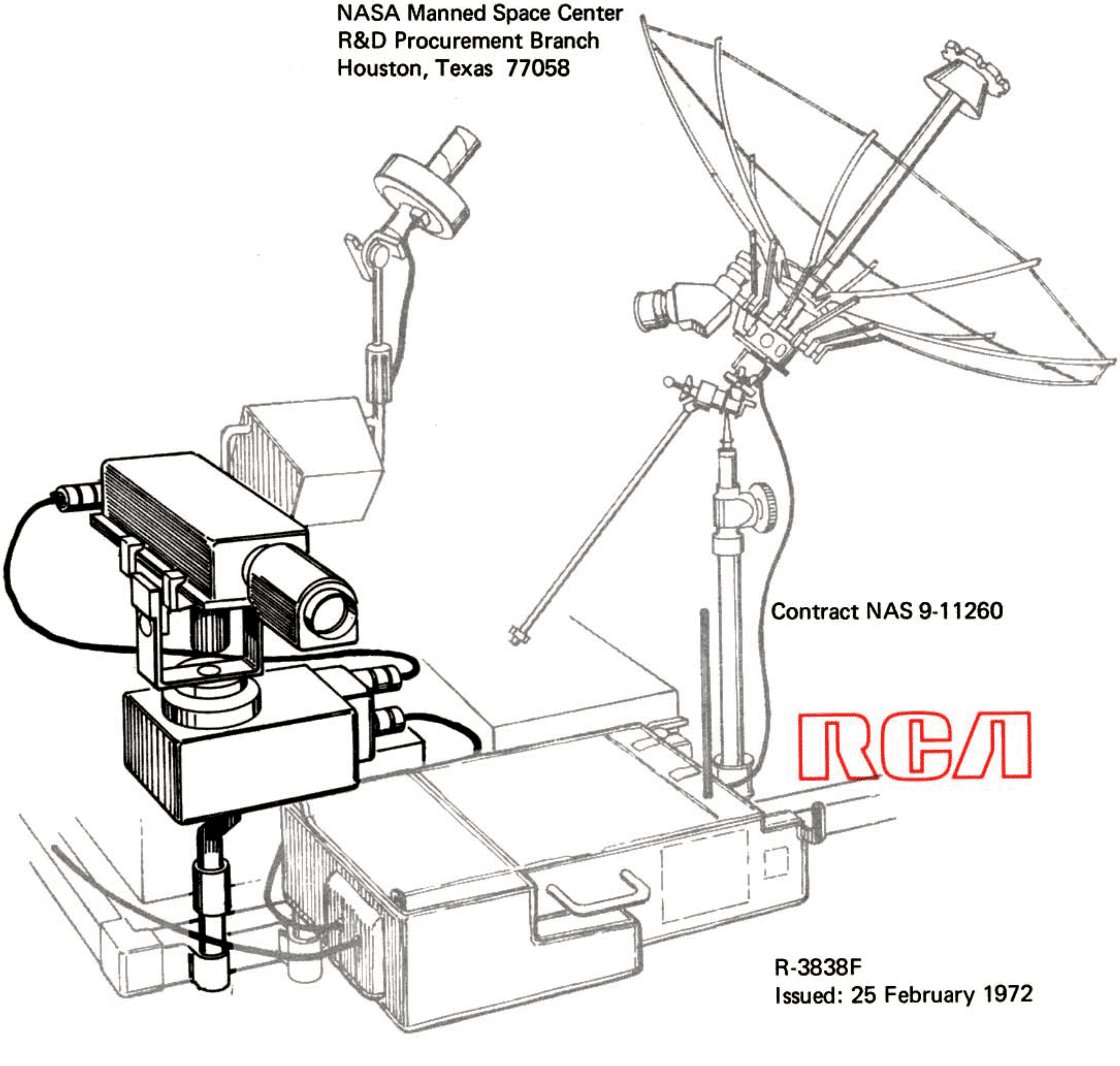
Ground-Commanded Television Assembly (GCTA)

Interim Final Report

Prepared for:
NASA Manned Space Center
R&D Procurement Branch
Houston, Texas 77058



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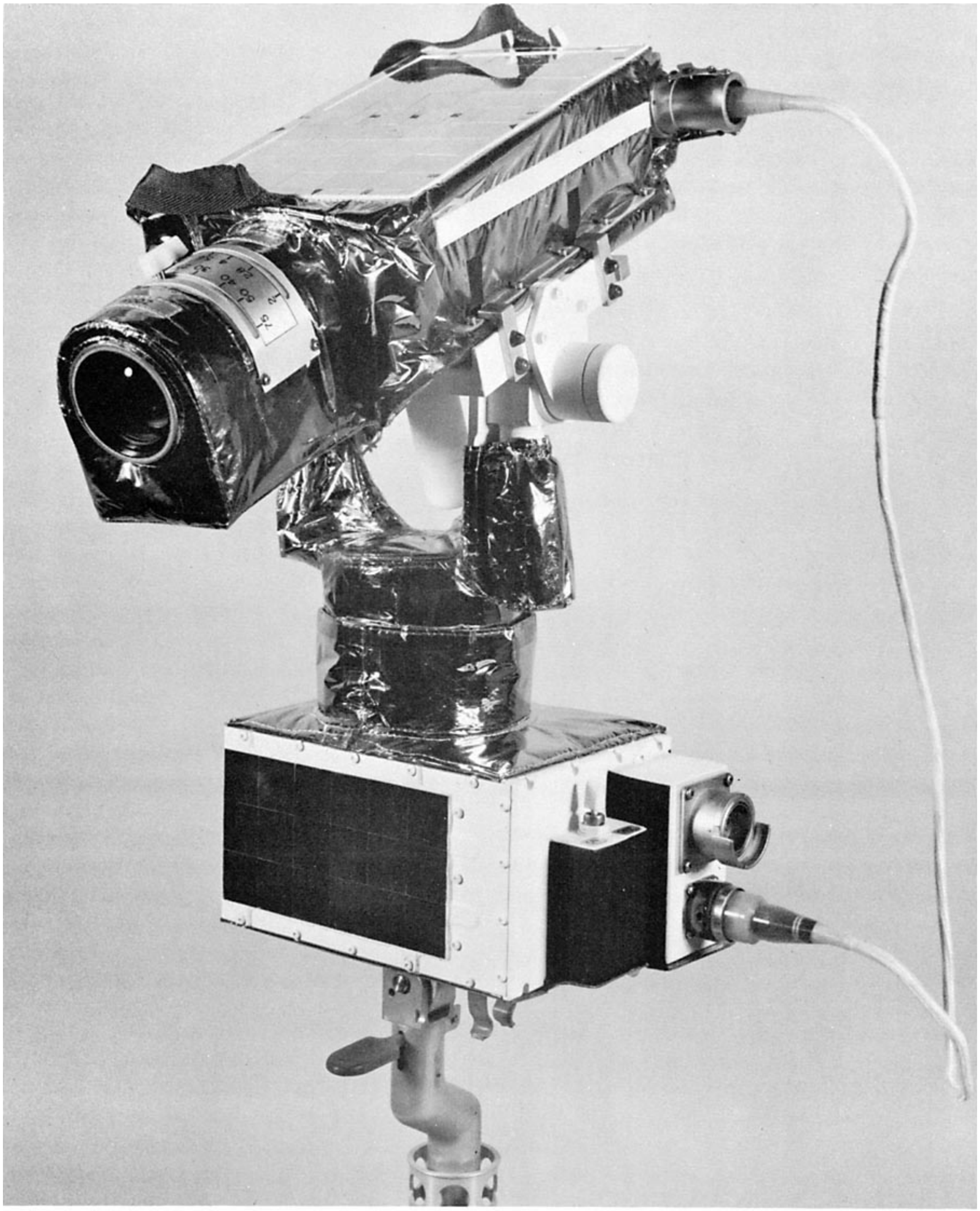

Frontispiece. RCA Ground-Commanded Television Assembly

June 2005 Publication Notes

This PDF version of the RCA Ground-Commanded Television Assembly Interimn Final Report was produced by Bill Wood using Adobe Photoshop CS2 and Acrobat 7 Pro. This report includes changes made to the GCTA after Apollo 15. The source was an original copy of the report provided by Bill Perry, the MSC television engineer who conceived the system in 1970. Each page was scanned using an Epson Expression 636 scanner using Lasersoft Silverfast AI scanning software. Final page cleanup and production was done using Photoshop CS2. Composition was accomplished using Microsoft Word 2002. It was converted to PDF using Acrobat 7 Pro.

Bill Wood was a Unified S-Band Lead Engineer at the Goldstone Apollo MSFN station during the lunar missions. He was primarily responsible for the development of the MSFN Subcarrier Cancellation Unit that enabled the full video bandwidth of the Apollo 15, 16 and 17 color television downlink to be recovered.

PREFACE

The RCA Ground-Commanded Television Assembly (GCTA) consists of a color television camera (the CTV), a television control unit (the TCU) and associated cabling, bracketry, and hardware. Design of the GCTA is based on the RCA Lunar Surface Color Camera produced for NASA under Contract NAS 9-10781. Both systems use a silicon intensifier target (SIT) sensor and field-sequential color wheel to generate color television images. The assemblies are being produced by RCA for the NASA Manned Spacecraft Center (MSC) in Houston, Texas under Contract NAS 9-11260.

This Interim Final Report summarizes work performed under Contract NAS 9-11260 from contract award (July 31, 1970) through February 15, 1972.

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SECTION I

INTRODUCTION

A. Mission Requirements

The RCA Ground-Commanded Color Television Assembly (GCTA) was designed for use on lunar explorations associated with NASA manned Apollo missions. The camera system as seen on Apollo 15 provided television coverage in the vicinity of the Lunar Module (LM) landing site, and was mounted on the Lunar Roving Vehicle (LRV) to provide color coverage of astronaut activity and lunar topography during traverses on the surface. Remote control of the camera from Earth was accomplished through the existing real-time Apollo command links. The assembly is illustrated in the Frontispiece.

The RCA GCTA configuration satisfied all anticipated requirements of the Apollo 15 mission and was fully responsive to customer specifications. The technical approach was based on proven designs and offered maximum mission flexibility, potential growth, and capability to withstand environmental extremes encountered on the lunar surface. In addition:

- Maximum use was made of existing flight-qualified subsystem designs to reduce cost and permit rapid hardware fabrication. Confidence in the design was enhanced by excellent performance of the QTV-9 camera previously designed for NASA. Both cameras use the Silicon Intensifier Target (SIT) sensor and field-sequential color wheel.

- The thermal design engineers who participated in the GCTA project performed a similar function for the LCRU. This fact assured compatibility of the thermal, electrical, and mechanical interfaces between the LCRU and the GCTA.

- Positional data for GCTA ground-commanded functions were provided by stepper motors. No telemetry was required to determine camera position for pointing at a desired scene.

As noted above, design of the GCTA camera was based on the RCA QTV-9. Both systems were designed with grounding techniques that separate video signals from power returns to prevent degradation of picture quality. The cameras were free of internal interference that might produce spurious patterns in the picture. Thermal design of the GCTA system allowed continuous operation on the lunar surface during astronaut extra-vehicle activity (EVA's), and did not interfere with operation of the LRV. Thermal surfaces were brushed free of dust without damage.

Use of the SIT sensor in the GCTA provided high sensitivity, freedom from "sticky" images at high light intensities, wide intra-scene dynamic range, very rugged construction, freedom from microphonics, and wide-range automatic light control (ALC). SIT performance is summarized in Table I-1.

The GCTA camera featured automatic color-wheel phasing, an approach that eliminated synchronizing perturbations. The camera system also was designed with sufficient flexibility to allow simply modifications (i.e., incorporation of striped filters to replace the rotating wheel) and service in other missions where low light-level performance is mandatory.

An overall summary of GCTA performance is given in Table I-2.

TABLE I-1. SIT PERFORMANCE CHARACTERISTICS

Parameter	Value
• Spectral Response	3500-7000 Angstroms
• Resolution	Minimum 40% @ 200 TVL
• Signal Current	Typical 400 nA
• Dark Current	Maximum 15 nA @ 30°C
• Sensitivity & Dynamic Range Typical	1 to 10,000 foot-lambert Scene
• Gamma	1.0
• Scene Dynamic Range	32:1 Minimum
• Shading	Maximum 20%
• Operating Temperature	(-10°C to +50°C)
• Life	Minimum 500 Hours

TABLE I-2. PERFORMANCE SUMMARY OF RCA GCTA

Parameter	Characteristic
Sensor	Silicon Intensifier Target (SIT) Tube
Sensitivity	Better than 32-dB signal-to-noise ratio at 3 foot-lamberts
Resolution	80 percent response at 200 TVL
ALC Dynamic Range	1000 to 1 (minimum)
Non-linearity	3 percent (maximum)
Shading	20 percent (maximum)
Gray Scale	Ten $\sqrt{2}$ steps
Video Output Level	1 volt p-p into 75-ohm load Full EIA sync
ALC	PEAK or AVERAGE detection modes Remote control with manual override
Optics	
Zoom ratio	6:1
Iris control	f/2.2 to f/22
Pan angle	+214(R), -134(L)
Tilt angle	$^{+85}_{-45}$ degrees from horizontal
Power	16.65 watts (operate), 7.95 watts (standby)
Physical Characteristics	
Weight	18.24 pounds
Volume	455 cubic inches

B. Equipment Description

Functional block diagrams of the GCTA Color Television Camera (CTV) and the Television Control Unit (TCU) are provided in Figures I-1 and I-2 for reference by the reader during technical discussions.

The Color Television Camera (CTV) uses basic monochrome techniques to produce high-quality, field-sequential color television at standard (NTSC) line and frame rates. The camera uses a single silicon intensifier target (SIT) tube and a synchronous rotating filter wheel to generate color video data. A zoom lens is incorporated with provisions for manual or remote control of zoom and iris settings. Automatic light control (ALC) operating on average or peak scene luminance also is incorporated. ALC may be selected manually or by remote control.

The Television Control Unit (TCU) permits ground-commanded operation of the CTV. A 70-kHz modulated subcarrier signal is sent to the TCU from the LCRU, and the TCU decodes this signal and executes valid real-time commands. The TCU cradle, mechanically driven in azimuth and elevation, holds the CTV for remote pointing in response to ground commands. The TCU electronics provide control signals to operate the zoom, iris, and ALC functions of the camera, and provides CTV power ON/OFF control in response to ground command or manual switch operation. Commands to the LCRU for ON/OFF control of the FM transmitter and ON/OFF control of the 1.25-MHz voice subcarrier also are generated in the TCU. After adding a vertical-interval test signal on line 17 of each field, the TCU routes the CTV composite video output signal to the LCRU.

A short staff at the base of the TCU electronics box mounts the GCTA to a fitting on the LRV chassis frame. The mounting staff has a swing-away capability to allow removal of the LCRU from the LRV chassis frame without removing the GCTA.

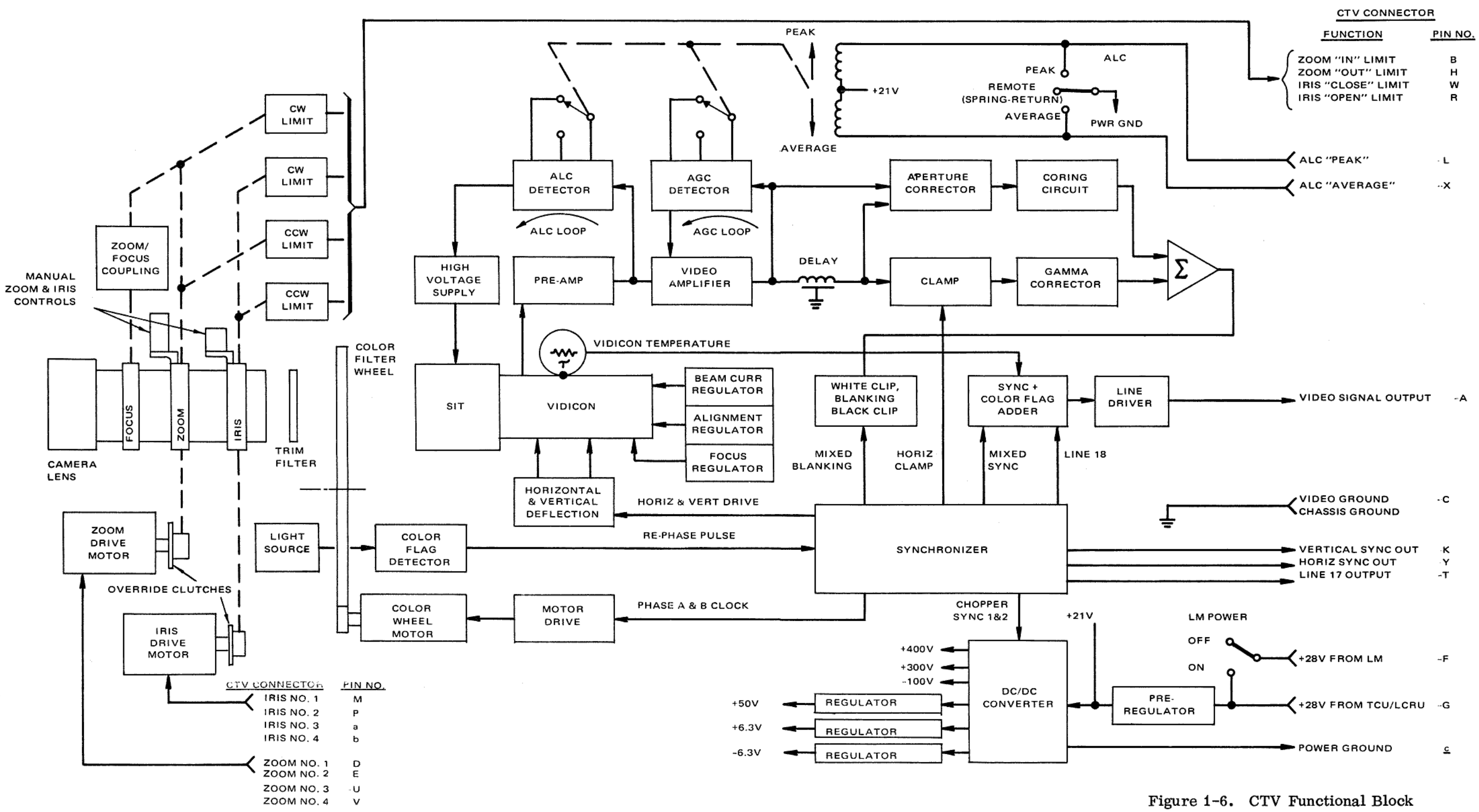

Figure 1-6. CTV Functional Block Diagram

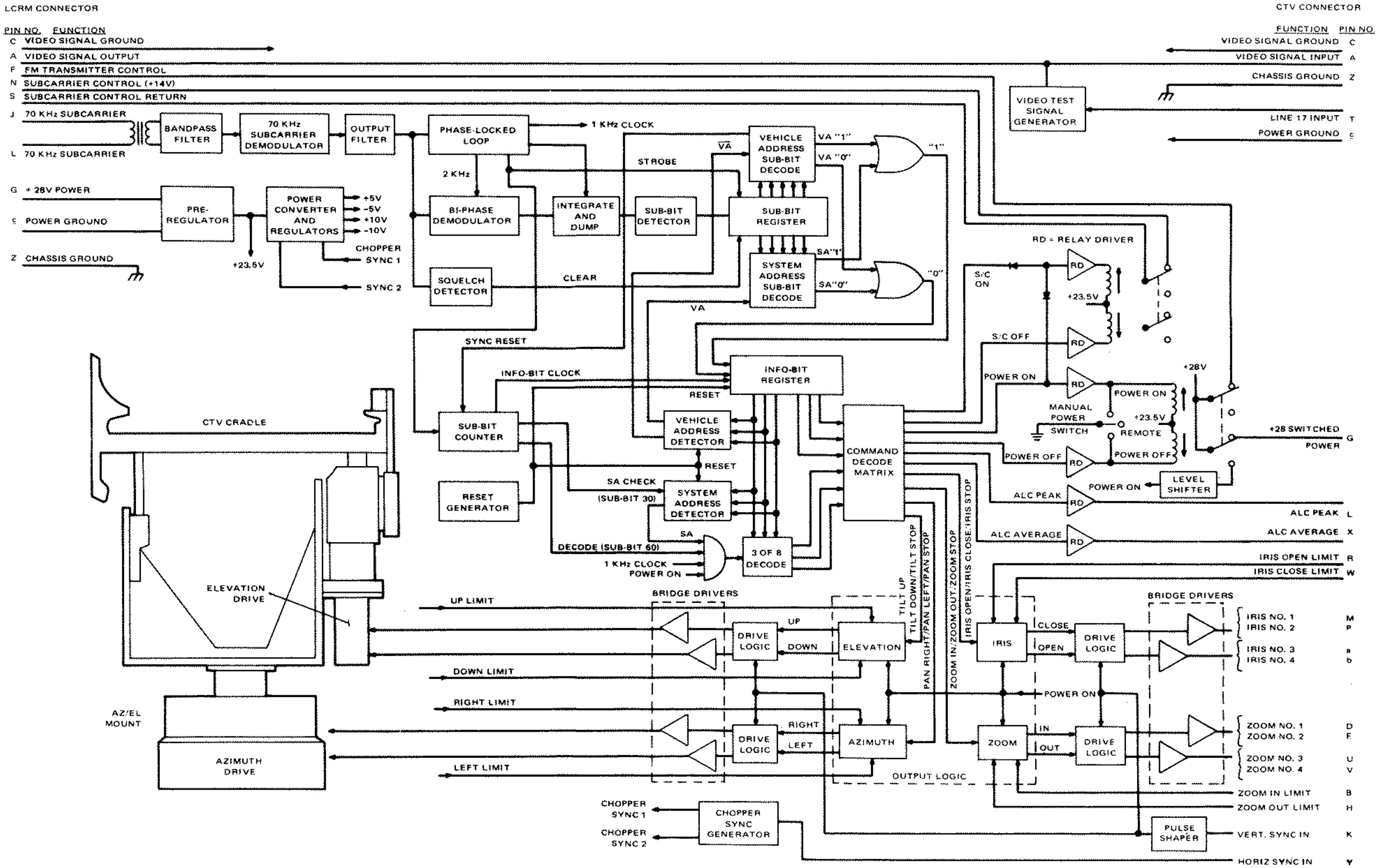

Figure 1-25. TCU Functional Block Diagram

C. Program Summary

RCA was informed of the GCTA contract award on 3 August 1970. To meet the critical schedules involved, immediate action was taken to staff the program, define the technical problems and equipment interface requirements, and initiate long-lead item procurement to meet contract end-item delivery dates. Organization and task definition for the program are shown in Figure I-3.

The preliminary GCTA design and system interface review was held early in September. Recommendations resulting from these meetings included:

- Addition of a thermal sensor to provide an indication of CTV vidicon faceplate temperature,
- Use of a compensator on the TCU elevation drive during operation in a 1-G environment,
- Deletion of the direct CTV-LCRU mode of GCTA operation and the requirement for a junction box,
- Reappraisal of the overall GCTA grounding philosophy and the isolation of power and signal grounds,
- Additional analysis and testing of CTV pre-emphasis and/or aperture correction requirements for a typical lunar scene, and
- Additional analysis of the GCTA thermal design to permit use of the assembly during inter-sortie (non-EVA) periods on the lunar surface.

A detailed GCTA Program Plan was submitted to the customer in late September. The plan defined the RCA technical, managerial, and related tasks required to assure GCTA performance specified by the Contract. RCA planned a 20-month development and production program for the Ground Commanded Television Assembly. During the development phase, RCA delivered five GCTA systems that were non-functioning, but accurate in mechanical configuration. An EMC project evaluation unit (functioning brassboard) also was delivered. During the production phase, two GCTA Qualification Units and seven Flight Units were scheduled for delivery.

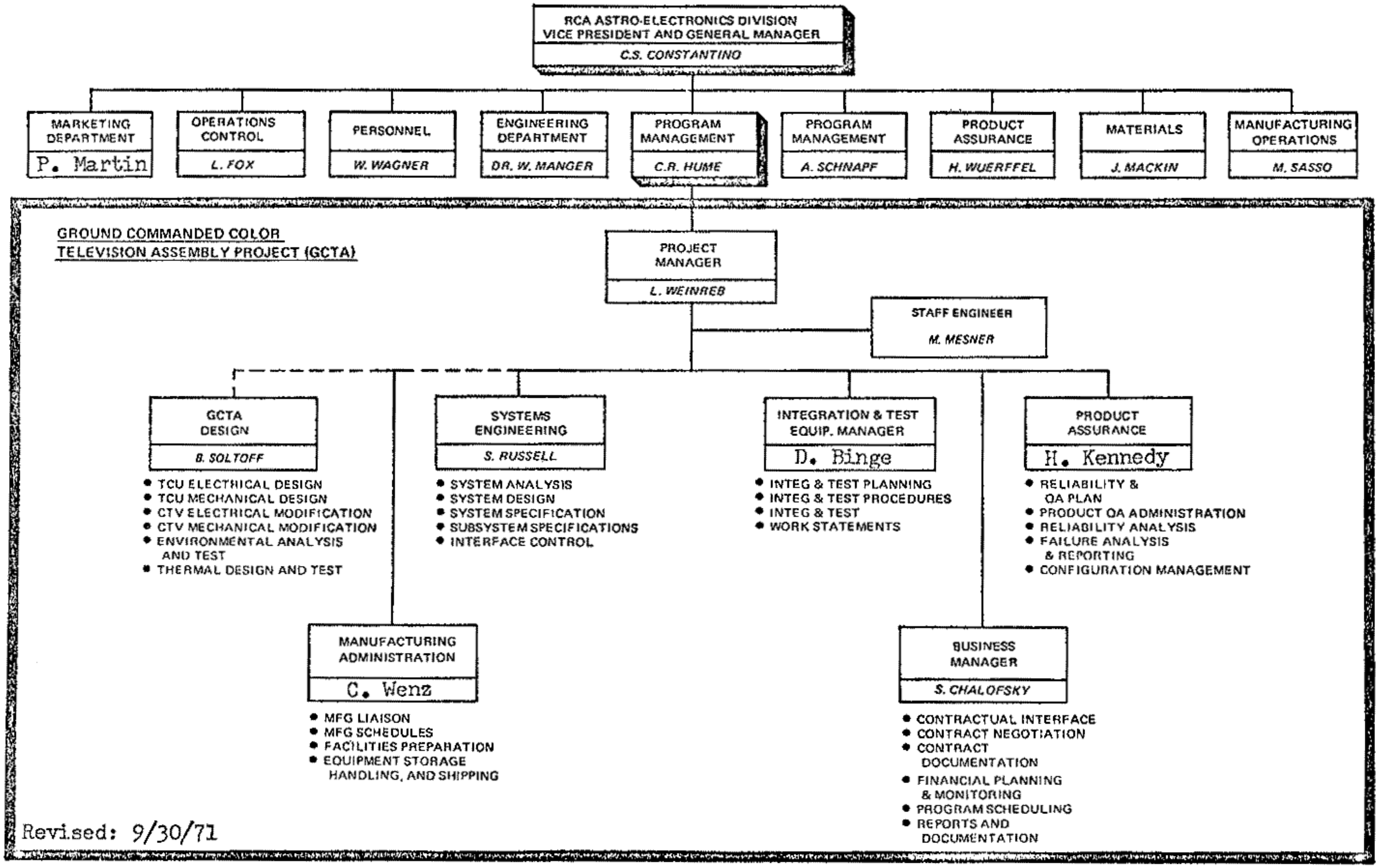

FIGURE 1-3. GCTA ORGANIZATION AND TASK DEFINITION CHART

During October 1970, overall design of the GCTA was reviewed by senior RCA staff engineering personnel, and additional systems management support was provided to improve overall GCTA/LCRU/MSFN video system performance. See Section II.B. Two GCTA models were delivered to MSC for evaluation. On October 28, NASA notified RCA that Flight Model No. 6 and No. 7 should be deleted from the contract, leaving five deliverable Flight Units.

A critical design review of the GCTA was held in mid-November. The following recommendations were made and actions taken:

- Calibration data for the CTV vidicon faceplate temperature sensor were provided to permit system analysis of mission thermal profiles,
- Test signals were inserted in the GCTA video output during a CTV blanking period to allow system performance testing,
- Periodic activation of the GCTA vidicon was recommended to prolong shelf life. The camera will be turned ON for 30 minutes every 90 days,
- A revised test procedure was generated to verify steady-state and transient thermal performance of the assembly,
- The thermal blankets supplied with the camera were vented,
- RCA recommended that the CTV focus and iris controls be mechanically coupled through a portion of setting ranges,
- Simulated lunar dust tests were suggested. (The GCTA was subjected to dust tests specified by NASA later in the program), and
- System tests of the GCTA with the LCRU will be conducted and recorded on videotape to provide systems analysis data and verify CTV gamma correction, coring, ALC, and AGC performance.

As a result of bearing failures in the filter wheel assembly of the QTV-9 camera (Contract NAS 9-10781), new bearings and retainers using a "wet" lubrication process were incorporated in the GCTA filter wheel assembly during November. Tests of the GCTA/LCRU chain also were performed to verify the functional operation of all GCTA commands, the up-link command system, and electrical compatibility between the two units.

The EMC Evaluation Unit (S/N 001) was delivered in November 1970. Aperture correction circuitry was incorporated in the EMC to permit NASA evaluation.

During December, fabrication of GCTA Qualification Model Nos. 1 and 2 (S/N 002, 003) commenced. Design changes generated by the critical design review in November and ALC/AGC circuits were incorporated. Test and evaluation of GCTA performance in the overall video chain continued to determine optimum parameters for an improved picture. Videotapes were generated for NASA/MSC study.

GCTA Flight Model Nos. 1 and 2 (S/N 004, 005) were released for production during January 1971. Thermal analysis of NASA-modified mission timeline requirements indicated that a thermal blanket would be required on the GCTA during the initial lunar EVA. The EMC (S/N 001) was returned to AED.

Assembly and test of the two Qualification Assemblies (Q1 and Q2) and Flight Model Nos. 1 and 2 continued during February 1971. Q1 was shipped to NASA/MSC for EMC testing on March 21. The unit then was shipped to KSC (Kennedy Space Center) for electrical compatibility testing and was returned to AED on April 26 for completion of acceptance testing.

Flight Model No. 1 was delivered to KSC on April 15 for fit checks and electrical testing. This unit was returned to AED on April 26 for incorporation of changes and completion of acceptance tests. The GCTA Command Simulator (GSE) and a system-level Failure Mode, Effects, and Criticality Analysis (FMECA) for the GCTA were completed and submitted to NASA for approval. The Q1 assembly completed required tests and was shipped to MSC on May 21. Prior to final testing, the Q1 camera vidicon was replaced. Qualification tests on Q2 were completed in May. The finished assembly was retained at AED for backup and dust testing. Flight Model No. 2 (S/N 005) was delivered to KSC on June 8. Flight Model No. 3 (S/N 006) was shipped on July 6. AED personnel were provided at NASA/MSC to assist in setup of similated lunar scenes and training of MSC flight controllers. At liftoff of Apollo 15 on July 26, GCTA Flight Model Nos. 4 and 5 (S/N 007, 008) were scheduled for delivery on August 9 and September 1, respectively.

GCTA Flight Unit No. 1 (S/N 004) accompanied astronauts Scott, Irwin, and Worden at liftoff of Apollo 15 on 26 July. After translunar flight, lunar orbit, descent, and a lunar landing near Hadley Rille, the GCTA was deployed to the Lunar Roving Vehicle on 31 July. The unit remained on the LRV during the three exploratory traverses scheduled for the mission, and televised lunar liftoff of the LM ascent stage on 2 August.

Ground-commanded operation of the GCTA provided MCC with visual surveillance of astronaut activity on the lunar surface. Overall picture quality was excellent. The provision for "peak" and "average" modes of automatic light control (ALC) in the CTV increased the bounty of scientific data gathered during the EVAs, and proved the camera's ability to handle extremes of scene luminance.

Activity on the program following the successful Apollo 15 mission centered on analysis of GCTA performance and changes required to improve GCTA operation for the Apollo 16 mission. A redesign effort was initiated to increase the margins of GCTA thermal performance. Apollo 15 experience indicated that the temperatures at which the assembly must operate should be increased. Section V, Refurbishment, details this activity during the latter half of 1971 and early 1972.

SECTION II

EQUIPMENT DESIGN

The GCTA equipment used during the Apollo 15 mission was fully responsive to customer requirements. During the entire design and fabrication phases of the Program, technical tradeoff studies and customer-approved design changes were made to ensure maximum reliability and operational flexibility of the GCTA/LCRU/MSC video chain. The following paragraphs identify briefly the major areas of design effort.

A. Project "Rainbow"

In October 1970, RCA corporate management initiated a company-sponsored program designated Project "Rainbow" to review all aspects of the GCTA Apollo 15 television mission. The objective of this systems engineering effort was twofold: (1) to ensure that RCA equipment in the video chain interfaced and performed properly with other elements in the system; and (2) to assist NASA in improving overall picture quality and signal processing throughout the ground station complex. By detailed review of each link in the video signal chain, video noise, feedback, and related technical problems were minimized:- from the lunar scene to reception at a home receiver.

The Project "Rainbow" effort resulted in substantial improvements in the overall performance of Apollo 15 television. Gamma correction was suggested and incorporated in the GCTA camera to reduce "blooming" and compensate for extreme variations in lunar-surface light levels. LCRU grounding was modified to improve isolation between video and audio signals. In several cases, the video links between ground stations were rerouted to reduce picture smear, ringing, and loss of "sync". Minor modifications also were made to improve link tolerance to noisy video signals. In addition, the time delays inherent in the use of the available data links were simulated to provide NASA personnel with realistic operational data for GCTA control during the mission. More details of this aspect of Project "Rainbow" are provided in Section IV, Launch Support.

B. Mission Timelines

The GCTA was designed to perform as specified during both of the following lunar surface schedules (timelines):

- Timeline No. 1

  Operation during extra-vehicle activity (EVA) periods of three to seven hours duration with a 14-hour period between EVA periods and prior to liftoff of the Lunar Module (LM) from the lunar surface.

- Timeline No. 2

  Operation during EVA No. 1 (5-hour duration) followed by a 14-hour period to the next EVA; operation during EVA No. 2 (6-hour duration) followed by a 13-hour period to the next EVA; operation during EVA No. 3 (4-hour duration) followed by a 5-hour period to the next EVA; and operation during EVA No. 4 (4-hour duration) followed by a 14-hour period prior to LM liftoff and ascent.

The assembly was not required to operate while the Lunar Roving Vehicle (LRV) was in motion on the lunar surface. Continuous operation, however, was a requirement during the EVA periods and the intervals between EVAs and prior to lunar liftoff. The GCTA also was required to be capable of withstanding solar inputs at the following sun angles during the mission:

- A 5-degree sun angle at lunar touchdown (cold-case design), and
- A 60-degree sun angle at lunar liftoff (hot-case design).

Provisions for thermal control of the GCTA considered degradation from lunar dust and assumed worst-case thermal conditions. Tables II-1 and II-2, and Figure II-1 provide the basis for thermal design (both hot and cold cases) of the GCTA.

TABLE II-1. HOT CASE GCTA THERMAL DESIGN GUIDELINES

1. Use this Table for all EVAs in conjunction with lunar surface timelines for hot case.

2. This traverse is for a 7-hour EVA. Scale down all times except those at the LM for a shorter EVA.

3. Assume a 20° sun angle (to true horizon) at landing + $\frac{1}{2}^{\circ}$/hour increase during lunar stay.

4. LM landing on 7° slope.

5. Use lunar surface temperatures derived from Figure II-1 (Variation of Lunar Surface Temperature With Sun Angle.)

6. Detailed hot traverse timeline (Copernicus peaks):*

STOP	TIME AT STOP (MIN)	LURAIN ANGLE	TRAVERSE TIME TO NEXT STOP (MIN) (No power available)
LM	30	$+7^{\circ}$	33
1	20	Level	14.4
2	25	$+7^{\circ}$	17.5
3	15	$+2^{\circ}$	5.9
4	25	$+7^{\circ}$	14.1
5	25	$+7^{\circ}$	6.7
6	15	$+7^{\circ}$	9.6
7	20	Level	24.4
8	20	$+20^{\circ}$	27.4
9	15	$+20^{\circ}$	6.0
10	15	$+2^{\circ}$	6.0
LM	30	$+7^{\circ}$	--
	255 min.		165 min.

7. GCTA Operation for 30 minutes after LM liftoff is required.

8. Power will not be considered available to the GCTA during periods between EVAs and after the last EVA prior to LM lift-off. The GCTA will be in the sunlight for these periods.

9. The CTV must operate for one hour prior to the start of this traverse.

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* Lurain angle during LRV moving operations is assumed to be same as at last stop. Lurain angles are to be considered biased to worst-case conditions.

TABLE II-2. COLD CASE GCTA THERMAL DESIGN GUIDELINES

1. Use this Table for all EVAs in conjunction with lunar surface timelines for cold case.

2. This traverse is for a 7-hour EVA. Scale down all times except those at the LM for a shorter EVA.

3. Assume a 5^{o} sun angle at LM landing + $\frac{1}{2}^{o}$/hour increase during lunar stay.

4. Use lunar surface temperatures derived from Figure II-1. (Variation of Lunar Surface Temperature With Sun Angle.)

5. GCTA operations for 1 hour in shadow prior to the first LRV traverse is required.

6. Detailed cold traverse timeline:*

STOP	TIME AT STOP	SUN/SHADE	TRAVERSE TIME TO NEXT STOP (No power available)	
LM	60 Sun	Sun	26	Sun
Shadow Line	---	Sun/Shade	33	Shade
1	25 Shade	Shade	31	Shade
2	20 Shade	Shade	26	Shade
3	15 Shade	Shade	34	Shade
Shadow Line	---	Shade/Sun	120	Sun
LM	30 Sun	Sun	--	
	150 Min.		270 Min.	

7. Power will not be available to the GCTA during periods between EVAs and after the last EVA prior to LM liftoff. The GCTA will be in the sunlight for these periods.

8. GCTA operation for 30 minutes after LM liftoff is required.

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* Lurain angle is assumed to be level.

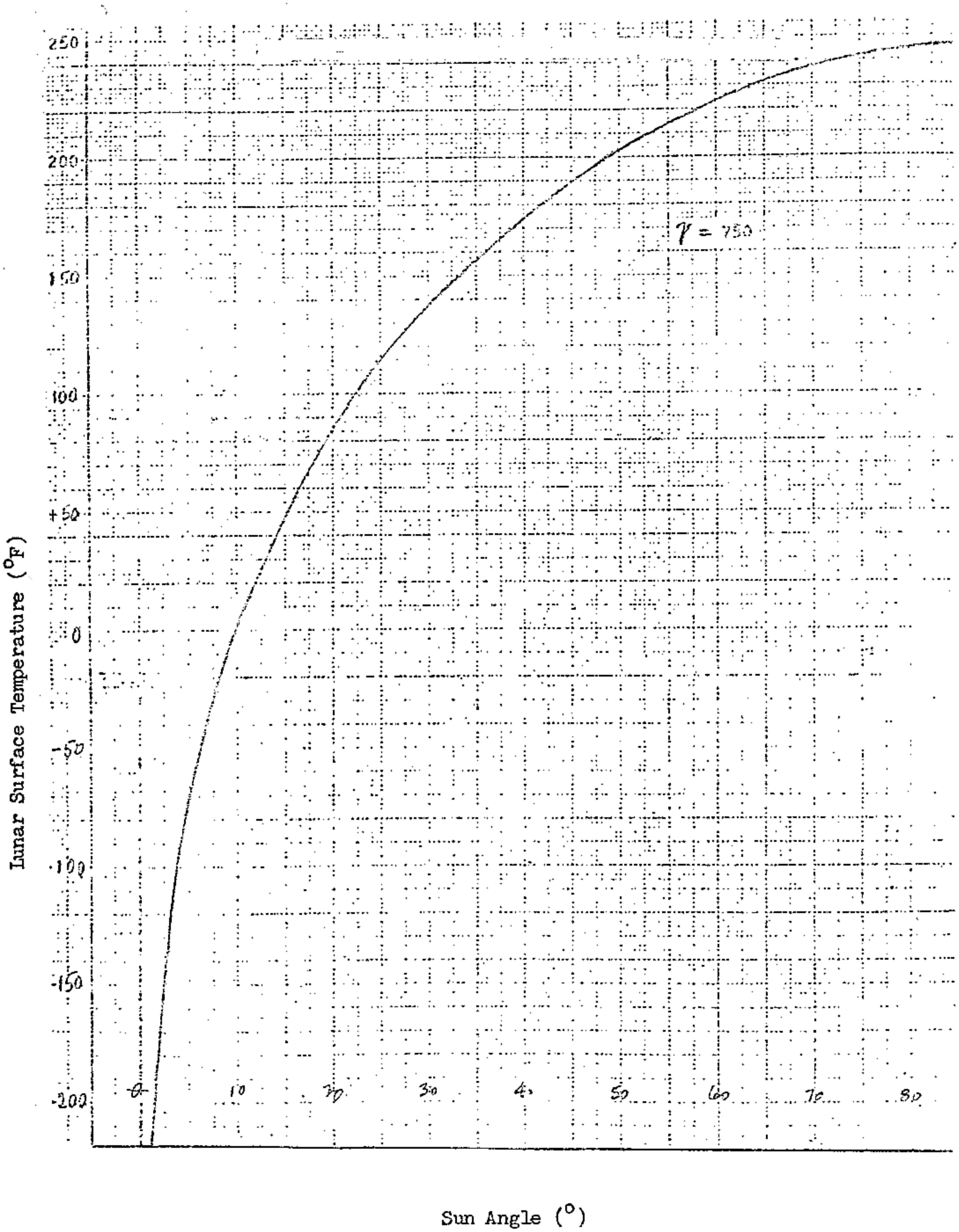


Figure II-1. Variation of Lunar Surface Temperature with Sun Angle

SECTION III

GCTA TEST HISTORIES

MATERIAL TO BE SUPPLIED

SECTION IV

LAUNCH SUPPORT

A. Mission Thermal Analysis

AED personnel traveled to the NASA Manned Spacecraft Center in Houston, Texas to analyze GCTA thermal performance during the Apollo 15 mission, to provide recommendations for improvements and to analyze the thermal problems inherent in the Apollo 16 Mission.

Results of the Apollo 15 Mission were compared with preflight predictions. See Figure IV-1. The flight temperatures are higher. The major cause was more severe degradation of the solar absorptivity (α) of the radiator surfaces than originally anticipated. The worst-case dust α values for the mirrors was assumed to be 0.2, but the flight results indicate that the value could be as high as 0.4.

Individual events, the 2 cooldown periods between EVA's and also EVA 3 (including liftoff) were analyzed. The cooldown period between EVA 1 and 2 is shown in Figure IV-2. The camera radiator facing the sun and tilted 45° to the lunar surface condition was satisfied by considering the mirrored portion of the radiator to have a solar absorption value of 0.17 and by considering the white paint portion of the radiator to have a solar absorption value of 0.4. The cooldown period between EVA 2 and 3 is shown in Figure IV-3 was satisfied by considering that the radiator received solar heat at a 10° incidence sun angle with a mirror α=0.2 and a white paint α= 0.5. The radiator also had a view factor to the high-gain antenna of 0.10.

The correlation of EVA 3(the TV standby period) and liftoff coverage is shown in Figure IV-4. The solar absorptance of the radiator was considered to be 0.25 during all operating periods except for the period between 3.5-4.3 hours. During this period, 0.35 was used for radiator solar absorptance.

The analytical effects of changing the surface finish on the radiator retainer ring from white paint to second-surface mirrors, and of changing the surface finish of the bottom of the camera base mount is shown on Figures IV-2 and IV-3 for the two cooldown periods. See Section V for complete details on thermal design changes for the Apollo 16 mission.

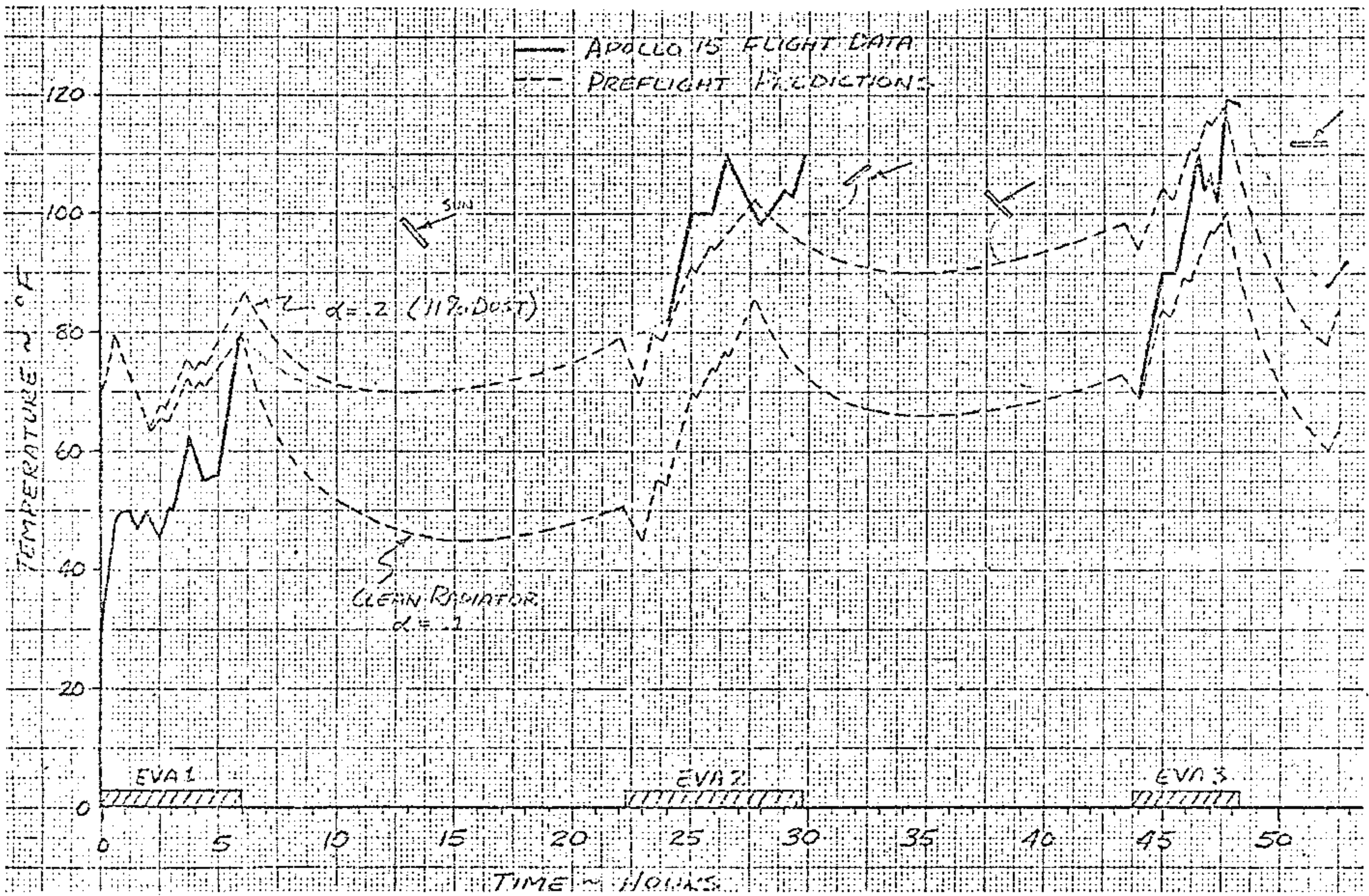


Figure IV-1. Predicted and Actual Apollo 15 SIT Target Temperatures

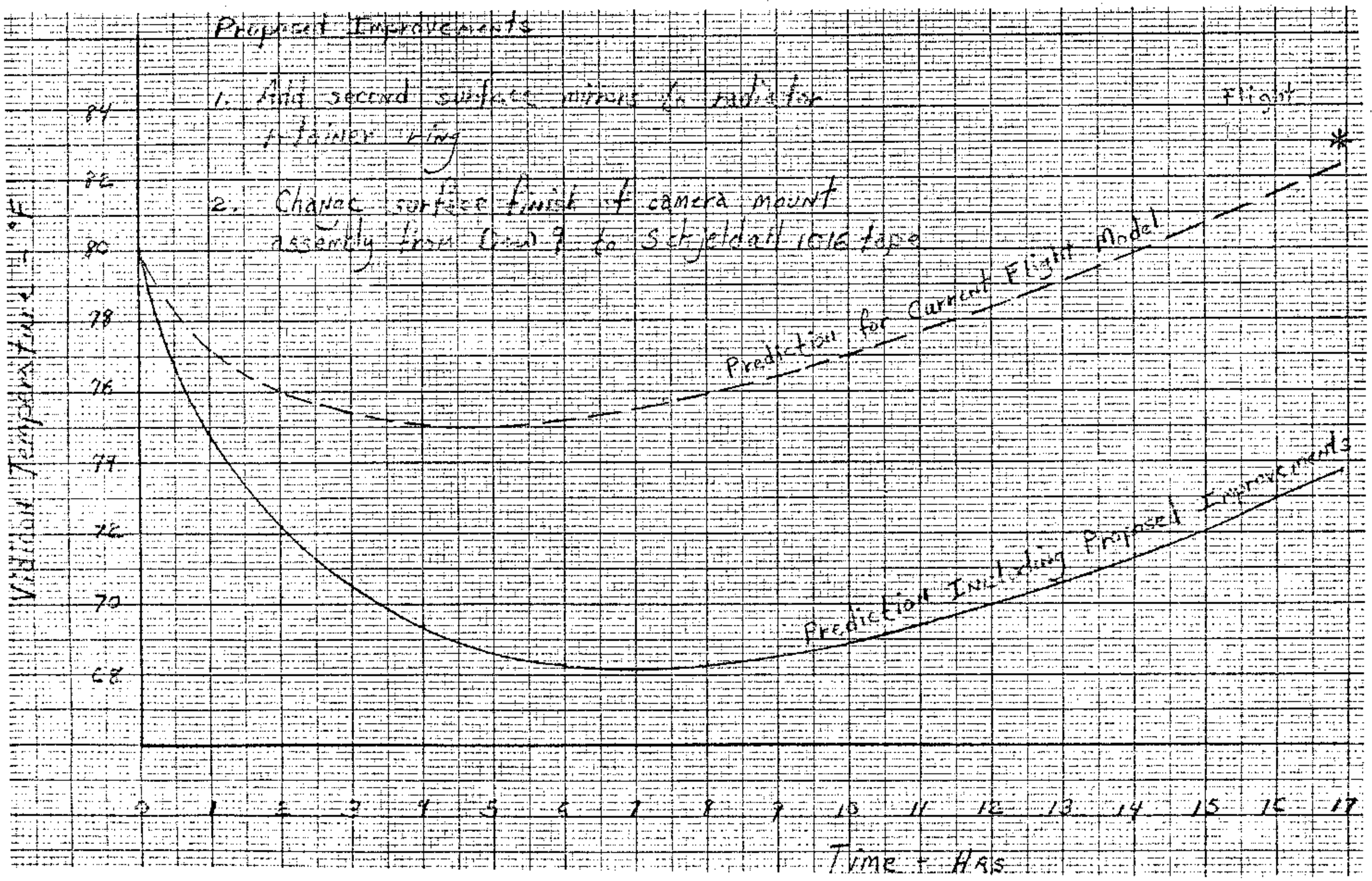


Figure IV-2. CTV Vidicon Temperature During Apollo 15 Cooldown Period Between EVA 1 and EVA 2

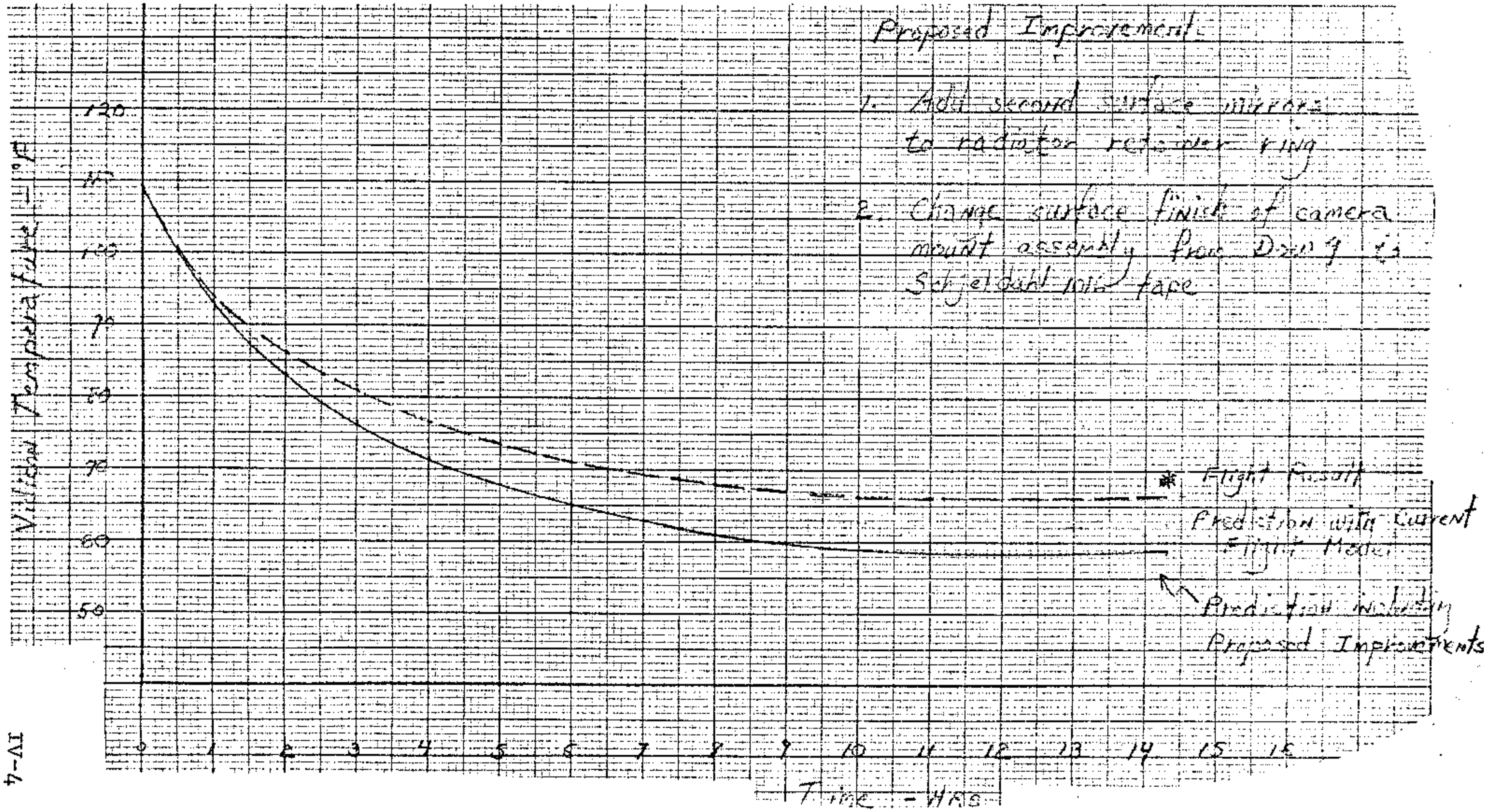


Figure IV-3. CTV Vidicon Temperature During Apollo 15 Cooldown Period Between EVA 2 and EVA 3

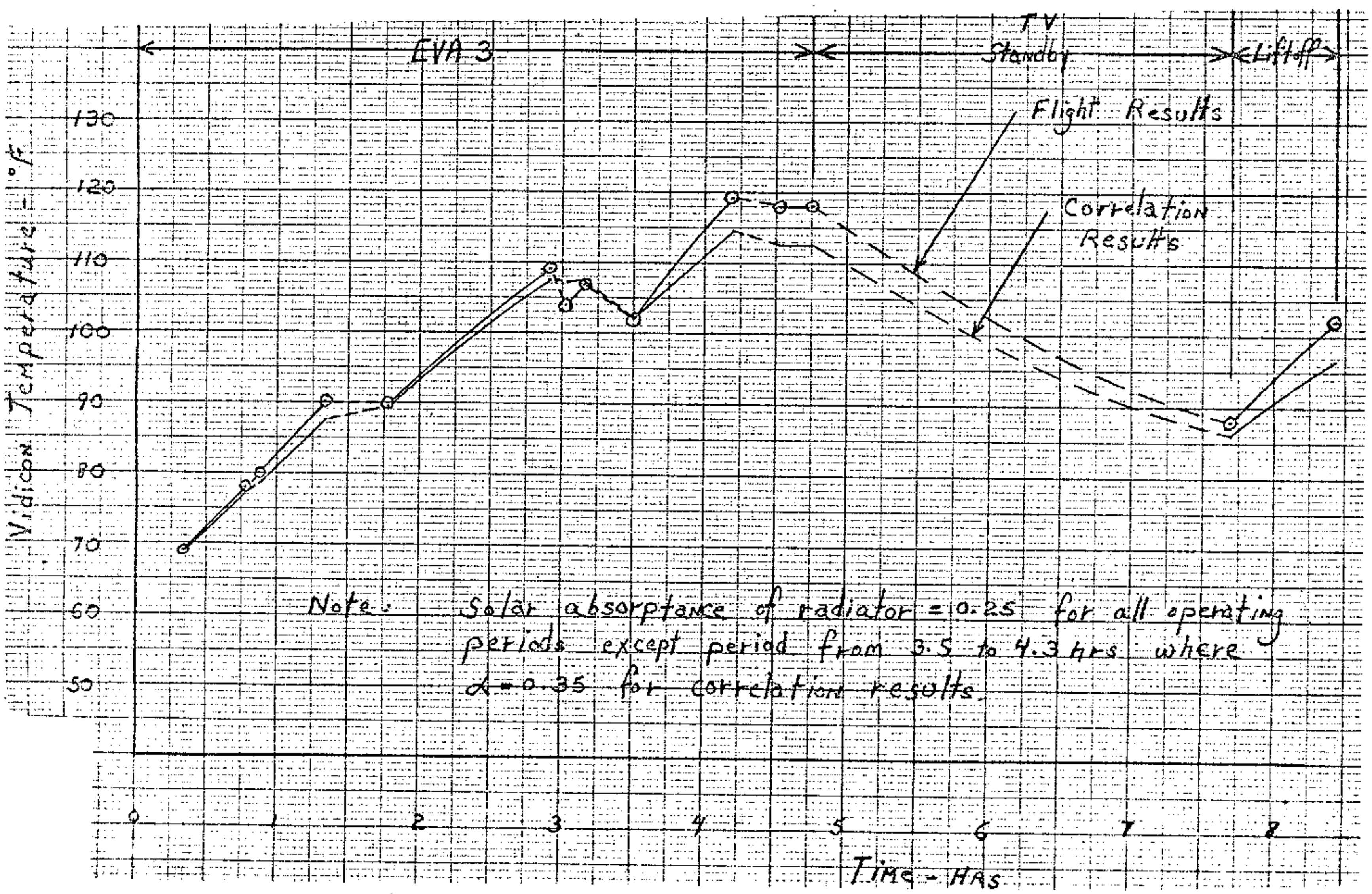


Figure IV-4. CTV Vidicon Temperature During Apollo 15 EVA 3 (TV Standby & Liftoff)

B. Lunar Scene Modeling

Early tests with the GCTA indicated clearly the need for realistic modeling of the lunar surface to train NASA flight controllers and to optimize the performance of each GCTA camera. The use of a simulated lunar scene could provide the controllers with actual data-link time delays that would be present during the Apollo 15 mission, and also train them in the use of ALC, iris and zoom changes, and overall control of available lunar lighting.

Based on experience with a small lunar scene constructed at RCA, recommendations were made to NASA for construction of a 16x24 foot model of the Hadley-Apennine lunar surface region at MSC (Houston). The 16 x 24 foot model was constructed at MSC and illuminated by a single 30-kilowatt light source. The single-source lighting provided realistic lunar contrast and shadow conditions. The Q-1 GCTA camera then was placed near the center of the model and allowed to operate through simulated azimuth angles (and sun-phase angles) from 0° to 180° A 3.5-second time delay was incorporated in the video output from the camera to simulate the actual time delays anticipated during the mission.

SECTION V

REFURBISHMENT

The basic objective of GCTA refurbishment effort has been the improvement of thermal performance margins at the temperatures experienced on the lunar surface during the Apollo 15 mission. Based on an analysis of Apollo 15 data, thermal design changes were indicated. As a result, CTV radiator size was increased, the thermal coatings on the CTV cradle and TCU painted surfaces were modified to reduce operating temperatures, and thermal couplings within the CTV were improved to reduce temperature gradients within the camera. In addition to thermal design changes, minor electrical and several mechanical modifications were made to the Assembly. The following paragraphs discuss each of these changes in greater detail.

A. Thermal Design Changes

1. Increased CTV Radiator Area

Total CTV radiator surface was increased by 22.4% by the use of second-surface mirrors on the existing CTV radiator retaining ring. The efficiency of the radiator surface also was improved by incorporating the mirrors ($\alpha = 0.1/\varepsilon = 0.8$) to replace the white paint ($\alpha = 0.2/\varepsilon = 0.9$) previously used on the ring surface.

2. Improved CTV Internal Couplings

RTV-60 was applied to interface surfaces with the CTV to improve thermal conduction couplings. The surfaces included: (1) the radiator/side cover, (2) the radiator/vidicon sleeve mounting bracket, (3) the camera base/vidicon sleeve mounting bracket, and (4) the camera base/side cover interface surface. A distinct improvement in conduction coupling within the camera resulted. Temperature gradients were reduced and a 5°C reduction in vidicon operating temperature was noted during the test. The efficiency of the radiator increased due to greater heat flow from hotter areas to the radiator surface. The radiator also rejected heat at a higher temperature. The overall result is a more isothermal and desirable system for camera-operating lunar timelines. When the camera is not operating, the improved joint configuration does not reduce vidicon temperatures below predicted levels, however.

Measurement of the initial temperature gradients was performed by mounting the camera in a bell jar at $2x10^{-5}$ torr and exposing it to a low-temperature surrounding (approximately -50°C). The camera was turned ON in a normal operating mode and the entire system was allowed to reach equilibrium. The resulting temperature levels and gradients between selected bodies is shown in Figure V-1a labeled TEST 1 (Without RTV).

The camera then was removed from the chamber and RTV-60 was applied between the following joints: (1) radiator to clamp above vidicon sleeve; (2) radiator to side covers; (3) side covers to base; and (4) base to clamp above vidicon sleeve. All joint screws were torqued to specified levels after RTV application. The test then was rerun in the same environment as TEST 1. The results are shown in Figure V-1b labeled TEST 2 (With RTV).

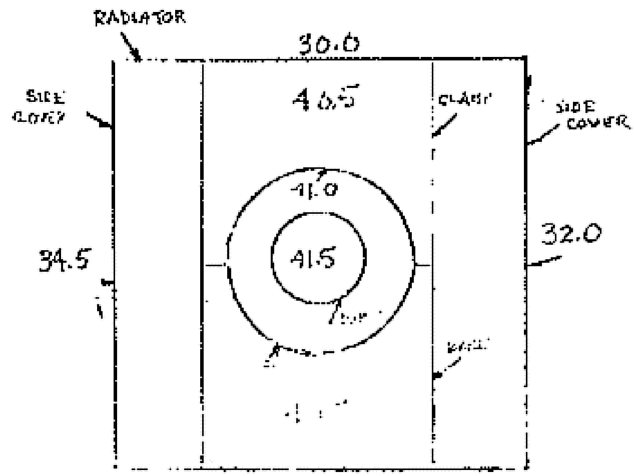
3. Replacement of DOW 9 Finish on TCU

DOW 9 has a $\alpha = 0.95$ and a $\epsilon = 0.6$ and contributed to high temperatures at the TCU elevation drive assembly if the camera cradle bottim was exposed to direct sunlight for long periods of time. For this reason, the DOW 9 surface finish on the bottom of the TCU camera cradle was replaced.

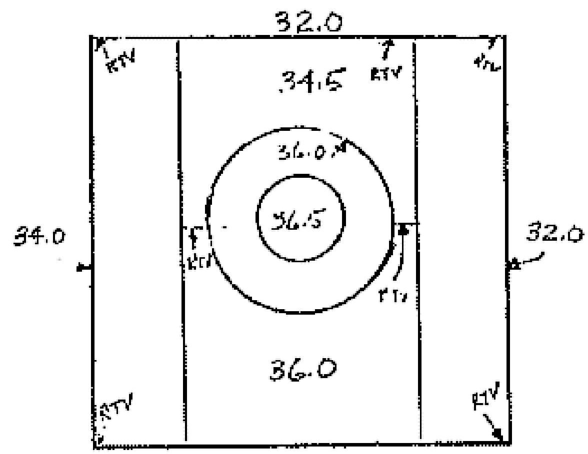
Three candidates were considered as replacement coatings:

- Balsa-Mylar Insulator
- Schjeldahl Tape, and
- White Paint

A series of tests were performed to evaluate the effective emissivity of the proposed balsa-mylar insulator after bonding it to the camera mounting bracket. All surfaces not covered by the insulator were covered with a thermal blanket. Heat was applied to the bracket in a LN_2 environment, the equilibrium temperature measured, and the effective emissivity calculated. The tests resulted in values for emissivity between 0.2 and 0.4. It was difficult to obtain a more exact measure of emissivity because of the uncertainty in blanket emittance for the insulated areas as well as uncertain effects from cavities in the bottom of the bracket. The results show that the effective emissivity is above the expected value of 0.1. The insulator also was found to be subject to damage during handling due to fragile construction.



a. TEST 1 (Without RTV)



b. TEST 2 (With RTV)

(All temperatures in °C)

ΔT LEVELS (°C)

Joint #	TEST 1 (without RTV)	From To	TEST 2 (with RTV)
1	11.0	RAD TO VID SLEEVE	4.0
2	3.25	RAD TO AVG SIDE COVER	2.25
3	4.5	RAD TO RING	5.0
4	10.5	RAD TO CLAMP ABOVE VID	2.5
5	7.25	BASE TO AVG SIDE COVER	3.0
6	0.5	BASE TO VID SLEEVE	0.0
7	0.0	BASE TO CLAMP ABOVE VID	1.5
8	0.5	VID SLEEVE TO CLAMP	1.5
9	0.5	VID TUBE TO VID SLEEVE	0.5

FIGURE V-1. CTV Temperature Gradient Test Results

In summary, difficulty in handling, and a greater effective emissivity than expected made the balsa insulator less advantageous than expected over other suggested materials for this application. Additional analysis showed only a marginal difference between the other two proposed coatings (2.4°F at the elevation motor), and white paint was selected to replace the DOW 9 finish.

4. Repainted TCU Surfaces

Lunar dust degraded TCU surface solar absorption properties much more than originally expected during the Apollo 15 mission. To help reduce TCU operating temperatures in the presence of lunar dust, white paint has been substituted for black paint areas on the TCU. Five square inches on the "park" side, five square inches on the "LRV" side, and all upper surfaces of the end cover of the TCU now are finished with white paint.

5. Thermal Design Verification

The effects of the above changes in thermal design were analysed using the GCTA thermal design computer model. Change No. 1, (increase in CTV radiator size) affected the following computer model parameters:

- Node 46 Radiation coupling to space - 10.43 in^2 when the camera is level.
- Node 46 Radiation coupling to space (including a .05 view factor to the high gain antenna) = 8.82 in^2 when the camera is tilted 45°.
- Node 46 Radiation coupling to the moon = 1.61 in^2 when the camera is tilted 45°.

The effects of Change No. 2 (improvement in CTV internal conduction couplings) were determined by the test program described above. The test results showed the following improvement in conduction couplings:

- $K_{vidicon\text{-}radiator} = K_{1-7}$ 0.29 $\frac{watts}{^{o}C}$ (Previous)→0.6 $\frac{w}{^{o}C}$ (Now)
- $K_{radiator\text{-}side\ cover} = K_{1-5}$ 1.0 $\frac{w}{^{o}C}$ (Previous)→1.5 $\frac{w}{^{o}C}$ (Now)

- $K_{side\ cover-base} = K_{5-6}$ $\frac{w}{^oC}$ (Previous) $0.9 \frac{w}{^oC}$ (Now)
- $K_{base-vidicon} = K_{6-7}$ $0.2 \frac{w}{^oC}$ (Previous) $0.5 \frac{w}{^oC}$ (Now)
- $K_{radiator-retaining\ ring} = K_{1-46}$ $0.119 \frac{w}{}$ (Previous) $0.28 \frac{w}{^oC}$ (Now)

The change to white paint on the bottom of the CTV cradle (Change No. 3) resulted in the following input changes to the computer model for both clean or dusty conditions:

- Level Camera
  - $R_{12-space} = 7.95\ in^2$
  - $R_{12-moon}$ 30.12
  - $R_{9-12} = 1.60$
- 45^o Tilt Camera
  - $R_{12-space} = 11.47$
  - $R_{12-moon} = 26.53$
  - $R_{9-12} = 1.60$

Use $\alpha 12 = 0.2$ for the clean condition case, and $\alpha 12 = 0.5$ for the dusty condition case. $\varepsilon 12 = 0.9$ is used in both clean and dusty cases.

Change No. 4 (repainted TCU surfaces) is satisfied in the computer model by changing $\alpha 25$ to 0.26 for clean-case values and 0.40 for dusty-case values. $\alpha 24$ also must be changes to 0.2 for clean case values, and to 0.5 for dusty case values.

In summary, computer runs were made to verify the impact of the above thermal design changes. Results for the present Descartes Timeline were as follows:

Event	Begin (^{o}F)	End (^{o}F)
EVA 1	70	80
EVA 2	43.3	93.4
EVA 3	50.5	114.1
LIFTOFF	71.2	80.5

For the Apollo 16 mission, additional definition of the thermal design requirement, or a final Descartes Timeline, is required. A formalized procedure for GCTA thermal control and management during the Apollo 16 & 17 missions also is necessary.

B. Electrical Design Changes

1. CTV Temperature Telemetry

Changes were made in the CTV T/M circuitry to provide increased sensitivity in the region from +40°C to +70°C, and to improve the calibration accuracy of individual camera temperature telemetry. Figure V-2 illustrates the original and revised telemetry circuit configurations, and Figure V-3 shows the sensitivity increase after the circuit changes.

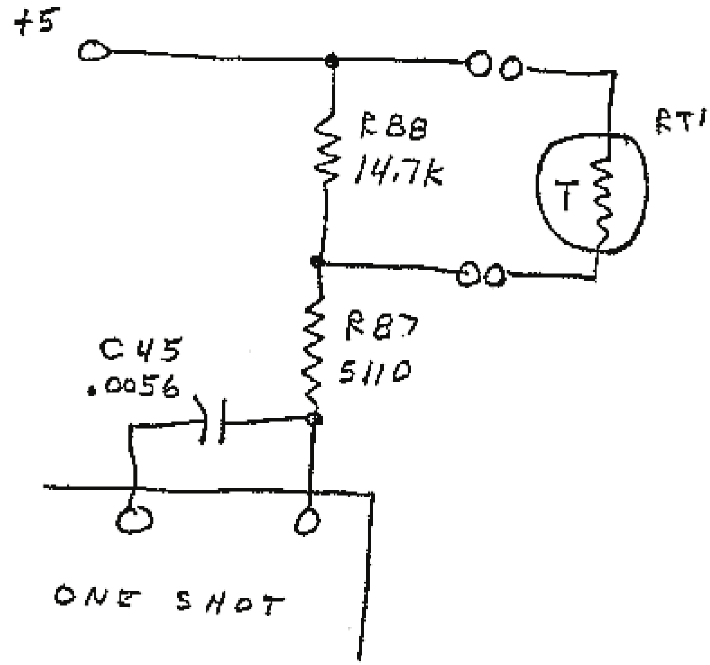
2. Black Level Clamp

Anomalous behavior of the video black level was observed on the F-4 camera (S/N 007) during thermal-vacuum testing. In particular, the black level at 40°C, referenced to the porch level, was 200 millivolts, as compared to the maximum value specified in the procedure of 100 millivolts (for a capped lens condition). The Apollo 16 mission will require operation of the GCTA at temperatures up to 60°C. The video black level clamp and set-up procedures, therefore, were reviewed to determine what changes were possible to improve black level performance with minimum impact on existing circuitry.

The effects of gamma correction and AGC on the dark current variation of the sensor are prime influences on the video black level. The gamma correction has an approximate gain of two for low-level signals near black, and the AGC circuit provides a 3 to 1 boost in dark signal from a low-highlight scene to a capped lens condition. Both of these circuits were incorporated after AED's adoption of the 100 millivolt maximum black level tolerance.

Results of the review indicate that optimum use of the present circuit characteristics can be obtained by adjusting camera black level to 40 millivolts using a scene with 10-30 foot-lamberts highlight brightness that contains a black reference with a minimum contrast ratio of 30 to 1. Data was obtained for Q-2 (S/N 003) in this manner. Additional data also will be obtained for F-2 (S/N 005) and F-4 (S/N 007) using this technique and a capped lens reference.

a. Original



b. Revised

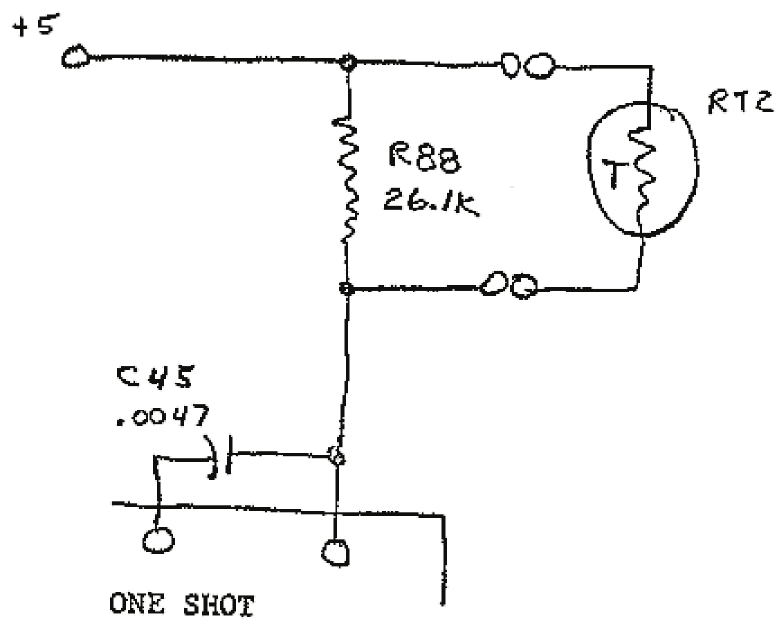


FIGURE V-2. REVISED CTV TEMPERATURE TELEMETRY CIRCUIT CONFIGURATION

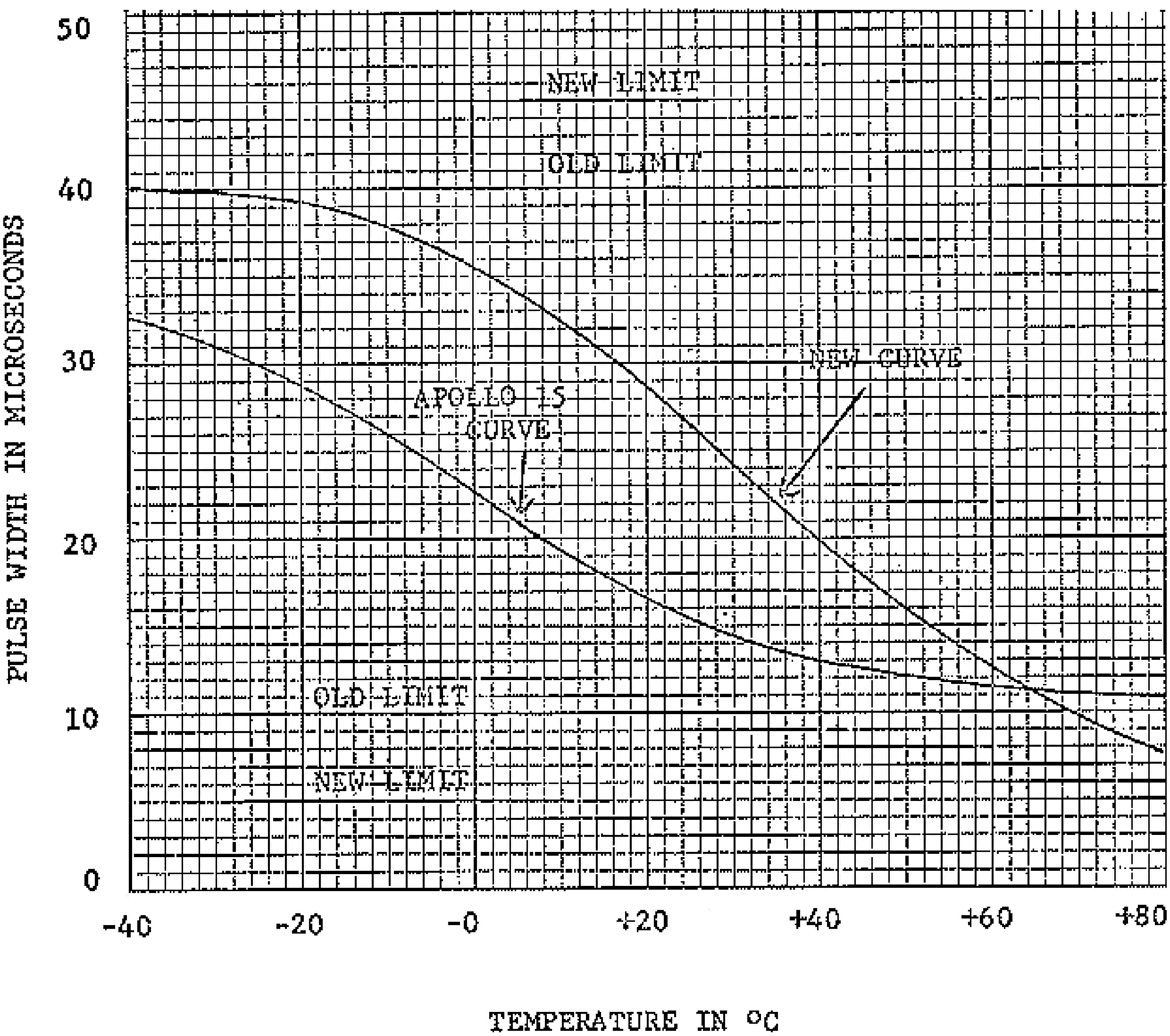


FIGURE V-3. SENSITIVITY IMPROVEMENT - CTV TEMPERATURE TELEMETRY

a. Discussion

Table V-1 summarizes the results of the initial review. All cameras, except F-3 (S/N 006), were set up using the capped lens reference for black level. Several questions arose in reviewing this data. First, the 25°C readings with capped lens exceeded the setup procedure limits (50 ± 10 millivolts). Black level adjustment was being made in a room environment after the camera was in operation for some time. Thus, the SIT temperature was well above 25°C. When tested in thermal-vacuum at a controlled temperature, the values decreased by the reduction in dark current. To correct this, the black level on each camera will be set shortly after turn-on, at a known temperature, before self-heating occurs.

Second, since the AGC gain increases by a factor of 3 from an illuminated scene to a capped-lens condition, the capped lens data should, in all cases, equal or exceed the scene black data. This was found to be true only for F-3 (S/N 006). Further examination showed the probable cause for this. Scene black data for each of the other cameras was reduced from available thermal-vacuum photographs not intended for this purpose. The test scene is outside the chamber and has a low contrast ratio (about 10 to 1). Thus, the effective scene black contributes a measurable signal level. To eliminate this effect, new data will be taken with a high contrast chart, excluding room ambient-light effects. Further evidence of this is given by F-3 (S/N 006) data which was taken with a 70:1 contrast ratio chart. Here, as predicted, the capped lens levels exceeded the scene black levels. The adjustment procedure for F-3 (S/N 006) was changed due to the higher-than-average dark dur-rent of the SIT sensor. To improve the performance of the GCTA at increased temperatures, the individual sensor must be adjusted for optimum black level performance.

The block diagram in Figure V-4 shows the major video processing blocks pertinent to this discussion. The AGC circuit character-istics are shown in Figure V-5.

TABLE V-1. SUMMARY OF GCTA VIDEO BLACK LEVELS

Temp. °C	S/N-002 (Q1) Black Levels Capped Lens	S/N-002 (Q1) Black Levels Scene Black	S/N-003 (Q2) Black Levels Capped Lens	S/N-003 (Q2) Black Levels Scene Black	S/N-004 (F1) Black Levels Capped Lens	S/N-004 (F1) Black Levels Scene Black	S/N-005 (F2) Black Levels Capped Lens	S/N-005 (F2) Black Levels Scene Black	*S/N-006 (F3) Black Levels Capped Lens	*S/N-006 (F3) Black Levels Scene Black	S/N-007 (F4) Black Levels Capped Lens	S/N-007 (F4) Black Levels Scene Black
-10°	-		-	40mv	10mv	30mv	18mv	40mv	5mv	0mv	25mv	40mv
0°	-		10mv	40mv	10mv	30mv	19mv	50mv	5mv	5mv	25mv	40mv
25°	20mv	100mv	40mv	70mv	30mv	60mv	35mv	70mv	90mv	45mv	50mv	60mv
40°	88mv	150mv	90mv	110mv	50mv	100mv	50mv	120mv	140mv	90mv	200mv	110mv
50°	250mv	205mv	220mv	160mv	90mv	140mv	70mv	170mv	350mv	165mv	325mv	180mv

NOTES

1. Camera video black level set-up using capped lens black as the reference except S/N-006.

2. *Camera video black level set up using scene black. Reference for scene black was a back-illuminated bar chart with a highlight brightness of 30 foot-lamberts. The ratio between the black and white on the chart was 70:1.

3. Video black level data for S/N-003, -004, -005, -006 and -007 were obtained from the results of Thermal-Vacuum Tests, paragraph 5.4 of TP-OP-2265826. Video black level data for S/N-002 was obtained from Thermal Test.

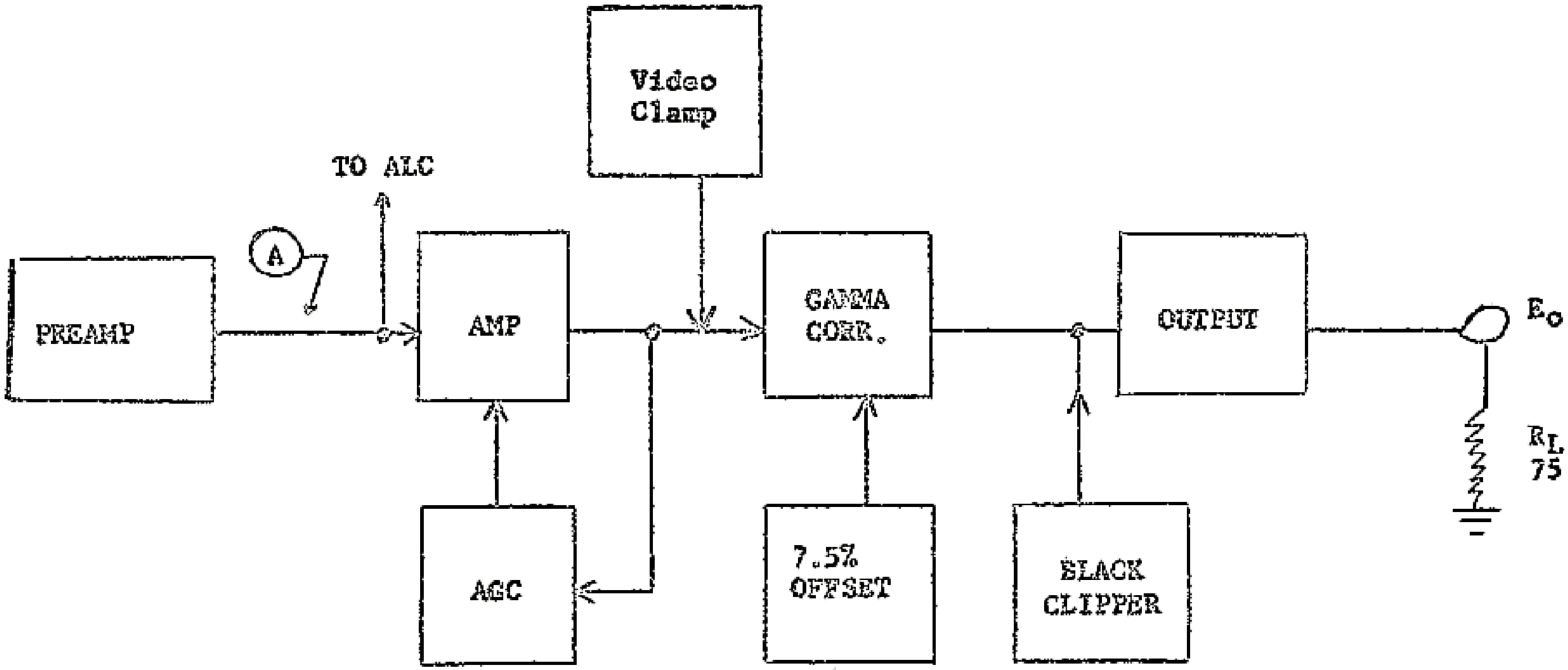


FIGURE V-4. VIDEO PARTIAL BLOCK DIAGRAM

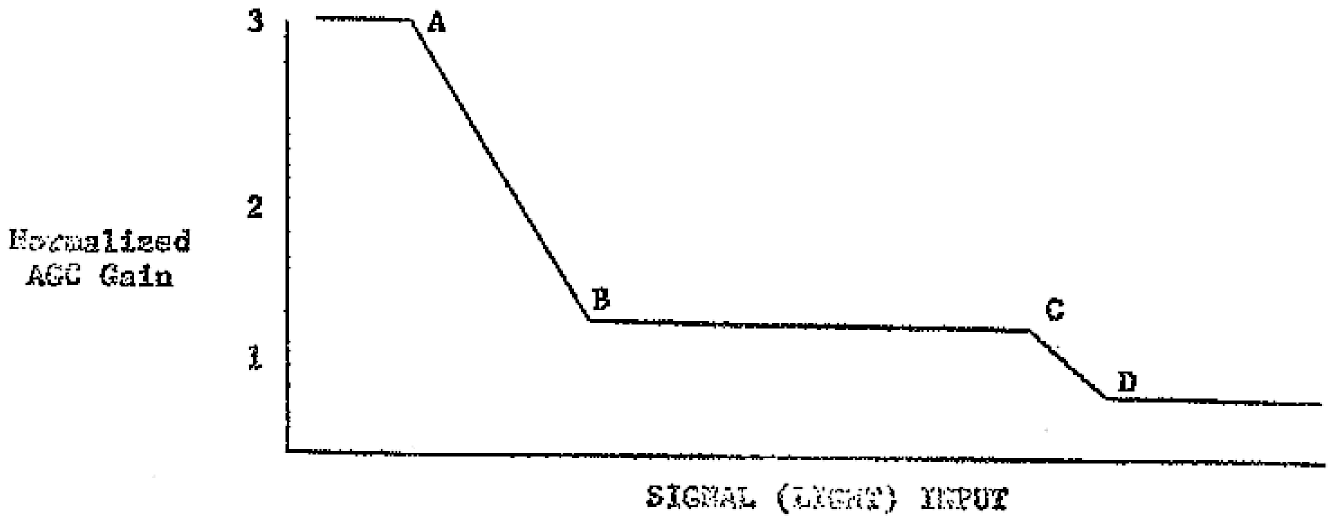


FIGURE V-5. AGC CIRCUIT CHARACTERISTICS

With the lens capped, the AGC gain is fixed at point "A" in Figure V-5 (gain of 3). When the lens is uncapped and the scene illuminated, the gain decreases to point "B" (unity gain). This occurs at about 3 foot-lamberts and is a function of individual SIT sensitivity. The gain holds constant until point "C" is reached at about 1000 foot-lamberts. The actual point is set by the ALC "catcher" diode. Increased light levels then move the AGC to point "D" which provides an attenuation of about 1/2. Operation beyond this point results in overload, and the lens iris must be used to limit light levels. The AGC affects dark current contributions to the signal. With the lens capped, the AGC operates at maximum gain and amplifies the dark current variation with temperature by a factor of 3.

The circuit configuration of the gamma corrector provides a gain of 2 for signals in the black or near-black region when compared to mid-range and white signals. This further increases the effect of dark-current variations on black level output. The gamma correction circuit gain of camera Q-2 (S/N 003) was measured to verify this and found to agree quite well with the expected results.

Two other items were noted at this time. A 7.5 percent offset bias signal is supplied to the gamma corrector that sets a nominal 50 millivolt black level at the output in the absence of any other input signal. The camera black-level adjustment (video clamp reference) allows for an increase or decrease in this value. The second item noted was that the black clipper has a hard-clip point between 0 and -15 millivolts (referenced to the porch) but also has a soft knee between 0 and about +50 millivolts. This soft knee, in effect, flattens the gamma characteristics in this region and minimizes the influence of dark current on black level caused by the presence of AGC and gamma correction.

The soft knee of the black clipper can provide maximum use of the video dynamic range (for the majority of scenes of interest) by setting the black level to 40 millivolts, using a low light scene. As the scene illumination decreases toward the capped-lens case, the black level should increase slowly.

After obtaining test data on F-2 (S/N 005) and F-4 (S/N 007) performance will be reviewed again. Based on the present analysis, the original anomaly noted in F-4 (S/N 007) is shown to be setup-related, and not a "failure" mechanism.

The presence of transient-type noise in the blanking region, prior to the video clamp, also was suspected of contributing to the changes in black level noted over the range of AGC control. Photographs were taken of the noise present at the video clamp in Q-2 (S/N 003). These photos showed that the clamp circuit is quite effective in averaging the noise content. The noise transients, therefore, do not appear to be a significant factor. The test data for Q-2 (S/N 003) is contained in RCA Engineering Notebook 47421.

b. Conclusions

Based on the above investigation of video black level stability and performance in the CTV, no circuit changes were made. The advantages of modifying the camera circuitry did not justify the time and costs required to make the possible improvements. The problem was solved through changes in the setup procedures for each unit.

C. Mechanical Design Changes

The elevation clutch assembly, the azimuth clutch, and the azimuth stops were modified as the result of post-mission analysis. The motor drive circuitry also was changed to increase motor torque margins.

1. Elevation Clutch

The performance of the Apollo 15 elevation clutch was investigated at temperatures from ambient to 110°C. Using Flight Unit No. 4 (S/N 007), the following test sequence was followed:

- Test 1

  A. Remove electronics housing from the TCU.

  B. Mount the elevation yoke assembly on a stable base.

  C. Verify clutch setting at 18 inch-pounds, and measure torque at horizontal, +45°, -45°, and -85° tilt angles.

  D. Set-up the elevation yoke assembly in Tenney box.

  E. Raise temperature in 10°C increments from ambient to 110°C. Measure torque as in Step C for each temperature and record. Let unit stand at least 30 minutes at each temperature prior to reading torque.

- Test 2

  A. Set-up the elevation yoke assembly in Tenney box.

  B. Measure torque at ambient.

  C. Heat chamber to 100°C and let stand for approximately 20 hours.

  D. Record torque as in 1C.

  E. Return to ambient temperature and record torque.

  F. Recycle to 100°C for 65 hours and record torques.

Results of the above tests were as follows:

Test 1-E. Torque Measured at 10° Increments (25° to 110°C)

FORCE (Lb.)*

Temperature	+45°	Horizontal	-45°	-85°
Ambient	5.5	5.5	5.5	5.5
47°C	5.4	4.0	4.5	5.4
60°C	4.2	3.7	3.8	4.8
70°C	5.4	3.6	4.2	5.0
80°C	5.4	3.7	3.6	4.4
90°C	5.4	3.5	3.9	4.8
100°C	5.5	3.4	3.5	4.5
110°C	4.8	3.3	3.5	4.5

Test 2-C. Unit Returned to Ambient and Recycled to 100°C for 17 Hours

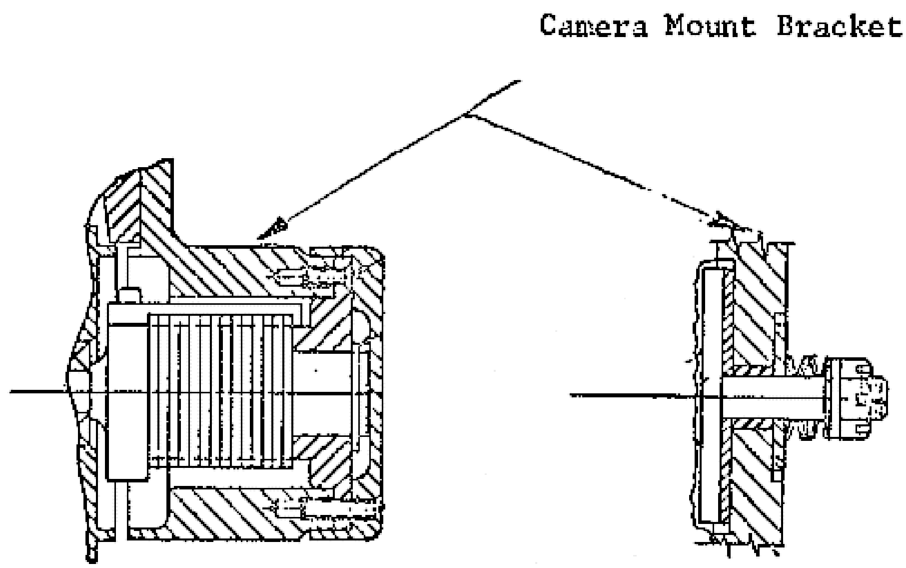
Ambient	4.5	4.7	4.8	5.8
100°C	3.3	2.9	2.8	3.5

Test 2-F. Unit Returned to Ambient and Recycled to 100°C for 65 Hours

Ambient	4.3	4.0	3.2	3.8
100°C	3.0	2.1	1.3	2.8
Ambient	3.5	4.2	2.4	3.4

*Torque = Force x 3.3 inches

Based on the above tests, the elevation clutch was redesigned from a disc clutch with adiprene pad (Apollo 15 configuration) to a single-wrap spring clutch made of music wire. The body of the clutch is made of lubricated sintered bronze. See Figure V-6 a & b.



a. Redesigned Clutch b. Apollo 15 Clutch

Figure V-6. Apollo 15 and Redesigned Clutch Configurations

The redesigned clutch and elevation drive assembly was qualification-tested in a vacuum chamber with a changing thermal environment. Clutch override torque was measured using a strain gauge for temperatures ranging from -20°C to 100°C ± 5°C in increments of 20°C. Test equipment and data recording were witnessed by Quality Assurance personnel and noted in an engineering test log book. The method employed to measure override torque was to slip the clutch for a number of revolutions (10 minimum in each direction) and record strain with a Bridge Amplification Meter (BAM). By using the calibration curve in Figure V-7, the related override was obtained. The results of this test are shown in Table V-2. The maximum percent deviation from the original ambient value was 12.2 percent, well below the allowable deviation of 20 percent. At the end of the test, the chamber was returned to ambient (≈25°C) and the override torque was measured. The value did not change from the pretest value, thereby exemplifying the ability of the clutch to return to its pretest condition. The assembly was disassembled and observations were recorded. The clutch exhibited little wear and was free of loose particles. Photographs shown in Figure V-8 are of the test setup and clutch after the thermal-vacuum test. The total number of revolutions on the clutch for this test, including setup and checkout, was approximately 230.

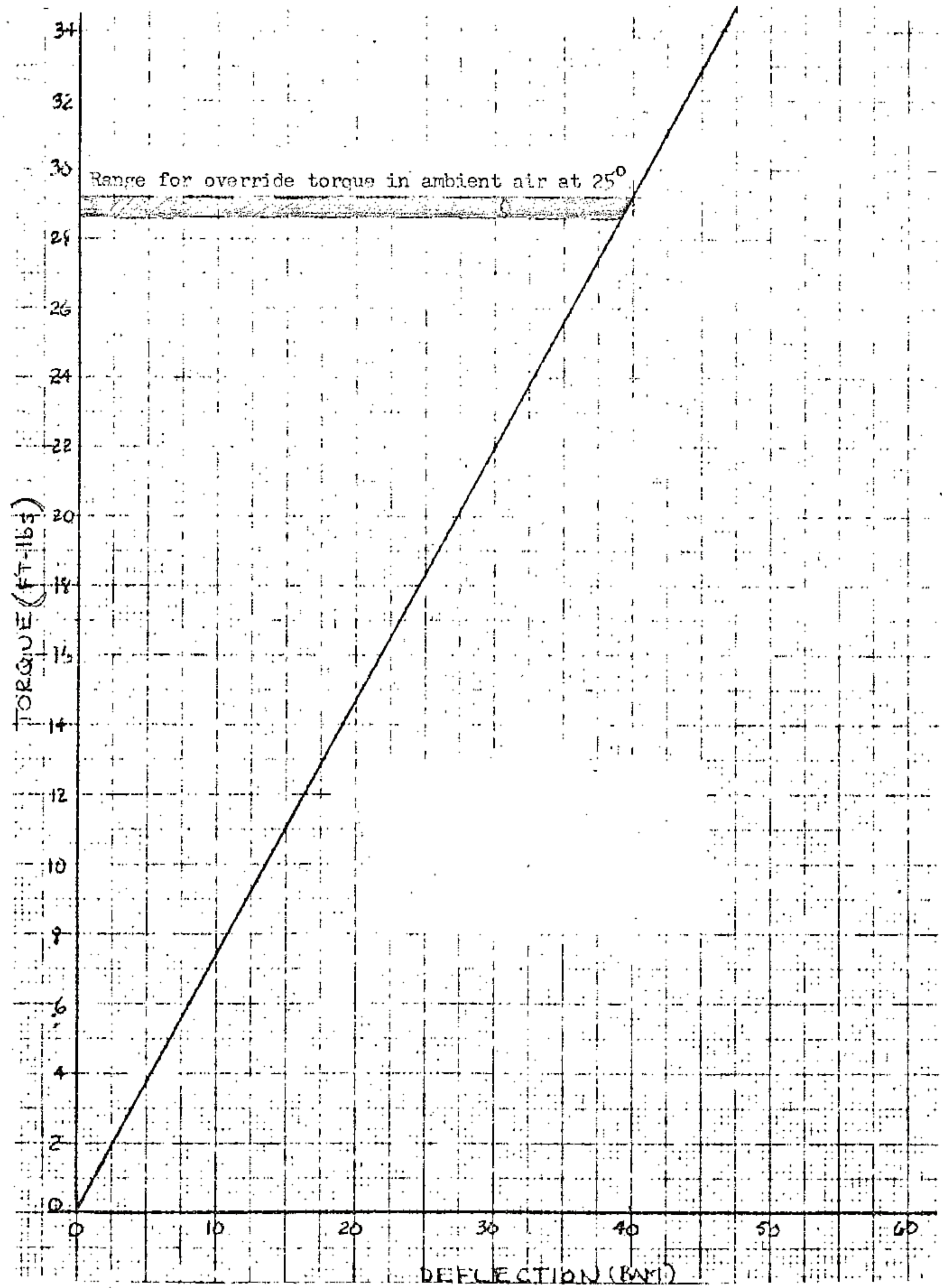


Figure V-7. Calibration Curve - Redesigned Elevation Drive Assembly

TABLE V-2. RESULTS OF REDESIGNED ELEVATION CLUTCH QUALIFICATION TESTS

Time	Temp °C	BAM Deflection to Left (cw)*	BAM Deflection to Right (ccw)*	No. of Revolutions Ea. Direction**	Related Torque in Average ft-lb (cw)	Related Torque in Average ft-lb (ccw)	Percent Change from Original Ambient Value (cw)	Percent Change from Original Ambient Value (ccw)
11/11/71								
0800	25.0	39-40	39-40	≈ 12	28.8	28.8		
1100	-20.0	34-35	38-39	≈ 12	25.3	28.1	12.2	2.4
1400	1.0	37-38	38-39	≈ [illegible]	27.4	28.1	4.9	2.4
1700	22.0	40-41	40-41	≈ 12	29.5	29.6	2.8	1
11/12/71								
0800	40.0	42-43	42-43	≈ 12	31.1	31.1	8.0	8.0
1100	60.0	42-43	41-42	≈ 12	31.1	30.4	8.0	5.6
1400	79.0	40-42	40-42	≈ 12	30.0	30.0	4.2	4.2
1700	98.0	43-44	42-43	≈ 12	31.8	31.1	10.4	8.0

NOTES:

* cw Rotation in a clockwise direction from the gear side (Figure 2)

ccw Rotation in a counterclockwise direction from the gear side (Figure 2)

(Due to small variations in torque over an entire revolution, a range of deflection was recorded.)

** Revolutions occurred at a rate of 2.5 RPM.

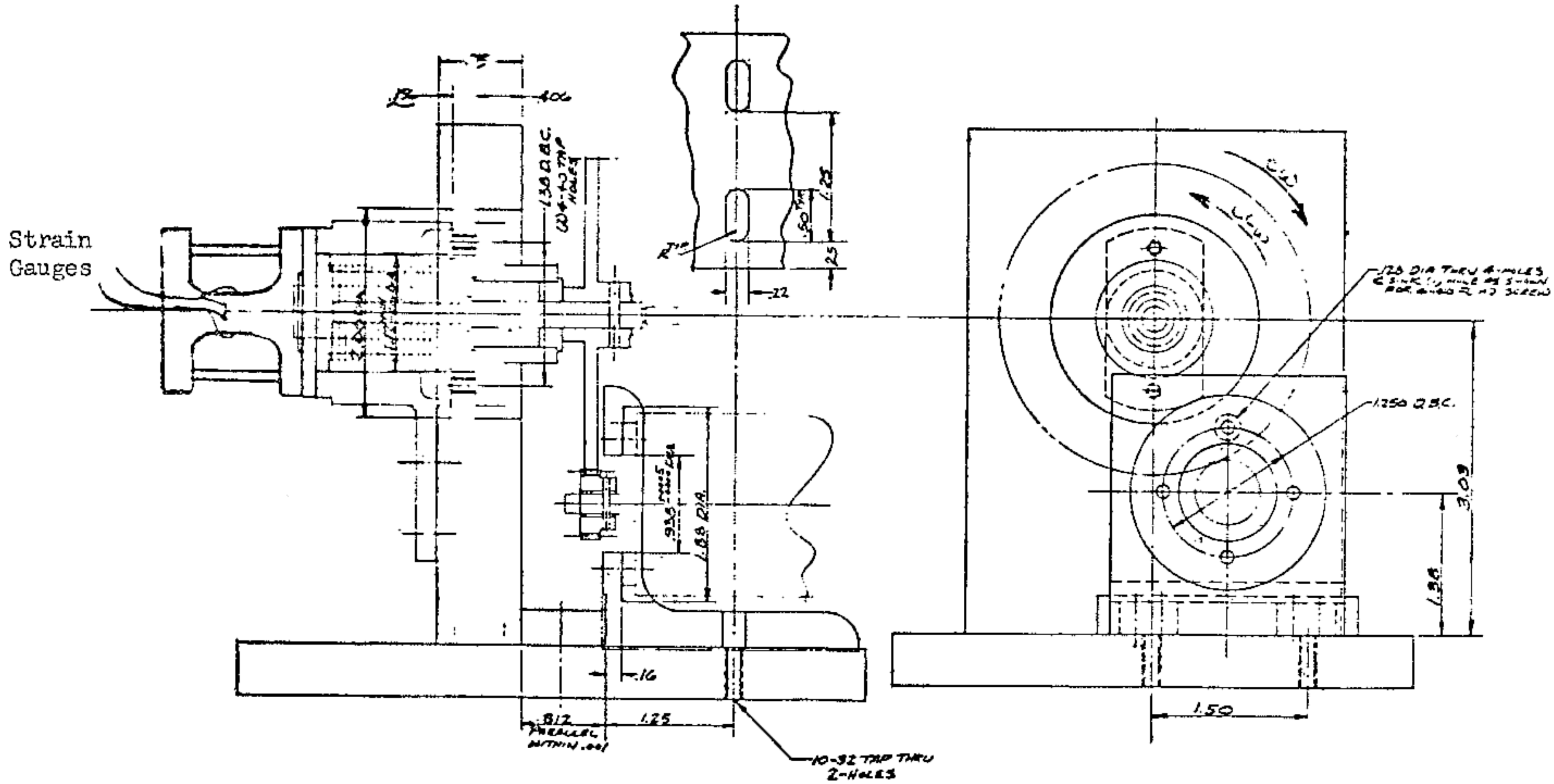


Figure V-8. Torque Test Fixture and Test Setups - Elevation Drive

Life testing of the redesigned clutch consisted of exercising the unit in a vacuum at ambient (27°C) temperature by slipping for a minimum of 1000 revolutions over a period of 120 hours. Override torque was measured in the same manner as the thermal-vacuum test. The results were as follows: Maximum deviation in override torque from the original ambient value was 13.2 percent. Due to a drain in battery power in the Bridge Amplification Meter (discovered after test), the final readings were checked using a torque wrench. Override torque was measured to be within 2.8 percent of original ambient value, thereby attributing the 13.2 percent deviation to meter fluctuation rather than an actual change in override torque. However, during the entire course of testing, the maximum deviation remained well below the allowable 20 percent. Examination of the assembly produced little evidence of scoring or loose particles and exhibited an extremely even lubricant distribution.

In summary, the redesigned Elevation Drive Assembly has proven to be an extremely reliable and uncomplicated device, insensitive to thermal variations over the temperature range tested. This assembly has been incorporated in the GCTA design and will be used during the Apollo 16 mission.

2. Azimuth Clutch Assembly

The azimuth clutch assembly was modified in the same manner as the elevation unit. The disc/adiprene pad configuration was replaced by a single-wrap spring clutch. In the case of the azimuth unit, only a three-turn spring is required.

3. Azimuth Stops

The azimuth stops and dead zone of the GCTA azimuth drive were modified to permit TV viewing of the astronauts while sitting on the LRV. During the Apollo 15 mission, a 20° dead zone directly to the rear of the Rover foreward heading precluded rearward TV coverage directly over the vehicle. The revised stops and 12° dead zone permit rearward viewing and increase azimuth coverage of the camera. See Figure V-9.

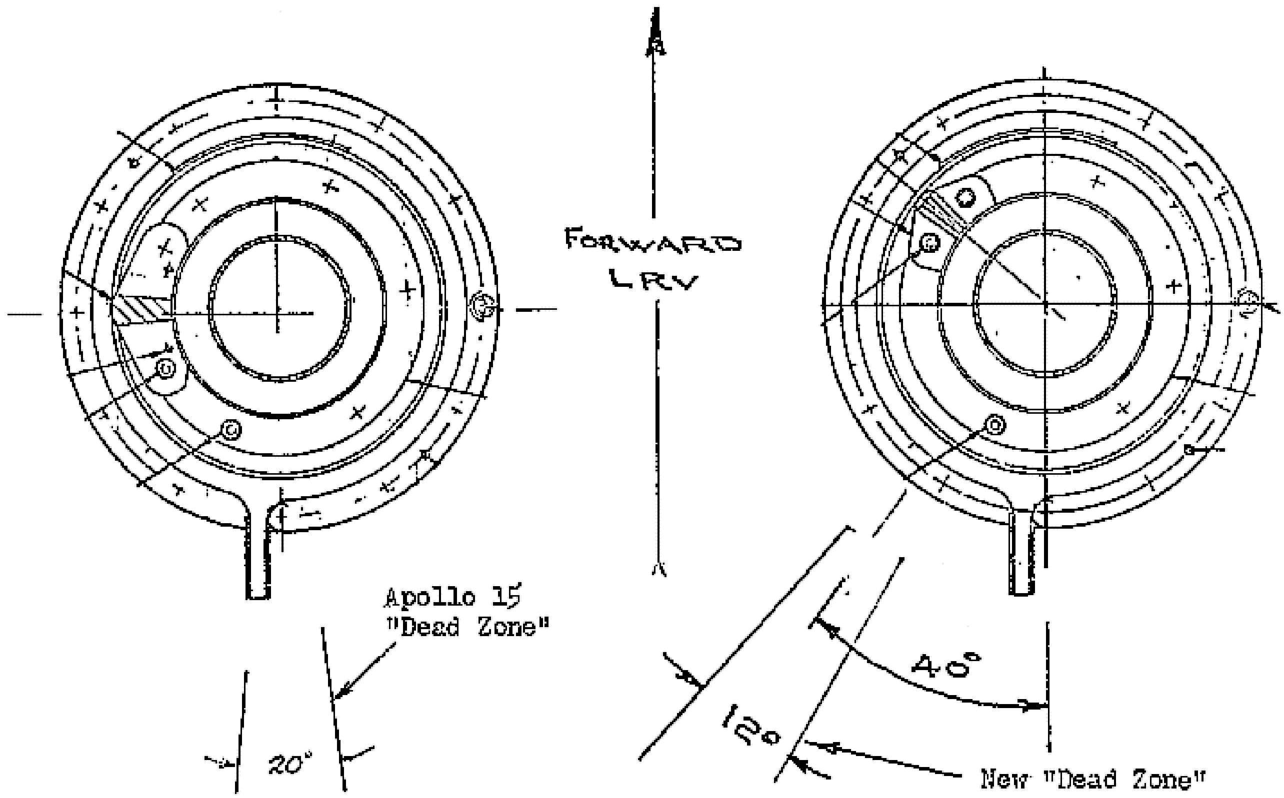


Figure V-9. Revised Azimuth Stop Location

4. Motor Drive Circuitry

The elevation drive motor used on the Apollo 15 mission was a Size 11, 90° stepping angle, Kearfott PM unit. Stepping rate was 200 pulses per minute maximum with a 0.25 in. oz. run torque. Gearhead for the drive motor had a 48:1 ratio. The elevation gearhead spiroid gear set had a 36:1 ratio. The torque developed at ambient temperatures for the overall assembly was as follows:

	Torque (Ambient)	Efficiency
Motor	0.25 in. oz.	-
Gearhead	9.6 in. oz.	0.80
Spiroid Gear	216 in. oz.	0.62

To Elevate the CTV from 85° Position

Lunar Weight	2.2 lbs.
Over-Hung Moment	2.2 x 3.3 = 7.2 in. lbs. = 115 in. ozs.

The torque margin at ambient temperature, therefore, was 101 in. ounces.

At elevated temperatures (to 100°C), motor winding resistance can increase by 30 percent and torque may be reduced by approximately 30 percent. Efficiency of the assembly gear trains also may drop to 40 percent of ambient temperature values. Torque margin at 100°C for the present unit, therefore, is reduced to a nominal value as shown below:

Motor Torque 0.17
Total Gear Ratio x 1728
Gear Train Efficiency 0.40

$0.17 \times 1728 \times 0.40 = 117$ in. ounces

The torque required to elevate the CTV remains at 115 in. ounces, however, with a resulting torque margin at 100°C of <u>2</u> in. ounces.

A motor with increased torque capacity, therefore, has been substituted for the Apollo 15 unit. The unit is similar to the existing motor, and has a run torque of 0.5 inch ounce. Resistance of motor windings was modified to result in a 290 ohm value. With the more powerful unit, torque margins at 100°C are shown in Table V-3. The circuit changes required by the new motor are illustrated in Figure V-10. Motor torque, assuming a 30 percent loss at 100°C due to temperature, is 0.33 in. ounce; total gear ratio is 1728, and assumed gear efficiency is 0.40. Torque developed at the elevation shaft is 228 inch ounces, the torque required to elevate CTV 85° is 115 inch ounces, resulting in a torque margin at 100°C of 113 inch ounces.

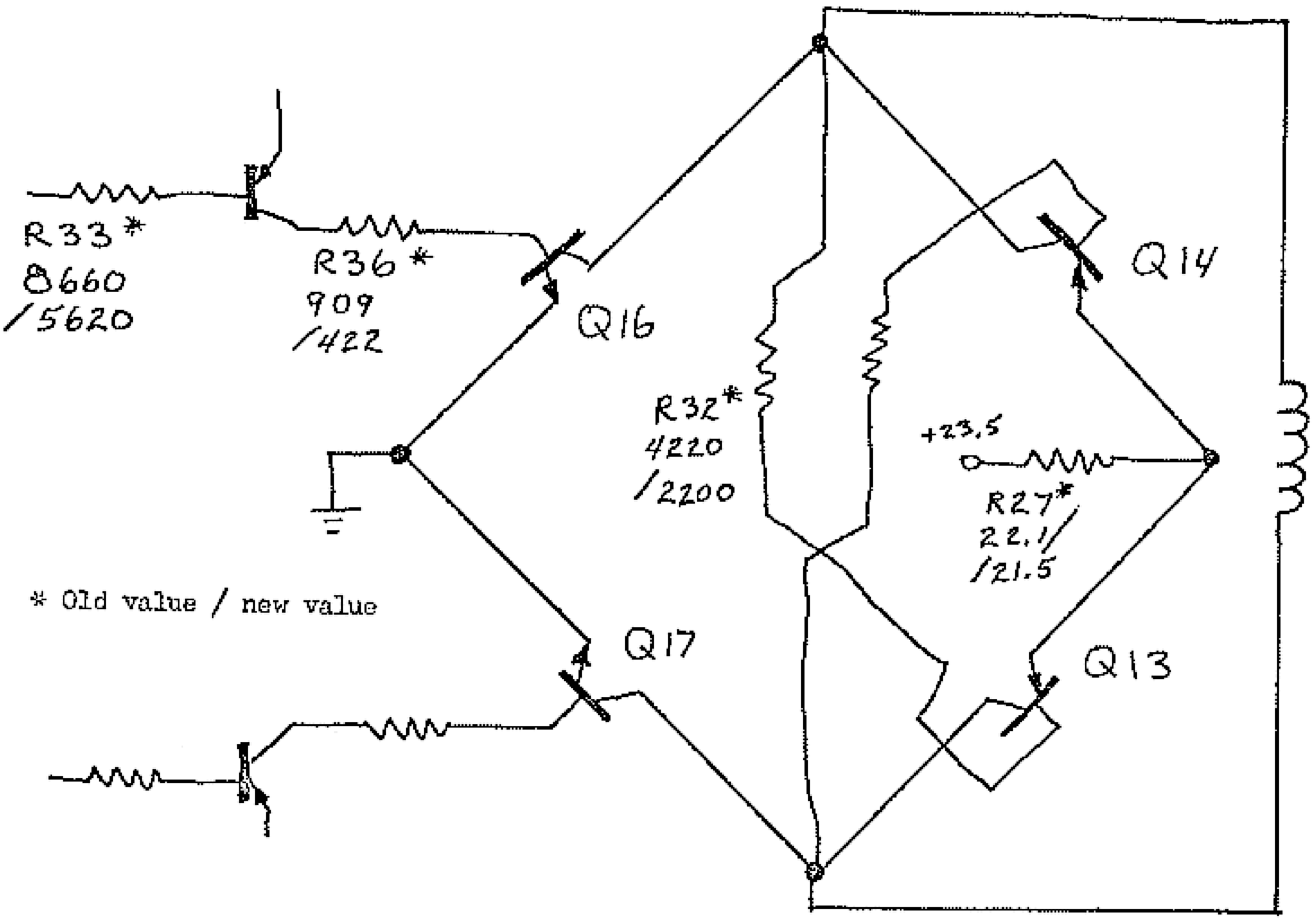


Figure V-10. Elevation Drive Motor Circuit Changes

Table V-3. Elevation Motor Torque Comparisons

	Required for operation	Torque (in. oz.)			
		Dev. at 25°C	Margin at 25°C	Dev. at 100°C	Margin at 100°C
Present Motor	115	216	101	117	+2
New Motor	115	413	298	228	113

5. Other Changes

Two power transistors in the TCU DC/DC converter were relocated to improve GCTA thermal performance margins during operation at high temperature.

A gear-housing bearing (outboard) was added to both elevation and azimuth drive assemblies to strengthen the overall mechanical structure of the unit. The material used for the bearings in the drive assemblies also was changed - from "Rulon B" to "Vespel SP31". A comparison of the properties of these two materials is shown in Table V-4.

Table V-4. Properties of Rulon B and Vespel SP31

Property	Vespel SP31 (new)	Rulon B (old)
Specific gravity	1.6	3.3
Tensile Strength, 75°F; psi	14,200	1060-1230
Elongation, 75°F; %	5	5.0
Flexural Strength, 75°F; psi	22,000	2820
Impact Strength, 75°F; ft-lb/in	-	3.12
Compressive Strength; psi	36,000	2300-3000
Specific Heat; B.T.U./lb./°F	.27	0.19
Coefficient of Linear Expansion per °F	2.5×10^{-5}	

When installed in the TCU/LRV interface fitting, the Flight 4 and 5 staffs (masts) did not locate properly. The locking pin that engages the locking sleeve would not detent properly. A dimension analysis has shown that, with nominal tolerancing, the locking pin would be 0.018 inch from being fully detented. See Figure V-11. The problem appears to be in the slots which should be clear of the position screws when the locking pin is fully detented. A solution, which has been applied to all TCU staffs, requires that the 0.070 inch radius in the screw slot be increased to 0.18 inch radius. This also accommodates the variation that was noted in the Flight 2 TCU/LRV adapter.

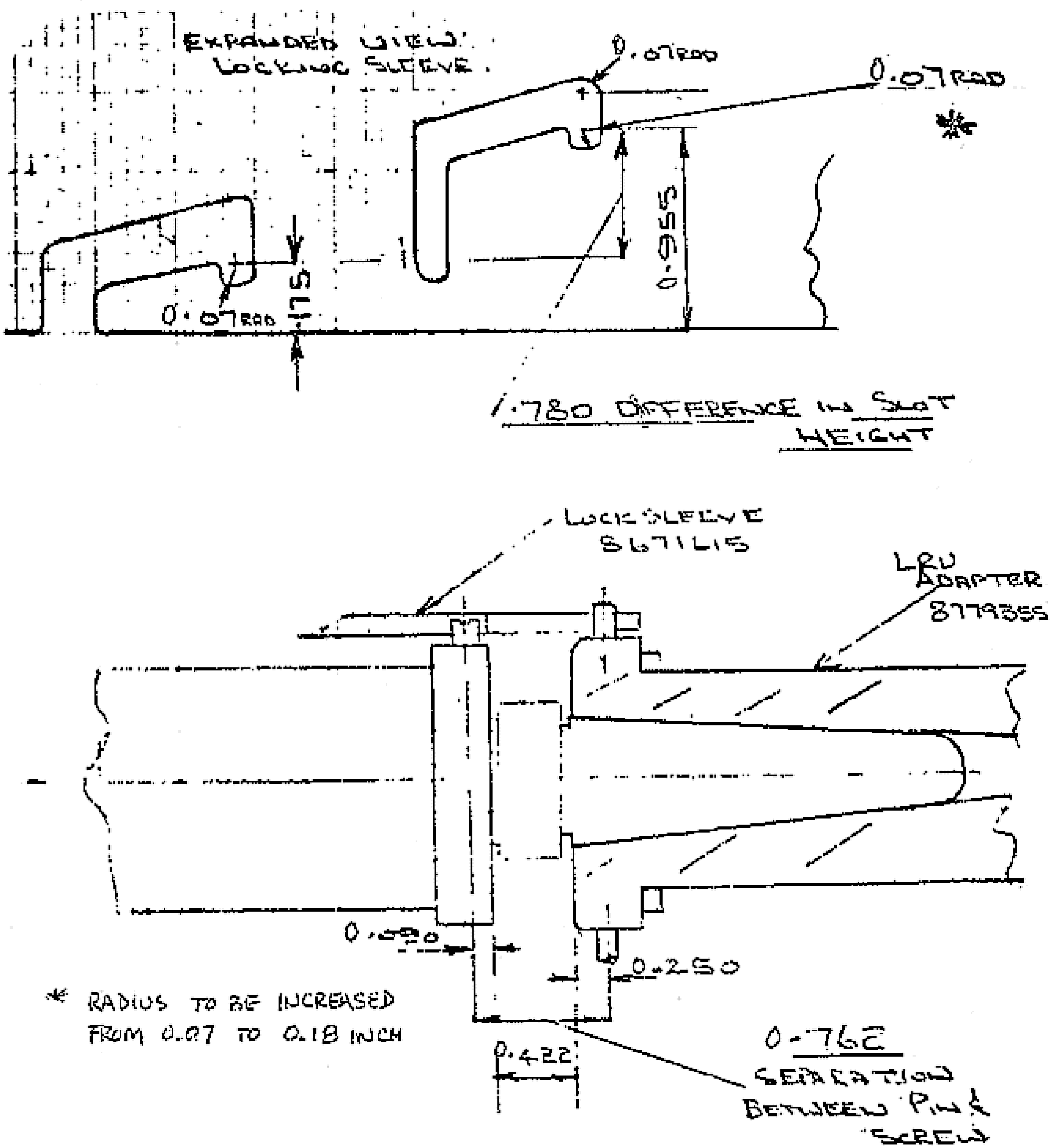


Figure V-11. Change to TCU/LRV Interface Staff

In addition to the above hardware modifications during the refurbishment effort, software changes also were made as required. All hardware changes were reflected in the GCTA Qualification and Acceptance Test Procedure, the O&M Manual, Flight Calibration Tapes for each unit, and in applicable drawings, ICD's, and thermal predictions.

D. Rework Drawing Changes

Updated GCTA drawings have been forwarded to MSC periodically and reflect the refurbishment effort. The following Class I and Class II Contract changes have been submitted:

1. Class I Changes

Drawing No.	Rev.	Remarks
2262457* PL-2262457*	C C	Reidentified Motor Damping Bd., 2A12 to -503 Configuration. (CCBD#110045)
2262832*	A	Revise painting information. (CCBD#110041)
2262833*	B	Revise painting information. (CCBD#110041)
2264702*	D	Revise painting information. (CCBD#110041)
PL-2264702*	C	Revise painting information. (CCBD#110041)
2264703*	E	Revise painting information. (CCBD#110041)
2265817* PL-2265817*	J J	Reidentified Video Circuit to -503 Configuration. (CCBD#110039)
2265825* PL-2265825*	K H	Reidentified TCU Assembly to -502 Configuration. (CCBD#110039, 41, 45, 46, & 47)
2265826* PL-2265826*	D D	Reidentified GCTA Assembly to -502 Configuration. (CCBD#110039, 41, 45, 46, & 47)
TP-OP-2265826	A	Update procedure to include measurement in thermal/vacuum at +60°C, Temperature Telemetry, and Delta QM-2 Test Flow Diagram. (CCBD#110039, Amendment 18C)
2265837*	H	Revise Painting information. (CCBD#110041)
2265839* PL-2265839*	D D	Reidentified Camera Mount Assembly to -503 Configuration. (CCBD#110041)
2265840* PL-2265840*	F E	Reidentified CTV Assembly to -502 Configuration. (CCBD#110039, 41)
2265871	C	Revise to reflect TCU changes. (CCBD#110039)

*Multiple ECN

Drawing No.	Rev.	Remarks
2268181* PL-2268181* 2269237* 2270618*	B A C C	Revise new Clutch Assembly. (CCBD#110046)
2271061* PL-2271061*	D C	Reidentified Motor Drive Bd., 2A10 to -504 Configuration. (CCBD#110045)
TP-OP-2265826	B	Revised procedure to reflect changes in the measurement of the video black level, max. and min. video levels of the CTV when operating on the 100-ft cable, and nominal times of the azimuth, elevation, zoom and iris drives. (CCBD#110039).

2. Class II Changes

Drawing No.	Rev.	Remarks
1840911	G	Update to add new thermistor.
2265606* PL-2265606* 2265823* PL-2265823*	J L] K G	Reidentified Converter Bd. Assembly to -504 Configuration and reflect same on N.H.A., along with Motor Drive Assembly.
2265824* PL-2265824*	E E	Update to reflect latest drawing information from RCA-Camden on Mast Assembly.
2260102	D	Change will increase focus inductance and sensitivity, will accommodate existing design.
2265807	E	Revise existing hole locations and add new ones for the purpose of relocating two (2) limit switches.

*Multiple ECN

Drawing No.	Rev.	Remarks
1978797* PL-1978797*	C B	Add Moly Kote X15 dry lube, will ease pip pin removal.
2260594	B	Revise note 11 for better clarification of DC resistance on motor part number callout.
2265261* PL-2265261*	D D	Reflect new cable assembly, will aid removal of pip pins when removing CTV from Mount.
2265261* PL-2265825* PD-2265826* PD-2265826*	L J F G	Add handle strap and general update of drawing to reflect present as built configuration of TCU. Update to reflect new cable assembly.
2268104* PL-2268104*	A A	Add group 502 configuration for new cable assembly, will aid removal of pip pins when removing CTV from Mount.
2269234	B	Change .625 dia. to $.625^{+.001}_{-.000}$, will improve fit of part.
2270661* PL-2270661*	A A	Correct part number callout for item 14.
2271057	J	Correct designation of Q2 terminals, delineation change only.
2271530* PL-2271530*	B A	Change part number of item 23, will reflect as built configuration of unit.
2271567* PL-2271567*	A A	Drawing update to reflect as built configuration of unit.

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*Multiple ECN

Drawing No.	Rev.	Remarks
TP-1971381*	A	Add temperature test for motor at +60°C.
1974801*	C	Add group 504 configuration for
PL-1974801*	C	new stand-off assembly.
1974801*	D	Delete previous ECN in its en-
PL-1974801*	D	tirety, not to be incorporated.
2262195*	D	Change Part No. of item 7, will
PL-2262195*	D	provide for longer screw length.
2262196*	F	
PL-2262196*	F	
2262889*	B	Update to include weld note in-
2262895*	B	formation, will strengthen welds and prevent breaking.
2263099*	G	General update of dwg. to show pictorially, filters in respective cavities.
2264293*	B	Revision to module will provide
PL-2264293*	D	proper clearances and mounting surface when module is installed in filter wheel drive assembly.
TP-BD-2264293	A	Revise procedure to change temperature test limit from +55°C ±2°C to +60°C ±2°C.
2264779*	A	Revise to reflect resulting
PL-2264779*	A	changes of module, color flag detector.
TP-OP-2265826	C	Add test to monitor and record GCTA input current and voltage during thermal-vacuum, and post thermal-vacuum test.
2265840*	G	Reflect group 504 configuration
PL-2265840*	F	for new stand-off assembly.
PD-2265840*	D	

*Multiple ECN

Drawing No.	Rev.	Remarks
2265840* PL-2265840* PD-2265840*	H G E	Delete previous ECN in its entirety, not to be incorporated. Add new spacer insulator blocks and change existing insulator to new dash number. Update, resulting from changes on color flag detector assembly.
TP-2265840	A	Update to reflect changes on method of video black level set-up, test for black clip level, calibration of color-flag temp. telemetry, and black level variation over temperature.

*Multiple ECN

Incorporation of ECNs to GCTA flight drawings also resulted in the following drawing submissions during the refurbishment period.

Drawing No.	Rev.	Drawing No.	Rev.	Drawing No.	Rev.
1974482	A	2269234	A	2270626	A
2260594	A	2269235	A	PL-2270626	-
2262472	C	2269237	B	2270655	-
2262485	A	2269238	A	PL-2270655	-
TP-OP-2265826	A	PL-2269238	-	2270661	-
2268149	A	2269242	A	PL-2270661	-
2268180	A	PL-2269242	-	2270662	-
PL-2268180	-	2269291	-	2271530	A
2268181	A	2270607	A	PL-2271530	-
PL-2268181	-	2270615	A	2271567	-
2268184	-	PL-2270615	-	PL-2271567	-
2268185	-	2270618	B	8151931	B
2269199	A	2270624	A	8151937	-
2269230	A	PL-2270624	-	8671615	A
1840911	G	2265606	J	PL-2265839	D
1973839	D	PL-2265606	L	PD-2265840	C
1974441	D	2265817	J	2265840	F
1974724	G	PL-2265817	J	PL-2265840	E
1974784	E	2265823	K	2265871	C
PL-1974784	B	PL-2265823	G	2268181	B
2260966	-	2265824	E	PL-2268181	A
2262198	E	PL-2265824	E	2268190	-
2262199	E	2265825	K	2268193	-
2262457	C	PL-2265825	H	2269237	C
PL-2262457	C	PD-2265826	E	PL-2269291	-
2262832	A	2265826	D	2270618	C
2262833	B	PL-2265826	D	2271061	D
2264702	D	2265836	C	PL-2271061	C
PL-2264702	C	2265837	H	2271569	-
2264703	E	2265839	D	2271578	-
1974482	A	2269238	A	2270655	-
2260594	A	PL-2269238	-	PL-2270655	-
2262472	C	2269242	A	2270661	-
2262485	A	PL-2269242	-	PL-2270661	-
2268149	A	2269291	-	2270662	-
2268180	A	2270607	A	2271530	A
PL-2268180	-	2270615	A	PL-2271530	-
2268184	-	PL-2270615	-	2271567	-
2268185	-	2270624	A	PL-2271567	-
2269199	A	PL-2270624	-	8151931	B
2269230	A	2270626	A	8151937	-
2269234	A	PL-2270626	-	8671615	A
2269235	A			2271579	-

Drawing No.	Rev.
TP-1971381	A
1974064	A
PL-1978797	B
2260594	B
2260925	-
PL-2265261	D
2265807	E
PL-2265825	J
TP-OP-2265826	B
TP-2265840	A
PL-2268104	A

Drawing No.	Rev.
2268244	A
2269234	B
2269344	-
2270661	A
PL-2260661	A
2271530	B
PL-2271530	A
2271567	A
PL-2271567	A
8671615	B

E. Color Wheel Motor Bearing Failure

During final preparation and testing of GCTA Flight Model No. 2 (S/N 005), the Filter Wheel Motor (S/N 028) failed to start when the CTV was turned ON. The motor was removed from F-2 and all other CTVs at AED and returned to the vendor, Ball Brothers Research Corporation (BBRC). The units were dismantled and subjected to intensive investigation to determine the cause of the F-2 failure. Inspections and photographic records were made in the BBRC mechanical assembly clean room, and all parts were viewed under a x10 to x30 stereo-microscope equipped with a polaroid camera.

a. Discussion

A considerable amount of debris was found in the gearhead cavity. It was in the form of an opaque white flockular material similar to a metallic soap. The No.4 bearing (see Figure V-12) in the gearhead was filled with similar material. A torque reading on this bearing showed that the motor/gearhead would be in a stalled condition.

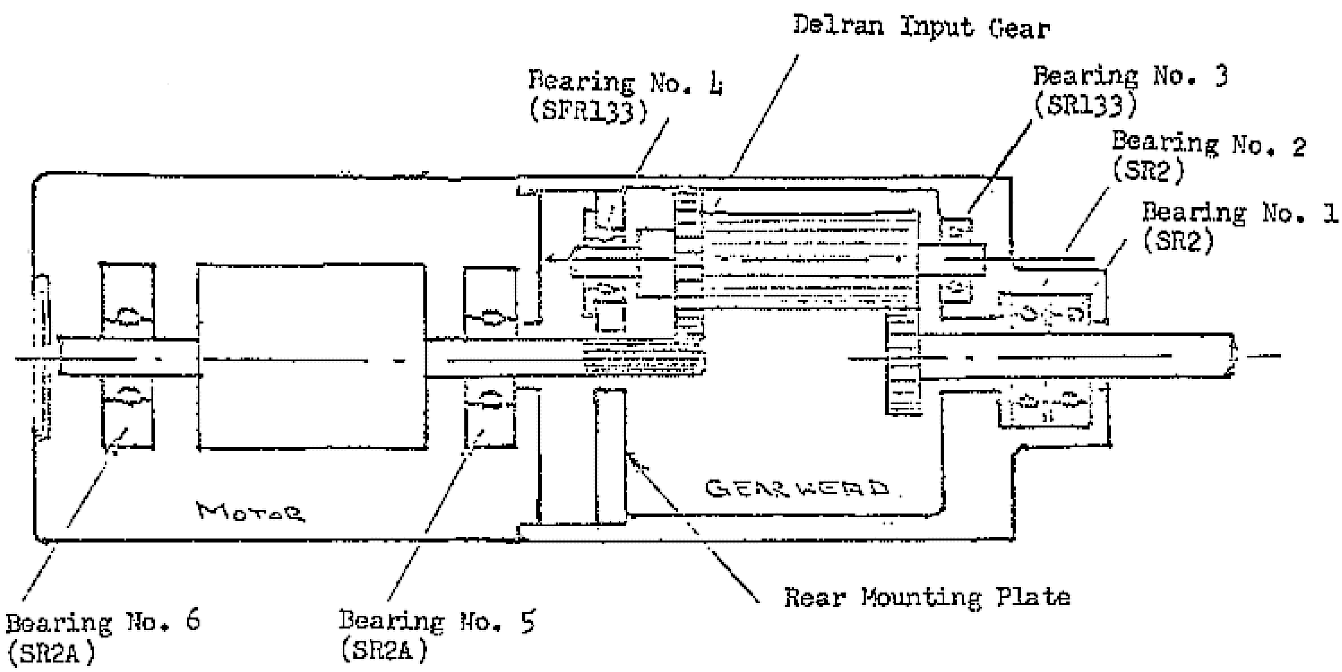


Figure V-12. Color Wheel Motor/Gearhead Bearing Conf.

The loose material in the gearhead and in the No. 4 bearing were subjected to a spectral analysis (see Figure V-13) and were found to be similar in composition. It was speculated that the lube in the bearing had changed state or been contaminated by a foreign material (not identifiable at the time). Further testing and a material search still were required to pinpoint the cause of the failure.

The following observations also were made during the BBRC investigations. No signs of contamination or degradation were found in the rotor or stator. The two SR2A bearings were clean. In the opinion of the BBRC personnel they were in an "as lubed" condition. In the gearhead, however, a considerable number of particles were found on the walls of the gear housing. Initially, these particles were believed to be the breakdown of the Delrin input gear. The gear showed no signs of degradation, and subsequent IR scans showed that no Delrin was present in the debris. A sample of the debris was subjected to spectral analysis and found to be similar to the BBRC "Vackote" lubricant.

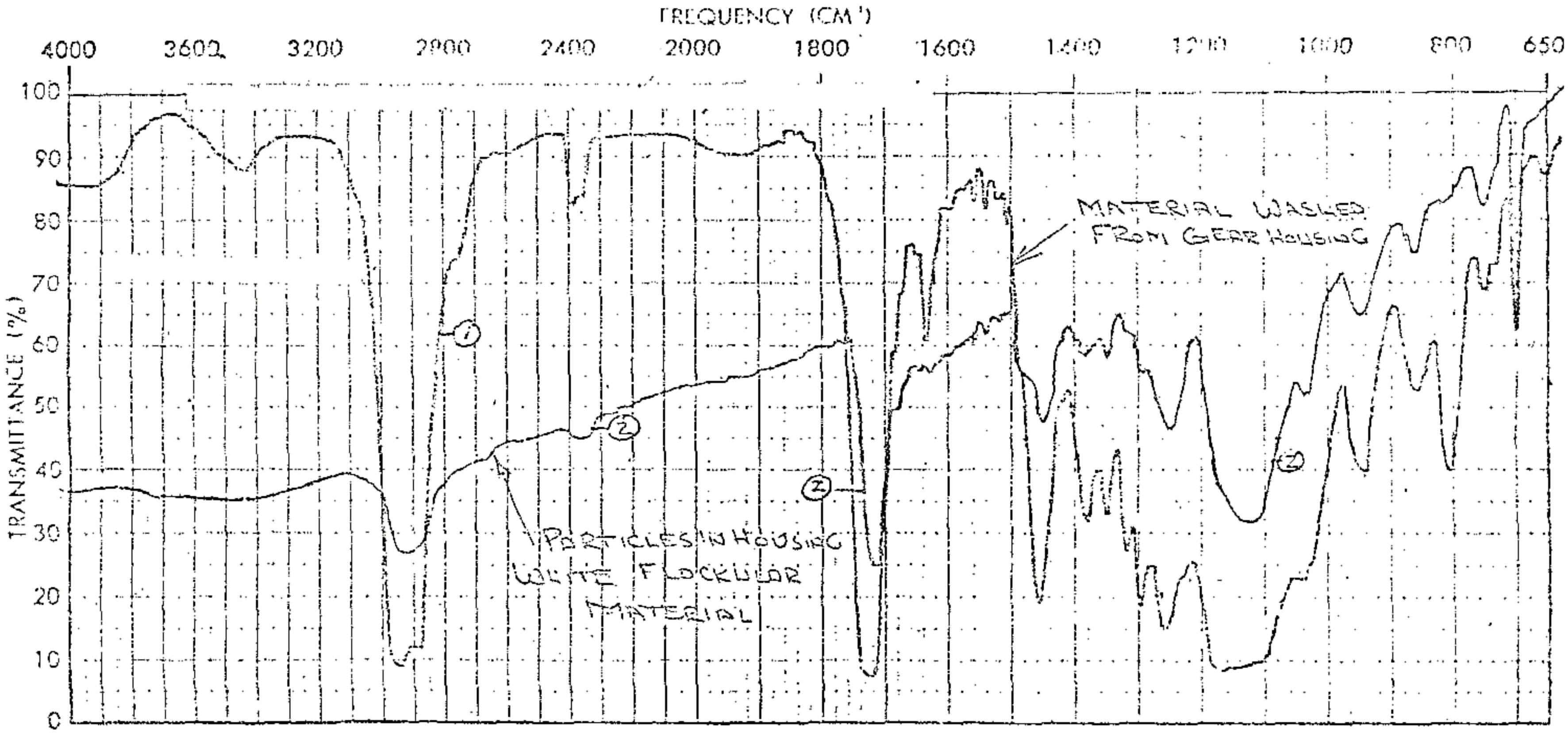
The No. 4 bearing also was full of the white, flockular material that spectral analysis had shown to be similar to the"Vackote" lube. A torque measurement on the bearing showed the breakaway torque to be in the range of 0.22 to 0.45 oz. in. A similar bearing obtained from G&R Monaco stock was found to require 36-milligram-millimeters of torque to turn it.

Since the motor delivers 0.22 oz. in starting torque at the No. 4 bearing shaft, the drive train was considered to be in a stalled condition.

The outer race of the bearing (No. 4) would rotate in the rear mounting plate before the bearing assembly rotated. This could explain the drive train rotation at AED after the initial failure. Some lube may have been present between the bearing and flange. No visible scoring was evident on the outer race or in the bore of the flange. The bearing outer diameter and flange bore were measured and two readings (taken 180° apart) were:

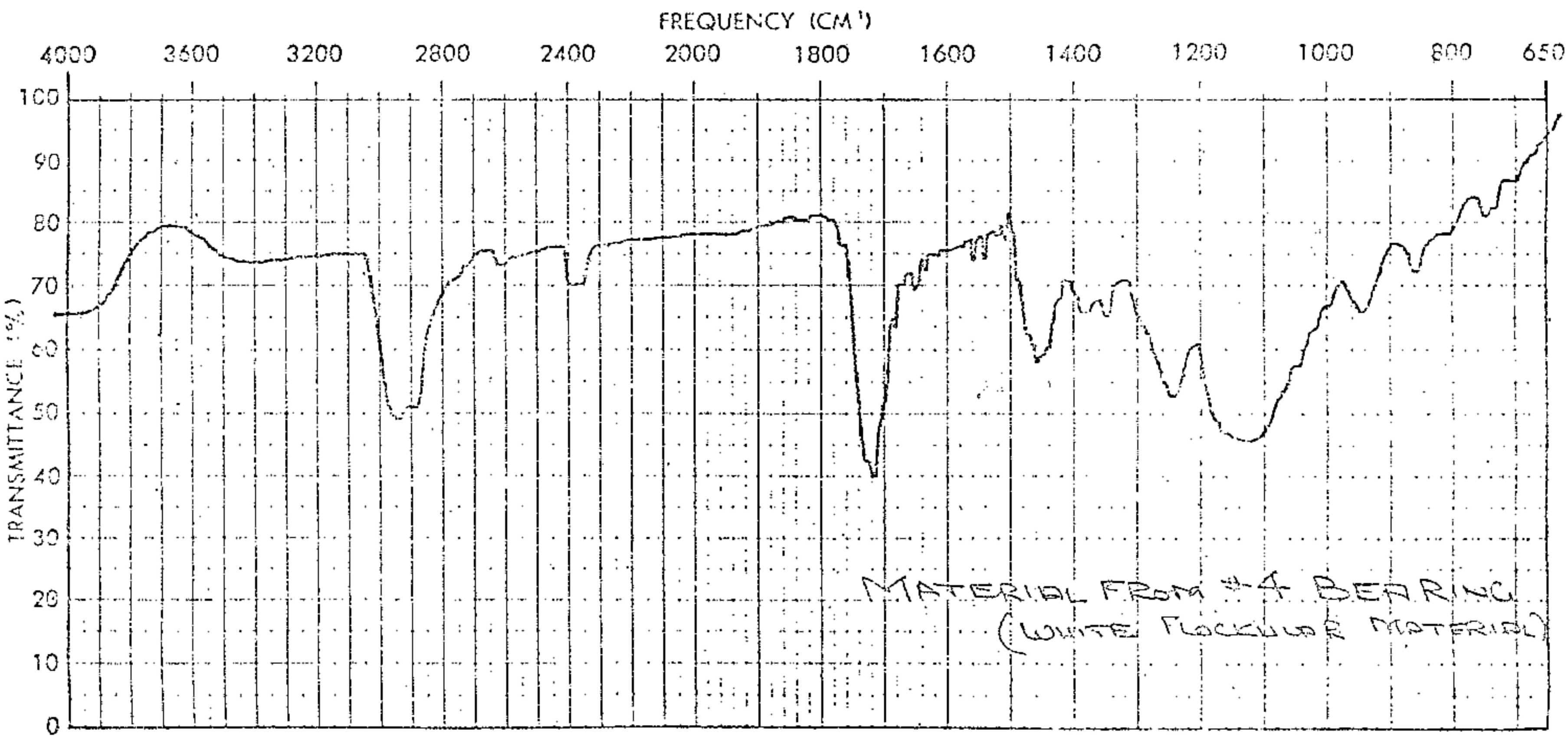
Hole in Flange	0.18747	inches diameter
	0.1875	" "
Outer Diameter	0.1875	" "
of bearing	0.18744	" "

One shield was removed from the remaining bearings in the gearhead (designated in Figure V-12 as bearings Nos. 1, 2 and 3).



a. Loose Material from Motor Gearhead

FIGURE V-13. Spectral Analysis of Filter Wheel Motor Debris



b. Material from No. 4 Bearing (Gearhead Rear Mounting Plate)

FIGURE V-13 Spectral Analysis of Filter Wheel Motor Debris (Cont'd.)

Bearing No. 1

This bearing was completely clean with no evidence of particles. The phenolic retainer appeared somewhat drier than the motor bearings. However, lube was evident on the retainer and raceways.

Bearing No. 2

A few particles of the white flockular material were seen in the bearing and on the bearing shield. These were similar to the particles in the gear housing; it was concluded that they originated from the debris scattered in the housing. The condition of the bearing and retainer was otherwise "as lubed".

Bearing No. 3

This bearing is similar in construction to the failed No. 4 bearing. The metal ribbon retainer and balls showed evidence of lubricant with no particles. The IR sample was taken from the housing with this bearing in place, and the solvent could have dissolved any particles that were present. In the opinion of the review team, however, the bearing had not been contaminated with debris.

Bearings Nos. 1, 2, 3, 5 and 6 were photographed and retained for further evaluation.

Bearing No. 4 was disassembled completely to determine if retainer or ball damage had occurred. An examination under a x30 microscope did not revel anything other than normal wear marks on the raceways.

A meeting was held with the BBRC spectral analyst and their chemist. The IR scans and possible contaminants that could change the state of their lubricant were discussed. The BBRC personnel feel the white material is "Vackote" lubricant modified or contaminated by a foreign ester (or possibly an alkene). Polymerization due to excessive pressure or heat was discounted; - the "Vackote" lube changes into a hard varnish-like material when polymerized. The IR scans did not show signs of silicones in the housing or in the bearing.

Investigations at BBRC and AED continued to find a material in the motor/gearhead assembly which can react with the BBRC "Vackote" lubricant to form the white flockular material. Action items were assigned to BBRC to check the compatability of their lubricant with rosin and with another "Vackote" type. No reaction was found with either of these materials. Both BBRC personnel and RCA Engineering feel that the contamination occurred prior to the assembly of the motor to the gearhead. Possible areas for contamination are at BBRC either in the lubricant mix, during the lubrication process, or in G. Monaco's assembly area. The various materials used within the motor/gearhead assembly were investigated, and the following three were considered to be possible problem areas.

"Loctite" (Grade C) is used to stake four screws that attach the motor to the gearhead. These screws are in close proximity to the No. 4 bearing. Eastment 910 is used to stake the Delrin gear to the intermediate shaft. A cement (GE-2903) also was found on the heads of the two screws which secure the gearhead back plate. This material should not have been present, as all assemblies had been solvent-cleaned prior to initial lubrication. Monaco does not use this material in any assembly process. A sample for IR analysis, however, was available.

In talking to the manufacturers of the above materials, the following information was supplied:

"Loctite" (Grade C) is used to stake the four screws attaching the gearhead to the motor. The material is anerobic and sets up in the absence of air. No outgassing products of "Loctite" (Grade C) polymers in the cured state exist, according to John O'Conner, chemist. However, accelerators (hydrogen peroxide and trialkylamine) are added, which can be removed under high vacuum. All "Loctite" materials have a fluorescent material added for traceability. The IR spectral scans made from the contaminent in the Serial No. 028 motor (See Figure V-13a and Figure V-14 "Loctite-C") show common absorption bands. The debris found in and around the No. 4 bearing, in motor Serial No. 038, was strongly fluorescent.

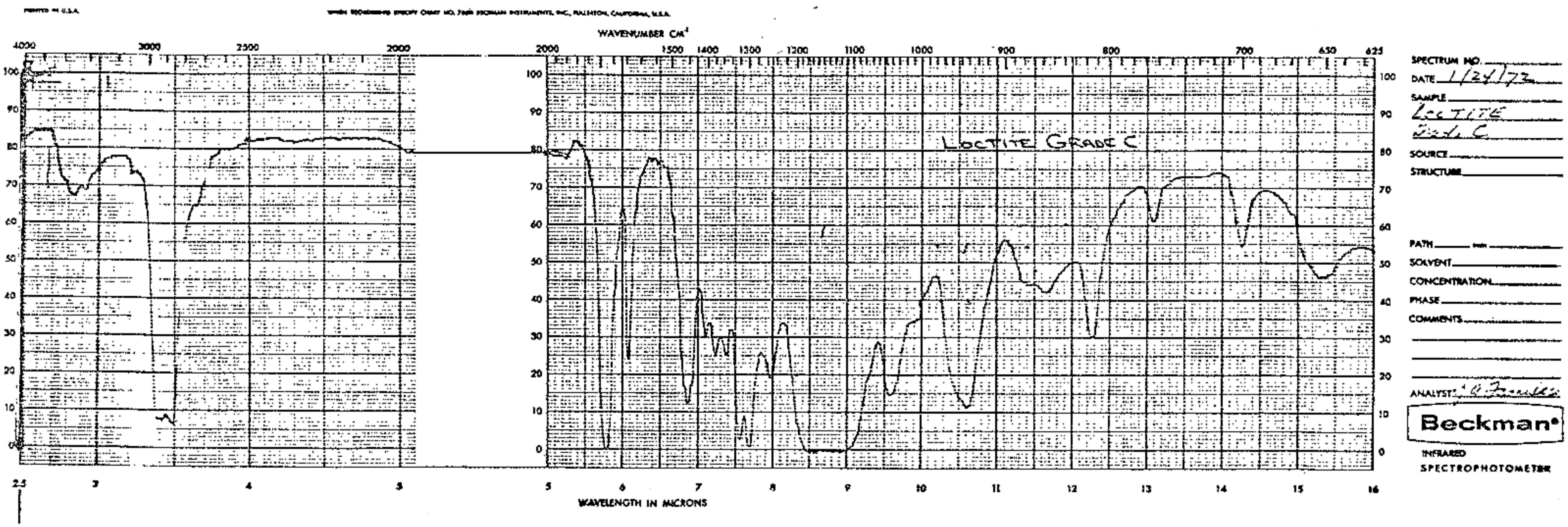


FIGURE V-14. Spectral Analysis of "Locktite (Grade C)" Staking Material

In tests made at BBRC, a reaction was created between "Loctite" and "Vackote" within a bead of the mixed materials. The resulting material was similar to the white flockular material. The two materials also react in smaller concentrations or in thin films if subjected to a vacuum environment. The reaction material showed absorption bands common to those obtained from IR scans of the debris in the bearing and gear housing of motor Serial No. 028.

Eastman 910 (methyl-2-cyanoacrylate) is highly reactant in the uncured state. Two days are required for optimum polymerization of the bond. The polymer also degrades rapidly above 150°F. The material contains a plasticizer to improve the resiliency of the bond. This plasticizer (diamethyl sebacate) gives off a diabasic acid when exposed to high vacuum and temperature; it leaves the cement freely above 60°C. Eastman 910-FS and -MHT do not contain the plasticizer. In our discussions with BBRC chemists, diabasic acid was mentioned as a possible contaminant, and in a test at BBRC, the uncured cement did react with the lubricant to form a white solid material.

The behavior of the material in thermal/vacuum fits the history of the Flight 2 camera motor rather well. The bearing failed following a T/V test where the camera was seeing 60°C for the first time due to a revision to the acceptance test procedure. The cemented joint is in close proximity to the No. 4 bearing. Spectral analysis of the Eastman 910, however, did not reveal any common absorption bands when compared with the IR scans taken of the contaminated lubricant. Mixing the cement with the lubricant did not produce a variation in the IR scan.

GE-2093 is a violet-colored cement commonly used as a staking material. A drying oil-alkyde, air-oxydizing material, it will outgass if not fully cured for 24 hours in air. The material also may become liquid above 100°C. Outgassing produts are glyceral phthalates. A chemist at General Electric in Schenectady, N.Y., indicated that the cement may be softened in the presence of an ester. In several of the disassembled units (two gearheads) the cement appeared to have "run". No reaction was noted when the cement was mixed with "Vackote",however. The IR scan also did not show common absorption bands with those recorded from the contaminated lubricant.

b. Conclusion

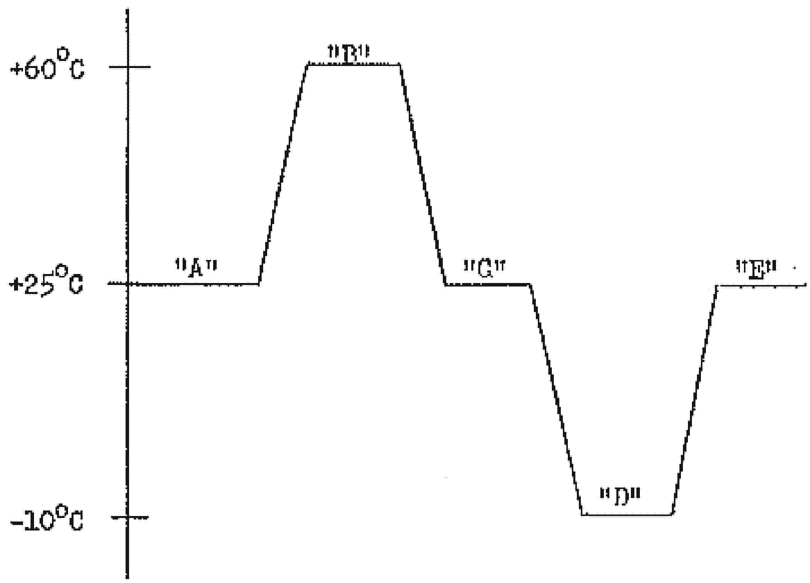
Of the three subject materials above, only "Loctite" was proven to be in the contaminated lubricant in discernible quantities. Spectral analysis showed unmistakably that "Loctite" was present in the failed motor gear-housing. The test under blacklite showed the debris in the No. 4 bearing to be fluorescent - a definite sign of "Loctite." The mechanism for transfer of the contaminant into the bearing is migration. If outgassing products were present, other bearings in the gearhead assembly would have been affected to some extent.

"Loctite" was applied to the attachment screws as the motor and gearhead were mated. The material may have been transferred onto the gearhead backplate as the screws were inserted. The wet "Loctite" remained until subjected to vacuum or until it migrated into contact with the lubricant in the bearing. The reaction then started. The timing required until the material is formed or if it is progressive once the reaction starts has not been determined. Also, no evidence was found in the spectral analysis to indicate an inter-reaction between the three suspect materials.

To expedite the refit of the Flight Model No. 2 camera, all flight and spare motor/gearheads were reworked according to the following refurbishment program:

- o All suspect materials were eliminated from the motor-gearhead assembly.
- o All Flight model and spare motors were returned to BBRC for rework.
- o Following disassembly, the parts were subjected to a solvent extraction process to remove all foreign material, including the existing lubricant.
- o The joint between the Delrin gear and the intermediate shaft was overcoated with Epon 828 Epoxy to seal-in any outgassing products from the Eastman 910 cement used in the initial assembly.
- o Parts were vacuum-baked to remove all volatile materials.
- o Bearings and gears were relubricated using the specified "Vackote" process.
- o Acceptance tests were run over the temperature range from $-10^{\circ}C$ to $+60^{\circ}C$. Revised test levels and test data is shown in Figures V-15 and V-16.

All rework and testing at BBRC was witnessed by NASA and RCA/AED Quality Assurance Representatives. A copy of the Failure Investigation Action Report is shown in Figure V-17.



A - Stabilize at +25°C, start motor, and perform electrical test per TP-1971381, paragraph 5.2, Steps 1 through 6.

B - Stabilize at +60°C ± 3°C, and conduct test per TP-1971381, paragraph 5.3, Steps 1 through 3.

C - Same as "A"

D - Stabilize at -10°C, and conduct test per TP-1971381, paragraph 5.4, Steps 1 through 3.

E - Same as "A"

FIGURE V-15. Revised Test Levels for Filter Wheel Motor Acceptance

Motor S/N	Plateau A +25°C			Plateau B +60°C (Test Init)			Plateau B +60°C (Test Final)			Plateau C +25°C			Plateau D −10°C (Test Init)			Plateau D −10°C (Test Final)			Plateau E +25°C		
	Start Current @ 0.22 in oz	Run Current @ 0.2 in oz	Pull Out Torque in oz	Start Torque in oz	Run Current @ 0.2 in oz	Pull Out Torque in oz	Start Torque in oz	Run Current @ 0.2 in oz	Pull Out Torque in oz	Start Current @ 0.22 in oz	Run Current @ 0.2 in oz	Pull Out Torque in oz	Start Torque in oz	Run Current @ 0.2 in oz	Pull Out Torque in oz	Start Torque in oz	Run Current @ 0.2 in oz	Pull Out Torque in oz	Start Current @ 0.22 in oz	Run Current @ 0.2 in oz	Pull Out Torque in oz
71-3-25	275 ma	83.5 ma	0.7 in oz @ 120 ma	0.45 in oz @ [illegible]	85.0 ma	0.75 in oz @ 123 ma	0.44 in oz @ 285 ma	84.5 ma	0.70 in oz @ 123 ma	274 ma	87.0 ma	0.66 in oz @ 120 ma	0.32 in oz @ 280 ma	88.0 ma	0.59 in oz @ 118 ma	0.51 in oz @ 280 ma	90.0 ma	0.52 in oz @ 118 ma	273 ma	81.0 ma	0.66 in oz @ 120 ma
71-3-24	265 ma	80.5 ma	0.6 in oz @ 115 ma	0.32 in oz @ 275 ma	87.0 ma	0.60 in oz @ 120 ma	0.35 in oz @ 275 ma	85 ma	0.70 in oz @ 120 ma	270 ma	85.0 ma	0.65 in oz @ 120 ma	0.30 in oz @ 265 ma	82.0 ma	0.55 in oz	0.30 in oz @ 265 ma	82.0 ma	0.56 in oz	270 ma	85.0 ma	0.65 in oz @ 118 ma
71-3-27	275 ma	85.0 ma	0.63 in oz @ 122 ma	0.37 in oz @ 265 ma	84.0 ma	0.66 in oz @ 120 ma	0.33 in oz @ 284 ma	84.0 ma	0.70 in oz @ 120 ma	276 ma	86.0 ma	0.66 in oz @ 121 ma	0.26 in oz @ 273 ma	89.0 ma	0.46 in oz @ 115 ma	0.30 in oz @ 276 ma	87.5 ma	0.47 in oz @ 118 ma	278 ma	83.0 ma	0.61 in oz @ 119 ma
70-12-39	250 ma	80.0 ma	0.7 in oz @ 120 ma	0.35 in oz @ 261 ma	77.5 ma	0.70 in oz @ 118 ma	0.30 in oz @ 255 ma	78.0 ma	0.66 in oz @ 118 ma	250 ma	80.0 ma	0.65 in oz @ 120 ma	0.30 in oz @ 252 ma	86.0 ma	0.54 in oz @ 116 ma	0.27 in oz @ 245 ma	82.0 ma	0.56 in oz @ 118 ma	245 ma	76.0 ma	0.65 in oz @ 118 ma
70-12-37	302 ma	94.0 ma	0.67 in oz @ 125 ma	0.33 in oz @ 303 ma	93.0 ma	0.65 in oz @ 125 ma	0.32 in oz @ 303 ma	99.0 ma	0.57 in oz @ 125 ma	305 ma	96.5 ma	0.55 in oz @ 126 ma	0.30 in oz @ 305 ma	100.0 ma	0.50 in oz @ 127 ma	0.30 in oz @ 305 ma	99.0 ma	0.47 in oz @ 126 ma	308 ma	96.5 ma	0.61 in oz @ 125 ma
70-12-36	280 ma	87.0 ma	0.53 in oz @ 121 ma	0.35 in oz @ 285 ma	86.5 ma	0.53 in oz @ 125 ma	0.28 in oz @ 285 ma	85.0 ma	0.50 in oz @ 125 ma	280 ma	88.0 ma	0.52 in oz @ 113 ma	0.28 in oz @ 285 ma	* 0.16 in oz @ 107 ma	* —	* —	* —	* —	280 ma	88.0 ma	0.65 in oz @ 122 ma

Notes

1. Tests Performed @ Ball Brothers Research Co Boulder, Colorado 1/26/72 – 1/29/72
2. * Motor SN 70-12-36 Resistor Motor, Will Not Run @ 0.22 in oz @ −10°C

[illegible]

FIGURE V-16. Summary of Motor Acceptance Testing (TP-1971381)

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NASA - MANNED SPACECRAFT CENTER
FAILURE INVESTIGATION ACTION REPORT

NO. P-RC-035

1. PROJECT: Color Camera
2. WHERE DETECTED: FACILITY: ATI; Organization: RCA; LOCATION: Princeton
3. ORIG. REPORT NO.: S-0324
4. PROB. CLASSIF.: [X] FAILURE [ ] UNSAT. COND.
5. DATE REPORTED: 1/7/72
6. CONTRACTOR: RCA
7. END ITEM NAME: Color TV Camera
8. ITEM UNDER TEST: Color TV Camera
9. NEXT ASSY. NAME:
10. REPORTED ITEM:
11. TPS NUMBER:
7a. EI MODEL NO.: F-2
8a. CONTR. PART NO.: 2265826
9a. CONTR. PART NO.:
10a. CONTR. PART NO.:
12. ROUTING VIA: -
7b. EI SERIAL NO.: 005
8b. SUPPLIER PART NO.:
9b. SUPPLIER PART NO.:
10b. SUPPLIER PART NO.:
13. SPEC/PROCESS NO.: TP-OF-2265826 DATE: PARA.:
8c. SERIAL NO.: 005
9c. SERIAL NO.:
10c. SERIAL NO.:
14. COND. | 15. CAUSE | 16. SYMPT | 17. Fail TYP | 18. Detected During | 19. | 20. SYSTEM NAME | 10d. Time/Cycles (ACUM)

21. DESCRIPTION OF FAILURE/CONDITION

Color filter wheel failed to rotate upon application of power. Cycling of ON/OFF switch failed to produce motor rotation. However, the filter wheel segment appeared in various positions and video signals from the camera were observed. Camera input current was 540 ma.

22. CRITICALITY

23. INITIATOR/CONTACT	ORG.	DATE	24. RIE	ORG.	DATE
F. Hubit	Eng. Spec.	1/6/72	H. Kennedy	R&QAE	1/6/72

25. HARDWARE ANALYSIS REQUESTED/INSTRUCTIONS

ASSIGNED TO	ORG.	DATE	27. REQUESTER	ORG.	DATE

28. CAUSE OF FAILURE/ANALYSIS RESULTS

See attached failure analysis from D. Binge, 2/4/72.

29. SYSTEM ENGINEER	ORG.	DATE	30. RIE	ORG.	DATE
D. Binge	Eng.	2/4/72	H. Kennedy	R&QAE	2/4/72

31. CORRECTIVE ACTION REQUESTED

32. ACTION ASSIGNED TO	ORG.	DATE	33. REQUESTER	ORG.	DATE

34. CORRECTIVE ACTION TAKEN

Delete the use of Loctite, Glyptal and Eastman 910 material.

The motor vendor is directed not to use the above material unless directed by RCA/AED.

35. ACTION BY	ORG.	DATE	36. RIE	ORG.	DATE	37. CLOSE-OUT	DATE
D. Binge	Eng.	2/4/72				H. Kennedy	2/4/72

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Figure V-17. Bearing Failure Investigation Action Report (P-RC-035)