(\bar{P}_{\substack{Control\\Programmer\\seq.\ \&\ P.S.}} \bullet P_{\substack{P\ Video\\Combiner}} \bullet P_{\substack{P\ Transmitter\\Channel}}\right)$$

$$+\left(P_{\substack{Control\\Programmer\\seq.\ \&\ P.S.}} \bullet \bar{P}_{\substack{P\ Video\\Combiner}} \bullet P_{\substack{P\ Transmitter\\Channel}}\right)$$

$$+\left(P_{\substack{Control\\Programmer\\seq.\ \&\ P.S.}} \bullet P_{\substack{P\ Video\\Combiner}} \bullet \bar{P}_{\substack{P\ Transmitter\\Channel}}\right)$$

$$+\left(\bar{P}_{\substack{Channe\\Programmer\\seq.\ \&\ P.S.}} \bullet \bar{P}_{\substack{P\ Video\\Combiner}} \bullet P_{\substack{P\ Transmitter\\Channel}}\right)$$

$$+\left(\bar{P}_{\substack{Control\\Programmer\\seq.\ \&\ P.S.}} \bullet P_{\substack{P\ Video\\Combiner}} \bullet \bar{P}_{\substack{P\ Transmitter\\Channel}}\right)$$

$$+\left(P_{\substack{Control\\Programmer\\seq.\ \&\ P.S.}} \bullet \bar{P}_{\substack{P\ Video\\Combiner}} \bullet \bar{P}_{\substack{P\ Transmitter\\Channel}}\right)$$

$$+\left(\bar{P}_{\substack{Control\\Programmer\\seq.\ \&\ P.S.}} \bullet \bar{P}_{\substack{Video\\Combiner}} \bullet \bar{P}_{\substack{P\ Transmitter\\Channel}}\right)\Bigg]$$

$$P_B = \Bigg[\left(\bar{P}_{\substack{P\ Video\\Combiner}} \bullet P_{\substack{P\ Transmitter\\Chain}}\right) + \left(P_{\substack{P\ Video\\Combiner}} \bullet \bar{P}_{\substack{P\ Transmitter\\Chain}}\right) + \left(\bar{P}_{\substack{P\ Video\\Combiner}} \bullet \bar{P}_{\substack{P\ Transmitter\\Chain}}\right)\Bigg]$$

*$\bar{P} = (1 - P)$

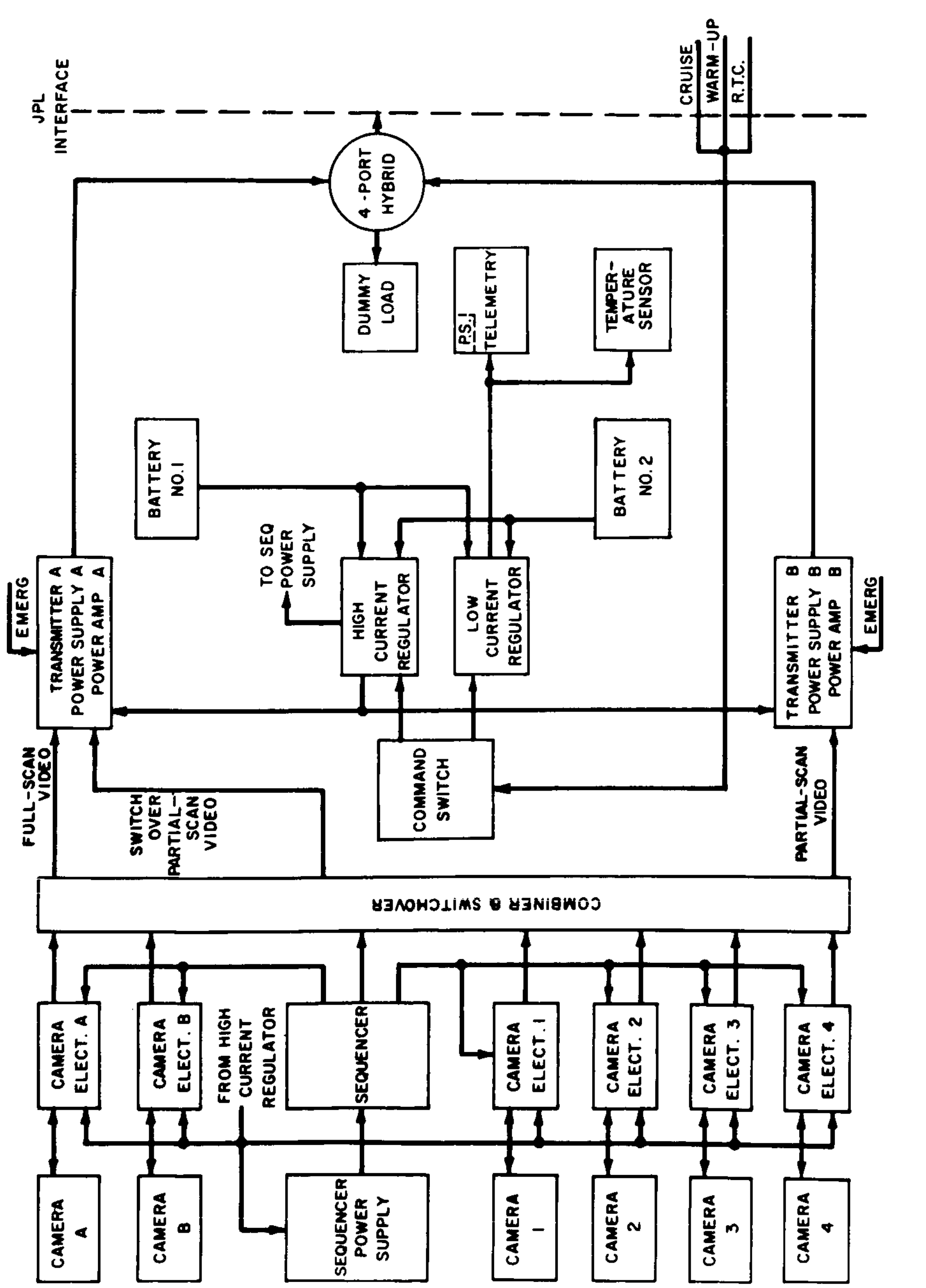


Figure 23. Functional Block Diagram of Initial Ranger TV Subsystem

$$P_C = \Big[\big(\bar{P}_{P\ \text{camera 2}} \bullet P_{P\ \text{camera 3}} \bullet P_{P\ \text{camera 4}}\big)$$
$$+ \big(P_{P\ \text{camera 2}} \bullet \bar{P}_{P\ \text{camera 3}} \bullet P_{P\ \text{camera 4}}\big)$$
$$+ \big(P_{P\ \text{camera 2}} \bullet P_{P\ \text{camera 3}} \bullet \bar{P}_{P\ \text{camera 4}}\big)$$
$$+ \big(\bar{P}_{P\ \text{camera 2}} \bullet \bar{P}_{P\ \text{camera 3}} \bullet P_{P\ \text{camera 4}}\big)$$
$$+ \big(\bar{P}_{P\ \text{camera 2}} \bullet P_{P\ \text{camera 3}} \bullet \bar{P}_{P\ \text{camera 4}}\big)$$
$$+ \big(P_{P\ \text{camera 2}} \bullet \bar{P}_{P\ \text{camera 4}} \bullet \bar{P}_{P\ \text{camera 4}}\big) \Big]$$

$$P_{A'} = \left[P_A - \left(P_{\substack{\text{Control} \\ \text{Programmer} \\ \text{seq. \& P.S.}}} \bullet P_{\substack{P\ \text{Video} \\ \text{Combiner}}} \bullet P_{\substack{P\ \text{Transmitter} \\ \text{Chain}}} \right) \right]$$

The probabilities for States (6) through (10) are expressed in the same manner as States (1) through (5); however, as noted in Figure 24, the success probability for 2 F cameras is replaced with the success probability for 1 F camera.

The expression for State (11) reflects the probability for the failure of both F cameras. This expression is as follows:

State (11) = Exact probability of having 0 F cameras, 4 P cameras, 15-point T/M, and 90-point T/M operating satisfactorily

$$= \Big[P_{\substack{0\ F \\ \text{cameras}}} \bullet P_{\substack{\text{High-current} \\ \text{voltage} \\ \text{regulator}}} \bullet P_{\substack{\text{Battery} \\ \text{Pack}}} \bullet P_{\substack{4\ P \\ \text{Cameras}}}$$
$$\bullet P_{\substack{P\ \text{Video} \\ \text{cameras}}} \bullet P_{\substack{\text{Command} \\ \text{Switch}}}$$
$$\bullet P_{\text{Hybrid}} \bullet P_{\substack{\text{Dummy} \\ \text{load}}} \bullet P_{\substack{\text{15-point T/M} \\ \text{and VCO}}}$$
$$\bullet P_{\substack{\text{90-point T/M} \\ \text{and SCO}}} \bullet P_{\substack{P\ \text{Transmitter} \\ \text{chain}}}$$
$$\bullet P_{\substack{\text{Low-current} \\ \text{voltage regulator}}} \Big]$$

where

$$P_{\substack{0\ F \\ \text{cameras}}} = \Big\{ \bar{P}_{\substack{F\ \text{cam-} \\ \text{era A}}} \bullet \bar{P}_{\substack{F\ \text{cam-} \\ \text{era B}}} \Big[\Big[\Big(P_{\substack{F\ \text{Video} \\ \text{Combiner}}}$$
$$\bullet P_{\substack{F\ \text{Transmitter} \\ \text{chain}}} \Big) + \Big(\bar{P}_{\substack{F\ \text{Video} \\ \text{Combiner}}}$$
$$\bullet P_{\substack{F\ \text{Transmitter} \\ \text{chain}}} \Big) + \Big(P_{\substack{F\ \text{Video} \\ \text{Combiner}}}$$
$$\bullet \bar{P}_{\substack{F\ \text{Transmitter} \\ \text{chain}}} \Big) + \Big(\bar{P}_{\substack{F\ \text{Video} \\ \text{Combiner}}}$$
$$\bullet \bar{P}_{\substack{F\ \text{Transmitter} \\ \text{chain}}} \Big) \Big] + \Big[\Big(P_{\substack{F\ \text{cam-} \\ \text{era A}}} \bullet P_{\substack{F\ \text{cam-} \\ \text{era B}}} \Big)$$
$$+ \Big(\bar{P}_{\substack{F\ \text{cam-} \\ \text{era A}}} \bullet P_{\substack{F\ \text{cam-} \\ \text{era B}}} \Big) + \Big(P_{\substack{F\ \text{cam-} \\ \text{era A}}} \bullet \bar{P}_{\substack{F\ \text{cam-} \\ \text{era B}}} \Big) \Big]$$
$$\bullet \Big[\Big(\bar{P}_{\substack{F\ \text{Video} \\ \text{Combiner}}} \bullet P_{\substack{F\ \text{Transmitter} \\ \text{chain}}} \Big) + \Big(P_{\substack{F\ \text{Video} \\ \text{Combiner}}}$$
$$\bullet \bar{P}_{\substack{F\ \text{Transmitter} \\ \text{chain}}} \Big) + \Big(\bar{P}_{\substack{F\ \text{Video} \\ \text{Combiner}}}$$
$$\bullet \bar{P}_{\substack{F\ \text{Transmitter} \\ \text{chain}}} \Big) \Big] \Big] \Big\}$$

The probability expressions for States (12), (13), and (14) are essentially the same as that for State (11), differing only in the number of P cameras that remain in satisfactory operating condition. State (15) is the last system state depicted in Figure 24. This state is that of no video return but complete telemetry return. The expression for State (15) is as follows:

State (15) = Exact probability of having 0 F cameras, 0 P cameras, 15-point T/M, and 90-point T/M operating satisfactorily

$$= \Big\{ \Big(P_{\substack{0\ F \\ \text{cameras}}} \bullet P_{\substack{0\ P \\ \text{cameras}}} \Big) \Big[\Big(P_{\substack{F\ \text{Trans-} \\ \text{mitter}}} \bullet P_{\substack{P\ \text{Trans-} \\ \text{mitter}}} \Big)$$
$$+ \Big(\bar{P}_{\substack{F\ \text{Trans-} \\ \text{mitter}}} \bullet P_{\substack{P\ \text{Trans-} \\ \text{mitter}}} \Big) + \Big(P_{\substack{F\ \text{Trans-} \\ \text{mitter}}} \bullet \bar{P}_{\substack{P\ \text{Trans-} \\ \text{mitter}}} \Big) \Big]$$
$$\bullet P_{\substack{\text{Battery} \\ \text{pack}}} \bullet P_{\substack{\text{Command} \\ \text{switch}}} \bullet P_{\substack{\text{Low-} \\ \text{current} \\ \text{voltage reg.}}} \bullet P_{\text{Hybrid}} \bullet P_{\substack{\text{Dummy} \\ \text{load}}}$$
$$\bullet P_{\substack{\text{15-point} \\ \text{T/M and} \\ \text{VCO}}} \bullet P_{\substack{\text{90-point} \\ \text{T/M and} \\ \text{SCO}}} \bullet P_{\substack{\text{High-current} \\ \text{voltage reg.}}} \Big\}$$

LEGEND FOR FIGURES 24 AND 26

$P_{Battery\ Pack}$ = *Probability of at Least One Battery Operating (See Exhibit 1 for Details)*

$P_{2\ F\ Cameras}$ = *Exact Probability of Having 2 Full-Scan Cameras (See Exhibit 2 for Details)*

$P_{1\ F\ Camera}$ = *Exact Probability of Having Just One Full-Scan Camera (See Exhibit 2 for Details)*

$P_{0\ F\ Cameras}$ = *Exact Probability of Having Zero Full-Scan Cameras (See Exhibit 2 for Details)*

$P_{4\ P\ Cameras}$ = *Exact Probability of Having 4 Partial-Scan Cameras (See Exhibit 3 for Details)*

$P_{3\ P\ Cameras}$ = *Exact Probability of Having 3 Partial-Scan Cameras (See Exhibit 3 for Details)*

$P_{2\ P\ Cameras}$ = *Exact Probability of Having 2 Partial-Scan Cameras (See Exhibit 3 for Details)*

$P_{1\ P\ Camera}$ = *Exact Probability of Having 1 Partial-Scan Camera (See Exhibit 3 for Details)*

$P_{0\ P\ Cameras}$ = *Exact Probability of Having 0 Partial-Scan Cameras (See Exhibit 3 for Details)*

$P_{Transmitters}$ = *Probability of at Least One Transmitter (See Exhibit 4 for Details)*

P_1 = P_s *of High-Current Voltage Regulator From Terminal Maneuver to Impact*

P_2 = P_s *of Control Program Sequencer and Power Supply*

P_3 = P_s *of "F" Video Combiner*

P_4 = P_s *of "P" Video Combiner*

P_5 = *Operational Probability of Command Switch*

P_6 = P_s *of Four-Port Hybrid*

P_7 = P_s *of Dummy Load*

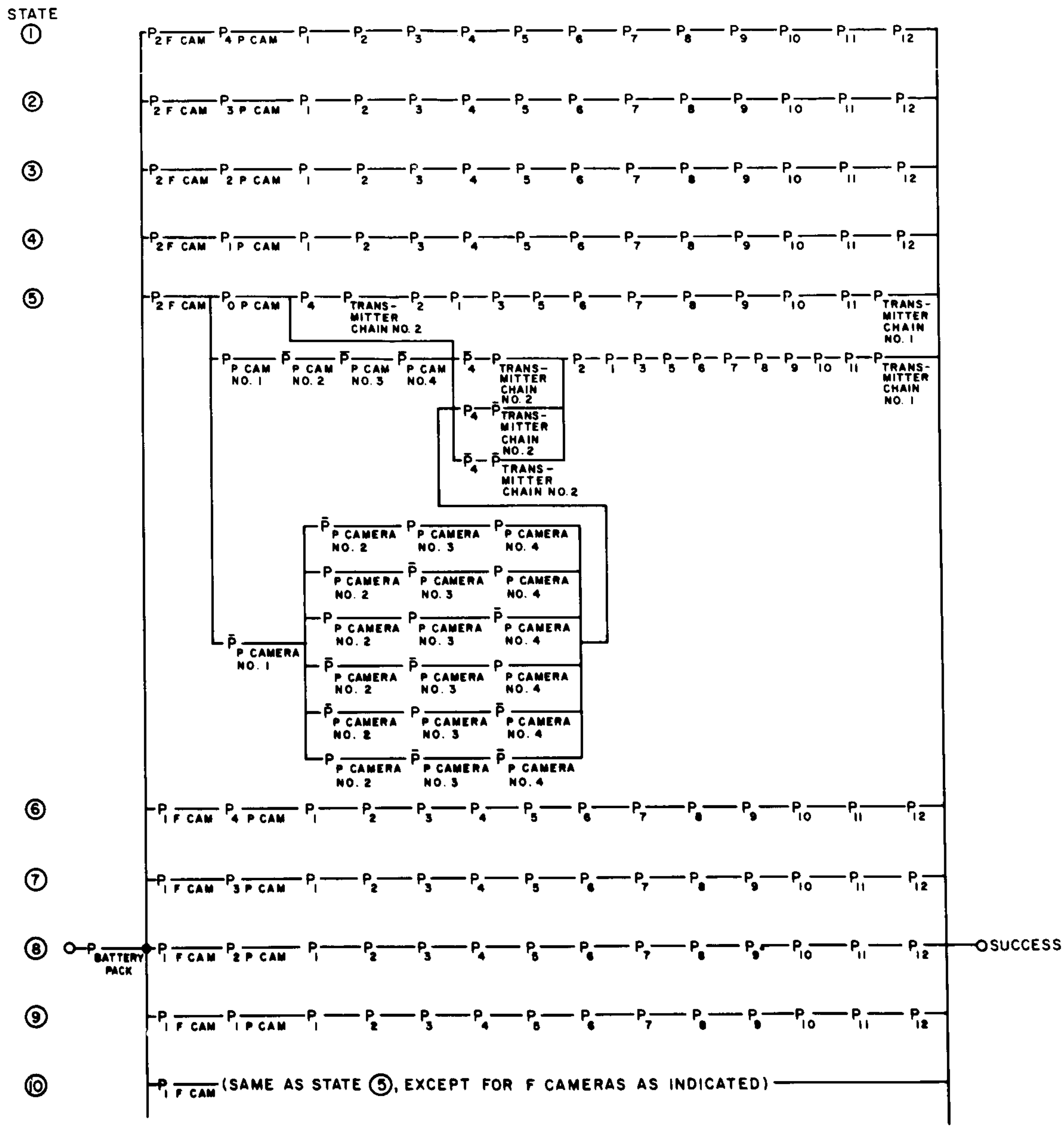
P_8 = P_s *of Low-Current Voltage Regulator From Start of Cruise Mode to Impact*

P_9 = P_s *of 15 Point T/M, Including VCO From Start of Cruise Mode to at Least Terminal Maneuver*

P_{10} = P_s *of 90-Point T/M (Does Not Include VCO)*

P_{11} = P_s *of 90-Point VCO From Terminal Maneuver to Impact (See Exhibit 5 for Details)*

P_{12} = P_s *of Both Transmitter Chains (Includes Modulators, Multipliers, Power Supply, and Appropriate Accessories)*


STATE
BATTERY PACK
SUCCESS
2 F CAM
4 P CAM
3 P CAM
2 P CAM
1 P CAM
0 P CAM
1 F CAM
TRANS-MITTER CHAIN NO. 2
TRANS-MITTER CHAIN NO. 1
P CAM NO. 1
P CAM NO. 2
P CAM NO. 3
P CAM NO. 4
P CAMERA NO. 1
P CAMERA NO. 2
P CAMERA NO. 3
P CAMERA NO. 4
(SAME AS STATE ⑤, EXCEPT FOR F CAMERAS AS INDICATED)

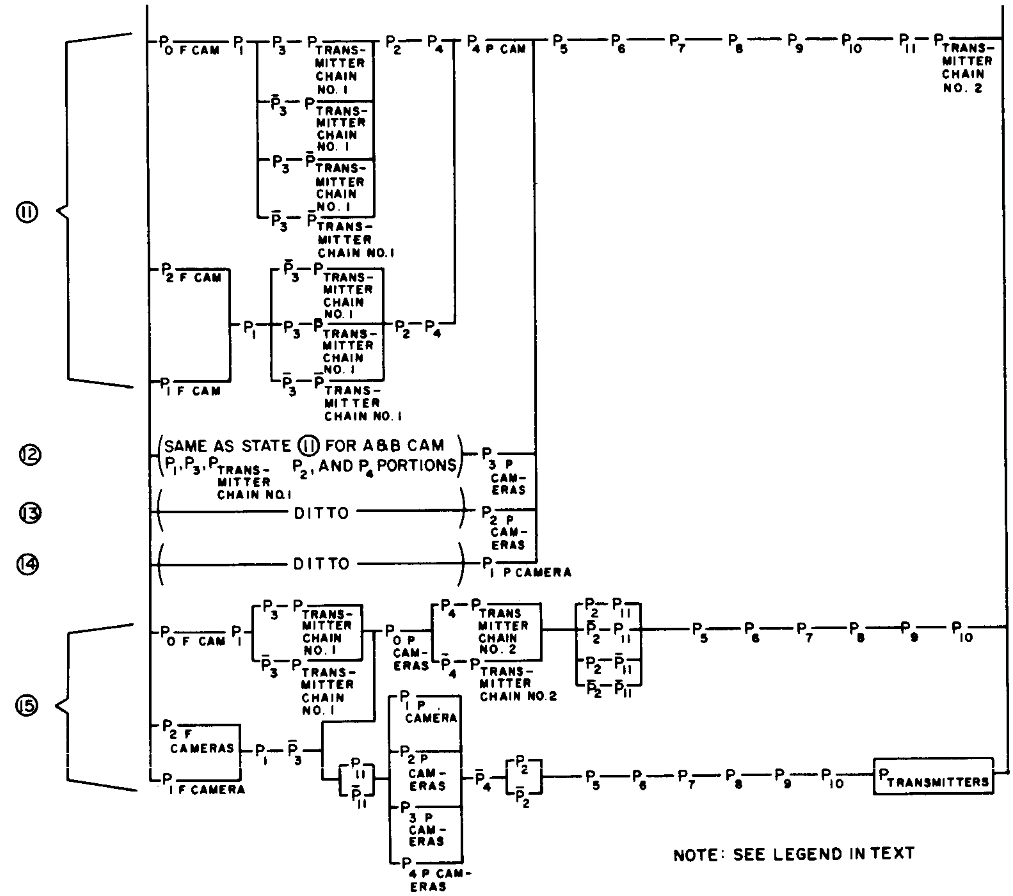


Figure 24. Reliability Mathematical Model of the Initial Configuration of the Ranger TV Subsystem

where

$P_{0\ P\ cameras}$ is as defined for State (5) and

$P_{0\ F\ cameras}$ is as defined for State (11).

As a matter of reference, for no data return from the Ranger TV cameras, the Subsystem is as follows:

State (60) = Probability of no data return

$$= \bar{P}_{\substack{Battery\\Pack}} + \bar{P}_{Hybrid} + \bar{P}_{\substack{Dummy\\Load}} + \bar{P}_{\substack{Com-\\mand\\Switch}} + \bar{P}_{\substack{Simultaneous\\Loss\ of\ all\\Video\ and\ T/M}}$$

Exhibit 1

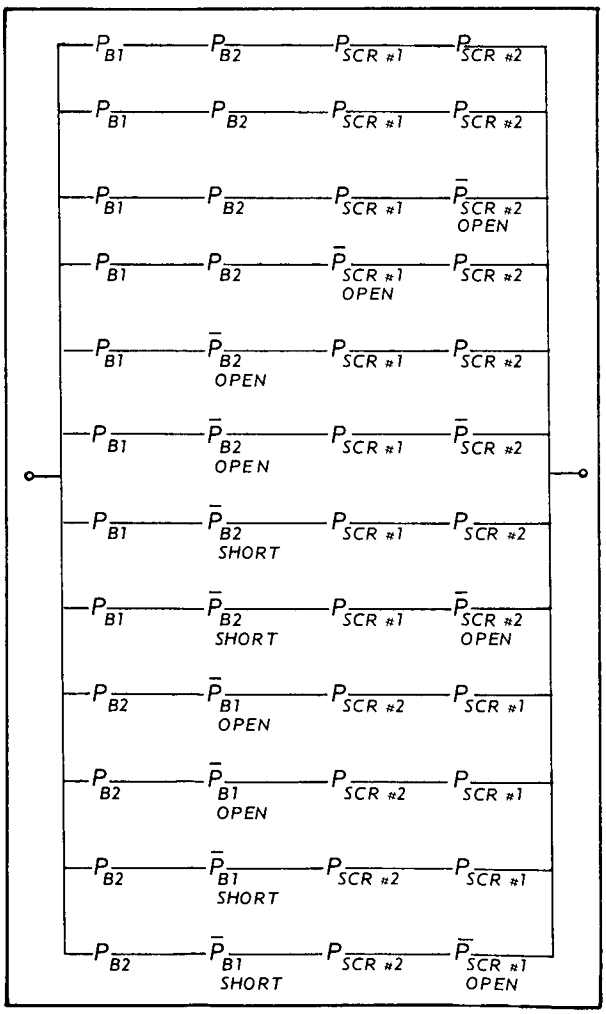


Exhibit 1 (Continued)

$$P_{Battery} = \Big\{ [P_{B1} \bullet P_{B2} \bullet P_{SCR\#1} \bullet P_{SCR\#2}]$$

$$+ [P_{B1} \bullet P_{B2} \bullet P_{SCR\#1} \bullet \bar{P}_{\substack{SCR\#2\\OPEN}}]$$

$$+ [P_{B1} \bullet P_{B2} \bullet P_{B2} \bullet \bar{P}_{\substack{SCR\#1\\OPEN}} \bullet P_{SCR\#2}]$$

$$+ \Big[P_{B1} \Big(\bar{P}_{\substack{B2\\OPEN}} P_{\substack{SCR\\\#1}} + \bar{P}_{\substack{B2\\SHORT}} P_{\substack{SCR\\\#1}} \Big) \bullet \Big(P_{SCR\#2} + \bar{P}_{\substack{SCR\#2\\OPEN}}\Big)\Big]$$

$$+ \Big[P_{B2} \Big(\bar{P}_{\substack{B1\\OPEN}} P_{\substack{SCR\\\#2}} + \bar{P}_{\substack{B1\\SHORT}} P_{\substack{SCR\\\#2}} \Big) \Big(P_{SCR\#1} + \bar{P}_{\substack{SCR\#1\\OPEN}}\Big)\Big]\Big\}$$

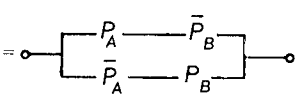
Exhibit 2

F CAMERAS

TWO CAMERAS $= P_A \bullet P_B =$

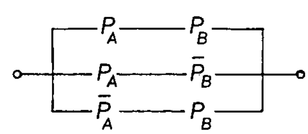
ONE CAMERA $= \{ P_A (\bar{P}_B) + P_B (\bar{P}_A) \}$

$=$



AT LEAST ONE $= [P_A \bullet P_B] + [P_A (\bar{P}_B) + P_B (\bar{P}_A)]$

$=$



NO CAMERAS $= (\bar{P}_A \bullet \bar{P}_B) =$

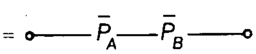


Exhibit 3

$$P_{4\ P\ cameras} = P_{P1\ Camera} \bullet P_{P2\ Camera} \bullet P_{P3\ Camera} \bullet P_{P4\ Camera}$$

$$= P_{P1\ Camera} \left(P_{P2,3,\ or\ 4\ camera}\right)^3, \text{ since P2, 3, and 4 Cameras are basically equal.}$$

$$P_{3\ P\ cameras} = \left[\left(P_{P1\ Camera}\right) 3 \left(\bar{P}_{P2,\ 3,\ or\ 4\ Camera}\right)\left(P_{P2,\ 3,\ or\ 4\ Camera}\right)^2\right]$$

$$+ \left[\left(P_{P2,\ 3,\ or\ 4\ Camera}\right)^3 \left(\bar{P}_{P1\ Camera}\right)\right]$$

$$P_{2\ P\ cameras} = \left\{\left[3\left(P_{P2,3,\ or\ 4\ Camera}\right)\left(\bar{P}_{P2,3,\ or\ 4\ Camera}\right)^2 \left(P_{P1\ Camera}\right)\right]\right.$$

$$\left. + \left[3\left(P_{P2,3,\ or\ 4\ Camera}\right)^2 \left(\bar{P}_{P2,3,\ or\ 4\ Camera}\right) \left(\bar{P}_{P1\ Camera}\right)\right]\right\}$$

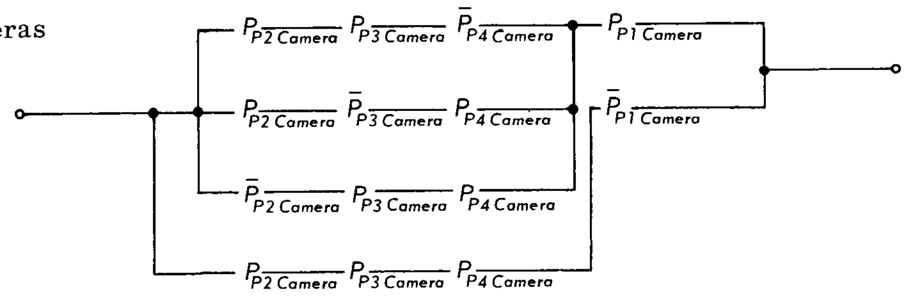
$$P_{1\ P\ camera} = \left\{\left[\left(\bar{P}_{P2,3,\ or\ 4\ Camera}\right)^3 \left(P_{P1\ Camera}\right)\right] + \left[3\left(P_{P2,3,\ or\ 4\ Camera}\right)\left(\bar{P}_{P2,3,\ or\ 4\ Camera}\right)^2 \left(\bar{P}_{P1\ Camera}\right)\right]\right\}$$

$$P_{0\ P\ cameras} = \left(\bar{P}_{P1\ Camera}\right)\left(\bar{P}_{P2,3,\ or\ 4\ Cameras}\right)^3 \left[\sum_{N=0}^{2} \binom{2}{N} \left(P_{P\ Video\ Combiner}\ P_{Control\ Prog.\ Seq.\ \&\ P.S.}\right)^2\right.$$

$$\left. + \left(\bar{P}_{P\ Video\ Combiner}\ \bar{P}_{Control\ Prog.\ Seq.\ \&\ P.S.}\right)^N\right]$$

Exhibit 3 (Continued)

P_s of just 3 cameras



P_s of just 2 cameras

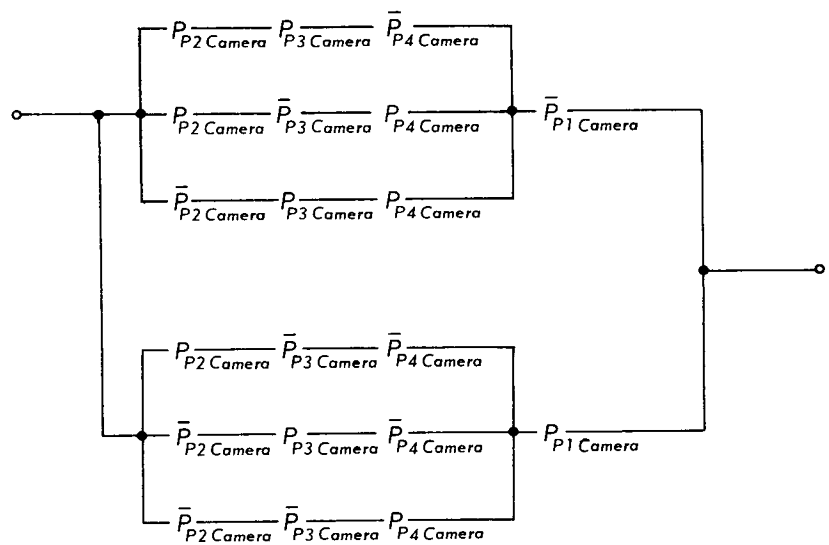


Exhibit 3 (Continued)

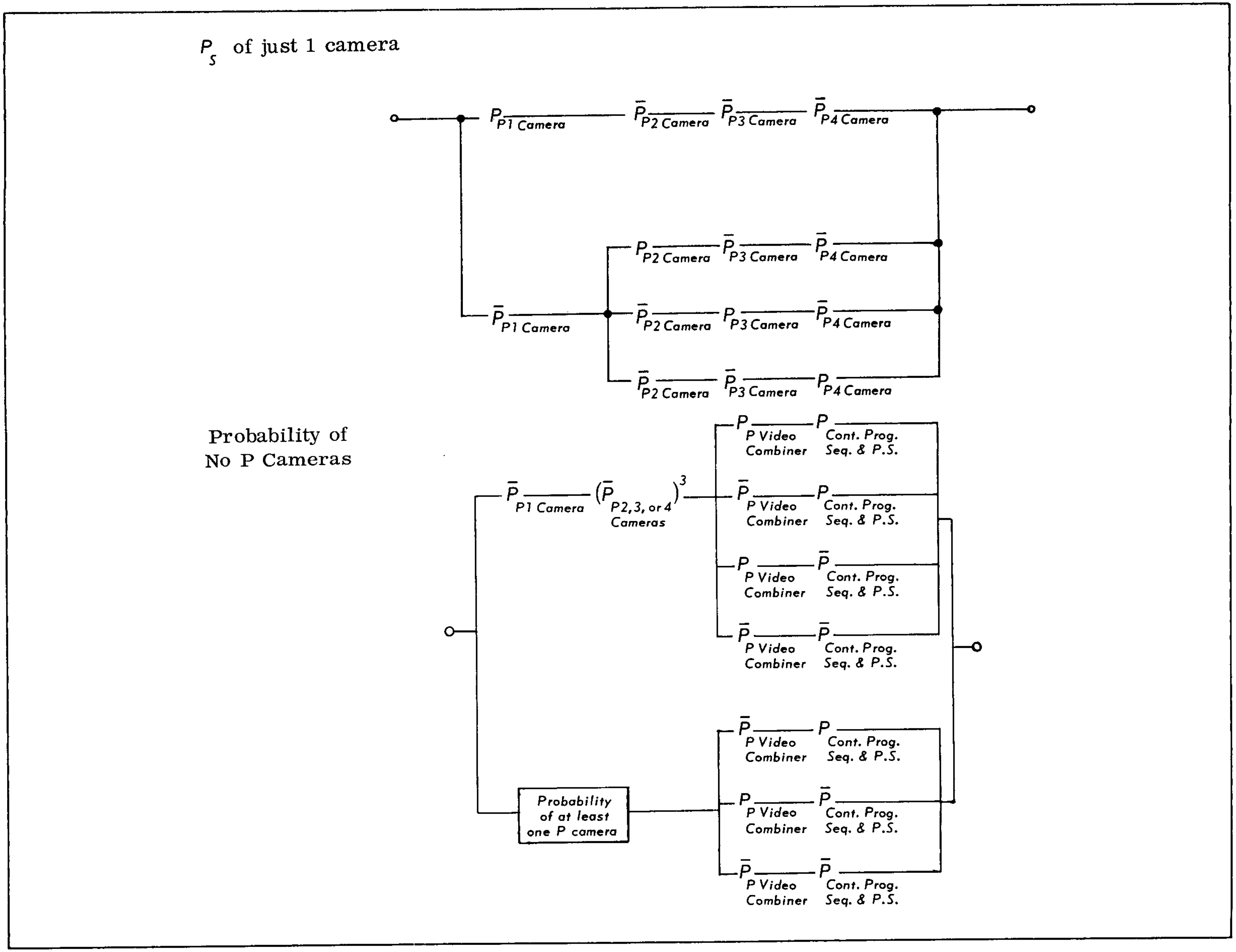
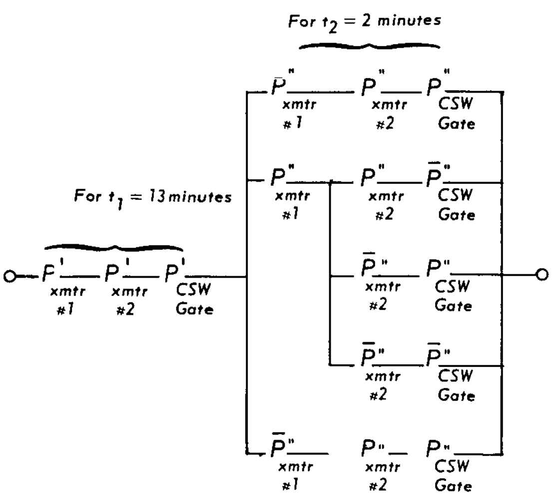


Exhibit 4



$$P_{transmitters} = \left\{ P'_{xmtr\#1} \bullet P'_{xmtr\#2} \bullet P'_{\substack{CSW\\Gate}} \right\}$$

$$\Bigg\{ \left[\left(P''_{xmtr\#1} \bullet P''_{xmtr\#2} \bullet P''_{\substack{CSW\\Gate}} \right) \right]$$

$$+ \left[P''_{xmtr\#1} \left(P''_{xmtr\#2} \bullet \bar{P}''_{\substack{CSW\\Gate}} + \bar{P}''_{xmtr\#1} \; P''_{\substack{CSW\\Gate}} \right. \right.$$

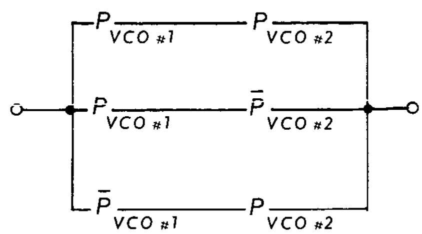
$$\left. \left. + \; \bar{P}''_{xmtr\#2} \; \bar{P}''_{\substack{CSW\\Gate}} \right) \right]$$

$$+ \left[\bar{P}''_{xmtr\#2} \bullet P''_{xmtr\#1} \bullet P''_{\substack{CSW\\Gate}} \right] \Bigg\}$$

P' = P prime probabilities reflect first 13 minutes (t_1) of terminal mode.

P'' = P double prime probabilities reflect last 2 minutes (t_2) of terminal mode.

Exhibit 5



Assuming VCO #1 = VCO #2

$$P_{VCO's}\left(\substack{at\ least\\one}\right) = \left(P_{VCO\#1}\right)^2 + 2P_{VCO\#1} \; \bar{P}_{VCO\#1}$$

c. SPLIT-SYSTEM CONFIGURATION MODEL

The reliability mathematical model for the split-system configuration was based on the functional diagram of the configuration shown in Figure 25. The graphic reliability model of the system is shown in Figure 26. As in the case of the revised model for the initial system detailed consideration is given here to 15 of the 60 possible states. These states include the various success-failure combinations for the P and F cameras, but it is assumed that the telemetry systems are fully operable.

The probabilities for States (1) through (15) are as follows:

State (1) = Probability of complete success (i.e., probability of having 2 F cameras, 4 P cameras, and both telemetry systems operating satisfactorily)

$$= \left[P_{\substack{Battery\\No.\ 1}} \bullet P_{\substack{Reg\\No.\ 1}} \bullet P_{\substack{2F\\Cameras}} \bullet P_{\substack{Control\ Pro-\\grammer\ Seq.\ \&\\P.S.\ No.\ 1}} \right.$$

$$\left. \bullet \; P_{\substack{Low-\\Current\\Voltage\\Reg.}} \bullet P_{\substack{15\text{-}point\\T/M}} \bullet P_{\substack{Transmitter\\A\ chain}} \bullet P_{\substack{F\ Video\\Combiner}} \right]^{*}$$

*Denotes F camera chain probability

$$\bullet \Big[P_{\substack{\text{Battery} \\ \text{No. 2}}} \bullet P_{\substack{\text{Regulator} \\ \text{No. 2}}} \bullet P_{\substack{\text{4 P} \\ \text{Cameras}}} \bullet P_{\substack{\text{P Video} \\ \text{Combiner}}}$$

$$\bullet P_{\substack{\text{Control} \\ \text{Programmer} \\ \text{Seq. \& P.S.} \\ \text{No. 2}}} \bullet P_{\substack{\text{Trans-} \\ \text{mitter} \\ \text{B chain}}} \Big]^{**} \bullet \Big[P_{\substack{\text{90-} \\ \text{point} \\ \text{T/M}}} \bullet P_{\text{Hybrid}}$$

$$\bullet P_{\substack{\text{Dummy} \\ \text{Load}}} \bullet P_{\substack{\text{Command} \\ \text{Switch}}} \bullet P_{\substack{\text{Distribution} \\ \text{Control Units} \\ \text{A \& B}}} \Big]^{***}$$

State (2) = *Exact probability of having 2 F cameras, 3 P cameras, 15-point T/M, and 90-point T/M operating satisfactorily.*

= *Same as P camera chain in State (1), except the 4 P camera configuration is replaced by the 3 P camera configuration as given in Exhibit 3*

State (3) = *Exact probability of having 2 F cameras, 2 P- cameras, and all telemetry.*

= *Same as P camera chain in State (1) except 4 P-camera configuration is replaced by 2 P-camera configuration as given in Exhibit 3.*

State (4) = *Exact probability of having 2 F cameras, 1 P camera, and all telemetry.*

= *[Same as P camera in State (1) except 4 P-camera configuration is replaced by 1 P-camera configuration as given in Exhibit 3]* •

$$\left(1 + \bar{P}_{\substack{\text{Seq. \& P.S.} \\ \text{No. 2}}}\right)$$

State (5) = *Exact probability of having 2 F cameras, 0 P cameras and all telemetry.*

= *[F- camera-chain probability]* • *[Exact probability of having 0 P cameras]* • *[Sixty-four possible combinations involving*

$$P_{\substack{\text{Battery} \\ \text{No. 2}}}, P_{\substack{\text{Reg.} \\ \text{No. 2}}}, P_{\substack{\text{P Video} \\ \text{Combiner}}}, P_{\substack{\text{Seq. \&} \\ \text{P.S.No.2}}}, P_{\substack{\text{xmtr} \\ \text{B chain}}}$$

and $P_{\substack{\text{Distribution} \\ \text{\& Control B}}} \Big] \bullet P_{\substack{\text{90-pt.} \\ \text{T/M} \\ \text{incl.} \\ \text{VCO's}}} \bullet P_{\text{Hybrid}} \bullet P_{\substack{\text{Dummy} \\ \text{Load}}}$

$$\bullet P_{\substack{\text{Command} \\ \text{Switch}}}$$

State (6) = *Exact probability of having 1 F camera, 4 P cameras and all telemetry.*

= *Same as State (1) except 2 F cameras become 1 F camera. See Exhibit 2 for just one F camera model.*

State (7) = *Exact probability of having 1 F camera, 3 P cameras, and all telemetry.*

= *[F cameras same as state (6)]* • *[P cameras same as State (2)] multiplied by the auxiliary-function probability.*

State (8) = *Exact probability of having 1 F camera, 2 P cameras, and all telemetry.*

= *[F cameras same as State (6)]* • *[P cameras same as State (3)] multiplied by the auxiliary-function probability.*

State (9) = *Exact probability of having 1 F camera, 1 P camera, and all telemetry.*

[F cameras same as State (6)] • *[P cameras same as State(4)] multiplied by the auxiliary-function probability.*

State (10) = *Exact probability of having 1 F camera, 0 P cameras, and all telemetry.*

[F cameras same as State (6)] • *[P cameras same as State (5)] multiplied by the auxiliary-function probability.*

**Denotes P-camera-chain probability

***Denotes auxiliary-functions probability

State (11) = Exact probability of having 0 F cameras, 4 P cameras and all telemetry.

$= P_{\text{Battery No. 1}} \left[P_{\text{0 F camera}} \bullet \right.$ *(Summation of all probability combinations of the F Video Combiner, Seq. & P.S. No. 1, xmtr A chain, DCU A portion, and Reg. No. 1)*

$+ \; P_{\text{2 F Cameras}}$

$+ \; P_{\text{1 F Camera}} \bullet$ *(The summation of all probability combinations of the F Video Combiner, Seq. & P.S. No. 1, xmtr A chain, DCU A portion, and Reg. No. 1 except the one case where everything is operating)* $\Big]$

$\bullet \; \left[P \text{ Camera Chain Probability} \right]$

$\bullet \; P_{\text{Redundant Low-Current Voltage Regulator with High-Current Voltage Regulator No. 1}}$

$\bullet \; P_{\text{15-pt. T/M commutator, VCO \& amplifier}} \bullet P_{\text{90-pt. T/M Commutator \& VCO's}} \bullet P_{\text{Hybrid}} \bullet P_{\text{Dummy Load}}$

$\bullet \; P_{\text{Command Switch}} \bullet P_{\text{Distribution. Control B}}$

State (12) = Exact probability of having 0 F cameras, 3 P cameras and all telemetry.

= Same as State (11) except 4 P cameras become 3 P cameras.

State (13) = Exact probability of having 0 F cameras, 2 P cameras and all telemetry.

= Same as State (11) except 4 P cameras become 2 P cameras.

State (14) = Exact probability of having 0 F cameras, 2 P cameras and all telemetry.

= Same as State (11) except 4 P cameras become 1 P camera.

State (15) = Exact probability of having just telemetry, both 15-point and 90-point.

= (F camera state same as in State (11) except xmtr A chain is not included)

• (P camera state same as in State (5) except xmtr B chain is not included)

$\bullet \; \left(P_{\text{Redundant Low-Current Voltage Regulator with High-Current Voltage Regulator}} \right)$

$\bullet \; P_{\text{15-pt. T/M Commutator VCO \& Amplifier}} \bullet P_{\text{90-pt. T/M Commutator \& VCO's}} \bullet P_{\text{Hybrid}} \bullet P_{\text{Dummy Load}}$

$\bullet \; P_{\text{Command Switch}} \bullet \left(P_{\text{Redundant xmtr's A\&B Chains -- at least one}} \right) .$

For at least telemetry return, the reliability of the split system is the sum of the fifteen states enumerated above. The exact probability states of the P and F cameras are the same as those given in Exhibits 2 and 3. The reliability model for the battery pack in Exhibit 1 no longer applies since each video chain has a single nonredundant battery. The time-sequenced redundancy of transmitter chains no longer applies. There is no last-two-minute switchover as in the initial Subsystem. However, in considering 90-point telemetry return, particularly in the absence of either F or P video, at least one transmitter must operate as noted in State (15) above.

State (60) is represented by:

$$\bar{P}_{\text{complete system}} \approx \left(\bar{P}_{\text{Battery No. 1}} \bullet \bar{P}_{\text{Battery No. 2}} \right) + \left(\bar{P}_{\text{SCR No. 1 Short}} \bullet \bar{P}_{\text{SCR No. 2 Short}} \right)$$

+ *[Simultaneous failure probabilities of no video output or lost transmission in P camera chain times the same effect in the F camera chain.]*

For States (2) through (15) of the Split System, there is a 0.0010276 probability that the Subsystem will be in one of these fourteen conditions.

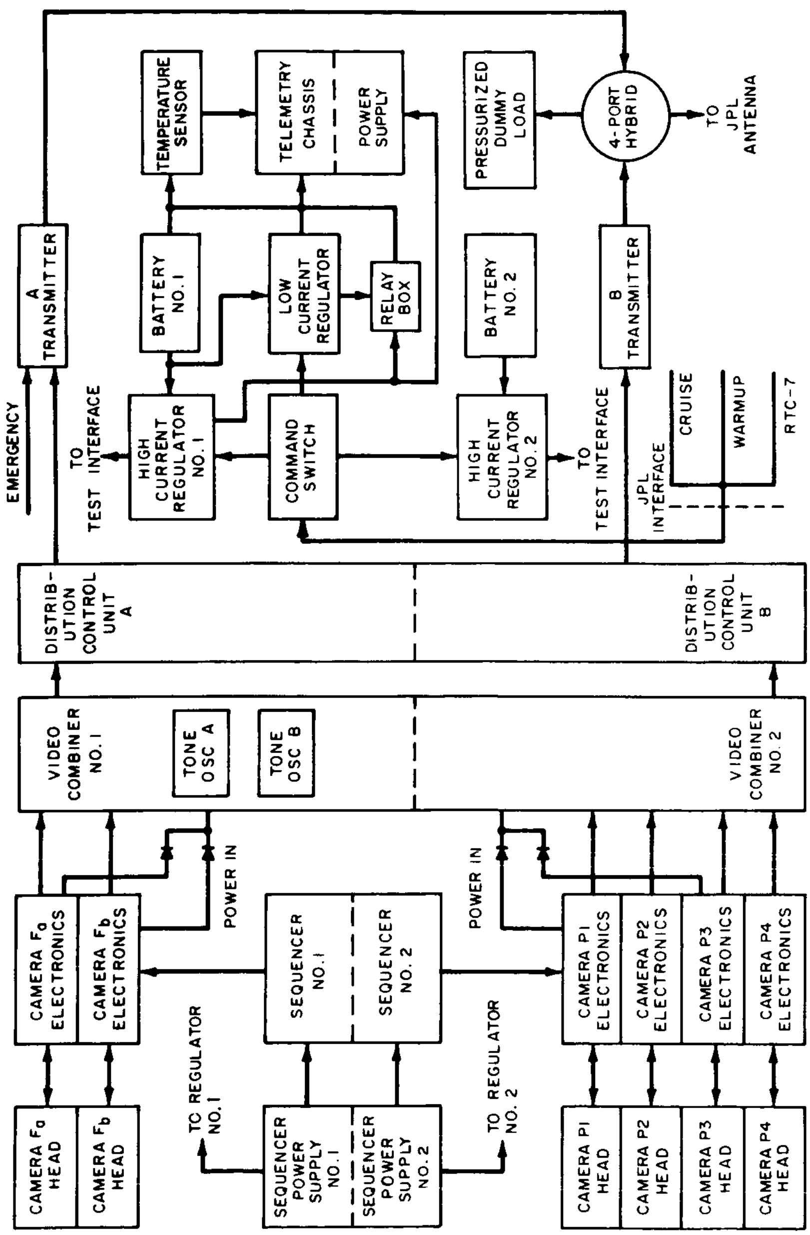
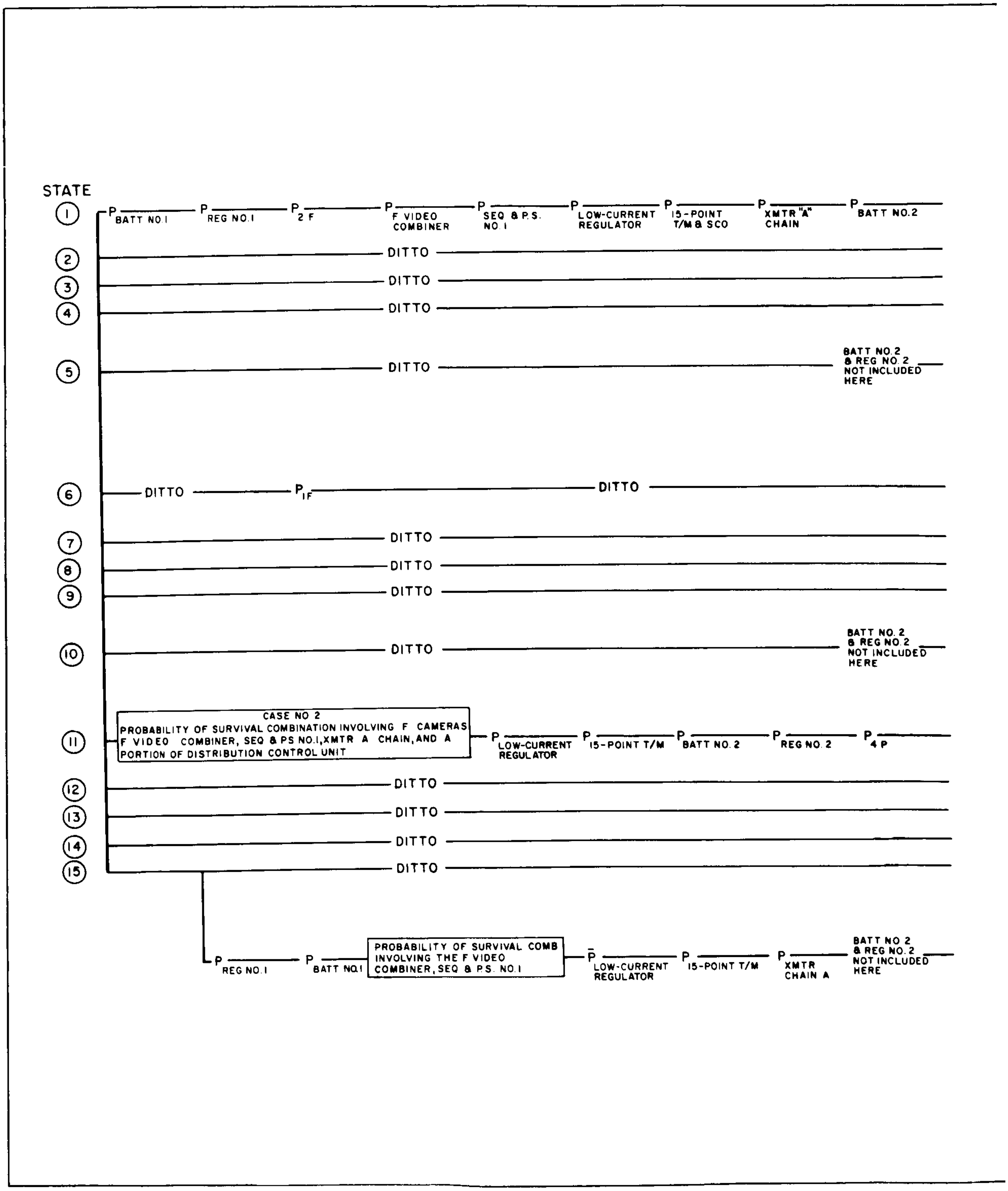


Figure 25. Functional Block Diagram of the Split-System Configuration of the Ranger TV Subsystem


STATE
1
P BATT NO.1
P REG NO.1
P 2F
P F VIDEO COMBINER
P SEQ & P.S. NO.1
P LOW-CURRENT REGULATOR
P 15-POINT T/M & SCO
P XMTR "A" CHAIN
P BATT NO.2
2 DITTO
3 DITTO
4 DITTO
5 DITTO
BATT NO.2 & REG NO.2 NOT INCLUDED HERE
6 DITTO
P 1F
DITTO
7 DITTO
8 DITTO
9 DITTO
10 DITTO
BATT NO. 2 & REG NO. 2 NOT INCLUDED HERE
11
CASE NO 2
PROBABILITY OF SURVIVAL COMBINATION INVOLVING F CAMERAS, F VIDEO COMBINER, SEQ & PS NO.1, XMTR A CHAIN, AND A PORTION OF DISTRIBUTION CONTROL UNIT
P LOW-CURRENT REGULATOR
P 15-POINT T/M
P BATT NO. 2
P REG NO. 2
P 4 P
12 DITTO
13 DITTO
14 DITTO
15 DITTO
P REG NO.1
P BATT NO.1
PROBABILITY OF SURVIVAL COMB INVOLVING THE F VIDEO COMBINER, SEQ & P.S. NO.1
P̄ LOW-CURRENT REGULATOR
P 15-POINT T/M
P XMTR CHAIN A
BATT NO 2 & REG NO. 2 NOT INCLUDED HERE

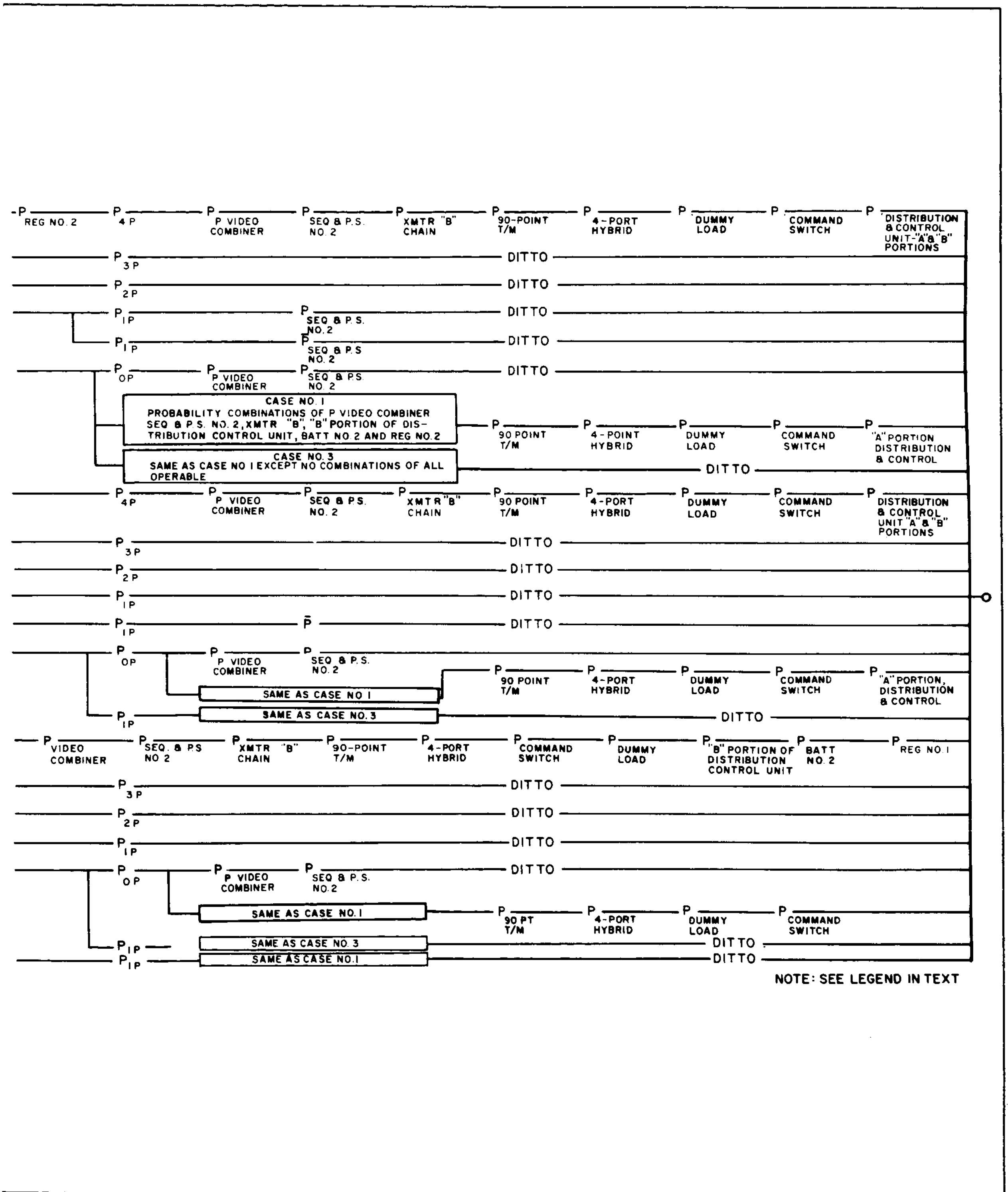


Figure 26. Reliability Mathematical Model of the Split-System Configuration of the Ranger TV Subsystem

d. POST-RA-6 CONFIGURATION

Post-RA-6 configuration changes did not change the mathematical model prepared for the split system.

3. Redundancy Requirements

a. INITIAL SUBSYSTEM CONFIGURATION

As a result of failure mode and effects analyses performed, areas for additional redundancy requirements were found. The following redundancy considerations were examined.

- To prevent a failure in the sequencer clock circuit or a sequencer power supply from disabling both the F and P Cameras, a redundant, standby 18-kc clock circuit was provided in the sequencer along with a standby redundant capability in the sequencer power supply. In addition, the P1 Camera was provided with a free-running, self-synchronous capability to provide operation in the event of a sequencer failure.
- An evaluation was made of two alternate systems for transmitting video information.

  In the first method, which used a time-sharing technique, the various outputs of the cameras would be switched by the sequencer to the modulator. The output of the modulator would, in turn, be switched to one of two transmitters, only one of which was to be in operation, the other being in standby.

  In the second alternative, both transmitters operated simultaneously. The outputs of the two transmitters were multiplexed and coupled at the RF output.

  The second method was selected for use in the Ranger TV Subsystem. It avoided the need for sequencer switching and provided separate transmission paths prior to switchover, and redundant transmission for P-Camera video after switchover.
- An emergency telemetry mode was provided for use in the event of loss of spacecraft stabilization or loss of high-gain antenna lock. A real-time command (RTC-7) was to be used to switch out the video signals and to permit the 90-point telemetry to directly modulate the transmitters. Full transmitter power was to be concentrated in the narrow telemetry band to compensate for reduction in antenna gain. If the original malfunction corrected itself, RTC-7 commands were to be used to switch the TV Subsystem back to normal operation.
- The power requirements of the TV Subsystem were supplied by two batteries connected through isolation diodes. If one of the batteries were to fail, the other could have carried the entire load.
- It was determined that it was not necessary to make the RF combiner redundant. The RF combiner consisted of the Four-Port Hybrid and the Dummy Load, both of which were passive devices with low failure rates.
- The original Subsystem configuration used only one High-Current Voltage Regulator to supply regulated power from the batteries to each of the two channels.

  At that time, analysis indicated that a single regulator with sufficient power capabilities could reliably supply the two video channels. Subsequent analysis for the split system altered this conclusion.

b. SPLIT-SYSTEM CONFIGURATION

Redundancy considerations examined in the split-system configuration design included the following:

Individual fuses were added to protect each of the camera and camera electronics assemblies to prevent a short in a single assembly from resulting in loss of complete channel capability.

- Redundant inputs were provided for supplying 6.3-volt power to the Video Combiner. The F-Channel Video-Combiner circuits were supplied power from the F_a and F_b Camera Electronics Assemblies. The P-Channel Video-Combiner circuits were supplied power from the P1 and P2 Camera Electronics Assemblies. These insured continuous operation of the F-portion of the Video Combiner in the event of a failure of one of the F-scan Camera Electronics Assemblies and the P-portion of a failure of either the P1 or P2 Camera Electronics Assemblies.

- Overvoltage protection was investigated for certain transistors in the Camera Electronics assemblies and circuit changes were made to limit the voltage to acceptable values.

- To prevent loss of telemetry in the terminal mode due to failure of the Low-Current Voltage Regulator, a relay was added to the split-system design. Previously failure of the Low-Current Voltage Regulator caused loss of 90-point telemetry in both the cruise and terminal modes. The relay permitted the High-Current Voltage Regulator to supply power during the terminal mode.

c. POST-RA-6 SUBSYSTEM CONFIGURATION

The following redundancy changes were implemented in the post-RA-6 configuration:

- Separate RTC-7 commands were provided to the relays of the gate circuits of the SCR in the HCVR which isolated turn-on with this command.

- A voltage regulator, which operated from either the F or P unregulated power source, was added to the Telemetry Assembly. This unit functioned only during the terminal mode after warm-up was commanded, and served to increase reliability by eliminating the dependence on the F-Channel High-Current Voltage Regulator.

- To assure that 90-point telemetry would be obtained, the output of the 90-point commutator was fed into the Channel-8 VCO as well as to the P-Channel for transmission. This switchover took place when either transmitter channel was placed in warm-up.

  The output of the 15-point commutator was placed on the F-Channel for transmission after this switchover took place. This configuration was used to assure receipt of diagnostic telemetry data should a problem be encountered which prevented high-power transmission.

4. Mission Success

The fourth phase of the reliability requirements study was the formulation of a definition of mission success and the establishment of a criterion of that success. The definition, which was derived during the initial configuration work, remained unchanged throughout the entire Ranger program. The criterion, called a figure of merit, was evolved in the initial configuration study and refined in the split-system effort.

a. DEFINITION OF SUCCESS

(1) Approach to Problem

Evaluation of the Ranger TV Subsystem design goals in terms of subassembly performance formed the basis of the definition studies. These goals were to obtain high-quality, high-resolution, television pictures of the lunar surface; to obtain reasonable nesting of a sequence of television pictures, starting from a resolution of approximately 350 meters per line pair (and also initially a color image of the lunar surface); and to obtain wide-area coverage of the lunar surface.

It was realized that there were a number of equipment combinations which would satisfy the overall mission objectives to varying degrees depending upon the extent to which the equipments operated successfully. Therefore, it was decided to utilize a straightforward approach, examining each design goal from two standpoints: the minimum of operating equipments which would result in mission success; and an ideal condition where all equipments required for success of the design goals operated successfully. In between these two extremes would lie all other equipment combinations capable of satisfying the design goals with varying probabilities of success.

The viewing area of the lunar surface as seen by the P Cameras was analyzed as the basis of determining camera requirements. As seen in Figure 27, the area covered by the P Cameras is divided into nine equal areas, each camera covering four-ninths of the total. Camera P1, for example, covers the shaded portion of the diagram. There was an overlap in the fields of all four cameras in the area marked "A".

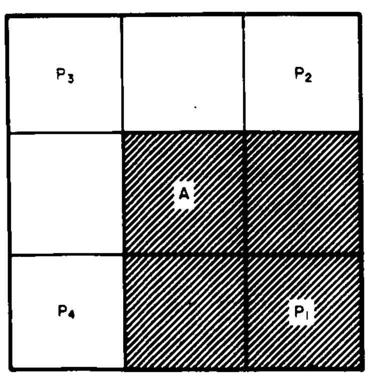


Figure 27. Terminal Viewing Area

(2) Coverage Requirements and Mission Success

Analysis of the viewing area produced the following conclusions in terms of successfully meeting the design goals.

(a) FIRST DESIGN GOAL

To meet the first design goal (to obtain a high-quality, high-resolution, television picture) it would be necessary to have a P-Camera operative for the last or next-to-the last frame. The minimum number of operation P-Cameras required to meet this requirement would be three out of four. With three cameras there would be three chances in four (a 75-percent probability) of having an operative camera called upon for the last frame. There would be a 100-percent probability of having an operative camera for at least one of the last two exposures.

Table 4 lists the possible camera combinations and the probabilities associated with each.

(b) SECOND DESIGN GOAL

To meet the second design goal (to obtain a reasonable nesting of a sequence of television pictures, starting from a resolution of approximately 350 meters per line pair) the minimum number of cameras required for successful operation was one F Camera and any two P Cameras. Only the F_a camera would provide the necessary coverage of the P-Camera area. The minimum condition would be the F_a Camera and two P Cameras; the ideal condition would be the F_a Camera and four P Cameras.

(c) THIRD DESIGN GOAL

The third design goal (to obtain wide area coverage of the lunar surface) could be met only by the F Cameras. The minimum condition would be successful operation of the F_a camera; the ideal condition would be successful operation of both the F_a and F_b Cameras.

TABLE 4
P-CAMERA COMBINATIONS AND COVERAGE

Camera(s) Operating	Fraction of Total Area Covered	Percent of Total Area Covered	Probability of Operable Camera For Last Two Frames
1, 2, 3, or 4	4/9	44	0.25
(1,2), (1,4), (2,3) or (3,4)	6/9	67	0.50
(1,3) or (2,4)	7/9	78	0.50
Any Combination of 3 Cameras	8/9	89	1.00
1, 2, 3, and 4	9/9	100	1.00

b. FIGURE OF MERIT

(1) Initial Subsystem Configuration

The figure of merit for mission success of the various P-Camera configurations during the final minute of operation was defined as:

$$F.M. = P_S A_c O_c$$

where:

P_S represents the previously derived probabilities for the P Cameras;

A_c represents the percentage of lunar area covered, with values ranging from 44 to to 100; and

O_c represents the probability of having an operable camera for either of the last two frames, with values ranging from 0.25 to 1.00.

B. RELIABILITY ANALYSIS AND PREDICTION

The second major task of the Ranger TV Subsystem reliability program for each of the three configurations was reliability analysis and prediction. In this subsection the results of the reliability analysis and prediction are considered: (1) the preliminary reliability estimate, (2) detailed reliability analysis, (3) failure mode and effects analysis, (4) computed probabilities of survival, and (5) computed figure of merit for mission success.

1. Preliminary Reliability Estimate

The preliminary reliability estimate was undertaken and calculations were completed in accordance with standard RCA Defense Electronic Product methods.* The following discussion summarizes those methods and the results obtained.

a. METHOD

Preliminary circuit information on the type and number of electromechanical parts to be utilized in the Subsystem was gathered from the designers. Assumptions were made as to the electrical and thermal stresses which would be applied to each part. These assumptions were based on the designers' estimates,

*As outlined in Volume 14, Defense Electronic Standards (Parts Reliability Factors for Electronic Equipment).

experience with similar circuitry, and the requirements of the applicable JPL environmental specification. All failure rates were expressed in percent of failure per 1000 hours. Calculations were made for ambient temperatures of both 25 and 70° C to permit comparison at these two temperature extremes which included the worst anticipated condition. Typical failure rates were obtained using equivalent part types selected from the tables of Volume 14 of Defense Electronic Standards. All parts were considered to have been derated in accordance with the policies established for the Ranger TV Subsystem.

b. RESULTS

Total failure-rate estimates for the flight equipment were 327.633 percent failures per 1000 hours at 25° C, and 422.036 percent failures per 1000 hours at 70° C. Expressed as Mean Time Between Failure (MTBF) these rates were equivalent to 306 hours at 25° C and 236 hours at 70° C. Figure 28 presents these data graphically as probabilities of survival versus time from zero to 45 hours. Table 5 summarizes the TV Subsystem parts-countdown and failure-rate estimates by components and equipment group. Detailed breakdowns of the equipment groups are similarly treated in Tables A-1 through A-6 in Appendix A, Volume 4b.

It is important to note that the above estimates were approximations only at the time of calculation and were significant only in reference to the concepts and conditions upon which they were based.

2. Detailed Reliability Analysis

a. INITIAL SUBSYSTEM CONFIGURATION

The detailed reliability analysis for the initial Subsystem was a refinement of the preliminary prediction and was based upon actual circuit application data gathered from design engineers.

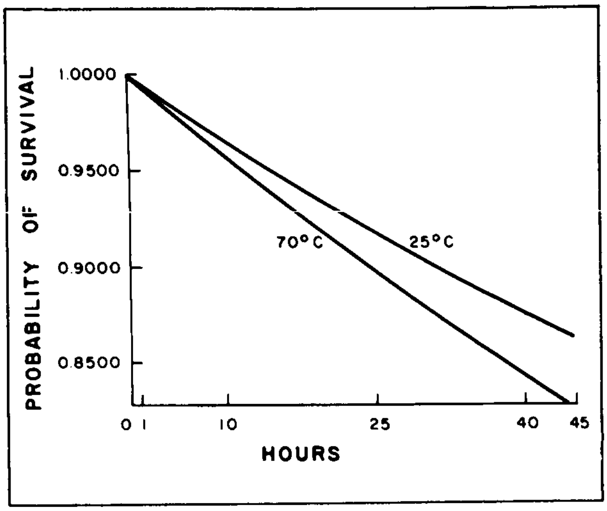


Figure 28. Probability of Survival as a Function of Time

(1) Method

Each part in each assembly was analyzed to determine its operating stress level. Using the stress level an individual failure rate was assigned. The failure rates of the individual parts were then summed to obtain a total figure for each assembly. Individual failure rates assigned were obtained, as in the preliminary estimate, from Volume 14 of Defense Electronic Standards. Reliability calculations were carried out using standard RCA methods.* All failure rates were given as percent failures per 1000 hours.

(2) Results

A total failure rate for the Subsystem of 476.683 percent failures per 1000 hours at 70° C was obtained. Expressed as Mean Time Between Failures this figure represented an MTBF of 210 hours. Compared to the preliminary failure rate of 422.036 percent failures per 1000 hours at 70° C, the newer figure represented an increase of 13 percent. The magnitude of this

*As outlined in RCA Technical Report TR59-416-1, Reliability Stress Analysis for Electronic Equipment.

TABLE 5
SUBSYSTEM SUMMATION OF PRELIMINARY PARTS—COUNT RELIABILITY ANALYSIS FOR RANGER TV SUBSYSTEM

Subsystem	Tran-sistors	Diodes	Capa-citors	Resis-tors	Inductive Compo nents	Connectors	Relays and Switches	Vacuum Tubes	Misc.	Total Parts	Total Failure Rates
Communications											
Parts	38	57	193	185	89	70	8	4	29	673	
F. Rate @ 25° C	1.520	1.990	2.777	4.007	1.090	3.455	18.500	12.000	16.720		62.059
F. Rate @ 70° C	1.596	2.207	8.826	6.562	2.530	3.455	18.900	14.000	18.810		76.886
Control Programmer and Camera Sequencer											
Parts	231	999	454	1122	2	188	2			2998	
F. Rate @ 25° C	10.680	30.310	2.105	25.682	0.080	19.710	0.600				89.167
F. Rate @ 70° C	11.214	33.349	4.486	44.245	0.400	19.710	0.700				114.104
TV Cameras and Circuitry											
Parts	731	1168	876	2087	53	65	25	6	38	5049	
F. Rate @ 25° C	29.240	38.280	7.732	42.002	0.860	7.605	9.900	24.000	7.473		167.092
F. Rate @ 70° C	30.702	42.201	19.892	69.363	3.310	7.605	11.750	27.000	8.555		220.378
Test and Control Functions											
Parts	2	2	-	4	-	3	2			13	
F. Rate @ 25° C	0.080	0.090	-	0.164	-	0.315	6.000				6.649
F. Rate @ 70° C	0.084	0.100	-	0.296	-	0.315	6.400				7.195
Power Source and Regulator											
Parts	7	3	2	8	-	3	4		3	30	
F. Rate @ 25° C	0.280	0.135	0.045	0.152	-	0.385	0.600		1.069		2.666
F. Rate @ 70° C	0.294	0.150	0.126	0.240	-	0.385	0.700		1.580		3.475

TABLE 5

SUBSYSTEM SUMMATION OF PRELIMINARY PARTS—COUNT RELIABILITY ANALYSIS FOR RANGER TV SUBSYSTEM (Continued)

Subsystem	Tran-sistors	Diodes	Capa-citors	Resis-tors	Inductive Compo nents	Connectors	Relays and Switches	Vacuum Tubes	Misc.	Total Parts	Total Failure Rates
Totals for Ranger TV Subsystem											
Parts	1009	2229	1525	3406	144	329	41	10	70	8763	
F. Rate @ 25° C	41.800	70.805	12.659	72.007	2.030	31.470	35.600	36.000	25.262		327.633
F. Rate @ 70° C	43.890	78.007	33.330	120.706	6.240	31.470	38.450	41.000	28.945		422.038

change was not considered to be significant because it represented a change in probability of survival of only 1 or 2 parts in 10,000.

A summation of the TV Subsystem failure rates at 70° C is presented in Table 6. Failure rates for the various component groups are presented in Tables B-1 through B-13 in Appendix B, Volume 4b.

b. SPLIT-SYSTEM AND POST-RA-6 SUBSYSTEM CONFIGURATIONS

The detailed reliability analysis for the split-system and post-RA-6 Subsystem was not updated because the equipment changes did not significantly affect the values already obtained.

3. Failure Mode and Effects Analysis

a. INITIAL SUBSYSTEM CONFIGURATION

On the initial Subsystem configuration, failure mode and effects analysis was first performed informally. While confined principally to functional assemblies, lower level components were, at times, examined. Assembly failure was considered in regard to its effect on a specific Subsystem function and compensating provisions were considered. Where compensating provisions did not exist, or did not minimize the effect of the failure mode if they did exist, recommendations for design changes were made. In the majority of these cases, the recommendations were incorporated into the Ranger TV Subsystem as it existed in the initial configuration.

b. INITIAL CONFIGURATION VERSUS SPLIT-SYSTEM CONFIGURATION

Prior to implementation of the split-system configuration, a failure mode analysis was performed comparing the initial Subsystem configuration to the then proposed split-system configuration. A description of this analysis is given here; detailed drawings and tables supporting the analysis are contained in Appendix C, Volume 4b.

(1) Scope

The failure-effects analysis was performed in two phases. The first phase comprised a complete analysis on both the Subsystem and assembly levels of the initial configuration. The second phase comprised an analysis of somewhat less detail which primarily compared the Subsystem-level failure modes and effects of the initial configuration with those of the split-system.

(2) Objectives

There were two objectives of the analysis. The first aim was to ascertain potential failure modes of the Subsystem black boxes and the effects on the initial TV Subsystem configuration performance of the respective failure modes. This procedure was followed to potential reliability problem areas and to develop appropriate solutions for these problems. The second aim of the analysis was to compare the failure modes and effects of the initial configuration and those of the split-system.

(3) Method

Established procedures were utilized to develop and systematically tabulate data.

The first step in the procedure was the preparation of a block diagram to graphically depict the functional elements of the Subsystem or the particular assembly component under consideration. Each block was considered successively. The ability of each of the respective units to demonstrate either degradative or catastrophic failure, or both, was ascertained by considering the internal failure modes of the unit.

Potential failures of each of the outputs were tabulated on an analysis form together with a

TABLE 6
COMPONENT-PART FAILURE RATES AT 70° C; SUMMATIONS FOR THE TV SUBSYSTEM

Assemblies	Transistors	Diodes	Capa-citors	Resis-tors	Inductive Components	Connectors	Relays and Switches	Vacuum Tubes	Miscel-laneous	Totals
Communications										
Parts	37	88	186	287	79	47	12	6	14	754
FR	1.600	24.190	6.122	16.813	1.338	2.878	6.554	57.000	20.540	137.125
Sequencer A9										
Parts	362	467	185	1494	4	14	1	-	5	2532
FR	11.250	9.173	1.417	60.811	454	2.895	0.232	-	0.100	86.332
TV Camera and Camera Electronics										
Parts	743	779	609	2393	42	54	24	12	20	4676
FR	25.015	20.649	37.338	108.639	1.440	9.870	11.400	31.440	1.805	247.596
Test and Control Function										
Parts	4	11	2	55	-	-	2	-	-	74
FR	0.270	371	0.060	3.263	-	-	0.070	-	-	4.034
Power Source and Regulator										
Parts	10	9	3	37	-	-	-	-	2	61
FR	0.238	0.144	0.033	0.431	-	-	-	-	0.750	1.596
Totals										
Parts	1156	1354	985	4266	125	115	39	18	41	8097
FR	38.463	54.527	44.970	189.957	3.232	15.643	18.256	88.440	23.195	476.683

summary of all malfunctions that could directly result and their effects, whether or not discernible, on the dependent Subsystem blocks. Compensating provisions inherent in the Subsystem design were taken into account at this point. These provisions, which minimized the effects of failures, included redundant circuits or channels, backup switches or power supplies. However, the use of high reliability and/or preconditioned parts was not considered to be a compensating provision for an assumed failure.

Assumed failures were analyzed in the light of their ultimate effects on the performance of the Subsystem. Particular emphasis was given to such levels as effects on the missions and effects on telemetry capability.

Ultimate effects of various failures were ranked qualitatively by anticipated frequency of failure occurrence relative to the frequency of occurrence of other failures and by the resultant relative levels of Subsystem or assembly degradation. Potential failures which represented serious deterrents to reliability were exposed by qualitative rankings such as those indicated above. Such exposure was of great importance to the improvement of reliability.

Appendix C, Volume 4b, contains the qualitative development of assembly and subassembly mission failure modes. A detailed listing of the rankings used for the analysis appears in the following paragraph (4). Whenever possible, the failure-effects-analysis forms list both the failure-class ranking which considers only specific aspects of the mission, for example, partial-scan capability, and the failure-class ranking which considers the effect on the overall mission.

(4) Failure Class Factor and Failure Probability Factors

(a) FAILURE CLASS FACTOR

To classify this study, the Engineering Reliability Activity made several assumptions. These assumptions, based upon knowledge of the TV Subsystem and the objectives of its mission were as follows:

- The P-Scan Cameras would contribute more to mission success than the F-Scan Cameras; the F-Scan Cameras would contribute more to mission success than the telemetry and, in like manner, the 90-point telemetry would contribute more than the 15-point telemetry.
- The contributions to the overall mission success provided by each of the TV Subsystem elements was assumed to follow an rms function, that is,

Total Mission Success =

$$\left[(P\ scan)^2 + (F\ scan)^2 + (90\ PT\ T/M)^2 + (15\ PT\ T/M)^2\right]^{1/2}$$

- In addition, each of the P and F Cameras was assumed to be related to the total P or F mission phase by an rms function. The individual telemetry points within the 15-point telemetry were assumed to be equally important and are shown on the graph of Figure 29 as a straight line. Likewise, each of the points of the 90-point telemetry was assumed to contribute linearly to the total 90-point mission phase.

Based on these assumptions, a degree of degradation was calculated as: degree of degradation = [100 - (total mission success)] percent. The range of degradation was divided into six categories with each category being assigned a code letter as shown in Table 7. This code letter or failure-class factor as it was referred to in this analysis also carried a subscript.

The subscript identified that portion of the TV Subsystem to which the failure-class factor applied. A subscript "o" was used for the overall Subsystem and the subscripts "p", "f", "T90", and "T15" for the partial-scan, full-scan, 90-point and 15-point telemetry, respectively.

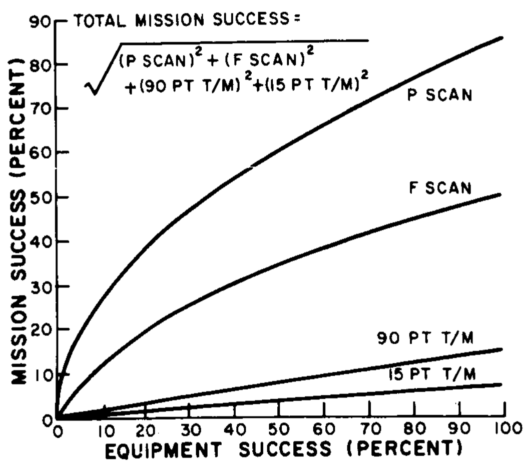


Figure 29. Mission Success as a Function of Equipment Success

The failure-class factors shown on the failure effects analysis charts were determined by subtracting the percentage of total mission success from 100 percent and entering the result into the degree of degradation column of Table 7. The individual failure-class factors were determined by scaling the curve for that function up to 100 percent. The desired point was then selected from the curve, subtracted from 100 percent, and entered into the degree of degradation column.

(b) FAILURE PROBABILITY FACTOR

This factor was an estimate of the relative probability of occurrence of a particular failure mode. The range of probabilities was divided into five levels starting from a factor of one, which denoted the most probable failure occurrence, and progressed to five which was the least probable. Assigning a factor to a particular failure mode involved an examination of such items as circuit function, past performance, and relative complexity of the circuit.

TABLE 7
DEGREE OF DEGRADATION

Failure Class Factor					Degree of Degradation = 100%-(Total Mission Success %)
Overall Task	Individual Tasks				
	Partial-Scan Channel	Full-Scan Channel	90-Pt T/M	15-Pt T/M	
A_o	A_p	A_f	A_{T90}	A_{T15}	76% to 100%
B_o	B_p	B_f	B_{T90}	B_{T15}	51% to 75%
C_o	C_p	C_f	C_{T90}	C_{T15}	26% to 50%
D_o	D_p	D_f	D_{T90}	D_{T15}	0% to 25%
E_o	E_p	E_f	E_{T90}	E_{T15}	0% to 10%
F_o	F_p	F_f	F_{T90}	F_{T15}	0% to 3%

If a failure mode had combined a failure probability factor of 3 or less with a failure class factor of A_o or B_o, a serious situation would have been indicated. No such failure modes were found in this analysis.

(5) Resulting Changes to TV Subsystem

The primary concern of the split-system configuration was a maximum probability of obtaining at least one good picture of the lunar surface. The Subsystem changes implemented to accomplish this purpose can be seen by comparing the block diagrams of the initial configuration (Figure C-1) and the split-system configuration (Figure C-2) in Appendix C.

The split-system involved two essentially independent operating channels. One channel transmitted full-scan information, and the other transmitted partial-scan information. Telemetry was transmitted over both channels for redundancy. An emergency-mode capability permitted telemetry transmission through one channel only, thereby allowing the other channel to transmit video information at any time possible. The full-scan channel carried the emergency information while the partial-scan channel transmitted video information continuously. With these arrangements for a split system, the probability of transmitting an image of the lunar surface was increased.

The design philosophy of the split system involved the additional consideration of obtaining the maximum probability with a minimum number of changes to the initial configuration. To this end, redundant circuitry was incorporated, and only two assemblies (a Distribution Control Unit and a second High-Current Voltage Regulator) were added to the initial configuration. The remaining additions and modifications related primarily to the interconnecting harness cables and power inputs.

(a) COMPARISON OF CONFIGURATIONS

A detailed analysis of the failure modes and effects of both configurations is tabulated in Appendix C, Volume 4b. The differences between the two configurations and between their respective effects on mission capability are described below:

Separation of Batteries and Addition of Second High-Current Voltage Regulator

Independent operation of the two video channels in the split-system configuration was achieved by separating the redundant battery arrangement and adding a second High-Current Voltage Regulator. It was considered to be highly improbable that a severe catastrophic failure would occur to the spacecraft. However, if such a failure were to occur, the complete isolation of the channels would preclude the consequent draining of the central power system and the complete loss of mission capability. In carrying this consideration one step further, fuses were added to the inputs of the assemblies so that a power short in a single assembly would not result in the loss of complete channel capability.

The changes had two additional effects:

- Failure of a single battery would have had no effect on the operation of the two channels in the initial configuration. In the split system, the same failure would have disabled one of the two independent channels.
- A single short in the silicon-controlled rectifier would have produced complete disablement of the initial configuration TV Subsystem. In the split system, the same failure would have disabled only one channel.

Back-Up Arrangement for the Low-Current Voltage Regulator

In the initial configuration, the Low-Current Voltage Regulator powered both the telemetry and the 225-kc VCO's. Thus, a failure in this regulator would have caused loss of telemetry in both the cruise and terminal modes. In the split system, a relay was added which made possible the use of the High-Current Voltage Regulator to provide telemetry power during the terminal mode in the event of failure of the Low-Current Voltage Regulator. Therefore, the probability of receiving the 90-point Telemetry data was substantially improved.

Video-Combiner Power Inputs

In the split system, the 6.3-volt inputs to the Video Combiner from the Full-Scan Cameras A and B electronics were combined into a diode isolation circuit. Consequently, continuous operation of the Video Combiner was ensured in the event of a failure of one of the full-scan camera electronics units. The occurrence of such a failure in the initial configuration would have disabled the full-scan portion of the Video Combiner, causing loss of full-scan video.

The same arrangement was incorporated in the Partial-Scan Channel where two of the four camera-electronics power inputs were combined. One of the power inputs came from the P1 Camera Electronics to ensure the free-running capability of this camera.

Sequencer and Sequencer Power Supply

In the split system, the Sequencer Power Supply for each of the two channels was independently powered via its respective regulator. The outputs of the existing 18-kc dual clock in the Sequencer were separated to provide individual operation for each channel. The last-two-minute switchover capability was removed in the interest of obtaining at least one good picture of the lunar surface. Deletion of the switchover capability insured receipt of video information as long as either channel was operative.

In the initial configuration, if switchover occurred when the partial-scan cameras and/or electronics were disabled, no video information could be obtained. The addition of a second relay in the Sequencer provided separate full-power turn-on capability.

c. SPLIT-SYSTEM CONFIGURATION

As a continuing effort of evaluating the split-system configuration, a detailed failure mode and effects analysis was performed later in the TV Subsystem program prior to the initiation of post-RA-6 effort.

(1) Scope and Objectives

The preceding analysis of failure modes and effects was concerned with major assemblies and did not delve into component or module failures. To enlarge the scope of the analysis, a lower level of Subsystem equipment was investigated. At this level, it was possible to ascertain the effects of a malfunctioning critical part on associated functions and ultimately, its related effects on Subsystem performance.

(2) Method and Results

The failure mode and effects analysis included all split-system modifications incorporated by June 1, 1963. The results of the analysis were tabulated along with proposed recommendations. These tabulations and accompanying schematics are contained in Tables D-1 through D-9, and Figures D-1 through D-13, of Appendix D, Volume 4b.

d. POST-RA-6 CONFIGURATION ANALYSIS

(1) Scope and Objectives

An extensive failure mode and effects analysis was performed at the part level to determine the effects of failure on the modification to the TV Subsystem. The modifications were examined to ascertain whether performance could be affected by any combination of critical operation and part failure occurring simultaneously.

(2) Method

From the circuit schematics of the modifications, the effects of part failures on total Subsystem operation was ascertained. The symptoms manifested by each part failure in all its most probable failure modes were determined, together with compensating provisions inherent in the design. Previously developed procedures were utilized and the data, then obtained, was systematically tabulated. Where necessary to avoid confusion, prefixes denoting particular circuit boards were added to identify the parts analyzed and tabulated.

(3) Results

(a) GENERAL

This failure mode and effects analysis revealed that no single part failure, in that equipment analyzed, would completely inhibit TV Subsystem performance and that total video could be inhibited only by a multiplicity of failures. Various levels of telemetry could be lost as a result of individual failures, however, the overall failure probability was lessened as a result of the changes incorporated in the Ranger VII configuration.

Four of the six functional groups of the TV Subsystem were modified. These were the Camera Group, Telecommunications Group, Controls Group, and Power Group. The effects of the individual modifications on TV Subsystem performance are summarized in the following paragraphs. Detailed tabulations and supporting schematics are contained in Tables E-1 through E-7 and Figures E-1 through E-7 in Appendix E, Volume 4b.

(b) CAMERA GROUP

Video Combiner Assembly (A8)

The telemetry circuitry in the Video Combiner was modified to obtain more useful information from the telemetry points. Two DC differential amplifiers were used as peak detectors to monitor the level of the video outputs from the P- and F-Channel cameras. This modification involved six parts and seven probable failure modes. Table E-1 lists the seven probable part-failure modes and presents their effects on TV Subsystem performance. In effect, 70 percent of the failure modes result in no video telemetry, and the remaining 30 percent of the failure modes result in a fixed upper (-5 volts) level regardless of input and a noisy output. The overall probability of these failures occurring is negligibly small. Also, failures in these areas, if they do occur, will not eliminate video output. The schematics for the F- and P-Channel Video Combiners are shown in Figure E-1.

Control Programmer and Camera Sequencer Assembly (A9)

The telemetry circuit was redesigned so that, rather than telemetering the output of the flip-flops, the outputs of the relay and relay driver were sampled. The manual reset was changed to a full-power command inhibit, and a set of redundant full-power command relay contacts were added.

The timer circuits for the F- and P-Channel full-power turn-on were redesigned to change the warm-up period from five minutes to 80 seconds. This resulted in an overall reduction in the number of components in the circuits. There was no analysis of this modification as components were deleted rather than added. The reduction of the number of components in the timer circuits, of itself, enhanced the reliability of the TV Subsystem.

Table E-2 lists the probable failure modes and presents their effects on TV Subsystem performance. The analysis is referenced to the Modulator Controller shown in Figure E-2.

(c) TELECOMMUNICATIONS GROUP

Telemetry Assembly (A26)

The major failure probability associated with the modifications to the Telemetry Assembly was the loss of 90-point telemetry data. This would result from certain failures in the telemetry regulator circuit. In the modification program 15 parts with 28 associated failure modes were analyzed. Approximately 33 percent of these failure modes would result in loss of 90-point telemetry. 17 percent would result in unregulated-bus voltages appearing in the telemetry circuitry. This, in itself, is not a catastrophic failure but would cause commutator speed-up and apply excess voltages to the telemetry circuits. Stress levels would be high and the calibration levels affected, but the Telemetry Assembly would continue to operate. The maximum effect of the remaining failures would be the loss of 15-point telemetry during cruise mode, or little or no effect overall. The overall probability associated with any of the assumed part failures, however, was very low, and when viewed from the probability of the Telemetry Assembly performing its intended mission, the modifications made improved the reliability.

A summary of the failure-mode and effects analysis performed on the modifications to the Telemetry Assembly is listed in Table E-3. A schematic of the modified Telemetry Assembly is shown in Figure E-3.

Current Sensor Unit

A Current Sensor Unit was incorporated into the TV Subsystem to enable a precise monitoring of the F- and P-Battery currents. The circuitry required to implement this modification consisted of a magnetic amplifier and magnetic oscillator. A constant-current input stage was also provided to limit the current drain on the LCVR to 80 ma under worst-case probable failure conditions. This modification involved 23 parts and 46 probable part-failure modes. In the failure mode and effects analysis performed, approximately 50 percent of the part-failure modes would result in erroneous telemetry output data; approximately 33 percent would result in no telemetry output; and the remaining 17 percent would result in either a fixed or a noisy output.

A summary of the failure mode and effects analysis performed on the modifications to the Current Sensor Unit is listed in Table E-4. A schematic of the modified current sensor unit is shown in Figure E-4.

(d) CONTROLS GROUP

Command Control Unit

The Command Control Unit, with the exception of the HCVR turn-on circuits, represented a completely new unit. The failure mode and effects analysis performed on new parts in this unit is summarized in Table E-5. There are 20 parts with 40 associated parts failure modes analyzed. Twenty-five percent of these failure modes result in a loss of the 32-hour clock pulse, 11 percent will cause the RTC-5 command to the clock to be inhibited, and approximately 3 percent of the failure modes will cause a premature turn-on of the Channel-8 telemetry. The remaining failure modes will have little or no effect on the operation of the TV Subsystem.

A schematic of the Command Control Unit is shown in Figure E-5.

Electronic Clock (A35)

Modifications to the Clock circuitry were relatively minor. The failure mode and effects analysis performed on the modified Clock revealed that two major failure categories existed as a function of the modifications. These were the loss of the Clock turn-on and erroneous telemetry readings for the various Clock times as a function of voltage outputs. The most significant of these was the loss of the Clock turn-on; however, this is a back-up turn-on mode for the F-Channel. On a single failure basis, this alone would not cause complete Subsystem failure.

The erroneous telemetry would result from digital-to-analog conversion failures. The probabilities associated with these failures are very small, however, as the part quantities are small (6 resistors, 2 gates, and 2 flip-flops) and the part operating levels are only nominal.

Table E-6 summarizes the failure mode and effects analysis performed on the modifications to the Clock. A schematic of the modified Clock is shown in Figure E-6.

(e) POWER GROUP

High-Current Voltage Regulators (A37 & A12)

The modifications to the High-Current Voltage Regulators (HCVR) did not involve the electrical performance of the regulators directly, but rather were concerned with turn-on of the TV Subsystem and with more meaningful telemetry.

The modifications concerned with Subsystem turn-on included the addition of an SCR-desensitizing circuit and changes in the command-logic circuitry to provide complete isolation of individual channel turn-on at the command source and in the relay circuitry. The telemetry modifications consisted of replacing a portion of series-resistance networks with zener diodes that act as constant voltage sources in series with the Battery and Regulator outputs. The modifications involved approximately 24 parts and 46 failure modes. In the failure mode and effects analysis performed, none of the parts failing singly in any of their modes would inhibit the TV Subsystem. Because of the high degree of redundancy provided, any single part failure would result only in the malfunction of a redundant turn-on mechanism, in some loss of protection, or in a reduction of safety margin. However, Subsystem operation would not be inhibited unless the part failure were coupled with other failure.

A summary of the analyses for the P-Channel HCVR is presented in Table E-7 and for the F-Channel HCVR is presented in Table E-8. A schematic diagram of the modified High-Current Voltage Regulator is shown in Figure E-7.

4. Computed Probabilities of Survival

a. INITIAL SUBSYSTEM CONFIGURATION

Reliability associated with survival probability was determined by computing individual subassembly probabilities and substituting these values in the appropriate places in the mathematical model for the initial Subsystem configuration.

(1) Method

Using initial Subsystem profile II (15-minute mission plus five 5-minute prelaunch test periods) and 70° C failure rates, probabilities of success for each subassembly were calculated based on the exponential distribution (see initial Subsystem mathematical model):

$$P_S = e^{-\lambda t} = 1 - Q$$

The derived probabilities were substituted in the mathematical model to obtain combined probabilities.

For example the probability that camera A would operate and transmit video (0.996947) was determined by using its mathematical model $P_A P_X$ (which in turn, is equal to $P_A P_p P_h P_i P_m P_Q P_a P_b P_g P_r P_s P_t$) and substituting in the model the values from Table 8.

(2) Results

Probability of survival values for the F and P Cameras equipments are given below.

(a) F-VIDEO TRANSMISSION

$P_A P_X$ — *Probability that Camera A will operate and transmit video* = 0.996947

TABLE 8
PROBABILITIES OF SUCCESS OF ASSEMBLIES

Equipments	Profile II Mission + 25 Minutes Test on Pad		Symbol Used for Component on Subsystem
	Hours	P_S	
TV Camera and Electronics:			
Camera A (includes color)	0.6500	0.999782	P_A
Camera B	0.6500	0.999785	P_B
VMA 1, 2, or 3	0.6500	0.999975	P_m
Camera 1, Free Running Sync.	0.6667	0.999968	P_n
Camera 1, 2, 3, or 4	0.6667	0.999789	P_1, P_2, P_3 or P_4
Time Code Generator	0.6667	0.999966	P_p
1-Minute-to-Go Switch	0.0167	0.999999	P_q
Test and Control Functions:			
Test Mode Switch	0.4167	0.999986	P_r
Command Switch and Drive Amplifer	0.4167	0.999975	P_s
Prime Power Source:			
Regulator and Batteries	65.6667	0.997723	P_t
Communications:			
Transmitter 1 (or Transmitter 2)	0.5834	0.999924	P_a
Power Amplifier 1 (or Power Amplifier 2)	0.6667	0.999977	P_b
Transmitter 1 and 2, Assoc. Telemetry			
90-Point Commutator	0.6667	0.999887	P_d
225-kc VCO 1 or 2	0.6667	0.999971	P_e
Cruise Mode Telemetry	47.1667	0.996869	P_f
RF Combiner	0.5834	0.999916	P_g
Normal Emergency Switch	-	0.999999	P_o

TABLE 8
PROBABILITIES OF SUCCESS OF ASSEMBLIES (Continued)

Equipments	Profile II Mission + 25 Minutes Test on Pad		Symbol Used for Component on Subsystem
	Hours	P_S	
Control Programmer & Sequencer:			
18-kc Oscillators and "OR" Gate	0.6667	0.999992	P_h
Camera A, B, Sequencer and P/S	0.6500	0.999730	P_i
Camera 1, 2, 3, 4 Sequencer and P/S	0.6667	0.999701	P_j
Counter Circuits	0.6667	0.999830	P_k

$P_B P_X$ = *Probability that Camera B will operate and transmit video* = 0.996949

$P_A P_B P_X$ = *Probability that Camera A & B will operate and transmit video* = 0.996731

$(P_A + P_B - P_A P_B) P_X$ = *Probability that at least one F camera will operate and successfully transmit video* = 0.997164

$P_X = P_p P_h P_i P_m P_Q P_a P_b P_g P_r P_s P_t$ = *Probability of success of the F-Telemetry transmitting channel* = 0.997164

(b) P VIDEO TRANSMISSION UP TO THE LAST MINUTE

$P^4 P_w$ = *Probability of at least 4 Camera Transmission* = 0.996289

$(P^4 + 4P^3Q) P_w$ = *Frobability of at least 3 Camera Transmission* = 0.997135

$(P^4 + 4P^3Q + 6P^2Q^2)$
$\bullet\ P_w$ = *Probability of at least 2 Camera Transmission* = 0.997135

$(P^4 + 4P^3Q + 6P^2Q^2$
$+ 4PQ^3) P_w$ = *Probability of at least 1 Camera Transmission* = 0.997135

$P_w = P_p P_h P_j P_m P_a P_b$
$\bullet\ P_g P_r P_s P_t$ = *Probability of success of the P transmitting channel* = 0.997135

(c) P VIDEO TRANSMISSION DURING THE LAST MINUTE

$P^4 P_v$ = *Probability of at least 4 Camera Transmission* = 0.996413

$(P^4 + 4P^3Q) P_v$ = *Probability of at least 3 Camera Transmission* = 0.997259

$(P^4 + 4P^3Q + 6P^2$
$\bullet\ P_r P_s P_t$ = *Probability of at least 2 Camera Transmission* = 0.997259

$(P^4+4P^3Q+6P^2Q^2$
$+4PQ^3)P_v =$ *Probability of at least 1 Camera Transmission* = 0.997259

$P_v = P_p P_h P_i P_r P_g$

• $\overline{Q^2)}P_v =$ *Probability of transmitting P video during the last minute of operation* = 0.997259

(d) THE P1 "FREE RUN" MODE TRANSMISSION

The probability of failure of the sequencer:

$$Q_n = (1 - P_n) = (1 - P_p P_h P_i)$$

The probability of P1 operating times transmitting prior to the last minute:

$$P = P_1 P_n P_m P_a P_b P_g P_r P_s P_t = 0.997232$$

The probability of P1 operating and transmitting if switchover occurs:

$$P = P_1 P_n P_R P_g P_r P_s P_t = 0.997356$$

(e) 90-POINT TELEMETRY

The 90-point telemetry has two probabilities associated with its operation. These are P_J for the normal mode and P_J for the emergency mode.

P_J = *Normal mode of at least one telemetry channel* = 0.997486

P_J = *Emergency mode of at least one telemetry channel* = 0.997516

The cruise mode telemetry $P_{cmt} = P_f P_t =$ 0.994598 as the probability of success for the entire cruise mode.

b. SPLIT-SYSTEM CONFIGURATION

For the split-system, reliability associated with survival probability was determined in the same manner as for the initial configuration, that is, individual assembly probabilities were calculated and substituted in the appropriate places in the split-system mathematical model.

(1) Method

Using the split-system profile (a 15-minute mission) and the 70° C failure rates computed for the initial system, probabilities of success for each assembly were calculated. The values derived were then substituted in the mathematical model for the split-system.

For comparison purposes, similar survival figures were derived for the initial configuration using a 15-minute profile and the initial Subsystem model.

(2) Results

Results of the calculations are summarized in Table 9 which compares the split-system with the initial configuration.

Probability of complete mission success for the split-system was determined to be 0.99378, a slight reduction from the 0.99468 computed for the initial configuration. On the other hand, the probability of complete failure for the split-system was only 1.5×10^{-7} compared to 5.2×10^{-5} for the initial configuration. Thus, the probability of complete success for the split-system was slightly reduced but the probability that some data would be returned was significantly enhanced.

5. Evaluation of Mission Success

a. MISSION SUCCESS CALCULATIONS

Probabilities of mission success as defined in the reliability requirements study were computed for the minimum and ideal conditions of each of the three design goals.

TABLE 9
COMPARATIVE RELIABILITIES

Operating States	Initial	Split-System
4 P's, 2 F's, all T/M (State 1 only)	0.99468	0.99378
At least all T/M (States 1 through 15 inclusive)	0.99529	0.99481
The 15 video states of zero 90-point and all 15-point T/M, summed.	4.96×10^{-5}	4.92×10^{-5}
The 15 video states of zero 15-point and all 90-point T/M, summed.	4.44×10^{-3}	4.61×10^{-3}
The 15 video states of zero 15-point and zero 90-point T/M, summed.	2.19×10^{-4}	5.28×10^{-4}
Exact State of no return: State (60)	5.2×10^{5}	1.5×10^{-7}

(1) First Design Goal

To obtain high-quality, high-resolution, television pictures of the lunar surface.

Minimum: *At least 3P Cameras during last minute* = 0.997259

Ideal: *At least 4P Cameras during last minute* = 0.996413

(2) Second Design Goal

To obtain a reasonable nesting of a sequence of television pictures, starting from a resolution of approximately 350 meters per line pair.

Minimum: P_A *at least 2P* = 0.996526

Ideal: P_A *at least 4P* = 0.995680

(3) Third Design Goal

To obtain wide area coverage of the lunar surface.

Minimum: P_A = 0.996947

Ideal: $P_A \bullet P_B$ = 0.996731

b. FIGURE OF RELATIVE MERIT

The figure of relative merit for the P Cameras was computed using the formula previously developed.

$$F.M. = P_s A_c O_c$$

A composite bar chart for the values computed from this equation is shown in Figure 30.

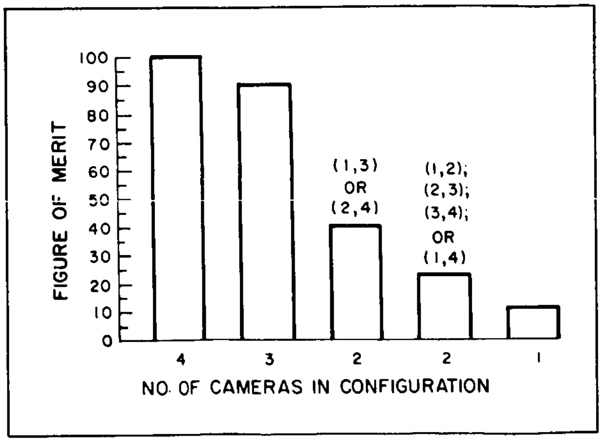


Figure 30. Relative Merit as a Function of Number of Cameras

6. Post-RA-6 Reliability Analysis and Prediction

a. POST-RA-6 APPROACH

Because of the failure of Ranger VI to return video data before impact on the moon, post-RA-6 reliability efforts were concentrated on those functions of immediate assistance to the redesign effort. Thus, the reliability predictions and the mathematical models were not formally updated although informal reliability estimates were made. These estimates revealed that the post-RA-6 Subsystem was less likely to have a complete mission abort due to the changes implemented.

Formal reliability effort included the post-RA-6 failure mode effects analysis already described (sub-section B3d) and a component electrical stress evaluation. This evaluation is described in the following paragraphs; supporting tables are contained in Appendix F, Volume 4b.

b. COMPONENT ELECTRICAL STRESS EVALUATION

As part of the redesign program, a reliability stress reevaluation of the Ranger TV Subsystem was completed. This study examined specific applications of the individual component parts and determined their reliability using the electrical and thermal operating conditions as judgment criteria. The details and conclusions of this evaluation, which are presented here, reflect the design status as it existed on approximately April 4, 1965.

(1) Method

The stress evaluation was performed by measuring the electrical operating conditions across each component part. In areas of duplications, such as flip-flop circuits and gating circuits, a typical circuit was selected and subjected to the measurement analysis. In RF circuits where tuning was extremely critical, no measurements were attempted. Table F-1 lists the assemblies of the Subsystem tested.

The electrical operating conditions were determined using the schematic diagrams and the list of materials given in Table F-2. This source of electrical data was supplemented by thermal measurements and component part testing to achieve a realistic evaluation of specific part applications.

(2) Appraisal of Component Part Applications Operating Conditions Versus Manufacturer Specifications

In analyzing the applications of the individual component parts, each part was examined with respect to its electrical operating stress and its thermal environment. These operating conditions were compared with the ratings imposed by the manufacturers' specifications of the individual parts, and the reliability aspects of the applications were then judged accordingly. It was the objective of this review to point out such applications as were clearly out of the established derating policy. The detailed data on the component parts and their operating conditions are given in Tables F-4 to F-37. It should be noted that a dash in any of the stress analysis columns indicates that the value for that column was negligible.

(a) ANALYSIS OF QUESTIONABLE RELIABILITY

The questionable reliability areas, where parts exceeded the derating policy on the Ranger program, are tabulated in Table F-3. Each part-application level listed in Table F-3 was reviewed with component-part specialists concerning the reliability risk involved. This review considered the risk from two aspects. The first was Ranger mission and testing requirements as opposed to those of longer-lived spacecraft. The second was the decrease in reliability if a part replacement was attempted on completed assemblies to assure meeting the derating policy.

(b) RESISTORS

The resistors listed as exceeding the derating policy were not a serious reliability risk. The most heavily operated units, contained in the Sequencer Power Supply, were measured by thermocouples to determine their body temperatures. A review of temperature data showed that resistors R16 and R45 in the Sequencer Power Supply reached a stable temperature of approximately 163 and 169° C, respectively, while operating in thermal vacuum at +55° C ambient. Maximum body temperature of 275° C (as a minimum value) was permissible.

(c) CAPACITORS

The capacitors listed as exceeding the derating policy were not considered a reliability risk. The majority of the capacitors were tantalum units with a series resistance of four ohms per volt or greater. This allowed a self-healing process to become effective during a scintillation mechanism, should it be encountered. The remaining types of Mylar, mica, paper, ceramic, and glass were capable of operating also at higher voltages, and more recent derating policies increased these levels.

(d) TRANSISTORS

In this review, six transistors exceeded the manufacturer's rating by factors of 125 to 240 percent of the BV_{EBO} rated value. There were two points of concern. The first was the degree of current limitation in the circuits in the event that the applied voltage caused an avalanche breakdown of the junction. The second was the effect on the gain characteristics of the device in the event that the units were broken down but were current limited.

Both areas were evaluated. Limited testing of the 2N930's showed that the BV_{EBO} avalanche level was greater than 15 volts. This represented a considerable safety margin over the manufacturer's published ratings. In the Ranger application none of the devices ever encountered this level; maximum level was 12 volts. A test was performed on a small number of samples at a V_{BE} of 20 volts and the power dissipation within the diode junction was limited to various levels. A control sample was operated in a normal forward-bias condition. The gain characteristics of the devices were measured before setup and after three days of continuous operation. The reduction in gain characteristics varied from three to five percent and was evident in both the control sample and all the samples operated in the breakdown region. On this basis, the application of these devices was accepted and the equipments released to production.

C. PARTS SELECTION, EVALUATION, AND CONTROL

To insure the highest possible reliability of parts used in the Ranger TV Subsystem, firm policies and procedures were established for the selection, evaluation, and control of the components used. To implement these policies and procedures, RCA Engineering Reliability, Design Engineering, and Central Engineering (at DEP) worked in close cooperation. The activities of these groups included not only control of the selection procedures but, also the delineation of preconditioning procedures to further guarantee proper part operation in its Ranger TV Subsystem environment.

1. Parts Selection

a. INITIAL SELECTION

Individual parts selections were first made by the respective design engineers in the following order of preference established by RCA Reliability Engineering: (1) RCA Satellite Standards, (2) military approved parts, and (3) JPL preferred parts. Lists of these selections were each generated on a subassembly basis using the Ranger Part Worksheet shown in Figure 31. The "requested part" side of the worksheet for each subassembly was completed by Design Engineering.

b. REVIEW AND APPROVAL

The worksheets were then submitted to Engineering Reliability for review action. Defense Electronic Products Central Engineering, working in close coordination with Engineering Reliability, reviewed and approved or rejected all parts listed on the worksheets. Factors considered in the approval cycle were stress, part history, Ranger environment, effect of sterilization temperature (125° C), and vendor qualifications. Parts rejected as reliability risks were replaced with recommended approved parts. Approved parts, in addition to meeting the structural requirements cited above, also were required to adhere to the functional standards set forth in the Ranger derating policy.

c. DERATING POLICY

A standard derating policy for all Ranger TV Subsystem Parts was established by RCA Engineering Reliability. Highlights of the requirements are summarized below.

- Semiconductors. The power dissipated by any semiconductor, averaged over a thirty-second period, could not exceed one-fifth of the room-ambient power rating of the semiconductor. In addition, no semiconductor could ever be subjected to a voltage transient exceeding four-fifths of its rated breakdown voltages.
- Capacitors. No mica and ceramic capacitors could operate at a voltage in excess of 10 percent of their + 25° C voltage rating nor could tantalum capacitors operate in excess of 70 percent of their + 65° C voltage rating.
- Resistors. The power dissipated by any resistive element, averaged over a thirty-second period, could not exceed one-half of the + 25° C power rating nor could it ever be subjected to a voltage exceeding four-fifths of its maximum rating.
- All other parts were reviewed on an individual basis.
- Special Applications Releases. Design engineers could request release from the derating requirements of the preceding paragraphs when such derating would seriously conflict with other design parameters. The design engineer was required to furnish Engineering Reliability with complete details of the component application and the reason for the request. Waiver requests were reviewed by component parts specialists and were processed as described in Parts Classification below.

d. PARTS CLASSIFICATION

All parts approved for use in the Ranger TV Subsystem were classified either as standard or nonstandard parts.

Standard parts were those parts selected from the Satellite Standards manual and/or Military Standard approved parts which met the minimum part environmental specifications tabulated in the Satellite Standard manual.

REVISION NO. ______ **RANGER PART WORK SHEET** LOCATION ______

SECTION ______ DESIGN ENGINEER ______ EXT. ______

SUBSYSTEM ______ CIRCUIT IDENTIFICATION ______ DATE ______

			REQUESTED PART				RECOMMENDED PART				
ITEM NO.	CKT. SYM.	TYPE PART	VENDOR	TYPE NO.	RATINGS	STRESS	VENDOR	TYPE NO.	STD. NON-STD.	INSP. LOG OR STD. ITEM NO.	FAILURE RATE %/1000 HRS. 70° C

SHEET ___ OF ___ SHEETS

Figure 31. Ranger Part Work Sheet

Nonstandard parts were those which did not meet the standard-part requirements, but for which limited data of performance in a similar environment was available. In special cases, part performance was verified by qualification testing.

All parts were grouped into lists of standard (Table G-1) and nonstandard (Table G-2) parts. Information was included to identify the subassemblies in which the parts were used. These lists were maintained throughout the program.

2. Part Preconditioning

a. INITIAL AND SPLIT-SYSTEM CONFIGURATION

A part preconditioning program was implemented. The bake cycle, parameters measured, acceptance criteria, and program results are presented briefly here.

(1) Bake Cycle

High-population electronic parts were first measured for the parameters listed in Table 11 and then subjected to a 168-hour baking period under specific conditions varying according to the component. Table 10 summarizes the temperature of the preconditioning cycle.

(2) Measurement Parameter

Table 11 lists the parameters measured before and after the 168-hour baking period.

(3) Accept-Reject Criteria

Criteria for acceptance and rejection were based upon the extent of deviation from part specifications, or upon the allowable percent of change from the initial parameter measurements for all preconditioned components.

Erratic behavior was also considered cause for rejection; the final decision was made after an engineering analysis on an individual device basis, for example, on units drifting excessively from measurements.

TABLE 10
BAKE-CYCLE CONDITIONS (INITIAL AND SPLIT-SYSTEM CONFIGURATIONS)

Component Type	Temperature (°C)	Specific Conditions
Silicon Semiconductors	100	None
Tantalum Capacitors	100	Appropriate polarizing voltage applied
Ceramic Capacitors	-	Not baked - Initial measurement only
Other Capacitors	100	None
Carbon Composition Resistors	100	Initial measurement after a 48-hour drying period before 168-hour bake
Other Resistors	100	None
Transformers and Coils	85	None

TABLE 11
PARAMETERS MEASURED (INITIAL AND SPLIT-SYSTEM CONFIGURATIONS)

Component Type	Parameters Measured
Transistors	DC gain (Beta), leakage current, breakdown voltage
Diodes	
General Purpose	Leakage current, forward voltage drop
Zener	Leakage current, forward voltage drop
Varactors	Leakage current, capacitance, breakdown voltage
Capacitors	
Tantalum	Capacitance, dissipation factor, dc leakage
Dura-Mica, Ceramic, Paper	Capacitance, dissipation factor, insulation resistance, dielectric strength (where indicated)
Trimmer	Capacitance (min. and max.), dielectric strength, and insulation resistance
Resistors	Resistance, or percent of deviation
Chokes	Insulation resistance, inductance, Q, self-resonant frequency, dielectric strength
Transformers	Insulation resistance, dielectric strength
Relays	DC coil resistance, pull-in or drop-out voltage or current, contact resistance, insulation resistance

Particular attention was given to semiconductors, for which additional accept-reject criteria can be stated simply as follows:

- Accept. Change in leakage current was not greater than 100 percent; change in Beta was not greater than 20 percent; all parameters measured were within specification limits.
- Reject. Change in leakage current was greater than 100 percent and the absolute value of the leakage current was greater than one microampere; change in Beta was greater than 20 percent.
- Special Cases. Where leakage current was less than one microampere but its change was greater than 100 percent, rejection or acceptance was determined on an individual basis. The device was accepted if its behavior was typical of the overall lot; it was rejected if its behavior was abnormal with respect to the overall lot.

(4) Program Results

Table 12 summarizes the preconditioning experience during the initial and split-system

TABLE 12 PRECONDITIONING RESULTS			
Component	Total Quantity	Rejects	
		Quantity	Percentage
Capacitors	9455	535	5.65
Resistors	37502	591	1.57
Diodes	9699	204	2.10
Transistors	6765	465	6.88
Chokes	1212	32	2.61
Transformers	93	-	-
Relays	345	14	4.05
Total	65071	1841	2.83

phases of the program. Rejections listed in the table included both initial inspection and post-bake rejects.

(5) Additional Program Development

Until the Ranger VI configuration rework, the only modification to the preconditioning program was deletion of the bake cycle for carbon composition resistors. The resistors were, however, subjected to 100-percent electrical inspection, as were all nonpreconditioned electrical parts.

b. POST-RANGER VI CONFIGURATION

At the beginning of the Post-Ranger VI rework the preconditioning program was reviewed. Substantially, the same program was maintained with changes principally in the capacitor and relay areas. Capacitor types were classified with temperature and time-cycles conditions recommended by RCA part specialists. Special relay tests were arranged in consultations with both RCA and JPL parts personnel. The following paragraphs describe the modified preconditioning program.

(1) General

All incoming parts and materials were 100-percent inspected and tested. Semiconductors were identified and permanent records were maintained of all values recorded during the incoming inspection.

All acceptable electronic parts were baked at specified temperatures. After the bake cycle, all electronic parts were 100-percent inspected. Traceability by part serial number was maintained for certain critical semiconductor applications.

(2) Bake-Cycle Conditions

Table 13 lists the components and conditions of the bake cycle.

(3) Parameters Measured

The parameters measured before and after the bake cycle are listed in Table 14.

TABLE 13
MODIFIED BAKE-CYCLE CONDITIONS

Component Type	Temperature (° C)	Duration (Hours)	Conditions
Silicon Semiconductor	100	168	No voltage applied
Capacitors			
Electrolytic Tantalum (Wet Slug)	125	168	Rated voltage applied
Paper, Plastic	125	72	140% of rated voltage applied
Ceramic	85	96	140% of rated voltage applied
Solid Tantalum	100	168	Rated voltage applied
Others	100	168	No voltage applied
Resistors			
Carbon Composition	-	-	No baking. 100% inspection
Others	100	168	-
Transformer and Coils	85	168	-

(4) Special Tests

An acid indicator test was performed on the seal of electrolytic tantalum (wet slug) capacitors after each of the following temperature cycles accomplished before the 168-hour bake: 30 minutes at -55° C, 15 minutes at 25° C, 30 minutes at 85° C, and 15 minutes at 25° C. A thymal blue indicator, which changed from orange to bright red in the presence of acid, was used to detect leakage. Leaky capacitors were rejected and removed from the lot. This test was repeated after the 168-hour bake cycle.

(5) Accept-Reject Criteria

Acceptance and rejection criteria were as described for the initial and split-system configuration.

(6) Special Cases of Preconditioning

(a) POTTER AND BRUMFIELD RELAY TYPE SC11DB

Each relay had its contacts cycled at a rate of 10 ±1 operations per minute with 100 ma,

TABLE 14 PARAMETERS MEASURED BEFORE AND AFTER BAKE-CYCLE	
Component Type	**Parameters Measured**
Transistors	DC gain (Beta)
Diodes	
General Purpose	Leakage current, forward voltage drop
Zener	Leakage current, forward voltage drop
Varactor	Leakage current, capacitance breakdown voltage
Capacitors	
Tantalum	Capacitance, dissipation factor, DC leakage
Trimmer	Capacitance (min. and max.), dielectric strength, insulation resistance
Others	Capacitance, dissipation factor, insulation resistance, dielectric withstanding voltage
Resistors	Resistance or percent of deviation
Transformers	Insulation resistance, dielectric strength
Chokes	Insulation resistance, inductance, self-resonant frequency, dielectric strength
Relays	DC coil resistance, pull-in and drop-out voltage or current, contact resistance, insulation resistance.

28 volts DC applied. The contacts were monitored so as to indicate when the contact resistance of any set exceeded 100 milliohms. The apparatus was constructed to cut off when a resistance failure was encountered. Any relay experiencing a contact failure was rejected.

Each relay was tested for dielectric withstanding voltage (at sea level) as outlined in MIL-R-5757. In addition to the requirements specified in that document, a leakage current of greater than one milliampere was a failure. Only those units passing these tests were used in equipment.

(b) POTTER AND BRUMFIELD RELAY TYPE SL11DB

A 100-percent initial inspection of the DC resistance of each coil winding on this relay was made and recorded. Accept-reject criteria were based on the detailed specification requirements.

All parts were exposed to a temperature-preconditioning cycle.

All samples were subjected to the low temperature extreme -65° C for a minimum of eight hours nonoperating. Samples were then immediately placed into a chamber at 125° C for one-half hour nonoperating and then cooled to room ambient.

All samples were then placed in a chamber at 125° C for three hours with a coil voltage of 39.6 volts applied to one of the latching coils of each relay; the second coil was not energized. During this exposure to 125° C, the relays were also operated by applying 22 volts DC to each coil, alternately, for a minimum of one hundred operations at approximately one per minute. The 39.6 volts was removed from the latching coil during the 100 operations at 22 volts DC and was reconnected for the completion of the three-hour test.

At the conclusion of the power test above, and while the units were still in the chamber with the temperature reduced and stabilized at +25° C, each mating contact was checked for closure using an ohmmeter. The coils were then allowed to stabilize to room temperature and DC resistance was then measured.

The relay was rejected if physical damage resulted due to preconditioning, if DC resistance changed by more than plus or minus ten percent of initial value, if mating of contacts was not proper, or if the dielectric withstanding voltage test failed.

(c) ENVIRONMENTAL TEST FOR POTTER AND BRUMFIELD RELAYS

Before environmental acceleration, shock, and vibration tests were undertaken, contact resistance of the normally closed contacts, pull-in and drop-out voltage, and contact resistance (closed) were measured. The closed contact was then monitored during the following tests:

- Acceleration at 100g maximum for 2.5 minutes; three-axes, coil energized and deenergized.
- Shock at 50g sawtooth for 5 ms; three axes, coil energized and deenergized.
- Vibration (three axes) at 10 to 55 cps, 195 sine excursions for 2.5 minutes on each axis; 55 cps to 2000 cps, 30g sweep for 2.5 minutes on each axis. The pretest measurements were then repeated.

(d) SILICON CONTROLLED RECTIFIER (SCR) C50 DR308

The SCR's, C50 DR308, used in the High-Current Voltage Regulator were selected and preconditioned by the vendor, General Electric, to the following specifications:

<u>Preconditioning</u>

Eighty hours at 200° C storage; ten temperature cycles from -40 to +150° C; thermal conductivity (θ_{JC}) test; a 48-hour elevated temperature blocking-voltage test performed at 60 cycles AC, peak voltage; a bubble leak test; and a radiflow test.

<u>Selection Criteria</u>

Forward leakage current (I_{FOM}) equal to or less than 0.8 ma at 75° C; turn-off equal to or less than 50 microseconds at 75° C with a 50 ampere load; dv/dt greater than 30 volts per microsecond at 75° C; holding current -10 to -100 ma at 75° C; gate turn-on current 70 ma at -40° C; di/dt equal to or greater than 80 amperes per microsecond.

(e) SILICON CONTROLLED RECTIFIER (SCR) C35 DR879

The SCR's, C35 DR879, (RCA drawing 1721984) used in the Command Control Unit were selected and preconditioned by the vendor, General Electric, to the following specifications:

<u>Preconditioning</u>

168 hours at 200° C storage; ten temperature cycles from -65 to +150° C; thermal conductivity (Θ_{JC}) test; a 48-hour elevated temperature blocking voltage test, performed at 60

cycles AC, peak voltage; a bubble leak test; and a radiflow test.

Selection Criteria

Forward leakage current (I_{FOM}) equal to or less than 0.1 ma at 75° C; turn-off equal to or less than 30 microseconds at 75° C; dv/dt greater than 30 volts per microsecond at 75° C; holding current -10 to -100 ma at 75° C.

(f) TRANSISTOR SN 169

The SN 169 transistors (RCA drawing 8545229) used in the X12 multiplier of the TV Subsystem Transmitter were selected and preconditioned by the vendor, National Semiconductor Corporation (Clock Division) to the following specifications:

Hermetic Seal Test

Prior to final electrical inspection each transistor was immersed in a solution of liquid detergent (two percent by volume) in water for a minimum of 24 hours at 70 psi gage pressure. The transistor was then removed from the solution, rinsed in pure water, and air-dried. A final electrical inspection was completed within eight hours after removal of the transistor from the solution.

RF Test

Each unit was tested in an RCA X12 multiplier unit (RCA Dwg. 8324675). The minimum power output of the unit required at 240 Mc was 2.2 watts, I_E was 150 ma maximum.

DC Burn-in Test

Each transistor was operated at four watts of dissipation at a case temperature of 141° C for a minimum period of 250 hours. I_{CBO}, BV_{CBO}, and h_{FE} were measured before and after this test. The transistor was required to meet minimum specification levels and those of Table 15.

High-Temperature Storage Test

The units were stored at a temperature of 200° C for a period of 340 hours. Measurements of I_{CBO}, BV_{CBO}, and h_{FE} before and after bake were required to meet minimum specification levels and those of Table 15.

Thermal Impedance

The junction-to-case temperature differential with the case at 100° C could not exceed 70° C per watt.

D. DESIGN REVIEW

The design of all equipments on the Ranger TV Subsystem was reviewed in detail to evaluate the technical approach, performance, and reliability. This review was accomplished in accordance with established company procedures for design review as an integral part of the RCA engineering and product assurance processes.

1. Types of Reviews

Four types of reviews were held, as required.

a. PRELIMINARY

After start of work and definition of a tentative Subsystem block diagram, preliminary design reviews were held to assess the design concept and the approach to the various program aspects. In these reviews the following were considered: the complete Subsystem; the mission requirements; the specification performance goals; the failure mode analysis; the reliability policies, estimates, and allocations and safety factors; documentation control; the power and weight budget; and identifying interfaces as well as the scheduling of the creation of interface drawings.

TABLE 15
ELECTRICAL REQUIREMENTS

Test	Conditions	Limits	
		Minimum	Maximum
I_{CBO}	V_{CB} = 70 volts DC I_E = 0	-	10 μa DC
BV_{CBO}	I_C = 500 μ a I_E = 0	175 volts	
BV_{EBO}	I_E = 500 μ a I_C = 0	2.0 volts	
BV_{CBO}	I_C = 1 ma I_B = 0	140 volts	
C_{OB}	V_{CB} = 50 volts DC I_E = 0	-	12 pf
h_{FE} (curve tracer)	V_{CB} = 10 volts DC I_C = 500 ma	10	

b. MAJOR

At the completion of breadboard testing and before shop work started, major design reviews were held to evaluate the breadboard designs. In these reviews each assembly was considered in relation to: manufacturability; use of standard parts; cost; reliability, stress analysis, Subsystem and circuit recommendations; power and weight parameters; and compatibility of the design with contractual requirements.

c. FINAL

After completion of testing of the engineering model, final design reviews were held. Considered in these reviews were the following: circuit design; mechanical design, wire dress, and packaging; malfunction reports; reliability predictions, manufacturability; inhouse capability, new facility requirements; compatibility of design with contractual requirements; Subsystem compatibility of the design; and completeness of the drawing package, in terms of both contractual and internal requirements.

d. SPECIAL

Special design reviews were held to resolve design problems and changes through the balance of the program. These reviews were called at the request of the engineering leader or manager concerned, Manufacturing Engineering, the Manager of Reliability Engineering, or the Project Manager.

2. Organization of Design Reviews

Design reviews were conducted by a design review committee composed of a chairman and committee members qualified to pass on the merits of the subject matter discussed. Participants in the review and their functions are described below.

The Manager of the Technical Advisory Staff was an ex-officio member and had overall cognizance of all design reviews. He appointed the chairman, scheduled reviews, assisted in and approved selection of committee members, approved reports of the meetings, prepared monthly summary reports for the Chief Engineer, and estimated costs of the design review programs.

The Chairman of the Design Review distributed all technical material to the participants at least one week in advance of the meeting, notified participants, obtained facilities and prepared the agenda, chaired the meeting, assisted in selection of committee members, wrote the report of the meeting, and wrote the close-out report when all outstanding items were satisfactorily resolved.

The Technical Secretary was appointed by the Chairman and assisted him in writing a report within one week after the meeting and in identifying the action items.

The Engineering Reliability member, appointed by the Manager of Engineering Reliability, had cognizance of malfunction reports and reliability predictions. He followed up on action items within two weeks after the meeting.

The Manufacturing Engineering member, appointed by the Manager of Manufacturing Engineering had cognizance of manufacturability and of manufacturing costs.

The project member, appointed by the Project Manager had cognizance of meeting specifications and performance goals, design and reliability recommendations, and cost reduction.

Other RCA members were appointed by the Chairman with the approval of the Manager, Technical Advisory Staff from AED, other RCA divisions, and the RCA Service Company to provide design and reliability recommendations and to assist the chairman in writing reports, when requested.

Non-RCA members were appointed by the Chief Engineer or the Manager, Technical Advisory Staff when required, to provide design and reliability recommendations. Other RCA members and non-RCA members were usually top level technical personnel from other divisions of DEP and RCA and consultants from outside RCA, invited as participants when deemed appropriate by the Manager of the Technical Advisory Staff.

3. Response to Design Review Recommendations

The following procedure was used to implement the committee recommendation.

a. Within one week after the meeting, the chairman issued a report to the design activity listing the findings and recommendations of the Review Committee.

b. The design activity gave careful consideration to the recommendations and prepared a written reply to the chairman with copies to committee members. The letter clearly indicated the proposals accepted or rejected. Where rejections were made, adequate reasons were given. This reply was made within two weeks from the issuance of the Design Review report.

c. Alternately, the reply was communicated to Engineering Reliability rather than issued directly by the design activity. In this case Engineering Reliability prepared the report, listing only the responses of the design activity. Recommendations of Engineering Reliability were forwarded as a separate report.

d. Upon receipt of the design activity's reply, the Design Review Committee considered the design activity position on all of the recommendations in the original Design Review Report. If all items were resolvable, the chairman issued a close-out report. Where differences still existed, they were submitted to the Chief Engineer for final resolution.

4. Initial Subsystem Configuration Design Reviews

a. REVIEWS HELD

A total of 51 design reviews ranging from preliminary to special, were held on initial Subsystem Assemblies and subassemblies. Table 16 lists these reviews by subassembly and type of review, giving the date and location of each.

b. COVERAGE AND RESULTS

To provide an indication of the coverage of the reviews and the nature of the results produced, summaries of the design-review discussion and/or resulting action on twelve assemblies are listed in this paragraph. These assemblies were selected as illustrations only and the list does not attempt to summarize the entire initial configuration design-review effort. A complete and detailed listing of design changes is contained in the Design section of this report.

- High-Current Voltage Regulator. Satisfactory performance of a replacement Zener diode type 4111 was monitored during a 500-hour life test as a result of review recommendations.

- Temperature Sensor. The use of matched diodes was reviewed and adequate notes were added to the control drawings. Thermal expansion of the thermistor and its potting encapsulation were checked and found to be compatible. The effects of mounting thermistors in direct sunlight were evaluated and it was found that calibrations were not affected.

- Structure. The results of the vibration test were carefully reviewed. A torquing tabulation was produced which included the mounting of all subassemblies on the TV Subsystem structure.

- TV Subsystem Thermal. The effect of the sterilization bake on the surface emissive properties were rechecked and found to be negligible. The effects of opening the camera aperture recess was reviewed from a thermal standpoint. An overall thermal evaluation was performed.

- Test Console. A time delay was added to prevent a premature turn on without proper filament warm-up time of the Power Amplifier tube. The test-console power-control relay was checked with the Subsystem. Running-time meters were added to record TV Subsystem operating time.

- Command Switch. The performance of the units was checked at 80° C after 1-hour temperature stabilization. Arc suppression networks for relay contacts were investigated and found unnecessary because of the low contact-current levels. The

TABLE 16
RANGER DESIGN REVIEW STATUS (INITIAL CONFIGURATION)

Equipment	Preliminary	Major	Final	Special
High- and Low-Current Voltage Regulators	12/15/61	4/19/62	6/8/62	
Temperature Sensor	-	3/20/62	6/8/62	
Structure	1/15/62	3/15/63	6/14/62	
TV Subsystem Thermal Design	12/8/61	4/16/62	6/16/62	8/15/62
Batteries	1/25/62	4/19/62	8/29/62	
Test Console	1/12/62	5/4/62	8/29/62	
Command Switch	1/12/62	4/13/62	8/27/62	
Video Combiner	1/16/62	4/12/62	8/27/62	
Camera Mounting Bracket	12/13/61	4/17/62	5/4/62	
Ground Equipment Control Panel Demodulator	1/16/62	5/29/62	6/15/62	
Ground Power Supply Equipment	1/11/62	3/29/62	9/6/62	
Camera and Camera Electronics	1/17/62	4/6/62	5/8/62	10/30/62
Interconnecting Cables	1/12/62	4/17/62	8/8/62	
Sequencer & Dual Power Power Supply	12/7/61	1/15/62 1/17/62	12/22/62	
Telemetry	1/25/62	4/16/62	8/15/62	
Communications	12/13/61	4/16/62	8/15/62	6/1/62

resistor in the base circuit of Q1 and Q2 was reduced from 100k to 22k.

- Camera Mounting Bracket. The torsional rigidity of the camera mounting bracket was checked fully loaded by vibration testing. The effect of vibration on a camera high-voltage capacitor mounted in the harness was established by vibration testing and found to be acceptable. Mechanical interference between the collimators and the structure, resulted in collimators being repositioned.

- Cable Interconnections. Spare wires in the cable were properly terminated. Procedures were developed for installing camera cables. The conformance to JPL workmanship specification was verified.

It was noted that potting of connectors made cables nonrepairable. JPL was consulted and required cable potting.

- Ground Power Supply, Block House Panel, and Shelter Panel Preliminary Review. Electrical specifications were required and were produced. The maximum ambient operating temperature of the equipment was determined to be within the limits of the equipment capability. The grounding philosophy for coax in the OSE was verified.

- Camera and Camera Electronics. During dark-current sampling, peak-to-peak video was too high. Design changes were made to reduce this value. Power supply spikes were reduced to acceptable levels through improved grounding and shielding. The video amplifier was redesigned to improve performance. RFI filters were added to power supply leads. The shutter-drive circuit was AC-coupled to the shutter coil.

- Sequencer. Feasibility of replacing Q6, Q7, and Q8 with a 12-volt zener diode was investigated and rejected by the design group A resistor was substituted for Q8. A 150-ohm resistor and a 0.033 mf capacitor were placed across the contacts of the "Full Power" relay in the sequencer. The thickness of the mica washer under the power transistors in the power supply was reduced from 0.020 to 0.002 inch.

- Communication. The tube in the Power Amplifier was changed from ML-7289/3CX100A5 to ML 7855 for added temperature-frequency stability. The 85° C double-case capacitors in the transmitter power supply were replaced with an approved part. All high-voltage connector applications were rechecked for voltage breakdown.

5. Split-System Configuration Design Reviews

a. REVIEWS HELD

Because the split-system configuration evolved from the initial Subsystem design which had undergone prerelease design review, all split-system reviews were considered to be special design reviews. Thus, only a total of ten design reviews were required on the split-system. Table 17 lists these reviews by equipments and dates.

b. COVERAGE AND RESULTS

The split-system reviews covered both changes necessary to implement the split-system and its overall system concept and changes intended to improve performance. Three of these reviews are presented here for purposes of illustration. As in the case of the initial Subsystem, a complete and detailed listing of design changes is contained in the Design section of this report.

- Split-System Concept. The split-system concept was reviewed and approved, based on improving the probability of obtaining mission video data. It was concluded that relay performance in space applications had been proved on the TIROS program; no relay failures had been reported on any RCA satellite or subsystem during space operation. Test data of fuzing operation in a thermal-vacuum environment were discussed and split-system fuzing philosophy and implementation were approved.

- Electronic Clock. Possible occurrence of the activating pulse at the wrong time in time-interval selection was examined and methods to overcome this circumstance were evaluated. It was concluded that the situation did not warrant the major redesign necessary to insure against this occurrence. It was determined that the

TABLE 17
SPLIT-SYSTEM DESIGN REVIEWS

Equipment	Type Review	
	Electrical	Mechanical
Split-System Concept	2/14/63	2/14/63
Electronic Clock (New Unit)	4/18/63	5/3/63
Distribution Control Unit (New Unit)	3/7/63	3/7/63
Power Control Unit (New Unit)	4/8/63	4/8/63
High-Current Voltage Regulator	3/22/63	-
Camera, Camera Electronics, Sequencer and Power Supply, Video Combiner	3/6/63	-
Transmitter	2/27/63 5/14/63 5/15/63	-
Fast Erase for F Camera	4/5/63	-

output transistors should be screened for a leakage current (I_c) of 100 microamperes at a V_{CEO} of -48 volts to provide for an excessive initial turn-on voltage of 41 volts.

The Electronic Clock mechanical review approved the use of bifurcated terminals, mounting of the 2N1486 as in the other subassemblies, maintenance of accessibility of the time-interval connection, a short cable length between the Clock and the CCU and potting compounds as specified by RCA Specification 2020473D.

- Power Control Unit. The use of bifurcated terminals was approved. The effects of surge currents on relays and capacitors were examined and found not to be a problem. The part-mounting techniques were reviewed and, as a result, checked during qualification testing where they were found to be satisfactory.

6. Post-Ranger VI Configuration Design Reviews

a. REVIEWS HELD

Post-Ranger VI design reviews were also all special reviews because the modified configuration was also a further development of the initial Subsystem. As in the case of the split-system, only six additional design reviews were required to cover the Subsystem changes. Table 18 lists these reviews by equipment and dates.

b. COVERAGE AND RESULTS

The Post-Ranger VI reviews were concerned principally with changes in the command control circuits because of the failure of Ranger VI to return video data before impacting on the Moon. Other design changes were made to improve performance of telemetry data and

TABLE 18
POST-RANGER VI DESIGN REVIEWS

Equipment	Dates Held
Command Control	2/26/64, 2/27/64
Thermal Design, Block III	2/25/64
Command Regulator, Current Sensor	3/6/64, 3/12/64
TV Ground Support and Telemetry	3/11/64
Transmitter Power Supply and Sequencer	4/14/64
Current Sensing Unit	3/17/64

the thermal characteristics. Representative portions of these reviews are presented here for the purposes of illustrating review coverage.

- Command Sequencer. Power turn-on commands were established as (1) Central Computer and Sequencer, (2) RTC-7, and (3) Electronic Clock. For turn-off, RTC-5 (a real-time command), which was a momentary closure, was agreed upon. The RTC-5 command would also turn off the Clock if the Subsystem were not in warm-up. The possibility of locking out the Clock turn-off circuit (activated by RTC-5) for the first 32 hours was discussed but tabled for further investigation. Subsequently, this lock-out was implemented in the design.

- Thermal Design. During the Ranger VI mission, recorded temperatures were approximately 20° C higher than anticipated in the lower section of the Subsystem and 10° C higher than anticipated in the upper section. Although neither previous tests nor the telemetry data indicated that operation of the Ranger components was adversely affected by these higher temperatures, a special design review was held to evaluate possible design changes to produce lower payload operating-temperatures. The proposed modifications were discussed and action items identified. These action items were later implemented by the following changes: (1) The absorptivity of the paints was reduced, producing a 30-watt reduction in solar input; (2) variation of solar radiation input with the time of launch was taken into account as a design parameter; and (3) telemetry points were inserted on the 15- and 90-point commutators to permit recording of the temperatures on the third deck near the camera electronics and the camera lens housing.

- Electronic Clock. The effect of leakage current of the output stage on the energy available to activate relay K2 was investigated and found to be insignificant in the worst case. Noise rejection by drawing continuous current in the emitter diode was evaluated; it was found that the noise rejection which would be obtained would not justify the continuous current drain. The 32-hour output wire was isolated from the other Clock leads to minimize the probability of capacitive coupling.

E. FAILURE REPORTING AND ANALYSIS

One of the most important aspects of the RCA Engineering Reliability Program was the failure reporting and analysis procedure used to document and analyze equipment malfunctions. This procedure, extending from the start of testing until after impact of the Ranger Spacecraft on the Moon, was the avenue by which failures were defined to permit subsequent corrective action as applicable.

In this section, the failure-reporting and analysis policies and procedures followed in the Ranger TV Subsystem program are described both in terms of the initial and split-system configurations and in terms of the modified configuration. Following this description, representative corrective actions resulting from the failure-reporting and analysis procedure are briefly discussed. Finally, tabulations of malfunction history are presented for the Ranger Subsystems and for supporting equipment.

1. Initial and Split-System Configurations

a. SCOPE OF MALFUNCTION REPORTING

The failure-reporting and analysis policies and procedure required the reporting and subsequent analysis of all malfunctions detected by RCA engineers and subcontractor personnel. Each malfunction was reported separately on its own malfunction report form, whether detected separately or detected as one of multiple malfunctions occurring, for example, during troubleshooting or testing. Both part malfunctions requiring replacement and nonpart malfunctions requiring repair were reported.

b. PREPARATION AND DISTRIBUTION OF MALFUNCTION REPORT

The malfunction report form was prepared to permit recording of complete information for subsequent failure analysis. In completing the malfunction report, the originator provided the following data: (1) the name of the facility originating the report, (2) the name of the originator, (3) date of the malfunction, (4) the equipment test environment, (5) the test phase during which the malfunction occurred, (6) total part or unit time, (7) total time out of operation because of the malfunction, (8) location of the malfunction within the equipment, (9) a brief description of the malfunction, (10) repair action taken to correct the malfunction, (11) abnormal equipment conditions noted, (12) disposition of the replaced parts, and (13) numbers of related malfunction reports.

The malfunction report form was prepared in triplicate. One copy was sent to Engineering Reliability, the second copy to the cognizant design area, and the third copy was retained by the originator.

c. FAILURE ANALYSIS PROCEDURE

A failure analysis was performed by Reliability Engineering on every malfunction reported. This analysis not only resulted in recommendations for corrective action but provided an adequate basis for further reliability analysis of equipment performance. Where information furnished on the malfunction report was inadequate, a detailed investigation was conducted. Results of this investigation and other aspects of the failure analysis were summarized on a failure analysis report. More than one malfunction was covered on a single report if the malfunctions were closely associated. The completed report then provided a comprehensive and readily accessible summary permitting determination of the exact cause of the failure, the effects of the failure, and recommended corrective action.

The completed report was forwarded to the product assurance office together with a description of remedial action which had already been taken or with suggestions for improvement. Monthly summaries were reported to JPL covering all malfunction analyses processed through RCA during the reporting period.

d. CLASSIFICATION OF FAILURES

To assist in monitoring, controlling, analyzing, and identifying failure modes, failures were classified according to cause. Table 19 lists these standard failure modes and their definitions.

2. Modified Split-System Configuration

To increase the effectiveness of the failure reporting and analysis function in the modified split-system (after Ranger VI) configuration, certain procedural changes were made; basic policy, however, remained essentially unmodified. The changes effected included both in-plant and field failure reporting.

a. IN-PLANT PROCEDURES

Additional emphasis was placed on expediting reporting of the malfunctions, increasing the depth of the analyses and maintaining adequate controls. These controls were to assure proper implementation of recommended corrective actions and to assure concurrence of RCA and JPL on the adequacy of the analyses and the corrective actions taken.

To secure this necessary emphasis the following steps were taken.

- Responsibility for filling out the malfunction report was assigned to Quality Control personnel monitoring the respective test areas or work areas.
- To assure prompt handling and awareness of existing malfunctions, malfunction reports were picked up from the Quality Control area twice each day.
- The status of each malfunction report and its analysis was reported weekly.
- Responsible RCA skill center sign-off was required on the recommended corrective action and on the status of its implementation.
- Sign-off by the Ranger Project Manager was required to complete the analysis report at RCA prior to submittal to JPL.
- JPL sign-off.

In conjunction with these steps to emphasize proper handling of MR's and analyses, the malfunction report form was changed to AED Form 300 and the analysis form was modified to allow additional information to be added concerning the status of the recommended corrective actions. These forms are illustrated in Figures 32 and 33 respectively.

After the Ranger VII launch, completed analyses approved by RCA were submitted to JPL on JPL Form 1798, Vendor Problem/Failure Report, for their approval. A sample of this form is provided in Figure 34.

b. FIELD FAILURE REPORTING

As the TV Subsystems were tested at JPL and at ETR, a new procedure was established to expedite the review and approval cycle.

Failures that occurred at the sites which did not require that subassemblies be returned to RCA for repair were analyzed by the spacecraft project engineer. Copies of the MR and failure analysis were submitted directly to JPL. Copies of both documents were sent to RCA Reliability Engineering for review and follow up as required.

Subassemblies returned to RCA for repair were handled by Engineering Reliability in the same manner as for an in-plant malfunction.

3. Representative Corrective Action

Corrective action resulting from the failure-reporting and analysis program consisted of

TABLE 19 FAILURE MODE DEFINITIONS	
Mode	**Definition**
Random	A chance failure in a controlled system whose occurrence is unpredictable.
Wearout	Failure due to deterioration as a consequence of excessive use.
Design	A failure which is remedied by a circuit, equipment design, or part specification change.
Workmanship	A failure due to improper or substandard fabrication methods and quality control.
Nonassignable	A failure whose exact cause cannot be determined, and insufficient evidence exists to classify it in any other category.
Under Analysis	A failure which is still under investigation.
Accidental	A failure induced as a result of test error, procedures, or handling. Failure due to improper or careless manipulation of parts, harnesses, or equipments either in their use or repair.
Secondary (Dependent)	A failure which is induced by another failure.
Nonconfirmed	An apparent failure occurrence which cannot be verified through subsequent analysis.
Test Method or Specification Error	A failure which resulted from an error in a test method or specification.

changes in both design and methods. Design changes were effected by coordination of Engineering Reliability with the Design Skill Centers. Methods changes were effected in conjunction with the activities whose methods caused the malfunctions.

For the purpose of illustration, corrective actions taken as the result of several malfunction reports are discussed below. These discussions are representative samples only of the information contained in the Malfunction Analyses Summary (Appendix H, Volume 4b) which lists all such data from the start of split-system testing.

As a result of a failure of the PTM in thermal vacuum due to a premature power turn-on, the test procedure was changed to require a minimum of eight hours of pump-down before power could be turned on. In addition, battery cutoff switches were added to the thermal-vacuum test setup, permitting external battery switching. Pressure readings were monitored both inside the unit and in the chamber.

1. REPORT NO. Nº 5081	2. PREVIOUS FAILURE REPORT NOS.	3. REPORTING ACTIVITY	4. PROJECT	5. SYSTEM SERIAL NO.
6. FAILED ITEM PART NO.	7. FAILED ITEM S/N	8. FAILED ITEM NAME	9. FAILED ITEM MFR.	10. DATE OF FAILURE REPORT
11. NEXT ASSY PART NO.	12. NEXT ASSY NAME	13. NEXT ASSY MFR.	14. NEXT ASSY REF. DESIG.	15. DATE OF FAILURE DAY MONTH YEAR
16. FAILURE CODE	17. F/I MFG. PART NO.	18. SUBSTITUTE ITEM NO.	19. REPLACEMENT S/N	20. SUBSTITUTE ITEM VENDOR
21. OPERATIONAL USAGE HR. MIN. SEC.	22. CYCLES	23. MONTHS	24. REMARKS:	
25. FAILURE DISCOVERED DURING (CIRCLE ONE) .1 BENCH TEST .5 CHECKOUT .2 INSPECTION .6 MAINTENANCE .3 STORAGE .7 MFR. TEST .4 SHIPPING .8 OPERATION .9 OTHER (SPECIFY) ______	26. REASON FOR REPORT (CIRCLE ONE) .1 FAILED ITEM .2 T. O. DIRECT .3 TIME EXPIRED .4 OTHER (SPECIFY)	27. REPAIR OR DISPOSITION ACTION (CIRCLE ONE) .1 REPAIRED IN PLACE .5 CONDEMNED .2 REP. REINSTALLED .6 HELD FOR REP. .3 ADJUSTED .7 DEPOT REP. .4 ELIMINATED .8 FAILURE ANALYSIS (ON SITE ONLY)	28. REPLACEMENT (CIRCLE ONE) .1 IDENTICAL PART .2 SUBSTITUTE PART .3 NONE NEEDED .4 NOT AVAILABLE (ON SITE ONLY)	
29. DESCRIPTION OF TROUBLE				
30. DISPOSITION				
31. TEST CONDITION CODE	32. ENVIRONMENT CODE	33. EFFECTS OF THIS FAILURE ON SYSTEM	34. REPORTED BY	

AED FORM 300

MALFUNCTION REPORT

Figure 32. Malfunction Report

FAILURE ANALYSIS REPORT

PAGE 1 OF ______

PROGRAM ____________________

IDENTIFICATION

1 MALFUNCTION REPORT NO.	2 DATE OF MALFUNCTION	3 TEST LOCATION/ENVIRONMENT
______	____ MO. ____ DAY ____ YR.	______
4 SYSTEM	5 SUBSYSTEM	6 UNIT
NAME ______ SER.# ______	NAME ______ SER.# ______	NAME ______ SER.# ______
OPERATING TIME ______ HRS.	OPERATING TIME ______ HRS.	OPERATING TIME ______ HRS.

ANALYSIS DESCRIPTION

7 ANALYSIS DESCRIPTION

FAILURE CLASSIFICATION

8 MALFUNCTION CATEGORY

- 1 ☐ SECONDARY (DEPENDENT)
- 2 ☐ DESIGN
  - A ☐ AED
  - B ☐ VENDOR
- 3 ☐ RANDOM
- 4 ☐ NOT CONFIRMED
- 5 ☐ NON-ASSIGNABLE
- 6 ☐ WEAROUT
- 7 ☐ WORKMANSHIP
  - A ☐ VENDOR AND SUB-CONT.
  - B ☐ DESIGN
  - C ☐ AED MANUFACTURING
- 8 ☐ ACCIDENTAL
  - A ☐ DESIGN
  - B ☐ INTEGRATION
  - C ☐ FIELD
  - D ☐ AED MFG.
  - E ☐ TEST EQUIP. INDUCED
- 9 ☐ TEST METHOD OR SPEC. ERROR

9 PART DISPOSITION:	10 COGNIZANT SKILL GROUP

CORRECTIVE ACTION

11 RECOMMENDED CORRECTIVE ACTION:

12 CORRECTIVE ACTION IMPLEMENTION	13 DISTRIBUTION (FOR ACTION)	14 DISTRIBUTION (FOR INFORMATION)
PAGE 2 OF THIS FORM TO BE COMPLETED BY: 1 ☐ PROJECTS 2 ☐ QC 3 ☐ DESIGN ENGINEERING 4 ☐ MANUFACTURING REPLY REQUIRED BY:		
15 COMPLETED BY:	16 COMPLETED ON:	17 FIX CONFIRMED
______	______	______ INITIALS ______ DATE

FAILURE ANALYSIS REPORT FORM
ASTRO-ELECTRONICS DIVISION RADIO CORPORATION OF AMERICA PRINCETON, NEW JERSEY

AED 290 REV. 8/64

Figure 33. Failure Analysis Report

VENDOR

☐ Flight (S/C Ser. No. ________)
☐ OSE (Complex Ser. No. ________)

☐ **PROBLEM** / ☐ **FAILURE REPORT**

№ 103553 V

I

1. PROJECT ☐ Ranger ☐ Mariner ☐ Other ________
2. PROBLEM/FAILURE DATE
3. LOG NO.

	A) REFERENCE DESIGNATIONS	B) NOMENCLATURE	C) SERIAL NUMBER	D) OPERATING TIME
4. SUB-SYSTEM				
5. ASSEMBLY				
6. SUB-ASSEMBLY				

7. REPORTING LOCATION ☐ JPL Sec. ________ ☐ Vendor ________ ☐ SAF ☐ AMR Other ________
8. PROBLEM/FAILURE NOTED DURING ☐ Bench Testing ☐ In-Process Testing ☐ TA Testing ☐ FA Testing ☐ Systems Testing ☐ Specific Environment ________ ☐ Other ________

INITIAL DISTRIBUTION DATE

9. DESCRIPTION OF PROBLEM/FAILURE

Originator ________ Date ________ Cognizant Engineer ________

II

10. VERIFICATION & ANALYSIS

11. CAUSE OF PROBLEM/FAILURE ☐ Design ☐ Piece Part Failure ☐ Operator Error ☐ Damage (Mishandling) ☐ Adjustment ☐ Workmanship ☐ Manufacturing ☐ O.S.E. Failure ☐ Other ________
12. FOLLOW-UP ASSIGNMENT ☐ Cognizant Engineer ☐ Design Review ☐ Vendor ________ ☐ Components Evaluation Group ☐ Material Review Board ☐ Quality Assurance ☐ Other ________

13. PART DATA

A) PIECE PART NAME & NUMBER	B) SERIAL NO.	C) CIRCUIT SYMBOL	D) MANUFACTURER	E) DEFECT	F) PRI.	G) SEC.

PERSON COMPLETING SECTION II Signature ________ Date ________

III

14. CORRECTIVE ACTION TAKEN

15. DISPOSITION ☐ Reworked ☐ Redesigned ☐ Readjusted ☐ Scrapped ☐ Other ________
16. EFFECTIVITY ☐ This Unit ☐ All Units ☐ Other ________ ECR No. ________

Signature, Cognizant Engineer ________ Sec. ________ Date ________ Signature Cognizant Sec. Chief ________

IV

17. REVIEW CONCURRENCE
Reliability Coordinator: ________ Date ________
Space Project Engineer: ________ Date ________

18. CLASSIFICATION ☐ Critical ☐ Non-Critical

V

19. STANDARD & SPECIAL DISTRIBUTION

P/FR RELIABILITY STAFF

JPL 1798 APR 64

Figure 34. Vendor Problem Failure Report

- A TV Subsystem failure which produced numerous subassembly secondary failures and occurred during testing at ambient conditions in the integration test area. The cause was shorting of a battery lead in the High-Current Voltage Regulator by mounting screws. Mounting screws were, subsequently, carefully checked when subassemblies were installed on the structure. A change in wire size was made in a ground-return wire in the High-Current Voltage Regulator. The structure was tied directly to the positive side of the battery, and structure grounds were improved.

- A failure occurred on the PTM at JPL when the mica dielectric of a capacitor in the Resdel Power amplifier cracked. As a result of the analysis and recommendations, a change of the material was made substituting Mylar for the mica. The Mylar was heat treated at 125° C for 4 to 6 hours before it was installed in the Power Amplifier.

- The vidicon pins were being bent. In some cases, this resulted in a cracking of the glass in the area of the pins due to excessive mating and demating. The final resolution of the problem was the use of a buffer connector in the camera head.

- Repeated failures of the Q32 (2N718A) transistor shorting in the high-voltage regulator of the camera electronics was resolved by changing the transistor type to one with a higher rating, adding a limiting series resistance in the emitter circuit, and isolation of ground returns.

- The Q1 (2N916) transistors of the P1 Camera G1 regulator were shorting from base to emitter. A surge protecting diode was added to the emitter circuit to prevent the occurrence of this failure mode.

- Failures in the transmitters IPA tubes resulted in an investigation of the turn-on transients of the transmitter power-supply high-voltage circuits. Design changes reduced the transients to acceptable levels.

- Current-limiting resistors were added to the -750-volt and +1000-volt relay circuits to protect the relay contacts.

- The 2N1656 transistor as used in the G1 regulator of the P- and F-type Camera Electronics were failing as a result of a high-voltage stress between the collector and emitter. To correct this failure mode, a resistor and zener diode were added to limit the collector-to-emitter voltage.

- As a result of material deposition on the lenses of the cameras during thermal-vacuum testing, an investigation of the outgassing properties of Raychem wire was conducted. The results of this investigation were negative and the use of this wire for the Ranger TV Subsystem application was continued.

- Special tests were conducted in a thermal-vacuum environment to evaluate the use of silicone grease for heat-sinking of transistors. The conclusion reached was that silicone grease was required and was satisfactory for heat sinking of transistors in the Subsystem transmitter.

4. Malfunction History

The malfunction history of the Ranger program is summarized in the tables of this subsection and in the Malfunction Analyses Summary of Appendix H.

a. TOTAL SUBSYSTEM FAILURES

Table 20 lists the failure totals of all Assemblies by equipment and types of failures for the entire Ranger TV Subsystem project.

TABLE 20
TOTAL ASSEMBLY FAILURES DURING PROGRAM

Equipment	No. of Malfunctions	Type of Failure: Workmanship	Accident	Random	Design	Nonconfirmed	Secondary (Dependent)	Nonassignable	Wearout	Awaiting Analysis
Camera and Camera Electronics**	571	145	153	24	98	36	66	35	14	0
Communications	386	104	79	15	73	34	43	23	15	0
Sequencer and Sequencer Power Supply	114	50	31	2	18	2	6	5	0	0
Command Control Unit	8	1	4	0	1	1	0	1	0	0
Video Combiner	30	11	2	1	6	1	9	0	0	0
Battery and Regulators*	146	38	32	6	28	18	14	4	6	0
Total	1255	349	302	48	224	92	138	68	35	0
Percent of Total	100	27.76	23.94	3.82	17.75	7.55	11.00	5.40	2.78	0

*This category also includes Temperature Sensor, Electronic Clock, DCU, Current Sensor Unit, Current Transformer Unit, Thermal Control, and Harness Assembly malfunctions.

**This category also includes the Filter Assembly malfunctions.

b. OPERATIONAL SUPPORT EQUIPMENT FAILURES

Table 21 lists the Operational Support Equipment (OSE) failures for the entire Ranger TV Subsystem project. The OSE failure-reporting and analysis program supported the operation of equipment at RCA, JPL, ETR, and Goldstone.

Malfunction reports and failed parts were sent from these activities to RCA Engineering Reliability for analysis. Completed analyses were returned to each site for implementation of corrective action.

c. MALFUNCTION ANALYSES SUMMARY

Details of TV Subsystem failures and recommended corrective actions are contained in Appendix H. These listings are arranged by equipment, serial number, and chronological

TABLE 21
OPERATIONAL SUPPORT EQUIPMENT FAILURES

	No. of Malfunctions	Type of Failure								
		Workmanship	Accident	Random	Design	Nonconfirmed	Secondary (Dependent)	Nonassignable	Wearout	Awaiting Analysis
Total	382	32	54	38	22	58	77	78	23	0
Percentage	100%	8.35%	14.2%	9.9%	5.75%	15.2%	20.2%	20.4%	6.0%	0

order of malfunction-report dates. Coverage extends from the start of split-system concept through the successful completion of the Ranger IX mission. All Ranger equipment are included.

d. FAILURE SUMMARIES OF FINAL FLIGHT MODEL III TV SUBSYSTEMS

Tables 22 through 26 present data on the four Ranger flight Subsystems, Ranger VI, Ranger VII, Ranger VIII, and Ranger IX. Table 22 summarizes the significant dates of design, test, and flight for each flight model and lists the title, number, and issue date of its respective test report and flight evaluation report. Tables 23 through 26 are failure summaries of the subassemblies which were part of the actual flight model TV Subsystem configurations. For each piece of equipment, the malfunction report number, the date of the malfunction and the serial number are presented. Further details on particular malfunctions can be found in Appendix H, Volume 4b.

F. RELIABILITY DEMONSTRATION TESTING AND ANALYSIS

The last task of the Ranger reliability program was demonstration testing and analysis to verify the theoretical predictions of the previous tasks. In this subsection, life tests on the TV Subsystem and assembly level are described and the significance of the test results is presented along with an analysis of failure rates at the part level. The tests described here are treated only in relation to their reliability significance. Complete details of the engineering test programs, particularly for the Life Test Models, are contained in Section IV, Test History of the TV Subsystem.

1. Assembly Testing at RCA

Life testing of the assemblies was performed at the assembly level at RCA. Test conditions (particularly test duration) were established on the basis of obtaining the greatest

TABLE 22
SIGNIFICANT DATES AND DOCUMENTATION SUMMARY

	Ranger VI	Ranger VII	Ranger VIII	Ranger IX
Start of Electrical Integration	6/22/63	4/5/64	8/10/64	10/1/64
Environmental Vibration Test	7/13/63	Waived by JPL	9/17/64	Waived by JPL
Thermal Vacuum Test	8/14/63	4/22/64, 4/26/64	9/19/64 to 10/7/64	11/27/64, 11/29/64
Shipped to JPL	8/24/63	5/1/64	10/17/64	12/3/64
Shipped to ETR	12/15/63	6/21/64	1/4/65	2/20/65
Launched	1/30/64	7/28/64	2/17/65	3/21/65
Impact on Moon	2/2/64	7/31/64	2/20/65	3/24/65
Test Report	Test Report for Flight Model III-1 Ranger TV Subsystem	Test Report Modified Flight Model III-2 Ranger TV Subsystem	Test Report for Modified Flight Model III-3 Ranger TV Subsystem	Test Report for Modified Flight Model III-4 Ranger TV Subsystem
AED No:	AED R-3003	AED R-2407	AED R-2521	AED R-2601
Issued:	11/15/63	7/17/64	2/2/65	2/15/65
Flight Evaluation Report	Flight Evaluation Report for Flight Model III-1 (Ranger VI)	Flight Evaluation Report for Modified Flight Model III-2 (Ranger VII)	Flight Evaluation Report for Modified Flight Model III-3	Flight Evaluation Report for Modified Flight Model III-4 Ranger TV Subsystem
AED No:	AED 2155	AED R-2473	AED 4-2677	AED R-2692
Issued:	4/6/64	10/30/64	5/14/65	6/24/65

TABLE 23
RANGER VI FAILURE SUMMARY OF FINAL FLIGHT ASSEMBLIES

Assembly	Serial Number	MR Number	Date
P1 Camera and Camera Electronics	034/036	2826	6/9/63
		3271	7/1/63
		3973	8/5/63
P2 Camera and Camera Electronics	025/025	3974	8/10/63
		3433	9/16/63
P3 Camera and Camera Electronics	019/019	No Failures Reported	
P4 Camera and Camera Electronics	018/021	2647	4/17/63
		2648	4/17/63
		3962	7/6/63
		4002	9/7/63
F_a Camera and Camera Electronics	032/029	2688	6/25/63
		2689	6/25/63
		2690	6/25/63
		4262	11/24/63
F_b Camera and Camera Electronics	020/041	3363	6/7/63
Video Combiner	001	3361	5/26/63
Sequencer	007	No Failures Reported	
High-Current Voltage Regulator	5	3351	6/28/63
		3355	6/28/63
Command Switch	005	3360	7/13/63
Transmitter Assembly	016	3226	5/18/63
		3303	6/22/63
		3304	6/24/63
		2861	7/22/63
Power Amplifier	008	No Failures Reported	
Transmitter Power Supply	014	No Failures Reported	
Low-Current Voltage Regulator	8	No Failures Reported	
Transmitter Assembly	012	3227	5/9/63
		2864	7/3/63
Power Amplifier	007	No Failures Reported	
Transmitter Power Supply	018	No Failures Reported	

TABLE 23
RANGER VI FAILURE SUMMARY OF FINAL FLIGHT ASSEMBLIES (Continued)

Assembly	Serial Number	MR Number	Date
Four-Port Hybrid	001	No Failures Reported	
Dummy Load	011/003	4267	1/15/64
Telemetry Assembly	108	2800	1/25/64
Temperature Sensor	007	4268	1/16/64
Sequencer Power Supply	0008	No Failures Reported	
Telemetry Processor	008	No Failures Reported	
Telemetry Processor	022	No Failures Reported	
Distribution Control Unit	001	No Failures Reported	
Electronic Clock	001	No Failures Reported	
Power Control Unit	001	3278	7/18/63
High-Current Voltage Regulator	009	3352	6/23/62
Filter Assembly	003	No Failures Reported	
Harness Assembly	001	3972	7/27/63
Batteries	67,68	No Failures Reported	

TABLE 24
RANGER VII FAILURE SUMMARY OF FINAL FLIGHT ASSEMBLIES

Assembly	Serial Number	MR Number	Date
P1 Camera and Camera Electronics	31/28	4234	12/8/63
		3371	7/28/63
		3372	7/28/63
		3380	7/28/63
		3802	5/4/64
		3809	5/5/64
		2178	5/13/64
		2179	5/13/64
		2195	5/15/64
		2192	5/22/64
		1536	11/14/64

TABLE 24
RANGER VII FAILURE SUMMARY OF FINAL FLIGHT ASSEMBLIES (Continued)

Assembly	Serial Number	MR Number	Date
P2 Camera and Camera Electronics	36/34	3380	8/2/63
		3554	8/29/63
		4698	4/10/64
		3990	4/26/64
		2194	5/15/64
P3 Camera and Camera Electronics	21/39	2646	3/7/63
		2822	6/19/63
		2823	6/19/63
		2839	8/19/64
		4590	1/3/64
		4097	1/6/64
		2196	5/13/64
		2154	5/31/64
		1539	11/19/64
P4 Camera and Camera Electronics	37/40	2828	6/21/63
		2829	6/21/63
		2832	7/15/63
		3979	9/9/63
		4022	9/13/63
		3991	4/28/64
		3978	9/3/64
F_a Camera and Camera Electronics	41/38	2624	1/12/63
		3344	6/13/63
		2824	6/20/63
		3275	7/13/63
		3276	7/14/63
		3277	7/15/63
		3939	3/24/64
F_b Camera and Camera Electronics	35/35	2833	7/18/63
		2834	7/18/63
		2835	7/18/63
		3936	3/21/64
		3937	3/23/64
		4785	3/23/64
		3938	3/30/64
Video Combiner	006	3930	3/24/64
		3931	3/24/64
		4800	3/24/64

TABLE 24
RANGER VII FAILURE SUMMARY OF FINAL FLIGHT ASSEMBLIES (Continued)

Assembly	Serial Number	MR Number	Date
Sequencer	008	3553	8/29/63
		4795	4/2/64
		3940	4/8/64
		3950	5/2/64
High-Current Voltage Regulator	10	4057	4/1/64
		3929	6/1/64
Transmitter Assembly	013	3806	5/1/64
		3948	5/2/64
		2155	6/31/64
Power Amplifier	011/140	5877	4/3/64
		5878	4/3/64
		5879	4/3/64
Transmitter Power Supply	016	3300	6/15/63
Low-Current Voltage Regulator	004	3926	3/25/64
Transmitter Assembly	010	2798	1/14/63
		1673	4/19/63
		1674	4/26/63
		1675	4/29/63
		10458	6/15/63
		10459/3308	7/10/63
		4038	9/1/63
		4046	10/20/63
		5886	3/25/64
		5861	3/26/64
		3825	4/1/64
		3949	5/2/64
		3818	5/8/64
Power Amplifier	123/21	2188	5/19/64
Telemetry Assembly	008	2897	5/2/63
		2863	7/25/63
		5887	3/26/64
		2264	12/17/64
Temperature Sensor	006	3824	5/12/64
Sequencer Power Supply	0009	No Failures Reported	
Telemetry Processor	011	No Failures Reported	

TABLE 24
RANGER VII FAILURE SUMMARY OF FINAL FLIGHT ASSEMBLIES (Continued)

Assembly	Serial Number	MR Number	Date
Telemetry Processor	019	No Failures Reported	
Distribution Control Units	002	3357	6/30/63
		3933	3/24/64
		5931	4/15/64
Electronic Clock	005	3877	3/24/64
		4700	4/15/64
High-Current Voltage Regulator	014	4083	10/13/63
		4475	12/7/63
		4027	1/4/64
		4724	1/16/64
		4707	1/24/64
		4056	4/9/64
		4797	4/12/64
		5820	4/12/64
Filter Assembly	008	No Failures Reported	
Command Control Unit	003	No Failures Reported	
Current Sensing Unit	002	3928	3/31/64
Current Transformer Unit	3	No Failures Reported	
Current Transformer Unit	4	No Failures Reported	
Harness		No Failures Reported	
Batteries	94, 93	No Failures Reported	

amount of usable data consistent with the time and costs involved. In most cases the test duration was several times the length of the actual MTBF for a single unit.

a. TESTS CONDUCTED

A 500-hour life test was performed on each of three equipment groupings of assemblies, and on five individual units. Before start of the 500-hour life test, 40 hours of equipment testing took place. Ten hours after start of the life test the equipment was turned off and then turned on again. This was done every ten hours for a total of 50 times during the 500-hour life test. A total of 500 hours of operation at ambient temperature and pressure was logged. the specification requirements of each assembly were met prior to or at the conclusion of its life test.

Tests were conducted in three equipment groups and by individual units. The

TABLE 25
RANGER VIII FAILURE SUMMARY OF FINAL FLIGHT ASSEMBLIES

Assembly	Serial Number	MR Number	Date
P1 Camera and Camera Electronics	42/42	4087	10/25/63
		4090	11/6/63
		4095	12/6/63
		4692	1/28/64
		3762	6/22/64
		3763	6/22/64
		3764	6/23/64
		3900	6/25/64
		3961	6/27/64
		2125	8/5/64
		1351	9/17/64
		1352	9/17/64
P2 Camera and Camera Electronics	22/22	5817	4/3/64
		3345	8/15/63
		4269	1/24/64
		5818	4/5/64
P3 Camera and Camera Electronics	40/37	4231	10/8/63
		2840	1/64
		3599	5/12/64
		2268	12/28/64
P4 Camera and Camera Electronics	48/48	3896	4/22/64
		3989	4/28/64
		3995	4/30/64
		2376	5/11/64
		3753	5/18/64
		3754	5/19/64
		3755	5/19/64
		1338	9/1/64
		1322	9/17/64
		2259	12/7/64
F_a Camera and Camera Electronics	38/32	4007	9/18/63
		4009	9/28/63
		4089	11/2/63
		4651	12/2/63
		3870	6/20/64
		3884	8/21/64
		1580	10/19/64

TABLE 25
RANGER VIII FAILURE SUMMARY OF FINAL FLIGHT ASSEMBLIES (Continued)

Assembly	Serial Number	MR Number	Date
F_b Camera and Camera Electronics	47/47	3964	10/2/63
		4586	11/20/63
		4587	11/20/63
		4589	11/20/63
		4474	11/23/63
		4093	11/25/63
		3594	5/3/64
		3781	8/24/64
		3782	8/24/64
		1578	9/29/64
		3570	10/2/64
		1358	10/7/64
		1364	10/13/64
		1368	10/16/64
Video Combiner	008	4081	10/21/63
		4100	1/6/64
Sequencer	0003	3375	7/25/63
		3379	7/25/63
		3348	8/22/63
High-Current Voltage Regulator	013	1689	11/18/63
		4682	1/7/64
		5835	4/26/64
		3593	4/27/64
		3903	5/27/64
Transmitter Assembly	205	4652	2/28/64
		3796	9/22/64
Power Amplifier	020	4048	11/5/63
Transmitter Power Supply	013	3971	7/8/63
		4684	1/8/64
		4695	2/8/64
		4751	2/8/64
Low-Current Voltage Regulator	011	No Failures Reported	
Transmitter Assembly	206	No Failures Reported	
Power Amplifier	302	No Failures Reported	
Transmitter Power Supply	015	2124	9/12/64

TABLE 25
RANGER VIII FAILURE SUMMARY OF FINAL FLIGHT ASSEMBLIES (Continued)

Assembly	Serial Number	MR Number	Date
Four-Port Hybrid	006	4491	1/3/64
Dummy Load	301/301	2109	6/20/64
		3882	6/20/64
Telemetry Assembly	006	5876	4/2/64
		3771	7/6/64
		3773	7/11/64
		3787	8/31/64
		2148	10/28/64
		2307	2/4/65
Temperature Sensor	008	3373	7/23/64
Sequencer Power Supply	0006	2950	9/20/63
		3560	9/20/63
		4080	10/14/64
Telemetry Processor	301	No Failures Reported	
Telemetry Processor	302	No Failures Reported	
Distribution Control Unit	004	No Failures Reported	
Electronic Clock	003	3862	8/8/63
Current Transformer Unit	002	No Failures Reported	
Batteries	102/104	No Failures Reported	

Telecommunications Group consisted of the Transmitter, Transmitter Power Supply, Telemetry Processor, the Power Amplifier, and the Dummy Load. The Camera Group consisted of the F Camera and Camera Electronics, the Video Combiner, and the Sequencer and Sequencer Power Supply. The Telemetry Group consisted of the Power Supply, the 15-Point and 90-Point Commutators, the 3-kc VCO, two 225-kc VCO's, and the AC Amplifier. The Battery, Temperature Sensor unit, Command Switch, the High-Current Voltage Regulator, and the Low-Current Voltage Regulator were tested as individual units. The assemblies are listed by serial numbers and test hours in Table 27.

b. TEST RESULTS AND SIGNIFICANCE

Only one failure occurred during the 500-hour life test. This was the shorting of an input transistor in the telemetry power supply. It was classed as a random part failure and considered to be relevant in MTBF determination.

Based upon the assumption that this first and only failure, occurring in a single assembly, was representative of all the assemblies, the MTBF's were stated as 420 hours. For a 15-minute mission this was equivalent to a probability of success of 0.99940.

TABLE 26
RANGER IX FAILURE SUMMARY OF FINAL FLIGHT ASSEMBLIES

Assembly	Serial Number	MR Number	Date
P1 Camera and Camera Electronics	15/15	3342	5/3/63
		3963	7/10/63
		3375	7/23/63
		3980	9/10/63
		5813	3/25/64
		3935	4/3/64
		3830	4/22/64
		3985	4/22/64
		1783	5/7/64
		3752	5/16/64
		2120	8/31/64
P2 Camera and Camera Electronics	039/033	4021	9/16/63
		4711	1/19/64
P3 Camera and Camera Electronics	43/43	2830	9/3/63
		4105	9/16/63
		4006	9/17/63
		2117	7/1/64
		3844	10/11/64
P4 Camera and Camera Electronics	049/049	3760	5/26/64
		3786	8/30/64
		1346	9/11/64
		3794	9/20/64
		1354	9/30/64
		4112	10/2/64
		1356	10/4/64
		1360	10/12/64
		1367	10/16/64
		2068	10/22/64
		3892	10/23/64
		3889	11/1/64
		3896	11/4/64
		2072	11/4/64
F_a Camera and Camera Electronics	044/044	4582	11/5/63
		4591	11/18/63
		4686	1/8/64
		4696	1/23/64
		3600	5/12/64
		3853	5/12/64
		3780	8/24/64
		1538	11/16/64

TABLE 26
RANGER IX FAILURE SUMMARY OF FINAL FLIGHT ASSEMBLIES (Continued)

Assembly	Serial Number	MR Number	Date
F_a Camera and Camera Electronics (Continued)	044/044	1543	11/30/64
		2263	12/14/64
		2272	2/1/65
F_b Camera and Camera Electronics	014/014	2943	8/8/63
		2947	8/25/63
		4008	9/22/63
		2838	10/11/63
		2112	6/28/64
		2113	6/29/64
		3772	7/9/64
		3883	8/18/64
		3792	9/19/64
		1357	10/9/64
		1371	10/20/64
		1529	10/29/64
		1547	11/19/64
		2074	11/21/64
		2073	11/22/64
		1545	11/27/64
Video Combiner	009	3279	8/8/63
Sequencer	005	2831	5/5/63
		3261	7/8/63
		3272	7/8/63
		4786	3/26/64
		4787	3/26/64
		3981	4/19/64
		3953	4/23/64
High-Current Voltage Regulator	011	4273	2/7/64
Transmitter Assembly	211	3890	10/5/64
Power Amplifier	301/158	4693	1/28/64
		4752	2/11/64
		2114	6/30/64
Transmitter Power Supply	012	2895	4/23/63
		3307	7/10/63
		10460	7/10/63
Low-CurrentVoltage Regulator	009	4775	4/14/64

TABLE 26
RANGER IX FAILURE SUMMARY OF FINAL FLIGHT ASSEMBLIES (Continued)

Assembly	Serial Number	MR Number	Date
Transmitter Assembly	204	2065	7/6/64
		3774	7/10/64
		3798	9/24/64
		3799	9/24/64
Power Amplifier	016/145	10452	5/3/63
Transmitter Power Supply	020	4461	12/6/63
		4462	12/11/63
		4545	12/11/63
		3967	1/4/64
		4492	1/21/64
Four-Port Hybrid	003	No Failures Reported	
Dummy Load	027/005	1544	11/30/64
Telemetry Assembly	107	4039	10/2/63
		3765	6/23/64
		3766	6/23/64
		3767	6/29/64
		3768	6/29/64
		1542	11/27/64
Temperature Sensor	009	2273	2/2/65
Sequencer Power Supply	0005	3356	6/28/63
		4075	10/10/63
		1534	11/12/64
Telemetry Processor	021	No Failures Reported	
Telemetry Processor	006	No Failures Reported	
Distribution Control Unit	005	3980	4/17/64
		4778	4/17/64
		3788	9/3/64
Electronic Clock	007	2075	11/29/64
High-Current Voltage Regulator	015	3559	9/17/63
		4082	10/12/63
		4685	1/8/64
		4702	1/8/64
		4798	4/16/64

TABLE 26
RANGER IX FAILURE SUMMARY OF FINAL FLIGHT ASSEMBLIES (Continued)

Assembly	Serial Number	MR Number	Date
Filter	005	No Failures Reported	
Command Control Unit	007	3778	8/11/64
Current Sensing Unit	006	3789 3790	9/13/64 9/13/64
Current Transformer Unit	023	No Failures Reported	
Current Transformer Unit	022	No Failures Reported	
Battery	109	2311	2/23/65
Battery	107	2313	3/7/65

The significance of this probability must be qualified by consideration of the facts that it was based on the above assumption, upon limited test data, and upon selective testing. For example, only one of the six Cameras and Camera Electronics Assemblies and only one of two Transmitters were tested.

2. Life Test Model Testing at JPL

Following successful completion of flight acceptance testing at RCA and the inauguration of the split-system configuration, Flight Model III-2 of the initial configuration was designated as the Life Test model (LTM) and shipped to JPL for mission verification tests. These tests were completed to evaluate the performance of the Ranger LTM TV Subsystem over an extended period of time and to investigate special problem areas.

a. TESTS CONDUCTED

Three series of mission verification tests were conducted, each preceded by a Subsystem verification test. The Subsystem verification tests were performed to document the condition of the LTM before the mission verification tests; the mission verification tests were conducted to evaluate performance in a space environment. At the conclusion of the mission verification tests, a series of five special tests was completed to investigate and isolate the cause of momentary RF power fluctuations observed during the mission verification tests. The sequence of these tests along with their environmental conditions is listed in Table 28.

b. TEST RESULTS AND SIGNIFICANCE

(1) Distribution of Malfunctions

A total of 24 malfunctions was reported during the testing at JPL. The distribution of these malfunctions and type of failure are shown in Table 29. Of these, only one was finally considered to be a relevant failure and was classed as random. It occurred when the Camera Electronics Serial No. 020 lost video as a result of arcing of the 1000-volt circuit to a +40-volt printed-circuit lead in the Low-Current Voltage Regulator (Reported in MR 2613). The total test time was 114 hours, including both flight acceptance testing at RCA and mission verification testing at JPL.

TABLE 27
LIFE TEST OF ASSEMBLIES

Assembly	Serial Number	Duration (Hours)
Video Combiner	003	504
Camera and Camera Electronics	012	625
Sequencer and Sequencer Power Supply	003	3,313
Transmitter	006	500
Modulator	014	
X12	004	
X4	012	
IPA	012	
2nd IPA	011	
Signal Sampler	015	
Transmitter Power Supply	008	
Telemetry Processor	013	
Power Amplifier Housing/Resdel	016/127	
Dummy Load	012	
Telemetry Unit	002	500*
Power Supply	005	
15-Point Commutator	1007	
90-Point Commutator	1009	
3-kc VCO	4011	
225-kc VCO (2)	1027A/1228B	
AC Amplifier		
Low-Current Voltage Regulator	B3	545.75
High-Current Voltage Regulator	3	540.32
Temperature Sensor Unit	002	500
Command Switch	002	500
Battery	019	500

*At 420 hours, an input transistor shorted in the power supply.

TABLE 28
LIFE TEST MODEL TESTS AT JPL

Date	Test	Environment
March 4, 1963	SVT-1	Ambient Temperature and Pressure
March 11 to 14	MVT-1	Ambient Temperature and Pressure
March 18 to 21	MVT-2	Ambient Temperature and Pressure
March 26	SVT-2	Ambient Temperature and Pressure
March 27 to 30	MVT-3	Thermal Vacuum Avg. Case Temp. 100° F
April 3 to 6	MVT-4	Thermal Vacuum Avg. Case Temp. 50° F
April 9 to 12	MVT-5	Thermal Vacuum Avg. Case Temp. 100° F
April 16 to 19	MVT-6	Thermal Vacuum Avg. Case Temp. 50° F
April 23 to 27	MVT-7	Thermal Vacuum Avg. Case Temp. 100° F
April 30 to May 5	MVT-8	Thermal Vacuum Avg. Case Temp. 50° F
May 6 to 9	MVT-9	Thermal Vacuum Avg. Case Temp. 100° F
May 13	SVT-3	Ambient Temperature and Pressure
May 14 to 17	MVT-10	Thermal Vacuum Avg. Case Temp. 50° F
May 20 to 23	MVT-11	Thermal Vacuum Avg. Case Temp. 70° F
May 28 to 31	MVT-12	Thermal Vacuum Avg. Case Temp. 32° F
June 5 to 8	MVT-13	Thermal Vacuum Avg. Case Temp. 130° F
June 11	Special Test Nos. 1 and 2	Thermal Vacuum Avg. Case Temp. 70° F
June 12, 1963	Special Test Nos. 3, 4, 5	Thermal Vacuum Avg. Case Temp. 70° F

(2) Results Assuming Four Failures

Originally, (as reported in the Ranger TV Subsystem Mission Verification Report for the Life Test Model) the number of relevant failures was considered to be four. Three of these relevant failures occurred during acceptance testing at RCA and one (MR 2613) occurred during testing at JPL.

Therefore, the MTBF was calculated as:

$$\frac{114 \text{ hrs}}{4} = 28.5 \text{ hrs}$$

Using a two-tailed estimate with a 90% confidence level, there was a five-percent probability that the MTBF would be higher than the upper limit and a five-percent probability that the MTBF would be less than the lower limit.

TABLE 29
CLASSIFICATION OF LIFE TEST MODEL FAILURES DURING JPL TESTING

Equipment	Type of Failure								
	No. of Malfunctions	Workmanship	Accident	Random	Design	Nonconfirmed	Nonassignable	Wearout	Nonequipment Malfunction
Camera and Camera Electronics	4	0	0	1	1	1	0	0	1
Communications	18	2	1	0	5	4	6	0	0
Battery and Regulator	2	0	1	0	0	0	0	1	0
Total	24	2	2	1	6	5	6	1	1
Percent of Total	100	8.3	8.3	4.2	25	20.8	25	4.2	4.2

Therefore, there was a 90-percent probability that the MTBF was between the upper and lower limit.

$$MTBF = 14.7\ hrs < 28.5\ hrs < 83.5\ hrs$$

Using these MTBF's, the probabilities of survival (P_S) for a 15-minute mission was as follows:

$$P_S = 0.9831 < 0.9913 < 0.9970$$

(3) Results Assuming One Failure

These four failures were reviewed again and it was determined that three of the four failures which occurred were in the Second IPA of the Transmitter Assembly. This Second IPA was deleted from the Transmitter as a design product improvement for the split-system and modified split-system configurations of the TV Subsystems. Therefore, the number of failures relevant to these configurations was one.

The revised MTBF was calculated to be as follows:

$$\frac{114}{1} = 114\ hrs$$

Using a two-tailed estimate with a 90-percent confidence level, there was a five-percent probability the MTBF was higher than the upper limit and a five-percent probability that the MTBF was lower than the lower limit. Therefore, there was a 90-percent probability that the MTBF was between the upper and lower limit.

$$MTBF = 39\ hrs < 114\ hrs < 2215\ hrs$$

Using these MTBF's, the probability of survival (P_S) for a 15 minute mission of the split-system and modified split-system configurations was calculated as:

$$P_S = 0.9936 < 0.9978 < 0.9998$$

3. Average Part Failure Rate Analysis

As part of the reliability demonstration effort, a special analysis of part failure rates was performed and the results submitted to JPL in October 1963. The analysis covered all test time up to August 23, 1963.

a. FAILURE RATE CALCULATIONS

Average part failure rates were calculated on a Subsystem basis using as parameters the subassembly operating times, the number of assembly parts, and the number of relevant Subsystem failures. The TV Subsystems included in the analysis were the PTM of the initial Ranger VI through Ranger IX Subsystem configuration, FM 1, FM 2, the LTM (a composite group of assembly life tests), the Block III PTM, and FM III-1.

The failure rates were calculated using the following formulas:

$$\Sigma \frac{\textit{Assembly parts x operating time}}{\textit{Relevant failures}} = \text{Mean Time Between Failures } (MTBF)$$

$\Sigma =$ Summation product of all assemblies for a particular TV Subsystem Model.

$\frac{10^5}{MTBF} =$ average failure rate percent per 1000 hours.

$10^5 =$ conversion factor for failures per hour to percent failures per 1000 hours.

Results of these calculations are presented in Table 30.

b. SURVIVAL PROBABILITY CALCULATIONS

Based on average part failure rates, probabilities of survival were calculated for both initial system configuration and split-system configuration subsystems.

(1) Initial System Configuration

Using the revised initial system mathematical model (see subsection A of this section) calculations of survival probability were made for the PTM, FM 1, FM 2, and the LTM Subsystems. The results of these calculations are presented in Tables 31 and 32.

TABLE 30
AVERAGE PART FAILURE RATES

Subsystem	Total Part Hours	No. of Relevant Failures	Total Failure Rate
PTM	1,895,151	8	0.422
FM 1	1,636,720	6	0.367
FM 2	1,539,649	3	0.195
LTM	8,865,248	1	0.0113
Block III PTM	1,772,977	3	0.169
FM III-1	1,582,527	1	0.063

TABLE 31
PROBABILITY OF OCCURRENCE FOR VARIOUS SURVIVAL STATES OF MATHEMATICAL MODEL, PTM, FM 1, FM 2, AND LTM

Survival State	Description	Math Model	PTM	FM 1	FM 2	LTM
1	4 P Cameras 2 F Cameras All T/M	0.994680	0.965916	0.970333	0.984196	0.999081
2	3 P Cameras 2 F Cameras All T/M	3.64×10^{-4}	3.272×10^{-3}	2.858×10^{-3}	1.540×10^{-3}	9.05×10^{-5}
3	2 P Cameras 2 F Cameras All T/M	5.02×10^{-8}	4.14×10^{-6}	3.15×10^{-6}	5.38×10^{-7}	1.38×10^{-7}
4	1 P Camera 2 F Cameras All T/M	2.43×10^{-12}	2.33×10^{-9}	1.54×10^{-9}	6.81×10^{-10}	4.61×10^{-12}
5	4 P Cameras 1 F Camera All T/M	1.66×10^{-4}	1.497×10^{-3}	1.308×10^{-3}	7.05×10^{-4}	4.14×10^{-5}
6	3 P Cameras 1 F Camera All T/M	6.09×10^{-8}	5.07×10^{-6}	3.85×10^{-6}	1.10×10^{-6}	3.75×10^{-9}
7	2 P Cameras 1 F Camera All T/M	8.38×10^{-12}	6.42×10^{-9}	4.24×10^{-9}	3.85×10^{-9}	5.72×10^{-12}
8	1 P Camera 1 F Camera All T/M	4.05×10^{-16}	3.58×10^{-12}	2.07×10^{-12}	4.88×10^{-13}	1.91×10^{-16}

Table 31 shows the probabilities for eight of the mathematical model survival states for the PTM, LTM, FM 1, and FM 2 compared to previous mathematical model calculations.

Table 32 makes a similar comparison for various equipment groups of the TV Subsystem.

(2) Split-System Configuration

Results for the Block III split-system configuration survival state were 0.994620 for the Block III PTM Subsystem and 0.994620 for the FM III-1 Subsystem. These compared to a mathematical model figure of 0.993780. State 1 represents operation of four P cameras, two F cameras, and all telemetry.

c. CONCLUSIONS

The average part failure rates obtained from Subsystem and assembly testing approach, but do not equal, the established failure rates used for the mathematical model calculations. Of necessity, the average failure rates were test-limited compared to the established rates; actual test time was significantly less than that used in determination of the established values. However they were sufficiently valid to permit a degree of confidence that the mission requirements could be met with the equipment. Table 33 summarizes, in tabular form, the MTBF's and survival probabilities (15-minute mission) of the mathematical model and five Subsystem configurations.

TABLE 32
SURVIVAL PROBABILITIES FOR VARIOUS TV CAMERA CONFIGURATIONS OF MATHEMATICAL MODEL, PTM, FM 1, FM 2 AND LTM

Equipment	Math Model	PTM	FM 1	FM 2	LTM
4 P Cameras	0.999636	0.996616	0.997057	0.998436	0.999909
Exactly 3 P Cameras	0.000364	0.003376	0.002937	0.001562	0.000091
Exactly 2 P Cameras	5.04×10^{-8}	4.28×10^{-6}	3.23×10^{-6}	5.45×10^{-7}	1.38×10^{-7}
Exactly 1 P Camera	2.44×10^{-12}	2.40×10^{-9}	1.58×10^{-9}	6.91×10^{-10}	4.61×10^{-12}
2 F Cameras	0.999833	0.998451	0.998653	0.999284	0.999959
Exactly 1 F Camera	0.000167	0.001548	0.001346	0.000715	0.000042

TABLE 33
MTBF AND PROBABILITY OF SURVIVAL

Subsystem	No. of Parts	Total Failure Rate	Average Part Failure Rate %/1000 Hrs.	MTBF	P_S for 15 Min.
Math Model	8094	-	477	210	0.99880
PTM 1	8093	0.422	3415	29.3	0.99153
FM 1	8093	0.367	2960	33.8	0.99262
FM 2	8093	0.195	1568	63.9	0.99600
Block III PTM	8602	0.169	1458	76	0.99670
FM III-1	8602	0.063	540	204	0.99880

Section III

Quality Assurance

To assure that TV Subsystem hardware would meet or exceed the quality standards required for Ranger TV Subsystem missions, a comprehensive quality assurance program was established. This quality assurance program was set forth in the design proposal and later defined in detail in the Product Assurance Plan of February 15, 1962. This section describes that program, its results, and their significance.

A. QUALITY CONTROL SYSTEM

1. Organization and Function

An effective and economical quality control system was maintained to implement the quality assurance plan. Fully integrated with production planning and subcontract requirements, the quality control system considered problems of design, interchangeability, reliability, manufacturing, and scheduling.

The system assured that adequate control of quality was maintained throughout the entire process of manufacture, including packaging and shipping. It also provided a means for the ready detection of discrepancies, together with means for necessary corrective actions. All supplies delivered under the Ranger contract received 100-percent incoming inspection to assure conformance with contractual requirements. Records of inspection and tests were maintained in compliance with the RCA Quality Assurance Procedures.

2. Policy and Procedures

The TV Subsystem quality control activities were guided by RCA corporate and division policy-and-procedures documentation.

a. CORPORATE LEVEL

The quality control system was established in accordance with the policies contained in the RCA Defense Electronic Products Procedures Manual. These procedures provided for a corporate central engineering group which was responsible for preparation and dissemination of standards and specifications to guide each division's quality control system. These standards and specifications are contained in the 14-volume set of RCA Defense Standards.

b. DIVISION LEVEL

Governing the quality control system at the division level was the Product Assurance Manual. This manual contained the product assurance organization, applicable RCA Defense Electronic Products procedures, divisional operating instructions to implement the DEP procedures, administrative notices, and product assurance practices. In addition, the manual provided Manufacturing Engineering and Quality Control with a comprehensive set of quality control procedures, policy statements, and detailed specifications.

B. INSPECTION, MEASURING AND TEST EQUIPMENT

1. Calibration Standards

Suitable gages, meters and test equipments were utilized by quality control and test personnel to verify and check product requirements. These devices were kept in accurate calibration at all times by comparison with primary standards. The responsibility for the control, maintenance and calibration of this equipment was assigned to Product Quality Control for all mechanical tools, and to the Calibration and Repair activity for all other test equipment.

These groups maintained secondary and working standards calibrated in accordance with manufacturers' specifications, Air Force technical orders, and RCA calibration procedures. All standards utilized on the program were traceable to the National Bureau of Standards in Washington, D.C. through the RCA Measurement Engineering Laboratory in Camden, N.J. and the AED Measurements Standard Laboratory in Princeton, N.J.

2. Calibration Procedures

Incoming acceptance tests and calibrations were performed on all testing equipment and critical tooling utilized on the program. Calibration schedules were established and records were maintained for each piece of equipment. Each piece had a calibration record label affixed to reflect its status.

Ranger activities utilizing measuring and testing equipment were notified when recalibration or certification was required and delivery of the equipment to the calibration activity was arranged. Product Quality Control had responsibility for policing Ranger test and measuring equipment and assuring that out-of-calibration equipment was not being used. Quality Control tagged such equipment and notified the calibration activity for corrective action.

C. PURCHASED MATERIAL INSPECTION

1. Scope of Program

To insure that vendor and subcontractor parts would perform satisfactorily under the exacting Ranger mission requirements, a comprehensive subcontractor quality control program was established. This program determined conformance of purchased parts and materials to their applicable specifications, standards, and drawings through an intensive system of purchased material inspection. This inspection was performed at RCA plants and at subcontractor facilities as required.

In addition, suppliers of non-MIL-qualified parts were required to conform to RCA specification 96409-A, Supplier Quality Control. This specification called for the vendor to maintain a quality system which established and enforced adequate controls, provided objective evidence that the controls were effective, and produced sufficient inspection and test data to assure that control of quality was being maintained and that the vendor product conformed to the contract requirements.

2. RCA Incoming Inspection

a. INSPECTION PROCEDURE

Each lot of parts and materials coming into RCA was processed by receiving and purchased material inspection (PMI) personnel according to standardized procedures. Parts performance data were kept by PMI to record the results of its inspection of received parts. A Material Discrepancy Report (MDR) was completed for any parts, materials or subassemblies which did not conform to requirements of inspection; disposition of the material was indicated thereon. Vendors and subcontractors were informed of any such reports concerning their products. Effective follow-up procedures were instituted to insure vendor and subcontractor compliance with applicable drawings, specifications and/ or standards.

b. DETAILED FUNCTIONS

The flow of both electronic and nonelectronic materials through receiving to the ultimate user is shown in Figure 35. The responsibilities of each station shown in the flow chart are described in the following paragraphs.

(1) Receiving

All parts and materials received from vendors or subcontractors were logged in through the receiving section.

(2) Purchased Material Inspection

All parts and materials coming out of the receiving section were routed through the PMI section. The PMI section inspected and tested all parts and materials for conformance with specifications, drawings, and standards. Accept-reject criteria for each lot conformed to inspection instructions. All parts and materials not in conformance with specifications, drawings, and standards were set aside in an area in the PMI section to await disposition. Accepted mechanical parts and raw materials went directly to the stock room, while electronic components were processed through the preconditioning cycle.

(3) Electronic Component Preconditioning

All electronic component parts were put through the preconditioning cycle as specified in Section II Subsection C2 of this volume.

(4) PMI Retest

The PMI section tested electronic components after preconditioning. The procedures for test after preconditioning and the accept-reject criteria are detailed in the same reference mentioned in item (3) above. All the electronic components considered acceptable after preconditioning were transferred to the stock room.

(5) Stock Room

The stock room stored all parts and materials coming from PMI.

(6) Manufacturing Control

The Manufacturing Control section assigned the work to be done to the production facility. This included supplying the production facility

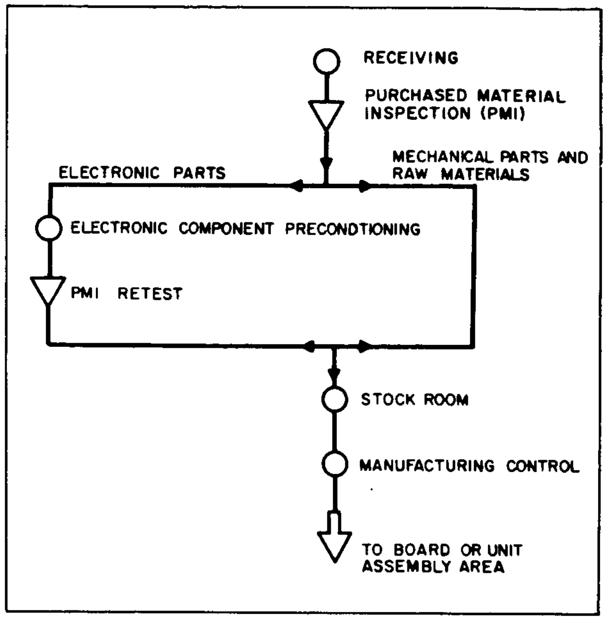


Figure 35. Incoming Materials Inspection and Routing

with all the applicable drawings and additional production instructions.

3. Field Quality Control

Where complex parts and assemblies were procured through subcontracts, a field quality-control specialist was assigned to the vendor's plant. During his visits he performed a vendor survey, reviewed and approved the vendor's quality control manual, conducted in-process inspections, and surveyed vendor operations for conformance to RCA requirements. He also represented RCA on vendor material-review boards, monitored electrical and mechanical testing, performed final inspection, and gave shipping approval.

Field quality-control specialists represented RCA at six subcontractors in this manner. The subcontractors and subcontracted equipments are listed below:

Batteries	Electric Storage Battery Co.
Structure	Lavelle Aircraft Corp.
Power Amplifier	Resdel

Intermediate Power Amplifier	Resdel
Dummy Loads	Douglas Microwave
Commutators	Instrument Div. Lab
	Fifth Dimension

D. IN-PROCESS QUALITY CONTROL

In-process inspection was maintained in all RCA plants by means of the procedures of their respective quality control manuals. Travel tags and inspection reports were utilized to properly route and document acceptance of material throughout the assembly process. These records were maintained by the quality control department so that inspection and performance status of the various units was readily identifiable at all times.

1. Operations

a. INITIAL AND SPLIT-SYSTEMS

Quality control inspectors and a quality control specialist performed the principal inspection operations.

The specialist's duty was to see that the manufacturing and engineering activities were complying with the Ranger project policies and procedures. The specialist was also responsible for monitoring of all acceptance tests and for reporting deficiencies in the manufacturing processes which could have caused a degradation of the product. These deficiencies were reported to the product assurance engineer who saw that corrective action was taken.

The quality control inspector's duties were to perform the detailed acceptance inspection of the Ranger hardware for conformance of the material to the drawing and workmanship requirements at fixed predetermined points in the production flow. The JPL quality assurance representative performed surveillance over all manufacturing operations and was notified by the QC specialist of all acceptance tests.

b. POST-RA-6 SYSTEM

For the post-RA-6 program, the scheme of operation was modified to provide for a specialist's review in series with the inspection performed by the inspector. In addition, the JPL quality assurance representative performed a 100-percent tollgate inspection after each quality control specialist review. All acceptance-level testing to PTM, Qualification, and flight units was witnessed 100 percent by the quality control specialist. JPL quality assurance witnessed tests on a surveillance basis.

2. Manufacturing Procedures and Flow Charts

Manufacturing procedures and associated flow charts were established for each unit fabricated or assembled for the TV Subsystem. These procedures and flow charts were inspection-oriented to show the points at which quality control inspection or test monitoring occurred. Figure 36 shows a typical flow chart of the type prepared for each assembly on the program.

Upon the initiation of the Ranger rework program, immediate effort was placed on completing a set of flow charts to govern the movement of hardware through the disassembly, inspection, rework and reassembly operations. The basic flow chart for all assemblies and the characteristics for each inspection station are summarized in Figure 37 and Table 34. The flow chart used in controlling operations during integration of the TV Subsystem and the associated operation descriptions are presented in Figure 38 and Table 35, respectively. Table 36 summarizes all Ranger flow charts and checklists. Corrective action was taken by quality control to eliminate repetitive discrepancies, violations of specifications and to correct those operations which evidenced lack of control. The procedure employed in effecting corrective action was the initial issuing of a Quality Hold Notice (Figure 39), which required the management of an

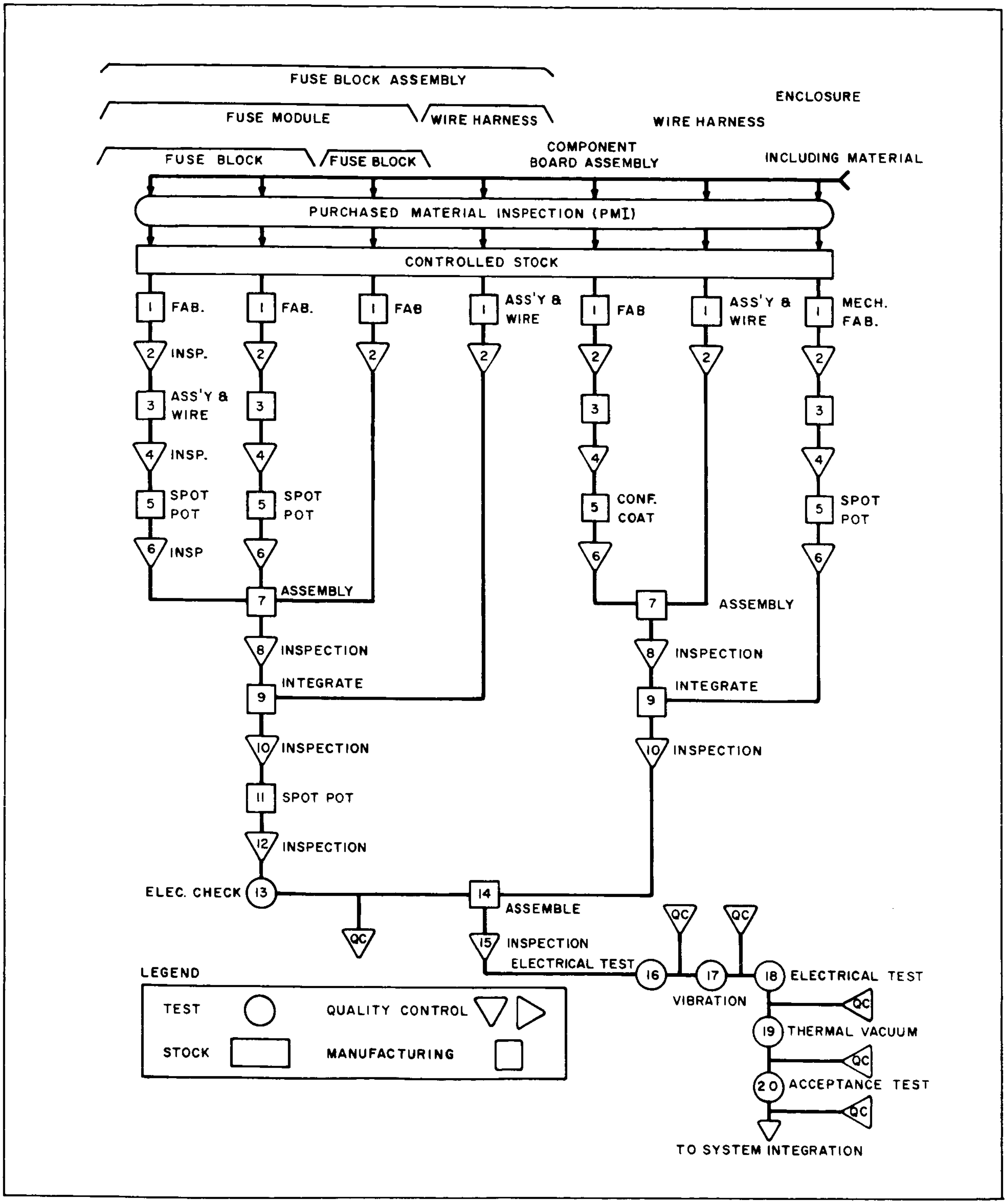


Figure 36. Typical Assembly-Level Flow Chart of Manufacturing and Quality-Control Sequences

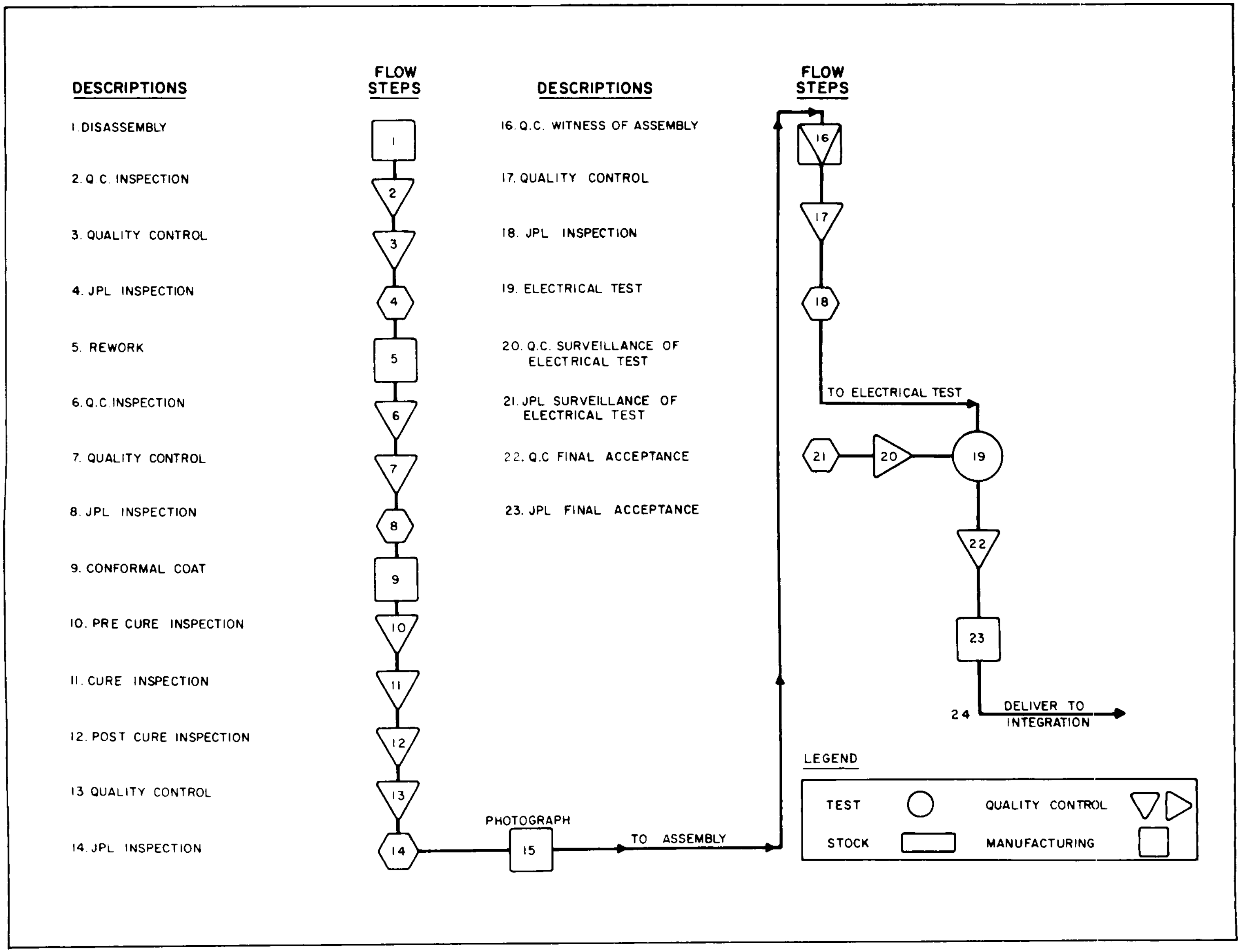


Figure 37. Basic Assembly Flow Chart For TV Subsystem Rework Program

TABLE 34
SUMMARY OF BASIC ASSEMBLY LEVEL FLOW CHART
CHARACTERISTICS FOR RANGER REWORK PROGRAM

Step Number	Step Characteristics
1	Disassemble: Manufacturing will disassemble, per disassembly instructions, to such an extent that all printed boards and components will be exposed for a workmanship-and-damage inspection. Manufacturing will institute a new log book for each unit as received from mechanical integration. This log book will be marked with the unit name, drawing number, part number, and revision letter. The flight number and a star will also be placed on the cover. Manufacturing will affix a travel tag to each unit at disassembly. The unit will be kept in a plastic bag with its log book and paperwork. Manufacturing will make an entry in the log book for all operations, tests, and review dispositions affecting the unit.
2	Inspection: A complete inspection will be performed by inspection for workmanship, degradation due to extensive testing, and connector pin withdrawal force. See Ranger workmanship specification GER-7, Special Inspection Instruction 011 (attached), Ranger Retrofit Special Inspection Instructions (attached). Make log book entry at completion of inspection.
3	Quality Control: Quality Control will perform surveillance over the disassembly and inspection of the units.
4	UPR Review: The Quality Control Specialist will review the UPR discrepancies. He will make the decision "for rework" or "not for rework" based upon his good judgment, technical consultants, and other sources at his command. He will check the travel tag and log book for completion and make his entry to the log book. The Specialist will submit the unit to the customer with form AED 268. Such sources at his command are Manufacturing Engineering and Design Engineering groups.
5	JPL: The customer will perform his inspection.
6	Rework: Manufacturing will perform the items designated for rework on the "UPR" and JPL's "IR". He will use standard repair methods and procedures from Manufacturing Engineering. All outstanding discrepancies except those involving conformal coating will be reworked in this step. Those items requiring conformal rework and correction will be completed and released by inspection, prior to the application of the newly imposed conformal coating.
7	Inspection: An inspection of the outstanding items on the UPR will be performed. The inspector will make his entries on the associated paperwork.

TABLE 34
SUMMARY OF BASIC ASSEMBLY LEVEL FLOW CHART CHARACTERISTICS FOR RANGER REWORK PROGRAM (Continued)

Step Number	Step Characteristics
8	Quality Control: The Quality Control Specialist will survey the rework and inspection. When all is in order, he will make submission to the customer using AED Form 268. One copy will be kept in a loose-leaf binder by Quality Control and the original will go to the customer.
9	JPL: The unit is submitted to the customer. Quality Control will stamp the travel tag when the submission sheet is returned accepted by the customer.
10	Conformal Coating: Manufacturing will conformally coat to the following specifications: JPL Specification RCA-50261-PRS, and JPL Procedure A90539. Manufacturing will make the appropriate log book entry.
11	Inspection: An inspection of the conformal coating will be performed.
12	Quality Control: The Quality Control Specialist will survey the application of the conformal coating and inspection. When all is in order he will submit the unit with AED form 268.
13	JPL: The unit is submitted to the customer for inspection of the conformal coating. The Quality Control Specialist will stamp the travel tag when the submission sheet is returned accepted.
14	Photograph: Quality Control photographic facilities will take color photographs of the conformally coated areas of the unit. Photographs will be representative of the latest flight configuration in all cases. The photographs shall be taken in such a manner that the components placement, wiring, soldering, and details of workmanship are clear. This shall include photographs showing connector details, units joined by connectors, cables and harnesses and any critical items that are to be permanently sealed.
15	Assemble: Manufacturing will assemble the unit. The travel tag will be stamped by the operator and an entry will be made in the log book.
16	Inspection: A final mechanical assembly inspection will be performed and the disposition of the inspection noted in the log book. Also inspect for cleanliness, chassis finish, identification, and spot bonding.
17	Quality Control: The Quality Control Specialist will perform surveillance of the assembly and inspection. He will make submission of the unit to the customer.

TABLE 34
SUMMARY OF BASIC ASSEMBLY LEVEL FLOW CHART CHARACTERISTICS FOR RANGER REWORK PROGRAM (Continued)

Step Number	Step Characteristics
18	JPL: The unit is submitted to the customer. Quality Control will stamp the travel tag when the submission sheet is returned.
19	Test: Bench testing will be performed by Manufacturing Test or Engineering to verify conformance to the Ranger Test Specification.
20	Quality Control Surveillance: The Quality Control Specialist will be present for the acceptance Bench Test. He will verify that all is in order and will notify JPL that the test is to be performed.
21	JPL Surveillance: The customer will perform his surveillance of the test with the Quality Control Specialist.
22	Quality Control Final Acceptance: The Specialist will review all data, UPR's, Travel Tags, log books, and the unit for his approval for acceptance to Integration. He will make submission to JPL for their final acceptance.
23	JPL Final Acceptance: JPL will perform their final acceptance inspection.
24	To Integration: Release unit with a "Don't Break" seal affixed.

Note: Testing may be modified by R.T.R.B. Direction.

operation to bring undesirable situations under control and to report to quality control the actions taken.

If corrective action was not forthcoming within the specified time, quality control had absolute authority to stop the operation in question until the appropriate remedial measures were taken.

3. Documentation

Documentation of basic in-process inspection and test monitoring was accomplished through the use of the travel tag, the unit performance record, the environmental test summary, and the equipment logbook.

a. TRAVEL TAG (FIGURE 40)

The travel tag was used for identification, process control, and quality control. The tag was prominent and identified parts not having nameplates. It indicated to the quality control inspector that all previous steps in the manufacturing process had been completed and controlled. The tag also served as a record of completion of necessary product quality-control inspections.

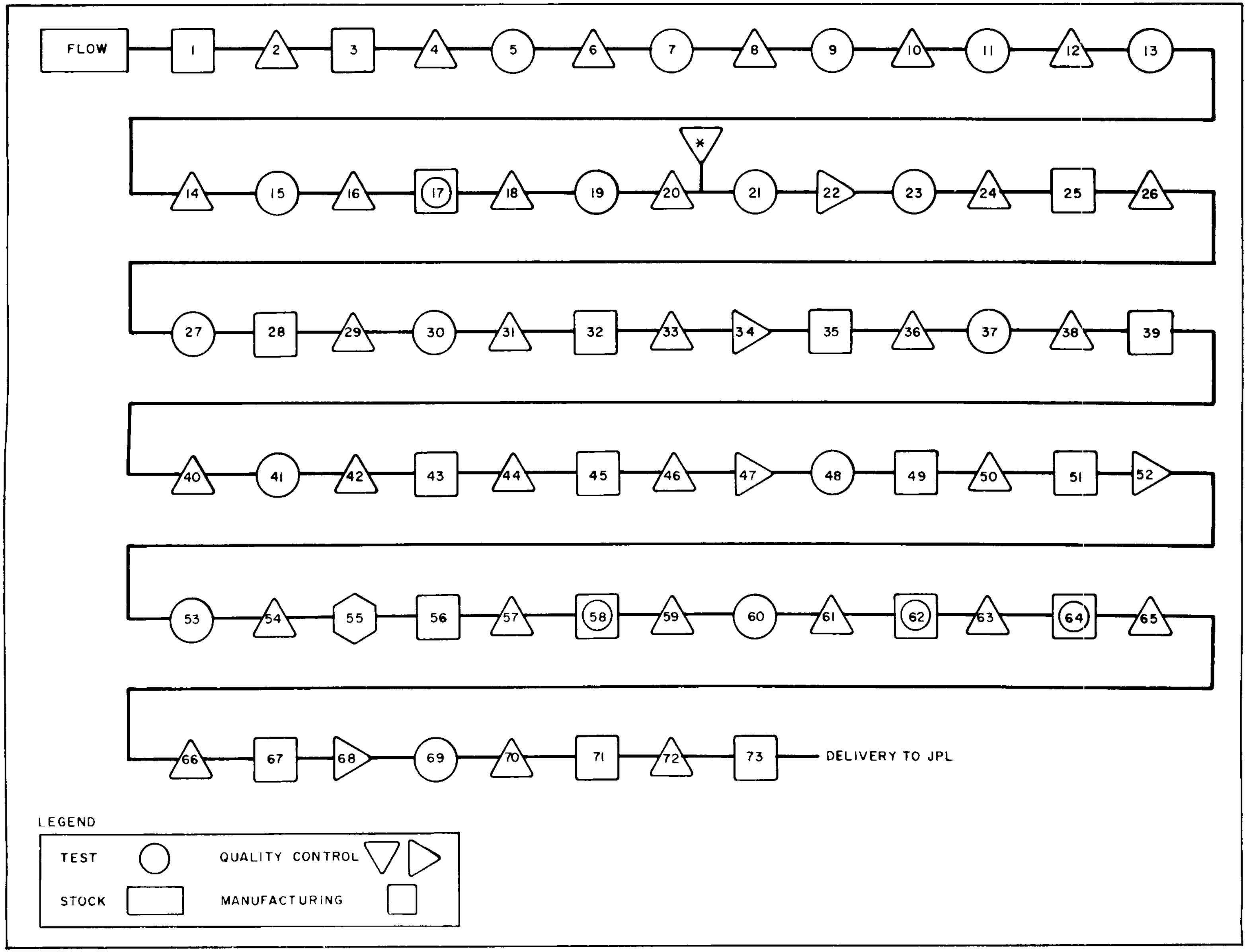


Figure 38. Flow Chart of Integration Operation

TABLE 35
SUMMARY OF FLOW CHART OPERATION DESCRIPTIONS FOR RANGER TV SUBSYSTEM INTEGRATION

Step Number	Operation Description
1	Preparation & Weighing of Assemblies Prior to installation all units are weighed with their associated hardware.
2	Quality Control Surveillance Prior to installation Quality Control verifies the weights, and records all information specified in Check List 100.
3	Mechanical Integration The TV Subsystem is assembled in the Ranger Integration Area.
4	Quality Control Surveillance Quality Control surveillance of the assembly operations assuring correct electrical connections and correct torque on hardware using Check List.
5	Initial Power Application & Checkout Electrical debugging is performed using initial power application and checkout procedure.
6	Quality Control Surveillance Quality Control assures that the debugging procedures are followed.
7	Voltage & Current Distribution Verifies proper operation of the F and P Transmitters, F and P Sequencers, all cameras, LCVR, and Clock.
8	Quality Control Surveillance
9	Noise Immunity Tests The subsystem command and control circuitry is tested for noise immunity.
10	Quality Control Surveillance
11	Communications Equipment Alignment & Calibration The communications is aligned and calibrated.

TABLE 35
SUMMARY OF FLOW CHART OPERATION DESCRIPTIONS FOR RANGER TV SUBSYSTEM INTEGRATION (Continued)

Step Number	Operation Description
12	Quality Control Surveillance
13	Camera Alignment & Calibration The calibration of the ground support equipment is verified, after which the cameras are aligned and calibrated.
14	Quality Control Surveillance
15	Telemetry Calibration The output of the Subsystem telemetry is calibrated.
16	Quality Control Surveillance
17	Preparation for Test The Subsystem is prepared mechanically less top-hat, omnidirectional antenna, shrouds & batteries; also calibration of the operational support equipment is verified.
18	Quality Control Surveillance
19	Systems Test The Subsystem is tested in accordance with the test procedure.
20	Quality Control Surveillance
*	JPL QA Surveillance
21	Mechanical Previbration Preparation The batteries, top hat, omnidirectional antenna and shrouds are installed.
22	Quality Control & JPL Inspection
23	Electrical Previbration Preparation The Subsystem is tested in accordance with the applicable procedure, after which the following plugs are installed: 30P13, 30P8, 30P9.
24	Quality Control & JPL Surveillance

TABLE 35
SUMMARY OF FLOW CHART OPERATION DESCRIPTIONS FOR RANGER TV SUBSYSTEM INTEGRATION (Continued)

Step Number	Operation Description
25	Transport to Environmental Area The Subsystem is transported to the Environmental Area. Cable 23W25 is installed in jack 30J1.
26	Quality Control & JPL Surveillance
27	Vibration Test The Subsystem is subjected to vibration in accordance with the applicable test procedure.
28	Transport to Integration Area The Subsystem is transported to the integration area.
29	Quality Control & JPL Surveillance
30	Post-Vibration Test The Subsystem is checked out with the applicable procedure.
31	Quality Control & JPL Surveillance
32	Removal of Shrouds The shrouds are removed for inspection.
33	Quality Control Surveillance
34	Quality Control & JPL Inspection Quality Control inspection is performed to verify that there was no mechanical degradation due to vibration.
35	Mechanical Pre-Thermal-Vacuum Preparation The Subsystem is prepared in accorance with the applicable procedure. The pressure in the Dummy Load and P.A.'s is verified.
36	Quality Control Surveillance

TABLE 35
SUMMARY OF FLOW CHART OPERATION DESCRIPTIONS FOR RANGER TV SUBSYSTEM INTEGRATION (Continued)

Step Number	Operation Description
37	Electrical Pre-Thermal-Vacuum Preparation The Subsystem is tested in accordance with the applicable procedure.
38	Quality Control & JPL Surveillance
39	Transport to Environmental Area The Subsystem is transported to the Environmental Area.
40	Quality Control & JPL Surveillance
41	Thermal Vacuum Tests The Subsystem is subjected to thermal vacuum in accordance with the applicable test procedure.
42	Quality Control Surveillance
43	Transport to Integration Area The Subsystem is transported to the Integration Area.
44	Quality Control Surveillance
45	Removal of Shrouds The shrouds, top hat, omni-antenna, and batteries are removed.
46	Quality Control Surveillance
47	Quality Control Inspection Inspection is performed to verify there was no mechanical degradation due to thermal vacuum exposure. Pressure is checked in dummy load and P. A.'s.
48	Review of Shutter Operations A review is made of shutter-operating times; all shutters with greater than 250,000 operations are replaced.
49	Removal of Cameras for Shutter Replacement The cameras are removed in accordance with the applicable test procedure.

TABLE 35
SUMMARY OF FLOW CHART OPERATION DESCRIPTIONS FOR RANGER TV SUBSYSTEM INTEGRATION (Continued)

Step Number	Operation Description
50	Quality Control Surveillance
51	Shutter Replacements The shutters are replaced per the applicable assembly drawings.
52	Quality Control Inspection
53	Microphonics Test The camera heads are checked for microphonics with the applicable procedure.
54	Quality Control Surveillance
55	JPL Quality Assurance The replacement of the shutter assembly is inspected by JPL Quality Assurance.
56	Installation of Cameras after Shutter Replacement Any cameras removed for shutter replacement are installed in accordance with the applicable procedure.
57	Quality Control Surveillance
58	Camera Array Alignment The cameras are aligned in accordance with the applicable procedure.
59	Quality Control Surveillance
60	Camera Alignment and Calibration The cameras are aligned and calibrated in accordance with the applicable procedure.
61	Quality Control Surveillance

For the post-RA-6 system, a traveler flow chart (Figure 41) was utilized which offered greater flexibility in programming the unique operations required for each assembly, in addition to providing the controls afforded by the control tag.

TABLE 35
SUMMARY OF FLOW CHART OPERATION DESCRIPTIONS FOR RANGER TV SUBSYSTEM INTEGRATION (Continued)

Step Number	Operation Description
62	Outdoor Pictures A. Subsystem mounted to align fixtures B. Subsystem transported to site C. Take pictures D. Subsystem transported to Integration Area
63	Quality Control Surveillance
64	Final Acceptance Test A. Subsystem prepared for test B. Subsystem tested
65	RCA Quality Control Surveillance
66	JPL Quality Assurance Surveillance
67	Final Mechanical Assembly
68	Final Inspection by RCA Quality Control and JPL Quality Assurance
69	Final Electrical Check
70	Quality Control Surveillance
71	Package Subsystem for Shipment
72	Quality Control Surveillance
73	Deliver to JPL

b. UNIT PERFORMANCE RECORD (FIGURE 42)

The unit performance record (UPR) was designed to aid both quality control and manufacturing. It served quality control as a record of all inspections performed and reflected ultimate acceptance of a given unit for each inspection station. It also provided manufacturing with detailed defect descriptions necessary to perform rework.

The unit performance record was used throughout the entire program with only the addition of chronological numbering during the post-RA-6 phase to facilitate the cross-referencing

TABLE 36
RANGER FLOW CHARTS AND CHECKLISTS

PQCC No.	Flow Charts
1	Black Box Retrofit (Disassemble and Rework)
2	Black Box Reassembly
3	Black Box Testing and Delivery to Integration
4	Harness Retrofit
5	Transmitter Retrofit
6	Telemetry Chassis Retrofit
7	Transmitter Power Supply Retrofit
8	Power Amplifier Retrofit
9	TV Subsystem RA-7
10	TV Subsystem PTM
11	TV Subsystem RA-8
12	Not used
13	Special Rework Cycle RA-8 TV
14	Camera Electronics-Special Rework of A 3 Frame Video Amp Board (10-7-64)
PQCL No.	**Check Lists**
1	Black Box - Inspection Station 2; Flow Chart 1
2	Black Box - Inspection Station 3; Flow Chart 1
3	Black Box - Inspection Station 11; Flow Chart 1
4	Black Box - Inspection Station 1; Flow Chart 2
5	Parts Replacement PTM and Flight Models
6	Black Box Test - Flow Chart 3; Station 1
100	TV Subsystem Mechanical Assembly Inspection
101	Pre-Test Inspection TV Subsystem
102	Pre-Turn-on Inspection TV Subsystem
103	Surveillance of Electrical Test TV Subsystem
104	Final Inspection - TV Subsystem
104A	Inspection Before Weighing - TV Subsystem
105	Delivery to JPL - TV Substem
106	Inspection Check List of Cameras
107	Trip Recorder - TV Subsystem
108	Delivery to ETR - TV Subsystem
109	Visual Inspection Upon Arrival at ETR - TV Subsystem
110	Initial Inspection Before Test at ETR - TV Subsystem
200	Visual Inspection Upon Arrival at ETR - TV Subsystem
118	Final Inspection at ETR - TV Subsystem
120	Black Box Packing and Shipping
121	All Shutters

NO.

QUALITY CONTROL HOLD NOTICE

TO: DATE:

REFERENCE "Quality Action Notice" No. Date

ACTIVITY AFFECTED: PROJECT

OPERATION: ☐ IN-PROCESS ____ ☐ TEST ____

☐ FINAL ____ ☐ OTHER ____

EQUIPMENT:

☐ PART(S) ☐ COMPONENT(S) ☐ SYSTEM(S) DWG. NO.(S) ____ SER/KIT NO.(S) ____

Quality Control acceptance of the above equipment/operation is withheld at the point(s) indicated pending correction of:

CC:

AUTHORIZED SIGNATURE:

QUALITY CONTROL MGR. DATE

TO BE COMPLETED BY ADDRESSEE

Cause for above condition:

Corrective Action taken:

Effectivity date:

Signature ____ Title ____ Date ____

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Figure 39. Quality Control Hold Notice (Front)

(TO BE COMPLETED BY QUALITY CONTROL ACTIVITY)

Corrective Action verification performed:

Results observed/recorded:

Corrective Action ☐ Accepted ☐ Rejected ☐ Acceptance Withheld (State reason (s)

Signature ______________________ Title ____________________ Date ____________

Figure 39. Quality Control Hold Notice (Back)

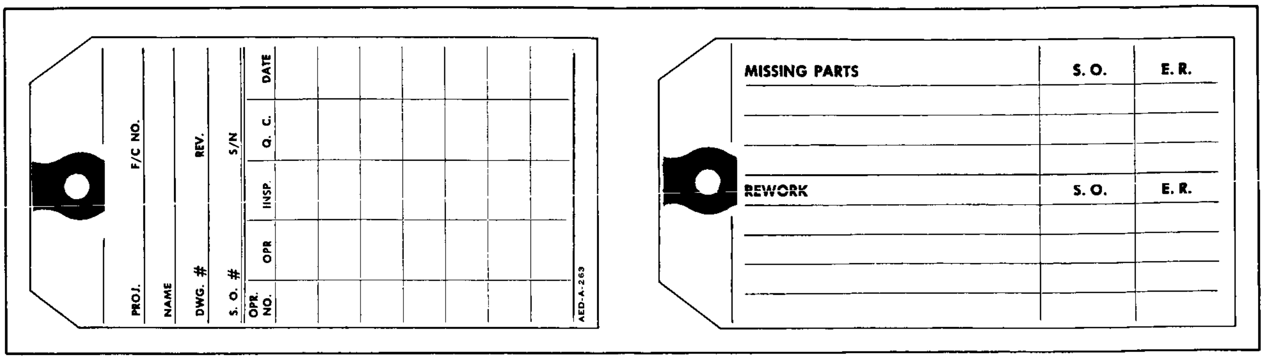

Figure 40. Equipment Travel Tag

of UPR's to the JPL Inspection Report.

c. ENVIRONMENTAL TEST SUMMARY (FIGURE 43)

The purpose of the environmental test summary (ETS) was to document the performance of an environmental test and to clearly reflect the acceptance or rejection of the test results by quality control. This form was completed by the product quality control specialist at the time that the test was being monitored. It was through the use of this document that the JPL test results summary forms were completed on environmental tests prior to the post RA-6 program.

d. EQUIPMENT LOG BOOK (FIGURE 44)

A separate equipment log book was maintained by RCA for each assembly and for each TV Subsystem. The log books contained a life history of the unit from the start of electrical tests through the completion of the environmental program.

New log books were initiated for each black box as they were disassembled for the post-RA-6 phase of the program. Thus the log books contained not only test information but also manufacturing and quality-control process information. In addition the log book served as the focal point for accumulation of the high level of documentation maintained during the post-RA-6 program.

Each serialized unit had a log book, which accompanied the unit through all phases of the assembly and test operation. Contained in the log book were a copy of test data for both environmental and acceptance tests to Ranger Test Specifications; test result summary forms for tests performed during the post-RA-6 program; all unit performance records; all traveler flow charts and quality control check lists; time of "power on" equipment; and a copy of each malfunction report. Entries were in sufficient detail to permit an understanding of the stated action or else they provided a complete reference to the document in which this detail could be found. Each entry was dated and either signed or stamped by the operator or inspector.

The log book and appended data and records for each unit were reviewed for completeness as part of the final quality-control approval. The unit log book was then filed in the Ranger quality documentation file. When a unit had been released to the TV Subsystem integration area for final assembly into the TV structure and, at a later date, was removed from the integration area, it was necessary that the unit and the logbook be approved by the quality control office before the unit could be resubmitted to the integration area.

PROJECT RANGER
TRAVELER FLOW CHART

Page 1 of 2

UNIT SN DRAWING REV.

OPERATION	OPER. STAMP	DATE	OPERATION	OPER. STAMP	DATE
Disassembly			Quality Control		
QC Inspection			JPL		
Quality Control			Photo		
JPL			Conf. Coating		
Rework or Assembly			Pre Cure Inspection		
QC Inspection			Cure		
Quality Control			Post Cure Inspection		
JPL			Quality Control		
Conf. Coating			JPL		
Pre Cure Inspection			Photo		
Cure			Assy. /Inspection		
Post Cure Inspection			Quality Control		
Quality Control			Test		
JPL			QC/JPL		
Photo			Pre Vibration		
Conf. Coating			Vibration		
Pre Cure Inspection			Post Vibration		
Post Cure Inspection			Pre Thermal Vacuum		

Figure 41. Traveler Flow Chart (Page 1)

PROJECT RANGER
TRAVELER FLOW CHART

Page 2 of 2

UNIT SN DRAWING REV.

OPERATION	OPER. STAMP	DATE	OPERATION	OPER. STAMP	DATE
Thermal Vacuum					
Post Thermal Vacuum					
Final Quality Control					
Final JPL					

Figure 41. Traveler Flow Chart (Page 2)

No. 9805

RCA QUALITY CONTROL
DEFENSE ELECTRONIC PRODUCTS

UNIT PERFORMANCE RECORD

SUB-CHASSIS NAME____________________ Line #________________

DEF. #	DATE	INSPECTION OR TEST STATION	DEFECT DESCRIPTION	TIME OF FAILURE	INSP. STAMP	REPAIR	REPAIR CHECK OFF	MAJOR	MINOR

DE 245

Figure 42. Unit Performance Record (Front)

REQUEST FOR GOVERNMENT INSPECTION

DATE	TIME AM PM		BUILDING FLOOR
QUANTITY	NOMENCLATURE	M. I. No.	DRAWING OR SPECIFICATION
CONTRACT NO.	LINE OR SERIAL No.		S. M. OR S. O. No.

REMARKS:

☐ ACCEPTED ☐ REJECTED	SIGNATURE	DATE

Figure 42. Unit Performance Record (Back)

RCA

DEFENSE ELECTRONIC PRODUCTS
ASTRO-ELECTRONICS DIVISION
PRINCETON, NEW JERSEY

TEST SUMMARY No 0852

ENVIRONMENTAL TEST SUMMARY

PROJECT NAME		ITEM NAME		S/N	DATE / /
AED DWG. #	REV.	ITEM SPEC. #	REV.		TYPE OF TEST
TEST SPEC. #	REV.	TEST PROC. #	REV.		QUAL. ☐
TESTED TO ENV. SPEC. YES ☐ NO ☐	TEST EQUIP. CAL. YES ☐ NO ☐	ETR #	VISUAL INSP. YES ☐ NO ☐		ACCEPT ☐
TYPE ENV. TEST		TEST FACILITY	ENV. FAC. LOG #		RETEST ☐
LIST DEVIATIONS TO SPEC. IN COLUMNS BELOW					OTHER

				TIME (MIN.)			

REMARKS:

DES LOG #	DESIGN ENGINEER	ENVIRONMENTAL ENGINEER	MALFUNCTION REPORT #
ACCEPTED ☐ REJECTED ☐ HOLD ☐		QUALITY CONTROL	DATE / /

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Figure 43. Environmental Test Summary

29

SECURITY CLASSIFICATION (THIS PAGE) ____________________

LOG NUMBER ____________ SYSTEM SERIAL NUMBER ____________

EQUIPMENT LOG FOR ____________________
(Subsystem, Major Unit, Etc.)

EQUIPMENT SERIAL NUMBER (S) ____________________

DESCRIBE OR REFERENCE OPERATING, MAINTENANCE TEST AND OTHER PERTINENT INFORMATION DATE AND SIGN EACH ENTRY (1)	TIME AND HOURS OF OPERATION (2)	TYPE OF OPERATION (3)		CUMULATIVE OPERATING TIME (4)	
		STANDBY ✓	ON ✓	STANDBY	ON

Figure 44. Equipment Log Book

4. Central File

From the start of the program, product quality control maintained a documentation file on UPR's and travel tags, along with a chronological file of the environmental test summary form. The equipment log books were maintained by the cognizant design engineer. At the start of the post-RA-6 program this procedure was modified to provide a central log book and quality control file containing all documentation associated with the acceptance of Ranger assemblies. This acceptance data, in addition to including the documentation already described, included 8 x 10 color photographs, malfunction reports, copies of JPL inspection reports, copies of JPL test summary forms, and material review actions.

5. Documentation Package

All deliveries of spacecraft after the start of the post-RA-6 program were supported by a comprehensive documentation package. The package was a reproduction of much of the data included in the central file and involved several volumes for each shipment. The contents of the documentation package are shown in Table 37.

6. Photographic Documentation

Photographic documentation of assemblies required by the contract was performed and submitted from the start of the program. For the post-RA-6 program this effort was repeated.

Photographs were taken of all modules, reworked qualification test units, PTM and flight units. Three 8 x 10 colored photographs and their negatives were transmitted to JPL. The photos were representative of the latest flight configuration and were taken so that component placement, wiring, soldering and workmanship details were clear.

7. Malfunction Reporting

The product quality control activity monitored all black-box acceptance-level and spacecraft tests performed at RCA, JPL (Pasadena) and ETR. The quality control personnel reported all malfunctions to the reliability engineering activity and Ranger product assurance engineer by the issuing of a quality control notice (Figure 45). This notice identified the problem, equipment and date of the malfunction. The malfunction report was prepared after the problem had been isolated, and provided a more detailed malfunction description (See Reliability Section for details and illustration).

For the post-RA-6 program, the above procedure was modified to eliminate the use of the quality action notice. Quality Control was assigned the responsibility for preparing the malfunction report at the time of a malfunction occurrence.

8. Inspection Techniques

Various inspection techniques were developed to control the quality of the Ranger assemblies.

a. PIN RETENTION

Pin-retention tests were performed on all connectors assembled on a unit on cable harnesses and were identified as having been tested by using a dot of green paint on the body of the connector. A complete pin-retention test was repeated on every connector of the TV Subsystem prior to shipment to JPL.

b. ULTRAVIOLET TRACER

An ultraviolet tracer was placed in the urethane conformal-coating material as an inspection aid. Inspection was performed using a black light and the ultraviolet tracer aid in determining the thickness of the conformal coating on components and terminals.

TABLE 37 CONTENTS OF DOCUMENTATION PACKAGE	
1	Contract definition and acceptance form. AED-273 6/62
2	Customer-accepted nonconformances. AED-269 6/62
3	Supplementary contract definition. AED-270 6/62
4	Supplementary contract definition. AED-270 6/62
5	Packaging, packing and shipping. AED-279 6/62
6	List of ship-loose items. AED-274 6/62
7	Conformance verification - Control drawing acceptance criteria conformances. AED-277 6/62
8	Conformance verification - Acceptance test data. AED-278 6/62
9	Certificates of compliance for special processes and materials. AED-280 6/62
10	Age-sensitivite items. AED-281
11	Equipment time records. AED-282
12	Request for customer inspection. AED-268
13	Inspection check lists 100 - 101 - 102 - 103 - 104 - 104A - 105 - 106 - 107 - 200.
14	Unit performance record (UPR).
15	Material review action (MRA). AED-411 2/63
16	Perpetual inventory operating time of shutters and 15- and 90-point commutators.
17	Record of shutter changes and shutter log.
18	Cumulative operating time of complete TV Subsystem.
19	Log of batteries consisting of all pertinent test data by individual serial number.
20	Weight by black box. (pounds and ounces)
21	Test Results Summary Form.
22	One copy of all failure reports.
23	One copy of all ECN's not incorporated on drawings at time of shipment from RCA.

QUALITY CONTROL NOTICE

TO: DATE:

FROM:

SUBJECT: Failure Report

DATE OF FAILURE ____________ TIME OF FAILURE ____________

EQUIPMENT ____________

DESCRIPTION OF FAILURE ____________

SIGNATURE - QUALITY CONTROL

cc: Engineering Reliability
Project Product Assurance
A. W. Anastasia

AED-529 2/64

Figure 45. Quality Control Notice

c. QUALITY CONTROL "DON'T BREAK" SEALS

After quality control acceptance of all units and prior to bench test, the quality control specialist affixed a serialized "Don't Break" seal to the unit. The seal was placed on the unit in such a manner as to preclude the unauthorized opening of the unit without damaging the seal. The serial numbers of the seals were recorded in the equipment log at the time the seals were affixed to the unit. In the event that a unit had to be opened, the quality control specialist was the only person authorized to break the seal. When the seal was broken, a UPR and log entries were completed, indicating the reason for the breaking of the seal.

d. WEIGHT OF BLACK BOXES

Each black box was weighed before it was mounted on the spacecraft. The weight of each assembly was recorded in the spacecraft integration equipment log and on PQC check list 100.

E. MATERIAL REVIEW

Reviews were held both to establish the status of nonforming materials and to determine the extent of retesting required following rework performed after flight acceptance.

1. Nonconforming Material

a. CLASSIFICATION

Material found to differ from specifications requirements or found to be incapable of standard repair was diverted from normal material movement and handled as nonconforming material. Its review, control, and disposition were accomplished in accordance with the quality control manual procedures pertaining to the coordinated standard repair list, preliminary material review, and formal material review. On all such material the Ranger product assurance engineer and the JPL quality assurance representative were contacted and advised of the nonconformance.

b. REVIEW PROCEDURE

Each of the RCA Divisions assembling equipment for the Ranger TV Subsystem maintained a standard repair list which itemized satisfactory repair to certain manufacturing defects. If material required repairs beyond the scope of the standard repair list, a preliminary review was conducted by the quality control specialist and the engineer concerned to establish which of four courses of action should be taken. Possible actions were (1) to scrap, (2) to complete operation, (3) to use "as is" (JPL reserved the right to require formal material review board (MRB) action on this category), and (4) to hold for formal MRB action.

In the post-RA-6 program, the category of preliminary review was eliminated and all repairs beyond the scope of the standard repair list were submitted for formal review.

Formal review was accomplished by a Material Review Board composed of the JPL project engineer, the RCA quality control engineer, the RCA equipment engineer concerned with the Ranger project staff product assurance engineer. Concurrence of all board members was requisite to approval of action recommendations.

c. MATERIAL REVIEW ACTIONS

A summary of the formal material review items covered during the course of the post-RA-6 program is presented in Table 38 below. A total of 196 review actions were conducted on the equipment forming the RA-7, -8, and -9, and spares 1 and 2 Subsystems.

2. Test Review Board

When Ranger assemblies required rework during or after flight acceptance test, a test

TABLE 38
SUMMARY OF MATERIAL REVIEW ACTIONS

MRA Classification	Number of MRA's	Percentage of Total
Workmanship or deviation from drawing: Use "as is"	60	30.6
Workmanship: Repair beyond scope of standard repair list	43	21.9
Design: Drawing change required	16	8.2
Deviation from specification: Use "as is"	46	23.5
Deviation from specification: Specification revised	9	4.6
Deviation from flow: Use "as is"	18	9.2
Test error and/or test equipment problem	4	2.0
	196	100%

review board was responsible for establishing the level of retest necessary to recertify the unit. The board was composed of the design engineer concerned, the equipment project engineer, the Ranger product assurance engineer, and the JPL resident engineer. Concurrence of all board members was required to establish the extent of retest necessary. A sample of a review board action memorandum is shown in Figure 46.

During the course of the program, 170 test review actions were conducted on equipment after satisfactorily passing an initial flight-acceptance test. Included in the 170 were 27 review actions which were written against complete equipment groups (for example Camera and Camera Electronics). Table 39 lists the reasons for review action and the type of test performed.

F. FIELD SUPPORT

Field support of the TV Subsystem was provided at JPL (Pasadena) and at the Eastern Test Range (ETR) by Product Quality Control at a level comparable to that maintained in the integration and test areas at RCA.

1. Assembly Support

Quality control specialists assigned to field support were responsible for performing inspections and test monitoring on flight hardware at predetermined points in accordance with JPL and RCA test procedures and assembly operations.

All material received from RCA was inspected upon arrival at the field site (either JPL Pasadena or ETR). No material was mounted on the Subsystem without approval of the quality control specialists. Upon completion of assembly operations, an inspection was performed on flight hardware before the equipment was released for acceptance testing.

2. Testing Support

Tests conducted on the TV Subsystem were monitored 100 percent by the quality control representative. Inspections and acceptance tests performed in the field were submitted to JPL on AED 268 form (Request for Customer Inspection). Rework, modifications, and/or ECN incorporation required in the field were

INTERNAL CORRESPONDENCE

To Distribution | Location Varied | Date January 6, 1965

From Review Board | Location AED | RTRB 132

Subject

1.0 Assembly

1.1 Name: Sequencer

1.2 Serial Number: 0002

2.0 Description of Failure and/or Defect

2.1 Malfunction Report No. 1527 dated 10/27/64

2.2 List of Failed Components or Defect

None: Video gate not switching off during horizon blanking of P1.

2.3 Description of Repair Action

Replace Inter Frame connecting cable.

2.4 Disposition of Repaired Assembly

Inspection RCA and JPL Q.C.
Perform paragraph 4.3 of RTSP 1121.

R. G. Abrams
Chairman of the Review Board

Distribution:
J. Graham (5)
S. Flood
R. Kramer (5)
K. Tate (JPL)
D. Kindt (JPL)
Project Staff
R. Ficken
B. Mulholland
G. Paxton
A. Gravel
F. Beisel

Attendees: At JPL 12/30/64
D. Kindt, R. Smith, B.P. Miller, G. Abrams

Figure 46. Sample of Review Board Action Memorandum

TABLE 39
REVIEW BOARD ACTIONS

Test Performed	Reason for Review Action				Total	Percentage of Total
	Redesign	Realignment	Parts Replacement	Correction of Defect		
Complete flight acceptance	17	--	25	--	42	24%
Performance only	16	1	39	9	65	38%
Vibration and performance	5	--	10	1	16	10%
Thermal vacuum and performance	1	2	7	1	11	7%
Qualification	12	--	--	--	12	7%
Thermal	--	2	6	--	8	4%
Special engineering	1	2	2	--	5	3%
Inspection only	6	--	4	1	11	7%
Total	58	7	93	12	170	100%
Percentage of total	34%	4%	55%	7%	100%	

inspected and retested. The quality control specialist monitored all the required operations.

Prior to launch, the quality control specialist completed the Ranger TV Subsystem Prelaunch Checklist 118. Completion of this list verified the acceptability of the conditions checked. Some typical conditions checked were the pressurization of the Power Amplifier Assembly, the correct mating of all harness connectors, the proper amount of torque applied to mounting hardware, the conditions of potting and conformal coating, and the proper installation of batteries and camera equipment.

3. Reporting and Documentation

Malfunction reports were issued whenever a failure occurred on the TV Subsystem. They were completed at the time of failure, distributed to the field, and forwarded to the Engineering Reliability activity at RCA. Quality Control assured that a JPL Problem/Failure Report was completed for each RCA malfunction report.

Narrative reports were submitted to Product Assurance on a weekly basis. These reports contained results of inspections performed, descriptions and results of tests monitored, the number of malfunction reports issued, and other pertinent information. When an emergency arose which required immediate action by an activity at RCA, QC notified the activity by telephone without delay.

Records were maintained for all inspections and tests monitored by quality control. These consisted of unit performance records, requests for customer inspection (AED-268) quality control checklists, equipment time records, quality control log books, and equipment log books. Copies of these records were forwarded to RCA Product Quality Control department on a weekly basis for filing in the Ranger documentation control center.

4. Equipment Return

The quality control specialist monitored the packaging, packing, and shipping of all RCA hardware from JPL to ETR and material being returned to RCA for rework or modification and test. The applicable JPL paperwork was delivered with the shipment.

G. WORKMANSHIP STANDARDS AND SPECIFICATIONS

1. Documentation of Standards

Workmanship standards for the Ranger TV Subsystem equipment conformed to the requirements of Defense Electronic Products standards as modified by contract agreement. These workmanship standards were set forth in RCA Specifications on Design, Manufacturing, and Workmanship for Ranger Television System dated March 10, 1962, after a thorough review of the JPL specifications by RCA Central Engineering. This document provided, in one publication, a list of all applicable specifications and copies of those specifications generated to supplement existing RCA standards. It was divided into three sections: design and drafting information, manufacturing information, and workmanship and quality control information.

2. Manufacturing Specifications

Table 40 lists the type, number, and title of the applicable manufacturing specifications.

3. Workmanship Requirements and Practices

The general specification for Ranger Workmanship (Specification 8030001) governed, although certain additional requirements applied. Among these were use of the following: thermal wire strippers; bifurcated terminals on printed circuit boards; hard-mounting techniques; non-fungus-nutrient materials; locking-type nuts for all fastenings; deburring to remove sharp edges on sheet metal parts; and stamping or stenciling of nameplate information on flight hardware. In the following paragraphs certain of these workmanship practices are described more fully.

a. PRINTED WIRING TERMINAL BOARD TECHNIQUE

Ranger electronic components were packaged utilizing printed wiring terminal board techniques. This technique employed a printed wiring board as a base, on which components were mounted to terminals, which in turn had been mounted to the printed wiring board and soldered normally (See figure 47a).

b. MATERIALS

The base material of the wiring boards was a copper-clad glass-epoxy laminate. All solder used was 60/40 (tin/lead) composition conforming to specifications QQ-S-571. Flux for soldering was rosin base. No acid fluxes were used in preparation or during soldering. Terminals were of the bifurcated type, gold-plated, and mechanically secured to the base material by rolling.

c. COMPONENT MOUNTING

Components lay on the wiring board and were secured by a coating fillet applied during the

TABLE 40
MANUFACTURING SPECIFICATIONS

Type of Specification	Number	Title
Manufacturing	1985983	Finish, Black Epoxy-Polyamide Coating
Manufacturing	2020255	Bonding with Epoxy Adhesives
Manufacturing	2020303	Repair of Printed Wiring Boards
Manufacturing	2020376	Application of Urethane Coating to Printed Circuit Boards
Manufacturing	2020388	Treatment for Making Polyethylene Bondable
Manufacturing	2020389	Chemical Cleaning of Printed Circuit Boards
Manufacturing	2020390	Mechanical Cleaning of Printed Circuit Boards
Manufacturing	2020391	Circuit Screen Printing of Wiring Boards
Manufacturing	2020394	Etching of Printed Circuits (Mechanized)
Manufacturing	2020401	Screen-Resist Stripping
Manufacturing	2020473	Bonding and Coating Printed Circuit Assemblies
Manufacturing	2020474	Immersion Tin Plating of Printed Circuits
Manufacturing	2020476	Electrostatic and Magnetic Shielding of Camera Electronic Frames
Manufacturing	2020479	Soldering by Means of Flux-Cored Solder Preforms
Manufacturing	2020483	Chemical Treatment for Magnesium Alloys
Manufacturing	2020487	Insulating Tubing—Heat-Shrinkable—Application of Irradiated Polyolefin

board-coating operation (see Figures 47b and 47c). Leads of the components located above the terminals were bent down to be secured in the terminals (see Figure 47d). More than one lead was placed in a bifurcated terminal provided that the maximum capacity of the terminal was not exceeded. Maximum terminal capacity was reached when more than one-third of the top lead was protruding above the top of the terminal (see Figure 47e).

d. PAD REQUIREMENTS FOR PRINTED WIRING

Pads were designed to enable final product requirements to be achieved. Thus, when pad sizes were chosen, consideration had to be given to allowances for human error and fabrication tolerances. The minimum pad diameter was determined by adding the maximum terminal body diameter to 0.055 inch (fabrication tolerance plus twice the minimum pad extension beyond the body). For example, for a maximum terminal body diameter of 0.095 inch, the minimum pad diameter would be 0.150 inch (0.095 + 0.055 = 0.150). When pads having diameters greater than minimum were utilized, the pads were trimmed where required to facilitate routing of printed wiring conductors. When trimmed, however, the diameter remaining was no less than the minimum pad diameter for that terminal (See Figure 47f).

e. DIMENSIONAL TOLERANCES OF PRINTED CIRCUITRY

The following minimum dimensions were the minimum requirements for printed circuitry used on the Ranger program:

Path width	0.032 inch
Clearance between printed wiring and other conductors	0.030 inch
Printed wiring radius	0.036 inch
Printed wiring fillets	0.036 inch
Printed wiring clearance to board edge	0.065 inch
Clearance to cut-outs or holes within board (excluding terminal holes)	0.040 inch
Terminal-to-terminal clearance	0.060 inch

f. SECURING OF COMPONENTS (SPOT-POTTING)

All terminal boards were treated with a coating which had no deleterious effects on the assembled terminal boards or upon parts within assemblies. Components were secured by adhesives which similarly had no deleterious effects. A fillet of potting between the component and board was used where possible. Where potting would not adhere, the materials were encapsulated. All coatings and adhesives were oil-proof and nonfungus-nutrient.

g. POST-RA-6 CONFORMAL COATING

As part of the post-RA-6 program, RCA Manufacturing Specification 2021015 was used to delineate conformal coating requirements. The specification was divided into six parts as follows:

2021015-1	Coating of uninsulated conductors which are subjected to less than 300 volts;
2021015-2	Insulation of back side of Cannon D connectors;
2021015-3	Coating of uninsulated conductors which are subjected to more than 300 volts;
2021015-4	Spot bonding of parts, wires and other special requirements;
2021015-5	Potting of harness connectors;
2021015-6	Fabrication of P- and F-type shutter isolators.

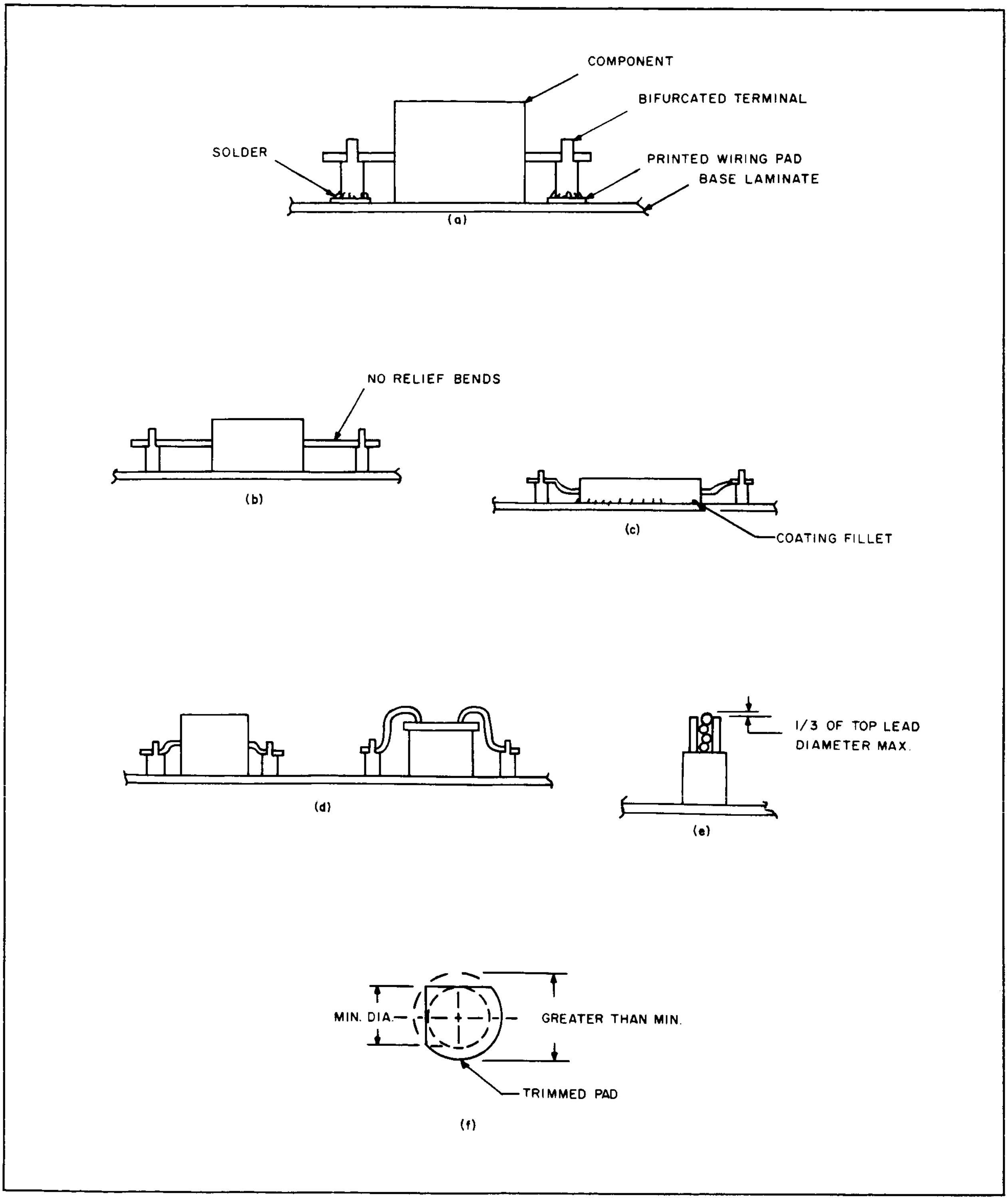

Figure 47. Mounting Techniques

Section IV

Summary of Ranger TV Subsystem Test Program

A. INTRODUCTION

The testing philosophy applied to the Ranger TV Subsystem consisted of operation verification at the assembly and subsystem levels. The testing program was designed to demonstrate performance, verify design, and ensure the delivery of reliable equipment. Both electrical and environmental tests were performed at the assembly and subassembly levels to ensure proper operation when integrated with the Subsystem. The electrical testing was designed to evaluate the operation at ambient conditions prior to testing under environmental conditions. Electrical tests were also performed during some environmental tests (e.g., thermal-vacuum), and after the completion of environmental tests.

Environmental testing was performed to demonstrate the capability of the TV Subsystem to reliably meet the required design characteristics in the environments anticipated during its operational life. A prototype model of each of the assemblies was subjected to the qualification tests in order to obtain type-approval for the use of similar assemblies in the proof test model and the flight models. Similar qualification tests were conducted on the mechanical test and thermal control models in order to demonstrate the adequacy of the structural configuration and the thermal-control techniques. Electrical and environmental tests of the proof test model demonstrated the operation of the overall TV Subsystem. All flight model and spare assemblies were subjected to acceptance tests, as were the flight models of the overall TV Subsystem, to demonstrate the electrical performance of the assemblies and the Subsystem after exposure to the space environment.

The environmental tests conducted on each subassembly and on the complete TV Subsystem were performed in accordance with the governing specifications. These specifications determined the required configuration of the test unit, the types and levels of testing to be performed, and the required mechanical, electrical, and optical performance to be obtained during and after the tests.

Assembly-level tests were conducted either for qualification (type approval) or for acceptance of assemblies to be installed as part of the TV Subsystem. Qualification tests were performed on one prototype assembly of each type to demonstrate conformance to the detailed specifications. The environmental tests performed as part of the qualification testing were intended to simulate the actual environments to be experienced by these assemblies, with an appropriate margin of safety.

The assembly-level test environments for qualification and acceptance testing are defined by RCA Specification 1171807, "Assembly-Level Environmental Specification for the Ranger TV Subsystem." This document governs all environmental testing to be performed at the assembly level. The specifications are summarized in Volume 1 of this report. Figures 48 and 49 illustrate the sequence of major events during testing of the PTM and flight models respectively. Figure 50 is a flow chart of Ranger TV Subsystem environmental tests performed from January 1962 through December 1964. These tests were performed in accordance with RCA Ranger Specification RTSP-1101. "Test Specification for the Environmental Testing of the Proof Test Model and the Flight Models of the Ranger TV Subsystem".

Environmental testing of the TV Subsystem at RCA was performed without the JPL Ranger Spacecraft; the command capability of the JPL

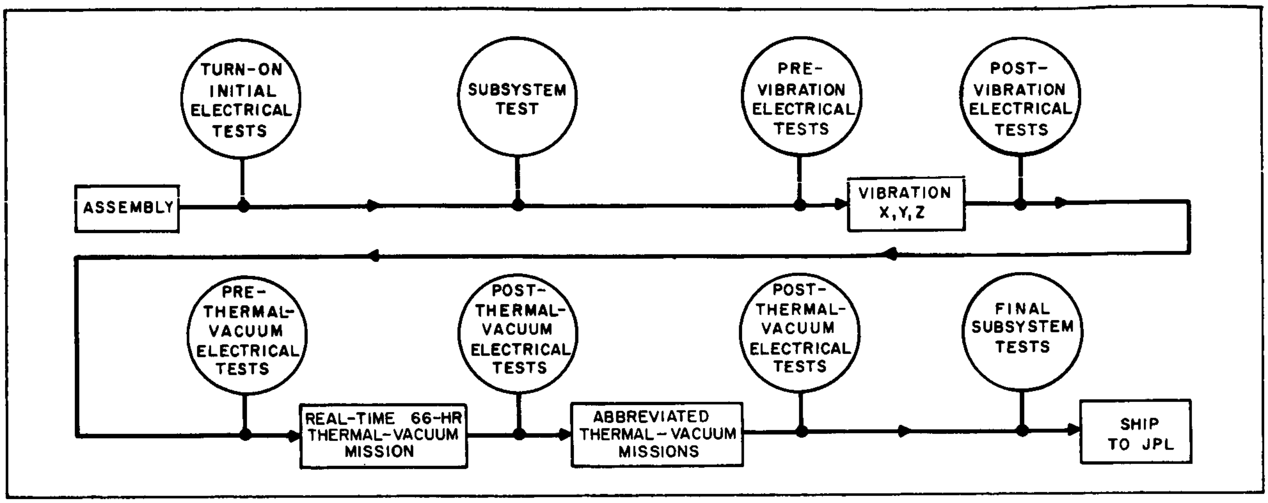

Figure 48. Sequence of Major Events During Testing of PTM

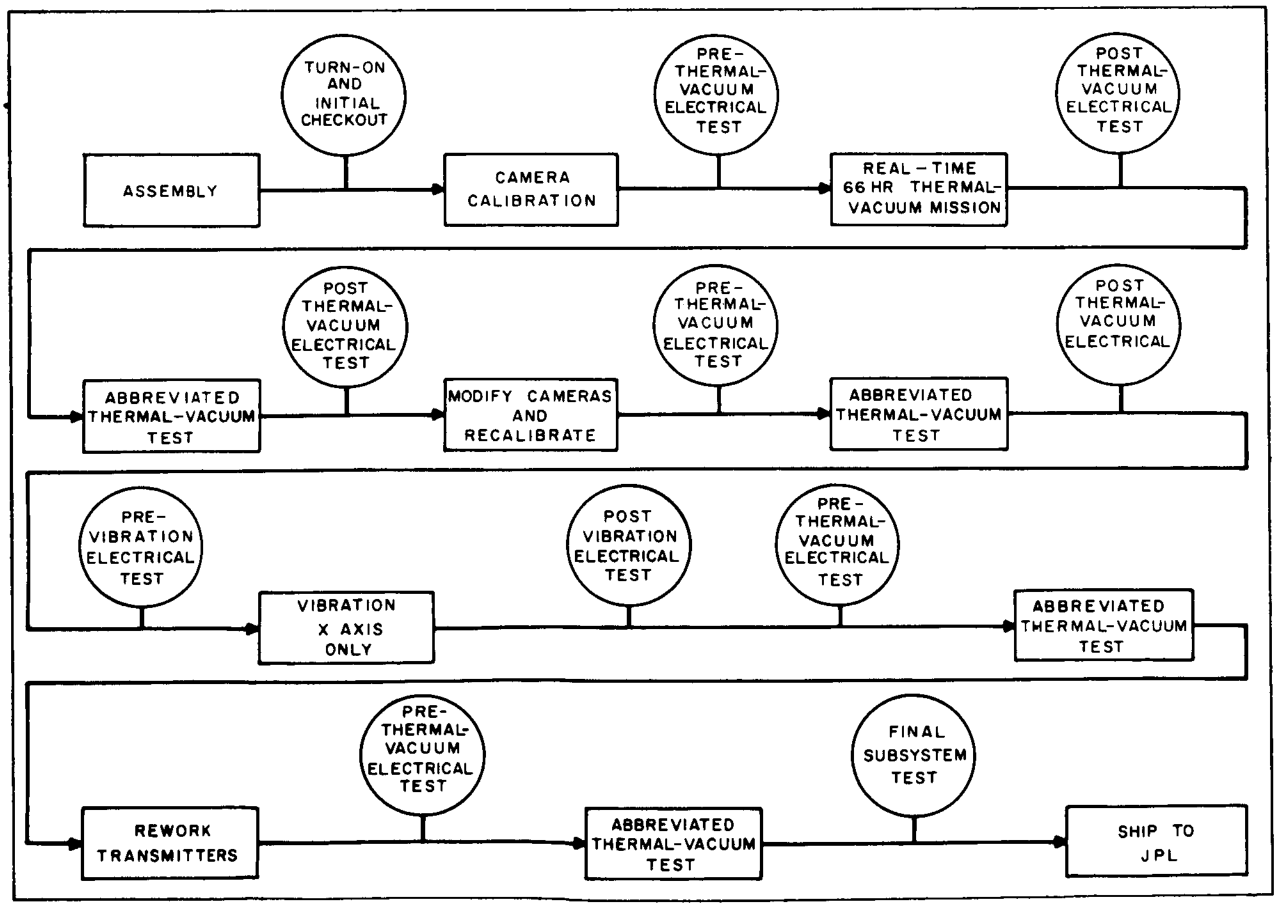

Figure 49. Sequence of Major Events During Testing of Flight Models

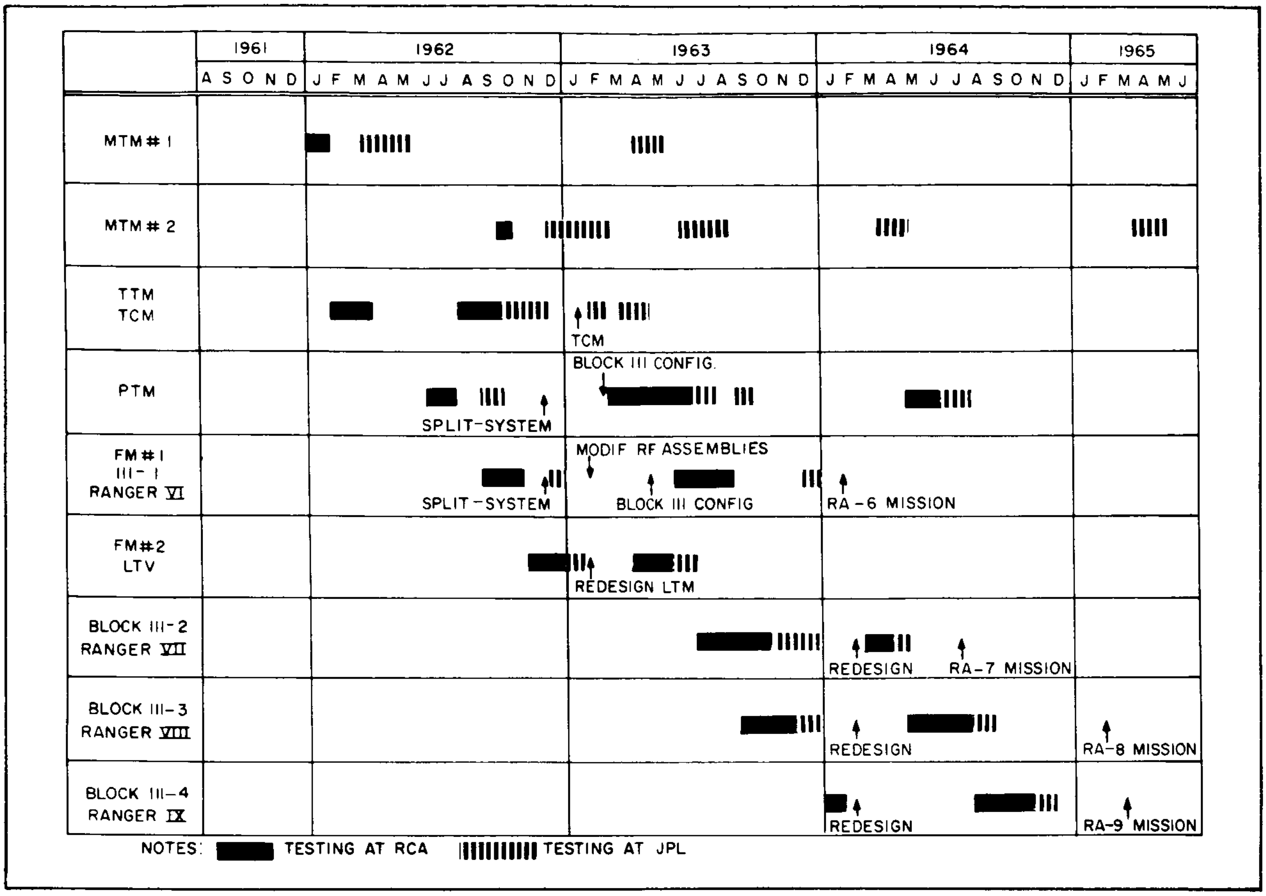

Figure 50. Flow-Chart of Ranger TV Subsystem Environmental Testing

Ranger Spacecraft was simulated by the RCA operational support equipment. Figure 51 shows the TV Subsystem test configuration without the JPL Ranger Spacecraft. Collimated light sources were used to stimulate the cameras during testing. The procedures for electrically testing the TV Subsystem during and after environmental exposure are detailed in RCA Ranger Specification RTSP-1100, "Test Specification for the Ranger TV Subsystem". The hardline video output capability of the RCA Test Connector was not used in the final (system-test) configuration. Instead, the TV Subsystem was commanded via the RCA/JPL Interface Connector, and the video and telemetry outputs were provided to the RCA operational support equipment from the RF output connector.

When the TV Subsystem was installed on the Ranger Spacecraft, the command function was assumed by the Spacecraft. Externally generated commands could be provided by either the RCA Command Console or the JPL operational support equipment. During system tests, the hardline video output from the RCA Test Connector was furnished to the RCA operational support equipment when the TV Subsystem was in the warm-up mode. The output from the RF Output Connector was used during full-power operation, and video and telemetry data were relayed to the RCA operational support equipment via the Ranger Spacecraft and JPL operational support equipment. Figure 52 illustrates the TV Subsystem test configuration with the Ranger Spacecraft.

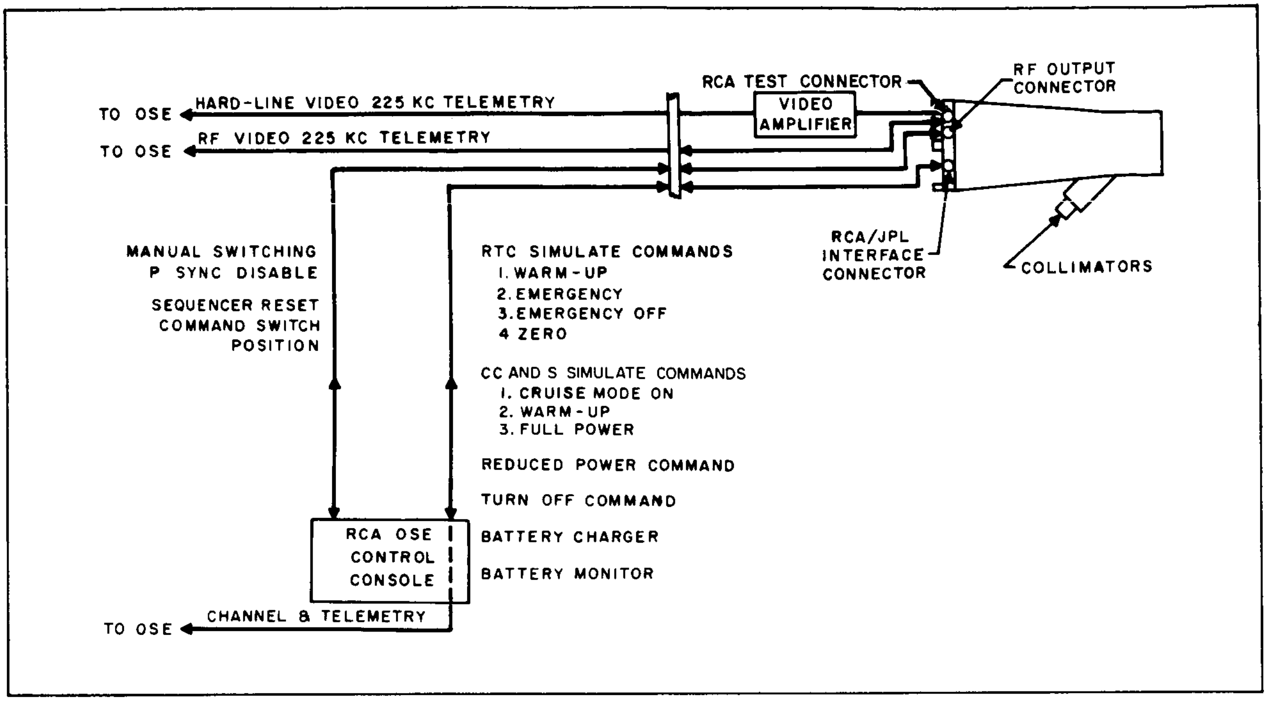

Figure 51. TV Subsystem Test Configuration (Without Spacecraft Bus)

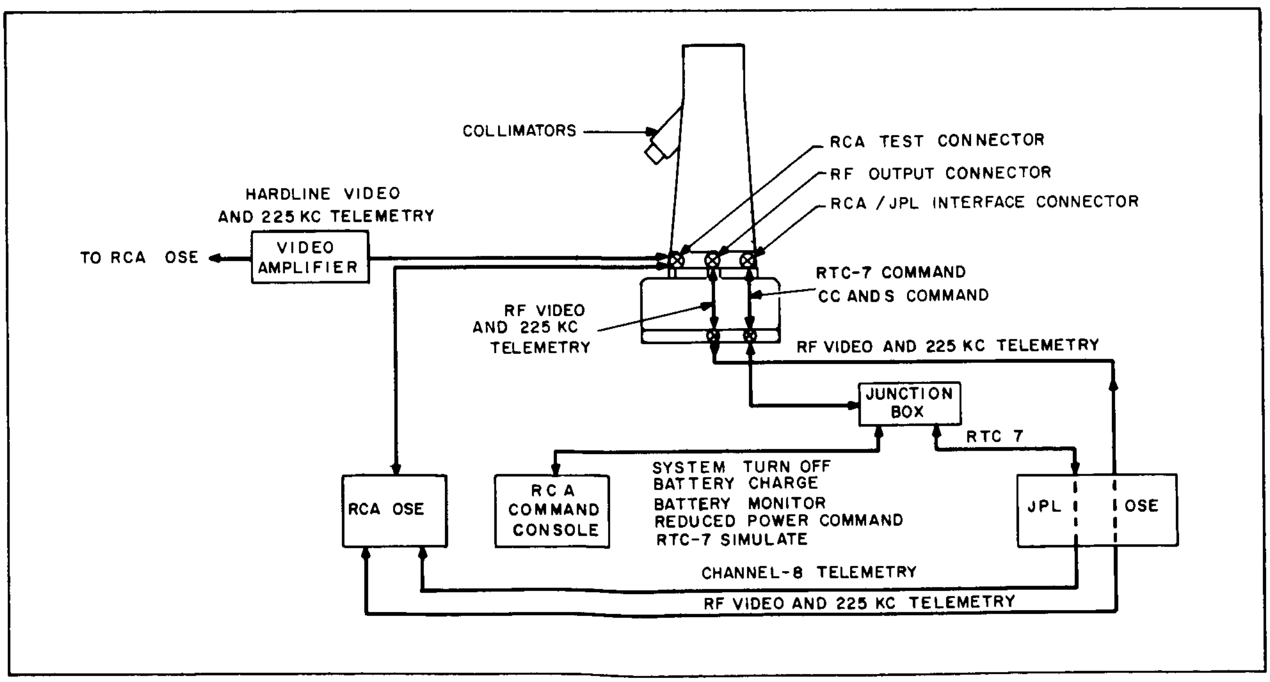

Figure 52. TV Subsystem Test Configuration (With Spacecraft Bus)

In the launch pad test configuration (see Figure 53), the TV Subsystem was commanded by the spacecraft CC&S. Externally generated commands were provided to the spacecraft from the blockhouse through the umbilical connector. The video and telemetry test outputs were relayed from the launch area to RCA receiving equipment at the AM building, and were displayed on the RCA operational support equipment. All launch-pad testing was performed in a reduced-power mode; GO-NO-GO test lamps in the Agena shroud were used to stimulate the cameras during this testing.

B. PROOF TEST MODEL (PTM)

1. PTM Tests at RCA

Electrical and environmental evaluation, and acceptance testing, of the PTM was performed during the period from May 9 through August 1, 1962. The chronological sequence of all the tests is given in Table 41. Two catastrophic failures occurred during the tests: one took place during thermal-vacuum testing; and the other just prior to the final acceptance test.

The catastrophic failure in a thermal-vacuum environment was the result of the TV Subsystem being turned on prematurely in a partial-pressure environment that was conducive to arcing inside several assemblies. Several theories were advanced as to the cause of the arcing; the prime suspect was believed to be the occurrence of heavy glow discharge resulting from the presence of high voltage in a rarefied atmosphere. Control of the battery voltage was lost when the arcing occurred, and this resulted in damage to several assemblies. The operation of the TV Subsystem in any environment other than the vacuum of outer space was not a requirement of the Ranger mission profile. Thereafter, all care and caution was taken to ensure that the

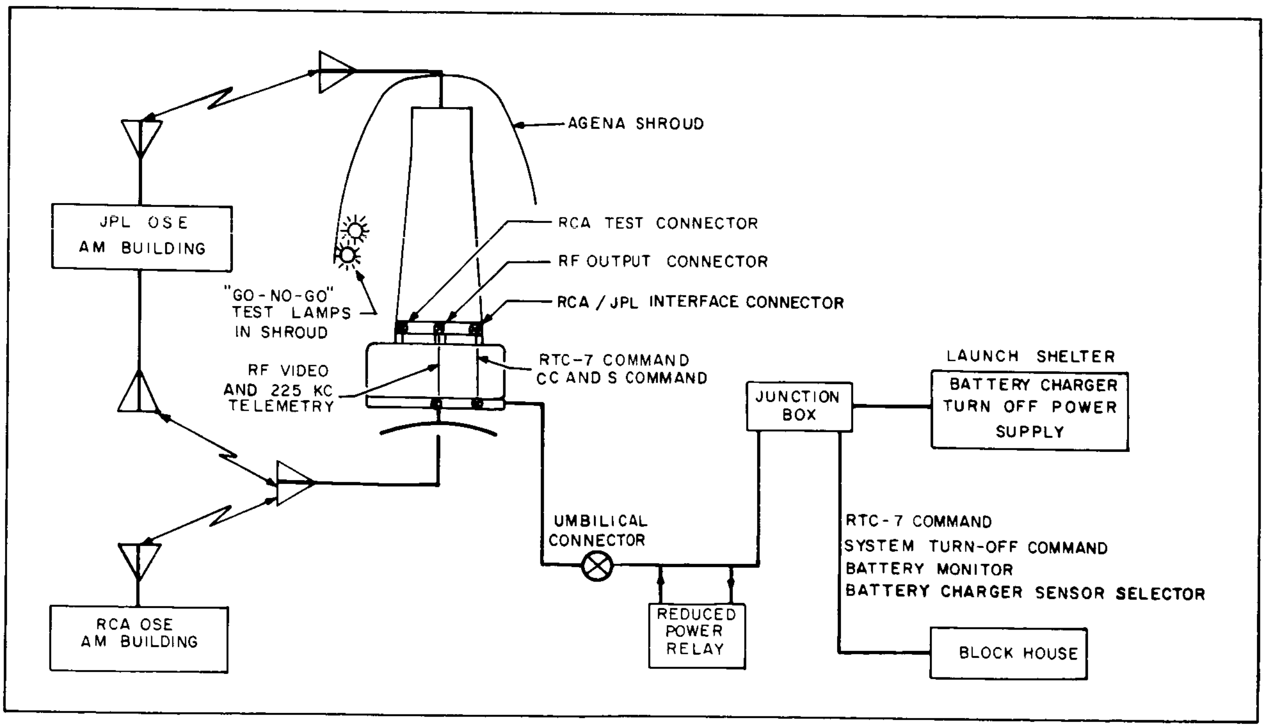

Figure 53. TV Subsystem Test Configuration (Launch Pad)

TABLE 41
SUMMARY OF PTM TESTS AT RCA
MAY 9, 1962 THROUGH AUGUST 1, 1962

Description of Test	Date	Test Procedure
Pre-RFI Test	May 9, 1962	JPL Interoffice Memo ERG 107, dated 6/12/62
Line-Conducted Interference Test	June 3, 1962	RCA Specifications RTSP-1101 and RTSP-1102
Radiated Interference Test	June 4, 1962	RCA Specifications RTSP-1101 and RTSP-1102
Antenna-Conducted Interference Test	June 5, 1962	RCA Specifications RTSP-1101 and RTSP-1102
RF Radiated Susceptibility Test	June 6, 1962	RCA Specifications RTSP-1101 and RTSP-1102
Operational Checkout	June 21, 1962	RCA Specification RTSP-1100
Previbration Test	June 22, 1962	RCA Specification RTSP-1100
Vibration Test	June 23 through 24, 1962	RCA Specification RTSP-1101
Prelaunch Check	June 25 through July 14, 1962	RCA Specification RTSP-1100
Abbreviated Mission Test at 10° C	June 25 through July 14, 1962	RCA Specification RSTP-1100
Abbreviated Mission Test at 0° C	June 25 through July 14, 1962	RCA Specification RTSP-1100
Abbreviated Mission Test at 20° C	June 25 through July 14, 1962	RCA Specification RTSP-1100
Real-time (66-hour) Simulated Mission	June 25 through July 14, 1962	RCA Specification RTSP-1100
Post Thermal-Vacuum Check	June 25 through July 14, 1962	RCA Specification RTSP-1100
Thermal-Sterilization Test	July 15 through 17, 1962	RCA Specification RTSP-1100
Post Thermal-Sterilization Test	July 15 through 17, 1962	RCA Specification RTSP-1100
Operational Verification Test	July 15 through 17, 1962	RCA Specification RTSP-1100
Ethylene Oxide Compatibility Test	July 18 through 19, 1962	RCA Specification RTSP-1100
Acceptance Test	August 1, 1962	RCA Specification RTSP-1100

environmental test conditions did approach those of a perfect vacuum.

On July 25, 1962, following a series of RFI tests, a number of minor changes were made to the PTM. In the course of this work, the High-Current Voltage Regulator was removed from the structure to replace a loose terminal lug. At the completion of the modifications, the PTM was to be checked. When the PTM was placed in the warm-up mode, the sequencer prematurely cycled the equipment to full power. Shortly after the turn-on, a popping noise was heard and the power to the Subsystem was turned off. Investigation revealed that one of the battery cables was hot and several assemblies were damaged.

After considerable investigation, it was determined that the probable cause of failure was accidental grounding of the battery "hot" side. There is evidence that when the High-Current Voltage Regulator was replaced in the structure a mounting screw had cut into the heat sink of the SCR. Extensive circuit and failure analyses, together with failure effects analyses, were inconclusive in pinpointing another possible cause. All damaged components were repaired, inspected by Quality Control, subjected to electrical checks, and reassembled into the structure. The PTM was then tested through all modes of operation on internal and external power for a 24-hour period before predelivery acceptance test. Conditions causing the earlier catastrophic failure could not be reproduced.

2. PTM Tests at JPL (August 1, 1962 through January 31, 1963)

The purpose of tests performed at JPL was to verify the performance of the electrical equipment in the TV Subsystem PTM when integrated with the Ranger Spacecraft Bus. The tests were designed to verify satisfactory operation of the PTM in ambient and simulated space environments. The tests were performed at JPL between August 1, 1962 and January 31, 1963, and are listed in Table 42.

Only a few minor difficulties occurred during the Mission Verification Tests, and the PTM performed normally during all the tests.

3. Block III PTM Tests at RCA (April 3 through June 17, 1963)

The Block III Proof Test Model was the first TV Subsystem modified to permit independent operation of the F- and P-Channel camera-communications chains. This configuration, known as the split system, was capable of either independent or simultaneous operation of F- and P-Channels. In the modified PTM, the partial-scan and full-scan channels were completely independent and powered by individual batteries and voltage regulators, thus providing a reduced probability that an equipment failure in one chain would affect the performance of the other chain. A Distribution Control Unit (DCU) was incorporated to provide power distribution and fuse protection for the redundant capability. In addition, an Electronic Clock was provided for full-scan channel turn-on, and a Power Control Unit (PCU) for remote Subsystem turn-off.

The Block III PTM was built to demonstrate the operation of the TV Subsystem after the extensive redesign to achieve the split-system configuration. The purpose of testing was to demonstrate the normal and failure-mode operation of the TV Subsystem. Table 43 outlines the tests which were performed at RCA. The results of the PTM tests demonstrated that the split-system design fulfilled the design objectives. The PTM was shipped to JPL on June 20, 1963.

4. Block III PTM Tests at JPL (June 22 through October 21, 1963 and November 9 through December 5, 1963)

The Block III PTM of the Ranger TV Subsystem was delivered to JPL on June 21, 1963. After it was mated to the Ranger Bus, the PTM was subjected to a series of Mission and System Verification Tests performed in

TABLE 42
SUMMARY OF PTM TESTS AT JPL
AUGUST 1, 1962 THROUGH JANUARY 31, 1963

Description of Test	Test Procedure
TV Subsystem Verification Test	RCA Specification RTSP-1100
Spacecraft Verification Test	JPL Procedure 3R212.00
Space Science Camera Test	JPL Procedure 3R220.00
System Verification Test No. 1	JPL Procedure 3R300.00
Backup Function Test	JPL Procedure 3R305.00
VSWR Test	-
System Verification Test No. 2	JPL Procedure 3R300.00
Spacecraft-SFOF Compatibility Test	JPL Procedure 3R318.00
Space Science Camera Test	JPL Procedure 3R220.00
System Verification Test No. 3	JPL Procedure 3R300.01
Precountdown Dummy Run	JPL Procedure 3R304
Countdown Dummy Run	JPL Procedure 3R309
Vibration Tests	JPL Procedure 3R311.00
TV Subsystem Verification Test	JPL Procedure 3R300.01
Thermal-Vacuum Test	JPL Procedure 3R301.00
RFI Test	Special Test
Mission Verification Test No. 1	JPL Procedure 3R302.00
Mission Verification Test No. 2	JPL Procedure 3R302.00
Mission Verification Test No. 3	JPL Procedure 3R302.00
RF Shorting Tests	-
Mission Verification Test No. 4	JPL Procedure 3R302.00
Vibration Test	JPL Procedure 3R311.00
Special Thermal-Vacuum RF Test	Special Test
System Verification Test No. 4	JPL Procedure 3R300.07

TABLE 43
SUMMARY OF PTM TESTS AT RCA
APRIL 3, 1963 THROUGH JUNE 17, 1963

Description of Test	Date	Test Procedure
Ambient Failure Mode Test	March 24, 1963	Block III PTM Test Plan
Thermal-Vacuum Tests	April 8 through April 26, 1963	Block III PTM Test Plan
Previbration Electrical Test	May 20, 1963	Block III PTM Test Plan
Vibration Test	May 20, 1963	Block III PTM Test Plan
Postvibration Electrical Test	May 20, 1963	Block III PTM Test Plan
Light Dispersion Test	May 27, 1963	Block III PTM Test Plan
VSWR Mismatch Test	June 5, 1963	Block III PTM Test Plan
Acceptance Test	June 17, 1963	Block III PTM Test Plan
Outdoor Pictures	June 19, 1963	Special Test

accordance with JPL test procedures as listed in Table 44. The two-fold purpose of the tests was to determine the compatibility of the TV Subsystem with the Ranger Bus, and to evaluate the performance of the complete Ranger PTM Spacecraft over an extended period of time in a simulated space environment. Special tests were also conducted, as necessary, for the investigation of special problem areas.

5. Block III PTM Tests at Goldstone (October 23 through November 8, 1963)

The Block III PTM TV Subsystem arrived at the Deep Space Instrumentation Facility (DSIF) at Goldstone, California, on October 21, 1963. The tests performed on the Block III PTM and the applicable test procedures are listed in Table 45. These tests were performed to evaluate the Deep Space Instrumentation Facility operation during simulated missions. The operation of the TV Subsystem was both normal and satisfactory throughout these tests.

Upon the successful completion of testing at JPL and at Goldstone, the PTM TV Subsystem was placed in its shipping container for storage at JPL. The PTM TV Subsystem was returned to JPL on November 9, 1963 after the satisfactory completion of the DSIF checkout tests.

6. Block III PTM Tests at RCA (March 23 through March 31, 1964)

The modified Block III PTM of the Ranger TV Subsystem was the first Subsystem to incorporate the design changes resulting from the study undertaken as a result of the Ranger VI flight. These changes can be summarized as follows:

- Modification to the command and control circuitry to both prevent the possibility of inadvertent turn-on of the TV Subsystem until after the spacecraft separates from the Agena and provide a method of rapid Subsystem turn-off; and
- Modifications to the Telemetry Assembly, and modifications and additions to the telemetry sensors to improve the readability and usefulness of the telemetry data.

In addition, a special method of inspection of the Subsystem assemblies was implemented to determine the effects of life and usage on the equipment. As a part of this program, all exposed terminals were coated and all exposed connectors were potted on all flight equipment to minimize the possibility of an accidental short. Because of the urgency of the modified Block III PTM test program, engineering models with exposed terminals were used on the Subsystem for some of the testing.

The testing and checkout of the modified Block III PTM TV Subsystem at RCA commenced on March 23, 1964, and was completed on March 31, 1964. This testing and checkout cycle verified the satisfactory operation of the modified PTM TV Subsystem. Table 46 lists all major tests performed during this period.

7. Modified Block III PTM Tests at JPL (April 2 through September 1964)

The modified Block III PTM arrived at JPL on April 2, 1964, and the electrical testing of the TV Subsystem was started immediately. The testing was continued until the launching of the RA-7 Spacecraft. A chronological listing of the tests performed on the modified Block III PTM is given in Table 47. The PTM was placed in a storage container during the later part of July 1964, but was reactivated in August of the same year. The PTM was updated to the Ranger VIII configuration, and a number of tests were performed before it was again placed in the storage container.

TABLE 44
SUMMARY OF PTM TESTS AT JPL
JUNE 22, 1963 THROUGH OCTOBER 21, 1963

Description of Test	Date	Test Procedure
Verify TV Subsystem Operation upon Arrival at JPL	June 22 to 25, 1963	RCA Specification RTSP-1100
System Verification Test	June 26 to 27, 1963	JPL Procedure 3R212.00
Space Science Camera Tests	June 28 to July 1, 1963	JPL Procedure 3R220.00
System Verification Test No. 1	July 2, 1963	JPL Procedure 3R300.00
Backup Function System Test	July 3, 1963	JPL Procedure 3R305.00
VSWR Tests	July 5 to 10, 1963	Special Test
System Verification Test No. 2	July 11 to 12, 1963	JPL Procedure 3R300.00
Systems Flight Operations Facility	July 16, 1963	JPL Procedure 3R318.00
Compatibility Test	-	-
Space Science Camera Tests	July 22 to 29, 1963	JPL Procedure 3R220.00
System Verification Test No. 3	Aug 5, 1963	JPL Procedure 3R300.00
Precountdown Dummy Run	Aug 8 to 9, 1963	JPL Procedure 3R303.01
Countdown Dummy Run	Aug 8 to 9, 1963	JPL Procedure 3R308.01
PYRO Test No. 1	Aug 11, 1963	JPL Procedure 3R313.00
PYRO Test No. 2	Aug 13, 1963	JPL Procedure 3R313.00
Vibration Tests	Aug 19 to 24, 1963	JPL Procedure 3R311.00
System Verification Test	Aug 28 to 29, 1963	JPL Procedure 3R300.01
Thermal-Vacuum Temperature Test	Aug 31 to Sept 3, 1963	JPL Procedure 3R301.00
Radio Frequency Interference Test	Sept 4, 1963	Special Test

TABLE 44
SUMMARY OF PTM TESTS AT JPL
JUNE 22, 1963 THROUGH OCTOBER 21, 1963 (Continued)

Description of Test	Date	Test Procedure
Mission Verification Test No. 1	Sept 14 to 17, 1963	JPL Procedure 3R302.00
Mission Verification Test No. 2	Sept 21 to 23, 1963	JPL Procedure 3R302.00
Mission Verification Test No. 3	Sept 27 to 30, 1963	JPL Procedure 3R302.00
RF Shorting Tests	Oct 8 to 9, 1963	Special
Mission Verification Test No. 4	Oct 12 to 15, 1963	JPL Procedure 3R302.00
SUMMARY OF PTM TESTS AT JPL NOVEMBER 9 THROUGH DECEMBER 5, 1963		
Torsional-Vibration Tests	Nov 15 to 18, 1963	JPL Procedure 3R200.07
Thermal-Vacuum RF Tests	Nov 23 to Dec 4, 1963	Special
Final PTM Video Evaluation Test	Dec 5, 1963	JPL Procedure 3R300.07

TABLE 45
SUMMARY OF PTM TESTS AT GOLDSTONE
OCTOBER 23, 1963 THROUGH NOVEMBER 8, 1963

Description of Test	Date	Test Procedure
TV Subsystem Checkout Tests upon Arrival at Goldstone	Oct 23, 1963	RCA Specification RTSP-1100
DSIF Tests	Oct 23 to 25, 1963	Goldstone-modified JPL Procedure 3R232.00
Threshold Tests with TV Subsystem Operating in Full Power	Oct 28, 1963	Goldstone-modified JPL Procedure 3R232.00
Noise and Transfer Characteristic Measurements on P1 and P4 Cameras	Oct 30, 1963	Goldstone-modified JPL Procedure 3R232.00
SFOF Tests and High- and Medium-Temperature Thermistor Calibration Tests	Oct 31, 1963	Goldstone-modified JPL Procedure 3R232.00
Noise and Transfer Characteristic Measurements on P2, P3, F_a, and F_b Cameras	Nov 1, 1963	Goldstone-modified JPL Procedure 3R232.00
Outdoor Pictures	Nov 4, 1963	Goldstone-modified JPL Procedure 3R232.00
Nominal Temperature Thermistor Calibration	Nov 5, 1963	Goldstone-modified JPL Procedure 3R232.00
Command Threshold Test	Nov 6, 1963	Special Goldstone Test Plan dated November 5, 1963
Space Science Lunar Slide Tests	Nov 7, 1963	Goldstone-modified JPL Procedure 3R232.00
Threshold Tests and TV Subsystem Picture-Quality Tests	Nov 8, 1963	Goldstone-modified JPL Procedure 3R232.00

TABLE 46
SUMMARY OF PTM TESTS AT RCA
MARCH 23, 1964 THROUGH MARCH 31, 1964

Description of Test	Date	Test Procedure
Initial RF Power Checkout	March 23, 1964	Special Test
Initial Electrical Checkout	March 26, 1964	RCA Specification RTSP-1100 A, App. A
TV Subsystem Test	March 29, 1964	RCA Specification RTSP-1100 A, App. F
Operational Verification Test	March 31, 1964	RCA Specification RTSP-1100 A, App. G
Preshipment Electrical Test	March 31, 1964	RCA Specification RTSP-1100 A, App. G

TABLE 47
SUMMARY OF PTM TESTS AT JPL
APRIL 2, 1964 THROUGH SEPTEMBER, 1964

Description of Test	Date	Test Procedure
Postshipment Test	April 1, 1964	RCA Specification RTSP-1100A, App. G
Parts of Debugging Procedure	April 2, 1964	RCA Specification RTSP-1100A, App. A
Telemetry Calibration	April 6 to 7, 1964	RCA Specification RTSP-1100A, App. N
Pin Retention Test	April 8, 1964	RCA Specification RTSP-1100A, App. L
Post-Tiedown	April 10, 1964	RCA Specification RTSP-1100A, App. G
Compatibility Test	April 11, 1964	JPL Procedure 3R212.03
System Verification Test No. 10	April 13, 1964	JPL Procedure 3R300.10
Vibration Tests	April 16 to 24, 1964	JPL Procedure 3R311.02
System Verification Test No. 11	April 25, 1964	JPL Procedure 3R300.11
Pre-Thermal Vacuum TV Subsystem Test	April 29, 1964	RCA Specification RTSP-1100A, App. G
Thermal Vacuum Tests	April 30 to May 12, 1964	JPL Procedure 3R303.02
Special Thermal-Vacuum Instrumentation Run	May 16 to 20, 1964	Special Test
Backup Functions System Test No. 1	June 3, 1964	JPL Procedure 3R305.07
Operational Checkout, RF Link Only	June 5, 1964	JPL Procedure 3R315.01
Explosive-Safe Area, High-Power Test	June 8, 1964	JPL Procedure 3R235.00
System Verification Test No. 12		JPL Procedure 3R300.12
Decompression Vibration Test	June 16 to 17, 1964	JPL Procedure 3R316.00
System Verification Test No. 13	June 18 to 19, 1964	JPL Procedure 3R300.13
Acoustic Verification Test	June 23, 1964	JPL Procedure 3R312.01

TABLE 47
SUMMARY OF PTM TESTS AT JPL
APRIL 2, 1964 THROUGH SEPTEMBER, 1964 (Continued)

Description of Test	Date	Test Procedure
Vibration Verification Test	June 24 to 27, 1964	JPL Procedure 3R311.03
System Test No. 14	June 30, 1964	JPL Procedure 3R300.13
Special Test to Verify Operation of New P-Channel Transmitter Power Supply	July 2, 1964	Special Test
Vibration Spectrum Test	July 3 to 5, 1964	JPL Procedure 3R311.03
System Verification Test No. 15	July 7, 1964	JPL Procedure 3R300.13
Hardline Special Test to Verify the Operation of P3 Camera	July 8, 1964	Special Test
Pyrotechnic Shock Test	July 11, 1964	JPL Procedure 3R313.05
System Verification Test No. 16	July 14, 1964	JPL Procedure 3R300.13
Umbilical Short Test	July 14, 1964	JPL Procedure 324.00
Special FMI High-Voltage Tests		JPL Procedure 3159.221
System Verification Test No. 17	July 20, 1964	JPL Procedure 3R300.13
Inadvertent Turn-on Test	July 21, 1964	JPL Procedure 3R304.00 and Memo 313-1674
Second Umbilical Transient Test	July 22, 1964	JPL Procedure 3R324.00 and Memo 315-9220
TV Subsystem and Bus Interface Compatibility Test	July 23, 1964	JPL Memo 313-1575A
TV Subsystem Checkout	Sept 4, 1964	RCA Specification RTSP-1100A, App. F
TV Subsystem Checkout with Bus	Sept 9, 1964	JPL Procedure 3R212.04
System Verification Test No. 18	Sept 11, 1964	JPL Procedure 3R300.14

C. FLIGHT MODEL NO. 1

1. Flight Model No. 1 Tests at RCA (August 17 through October 16, 1962)

Testing of Flight Model 1 began August 17, 1962 at RCA. The communications equipment and cameras had been bench-tested and integrated with the structure.

The first Subsystem test was performed on September 12, 1962; Flight Model 1 was subjected to thermal-vacuum testing prior to vibration testing to permit the incorporation of certain mechanical design changes in the Camera Assembly. The thermal-vacuum test consisted of two stages: (1) A 66-hour "real-time" simulated mission (without the use of collimators) for the purpose of verifying the thermal configuration of the TV Subsystem; and (2) An abbreviated mission (with the use of collimators) to verify the electrical performance of the Subsystem in a simulated thermal-vacuum environment. Flight Model 1 successfully completed the 66-hour "real-time" mission test.

At the conclusion of thermal-vacuum testing, a Subsystem test was performed to evaluate the effect of the thermal-vacuum environment on the TV Subsystem. Following this test, an improvement program was initiated involving the following circuit modifications:

- A black-clip circuit was installed to prevent noise spikes from interrupting the sync;
- Shutter apertures were enlarged to obtain 0.004-second exposures on the partial-scan cameras;
- Shock-absorbing isolators were installed on all camera shutters;
- Double-cased tantalytic capacitors already in the power supplies were replaced by single-cased tantalytic capacitors;
- Camera-switchover logic was changed to two-tone logic (from the original three-tone logic); and
- The RC time-constant of the emergency data input to the modulator was changed to improve emergency telemetry.

Following the adoption of these improvements, the necessary adjustments were made to re-integrate the cameras and communications equipment.

On September 28, 1962, following a Subsystem test and a simulated mission, Flight Model 1 was mounted in the thermal-vacuum chamber for an abbreviated thermal mission. When the vacuum-chamber door was closed, a battery lead was caught; this caused a short and resulted in damage to the Subsystem harness and one battery. After replacing the harness and battery, and performing another Subsystem test, the Subsystem was returned to the thermal-vacuum chamber on September 29, 1962; the terminal maneuver and simulated mission in thermal-vacuum were performed on September 30, 1962. The chamber was returned to ambient conditions and a final simulated mission was performed to verify the fully operational condition of the Subsystem. The tests that were performed at RCA are listed in Table 48.

2. Flight Model No. 1 Tests at JPL (December 11 through December 18, 1962)

Flight Model 1 was delivered to JPL on October 18, 1962 after successfully completing environmental and electrical testing at RCA. At JPL, the Subsystem was mated with the Ranger VI Spacecraft, and successfully underwent Subsystem and System tests. The tests performed at JPL are listed in Table 49.

D. FLIGHT MODEL NO. 2

1. Flight Model No. 2 Tests at RCA (October 24 through November 1, 1962)

Flight Model 2 was assembled and delivered to the electrical test area on October 24, 1962.

TABLE 48
SUMMARY OF FM 1 TESTS AT RCA
AUGUST 17, 1962 THROUGH OCTOBER 16, 1962

Description of Test	Date	Test Procedure
TV Subsystem Verification Test	Aug 17, 1962	RCA Specification RTSP-1100
Camera Calibration	-	RCA Specification RTSP-1100
TV Subsystem Test No. 1	-	RCA Specification RTSP-1100
Thermal-Vacuum Test (66-hour real-time simulated mission)	Sept 15 through 18, 1962	RCA Specification RTSP-1100
Abbreviated Mission Test No. 1	Sept 30 through Oct 1, 1962	RCA Specifications RTSP-1100 and RTSP-1101
Abbreviated Mission Test No. 2	Oct 5 through 6, 1962	RCA Specifications RTSP-1100 and RTSP-1101
Abbreviated Mission Test No. 3	Oct 6 through 7, 1962	RCA Specifications RTSP-1100 and RTSP-1101
Abbreviated Mission Test No. 4	Oct 8 through 9, 1962	RCA Specifications RTSP-1100 and RTSP-1101
Abbreviated Mission Test No. 5	Oct 11 through 12, 1962	RCA Specifications RTSP-1100 and RTSP-1101
Abbreviated Mission Test No. 6	Oct 13 through 14, 1962	RCA Specifications RTSP-1100 and RTSP-1101
Electrical Performance Check	Oct 15, 1962	RCA Specification RTSP-1100
Electrical Performance Check	Oct 15, 1962	RCA Specification RTSP-1100
Vibration Test	Oct 15 to 16, 1962	RCA Specification RTSP-1100
Electrical Performance Check	Oct 16, 1962	RCA Specification RTSP-1100

TABLE 49
SUMMARY OF FM 1 TESTS AT JPL DECEMBER 11 THROUGH DECEMBER 18, 1962

Description of Test	Date	Test Procedure
Pre-Vacuum Power Profile	December 11, 1962	JPL Procedure 3R303.02
Thermal-Vacuum Test	December 13, 1962	JPL Procedure 3R303.02
Thermal-Vacuum Test	December 13, 1962	JPL Procedure 3R303.02
Chamber Open Test	December 13, 1962	Special Test
Chamber Open Test (abbreviated mission)	December 14, 1962	Special Test
Chamber Open Power Profile (abbreviated mission)	December 14, 1962	Special Test
Thermal-Vacuum Test	December 15, 1962	JPL Procedure 3R303.02
Chamber Open Test (after Subsystem reinstrumentation)	December 17, 1962	JPL Procedure 3R303.02
Thermal-Vacuum Test	December 18, 1962	JPL Procedure 3R303.02
Thermal-Vacuum Test (split load, no Four-Port Hybrid)	December 18, 1962	JPL Procedure 3R303.02

The test plan and test objectives were the same as those for Flight Model 1. The tests comprised: electrical tests, vibration tests, initial thermal-vacuum tests, investigation of the RF failures, final thermal-vacuum tests, and acceptance tests.

During the initial thermal-vacuum tests, it was discovered that an oily film covered the Subsystem thermal shroud. The source, cause, and method of eliminating this film from future tests were investigated by the materials engineering group at RCA. While the results of the investigation were inconclusive, recommendations were made concerning thermal-shield polishing. Also, it was determined that some of the film was due to the oil from the diffusion pump. Environmental test engineers eliminated this source of contamination.

Each time the Subsystem was operated during the initial thermal-vacuum tests, the RF power failed. Therefore, RF failure tests were run to determine the exact cause of failures before continuing with the thermal-vacuum testing. The results of these tests showed that the right-angle connectors, the signal samplers, and the RF power connectors and cables were breaking down either independently or together whenever the TV Subsystem was placed in the full-power mode of operation. The problem was eliminated by removing the signal samplers and all right-angle connectors (except the one inside the Dummy-Load pressure vessel) and by applying DC-4 silicone grease between the connector shell and the cable during the assembly of coaxial cables. After the modifications were made, the final thermal-vacuum tests were started and four simulated missions were performed in the thermal-vacuum chamber; no RF power failures were experienced. However, the video display of the P1 Camera deteriorated progressively throughout the four simulated mission tests. An investigation made at the end of testing showed that the light output of the P1 Camera collimator dropped from 1250 to 335 footlamberts because of flaking of the reflective coating from the bulb of the collimator.

A final Subsystem test was run in accordance with the applicable specification. The results of this test were satisfactory, and Flight Model 2 was accepted for delivery to JPL.

2. Life Test Model (LTM) Tests at JPL (March 4 through June 12, 1963)

When the split-system design was adopted as a modification to the Ranger TV Subsystem project, the original, nonredundant configuration Flight Model 2 was redesignated as the Life Test Model. It was shipped to JPL on February 19, 1963, for mission verification testing.

Tests were conducted at JPL to evaluate the performance of the LTM TV Subsystem over an extended period of time in a simulated environment. Additional tests were conducted to investigate special problem areas. The tests performed at JPL are summarized in Table 50.

Upon completion of the mission verification tests (MVT) at JPL, the LTM was returned to RCA on July 5, 1963, for an evaluation of the effects of the testing at JPL.

The principal objective of the LTM test program was to evaluate the performance of the TV Subsystem over an extended period of time and under various environmental conditions. Even though this Subsystem did not incorporate the Block III modified split-system design, the following general conclusions were drawn:

- Performance of the Subsystem, although not always optimum, was generally adequate because data on the lunar surface would have been obtained if any of the tests had been an actual mission;
- Evaluation of data from the mission verification tests corroborated the desirability of the split-system design improvements which would optimize

TABLE 50
SUMMARY OF LTM TESTS AT JPL

Test	Date	Test Conditions	Comments
SVT 1	March 4, 1963	Ambient Temperature and Pressure	None.
MVT 1	March 11 to 14, 1963	Ambient Temperature and Pressure	(1) Low Power output (2) Fuse failure HCVR.
MVT 2	March 18 to 21, 1963	Ambient Temperature and Pressure	None.
SVT 2	March 26, 1963	Ambient Temperature and Pressure	F_a Camera video level changed from previous tests.
MVT 3	March 27 to 30, 1963	Thermal-Vacuum, Average Case Temperature 100° F	(1) 15-point commutator failure. (2) F-Channel transmitter failure.
MVT 4	April 3 to 6, 1963	Thermal-Vacuum, Average Case Temperature 50° F	Intermittent P1 Camera shutter during Sync Disable.
MVT 5	April 9 to 12, 1963	Thermal-Vacuum, Average Case Temperature 100° F	(1) Intermittent B-Channel 90-pt telemetry. (2) Intermittent 3 A-Channel Transmitter. (3) Low video level on P4-Camera.
MVT 6	April 16 to 19, 1963	Thermal-Vacuum, Average Case Temperature 50° F	(1) Intermittent 90-point commutator. (2) Intermittent A-Channel transmitter. (3) B-Channel Transmitter output low.
MVT 7	April 23 to 27, 1963	Thermal-Vacuum, Average Case Temperature 100° F	Combined power output dropped 6 db after 15 minutes of operation.
MVT 8	April 30, to May 3, 1963	Thermal-Vacuum, Average Case Temperature 50° F	(1) B-Channel power output low (2) P1-Camera Shutter operated intermittently during sync disable.

TABLE 50
SUMMARY OF LTM TESTS AT JPL (Continued)

Test	Date	Test Conditions	Comments
MVT 8 (cont.)			(3) RF Power Dropout for 1/4 sec after 12 min of full power.
MVT 9	May 6 to 9, 1963	Thermal-Vacuum, Average Case Temperature 100° F	(1) B-Channel power output low (2) Intermittent P1 Camera shutter during sync disable.
SVT 3	May 13, 1963	Ambient Temperature and Pressure	None.
MVT 10	May 14 to 17, 1963	Thermal-Vacuum, Average Case Temperature 50° F	Combined RF power dropout for 1/4-second after 9 minutes of full power.
MVT 11	May 20 to 23, 1963	Thermal-Vacuum, Average Case Temperature 70° F	Combined RF power dropped out momentarily.
MVT 12	May 28 to 31, 1963	Thermal-Vacuum, Average Case Temperature 32° F	Combined RF power dropped out momentarily.
MVT 13	June 5 to 8, 1963	Thermal-Vacuum, Average Case Temperature 130° F	Combined RF power dropped out momentarily.
Special Tests 1 and 2	June 11, 1963	Thermal-Vacuum, Average Case Temperature 70° F	
Special Tests 3, 4 and 5	June 12, 1963	Thermal-Vacuum, Average Case Temperatures 70° F	

Notes: SVT: System Verification Test: JPL Procedure PS3R300
MVT: Mission Verification Test: JPL Procedure PS3R302

performance and improve the probability of successful missions;

- General working knowledge of the TV Subsystem was acquired by the test teams; and
- Improved test procedures and techniques were developed.

The experience gained during the test program on the LTM led to the incorporation of several modifications in the cameras for the Block III effort; these modifications resulted in improved overall picture quality and camera reliability.

A situation referred to as shutter microphonics existed in the LTM full-scan cameras. This problem was evidenced as a transient in the full-scan video readout; the display showed 12 such transients in each full-scan camera photograph. It was correlated with the actuation of the shutters for the partial-scan cameras. This problem was eliminated by installing an electrostatic shield between the moving shutter vane and the vidicon faceplate. The Block III camera redesign was directed toward a general improvement of parts application in each circuit to achieve maximum camera reliability. The vidicon connector design, referred to as the top-hat connector, was changed to a bulkhead-mounted Cannon connector and relieved the handling stresses induced on the vidicon during assembly of the connector to the vidicon. The redesign also provided for damping out shock inputs to the vidicon end which reduced the microphonics. Reduction of shutter cross-talk in the full-scan cameras and reduction of handling stresses on vidicons were two improvements made in the Block III TV Cameras as a direct result of the experience gained with the LTM.

The LTM was also utilized for the testing, evaluation, and use of the modified Four-Port Hybrid and of the TNC connectors for the elimination of RF arcing. This arcing was ascertained to be one of the causes of the RF power fluctuations. The LTM tests led to the development of improved techniques for the recording of test data, the calibration of equipment, and the demonstration of the importance of a complete test record (which included the observation of the Spectrum Analyzer for the determination of amplitude), frequency with respect to a calibrated JPL Beacon, and the level of intermodulations. In this regard, the value of a calibrated external RF signal for the calibration of the Spectrum Analyzer display was demonstrated. The test teams developed a technique to calibrate the Brush Recorder so that a 4-db decrease in RF power output could be detected on the strip chart.

E. FLIGHT MODEL III-1

1. Flight Model III-1 Tests at RCA (July 7 through August 22, 1963)

After the conversion of Flight Model 1 into a split-system configuration, this TV Subsystem was designated as Flight Model (FM) III-1. The tests performed on this Subsystem to verify its operation are listed in Table 51. Only minor difficulties occurred during TV Subsystem Test 1, thermal-vacuum test performed on August 4, 1963, and Camera Calibration Check 3. The Subsystem performed normally. On August 21, 1963, Flight Model III-1 was given a complete Subsystem test for customer approval of the Subsystem. The F-Channel telemetry was found to be erratic because of a broken connector in the Intermediate Power Amplifier; it was corrected. All other assemblies functioned properly. On the basis of these tests, witnessed and approved by JPL representatives, Flight Model III-1 was accepted for shipment to JPL.

2. Flight Model III-1 Tests at JPL (August 26 through December 15, 1963)

The purpose of the testing program at JPL was to verify that Flight Model III-1 of the Ranger TV Subsystem was in flight-ready

TABLE 51
SUMMARY OF FM III-1 TESTS AT RCA JULY 7 THROUGH AUGUST 22, 1963

Description of Test	Date	Test Procedure
Camera Calibration Check No. 1	July 7, 1963	RCA Specification RTSP-1100 A, App. C
TV Subsystem Test No. 1	July 11, 1963	RCA Specification RTSP-1100 A, App. F
Subsystem Command Checkout No. 1	July 12, 1963	RCA Specification RTSP-1100 A, App. G
Vibration Test	July 13, 1963	RCA Specification RTSP-1101
Subsystem Command Checkout No. 2	July 14, 1963	RCA Specification RTSP-1100 A, App. G
Thermal-Vacuum Test (66-hour real-time)	July 14 through July 18, 1963	RCA Specification RTSP-1100 A, App. J
Camera Calibration Check No. 2	July 27, 1963	RCA Specification RTSP-1100 A, App. C
TV Subsystem Test No. 2	August 2, 1963	RCA Specification RTSP-1100 A, App. F
Thermal-Vacuum Test (Terminal phase only)	August 4, 1963	RCA Specification RTSP-1100 A, App. J
Mission Verification Test No. 1 (incomplete)	August 5, 1963	RCA Specification RTSP-1100 A, App. D
Mission Verification Test No. 2 (modified)	August 14, 1963	RCA Specification RTSP-1100 A, App. D
Camera-Array Alignment Determination	August 16, 1963	RCA Specification RTSP-1100 A, App. H
Camera Calibration Check No. 3	August 21, 1963	RCA Specification RTSP-1100 A, App. C
TV Subsystem Test No. 3 (Acceptance Test)	August 21, 1963	RCA Specification RTSP-1100 A, App. F
Preshipment Electrical Test	August 22, 1963	RCA Specification RTSP-1100 A, App. G

condition before shipment of the RA-6 Spacecraft to the Eastern Test Range (ETR). This testing program (summarized in Table 52) began on August 26, 1963 with a quality-control inspection and a Subsystem test performed to document the condition of the TV Subsystem after delivery to JPL and to establish its operational capabilities before starting System Verification Tests.

A total of six System Verification Tests, designed to verify the electrical performance of the entire Ranger Spacecraft, were performed. Other special electrical tests were conducted separately on the TV Subsystem, either to ensure proper Subsystem operation before a system test or to perform necessary calibration and analysis. In addition, environmental tests and a simulated-mission test were performed to demonstrate that the spacecraft was capable of operation in space. During the testing at JPL and RCA, the P-Channel was operated for a total of 163 hours, 50 minutes, and the F-Channel was operated for 152 hours, 5 minutes. All malfunctions were documented, repaired, and the test was then repeated to verify Subsystem and System operation. Flight Model III-1 was shipped to the Eastern Test Range on December 15, 1963.

3. Flight Model III-1 Tests at ETR (December 28, 1963 through January 25, 1964)

Prelaunch checkouts were performed on the TV Subsystem at the Eastern Test Range (ETR) and on the operational station equipment (OSE) at the Deep Space Instrumentation Facility (DSIF) at Goldstone, California. A series of thirteen checkouts were performed on the TV Subsystem beginning on December 28, 1963 and ending on January 25, 1964; these tests are summarized in Table 53.

A series of two operation-readiness tests and three OSE prelaunch calibrations were performed at the DSIF at Goldstone between January 21 and January 30, 1964. In addition, calibrations of DSIF Film Recorders No. 1 and 2 were performed during the period beginning December 26, 1963 and continuing through the second pass of Ranger VI over Goldstone.

Ranger VI, consisting of the Ranger Spacecraft Bus and Flight Model III-1 of the Ranger TV Subsystem, was launched from Cape Kennedy, ETR on an Atlas-D/Agena-B vehicle. Liftoff occurred at 15:49:00 GMT, January 30, 1964.

F. FLIGHT MODEL III-2

1. Flight Model III-2 Tests at RCA (August 28 through September 26, 1963)

The testing of the Ranger TV Subsystem, Flight Model III-2, commenced on August 28, 1963 and was completed on September 26, 1963. The tests performed during this period are listed in Table 54. Every test was successfully completed in the scheduled order. All resulting data either met or exceeded the specifications. With the exceptions of the shutter failures, no equipment malfunction necessitated removal of assemblies or subassemblies from the Subsystem. However, the Telemetry Processor Assembly was removed once to incorporate a design modification. The communications equipment was tuned at the beginning of the testing cycle, and performed satisfactorily for the balance of the testing cycle without any further tuning or adjustments. All six cameras met or exceeded specifications in all the tests. The cameras exceeded specifications for response, percent erase, and signal-to-noise ratio. No significant degradation was noticed between the first and second camera-calibration verifications.

2. Flight Model III-2 Tests at JPL (September 30, 1963 through January 23, 1964)

Flight Model III-2 was shipped to JPL on September 27, 1963. Integration personnel were on hand at JPL for continued support and testing. The Operational Support Equipment was

TABLE 52
SUMMARY OF FM III-1 TESTS AT JPL AUGUST 26 THROUGH DECEMBER 15, 1963

Description of Test	Date	Test Procedure
Quality-Control Inspection	August 26, 1963	RCA Specification RTSP-1100, App. L
Subsystem Command Checkout	August 26, 1963	RCA Specification RTSP-1100A, App. G
Subsystem Command Checkout	August 27, 1963	RCA Specification RTSP-1100A, App. G
System Verification Test 1	August 27, 1963	JPL Procedure 3R212.00
System Verification Test 2	August 28, 1963	JPL Procedure 3R300.01
System Verification Test 3	August 30, 1963	JPL Procedure 3R300.01
Subsystem Command Checkout	September 4, 1963	RCA Specification RTSP 1100A, App. G
Agena Match-mate Mechanical Test	September 6, 1963	JPL Procedure 3R300.01
TV-Shroud Light-Compatibility Test	September 6, 1963	JPL Procedure 3R405.00
Precountdown Dummy Run	September 9, 1963	JPL Procedure 3R303.04
Special Subsystem Communications Test	September 11 to September 13, 1963	Special Test
Subsystem Command Checkout	September 13, 1963	RCA Specification RTSP-1100 A, App. G
System Verification Test 4	September 14, 1963	JPL Procedure 3R300.02
Subsystem Command Checkout	September 16, 1963	RCA Specification RTSP-1100A, App. G
Subsystem Test	September 18, 1963	RCA Specification RTSP-1100A, App. F

TABLE 52
SUMMARY OF FM III-1 TESTS AT JPL AUGUST 26 THROUGH DECEMBER 15, 1963 (Continued)

Description of Test	Date	Test Procedure
Subsystem Test	September 18, 1963	RCA Specification RTSP-1100A, App. F
Vibration Test	September 20, 1963	JPL Procedure 3R311.00
Subsystem Test	September 26, 1963	RCA Specification RTSP-1100A, App. F
Pre-Thermal-Vacuum Mission Test	September 26, 1963	JPL Procedure 3R302.01
Thermal-Vacuum Mission Test (93° F)	September 27 to September 30, 1963	JPL Procedure 3R302.01
Special Thermal-Vacuum Mission Test (93° F)	October 1 to October 2, 1963	Special Test
Pre-Thermal-Vacuum Mission Test	October 2, 1963	JPL Procedure 3R302.01
Pre-Thermal-Vacuum Mission Test (53° F)	October 2 to October 8, 1963	JPL Procedure 3R302.02
Determination of TV Subsystem Response Characteristics	October 10 to October 11, 1963	JPL Procedure 3R200.00
Temperature Sensor Calibration	October 12, 1963	RCA Specification RTSP-1100A, App. J
Focus and Overlap Check	October 14, 1963	JPL Procedure 3R220.00
Quality-Control Inspection	October 16, 1963	JPL Form AA20772
Final Acceptance Test (System Test 5)	October 17, 1963	JPL Procedure 3R300.04
Special (Subsystem) Thermal-Vacuum Test	October 21 to October 22, 1963	Special Test

TABLE 52

SUMMARY OF FM III-1 TESTS AT JPL AUGUST 26 THROUGH DECEMBER 15, 1963 (Continued)

Description of Test	Date	Test Procedure
Camera and Vidicon Operating-Point Verification	November 6, 1963	RCA File No. 92705-20
Special Communications Check	November 12, 1963	Special Test
Special Pre-Thermal-Vacuum Test	November 13, 1963	Special Test
Special Thermal-Vacuum Test	November 14, 1963	RCA Specifications RTSP-1100A, App. D
Camera Black-Level Checks	November 21 to November 22, 1963	Special Test
Special Transmitter Tests	November 26, 1963	Special Test
Subsystem Test	November 27, 1963	RCA Specification RTSP-1100A, App. F
Subsystem Test	December 4, 1963	RCA Specification RTSP-1100A, App. F
Vibration Test	December 4, 1963	RCA Specification RTSP-1100A
System Verification Test No. 6	December 5, 1963	JPL Procedure 3R300.07
Space Flight Operations Center Test	December 6, 1963	JPL Procedure 3R300.05
Space-Simulator Pre-Mission Verification Test	December 10, 1963	JPL Procedure 3R302.04
Space-Simulator Mission Verification	December 10 to December 13, 1963	JPL Procedure 3R302.04
Quality-Control Inspection	December 14, 1963	RCA Specification RTSP-1100A, App. L

TABLE 53
SUMMARY OF FM III-1 TESTS AT ETR DECEMBER 28, 1963 THROUGH JANUARY 25, 1964

Description of Test	Date	Test Procedure
Subsystem Command Checkout	December 28, 1963	RCA Specification RTSP-1100A, App. G
Transmitter Frequency Check	December 29, 1963	Special Test
Subsystem Command Checkout	December 30, 1963	RCA Specification RTSP-1100A, App. G
System Verification Test 1	January 2, 1964	JPL Procedure 3R300.07
ESA Test	January 8, 1964	JPL Procedure 3R304.02
Precountdown Dummy Run	January 9, 1964	JPL Procedure 3R304.02
Combined Radiation Test	January 10, 1964	JPL Procedure 3R310.01
Countdown Dummy Run	January 11, 1964	JPL Procedure 3R309.02
J-Fact Test	January 13, 1964	JPL Procedures 3R390.02 and 3R307.01
Combined Radiation Test	January 14, 1964	JPL Procedure 3R310.01
TV Subsystem Checkout	January 16, 1964	RCA Specification RTSP-1100A, App. G
Final System Verification Test	January 18, 1964	JPL Procedure 3R300.09 and ETR 3R300.01
Final Assembly and Flight Preparation	January 21, through January 25, 1964	JPL Procedure 3R134.03

TABLE 54

SUMMARY OF FM III-2 TESTS AT RCA AUGUST 28 THROUGH SEPTEMBER 26, 1963

Description of Test	Date	Test Procedure
Camera Calibration Verification No. 1	August 28 through September 2, 1963	RCA Specification RTSP-1100 A, App. C
TV Subsystem Test No. 1	September 3, 1963	RCA Specification RTSP-1100 A, App. C
Subsystem Command Checkout Test	September 5, 1963	RCA Specification RTSP-1100 A, App. G
Vibration Test	September 5, 1963	RCA Specification RTSP-1101
Subsystem Command Checkout Test	September 6, 1963	RCA Specification RTSP-1100 A, App. G
Thermal-VacuumTest	September 6 through September 9, 1963	RCA Specification RTSP-1101 A
Simulated Mission Test No. 1	September 12, 1963	RCA Specification RTSP-1100 A, App. D
Simulated Mission Test No. 2	September 12, 1963	RCA Specification RTSP-1100 A, App. D
Simulated Mission Test No. 3	September 13, 1963	RCA Specification RTSP-1100 A, App. D
Camera-Array Alignment Determination	September 15, 1963	RCA Specification RTSP-1100 A, App. H
Camera Calibration Verification No. 2	September 16 through September 19, 1963	RCA Specification RTSP-1100 A, App. F
Acceptance Test	September 24, 1963	RCA Specification RTSP-1100 A, App. F
Preshipment Electrical Test	September 26, 1963	RCA Specification RTSP-1100 A, App. G

aligned and calibrated to eliminate sensitivity problems, and on September 30, the testing (as listed in Table 55) was started.

On December 7, 1963 rework on the P Camera was completed, and the F_a Camera was removed and new bottom shutter shock isolators installed. All camera lenses and vidicon faceplates were cleaned. All shutter shock isolators were replaced with new types. On January 6, 1964, when the terminal maneuver for Mission Test No. 1 was performed, a dropout was observed on P2 Camera video. Subsequently, Flight Model III-2 was removed from the Bus, and further investigation indicated a possible malfunction of the P2 Camera. On January 7, 1964, the P2 Camera (Serial No. 039) and the Camera Electronics Assembly (Serial No. 033) were replaced by P Camera Serial No. 036 and Camera Electronics Assembly Serial No. 034. Then, prior to the resumption of thermal-vacuum testing, an electrical test was conducted. During this test, the P-Channel did not come on during full power. This problem was traced to a malfunction in the P-Channel Transmitter Power Supply. This was the second transmitter failure to occur in a short time; therefore, the P-Channel Transmitter was replaced.

The Subsystem was then reassembled and tested. During this test, the video cables from the cameras to the video combiner were found to be loose and improperly inserted. This situation was corrected; and, on January 8, 1964, further testing was performed and the TV Subsystem operated satisfactorily. Thermal-vacuum testing was resumed later the same day, and the testing at JPL was successfully concluded on January 23, 1964.

3. Flight Model III-2 Tests at ETR and RCA (February 3 through February 14, 1964)

Flight Model III-2 arrived at ETR on February 3, 1964 and, after inspection and a brief electrical test, it was concluded that no damage occurred during shipping. Final sty-casting of the connectors was performed, and a final mechanical inspection and preparation for launch were completed on February 6. On February 7, a backup-function test was performed. A review of the postshipment test indicated that two noisy telemetry frames existed on the Channel-8 Telemetry.

On February 12, following the Ranger VI failure, TV Subsystem Flight Model III-2 was shipped to RCA and arrived there on February 14. An electrical test indicated that the Subsystem operated properly. On February 14, Flight Model III-2 of the TV Subsystem was prepared for rework in conjunction with the anticipated Ranger redesign as a result of the Ranger VI flight and, where necessary, all components were released for evaluation, rework, and redesign.

4. Modified Flight Model III-2 Tests at RCA (April 5 through May 1, 1964)

The Modified Flight Model III-2 TV Subsystem was the first flight model containing the design changes resulting from the Ranger VI failure analysis. The philosophy of testing was to perform a series of tests which would cover all of the expected conditions of the lunar mission in order to gain a high level of confidence in the TV Subsystem in light of the post-Ranger VI design changes.

A complete listing of the tests performed at RCA is given in Table 56. The TV Subsystem performed satisfactorily during the testing cycle with the following exceptions. Both the 15- and 90-point telemetry exhibited excessive noise during the pre-thermal-vacuum test of April 19, 1964. The problem was traced to a malfunction of the commutators and these were replaced. Studies were conducted to establish a new source for commutators to prevent a recurrence of this problem during a mission; Fifth Dimension Inc. commutators were subsequently used.

All resolvable problem areas were corrected and the TV Subsystem was shipped to JPL on May 1, 1964.

TABLE 55
SUMMARY OF FM III-2 TESTS AT JPL
SEPTEMBER 30, 1963 THROUGH JANUARY 23, 1964

Description of Test	Date	Test Procedure
Postshipment Electrical Test	Sept 30, 1963	RCA Specification RTSP-1100A, App. G
Subsystem Command Checkout Test	Oct 9, 1963	RCA Specification RTSP-1100A, App. G
System Verification Test	Oct 11, 1963	JPL Procedure 3R300
Backup Function Test	Oct 12, 1963	JPL Procedure 3R305
Agena Match-mate, Umbilical Safety Check	Oct 14 through 17, 1963	Special Test
TV Subsystem and Shroud-Lights Compatibility and RF Losses Test	Oct 17, 1963	JPL Procedure 3R405
Precountdown Dummy Run	Oct 18, 1963	JPL Procedure 3R303
RF Interference Test	Dec 12, 1963	JPL Procedure 3R212.01
Previbration Test	Dec 13, 1963	JPL Procedure 3R300.07
Structural Fitness Vibration Survey	Dec 16, 1963	JPL Procedure 3R117.01
Vibration Test	Dec 17 through 24, 1963	JPL Procedure 3R311.01
Postvibration Test	Dec 24, 1963	JPL Procedure 3R117.01
Camera Calibration and Alignment	Dec 30, 1963	RCA Specification 1100A
Power Profile	Jan 1, 1964	Special Test
Short Electrical Test	Jan 2, 1964	Special Test
Mission Verification Test 1	Jan 2 through 6, 1964	JPL Procedure 3R302.04
System Command Checkout Test	Jan 8, 1964	RCA Specification RTSP-1100A, App. G
Mission Verification Test 2	Jan 8 through 11, 1964	JPL Procedure 3R302.04

TABLE 55
SUMMARY OF FM III-2 TESTS AT JPL
SEPTEMBER 30, 1963 THROUGH JANUARY 23, 1964 (Continued)

Description of Test	Date	Test Procedure
Mission Verification Test 3	Jan 11 through 14, 1964	JPL Procedure 3R302.04
Camera Calibration	Jan 15 through 20, 1964	JPL Procedure 3R220.01
Spacecraft-SFOF Compatibility Test	Jan 21, 1964	JPL Procedure 3R318.03
System Verification Test	Jan 23, 1964	JPL Procedure 3R300.08

TABLE 56
SUMMARY OF MODIFIED FM III-2 TESTS AT RCA
APRIL 5, 1964 THROUGH MAY 1, 1964

Description of Test	Date	Test Procedure
Initial Power Application and Checkout	April 5 through 9, 1964	RCA Specification RTSP-1100 A, App. A
Camera Alignment	April 9 through 14, 1964	RCA Specification RTSP-1100 A, App. C
Telemetry Calibration	April 14 through 15, 1964	RCA Specification RTSP-1100 A, App. N
TV Subsystem Test	April 18, 1964	RCA Specification RTSP-1100 A, App. F
Abbreviated Subsystem Test No. 1		RCA Specification RTSP-1100 A, App. R
Abbreviated Subsystem Test No. 2		RCA Specification RTSP-1100 A, App. R
Operational Verification Test		RCA Specification RTSP-1100 A, App. G
Abbreviated Subsystem Test No. 3		RCA Specification RTSP-1100 A, App. R
Abbreviated Mission Test	April 20 to 22, 1964	RCA Specification RTSP-1100 A, Addendum 1 to App. D
Mission Verification Test No 1 (incomplete)	April 22, 1964	RCA Specification RTSP-1100 A, App. R
Operational Verification Test	April 22, 1964	RCA Specification RTSP-1100 A, App. G
Abbreviated Subsystem Test No. 4	April 22, 1964	RCA Specification RTSP-1100 A, App. R
Abbreviated Subsystem Test No. 5	April 22, 1964	RCA Specification RTSP-1100 A, App. R
Camera Alignment	April 23 through 24, 1964	RCA Specification RTSP-1100 A, App. C
Abbreviated Subsystem Test No. 6 (modified)	April 25, 1964	RCA Specification RTSP-1100 A, App. R
Abbreviated Subsystem Test No. 7 (modified)	April 25, 1964	RCA Specification RTSP-1100 A, App. R
Abbreviated Subsystem Test No. 8	April 25, 1964	RCA Specification RTSP-1100 A, App. R
Operational Verification Test	April 25, 1964	RCA Specification RTSP-1100 A, App. G
Abbreviated Subsystem Test No. 9	April 25, 1964	RCA Specification RTSP-1100 A, App. R

TABLE 56
SUMMARY OF MODIFIED FM III-2 TESTS AT RCA
APRIL 5, 1964 THROUGH MAY 1, 1964 (Continued)

Description of Test	Date	Test Procedure
Mission Verification Test No. 2	April 26, 1964	RCA Specification RTSP-1100 A, App. R
Operational Verification Test	April 26, 1964	RCA Specification RTSP-1100 A, App. G
Camera-Array Alignment Determination	April 27, 1964	RCA Specification RTSP-1100 A, App. H
Pin-Retention Test	April 27, 1964	RCA Specification RTSP-1100 A, App. L
Acceptance Test	April 30, 1964	RCA Specification RTSP-1100 A, App. F
Preshipment Electrical Test	May 1, 1964	RCA Specification RTSP-1100 A, App. G

5. Modified Flight Model III-2 Tests at JPL (May 2 through June 1, 1964)

Modified Flight Model III-2 TV Subsystem arrived at JPL on May 2, 1964. At JPL the Subsystem was integrated with the spacecraft Bus to form the complete Ranger VII Spacecraft. A tabulation of the tests performed while at JPL is given in Table 57.

During the testing cycle at JPL, the telemetry chassis was changed to incorporate the new 5-D commutators into the TV Subsystem.

The TV Subsystem performed satisfactorily throughout the testing at JPL with the exception of the five minor discrepancies presented below.

- Point No. 8 of the 15-point telemetry indicated a failure during the RF Link Test. This point monitors the -y axis shroud temperature. The failure was traced to the temperature sensor; a new unit was installed and operation was normal.
- Tearing of sync on the F-Channel video was noted during several of the tests. The problem was associated with the OSE and did not reflect on the operation of the TV Subsystem because the tearing was not exhibited on the tape playbacks.
- F-Channel power output did not meet the two-minute specifications of 19.5 watts during Mission Verification Test No. 5. The problem was attributed to both a marginal battery voltage of 29.7 volts and the fact that the F-Channel tuning was for a slow power rise which would permit a satisfactory one-hour mission. Later testing demonstrated that the F-Channel transmitter and power amplifier were working normally.
- RFI problems were noted during the match-mate test and the space-simulator operational checkouts; these were apparently caused by the test setup. (Both of these tests were conducted using an RF link.) The Explosive-Safe Area (ESA) test No. 2 showed that RFI was not a problem when the high-gain antenna was radiating into a microwave absorber or free space.
- Noise, in the form of fast noise spikes and some microphonics, was observed on the P Cameras throughout the testing cycle. The noise was within specified limits and not considered objectionable.

With the conclusion of testing at JPL, sufficient data had been gathered to establish a high level of confidence in the Ranger VII Spacecraft. On June 21, 1964, the Ranger VII Spacecraft was shipped to the Eastern Test Range (ETR) for a final series of tests prior to launch.

6. Modified Flight Model III-2 Tests at ETR (June 23 through July 28, 1964)

The tests at ETR were performed on the Modified Flight Model III-2 as part of the spacecraft, and on the spacecraft when adapted to the launch vehicle. The purpose of these tests was to ensure correct TV Subsystem operation, to train personnel in spacecraft and launch-vehicle procedures, and to verify these procedures. A list of tests performed at ETR is given in Table 58.

Discrepancies that occurred during ETR testing and their resolution are listed below.

- RFI was noted during Agena shroud testing. This was traced to the omni-antenna reflecting into the high-gain antenna in the Agena shroud. This condition would not exist in the lunar mission, therefore, the RFI was not considered a problem.
- Noise previously noted was observed throughout testing at ETR.
- No P1 Camera video was observed during the initial tests under the Agena

TABLE 57
SUMMARY OF MODIFIED FM III-2 TESTS AT JPL
MAY 2, 1964 THROUGH JUNE 1, 1964

Description of Test	Date	Test Procedure
Postshipment Electrical Test	May 2, 1964	RCA Specification RTSP-1100A, App. R
Match-mate Test	May 2, 1964	JPL Procedure 3R212.04
System Verification Test No. 8	May 4, 1964	JPL Procedure 3R300.11
RF Link Test	May 5, 1964	JPL Procedure 3R315.00
Post x-Axis Vibration	May 8, 1964	JPL Procedure 3R311.03
Post y-Axis Vibration	May 8, 1964	JPL Procedure 3R311.03
Post z-axis Vibration	May 12, 1964	JPL Procedure 3R311.03
Vibration Test	May 12, 1964	JPL Procedure 3R311.03
System Verification Test No. 9	May 14, 1964	JPL Procedure 3R300.12
Subsystem Verification Test	May 21, 1964	RCA Specification RTSP-1100A, App. R
Pre-Thermal-Vacuum Verification Test	May 24, 1964	JPL Procedure 3R302.05
Mission Verification Test Nos. 4 and 5	May 28 to 31, 1964	JPL Procedure 3R302.05
Special TV Subsystem Test	June 8, 1964	RCA Specification RTSP-1100A, App. D
Space-Simulator Operational Check	June 8, 1964	JPL Procedure 3R320.01
Space-Simulator Operational Check	June 9, 1964	JPL Procedure 3R320.01
ESA Test No. 1	June 10, 1964	JPL Procedure 3R235.00
ESA Test No. 2 (RFI Test)	June 10, 1964	JPL Procedure 3R235.00
Backup Function Test No. 3	June 11, 1964	JPL Procedure 3R305.06

TABLE 58
SUMMARY OF MODIFIED FM III-2 TESTS AT ETR
JUNE 23, 1964 THROUGH JULY 28, 1964

Description of Test	Date	Test Procedure
Postshipment Electrical Test	June 23, 1964	RCA Specification RTSP-1100A, App. R
Backup Functions Test	June 25, 1964	JPL Procedure 3R305.07
System Verification Test 10	June 27, 1964	JPL Procedure 3R300.13
Operational Checkout, RF Link Test	June 29, 1964	JPL Procedure 3R315.02
ESA High-Power Test	July 1, 1964	JPL Procedure 3R235.01
ESA Low-Power Tests	July 2, 1964	JPL Procedure 3R317.02
Special RFI Test	July 2, 1964	JPL Procedure 3R317.02
Special ESA Test	July 6, 1964	JPL Procedure 3R317.02 (1-A)
Precountdown Dummy Run	July 6, 1964	JPL Procedure 3R304.04
Combined Radiation Test	July 7, 1964	JPL Procedure 3R310.02
Joint Flight Acceptance Composite Test	July 10, 1964	JPL Procedure 3R309.05
Camera Calibration	July 11, 1964	JPL Procedure 3R220.02
Preflight System Test 11	July 15, 1964	JPL Procedure 3R300.13
ESA High-Power Test	July 20, 1964	JPL Procedure 3R235.02
ESA Low-Power Test	July 22, 1964	JPL Procedure 3R317.03
Precountdown Test	July 23, 1964	JPL Procedure 3R304.05
Simulated Launch	July 25, 1964	JPL Procedure 3R309.06
Countdown on First Day	July 27, 1964	JPL Procedure 3R309.06
Countdown on Second Day	July 28, 1964	JPL Procedure 3R309.06

shroud. The problem was that the shroud-light was obstructed from the P1 Camera view; this was corrected by enlarging the shroud-light hole.

Data from the entire test program of the Ranger VII Spacecraft was evaluated and indicated that the spacecraft was ready to perform its lunar mission. Countdown for launch started on July 27, 1964, but was aborted at T+22 minutes because of a problem in the Atlas guidance system. On July 28, 1964, the second day of the launch window, the countdown was started again. Countdown tests on the TV Subsystem verified that, in every aspect, the equipment was working satisfactorily. Launch of the Ranger VII Spacecraft took place at 16:50:00 GMT on July 28, 1964. The successful results of the mission justified the high level of confidence in the spacecraft generated by the complete and exacting test cycle to which it had been subjected.

G. FLIGHT MODEL III-3

1. Flight Model III-3 Tests at RCA (November 23, 1963 through January 3, 1964)

A Subsystem Test was performed on Flight Model III-3 of the Ranger TV Subsystem on December 4, 1963. The test objective was to verify overall Subsystem operation prior to the start of environmental testing.

The TV Subsystem was exercised through all modes of operation by simulated and real-time commands. Overall results were satisfactory and verified proper operation of the Subsystem. Following the thermal-balance tests, the communications equipment was returned and checked. A leak test was performed on the pressure vessels and revealed that the pressure in the Dummy Load Assembly was zero psi. The O ring, pressure valve, valve core, and RF connector were replaced when a deformed pressure-valve core was discovered.

A thermal-vacuum verification test of Flight Model III-3 was conducted from December 9 to 12, 1963 after which three abbreviated missions were performed for electrical verification of Subsystem operation. The collimators were then installed, a successful command checkout test performed, and the Subsystem was placed in the thermal-vacuum chamber on December 14, 1963.

The actual turn-on of the commands for the Simulated Mission Tests were performed on December 15, 1963, following pump-down of the chamber. All operations and commands appeared normal except for some RF power fluctuations. Investigation disclosed that these fluctuations were caused by the AC transients in the monitoring equipment, and the tests continued. Three simulated missions were completed on December 15, 1963 and the results were satisfactory.

On December 18, vibration testing was satisfactorily completed. Electrical tests were run before and after vibration and there was no significant degradation in the Subsystem. The thermal-vacuum retest was satisfactorily completed on December 19, 1963.

The acceptance test was performed December 30, 1963 and was satisfactory except for noisy video. The following corrections were accomplished prior to performing a second acceptance test.

- The P-Channel communications chain was tuned on December 31, 1963; subsequent tests indicated that the video was now satisfactory.
- The 15-kc noise and power-supply spikes were reduced to 30 mv and the background noise was almost completely eliminated.

On January 3, 1964, a preshipment electrical test was satisfactorily completed, and Flight Model III-3 was shipped to JPL. A chronological listing of tests performed at RCA is given in Table 59.

TABLE 59
SUMMARY OF FM III-3 TESTS AT RCA
NOVEMBER 23, 1963 THROUGH JANUARY 3, 1964

Description of Test	Date	Test Procedure
Camera-Calibration Verification 1	Nov 23 through 26, 1963	RCA Specification RTSP-1100A, App. C
TV Subsystem Test 1	Dec 4, 1963	RCA Specification RTSP-1100A, App. F
Subsystem Command Checkout Test	Dec 7, 1963	RCA Specification RTSP-1100A, App. G
Thermal-Vacuum Test (thermal balance)	Dec 9 through 13, 1963	RCA Specification RTSP-1100A, App. D
Subsystem Command Checkout Test	Dec 14, 1963	RCA Specification RTSP-1100A, App. G
Mission Verification Test 1	Dec 15, 1963	RCA Specification RTSP-1100A, App. D
Subsystem Command Checkout Test	Dec 18, 1963	RCA Specification RTSP-1100A, App. G
Vibration Test	Dec 18, 1963	RCA Specification RTSP-1101A
Subsystem Command Checkout Test	Dec 18, 1963	RCA Specification RTSP-1100A, App. G
Mission Verification Test 2 (abbreviated)	Dec 19, 1963	RCA Specification RTSP-1100A, App. D
Camera-Calibration Verification 2	Dec 23 through 24, 1963	RCA Specification RTSP-1101A, App. C
Camera-Array Alignment Determination	Dec 26, 1963	RCA Specification RTSP-1101A, App. H
Acceptance Test	Dec 30, 1963	RCA Specification RTSP-1100A, App. F
Camera-Calibration Verification 3 (partial)	Dec 31, 1963 through Jan 2, 1964	RCA Specification RTSP-1100A, App. C
Preshipment Electrical Test	Jan 3, 1964	RCA Specification RTSP-1100A, App. G

2. Flight Model III-3 Tests at JPL (January 4 through February 28, 1964)

After Flight Model III-3 arrived at JPL, it was removed from the shipping container and an electrical test verified proper operation of the Subsystem. While at JPL, the P-Channel communications chain and the P2 Camera were removed from Flight Model III-3 and mounted on Flight Model III-2. The testing of Flight Model III-3 was delayed pending the receipt of replacement assemblies. P-Channel communications equipment from Flight Model III-2 and the Transmitter Power Supply from the LTM were installed in Flight Model III-3 and tuned. A Subsystem command checkout without the P2 Camera was conducted and results showed that the Subsystem performed satisfactorily.

On January 27, 1964, P2 Camera, Serial No. 39, and P2 Camera Electronics, Serial No. 33, were installed in the Flight Model III-3 Subsystem and calibration was completed on January 28. After retuning the Subsystem to flight configuration, a Subsystem Test was conducted and satisfactory performance was observed. The Subsystem was again mated with the Ranger VIII Bus, and System Verification Test No. 2 was conducted. Fifteen minutes after turn-on of the external power to the Subsystem, F-Channel unexpectedly turned on in warm-up. F-Channel was turned off and the test continued in the normal cruise-mode operation. It was concluded that the Clock-Start relay in the Distribution Control Unit had not been reset after the previous operations. The Backup-Function System test and RFI tests were conducted on February 3 and 4, 1964, respectively. Both tests indicated satisfactory performance of the Subsystem. On February 7, a System Verification Test was performed. During this test, two abnormal conditions were observed during the operation of the Subsystem:

- F-Channel turned on in warm-up when power was switched from external to internal at T+30 minutes; and
- P-Channel went to full power approximately two minutes early, at T+48 minutes.

The first problem appeared to be caused by a transient turn-on of the High-Current Voltage Regulator by the initial application of voltage to the SCR cathode. The second problem initially appeared to be a Camera Sequencer failure; however, the problem was still evident after Camera Sequencer, Serial No. 002, and Sequencer Power Supply, Serial No. 005, were replaced with Sequencer, Serial No. 006, and Sequencer Power Supply, Serial No. 010. Further investigation revealed the problem to be due to OSE malfunction, although the specific source of the noise that caused the early full-power turn-on of the P-Channel could not be isolated. Match-mate tests were performed and proved to be satisfactory. Two preshipment electrical tests were conducted and two problems were encountered during the first test:

- The P-Channel RF output ceased when the CC&S warm-up command was released at the Test Console (Unit 18); and
- The emergency telemetry amplitude was approximately 50 percent below normal.

Performance during the second test was normal. After the Ranger VI mission, the Subsystem was packed and shipped from JPL to RCA for modification on March 2, 1964. A chronological listing of tests performed on FM III-3 at JPL is given in Table 60.

3. Modified Flight Model III-3 Tests at RCA (August 10 through October 17, 1964)

The testing and checkout of Modified FM III-3 commenced on August 10, 1964 and was completed on October 17, 1964. The testing cycle verified the satisfactory operation of the TV Subsystem. Table 61 lists the testing performed on Modified FM III-3 at RCA.

TABLE 60
SUMMARY OF FM III-3 TESTS AT JPL
JANUARY 4, 1964 THROUGH FEBRUARY 28, 1964

Description of Test	Date	Test Procedure
Postshipment Electrical Test	Jan 4, 1964	RCA Specification RTSP-1100A, App. G
System Command Checkout (less P2 Camera)	Jan 24, 1964	RCA Specification RTSP-1100A, App. G
System Verification Test 1 (less P2 Camera)	Jan 25, 1964	JPL Procedure 3R300
TV Subsystem Test	Jan 29, 1964	RCA Specification RTSP-1100, App. R
System Verification Test 2	Jan 30, 1964	JPL Procedure 3R300
Backup Function System Test	Feb 3, 1964	JPL Procedure 3R305
RFI Test	Feb 4, 1964	JPL Procedure 3R212.01
TV Subsystem Test	Feb 5, 1964	RCA Specification RTSP-1100A, App. R
System Verification Test 3	Feb 6, 1964	JPL Procedure 3R300
Match-mate Test	Feb 10 through 17, 1964	JPL Procedure 3R212.04
Preshipment Electrical Test No. 1	Feb 28, 1964	RCA Specification RTSP-1100A, App. G
Preshipment Electrical Test No. 2	Feb 28, 1964	RCA Specification RTSP-1100A, App. G

TABLE 61
SUMMARY OF MODIFIED FM III-3 TESTS AT RCA
AUGUST 10, 1964 THROUGH OCTOBER 17, 1964

Description of Test	Date	Test Procedure
Initial Power Application and Checkout	Aug 10 to Sept 15, 1964	RCA Specification RTSP-1100A, App. A
Communications Calibration	Aug 10 to Sept 15, 1964	RCA Specification RTSP-1100A, App. C
Camera Calibration	Aug 10 to Sept 15, 1964	RCA Specification RTSP-1100A, App. C
Telemetry Calibration	Aug 10 to Sept 15, 1964	RCA Specification RTSP-1100A, App. N
Subsystem Test	Sept 16, 1964	RCA Specification RTSP-1100A, App. F
Previbration Electrical Check	Sept 17, 1964	RCA Specification RTSP-1100A, App. R
Vibration	Sept 17, 1964	RCA Specification RSP/RTSP-1101A, App. A
Postvibration Electrical Check	Sept 17, 1964	RCA Specification RTSP-1100A, App. R
Pre-Thermal-Vacuum Test 1	Sept 19, 1964	RCA Specification RTSP-1100A, App. R
Thermal-Vacuum Test (+25° C)	Sept 20, 1964	RCA Specification RTSP-1100A, App. D, Part A
Thermal-Vacuum Test (+35° C)	Sept 20, 1964	RCA Specification RTSP-1100A, App. D, Part B
Thermal-Vacuum Test (+15° C)	Sept 22, 1964	RCA Specification RTSP-1100A, App. D, Parts C and D
Post-Thermal-Vacuum Test 1a	Sept 22, 1964	RCA Specification RTSP-1100A, App. R
Post-Thermal-Vacuum Test 1b	Sept 22, 1964	RCA Specification RTSP-1100A, App. R
P4 Camera Calibration	Sept 23, 1964	RCA Specification RTSP-1100A, App. C
Pre-Thermal-Vacuum Test	Sept 25, 1964	RCA Specification RTSP-1100A, App. R
Thermal-Vacuum Test (+15° C)	Sept 26, 1964	RCA Specification RTSP-1100A, App. D
Thermal-Vacuum Test (+35° C)	Sept 26, 1964	RCA Specification RTSP-1100A, App. D
Post-Thermal-Vacuum Test	Sept 26, 1964	RCA Specification RTSP-1100A, App. R

TABLE 61
SUMMARY OF MODIFIED FM III-3 TESTS AT RCA
AUGUST 10, 1964 THROUGH OCTOBER 17, 1964 (Continued)

Description of Test	Date	Test Procedure
Post-Thermal-Vacuum P2 and P3 Camera Optical Focusing	Sept 28, 1964	RCA Specification RTSP-1100A, App. R
Pre-Thermal-Vacuum Test	Sept 29, 1964	RCA Specification RTSP-1100A, App. R
Thermal-Vacuum Test (+35° C)	Sept 29, 1964	RCA Specification RTSP-1100A, App. D
Thermal-Vacuum Test (25° C)	Sept 30, 1964	RCA Specification RTSP-1100A, App. R
Post-Thermal-Vacuum Test (35° C)	Sept 30, 1964	RCA Specification RTSP-1100A, App. R
Post-Thermal-Vacuum Test (25° C)	Sept 30, 1964	RCA Specification RTSP-1100A, App. R
Pre-Thermal-Vacuum Test	Oct 6, 1964	RCA Specification RTSP-1100A, App. R
Thermal-Vacuum Test (35° C)	Oct 7, 1964	RCA Specification RTSP-1100A, App. R
Thermal-Vacuum Test (25° C)	Oct 7, 1964	RCA Specification RTSP-1100A, App. R
Post-Thermal-Vacuum Test	Oct 7, 1964	RCA Specification RTSP-1100A, App. R
Camera Array Alignment	Oct 10, 1964	RCA Specification RTSP-1100A, App. C
Final Subsystem Test	Oct 12, 1964	RCA Specification RTSP-1100A, App. F
Camera Array Alignment	Oct 12, 1964	RCA Specification RTSP-1100A, App. H
Outdoor Pictures No. 1	Oct 13, 1964	Special Test
Outdoor Pictures No. 2	Oct 14, 1964	Special Test
Preshipment Test 1	Oct 14, 1964	RCA Specification RTSP-1100A, App. R
Preshipment Test 2	Oct 14, 1964	RCA Specification RTSP-1100A, App. R
Preshipment Test 3	Oct 16, 1964	RCA Specification RTSP-1100A, App. R
Preshipment Test 4	Oct 17, 1964	RCA Specification RTSP-1100A, App. R

During the initial power application and checkout, the TV Subsystem performed satisfactorily; the only problem occurred when the Subsystem failed to turn off in response to an RTC-5 command. The cause was found to be a faulty turn-off circuit in the CCU. A Subsystem test was then performed to verify the overall operation of the integrated TV Subsystem before environmental testing. The vibration test cycle was preceded by an electrical verification test that was normal in all respects, as was the test run made after the vibration testing.

The TV Subsystem was exercised through four thermal-vacuum test cycles because a series of problems arose during the tests. The operation of the TV Subsystem during the first thermal-vacuum test cycle showed low-power output from the communications equipment and a defocusing of the partial-scan cameras. These problems were corrected and a second test cycle was performed. The results of the second test cycle did not show any improvement in the operation of the P-scan cameras; Cameras P2 and P3 were then removed and refocused. A third test cycle was performed to determine the extent of defocusing caused by operation at different temperatures and pressures. An additional refocusing of the cameras took place following the third thermal-vacuum test cycle and a fourth cycle was performed to verify the refocusing techniques employed. As a result of camera defocusing, a thorough study was initiated to investigate the cause of this problem. The problem was caused by a changing index of refraction in the environment surrounding the lenses. Compensation was made for this difference by revised focusing techniques. The data recorded during the test indicated that the Subsystem operated normally in all respects. Outdoor pictures were taken as an additional verification of the camera characteristics, particularly resolution. Camera performance was satisfactory.

The preshipment electrical test was repeated three times before normal operation of the TV Subsystem was acquired. The initial run was terminated when a loss of video in the F_b camera occurred; investigation revealed that a short circuit existed on the G2 regulator output. In the second test, a review of the telemetry data indicated an abnormality in the G1 regulator of the F_b Camera; a shorted transistor in the telemetry circuit was discovered to be the cause. This component was replaced as were other components electrically overstressed by the short-circuit condition. A third test run was made and although operation appeared to be normal, the video tape recorder did not record and the test was voided. All operations were analyzed and indicated the fourth test run to be normal. Following the four preshipment electrical tests, the Flight Model III-3 TV Subsystem was shipped from RCA on October 17, 1964 and arrived at JPL on October 18, 1964.

4. Modified Flight Model III-3 Tests at JPL and ETR (October 19, 1964 through February 17, 1965)

Tests were performed at JPL to verify the performance of the electronic equipment in the TV Subsystem and the electrical integrity of the TV Subsystem integrated with the spacecraft Bus. These tests were designed to verify the satisfactory operation of the TV Subsystem in ambient, simulated-launch, and simulated-flight (space) environments. The test program also verified the procedures and operational readiness of the operational support equipment used to check out the integrated Ranger Spacecraft prior to launch. The ETR test program consisted of checkout and test of the TV Subsystem integrated with the Spacecraft Bus in the Spacecraft Checkout Facility (SCF) Hangar AO, operations in the Explosive-Safe Facility (ESF), and operations on the launch pad in conjunction with the Atlas/Agena launch vehicles. The purpose of the prelaunch testing at ETR was: to reaffirm the operational readiness of the TV Subsystem when integrated with the Spacecraft Bus; to ensure that all Subsystems of the Ranger VIII Spacecraft were compatible with the launch vehicle; and to ensure that all Subsystems of the Ranger VIII Spacecraft were in a "go" condition at the time of launch. These tests also provided the opportunity to verify launch procedures and to increase the proficiency of operating personnel, thus ensuring smooth launch operations. The results of all the tests were normal, and only minor problems were encountered during the testing of Modified Flight Model III-3. The tests performed at JPL are listed in Table 62, and the tests performed at ETR are listed in Table 63. The Ranger VIII Spacecraft was launched at 12:05:00 GMT on February 17, 1965.

H. FLIGHT MODEL III-4

1. Flight Model III-4 Tests at RCA (January 19 through February 1, 1964)

Camera-performance calibration for Flight Model III-4 was completed on January 19, 1964. The first Subsystem test was performed and satisfactory operation of the Subsystem was verified. However, the start of environmental testing was delayed to perform adjustments that resulted in refinements of the camera picture quality.

During this period, the output of telemetry point 57 of the 90-point telemetry was observed to be zero instead of the normal 4.7 volts for the Command Switch in the ZERO position. The problem was traced to a wire within the Command Switch which had shorted to one of its mounting screws; this condition was subsequently corrected.

The vibration test was conducted and subsequent command checkout tests performed before and after the vibration tests; these checkout tests proved there was no electrical or mechanical degradation of FM III-4 due to the vibration testing.

During thermal-vacuum tests, the 90-point commutator was causing noise in the output from the 225-kc VCO. The faulty commutator was replaced and normal operation was restored. Also, during the terminal-mode operation of the thermal-balance test the voltage of the P-Battery dropped to 30.45 volts and the P-Channel was turned off; the F-Channel also ceased to provide any detectable RF output at T + 49 minutes and 30 seconds. The cause of the malfunction of the F-Channel was a short in the +100-volt circuit of the transmitter power supply. Thermal-vacuum testing was discontinued pending results of the Ranger VI investigation. The Subsystem was placed in a container in the integration area awaiting rescheduling and modifications prior to future testing. The summary of tests performed on Flight Model III-4 is given in Table 64.

2. Modified Flight Model III-4 Tests at RCA (October 1 through December 2, 1964)

The testing and checkout of the Modified Flight Model III-4 commenced on October 1, 1964 and was completed on December 2, 1964. This cycle verified the satisfactory operation of the Modified FM III-4 and it was shipped to JPL on December 3, 1964. Table 65 lists the testing performed on the Modified FM III-4 at RCA.

An initial power application and checkout was performed on the power and command circuits of Flight Model III-4. The order of the testing varied in sequence because the cameras were not available at the start of the testing. The overall results of the tests were satisfactory except as follows.

- P1 Camera met performance specifications; however, it exhibited horizontal sync pulses that were lower in amplitude and shorter in duration than the sync pulses of the other P-scan cameras.
- Three base-ring connectors (30J1, 30J2, and 30J9) were not grounded to the frame; the situation was corrected by

TABLE 62
SUMMARY OF MODIFIED FM III-3 TESTS AT JPL
OCTOBER 19, 1964 THROUGH NOVEMBER 24, 1964

Description of Test	Date	Test Procedure
Postshipment Electrical Test	Oct 19, 1964	RCA Specification RTSP-1100A, App. R
TV Subsystem Checkout	Oct 20, 1964	JPL Procedure 3R212.05
System Verification Test 2	Oct 21, 1964	JPL Procedure 3R300.15
Backup Functions System Test	Oct 23, 1964	JPL Procedure 3R305.07
System and EMI Test 3	Oct 26, 1964	JPL Procedure 3R300.15
ESF Television Full-Power RF Test	Oct 28, 1964	JPL Procedure 3R235.02
TV Subsystem and Shroud-Lights Compatibility, and RF Losses Test	Oct 31, 1964	JPL Procedure 3R405.03
ESF Operational Checkout	Nov 2, 1964	JPL Procedure 3R317.03
Precountdown Dummy Run	Nov 2, 1964	JPL Procedure 3R303.06
Countdown Dummy Run	Nov 3, 1964	JPL Procedure 3R308.06
Pyrotechnic-Extension System Test	Nov 4, 1964	JPL Procedure 3R313.06
Communications Verification Test	Nov 6, 1964	Special Test
Camera Calibration	Nov 7, 1964	Special Test
Abbreviated Subsystem Test	Nov 13, 1964	RCA Specification RTSP-1100A, App. R
Previbration Verification Test	Nov 13, 1964	Special Test
Vibration Test	Nov 16 through 20, 1964	JPL Procedure 3R311.04
Postvibration System and EMI Test 4	Nov 23, 1964	JPL Procedure 3R300.16
Abbreviated TV Subsystem Test	Nov 24, 1964	RCA Specification RTSP-1100A, App. R
Premission Verification Test	Nov 24, 1964	JPL Procedure 3R302.05

TABLE 62
SUMMARY OF MODIFIED FM III-3 TESTS AT JPL
OCTOBER 19, 1964 THROUGH NOVEMBER 24, 1964 (Continued)

Description of Test	Date	Test Procedure
Mission Verification Test 1	Dec 1, 1964	JPL Procedure 3R302.08
Mission Verification Test 2	Dec 4, 1964	JPL Procedure 3R302.08
Special P2 and P4 Camera Thermal-Vacuum Test	Dec 5, 1964	Special Test
Special RFI Test	Dec 7, 1964	Special Test
F-Channel Transmitter Power Supply Rework Test	Dec 9, 1964	Special Test
P-Channel HCVR Rework Test	Dec 10, 1964	Special Test
Pre-RF Link Verification Test	Dec 10, 1964	JPL Procedure 3R320.02
RF Link Verification Test	Dec 12, 1964	JPL Procedure 3R320.02
Directional Antenna Deployment Test	Dec 14, 1964	JPL Procedure 3R243.00
Spacecraft SFOF Compatibility Test	Dec 28, 1964	JPL Procedure 3R318.03
Preshipment System Test	Dec 29, 1964	JPL Procedure 3R300.18

TABLE 63
SUMMARY OF MODIFIED FM III-3 TESTS AT ETR
JANUARY 12, 1965 THROUGH FEBRUARY 17, 1965

Description of Test	Date	Test Procedure
Postshipment Electrical Test	January 12, 1965	RCA Specification RTSP-1100A
Clock Verification and TV Subsystem Tilt Test	January 15, 1965	Special Test
Backup Functions Test	January 15, 1965	JPL Procedure 3R305.09
System Verification Test 6	January 18, 1965	JPL Procedure 3R300.19
Operational Checkout-RF Link	January 20, 1965	JPL Procedure 3R315.04
ESF Television Full-Power Test	January 26, 1965	JPL Procedure 3R235.04
ESF Operational Checkout	January 28, 1965	JPL Procedure 3R317.04
Precountdown Dummy Run	January 29, 1965	JPL Procedure 3R304.06
Countdown Dummy Run	January 29, 1965	JPL Procedure 3R309.07
Joint Flight Acceptance Composite Test	February 1, 1965	JPL Procedures 3R309.05 and 3R307.02
Camera Calibration	February 4, 1965	JPL Procedure 3R220.03
Special RFI Test	February 4, 1965	Special Test
Final System Verification Test	February 5, 1965	JPL Procedures 3R300.20 and ETR 3R300.06
ESF Television Full-Power Test	February 9, 1965	JPL Procedure 3R235.05
ESF Operational Checkout	February 12, 1965	JPL Procedure 3R317.05
Precountdown Test	February 13, 1965	JPL Procedure 3R304.07
Simulated Countdown Test	February 15, 1965	JPL Procedure 3R309.08
Launch Countdown Test	February 17, 1965	JPL Procedure 3R309.08

TABLE 64
SUMMARY OF FLIGHT MODEL III-4 TESTS AT RCA
JANUARY 19, 1964 THROUGH FEBRUARY 1, 1964

Description of Test	Date	Test Procedure
Camera Calibration	Jan 19, 1964	RCA Specification RTSP-1100A, App. C
TV Subsystem Test	Jan 21, 1964	RCA Specification RTSP-1100A, App. F
TV Subsystem Command Checkout Test	Jan 31, 1964	RCA Specification RTSP-1100A, App. G
Vibration Test	Jan 31, 1964	RCA Specification RTSP-1101
Thermal-Vacuum Tests	Feb 1 through 9, 1964	RCA Specification RTSP-1100, App. J

TABLE 65
SUMMARY OF MODIFIED FM III-4 TESTS AT RCA
OCTOBER 1, 1964 THROUGH DECEMBER 2, 1964

Description of Test	Date	Test Procedure
Initial Power Application and Checkout	Oct 1 to 21, 1964	RCA Specification RTSP-1100A, App. A
Castellated Pads (before and after)	Oct 21 to 30, 1964	RCA Specification RTSP-1100A, App. C
Component Alignment	Oct 23 to Nov 29, 1964	RCA Specification RTSP-1100A, App. N
Abbreviated Subsystem Test	Nov 14, 1964	RCA Specification RTSP-1100A, App. R
Abbreviated Subsystem Test	Nov 24, 1964	RCA Specification RTSP-1100A, App. R (Modified)
Abbreviated Subsystem Test	Nov 25, 1964	RCA Specification RTSP-1100A, App. R (Modified)
Subsystem Test	Nov 25, 1964	RCA Specification RTSP-1100A, App. F
Abbreviated Subsystem Test	Nov 26, 1964	RCA Specification RTSP-1100A, App. R (Modified)
Thermal-Vacuum Test (25^{o} C)	Nov 27, 1964	RCA Specification RTSP-1100A, App. D
Thermal-Vacuum Test (35^{o} C)	Nov 27, 1964	RCA Specification RTSP-1100A, App. D
Thermal-Vacuum Test (15^{o} C)	Nov 29, 1964	RCA Specification RTSP-1100A, App. D
Abbreviated Subsystem Test	Nov 29, 1964	RCA Specification RTSP-1100A, App. R (Modified)
Camera Array Alignment	Nov 30, 1964	RCA Specification RTSP-1100A, App. H
Preacceptance Test	Dec 1, 1964	RCA Specification RTSP-1100A, App. R (Modified)
Acceptance Test	Dec 1, 1964	RCA Specification RTSP-1100A, App. F
Preshipment Electrical Test	Dec 2, 1964	RCA Specification RTSP-1100A, App. R (Modified)

removing the insulating material and making a proper ground connection.

The Subsystem test was performed prior to thermal-vacuum testing and the overall results were satisfactory and verified; the requirement to perform a vibration test at RCA on the Ranger IX TV Subsystem (Flight Model III-4) was waived by JPL. The thermal-vacuum test consisted only of simulated mission testing.

The investigation of the camera-defocusing problem during thermal-vacuum testing was corrected by offsetting the vidicon to account for index-of-refraction differences between ambient and vacuum condition.

During the Clock Command test, F-Channel did not turn on as expected; an investigation revealed that the SCR gates had not been enabled by the console operator. After the Cruise-On push button was depressed, the next Clock pulse turned on F-Channel as expected. The remaining portions of the thermal-vacuum tests were performed successfully.

The Ranger TV Subsystem was given a complete Subsystem acceptance test for JPL approval. Data derived from this test indicated normal and satisfactory operation of the entire Subsystem. The preshipment electrical test prior to delivery to JPL was performed successfully with no malfunctions observed. The TV Subsystem was shipped to JPL on December 3, 1964.

3. Modified Flight Model III-4 at JPL and ETR (December 5, 1964 through March 21, 1965)

The tests performed at JPL on Modified FM III-4 were designed to verify the performance of the electronic equipment in the TV Subsystem and the electrical integrity of the TV Subsystem when integrated with the Spacecraft Bus. These tests were designed to verify the satisfactory operation of the TV Subsystem in ambient, simulated-launch, and simulated-flight (space) environments. The test program also served to verify the procedures and operational readiness of the operational support equipment used to check out the integrated spacecraft prior to launch. The test program of Flight Model III-4 at JPL is summarized in Table 66.

Following the preshipment electrical test on February 11, 1965, Flight Model III-4 TV Subsystem was shipped from JPL on February 18, 1965, and arrived at the Eastern Test Range (ETR) on February 22, 1965. The test program at ETR commenced on February 23, 1965, with the postshipment electrical test, and terminated with the launch on March 21, 1965. A summary of the tests performed on Flight Model III-4 at ETR is presented in Table 67.

The ETR test program consisted of checkout and test of the TV Subsystem integrated with the Spacecraft Bus in the Spacecraft Checkout Facility (SCF) Hangar AO, operations in the Explosive-Safe Facility (ESF), and operations on the launch pad in conjunction with the Atlas and Agena launch vehicles. The purpose of the prelaunch testing at ETR was to reaffirm the operational readiness of the TV Subsystem integrated with the Spacecraft Bus; to ensure that all Subsystems of the Ranger IX Spacecraft were compatible with the launch vehicle; and to ensure that all Subsystems of the Ranger IX Spacecraft were in a "go" condition at the time of launch. These tests also provided the opportunity to verify launch procedures and increase the proficiency of operating personnel to ensure smooth launch operations. The results of all the tests were normal, and only minor problems were encountered during the testing of Modified Flight Model III-4. The Ranger IX Spacecraft was launched at 16:37:00 GMT on March 21, 1965.

TABLE 66
SUMMARY OF MODIFIED FM III-4 TESTS AT JPL
DECEMBER 5, 1964 THROUGH FEBRUARY 11, 1965

Description of Test	Date	Test Procedure
Postshipment Electrical Test	Dec 5, 1964	RCA Specification RTSP-1100A, App. R
Camera Gain Adjustment Evaluation Gain	Dec 9, 1964	RCA Specification RTSP-1100F1, App. R (Modified)
TV Subsystem Checkout	Dec 9, 1964	JPL Procedure 3R212.05
System Verification Test 2	Dec 10, 1964	JPL Procedure 3R300.17
Backup Function System Test	Dec 14, 1964	JPL Procedure 3R305.08
System and EMI Test 3	Dec 17, 1964	JPL Procedures 3R300.18 and 3R409.02
ESF Television Full-Power RF Test	Dec 21, 1964	JPL Procedure 3R235.03
TV Subsystem and Shroud-Light Compatibility, and RF Losses Test	Dec 28, 1964	JPL Procedure 3R405.03
ESF Operational Checkout	Dec 29, 1964	JPL Procedure 3R317.03
Precountdown Dummy Run	Dec 30, 1964	JPL Procedure 3R303.07
Countdown Dummy Run	Dec 30, 1964	JPL Procedure 3R308.06
Pyrotechnic Extension Test	Jan 6, 1965	JPL Procedure 3R313.07
x-Axis Vibration Test	Jan 8, 1965	JPL Procedure 3R311.05
y-Axis Vibration Test	Jan 9, 1965	JPL Procedure 3R311.05
Torsional Vibration Test	Jan 11, 1965	JPL Procedure 3R311.05
z-Axis Vibration Test	Jan 12, 1965	JPL Procedure 3R311.05
Postvibration System Test 4	Jan 14, 1965	JPL Procedure 3R300.19
Premission Verification Test	Jan 19, 1965	JPL Procedure 3R302.09

TABLE 66
SUMMARY OF MODIFIED FM III-4 TESTS AT JPL
DECEMBER 5, 1964 THROUGH FEBRUARY 11, 1965 (Continued)

Description of Test	Date	Test Procedure
Mission Verification Test 1	Jan 22, 1965	JPL Procedure 3R302.09
Mission Verification Test 2	Jan 22, 1965	JPL Procedure 3R302.09
Pre-RF Link Verification Test	Jan 27, 1965	JPL Procedure 3R320.03
RF Link Verification Test	Jan 27, 1965	JPL Procedure 3R320.03
Directional Antenna Deployment Test	Jan 30, 1965	JPL Procedure 3R243.01
TV Subsystem Tilt Test	Feb 1, 1965	Special Test
TV Subsystem Evaluation Test	Feb 8, 1965	Special Test
Preshipment System Test	Feb 11, 1965	JPL Procedure 3R300.19
Special F_a Camera Test	Feb 11, 1965	Special Test

TABLE 67
SUMMARY OF MODIFIED FM III-4 TESTS AT ETR
FEBRUARY 23, 1965 THROUGH MARCH 21, 1965

Description of Test	Date	Test Procedure
Postshipment Abbreviated TV Subsystem Test	Feb 23, 1965	RCA Specification RTSP-1100A, App. R
Clock Verification Test	Feb 26, 1965	Special Test
Backup Functions Test	Mar 1, 1965	JPL Procedure 3R305.09
Operational Checkout by RF Link	Mar 3, 1965	JPL Procedure 3R315.05
Abbreviated TV Subsystem Test	Mar 7, 1965	RCA Specification RTSP-1100A, App. R
System Verification Test 7	Mar 12, 1965	JPL Procedures 3R300.20 and ETR 3R300.06
ESF Television Full-Power RF Test	Mar 12, 1965	JPL Procedure 3R235.06
ESF Reduced-Power Operational Checkout	Mar 16, 1965	JPL Procedure 3R317.06
Precountdown Test	Mar 17, 1965	JPL Procedure 3R304.08
Simulated Countdown	Mar 19, 1965	JPL Procedure 3R309.09
Prelaunch Countdown	Mar 21, 1965	JPL Procedure 3R309.09