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LIMB RADIANCE INVERSION RADIOMETER

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16. Abstract

This Final Report documents the design, and operation of the LIMB Radiance Inversion Radiometer (LRIR) Protoflight Model

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FOREWORD

This report documents the scientific and engineering design requirements and accomplishments of the Limb Radiance Inversion Radiometer (LRIR) Protoflight Model.

This report is prepared per the requirements of GSFC specification S-250-P-1B, Contractor Prepared Monthly, Periodic and Final Reports in accordance with the requirements of paragraph 4.7.5 of the LRIR Statement of Work as amended by NASA/GSFC TWX 08/1503, dated 2 October 1974.

The LRIR Protoflight Model has been assembled and has successfully completed the required environmental, performance and calibration test programs. The measured instrument performance indicates that the scientific objectives will be met with the data processed by the LRIR system, Protoflight Model, from the orbital Nimbus F Spacecraft.

Management of the LRIR program was the responsibility of the Honeywell Radiation Center (HRC) of Honeywell Inc. In addition HRC responsibility included system analysis and mechanization, design of the Frame Housing Assembly and scan control electronics, and system integration and test. The data processing electronics and bench check units were designed, fabricated and tested by the Honeywell Aerospace Division, St. Petersburg, Florida. The Solid Cryogen Cooler was designed, fabricated and tested by the Lockheed Missiles and Space Company, Palo Alto, California.

HRC acknowledges the technical and program guidance provided by the GSFC ERTS/Nimbus Project Office personnel under the program technical direction of Mr. Lou Wilson. We also acknowledge the contribution of the Science Team, headed by Dr. John Gille, Prinicpal Investigator, National Center for Atmospheric Research, Boulder, Colorado with Co-Investigators Dr. R. A. Craig, Florida State University Department of Meteorology, Dr. F. B. House, Drexel University, and Mr. J. C. Bates of Honeywell Radiation Center. The Science Team provided scientific objectives, radiometer performance requirements, orbital data reduction requirements and will be responsible for orbital data interpretation, analysis, and publication.

Section 1 is a detailed description of engineering and scientific objectives of the LRIR experiment. The LRIR system requirements as specified in GSFC-S-450-P11 are defined in Section 2. Section 3, LRIR System Description, describes the LRIR subassemblies and how the LRIR experiment operates. This section also includes a detailed description of each of the major subassemblies.

Section 4 defines the basic mechanical, electrical and thermal interfaces between the LRIR experiment and the Nimbus F Spacecraft. This section also includes the weight and center of gravity of the FHA, an electrical measurements list, a commands list, data processing operation and data word format.

Section 5 describes the PM qualification and acceptance test program. This section includes a summary of system and subsystem tests. The test data are summarized in tables to give the reader an overall view of each test parameter and possible trends of the performance of the LRIR experiment.

Section 6 contains the calibration curves generated by primary calibration in thermal-vacuum of the LRIR. Systems deviations from specification requirements are specified in Section 7.

Section 8 briefly describes the Bench Checkout Unit and how it operates. A more detailed description of the BCU is contained in the Instruction Manual for the Nimbus F Bench Checkout Unit (BCU) DUG8508A1 (HRC document 74-9) which was submitted to GSFC as part of the PM data package.

Section 9 is a brief definition of the safety criteria of the LRIR.

Section 10, New Technology, indicates that during the PM phase of the LRIR program, there was no new technology developed.

Section 11 provides conclusions and recommendations.

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ACRONYMS AND ABBREVIATIONS

A/D	Analog to Digital
BCU	Bench Checkout Unit
CG	Center of Gravity
CH_4	Methane
cm	Centimeter
CO_2	Carbon Dioxide
DCA	Detector Capsule Assembly
EMI	Electromagnetic Interference
ETP	Engineering Test Procedure
F	Fahrenheit
FHA	Frame Housing Assembly
FEU	Frame Housing Electronics Unit
Freq.	Frequency
FOV	Field of View
G	Gravity
GSFC	Goddard Space Flight Center
HDRSS	High Data Rate Storage System
HgCdTe	Mercury-Cadmium-Teluride
H_2O	Water
HIRS	High Resolution Infrared Sounder Experiment
HNO_3	Nitric Acid
HRC	Honeywell Radiation Center
IEU	Interface Electronics Unit
IFOV	Instantaneous Field of View
IFC	Inflight Calibrator
IPAT	Inverted Profile Archival Tape
K	Kelvin
KM	Kilometer
LTD	Local Time Difference
LN_2	Liquid Nitrogen
LOS	Line of Sight
LRIR	Limb Radiance Inversion Radiometer
MAT	Map Archival Tape
mb	Millibar
MTF	Modulation Transfer Function
MLI	Multi-Layer Insulation
MDHS	Meteorlogical Data Handling System

ACRONYMS AND ABBREVIATIONS
(continued)

MoS_2	Molybdenum Disulfide
mrad	Milliradian
NADUC	Nimbus-ATS Data Utilization Center at GSFC
NEN	Noise Equivalent Radiance
NCAR	National Center for Atmospheric Research
NOAA	National Oceanographic Atmospheric Administration
N_2O	Nitrous Oxide
NO_2	Nitrogen Dioxide
NSSDC	National Space Science Data Center
O_3	Ozone
OMP	Optical Mechanical Package
PM	Protoflight Model
PMR	Pressure Modulated Radiometer
PRT	Platinum Resistance Thermometer
RAT	Radiance Archival Tape
RFI	Radio Frequency Interference
rms	Root Mean Square
RVDT	Rotary Variable Differential Transformer
S/C	Spacecraft
SCC	Solid Cryogen Cooler
SCP	Solid Cryogen Package
UFOT	User Formatted Output Tape
VDC	Volts direct current
VIP	Versatile Information Processor
w/m^2-sr	watts/meter^2-steradian
μm	10^{-6}meters

SECTION 1

LIMB RADIANCE INVERSION RADIOMETER EXPERIMENT

1.0 INTRODUCTION

The Limb Radiance Inversion Radiometer (LRIR) is a multiband calibrated radiometer operating in the 8.5μ to 30μ spectral region that will be flown aboard the Nimbus F Observatory spacecraft. As shown in Figure 1-1, the LRIR is mounted to the sensory ring viewing the Earth's horizon with a line of sight angle of 32° from the orbital plane. The nominal orbital altitude of the Nimbus F spacecraft will be 1100 kilometers in a sun synchronous, circular, polar orbit. The LRIR experiment views the infrared emission by the atmosphere along a path through the atmosphere at the planetary limb with space as the background. The radiance received depends upon the path through the atmosphere defined by the height or pressure of the lowest point above the surface. The lowest point is denoted the tangent point, and its height is the tangent altitude. A scan of the limb results in a radiance profile, a set of measured radiance values as a function of tangent height.

The scientific objective of the LRIR experiment is to acquire the vertical distribution of temperature, ozone, and water vapor from the lower stratosphere (≃15KM) through the stratosphere and into the lower mesophere (≃60KM) on a global scale. Radiance proflies measured in two spectral intervals centered in slightly different positions within the 15 micron CO_2 band will be inverted to obtain temperature profiles from an altitude of 15 kilometers to more than 60 kilometers. Radiance profiles measured at 9.6 microns and 25 microns will be used to determine ozone and water vapor density profiles respectively. Data presentation will be in the form of vertical soundings and daily maps will be available for use by the scientific community. The maps and the associated profiles are the observational data with which many of the basic questions about the properties and behavior of the stratosphere and lower mesophere may be answered.

The radiometer employs (HgCd)Te detectors for all channels cooled to 65° Kelvin using a solid cryogen cooler. The primary cryogen coolant is solid methane at 62° Kelvin and the secondary cryogen is

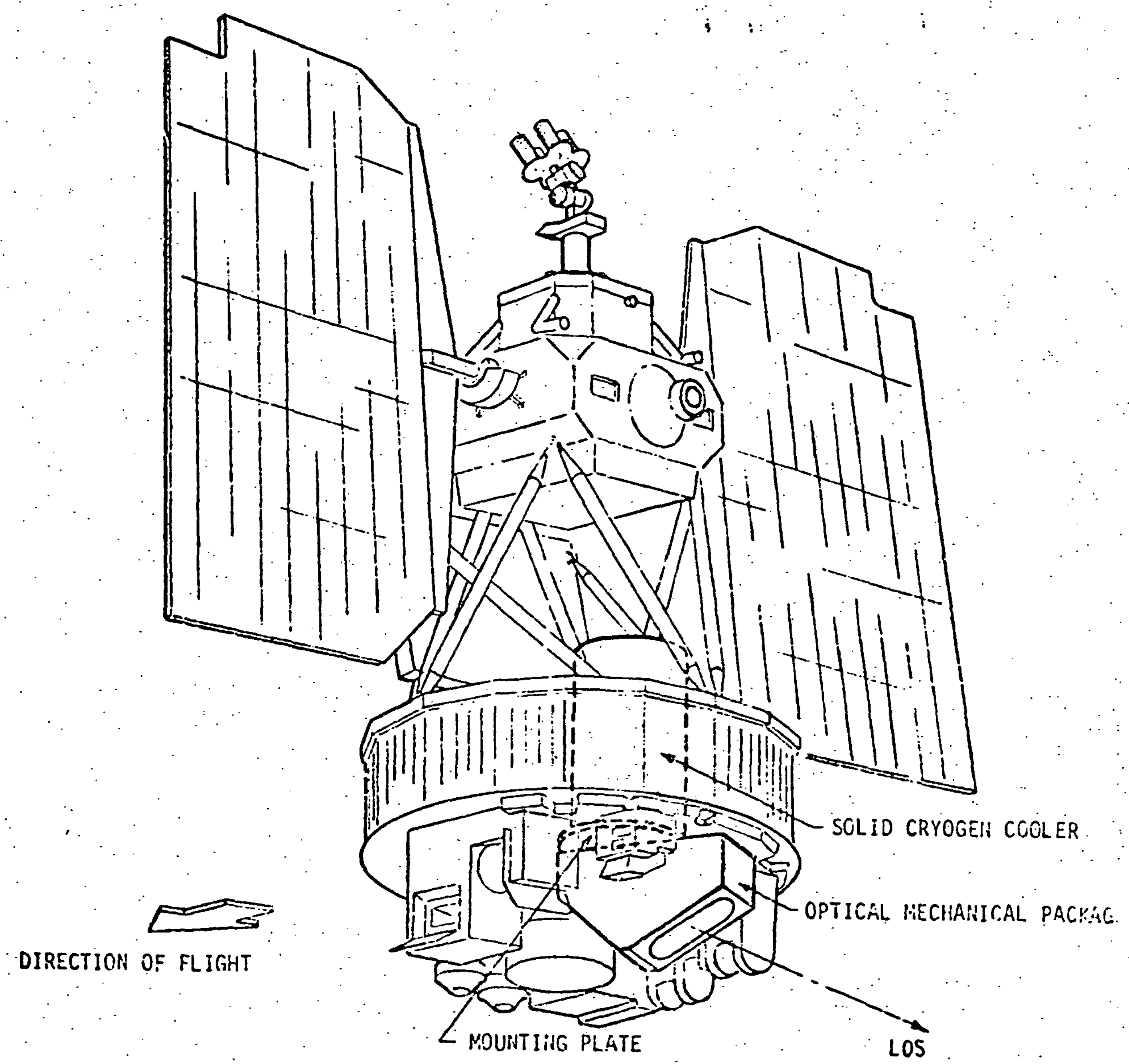

Figure 1-1 NIMBUS "F" LRIR

solid ammonia operating at 152° Kelvin. The four radiance spectral bands are:

(1) CO_2 14.7μ to 15.8μ
(2) CO_2 14.2μ to 17.2μ
(3) O_3 8.5μ to 10.3μ
(4) H_2O 22 μ to 30 μ

A programmed scanning mirror in the radiometer causes the field of view (FOV) of the ozone channel followed by the FOV of the CO_2 channels and finally the H_2O FOV to make a vertical scan across the Earth's horizon. The resulting CO_2 limb radiance profile data is then operated on by inversion algorithms during the data reduction to determine the vertical temperature distribution. The inferred temperature profile, together with the radiance profiles in the ozone and water vapor bands, are then used to infer the vertical distribution of the constituents.

1.1 EXPERIMENT SCIENTIFIC OBJECTIVES

The scientific objectives of the LRIR experiment are to:

- Acquire the present global measurements of temperature, ozone and water vapor in the stratosphere and lower mesosphere for one year.

- Obtain the geostrophic component of the wind up to a level of 1 mb (48 KM) through integration of the temperature profile in the thermal wind equation.

In order to meet these scientific objectives, specifications were placed on the instrument design to provide observations of sufficient quality to yield atmospheric parameters to the desired accuracy and precision. In this regard, minimum scientific data requirements were established as indicated in Table 1-1. Instrument specifications were determined relative to these data requirements.

Referring to Figure 1-2 LRIR receives infrared radiation emitted by the atmosphere along a ray path that may be identified by the height (tangent height) or point (tangent point) closest to the surface. The atmosphere may be scanned by sweeping the view direction from tangent heights, $H<0$ (ray path intersecting the

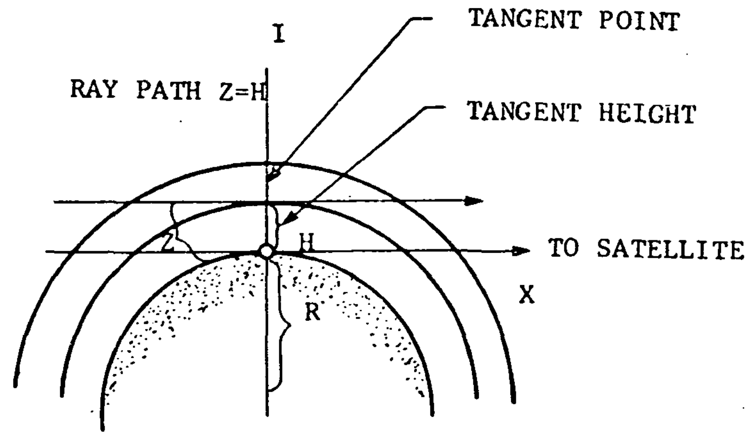

Figure 1-2 LRIR LIMB VIEWING GEOMETRY

Table 1-1

LRIR SCIENCE DATA REQUIREMENTS

PARAMETER	ACCURACY	VERTICAL RESOLUTION OF PARAMETERS	ALTITUDE RANGE
Temperature	±3°K RMS	2 km	15-54 km
Ozone	±20%	2 km	15-48 km (1mb)
Water Vapor	±50%	5 km	15-48 km (1mb)
Geostrophic Winds	±10 m/sec (Thickness ±70 m or T to ±1.5°K)	Mandatory levels	to 48 km (1mb)

surface) to large positive values. The following advantageous features of limb scanning are apparent from a consideration of Figure 1-2.

- High inherent vertical resolution - for geometric reasons, none of the signal originates from below the tangent height, and most of the signals originate from a 3 to 4 KM layer above the tangent height.

- Zero background - for $H > 0$, all radiation received originates in the atmosphere, and all variations in signal are due to the atmosphere since the radiation is viewed against the cold background of space.

- Large opacity - there is at least 60 times more emitting gas along a horizontal path grazing the surface than there is in a vertical path to the tangent point. Thus, the atmosphere can be sampled to high altitudes.

There are, of course, disadvantages associated with these features. The long paths mean that even for rather transparent spectral regions, it will be difficult to see the solid surface of the planet. A cloud along a path will act as a body of infinite opacity, and may cause a considerable alteration in the emerging radiation. For the earth's atmosphere, where clouds are present but usually below the tropopause, these facts suggest that reliable operation will be limited to the upper troposphere and above, with even the coverage of the upper troposphere and lower stratosphei being subject to occasional interruption. For these reasons parameters are determined only above a nominal tropopause at 15 KM.

The radiative transfer equation for a non-scattering atmosphere in local thermodynamic equilibrium may be written as

$$I_i(h) = \int_{\infty}^{\infty} B_i[T] \frac{dt_i(h; x)}{dx} dx$$

where I is the observed radiance at tangent height h and spectral interval i, B is the Planck blackbody function, T is temperature, x the distance coordinate along the ray path, with the origin at the tangent point and positive toward the satellite (located at $+\infty$) and $t(h;x)$ the mean transmission in the spectral interval along the path with tangent height h from point x to the satellite.

The temperature inversion problem is to determine B and therefore T from measurements of I, assuming that dt/dx is known. The latter requires that the distribution of the emitting species be known, which in practice means that radiation from CO_2, a uniformly mixed gas, is measured. In the limb problem dt/dx is also crucially affected by the atmospheric structure.

In the case of the constituent inversion problem, the solution to the temperature inversion problem is utilized with the constituent limb radiance profile to determine the gas concentration as a function of altitude. In equation (1), B is known from the temperature solution. The constituent concentration is determined as an implicit function of transmission $t_i(h; x)$.

In order to gain a better understanding of the data to be observed by the LRIR, examples of calculated profiles of limb radiance as functions of tangent height are shown from a mid-latitude winter sounding in Figure 1-3.

The broad carbon dioxide (BCO_2) channel refers to the 585-705 cm^{-1} spectral band, and the narrow carbon dioxide (NCO_2) channel covers the band 630-685 cm^{-1}. The signals are quite similar at upper levels where only the strong lines near the centers of the bands are contributing. Below about 30 KM, the BCO_2 signal is much larger because the weaker lines in the band wings are contributing energy from the lower atmosphere. The dashed line presents the difference between BCO_2 and NCO_2 signals, or the contribution from the 585-630 cm^{-1} and 685-705 cm^{-1} regions. The steeply sloping portions of the curve occur in situations where the whole path through the atmosphere is moderately transparent, and an appreciable portion of the signal is coming from the tangent point. Figure 1-3 demonstrates the BCO_2-NCO_2 regions provides better information on the lower levels of the stratosphere and upper levels of the troposphere.

The profile depicting inversion results in Figure 1-3 illustrates realistic solution for typical instrument errors, defined by the science requirements in Table 1-1. These results are based on computed limb radiance profiles in Figure 1-3 which were perturbed for realistic radiometer and pointing errors, and included in 1.5 KM instrumental field-of-view. The procedures for inverting CO_2 radiance profiles to obtain a solution to the temperature distribution are presented in a paper by Gille and House (1971).

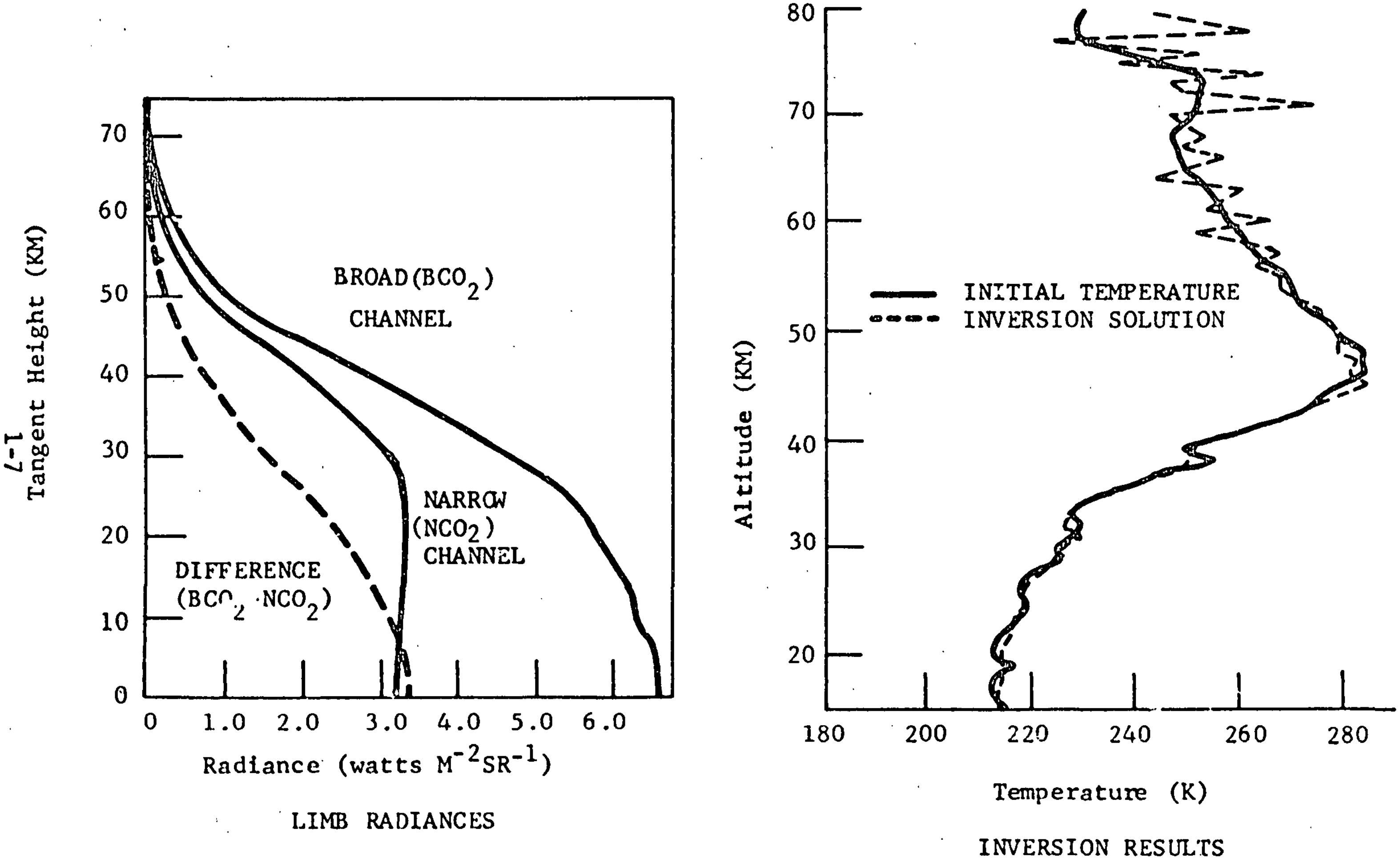

Figure 1- 3 COMPUTED LIMB RADIANCES AS A FUNCTION OF TANGENT HEIGHT FOR BROAD (585-705cm^{-1}) AND NARROW (630-685 cm^{-1}) CHANNELS IN THE 15 μm BAND OF CO_2. INVERSION RESULTS FOR TYPICAL INSTRUMENTAL ERRORS, (NO VERTICAL SMOOTHING) DEFINED IN REQUIREMENTS IN TABLE 1-1 FOR FURTHER DETAILS SEE GILLE AND HOUSE (1971).

The inversion results in Figure 1-3 are in good agreement with the initial temperature profile up to about the 55 KM level and becomes more and more "saw toothed" in nature at higher altitudes. This characteristic is caused by the random error of the instrument which dominates the natural limb signal at high altitudes. The signal to noise ratio of the measurement becomes increasingly smaller as the LRIR scans to higher altitude. One obvious procedure to employ in the data processing of real observations is to mathematically smooth the solutions at higher altitudes and/or average adjacent limb profiles before inversion. Mathematical smoothing techniques can also be employed during the inversion procedure.

Solutions to the constituent inversion problem for vertical distributions of ozone and water vapor show similar characteristics as the temperature inversion results shown in Figure 1-3. The sawtoothed character of the solution develops in a similar manner and altitude for ozone distributions, but at about a 40 KM level for water vapor distributions since the signal to noise ratio degrades at a lower altitude.

SECTION 2

SYSTEM REQUIREMENTS

2.0 INTRODUCTION

The LRIR system design has evolved from (1) the initially configured design requirements as specified in GSFC-S-450-P11, "GSFC Specification, Limb Radiance Inversion Radiometer," dated April 1, 1970, (2) the Nimbus E and F Experiment Interface Requirements Handbook, X-450-68-415, revised June 1973, (3) the LRIR Study Phase Final Report, P.D. No. 1CDY-G400, dated August 1970, and (4) GSFC Quality Control Documents. The as-configured system performance requirements and design goals are discussed in the following paragraphs of this section identifying the radiometric, electronic measurements, and opto-mechanical requirements of the LRIR system. The qualification vibration test levels and the thermal vacuum cycle to which the LRIR Protoflight was tested are also identified.

Performance test data and an evaluation of the data obtained for the PM LRIR system is discussed in Section 5 of this report. The LRIR electronic and mechanical assemblies have been designed to meet the environmental requirements of GSFC specification S-320-EN1, "Environmental Test Specification for the ERTS (A and B) and Nimbus (E and F) Observatory Systems, Subsystems, and Experiments," dated November 1971. In addition, LRIR system interface with the Nimbus spacecraft have been designed to meet the requirements of GSFC specification X-450-68-415 "Nimbus E and F Experiment Interface Requirements," as revised June 1972.

2.1 RADIOMETRIC REQUIREMENTS

The LRIR radiometer consists of four spectral channels; ozone, carbon dioxide (narrow and wide band) and water vapor. A vertical scan of the earth's limb detects the presence of each constituent with the requirements as noted in Table 2-1.

2.2 DETECTOR REQUIREMENTS

2.2.1 Detector Selection Criteria

The detectors are (HgCd)Te, selected to meet the spectral and noise equivalent radiance (NEN) requirements specified in Table 2-1.

Table 2-1

LRIR RADIOMETRIC REQUIREMENTS

	Spectral Filter Bands, microns	Noise equivalent Radiance, w/m²-sr Specification	Noise Equivalent Radiance, w/m²-sr Design Goal	Vertical Resolution, km	Horizontal Resolution, km	Dynamic Range, max. radiance w/m²-sr	Max. Scene Radiance Expected w/m²-sr	Dynamic Range Bit Resolution	Los Scan Angle, acquisition mode	Los Scan Angle, adaptive mode	Square wave O_3 & CO_2, .77 cycle/mr H_2O, .63 cycle/mr
Ozone, O_3	8.5-10.3	.01	.002	2	20	20	4	4096:1	±5°	±1°	.68
CO_2, wide band	14.2-17.2	.01	.002	2	20	20	4.4	4096:1	±5°	±1°	.68
CO_2, narrow band	14.7-15.8	.01	.002	2	20	5	1.4	4096:1	±5°	±1°	.68
Water vapor, H_2O	22.0-30.3	.01	.0022	2.5	48	12	4.8	4096:1	±5°	±1°	.68

Accuracy of each radiometric channel readout:
1% x scale factor plus 1 x NEN

Precision of readout:
.01 w/m^2 - sr

2.2.2 Detector Operating Temperature

The (HgCd)Te detectors are maintained at a temperature of 65 ±2°K during the orbital life of the instrument.

2.2.3 Detector Bias Power

Twenty (20) milliwatts is the maximum power to be dissipated in the (HgCd)Te detectors during operational performance.

2.3 COOLER REQUIREMENTS

2.3.1 Cryogen Selection

A dual stage cryogen cooler uses solid methane, CH_4, as the primary cryogen to cool the detectors and solid ammonia, NH_3, as the secondary cryogen to cool the thermal shield which surrounds the methane tank.

2.3.2 Cryogen Temperatures

The methane temperature is 64 ±2°K and the ammonia temperature is 152°K nominal. (NOTE: The 64°K methane temperature with the temperature drop at the DCA/Cooler interface provides, the 65°K nominal detector temperature.)

2.3.3 Operational Life

The design goal for the cooler lifetime is a one-year orbital life.

2.3.4 Physical Characteristics

The cooler physical requirements are:

- diameter - 14 inches maximum
- length - 30 inches maximum
- weight - 54 pounds maximum (including detector capsule assy)

2.3.5 Cooler Vacuum Shell Temperature

The cooler vacuum shell ambient temperature is 295°K.

2.3.6 Vent Line Requirements

The cooler has six plumbing lines for servicing the cooler.

- methane common fill and vent line
- ammonia common fill and vent line
- vacuum line
- DCA vent line
- LN_2 cooling inlet line
- LN_2 cooling outlet line

The methane, and ammonia and vacuum lines have two types of valves installed on each line: (1) one type for ground servicing by manual operation, and (2) second type for orbital operation being opened in flight by firing a dual explosive squib located in each valve.

2.3.7 Squib Requirements

Dual electro-explosive ICC Class C Pressure Cartridges, G.E. part number 47D213540, with a firing current of 5 ± 0.1 amperes are inserted into the Pyrotechnic Valves on the cooler lines during final pre-launch checkout at WTR.

2.4 ELECTRONIC REQUIREMENTS

The LRIR electronics provide a twelve bit data processing system for the four data channels which interfaces with the HDRSS recorder of the Nimbus spacecraft. The requirements of the system electronics are as follows:

2.4.1 Primary Excitation

The nimbus spacecraft provides -24.5 Vdc ±2% excitation.

2.4.2 Maximum Power

The LRIR maximum available power is 34.5 watts.

2.4.3 Commands

Eleven command lines control the LRIR system initiated from the spacecraft by a -24V pulse with 40 millisec duration.

- Electronics On - commands LRIR power on.
- Electronics Off - commands LRIR power off.
- Heater On - commands the heater within the detector capsule assembly (DCA) to be on.(To be used should the cold window in the DCA become frosted.)
- Heater Off - commands the heater in the DCA to be off.
- Cage - commands the scan mirror to be driven against a soft stop.(Used during spacecraft launch).
- Uncage - removes the cage command.
- Acquisition Scan - commands the scan mirror to be driven through a 10 degree line of sight (LOS) scan angle centered about the optical center-line of the system.
- Adaptive Scan - commands the scan mirror to be driven through a 10 degree LOS scan angle for a period of 40 to 80 milliseconds before automatically switching to a 2 degree LOS scan. During the 40 to 80 millisecond 10° LOS scan, the earth limb is being scanned at a 1 degree per second rate to determine the scan angle at which 40% of the narrow band CO_2 peak radiance has occurred. When the changeover from the 10° scan to the 2° scan occurs the scan mirror is centered at the scan angle corresponding to 40% of the peak CO_2 radiance profile.
- Calibrate Override - overrides the calibration cycle which occurs every 32 seconds during the adaptive scan.
- Space Calibrate - commands the scan mirror to a space hold position.
- Source Calibrate - commands the scan mirror to the In-Flight Calibrator (IFC) source hold position.

2.4.4 Digital B Channels

There are eight modes for system operation, and mode status is displayed on VIP (versatile information processor) digital B telemetry. Digital B telemetry consists of one bit words, the off condition being -0.5 ± .5 Vdc and the on condition being -7.5 ±2.5 Vdc.

- Electronics On/Off - indicates status of system operational condition.
- Motor On/Off - indicates status of scan mirror being either caged for the launch or uncaged for normal system operation.
- Heater On/Off - indicates status of the heater in the DCA being either on or off.
- Acquisition Scan - indicates status of system operation being in an acquisition scan mode.
- Adaptive Scan - indicates status of system operation being in an adaptive scan mode.
- Calibrate Override - indicates status of system operation in a calibration override condition.
- Space Calibrate - indicates status of the scan mirror positioned at the space hold position.
- Source Calibrate - indicates status of the scan mirror positioned at the IFC source hold position.

2.4.5 Analog Channels

There are fifteen analog housekeeping functions which are continuously monitored whenever system power is applied. The range of the voltage monitored is 0 to -6.375 volts dc which the VIP converts to a 10 bit word, thus providing 6.25 millivolt resolution. A list of the 15 housekeeping functions monitored, the operational range, the scale factor, and the accuracy of each readout is shown in Table 2-2.

2.4.6 Data Bit Resolution and Rate

The LRIR data words are 72 bits in length formatted to include six 12 bit bytes. The six bytes are: (1) CO_2 narrow band radiance, (2) CO_2 wide band radiance, (3) O_3, (4) H_2O, (5) mode/status, and (6) word synch/parity bit. The bit rate is 4 KHz.

2.4.7 Sampling Rate

Data sampling occurs at a nominal rate of 45 samples per second. Data sampling is strobed during the linear scan cycle upon receipt of the scan angle encoder signal. During scan turnaround, scan stopped or scan slew, data sampling is on a fixed time basis of 55 samples per second.

Table 2-2
VIP ANALOG HOUSEKEEPING CHANNELS

ANALOG CHANNEL	RANGE	SCALE FACTOR	ACCURACY
Scan Motor Current	+363 to -330 ma	110 ma/v	±10 ma
-15 Vdc Monitor	0 to 18 V	2.94 V/V	±.1V
RVDT	-7° to +35° LOS	6.7° LOS/V	±.4° LOS
Detector Temperature	61°K to 73°K	.5V/°K	±.1°K
Cryogen Shield Temp.	61°K to 261°K	.032 V/°K	±.1°K
Cryogen Ext. Temp.	273°K to 336°K	.1 V/°K	±1°K
Primary Optics Temp.	273°K to 336°K	.1 V/°K	±1°K
Baffle Temp. 1	273°K to 336°K	.1 V/°K	±1°K
Baffle Temp. 2	273°K to 336°K	.1V/°K	±1°K
Blackbody Temp.	273°K to 336°K	.1 V/°K	±1°K
Scan Motor Temp.	273°K to 336°K	.1 V/°K	±1°K
OMP Housing Temp.	273°K to 336°K	.1 V/°K	±1°K
IFC Source Temp.	290°K to 353°K	.1 V/°K	±.1°K
IEU Temperature	273°K to 336°K	.1 V/°K	±1°K
FEU Temperature	273°K to 336°K	.1 V/°K	±1°K

2.4.8 Clock Input

The Nimbus command clock supplies a 200 KHz coherent frequency for use by the LRIR A/D converter.

2.4.9 Electronic Modules

There are two LRIR electronic subassemblies; (1) the data processing Interface Electronics Unit (IEU) and, (2) the scan controller Frame Housing Assembly Electronics Unit (FEU). The IEU is a standard Nimbus 3/0 module and the FEU is a standard Nimbus 2/0 module. The preamplifier assembly is packaged within the opto-mechanical assembly of LRIR designated as the Frame Housing Assembly. The module material, finish, and detail packaging requirements are designed to meet all the requirements in Section II of GSFC Specification X-450-68-415, with applicable waivers listed in Section 7.

2.5 MECHANICAL REQUIREMENTS

2.5.1 Radiometer

The radiometer consists of an opto-mechanical package (OMP) and the solid cryogen cooler, both secured to the radiometer mounting plate which is bolted to the Nimbus sensory ring.

2.5.2 Mechanical Interface

The radiometer has been designed to meet the interface requirements of Section II in GSFC specification X-450-68-415. The LRIR installation drawing HRC part number LK115A provides the volumetric constraints and the physical dimensions of the radiometer.

2.5.3 Mounting Pads

The radiometer mount has three pad surfaces contact with the Nimbus sensory ring. The pad surfaces are co-planar to ±.0005 and have a surface finish of better than 32 RMS.

2.5.4 Radiometer Finish

The radiometer finish is Alodine 600 per MIL-Spec-C-5541-C.

2.5.5 Radiometer Alignment Surface

An alignment pad is provided on the OMP housing to serve as an alignment surface during integration with the spacecraft. The alignment pad has a surface finish better than 32 RMS and has been aligned parallel to the radiometer mount to within plus or minus 6 arc minutes.

2.5.6 Radiometer Weight

The LRIR radiometer and associated electronic modules weights are as follows:

OMP and Cryogenic Cooler	90.5 lbs
Mounting Plate and Plumbing	24.0 lbs
IEU Electronic Module	9.8 lbs
FEU Electronic Module	6.2 lbs
	130.5 lbs

2.6 ENVIRONMENTAL REQUIREMENTS

2.6.1 Vibration Test Levels

The qualification vibration test levels as approved by GSFC are shown in Tables 2-3 and 2-4.

2.6.2 Thermal Vacuum Cycle

The thermal vacuum cycle to which the PM LRIR was exposed, consisting of a power on survival from -5°C to +45°C for a 96 hour period and performance test cycle from +15°C to 35°C is shown in Figure 2-1.

Table 2-3

FHA VIBRATION TEST LEVELS
11 March 1974

SINUSOIDAL VIBRATION SURVEY

5 to 2000 Hz at 2 oct/min 1 g peak limited to 0.5" D.A.

FULL LEVEL SINUSOIDAL VIBRATION LEVELS

FREQUENCY RANGE Hz	AMPLITUDE (g 0 to peak)
5-14	3.0*
14-20	1.0
20-36	3.0
36-42	2.0
42-200	3.0
200-2000	5.0

NOTE: Sweep rate at 2 octaves/minutes limited to 0.5 D.A.

RANDOM VIBRATION LEVELS

FREQUENCY RANGE Hz	P.S.D. (g^2/Hz)
20-40	0.02
40-2000	0.09

RMS accel. - 13.3 g
Duration - 2 minutes

Table 2-4

FHA VIBRATION LEVELS
22 May 1974

SINUSOIDAL VIBRATION

X Axis {10 - 1000 Hz at .5g

Y axis
10 - 14 Hz at 2g
14 - 19 Hz at 1g
19-200 Hz at 2g

Z Axis
10 - 13 Hz at .5" DA
16 - 25 Hz at 4.7 g's
25 - 34 Hz at 4 g's
34 - 44 Hz at 2.4 g's
44 - 120 Hz at 4 g's
120 - 165 Hz at 1 g
165 - 200 Hz at 4 g's

RANDOM VIBRATION

X Axis and Y Axis;

20 - 40 Hz from 01 g^2/Hz to 03 g^2/Hz
40 - 1000 Hz at .03 g^2/Hz
1000 - 2000 Hz from 03 g^2/Hz to .01 g^2 Hz

Z Axis;

20 Hz - 1000 Hz at .03 g^2/Hz
1000 Hz - 2000 Hz from .03g^2/Hz to .01 g^2/Hz

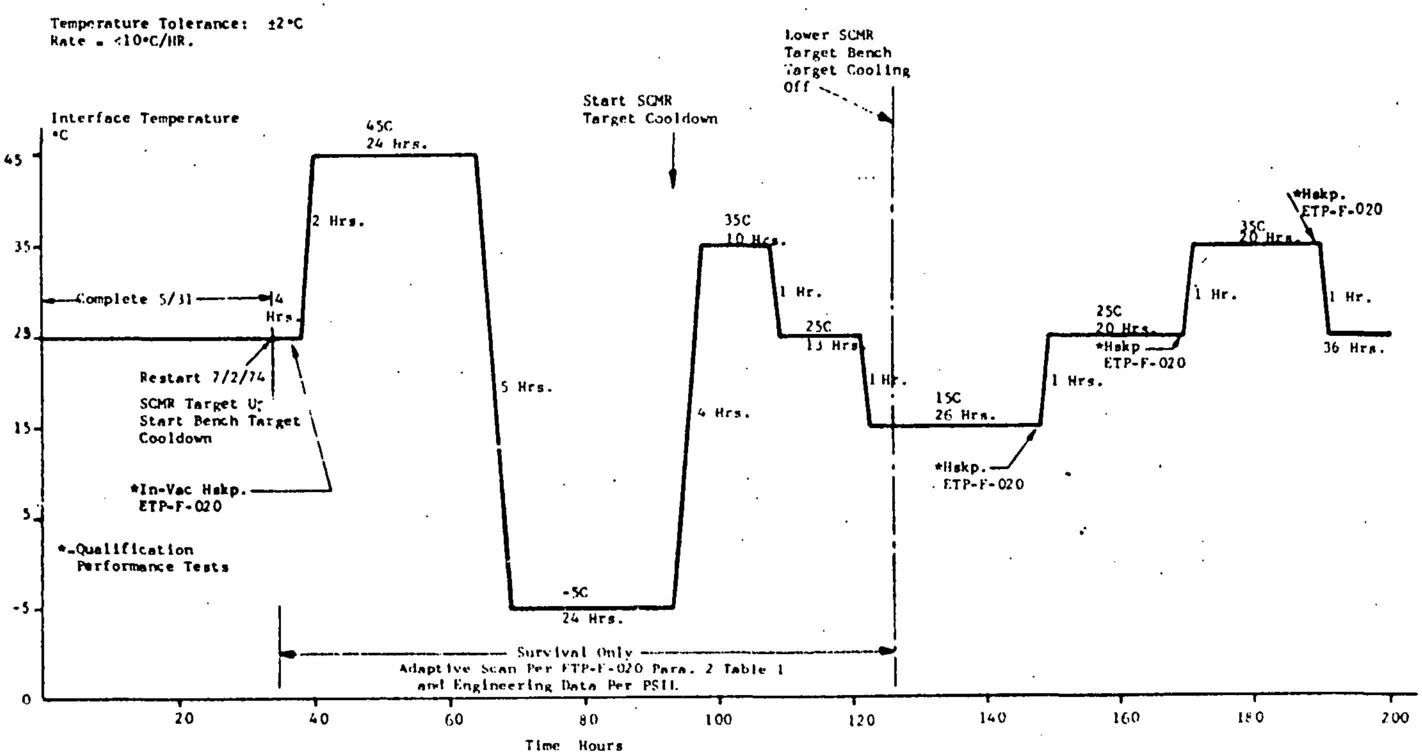

Figure 2-1 THERMAL VACUUM TEST SEQUENCE

SECTION 3

LRIR SYSTEM DESCRIPTION

3.0 INTRODUCTION

The LRIR as illustrated in Figure 3-1 consists of a frame housing assembly (FHA), a frame housing electronics unit (FEU) and an interface electronics unit (IEU). The FHA is an integrated unit consisting of the solid cryogen package, the S/C mounting plate, and the optical mechanical package (OMP) which mounts to the Nimbus F Spacecraft cross-beam and sensory ring. The IEU is a 3/0 bay mounted component and the FEU is a 2/0 bay mounted component. The solid cryogen package cools the detectors mounted within the detector capsule assembly (DCA). The OMP provides a stable optical bench containing the primary optics, the scan assembly, the light chopper and the preamplifier assembly.

The block diagram of Figure 3-2 shows the LRIR Signal Flow between the optical mechanical package (OMP), IEU and FEU. The scanning mirror, its drive motor, all of the optics, detectors and preamps are shown in the OMP. The scan control electronics, motor drive circuitry, chopper drive, command relays and decoder and VIP analog signal conditioners are a part of the FEU. The IEU contains video processors, sample and hold circuits, A/D converter, data formatting, timing and control circuits, and the power supply for the total experiment requirements.

The timing and control circuits receive the spacecraft master clock frequency of 200 kHz for internal timing and control. Spacecraft time is received and inserted in the data stream periodically.

The scan mirror is driven by a brushless dc torque motor, using a rotary variable differential transformer to provide scan mirror positional servo control. For each 40 arc seconds of mirror travel, a scan angle increment is generated by an encoder and interpreted by the timing and control logic. Each incremental pulse causes the data sampler to sample and hold each radiance output for conversion to a digital data word. Therefore each radiance sample is referenced to a known scan angle.

The scan mirror is controlled to oscillate about the limb with a scan rate of 1°/sec LOS by using radiation information from the

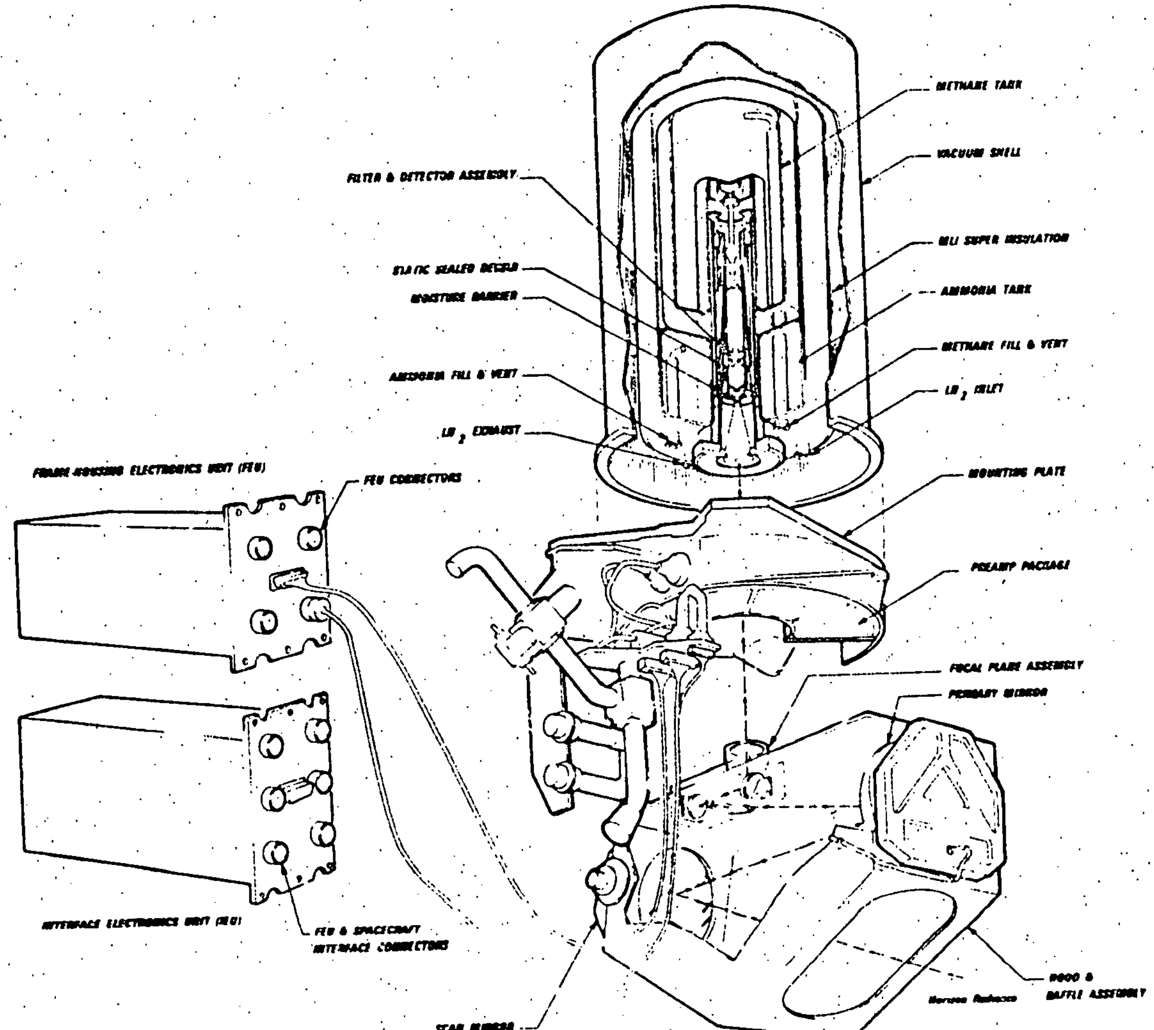

Figure 3-1 LIMB RADIANCE INVERSION RADIOMETER

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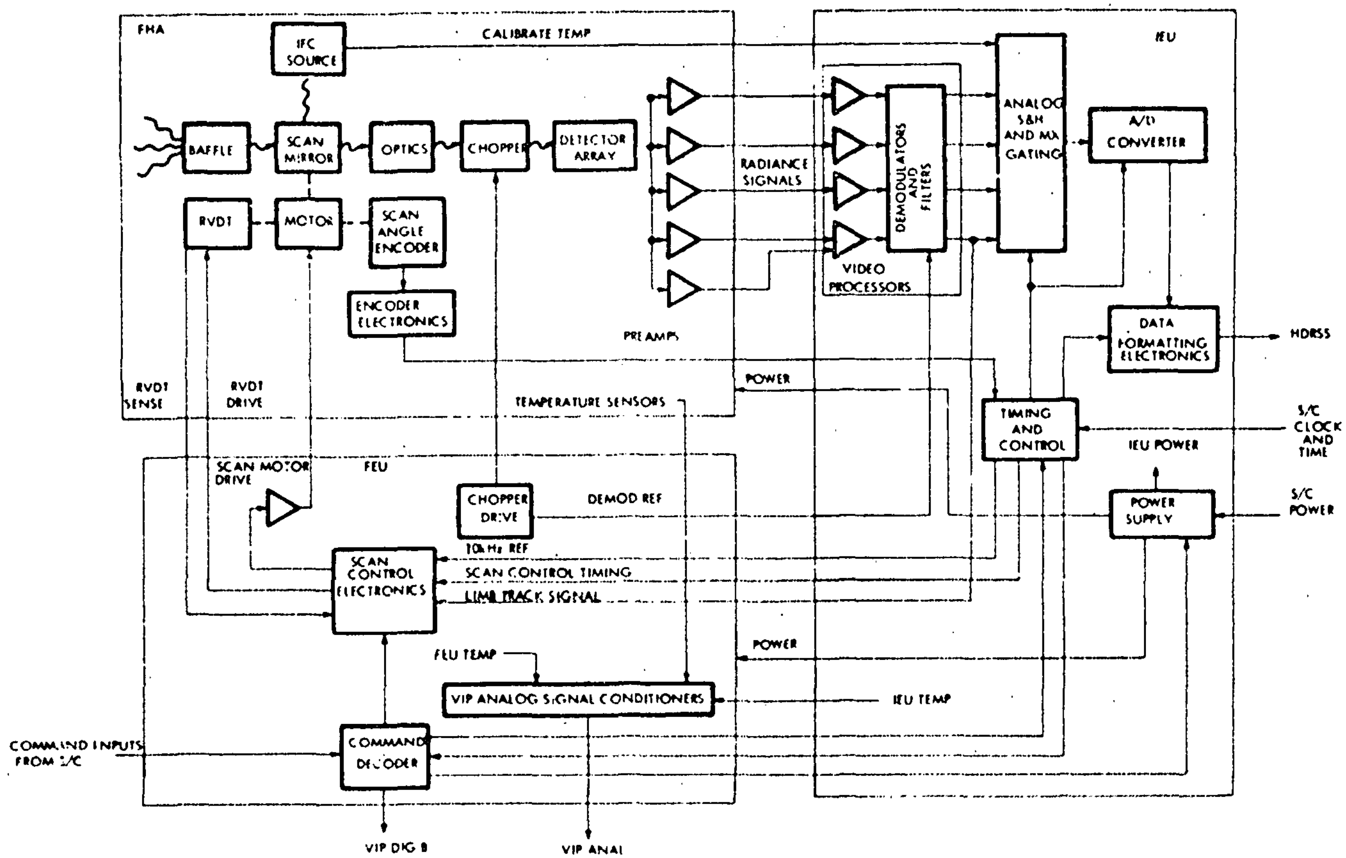


Figure 3-2 LRIR SIGNAL FLOW DIAGRAM

narrow band CO_2 (14.7 - 15.8μ) channel. The detected narrow-band CO_2 radiance analog output voltage is measured during the scan through the limb and used to determine a scan control position. Other specific commands can be given to the system scan controller to view space or the internal blackbody reference. A 15 bit encoder on the scan mirror shaft provides an incremental shaft position readout with a 1 σ error of less than 5 seconds arc.

The primary optics of the radiometer is a modified Czerny Turner design and provides resolution of 0.5 mrad over the required 2-degree field of view. The system is afocal with a beam demagnification of 10. The detector lens system covers a field of view of approximately 0.1 rad - 6 degrees - and has a speed of f/1. A schematic of the optical system is illustrated in Figure 3-3.

The Earth's limb spectral energy of 8.5 μm to 30 μm is directed through the hood and baffle assembly to the scan mirror. The black honeycomb baffle is designed to reduce scattered sunlight and earth light from impinging on either the focal plane or the detector capsule lens. The beam is directed from the scan mirror to a 18 cm off-axis parabolic mirror through a focal plane sub-assembly containing a secondary off-axis parabolic mirror. The secondary parabolic re-collimates the energy onto a folding mirror and into the DCA. An Irtran VI lens at 300°K focuses the beam from the OMP primary optics to a thermal baffle secondary field stop at the 152°K static sealed dewar (cooled by the cryogenic package). A .32 cm thick window of Irtran VI behind this stop on the dewar allows energy into the dewar. Then back-to-back parabolas focus to the detector with a final correction from an f/3 to a f/1 system by an Irtran VI lens. The parabolic lenses behind the Irtran VI window operate at 152°K and the final Irtran VI lens operates at 65°K.

The primary operating mode of the instrument is the adaptive scan mode in which the radiometer automatically acquires and tracks the horizon radiance profile.

During acquisition, radiation information from the narrow band CO_2 (14.7μ - 15.8μ) channel is peak detected during the 10 degree acquisition scan. At the radiance level corresponding to a nominal 40 Kilometer altitude, a gate is generated within 40 to 80 milliseconds after initializing acquisition scan which strobes out the scan mirror position. This scan mirror position signal becomes

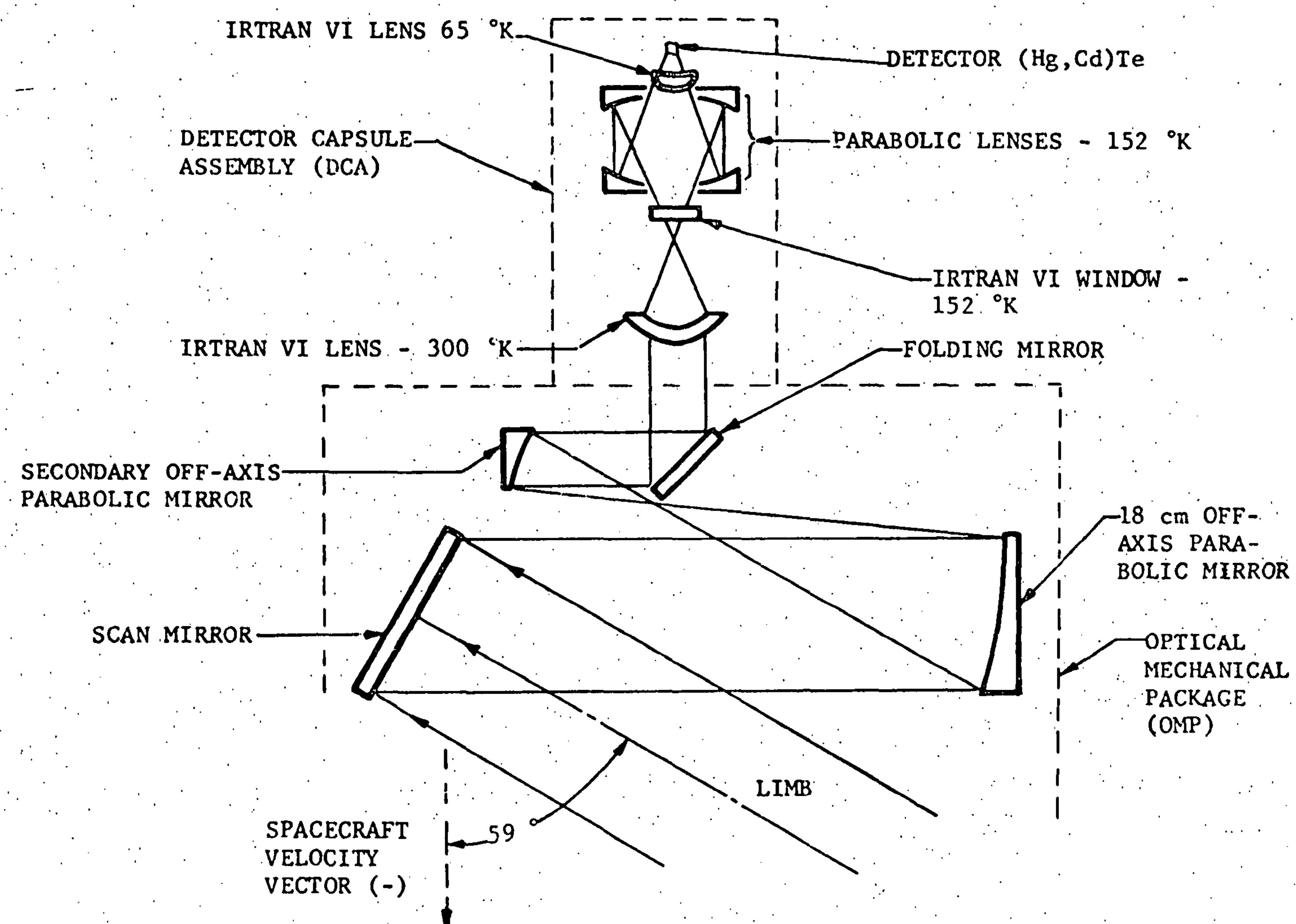


Figure 3-3 LRIR OPTICS SCHEMATIC

the reference optical line of sight about which the scan mirror adapts. System operation automatically switches to an adaptive scan covering a 2 degree LOS scan with the same scan rate of 1 degree per second. The system remains in the adaptive mode unless commanded otherwise completing seven scan cycles and updating the limb track position after each scan through the limb. After seven scan cycles requiring 28 seconds, a four second calibration mode is automatically sequenced. During the calibration mode, the scan mirror moves to a space hold position where all the detectors view space radiance for a period of one second. A calibration level for all four radiance channels corresponding to a cold target radiance is recorded. After the one second period is complete, the scan mirror moves to a position where an In-Flight Calibrator (IFC) warm blackbody (320°K) autocollimates onto the detectors. The IFC position is held for two seconds and provides the second point of a two point calibration for each signal processing channel. The scan mirror moves back to the OMP centerline position and awaits the resumption of the adaptive scan cycle. During the four second calibration sequence, the limb track position has been held and the scan re-adapts.

Other command modes of system operation include (1) calibration override, whereby automatic calibration is not required, (2) indefinite space hold and (3) indefinite source hold. During the launch environment, the LRIR system power is off but the scan mirror is caged against a soft stop by applying -24.5 VDC to the scan mirror torque motor. The mirror is commanded to be uncaged once orbital status has been obtained.

Several days prior to the launch, a final servicing of the cooler cyrogens is performed. Using LN_2, both the methane and ammonia are cooled to approximately 80°K. Once orbital status has been obtained, pyrotechnic valves are fired on the methane, ammonia, and cooler vacuum lines. By the process of space pumping on the cryogens, the methane cools down, stabilizes in about one week and controls the detector temperature at 65°K. The ammonia temperature warms up to 152°K and stabilizes.

3.1 OPTICAL MECHANICAL PACKAGE (OMP)

Figure 3-4 is an exploded illustration of the OMP which consists of the housing and baffle assemblies, the scan mirror assembly, the primary parabolic mirror, the focal plane assembly, the

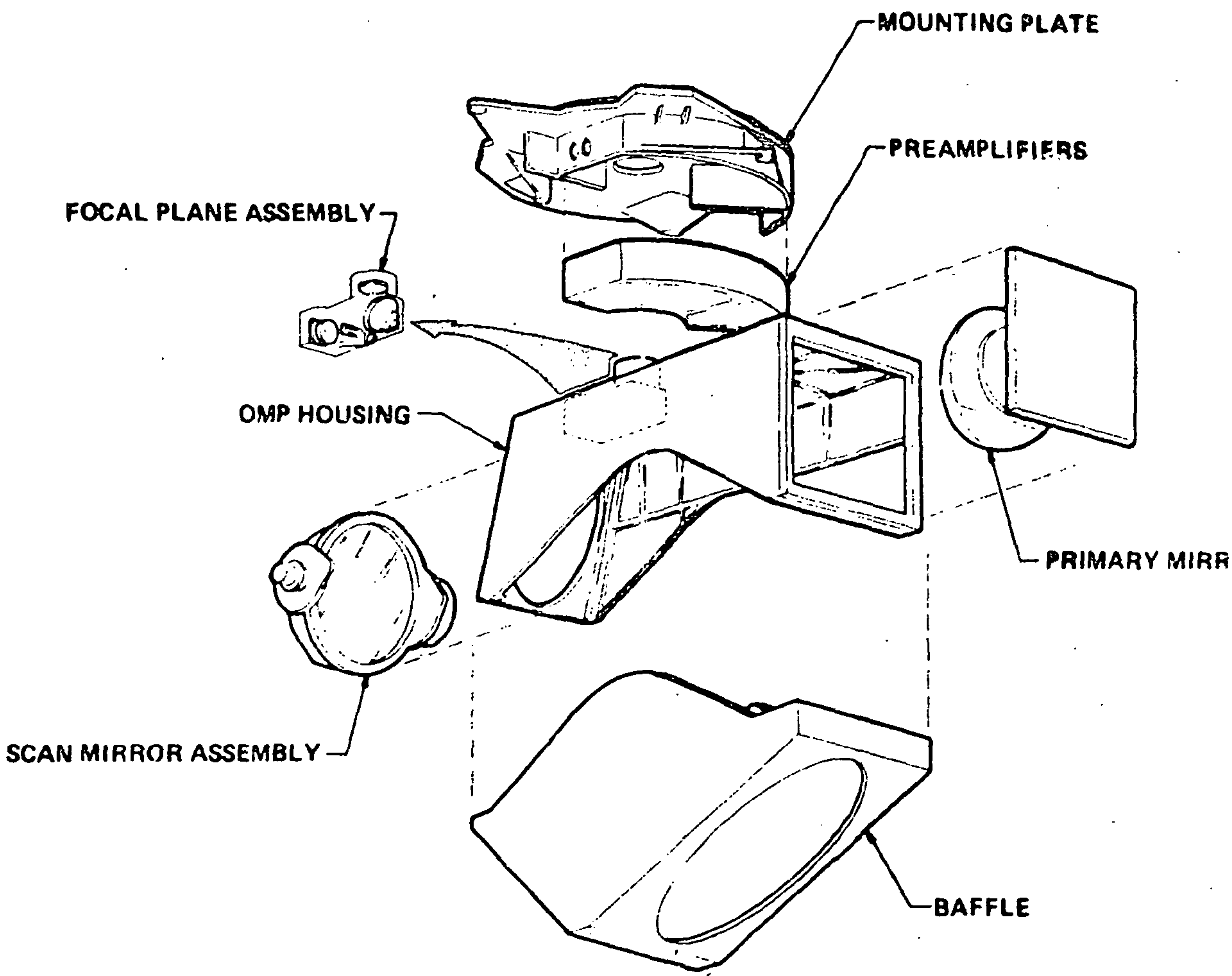


Figure 3-4 OPTICAL MECHANICAL PACKAGE (OMP)

mounting plate, and the preamplifier electronics assembly.

3.1.1 Optical Mechanical Package Housing

The Optical Mechanical Package is the structural support for the optics associated with the scanning system. The structure is made up of several 1/2 inch and 3/4 inch thick 6061 aluminum alloy members, which are locally "hogged out" to produce light weight ribbed plates. These plates are brazed together to produce a stiff structural member supporting the large off-axis parabolic mirror assembly and the focal plane assembly.

The internal structural components of the OMP must be held at a uniform constant temperature. Since at several orbital positions direct solar energy reaches the interior portions of the OMP and the amount of thermal energy to the interior is orbit varying, the structure must be shielded from this energy. Open celled honeycomb baffles, painted black and thermally isolated from the aluminum structure by several small pads of laminated glass epoxy, are assembled to the inside surface of the OMP. The baffles are used to attenuate stray light entering the OMP. In addition, these baffles absorb most of the input solar irradiance and re-radiate it to space thus preventing the structure from changing temperature rapidly in response to the varying energy input. To achieve thermal isolation, the baffle rear surface and the facing surface of the structure have a low emittance, and the connecting structure to the OMP housing is constructed of a material with a low thermal conductivity. The surface area of contact of the connecting structure is held to a minimum.

The space exposed external surface of the OMP is coated with a thermal control material, namely; "silverized teflon film." This surface acts as a radiator to eliminate the excess heat generated by the power dissipation of the electronics. The same surface also absorbs only a small amount of heat during exposure to solar energy. For this purpose a material with a low solar absorbance and high emittance was selected. All other sequences of the OMP housing are insulated with a multilayer aluminized mylar jacket which is installed after LRIR spacecraft integration.

3.1.2 Mounting Plate Assembly

The mounting plate assembly positions the LRIR on the Nimbus F spacecraft. This is accomplished by drilling and reaming the matching spacecraft holes in the mounting plate flange with a interchangeable drill template. In addition to structural support of the LRIR, the mounting plate provides a vacuum tight seal for the solid cryogen package, and necessary penetrations for the methane, liquid nitrogen, and ammonia lines exiting through the lower surface of the mounting plate. The mounting plate also supports the brackets which are provided for the terminating plumbing lines and to anchor the pyrotechnic squib valves. The preamplifier and calibration electronics are housed in the mounting plate.

The mounting plate is cast from 356-T6 Aluminum Alloy, machined, and stress relieved. Structural analysis of the mounting plate shows the first resonance to be greater than 100 Hz.

3.1.3 Focal Plane Assembly

The focal plane assembly contains the small off-axis aluminum parabolic mirror, the aluminum folding mirror, a light chopper, and the inflight calibration blackbody source. The light chopper optically chops the bundle of light energy at the focal plane using a 943 Hz tuning fork. Power required for this element is extremely low because it operates at resonance. A field stop limiting aperture is positioned directly in front of the light chopper.

The 45-degree folding mirror directs the chopped bundle of light energy from the parabolic mirror to the detector cooler assembly where the detector array is located. This mirror is adjusted during final alignment of the OMP and detectors in order to accurately direct the bundle of collimated light to the detector array. Access for adjustment of the mirror is achieved through the aperture in the baffle of the Optical Mechanical Package.

The in-flight calibration source is also contained within the focal plane assembly. A Minco heater blanket is wrapped around the copper blackbody and maintains the temperature at 320°K. The temperature of the blackbody is measured by the platinum resistance thermometer (PRT) buried within the copper blackbody. Every 32 seconds of time the scan mirror autocollimates the infrared energy emanating from the blackbody back into the detector array providing the calibration target for the LRIR experiment.

3.1.4 Primary Mirror Assembly

The Primary Mirror Assembly gathers the collimated energy from the scan mirror and focuses the light energy at the focal plane and light chopper. The seven inch octangularly shaped off-axis paraboic mirror is fabricated from 6061-T6 aluminum alloy and stress relieved. A silicon monoxide overcoat protects the aluminized mirror surface. A three pad mounting surface is provided on the rear surface of the mirror. This surface is undercut to minimize bending stress from being introduced into the reflective surface of the mirror. Additionally the three mounting pads are lapped flat to within 24 microinches. The holder to which the mirror is bolted and pinned is similarly treated to minimize bending stresses from being transmitted to the reflective surface of the mirror. After final optical alignment of the OMP optics, the primary mirror mount is pinned to the OMP housing.

3.1.5 Scan Mirror Assembly

The scan mirror assembly consists of an incremental encoder, a dc brushless torque motor, a Rotary Variable Differential Transformer (RVDT) and a scan mirror attached to a pivot bracket. The function of the Scan Mirror Assembly is as follows:

1. Control the scan rate of a 6.5-inch diameter aluminum mirror to one degree per second line of sight during the data acquisition mode using a dc brushless torque motor.

2. Provide an output signal every 40 seconds of arc (mechanical) with an accuracy of 5 arc seconds (1 σ) in any two-second time period using an incremental encoder.

3. Provide a torque motor capable of supplying a minimum of 4 in-ounce continuous torque during the mirror slewing mode or in the mirror cage position.

4. Starting and rolling friction of the bearings lubricated with Kryton 143AB is less than 0.5 inch-ounce.

During launch the scan mirror torque motor is energized caging the mirror so that it makes contact with a soft bumper made from

RTV 566 mounted on the inside surface of the mirror housing.

The torque motor is an Aeroflex dc brushless and bearingless torque motor. The rotor and stator are procured separately. The rotor is mounted to the scan mirror pivot bracket shaft using EA934 structural adhesive and the stator is bonded in its housing which attaches to the scan mirror housing. The pivot bracket and mirror assembly is then supported to the scan mirror housing using a pair of Krytox 143 AB processed duplex bearings.

The Rotary Variable Differential Transformer (RVDT) is excited by a 6-volt rms 10-kHz sinusoidal voltage and provides an output signal as a function of mechanical shaft angle. The RVDT is utilized in conjunction with the torque motor as a position follow-up servo. To avoid the use of additional bearings and couplings, the stator and Permalloy rotor of the RVDT are procured separately and the rotor is bonded using EA 934 to the pivot bracket mirror shaft. There is provision for the RVDT stator in its housing to be adjusted during final LRIR LOS optical alignment.

The incremental encoder (Optisyn) utilizes a rotating two-track 13-bit three-inch diameter glass disc fixed to the mirror shaft. The rotating disc is optically read by an assembly of parts consisting of an incandescent lamp, photo detectors, a stationary disc and electronics contained in a housing attached to the scan mirror housing. The rotating disc produces a Moire fringe pattern which provides a sharply defined light input to the detector. The electronics produce two 13-bit 5-volt square wave signals 90 degrees out of phase. The spacing between adjacent square wave edges corresponds to 15-bit (40 arc second) mechanical angular increments with an accuracy of better than 5 arc seconds (1σ).

3.1.6 Preamplifier Assembly

The Preamplifier and Calibration Electronics see Figure 3-5 is designed to meet the following requirements:

1. Amplify the low level detected DCA radiance signals to a high level compatible with the system design requirements.

2. House the detector temperature monitor.

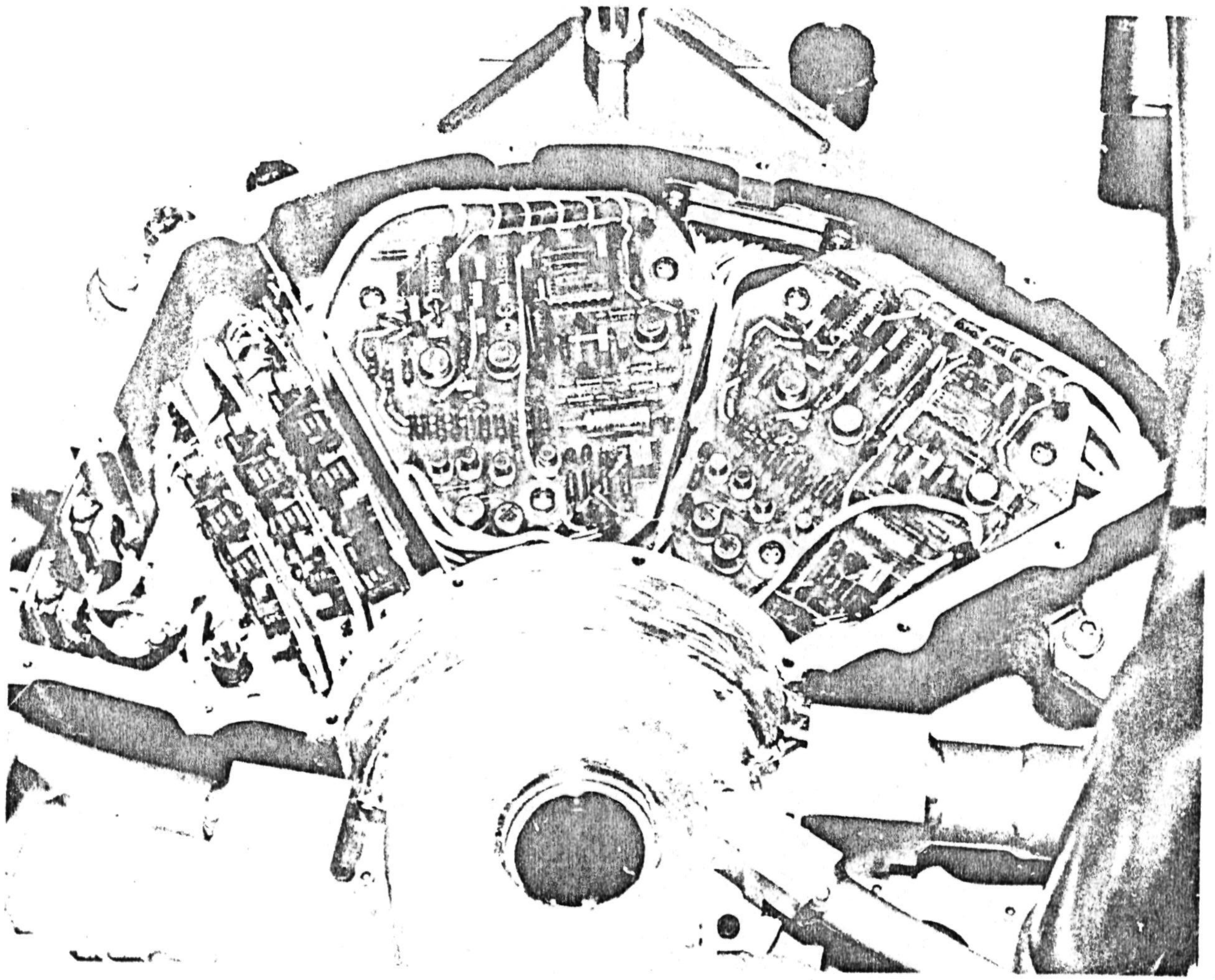


Figure 3-5 PREAMPLIFIER AND CALIBRATION ASSEMBLY

3. House the cryogenic shield temperature monitor.

4. House the blackbody controller electronics and blackbody temperature monitor.

The preamplifier electronics housing is an integral part of the mounting plate structure. The five preamplifier circuit boards plus a power distribution board are prewired with a 25-pin connector. The printed circuit boards are mounted together by three screws through the center of standoffs swaged to the boards and secured to a bottom plate. Three other printed circuit boards consisting of the blackbody controller and temperature monitors are prewired with two (2) nine-pin Cannon connectors.

The input signals to the preamplifiers and to the temperature monitors come from the detector capsule assembly (DCA) through EMI feedthrough terminals located adjacent to the DCA mounting flange. The preamplifier electronics assembly is installed in the mounting plate during the final integration and alignment of the OMP and SCP. A top cover with RF gasketing is added over the electronics which then become completely contained within the FHA.

3.2 SOLID CRYOGEN PACKAGE (SCP)

The solid cryogen package is composed of a dual stage solid cryogen cooler and a detector capsule assembly. The solid cryogen cooler is operated with expendable low temperature solid methane and ammonia which sublime to space during orbitable use. The purpose of the cooler is to contain the detector capsule assembly (DCA) and maintain the infrared detectors at an efficient operating temperature of approximately 65°K. The primary coolant used is solid methane. The secondary cryogen is solid anhydrous ammonia which also serves the function of cooling the DCA optics at 125°K thereby reducing thermal noise to the system. The cryogens containers are thermally isolated from each other and the external environment by evacuated multi layer insulation.

The DCA contains the detectors in a sealed vacuum dewar along with the optical elements necessary to focus collected radiation onto the detectors. The DCA is an integral unit that is inserted into the cooler before the cooler is charged with cryogens. Mechanical coupling of the DCA and cooler is accomplished by means of shrink fit couplings for both the 65°K and 152°K stations.

The solid cryogen cooler, as shown in Figure 3-6, can be subdivided into 3 systems; the methane system, the ammonia system, and the vacuum system. Four concentric fiberglass tubes support the methane and ammonia tanks. The inner fiberglass tube houses the DCA. The methane tank is thermally shielded by multi-layer insulation and a cooled aluminum shell that is grounded to the ammonia tank. The ammonia tank and shroud are covered with multi-layer insulation. There is a common fill and vent line to the methane tank and another common fill and vent line to the ammonia tank. The fill and vent lines are heat stationed to reduce conductive heat leaks. A common cooling coil used for solidifying the cryogens with LN_2 during the filling operation and maintaining them in a no loss condition is in contact with both tanks. An evacuation port to the insulation space is supplied for the vacuum tank.

Structural support for the cryogen tanks is provided by the four concentric fiberglass tubes with attachment to the mounting plate. The vacuum shell of the cooler attaches to the mounting plate which also provides a vacuum tight seal. The internal cooler plumbing is brought out through the mounting plate using leak-tight viton O-ring vacuum fittings. The external cooler plumbing is shown in Figure 3-7. Figure 3-8 shows the methane and vacuum lines and Figure 3-9 shows the ammonia line. During final cooler servicing the cooler is topped off with cryogens using the external plumbing hardware. LN_2 servicing before launch gets the cryogen temperatures stablilized at 80°K. Once in orbit, the methane, ammonia and vacuum lines are opened to space using pyrotechnic valves and within a week the methane temperature is stabilized at 65°K. The ammonia requires about a month for its temperature to become stabilized at 152°K.

The design goal of the cooler manufacturer was to produce a device that would have a life time of 1 year and would meet the vibration levels encountered during launch yet weigh less than 53 lbs.

The cooler produced for use on the Nimbus F spacecraft did successfully pass the environmental tests required building confidence that it would not be adversely affected by the launch and orbital environments to which it will be subjected. A vibration

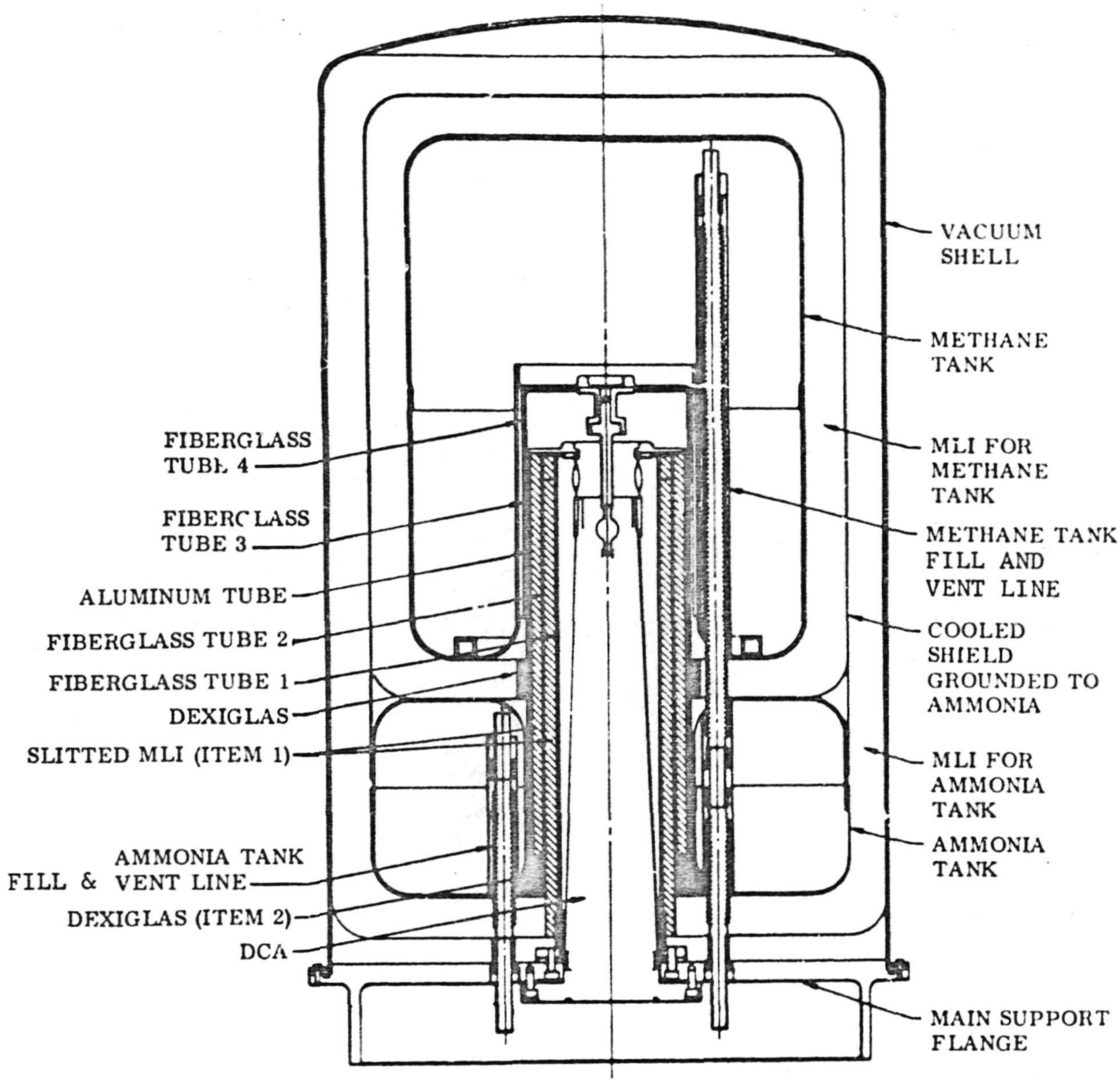


Figure 3-6 PHYSICAL CONFIGURATION OF HONEYWELL SOLID CRYOGEN COOLER

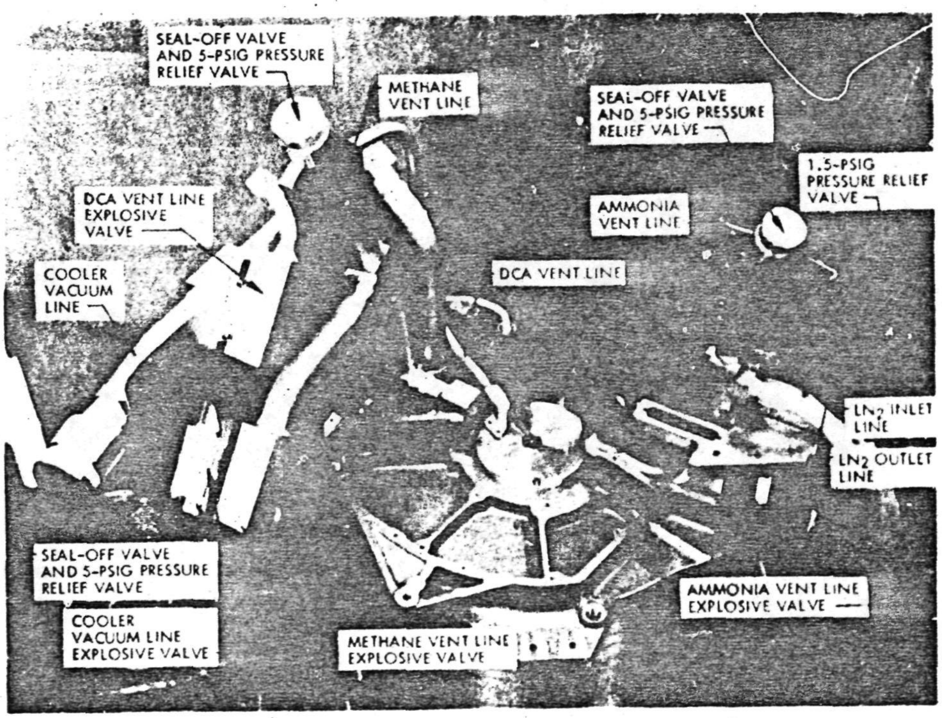


Figure 3-7 COOLER MOUNTING FLANGE AND EXTERNAL PLUMBING LINES

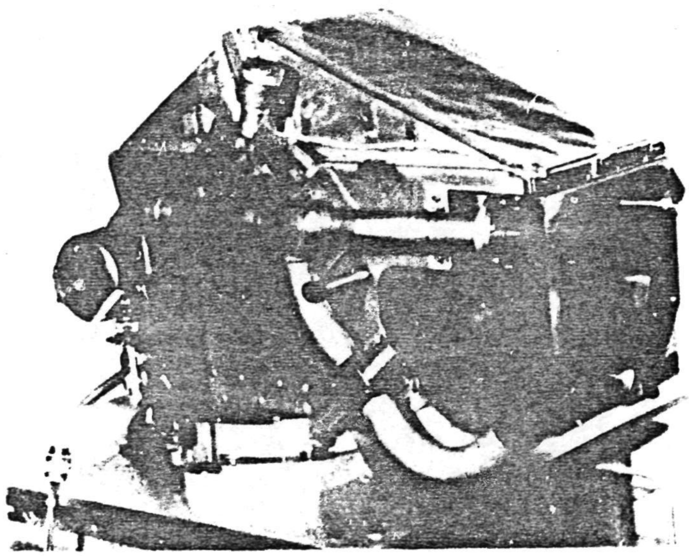


Figure 3-8 PM IN HOLDING FIXTURE SHOWING VACUUM AND METHANE LINES

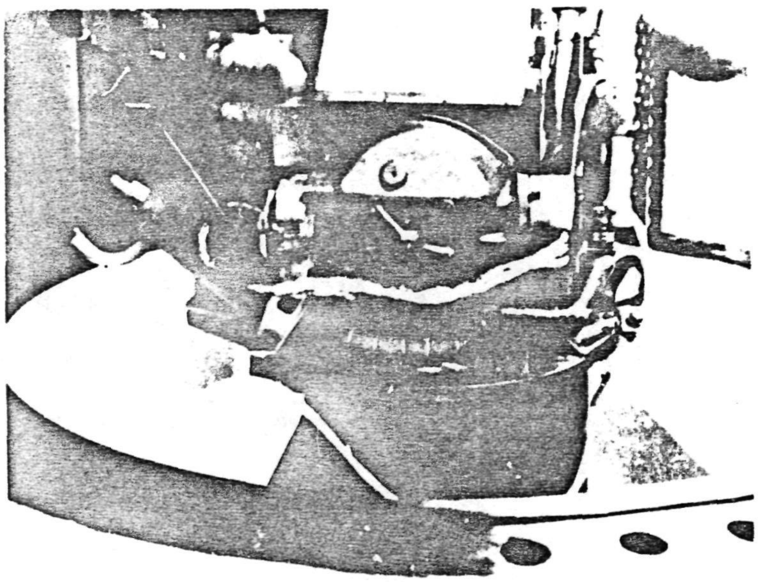


Figure 3-9 PM IN SHIPPING CONTAINER SHOWING AMMONIA LINES

test model (VTM) of the cooler was built utilizing simulated cryogen weights. The VTM was subjected to vibration levels as shown in Figures 3-10 and 3-11 in excess of the current GSFC S-320-EN-1 environmental requirements for experiments to be flown on Nimbus F, and successfully passed the tests.

The weight of the cooler and mounting plate is 51.3 pounds including 14 pounds of methane and 11.8 pounds of ammonia. The life of the cooler operating in its orbital operational mode will be 7.5 months. Cooler lifetime is based on the measured PM cooler performance data in a simulated orbital environment and is the length of time before all the methane would have been expended to space. The ammonia will last longer than the methane but the DCA detector temperatures will rise from 65°K to the solid ammonia temperature of about 155°K causing significant degradation in detector performance.

The Detector Capsule Assembly design as shown in Figures 3-12 and 3-13 has evolved for interfacing with the LRIR Solid Cryogen Cooler (SCC). The basic design considerations for the DCA are as follows:

1. A completely preassembled device with interfaces to permit a "drop-in" assembly/coupling with the solid cryogen cooler.

2. Less than 53 milliwatts (calculated) thermal heat loading to the methane and 81 milliwatts calculated to the ammonia. See Table 3-1.

3. Acceptance of an optical energy beam for the LRIR FHA that focuses collimated energy from a finite source onto the detectors. The optical elements consist of Irtran VI lenses and a pair of reflecting parabolic relay optics.

4. Thermal, mechanical, and optical stabilities commensurate to the system requirements.

5. Avoidance of degrading condensation affects utilizing a static sealed dewar, a labyrinth moisture barrier, and a 2 watt heater as a back-up.

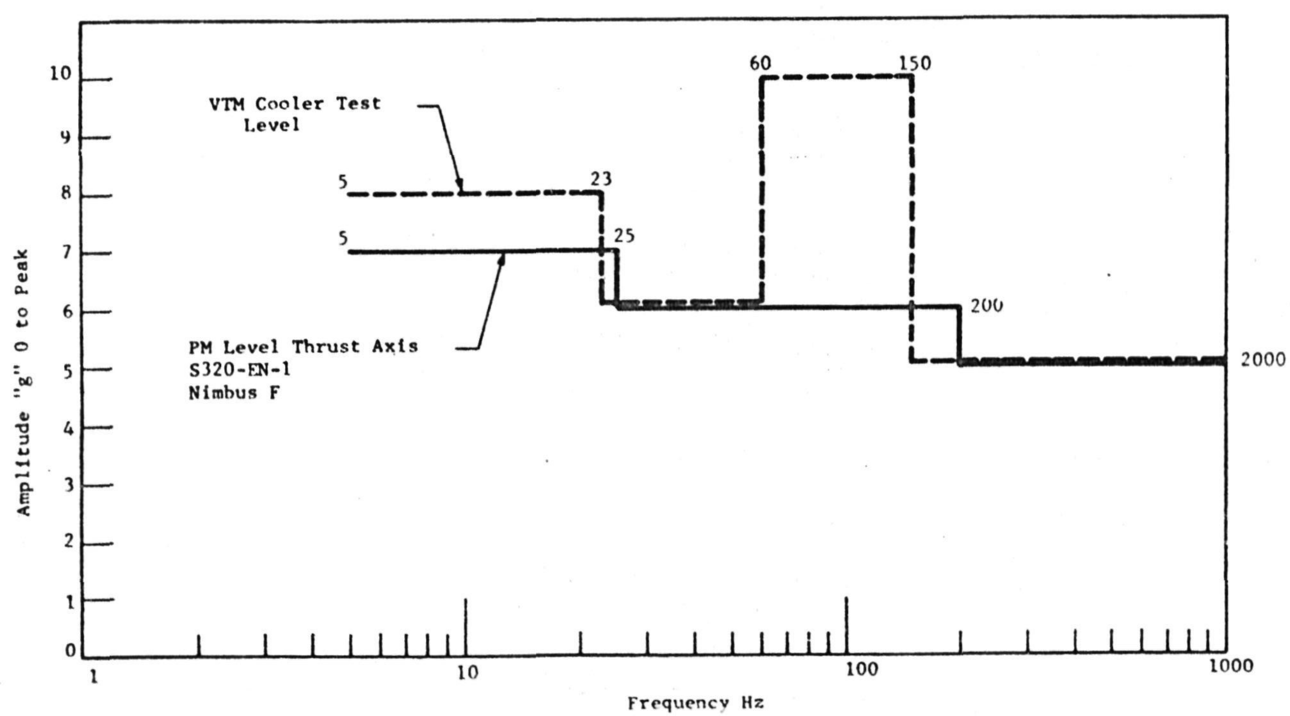


Figure 3-10 VTM LRIR COOLER VIBRATION TEST THRUST AXIS

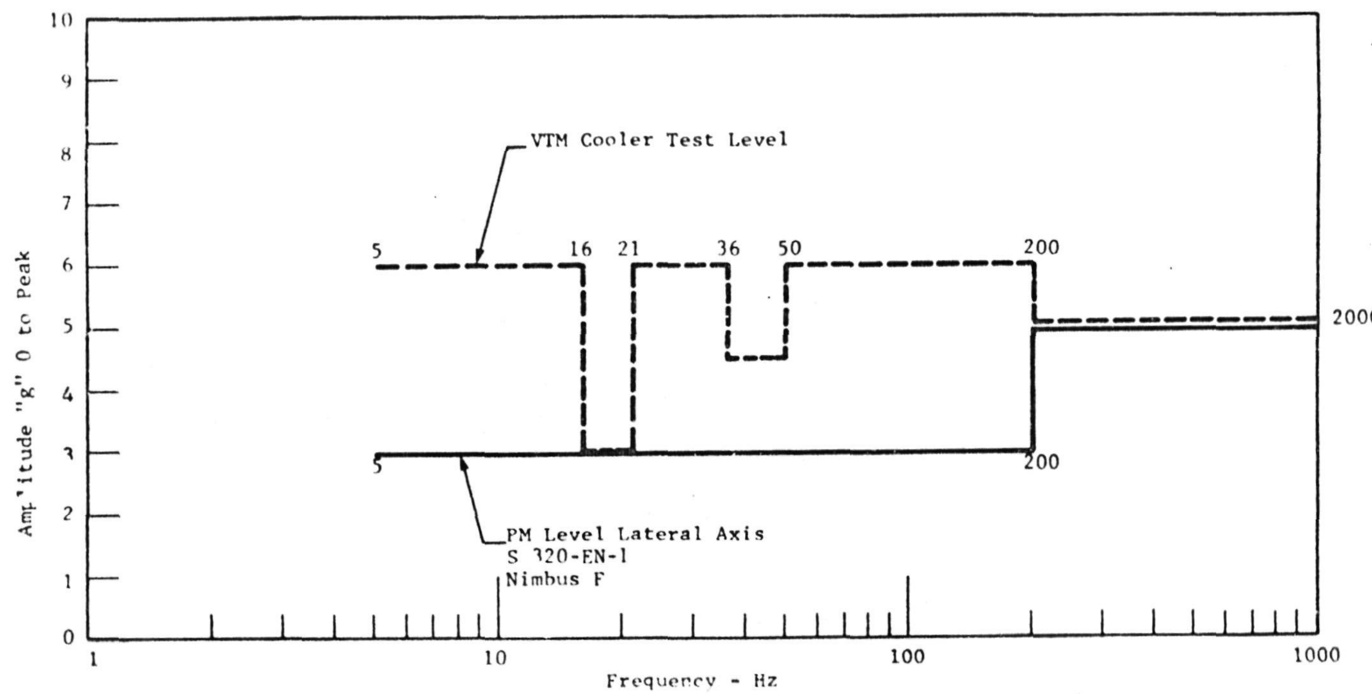


Figure 3-11 VTM LRIR COOLER VIBRATION TEST LATERAL AXIS

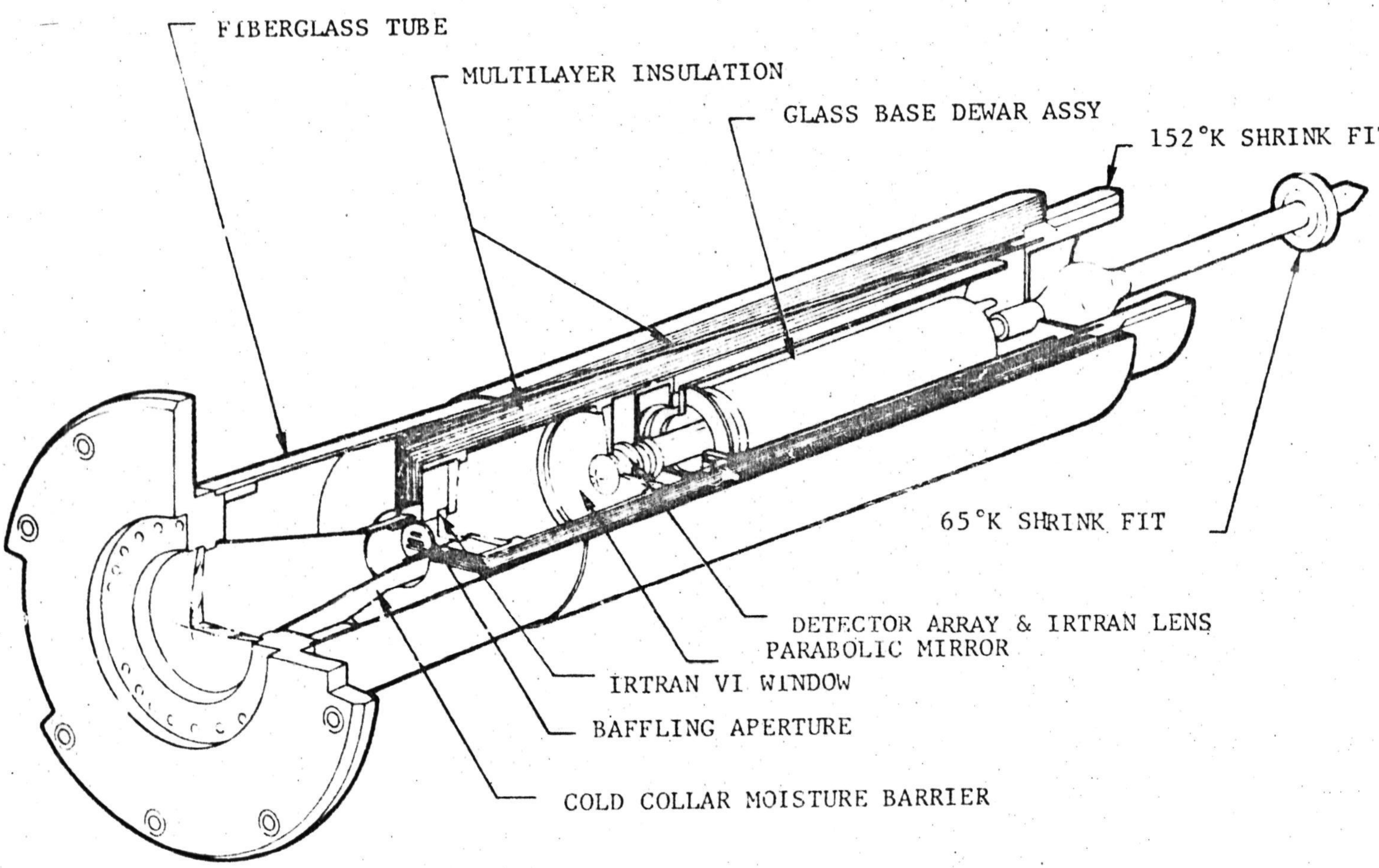


Figure 3-12 DETECTOR CAPSULE ASSEMBLY

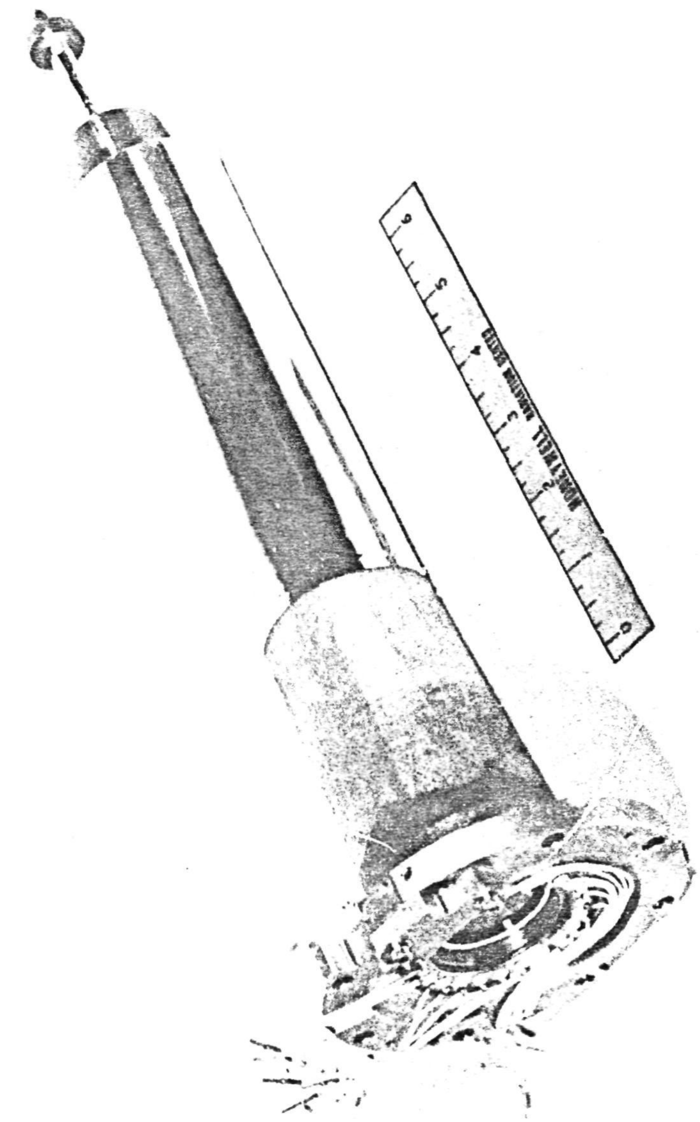


Figure 3.13 DETECTOR CAPSULE ASSEMBLY

Table 3-1

THERMAL HEAT LOADING

	CALCULATED HEAT LOAD (milliwatts)		MEASURED HEAT LOAD (milliwatts)		COMPUTED LIFE TIME (months)	
	METHANE	AMMONIA	METHANE	AMMONIA	METHANE	AMMONIA
INITIAL DESIGN (4-72)						
DCA (with Bias)	40	32				
Cooler	49	212				
	89	244			17	15.7
EM DESIGN						
DCA (with Bias)	57	70	63	91		
Cooler	95	225	128	175		
Integration Heat Load	0	0	17	(-26)		
	152	295	208	240	7.4	16
PM-2 DESIGN						
DCA (with Bias)	53	81	48	95		
Cooler	73	194	137	201		
Intergration Heat Load	0	0	14	(-56)		
	126	275	199	240	7.6	16

To meet these objectives HRC has preempted the entire volume contained within the LMSC support tube column (identified as support tube No. 1).

Within this volume the DCA is supported from a mounting flange containing the DCA feedthrough electrical terminals and the 300°K Irtran VI condensing lens. Attached to the mounting flange is a thin wall tapered fiberglass tube that supports the evacuated detector capsule dewar assembly. The entire DCA is decoupled structurally from the cryogen tank system. The temperature gradient along the support tube traverses the temperature range from the ammonia shrink fit coupling (NH_3 at 152°K) to the outer shell at 300°K. Manganen detector lead wires from the 152°K cold end of the DCA capsule to the 300°K flange terminals are bonded to the interior of the 16 mil fiberglass tube.

At the cold end of the tapered support tube, a bonded junction is made to the Kovar support tube of the dewar which functions as the male half of the 152°K shrink-fit coupling and also supports the evacuated dewar and mirror housing assembly. The female half of the 152°K coupling is made of copper and is connected to the solid cryogen cooler through a flexible coupling formed of numerous No. 36 A.W.G. copper wires.

The mirror housing assembly has been made from stainless steel because its properties are compatible with the kovar mirror housing end cap and the kovar window and cap. The kovar window and cap provides the material compatibility necessary for metallurgically sealing the dewar with the Irtran VI window. The parabolic mirrors are made from stainless steel to match the temperature coefficient of the stainless steel housing assembly.

A second shrink fit molybdenum/copper coupling is used to connect the methane (CH_4 at 65°K) tank to the detectors. The heat transfer path from the detectors in the sealed dewar to the methane cryogen incorporates a copper wire flexible braid soldered to a copper conduction rod to link the detectors to the CH_4. An IFOV mask placed two mils above the detectors provides the field of view (FOV) defining aperture. An FOV mask is used rather than the detectors to define the field of view because of the two arc second system parallelism requirement for the long sides of the two CO_2 channels. The FOV mask also provides a cold station, 65°K for the spectral filters which are bonded to the FOV mask above each respective detector. An Irtran VI lens is the final refractive element (f/1 at the detectors) and completes the lens housing and detector assembly. Lead connections from the detectors are made to a lead matrix array which provides the means for external dewar connections.

The evacuated capsule containing the detectors, reflective parabolic relay optics, and final condensing optics becomes the heart of the DCA. The dewar is vacuum baked and pinched-off, and maintained through the use of barium getters fired down into the glass base well. The primary emphasis for the incorporation of the permanently evacuated detector enclosure is to prevent the condensation of undesirable materials upon the detectors and lenses at 65°K. To obtain an acceptably low heat transfer between the 152°K source and the 65°K detectors, a glass re-entrant well glass base is used. Experience also shows that optical alignment stability is achieved by this construction.

Surrounding the evacuated capsule and also the exterior of the 152°K cold end of the DCA support, is a pair of multi-layer insulation (MLI) blankets. The MLI blankets are composed of 10 layers and 6 layers, respectively, of 1/4 mil double aluminized mylar with double layers of silk bridal veil spacers. Layer thickness is set at 0.75 mm each and each layer will be preformed on an individual mandrel. Thermally draw formed heavy aluminized mylar is used in formed MLI penetrations and protective shells. This shell technique is especially important in the area of the baffling aperture focal plane so that the MLI is evacuated near the 152°K base and does not vent in the vicinity of the aperture, thus reducing condensable gases from the MLI in that area.

Thermal design requirements dictated that an aperture cap (thermal shield) be used at the 152°K focal plane entrance to the evacuated capsule in order to minimize high energy radiation heat transfer from the warmer 300°K part of the LRIR to the solid cryogen. This aperture plate is not optically constraining but does form part of a black cavity entrance trap prior to the first Irtran VI seal window on the front of the evacuated capsule. This cavity provides thermal absorption and also absorption of any condensable gas molecules passing through the apertures and prior to their impinging on the seal window. Condensations on this seal window are unimportant in terms of thermal emittance; the only concern is one of window transmission through certain absorption bands, such as water (ice). In addition, a moisture baffle attaches to the DCA mounting flange assembly and extends down to the kovar window on the static sealed dewar. The aperture cap attached to the window end cap, the moisture barrier, and the MLI end cap provide a cold trap for moisture that has not been removed during fabrication and assembly of the DCA.

3.3 LRIR ELECTRONICS

The LRIR electronics are packaged in three separate assemblies: 1. Interface Electronics Unit (IEU) Figure 3-14, 2. Frame Housing Assembly Electronics Unit (FEU) Figure 3-15, 3. Preamplifier Assembly.

The functions performed by each assembly and the circuit cards associated with each function are listed in Figure 3-16.

3.3.1 Signal Processing Electronics

The most important components of the LRIR electronics are the signal processing circuits. The preamplifier, video processor, A/D converter, and data processing electronics transforms the modulated radiation incident on the detectors, into 12 bit digital words whose value is linearly proportional ($\approx 2\%$) to the modulated amplitude of incident radiation. A detailed block diagram of the signal processing electronics is shown in Figure 3-17.

The scanned scene collimated energy collected by the scan mirror is focused by the off-axis parabolic primary mirror to the primary optics focal point. At this focus point the energy is modulated by a tuning fork light chopper. The energy is then recollimated by a secondary off-axis parabolic mirror onto a folding flat which directs the recollimated beam from the Optical Mechanical Package (OMP) to the collecting lens of the Detector Capsule Assembly (DCA). Inside the DCA, the energy is focused by relay optics and a final focusing lens onto the detector array.

The chopper modulation frequency is 943 Hz and was selected to center the information bandpass at a frequency removed from the 1/f noise of the detectors and the preamplifier semiconductors

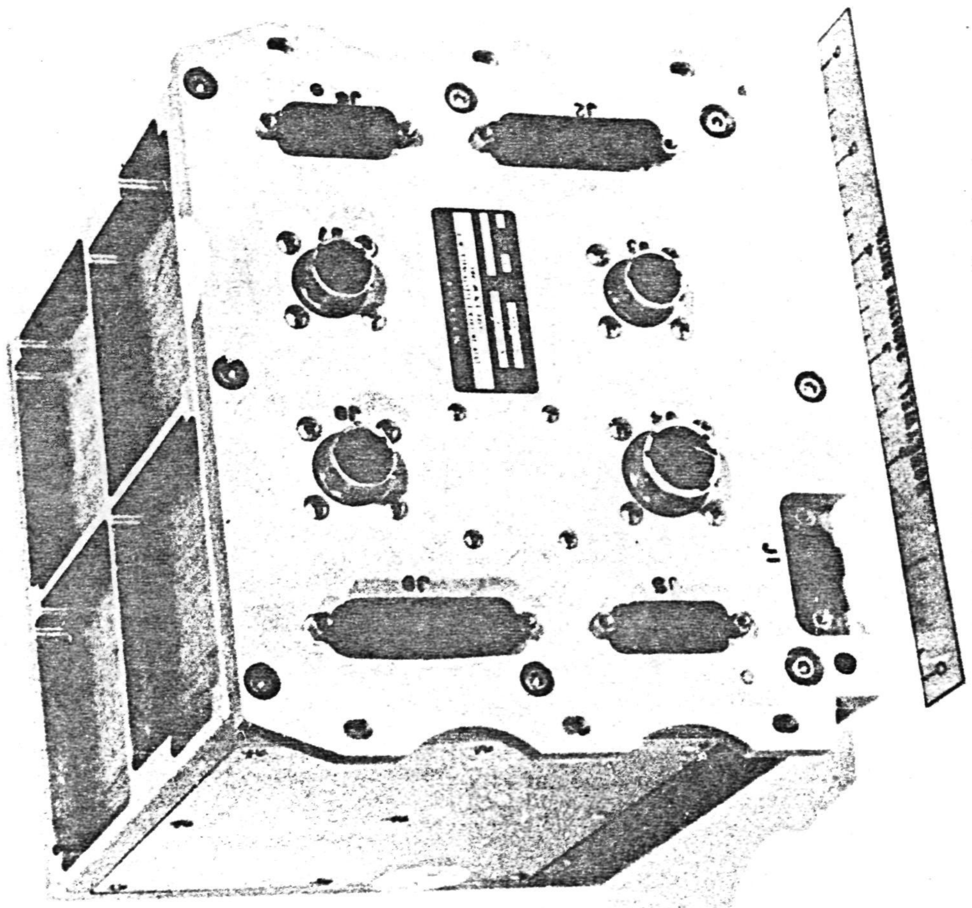


Figure 3-14 INTERFACE ELECTRONIC UNIT

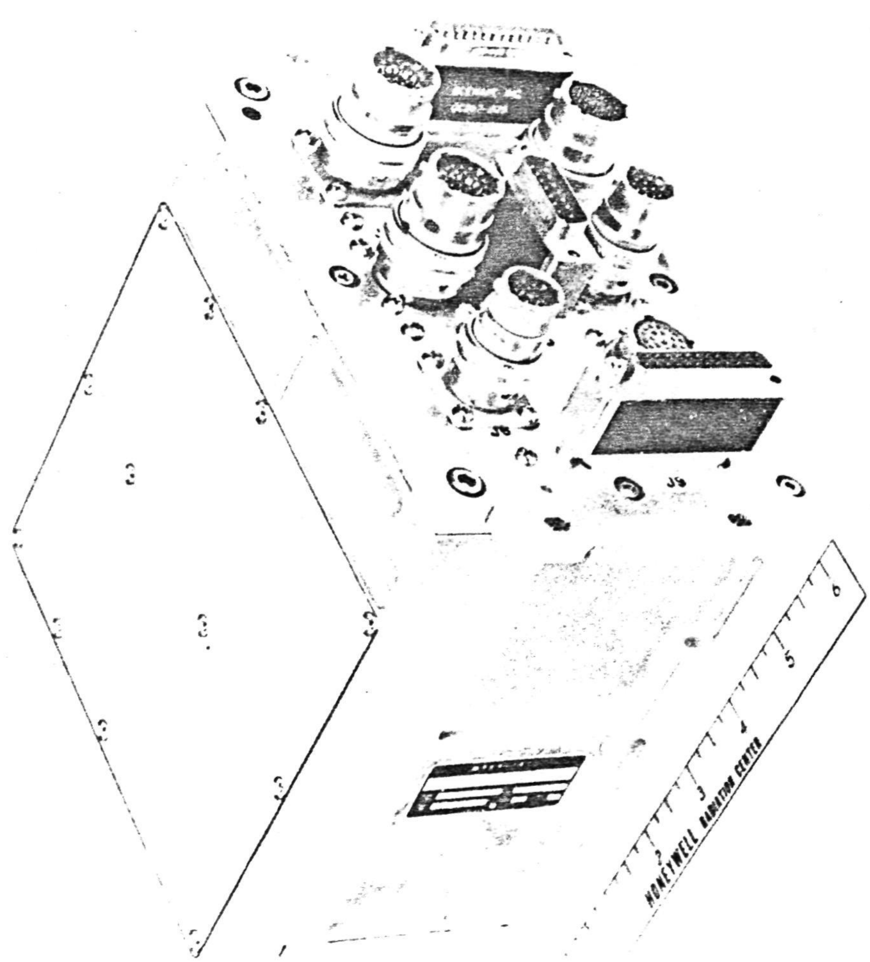


Figure 3-15 FRAME HOUSING ELECTRONIC UNIT

PREAMP ASSEMBLY	
FUNCTION	CIRCUIT CARDS
Amplify detector signal	5 Preamplifiers
Produce VIP analog signal corresponding to DCA cold tip rod temperature variations of 61°K to 71°K	Detector Temperature Monitor
Produce VIP analog signal corresponding to DCA warm coupling temperature variations of 61°K to 261°K	Cryogen Shield Temperature Monitor
Produce signal corresponding to IFC temperature variations of 290°K to 340°K and control IFC temp. to 320°K ±1°K	IFC Temperature Monitor
Distribute power within assembly	Power Distribution Board

INTERFACE ELECTRONICS UNIT	
FUNCTION	CIRCUIT CARDS
Demodulate, filter and multiplex preamp signals	2 Video Processors
Generate timing signals from 200KHz S/C clock	Clock Countdown
Configure output data word	Readout Control Logic
Process S/C Time Code for insertion into data word	Spacecraft Time Formatting Logic
Generate digital word from analog data	A/D Converter
Generate timing for A/D Converter	A/D Control
Interface with S/C data storage system	Data Buffer Register
Generate power requirements from S/C 24.5Vdc	Power Supply

FRAME HOUSING ASSEMBLY ELECTRONICS UNIT	
FUNCTION	CIRCUIT CARDS
Generate scan mirror drive signals	Scan Generator and Signal Logic
Generate scan mirror position signal and provide drive for optical light chopper	RVDT and 1 KHz Chopper Electronics
Control scan mirror and develop limb track position voltage	Scan Motor Drive and Limb Track Electronics
Produce VIP analog signal corresponding to 0°C to 50°C temperature variation for 7 temperature sensors located throughout experiment	Reference Voltage and Housekeeping Buffers
Interface with S/C command matrix and produce VIP Digital 'B' signals for command verification	Command Logic

Figure 3-16 FUNCTIONS OF LRIR ELECTRONICS

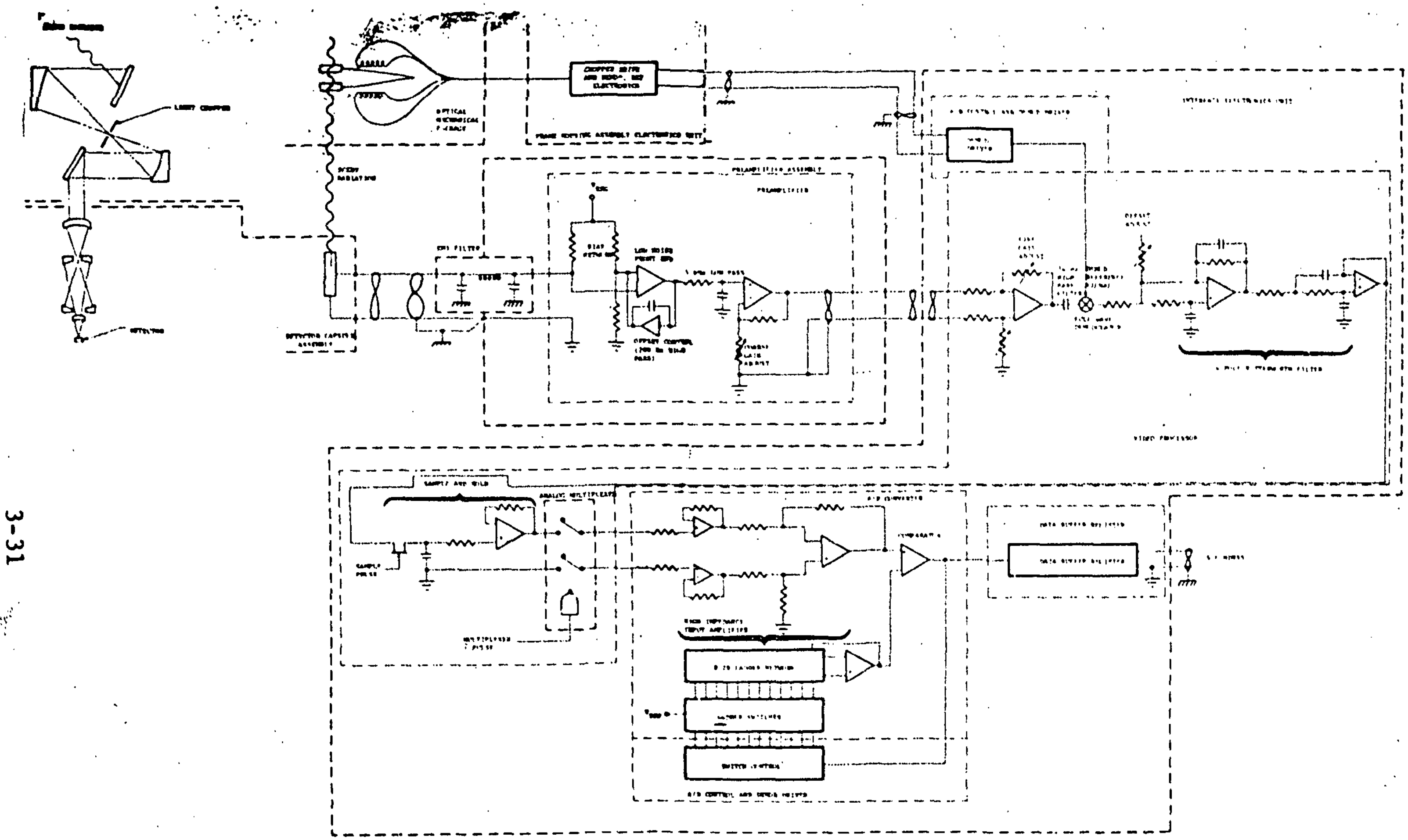


Figure 3-17 LRIR SIGNAL PROCESSING ELECTRONICS

but such that beat frequencies between the demodulator signal spectrum and all clock generated signal spectrums lie outside the information bandpass. This is necessary to prevent coherent noise that is either conductively coupled or capacitively coupled onto the preamplifier signal from passing through the 4 pole Butterworth filter which follows the demodulator.

The signal generated by the detector is fed through an EMI filter to the input of a low-noise, high gain bandpass preamplifier. The preamplifier has an equivalent input noise voltage of approximately $1nv/\sqrt{Hz}$ at the modulation frequency. Its bandwidth is 200 Hz to 5 kHz and it has an adjustable gain from 3300 to 104,000. The input bias network will handle bias currents from fractions of a milliampere to about 20 milliamperes. The signal ground at the input of the preamplifier is tied to chassis to eliminate noise coupling from the chassis to the preamplifier input circuit.

There are five preamplifiers in the PM LRIR of which four are operative (one disabled due to detector failure in one of the two water vapor detectors). The bias currents and preamplifier gains are listed in Table 3-2.

The preamplifier output signal is carried via a twisted shielded pair, with the shield tied to signal ground at the preamplifier, to the video processor which is located in the Interface Electronics Unit. The video processor receives the signal differentially in a variable gain inverting amplifier. The total system gain is set initially in the preamplifier from detector parameter measurements performed during final DCA testing. Final system gain adjustments are made in the video processor during system integration.

The output from the first stage amplifier of the video processor is a-c coupled to a full wave demodulator designed such that the coupling capacitor sees the same impedance regardless of the state of the demodulator. The demodulator gain is +1, -1 max; deviating from this only by the phase error between the signal and the demodulator reference.

From the demodulator, the signal passes through a 4 pole Butterworth filter which sets the total system electronic bandwidth. The bandwidth is selected based upon the scan rate of the system. The dc gain through the filter is +1. An adjustable offset voltage is used to counter the radiometric offset of the optical system.

Table 3-2

LRIR PREAMPLIFIER CHARACTERISTICS

PRAMPLIFIER	BIAS CURRENT	VOLTAGE GAIN	FREQUENCY RESPONSE
CHANNEL 1 (CO_2) (NB)	1.5 ma	47,400	200 Hz to 5 KHz
CHANNEL 2 (CO_2) (BB)	4.5 ma	13,750	200 Hz to 5 KHz
CHANNEL 3 (O_3)	1.0 ma	28,000	200 Hz to 5 KHz
CHANNEL 4L (H_2O)	3.0 ma	26,900	200 Hz to 5 KHz
CHANNEL 4R (H_2O)	INOPERATIVE		

NB means narrow spectral band

BB means broad spectral band

This adjustment is made during system integration with the instrument at room ambient. Sufficient dynamic range is allowed for variations in radiometric offset with varying instrument temperature.

After the filter, the signal is sampled and held on a capacitor until it can be multiplexed through the A/D converter. Sampling rate is 55 Hz clock controlled during non-scanning modes and is a nominal 45 Hz controlled by the optical encoder during scanning modes.

The analog multiplexer is the last function on the video processor circuit card. There are four video processor circuits in LRIR. Their gains and bandwidths are listed in Table 3-3. The input of the A/D converter is a high impedance common mode configuration amplifier with a gain of -1. The A/D converter is a 12-bit successive approximation type with a cycle time of 3 msec. From the A/D converter the digital information is parallel transferred into a data buffer register from which it is serially shifted at a 4 kHz rate onto the spacecraft High Data Rate Storage System (HDRSS).

3.3.2 Servo System Electronics

The collecting element for LRIR is the scan mirror. Scan mirror motion is controlled by the servo system electronics with a constant velocity of one degree per second to obtain a nominal data sampling rate of 45 samples per second. The optical encoder located on the scan mirror shaft provides digital state transitions every 39.55 arc-seconds of shaft rotation. These state transitions initiate a sampling and data conversion cycle at a nominal rate of once every 22.0 msec with a maximum variation of not more than ±2.5 msec during mirror scanning modes. During a calibration sequence which occurs every 32 seconds, the scan mirror must also point toward deep space and hold that position, and drive against a soft stop to view the In-Flight Calibrator (IFC) blackbody. All these requirements (summarized in Table 3-4) are satisfied by the servo system electronics.

The servo system electronics as shown in Figure 3-18 consists of a mirror drive signal generator, a mirror position signal, and a servo amplifier to power the torque motor according to the error signal generated by the difference between the drive signal and the position signal.

Table 3-3

LRIR VIDEO PROCESSOR CHARACTERISTICS

VIDEO PROCESSOR	VOLTAGE GAIN	BANDWIDTH	OFFSET
CHANNEL 1 CO_2 (NB)	3.16	17 Hz	+4.826V
CHANNEL 2 CO_2 (BB)	3.32	17 Hz	+4.486V
CHANNEL 3 O_3	3.32	17 Hz	+3.574V
CHANNEL 4 H_2O	11.0	14 Hz	+4.775V

Table 3-4

LRIR SERVO SYSTEM REQUIREMENTS

SCAN MIRROR MODE OF OPERATION	SCAN MIRROR POINTING POSITION	SCAN MIRROR VELOCITY
ACQUISITION SCAN	±5° line-of-sight centered about OMP centerline (31.07° down from local horizontal)	1°/second up and down, 20 sec. scan period
ADAPTIVE SCAN	±2° line-of-sight centered about the 40% point of channel 1 (CO_2 NB) peak radiance	1°/second up and down, 4 sec. scan period
SPACE CALIBRATE HOLD	≈8° above OMP centerline	Zero velocity
SOURCE CALIBRATE HOLD	≈31° above OMP centerline	Zero velocity
AUTOMATIC SEQUENCE	≈8° above OMP centerline for 1 second and then ≈31° above OMP centerline for 2 seconds	Zero velocity at fixed positions and a slew rate of ≈88°/second between positions

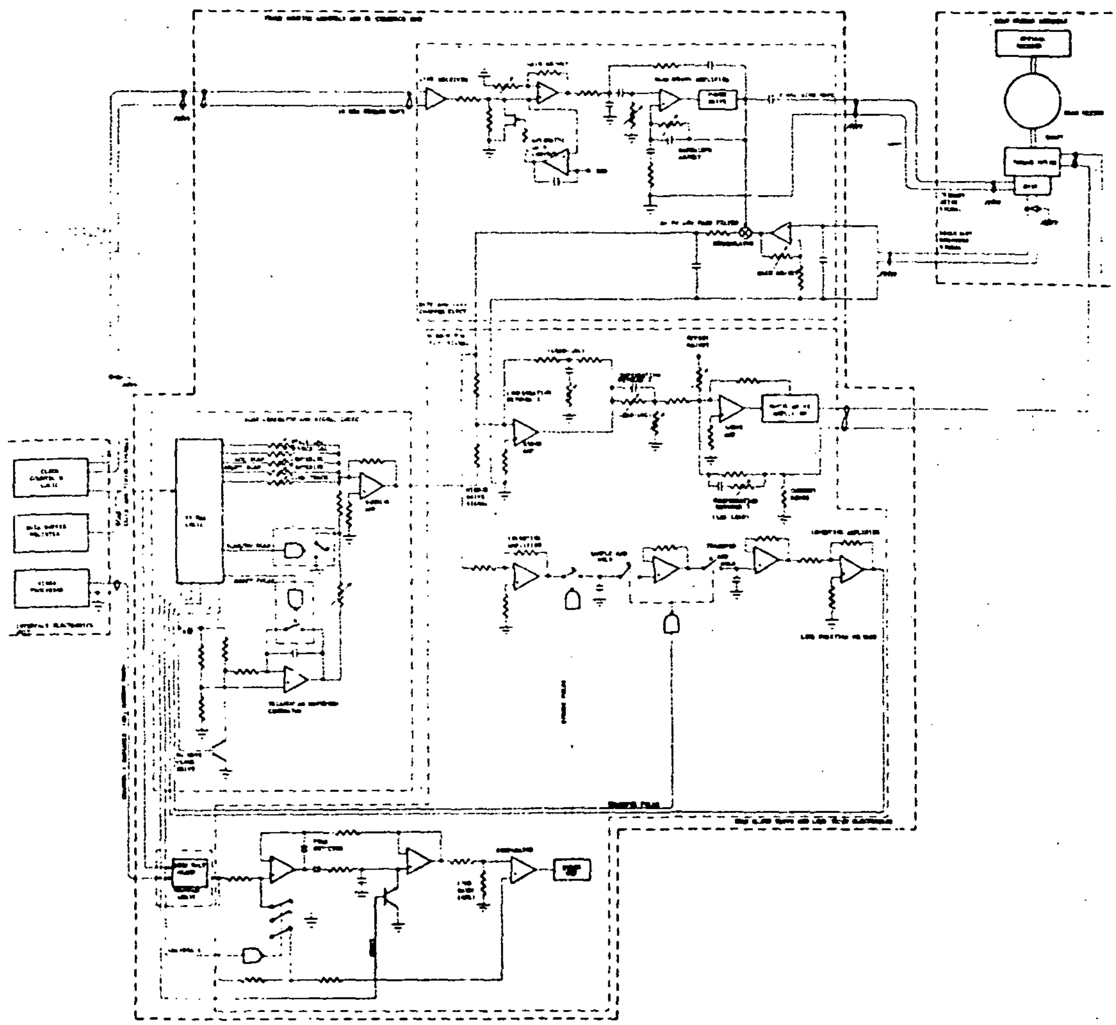


Figure 3-18 LRIR SERVO SYSTEM ELECTRONICS

A Rotary Variable Differential Transformer (RVDT) is used as a shaft position sensor. Its primary winding is supplied with a 10 kHz, 6 Vrms sine wave generated by passing an amplitude controlled 10 kHz square wave through a narrow bandpass amplifier. The secondary winding output voltage amplitude varies linearly with shaft angle over an angular range of ±70°.

To be compatible with the mirror drive signal, the RVDT secondary voltage is amplified, synchronously demodulated, and low pass filtered. Synchronous demodulation is necessary to get positive and negative voltages about the RVDT null point. The mirror position signal electronics are located on the RVDT and 1 kHz Chopper Electronics board in the FEU. The mirror position signal is sent to the input of the error amplifier to be summed with the mirror drive signal.

The Scan Generator and Signal Logic board located in the FEU receives scan clock and timing signals from the IEU and generates the triangular waveforms and dc voltage levels that constitute the mirror drive signals. The signal logic portion of the card combines mode commands and scan clocks to generate the appropriate signals for the dc level switches and triangular waveform producing the output voltage that is sent to the input of the servo drive error amplifier. Table 3-5 details the switch states and output voltage for the different modes of operation.

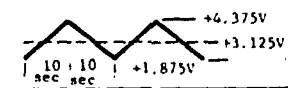
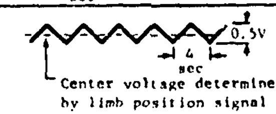
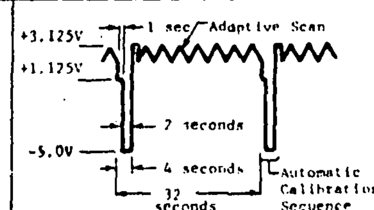
The error amplifier provides the drive for the servo motor drive amplifier. Maximum current available to the torque motor is ~270 ma resulting in a maximum torque of 4.2 in-oz. Normal run current is ~20 ma peak-to-peak resulting in a motor torque of 0.30 in-oz. Loop compensation is accomplished in the forward signal path consisting of lead networks in the error and servo amplifiers. Figure 3-19 shows the servo loop response and the components of that response due to the compensation networks shown in Figure 3-18.

The offset adjust provided at the input to the servo amplifier is used to eliminate electronic offsets due to the error amplifier and motor drive amplifier. The amount of offset required is determined by grounding the mirror drive signal input and the mirror position signal input and varying the offset voltage until zero current flows through the torque motor current sense resistor.

The limb position voltage is generated to position the center of the adaptive scan at the earth's limb. This concept results in

Table 3-5

SCAN GENERATOR OPERATION

MODE OF OPERATION	SOURCE CAL. SWITCH	SPACE CAL. SWITCH	ACQ. SCAN CENT. SWITCH	ADAPT. SCAN CENT. SWITCH	LIMB TRACK SWITCH	ONP ℄ SWITCH	SCAN SWITCH	SCAN CLOCK	OUTPUT WAVEFORM
ACQUISITION SCAN	OFF	OFF	ON	OFF	OFF	ON	ON	0.05 Hz	
ADAPTIVE SCAN	OFF	OFF	OFF	ON	ON	OFF	ON	0.25 Hz	
SPACE CAL. HOLD	OFF	ON	OFF	OFF	OFF	ON	OFF	0	+1.125 VOLTS
SOURCE CAL. HOLD	ON	OFF	OFF	OFF	OFF	ON	OFF	0	-5.0 VOLTS to assure overdrive into soft stop
AUTOMATIC CALIBRATE SEQUENCE	ON for 2 secs. every 32 seconds	ON for 1 sec. every 32 seconds	OFF	ON for 28 sec. out of 32 seconds	ON for 28 sec. out of 32 seconds	OFF	ON for 28 sec out of 32 seconds	0.25 Hz	

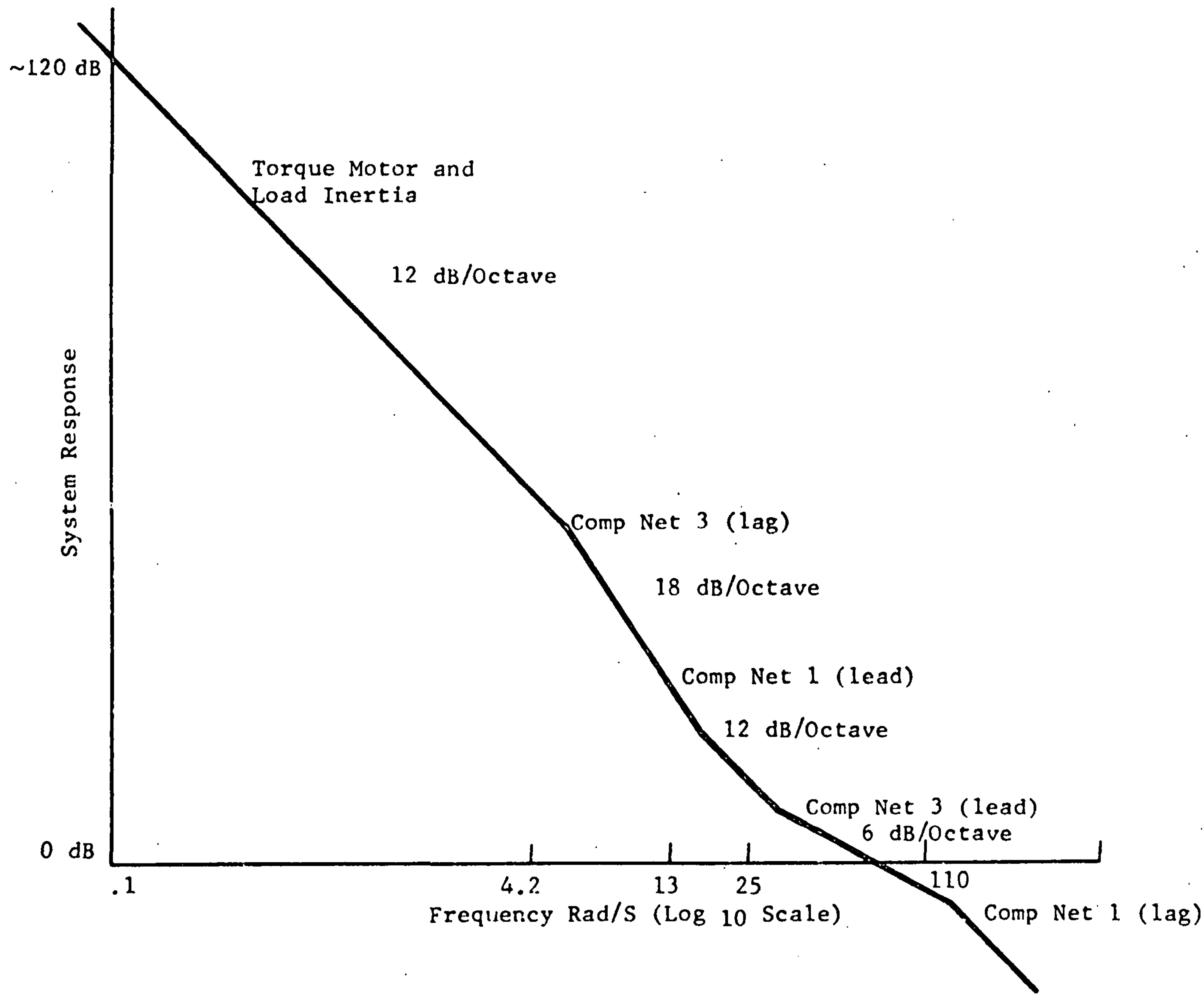


Figure 3-19 SERVO SYSTEM OPEN LOOP RESPONSE

the most desireable data because it allows for a high sample density in the area of scientific interest. To determine the limb position voltage, the channel 1 radiance voltage is zero clamped and then peak detected, and a percentage of the peak voltage is compared to the radiance profile. The percentage of peak voltage is chosen to represent the value of radiance at the earth's limb corresponding to a tangent height of 40 KM. The comparator transistion creates a strobe pulse which strobes the mirror position signal when the radiance profile crosses the 40% of peak voltage point. The strobed position signal represents the shaft angle corresponding to the scan mirror pointing at the earth's limb. This voltage, being held on a capacitor, is transferred to an output hold capacitor and buffer during scan turnaround to eliminate perturbations in the scan. The voltage then goes to the scan generator circuit for insertion into the drive signal as a bias for the adaptive scan waveform.

3.3.3 Command Relays

Commands are sent from the ground station through the spacecraft command pulse matrix to LRIR. LRIR uses relays to receive command pulses in order to provide isolation from the spacecraft. If ON/OFF control is required the relays are latching types. If no ON/OFF control is required, the momentary contact closure is used to set an integrated circuit latch which is reset according to rules established by the command decoder logic and shown in Figure 3-20.

Relay coil configuration is specified on page 3-10 of Nimbus E and F Experiment Interface Requirements (GSFC X450-68-415) and rigidly adhered to in LRIR as shown in Figure 3-21.

Commands received by LRIR are listed in Table 3-6 along with the relay type utilized.

3.3.4 VIP Digital 'B' Inputs

LRIR uses the spacecraft VIP Digital 'B' telemetry for verification of commands. Requirements for interfacing with VIP Digital 'B' can be found on pages 4-2 and 4-6 of Nimbus E and F Experiment Interface Requirements (GSFC X450-68-415). These requirements are rigidly adhered to in LRIR.

A typical command verification circuit is shown in Figure 3-22, command verification signals are listed in Table 3-7.

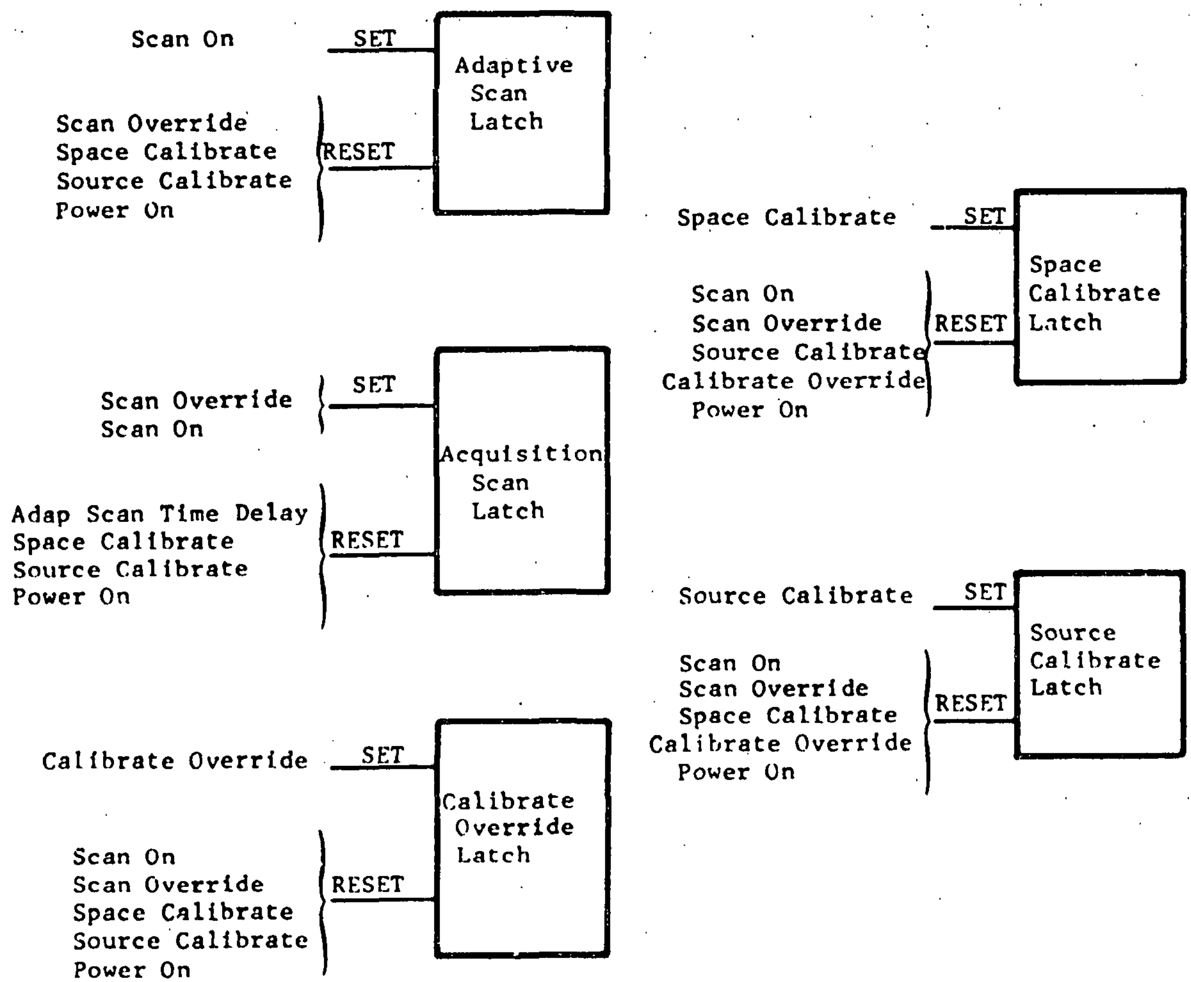
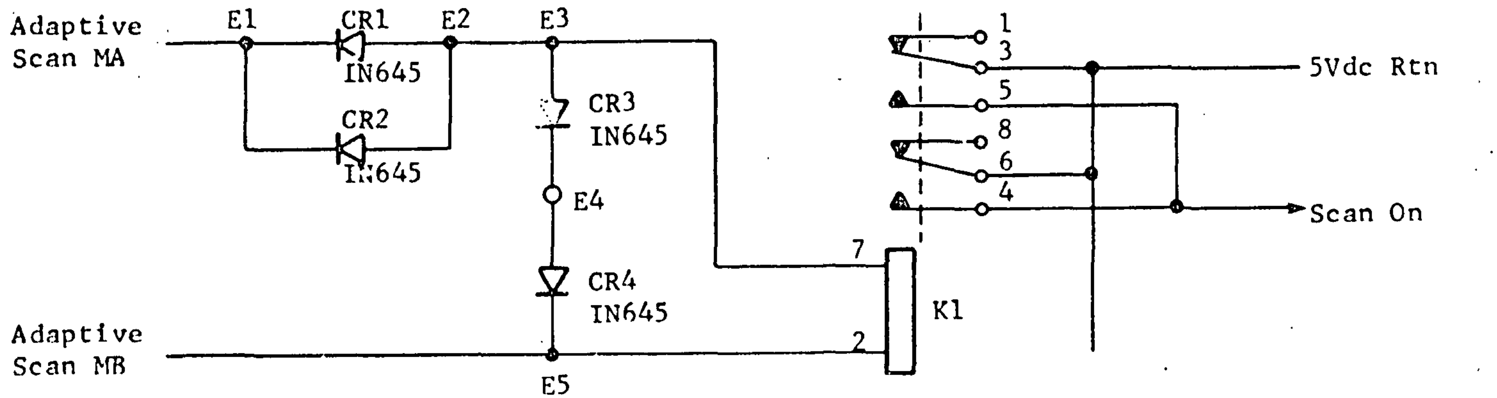
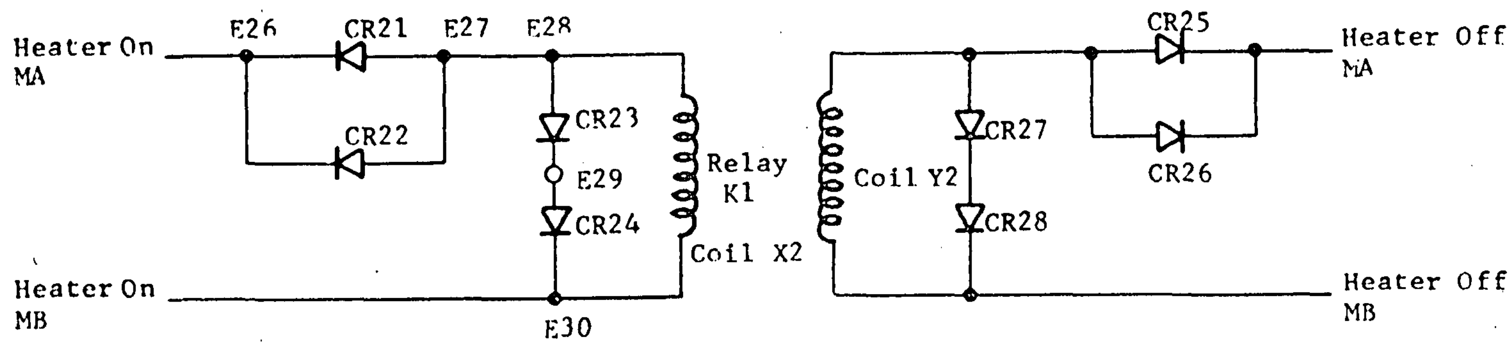


Figure 3-20 SCAN COMMAND OPERATION



Typical Non-Latching



Typical Latching

Figure 3-21 RELAY COIL CONFIGURATION

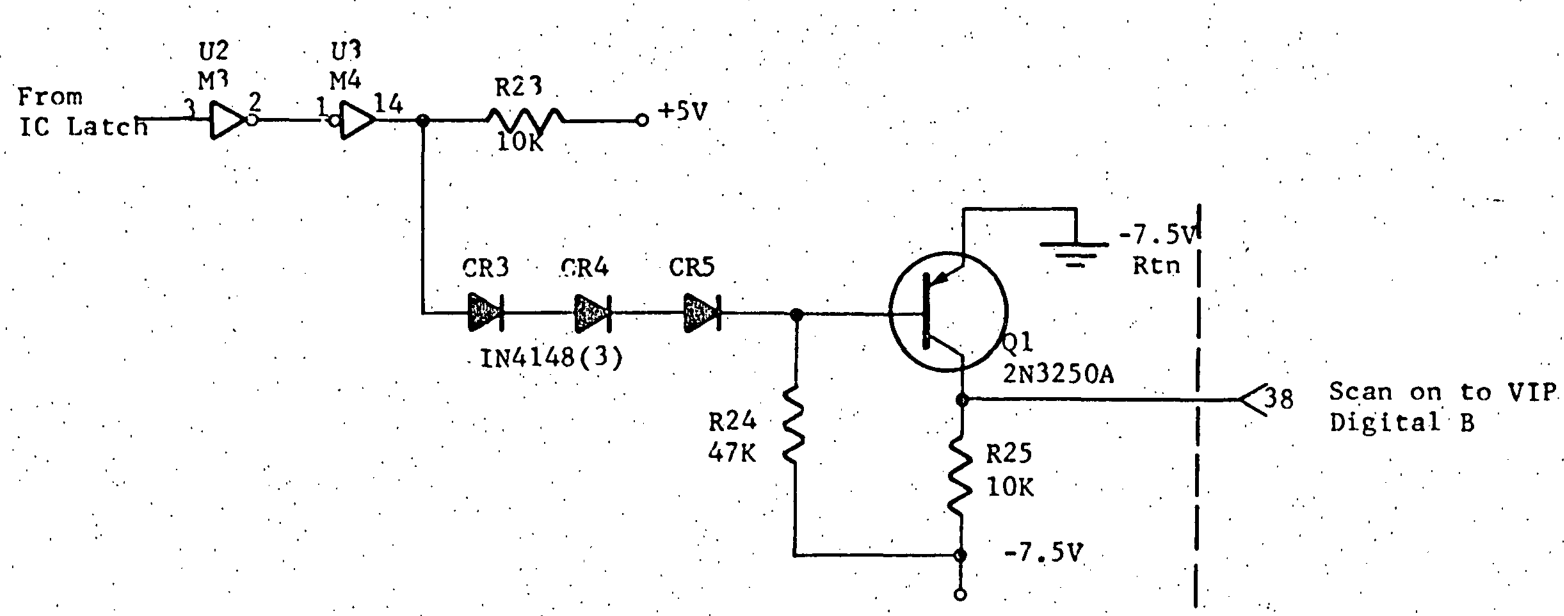


Figure 3-22 TYPICAL COMMAND VERIFICATION CIRCUIT

Table 3-6

LRIR COMMANDS

COMMAND	FUNCTION	RELAY TYPE
Electronics On/Off	Controls power to LRIR	Latching
Cage/Uncage	Powers mirror in launch mode against a soft from -24.5V S/C power/removes -24.5V power from mirror	Latching
Heater On/Off	Controls power to DCA Heater	Latching
Adaptive Scan	Initiates adaptive scan mode of operation	Non-Latching
Acquisition Scan	Inititates acquisition scan mode of operation	Non-Latching
Space Calibrate	Commands the pointing position of the scan mirror to deep space	Non-Latching
Source Calibrate	Commands the pointing position of the scan mirror to the in-flight calibration blackbody	Non-Latching
Calibrate Override	Removes any calibrate hold commands and inhibits automatic calibration sequence	Non-Latching

Table 3-7

COMMAND VERIFICATION SIGNALS

VIP Digital 'B' Input	Function
Cage/Uncage	"0" state is mirror uncaged "1" state is mirror caged
Electronics On/Off	"0" state is power off "1" state is power on
Heater On/Off	"0" state is DCA heater off "1" state is DCA heater on
Adaptive Scan	"0" state is scan off "1" state is adaptive scan command received
Acquisition Scan	"0" state is scan off "1" state is acquisition scan mode
Space Calibrate	"0" state is space cal. removed "1" state is space cal. command received
Source Calibrate	"0" state is source cal. removed "1" state is source cal. command received
Calibrate Override	"0" state is cal. override removed "1" state is cal. override command received

3.3.5 VIP Analog Inputs

LRIR uses the spacecraft VIP Analog telemetry for housekeeping data. Requirements for interfacing with VIP Analog can be found on pages 4-2 and 4-6 of Nimbus E and F Experiment Interface Requirements (GSFC X450-68-415). These requirements are rigidly adhered to in LRIR.

A typical housekeeping circuit is shown in Figure 3-23. VIP Analog signals are listed in Table 3-8.

3.3.6 Power Supply

The LRIR power supply is a DC to DC converter configuration supplying regulated power to all LRIR circuits. Figure 3-24 shows a block diagram of the power supply.

Nominal power drawn from the spacecraft -24.5 volts dc supply is 21.6 watts in the scan mode and 29.6 watts in the IFC hold position. During launch 8 watts of s/c regulated power (-24.5V) is required to cage the scan mirror against a soft stop.

Table 3-8

VIP ANALOG SIGNALS

VIP Analog Input	Function	Sampling Frequency
Scan Motor Current	Provide quantitative measure of scan motor current for Scan Mirror Assembly performance monitor	1 per 16 seconds
-15VDC Monitor	Monitor power supply operation	
IEU Temperature	Provide quanititive measure of temperature over the range of 0°C to +63°C at various locations.	
Cryogen Exterior Temperature		
Primary Optics Temperature		
Baffle 1		
Baffle 2		
Blackbody Temperature		
Scan Motor Temperature		
Housing Temperature		
FEU Temperature		
Detector Temperature	Provide quantitative measure of temperature of DCA coldTip Rod over the temperature range of 61°K to 73°K	
Cryogen Shield Temperature	Provide quantitive measure of DCA warm coupling over the temperature range of 61°K to 261°K	
IFC Temperature	Provide quantitive measure of blackbody temperature over the range of 290°K to 353°K	
RVDT Output	Provide quantitative measure of scan mirror position	5 per second

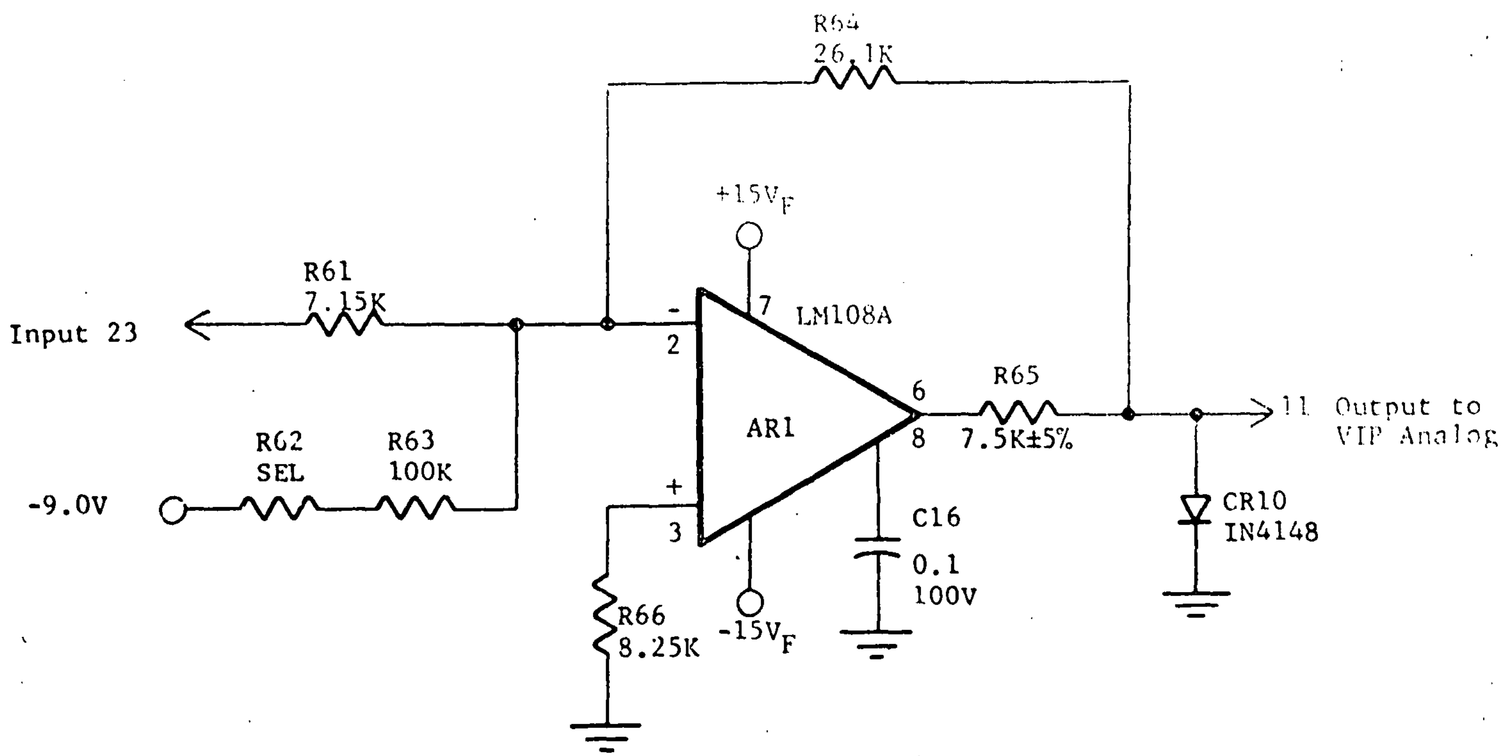


Figure 3-23 TYPICAL HOUSEKEEPING CIRCUIT

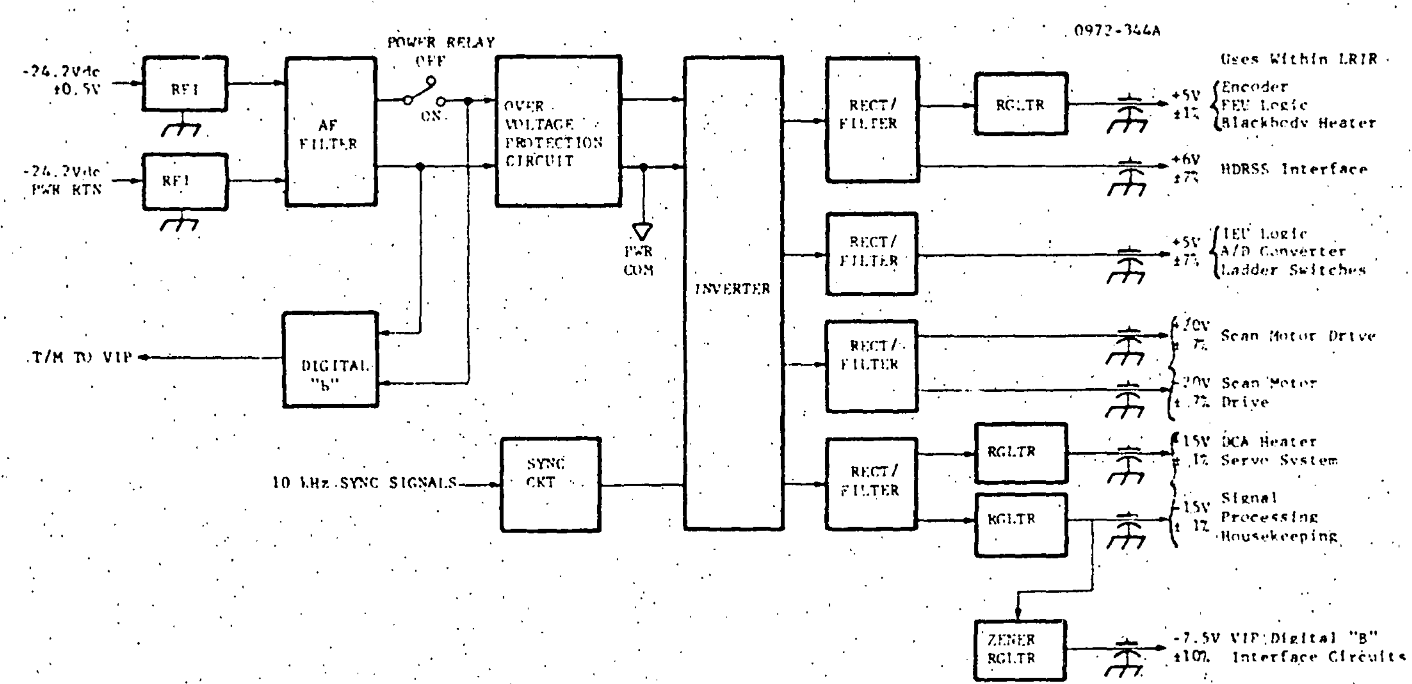


Figure 3-24 LRIR POWER SUPPLY BLOCK DIAGRAM

SECTION 4

LRIR - SPACECRAFT INTERFACE

4.0 INTRODUCTION

4.1 MECHANICAL INTERFACE

The LRIR is hard mounted to the spacecraft with four bolts through the mounting plate of the experiment into locking threads in the underside of the sensory ring. The mounting plate is the structural interface of the opto-mechanical package that is below the sensor ring and the solid cryogen cooler that projects through and above the sensory ring of the spacecraft. Plumbing lines associated with the experiment methane, ammonia fill lines, vacuum line, LN_2 cooling lines project radially to the outer diameter of the spacecraft adjacent to the OMP on the underside of the spacecraft.

Pictures of the FHA showing the cryogen cooler servicing lines are shown in Figures 3-8 and 3-9.

The optical centerline axis of the instrument is located down 31.07° ±.5° from the spacecraft X-Y plane toward the -Z axis direction as shown in Figure 4-12. The scan plane is oriented 32° ±0.5° toward the Nimbus F (+Y) axis as measured from the (-X) axis. See Figure 4-11.

4.2 THERMAL INTERFACE

The LRIR experiment is hard mounted to the sensory ring of the Nimbus F spacecraft. This condition provides an excellent thermal path between the experiment and the spacecraft. Since thermal stability is necessary for both the spacecraft and the experiment, a method must be employed to keep the experiment at a constant temperature throughout various orbital attitudes.

The LRIR uses a technique that combines insulation and a thermal control surface to maintain a relatively constant ambient operating temperature. Except for the aperture surface of the LRIR, all surfaces are insulated with an MLI Blanket that is protected with a fiberglass shell. This insulation package efficiently prevents either the absorption or emission of thermal energy from the experiment.

The thermal control aperture surface is covered with a layer of second surface silverized teflon film. The α/ϵ of this material is in the proper ratio for its area to keep the experiment at a constant temperature. The thermal control surface has been designed for a nominal noon orbit but can be modified if at any time the orbit definition is revised.

4.3 ELECTRICAL INTERFACE

The LRIR interfaces with the NIMBUS F Spacecraft are listed below:

Inputs to LRIR

200-kHz Clock
Spacecraft Time

- Time Code
- Time Strobe

Command Functions
Spacecraft Power

Outputs

HDRSS Data (A, B, and Real Time)
Housekeeping Functions

- VIP Digital 'B'
- VIP Analog

4.3.1 Inputs to LRIR

4.3.1.1 200-kHz Clock - The 200-kHz clock is transformer coupled into the Clock Countdown Logic card of the Interface Electronics Unit. The circuit used to interface with the 200-kHz clock signal is shown in Figure 4-1. The 200-kHz clock signal is combined with spacecraft time signals in connector L1J7 on the Interface Electronics Unit.

4.3.1.2 Spacecraft Time - Spacecraft time inputs to LRIR include Time Code and Time Strobe. Both inputs are direct coupled into the Spacecraft Time Formatting Logic card of the Interface Electronics Unit. The circuits used to interface with spacecraft time inputs are shown in Figures 4-2 and 4-3. Spacecraft time inputs are combined with the 200 kHz in connector L1J7 of the Interface Electronics Unit.

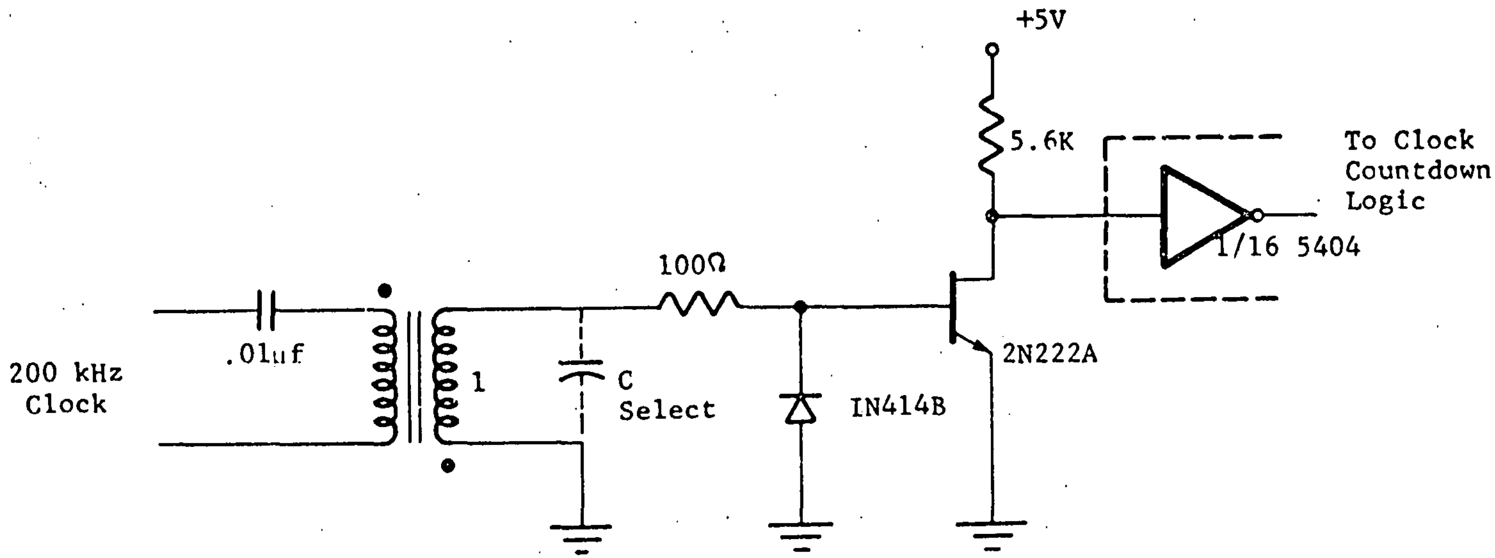
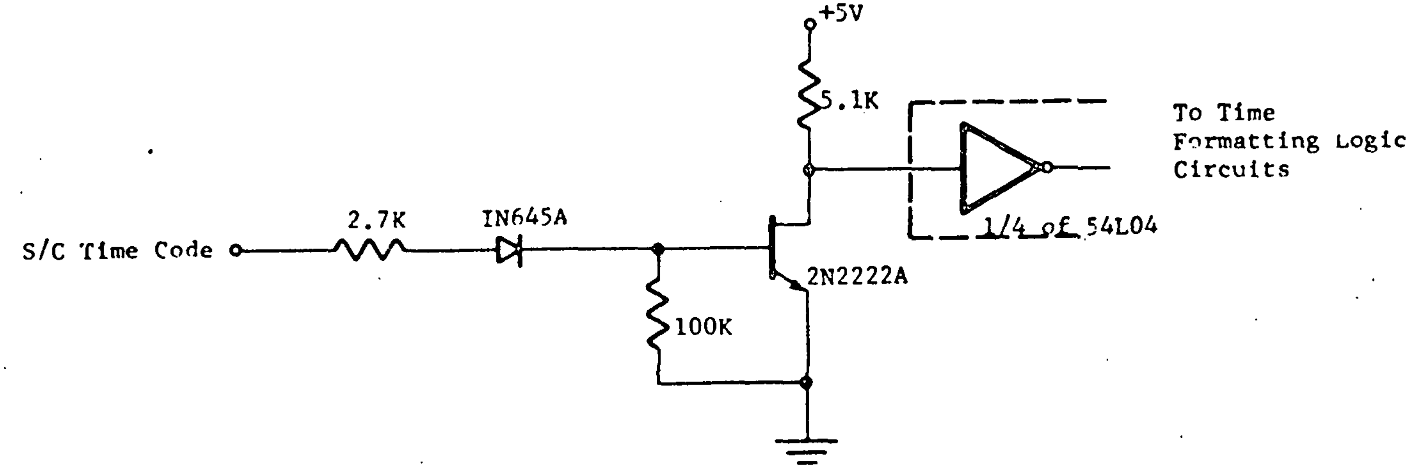


Figure 4-1 200-kHz CLOCK INTERFACE CIRCUIT



Fi[illegible] 2 TIME CODE INTERFACE CIRCUIT

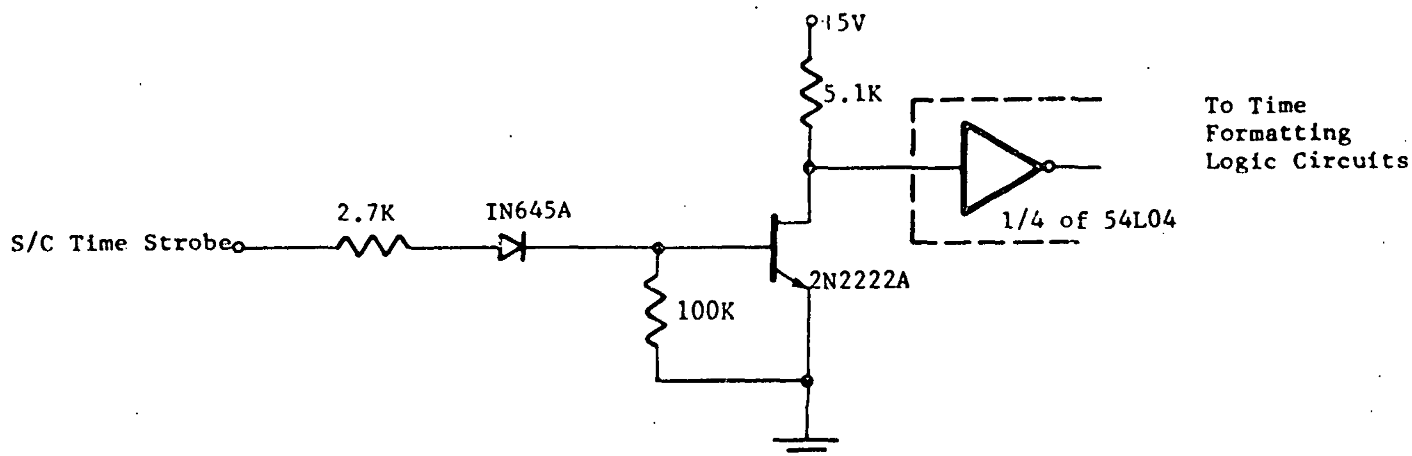


Figure 4-3 TIME STROBE INTERFACE CIRCUIT

4.3.1.3 Command Functions - The LRIR command functions are received from the spacecraft command matrix. The matrix generates a negative-going 24 volt pulse of 40 msec duration and routes the pulse to the appropriate MA, MB lines to create the command.

All commands are contained in one connector, L2J2, on the Frame Housing Assembly Electronics Unit. All command relays except Electronics On/Off are also located in the FEU. The electronics on/off relay is located in the Interface Electronics Unit with the power supply.

Table 4-1 lists the LRIR commands. The interface relay circuit is shown in Figure 3-13.

4.3.1.4 Spacecraft Power - LRIR draws power only from the spacecraft regulated buss (-24.5 Volts). The LRIR power supply is a dc-dc converter configuration to provide isolation between spacecraft power return and LRIR signal ground. (Refer to paragraph 3.3.6).

Power drawn from the spacecraft during various modes of operation is listed in Table 4-2.

LRIR signal ground is connected to the chassis of the Frame Housing Assembly at the input of the preamplifiers to minimize noise coupling into the high gain preamplifiers. There are no other hardwire connections of LRIR signal ground to spacecraft frame. Spacecraft power interfaces through one connector, L1J1, on the Interface Electronics Unit.

4.3.2 Outputs

4.3.2.1 HDRSS Data (A, B, and Real Time) - LRIR utilizes the High Data Rate Storage System (HDRSS) to transmit radiance channel information, In-Flight Calibrator temperature, and housekeeping information concerning mode of operation and status of certain functions. A complete list of HDRSS transmitted data is provided by Table 4-3.

The interface circuit for HDRSS is located on the Data Buffer Register board of the Interface Electronics Unit and is shown in Figure 4-4.

Table 4-1

COMMAND INTERFACE

COMMAND	FUNCTION	INDICATION
Cage/Uncage	Scan Mirror Caging	VIP
Electronics On/Off	Electronics Power	VIP
Scan On	Adaptive Limb Scan	VIP/Data Word
Acquisition Scan (Scan Override)	Continuous Acquisition Scan	VIP/Data Word
Calibrate Override	No Automatic Calibration	VIP
Space Calibrate	Space Calibrate Hold	VIP/Data Word
Source Calibrate	Source Calibrate Hold	VIP/Data Word
Heater On/Off	Backup Heater	VIP

Table 4-2

LRIR POWER CONSUMPTION

LRIR MODE OF OPERATION	NOMINAL POWER CONSUMPTION (from S/C -24.5V)
MIRROR CAGED (during launch only)	8.6 Watts
ACQUISITION SCAN, ADAPTIVE SCAN, (w/o auto cal) SPACE CALIBRATE	21.6 Watts
SOURCE CALIBRATE HOLD	29.6 Watts
ADAPTIVE SCAN WITH AUTOMATIC CALIBRATION SEQUENCE	22.1 Watts

Table 4-3

HDRSS DATA

PARAMETER		CHARACTERISTIC
CHANNEL 1 (CO_2 Narrow Band) Radiance		12 bit word
CHANNEL 2 (CO_2 Broad Band) Radiance		12 bit word
CHANNEL 3 (O_3) Radiance		12 bit word
CHANNEL 4 (H_2O) Radiance		12 bit word
SYNC		11 bit Fixed Pattern
PARITY		1 bit (even or odd)
*IN-FLIGHT CALIBRATOR TEMPERATURE		10 bit word
**A/D CALIBRATION VOLTAGE		12 bit word
**SPACECRAFT TIME		33 bit word
TIME EVENT	STATUS***	12 bit word
SCAN STOPPED	STATUS***	
MISSED DATA	STATUS***	
SCAN REFERENCE ANGLE	STATUS***	
SCAN DIRECTION	STATUS***	
SPACE CALIBRATION MODE	MODE	
SOURCE CALIBRATION MODE	MODE	
SLEWING	MODE	
ACQUISITION SCAN MODE	MODE	
ADAPTIVE SCAN MODE	MODE	
TIME READOUT MODE	MODE	

* Occurs during source calibrate mode only
**Occurs during Time Readout mode only
***There are no status flags during either source calibrate or time readout modes.

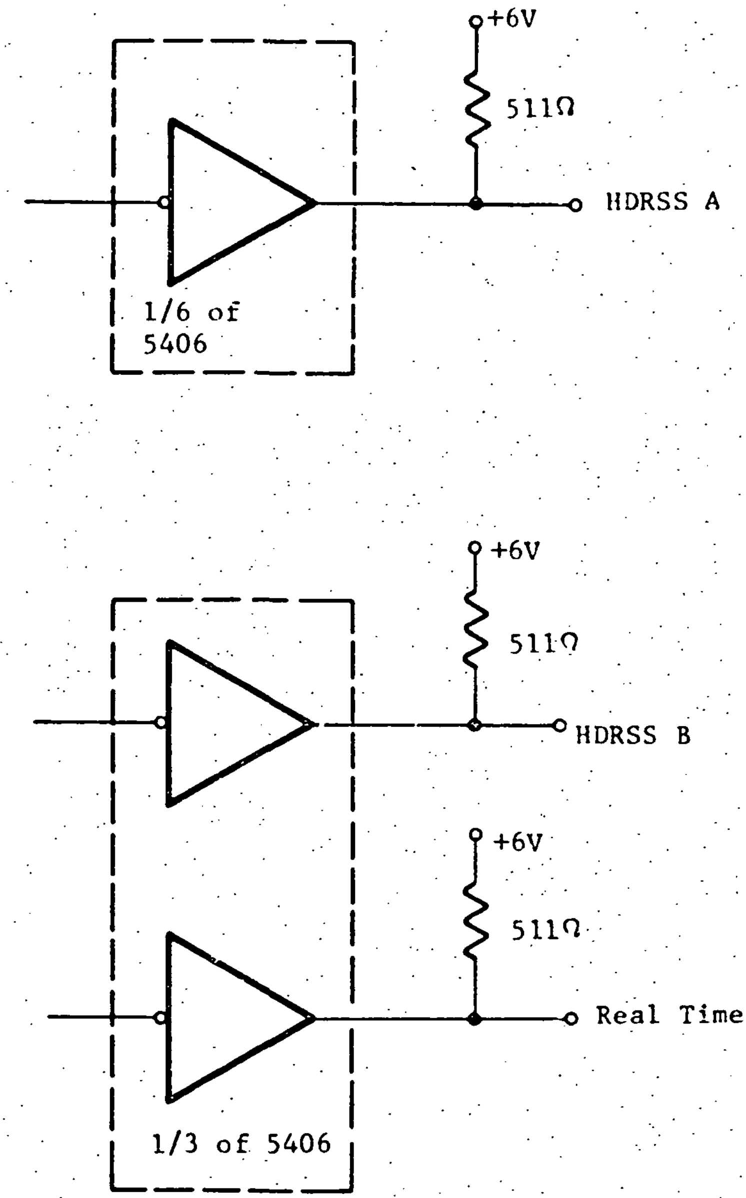


Figure 4-4 HDRSS INTERFACE CIRCUITS

All HDRSS signals interface through one connector, L1J8, on the Interface Electronics Unit.

4.3.2.2 VIP Digital 'B' - VIP Digital 'B' is used by LRIR to provide command verification. Section 3.3.4 discusses LRIR utilization of VIP Digital 'B' and provides an interface circuit diagram (Figure 3-14) and a list of command verification signals (Table 3-7).

All VIP Digital 'B' signals interface through one connector, L2J6, on the Frame Housing Assembly Electronics Unit.

4.3.2.3 VIP Analog - VIP Analog is used by LRIR to transmit housekeeping data. Section 3.3.5 discusses LRIR utilization of VIP Analog and provides an interface circuit diagram Figure 3-15 and a list of VIP Analog signals (Table 3-8).

All VIP Analog signals interface through one connector, L2J8, on the Frame Housing Assembly Electronics Unit.

VIP Analog data relates to an experiment parameter, such as temperature and mirror position, and hence, a scale factor is required to interpret the voltage measurement as a parameter quantity. The following sections describe each VIP Analog signal listed in Table 3-8 and provide scale factors for each. In addition, a summary table (Table 4-7) is included along with calibration curves and data for the precision temperature readout signals.

4.3.2.3.1 Detector Temperature Monitor - The temperature of the cold tip rod in the Detector Capsule Assembly is measured with a platinum resistance thermometer (PRT) at the lower end of the rod. This PRT provides a measure of the temperature variations of the detectors. The PRT used is a Minco type S1061-2 (HRC spec control print 21007390-102). The specific serial number used is S/N 82.

An electronics processing circuit is built into the LRIR to provide a voltage output proportional to the resistance of the PRT. This output voltage is processed to VIP Analog requirements (0 to -6.375V).

The resistance of the PRT is determined from the following equation:

$$R_{PRT} = \frac{V_{OUT} + 20.306}{.2527} \text{ ohms}$$

The calibration data for this PRT (S/N 82) is available at Table 4-4 of this section. Data is presented in 1°K increments from 60°K to 350°K. Linear interpolation between 1°K increments is recommended.

Accuracy of the total measurement including data reduction is +0.1°K. Repeatability of the electronics is ±0.05°K over the life of the instrument and throughout its performance temperature range (+15°C to +35°C).

A graph is included as Figure 4-5 of this section to allow a quick temperature reading and can be used except when .1°C accuracy is required.

4.3.2.3.2 Cryogen Shield Temperature Monitor - The cryogen shield is in thermal contact with the solid ammonia tank within the cooler. The PRT located on the DCA shrink-fit coupling that is coupled to the cryogen shield provides a measure of the temperature of the solid ammonia. This PRT along with the cold tip rod PRT allows tracking of the performance of the two stage solid cryogen cooler and Detector Capsule Assembly. The PRT used is a Minco type S1061-2 (HRC spec control print 21007390-102). The specific serial number used is S/N 75.

An electronic processing circuit is used to provide a voltage proportional to the PRT resistance. This voltage is processes to VIP Analog requirements (0 to -6.375V).

The resistance of the PRT is determined from the following equation:

$$R_{PRT} = \frac{V_{OUT} + 7.345}{.016279} \text{ ohms}$$

The calibration data is available for this PRT (S/N 75) as Table 4-5 of this section.

Accuracy of the total measurement including data reduction is ±0.3°C. Repeatability of the electronics is ±0.2°C under all specified conditions.

A graph is included as Figure 4-6 of this section to allow a quick temperature reading and can be used except when .3°C accuracy is required.

Table 4-4

MODEL S1061-2 PRECISION RESISTANCE THERMOMETER

Serial Number 82

T(F)	R(OHMS)	T(F)	R(OHMS)	T(F)	R(OHMS)	T(F)	R(OHMS)
60.0	52.61	105.0	[illegible]	150.0	[illegible]	195.0	[illegible]
61.1	54.69	106.0	[illegible]	151.0	[illegible]	196.0	[illegible]
62.0	56.77	107.0	[illegible]	152.0	[illegible]	197.0	[illegible]
63.0	59.85	108.0	[illegible]	153.0	[illegible]	198.0	[illegible]
64.0	60.91	109.0	[illegible]	154.0	[illegible]	199.0	[illegible]
65.0	63.00	110.0	[illegible]	155.0	[illegible]	200.0	[illegible]
66.0	65.07	111.0	[illegible]	156.0	[illegible]	201.0	[illegible]
67.0	67.14	112.0	[illegible]	157.0	247.71	202.0	[illegible]
68.0	[illegible]	113.0	[illegible]	158.0	249.65	203.0	335.63
69.0	[illegible]	114.0	[illegible]	159.0	[illegible]	204.0	[illegible]
70.0	[illegible]	115.0	[illegible]	160.0	[illegible]	205.0	[illegible]
71.0	[illegible]	116.0	[illegible]	161.0	[illegible]	206.0	[illegible]
72.0	[illegible]	117.0	[illegible]	162.0	[illegible]	207.0	[illegible]
73.0	[illegible]	118.0	[illegible]	163.0	[illegible]	208.0	346.19
74.0	[illegible]	119.0	172.72	164.0	[illegible]	209.0	[illegible]
75.0	[illegible]	120.0	174.72	165.0	[illegible]	210.0	[illegible]
76.0	85.71	121.0	176.71	166.0	[illegible]	211.0	351.92
77.0	[illegible]	122.0	[illegible]	167.0	[illegible]	212.0	353.83
78.0	[illegible]	123.0	180.69	168.0	269.14	213.0	355.74
79.0	[illegible]	124.0	[illegible]	169.0	[illegible]	214.0	357.64
80.0	93.91	125.0	184.67	170.0	[illegible]	215.0	359.55
81.0	[illegible]	126.0	186.66	171.0	[illegible]	216.0	[illegible]
82.0	[illegible]	127.0	[illegible]	172.0	[illegible]	217.0	[illegible]
83.0	[illegible]	128.0	190.63	173.0	[illegible]	218.0	[illegible]
84.0	[illegible]	129.0	192.61	174.0	280.79	219.0	367.17
85.0	[illegible]	130.0	194.59	175.0	282.72	220.0	[illegible]
86.0	[illegible]	131.0	196.58	176.0	[illegible]	221.0	370.97
87.0	[illegible]	132.0	198.56	177.0	286.59	222.0	372.87
88.0	[illegible]	133.0	200.54	178.0	288.52	223.0	374.78
89.0	[illegible]	134.0	202.51	179.0	[illegible]	224.0	[illegible]
90.0	[illegible]	135.0	204.49	180.0	[illegible]	225.0	[illegible]
91.0	[illegible]	136.0	206.47	181.0	294.32	226.0	[illegible]
92.0	[illegible]	137.0	208.44	182.0	296.25	227.0	[illegible]
93.0	[illegible]	138.0	210.41	183.0	298.19	228.0	[illegible]
94.0	122.45	139.0	212.39	184.0	300.11	229.0	[illegible]
95.0	[illegible]	140.0	214.35	185.0	[illegible]	230.0	[illegible]
96.0	[illegible]	141.0	216.33	186.0	303.97	231.0	389.96
97.0	[illegible]	142.0	[illegible]	187.0	[illegible]	232.0	[illegible]
98.0	130.55	143.0	[illegible]	188.0	307.82	233.0	[illegible]
99.0	132.57	144.0	222.23	189.0	309.75	234.0	395.64
100.0	[illegible]	145.0	224.20	190.0	[illegible]	235.0	397.54
101.0	136.61	146.0	226.16	191.0	[illegible]	236.0	399.43
102.0	[illegible]	147.0	228.13	192.0	315.52	237.0	401.32
103.0	[illegible]	148.0	[illegible]	193.0	317.44	238.0	403.21
104.0	142.66	149.0	232.05	194.0	319.37	239.0	405.10

Table 4-4 (Continued)

MODEL S1061-2 PRECISION RESISTANCE THERMOMETER

Serial Number 82

T(K)	R(OHMS)	T(K)	R(OHMS)	T(K)	R(OHMS)	T(K)	R(OHMS)
[illegible]	406.99	285.0	491.44	330.0	574.70	0.0	0.00
241.0	408.88	286.0	493.30	331.0	576.55	0.0	0.00
242.0	410.77	287.0	495.16	332.0	578.40	0.0	0.00
243.0	412.66	288.0	497.02	333.0	580.25	0.0	0.00
244.0	414.55	289.0	498.89	334.0	582.09	0.0	0.00
245.0	416.43	290.0	500.75	335.0	583.93	0.0	0.00
246.0	418.32	291.0	502.61	336.0	585.77	0.0	0.00
247.0	420.21	292.0	504.47	337.0	587.6	0.0	0.00
248.0	422.09	293.0	506.33	338.0	589.44	0.0	0.00
249.0	423.97	294.0	508.19	339.0	591.27	0.0	0.00
250.0	425.86	295.0	510.05	340.0	593.11	0.0	0.00
251.0	427.74	296.0	511.90	341.0	594.94	0.0	0.00
252.0	429.62	297.0	513.76	342.0	596.77	0.0	0.00
253.0	431.51	298.0	515.62	343.0	598.60	0.0	0.00
254.0	433.39	299.0	517.47	344.0	600.43	0.0	0.00
255.0	435.27	300.0	519.33	345.0	602.26	0.0	0.00
256.0	437.15	301.0	521.19	346.0	604.09	0.0	0.00
257.0	439.03	302.0	523.04	347.0	605.92	0.0	0.00
258.0	440.91	303.0	524.89	348.0	607.75	0.0	0.00
259.0	442.79	304.0	526.75	349.0	609.58	0.0	0.00
260.0	444.67	305.0	528.60	350.0	611.41	0.0	0.00
261.0	446.54	306.0	530.45	0.0	0.00	0.0	0.00
262.0	448.42	307.0	532.30	0.0	0.00	0.0	0.00
263.0	450.30	308.0	534.15	0.0	0.00	0.0	0.00
264.0	452.17	309.0	536.01	0.0	0.00	0.0	0.00
265.0	454.05	310.0	537.86	0.0	0.00	0.0	0.00
266.0	455.92	311.0	539.71	0.0	0.00	0.0	0.00
267.0	457.80	312.0	541.55	0.0	0.00	0.0	0.00
268.0	459.67	313.0	543.40	0.0	0.00	0.0	0.00
269.0	461.54	314.0	545.25	0.0	0.00	0.0	0.00
270.0	463.42	315.0	547.10	0.0	0.00	0.0	0.00
271.0	465.29	316.0	548.95	0.0	0.00	0.0	0.00
272.0	467.16	317.0	550.79	0.0	0.00	0.0	0.00
273.0	469.03	318.0	552.64	0.0	0.00	0.0	0.00
274.0	470.90	319.0	554.48	0.0	0.00	0.0	0.00
275.0	472.77	320.0	556.33	0.0	0.00	0.0	0.00
276.0	474.64	321.0	558.17	0.0	0.00	0.0	0.00
277.0	476.51	322.0	560.02	0.0	0.00	0.0	0.00
278.0	478.37	323.0	561.86	0.0	0.00	0.0	0.00
279.0	480.24	324.0	563.70	0.0	0.00	0.0	0.00
280.0	482.11	325.0	565.54	0.0	0.00	0.0	0.00
281.0	483.98	326.0	567.38	0.0	0.00	0.0	0.00
282.0	485.84	327.0	569.23	0.0	0.00	0.0	0.00
283.0	487.71	328.0	571.07	0.0	0.00	0.0	0.00
284.0	489.57	329.0	572.91	0.0	0.00	0.0	0.00

Table 4-5

MODEL S1061-2 PRECISION RESISTANCE THERMOMETER

Serial Number 75

T(K)	R(OHMS)	T(K)	R(OHMS)	T(K)	R(OHMS)	T(K)	R(OHMS)
240.0	407.02	285.0	491.46	330.0	574.81	0.0	0.00
241.0	[illegible]	286.0	493.34	331.0	576.65	0.0	0.00
242.0	[illegible]	287.0	495.21	332.0	578.48	0.0	0.00
243.0	412.68	288.0	497.17	333.0	580.32	0.0	0.00
244.0	414.57	289.0	498.93	334.0	582.15	0.0	0.00
245.0	416.46	290.0	500.80	335.0	584.00	0.0	0.00
246.0	418.35	291.0	502.66	336.0	585.83	0.0	0.00
247.0	420.23	292.0	504.52	337.0	587.67	0.0	0.00
248.0	422.12	293.0	506.38	338.0	589.50	0.0	0.00
249.0	424.03	294.0	508.24	339.0	591.34	0.0	0.00
250.0	425.89	295.0	510.10	340.0	593.17	0.0	0.00
251.0	427.77	296.0	511.95	341.0	595.01	0.0	0.00
252.0	429.65	297.0	513.81	342.0	596.84	0.0	0.00
253.0	431.54	298.0	515.67	343.0	598.67	0.0	0.00
254.0	433.42	299.0	517.53	344.0	600.50	0.0	0.00
255.0	435.30	300.0	519.39	345.0	602.33	0.0	0.00
256.0	437.18	301.0	521.24	346.0	604.16	0.0	0.00
257.0	439.05	302.0	523.09	347.0	605.99	0.0	0.00
258.0	440.94	303.0	524.95	348.0	607.82	0.0	0.00
259.0	442.82	304.0	526.80	349.0	609.65	0.0	0.00
260.0	444.70	305.0	528.65	350.0	611.48	0.0	0.00
261.0	446.58	306.0	530.51	0.0	0.00	0.0	0.00
262.0	448.45	307.0	532.36	0.0	0.00	0.0	0.00
263.0	450.33	308.0	534.21	0.0	0.00	0.0	0.00
264.0	452.21	309.0	536.06	0.0	0.00	0.0	0.00
265.0	454.08	310.0	537.91	0.0	0.00	0.0	0.00
266.0	455.96	311.0	539.76	0.0	0.00	0.0	0.00
267.0	457.83	312.0	541.61	0.0	0.00	0.0	0.00
268.0	459.71	313.0	543.46	0.0	0.00	0.0	0.00
269.0	461.58	314.0	545.31	0.0	0.00	0.0	0.00
270.0	463.45	315.0	547.16	0.0	0.00	0.0	0.00
271.0	465.33	316.0	549.01	0.0	0.00	0.0	0.00
272.0	467.20	317.0	550.85	0.0	0.00	0.0	0.00
273.0	469.07	318.0	552.70	0.0	0.00	0.0	0.00
274.0	470.94	319.0	554.54	0.0	0.00	0.0	0.00
275.0	472.81	320.0	556.39	0.0	0.00	0.0	0.00
276.0	474.68	321.0	558.23	0.0	0.00	0.0	0.00
277.0	476.55	322.0	560.08	0.0	0.00	0.0	0.00
278.0	478.42	323.0	561.92	0.0	0.00	0.0	0.00
279.0	480.29	324.0	563.76	0.0	0.00	0.0	0.00
280.0	482.15	325.0	565.61	0.0	0.00	0.0	0.00
281.0	484.02	326.0	567.45	0.0	0.00	0.0	0.00
282.0	485.89	327.0	569.29	0.0	0.00	0.0	0.00
283.0	487.75	328.0	571.13	0.0	0.00	0.0	0.00
284.0	489.62	329.0	572.97	0.0	0.00	0.0	0.00

Table 4-5 (Continued)

MODEL S1061-2 PRECISION RESISTANCE THERMOMETER

Serial Number 75

T(K)	R(OHMS)	T(K)	R(OHMS)	T(K)	R(OHMS)	T(K)	R(OHMS)
60.0	52.6[illegible]	105.0	144.65	150.0	233.99	195.0	321.29
61.0	54.6[illegible]	106.0	146.66	151.0	235.95	196.0	323.21
62.0	56.7[illegible]	107.0	148.67	152.0	237.91	197.0	325.13
63.0	58.85	108.0	150.68	153.0	239.87	198.0	327.05
64.0	60.91	109.0	152.69	154.0	241.83	199.0	328.97
65.0	62.9[illegible]	110.0	154.69	155.0	243.79	200.0	330.88
66.0	65.0[illegible]	111.0	156.70	156.0	245.74	201.0	332.80
67.0	67.13	112.0	158.70	157.0	247.69	202.0	334.72
68.0	69.23	113.0	160.71	158.0	249.65	203.0	336.63
69.0	71.25	114.0	162.71	159.0	251.60	204.0	338.55
70.0	73.33	115.0	164.71	160.0	253.55	205.0	340.46
71.0	75.3[illegible]	116.0	166.71	161.0	255.50	206.0	342.37
72.0	77.45	117.0	168.71	162.0	257.45	207.0	344.29
73.0	79.51	118.0	170.70	163.0	259.40	208.0	346.20
74.0	81.57	119.0	172.70	164.0	261.34	209.0	348.11
75.0	83.63	120.0	174.69	165.0	263.29	210.0	350.02
76.0	85.69	121.0	176.69	166.0	265.24	211.0	351.93
77.0	87.74	122.0	178.68	167.0	267.18	212.0	353.84
78.0	89.79	123.0	180.67	168.0	269.13	213.0	355.75
79.0	91.84	124.0	182.66	169.0	271.07	214.0	357.65
80.0	93.89	125.0	184.65	170.0	273.01	215.0	359.56
81.0	95.94	126.0	186.63	171.0	274.95	216.0	361.47
82.0	97.99	127.0	188.62	172.0	276.89	217.0	363.37
83.0	100.03	128.0	190.60	173.0	278.83	218.0	365.28
84.0	102.07	129.0	192.59	174.0	280.77	219.0	367.18
85.0	104.12	130.0	194.57	175.0	282.71	220.0	369.08
86.0	106.16	131.0	196.55	176.0	284.65	221.0	370.99
87.0	108.19	132.0	198.53	177.0	286.58	222.0	372.89
88.0	110.23	133.0	200.51	178.0	288.52	223.0	374.79
89.0	112.27	134.0	202.49	179.0	290.45	224.0	376.69
90.0	114.30	135.0	204.47	180.0	292.39	225.0	378.59
91.0	116.34	136.0	206.44	181.0	294.32	226.0	380.49
92.0	118.37	137.0	208.42	182.0	296.25	227.0	382.39
93.0	120.40	138.0	210.39	183.0	298.18	228.0	384.29
94.0	122.42	139.0	212.36	184.0	300.11	229.0	386.19
95.0	124.45	140.0	214.34	185.0	302.04	230.0	388.08
96.0	126.48	141.0	216.31	186.0	303.97	231.0	389.98
97.0	128.50	142.0	218.27	187.0	305.90	232.0	391.87
98.0	130.52	143.0	220.24	188.0	307.82	233.0	393.77
99.0	132.55	144.0	222.21	189.0	309.75	234.0	395.66
100.0	134.57	145.0	224.18	190.0	311.67	235.0	397.56
101.0	136.59	146.0	226.14	191.0	313.59	236.0	399.45
102.0	138.60	147.0	228.11	192.0	315.52	237.0	401.34
103.0	140.62	148.0	230.07	193.0	317.44	238.0	403.23
104.0	142.63	149.0	232.03	194.0	319.37	239.0	405.12

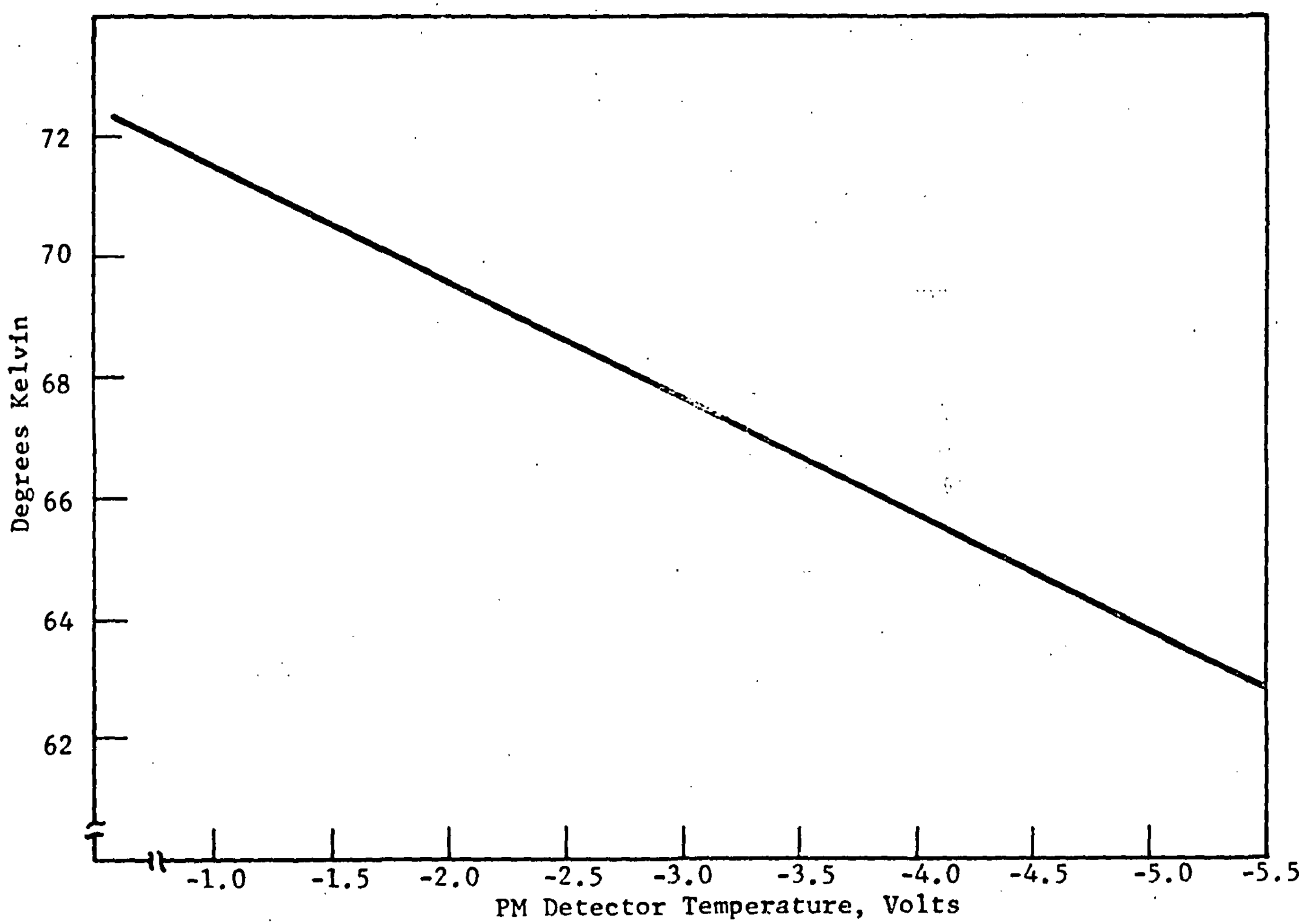


Figure 4-5 PM LRIR DETECTOR (DCA) TEMPERATURE VOLTS TO DEGREES KELVIN CONVERSION CHART (PRT SERIAL NO. 82)

C-2

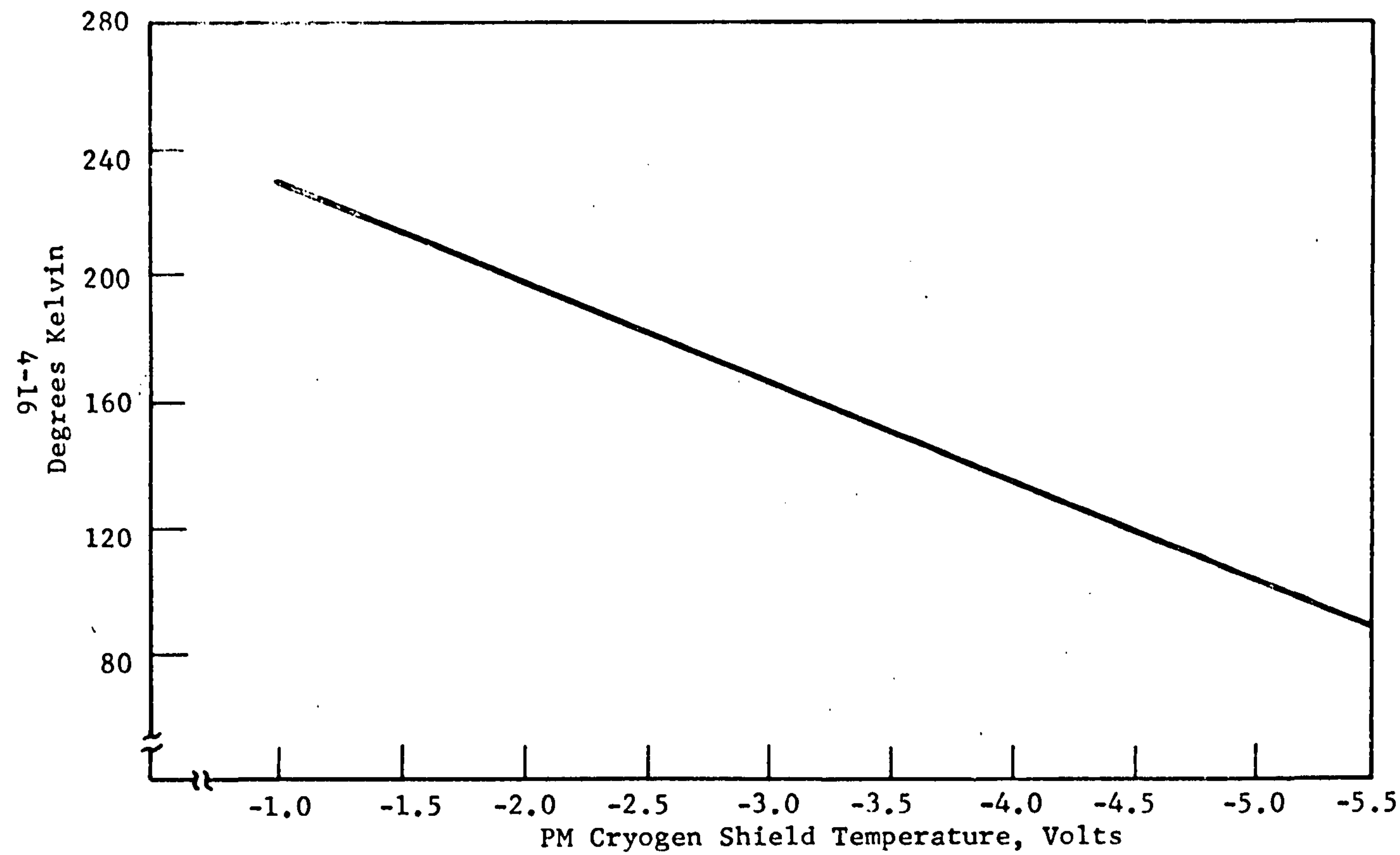


Figure 4-6 PM LRIR CRYOGEN SHIELD TEMPERATURE VOLTS TO DEGREES KELVIN CONVERSION CHART (PRT SERIAL NO. 75)

4.3.2.3.3 IFC Temperature Monitor - The In-Flight Calibrator (IFC) is a blackbody that provides a hot temperature reference for periodic calibration of the radiance channel gains. The temperature of the blackbody must be known very accurately to make it a useful reference. To accomplish this requirement, a platinum resistance thermometer (PRT) is installed inside the blackbody. This allows a direct measure of the blackbody temperature. The PRT used is a Minco type S1061-2 (HRC spec control print 21007390-102). The specific serial number used is S/N 80.

An electronic processing circuit is built into the LRIR to provide a voltage output proportional to the resistance of the PRT. This output voltage is processed to be compatible with the LRIR A/D converter as well as VIP Analog.

For the VIP Analog signal the resistance of the PRT is determined from the following equation:

$$PRT = \frac{(-2\ V_{OUT}) + 54.305}{.108144} \text{ ohms}$$

The calibration data for this PRT (S/N 80) is available as Table 4-6 of this section. Data is presented in 1°K increments from 60°K to 350°K. Linear interpolation between 1°K increments is recommended.

The accuracy of measurement is not critical since the blackbody temperature verses radiance channel output is calibrated. The measurement repeatability is critical and will be ±(.05°C) over the life and environment of the instrument.

A graph is included as Figure 4-7 of this section to allow a quick temperature reading and can be used except when high accuracy (.1°C) readings are required.

A thermistor temperature sensor has been added as a redundant temperature monitor should the PRT fail. Calibration curves are provided (Figures 4-8, 4-9, and 4-10) which provides a comparative readout for both sensors for a given temperature. The data was obtained during the LRIR calibration testing in the thermal vacuum chamber for LRIR at control plate interface temperatures of +15°C, +25°C, and +35°C.

Table 4-6

MODEL S1061-2 PRECISION RESISTANCE THERMOMETER

Serial Number 80

T(K)	R(OHMS)	T(K)	R(OHMS)	T(K)	R(OHMS)	T(K)	R(OHMS)
60.0	52.74	105.0	144.99	150.0	234.52	195.0	321.98
61.0	54.82	106.0	147.01	151.0	236.48	196.0	323.90
62.0	56.91	107.0	149.02	152.0	238.44	197.0	325.82
63.0	58.99	108.0	151.04	153.0	240.40	198.0	327.75
64.0	61.07	109.0	153.05	154.0	242.36	199.0	329.67
65.0	63.15	110.0	155.06	155.0	244.32	200.0	331.59
66.0	65.22	111.0	157.07	156.0	246.28	201.0	333.51
67.0	67.30	112.0	159.08	157.0	248.24	202.0	335.43
68.0	69.37	113.0	161.08	158.0	250.20	203.0	337.35
69.0	71.44	114.0	163.09	159.0	252.15	204.0	339.27
70.0	73.51	115.0	165.09	160.0	254.11	205.0	341.18
71.0	75.58	116.0	167.10	161.0	256.06	206.0	343.10
72.0	77.65	117.0	169.10	162.0	258.02	207.0	345.02
73.0	79.71	118.0	171.10	163.0	259.97	208.0	346.93
74.0	81.78	119.0	173.10	164.0	261.92	209.0	348.85
75.0	83.84	120.0	175.10	165.0	263.87	210.0	350.76
76.0	85.90	121.0	177.10	166.0	265.82	211.0	352.67
77.0	87.96	122.0	179.09	167.0	267.77	212.0	354.59
78.0	90.02	123.0	181.09	168.0	269.72	213.0	356.50
79.0	92.07	124.0	183.08	169.0	271.66	214.0	358.41
80.0	94.12	125.0	185.07	170.0	273.61	215.0	360.32
81.0	96.18	126.0	187.06	171.0	275.55	216.0	362.23
82.0	98.23	127.0	189.05	172.0	277.50	217.0	364.14
83.0	100.28	128.0	191.04	173.0	279.44	218.0	366.05
84.0	102.33	129.0	193.03	174.0	281.38	219.0	367.95
85.0	104.37	130.0	195.02	175.0	283.32	220.0	369.86
86.0	106.42	131.0	197.00	176.0	285.26	221.0	371.77
87.0	108.46	132.0	198.99	177.0	287.20	222.0	373.67
88.0	110.50	133.0	200.97	178.0	289.14	223.0	375.58
89.0	112.54	134.0	202.95	179.0	291.08	224.0	377.48
90.0	114.58	135.0	204.93	180.0	293.02	225.0	379.38
91.0	116.62	136.0	206.91	181.0	294.95	226.0	381.29
92.0	118.65	137.0	208.89	182.0	296.89	227.0	383.19
93.0	120.69	138.0	210.87	183.0	298.82	228.0	385.09
94.0	122.72	139.0	212.84	184.0	300.76	229.0	386.99
95.0	124.75	140.0	214.82	185.0	302.69	230.0	388.89
96.0	126.78	141.0	216.79	186.0	304.62	231.0	390.79
97.0	128.81	142.0	218.77	187.0	306.55	232.0	392.69
98.0	130.84	143.0	220.74	188.0	308.48	233.0	394.59
99.0	132.86	144.0	222.71	189.0	310.41	234.0	396.49
100.0	134.89	145.0	224.68	190.0	312.34	235.0	398.38
101.0	136.91	146.0	226.65	191.0	314.27	236.0	400.28
102.0	138.93	147.0	228.62	192.0	316.20	237.0	402.18
103.0	140.95	148.0	230.58	193.0	318.13	238.0	404.07
104.0	142.97	149.0	232.55	194.0	320.05	239.0	405.97

Table 4-6 (Continued)

MODEL S1061-2 PRECISION RESISTANCE THERMOMETER

Serial Number 80

T(K)	R(OHMS)	T(K)	R(OHMS)	T(K)	R(OHMS)	T(K)	R(OHMS)
240.0	407.86	285.0	492.48	330.0	575.97	0.0	0.00
241.0	409.75	286.0	494.35	331.0	577.81	0.0	0.00
242.0	411.65	287.0	496.22	332.0	579.65	0.0	0.00
243.0	413.54	288.0	498.08	333.0	581.49	0.0	0.00
244.0	415.43	289.0	499.95	334.0	583.33	0.0	0.00
245.0	417.32	290.0	501.81	335.0	585.17	0.0	0.00
246.0	419.21	291.0	503.68	336.0	587.01	0.0	0.00
247.0	421.10	292.0	505.54	337.0	588.85	0.0	0.00
248.0	422.99	293.0	507.41	338.0	590.69	0.0	0.00
249.0	424.88	294.0	509.27	339.0	592.53	0.0	0.00
250.0	426.77	295.0	511.13	340.0	594.37	0.0	0.00
251.0	428.65	296.0	512.99	341.0	596.20	0.0	0.00
252.0	430.54	297.0	514.86	342.0	598.04	0.0	0.00
253.0	432.43	298.0	516.72	343.0	599.87	0.0	0.00
254.0	434.31	299.0	518.58	344.0	601.71	0.0	0.00
255.0	436.20	300.0	520.44	345.0	603.54	0.0	0.00
256.0	438.08	301.0	522.29	346.0	605.38	0.0	0.00
257.0	439.97	302.0	524.15	347.0	607.21	0.0	0.00
258.0	441.85	303.0	526.01	348.0	609.05	0.0	0.00
259.0	443.73	304.0	527.87	349.0	610.88	0.0	0.00
260.0	445.61	305.0	529.73	350.0	612.71	0.0	0.00
261.0	447.50	306.0	531.58	0.0	0.00	0.0	0.00
262.0	449.38	307.0	533.44	0.0	0.00	0.0	0.00
263.0	451.26	308.0	535.29	0.0	0.00	0.0	0.00
264.0	453.14	309.0	537.15	0.0	0.00	0.0	0.00
265.0	455.02	310.0	539.00	0.0	0.00	0.0	0.00
266.0	456.89	311.0	540.86	0.0	0.00	0.0	0.00
267.0	458.77	312.0	542.71	0.0	0.00	0.0	0.00
268.0	460.65	313.0	544.56	0.0	0.00	0.0	0.00
269.0	462.53	314.0	546.41	0.0	0.00	0.0	0.00
270.0	464.40	315.0	548.26	0.0	0.00	0.0	0.00
271.0	466.28	316.0	550.11	0.0	0.00	0.0	0.00
272.0	468.15	317.0	551.97	0.0	0.00	0.0	0.00
273.0	470.03	318.0	553.81	0.0	0.00	0.0	0.00
274.0	471.90	319.0	555.66	0.0	0.00	0.0	0.00
275.0	473.78	320.0	557.51	0.0	0.00	0.0	0.00
276.0	475.65	321.0	559.36	0.0	0.00	0.0	0.00
277.0	477.52	322.0	561.21	0.0	0.00	0.0	0.00
278.0	479.39	323.0	563.05	0.0	0.00	0.0	0.00
279.0	481.27	324.0	564.90	0.0	0.00	0.0	0.00
280.0	483.14	325.0	566.75	0.0	0.00	0.0	0.00
281.0	485.01	326.0	568.59	0.0	0.00	0.0	0.00
282.0	486.88	327.0	570.44	0.0	0.00	0.0	0.00
283.0	488.75	328.0	572.28	0.0	0.00	0.0	0.00
284.0	490.61	329.0	574.12	0.0	0.00	0.0	0.00

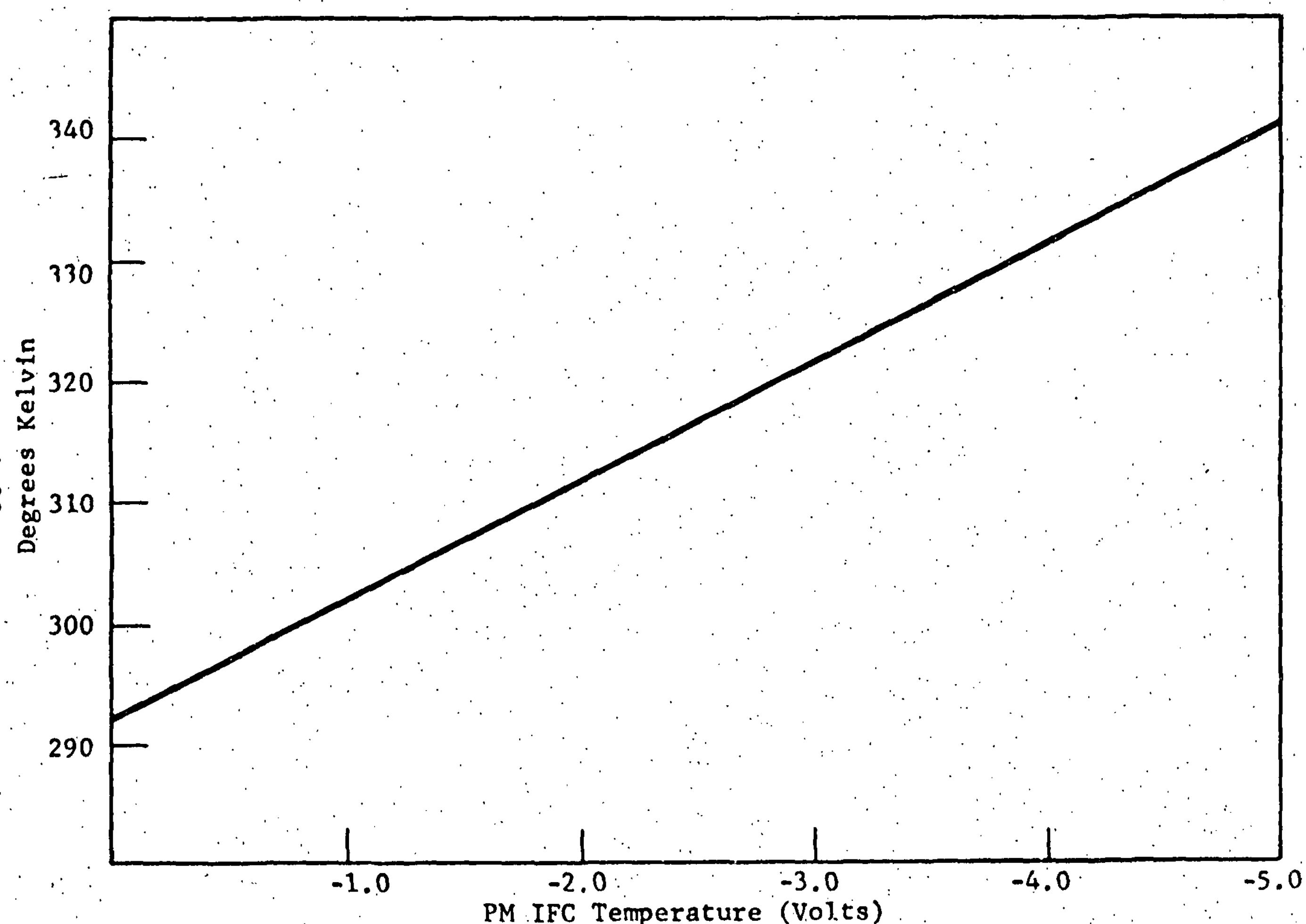


Figure 4-7 PM LRIR IFC TEMPERATURE
VOLTS TO DEGREES KELVIN CONVERSION CHART
(PRT SERIAL NO. 80)

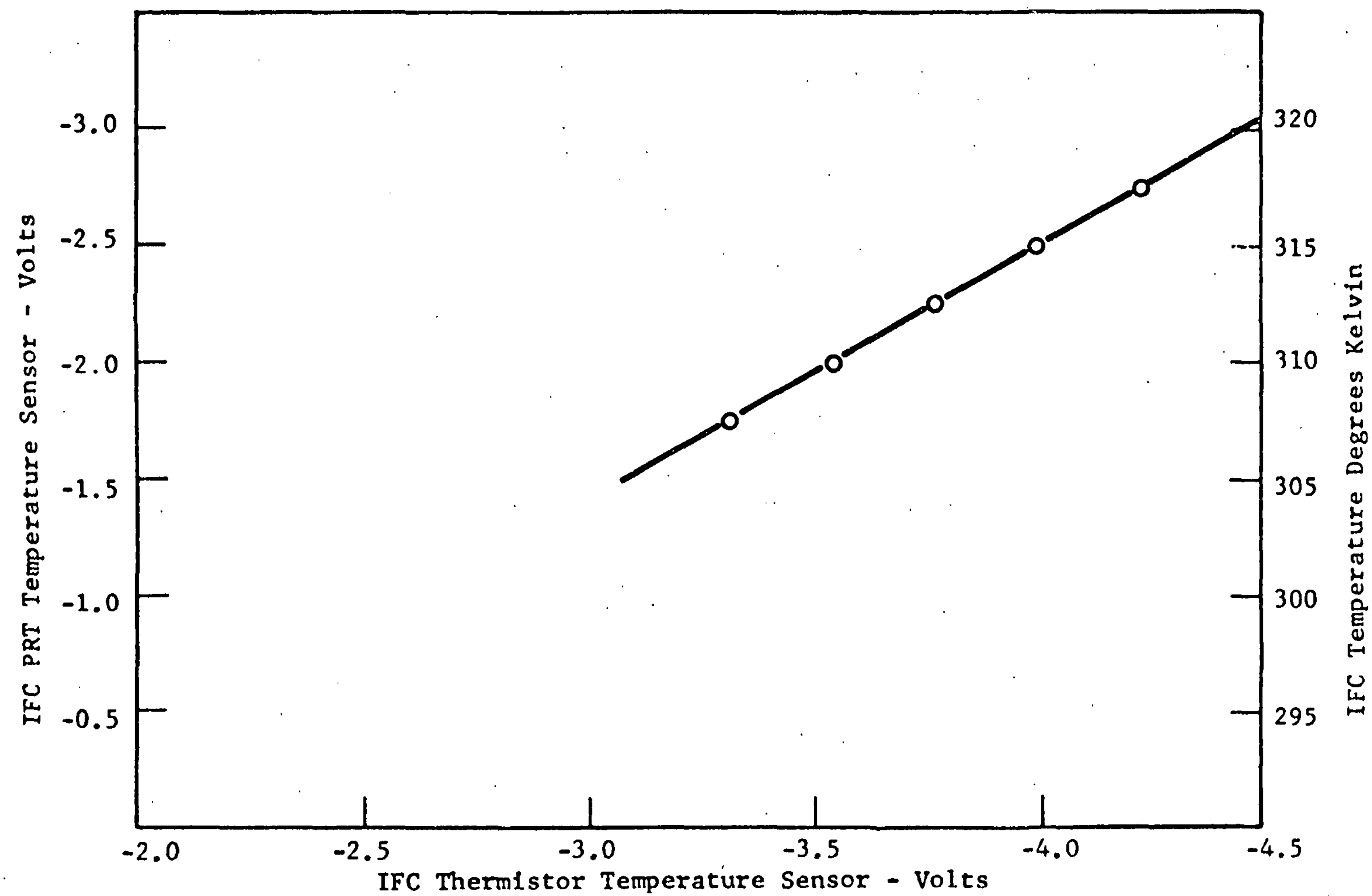


Figure 4-8 IFC PRT VS THERMISTOR OUTPUT
PM LRIR INTERFACE TEMPERATURE 35°C IN THERMAL VACUUM

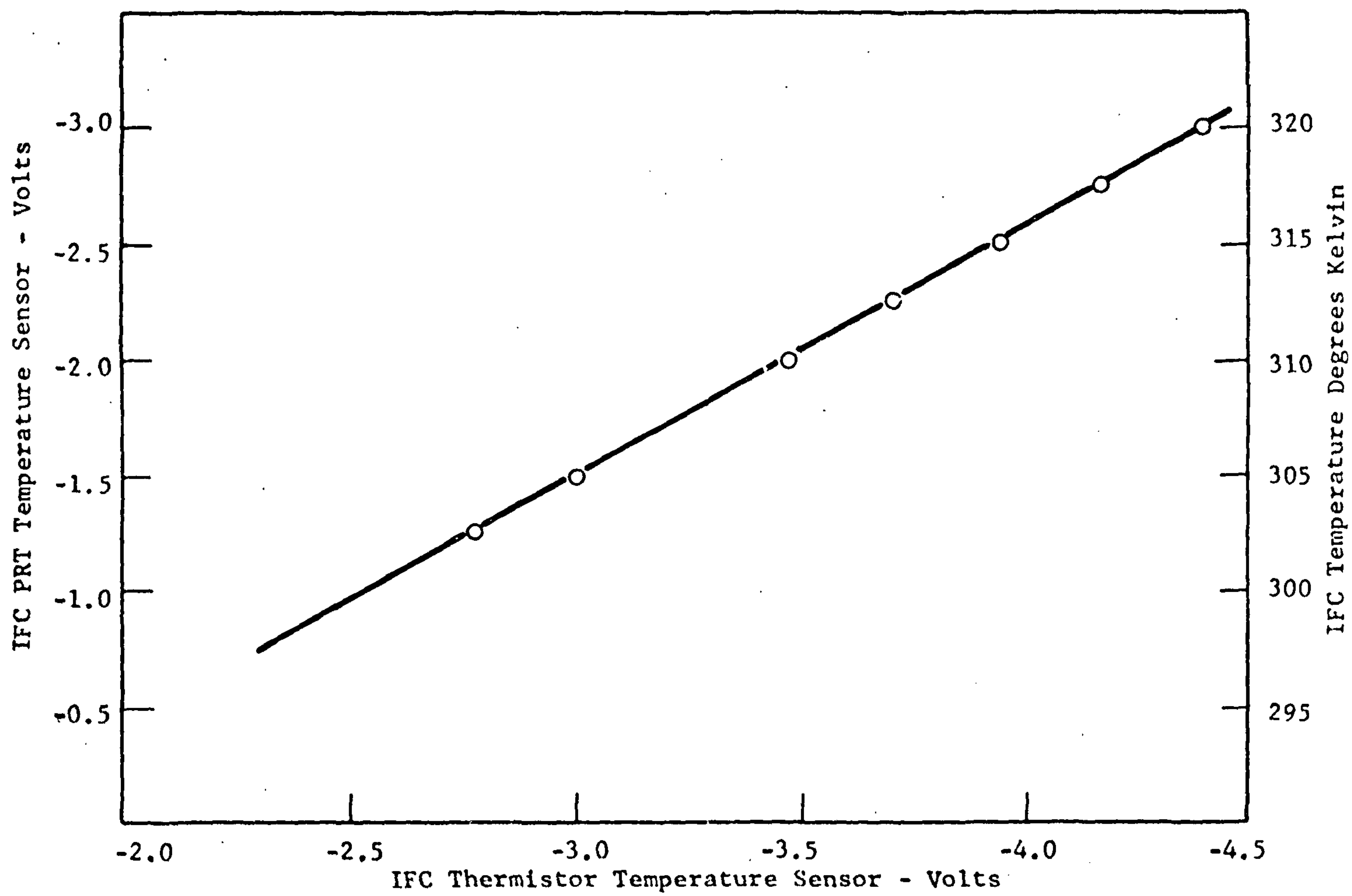


Figure 4-9 IFC PRT VS THERMISTOR OUTPUT
PM LRIR INTERFACE TEMPERATURE 25°C
IN THERMAL VACUUM

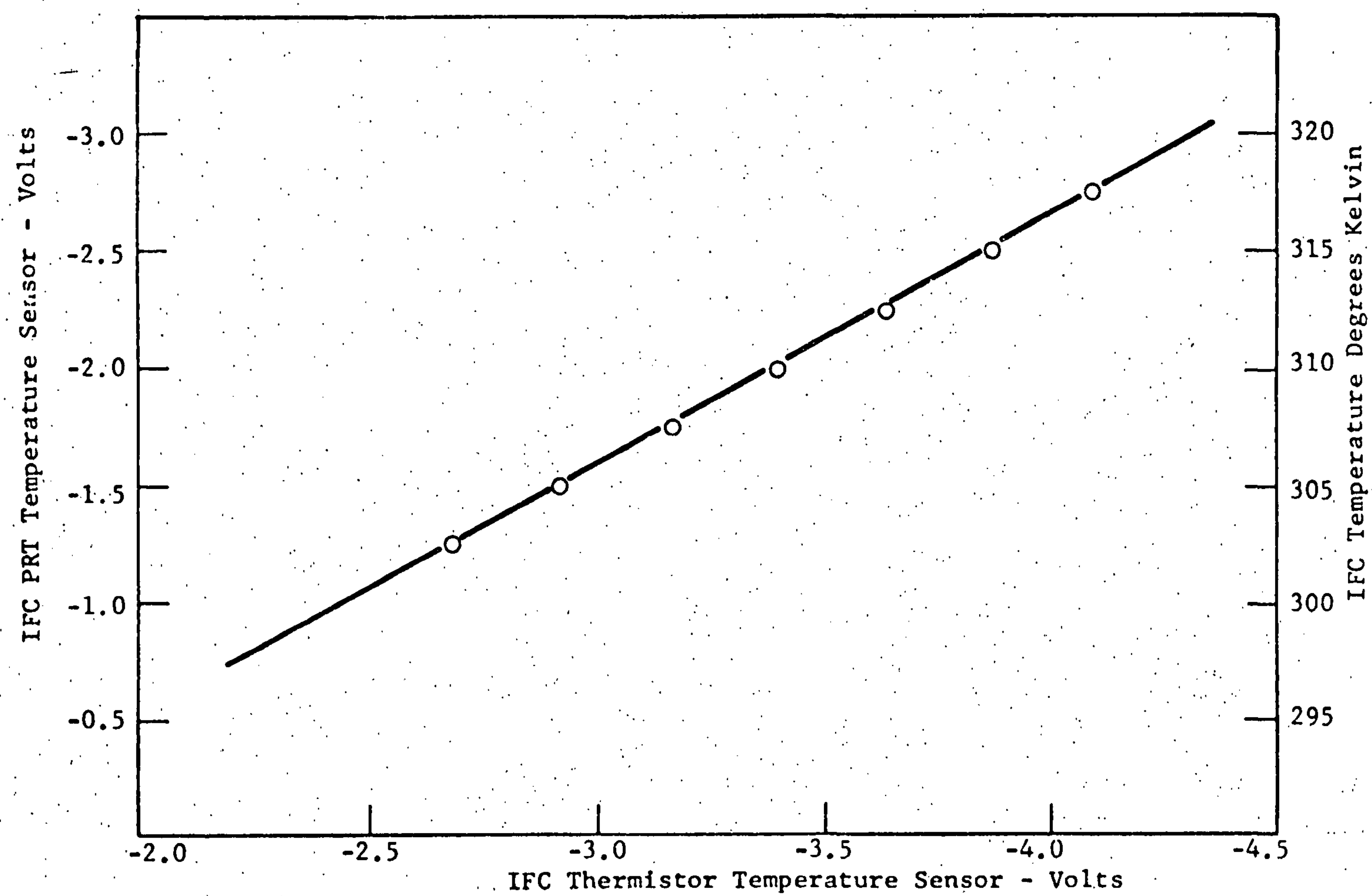


Figure 4-10 IFC PRT VS THERMISTOR OUTPUT
PM LRIR INTERFACE TEMPERATURE 15°C IN

4.3.2.3.4 Housekeeping Temperature Sensors - Temperatures gradients that exist across the LRIR are measured using thermistor sensors embedded in blocks of copper and bonded to the LRIR using thermally conductive epoxy. The thermistor used is a Yellow Springs Instruments Co. 44006 (Honeywell spec control drawing 21007450-101). The thermistor assemblies are defined by Honeywell print number 21007441-101 except where noted. The thermistor locations are listed below:

- IFC Blackbody - 1 assembly
- OMP Housing - 1 assembly
- Baffle - 2 assemblies
- Primary Mirror - 1 assembly
- Scan Motor - 1 assembly
- Cooler Vacuum Shell - 1 assembly

Identical electronic processing circuits are provided for each thermistor assembly. The output of each circuit provides a linear voltage to temperature scale factor over the temperature range of 0°C to +50°C with an accuracy of ±1°C. Moreover, since the scale factor is -10 degrees C/volt, the voltage reading obtained is a direct temperature reading.

EXAMPLE: $V_{OUT} = -2.395$ volts

$TEMP = (-10)(-2.393) = +23.95°C$

Accuracy of the total measurement is ±1°C. Repeatability of the electronics is ±0.3°C over the life of the instrument.

4.3.2.3.5 Scan Mirror Position Information - The Rotary Variable Differential Transformer (RVDT) located on the scan mirror shaft provides mirror position information used in the scan system feedback path, limb track circuit and VIP Analog telemetry data.

The electronic circuit, that processes RVDT output voltage for VIP analog, provides an output voltage linearly proportional to shaft position. Shaft position is referenced to the "No Scan" or "OMP Centerline" position of the mirror. All of the proceeding nomenclature refers to the 31.07° line of sight (LOS) down from local horizontal position of the mirror.

Mirror displacement is asymmetrical about the reference point due to the two calibration points; space and blackbody. This requires that the VIP Analog processed voltage be asymmetrical about the center point of its dynamic range with respect to mirror position. This allows for greater sensitivity for the output information but makes actual mirror position difficult to interpert on a real time basis. It is therefore more likely that useful information will be derived from the path the mirror follows over time than from its actual position at any one time; hence the greater sampling frequency by VIP. The repeatability of the electronic processing circuit is ±2° worst case LOS position and therefore long term position measurements would not be possible.

Mirror Position (degrees shaft) = $(V_{OUT} + 1.03) \times 3.37$

Mirror Position (degrees line-of-sight) $(V_{OUT} + 1.03) \times 6.74$

4.3.2.3.6 Scan Motor Current Information - The variations in scan motor current over the life of the instrument provides a useful measure of scan motor and bearing performance, and hence is desireable telemetry information.

An electronic processing circuit is provided to process voltage information from the 10 ohm torque motor current sampling resistor in the torque motor drive amplifier. This circuit develops an output voltage compatible with VIP Analog telemetry requirements. For zero torque motor current, the output voltage will be -3.30 volts (nominal).

The conversion from voltage to torque motor current is:

I(Torque Motor) = $-(V_{OUT} + 3.30)$(.11 amps/volts)

Positive going currents indicate the scan mirror being driven toward earth while increasing negative currents indicate the scan mirror is being driven toward space.

Accuracy of the buffer output voltage is affected by ground potentials because the torque motor current sampling resistor and the buffer are referenced to different grounds separated from unipoint ground by a length of wire and a number of interconnections. The inaccuracy of the measurement due to different grounds will be as much as ±1 ma. Inaccuracy of the voltage measurement due to component tolerances is ±3%. Repeatability of the electronics is ±1% of the voltage

Table 4-7

SCALE FACTOR CONVERSIONS FOR PM LRIR

ANALOG CHANNEL	SCALE FACTOR
Cryogen exterior temperature Primary mirror temperature Baffle temperature 1 Baffle temperature 2 Scan motor temperature OMP housing temperature FEU temperature IEU temperature IFC Blackbody	.1 volt/1°K OV = 273°K accuracy = ±1°K
Scan motor current	110 ma/volt -3.30V = 0 ma accuracy = ±10 ma
-15 Volt Monitor	2.94 volts/volt -5.1 = -15 volts accuracy = ±.1V
RVDT	6.7° (LOS)/volt OMP ℄ = -1.07 volts (nom) Space = -2.25 volts (nom) Source = -5.76 volts (nom) accuracy = ±4°
Detector Temperature (for CH_4 Temp < 75°K)	See curve attached for quick look volts to temperature convertion (Figure 4-5) For more accuracy, $R_{PRT} = \frac{V_{OUT} + 20.306}{.2527}$ Use R_{PRT} to °K calibration curve for PRT serial no. 82 in Addendum. Accuracy = ±.1°K
Cryogen Shield Temp.	See curve attached for quick look volts to temperature readout conversion. (Figure 4-6) For more accuracy, $R_{PRT} = \frac{V_{OUT} + 7.345}{0.016279}$ Use R_{PRT} to °K calibration curve for PRT serial no. 75 in Addendum. Accuracy = ±.1°K
IFC	.1 volt/°K OV = 290°K Accuracy = ±.1°K IFC PRT & thermistor tempature sensor calibration curve (Figures 4-8 thru 4-10)

measurement. This will lead to ambiguities in current direction when close to zero current.

4.3.2.3.7 -15 Volt Monitor - A resistor divider network from the -15 Volt power line directly measures the performance of the -15 volt regulator and indirectly measures the performance of the dc-to-dc converter. The resistor divider is used to obtain a monitoring voltage compatible with VIP Analog telemetry requirements. The expected voltage for normal operation is -5.10 ±0.25 volts. Scale Factor for correlation to -15 volt performance is:

$$V_{15\ Volt} = V_{measured}\ (2.94\ volts/volt)$$

Accuracy of this buffer is 2% of voltage reading and repeatability is less than 1%.

4.4 WEIGHT AND C.G.

The weights of the FHA, IEU and FEU were determined by performing ETP-F-050, Rev. A on September 9, 1974. The cryogen cooler was filled just prior to weighing the FHA. The weights of the FHA, IEU and FEU are as follows:

FHA	114.5 lbs
IEU	9.8 lbs
FEU	6.2 lbs

The center of gravity of the FHA (filled) was determined in accordance with ETP-F-050, Rev. A. The method used to determine the C.G. was to calculate the moments of the FHA with reference to a known weight and distance. The location of the center of gravity was determined to be

$X' = 1.355$
$Y' = .216$
$Z = 2.314$

Where X' is the distance from the geometric center of the DCA along the X' axis; Y' is the distance from the geometric center of the DCA along the Y' axis and Z is the distance from the bottom or mating surface of the FHA mounting ring. Figures 4-11 and 4-12 illustrate the location of the LRIR FHA CG in relation to the spacecraft.

MODEL = LRIR PROTOFLIGHT

DATE MEASUREMENTS TAKEN: 9 September 1974

WEIGHT: 114 lbs. 8 oz.

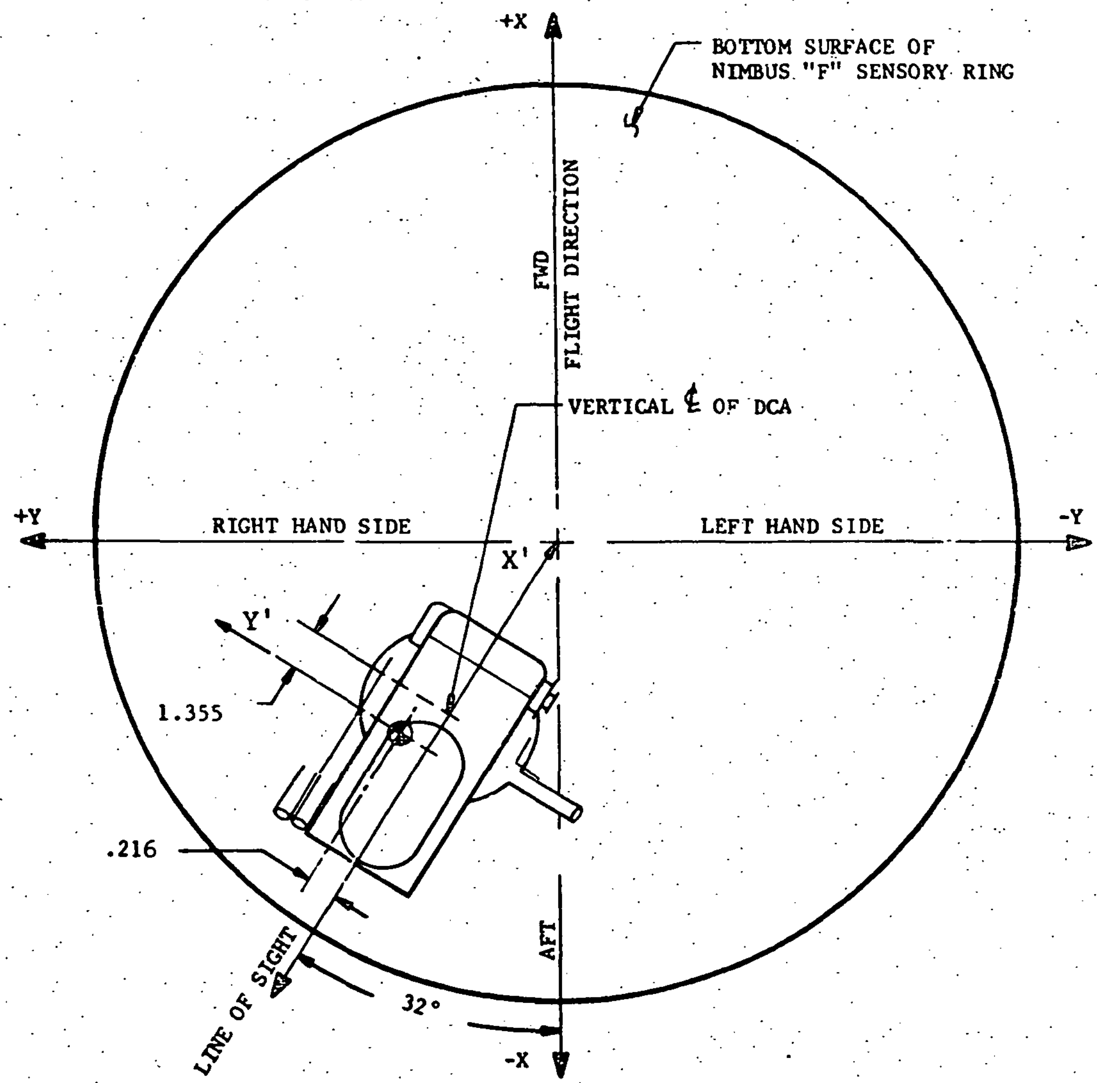


Figure 4-11 LRIR CENTER OF GRAVITY LOCATION
(VIEW LOOKING UP)

MODEL = LRIR PROTOFLIGHT

DATE MEASUREMENTS TAKEN: 9 September 1974

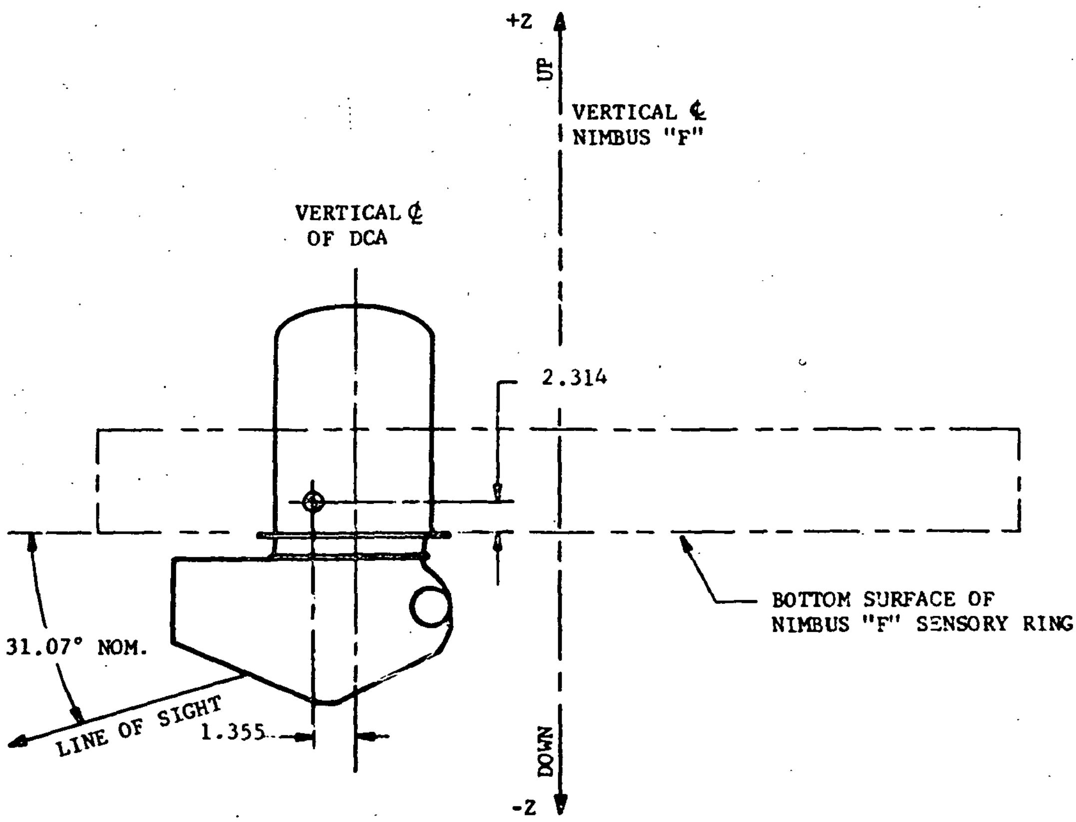


Figure 4-12 LRIR CENTER OF GRAVITY LOCATION
(VIEW LOOKING OUTBOARD)

4.5 DATA PROCESSING OPERATION

The entire chain of events from observations by LRIR from the spacecraft through the data processing flow, data analysis, and archiving is encompassed by the scope of functional data processing requirements. Principal stages in the processing occur at Meteorological Data Handling System (MDHS), at the Honeywell Radiation Center (HRC), and at the National Center for Atmospheric Research (NCAR). MDHS prepares both experimental data and supporting data for transmittal to HRC. Data reduction and preparation of archival tapes are accomplished at the Radiation Center. The data are verified and analyzed at NCAR before being transmitted to National Space Science Data Center (NSSDC) for storage and eventual dissemination to scientific users.

4.5.1 Scientific Significance of the Data

The LRIR, the first satellite-borne limb scanning radiometer, will open a new avenue for observing the upper atmosphere by demonstrating the usefulness of the limb scanning technique, and by proving the concepts of instrument requirements and experiment design developed by the science and engineering teams. Future experiments, based on the experience and results of LRIR, will benefit immensely from these data.

Of more particular immediate interest, the LRIR will return measurements which will yield atmospheric temperatures from 15-60 km or more with high vertical resolution, ozone concentration from 15-50 KM or more, also with high vertical resolution, and water vapor from 15-45 KM or more.

The last few years have seen an enormous increase in emphasis on stratospheric research, as the importance of ozone in shielding the earth from biologically harmful ultra-violet radiation has been realized. It has also been appreciated, for the first time, that the chemical balance creating ozone is very fragile, and subject to modification by human activities. To date, suitable long term global observations and understanding of the stratosphere and mesosphere have lagged behind our need to know about them.

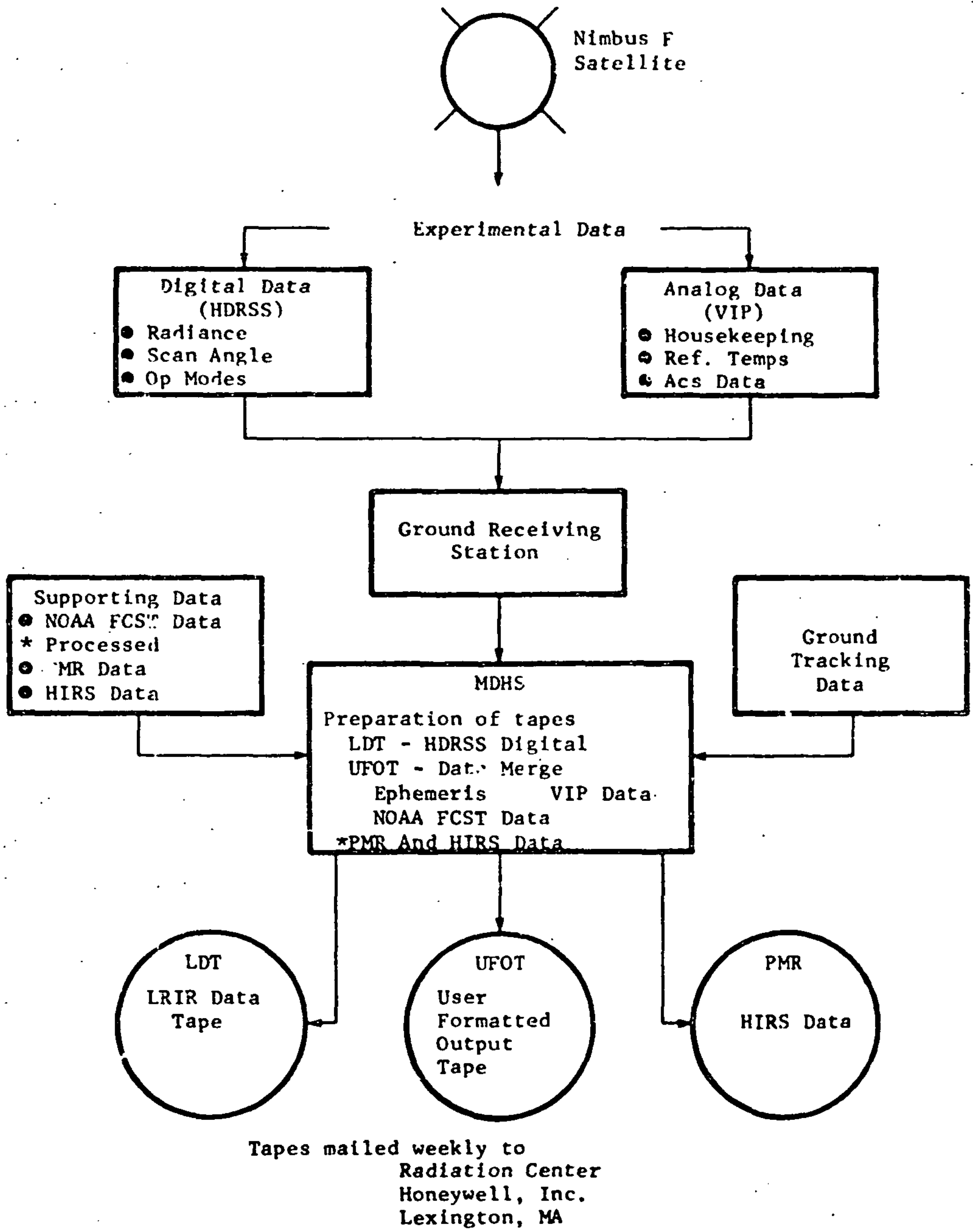
The LRIR, by providing information on temperature to high altitudes, will allow studies of diurnal variations and detailed energy budgets. Also, by integrating the hydrostatic equation, the geostrophic winds can be calculated and used to estimate transports of trace gases as well as for checking numerical models of the dynamics. The high resolution will also allow study of the upward propagation of planetary waves with short vertical wavelengths.

The ozone profiles will allow study of the transport, production, and depletion of ozone in the stratosphere, as well as providing some information on its diurnal variation. One important point is its use in establishing a baseline against which future measurements may be compared. From the distribution of water vapor with altitude, it will be possible to be more precise on the H_2O contribution to the energy budget of the stratosphere and its effect on ozone photochemistry above about 40 KM. Global measurements of concentration should lead to much more precise knowledge of the paths by which water vapor enters and leaves the stratosphere, and, by inference, of troposphere-stratosphere exchange.

One of the most spectacular, and least understood phenomena of the upper atmosphere is the sudden explosive warming. If the LRIR launch occurs at a suitable time, the initial phase of such a disturbance can be see at high altitudes, and followed in detail as it propagates down to the stratosphere. The changes that occur are not fully known, nor is the observed connection between the stratosphere, mesosphere and ionosphere D-Regions. The LRIR observations should shed a great deal of light on these dramatic phenomena.

4.5.2 MDHS Data Processing

The principal functions of MDHS will be Command, Data Acquisition, Data Reformat, Data Merge and Engineering Support. In general, MDHS acquires both experimental data and supporting data for eventual transmission to HRC. The LRIR ground flow of these data is shown in Figure 4-13. MDHS prepares both LDT's and UFOT's. LDT's include digital data from HDRSS relating only to the LRIR experiment. UFOT's consist of data combined from several sources including ephemeris information, VIP data pertaining to LRIR, ACS data, NOAA forecast meterological data and processed PMR and HIRS data in a stacked format, not necessarily coincident in time. It is noted that PMR and HIRS processed data may be transmitted to HRC on separate tapes.



* MDHS will act as middleman in transmitting processed PMR and HIRS data to Honeywell. Data may be stacked on UFOT (Ref memo from Shapiro to Gille, 5 June 1973 File No. 17459).

Figure 4-13 NIMBUS F LRIR EXPERIMENT EXPERIMENTAL AND SUPPORT DATA FLOW

4.5.3 Data Processing at Honeywell

The Radiation Center has the responsibility of data reduction and preparation of archival tapes for transmittal to NCAR. This data reduction process is shown in the block diagram of Figure 4-14. Several steps must be taken during this processing sequence. Each of these steps are discussed briefly in this section.

4.5.3.1 Decalibration and Profile Annotation

The decalibration program indicated in Figure 4-14 operates on both the LDT and UFOT provided by MDHS, to produce the Radiance Archive Tape (RAT). The RAT consists of all limb radiance and calibration observations made by the LRIR, located according to tangent point, and indicates the attitude of the spacecraft and condition of the instrument.

The computer code for this phase unpacks the data tapes, sorts the information, applies calibration factors to the observations (including corrections for radiometer non-linearity) and prepares an archival tape. The instrument parameters required for this function are noted in Figure 4-14.

In addition to the above, the tangent point calculation is performed for each profile set. The satellite position will be known quite accurately at any time from ephemeris information. However, the position coordinate of interest to a user is the apparent observation point of the data at the earth's limb. The location of this point is over the scan track, half way through the atmosphere at an altitude of about 30 km. The geographical location of this position may be calculated from S/C coordinates and attitude information at time of observation. Refer to Figure 4-15.

The RAT is the principal input of experimental and supporting data to the inversion process.

4.5.3.2 Profile Selection

Profiles are obtained every two seconds, or every 12 km along the earth's surface. Owing to the nature of the phenomena being investigated, it will not in general be necessary to invert every profile. A frequency of inversion of approximately every 400 km

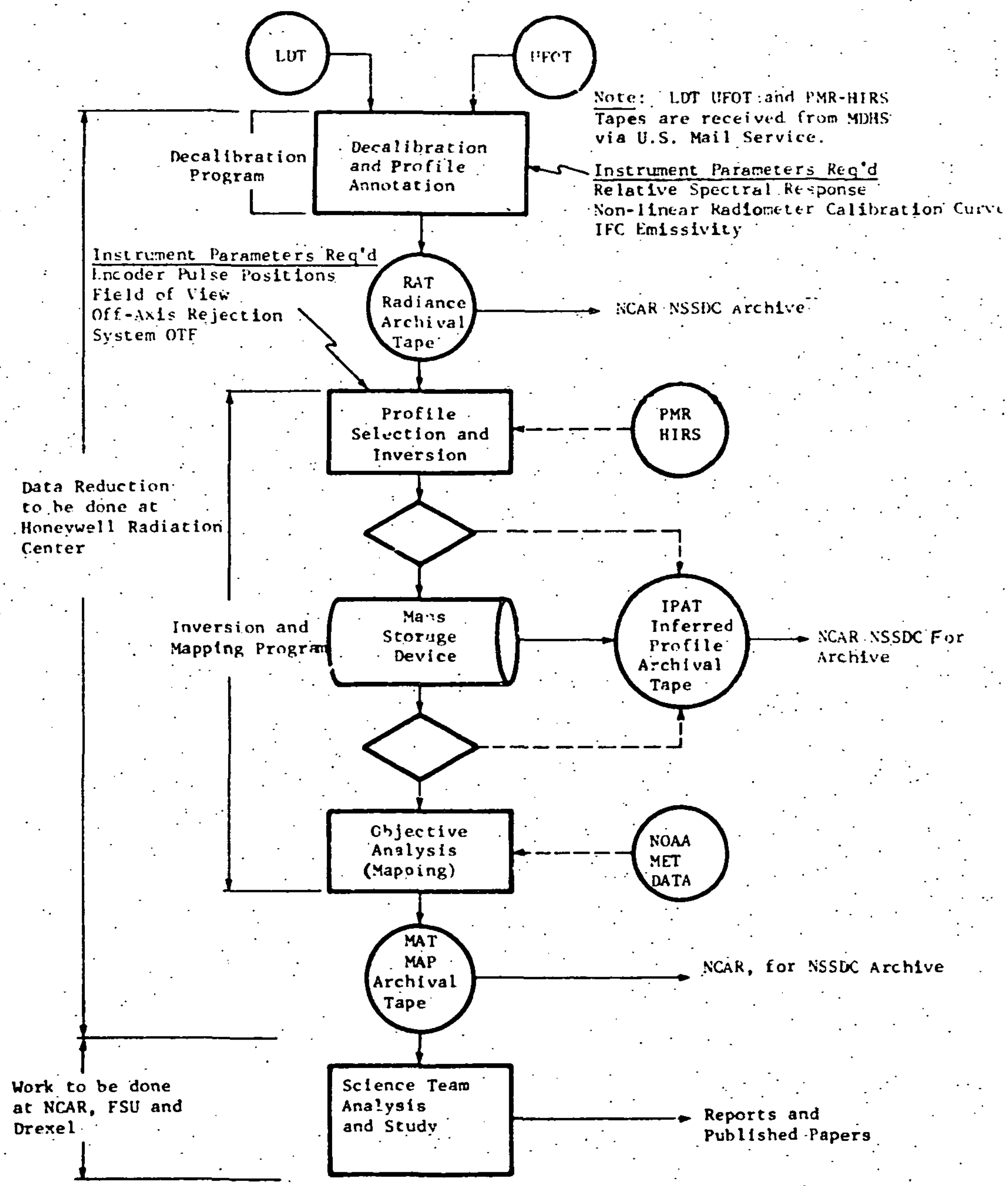


Figure 4-14 NIMBUS F LRIR DATA REDUCTION FLOW

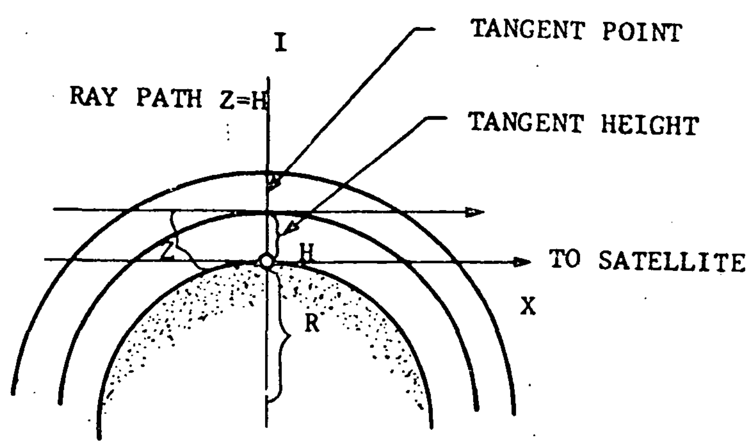


Figure 4-15 LRIR LIMB VIEWING GEOMETRY

along the scan track will usually produce sufficiently dense coverage. Thus, approximately every 32nd profile will be inverted, or roughly one profile per minute.

Profile selection will be based on making sure there are adequate calibration data and parity checks, that there is a down scan followed by a good up scan, that the S/C attitude control system values are not anomalous, that the radiance error values are not exceeded, and that there are not gross errors.

For down-up profile pairs that pass this selection process, the S/C rate about the scan axis is determined by noting the motion of the limb relative to S/C fixed reference points. This determined motion is added to the scan mirror motion, to get an accurate spacing of the data samples. These samples are nominally 1.5 km apart at the horizon, but S/C motion of 0.01°/second will lead to a 1% change in the spacing of the points. (Accelerations normally encountered are either too small to have an appreciable effect, or so large as to be immediately noticeable.)

The radiance data are then fitted with a least-squares cubic spline, and then data interpolated to standard levels for inversion.

A cloud detection algorithm is introduced at this point, to determine the lowest altitude to which the inverted results will be obtained.

4.5.3.3 Inversion of Radiance Data

The inversion algorithms intended for this process will be a modified version of the statistical approach used previously by experimenters dealing with nadir viewing instruments. In order to examine fine scale structure during blanket inversion investigations, an iterative statistical approach and/or an iterative convergence of the radiative transfer equation may be employed. Instrument parameters required are also shown on Figure 4-14. Any inversion employed in the reduction of LRIR data must meet the science data requirements listed in Table 4-8.

Goals for the temperature inversion are to obtain temperatures with 3°K RMS error to 75 km, and slightly larger error to nearly 90 km, and to map the locations of surfaces at 5, 2, 0.4 and 0.1 mb pressure with ±70m precision.

TABLE 4-8

LRIR SCIENCE DATA REQUIREMENTS

PARAMETER	ACCURACY	ALTITUDE RANGE (to)
Temperature	±3°K rms	15 to 54 km
Geostrophic Winds	±10 m/sec (thickness ±70m T to ±1.5°K)	1 mbar (48 km)
Ozone	±20%	1 mbar (48 km)
Water Vapor	±50%	1 mbar (48 km)

The ozone and water vapor distributions are determined in principal from the inverted temperature profiles and the radiance profiles in channels 3 and 4. It is expected that these will also be determined as part of the same statistical approach mentioned above.

A goal for the inversion of these constituents is to obtain ozone to 20% at 0.1 mb (roughly 64 km), where day-night differences may be measurable, and to measure secondary maxima of ozone in the lower stratosphere, from 15-22 km altitude.

Absolute Height Calibration - The temperature and constituent data are obtained as functions of pressure, or alternatively of relative altitude assuming hydrostatic equilibrium. Absolute altitude should be known in order to compare results with other observations such as rocket soundings. This will be accomplished by matching LRIR temperature vs pressure data against standard maps prepared by the National Meteorological Center (NMC).

NMC currently prepares by objective analysis lower-stratospheric weather maps at the following standard pressure levels: 100, 70, 50, 30, 10 mb. Maps are prepared daily for the two Greenwich times 00 and 12, but are produced only once daily. Data are available for the NMC grid on tapes within 24 hours, and will be provided on the LRIR UFOT.

The result of this stage in the analysis will be the Inverted Profile Archival Tape (IPAT).

4.5.3.4 Objective Analysis and Mapping

The last stage in the orderly processing of data is the objective analyses of profile data on IPAT. NOAA meteorological data will be incorporated in these analyses as indicated in Figure 4-14. The archival product generated from this stage of processing is denoted the Map Archival Tape (MAT).

Typically, meteorological data are presented in the form of "synoptic maps", i.e., quasi-horizontal distributions of the meteorological variables for particular pressure levels and particular Greenwich times.

There are many reasons why it is desirable to reduce the satellite data to standard "synoptic" form - comparison with standard data; tie-on with standard data, incorporation into prediction models, etc. This leads to the concept of mapping the LRIR data - not only interpolating the data to standard grid points at standard pressure levels, but also to standard Greenwich times. The interpolation in time, of course, implies the assumption that no large changes in meteorological conditions take place over the time period involved. Alternatively, we filter out such changes if they exist. In fact, our experience with the lower stratosphere up to 10 mb indicates that time changes are slow. Even during periods of stratospheric warmings, changes over a period of 24 hours are small, compared with the large-scale changes that take place during the entire warming, which may run its course during 1-2 weeks. There is no guarantee that this is true at higher levels, say, near the stratopause.

Standard pressure levels in the lower stratosphere are as noted above, at 100, 70, 50, 30, 10 mb. It is desirable to adhere to these. In selecting pressure levels above 10 mb, we should keep in mind the rule-of-thumb that halving the pressure corresponds to a height increment of 5-6 km, depending on the mean temperature. NMC personnel have produced historical maps at 5, 2, and 0.4 mb (averaged over a week) based on scattered rocketsonde and radiosonde data. If they are still doing this during the NIMBUS F period, then we should map and compare at the same levels. Levels of 5, 2, 1, 0.4 and 0.1 mb are the minimum number of levels to be mapped.

4.6 LRIR/HDRSS TRANSMISSION FORMATS

The LRIR data words are 72-bit words and formatted as shown in the accompanying figures. There are seven different data words, but only three different formats. The data modes represented are:

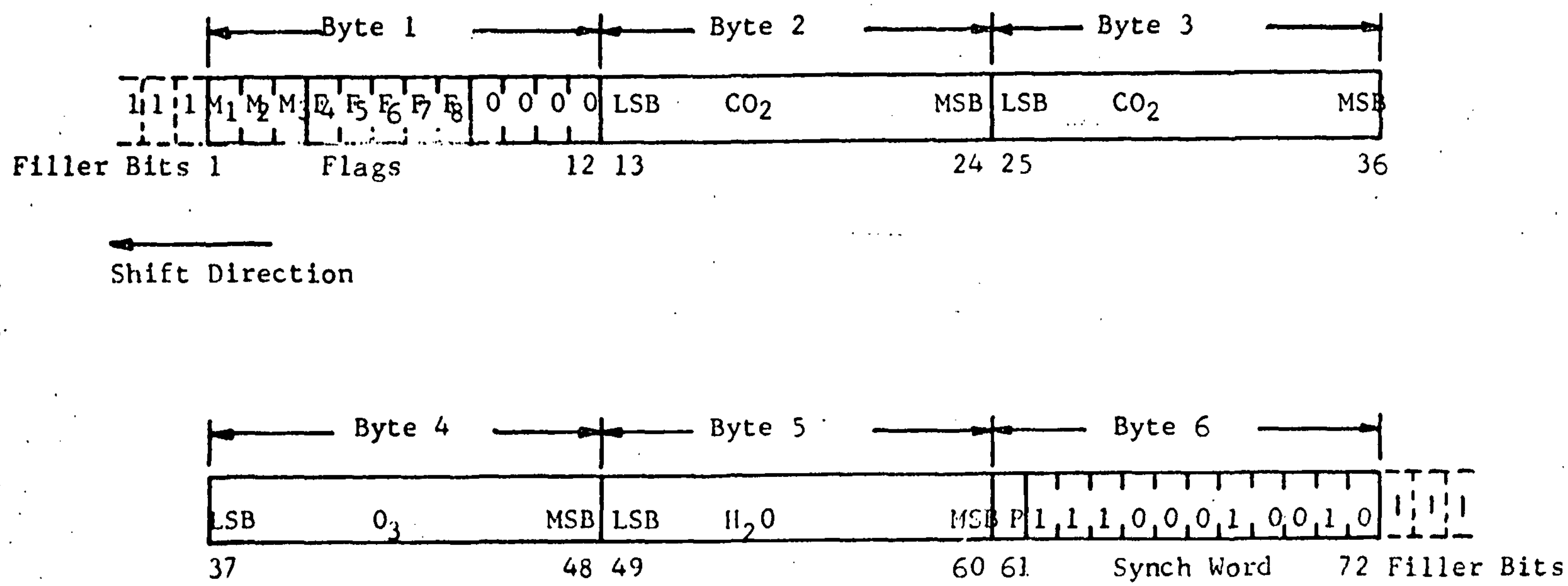
No Scan Acquisition Scan Adaptive Scan Positioning (slewing) Space Calibrate	Similar Formats - Type 1 Data Word
Source Calibrate	Type 2 Data Word
Time Readout	Type 3 Data Word

Data readout is initiated by the incremental change of the scan angle encoder for all scanning modes, and on a timed, or continuous readout basis, for all other modes. It is imperative to maintain scan angle readout accuracy as high as possible. This can only be done if data is taken at the moment of a scan angle increment change. Since the scan drive is analog, the scan rate is not sufficiently accurate to provide constant time and rate data sampling. Therefore, the data readout rate is an approximate number, not an exact number. Based on a scan rate of half a degree per second and an encoder increment of 40 arc-seconds (one degree per second and 80 arc-seconds in object space), the nominal sampling rate is about 45 samples per second during the linear portion of the scan cycle. The bit rate of 4 kHz will accommodate a sampling rate of approximately 55 words per second, so sufficient margin for scan nonlinearity is provided. A sampling rate of 45 samples per second with a bit rate of 4 kHz could result in a nominal word length of 89 bits. Since 72 are sufficient to encode all the information for a given data point, the space between words is filled with binary ones to maintain an uninterrupted bit rate.

4.6.1 Data Word Type 1

A detailed description of data word - type 1 is presented in Figure 4-16. The interpretation of each mode designation follows in the discussion of this section.

No Scan - All zeros in the mode designation denote a no-scan condition (other than the calibrate modes). The scan mirror is stationary and positioned at scan null. This mode is in effect only when power is first turned on and



MODE			DESIGNATION
M_1	M_2	M_3	
0	0	0	No Scan - No Filler Bits
0	0	1	Adaptive Scan - Variable Filler Bits
0	1	0	Acquistion Scan - Variable Filler Bits
1	0	0	Space Calibrate - No Filler Bits
1	0	1	Slewing - No Filler Bits

FLAG	DESIGNATION
$F_4 = 1$	Time Event has occurred
$F_5 = 1$	Scan slow down or stop
$F_6 = 1$	Missed Angle Encoder Pulse
$F_7 = 1$	Scan Coarse Angle Pulse
$F_8 = 1$	Scan Direction Down

Figure 4-16 Data Word - Type 1

when no operational commands are in effect. A type 1 data word will be readout during this mode. Readout will be time-base generated and there will be no filler bits between data words.

Acquisition Scan - The mode designator is 010 for acquisition scan, and a type 1 data word is read out. Data readout is initiated by detection of angle encoder pulses which will occur at approximately 45 times per second during linear scan. Filler bits nominally numbering 17 ±10 will space the data words.

Other data in byte 1 of the data word are the status flags which are defined in the figure for a type 1 data word. The remaining four bits of this byte are zero.

Bytes 2 through 5 are the radiance channel outputs. Byte 6 consists of a parity bit in bit one (bit 61 of the complete data word), and 11 bits constituting a synch word. A parity check is made of the previous 60 data bits and a "1" is inserted if the number of "1s" present is even. However, there are an odd number of "1s" in the synch word which means that the entire 72 bit word will contain an even number of "1s".

Adaptive Scan - Except for a mode designation of 001, the adaptive scan data word is identical to that for acquisition scan.

Slewing - The slewing mode is identified by 101 in the mode bits. The slewing mode is entered only during the automatic calibration sequence of the adaptive scan cycle when angle encoder outputs are received too rapidly to permit an orderly generation of data readouts (less than 12.5 msec apart).

As the time between encoder pulses decreases the slew mode is entered and data readout is determined by a fixed time base with no filler bits between words. The time base readout continues through the calibration sequence and ends when entry into the normal scan pattern is resumed.

The slew mode is not identified during any other modes of operation (such as command calibration modes when slewing to and from calibration is affected).

Space Calibrate - A mode designation of 100 identifies space calibrate. The word format is similar to the previously discussed modes. Like the no-scan mode, data readout is synchronized to a time base and no filler bits are used (data words follow each other without interruption at approximately a 55.5 samples per second rate).

4.6.2 Data Word - Type 2

A detailed description of data word - type 2 is presented in Figure 4-17. This type of data word corresponds to a source calibration condition of the radiometer. A two bit designation of 11 denotes this condition. The remaining ten bits of the first byte are used to indicate the temperature condition of the in-flight calibration source. All other remaining bytes of the data word - type 2 are the same as those for type 1. Like space calibrate above, source calibrate mode utilizes a time-base method of readout.

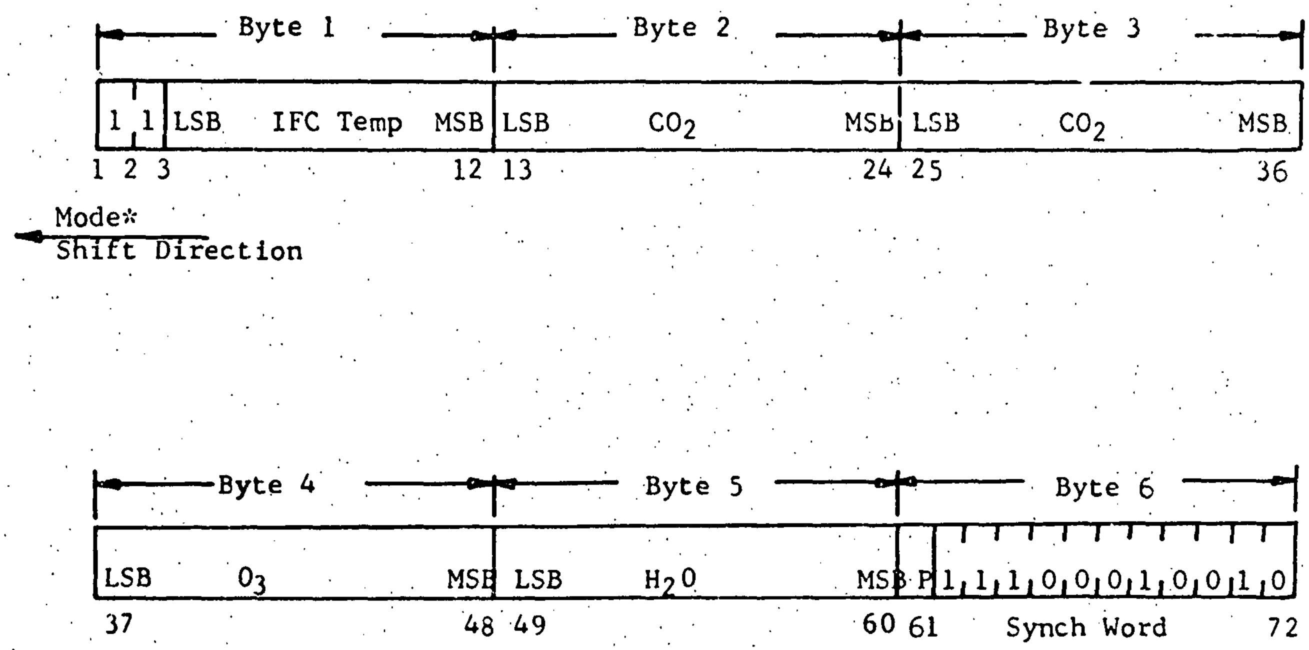
4.6.3 Data Word - Type 3

A detailed description of data word - type 3 is presented in Figure 4-18. The third type of data word format is that for the time code. Mode designation is 011. Time code is readout when scan stop (or slow down) is detected, or scan turnaround is detected. Spacecraft time is updated every second, and the data word immediately following the update is flagged with a time event bit. The time will not be readout, however, until the next scan turnaround or the next scan stop (as in a calibration sequence). The scan-stop initiated readout requires time to have been updated since the last time code readout, and units seconds to have been updated since a time event signal. This will insure that the time reading is up to date, but more important, will prohibit time from being readout continuously all the time that scan is stopped. Scan turnaround does not have this same restriction. Turnaround will cause one time code readout regardless of the time update status, provided that a slew mode is not indicated.

Any turnaround during slew is probably overshoot and not a true scan turnaround situation. Also, since slew is only identified during automatic calibration, it will always be followed by a period of scan stopped, in which case time will be read out. Because the experiment timing is derived from the spacecraft clock, the scan timing will always be phaselocked with spacecraft time, although the phasing is unknown and different for each power-on period of operation. It is possible to be in a time-read lock-out period at every scan turnaround if a time-for-update delay were required for turnaround-initiated time readout.

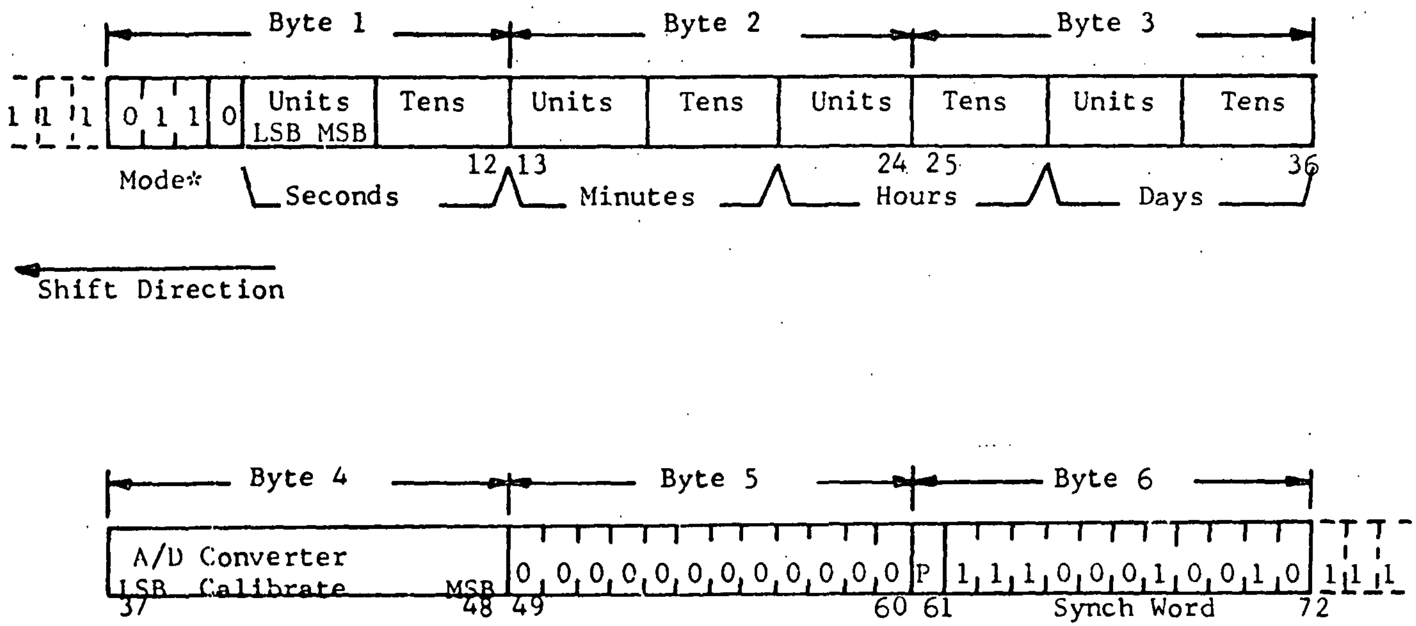
These two conditions for time readout mean that it is possible to have two time code readings close together, or even consecutively, if the transition through turnaround is first seen as a slowdown (scan stopped indication) followed by a turnaround signal. This situation is not important to the data because data from the radiometers during turnaround is not significant to the scientific aims of the experiment.

The rest of the data word format includes an A/D converter calibration word in byte 4, zeros in byte 5, and parity and word synch in byte 6. As evidenced from the discussion above, the time code mode can occur within a time-base initiated readout or during encoder-pulse initiated data, meaning the number of filler bits can vary from none to maximum.



*Source Calibration Mode - No Filler Bits

Figure 4-17 D·ta Word - Type 2



*Time Code Readout Mode - Variable Filler Bits

Figure 4-18 Data Word - Type 3

SECTION 5

PM QUALIFICATION TESTS

5.0 INTRODUCTION

Qualification testing of the LRIR Protoflight Model was conducted between December, 1973 and August, 1974 to demonstrate that the design of the LRIR is in accordance with the requirements of the LRIR performance specification after being subjected to the following induced environments:

Vibration
Electromagnetic Interference
Thermal-Vacuum

The vibration and EMI testing was conducted at the Acton Environmental Testing Corporation (AETC) in Acton, Massachusetts. Thermal-Vacuum testing was conducted at the HRC facility in Lexington, Massachusetts.

The environmental tests and performance tests were conducted using NASA approved engineering test procedures prepared by HRC. The LRIR Protoflight Model had successfully completed flight acceptance performance testing prior to entering the qualification test program. Flight acceptance performance testing was successfully conducted at the conclusion of the environmental qualification test program to verify the LRIR performance is within specification limits after being subjected to induced environments.

Test monitoring and control were accomplished using the LRIR Bench Control Unit (BCU), Ground Servicing Equipment (GSE) and supplemental standard laboratory test equipment.

5.1 TEST PROGRAM

The environmental qualification test program is summarized in Figure 5-1. The LRIR performance testing began on December 19, 1973. The qualification test program concluded on August 9, 1974.

5.1.1 Pre-Environmental Qualification Tests

Prior to subjecting the LRIR to vibration, the performance of the LRIR system was verified by conducting the following performance tests.

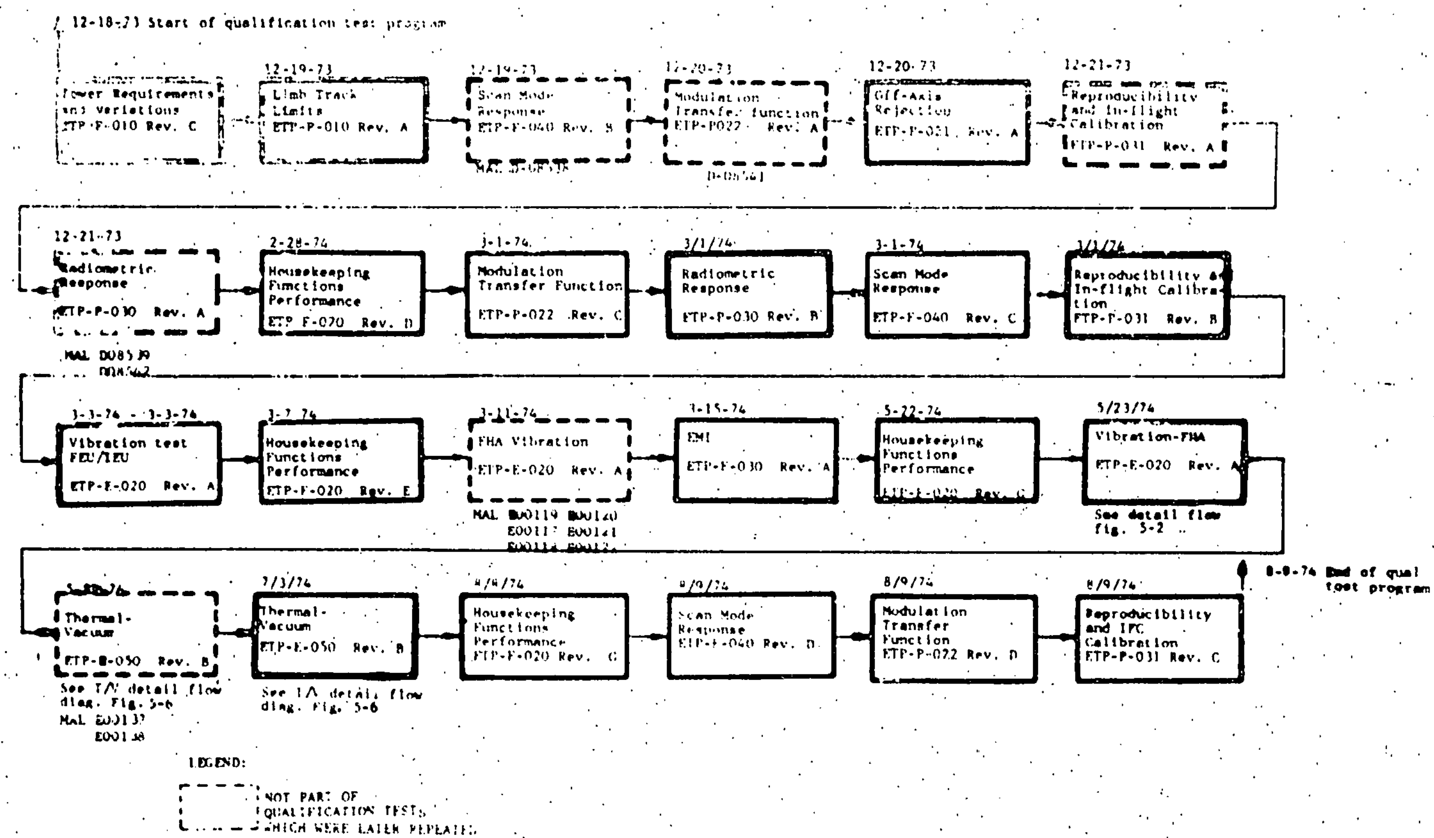


Figure 5-1 LRIR QUALIFICATION TEST PROGRAM TEST SEQUENCE FLOW DIAGRAM

Power Requirements and Variations	ETP-F-010, Rev. C
Housekeeping Functions	ETP-F-020, Rev. D
Limb Track Limits	ETP-P-010, Rev. A
Off Axis Rejection	ETP-F-021, Rev. A
Scan Mode Response	ETP-F-040, Rev. C
Modulation Transfer Function	ETP-P-022, Rev. C
Radiometric Response	ETP-P-030, Rev. B
Reproducibility & IFC Calibration	ETP-P-031, Rev. B

Summaries of the performance test data are given in Tables 5-1 thru 5-9. An engineering evaluation of the test data verifies that the LRIR system performance was within acceptance limits before subjecting the LRIR to the Qualification test environments as specified herein.

Table 5-1

POWER REQUIREMENTS AND VARIATIONS

Test Date 12-15-73 ETP-F-010 Rev. C

DATA SUMMARY

	24.5 VDC	25.05 VDC	23.79 VDC
VIP Digital B Data	No Anomalies	No Anomalies	No Anomalies
HDRSS Data	No Anomalies	No Anomalies	No Anomalies
VIP Analog Data			
SCAN MTR Current Scan Override (-3.30 ± 0.3)	-3.250	-3.345	-3.351
Scan MTR Current Space Cal (-3.30 ± 0.3)	-3.205	-3.201	-3.196
Scan MTR Current Source Cal (-3.30 ± 0.2)	-3.163	-3.154	-3.159
Scan MTR Current Uncage (-3.30 ± 0.2)	-3.209	-3.154	-3.159
-15 VDC Scan On (-5.100 ± .255)	-5.058	-5.059	-5.059
Detector Temp. Scan On (-4.40 ± 1.20)	-4.425	-4.422	-4.419
Cryogen Ext. Scan On (-2.0 ± 0.5)	-2.360	-2.394	-2.403
Primary Para. Scan On (-2.0 ± 0.5)	-2.284	-2.318	-2.333
Cryo. Shield Temp Scan On (-3.00 ± .3)	-3.361	-3.360	-3.359
Baffl Temp 1 Scan On (-2.00 ± .5)	-2.273	-2.298	-2.307
Baffle Temp 2 Scan On -2.0 ± .5	-2.275	-2.300	-2.312
Baffle Temp 3* Scan On -2.0 ± .5	-2.267	-2.292	-2.304
Scan MTR Temp Scan On $-2.0 ^{-.5}_{+1.0}$	-2.332	-2.367	-2.372
Housing OMP Temp Scan On -2.0 ± .5	-2.336	-2.370	-2.360
IFC Source Temp Source Cal -3.00 ± .15	-3.043	-3.044	-3.043
FEU Elec. Temp Source Cal -2.0 ± .5	-2.278	-2.305	-2.321
IEU Elec. Temp Source Cal $-2.0 ^{-.5}_{+1.0}$	-2.448	-2.476	-2.471

*This thermistor was later moved onto the IFC blackbody source and called "Blackbody Temp."

Table 5-2

OFF-AXIS REJECTION

Test date 12-20-73 ETP-P-021 Rev. A

DATA SUMMARY

	CHANNEL 1	2	3	4
% Energy outside one IFOV	37.5	37.2	20.6	10
% Energy outside two IFOV	12	20	0	**

** Measurement was not performed with 2 IFOV target because of cross-coupling into the second Channel 4 detector.

Requirement: Less than 40% outside 1 IFOV.

Table 5-3

LIMB TRACK LIMITS

TEST DATE 12-19-74 ETP-P-010 Rev. A

DATA SUMMARY

Limb Track Point - % of Peak Radiance ------- 45%

Minimum Earth/Space Contrast Tracked -------- $< 0.13\ wm^{-2}sr^{-1}$

COMMENTS AND CONCLUSIONS

Tracking point on earth limb must be at 40% ±5% of peak radiance for limb profile being tracked; test measured 45%, within spec.

Tracking must be performed over an earth-to-space radiance contrast of 10% of maximum expected orbital radiance; 1.86 $wm^{-2}sr^{-1}$. Minimum contrast tracked was .13 $wm^{-2}sr^{-1}$, within spec.

Table 5-4

HOUSEKEEPING FUNCTIONS PERFORMANCE TEST

Test Date 2/26/74 ETP-F-020 Rev. D

DATA SUMMARY

VIP Digital B Data		No Anomalies
HDRSS Data		No Anomalies
VIP Analog Data	Limits	Readings
Scan MTR Current Scan Override	-3.30 ± 0.3	-3.300
Scan MTR Current Space Cal	-3.30 ± 0.2	-3.261
Scan MTR Current Source Cal	-3.30 ± 0.2	-3.200
Scan MTR Current Ungage	-3.30 ± 0.2	-3.202
-15 VDC Scan On	-5.100 ± .255	-5.076
Detector Temp Scan On	-4.45 ± 1.20	-4.268
*Cryogen Ext. Scan On	-2.0 ± 0.5 (RM Temp x.1±1.0)	-2.662
*Primary Para. Scan On	-2.0 ± 0.5 (RM Temp x.1±1.0)	-2.564
Cryo. Shield Temp Scan On	-3.30 ± 0.3	-3.331
*Baffle Temp 1 Scan On	-2.00 ± 0.5 (RM Temp x.1±1.0)	-2.564
*Baffle Temp 2 Scan On	(-2.00 ± 0.5) (RM Temp x.1±1.0)	-2.560
Blackbody Temp	-4.0 ± 2.0	-4.404
*Scan MTR Temp Scan On	-2.0 -.5 + 1.0 (RM Temp x.1±1.0)	-2.649
*Housing OMP Temp Scan On	-2.00 ± 0.5 (RM Temp x.1±1.0)	-2.641
IFC Source Temp Source Cal	-3.00 ± 0.15	-3.011
*FEU Elec. Temp Source Cal	-2.0 ± 0.5 (RM Temp x.1±1.0)	-2.657
*IEU Elec. Temp Source Cal	-2.0 +1.0 -0.5 (RM Temp x.1±1.0)	-2.837

*MR reported out-of-spec condition. Corrective action changed required limits as shown in parentheses.

Table 5-5

MODULATION TRANSFER FUNCTION

TEST DATE 3-1-74 ETP-P-022 Rev. C

DATA SUMMARY

Square Wave Response

FREQUENCY (cycles/mr)	CHANNEL 1	2	3	4
.113	.98	.96	1.04	.90
.226	1.02	1.00	1.05	.91
.283	1.02	.98	1.00	.92
.378	.91	.89	.98	.71
.565	.75	.67	.77	.38
1.130	.15	.11	.12	0

COMMENTS AND CONCLUSIONS

Modulation transfer function results were below design capability value for channels 1, 2 and 3 by ≈10% and were better than design capability for channel 4.

Table 5-6

RADIOMETRIC RESPONSE

TEST DATE 3-1-74 ETP-P-030 Rev. B

DATA SUMMARY

CHANNEL	OUTPUT VOLTAGE		NEN $wm^{-2}sr^{-1}$
	IFC	ZERO SCENE	
1	8.67	0.80	.0031
2	8.76	0.80	.0043
3	8.76	0.92	.0096
4	8.64	0.62	.023

COMMENTS AND CONCLUSIONS

REQUIREMENTS:

1. Dynamic Range - At the IFC Source Cal position and with the IFC source temperature at 320 ±1°K, the output voltages of each of the four LRIR radiance channels shall be 9.0 ±0.5 when testing in the HRC space chamber.

2. Zero Offset - The response curve (volts out vs target radiance) when extrapolated to zero target radiance shall cross the volts out scale at 1.0 ±0.5 volts.

3 NEN - Noise equivalent radiance in all channels shall not exceed 0.01 $wm^{-2}sr^{-1}$.

The results of the Radiometric Response test summarized above verifies the LRIR Dynamic Range, zero offset and NEN meets the design specification requirements except for channel 4 NEN.

Table 5-7

SCAN MODE RESPONSE

TEST DATE 3-1-74 ETP-F-040 Rev. C

DATA SUMMARY

Limb Track Centering	Track Point 36.3 %
OMP ℄	RVDT Voltage -1.068V
Space Calibrate	RVDT Voltage -2.238V
	Coarse Angle Pulse to Space Cal Counts 30
Source Calibrate	RVDT Voltage -5.649
	Coarse Angle Pulse to Source Cal Counts 2.0

COMMENTS AND CONCLUSIONS

REQUIREMENTS:

1. The LRIR system aquistion and track of a radiance signal which is 35-45% of the radiance contrast observed on channel 1 during the normal scan cycle of a simulated earth limb target.
2. Verify scan mirror positioning for the following line-of-sight angles, on command:
   - A. OMP ℄ - within 0.5° of initial setting; i.e. RVDT voltage within ±.075V of baseline value of -1.069V.
   - B. SPACE CAL - within ±0.5° of initial setting; i.e. RVDT voltage within ±.075V of baseline value of -2.238 and coarse angle pulse to space cal counts within 23 counts of baseline value of 32.
   - C. SOURCE CAL - within ±0.33° of initial setting; i.e. RVDT voltage within ±.050V of baseline value of -5.649V and coarse angle pulse to source cal counts within 6 counts of baseline value of 5.

The results of the Scan Mode Response test summarized above verified the LRIR meets the design specification requirements.

Table 5-8

SCAN MODE RESPONSE COMPUTER DATA ANALYSIS

TEST DATE 3-1-74 ETP-F-040 Rev. C

COMMANDED MODE	WORDS	ANOMALIES			
		HARDWARE	%	SOFTWARE	%
Scan Override	6356	11	.17	3	.04
Scan On	3312	2	.06	1	.03
Non-Scan	--	--	---	-	---
TOTAL	9668	13	.13	4	.04

COMMENTS AND CONCLUSIONS

A review of the computer data printout was made to determine system data processing capabilities. The mode byte for each word was reviewed. Anamolies were classified into a category of either hardware or software. Hardware errors consisted of missed encoder flag, erroneous scan stop indication, multiple coarse angle pulses, unwanted time code. Software anamolies consisted of presence of parity error, missing data word, ...

Data processing anamolies were found to occur at a frequency of one per thousand data samples or less, well within acceptable data processing requirements.

Table 5-9

REPRODUCIBILITY AND IFC CALIBRATION

TEST DATE 3-1-74 ETP-P-031 Rev. B

DATA SUMMARY

Source Temperature Variation 0.0 Volts

Source Position RVDT Voltage -5.600V

COMMENTS AND CONCLUSIONS

1. The maximum spread for the reduced IFC voltage shall be ±.020 volts. The LRIR source temperature stability is within the required specification limits.

2. The source position RVDT voltage shall be within ±0.25V of the RVDT voltage corresponding to the baseline IFC source centerline position. The LRIR source position RVDT voltage is within 0.032V of baseline voltage (-5.649V baseline) and therefore meets the required specification limits.

5.1.2 Vibration

The PM IEU and FEU were subjected to sinusoidal and random vibration testing to the levels specified in Table 5-10. The electronics were functionally tested per ETP-F-060 after being vibrated in each axis to verify that the performance of the electronics was not degraded. The results of the performance tests showed no sign of degradation of the electronics due to environments of vibration in the X, Y and Z axes.

The FHA was transported to Acton Environmental Testing Corporation for vibration tests. A baseline Housekeeping Functions Performance Test was performed at HRC before shipment and a second Housekeeping Functions Performance Test was run at AETC prior to vibration testing. The FHA was subjected to vibration testing in three axes to the levels shown in Tables 5-11 and 5-12. Performance testing was conducted after each exposure as shown in Figure 5-2. Figure 5-3 shows the FHA on the shaker for vibration testing in the X-Axis. The engineering evaluation of the LRIR system concludes that the LRIR operated within specification limits after being vibrated to the limits shown in Table 5-12. The results of the Housekeeping Functions Performance Tests are summarized in the following tables.

TABLE	TITLE
5-13	Filler Bit and Anadex Data
5-14	VIP Digital B Data and Scan Motor Current (acquisition and adaptive)
5-15	VIP Analog Data
5-16	Encoder Pulse Count with and without reset
5-17	RVDT Output with and without reset
5-18	LRIR Radiometric Data
5-19	Computer Output Analyses

Table 5-10

IEU-FEU VIBRATION TEST LEVELS

Amplitude in "g" (zero to peak)

SINUSOIDAL Z & Y AXES

FREQUENCY RANGE HZ	AMPLITUDE (g-0 to peak) THRUST (Z)	LATERAL Y
5-100	7.5	7.5
100-200	5.5	5.5
200-900	5.0	5.0
900-2000	3.5	3.5

Sweep rate at 2 octaves/minute limited to 0.5" D.A.

SINUSOIDAL X-AXIS

FREQUENCY RANGE (HZ)	AMPLITUDE (g 0 to peak)
5-100	7.5
100-200	3.5
200-900	5.0
900-1600	3.5
1600-1700	2.1
1700-2000	3.5

RANDOM

AXIS	FREQ RANGE (HZ)	POWER SPECTRAL DENSITY(g^2/Hz)	g-rms	DURATION (Minutes)
Thrust	20-2000	.09	13.4	2
Lateral	20-900	.09	11.6	2
	900-2000	.05	11.6	2

Table 5-11

FHA VIBRATION TEST LEVELS
11 March 1974

SINUSOIDAL VIBRATION SURVEY

5 to 2000 Hz at 2 oct/min 1 g peak limited to 0.5" D.A.

FULL LEVEL SINUSOIDAL VIBRATION LEVELS

FREQUENCY RANGE Hz	AMPLITUDE (g 0 to peak)
5-14	3.0*
14-20	1.0
20-36	3.0
36-42	2.0
42-200	3.0
200-2000	5.0

NOTE: Sweep rate at 2 octaves/minutes limited to 0.5 D.A.

RANDOM VIBRATION LEVELS

FREQUENCY RANGE Hz	P.S.D. (g^2/Hz)
20-40	0.02
40-2000	0.09

RMS accel. - 13.3 g
Duration - 2 minutes

Table 5-12

FHA VIBRATION LEVELS
22 May 1974

SINUSOIDAL VIBRATION

X Axis {10 - 1000 Hz at .5g

Y Axis { 10 - 14 Hz at 2g
14 - 19 Hz at 1g
19-200 Hz at 2g

Z Axis { 10 - 13 Hz at .5" DA
16 - 25 Hz at 4.7 g's
25 - 34 Hz at 4 g's
34 - 44 Hz at 2.4 g's
44 - 120 Hz at 4 g's
120 - 165 Hz at 1 g
165 - 200 Hz at 4 g's

RANDOM VIBRATION

X Axis and Y Axis;

20 - 40 Hz from 01 g^2/Hz to 03 g^2/Hz
40 - 1000 Hz at .03 g^2/Hz
1000 - 2000 Hz from 03 g^2/Hz to .01 g^2 Hz

Z Axis;

20 Hz - 1000 Hz at .03 g^2/Hz
1000 Hz - 2000 Hz from .03g^2/Hz to .01 g^2/Hz

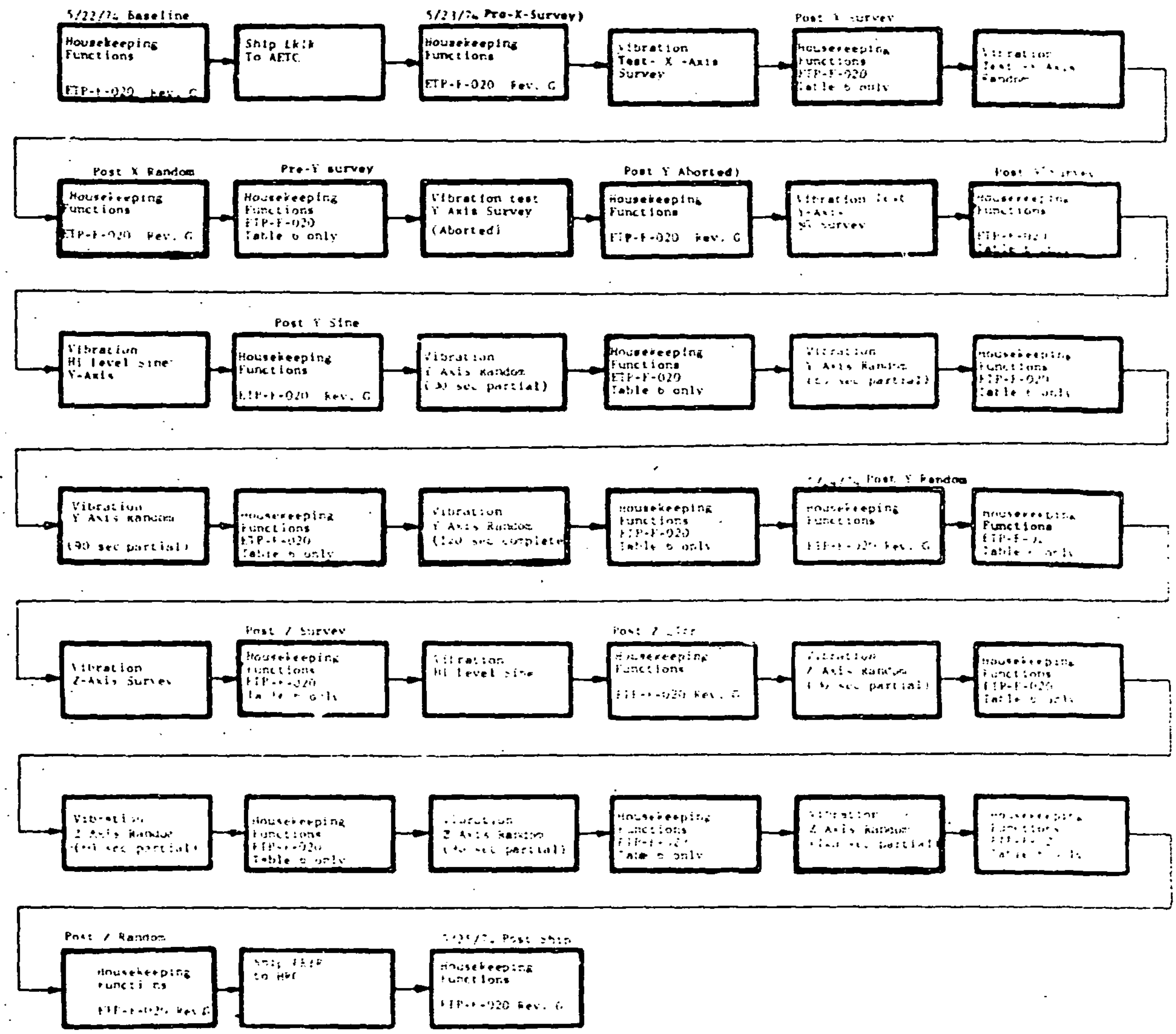


Figure 5-2 FHA VIBRATION TEST SEQUENCE

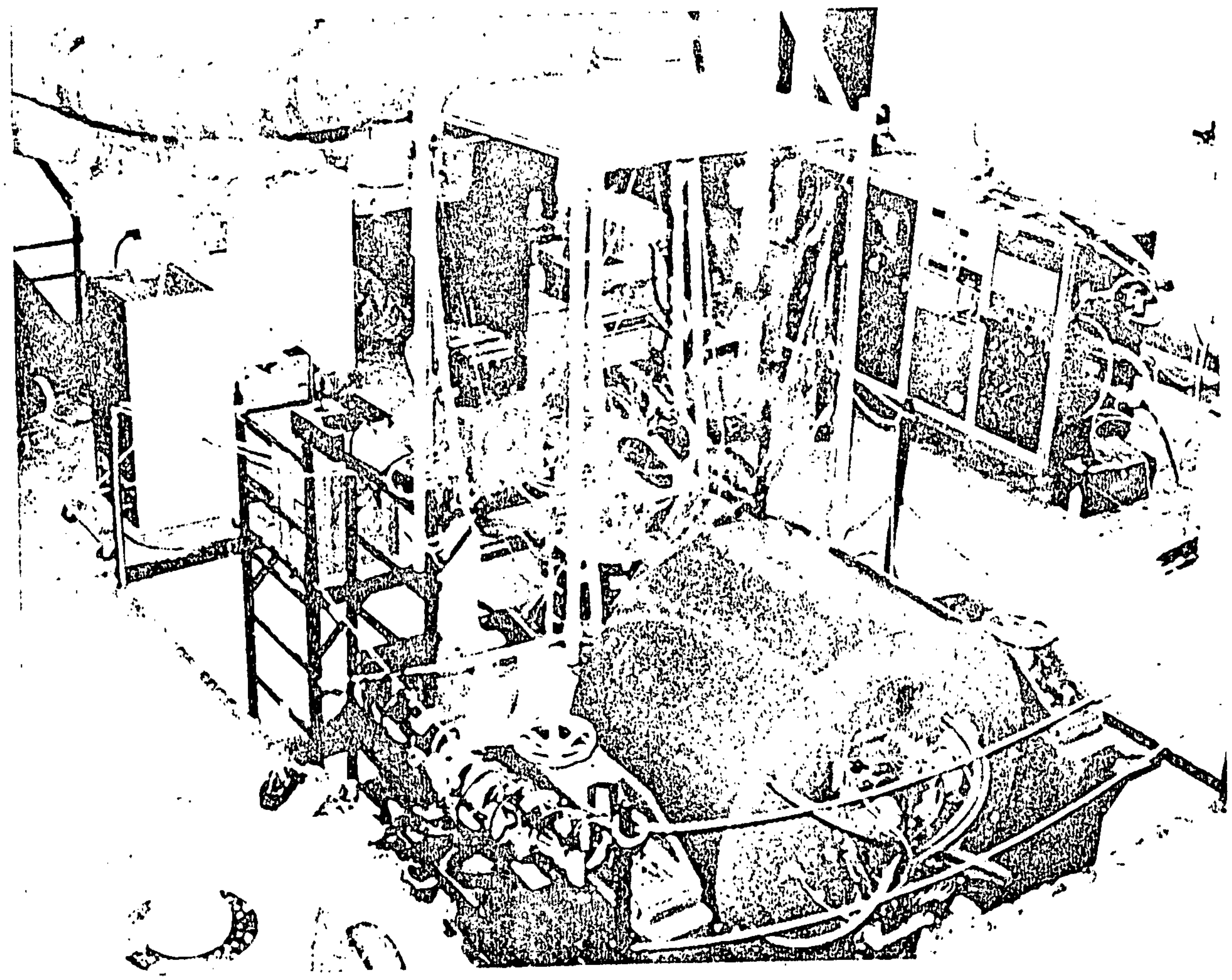


Figure 5-3 FHA INSTALLED ON SHAKER - X-AXIS VIBRATION

Table 5-13

VIBRATION DATA SUMMARY

FILLER BIT AND ANADEX DATA

DATE	TEST	FILLER BITS (shall be ≤18)	ANADEX DATA (<3 x Baseline) RAD 1	RAD 2	RAD 3	RAD 4
5/22/74	HRC Baseline	10, 10	7	3	8	39
5/23/74	Post Ship to AETC	13, 14	9	0	8	37
5/23/74	Post X-Axis Survey	----	----	------	------	----
5/23/74	Post X-Random	0, 4	11	5	16	34
5/23/74	Pre Y-Axis Survey	----	----	------	------	----
5/23/74	Post Aborted Y Survey	2, 3	6	4	10	31
5/23/74	Post Y-Axis Survey	----	----	------	------	----
5/23/74	Post Y-Axis Sine	4, 3	7	1	8	25
5/23/74	Post Y-30 Sec Random	----	----	------	------	----
5/23/74	Post Y-60 Sec Random	----	----	------	------	----
5/23/74	Post Y-90 Sec Random	----	----	------	------	----
5/23/74	Post Y-120 Sec Random	----	----	------	------	----
5/23/74	Post Y-Axis Random	3, 4	8	2	8	35
5/24/74	Pre Z-Axis Survey	----	----	------	------	----
5/24/74	Post Z-Axis Survey	----	----	------	------	----
5/24/74	Post Z-Axis Sine	3, 2	8	3	8	28
5/24/74	Post Z-30 Sec Random	----	----	------	------	----
5/24/74	Post Z-60 Sec Random	----	----	------	------	----
5/24/74	Post Z-90 Sec Random	----	----	------	------	----
5/24/74	Post Z-120 Sec Random	----	----	------	------	----
5/24/74	Post Z-Axis Random	5, 6	9	3	7	34
5/25/74	Post Ship AETC to HRC	2, 4	9	2	9	38

Table 5-14
VIBRATION DATA SUMMARY
VIP DIGITAL B DATA AND SCAN
MOTOR CURRENT (Acquisition and Adaptive)

DATE	TEST	VIP. DIG B DATA	RECORDED SCAN MOTOR CURRENT ACQUISITION & ADAPTIVE (ma - peak to peak)
5/22/74	HRC Baseline	NO ANOMALIES	20
5/23/74	Post Ship to AETC		20
5/23/74	Post X-Axis Survey		--
5/23/74	Post X-Axis Random		40
5/23/74	Pre Y-Axis Survey		--
5/23/74	Post Aborted Y Survey		25
5/23/74	Post Y-Axis Survey		--
5/23/74	Post Y-Axis Sine		25
5/23/74	Post Y-30 Sec Random		--
5/23/74	Post Y-60 Sec Random		--
5/23/74	Post Y-90 Sec Random		--
5/23/74	Post Y-120 Sec Random		--
5/23/74	Post Y-Axis Random		30
5/24/74	Pre Z-Axis Survey		--
5/24/74	Post Z-Axis Survey		--
5/24/74	Post Z-Axis Sine		30
5/24/74	Post Z-30 Sec Random		--
5/24/74	Post Z-60 Sec Random		--
5/24/74	Post Z-90 Sec Random		--
5/24/74	Post Z-120 Sec Random		--
5/24/74	Post Z-Axis Random		30
5/25/74	Post Ship AETC to HRC		35

Table 5-15

VIBRATION DATA SUMMARY
VIP ANALOG DATA

DATE	TEST	SCAN MOTOR CURRENT ACQUISITION VOLTS	SCAN MOTOR CURRENT SPACE CAL VOLTS	SCAN MOTOR CURRENT SOURCE CAL VOLTS	-15V MONITOR VOLTS	SCAN MOTOR TEMP VOLTS	DTC TEMP VOLTS	FEC TEMP VOLTS	TEC TEMP VOLTS
		(-3.3±.3)	(-3.3±.2)	(-3.3±.2)	(-5.100±.255)	(-KM Temp x .1±1.0)	(-3.50±.17)	(-KM Temp x	.1 ±1.0)
5/22/74	HRC Baseline	-3.35	-3.24	-3.32	-5.076	-2.47	-3.02	-2.50	-2.97
5/23/74	Post Ship To AETC	-3.35	-3.27	-3.30	-5.0[illegible]	-2.29	-3.02	-2.19	-2.2[illegible]
5/23/74	Post X-Axis Survey	—	—	—	—	—	—	—	—
5/23/74	Post X-Axis Random	-3.41	-3.15	-3.10	-5.0[illegible]	-2.13	-2.94	-2.65	-2.14
5/23/74	Pre Y-Axis Survey	—	—	—	—	—	—	—	—
5/23/74	Post Aborted Y Survey	-3.44	-3.27	-3.46	-5.0[illegible]	-2.26	-3.01	-2.25	-2.39
5/23/74	Post Y-Axis Survey	—	—	—	—	—	—	—	—
5/23/74	Post Y-Axis Sine	-3.37	-3.28	[-3.5[illegible]]	-5.0[illegible]	-2.36	-3.02	-2.35	-2.45
5/23/74	Post Y-30 Sec Random	—	—	—	—	—	—	—	—
5/23/74	Post Y-60 Sec Random	—	—	—	—	—	—	—	—
5/23/74	Post Y-90 Sec Random	—	—	—	—	—	—	—	—
5/23/74	Post Y-120 Sec Random	—	—	—	—	—	—	—	—
5/23/74	Post Y-Axis Random	-3.36	-3.28	-3.39	-5.0[illegible]	-2.44	-3.02	-2.41	-2.50
5/24/74	Pre Z-Axis Survey	—	—	—	—	—	—	—	—
5/24/74	Post Z-Axis Survey	—	—	—	—	—	—	—	—
5/24/74	Post Z-Axis Sine	-3.37	-3.27	-3.39	-5.07	-2.14	-2.99	-1.89	-1.9[illegible]
5/24/74	Post Z-30 Sec Random	—	—	—	—	—	—	—	—
5/24/74	Post Z-60 Sec Random	—	—	—	—	—	—	—	—
5/24/74	Post Z-90 Sec Random	—	—	—	—	—	—	—	—
5/24/74	Post Z-120 Sec Random	—	—	—	—	—	—	—	—
5/24/74	Post Z-Axis Random	-3.38	-3.27	-3.48	-5.0[illegible]	-2.19	-2.97	-2.09	-2.19
5/25/74	Post Ship AETC To HRC	-3.40	-3.24	[-3.53]	-5.05	-2.00	-2.88	-2.12	-2.52

[ ] REPORTED ON MRF00143

Table 5-16

VIBRATION DATA SUMMARY
ENCODER PULSE COUNT (With and Without Reset)

DATE	TEST	ENCODER PULSE COUNT (WITH RESET)				ENCODER PULSE COUNT (WITHOUT RESET)			
		OMP ℄	SPACE CAL	SOURCE CAL	SPACE CAL	SOURCE TO OMP ℄	OMP ℄ TO SPACE	SPACE OMP ℄	OMP ℄ TO SOURCE
5/22/74	HRC Baseline	+1	+35	-2	+35	-1404	+354	-354	+1404
5/23/74	Post Ship To AETC	+62	+33	-3	+33	-1406	+355	-354	+1405
5/23/74	Post X-Axis Survey	+62	+33	-0	+33	-1408	+354	-354	+1408
5/23/74	Post X-Axis Random	+38	+8	+34	+9	-1404	+355	-353	+1402
5/23/74	Pre Y-Axis Survey	+35	+6	+30	+7	-1403	+355	-353	+1401
5/23/74	Post Aborted Y Survey	+35	+6	-28	+7	-1408	+356	-355	+1407
5/23/74	Post Y-Axis Survey	+36	+8	-26	+8	-1409	+356	-355	+1408
5/23/74	Post Y-Axis Sine	+36	+8	-27	+8	-1408	+356	-355	+1407
5/23/74	Post Y-30 Sec Random	+37	+9	-26	+9	-1408	+355	-355	+1408
5/23/74	Post Y-60 Sec Random	+43	+16	-20	+15	-1407	+355	-354	+1406
5/23/74	Post Y-90 Sec Random	+45	+17	-20	+16	-1406	+356	-354	+1403
5/23/74	Post Y-120 Sec Random	+47	+18	-17	+18	-1407	+355	-354	+1405
5/23/74	Post Y-Axis Random	+45	+17	-19	+17	-1406	+356	-354	+1404
5/24/74	Pre Z-Axis Survey	+47	+18	-17	+18	-1407	+355	-354	+1406
5/24/74	Post Z-Axis Survey	+47	+19	-16	+18	-1408	+355	-354	+1406
5/24/74	Post Z Axis Sine	+45	+17	-19	+17	-1406	+355	-353	+1404
5/24/74	Post Z-30 Sec Random	+48	+19	-17	+19	-1407	+355	-353	+1404
5/24/74	Post Z-60 Sec Random	+47	+18	-18	+18	-1406	+355	-353	+1404
5/24/74	Post Z-90 Sec Random	+48	+19	-17	+19	-1406	+355	-353	+1404
5/24/74	Post Z-120 Sec Random	+46	+17	-19	+17	-1406	+355	-354	+1405
5/24/74	Post Z-Axis Random	+44	+15	-22	+14	-1406	+355	-353	+1404
5/25/74	Post Ship AETC to HRC	+47	+19	-18	+18	-1405	+355	-353	+1403

Table 5-17

VIBRATION DATA SUMMARY
RVDT OUTPUT (With and Without Reset)

DATE	TEST	RVD OUTPUT VOLTS (WITH RESET)*				RVDT OUTPUT VOLTS (WITHOUT RESET)*				
		CMP ℄	SPACE CAL	SOURCE CAL	SPACE CAL	SOURCE	SOURCE TO CMP ℄	CMP ℄ TO SPACE	SPACE TO CMP ℄	CMP ℄ TO SOURCE
5/22/74	HRC Baseline	-1.072	-2.250	-5.626	-2.250	-5.626	-1.072	-2.250	-1.074	-5.627
5/23/74	Post Ship To AETC	-1.067	-2.239	-5.616	-2.239	-5.616	-1.067	-2.239	-1.068	-5.616
5/23/74	Post X-Axis Survey	-1.064	-2.236	-5.615	-2.236	-5.614	-1.065	-2.236	-1.066	-5.614
5/23/74	Post X-Axis Random	-1.070	-2.247	-5.620	-2.249	-5.620	-1.070	-2.247	-1.075	-5.620
5/23/74	Pre Y-Axis Survey	-1.065	-2.236	-5.612	-2.240	-5.612	-1.065	-2.237	-1.070	-5.611
5/23/74	Post Aborted Y Survey	-1.071	-2.249	-5.629	-2.249	-5.627	-1.071	-2.249	-1.073	-5.627
5/23/74	Post Y-Axis Survey	-1.065	-2.238	-5.619	-2.239	-5.613	-1.064	-2.238	-1.067	-5.617
5/23/74	Post Y-Axis Sine	-1.067	-2.245	-5.625	-2.245	-5.623	-1.067	-2.245	-1.070	-5.623
5/23/74	Post Y-30 Sec Random	-1.066	-2.239	-5.617	-2.238	-5.615	-1.066	-2.239	-1.068	-5.616
5/23/74	Post Y-60 Sec Random	-1.066	-2.239	-5.616	-2.238	-5.612	-1.066	-2.239	-1.068	-5.615
5/23/74	Post Y-90 Sec Random	-1.066	-2.239	-5.617	-2.239	-5.614	-1.065	-2.239	-1.069	-5.615
5/23/74	Post Y-120 Sec Random	-1.066	-2.239	-5.617	-2.239	-5.615	-1.065	-2.239	-1.069	-5.615
5/23/74	Post Y-Axis Random	-1.069	-2.247	-5.624	-2.247	-5.622	-1.069	-2.247	-1.072	-5.623
5/24/74	Pre Z-Axis Survey	-1.069	-2.246	-5.625	-2.247	-5.623	-1.069	-2.246	-1.072	-5.623
5/24/74	Post Z-Axis Survey	-1.064	-2.237	-5.615	-2.237	-5.607	-1.061	-2.235	-1.067	-5.614
5/24/74	Post Z-Axis Sine	-1.069	-2.247	-5.624	-2.248	-5.624	-1.069	-2.248	-1.073	-5.623
5/24/74	Post Z-30 Sec Random	-1.064	-2.238	-5.618	-2.238	-5.611	-1.063	-2.237	-1.068	-5.614
5/24/74	Post Z-60 Sec Random	-1.065	-2.237	-5.616	-2.238	-5.611	-1.064	-2.237	-1.068	-5.614
5/24/74	Post Z-90 Sec Random	-1.064	-2.236	-5.617	-2.237	-5.610	-1.063	-2.236	-1.068	-5.614
5/24/74	Post Z-120 Sec Random	-1.064	-2.237	-5.616	-2.238	-5.610	-1.064	-2.237	-1.068	-5.614
5/24/74	Post Z-Axis Random	-1.069	-2.246	-5.625	-2.247	-5.623	-1.069	-2.246	-1.072	-5.623
5/25/74	Post Ship AETC To HRC	-1.064	-2.230	-5.579	-2.231	-5.576	-1.064	-2.230	-1.068	-5.576

*Reset refers to Encoder Pulse Counts (Table 7) values only. RVDT Output values are taken at the same time as Encoder Pulse Counts of Table 7 and the columns are labeled identically for correlation purposes "Reset" has no effect on RVDT outputs.

Table 5-18

LRIR RADIOMETRIC DATA

		Baseline HRC	Post Ship AETC Pre X	Post Random X-Axis	Post Sine Y-Axis	Post Random Y-Axis	Post Sine Z-Axis	Post Random Z-Axis	Post Ship
SPACE	Chan. 1	5.86	5.70	5.57	5.56	5.49	5.33	5.28	5.70
	Chan. 2	5.90	5.75	5.53	5.61	5.47	5.39	5.36	5.77
	Chan. 3	5.99	5.83	5.82	5.88	5.82	5.72	5.74	6.07
	Chan. 4	5.56	5.42	5.35	5.33	5.30	5.18	5.18	5.43
Space Counts		+35	+33	+8	+8	+17	+17	+15	+19
ΔHRC Baseline		0	-2	-27	-27	-18	-18	-20	-16
SOURCE	Chan. 1	6.30	6.13	5.88	5.89	5.78	5.52	5.48	6.06
	Chan. 2	6.58	6.43	6.00	6.19	5.97	5.85	5.81	6.36
	Chan. 3	7.85	7.80	7.72	7.71	7.71	7.70	7.71	7.77
	Chan. 4	5.87	5.67	5.49	5.56	5.49	5.38	5.35	5.69
IFC Temp.		5923	5952	5952	5962	5923	5903	5913	5201
Chan. 4 Det. Temp.		80.1°K	80.5°K	80.8°K	81.4°K	81.6°K	83.2°K	83.4°K	80.3°K
Pri. Mirror Temp.		24.4°C	22.7°C	21.7°C	23.1°C	23.7°C	21.2°C	22.1°C	20.3°C
OMP Housing Temp.		24.6°C	22.9°C	22.0°C	23.3°C	24.2°C	21.7°C	22.5°C	20.6°C

Table 5-19

COMPUTER OUTPUT ANALYSES

DIGITAL DATA	PRE SHIP TO AETC					POST SHIP					POST X-AXIS				
		ANOMALIES					ANOMALIES					ANOMALIES			
	WORDS	*H	%	*S	%	WORDS	*H	%	*S	%	WORDS	*H	%	*S	%
SCAN O'RIDE	10,026	25	.25	0	0	11,176	42	.38	96	.86	10,498	21	.20	72	.69
SCAN ON	5,184	2	.04	31	.6	4,140	14	.34	27	.65	4,600	1	.02	20	.43
NON-SCAN**	3,584	0	0	0	0	2,832	0	0	7	.25	2,968	0	0	7	.24
TOTAL	18,794	27	.14	31	.16	18,148	56	.31	130	.72	18,066	22	.12	99	.55

DIGITIAL DATA	POST Y AXIS					POST Z AXIS					POST SHIP TO HRC				
		ANOMALIES					ANOMALIES					ANOMALIES			
	WORDS	*H	%	*S	%	WORDS	*H	%	*S	%	WORDS	*H	%	*S	%
SCAN O'RIDE	8,190	23	.28	100	1.22	10,360	28	.27	28	.27	10,120	22	.22	0	0
SCAN ON	4,600	11	.24	34	.74	4,968	2	.04	12	.24	5,428	0	0	4	.07
NON-SCAN**	2,940	0	0	13	.44	3,408	0	0	3	.09	4,180	0	0	0	0
TOTAL	15,730	34	.28	147	.38	18,736	30	.16	43	.23	19,728	22	.11	4	.02

*Non-Scan words are totals from Source Cal and Space Cal printouts, 30 seconds each

H = Hardware

S = Software

5.1.3 EMI

The LRIR was subjected to RF radiated susceptibility test as specified in ETP-E-030, Rev. A on March 15, 1974.

A copper strap was connected between the bottom of the test item holding fixture and the test bench. A Biconical Antenna horizontally polarized was placed a distance of 1 meter away from the test item at Position No. 1 as shown in Figure 5-4.

0.5 watts of power at 136.5 MHz, modulated 100% with a 943 Hz squarewave, was applied to the antenna. The antenna was oriented for maximum change in performance of the test item. RF susceptibility was observed. The power level was reduced to find the threshold level. Susceptibility was still observed at 10 milliwatts Testing with 943 Hz modulation was stopped.

The modulation frequency was then changed to 1,000 Hz and susceptibility indications were noted on the test item, testing was stopped.

Testing was again resumed with the antenna placed in Position No. 1 and the RF frequency was 136.5 MHz at 80% modulation with a 4,000 Hz squarewave. The power to the antenna at this time was 0.5 watts. A housekeeping function performance test was then performed. No degradation of the LRIR performance was observed.

The antenna was then vertically polarized while still at Position No. 1 and a housekeeping function test again performed. No degradation of the LRIR performance was observed.

The antenna was then moved to Position No. 2 as shown in Figure 5-4 (i.e., horizontal polarization). Housekeeping function test was then performed. No degradation of the LRIR performance was observed.

The modulation frequency was then changed to 943 Hz.

The antenna position was moved to find the most susceptible location. At this location, power levels were changed from 500 to 1 milliwatts. RF susceptibility was again observed at this modulation frequency.

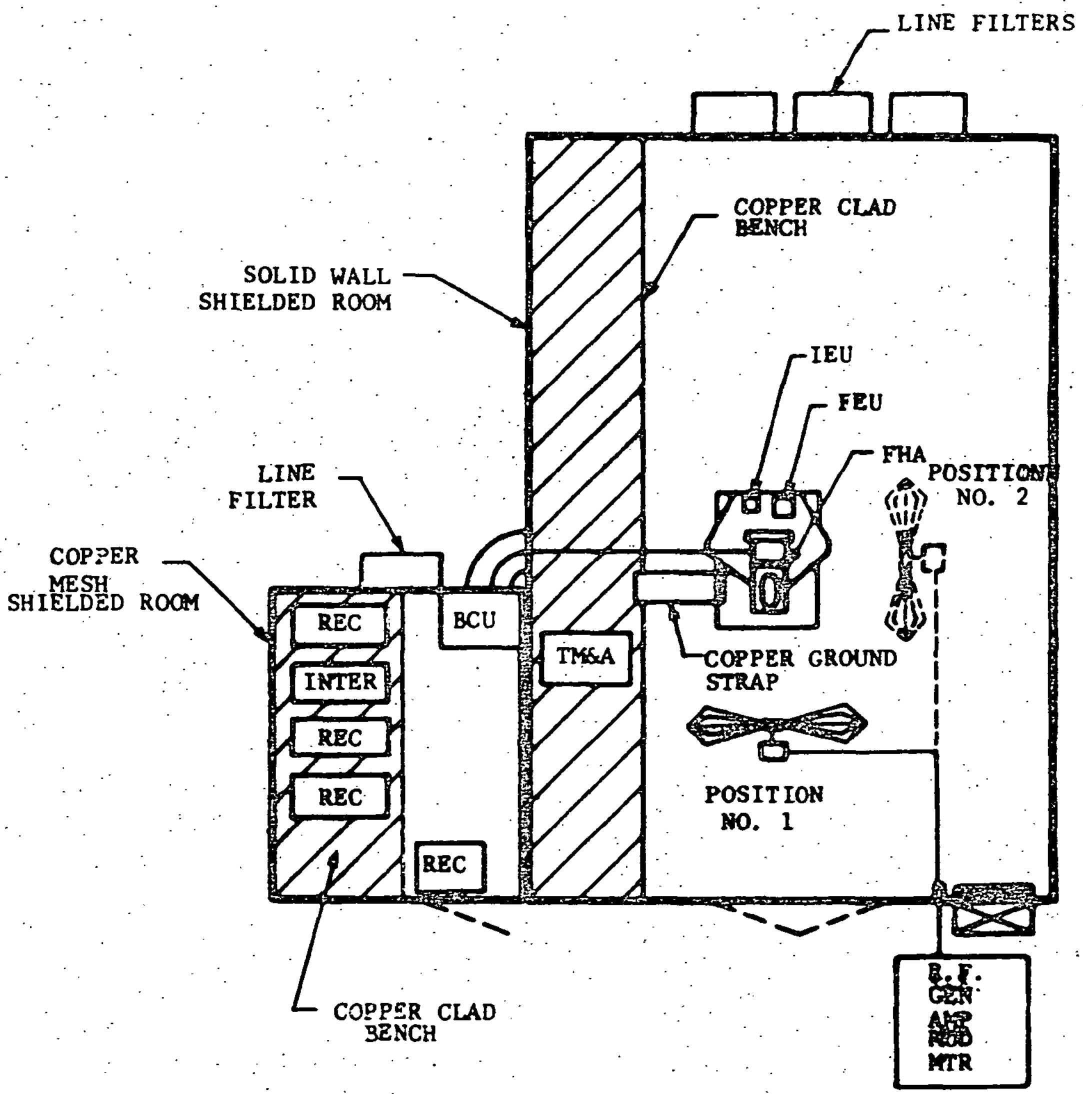


Figure 5-4 EMI TEST CONFIGURATION

A log spiral antenna was then placed at Position No. 1 and a 1705.4 MHz signal FM modulated at 128.05 kHz was applied to the antenna. The power level was 1 watt to the antenna. Housekeeping function measurements were performed under these conditions. No degradation of the LRIR performance was observed.

The antenna was then moved to Position No. 2 and was the same field strength as specified above. Housekeeping function measurements were again performed. No degradation of the LRIR performance was observed.

The same antenna was then changed to Position No. 1 and the applied frequency was changed to 2251.7 MHz. The RF was FM modulated with 4000 Hz. Housekeeping function measurements were performed while maintaining 1.0 watts to the antenna. No degradation of the LRIR performance was observed.

The antenna was then changed to Position No. 2 and under the same conditions as specified above, housekeeping functional measurements were again performed.

The results of the Housekeeping Functions Performance tests tabulated in Tables 5-20, 5-21 and 5-22 indicate that the LRIR did not deviate from its performance specification when exposed to RF Fields at 136.5, 1702,5 and 2253.0 MHz with 4 kHz modulation.

Table 5-20

EMI TEST DATA
HOUSEKEEPING FUNCTIONS PERFORMANCE TEST ETP-F-020 REV. F

DATE	TEST	VIP DIG B DATA	SCAN MTR CURRENT ACQ -3.3±.3	SCAN MTR CURRENT SPACE CAL -3.3±.2	SCAN MTR CURRENT SOURCE CAL -3.3±.2	-15V MON -5.100 ± .255	SCAN MTR TEMP -RM Temp x .1 ±1.0	IFC TEMP 100 ± .15	FEU TEMP -RM Temp x .1 ± 1.0	IEU TEMP -RM Temp x .1 ± 1.0
3/18/74	Baseline		-3.09	-3.14	-3.14	-5.06	-2.24	-2.99	-2.13	-2.13
3/18/74	#1		-3.11	-3.13	-3.14	-5.06	-2.13	-2.84	-2.02	-2.17
3/19/74	#2		-3.12	-3.13	-3.14	-5.06	-2.32	-3.01	-2.29	-2.48
3/19/74	#3	NO ANOMALIES	-3.11	-3.12	-3.14	-5.06	-2.47	-3.01	-2.47	-2.68
3/19/74	#4		-3.22	-3.13	-3.15	-5.06	-2.54	-3.02	-2.54	-2.76
3/20/74	#5		-3.13	-3.12	-3.14	-5.06	-2.32	-3.02	-2.27	-2.47
3/20/74	#6		-3.27	-3.11	-3.14	-5.06	-2.44	-3.01	-2.43	-2.63
3/20/74	#7		-3.12	-3.16	-3.15	-5.06	-2.51	-3.02	-2.50	-2.70
3/20/74	#8		-3.14	-3.12	-3.15	-5.06	-2.59	-3.02	-2.58	-2.78

TEST IDENTIFICATION
1 136 MHz 4KHz sq. Ant. Pos 1 Hor.

2 136 MHz 4KHz sq. Ant. Pos 1 Vert.

3 136 MHz 4KHz Ant. Pos. 2 Hor.

4 136 MHz 4KHz Ant. Pos. 2 Vert.

TEST IDENTIFICATION
5 1702 MHz 128KHz Antenna Pos. 1

6 1702 MHz 128 KHz Antenna Pos. 2

7 2253 MHz 4KHz Antenna Pos. 1

8 2253 MHz 4KHz Antenna Pos. 2

Table 5-21
PM LRIR EMI COMPUTER DATA ANALYSIS

	SCAN OVERRIDE			SCAN ON			NON-SCAN DATA		
		ANOMALIES			ANOMALIES			ANOMALIES	
	WORDS	HDWR.	DATA.	WORDS	HDWR	DATA.	WORDS	HDWR	DATA
Baseline	10,120	65	51	5,888	0	8	3,576	0	8
136 MHz 943 sq. Ant Pos 1 Hor.	10,080	161	49	4,800	8	9	3,392	0	6
136 MHz 4kHz sq Ant. Pos 1 Hor.	12,288	253	83	4,800	1	26	3,584	0	16
136 MHz 4kHz sq Ant Pos 1 Vert.	12,000	77	72	4,800	4	8	2,912	0	8
136 MHz 4kHz Ant. Pos. 2 Hor.	10,764	157	30	5,336	3	16	3,136	0	7
136 MHz 4kHz Ant. Pos. 2 Vert	11,500	95	65	4,324	1	7	3,494	0	6
1702 MHz 128kHz Antenna Pos. 1	10,580	72	62	5,244	2	20	3,808	1	15
1702 MHz 128 kHz Antenna Pos. 2	10,120	98	60	5,428	4	14	3,898	0	0
2253 MHz 4kHz Antenna Pos. 1	10,810	101	52	5,060	1	1	3,584	0	3
2253 MHz 4kHz Antenna Pos. 2	11,730	95	57	4,232	1	2	2,912	0	6

Table 5-22
MEASURED DATA SPREAD (PK TO PK COUNTS)
(Para. 7.1 Housekeeping Functions Performance Tests ETP-F-020 Rev. F)

CHAN.	BASELINE PRIOR TO SHIP	BASELINE AFTER SHIP	HOUSEKEEPING FUNCTIONS TESTS							
			1	2	3	4	5	6	7	8
1	7	4	8	5	6	8	7	4	4	7
2	2	3	5	3	2	2	2	0	0	1
3	10	6	3	6	3	8	11	8	6	6
4	31	30	40	31	42	38	34	28	32	19

DETECTOR TEMP - 80°K NOMINAL.

TEST NO.	IDENTIFICATION
1	136 MHz 4kHz sq. Ant. Pos. 1 Hor.
2	136 MHz 4kHz sq. Ant. Pos. 1 Vert.
3	136 MHz 4kHz Ant. Pos. 2 Hor.
4	136 MHz 4kHz Ant. Pos. 2 Vert.
5	1702 MHz 128 kHz Antenna Pos. 1
6	1702 MHz 128 kHz Antenna Pos. 2
7	2253 MHz 4 kHz Antenna Pos. 2
8	2253 MHz 4kHz Antenna Pos. 2

5.1.4 Thermal-Vacuum

Thermal vacuum testing of the PM LRIR consisted of a survivability test and a performance test as shown in Figure 5-5, Thermal Vacuum Test Sequence. A baseline Housekeeping Functions Performance Test ETP-F-020 was performed prior to closing the chamber door with the unit sitting on the optical bench. The chamber door was closed and the chamber was evacuated to less than 1 x 10^{-5} torr with the LRIR interface mounting temperature controlled to 25°C. The Housekeeping Functions Test was repeated and verification of no degradation in performance was obtained. The LRIR power remained on with the unit scanning across a simulated earth limb target while the LRIR interface mounting plate temperature was varied over a range of -5°C to +45°C for the period as shown in Figure 5-5.

During the entire thermal vacuum test the following functions were continuously monitored on an eight-channel strip chart recorder:

RECORDER CHANNEL	DESCRIPTION
1	Channel 1 Radiance
2	Channel 2 Radiance
3	Channel 3 Radiance
4	Channel 4 Radiance
5	RVDT
6	Encoder (A Track)
7	Scan Direction
8	Scan Motor Current

An example of a typical test monitor chart recording during the survivability test is shown in Figure 5-7. In addition, LRIR input voltage and current was monitored on a two-channel Brush Recorder.

At the completion of the survivability tests, the LRIR interface temperature was controlled to +15°C, +25°C, and +35°C for a period of 20 hours. Housekeeping Functions Performance Tests were performed at each temperature as indicated in Figure 5-6. Test data taken during the thermal vacuum test is summarized in Tables 5-23 through 5-25. An engineering evaluation of the test data indicates that the LRIR system performance did not deviate from its performance specification after being exposed to the Thermal Vacuum cycle shown in Figure 5-5.

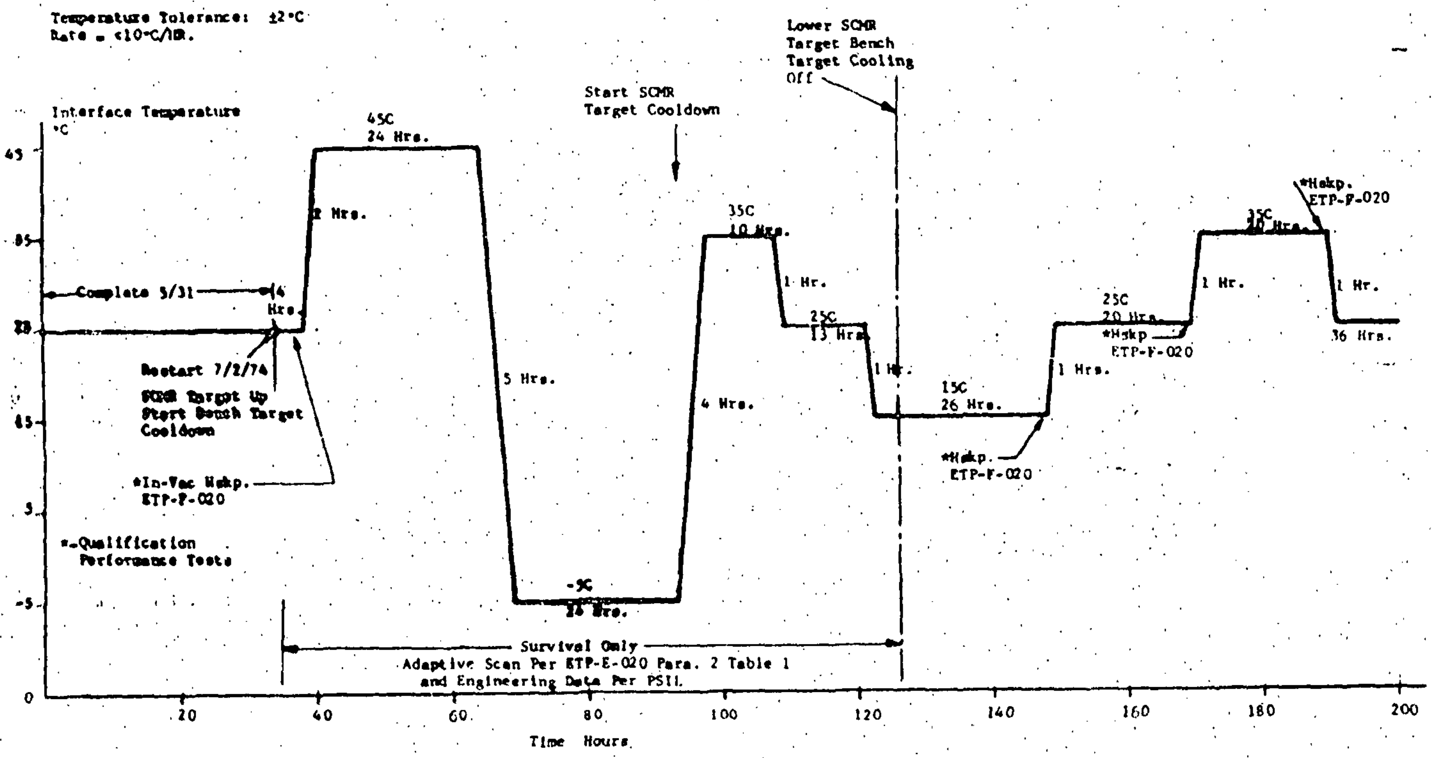
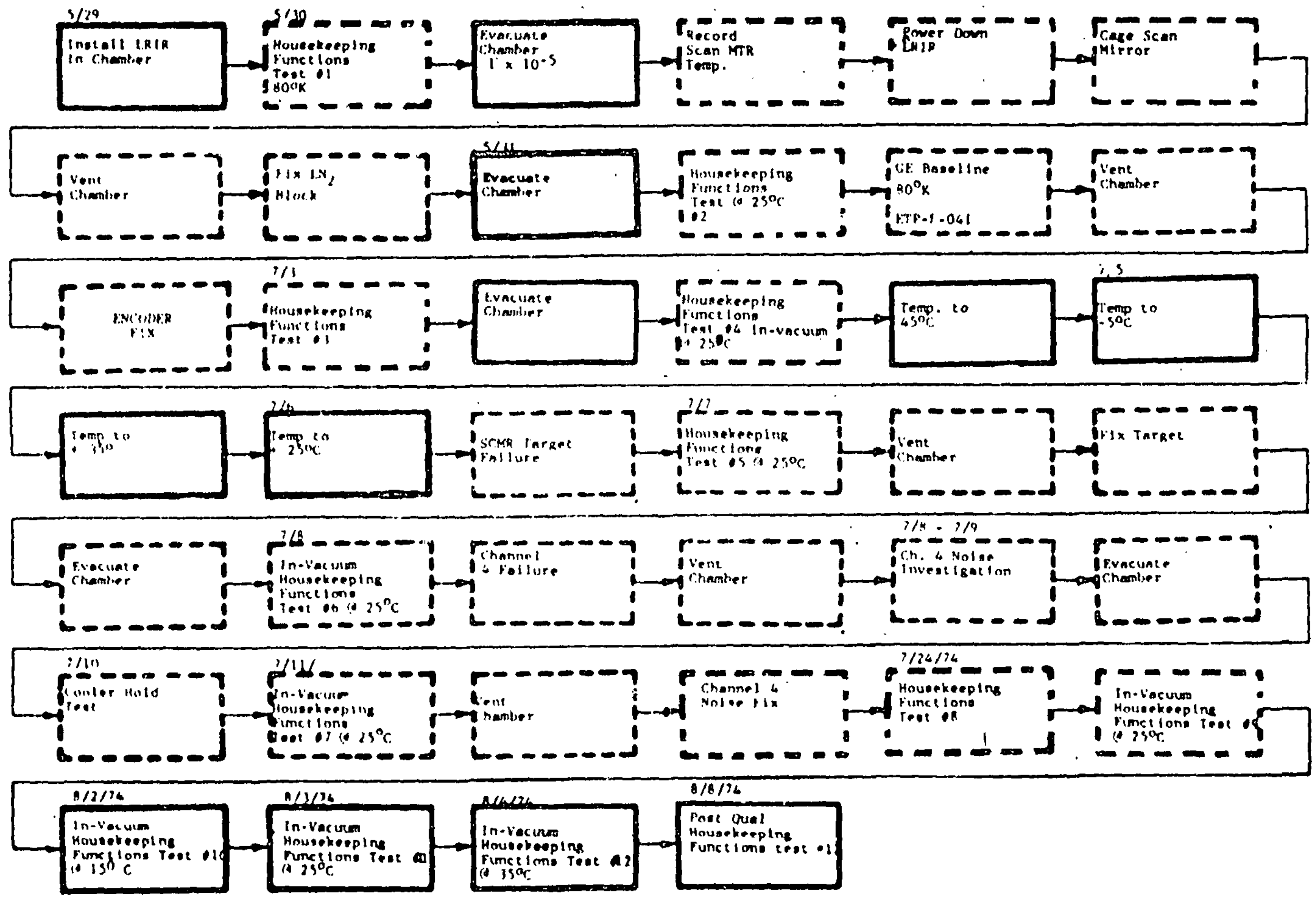


Figure 5-5 THERMAL VACUUM TEST SEQUENCE



LEGEND: [dashed box] NOT PART OF QUALIFICATION TEST

Figure 5-6 THERMAL VACUUM FLOW DIAGRAM

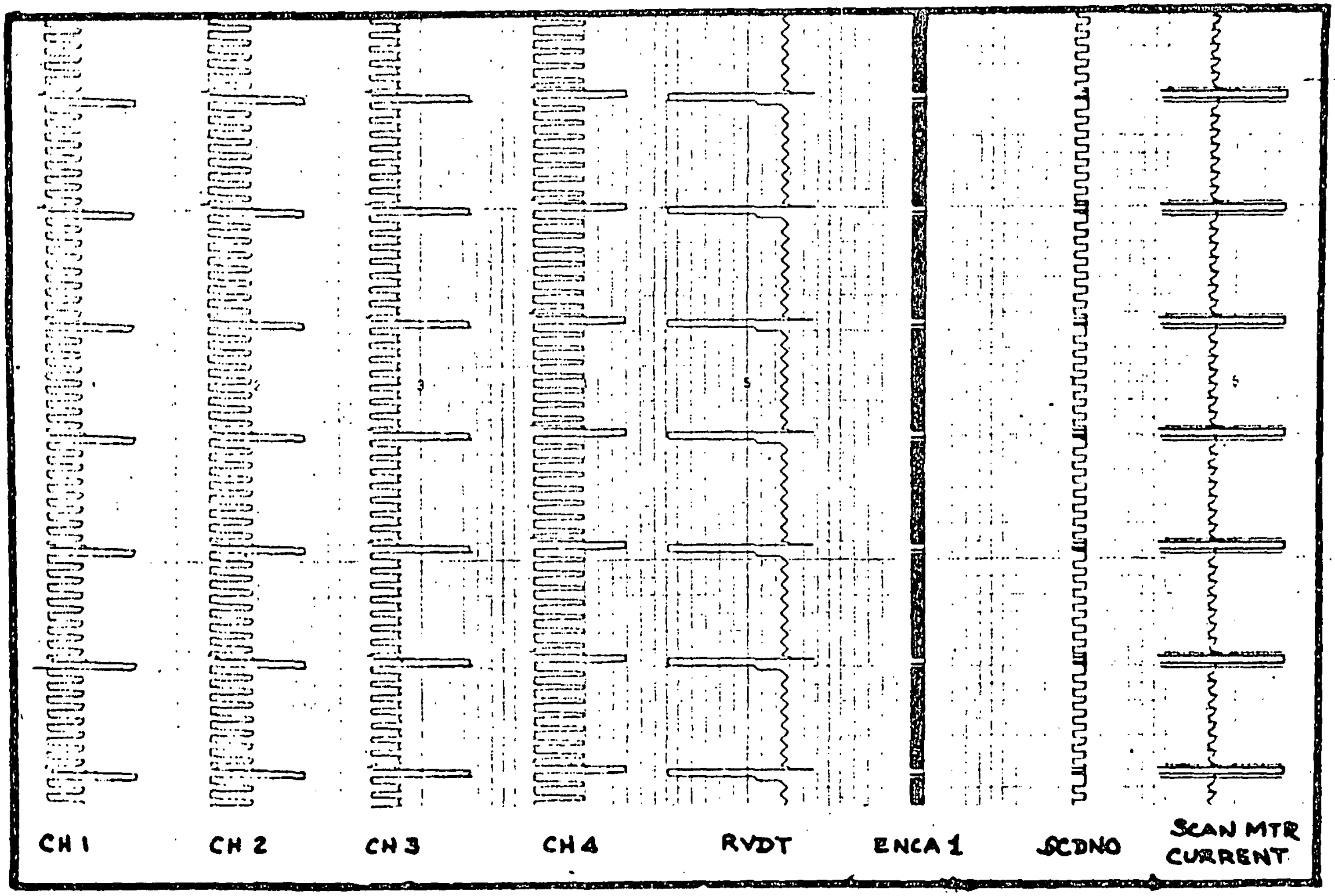


Figure 5-7 SAMPLE 8 CHANNEL RECORDER - FUNCTIONS CONTINUOUSLY MONITORED DURING THERMAL VACUUM TEST

Table 5-23

VIP ANALOG DATA

FUNCTION	OPERATIONAL COMMAND	Housekeeping Functions Performance Test ETP-F-020 Rev. C - See Fig. 5												
		1	2	3	4	5	6	7	8	9	10	11	12	13
SCAN MOTOR CURRENT	SCAN OVERRIDE	-3.[illegible]	-3.18	-3.42	-3.40	-3.25	-3.45	-3.27	-3.28	-3.28	-3.20	-3.37	-3.43	-3.4[illegible]
SCAN MOTOR CURRENT	SPACE CAL	-3.15	-3.17	-3.10	-3.15	-3.14	-3.17	-3.20	-3.20	-3.20	-3.20	-3.18	-3.21	-3.18
SCAN MOTOR CURRENT	SOURCE CAL	-3.41	-3.24	-0.77	- .75	- .72	- .72	- .76	- .76	- .69	- .69	- .76	- .81	- .77
SCAN MOTOR CURRENT	UNCAGE	-3.41	-3.24	-0.78	- .76	- .73	- .78	- .77	- .76	- .71	- .71	- .78	- .83	- .77
-15 Vdc MONITOR	SCAN ON	-5.06	-5.06	-5.07	-5.07	-5.06	-5.06	-5.06	-5.06	-5.06	-5.06	-5.06	-5.06	-5.06
DETECTOR TEMP	SCAN ON	-.619	+.06	-3.94	-3.93	-3.96	-3.94	-3.39	-3.19	-3.94	-3.94	-3.95	-3.94	-3.69
CRYOGEN EXTERIOR	SCAN ON	-2.04	-2.38	-2.36	-2.48	-2.08	-2.41	-2.48	-2.26	-1.55	-1.55	-2.34	-3.16	-2.39
PRIMARY PARABOLA	SCAN ON	-2.04	-2.21	-2.32	-2.33	-1.28	-2.19	-2.42	-2.18	-1.59	-1.59	-2.16	-2.82	-2.35
CRYO SHIELD TEMP	SCAN ON	-4.36	-4.19	-3.36	-3.36	-3.38	-3.37	-3.39	-3.38	-3.34	-3.34	-3.34	-3.34	-3.36
BAFFLE TEMP 1	SCAN ON	-2.05	-2.18	-2.32	-2.21	-1.39	-2.19	-2.35	-2.17	-1.66	-1.66	-2.15	-2.73	-2.36
BAFFLE TEMP 2	SCAN ON	-2.05	-2.18	-2.32	-2.22	-1.41	-2.20	-2.35	-2.17	-1.65	-1.65	-2.16	-2.76	-2.37
BLACKBODY TEMP	SCAN ON	-4.20	-4.48	-4.40	-4.49	-4.45	-4.48	-4.41	-4.23	-4.42	-4.42	-4.48	-4.56	-4.30
SCAN MOTOR TEMP	SCAN ON	-2.10	-2.34	-2.52	-2.48	-1.89	-2.49	-2.53	-2.32	-1.77	-1.77	-2.51	-3.26	-2.51
HOUSING OMP TEMP	SCAN ON	-2.08	-2.33	-2.38	-2.42	-1.77	-2.30	-2.45	-2.23	-1.63	-1.63	-2.33	-3.11	-2.41
IFC SOURCE TEMP	SOURCE CAL	-2.85	-3.05	-3.02	-3.06	-3.05	-3.05	-3.03	-2.85	-3.05	-3.05	-3.06	-3.07	-2.91
FEU ELECT TEMP	SOURCE CAL	-1.99	-2.45	-2.28	-2.58	-2.42	-2.50	-2.35	-2.16	-1.34	-1.34	-2.49	-3.51	-2.32
IEU ELECT TEMP	SOURCE CAL	-2.43	-2.66	-2.48	-2.75	-2.75	-2.82	-2.54	-2.27	-1.63	-1.63	-2.71	-3.70	-2.53

← 80K Det. Pre IFC Source Stop | → 65°K Det. After IFC Source Stop and Encoder Fix

Table 5-24

SCAN DRIVE DATA

COMMAND	HOUSEKEEPING FUNCTIONS PERFORMANCE TESTS - ETP-F-020 REV. G (See Fig. [illegible])												
	1	2	3	4	5	6	7	8	9	10	11	12	13
ENCODER PULSE COUNTS													
Calibrate Override (OMP ℄ Position)	-1414	-1416	+1443	+1447	+1432	+1441	+1443	+1435	+1441	+1442	+1441	+1439	+1435
Space Calibrate	+352	+353	-352	-352	-352	-353	-352	-352	-352	-352	-353	-354	-352
Calibrate Override (OMP ℄ Position)	-350	-352	+351	+351	+350	+351	+351	+351	+351	+351	+352	+353	+351
Source Calibrate	+1412	+1415	-1441	-1445	-1432	-1438	-1441	-1434	-1440	-1440	-1439	-1438	-1434
Calibrate Overide (OMP ℄ Position)	+49	+49	-59	-56	-12	-1	-61	-4	-64	-1	-64	-63	-5
Space Calibrate	+18	+18	-27	-24	-44	-32	-28	-36	-32	-33	-33	-31	-36
Source Calibrate	-6	-5	-30	-30	-34	-32	-30	-31	-32	-33	-31	-28	-31
Space Calibrate	+18	+18	-27	-24	-44	-32	-28	-36	-32	-33	-33	-31	-35
RVDT VOLTAGE													
Source Calibration	-5.587	-5.688	-5.771	-5.772	-5.740	-5.756	-5.763	-5.750	-5.764	-5.762	-5.756	-5.754	-5.74[illegible]
Calibrate Override (OMP ℄ Position)	-1.070	-1.072	-1.072	-1.065	-1.075	-1.070	-1.074	-1.073	-1.071	-1.067	-1.070	-1.076	-1.074
Space Calibrate	-2.248	-2.250	-2.250	-2.235	-2.253	-2.248	-2.252	-2.251	-2.253	-2.246	-2.247	-2.256	-2.251
Calibrate Override (OMP ℄ Position)	-1.073	-1.075	-1.075	-1.058	-1.080	-1.073	-1.076	-1.075	-1.073	-1.071	-1.072	-1.061	-1.076
Source Calibrate	-5.687	-5.688	-5.770	-5.769	-5.735	-5.753	-5.761	-5.748	-5.764	-5.757	-5.754	-5.750	-5.742
Calibrate Override (OMP ℄ Position)	-1.069	-1.072	-1.072	-1.065	-1.075	-1.071	-1.074	-1.074	-1.071	-1.068	-1.071	-1.075	-1.074
Space Calibrate	-2.245	-2.250	-2.250	-2.234	-2.253	-2.248	-2.252	-2.252	-2.253	-2.246	-2.244	-2.235	-2.25[illegible]
Source Calibrate	-5.689	-5.690	-5.772	-5.770	-5.738	-5.754	-5.762	-5.749	-5.765	-5.760	-5.756	-5.751	-5.74[illegible]
Space Calibrate	-2.249	-2.251	-2.251	-2.239	-2.254	-2.245	-2.252	-2.252	-2.253	-2.247	-2.245	-2.256	-2.25[illegible]

60°K Detectors ← | → 65°K Detectors and Encoder Fix

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Table 5-25

RADIANCE DATA

ANADEX PRINTOUT PEAK-TO-PEAK OCTAL COUNTS

CHANNEL	Housekeeping Functions Performance Tests - ETP-F-020 Rev. G Sec Figure 5												
	1	2	3	4	5	6	7	8	9	10	11	12	13
1	3	16	9	11	9	3	8	4	8	9	8	9	7
2	0	2	3	[illegible]	4	3	4	4	4	4	4	4	1
3	8	10	9	10	12	15	11	8	8	8	9	7	4
4	26	38	42	31	28	24	14	8	16	10	10	9	7

80°K Detectors — 65°K Detectors and Encoder Fix

Table 5-26

HOUSEKEEPING FUNCTIONS PERFORMANCE TEST

TEST PARAMETER	PRE QUAL TEST DATA 2/28/74 ETP-F-020, Rev. D Det. Temp 80°K					POST QUAL TEST DATA 8/8/74 ETP-F-020, Rev. G Det. Temp 65°K				
VIP ANALOG	NO ANOMALIES					NO ANOMALIES				
VIP DIGITAL B										
HDRSS										
		ANOMALIES					ANOMALIES			
DIGITAL DATA	WORDS	HDW.	%	SOFTWARE	%	WORDS	HDW.	%	SOFTWARE	%
SCAN OVERRIDE	1,610	12	.20	0	0	7,360	16	.22	7	.10
SCAN ON	2,084	0	.07	3	-	6,992	19	.27	78	1.12
NON-SCAN	-----	--	---	-	-	3,672	0	0	0	0
TOTAL	8,694	12	---	3	-	18,024	35	.19	85	.47

Post Qual scan performance can only be compared to test performed after the encoder fix. See Tables 15 and 16.

COMMENTS AND CONCLUSIONS

A comparison of pre and post qual housekeeping functions test data indicate that the induced environments had no adverse effects on the performance of the LRIR system.

5.1.5 Post Environmental Performance Tests

The following tests were conducted to verify the performance of the LRIR system after being subjected to induced environments.

Housekeeping Functions Performance Test ETP-F-020, Rev. G

Scan Mode Response ETP-F-040, Rev. D

MTF - ETP-P-022, Rev. D

Reproducibility and IFC Calibration ETP-P-030, Rev. C

An engineering evaluation of these tests verify the LRIR system did not deviate from the LRIR pre-environment performance tests after being subjected to Vibration, EMI and Thermal-Vacuum testing.

Summarized data of the Post Environmental Qualification performance verification tests compared to the pre-qualification test data are given in Tables 5-26 through 5-30.

Table 5-27
MODULATION TRANSFER FUNCTION
DATA SUMMARY
SQUARE WAVE RESPONSE

Pre Qual Test per ETP-P-022, Rev. C March 1, 1974
Post Qual Test per ETP-P-022, Rev. D August 9, 1974

FREQUENCY	CHANNEL 1 PRE-QUAL	CHANNEL 1 POST QUAL	CHANNEL 2 PRE QUAL	CHANNEL 2 POST QUAL	CHANNEL 3 PRE QUAL	CHANNEL 3 POST QUAL	CHANNEL 4 PRE QUAL	CHANNEL 4 POST QUAL
.113	.98	1.02	.96	.97	1.04	1.02	.90	.92
.226	1.02	1.00	1.00	1.00	1.05	1.01	.91	.97
.283	1.02	.98	.98	.97	1.00	.98	.92	.92
.378	.91	.89	.89	.88	.98	.93	.71	.78
.565	.75	.69	.67	.61	.77	.72	.38	.42
1.130	.15	.11	.11	.08	.12	.12	.00	.01

COMMENTS AND CONCLUSIONS

A comparison of the post qual test data to the pre qual test data indicates that the qualification test environments imposed on the LRIR had no adverse effect on the performance of the LRIR system.

Table 5-28

SCAN MODE RESPONSE DATA SUMMARIES

TEST PARAMETER		PRE QUAL TEST 3/1/74 ETP-F-040 Rev. C	POST QUAL TEST 6/6/74 ETP-F-040 Rev. D
Limb Track Centering	Track Point	36.3%	40.4%
OMP ℄	RVDT Voltage	-1.068	-1.066
Space Calibrate	RVDT Voltage	-2.238	-2.239
	Coarse Angle Pulse to Space Cal Counts	30	37
Source Calibrate	RVDT Voltage	-5.649	-5.734
	Coarse Angle Pulse to Source Cal Counts	2	32*

*After the start of thermal-vacuum testing, the encoder was modified and a new baseline value of source cal, counts was established. Pre qual baseline was 5 and the post qual baseline is 29.

COMMENTS AND CONCLUSIONS

REQUIREMENTS:

1. The LRIR system acquisition and track of a radiance signal which is 35-45% of the radiance contrast observed on channel 1 during the normal scan cycle of a simulated earth limb target.

2. Verify scan mirror positioning for the following line-of-sight angles, on command:

   a. OMP ℄ - within 0.5° of initial setting; i.e. RVDT voltage within ±.075V of baseline value of -1.069V.

   b. SPACE CAL - within ±0.5° of initial setting; i.e. RVDT voltage within ±.075V of baseline value of -2.238 and coarse angle pulse to space cal counts within 23 counts of baseline value of 32.

   c. SOURCE CAL - Source cal counts within 16 counts of baseline value. (See Note*)

The results of the Scan Mode Response Test Summarized above verify that the LRIR meets the design specification requirements before and after being subjected to induced environments.

Table 5-29

SCAN MODE RESPONSE COMPUTER DATA ANALYSIS

COMMAND MODE	PRE QUAL TEST MARCH 1, 1974 ETP-F-040, REV. C					POST QUAL TEST AUGUST 8, 1974 ETP-F-040, REV. D				
	WORDS	HARDWARE	%	SOFTWARE	%	WORDS	HARDWARE	%	SOFTWARE	%
SCAN OVERRIDE	6,356	11	.17	3	.04	2,760	2	.07	6	.22
SCAN ON	3,312	2	.06	1	.03	5,704	2	.04	3	.05
TOTAL	9,668	13	.13	4	.04	8,464	4	.05	9	.11

COMMENTS AND CONCLUSIONS

A review of the computer data printout was made to determine system data processing capabilities. The mode byte for each word was reviewed. Anamolies were classified into a category of either hardware or software. Hardware errors consisted of missed encoder flag, erroneous scan stop indication, multiple coarse angle pulses, unwanted time code. Software anamolies consisted of presence of parity error, missing data word,....

Data processing anamolies were found to occur at a frequency of one per thousand data samples or less, well within acceptable data processing requirements.

The results of the computer data analysis that the induced environments had no adverse effects on the performance of the LRIR system.

Table 5-30

REPRODUCIBILITY AND IFC CALIBRATION
DATA SUMMARY

TEST PARAMETER	PRE QUAL TEST 3-1-74 ETP-P-031 Rev. B	POST QUAL TEST 8-9-74 ETP-P-031 Rev. C
Source Temp. Variation	0 volts	0 volts
Source Pos. RVDT Voltage	-5.60	-5.74

COMMENTS AND CONCLUSIONS

A comparison of the post qual test data and the pre qual test data indicates that the qualification test environments imposed on the LRIR had no adverse effect on the performance of the LRIR system.

SECTION 6
CALIBRATION

6.0 INTRODUCTION

LRIR calibration is defined to be those processes and measurements culminating in a determination of the end-to-end radiometric transfer function of the instrument. Two separate types of measurements are required to obtain the necessary data. One measurement utilizes a blackbody target with accurately known emissivity and temperature distribution. This target provides a high accuracy source of diffuse blackbody radiation. The radiometric parameter of interest is not total blackbody radiation, however. It is, rather, the blackbody radiation seen by the instrument through the instrument spectral response. Thus the combination of measured instrument spectral response and measured blackbody radiation response provides the required data for determining instrument radiometric transfer function.

Analysis of the spectral response measurement with the LRIR protoflight model showed the presence of unexpected out-of-band spectral leaks. These leaks existed in spectral regions that do not compromise the scientific data provided that adequate compensations are incorporated in the data reduction. The presence of the leaks required that additional measurement be performed on the monochromator equipment to extend the region of high spectral accuracy through the spectral region of the out-of-band leaks. These measurements were being completed and final data reduction was being initiated to obtain final spectral response curves as this final engineering report was being generated. The final reduced data was not available for inclusion in this report and will be included in a final report to be published at the completion of the orbital data reduction and analysis phase.

The balance of this section contains a description of the spectral and radiometric response measurements and radiometric transfer function data based on estimated instrument spectral response.

6.1 SPECTRAL CALIBRATION

Spectral calibration was performed using the following spectral measurement equipment.

1. Spectral Source Assembly (source unit and monochrometer)
2. Collimating Spherical Mirror
3. Reference Assembly
4. Electronic and Display Equipment

The Spectral Source Assembly provides a modulated narrow spectral source of radiation. Included in the source is an image rotating mirror assembly which rotates the image of the vertical exit slit of the monochrometer to a horizontal orientation. A flat folding mirror and a spherical collimating mirror are used to direct and collimate the spectral radiation. The electronic equipment used to amplify, demodulate, and display the measured response were a lock-in amplifier (Princeton Applied Research - PAR-HR8) and a strip chart recorder (Hewlett Packard HP-7100B). The entire optical path was enclosed and purged with dry nitrogen synthetic air. Each channel was optically aligned and spectral response measurements made by scanning the monochrometer over the appropriate spectral range. Runs for channels 1, 2 and 3 were repeated three times. Two runs were made for channels 4b. Multiple runs are arithmetically averaged at each 5 cm^{-1} point.

The Reference Assembly contains a focussing mirror and a reference pyroelectric detector. This reference was calibrated at NELC in San Diego, California for transferral of the NELC spectral data obtained using the Reference Assembly in a manner similar to the LRIR spectral measurements.

The final relative spectral calibration data is obtained by dividing the averaged LRIR output by the relative spectral response correction factor derived from the Reference Assembly. Corrections are made at 5 cm^{-1} intervals for all channels.

6.2 RADIOMETRIC CALIBRATION

The LRIR was calibrated using a controllable blackbody radiation source in vacuum. The blackbody was the Nimbus E SCMR Earth Target modified for use with the LRIR. Modifications of the Nimbus E SCMR Earth Target include replacing the existing honeycomb cells and coating with 3M Black Velvet paint , type 401-C10.

The Blackbody Target was positioned in the HRC vacuum chamber in front of the LRIR completely filling its aperture. The LRIR target configuration is shown in Figure 6-1. Temperature of the LRIR mounting plate on the optical bench was controlled to 288°K and the LRIR permitted to soak for a period of four hours to stabilize. The LRIR was turned on and the scan mirror commanded to the SOURCE CALIBRATE position. During the LRIR warm up period, IFC temperature readings and LRIR output voltages were recorded continuously. An IFC calibration check point will thus be available over a large range of IFC temperatures in the event of an IFC heater failure.

The scan mirror was then commanded to the nominal scan center to view the external blackbody target. This target was operated at 10 temperature settings. All blackbody target temperatures (PRT and thermocouple) were read and recorded on a data sheet for each blackbody temperature setting. LRIR output voltage for each channel was also recorded at each blackbody temperature setting. Time code generator output was used to correlate blackbody temperature readings with LRIR output voltage readings.

The mounting plate on the optical bench was then taken up to a temperature of 298°K over a two hour period and the LRIR permitted to soak for an additional four hours. As the LRIR temperature was raised, the LRIR remained on. Cold external target and IFC target readings were made as the LRIR changed temperature. The LRIR was then shut off for the four hour period. After power was turned on, the IFC and external blackbody target temperatures and LRIR output voltages were measured as described above.

The mounting plate on the optical bench was then taken up to a temperature of 308°K over a two hour period and the LRIR permitted to soak for an additonal four hours. As the LRIR temperature was raised, the LRIR remained on. Cold external target and IFC target readings were made as the LRIR changed temperature. The LRIR was then shut off for the four hour soak period. After power was turned on, the IFC and external blackbody target temperatures and LRIR output voltages were again measured as described above.

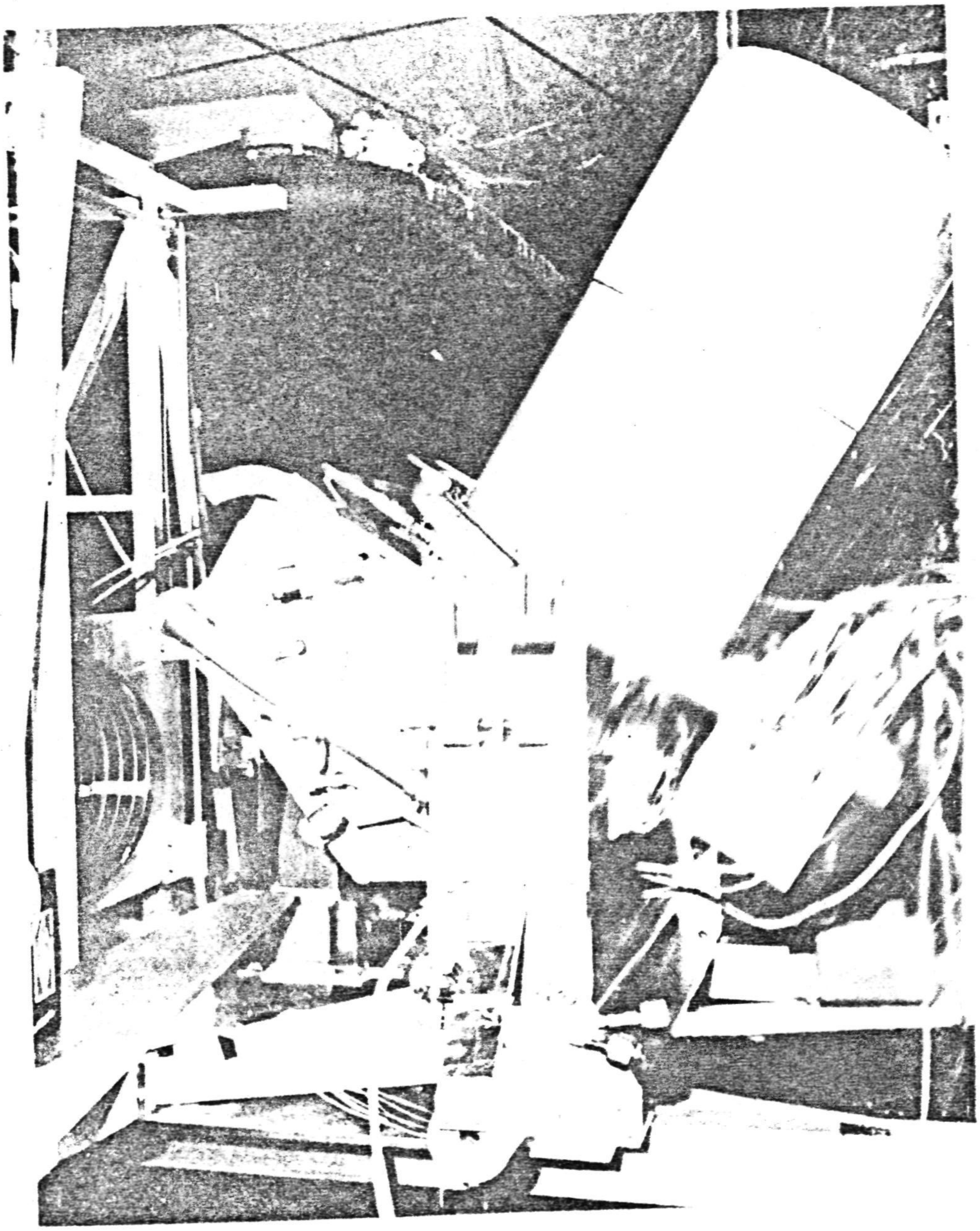

Figure 6-1 LRIR ON OPTICAL BENCH AT ENTRANCE OF TV CHAMBER

Temperature measurements were reduced to obtain in-band radiance for the estimated spectral response. Instrument output voltages were averaged over a 1 second time period to eliminate rms noise voltage effects. Results are shown in Figures 6-2 through 6-5, instrument output voltage vs in-band target radiance.

These results are based on preliminary values of in-band target radiance. Final results will not be available until final reduction of spectral calibration data, not scheduled for completion until after publication of this report. These preliminary results contained non linearities of the order of 2.5% over the radiometric dynamic range. In Figures 6.2 through 6.5, only the linear component of the reduced data has been shown. Final results will contain correct values of slope, offset, and magnitude of higher order terms.

The non-linearities have been traced to the IEU electronics and in particular due to the phase difference between the detected radiance signal and the video processor demodulator drive voltage. Measurements on the electronics taken following calibration testing are being analyzed at this writing to determine the necessary parameters to allow a non-linear data reduction. This is necessary to avoid compromising the data above 50 km, especially in Channel 3.

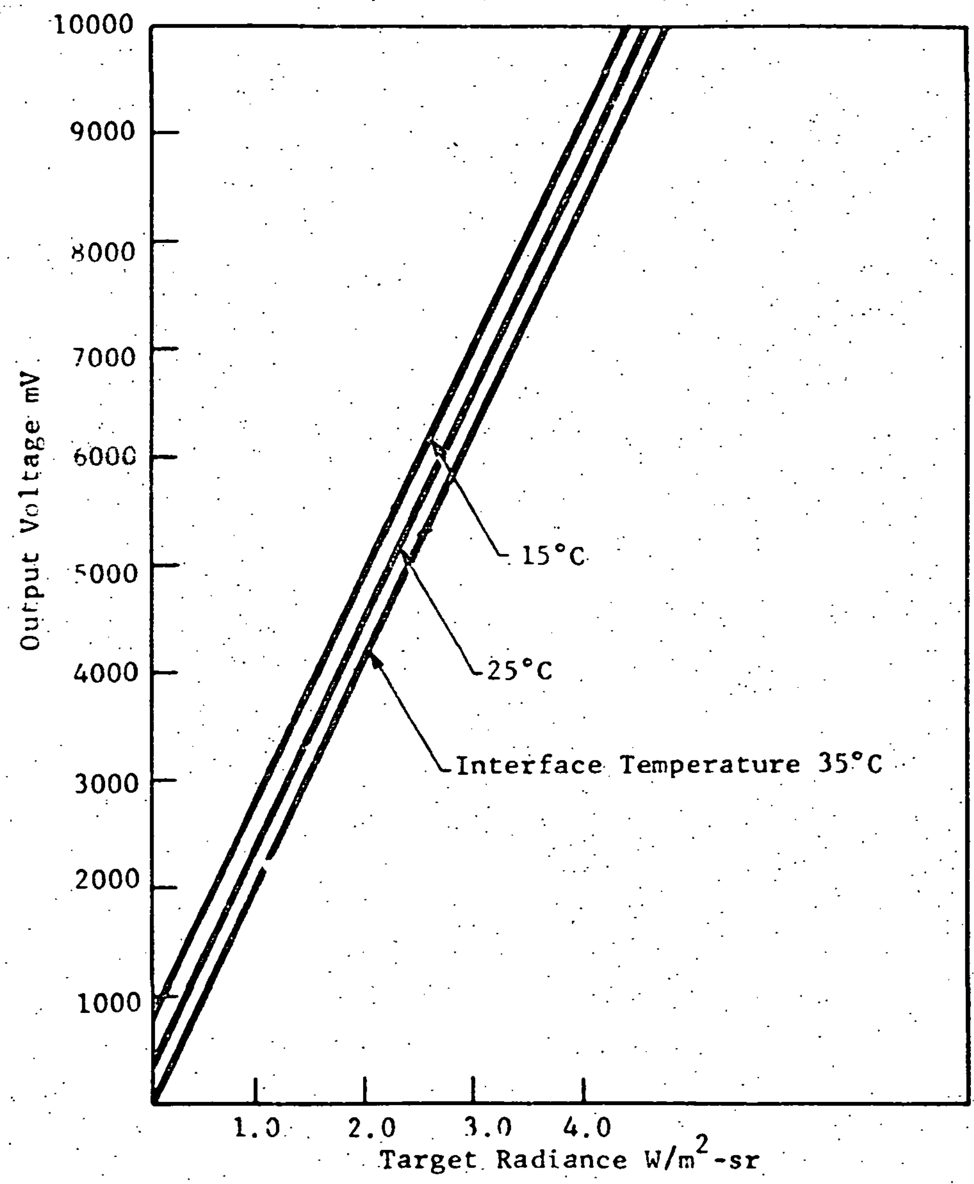

Figure 6-2 LRIR PRIMARY CALIBRATION PRELIMINARY RESULTS CHANNEL 1

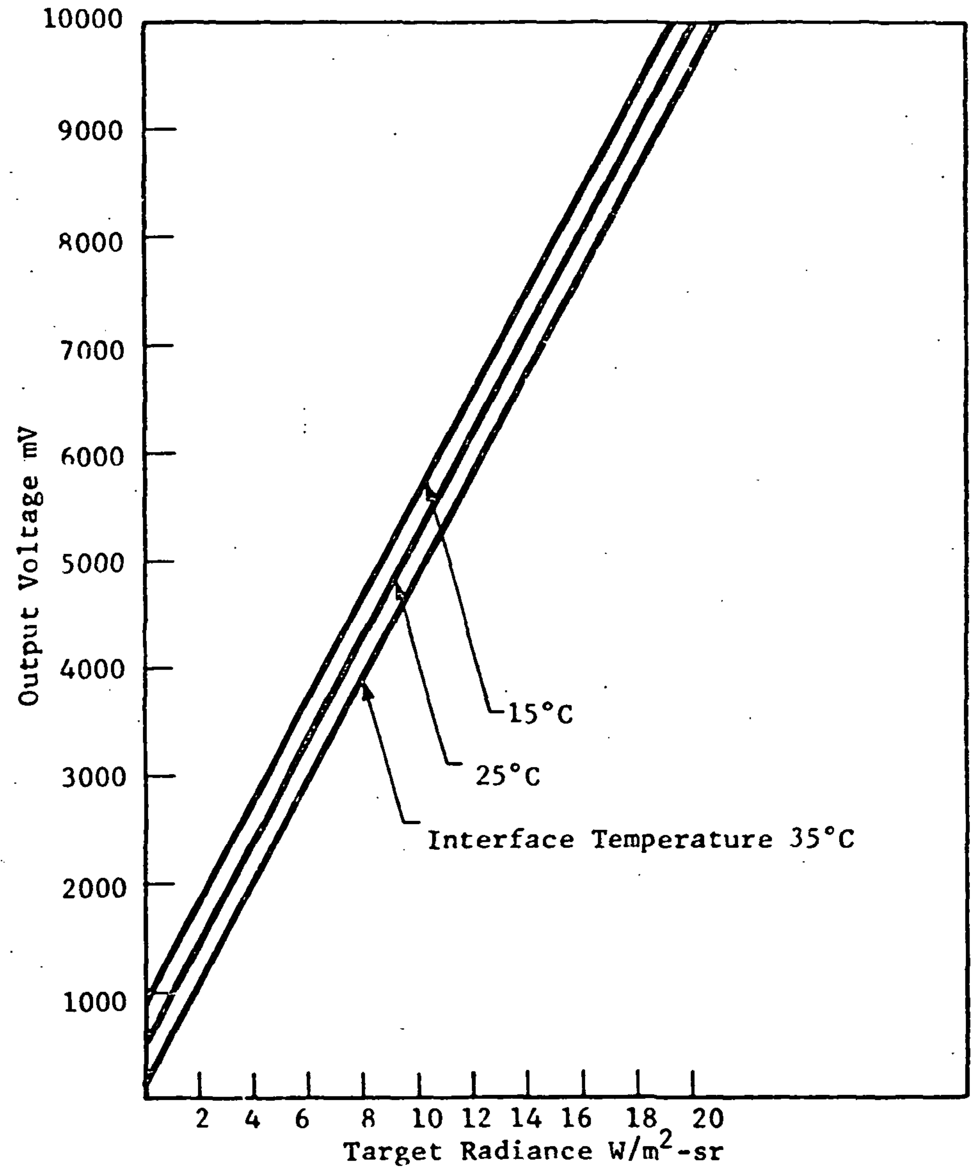

Figure 6-3 LRIR PRIMARY CALIBRATION PRELIMINARY RESULTS CHANNEL 2

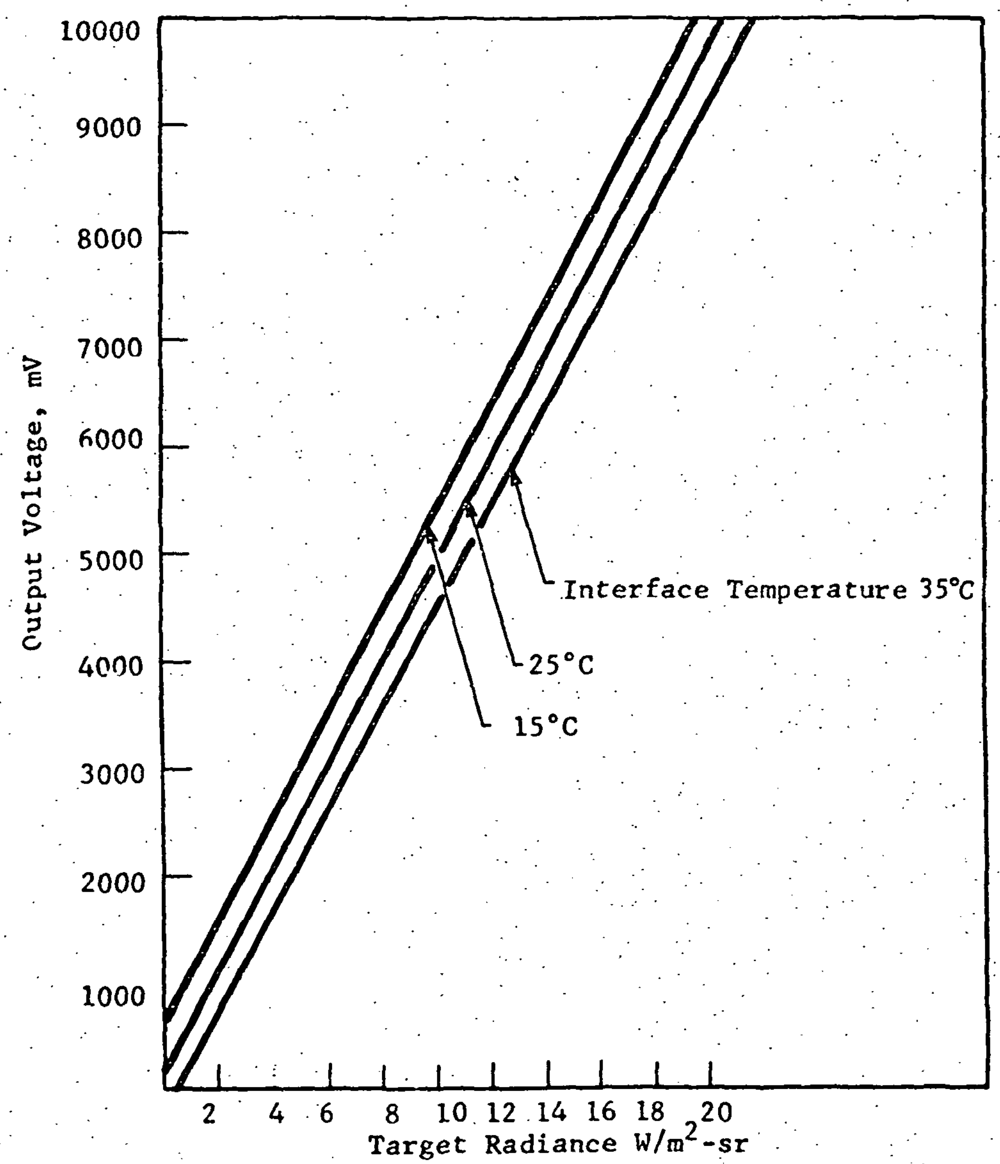

Figure 6-4 LRIR PRIMARY CALIBRATION PRELIMINARY RESULTS CHANNEL 3

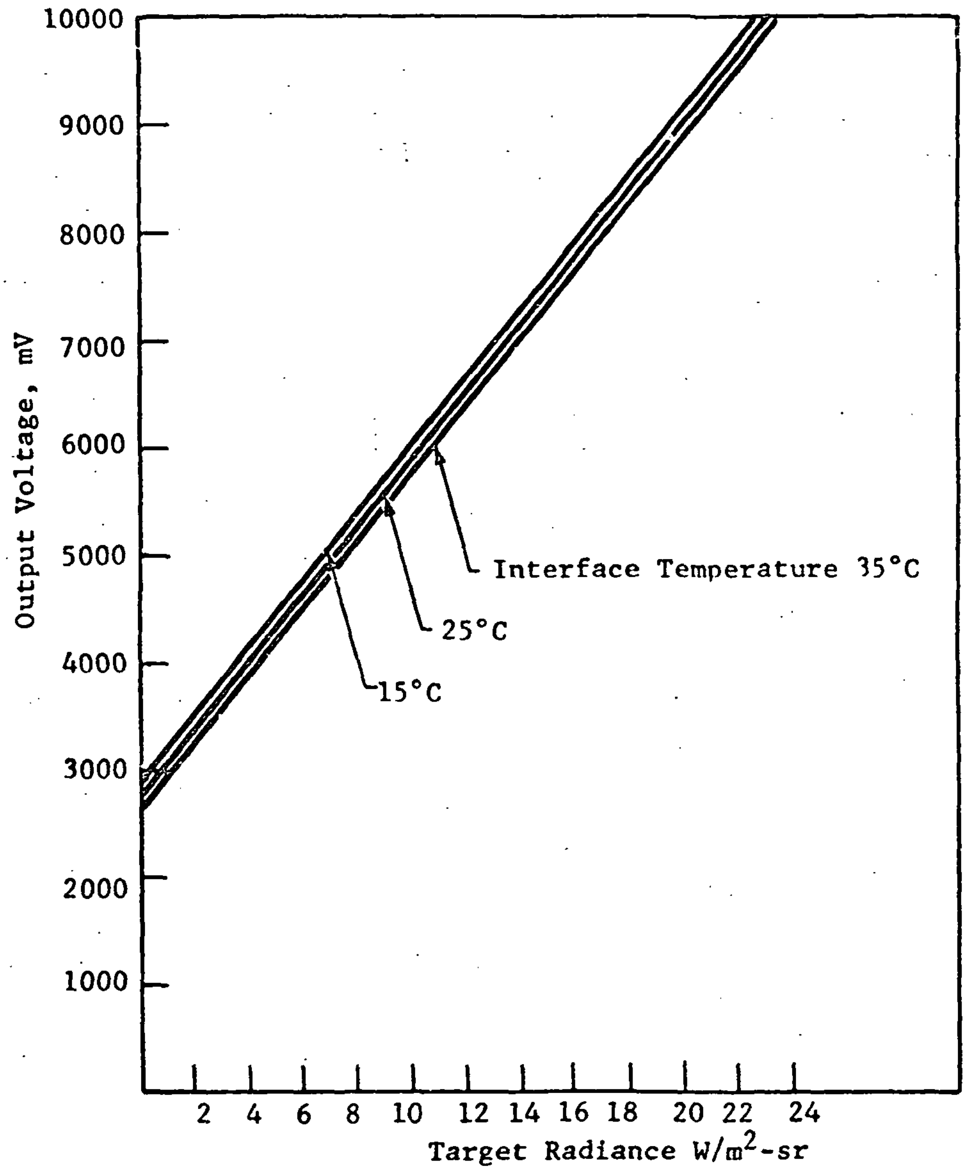

Figure 6-5 LRIR PRIMARY CALIBRATION PRELIMINARY RESULTS CHANNEL 4

SECTION 7

SYSTEM DEVIATION FROM REQUIREMENTS

7.0 INTRODUCTION

The following summary lists system deviations against "LRIR SPECIFICATION FOR NIMBUS F" (S-450-P-11) and "Experiment Interface Requirements" (X-450-68-415).

REFERENCE	SUBJECT	AFFECT ON SYSTEM PERFORMANCE
CEL-093	Waiver request on module dimensions to accommodate RFI gaskets. Z axis dimensions for both IEU & FEU increase from 6.505 inches maximum to 6.535 inches maximum.	NONE
CEL-159	Deviation request for wiring signal ground to chassis ground in preamplifier.	NONE
CEL-219	Performance parameters of noise-equivalent radiance (NEN) and modulation transfer function (MTF) exceed specified limits, refer to malfunction reports E00109 and E00110.	NONE-Dr. Gille has reviewed NEN & MTF values and has indicated that these values will allow useful scientific data to be obtained with LRIR.
CEL-250	Noisy Channel #4 Radiance output. Channel #4, the water vapor channel consists of dual detector/preamp channels, 4A and 4B. The noise problem was associated only with channel 4B. Channel 4B was disabled in lieu of a destructive teardown of the D.C.A. Refer to malfunction report E00141.	NONE-Measurements made on channel 4A alone revealed that its radiometric performance was acceptable to the science team.

SECTION 8

BENCH CHECKOUT UNIT (BCU)

8.0 INTRODUCTION

The NIMBUS F LRIR Bench Check Unit (BCU) is designed to check out the LRIR system, or subsystem, and to provide a means for operating the LRIR system on the bench. The BCU is shown in Figure 8-1. The BCU consists of power supplies and specialized electronic circuitry in one enclosure and an Anadex Model DP600 Line Printer as a separate piece of bench-top equipment. Provision is made for interfacing with a tape recorder and a Data General Nova 800 computer, although neither of these items are included as part of the system. Test points are provided on the BCU front panel for signal monitoring and troubleshooting. Voltmeters, oscilloscopes and strip chart recorders may be used as additional test instruments for these functions. Special test equipment required for test inputs to the BCU are a Time Code Generator with 36-bit NASA mini-track time format and a standard laboratory pulse generator, both with TTL-compatible output circuits.

The BCU is powered by 115V AC 60 Hz commercial power.

8.1 GENERAL DESCRIPTION

8.1.1 LRIR Power

The BCU provides -24.5V power for the LRIR experiment primary power requirements.

The BCU controls and meters the -24.5V power to the LRIR experiment.

The BCU provides the means for monitoring and metering some of the voltages generated by the internal LRIR power supply.

8.1.2 Experiment Control

The BCU provides the means for selecting and controlling operational commands to the LRIR experiment.

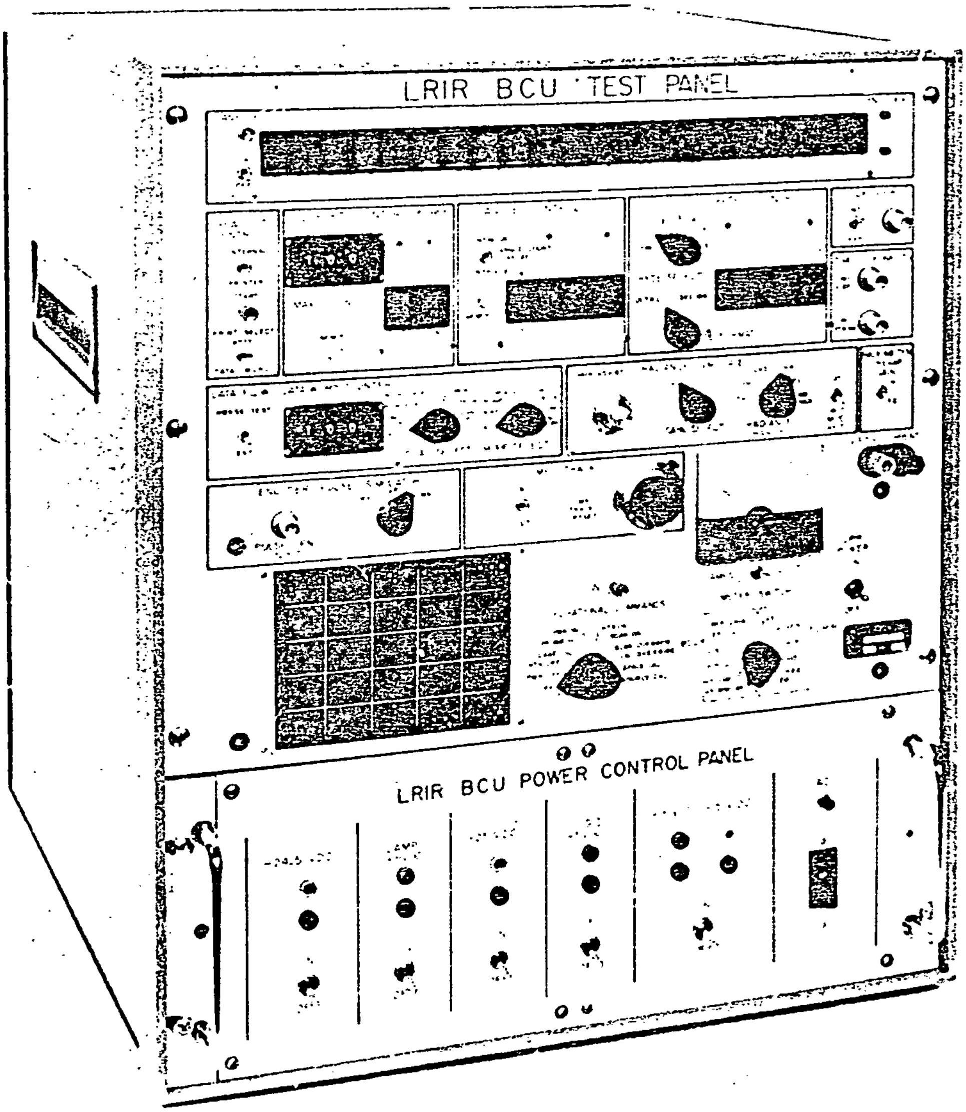

Figure 8-1 BENCH CHECK UNIT

8.1.3 Data Readout

A digital readout capability is provided by the BCU for the examination and analysis of digital HDRSS data. The data may be observed or collected in the following fashion:

a. Optical display of sampled data

   1. Data word display in octal format
   2. Selected byte display - octal format
   3. Selected byte display - decimal format

b. Printout of sampled data - same formats as optical display.

c. High-speed data interface, including decommutation capability for on-line computer or tape recorder.

d. Filler-bit count determination and display.

e. Analog conversion of radiance channel digital data to be displayed on either strip chart recorder or voltmeter.

8.1.4 Performance Monitoring

In addition to digital data readout capabilities, the BCU provides the means for monitoring the following classes of signals from the ?RIR experiment:

a. VIP analog signals

b. VIP digital B signals

c. Selected analog functions provided through the test cables to the BCU.

d. Selected digital signals provided through the test cables to the BCU.

e. Selected internal BCU functions and signals.

8.1.5 Input Signal Simulation

Two classes of input signals are provided by the BCU for simulation of inputs during various levels of system testing.

a. Analog inputs

1. Radiance input voltages - simulates radiometer preamp outputs.
2. Modulator reference
3. Limb track input

b. Digital inputs

1. 200 kHz spacecraft frequency standard.
2. Time code and strobe for spacecraft time.
3. Angle encoder outputs
4. Preamp gain control (level switching)

8.1.6 Detailed Description

The following detailed description of the BCU is based on the front control panel as shown in Figure 8-2.

8.1.6.1 LRIR BCU Power Control Panel - The power control panel consist of five ON/OFF switches, an AC pilot light and an AC main power breaker. Each of the ON/OFF switches control the dc output of the separate power modules. The separate power modules are:

a. -24.5 VDC
b. +5 VDC Lamp Display
c. +5 VDC Logic
d. -25 VDC
e. ±15 VDC

In addition banana jacks for each supply are available for monitoring the output voltages. All AC power to the separate supplies are controlled by the AC breaker.

Normally, the ON/OFF switches will be left in the ON position and only the primary power controlled, unless isolation is required for troubleshooting, etc. The supplies all have short circuit and overvoltage protection. The overvoltage controls on the two +5V supplies have been set relatively low in order to protect the logic circuits from possible harm. If one of these supplies should inadvertently cut out because of a transient or other unlikely disturbance, the AC breaker may be turned off, then turned back on with full restoration of power.

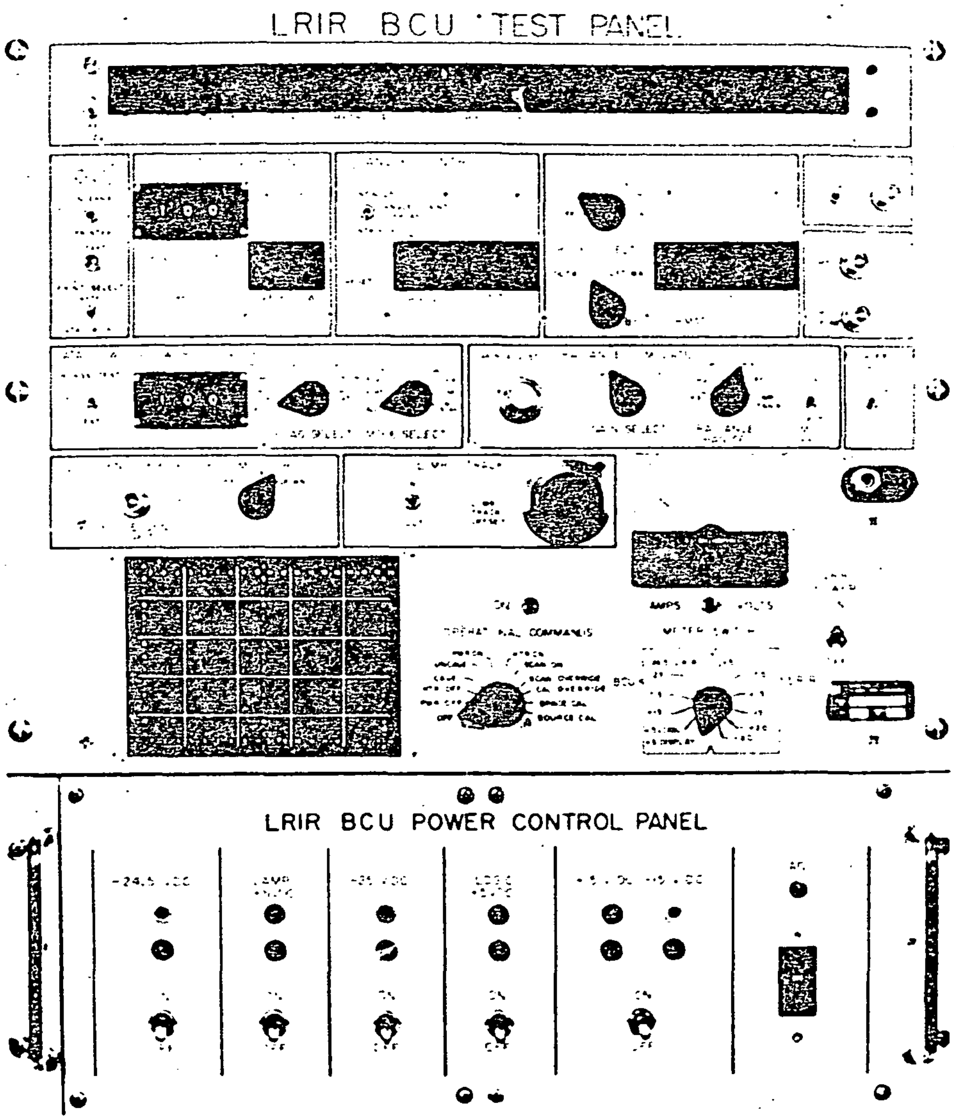

Figure 8-2 LRIR BCU TEST PANEL

8.1.6.2 Power Monitoring - The power monitoring functions are provided by a panel meter an AMPS/VOLTS switch, a METER SWITCH and a -24.5V CURRENT sampling resistor. Also located in this area is the LRIR POWER ON/OFF switch.

All of the voltages generated within the BCU and some of the voltages generated within the LRIR power supply can be metered on the BCU panel meter. The voltage to be monitored is selected by the METER SWITCH. The meter scale factors are set such that the nominal voltages will register 0.8 of full scale. The LRIR voltages that can be metered are:

a. +5 VDC ±1%
b. -7.5 VDC
c. ±15 VDC
d. ±20 VDC

These voltages are not accessible when the 2/0 module is being tested with the system. The only power supply monitor (other than input power) available is the VIP Analog voltage (derived from the -15 VDC supply) on test point (TP) G10.

The LRIR current can be measured by switching the meter to AMPS (only the -24.5V current is measurable in this fashion). 0.4 of full scale represents 1 amp of current. A more precise current measurement can be made by measuring the voltage drop across the 0.1 ohm resistor connected to the banana plug terminals on the front panel labeled -24.5V CURRENT. This resistor can be shorted out, if desired, by jumpering these two terminals.

The LRIR POWER circuit breaker controls the application of -24.5V power to the IEU. It does not control power to the command relays. The command relays operate off of the -25V supply and can be commanded independently of the application of -24.5V power.

8.1.6.3 Operational Commands - During system tests, any and all commands can be activated - one at a time - by setting the OPERATIONAL COMMANDS selector switch and operating the ON push button. These commands are as follows:

A. POWER OFF
B. HEATER OFF
C. CAGE
D. UNCAGE
E. POWER ON
F. HEATER ON
G. SCAN ON (Adaptive Scan)
H. SCAN OVERRIDE (Acquisition Scan)
I. CALIBRATION OVERRIDE
J. SPACE CALIBRATE
K. SOURCE CALIBRATE

The command lines are normally reversed biased as they would be on the spacecraft. Activation of the push button reverses the polarity on the selected pair of MA and MB lines for a period of 40 ±5 msec. to momentarily operate the command relay. During subsystem tests when only the IEU (3/0 module) is connected to the BCU, the Power ON/OFF commands are the only ones which may be activated.

8.1.6.4 Data Word - The DATA WORD function consists of a LAMP TEST pushbutton, a DISPLAY ON/OFF switch, 21 pinlight numerical displays, and two indicator lights SYNC LOCK, LOST SYNC.

Numerical displays are provided for most of the data readout functions. These display lights may be turned on or off by means of the DISPLAY switch in the upper left corner of the Test Panel. This switch controls a logic function for blanking all of the Pinlite displays, except the sign light for the ANGLE COUNT. It may be desirable to turn off these lamps, if for some reason or other, the displays are not being utilized. Lamp power can be controlled from the LAMP +5 VDC ON/OFF switch on the POWER CONTROL PANEL, but since all other indicator lights (except AC power) are also controlled, it is recommended that this switch be left on.

LAMP TEST, above the DISPLAY switch, will cause all of the Pinlites to display the figure 8 when depressed, provided, of course, the displays are on (again, the sign function is not affected).

The DATA WORD display shows 5 bytes + parity. The display is in octal format and represents 61 bits of the 72 bit data word. The mode is displayed in the least significant character position of byte 1, flag information in the next two and 0 in the most significant character position - for all modes except Time Readout and Source Calibrate.

Bytes 2, 3, 4 and 5 display the radiance channels outputs in octal form for all modes except Time Readout. Byte 2 for Time Readout displays units hours, tens and units minutes. Byte 3 displays tens and units days, and tens hours. Byte 4 provides a calibration reading for the A/D converter and should read between 4356 and 5352 octal. Byte 5 in the Time Readout mode is all zeros.

Byte 6 for all modes contains the sync word and parity bit but the DATA WORD display presents only the parity bit - either a 1 or a 0.

The presence of HDRSS data in the BCU is evidenced by the green SYNC LOCK light being on. The red LOST SYNC light may occasionally flash, but this is not necessarily cause for alarm, unless the green light flickers noticeably or stays out altogether. The red light will come on if there are transients in the data (but not necessarily loss of sync), usually occurring at scan turnaround, transitions from encoder-controlled readout to time-base readout, or vice versa. The red light will stay on and the green light will go off for a true loss of sync. If no data train is present, neither light will be on (the red light may flash momentarily when BCU power is first applied).

If a LOST SYNC should occur such that the red light goes on while printing, the data at that time will be printed in red. This does not mean that the data is necessarily bad, but it may be questionable. The display will not permit a data word that does not carry the proper sync code word to be displayed, it will hold onto the last good data until a proper sync code does again show up. This means the printed data may not be up to date. More likely, an occasional transient has occurred, such as turnaround or an abrupt change in scan speed.

8.1.6.5 Byte Control - The BYTE CONTROL function consists of a BYTE SELECT rotary switch, a BYTE FORMAT selectro switch and a 4 Pinlight numerical BYTE DISPLAY.

Any byte of the data word can be selected by the BYTE SELECT switch. The byte selected will be displayed spearately on the BYTE DISPLAY. The BYTE FORMAT switch determines the base of display.

Either OCTAL or DECIMAL may be selected. Decimal display is only meaningful for radiance data or other data processed through the LRIR A/D converter. Octal display should be used for all mode, flag, time and sync word data. Byte 6, which is not on the DATA WORD display, can be observed on the BYTE DISPLAY. It should read 2216 or 2217, depending on state of parity bit.

The BYTE DISPLAY is updated at the same rate as the DATA WORD display.

8.1.6.6 Data Display Control - The data display control function consists of the DATA WORD COUNTER, MODE SELECT rotary switch, FLAG SELECT rotary switch and a DATA FLOW switch. Each of these functions are discussed below.

8.1.6.6.1 <u>Data Word Counter</u> - The DATA WORD COUNTER determines the rate at which the data is updated on the DATA WORD display and BYTE DISPLAY. If there are no other conditions or constraints imposed by the MODE SELECT and FLAG SELECT switches (paragraphs 8.1.6.6.2 and 8.1.6.6.3, respectively) the DATA WORD COUNTER setting specified the number of data words to be counted before the display is again updated. A setting of at least 001 is required in order to affect this function. 000 will result in no updates.

An initial condition occurs when the BCU is turned on which results in a large count being set into the DATA WORD COUNTER. This count will normally time out in about 15 to 20 seconds, possibly more. It can also be reset by the ANGLE CONTROL RESET pushbutton, then no waiting will be required.

8.1.6.6.2 <u>Mode Select</u> - Operation of the MODE SELECT switch determines which data modes shall be displayed. With the switch on ALL, no constraints are placed on mode display. Any other setting of the switch will cause only data of that particular mode to be displayed.*

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*An exception occurs when no data of the selected mode is being generated. In this case, the display is frozen at the last valid update prior to the operation of the MODE SELECT switch.

The modes displayed are as follows:

MODE	BYTE 1
Space Cal.	0XX1
Acq. Scan	0XX2
Source Cal.	XXX3 or 7
Adap. Scan	0XX4
Slew	0XX5
Time Readout	XXX6

The displays updating is also subject to any constraints placed on it by the DATA WORD COUNTER (paragraph 8.1.6.6.1) and the FLAG SELECT switch (paragraph 8.1.6.6.3).

8.1.6.6.3 <u>Flag Select</u> - Data display control based on the FLAG SELECT switch conditions is similar to MODE SELECT switch in that the ALL position removes any flag constraints. Otherwise only a data word including the particular flag desired will be displayed. It should be noted that neither the Source Calibrate nor Time Readout modes include any flags. Therefore the FLAG SELECT conditions are ignored for these modes. Flags are not mutually exclusive, so selection of a particular flag does not rule out the presence of any others. The flags displayed are as follows:

FLAG	BYTE 1
Time Event	0X1X
	0X3X
	0X5X
	0X7X
Scan Stopped	0X2X
	0X3X
	0X6X
	0X7X
Missed Data	0X4X
	0X5X
	0X6X
	0X7X
Coarse Angle	01XX
	03XX
Scan Down	02XX
	03XX
Scan Up	00XX
	01XX

8.1.6.6.4 Data Flow Switch - The DATA Flow switch controls the flow of HDRSS data to the BCU. When this switch is in the HDRSS TEST position and the IEU test cable connected (IEU/P9), HDRSS data from the test cable is introduced to the BCU. If the switch is on EXT and the HDRSS output cable is connected to the BCU (IEU/P8), the HDRSS outputs can be jumpered from the test point panel to the BCU. This is effected by jumpering the HDRSS TPs, A13, A14, or A15 to the HDATA input at A12 (only 1 output should be connected at a time).

8.1.6.7 Filler Bit Counter Control - The FILLER BIT COUNTER CONTROL function consists of a 3 unit thumb switch labeled MAX COUNT, a RESET pushbutton, and a 2 pinlight numerical OVERFLOW display. The MAX COUNT thumb switches control a preset counter that may be set to any arbitrary number. Each time the number of filler bits between data words exceeds the present count an overflow is tallied in the overflow counter and displayed as OVERFLOW. Only 1 overflow is tallied per set of filler bits, whether the actual count of filler bits exceeds the present count by 1 or by 199, or by some other number. The counter may be reset to zero by the RESET pushbutton.

8.1.6.8 Readout Control - The READOUT CONTROL functions coordinate the display update process with the printer controls. If the Anadex printer is not being used the INTERNAL/PRINTER switch must be in INTERNAL, or the displays will not update. If the Anadex printer is on line, the switch may be in either position, however, it is recommended that it be placed in the PRINTER position.

The PRINT SELECT switch allows the printer to print either the 2. character DATA WORD as displayed, or the 4 character BYTE DISPLAY. The byte data will be either OCTAL or DECIMAL as selected by the BYTE FORMAT switch.

After the printer has been turned on, the printing operation can be partially controlled from the BCU control panel. If it is desired to selectively print data, a single line can be printed by pressing the START button once. To cause the printer to print continuously at its fastest rate, the EXTERNAL push button on the Anadex printer front panel must first be depressed. Then when the START button on the BCU is momentarily activated the printer will commence printing. To stop it requires a second activation of the EXTERNAL pushbutton to release it.

It should be noted that the printer will print data regardless of whether the data is being updated or not. If the display is not changing, the printer will continue to print the same thing.

8.1.6.9 External Timing Interfaces

8.1.6.9.1 Clock Source - There is an internal 1.000 MHz crystal frequency source for the BCU. This not only generates all of the frequencies used in the logic circuits of the BCU but also is used to generate the 200 KHz simulated spacecraft clock for the IEU when the cable from IEU/J7 is connected to the BCU. If the CLOCK SOURCE switch is in EXT, an external 1 MHz clock must be connected to the BCU in order for it to operate. There is no requirement that the BCU and IEU work from the same clock source. IEU/J7 can be connected to the S/C clock and time code source just as well, while the BCU operates off of its internal clock. The external clock source must be used, however, if the BCU is providing time and frequency inputs to the IEU.

8.1.6.9.2 Time Code Inputs - The BCU simulates the spacecraft TIME STROBE interfaces to the IEU. Only level conditioning of the signals is provided by the BCU. Whenever the time inputs are being utilized a coherent 1 MHz clock source must also be used, otherwise the time data may occasionally appear garbled. Both time information and the 1 MHz clock must be TTL compatible signals, that it, from about +3V to not more than +5V for a logic 1 and 0 $^{+0.5}_{-0}$V for a logic 0.

As for the clock source, the time code interface from the BCU may be omitted if IEU/J7 cable is connected to the S/C frequency and time code source. If the BCU is being used for a frequency source. but no time information is being provided, the Time Code and Time Strobe inputs must be shorted to keep noise from triggering the time input circuits of the IEU and thus causing a possible hangup in the Time Readout mode of data taking.

8.1.6.10 Angle Control - The ANGLE CONTROL function consists of a 4 Pinlight ANGLE COUNT display, a RESET pushbutton, and an

C-3

ANGLE COUNT DISPLAY switch.

A 3-decimal counter plus sign is used to record scan-angle encoder increments if the test cable from the IEU (IEU/J9) is connected to the BCU. If the scan direction is up, the counter will count up and will register + (or will change to + upon going through 0 if it has previously been counting down and is negative). For a scan direction of down, the counter will count down and will register -. When going through 0 in the down direction the counter will change to -999 and continue to count down. When counting up, after reaching 999 it will overflow to +000 and continue counting.

A RESET is provided for arbitrarily setting in zero at any desired portion of the scan cycle.

If the counter is reset at scan turnaround it should hit a max count (+ or -) at the next turnaround and read 0 at the third turnaround.

The ANGLE COUNT DISPLAY switch controls the display of the count angle. In CONTINUOUS, the counter contents are always displayed. In CONTROLLED, the display is updated only when the other displays are updated. The counter continues to count independently of the display function.

Test points B9 and B10 provide the encoder pulses and count direction signal for scope monitoring purposes. Test points B6 and B7 are the encoder square wave outputs to the IEU. Test point B8 is the coarse angle output from the angle encoder. These signals are only present when the test cable is connected.

8.1.6.11 Encoder Pulse Simulator - If the scan angle encoder is not connected to the IEU and it is desirable to simulate angle encoder pulses, the cable to the angle encoder from IEU/J6 may be connected to the BCU instead. A TTL-compatible pulse generator must be connected to the PULSE GEN INPUT. The waveform may be either a symmetrical square wave or a positive going pulse of about 100μ seconds in width. The frequency shall be the same as the encoder pulse frequency required (i.e., 45 Hz for normal scan). The three position switch controls the application of signals or the direction desired. If it is desired to simulate Slew mode, a frequency in excess of 100 Hz should be used, while for Scan Stopped, a frequency of less than 40 Hz is required (or switch to OFF).

8.1.6.12 Radiance Simulate - The RADIANCE SIMULATE function consists of a RADIANCE CHAN SEL rotary switch, a GAIN SELECT switch, a GAIN ADJUST potentiometer, and a MOD REF switch.

If preamp outputs from the OMP are not available, but it is desired to test the video processor, multiplexer, and A/D converter circuits in the IEU, IEU/J4 can be connected to the BCU and test signals can be inserted. Channels 1 through 4 can be selected one at a time by the RADIANCE CHAN SEL switch. The GAIN SELECT switch will set the coarse gain desired. Fine gain can be trimmed using the GAIN ADJUST pot. The signal generated can be monitored at TP's B13 (HI) and C13 (LO). The MOD REF switch changes the phasing from 0° to 180°.

The RADIANCE CHAN SEL switch also selects the IFC (Internal Flight Calibrator) input to the A/D converter circuit in the IEU and the LIMB TRACK input simulated signals to the video processor in the IEU.

With IEU/J4 connected and the RADIANCE CHAN SEL switch set to IFC an approximately 4V signal is applied to the IEU analog multiplexer. This voltage can be monitored between TP's B15 (HI) and C15 (LO).

8.1.6.13 Limb Track - The LIMB TRACK simulation is also performed without true radiance inputs. The LIMB TRACK IN/OUT switch allows a d-c bias or offset to be added to the signal in the IN position, or to hold it symmetrical about scan null in the OFF position. With LIMB TRACK in. the amount of bias, hence limb track offset is controlled by the LIMB TRACK OFFSET pot.

8.1.6.14 Preamp Gain Control - The coax connector breakout from the cable connecting FEU/J5 to IEU/J5 should be disconnected and reconnected to the BCU at J10. With all other system cable connections intact (including radiometer inputs), it is now possible to control the preamp gain setting from the RADIOMETER PREAMP GAIN switch on the BCU front panel. The switch will normally be placed in the LO position when the radiometers are looking at hot targets, or targets on the bench and outside the vacuum cold chamber.

8.1.6.15 Test Point Panel - A test point panel is provided for patching signals and monitoring signals with external equipment. The test points are located by a letter number matrix. The test point letter designates the row of the panel and the test point number designates the column of the panel. A complete description of the test points is shown in Figure 8-3, Test Point Matrix.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	P
20	+5V (LOGIC)	+5V (LOGIC)												RADIANCE OSCILLATOR REF., HI	COMMON 4
19		DEMOD REF TEST (15KHZ HI)	DEMOD REF TEST (15KHZ LO)				SCAN MTR TEMP							RAD. OSC. REF. LO	COMMON 4
18				0.05HZ PULSE (0.05 HPM)			B/BODY								COMMON 4
17		200KHZ HI (SC 200K)	200KHZ LO (SC 200K RTN)	CALIB (1/32 HP)			BAFFLE TEMP 2								COMMON 4
16	ADAPT SCAN INPUT (LIBD)	TIME STROBE (SCTMST)	TIME CODE (SCTCE)	0.25 HZ			BAFFLE TEMP 1			HEATER ON TM					COMMON 4
15	DATA 2 (HORSSB)	IFC TEMP (+3.0 VDC)	IFC TEMP RTN	0.05 HZ			PRI OPTICS TEMP	RVDT TP (SIP)		SOURCE CAL TM					COMMON 3
14	DATA 3 (HORSSC)	LIMB TRACK TEST HI	LIMB TRACK TEST LO	0.25HZ PLS-POS (0.25 HPP)			CRY SHLD TEMP	RVDT TP (TEST)		SPACE CAL TM					COMMON 3
13	DATA 1 (HORSSA)	RADIANCE TEST HI	RADIANCE TEST RTN	0.25HZ PLS-NEG (0.25 HPN)			CRY EXT TEMP	LIMB TRACK OFFSET TP (TEST)		CAL OVRD TM					COMMON 3
12	HDATA		SMPLG	0.5HZ PLS-NEG (0.5 HPC)			DET TEMP	FEU ELECT TEMP		ACQ SCAN TM					COMMON 3
11			VOIDD	0.5 HZO			IEU ELECT TEMP	IFC TEMP		ADAPT SCN TM					COMMON 3
10		SCDMO	HORSSTST	ADAPSC			-15V MONITOR	HOUSING TEMP		ELECT ON/OFF TM (FEU)					COMMON 2
9		ENCDRA	BANDO	SOURCE CAL TTL (SØRCØMD)			SCN MTR CURRENT	SIGNAL GND (FEU)		CAGE/ UNCAGE TM		DSPLGT			COMMON 2
8		SCRA	SNOBR	SPACE CAL TTL (SPACØMD)			10KHZ HI	10KHZ LO		0.25HZ (FEU)		STBCH			COMMON 2
7		ENC01	MPLC	CAL OVRD TTL (INCALO)			RVDT	SIGNAL GND (RVDT RTN)		0.05HZ (FEU)		FIBIT			COMMON 2
6		ENCAI	BT100	ACQ SCN TTL (AQSC)			DEMOD REF FEU (15KHZ HI)	DEMOD REF RTN-FEU (15KHZ LO)		0.5 HZ (FEU)		DRØUT			COMMON 2
5	RAD3 TP1	RAD3 TP1 RTN		ADAPT SCN TTL (ADPSC)	SCN MTR +20VDC	SCN MTR -20VDC	SCN MTR RTN			INTEG SLOPE SW (TP4)		SCLRE	IFCDA		COMMON 1
4	RAD4 TP2	RAD4 TP2 RTN	TDELJ	CAGE RTN	+5 VDC ±1%	5V ±1% RTN	RESET ACQ SCN (RAQSC)			CALIBRATE (TP3)		200KHZ	RAD4DA		COMMON 1
3	RAD1 TP1	RAD1 TP1 RTN	BT201	CAGE PWR	-7.5 VDC	7.5V RTN	GND PULSE PLUS (+)	GND PULSE MINUS (-)		SPACE CAL (TP2)		CLCKD (500KHZ)	RAD3DA		COMMON 1
2	RAD7 TP2	RAD7 TP2 RTN	CLCKI	ELECT ON/OFF TM(IEU ONLY)	+15 VDC	-15 VDC	15 VRTN			SOURCE CAL (TP1)		1MHZ	RAD2DA		COMMON 1
1	5V(LOGIC) RTN	5V(LOGIC) RTN	5V(LOGIC) RTN	5V(LOGIC) RTN	5V(LOGIC) RTN	5V(LOGIC) RTN			SIG GND (IEU)				RAD1DA	SIG GND (IEU)	SIG GND (IEU)
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	P

Figure 8-3 TEST POINT MATRIX

SECTION 9

SAFETY

9.0 INTRODUCTION

A detailed safety plan, HRC 22330ES29, is included at the end of this paragraph. The plan provides instruction for proper action both in normal and abnormal operation. The primary goal of the safety document is to prevent injury to personnel and to prevent damage to the working environment. The approach to attaining this goal is to prevent release, under any circumstances of methane or ammonia gas into the working environment.

In order that personnel associated with the LRIR cooler had an appreciation of the dangers involved, a description of each of the materials, its normal condition, and its hazards is included in the safety plan. The number of personnel that come in contact with the LRIR is held to a minimum.

Since in normal operation, the cryogens are in a safe condition, the mode of operation is to monitor the cryogen temperatures, make note of any unusual changes, and take appropriate steps to return them to normal operating temperature if necessary. Temperature monitoring is done on a continuous basis and recording of the cryogen temperature is on a periodic basis usually twice a day, early morning and evening.

In the ground storage mode the methane temperature is kept between 78°K and 85°K and the ammonia is kept between 80°K and 162°K. The procedure to maintain this is to cool with liquid nitrogen periodically to keep the methane temperature in control. Occasional rehardening of the vacuum space is necessary to keep the time between liquid nitrogen recoolings to a reasonable time interval. Daily monitoring and recording of the cryogen temperatures insures that the system is functioning properly.

Before the system is moved or an extended test is begun, the temperatures of both cryogens are cooled to their lowest point using LN_2. This insures an interval of time before any problem will need attention.

Honeywell

RADIATION CENTER

CODE IDENT NO. 01385

ENGINEERING SPECIFICATION NO. 22330ES29

THIS ENGINEERING SPECIFICATION IS FOR: LIST DEVICE AND/OR SUBASSEMBLY

☐ SYSTEM ☐ DEVICE ☐ ASSEMBLY ☐ OTHER

SAFETY PLAN FOR LRIR SOLID CRYOGEN COOLER HRC OPERATIONS

SIGNATURES	DATE
PREPARED BY	
APPROVED BY PROJECT ENGR.	
For approvals see sheet 2.	

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APR 20 1973

SAFETY PLAN

FOR

LRIR SOLID CRYOGEN COOLER

HRC OPERATIONS

Prepared By: Paul C. Dusting

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HRC Safety Officer

B "LRIR" WAS "LOCKHEED"

08Nov73 3-643

ORIGINAL PAGE IS
OF POOR QUALITY

1.0 INTRODUCTION

1.1 PURPOSE

The purpose of this safety plan is to set forth the requirements and procedures to be followed at HRC while the Lockheed Solid Cryogen Cooler (hereafter referred to as the SCP) is within the building, in order to prevent the release of methane or ammonia into the working environment or to control it if release should occur, to ensure the safety of personnel and facilities.

1.2 SCOPE

This plan defines:

(1) SCP operating procedures in summary form
(2) Daily checks for abnormal conditions
(3) Failure mode procedures in summary form
(4) Equipment to be provided for support of normal operation of the SCP and for emergencies.

1.3 APPLICABLE DOCUMENTS

The following listed documents are considered to be a part of this safety plan. They shall be referred to for further detail or specific operating instructions. In case of conflict regarding the operation of the SCP or its ground servicing equipment (GSE), the Project Engineer at Honeywell (HRC) shall be contacted.

(1) Systems Safety and Health Plan for the Honeywell Solid Cryogen Cooler: LMSC-D311805, 15 May 1973

(2) Instruction Manual, Ground Service Equipment (GSE) for Solid Cryogen Cooler for Nimbus F: LMSC-D311402, 5 November 1973 (Rev. B)

(3) Honeywell Radiation Center regulations, per Honeywell Safety Policy Statement IH-SA1

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2.0 GENERAL SAFETY CONSIDERATIONS

2.1 CHARACTERISTICS OF CRYOGENS

In addition to the normal hazards of cold temperature and gas evolution associated with cryogenic liquids, the SCP has two additional considerations. These are the flammability and/or toxicity of the gases contained within as solids. Although liquid nitrogen is utilized in the operation of the GSE, its handling can be considered as routine when done by competent personnel. On the other hand, both methane and ammonia, the working cryogens of the SCP, have properties which must be completely understood by all personnel working with the equipment.

The most important properties as related to the hazards associated with each gas are summarized below. A further, more comprehensive discussion, is contained in the LMSC Systems Safety and Health Plan.

<u>Methane</u>

The primary concern associated with methane is the fire hazard which occurs whenever methane vapors escape to the atmosphere. In confined spaces the concentration can rapidly build to the flammable range of 5 to 14% by volume in air. For this reason, care must be taken to properly vent all spaces which are likely to contain methane. If a methane leak is suspected, immediate action must be taken to admit clean air into the room and to remove any possible sources of ignition if they should be present. Because methane is lighter than air, it can be expected to concentrate near the ceiling and this should be taken into account when checking for possible methane leaks. Methane can best be detected by suitable gas detectors because it does not have a strong odor.

<u>Ammonia</u>

Like Methane, ammonia is a fire hazard when mixed with air, although to a lesser degree. The primary hazard associated with ammonia is

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its toxicity to personnel. Care must be taken to prevent a buildup in the laboratory. Ammonia does have a strong pungent odor which makes its identification easy and positive. For this reason, unlike methane, no additional sensing instrumentation is required.

2.2 RESTRICTED ACCESS TO LABORATORY

As a means of reducing the hazards to personnel, access to the laboratory containing the SCP and its GSE will be restricted to those people actively associated with the program or as designated by the LRIR Program Manager. A notice to this effect will be posted in a conspicuous place adjacent to the laboratory access.

A no-smoking ban will be rigidly enforced in the laboratory.

2.3 DAILY MONITORING

Continuous monitoring and recording of the primary SCP parameters is the most important safety consideration. If this is done, conditions which might give rise to a potentially dangerous situation will be indicated in sufficient time to allow for the required corrective action to be taken.

As a minimum the following data shall be taken and recorded once a day:

(1) Cryogen temperatures
(2) DCA temperatures (If LRIR system power is applied)
(3) SCP vacuum level - if connected to the GSE
(4) Wet test meter readings
(5) Methane monitoring instruments
(6) Verification of proper operation of laboratory venting systems

When the cryogenically loaded SCP is left in the LRIR lab or in the Howard chamber without a qualified operator, its status shall be monitored in one of the following ways:

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(1) A guard shall check the cryogen monitor panel once every hour. If an alarm is sounding he shall contact a qualified LRIR handler immediately.

(2) The methane and ammonia alarms on the cryogen monitor panel shall be connected to the guards' desk. If an alarm sounds, the guard shall contact a qualified LRIR handler immediately.

3.0 OPERATING PROCEDURES

3.1 INTRODUCTION

The information contained in this section has been extracted from the pertinent operating manuals for the equipment. It is not meant as a substitute for those manuals, but rather as a summation of the steps to be followed and a listing of the indication of both normal and abnormal conditions. Refer to the SCP-GSE operating instructions (Ref. 2) for the detailed steps to be followed to implement any of the servicing cycles referenced.

The single most important safety consideration is the constant observation of the equipment and monitoring of the major SCP parameters. If this is done, any potentially serious condition will be noticed in sufficient time to allow for the appropriate corrective action to be taken.

3.2 NORMAL OPERATION

3.2.1 Normal Warmup and Servicing Cycle

Table I on the following page lists the major system parameters upon which the normal servicing cycle is based. It can be seen that a substantial period of time exists between the alarm initiation and the time of expected venting. This was done to compensate for the uncertainty in the actual system performance pending the result of test data.

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TABLE I

	Normal Ground Temperature	Alarm Set Point	Venting Initia-tion	Time to Alarm Init.	Time to Init. Venting
Methane CH_4	79 - 85 °K	85° K	90° K	10 days	36 days
Ammonia NH_3	81 - 158 °K	168° K	196° K	10 days	49 days

This table is based upon the following assumptions:

(a) Both cryogens are at an initial temperature at "time zero" of approx. 80°K. This is obtained by LN_2 precooling.

(b) Cooler is filled to 90% capacity.

As an indicator of normal cooler operation, the daily temperature variation of both cryogens should be noted. An approximately linear variation with an extrapolated time of 10 days to the alarm set point should be indicated. If this is not the case, a new time must be computed and precooling of the solids commenced before the alarm set point is reached.

The cooler is returned to the initial conditions by flowing liquid nitrogen through the cooling coil and pumping on the vacuum container with a vacuum pump. Monitor the cryogen temperatures until both are at approximately 80°K and the vacuum is 10^{-5} torr or less, at which time the normal servicing cycle will again commence. It is anticipated that cooling and vacuum pumping can be accomplished in a 24 hour period.

In addition to cryogen servicing, the SCP vacuum space pressure must be

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continuously monitored. The warmup cycle is very much dependent upon maintaining an acceptable vacuum level. If the vacuum should rise above 10^{-4} torr, repump the vacuum space using the GSE high vacuum system.

3.2.2 Alarm Initiation and Servicing Cycle

High temperature alarms have been provided for both the methane and the ammonia tanks. Their set points have been chosen as shown in Table I to provide sufficient time for the normal LN_2 cool-down cycle to be performed. It should be emphasized that if precooling is begun at any time between initiation and before the temperature for initial venting is reached, no loss of cryogen from the SCP should occur.

Again, as discussed under Section 3.2.1, during the early stages of experience with the SCP, continuous monitoring of the daily temperature behavior of the cryogens must be accomplished. This will indicate any departure from the anticipated 10-day cycle.

If the alarm has gone off, perform the following checks and corrective actions, as an abnormal condition may have caused a sudden warmup.

(1) Observe cryogen temperatures
(2) Observe SCP vacuum level
(3) Check laboratory methane monitor

Assuming conditions are normal and that no equipment failures are indicated, proceed with the LN_2 precool cycle; otherwise refer to the equipment operating manual for the appropriate corrective action.

3.3 ABNORMAL CONDITIONS

Complete instructions for all failure modes are found in the LMSC Safety Plan (Ref. 1) where hazardous condition counteractions are summarized in Table II-1 on Page 11-3. Failure mode procedures are summarized below.

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3.3.1 Loss of Vacuum and Subsequent Servicing

It is unlikely that a major vacuum leak will occur in the SCP, other than perhaps that due to a structural failure during environmental testing. This condition would be indicated by a sudden increase in the warmup rate of the cryogens.

If a loss of vacuum has occurred, perform the following steps:

(1) If the SCP is being operated remotely from the GSE, return it and connect the servicing lines.
(2) Actively pump out the vacuum shell.
(3) Observe cryogen temperatures.
(4) Check for methane or ammonia leakage.
(5) Flow LN_2 through the cooling coil to prevent cryogen vapor venting.
(6) Check for the cause of the vacuum failure.

Although the LMSC Safety Plan lists the following times before venting following a loss of vacuum (in Table II), it must be remembered that they are based upon an initial temperature of 80°K. If a vacuum failure occurs after a significant portion of the normal 10-day cycle has expired, the hours listed will be greatly decreased. This is due to the cryogens being warmer than 80°K at the time of vacuum loss. It is expected, however, that at least two to four hours will be available in which to take corrective action as a minimum.

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TABLE II

	Hours to Initiation of Venting	Normal Service Cycle
Methane CH_4	19 hours	10 days
Ammonia NH_3	30 hours	10 days

Assuming that a non-repairable leak is found, the cryogens should be allowed to boil off the vent outside the building in a controlled manner. Perform the following steps:

(1) Shut off LN_2 flow.
(2) Monitor cryogen temperature.
(3) Control venting rate by actively pumping the vacuum space or backfilling with "exchange gas."
(4) Vent all vapors outside the building.

The following people shall be notified immediately if a vacuum leak is detected. A list of names with telephone numbers will be maintained by the LRIR Program office and a copy shall be posted in the LRIR Laboratory:

(1) LRIR project engineer
(2) HRC safety officer
(3) LMSC project engineer
(4) Other personnel as required.

3.3.2 Failure of Instrumentation - Temperature or Vacuum

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Temperature

The temperature of the cryogens is the primary indicator of the system condition. The servicing frequency and all other safety and operating procedures are based on this temperature. Both cryogen tanks have platinum thermometers installed to nomitor the cryogen temperatures. In the event that one or both of these should fail a backup indication can be obtained from the thermometers installed in the DCA.

The cause of any thermometer failure must be determined to ascertain whether it is a failure of the thermometer itself or of its external electronics. If it is the electronics, then a fix can be readily accomplished; otherwise a complete recycling and possible teardown of the SCP may be required. It should be noted that the operation of the alarm system depends upon the SCP installed thermometers.

Vacuum

A failure of the SCP vacuum gauge need not be considered a major failure. The condition of an acceptable vacuum level is directly indicated by the SCP thermometers because an abnormal vacuum will be shown by a higher than usual rate of rise of cryogen temperature. In addition since the gauge is externally mounted within the CSE, it can be replaced at any time. If the vacuum gauge is suspect, check the temperature level of the cryogens and in particular, note their response vs time.

3.3.3 Removal of Cryogen Line Blocks

Since the LN_2 lines are at approximately 80°K they must not be left opened exposed to atmospheres. Moisture from the air may diffuse and cause a water blockage. Special program are to be followed when servicing these lines.

On the other hand, a blockage of the methane or ammonia lines is a distinct possibility although also unlikely.

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The major concern in the event of a line blockage is the buildup of a dangerous internal pressure. This can be completely prevented by continuously flowing LN_2 through the cooling coils, thus maintaining the cryogens in a no-loss or nonventing condition. Continue this until the cause of the blockage is determined and the corrective action is undertaken.

3.3.4 Indication of Escaped Methane or Ammonia

If indications of methane or ammonia are found to be present in the laboratory, immediate action shall be taken to determine their source and to purge the room. Switch the exhaust fan to high speed. In addition, notify all personnel listed on the emergency personnel list posted in the lab area. Refer to the LMSC Systems Safety and Health Plan (Ref. 1) for remedial action.

4.0 HRC FACILITIES AND SAFETY EQUIPMENT

4.1 LRIR LAB FACILITY

The following equipment and installations shall be provided in the LRIR Lab for operation of the SCP and GSE:

(1) A GSE vent line directly connecting to the outside of the building. It shall be of sufficient size to allow the expeditious removal of methane and ammonia vapors. All discharge connections from the GSE must be piped into this vent line.

(2) A high velocity forced draft vent directly connecting to the outside of the building. The intake shall be positioned over the SCP and GSE, and a switch shall be provided in the lab to operate the system if methane or ammonia is found to be present in the lab. The system shall incorporate an explosion-proof fan and shall be capable of changing the lab air once every two (2) minutes.

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(3) At least two methane monitors must be provided for the SCP and GSE. Of these, one is to be a permanent installation which continuously samples the laboratory air. It shall, as a minimum, be equipped with a visual indicator of methane concentration and an audible alarm.

A portable instrument shall be kept close to the SCP and accompany it when it is remote from the GSE. This monitor can be a visual type without recording or alarm provisions.

Instruments to be used for these purposes are:

Continuous Monitoring

MSA series 500 combustible gas detection system, model 1-501 with single sensing head.

Portable Instrument

MSA model 457743 methane spotter

(4) Waterline (1/4") and drain
(5) Electrical power (115V, 60 amp)
(6) Compressed air at 80 psi min.
(7) One standard bottle GN_2, Medi-grade (99.997% pure)
(8) One filled LN_2 container - capacity 160 liters
(9) Limited access to lab (sign and/or lock)

4.2 ENVIRONMENTAL LAB FACILITY

The following equipment and installations shall be provided in the environmental lab for operation of the GSE adjacent to the Howard Chamber and for operation of the SCP inside the chamber:

(1) A GSE vent line directly connecting to the outside of the building shall

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be of sufficient size to allow the expeditious removal of methane and ammonia vapors. All discharge connections from the GSE must be piped into this vent line.

(2) A portable methane spotter, as described in Sec. 4.1, item 3, shall be kept with the GSE at all times.

(3) Provisions must be made to maintain the methane temperature at less than 85° K and the ammonia temperature at less than 168° K while the loaded SCP is in or about the Howard Chamber.

(4) Electrical power (115v, 60 amp)

(5) One filled LN_2 container - capacity 160 liters

(6) If the SCP is to be left in the chamber without a qualified operator, the SCP methane and ammonia temperature sensors must be connected through the chamber wall to the cryogen monitor panel.

4.3 SAFETY EQUIPMENT

The following safety equipment is required in the lab when a loaded LRIR cooler is present:

(1) LN_2 as described in Sec. 4.1 above
(2) First Aid Kit
(3) CO_2 fire extinguisher (in hall within 50 feet of lab)
(4) Copy of this document
(5) Copy of LMSC Systems Safety and Health Plan (Ref. 1)
(6) Copy of SCP-GSE Instruction Manual (Ref. 2)
(7) Telephone numbers of qualified LRIR handlers, LRIR project engineers, and HRC safety officers.
(8) Cryogen temperature monitoring and alarm panel
(9) MSA model 457743 portable methane spotter

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SECTION 10

NEW TECHNOLOGY

There has been no new technology developed during this phase of the LRIR program.

SECTION 11

CONCLUSIONS AND RECOMMENDATIONS

11.1 CONCLUSIONS

A protoflight model LRIR has been assembled and successfuly completed the required environmental, performance, and calibration test programs. The measured instrument performance deomonstrates that the critical performance parameters specified in GSFC S-450-P-11 have been met or surpassed. Noise equivalent radiance measurements in the 15μm carbon dioxide channels were a factor of at least 2 better than the required 0.01 $wm^{-2}sr^{-1}$. Resolution of 2 Km was obtained as deomonstrated by the 0.52 mr subtense of the instantaneous field of view and 1.5 Km sampling interval.

Environmental tests of vibration, vacuum-thermal and electromagnetic interference deomonstrate that the LRIR will successfully withstand the spacecraft test and launch environment and will provide deomonstrated performance in the orbital environment.

These tests and deomonstrated performance indicate that the scientific objectives of S-450-P-11 will be fully met.

11.2 RECOMMENDATIONS

11.2.1 Introduction

The following recommendations are suggested for consideration in planning future instrument programs.

11.2.2 Radiometric calibration of the LRIR was performed using an extended source blackbody located in close proximity to the LRIR aperture. Radiative coupling between the LRIR and calibration source was high as indicated by the fact that the OMP temperatures increased as the calibration source temperature was increased. This produces calibration uncertainties since the OMP temperatures significantly affect radiometric performance. Quality of the calibration data can be improved and calibration data reduction can be simplified on future instruments by incorporating radiative de-coupling between the radiometer and source. De-coupling can be approached by reducing the thermal impedance between the radiometer and its temperature control mechanism, by increasing the amount of temperature control of the optics and housing, and including, in the vacuum chamber, externally controllable baffle plates between the radiometer and source.

11.2.3 System performance acceptance tests should be performed in the interface configuration that the instrument would have on the spacecraft, i.e. test cables that are not a part of the instrucment flight configuration should not be connected unless previous tests have deomonstrated non-interaction.