Technical Report No. 32-680

Description and Flight Analysis of the Ranger VII TV Subsystem

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R. D. Williams

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ABSTRACT

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The TV subsystem flown as the payload on the *Ranger* spacecraft for the *Ranger VII* unmanned lunar probe is discussed. The *Ranger VII* mission started at liftoff of the launch vehicle (*Atlas–Agena* booster) on July 28, 1964 and ended with lunar impact on July 31, 1964. The major assemblies and the operation of the TV subsystem are described, along with the engineering and technical aspects of the subsystem, which included two full-scan cameras and four partial-scan cameras. An evaluation of the subsystem operation and performance, including a detailed analysis of the pertinent telemetry data received, is given.

All aspects of system operation were normal and the mission goals were surpassed, as shown by lunar photographs obtained by the *Ranger VII* subsystem. Samples of these photographs are included.

The *Ranger VII* TV subsystem was designed and manufactured by the Astro-Electronics Division of Radio Corporation of America (RCA), under contract to the Jet Propulsion Laboratory. The *Atlas D* stage was manufactured by General Dynamics/Astronautics, and the *Agena B* stage by Lockheed Missiles and Space Company.

Author

I. INTRODUCTION

The *Ranger VII* TV subsystem mission requirement was to provide the necessary equipment to obtain high-resolution video pictures of a selected portion of the lunar surface during the terminal phase of the *Ranger* Block III missions. The minimum design objective was to obtain resultant video pictures at least an order of magnitude better in resolution than any available Earth-based lunar photography to meet the requirements of the U.S. manned lunar program and benefit the scientific program. Figure 1 shows the *Ranger VII* spacecraft configuration.

The TV subsystem was designed and manufactured by RCA's Astro-Electronics Division, under contract to the Jet Propulsion Laboratory.

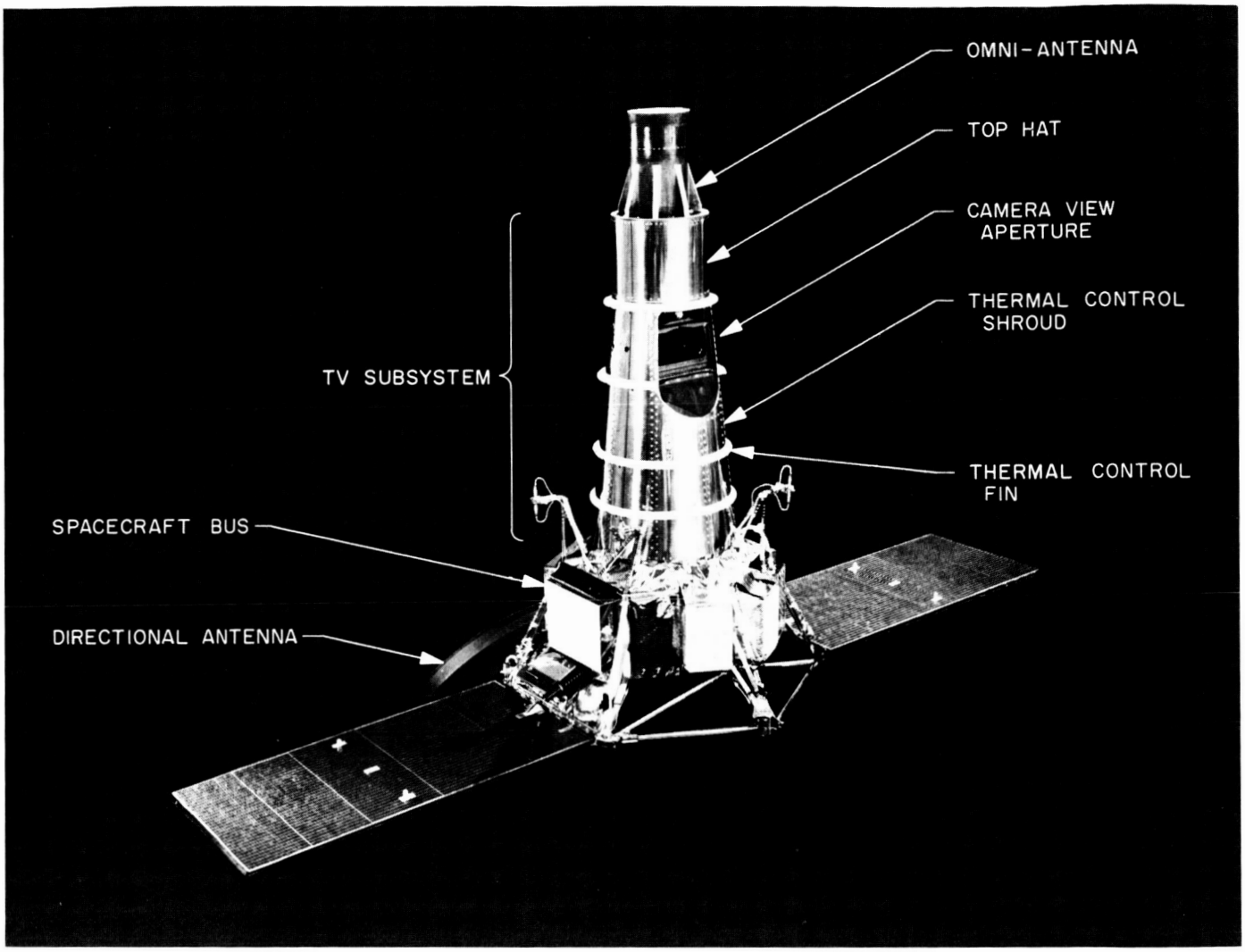

Fig. 1. Over-all view of the *Ranger VII* spacecraft

II. GENERAL DESCRIPTION OF THE TV SUBSYSTEM

A. Mechanization

The TV subsystem consists of two separate chains of equipment designed to give the greatest reliability and probability of receiving video pictures to meet the mission objectives. Each chain contains slow-scan video cameras, camera electronics, sequencing circuits, transmitters, power supplies, and control circuitry.

The two chains are essentially similar, with the exception of the camera configurations. One channel, designated the F channel, contains 2 fully scanned (F) 1-in. vidicons, while the other channel, designated the P channel, contains 4 partially scanned (P) 1-in. vidicons. The cameras are sequentially exposed and read out, with both channels operating simultaneously. The video is utilized to modulate the FM transmitters for subsequent transmission of the signal to the Earth-based receiving stations. Diagnostic telemetry is (1) combined with the video signal for transmission, (2) transmitted through the bus telemetry system, to be utilized in real-time subsystem performance analysis. Figure 2 shows the equipment contained in the two channels.

The TV subsystem is electrically complete and independent of the spacecraft, with the exception of (1) commands received either from the spacecraft command receiver or the on-board Central Computer and Sequencer (CC&S), and (2) the use of the spacecraft's data encoder for cruise telemetry transmission and the directional antenna for transmission of terminal video.

All Real Time Commands (RTC's) are sent to the spacecraft from stations of the Deep Space Instrumentation Facility (DSIF) on the Earth.

B. Modes of Operation

The *Ranger* TV subsystem is required to operate in two basic modes, cruise and terminal, during the *Ranger* Block III missions.

1. Cruise Mode Operation

Cruise mode TV subsystem operation furnishes (for subsequent transmission to the Earth-based data-recovery stations) commutated 15-point TV subsystem telemetry

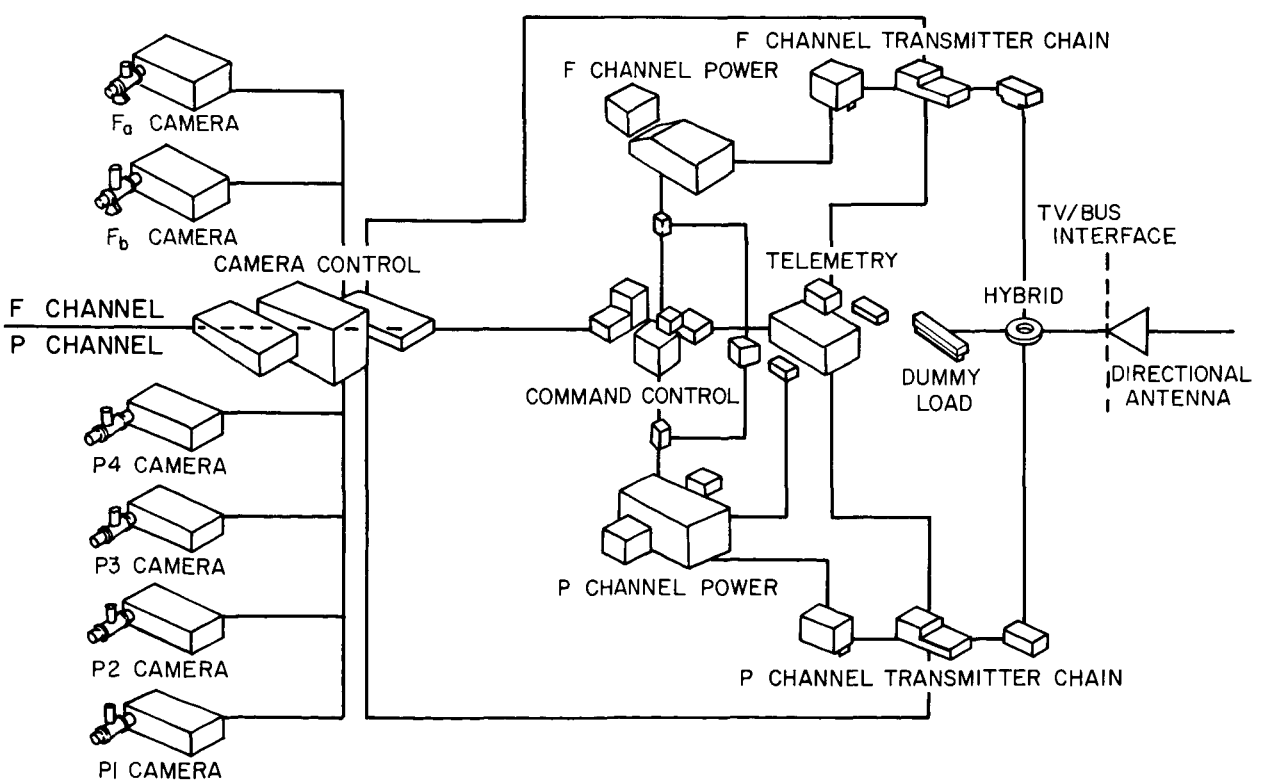

Fig. 2. F and P channel equipment for the TV subsystem

data from the telemetry assembly 3-kc voltage-controlled oscillator (VCO) to the spacecraft Channel 8 carrier. The cruise telemetry data consist of 15 points of measurements of battery voltages and currents and back-up clock and temperature parameters. The telemetry is initiated prior to launch and remains on throughout the mission, with the exception of spacecraft Telemetry Mode II operation during the midcourse maneuver. Also operating during the cruise mode is the TV back-up clock, which is initiated at *Agena*–spacecraft separation. The clock is preset to start the Channel F terminal phase video operation at a predetermined turn-on interval before the nominal predicted impact time. TV back-up clock operation and turn-off via RTC-5[1] is inhibited until separation plus 32 hr.

2. Terminal Mode Operation

At the initiation of TV warm-up during the terminal video phase, the 15-point data are switched from Channel 8 to the TV subsystem Channel F carrier, and 90-point data are transmitted over the Channel 8 carrier. The 90-point data contain engineering measurements of the operating parameters during the TV warm-up and video transmission periods.

Terminal mode TV operation furnishes a dual-channel (Channels F and P) FM signal in the 960-Mc band for transmission of video and telemetry to the Earth-based data-recovery stations. Channel F, centered at 959.52 Mc, contains composite video signals (0 to 177-kc video base band) from the two full-scan cameras, F_a and F_b, and 225-kc telemetry data (15 points). Channel P, centered at 960.58 Mc, contains composite video signals (0 to 144-kc video base band) from the four partial-scan cameras, P1, P2, P3, and P4, and 225-kc telemetry data (90 points).

The terminal mode is normally initiated via the CC&S warm-up command (TV-2) 15 min before lunar impact. The CC&S is backed up by an RTC-7 turn-on command at 12 min before impact. The warm-up signal applies the battery output to its high-current regulators. The 27.5-v dc output from the high-current regulator is applied to the camera and sequencer electronics and to the transmitter modulator, and the unregulated battery output is supplied to the telemetry and communications equipment. Each channel, after an 80-sec warm-up cycle (for the high-power transmitter tubes), is switched to the full-power mode via a command from the sequencer unit. Full-power command causes a relay in the appropriate transmitter power supply to apply high voltage to the intermediate and final power amplifiers in the communications chain, thereby allowing the video signal to be transmitted via the directional antenna to the ground equipment. A back-up for the full-power mode is provided by a CC&S full-power command (TV-3), which is given 5 min after the initial CC&S warm-up command and switches the transmitter power supply relays if the 80-sec warm-up command from the internal sequencer fails. The TV back-up clock initiates Channel F operation at a predetermined time (nominally 30 min) before impact, independent of the spacecraft commands.

[1]The commands used are identified in the Nomenclature section.

III. MAJOR ASSEMBLIES OF THE TV SUBSYSTEM

The major assemblies of the *Ranger VII* TV subsystem are the cameras, camera and control sequencer, telecommunications, electrical power, command and control, TV back-up clock, and structure and associated passive thermal control. The system electrical block diagram is shown in Fig. 3 and the structural configuration is shown in Fig. 4.

A. Cameras

The camera system is composed of six vidicons, which operate in a slow-scan mode. The F channel has two fully scanned cameras, F_a and F_b, [400 optical line pairs (o.l.p.)], and the P channel has four partially scanned cameras, P1, P2, P3, and P4 (100 o.l.p.). The camera tube is an electrostatically focused and deflected 1-in.-diameter vidicon with an ASOS[2] photoconductor target.

Each camera consists of a camera head assembly (vidicon, shutter, lens, preamplifier, and housing) and its individual camera electronics assembly. The received image is focused on the vidicon photoconductor target

[2]Antimony sulfide–oxygen sulfide, a vidicon target material. The vidicon was manufactured by the RCA Industrial Tube and Semiconductor Division.

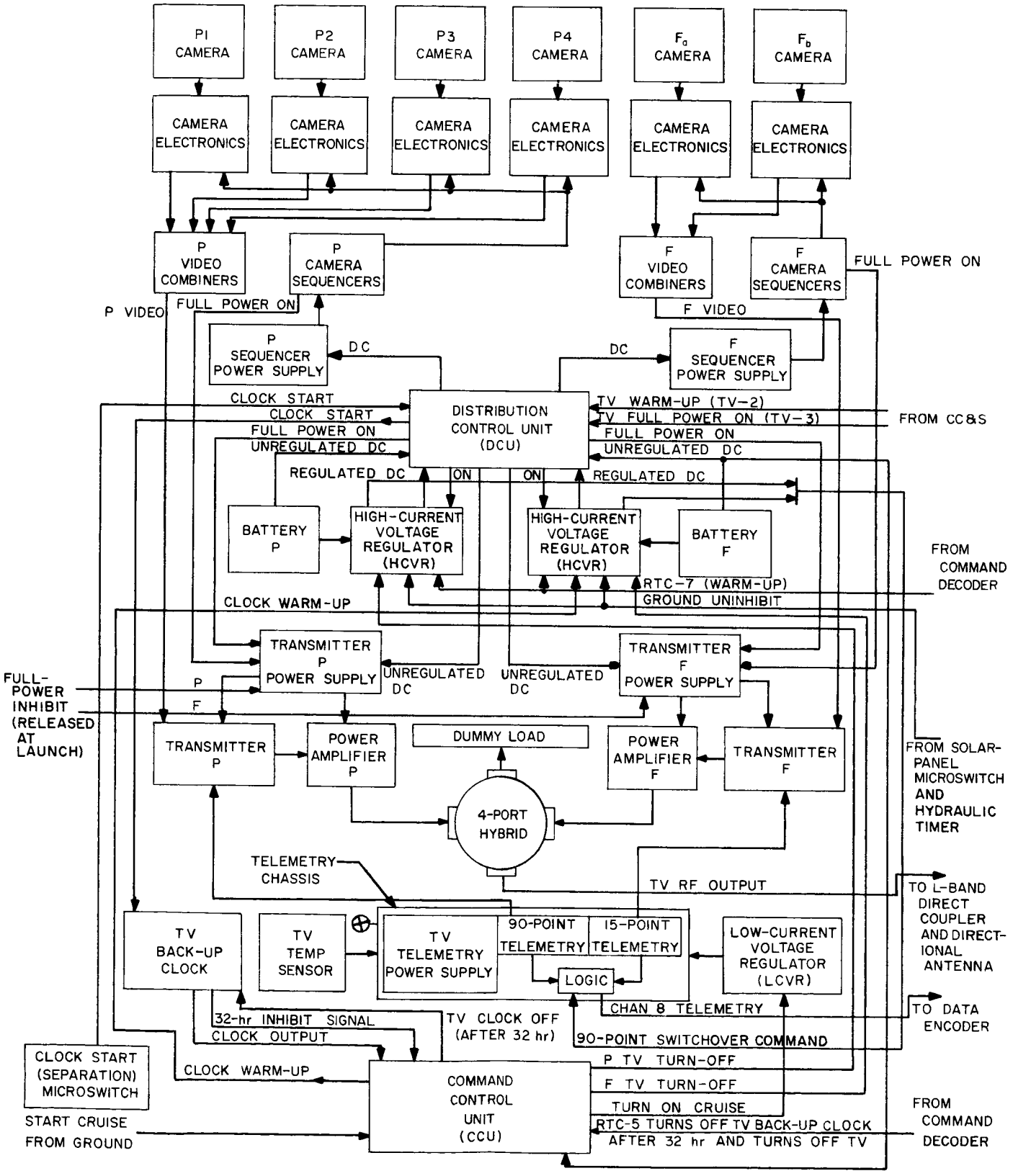

Fig. 3. Electrical block diagram of TV subsystem

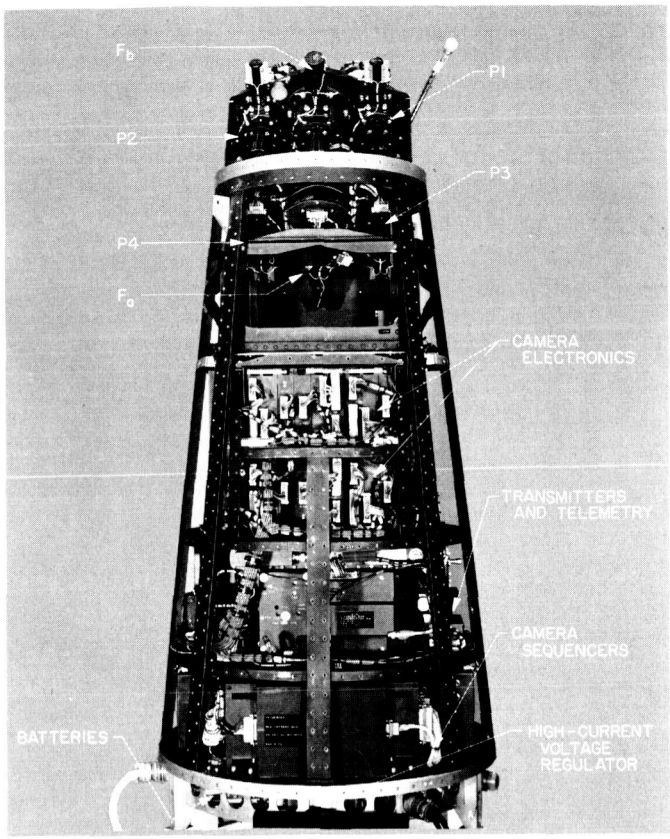

Fig. 4. Structural configuration of TV subsystem

by exposing the shutter located in front of the vidicon focal plane. The shutter utilized is an electromagnetically driven, linearly actuated slit type. The image formed on the photoconductor causes target resistance variations equivalent to the image brightness. After exposure, a high-frequency electron beam signal scans the target and restores the charges on the target. During the beam scan the charge current is conducted off the target as a video signal and coupled to a preamplifier. The signal is passed through the preamplifier and a video amplifier and is gated in a video combiner, then sent to the appropriate transmitter. The associated camera electronics supplies the necessary operating voltage, sweep signals, focus signals, and shutter pulses for the camera head assembly. The nominal camera fields of view are indicated in Fig. 5.

The dynamic ranges of the cameras were set to cover the lunar-luminance range from 20 to 2700 ft-lamberts. Cameras F_a, P3, and P4 cover 20 to 650 ft-lamberts, and camera F_b, P1, and P2 cover 80 to 2700 ft-lamberts. The P cameras have a 2-msec shutter-exposure time; P1 and P2 have 75-mm lenses, and P3 and P4 have 25-mm lenses. The F cameras have a 5-msec shutter-exposure time; F_a has a 25-mm focal-length lens and F_b has a 75-mm lens.

The F cameras utilize 1152 active horizontal scan lines over a vidicon faceplate area of 0.44 × 0.44 in. The horizontal scan rate is 450 cps, with 0.22 msec appropriated to horizontal blanking. The active scan lines, plus 46.6 msec for vertical blanking, add up to a 2.56-sec frame rate. At the end of the active scan, the camera enters an erase cycle to prepare the target for the next exposure. The two F cameras are alternately scanned and erased, so that while one is being scanned and read out, the other is being erased and prepared for the next exposure.

The P cameras utilize 300 horizontal scan lines over a vidicon faceplate area of 0.11 × 0.11 in. The horizontal line rate is 1500 cps, with 111.1 msec allocated to horizontal blanking. The vertical scan lines, plus a 6.6-msec blanking period, occupy 0.2 sec. At the end of the active vertical scan, the camera enters an erase cycle of 0.64 sec to prepare the target for the next exposure. The four P cameras are sequentially scanned and erased, so that while one is being scanned the remaining three are in various portions of the erase cycle. A 40-msec pulse is used to separate each sequence of the four P cameras. Therefore, the total time period per sequence is 0.84 sec.

The F and P camera characteristics are summarized in Table 1.

B. Camera and Control Sequencer

The sequencer equipment is split into two chains, one F and one P. Each chain contains a control programmer and camera sequencer, video combiner, and sequencer power supply. The programmer and sequencer generates the timing signals required for controlling the individual camera functions such as synchronizing, blanking, read (scanning) and erasing signals. An 18-kc crystal-controlled oscillator generates the basic timing signal, which is divided down to provide the required camera function signals. The counter also generates the full power on command for the transmitter, which is counted down 80 sec from the initial TV warm-up command.

The video combiner contains gates and summing circuits utilized to combine the individual camera video outputs and presents the summed signal to the transmitter modulators. The F channel combiner contains a tone oscillator output that is added to the signal to code the F_b camera. The power supply provides the required voltages for the sequencer and video combiner operation.

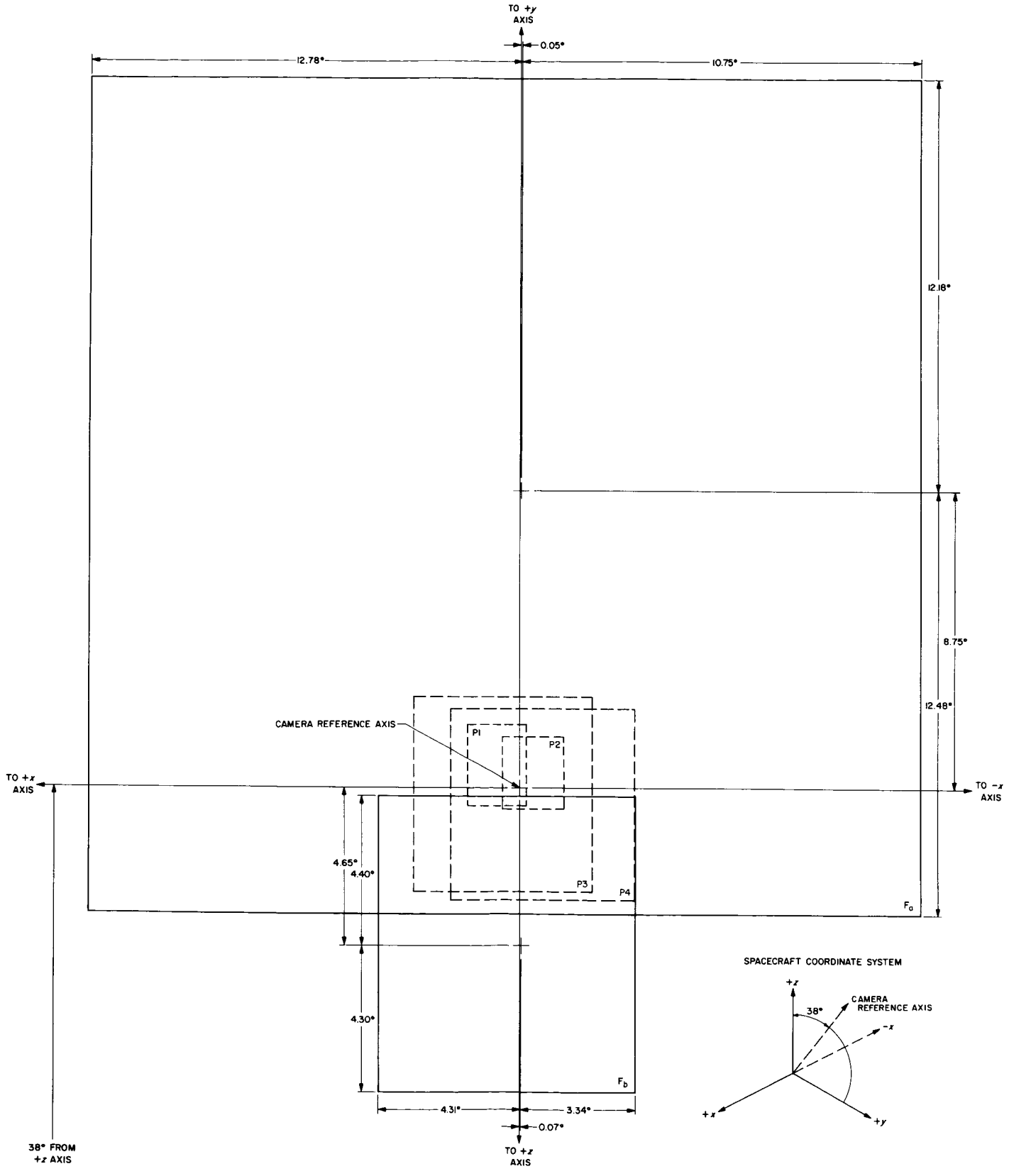

Fig. 5. *Ranger VII* camera fields of view

Table 1. Summary of camera characteristics

Characteristic	Camera F_a	Camera F_b	Cameras P1 and P2	Cameras P3 and P4
Aspect ratio	1 to 1	1 to 1	1 to 1	1 to 1
Active scan area, in.	0.44 × 0.44	0.44 × 0.44	0.11 × 0.11	0.11 × 0.11
Line rate, cps	450	450	1500	1500
Horizontal line time	2.22 msec	2.22 msec	666.6 μsec	666.6 μsec
Horizontal blanking time	0.22 msec	0.22 msec	111.1 μsec	111.1 μsec
Frame rate, cps	0.39	0.39	5	5
Frame time, sec	2.56	2.56	0.2	0.2
Vertical blanking time, msec	46.6	46.6	6.6	6.6
Group vertical blanking time, msec	—	—	40	40
Video bandwidth, kc	177	177	144	144
Lens optics	25 mm, f/1	75 mm, f/2	25 mm, f/1	75 mm, f/2
Shutter speed, msec	5	5	2	2
Horizontal erase rate, cps	900	900	3000	3000
Number of TV lines scanning	1152	1152	300	300
Number of optical line pairs	400	400	100	100

C. Telecommunications Equipment

The communication equipment of the *Ranger* TV subsystem consists of two transmitting channels and an RF combining section. Each channel consists of an L-band FM transmitter, intermediate power amplifier, 60-w power amplifier, telemetry processor, and transmitter power supply. A 4-port hybrid ring in the RF section is used to mix the output of the two transmitting channels, the combined output being fed to the spacecraft RF coupler for transmission over the directional antenna. A dummy load is included in the RF equipment to dissipate the combining loss. Each transmitter contains a modulator, two frequency multipliers, and an intermediate power amplifier. Each transmitter operates within a bandwidth of approximately 900 kc, with the output of the Channel F and Channel P transmitters centered at 959.52 and 960.58 Mc, respectively. A 160-kc band between the transmitter output frequencies is reserved for the spacecraft transponder transmitter.

The cruise mode telemetry, a 15-point sampling switch operating at a rate of 1 point per second, is used to sample the critical temperatures and voltages and the back-up clock position. The output of this switch is used to drive a Channel 8 IRIG subcarrier oscillator. An ac amplifier and transformer is used to connect the oscillator output across the spacecraft interface, where it is mixed with other telemetry signals for transmission by the spacecraft telemetry system.

Terminal mode telemetry is activated 80 sec before TV subsystem full-power activation. A 90-point sampling switch operating at a rate of 3 points per second samples subsystem parameters to provide the detailed diagnostic telemetry. The commutated output drives two redundant chains for transmission of the 90-point telemetry data. One output drives a 225-kc VCO, and this output is multiplexed with the P channel video at the input of the P transmitting channel. The second output of the 90-point commutator is fed to the Channel 8 3-kc VCO for subsequent transmission over the spacecraft mixed signal.

D. Electrical Power Assembly

The TV power assembly consists of batteries and voltage regulators, with each channel, F and P, having an individual battery and high-current voltage regulator (HCVR) for supplying regulated and unregulated power to the operating assemblies. Each battery consists of 22 series-connected silver–zinc oxide cells and has a capacity of 40 amp-hr. The high-current voltage regulators supply current at -27.5 ± 0.5 v dc, as well as the unregulated battery voltage between -30.5 and -36 v dc. Each HCVR has a silicon-controlled rectifier (SCR) turn-on device that is utilized to switch prime power on to the system. A low-current voltage regulator (LCVR) is utilized off the P battery to supply power to the cruise mode telemetry.

E. Command and Control Unit

The command and control unit contains control circuits to accomplish the following functions:

1. Turn-off of Channels F and P, when triggered by RTC-5.
2. Transfer of clock start command to the distribution control unit (DCU).

3. Inhibition of:
   a. Clock turn-on of Channel F before separation plus 32 hr.
   b. Clock turn-off via RTC-5 before separation plus 32 hr.
4. Turn-on of cruise mode telemetry either prior to launch or at separation plus 30 min.
5. Powering of telemetry assembly by either F or P unregulated voltage outputs via the use of isolation diodes.

F. TV Back-up Clock

The back-up clock is used as a back-up for Channel F turn-on in case of a failure in both the CC&S and the RTC-7 links and is activated at *Agena* separation. In addition, it can be disabled during the mission by a command from RTC-5 after separation plus 32 hr. The *Ranger VII* clock was set to activate the F channel at 67¾ hr after *Agena*–spacecraft separation. The clock is a solid-state timer with an over-all accuracy of ± 5 min.

G. Structure and Thermal Control

The external structure is that of the frustum of a right circular cone topped by a cylindrical section. The primary strength of the structure is provided by an external box span consisting of stiffened panel sections supported by eight longerons. The electrical assemblies are mounted on structural decks supported by the longerons. The cameras are mounted onto a solid machined camera bracket housing within the top cylindrical section, with a view area cut out of the external thermal shroud.

The thermal control of the TV subsystem is entirely passive, with a thermal shield (mounted externally on the structure body) and fins used to control the radiative exchange of energy between the TV subsystem and other sources (or links) of thermal energy. The thermal mass of the structure is the primary heat sink during the terminal mode of operation.

IV. PERFORMANCE OF THE TV SUBSYSTEM

A. General Performance

The *Ranger VII* mission started at liftoff of the launch vehicle (*Atlas–Agena*[3] booster) at 16:50:07.88 GMT on July 28, 1964, and ended with lunar impact at 13:25:49 GMT on July 31, 1964. The impact was at lunar coordinates (selenographic) of 10.7 deg South latitude and 20.7 deg West longitude. The performance of the *Ranger VII* TV subsystem, from its prelaunch checkout to its operation in the terminal phase of the mission, was normal. The only peculiarity that was noted for the entire mission was a slow shift of 1 or 2 cps in the Channel 8 VCO frequency. This is within the over-all tolerance of ± 2 cps for the VCO.

It was anticipated and noted that telemetry points 15-3 and 15-10, P and F battery current measurements, were difficult to interpret throughout the cruise mode portion of the mission. The only engineering information determined from these readings was that the system current was between 0.5 amp and zero. (The nominal cruise mode current is 150 ma on the P channel and 50 ma on the F channel.) Cruise mode resolution was sacrificed to obtain high resolution for the terminal phase.

During the *Ranger VII* mission it was determined that the attitude of the Sun-oriented spacecraft would be such as to give an acceptable figure of merit for good TV pictures. Therefore, in the terminal maneuver, the RTC-8 command was sent just prior to RTC-6. This sequence started the CC&S counter in order to turn on the P channel 15 min before impact without actually commanding turns to the attitude control system. It was further determined that the back-up clock would command F channel warm-up at 18 min, 30 sec before impact; therefore, it was decided that this clock

[3]The *Atlas D* first stage, No. 250 D, was manufactured by General Dynamics/Astronautics and procured by USAF Space Systems Division for the Lewis Research Center (LeRC), the Launch Vehicle System Manager. The *Agena B* stage, No. 6009, was manufactured by Lockheed Missiles and Space Company, under contract to LeRC.

would not be inhibited by an RTC-5 command. From these considerations it was decided that the RTC-7 would be held in readiness to be given at impact minus 12 min if the CC&S turn-on of the P channel failed. Since both the clock and the CC&S performed flawlessly, the need to initiate RTC-7 never arose.

B. Reception of Telemetry Data

Throughout the mission, telemetry data from the TV subsystem were received at stations of the DSIF.

1. Cruise Mode Data Reception

During the spacecraft passes over the DSIF stations at Goldstone, California, and Woomera, Australia, the 3-kc Channel 8 analog telemetry signal was recorded and sent directly to the Space Flight Operations Facility (SFOF) at the Jet Propulsion Laboratory, where it was displayed on a strip-chart recorder and fed into a computer that sampled each data point and printed out the actual telemetry voltage for that point. During the passage of the spacecraft over the DSIF station at Johannesburg, South Africa, the telemetry data were read out by the station personnel and were transmitted every 30 min to the SFOF via the administrative teletype network.

2. Terminal Mode Data Reception

During terminal mode operation, the Channel F and P transmitter outputs were radiated over the spacecraft's directional antenna and were received at the Pioneer and Echo DSIF stations at Goldstone. The ground recording equipment processed the received RF signal and reduced the signal to the video picture taken by the individual cameras. The video pictures were recorded on 35-mm photographic film and also recorded on magnetic tape. The 90-point telemetry data were processed and displayed on a strip-chart recorder and were also sent by microwave to the SFOF for computer reduction.

C. Mission Profile

The actual sequence of critical events involving the *Ranger VII* TV subsystem is summarized in Table 2. The events in Table 2 are discussed in the following paragraphs:

Item 1: The scheduled prelaunch turn-on test of the TV system into reduced power proceeded on schedule. All of the 15- and 90-point readings were normal. It was noted that battery voltage was high, indicating an exceptionally fine set of batteries.

Table 2. Time schedule of critical events for TV subsystem

Item	Predicted mission time	Actual GMT time	TV subsystem events
1	L − 115 min	210:13:51:45	Prelaunch reduced-power test
2	L − 15 min	210:16:25:25	Start of cruise mode telemetry
3	L	210:16:50:08	Launch
4	S	210:17:22:36	Start of back-up clock on signal
5	S + 30 min	.....	TV ground-enabled via hydraulic timer
6	S + 46 min L + 61 min	210:17:51:17	TV ground-enable back-up via microswitch on −X solar panel
7	S + 8 hr	211:01:22:40[a]	8-hr clock pulse
8	S + 16 hr	211:09:22:46[a]	16-hr clock pulse
9	Telemode II	211:10:16:41 to 211:10:30:39	TV Channel 8 removed from bus carrier for this time
10	S + 24 hr	211:17:22:40[a]	24-hr clock pulse
11	S + 32 hr	212:01:22:37[a]	32-hr clock pulse
12	S + 48 hr	212:17:22:31[a]	48-hr clock pulse
13	S + 64 hr	213:09:22:23[a]	64-hr clock pulse
14	S + 67 hr, 45 min	213:13:07:15	Warm-up of F channel via back-up clock
15	I − 17 min	213:13:08:35	Full power of F channel via internal sequencer
16	I − 15 min	213:13:10:49	Warm-up of P channel via CC&S
17	I − 13 min, 40 sec	213:13:12:09	Full power of P channel via internal sequencer
18	I − 10 min	213:13:15:48	CC&S and back-up of P channel full-power command
19	I	213:13:25:49	Impact

L — Launch
S — Separation
I — Impact
[a]Reading is +0, −15 sec.

Item 2: The scheduled prelaunch turn-on of the 15-point telemetry proceeded on schedule. The telemetry indicated that the TV system was ready for launch and that the batteries still had a high charge in them, even after the drain of the reduced-power test.

Item 3: During the boost phase, the ground station at the Air Force Eastern Test Range (AFETR) lost lock with the JPL transponder (960.05-Mc signal), so that at first it was hard to determine the TV performance during the critical launch phase of flight. However, after launch plus 24 hr, the *Agena* telemetry tapes were evaluated and showed conclusively that there were no inadvertent turn-ons during the launch phase and that all telemetry indicated normal system operation.

Item 4: The back-up clock start signal was generated by a microswitch closure when the spacecraft was separated from the *Agena*, and point 9 of the 15-point telemetry changed to 0.8 v to indicate this fact. The time of the point 9 step (210:17:22:40) was 4 sec later than the actual time of separation (210:17:22:36), because of the inherent error in reading this point of +0, −15 sec, owing to telemetry commutation.

Item 5: A ground-enable was provided for the SCR turn-on circuit by a switch closure initiated by the hydraulic timer. (Without having the ground circuit enabled, it is impossible to turn on the TV subsystem by any means. Since, at present, there is no telemetry point provided for this function, the exact time occurrence or the fact that the switch closure occurred cannot be confirmed.)

Item 6: The back-up to the hydraulic timer is provided by a microswitch on the −X solar panel. This switch closes when the solar panels lock into a horizontal position. As in Item 5, this switch closure is not monitored by telemetry.

Item 7: Verification of the clock counting operation was achieved by a clock pulse at 8 hr after separation, changing point 9 from 0.8 to 1.6 v.

Item 8: Further verification of the clock operation was achieved by a clock pulse at 16 hr after separation, changing point 9 from 1.6 to 2.4 v.

Item 9: Telemetry was lost owing to the Mode II telemetry change. (The mixing of Channel 8 data for modulation on the bus carrier is controlled entirely in the bus data encoder. Switching is normally done to obtain midcourse accelerometer data on Channel 8 during motor firing.) The TV cruise telemetry was switched back into the bus carrier at 211:10:30:39 GMT when the data encoder stepped to Mode III at the end of the midcourse maneuver. During this period the spacecraft turned in such a way that the TV cameras were pointing almost directly at the Sun. The temperature on the lens housing went up to 78°F and, after the maneuver was over, fell back to 66°F in about 5 hr.[4] There was also a temporary drop in "top hat" temperature and in the shroud temperature. (The top hat is the upper section of the thermal shroud, as shown in Fig. 1.)

Item 10: Another confirmation of proper clock operation occurred at separation plus 24 hr in the stepping of point 9 of the 15-point telemetry from 2.4 to 3.2 v. No clear trend of clock time error was determined at this point, because of the reading accuracy of +0, −15 sec.

Item 11: The next confirmation of proper clock operation occurred at separation plus 32 hr in the stepping of point 9 of the 15-point telemetry from 3.2 to 4.0 v. Still, there was no clear trend of clock time error. Also, at this time, both clock inhibits were released. (The first inhibit prevents the clock from commanding the TV subsystem into warm-up, and the second prevents RTC-5 from disabling the clock.)

Item 12: The next-to-last confirmation of proper clock operation occurred at separation plus 48 hr in the stepping of point 9 of the 15-point telemetry from 4.0 to 4.8 v. The trend was now established that the clock was running about 5 sec faster than nominal.

Item 13: The last confirmation of proper clock operation occurred at separation plus 64 hr in the stepping of point 9 of the 15-point telemetry from 4.8 v down to 0.8 v. At this point, the clock was running at least 13 sec faster than nominal.

[4]See Fig. 6.

Item 14: The back-up clock commanded the TV F channel into warm-up. The clock was 21 sec fast for the 67 hr, 45 min period; this performance is well within the design tolerance of ± 5 min. This event was observed by a change in the telemetry from the 15-point to the 90-point mode. The data received during this warm-up period indicated that the F channel operation was normal. The current drain, the battery voltage, and the heat-sink temperature indicated that the F channel would be able to operate for the full 18 min, 30 sec.

Item 15: The F channel went into full-power operation via the internal 80-sec sequencer. This was confirmed by a change in point 55 from 2.4 to 0.6 v and a change in current from 8 to 13 amp. At this point, the Goldstone DSIF station confirmed the receipt of good-quality video. The video level was higher than had been anticipated, as noted on the telemetry and the oscilloscope monitor and confirmed by subsequent photographic analysis. This high video level continued on the F channel throughout the rest of the mission.

Item 16: The P channel was turned into warm-up by a TV-2 command generated by the CC&S. (This command is timed to occur 45 min after the spacecraft receipt of the RTC-6 command. In effect, this puts the turn-on of the P channel approximately 15 min before impact.) This event was monitored by noting a change in point 60 from 0 to 2.6 v and a change in current level from approximately 0 to 10 amp. The rest of the data received during this warm-up period indicated that the P channel operation was normal. The current drain, the battery voltage, and the heat-sink temperature indicated that the P channel would be able to operate for the required 15 min.

Item 17: The P channel turned into full-power operation via the internal 80-sec sequencer. This was confirmed by a change in point 60 from 2.5 to 0.6 v, which indicated a change in current from 10 to 16 amp. At this point, the Goldstone station confirmed the receipt of good P channel video. The same high video level that was noted for the F channel was also noted for the P channel.

Item 18: The CC&S back-up command (TV-3) to initiate full power on both channels was timed to occur 50 min after the spacecraft received the RTC-6 command. This event was noted by monitoring a blip on the B2-1 channel. Since both channels were previously turned into full power by the TV's internal 80-sec sequencer, the TV-3 command had no effect.

Item 19: At impact, both video and telemetry signals closed simultaneously. At this time there was enough capacity in the battery[5] and the temperature was low enough to permit another 22 min of safe operation of the subsystem on both channels, operation time being limited by Channel P.

[5]See Fig. 14.

V. DISCUSSION OF TELEMETRY DATA

Figures 6 through 13 give an accurate description of the TV subsystem performance throughout the entire mission. Figures 6 through 11 depict the actual and predicted temperature and voltage curves plotted for the *Ranger VII* mission, both in cruise mode and terminal mode operation. It should be noted that all of the cruise temperatures came within 4°F of the predicted nominal values. Figures 12 and 13 depict only terminal mode operation.

During the cruise mode, the temperature of the lens housing (Fig. 6) held steady at approximately 67°F, as compared with the nominal temperature of 64.5°F. Three groups of high-temperature readings are shown in the

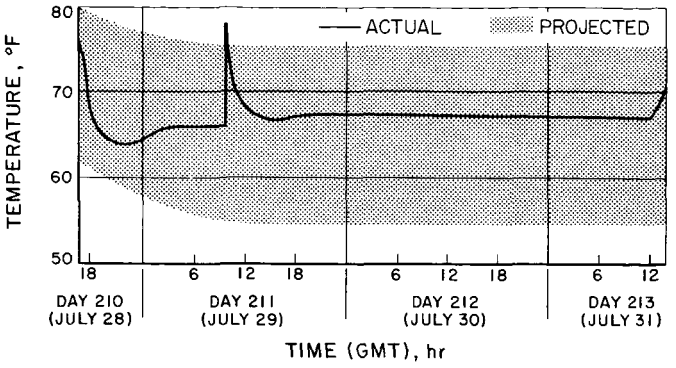

Fig. 6. Actual and projected lens temperatures

Figure. The first group was caused partially by the fact that the lens temperature on Earth before launch was 78°F, and partially by the tumbling of the spacecraft, which caused the lens to absorb reflected light from the Earth during this period (until the spacecraft was attitude-stabilized). The second group of high temperatures occurred during the midcourse maneuver, when the lenses were pointed directly into the Sun, thereby causing their temperature to rise. When the spacecraft was brought back to its proper attitude, the temperature returned to normal. The third group of high readings occurred during the terminal phase, and the heating was due to reflected light energy from the Moon's surface.

The top hat temperature (Fig. 7) stabilized at 84°F; the nominal temperature was 82°F. Two sharp drops in temperature occurred. The first drop took place when the spacecraft was in the Earth's shadow, and no sunlight could warm the top hat. The second drop in temperature took place during the midcourse maneuver, when the spacecraft was also so oriented that little sunlight warmed the top hat. The fast thermal response of the top hat accounts for the sharpness of the changes.

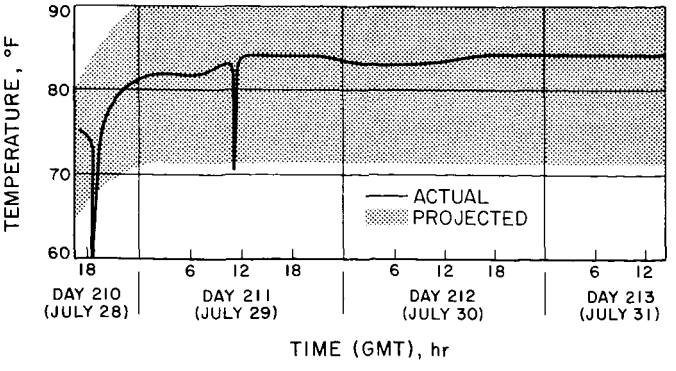

Fig. 7. Actual and projected top hat temperatures

The lower shroud temperature was normally between 74 and 76°F. The nominal temperature (Fig. 8) was 72°F. The drop in temperature during the midcourse maneuver was caused when the spacecraft was so oriented that little sunlight warmed the lower shroud. The sharp rise in temperature during the terminal phase was caused by internal heating from the TV subsystem in full-power operation. The fast thermal response of the lower shroud accounts for the sharpness of the changes.

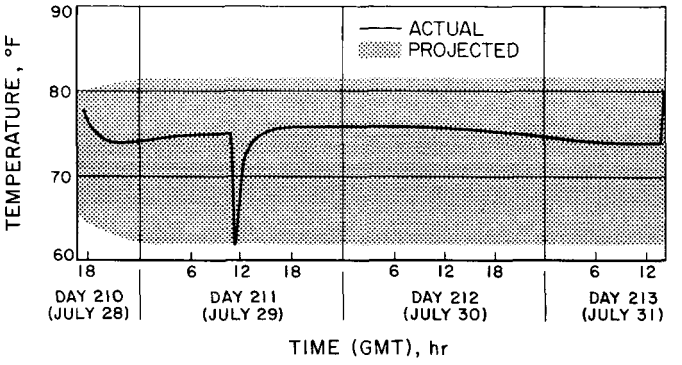

Fig. 8. Actual and projected shroud temperatures

The F_b camera electronics temperature (Fig. 9) was normally between 69 and 70°F. The nominal temperature was 72°F.

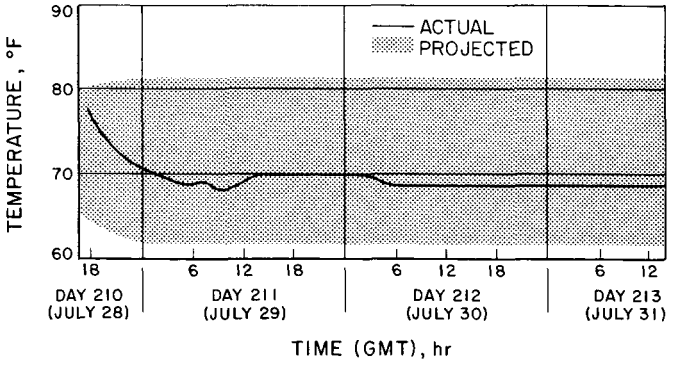

Fig. 9. Actual and projected F_b camera electronics temperatures

The P battery temperature during cruise was about 76°F (Fig. 10). The nominal temperature was 75°F. The sharp rise in temperature at the end of the mission was caused by the high current demands (16 amp) imposed on the battery at this time. The slow drop in temperature at the beginning of the mission was caused by the battery's high thermal mass.

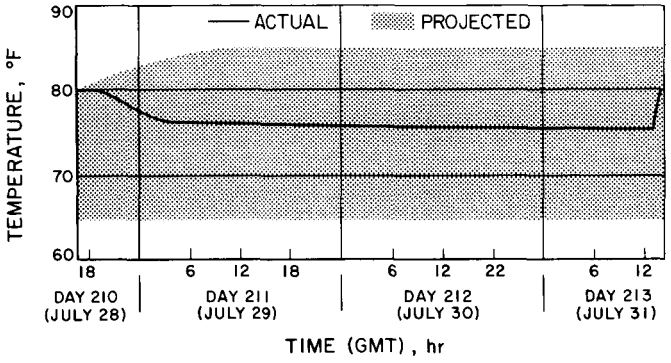

Fig. 10. Actual and projected P battery temperatures

The P battery (Fig. 11) plateaued at −34.3 v, while the F battery plateaued at −34.6 v. There are two reasons for the length of time required for the F battery to drop to its plateau level. First, during testing the F battery was subjected to less drain than the P channel battery (14 amp, as compared with 16 amp). Second, during cruise its drain was only 0.07 amp, compared with 0.15 amp for the P channel. The sudden drop in battery voltage at the terminal phase was caused by the high current demands at this stage of the mission. Yet the high voltage levels of −32.4 on the F and −31.9 on the P channel indicated that the batteries had at least another 30 min of life in them at the end of the mission, as seen in Fig. 14. Comparing Fig. 11a with Fig. 11b, we can see how closely the actual mission battery usage followed the predicted usage.

The normal rise in temperature for the P and F transmitter heat sinks is shown in Figs. 12 and 13. The 4° rise in heat sink temperature on the P channel before the initiation of warm-up for this channel was caused by the heat being generated by the F channel. The high reading of 106°F for the F transmitter heat sink was well below the safe maximum of 140°F, and the high reading of 98°F for the P transmitter heat sink was well below the maximum safe level of 132°F. This indicates that the temperatures were low enough to permit operation of the TV subsystem for at least another 22 min.

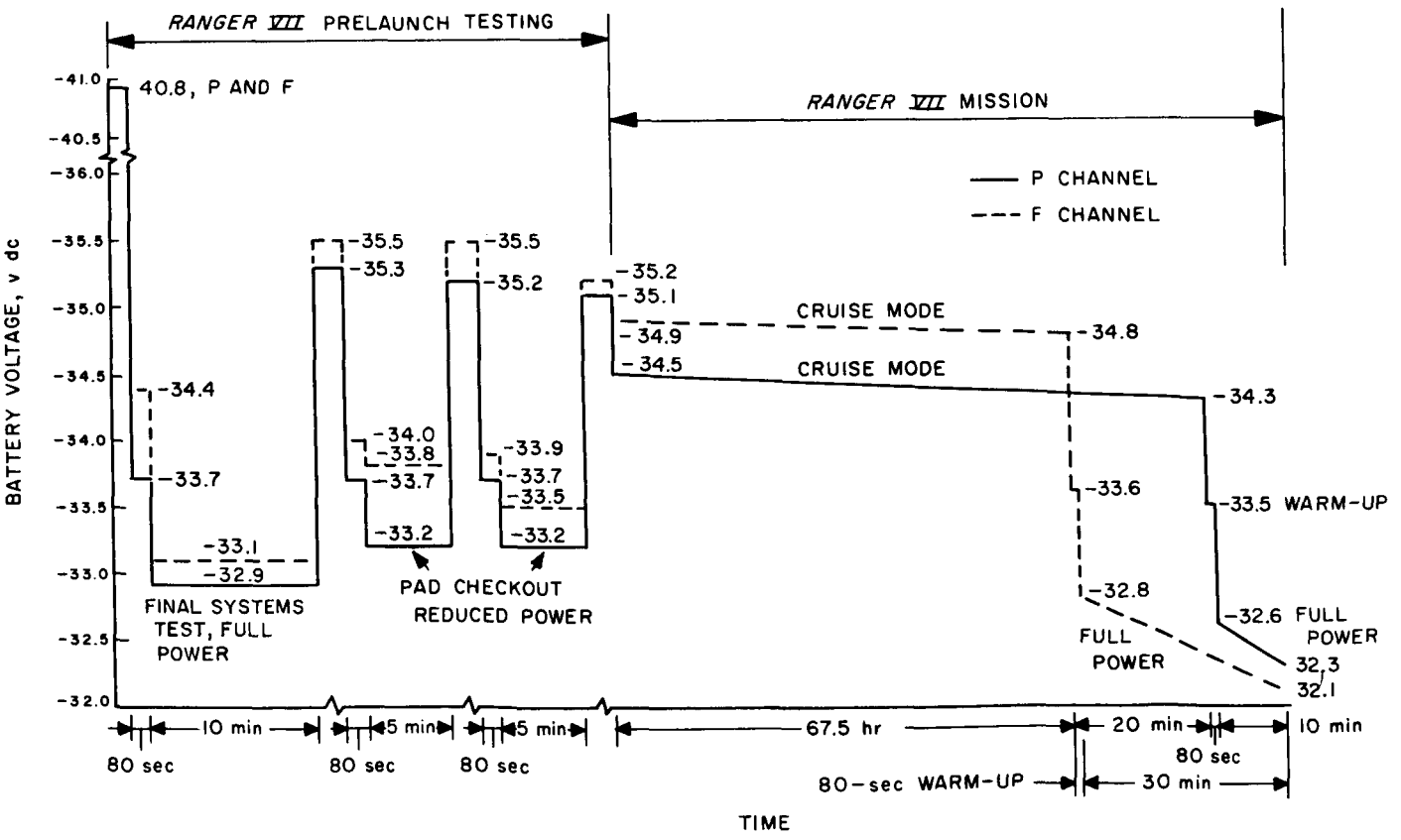

Fig. 11a. Projected F and P battery voltages

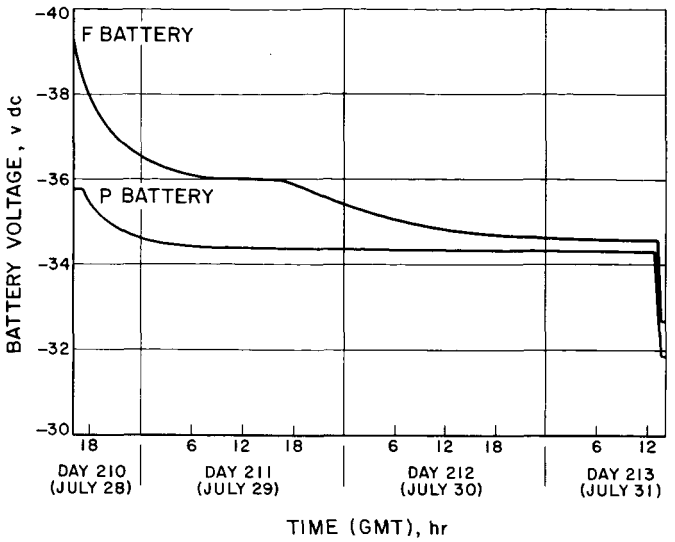

Fig. 11b. Actual F and P battery voltages

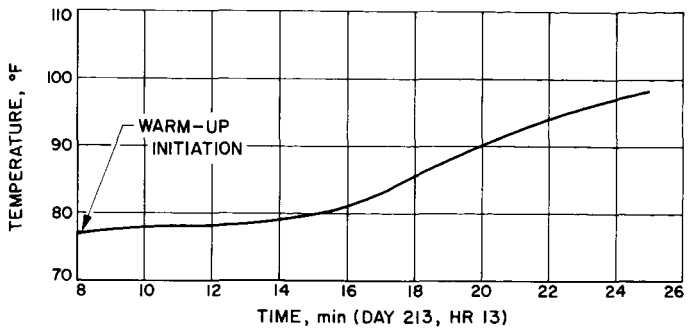

Fig. 13. Actual F transmitter heat sink temperature during terminal phase

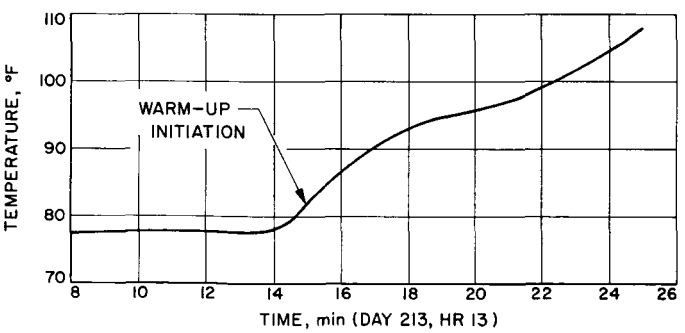

Fig. 12. Actual P transmitter heat sink temperature during terminal phase

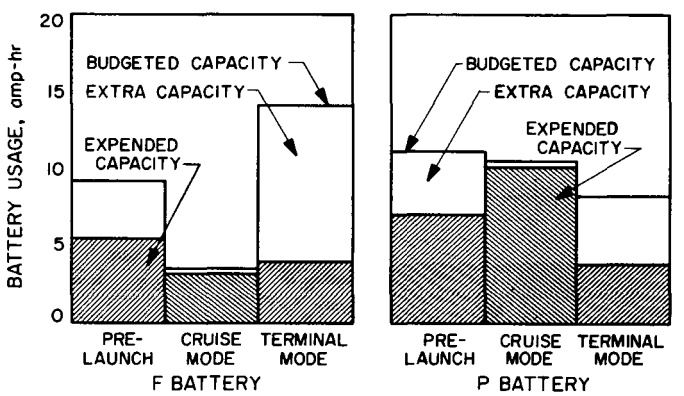

Fig. 14. Actual and budgeted battery capacities for the F and P channels

VI. SUMMARY

The *Ranger* TV subsystem performance during the 68 hr, 35 min, 43 sec of the *Ranger VII* lunar mission was normal. All operating parameters were within design specifications, and all cameras and systems performed perfectly.

As previously stated, the mission objectives for the *Ranger* TV system were to obtain television pictures of the lunar surface at least an order of magnitude better in resolution than any available Earth-based photography. The best Earth-based photographic records of the Moon currently have a resolution of about 0.5 mile. Thus, to meet the mission objectives, the TV system had to produce pictures with a resolution of about 300 ft. On the *Ranger VII* flight, the last picture before impact was taken with the P3 camera and had a resolution of about 18 in. This resolution was approximately 2,000 times greater than that of existing lunar photographs, or 200 times better than was necessary to meet the mission objectives.

A sample and discussion of the lunar photographs taken by cameras F_a, F_b, P1, P2, P3, and P4 are given in the Appendix.

APPENDIX

Lunar Photographs

This Appendix gives a sample of the lunar photographs obtained by the *Ranger VII* spacecraft during terminal mode operation. A photograph from each slow-scan vidicon camera is given with pertinent parameters such as altitude, area coverage, etc. (See Figs. A-1, A-2, and A-3, and Table A-1.)

The pictures shown were chosen to indicate the overlap features of the camera system.

The parameters listed in Table A-1 are defined below:

Altitude: The distance from the spacecraft to the surface directly below.

Central reticle: The principal cross mark on the camera face (Fig. A-4).

Slant range: The distance from the spacecraft to the surface point covered by the central reticle (Fig. A-5).

Inclination of surface: The angle from the local vertical at the central reticle to the camera direction. A normal view to the surface is then 0 deg inclination. A spherical surface is assumed.

Scale: The distance from the surface point covered by the central reticle to the surface point covered by the reticle immediately to the left of the central reticle (Fig. A-4).

Table A-1. Photograph parameter values

Camera	Time (GMT)	Altitude km	Slant range, km	Inclination of surface, deg (normal view, 0 deg)	Scale, km
F_a	13:24:55	125.1	137.0	24.9	13.15
F_b	13:25:23	59.8	61.3	11.6	2.08
P1	13:24:01	249.3	260.0	16.8	See Fig. A-3
P2	13:24:01	248.3	260.0	16.4	See Fig. A-3
P3	13:24:01	248.8	259.0	15.7	See Fig. A-3
P4	13:24:02	247.8	257.0	15.4	See Fig. A-3

The F_a camera central reticle in Fig. A-1 is located at selenocentric coordinates of $-10.90°$ latitude and $-20.99°$ longitude. Note that Crater A of Fig. A-1 is also contained in the P1, P3, and P4 pictures of Fig. A-3, while Crater B of Fig. A-1 is contained in the P2 photograph of Fig. A-3 and Crater C of Fig. A-1 is contained in the F_b photograph of Fig. A-2.

Cameras P3 and P4, which have identical optical parameters, yield pictures of approximately the same scale (differing only because of slight altitude changes between exposures) with a small difference in coverage due to camera pointing angles. The resolution of Crater A in the P1 picture of Fig. A-3 is greater by a factor of 3 than that of the same crater in the P3 picture, because of the different lens systems.

A complete presentation of the F_a camera photographs is given in *Ranger VII Photographs of the Moon, Part I: Camera "A" Series* (National Aeronautics and Space Administration, Washington, D.C., September 1964), from which the material on F_a photography in this Appendix is derived.

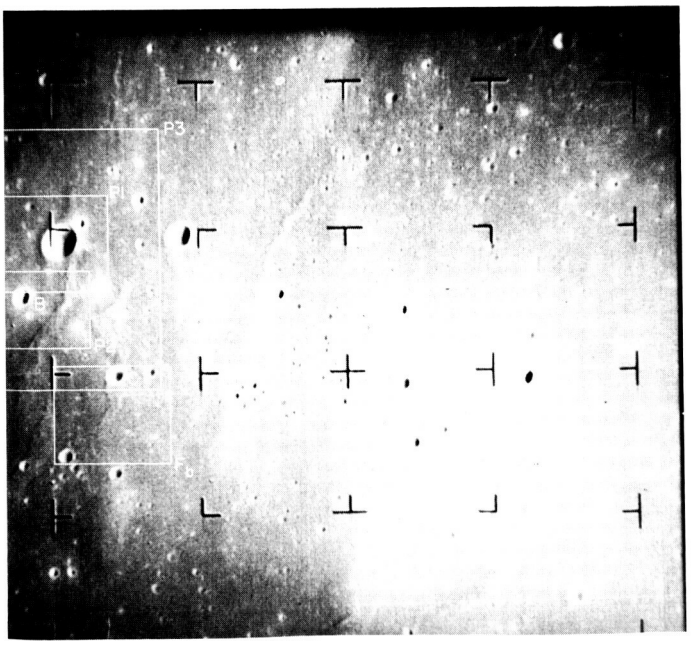

Fig. A-1. F_a camera lunar photograph showing camera overlap features

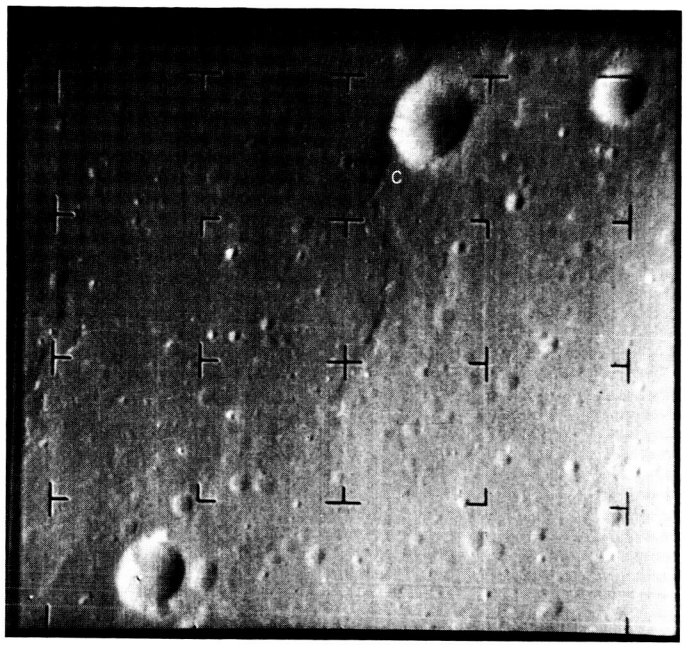

Fig. A-2. F_b camera lunar photograph

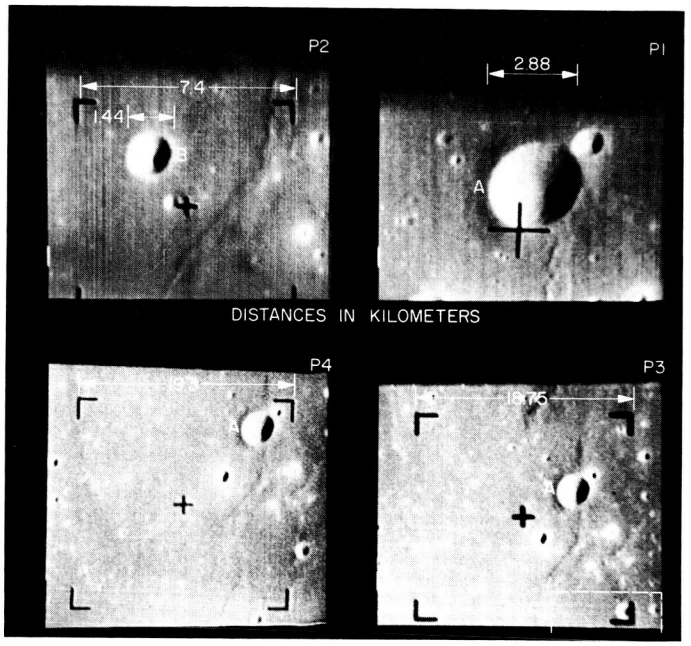

Fig. A-3. P camera lunar photographs

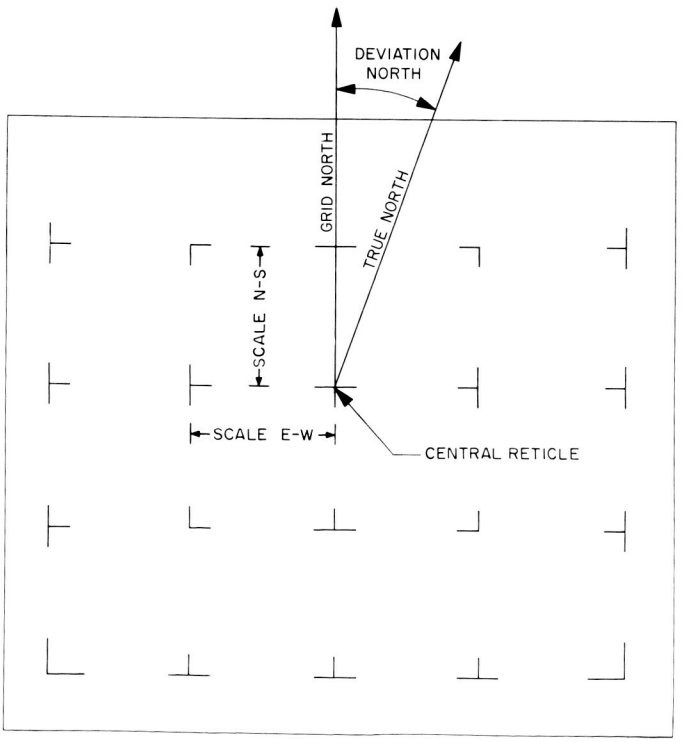

Fig. A-4. Definition of central reticle, deviation North, and scale

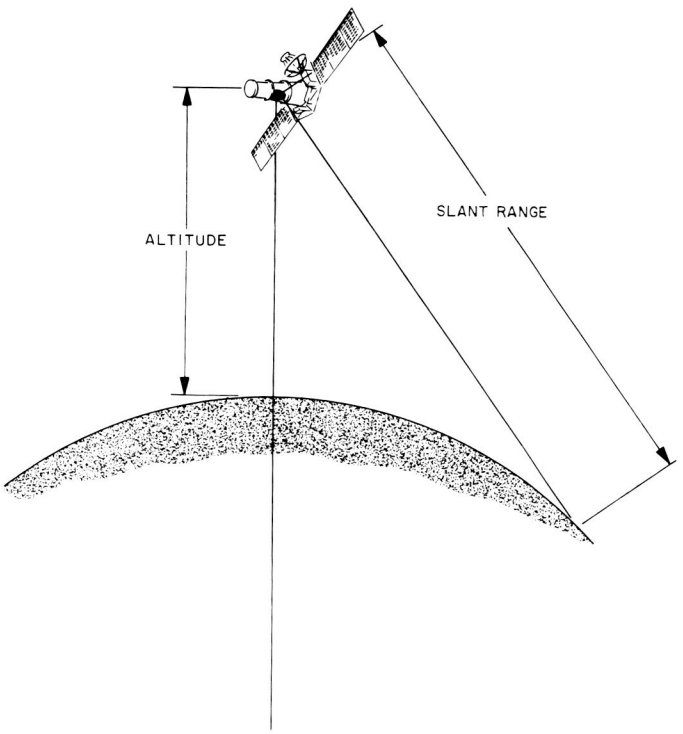

Fig. A-5. Altitude and range definition

NOMENCLATURE

Abbreviations

AFETR	Air Force Eastern Test Range
CC&S	Central Computer and Sequencer
DCU	distribution control unit
DSIF	Deep Space Instrumentation Facility
HCVR	high-current voltage regulator
LCVR	low-current voltage regulator
o.l.p.	optical line pair
RTC	real time command
SCR	silicon-controlled rectifier
SFOF	Space Flight Operations Facility
VCO	voltage-controlled oscillator

Commands

RTC-5	TV subsystem off / Telemetry mode change / Inhibit TV back-up clock
RTC-6	Initiate terminal maneuver
RTC-7	TV subsystem warm-up
RTC-8	Maneuver override
CC&S TV-2	TV subsystem warm-up
CC&S TV-3	TV subsystem full power on