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INVESTIGATION DEVELOPMENT PLAN
FOR
REFLIGHT OF THE
SMALL HELIUM-COOLED
INFRARED TELESCOPE EXPERIMENT

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VOLUME I: INVESTIGATION AND TECHNICAL/MANAGEMENT

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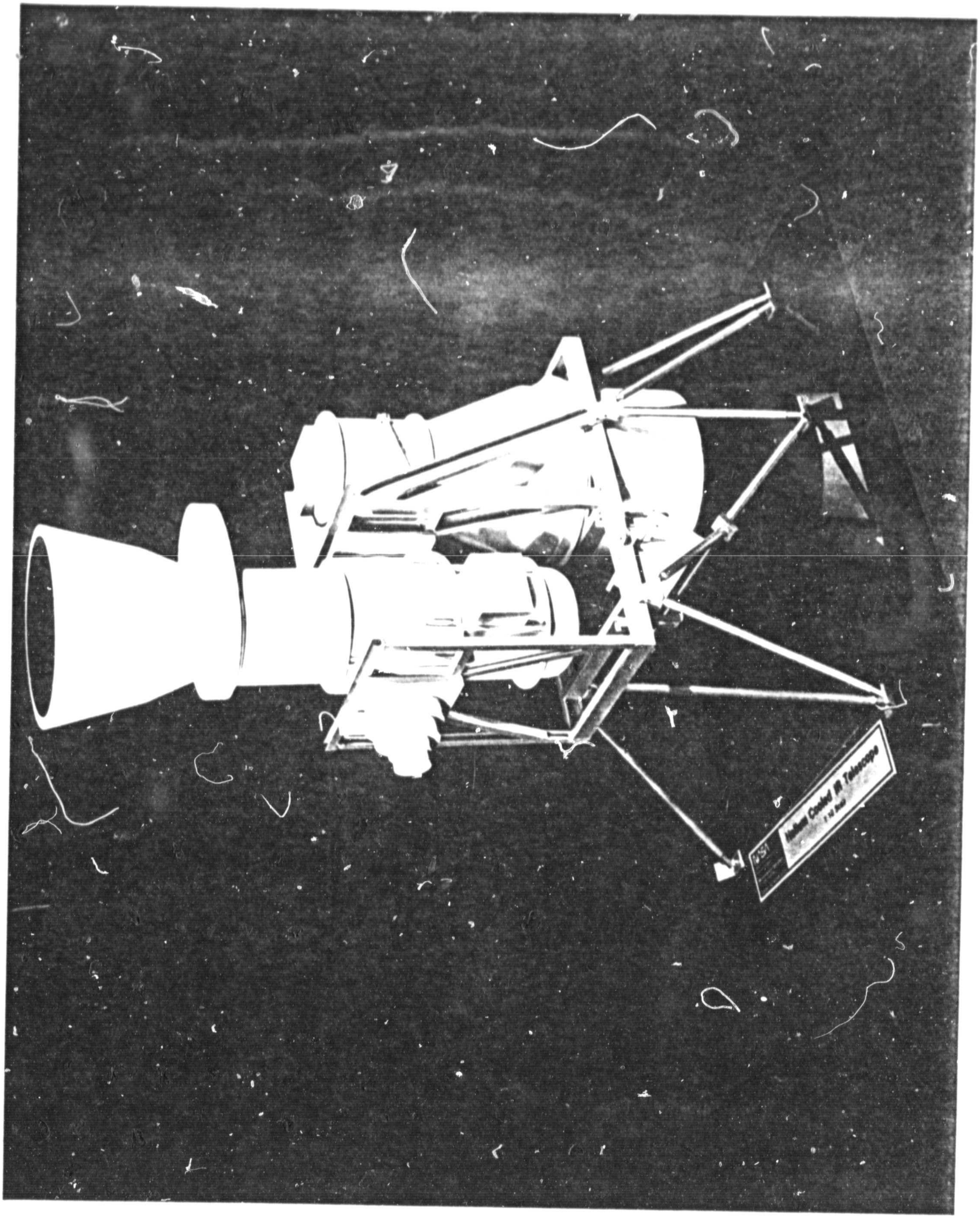

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INVESTIGATION DEVELOPMENT PLAN FOR IRT REFLIGHT
VOLUME I: INVESTIGATION AND TECHNICAL/MANAGEMENT

FRONTISPIECE

Scale model of the Small Helium-Cooled Infrared Telescope (IRT) being developed for Spacelab missions by the Smithsonian Astrophysical Observatory, the Steward Observatory of the University of Arizona, and the Space Sciences Laboratory of NASA's Marshall Space Flight Center.

INVESTIGATION DEVELOPMENT PLAN FOR IRT REFLIGHT

VOLUME I: INVESTIGATION AND TECHNICAL/MANAGEMENT

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1.0 INTRODUCTION

1.1 EXPERIMENT OBJECTIVES

The Infrared Telescope (IRT) is designed to survey extended celestial sources of infrared radiation between 4 and 120 micrometers wavelength. It will provide data regarding Space-Shuttle-induced environmental contamination and the zodiacal light. And, it will provide experience in the management of large volumes of superfluid helium in the space environment.

1.2 EXPERIMENTAL APPROACH

The IRT consists of a single-axis scanning telescope, which is an articulated cryostat extension of a superfluid helium dewar, carrying an optical system and detectors operating near absolute zero. Instrument commands and housekeeping data are routed via the Remote Acquisition Unit (RAU), permitting instrument operation from the aft flight deck or the ground. Detector data are digitized, formatted with selected housekeeping data, and transmitted to ground via three High Rate Multiplexer (HRM) channels.

The data processing combines the cryostat's scanning and the Orbiter's uniform continuous pitching motion into a series of rasters, one for each detector. Each raster "line" overlaps its predecessor by about one-third its width to permit short-time confirmation. Observations made over three contiguous orbital revolutions provide longer term confirmation, while three-rev sessions spread here and there over the mission provide very long-term confirmation. This repeated scanning will permit distinguishing among near-field, mid-range, and far-field objects as well as permitting identification of sources that may vary in intensity.

If possible, conversion of normal helium back to superfluid while on orbit will be studied after the required infrared observations are completed. (See Section 9.2.1).

1.3 DEVELOPMENT CONCEPT

The IRT, related GSE, and software systems are being developed for Spacelab 2. A major decision must be made at the conclusion of that mission, namely, whether or not to reconfigure the focal-plane array (FPA) of detectors. With that decision in hand the flight equipment, GSE, and software will be refurbished and requalified as dictated by postmission inspections and tests. It may be advisable to redesign the flight electronics around a microprocessor, in which case the new electronics must be developed on a schedule commensurate with the refurbishment of other subsystems. The system, ready for reflight, will be delivered to Level IV integration about 12 months after SL-2.

1.4 PROJECT ORGANIZATION

The Principal Investigator, Dr. Giovanni Fazio, will head the IRT Team. Raymond Watts, Jr., will continue as Program Manager. Both are at SAO, which will continue responsibility for program management, system electronics, and data reduction. Under the leadership of Dr. George Rieke, the University of Arizona will be responsible for refurbishing the optical system and for either refurbishing the old FPA or designing and building a new one. The cryogenic system, support structure, and scan drive will be refurbished at MSFC under the direction of Dr. Eugene Urban. Reassembly and reverification will be done at MSFC, supervised by the SAO program team. Ames Research Center will analyze the data for Orbiter-induced environmental effects; cryogenic science and engineering analyses are the responsibility of MSFC's Space Sciences Laboratory; UA and SAO will collaborate in the analysis of infrared astronomy data.

1.5 PROGRAMMATICS

As originally proposed, the reflight of the Infrared Telescope (IRT) was to have been a 20-month program. However, delays in the schedule of the Shuttle Orbiter have necessitated a considerable reshaping of IRT plans. The most significant change has been to spread the Definition Phase over four fiscal years, activities during the first two being at an extremely low level. This enabled us to have a preliminary Experiment Requirements Document (ERD) ready on a schedule in keeping with newly selected experiments so that payload studies and development of potential mission plans could progress. At the same time, major planning activities for equipment refurbishment could be delayed until the hardware is delivered to Level IV integration for its first flight.

Consequently, this document addresses two major activities: a) the continuation of the Definition Phase, and b) the Refurbishment and Reflight Phase. The Spacelab-2 mission (the first flight of the IRT) is assumed to occur in November 1983.* Changes in that date will of course have some impact upon this plan, particularly in the schedule area.

1.5.1 Definition Phase -

During the continuation of the Definition Phase existing documentation will be updated as necessary and two additional tasks will be undertaken. The first is a study of a possible redesign of IRT electronics. It appears that a number of improvements can be made that would simplify the IRT-to-SL interface and reduce the IRT's demand upon SL resources. If the study bears out this assumption and if

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*NOTE ADDED IN PRESS: Spacelab 2 has been delayed to November 1984.

the redesign is approved, the second task will be to execute the new design. Although such design activity is supposed to be part of a Development Phase, the fact that the IRT is to be reflown impacts the schedule in that it is desirable to minimize the time between flights. If the design is completed before the first IRT mission, fabrication and testing can be completed while the rest of the system is being cleaned and refurbished. Long-leadtime components must be ordered during the Definition Phase of the program, too.

1.5.2 Refurbishment And Reflight Phase -

Instead of a development phase the IRT will go through an R&R Phase. The interior of the telescope -- baffles, optics, and detectors -- is particularly sensitive to contamination. Any accumulation from the first mission must be carefully removed. In addition there are certain limited-use components such as O-ring seals and valve seats that must be replaced prior to a new round of exercises during reintegration and reflight. Furthermore, the results of the scientific analysis may indicate a need for changes in the FPA to optimize the return from the second flight.

It is also likely that GSE and software revisions will be necessary to take advantage of first-flight experience. These renovations and modifications along with mission planning, mission support and data reduction and analysis comprise the major activities of the R&R Phase.

1.6 THE PLAN

The emphasis in this document is upon the latter parts of the Definition Phase and the R&R Phase. However much detail work remains to be done. Consequently this plan has been developed in the form of an augmented pointer; more than just a cross reference, it not only directs the reader to other documents, some of which are yet to be written, but also gives as complete a picture as possible.

2.0 APPLICABLE DOCUMENTS

* GSFC S-420-10 -- General Guidelines and Requirements for Spacelab Experiments, September 18, 1979

* SLP/2104 -- Spacelab Payload Accommodation Handbook

* DR-1-79 -- Data Requirements for Spacelab Experiments, September 28, 1979

* JSC 07700, Vol. XIV -- Space Shuttle System Payload Accommodations

3.0 SYSTEM DESCRIPTION

3.1 INTRODUCTION

Because the IRT is reflown hardware, no new technology is anticipated to be necessary. If it is decided that a new focal-plane array (FPA) is appropriate, available detectors, lenses, and filters will be specified to avoid new-development problems. SAO also plans to study the addition of a dedicated experiment processor (DEP). If this addition is selected, specifications will be limited to proven systems and components.

This section describes the flight hardware, ground support equipment, and software that will be provided by the IRT experiment team. Operation of the equipment also requires software that runs in the Spacelab Experiment Computer. It is government-furnished, but nevertheless, briefly discussed in this section.

3.2 FLIGHT HARDWARE

3.2.1 The Experiment System -

The IRT is shown schematically in Figure 3-1.
It consists of four major subsystems: 1. A dewar subsystem, which includes a 250-liter liquid helium dewar, and a transfer assembly (TA) containing the porous-plug flow control and fill and vent plumbing; 2. A cryostat subsystem, which includes a gas-cooled, evacuated cryostat

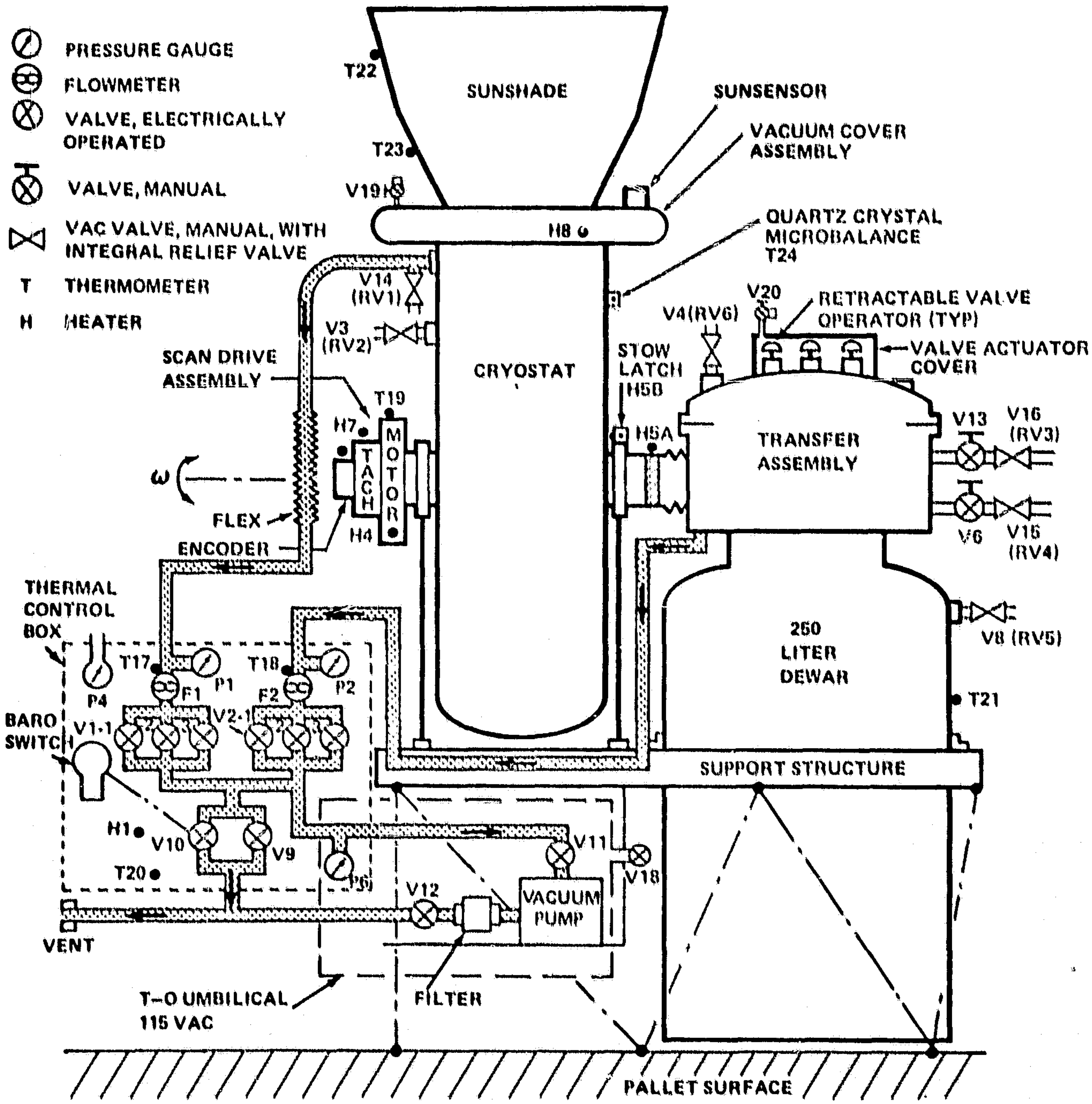

Figure 3-1. IRT Envelope and Plumbing

that contains the infrared telescope and detector array, a vacuum cover, and a sunshade; 3. A mechanical subsystem, which includes scan drive components, plumbing, valves, control instrumentation, and the support structure that interfaces with the Spacelab pallet; 4. An electronic subsystem (not shown) to control all infrared science and electromechanical activities and to interface with the Spacelab power, data, and command systems.

When the IRT is mounted on a Spacelab pallet, the top of the sunshade is about 3.5 meters above the pallet floor. The experiment is 2 meters long and about 0.5 meters wide. At liftoff the total weight of the experiment will be slightly more than 700 kg, including liquid helium and separately mounted electronics boxes. The scan drive motor shown in Figure 3-1 will be oriented toward the forward end of the cargo bay.

3.2.2 The Dewar Subsystem -

The superfluid liquid helium (LHe) dewar subsystem, shown schematically in Figure 3-2, consists of two major parts -- the 250-liter storage dewar and the transfer assembly (TA). The dewar is a somewhat modified commercial helium dewar design to which the TA has been added as an integral part. Thus the two become a single complex superfluid helium containment vessel surrounded by a common

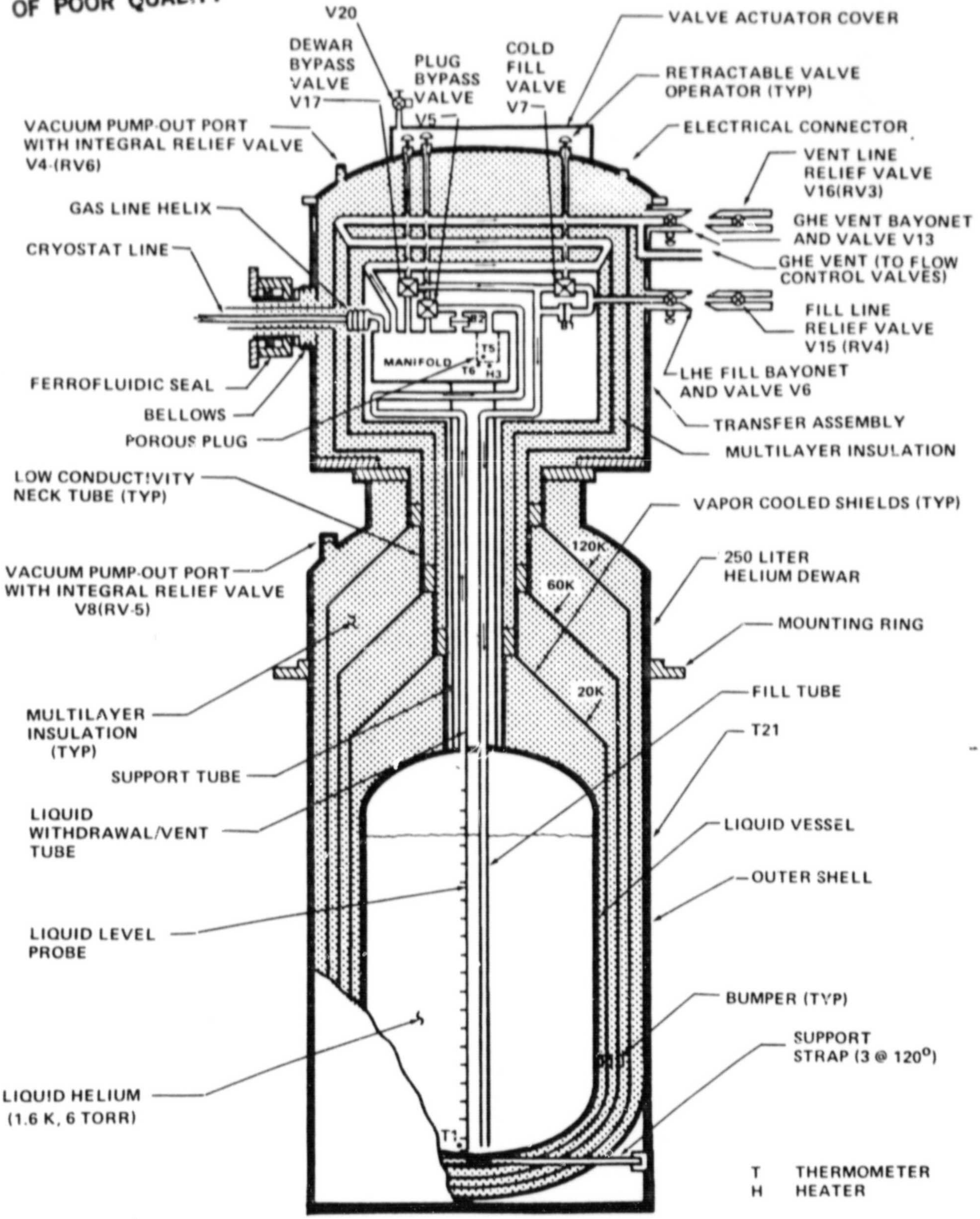

Figure 3-2. IRT Dewar Subsystem

set of vapor-cooled shields.

In a conventional storage dewar for ground use the liquid vessel is surrounded by a system of nested metal surfaces, separated by superinsulation (MLI) and mounted within a high-vacuum space. They serve to intercept heat being radiated and conducted in toward the cold liquid from the outer shell. The intercepted heat is then conducted up to the dewar neck where it warms the venting helium gas and is carried out of the dewar by the gas. Thus the metal surfaces act as vapor-cooled shields, and the dewar neck is a heat exchanger as well as a support structure. The source of the venting gas in the neck is the slow evaporation of the stored liquid caused by the unavoidable parasitic heat conducted down the neck tube and radiated in from the coldest vapor-cooled shield. A typical 250-liter dewar achieves a steady-state boiloff rate of about 2.5 liters of liquid per day.

To retain the stored LHe in space, it is necessary to close off the dewar neck at the liquid vessel entrance. Liquid is then inserted and withdrawn through tubes which pass down the neck from the TA. Valving and flow control is accomplished by the cold components in the TA. These components must also be insulated from the outside world by a vapor-cooled shield system. In the IRT the shields in the TA are connected to the shields in the dewar; there is a single heat exchanger in the TA.

The internal components of the TA will operate in space at the LHe temperature of 1.6 K. A cold fill valve prevents LHe from flowing out the fill line to the warm outer shell when the experiment is in space. A bypass burst disk permits controlled venting through the fill line in the event of accidental overpressurization. In space, liquid flows into the TA through the withdrawal line and is constrained by the porous plug. (The principles of operation of the porous plug, essentially a liquid-vapor phase separator for superfluid helium, are described later.) A second burst disk protects against blockage in the porous plug. When a dewar is being initially filled or when normal helium (4.2 K, 1-atmosphere vapor pressure) is being converted to superfluid, large gas flow rates must be vented. A bypass valve is provided in parallel with the porous plug to permit such rates and avoid possible contamination of the plug's pores.

The cold fill and bypass valves are operated by vacuum-tight retractable operator shafts having low thermal conductivity and low thermal mass. When retracted, the operator shafts will become warm. When inserted into the valves they will introduce pulses of heat into the cold environment. To minimize this problem the valves will be opened at the beginning of cryogenic operations and will not be closed except when the dewar subsystem must be turned on its side (launch attitude) for testing or just before the actual launch.

The cold helium vapor evaporates from the porous plug at about 1.6 K and is divided into two flows. The first passes through the heat exchanger which removes heat from both the TA and dewar. The second is delivered to the cryostat and the infrared telescope. The division of flow in the two lines is controlled by external valves that are discussed later.

As the dewar is filled with liquid helium, high flow rates of cold gas are conducted to vent lines through vacuum-jacketed bayonets and valves on the TA shell. When the filling and superfluid conversion operations have been completed, special inserts with relief valves will be fastened into the fill and vent bayonets. The jacketed valves will then be opened, providing a relief path for the two cold burst disks. The steady-state (low-flow) venting is via an unjacketed line to one set of flow control valves. The second vent line from the porous plug will deliver cold helium gas to the cryostat. After the gas is warmed in the cryostat vapor-cooled shields it is delivered to the second set of flow control valves. Both the gas line and the outer shell of the apparatus must permit the rotation of the cryostat. The outer shell must in addition maintain the high vacuum integrity of the TA and cryostat whenever atmospheric pressure exists around the apparatus. The cold gas line connecting the TA and cryostat is wrapped into a helical coil that flexes easily with the 90 degrees of cryostat rotation. At the exit from the TA a straight, insulated section of the gas line passes through a warm commercial rotary vacuum seal that utilizes magnetically retained sealing fluid to maintain the vacuum integrity of the outer shell of the apparatus. A short section of metal bellows prevents stress buildup between the TA and the cryostat.

3.2.3 Porous Plug -

The porous plug is a device for separating the gaseous phase from the superfluid phase of helium. In an inverted dewar or in the weightlessness on orbit superfluid helium attempts to flow out of the dewar driven by the vapor pressure within the liquid vessel and attraction towards warmer surfaces. Upon encountering the porous plug the liquid begins to flow through its small pores, which are typically on the order of a few micrometers in diameter. As the liquid evaporates in the plug or at the downstream surface of the plug it causes cooling and a small temperature gradient develops across the plug. This results in a thermal-mechanical or fountain-pressure gradient directed upstream, a characteristic unique to superfluid helium. This pressure gradient restrains fluid flow. Within reasonable bounds, the device is self-regulating for increasing pressure within the dewar drives more fluid through the plug which increases the evaporation rate and results in a larger thermal gradient and hence more fountain pressure across the plug to restrain the liquid.

A small heater is provided to destroy the fountain pressure if an abnormal heat load requires a flow of liquid into the system. The coldest parts of the system will operate at about 1.6 K, well above the superconducting transition temperature of materials used in the dewar.

3.2.4 The Cryostat Subsystem -

The cryostat shown schematically in Figure 3-3 is a special modification of an open-neck laboratory dewar. Its essential special features include mounting flanges for the two sections of the infrared telescope, an access port for focal-plane installation and alignment, and a side extension at the rotation axis through which the cold gas from the TA enters. A vacuum cover ensures that a high vacuum can be maintained within the cryostat and telescope before the experiment is in space. The cover opening mechanism is redundant for high reliability. The cold gas from the TA is first delivered at a temperature of about 2 K to the cold finger, a heat exchanger to which the IR detector block will be clamped. The gas then flows to cold rings for heat exchanging to the vapor-cooled shields. The two telescope sections will also be cooled by virtue of their being mounted to the cold rings. Thermal stability in

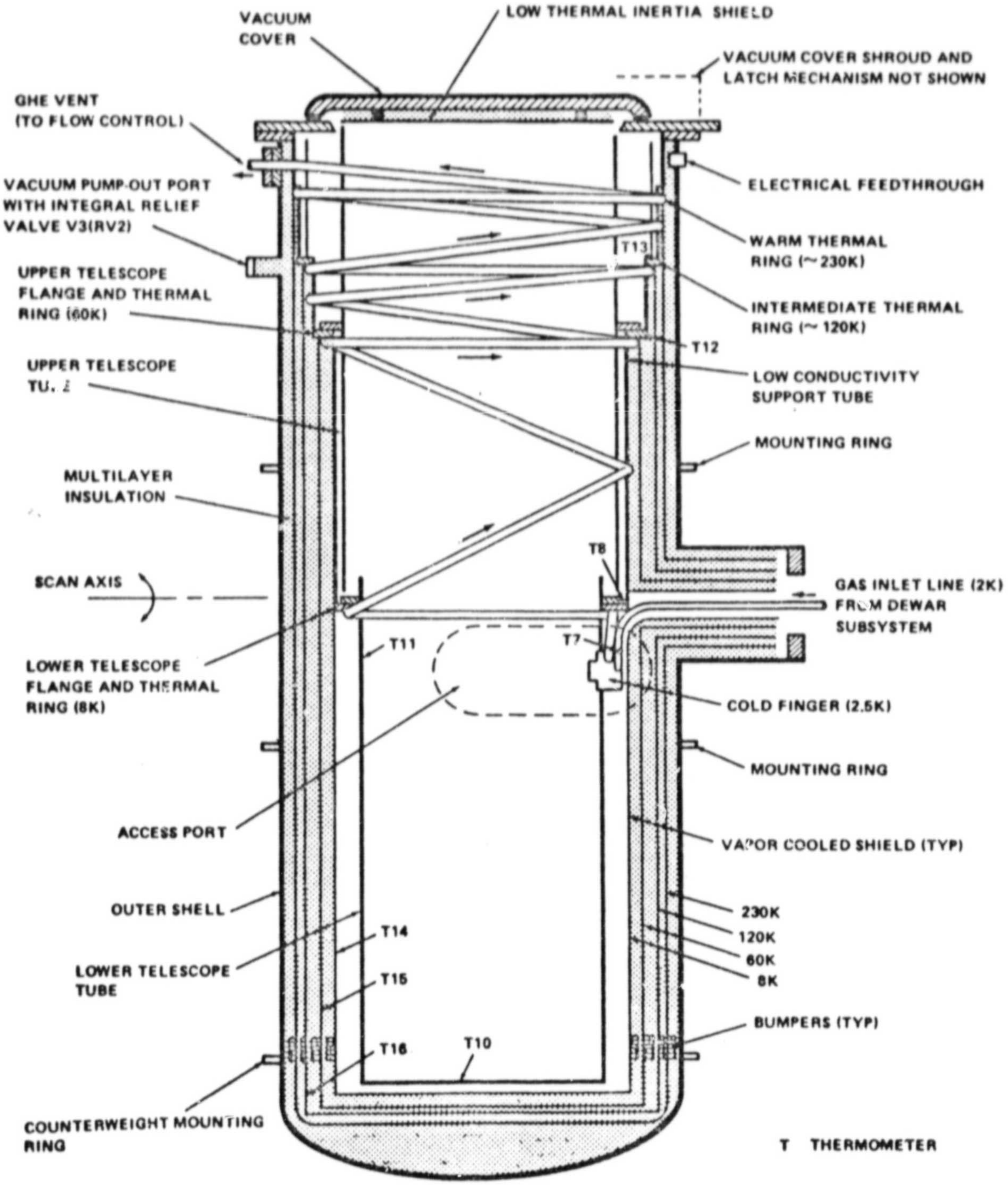

Figure 3-3. IRT Cryostat Subsystem

the FPA is maintained by the large thermal inertia of the cold finger and the FPA itself coupled with a steady flow of cold gas.

3.2.5 Control Valves -

Figure 3-1 also shows, schematically, the valving system in the thermal control box. The balance of gas flow through the cryostat and the dewar-TA is controlled by two valve manifolds. These valves are commandable and permit control of the helium flow to provide the necessary cooling of the telescope while conserving as much LHe as possible.

Before launch the helium is kept in the superfluid phase by a vacuum pump powered through the Orbiter's T-0 umbilical. At launch the vent line and pump are valved off and the pump is stopped. During ascent, when the ambient pressure has gotten sufficiently low, a barometrically controlled valve opens to permit the vacuum of space to "pump" the helium.

3.2.6 The Telescope -

The IRT telescope, shown schematically in Figure 3-4, has four major parts:
1) The focal-plane assembly, and a moveable shutter to block radiation to the focal plane and provide a zero-flux reference, 2) The lower telescope tube, supporting the mirror, both cooled to 8 K, 3) The upper telescope tube cooled to 60 K, which serves to intercept the aperture load, 4) The sunshade, which protects the 60 K tube from direct illumination by the earth, moon, sun or Shuttle surfaces.

The primary mirror is an f/8 15.2-cm off-axis paraboloid made of aluminum. Its surface is finished in gold to minimize its emissivity. The dimensions of the lower tube were dictated by the focal length of the primary mirror and the 4.5-degree diameter field of view at the focal-plane assembly. The dimensions of the upper tube and sunshade were optimized to allow the telescope to observe as close to the sun as possible yet fit within the Orbiter bay envelope. The design also requires that the lower telescope section not view a surface much warmer than the 60 K section and that the upper telescope section not receive direct illumination from the sun. Scattering and diffraction of off-axis radiation was minimized by a system of baffles. An analysis of the entire system for off-axis rejection was performed using the APART and GUERAP II computer models.

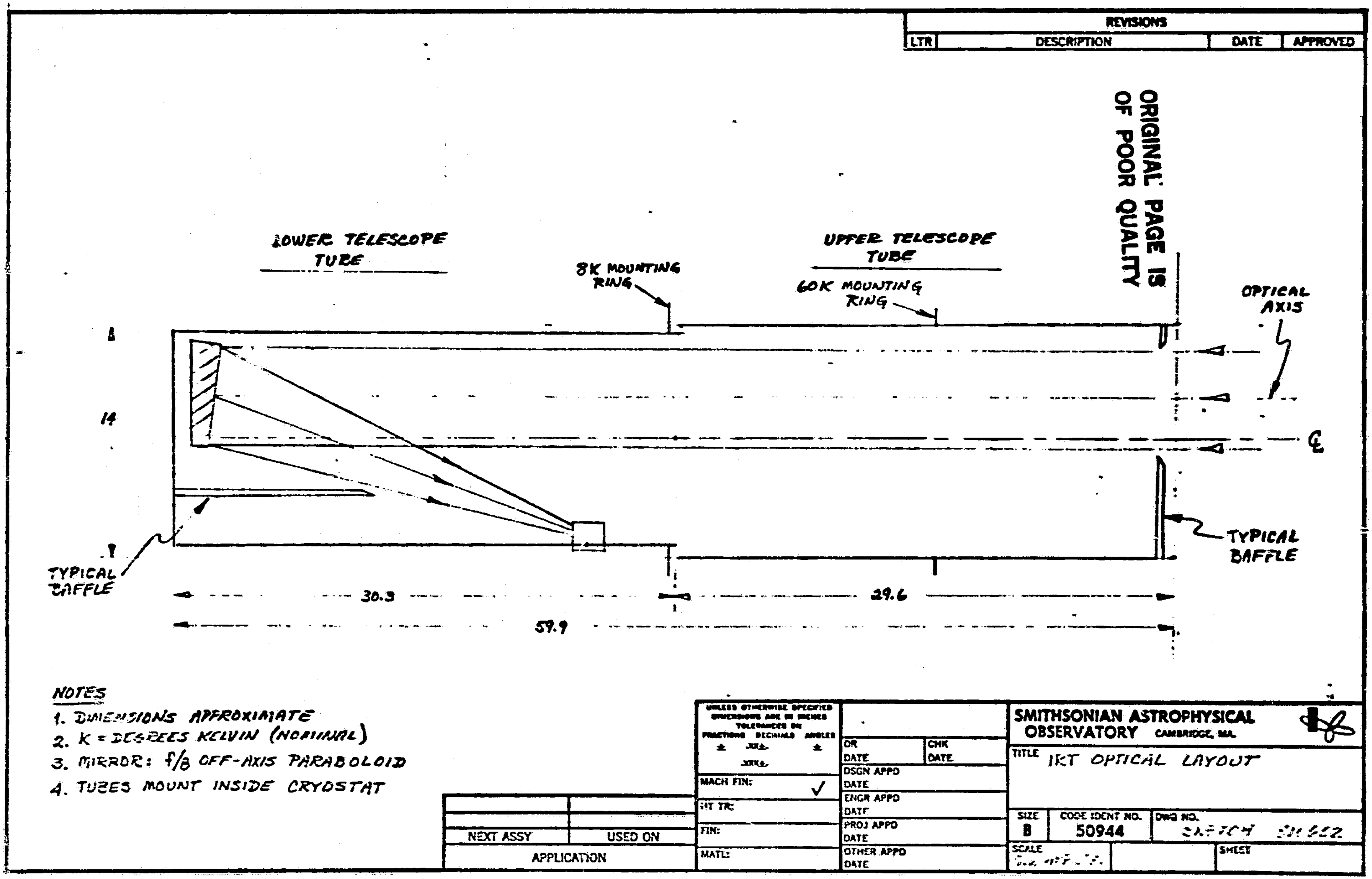

Figure 3-4. IRT Optical Layout

3.2.7 The Focal-Plane Assembly -

The FPA consists of the detector block shown in Figure 3-5, which contains the various detectors described in Table 3-1 and load resistors as well as the bandpass filters, Fabry lenses, and aperture stop. The FPA is designed to operate at 3 K. Preliminary tests indicate that the operating temperature will remain constant to well within 1 K over a wide range of heat loads. More precise measurements are planned prior to the first IRT mission. A shutter maintained at 8 K and a heater to initially warm the JFET preamps are provided.

The detectors are photoconductive devices with NEP's significantly less than the background NEP given in Table 3-1, except for the longest wavelength where it is comparable. The long wavelength detectors, the E-band, are placed in integration cavities to improve their efficiency. Each detector output is fed into a JFET preamp operated in the balanced-DC, transimpedance amplifier mode. The electrical power for the JFET'S is derived from isolated lithium batteries that are the type used in cardiac pacemakers. The JFET's operate at about 70 K. The effective capacitance of about 0.02 pF and load resistance of 1000 megohms result in a time constant of approximately 20 microseconds. This permits reduction of a saturated pulse caused by an energetic particle to the noise level

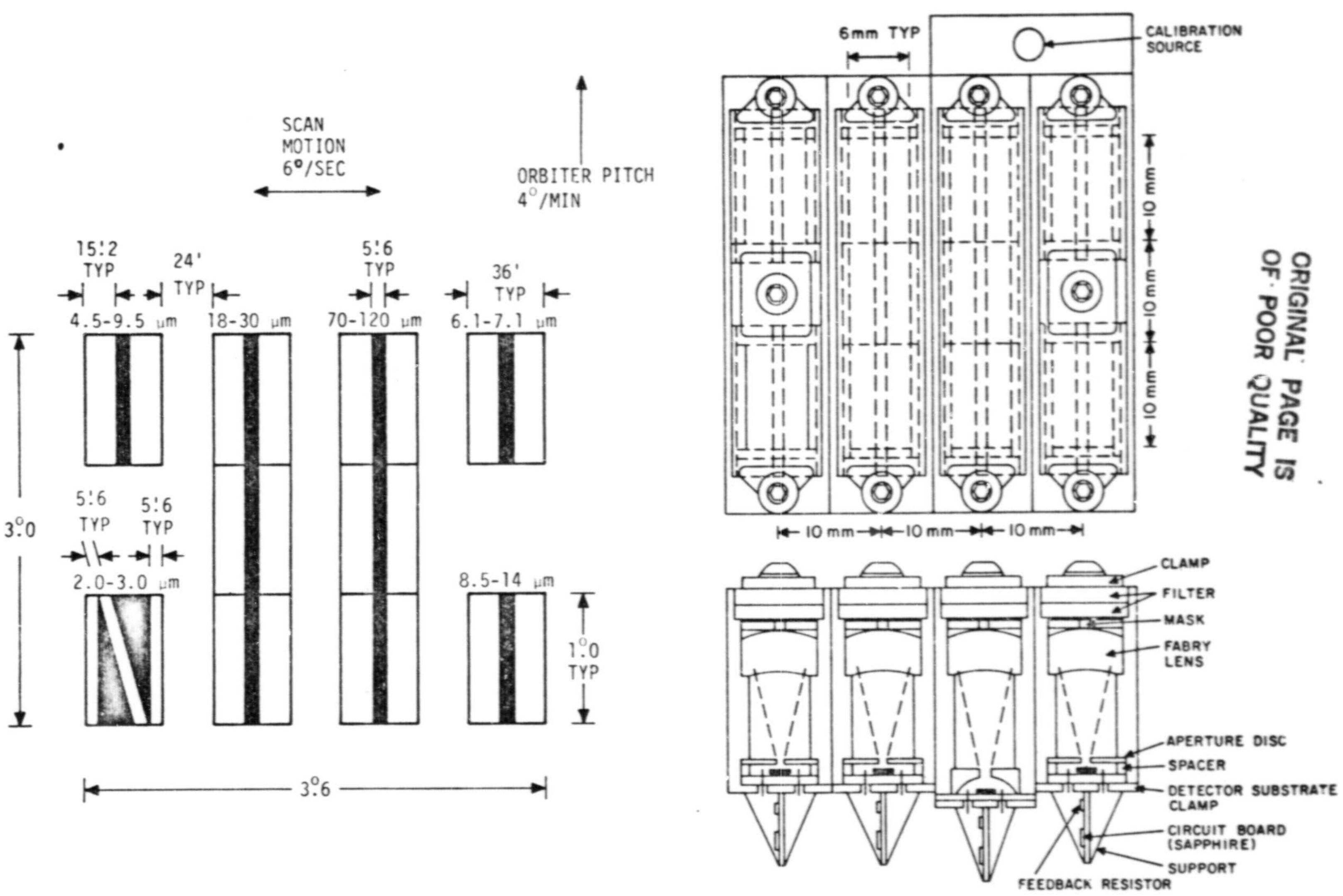

Figure 3-5. Focal plane configuration showing the masks, bandwidths, sizes and orientation of the ten detectors.

Table 3-1
Characteristics of Spacelab Infrared Telescope Detector Channels

Band	$\Delta\lambda$ (μ)	Detector Type	V_B (volts)	S (A/W)	η (%)	ϵ (%)	R_f (Ω)	Q (W)	NEP_Q ($W/Hz^{1/2}$)	NEP_D ($W/Hz^{1/2}$)	NEFD ($W/cm^2\mu m\ Hz^{1/2}$)
S	2.0-3.0	Si:Ga	22	0.03	~6	70	$1.7x10^{10}$	$1.2x10^{-13}$	$8x10^{-16}$	$3x10^{-15}$	$2.42x10^{-17}$
A	4.5-9.5	Si:Ga	14	0.45	40	50	$3x10^{9}$	$2.4x10^{-12}$	$8x10^{-16}$	$5x10^{-16}$	$1.8x10^{-18}$
B	6.1-7.1	Si:Ga	14	0.45	40	70	$1.7x10^{10}$	$4.4x10^{-13}$	$3.6x10^{-16}$	$2x10^{-16}$	$2.9x10^{-18}$
C	8.5-14.5	Si:Ga	19	0.85	45	70	$9x10^{8}$	$4.7x10^{-12}$	$9x10^{-16}$	$5x10^{-16}$	$1.3x10^{-18}$
D	18-30	Si:Sb	4	1.4	60	40	$3x10^{9}$	$1.7x10^{-12}$	$3.4x10^{-16}$	$2x10^{-16}$	$4.0x10^{-19}$
E	70-120	Ge:Ga	0.15	3	3	50	$3x10^{9}$	$3.7x10^{-14}$	$1.5x10^{-16}$	$7x10^{-17}$	$3.4x10^{-20}$

Definitions:

$\Delta\lambda$: wavelength range between half power points of effective filter transmission curve, including spectral characteristics of detectors, blockers, and optics

V_B: detector bias voltage

S: detector responsivity in the spectral band, 1-100 Hz

η: detector quantum efficiency in the spectral band

ϵ: optical efficiency

R_f: feedback resistor

Q: background flux (zodiacal) incident on the detector -- zodiacal thermal emission has been taken to be

$$\frac{2.5x10^{-6}}{\lambda(\mu)} B_\lambda(230)\ W/cm^2\ ster\ \mu,$$

zodiacal background at 2.5 μ to be 10^{-11} W/cm^2 ster μ

NEP_Q: background limited NEP

NEP_D: zero-background NEP, 1-100 Hz

NEFD: noise equivalent spectral flux density, background limited within a one-millisecond sample period. During data reduction these spikes can be readily identified and removed without severely affecting the deadtime or requiring baseline restoration as a result of a long decay time.

Fabry lenses are utilized to permit the smallest possible detectors and yet have a 0.6 by 1.0 degree field of view. These lenses also ensure that the detectors view only the cold mirror, which in turn views only the sky and has no obscuration. The mask which provides spatial filtering for source discrimination is evaporated directly onto the lenses. The lenses with high indices of refraction to control aberration are made from either optical-grade germanium or silicon with an extremely small focal ratio, an f-number of 0.8. The lenses are anti-reflection coated. Conventional bandpass interference filters are being used for all but the E-band where a long pass filter with additional crystalline material such as CaF is being used.

A single aspect sensor consisting of a PIN silicon detector sensitive in the 1.7 to 2.7 micron region with a Z-slit mask is used to obtain absolute aspect information. The layout of the focal plane is dictated by requiring complete coverage in the two longer wavelength bands and requiring the two bands used for detection of water to scan the same path. The off-axis distortions, image quality, and aspect will permit resolution of a few arcminutes in the scan direction.

A shutter cooled to 8 K used to cover the entire focal plane will provide a zero-flux reference. A solenoid with a spring return changes its position. A retracting solenoid serves as a backup for removing the shutter from the field of view. A pulsed hot-wire bilevel infrared source, providing scattered radiation from the back side of the shutter when closed, is used as a health check of the system. It can be commanded on at any time, either from the AFD or the POCC.

The sunshade is a biconical structure of fiberglass-epoxy honeycomb. Like all other external structures it has smooth rounded edges. Its painted outer surface was selected for thermal characteristics and low outgassing.

3.2.8 Command And Data Management -

There are three types of electrical interfaces with Spacelab, the Electrical Power Branching Distributor (EPBD), the Remote Acquisition Unit (RAU) and High Rate Multiplexer (HRM). A general block diagram of the overall electronics is given in Figure 3-6. The EPBD provides raw unregulated +28 VDC power. All motors, valves, and heaters are run directly off of the raw DC. All electronics are run from highly regulated and filtered DC-DC converters. Ascent

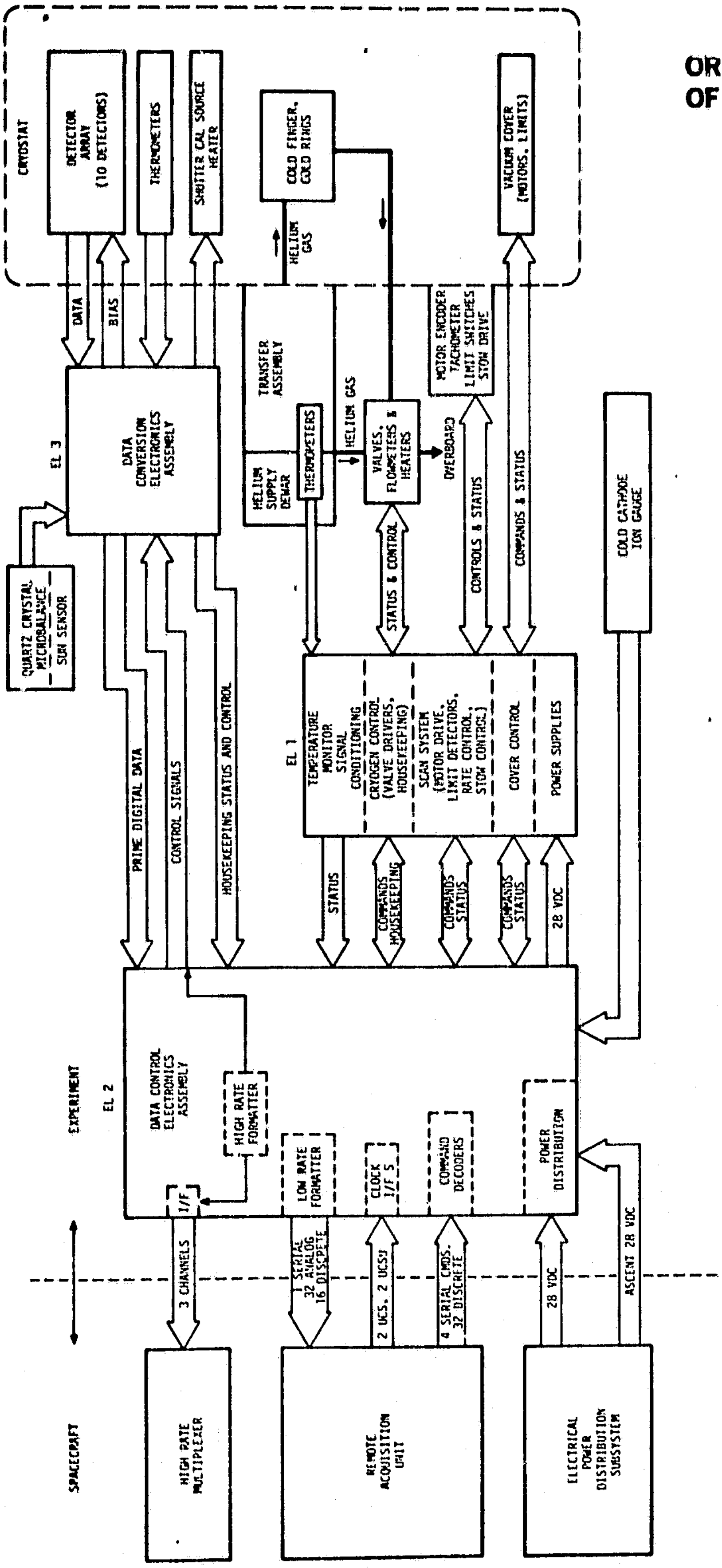

Figure 3-6. IRT Experiment Block Diagram

power is required to operate the baroswitch-controlled vent valve during rise to altitude.

The RAU is used for communicating with the instrument with the exception of not handling the scientific data. The RAU can send and receive both discrete and serial commands and messages and receive analog levels. The IRT uses: 4 serial and 32 discrete command lines, two 1024-kHz clocks, and two 4-Hz clocks from the RAU. Its output is carried via 1 serial, 16 discrete and 32 analog data lines. The data to the RAU will be available in real time to both the onboard Payload Specialist and to the investigators in the Payload Operations Control Center (POCC). These data will provide adequate information for successful operation of the experiment even if the detector data were to become inaccessible during the mission. The commands and data to the experiment originate from a number of sources. The discrete and one of the serial commands for operation of the instrument are sent by the investigators from the POCC. If the need arises, the same commands can be issued by the Payload Specialist from the Orbiter aft flight deck. The discrete and serial commands provide operation of the valves and heaters for cryogen management, control of the scan drive, vacuum cover, focal-plane shutter, calibration source, and override of the ion gauge and sun sensor. The ion gauge commands the cover closed if a predetermined ambient pressure is exceeded and the sun sensor stops the scan and closes the cover if the telescope is inadvertently scanning into the sun. A second serial command defines the scan limits. Normally these limits will be computed in real time onboard by the Experiment Computer Applications Software (ECAS) for either the primary or backup scan modes. The third and fourth serial messages contain Greenwich Mean Time and the Orbiter attitude and position. These are not necessary for real-time operation of the instrument; however, they are merged in the instrument with the scientific data stream so that the scientific data is completely self-contained.

The HRM receives the scientific data from the instrument. Three channels are being used each at a data rate of 204.8 kHz. The conversion electronics which generates this stream is shown schematically in Figure 3-7. The signal from each of the 10 detectors is fed into a set of preamps. To obtain an overall dynamic range of one million (i.e., 20-bit resolution) without requiring state-of-the-art analog-to-digital converters, the preamps provide three output gains, each being digitized with 12-bit resolution. The preamps also provide an absolute value flag for the lowest amplitude signal to allow for the small DC-offset characteristics of the detectors and preamps. Each of the 10 preamp outputs feeds into 3 boxcar integrators which have about a one-millisecond integration time. These are sequentially multiplexed into sample and holds before being reset. The output of each sample and

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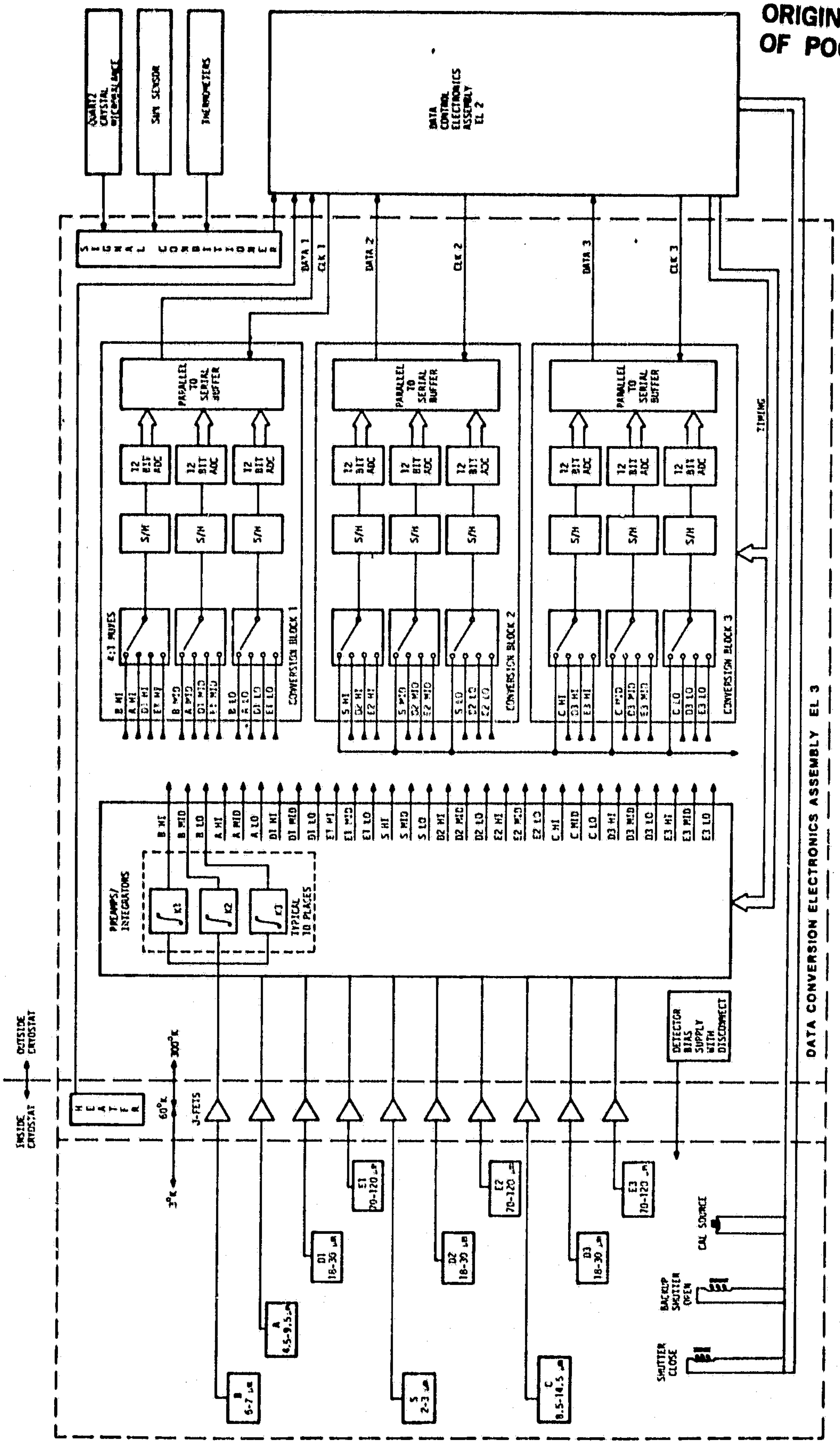


Figure 3-7. IRT Detector Flow Diagram

hold is digitized with a 12-bit analog-to-digital converter to which a parity bit is added. The digitized signal is formatted along with the Greenwich Mean Time, Orbiter attitude and position, the output of the shaft-angle encoder and housekeeping status bits.

3.3 GROUND SUPPORT EQUIPMENT

Ground support equipment may be divided into four classifications. There is a digital electronics system that receives data from the HRM; a commanding system that is used prior to Level-IV integration to simulate the functions of the RAU; cryogenic servicing equipment including control electronics, pumps, valves, plumbing, and storage dewars; and there is a variety of mechanical support equipment for handling the various subsystems and for mounting the assembled IRT. The following subsections describe each of these types of GSE in further detail.

3.3.1 Digital Ground Support Equipment (DGSE) -

The DGSE is centered around a Nova 3/12 digital computer. It is augmented with high-speed tape drives, floppy disks, and other I/O devices. The primary function of the DGSE is to record and display IR data transmitted from the flight equipment by way of the Spacelab HRM. To do this the GSE must receive 3 asynchronous 208-Kbit signals.

Specially designed receivers accept the HRM serial stream and convert it to a parallel output for the Nova.

The volume of data being received makes it impossible to display everything in real time. Near-real-time hardcopy of selected detector outputs is possible or, during periods when no data are being received, tape recorded data may be played back and displayed. Very limited data manipulation for quick-look analyses is possible.

3.3.2 Command Ground Support Equipment (CGSE) -

To operate the flight equipment and receive housekeeping data from it when the IRT is not installed in the Spacelab, the CGSE acts as an RAU simulator. The interface simulator is driven by a TRS-80 microcomputer. Augmented by floppy disk drives and a small printer, the TRS-80 can give a CRT display of command status and housekeeping data, generate some modest command sequences, or handle keyboard-entered commands.

After the IRT is mounted in the Spacelab the CGSE will be used by the team as a record-keeping tool that will provide a complete, detailed record of the status of the instrument at all times.

3.3.3 Cryogenic GSE -

The cryogenic GSE is described in Table 3-2.

Table 3-2.

IRT Cryogenic GSE

ITEM NAME	DIMENSIONS in. (cm)			WEIGHT lbs. (kg)	CONTAINER NUMBER	REMARKS
	L	W	H			
Dewar Fill Control and Display Box	22.0 (55.9)	13.0 (33.0)	12.0 (30.5)	67.0 (30.4)	N/A	
Umbilical Control & Display Box	22.0 (55.9)	13.0 (33.0)	13.0 (30.5)	33.0 (15.0)	N/A	
Tool Box/Work Stand	40.0 (101.5)	26.0 (66.0)	38.0 (96.5)	350.0 (158.8)	N/A	
Roughing Pump (RP1)	32.0 (81.3)	16.0 (40.6)	24.0 (61.0)	200.0 (90.7)	5-29	
Roughing Pump (RP2)	32.0 (81.3)	16.0 (40.6)	26.0 (66.0)	200.0 (90.7)	5-30	
Roughing Pump (RP3)	25.0 (63.5)	27.0 (68.6)	35.0 (88.9)	370.0 (167.8)	5-31	
Vacuum Pumping Station (VPS)	36.0 (91.4)	36.0 (91.4)	36.0 (91.4)	360.0 (163.3)	5-32	
Leak Checker	22.0 (55.9)	30.0 (76.2)	36.0 (91.4)	450.0 (204.1)	5-33	
Service Lines	-	-	-	273.0 (123.8)	5-34	

3.3.4 Mechanical GSE -

Each of the major subsystems is equipped with a supporting device for handling and transportation. In addition there is a transportation support structure upon which the assembled experiment can be mounted. This device can be attached to a rotation fixture with a horizontal axis so that the flight equipment can be tilted through slightly more than 90 degrees to simulate the launch attitude and to provide cryogen testing with the porous plug being wetted by liquid helium as will occur in space.

3.4 FLIGHT SOFTWARE

The IRT requires software that runs on the Spacelab Experiment Computer. This software is provided by the Spacelab integrator. The IRT utilizes both the ECOS and ECAS (Experiment Computer Operating System and Experiment Computer Application Software). ECOS is used to support the standard level and pulsed discrete outputs, the serial outputs (GMT and GN&C and two IRT-unique SO's), flexible inputs and one serial input message of seven words. ECOS also provides exception monitoring of several AI's, DI's and DI's embedded in the SI. ECAS is used to support the three displays needed for on-board monitor and control of the experiment and to provide permanent ECAS for several timed sequences which may be initiated either from the ground or the AFD. These sequences include valve reconfiguration, a calibration cycle and a timer for the porous plug heater. Another part of permanent ECAS is called BOAA for Bright Object Avoidance Algorithm. The first part of the algorithm is required by many of the experiments and it computes (based on the GN&C data) the position of the sun, moon, earth and Orbiter velocity vector in payload coordinates. The second portion of BOAA, which is unique to the IRT, computes the scan limits for the telescope based on the direction cosines of the four items and the avoidance criteria for each.

3.5 DATA REDUCTION SOFTWARE

The data reduction software is designed to run on a Digital Equipment Corporation VAX-11 computer. Its input will consist of the digitized samples of the detector data recorded at the rate of 1,024 samples/second at the three gains for each detector. The output will be maps of the celestial sphere showing infrared intensity in each of the wavelength bands covered. Discrete sources will have been filtered out so that the maps include only the diffuse radiation that is relatively slowly varying in spatial coordinates.

To produce this result several software modules are used. One computes the position on the sky for each instant. Another detects and removes discrete sources. Another puts the data into the correct "bins" on the sky. Others permit comparisons of data taken at various times, etc. In addition, there will be software prepared by individual investigators to assist them in their analyses of the data after the maps have been prepared. Appropriate software to assist the investigators in data handling will be provided.

4.0 SCHEDULES

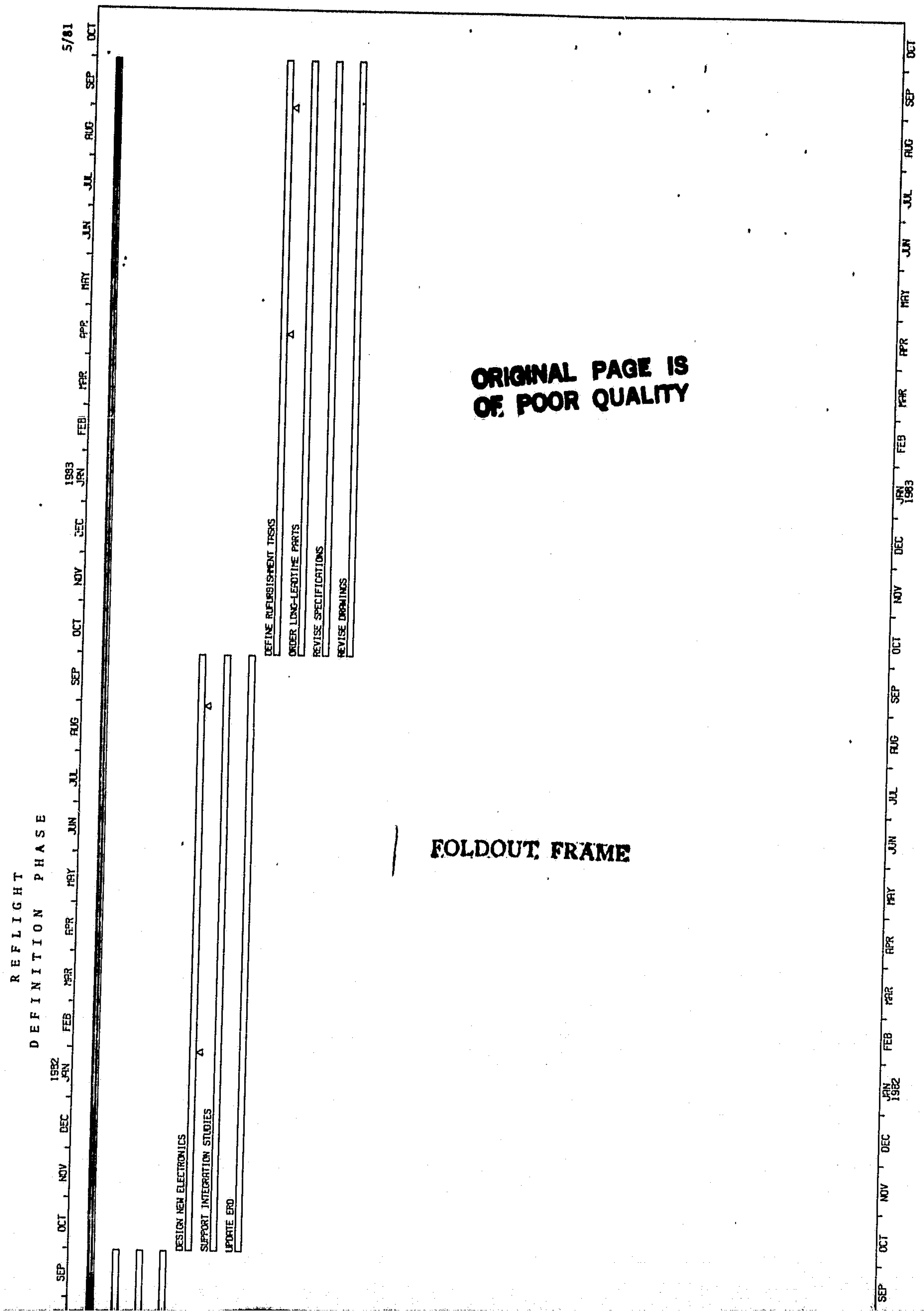
The following schedules embody several assumptions, which will have to be changed if Spacelab 2 does not fly in November 1983 or if the IRT reflight is not assigned to a June 1985 mission. However, they do show the major events and key milestones that will be found in the refurbishment of the IRT.

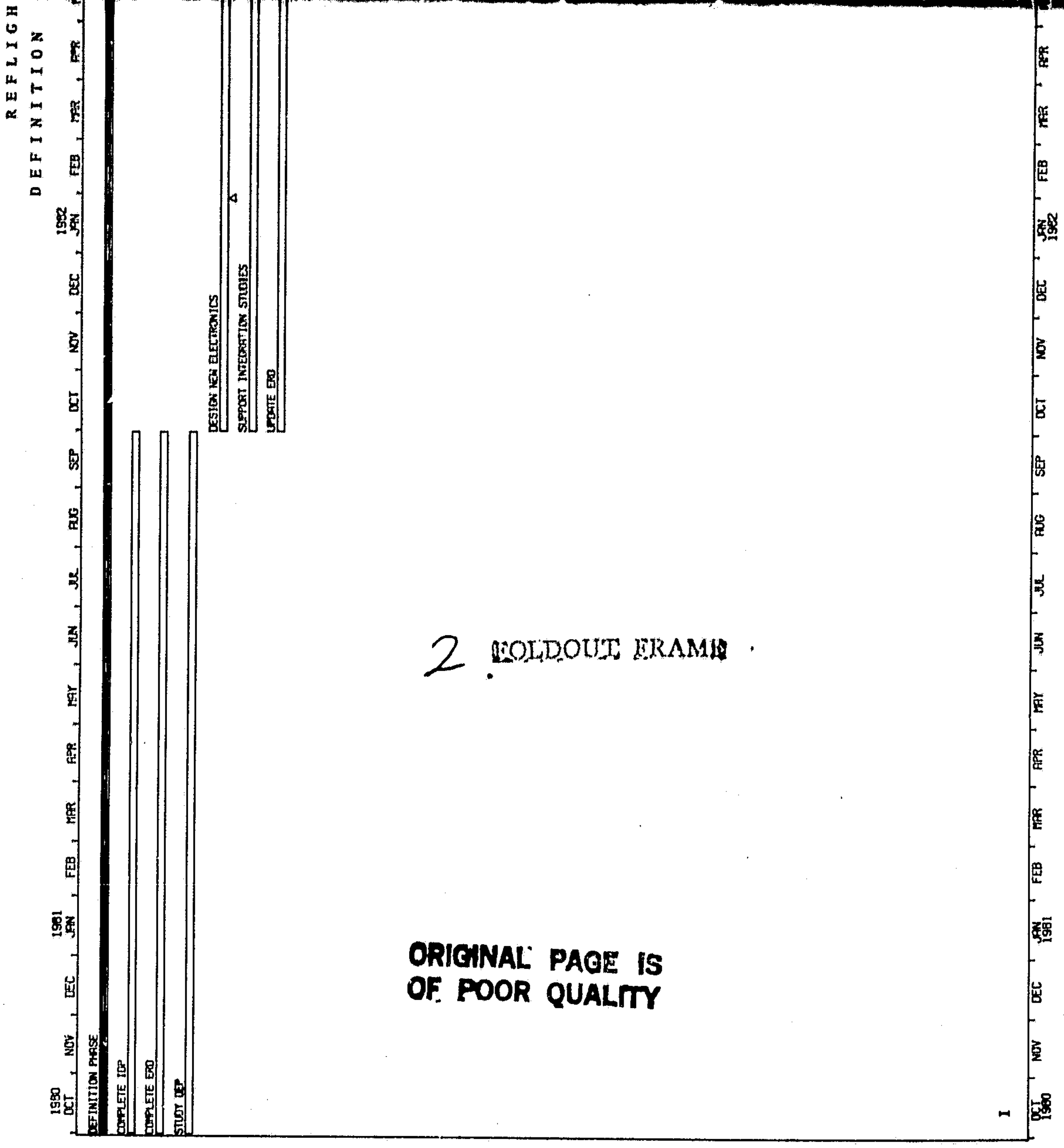
The Definition Phase covers a four-year span. (Only the three future years are shown on the chart.) Most of this period contains a very low level of activity, less than one manyear per year. The bulk of that time will be devoted to a redesign of the IRT electronics, if that option is selected.

Two design reviews are planned for FY 1982. Two additional planning reviews will be held in FY 1983, by which time the reflight activity will have grown to five or six times its earlier level.

The second chart shows the planned "Development Phase" which is really a refurbishment. The basic refurbishment is simply cleaning and reverification. However eleven months are scheduled for these tasks because major system repair or changeout may be required.

REFLIGHT
DEFINITION PHASE





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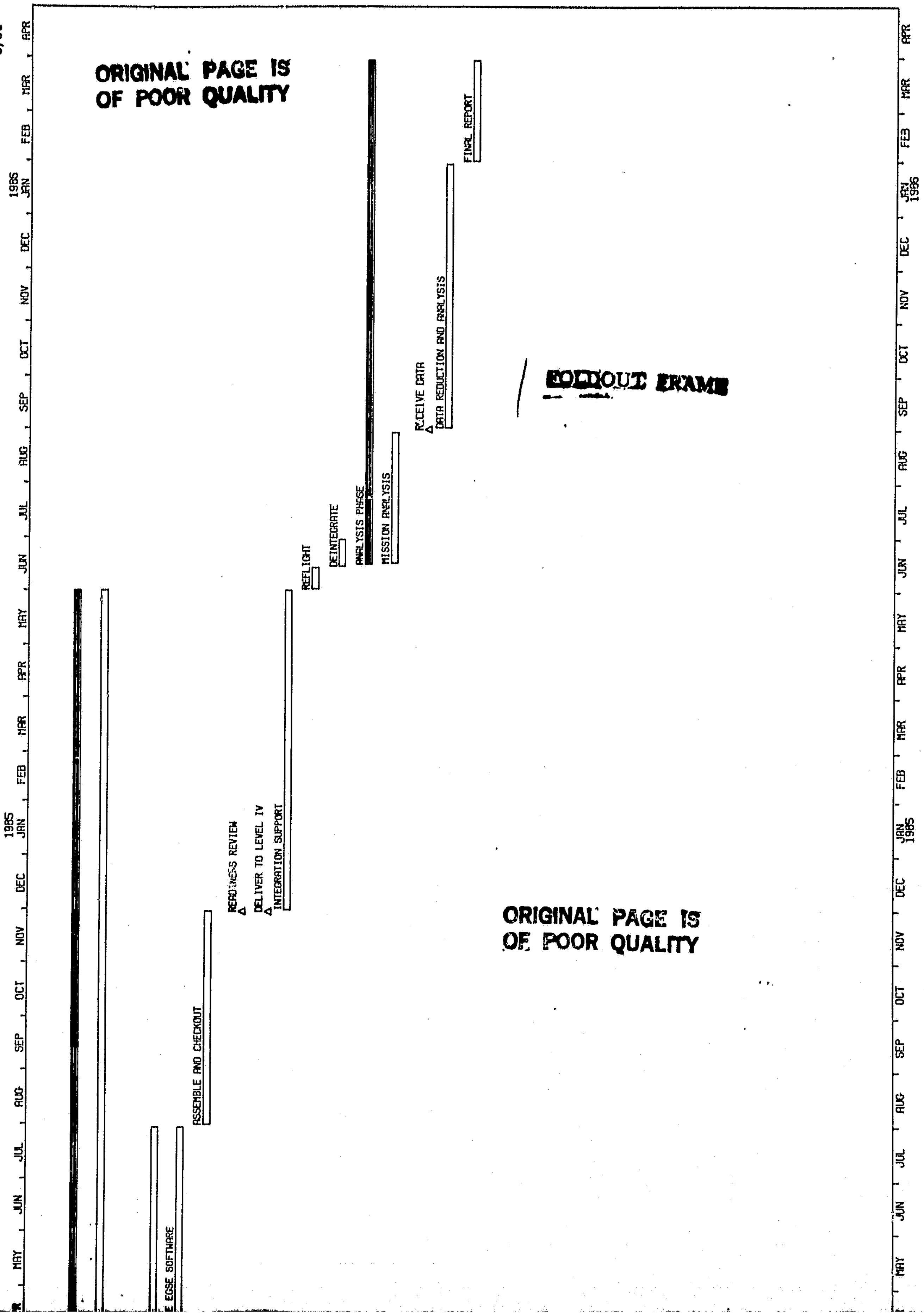
REFLIGHT
DEVELOPMENT AND DATA
ANALYSIS PHASES

5/81



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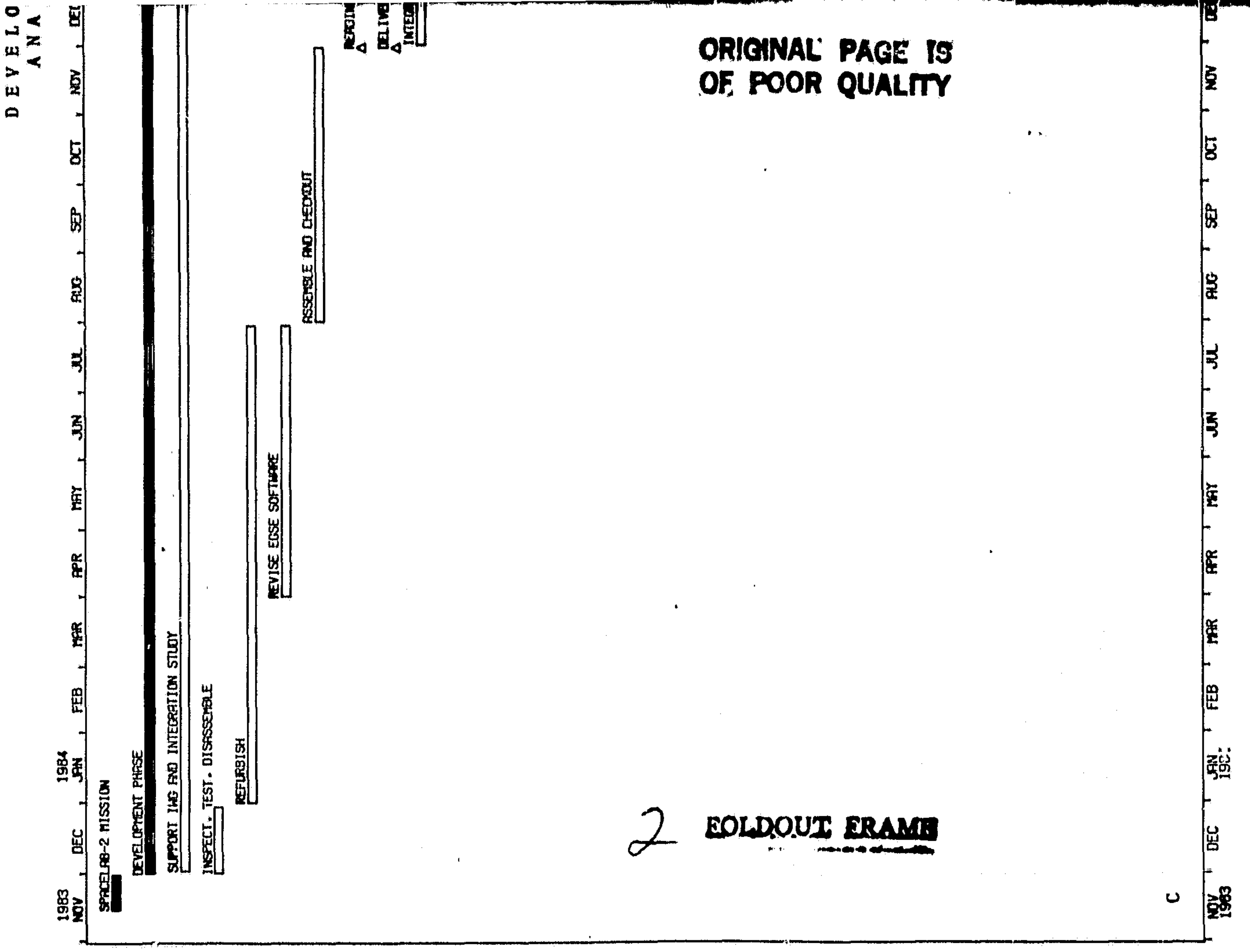

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A readiness review is planned before delivery to Level IV.

SAO will provide detailed work flow diagrams to GSFC showing the interrelationships between events and due dates. GSFC will use these inputs to develop a PERT network and the investigator will update status periodically.

5.0 WORK BREAKDOWN STRUCTURE

5.1 GENERAL COMMENTS

The GSFC Standardized Work Breakdown Structure is used for cost estimation and task control in the IRT Program Office. Because the instrument is already built a number of the standard elements or parts of them are not applicable. The following sections describe the IRT WBS and identify those places where it differs from the standardized WBS.

5.2 IRT WBS

5.2.1 Experiment Management -

Element 1.2 Resource Management was originally proposed as a minimal effort with summary financial reports only. This has been revised to provide more detailed cost estimates.

Element 1.5 Performance Assurance is minimal. Because the flight system is built and will have flown, special reliability and quality assurance plans will be prepared. Efforts necessary to support the R&QA plan of Section 14.1 are included.

5.2.2 Systems Engineering -

Because the flight system will have been flown, element 2.1 System Requirements and Interfaces will deal only with those interfaces that differ from the ones in Spacelab 2. No performance requirements will be allocated to subsystems and no total system performance analyses will be made. The IRT team will develop and maintain an ERD and will participate fully in external interface exercises. A safety program to update the hazard analysis done for Spacelab 2 will be instituted.

Element 2.2 System Analyses and Design will be limited to safety items. No EMC or radiation analyses are planned.

5.2.3 Flight Hardware -

This section of the WBS cannot be filled in until the extent of the refurbishment is determined. Not all subsystems are expected to require rework; some may require redesign, others may need only inspection and possibly cleaning.

5.2.4 Ground Support Equipment -

The IRT Program Office plans to use the standardized elements for GSE.

5.3 SOFTWARE DEVELOPMENT

5.3.1 NASA-Provided Software -

The IRT Program Office plans to use the standardized elements for software.

5.3.2 System Integration And Test -

The IRT Program Office plans to use the standardized elements for integration and test. However, there will be activity associated with testing and disassembling the flight system _before_ any refurbishing is done. An element will be added to cover that activity in this section.

5.3.3 Field Support Services -

The IRT Program Office plans to use the standardized elements for field support services.

5.3.4 Science Support -

The IRT Program Office plans to use the standardized elements for science support.

6.0 PLANNED ACTIVITIES

6.1 REMAINDER OF DEFINITION PHASE

The tasks to be accomplished are shown in Table 6-1, which also provides a cross reference to the Work Breakdown Structure. Tasks 1-5 are to be conducted on a continuing basis throughout the remainder of the Definition Phase -- Fiscal Years 1981-83. Tasks 6 and 7 will be undertaken in 1981. 1982 will be devoted to tasks 8-10 and will see the redesign of the electronics if this option is selected (Task 18). Tasks 11-17 will be accomplished in 1983, except that final focal-plane decisions will be reserved for early 1984, soon after the SL-2 mission.

6.2 REFURBISHMENT AND REFLIGHT PHASE

Table 6-2 lists R&R tasks and relates them to the WBS. This list is very tentative this early and updates are planned under Task 2 during the Definition Phase.

WORK BREAKDOWN STRUCTURE / TASKS (Remainder of Definition Phase)	1. PROJECT MANAGEMENT	2. SYSTEMS ENGINEERING	3 FLIGHT HARDWARE	4. GSE	5. SOFTWARE DEVELOPMENT	6. INTEGRATION AND TEST	7. FIELD SUPPORT	8. SCIENCE SUPPORT
1. Refine and update ERD	X	X						X
2. Refine and update IDP	X	X						X
3. Define reflight science goals								X
4. Support IWG	X	X						X
5. Progress reports	X							
6. Study rework of electronics		X						
7. Estimate cost of new electronics	X							
8. Reliability planning	X							
9. Quality assurance planning	X							
10. Safety planning	X	X						
11. Review GSE performance	X	X		X				
12. Specify necessary mods to GSE	X	X		X				
13. Specify focal plane			X					X
14. Design focal plane			X					X
15. Specify and order parts			X					
16. Revise drawings and specs	X	X	X					
17. Draft operating procedures	X	X						
18. Redesign electronics (if approved)		X	X	X	X			
19. Verification planning		X				X		

Table 6-1. IRT Reflight Tasks: Remainder of Definition Phase

WORK BREAKDOWN STRUCTURE / TASKS (Refurbishment and Reflight Phase)	1. PROJECT MANAGEMENT	2. SYSTEMS ENGINEERING	3. FLIGHT HARDWARE	4. GSE	5. SOFTWARE DEVELOPMENT	6. INTEGRATION AND TEST	7. FIELD SUPPORT	8. SCIENCE SUPPORT
1. Inspect and test used equipment	X	X	X	X		X		
2. Define refurbishment tasks	X	X						X
3. Refurbish			X	X				
4. Build and test new electronics (if approved)	X	X	X					
5. Write DEP software		X			X			
6. FMEA		X						
7. Parts and materials lists	X	X						
8. Reassemble system		X	X	X		X		
9. Test system						X	X	X
10. Spacelab integration	X	X	X	X		X	X	X
11. Review performance of data reduction software					X			X
12. Specify software changes								X
13. Implement software changes					X			X
14. Mission support				X			X	X
15. IWG support	X	X						X
16. Spacelab deintegration			X	X			X	
17. Data reduction and analysis					X			X
18. Final report	X	X						X
19. Mission planning	X	X						X
20. Progress reports	X							
21. Planning and schedules	X							
22. Safety	X	X						
23. Operating procedures	X	X						
24. Crew training	X	X						X

Table 6-2. IRT Reflight Tasks: Refurbishment and Reflight Phase

7.0 ORGANIZATION PLAN

The IRT is a cooperative program that emphasizes equal participation by the Steward Observatory of the University of Arizona (UA), the Space Sciences Laboratory of the Marshall Space Flight Center (MSFC), and the Smithsonian Astrophysical Observatory (SAO). Also participating, in the role of Associate Investigators, are scientists of the NASA Ames Research Center (ARC).

The cornerstone of the organization is the Science Steering Committee (SSC). It is composed of Dr. Giovanni Fazio, the PI, who serves as chairman, Dr. George Rieke representing UA, and Dr. Eugene Urban representing MSFC. The SSC is charged with responsibility for reviewing all major program decisions. Thus the committee establishes overall policy for the experiment and monitors its implementation.

Each of the participating organizations has responsibility for well-defined portions of the experiment:

UA -- detectors, optics, telescope, sunshade;

MSFC -- cryogenics, support structure, scan drive, cryogenic GSE;

ARC -- contamination forecasting and analysis, simulated data generation;

SAO -- electronics, electronic GSE, data reduction, program management.

Analysis and interpretation of data are a joint responsibility with each participating scientist bringing to bear his own particular expertise.

To ensure continued success the same organizational approach used for the initial definition and development will be applied to the reflight. This organization is shown in Figures 7-1 and 7-2.

The Principal Investigator has overall responsibility for the program. Working directly with the Program Manager and staff, he provides scientific and technical direction to the program. He leads the scientific team and ensures that both experiment development and supporting research are optimized with respect to the program goals and scientific objectives. The Principal Investigator serves on the Spacelab Investigators Working Group (IWG) and is the primary contact with NASA. It is hoped that the IWG will agree to include, as non-voting participants, the other two members of the SSC, in view of the cooperative nature of the IRT team. This arrangement was approved for Spacelab 2.

The Science Steering Committee contributes advice and consent to the PI. Providing an equal voice for the three major collaborators, the SSC reviews all major program activities to ensure effective liaison, a well-balanced scientific approach, and equitable application of resources. Although emphasis is placed upon the scientific and

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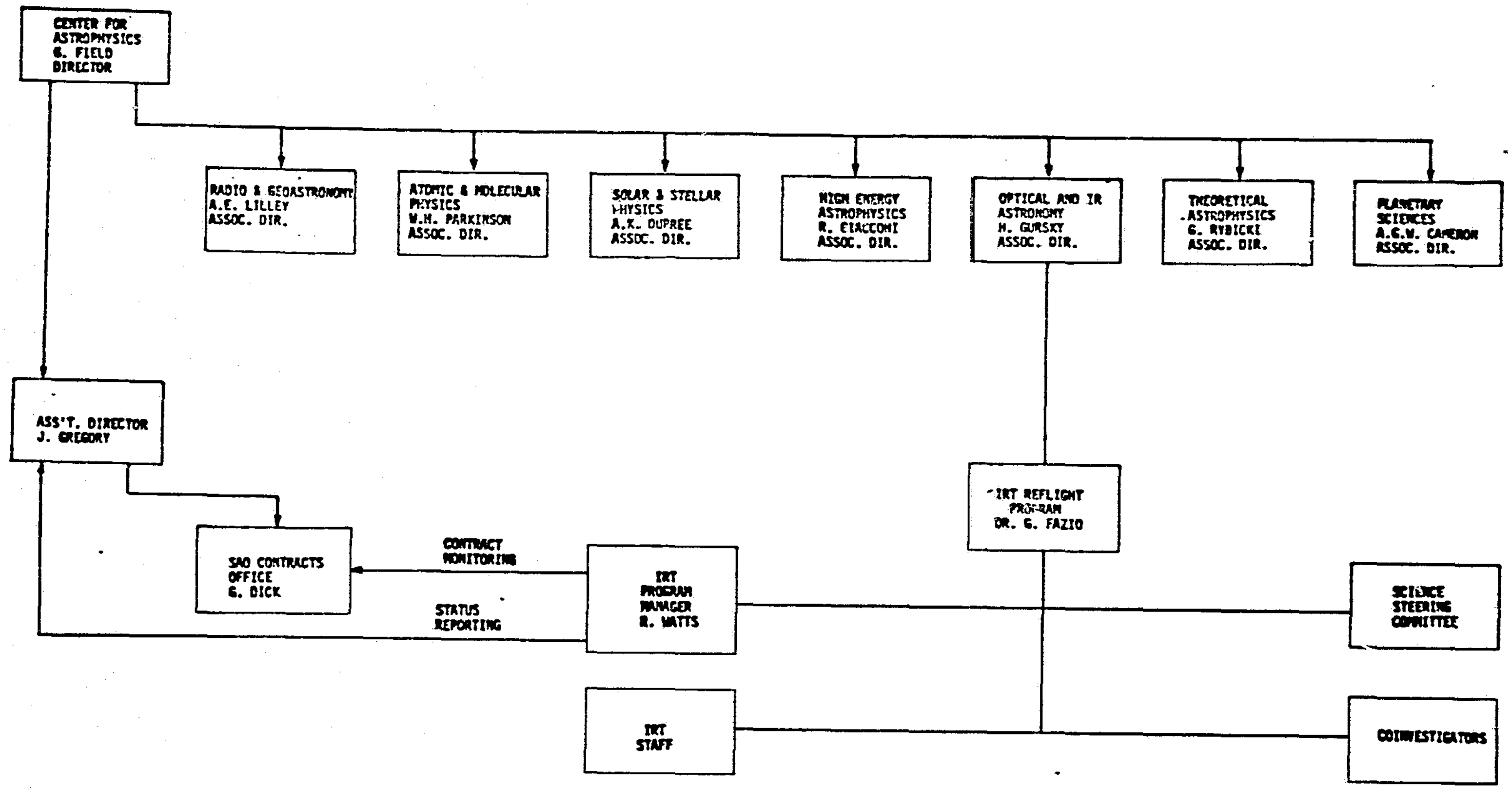

Figure 7-1. The Infrared Telescope Program within SAO

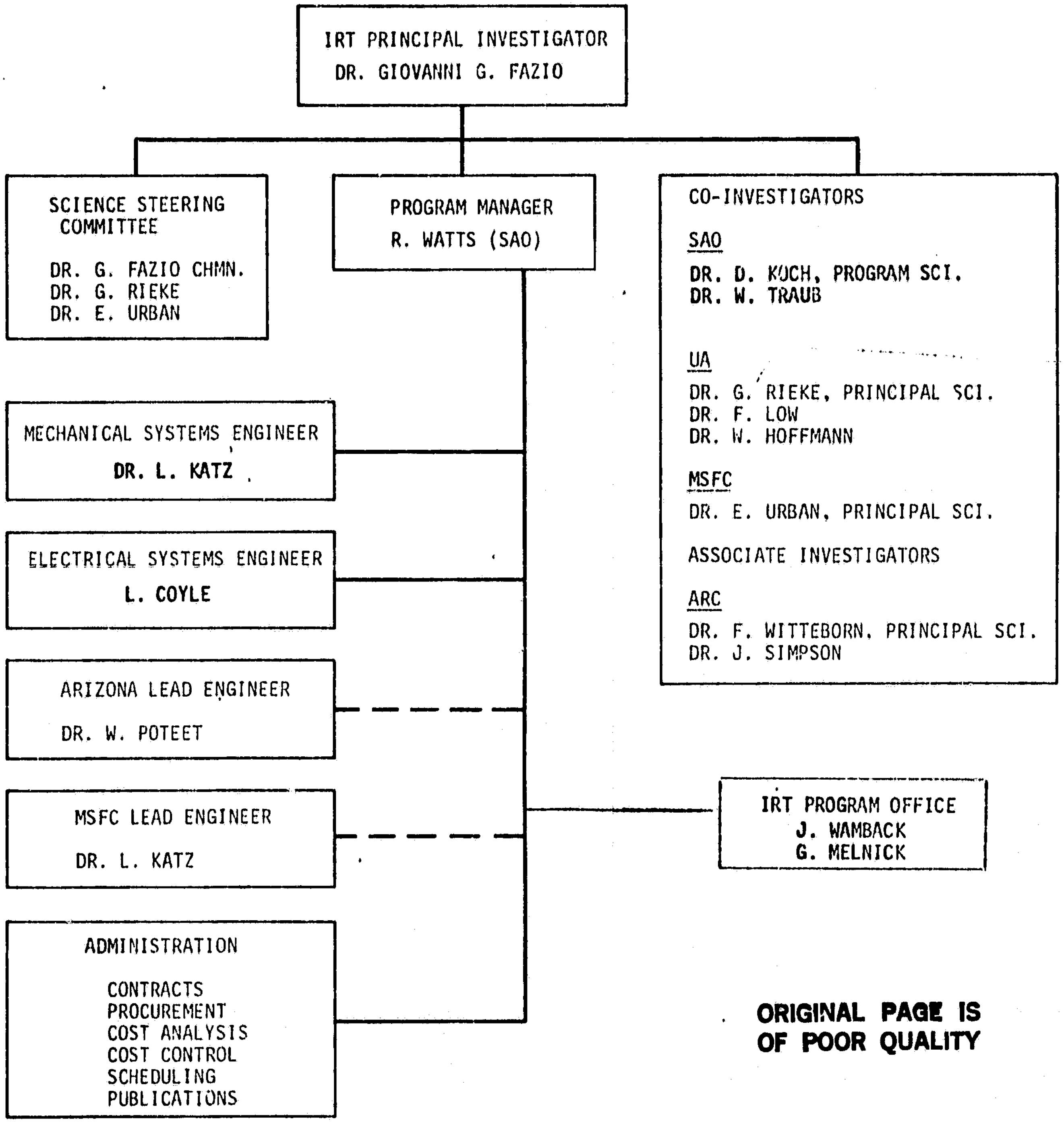

Figure 7-2. Organization of the Infrared Telescope Program

engineering aspects of the program, the SSC's role is not limited to these areas alone.

The Program Manager heads a Program Office that is the focus of engineering and financial activity, and serves as the primary point of contact on engineering and management matters for the NASA Project Office and collaborating organizations. The Program Manager is responsible for all technical, management, schedule, and financial activity as well as R&QA and safety. He will prepare and maintain all program plans, coordinate all engineering activity, and track progress against the baseline cost plan and program schedule. The IRT program team is drawn from the ranks of the engineering, scientific, and support staffs at SAO and assists the PI and Program Manager to establish program requirements and monitor all activities.

The status of the IRT Reflight Program will be reviewed monthly within the Director's office of SAO to ensure that the program is managed in accordance with SAO requirements and that cost, schedule, and technical performance is within established program constraints.

The Systems Engineers are responsible for the overall functioning of the experiment hardware. They will oversee the necessary refurbishment and subsequent reassembly and testing to ensure that the instrument is properly reconditioned. Responsibility for refurbishment will be partitioned according to the original lines of development authority.

The science team of Co-Investigators and Associate Investigators is responsible for the analysis and interpretation of data and publication of all scientific results.

8.0 CONTRACT PLANS

SAO plans to negotiate a cost reimbursement subcontract with the University of Arizona. It will provide support for all activity in the UA area of responsibility (as defined in Section 7.0). SAO will receive monthly progress letters and financial reports; this information will be summarized in SAO's monthly reports to GSFC.

Arrangements must be made for the flow of necessary funding to MSFC and ARC. Operationally these groups will perform as though they were SAO subcontractors. Information to GSFC and direction from GSFC will pass through the IRT Program Office at SAO. IRT Program Office staff will monitor, coordinate, and report on activity at UA, MSFC, and ARC.

9.0 MISSION OPERATIONS

9.1 THE FLIGHT SYSTEM

The IRT flight system is composed of one pallet-mounted unit and two cold-plate-mounted electronics boxes. (See Figure 9-1.) A revision to the electronics, under study, may reduce the cold-plate-mounted subsystem to one unit. The pallet-mounted unit is a vacuum-tight helium-cooled cryogenic telescope with supporting equipment. The telescope is a single-axis scanning, not pointed, infrared system.

To accomplish the scientific objectives of the experiment, that is, to produce large-scale infrared maps, it is necessary for this instrument to scan the sky about two axes. Figure 9-2 illustrates the solid angle scanned relative to the Orbiter. Precisely, the telescope is driven about a single axis which is parallel to the payload X-axis, that is, in the Y-Z plane. Nominally it scans within ±45 degrees of the vertical, that is, 45 degrees from the payload X-Z plane. The scan rate is fixed at 6 deg/sec. The turnaround at the end of each scan is accomplished in 1 sec. The scan limits are variable so as to avoid bright infrared objects, such as the sun, moon, and earth.

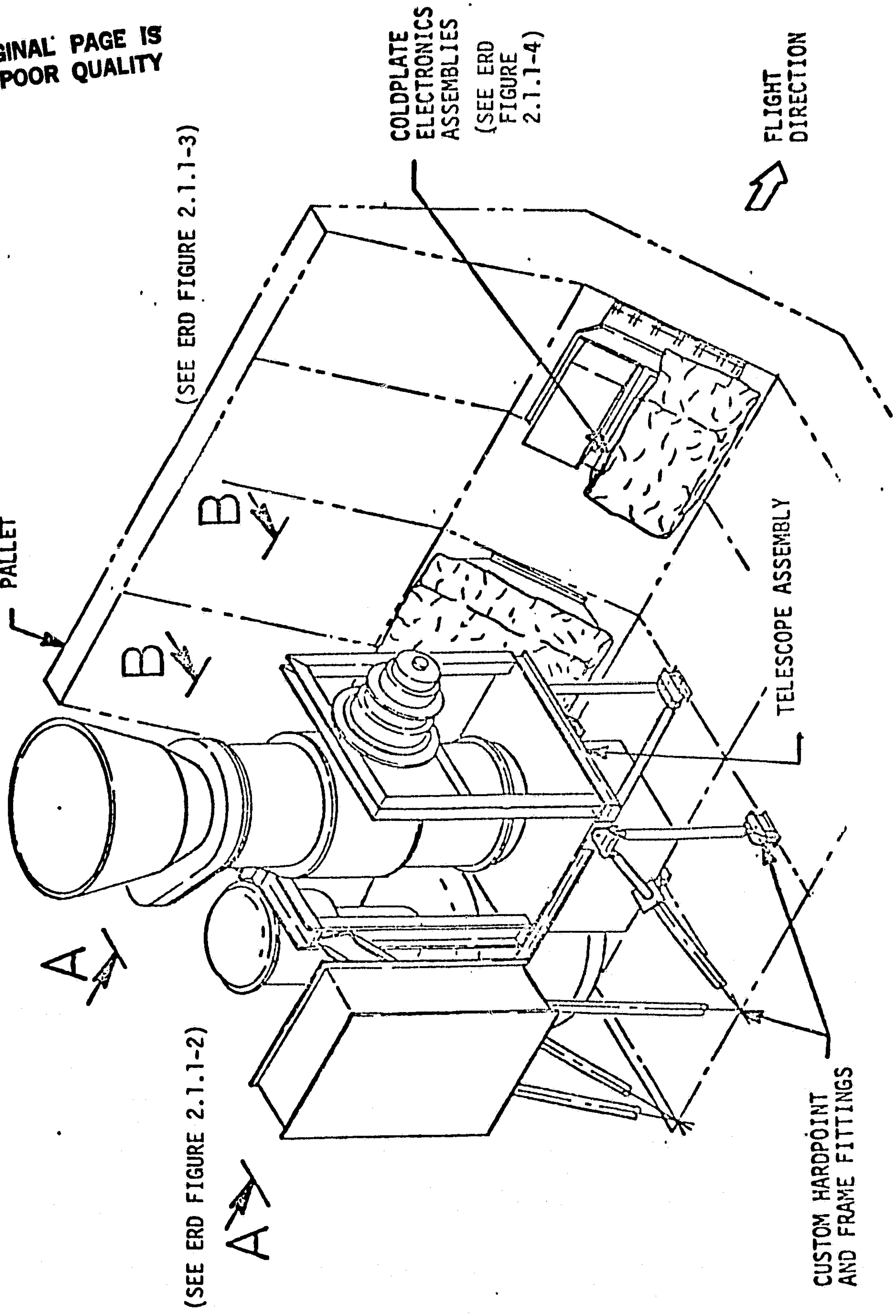

Figure 9-1. Pallet-Mounted Components

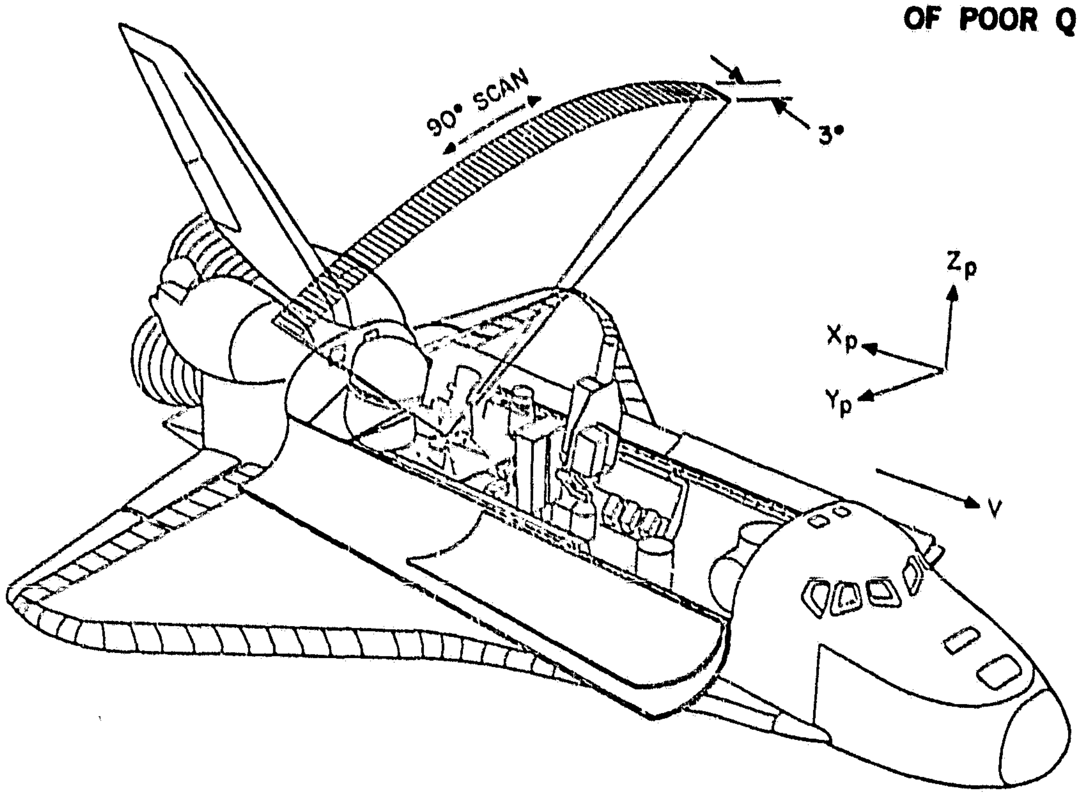

Figure 9-2. Telescope Scan Pattern in Relation to the Spacelab. Note that Spacelab coordinate system has +X toward the tail whereas Orbiter coordinates have +X toward the nose.

In concert with the telescope scan about the Orbiter X-axis, the Orbiter must <u>continuously</u> and <u>uniformly</u> pitch about its Y-axis so as to maintain the payload Y-Z plane (the scan plane) nominally parallel with the nadir (local vertical). This has been referred to as the airplane mode or XVV,ZLV, that is, the X-axis (in Orbiter coordinates) along the velocity vector and Z-axis along the local vertical (nose first, payload pointing away from the earth).

In the earth's atmosphere the system must be vacuum tight because even the most minute quantity of gas or dust will freeze out on the cold optical surfaces and degrade their performance. Furthermore, the liqud helium refrigerant must be kept at 1.6 K (6 torr) by continuously pumping away helium gas that boils slowly off its surface.

9.2 THE MISSION

At liftoff the power via the T-0 umbilical to the vacuum pump is removed. Once the vacuum of space is reached a barometrically controlled spacevent is opened to resume "pumping" on the helium. (A small rise in pressure and temperature is tolerable in the dewar during ascent.) The baroswitch and valve are energized by ascent power.

As soon as the Spacelab is powered up a crew member using the appropriate AFD display must verify that the spacevent is open, and, if not, power up the IRT and command open either the primary or backup valve.

To prepare for observing the normal verification of subsystems precedes the opening of the telescope's vacuum cover. Once the cover is open, sources of contaminating dust and gas, such as water dumps, flash evaporators, thruster firings, and effluents from other experiments must be carefully controlled and minimized to keep the Spacelab environment as clean as possible for infrared astronomical observing.

Helium flow control valves may be adjusted from time to time to maintain the desired temperatures. The Experiment Computer (EC) using the bright-object-avoidance algorithm (BOAA) calculates the sun, moon, and earth positions and the velocity vector and, when necessary, reduces the 90-degree arc over which the telescope scans to prevent bright objects from shining into the optical system. Orbiting with the velocity vector into the telescope aperture may cause rapid buildup of contaminants. At least three contiguous revs of observing are required with the Z direction close to the local vertical, with the Orbiter rolled 30 degrees right, and 30 degrees left. This sequence of 9 revs is performed at least three times with several days between each sequence.

Later in the mission observations will be continued during flash evaporator exercises, water dumps, and other contaminating events to measure their impact. Also, special observing sequences, coordinated with other Spacelab experiments, may be undertaken.

Finally a series of valve operations will be executed to explore the limits of superfluid helium management in space.

Before reentry the vacuum cover will be closed and the stow pin engaged. However, these are for experimenter convenience and failure of either operation will not jeopardize either the Orbiter or the IRT system. No power is required during normal reentry. A reentry following a launch abort requires power to reseal the vent to prevent ingestion of air into the cryogenic system.

9.2.1 Operating Modes -

The IRT will be operated in several "modes."

Activate: Power is applied and the various subsystems are checked out by monitoring both housekeeping and IR data as a series of commands is transmitted. EC software is verified and the cover is unlatched. A detector health check is performed.

Standby: This is the state of the instrument at the conclusion of the activation sequence. The electronics are energized, but the scan-drive motor is off to conserve energy. The system is returned to this state between active observing runs.

Prime Data: This is the celestial infrared observing mode. Orbiter attitudes are required in the -XVV orientations. Several contiguous orbital revolutions must be devoted to IRT operations in each of several roll attitudes. Exclusive observing time is not necessary provided gas and particulate contamination is not generated by other simultaneous activities or thruster firing activity increased. IRT operation is nearly "automatic" although it must be closely monitored. Constraint details are provided in the ERD.

Controlled Contamination: IRT data will be taken during such activities as thruster firings to measure their effects on the Orbiter environment.

Coordinated Observing: IR data will be taken in coordination with other Spacelab experiments if the payload complement justifies it. Some special command sequences not used for other IR data taking may be required, to coalign the IRT and some other instrument, for example.

Helium Management: A series of control-valve commands will be issued to adjust the helium-bath temperature and to observe the effects of a variety of management techniques. An important experiment will be to allow the temperature of the LHe to rise above the Lambda point by valving off the vents, then to observe temperature profiles, liquid loss and other parameters when the valves are open and the space vacuum pumps the bath back down to superfluid.

Deactivate: This series of activities will normally take place only once, at the conclusion of the mission.

The cover will be closed and latched, the cryostat secured for landing, helium-vent valves adjusted, and power turned off.

9.3 SUPPORT

9.3.1 Personnel -

The IRT team plans to operate the experiment from the POCC during all critical phases. However, housekeeping data and command capability will be available to the flight crew on the AFD should their intervention become necessary. Crew support is described in Section 11, but it is important to note a critical crew function here, namely verification that the spacevent valve opened during ascent (to be done as soon as Spacelab is powered up). The DGSE will be used to acquire as much of the high-rate science data as possible to provide a basis for quick-look analyses.

The IRT team plans 'round-the-clock' POCC activities with 5 to 7 people on each shift. Further details are in Section 10. NASA-provided manpower will be required to ensure that the HRM de-mux system is maintained.

Intense activity is anticipated when the experiment is first activated, when IR data are being taken, and when helium-management exercises are being conducted. More IRT personnel will be scheduled for duty during these periods. Experience gained during the Spacelab-2 mission will, of course, be applied to IRT operations in general.

The IRT requires one command and display console with software necessary to support displays similar to those on the AFD. Ports for 3 HRM data channels are needed to deliver these streams to the experimenter-provided DGSE.

9.3.2 Documentation -

IRT personnel will prepare operations manuals, diagnostic procedures, etc., prior to the mission. The content and extent of these materials is TBD.

9.4 DATA

The DGSE provided by SAO will be used to record the high-rate data at the POCC. Some of it will be displayed in near-real time to support operational decisions. Some of it will be prereduced during the mission to facilitate planning for subsequent parts of the mission. Some of it will be processed during the mission to enable the team to evaluate the quality of the observations, to announce new discoveries immediately, and to compare IR science with other on-board experiments.

10.0 FIELD SUPPORT

Field support falls naturally into several categories. Each is described separately below.

10.1 PREDELIVERY SUPPORT

Upon completion of all necessary refurbishment, all subsystems will be shipped to MSFC for reassembly and reverification. This work will be supported by personnel from UA and SAO. There will be one from each organization at all times and several at certain periods of peak activity.

10.2 INTEGRATION

There will be at least one member of the IRT team at KSC at any time that the flight system or any related GSE is handled or activated.

We plan an off-line pre-installation test of two weeks duration immediately preceding the start of Level-IV integration. This activity will be primarily a one-shift operation, but some round-the-clock monitoring of vacuum pumps will be required. Personnel will include 4 from SAO, 6 from UA, and 4 or more from MSFC. This same cadre will be required to support the active testing during Level IV.

No operations are planned for Level III/II, so the team will be represented by a single observer, and only at such times as the equipment is being handled.

At Level I liquid helium will be transferred to the flight dewar, converted to superfluid by vacuum pumping, and the system prepared for the mission. This operation involves the cryogenic system, electronics, and extensive GSE. Once the helium is converted to superfluid, continuous vacuum pumping is required. (No interruption longer than five hours is tolerable.) This implies 24-hours-per-day monitoring and a crew of 12 to 14 people will be on hand. Once the Orbiter is on the pad, some of this staff will travel to JSC, but the helium system will be monitored at KSC via the T-0 umbilical and developer-provided GSE right up to liftoff.

10.3 MISSION SUPPORT

The IRT is designed for primary control from the POCC with flight crew assistance at a very low level except for contingency operations. Three teams of scientists and engineers will operate the telescope and monitor data on a flexible three-shift schedule.

During data-taking sessions the team in the POCC will be at full strength, 3 scientists, 2 engineers, 2 operators, and 2 relief personnel. At other times the team will be reduced to about 3 people.

This staffing will permit smooth operations and provide for simultaneous support of mission control, planning meetings, press conferences, and other necessary off-line activities. We expect to have about 6 people actively at work on the POCC consoles and GSE during data taking. One or two will monitor the equipment and ongoing activities at other times.

10.4 OTHER FIELD ACTIVITIES

We plan to support several other activites in preparation for the reflight. These include IWG meetings, engineering and operations reviews, and other meetings appropriate for a safe and successful mission.

Postmission field activities will include preparing the flight system and GSE for return shipment to SAO, preparing the POCC GSE for return shipment to SAO, and data reduction and analysis at SAO. The latter is cited as field activity because team members from Arizona, Ames, and Marshall will be "in the field" at SAO.

11.0 CREW SUPPORT AND TRAINING

The design of the IRT minimizes the need for active operational control. Every effort has been made to make the cryogenic and electronic systems stable and self-protecting. A study being conducted during the Definition Phase will weigh the pros and cons of going another step in this direction through incorporation of a DEP. A plan for this activity may be found in IRT-119, "A DEP for the IRT System" (see Appendix A to this document). Costs will be discussed as a separate item in the continuation proposal for FY 1982.

During Spacelab 2 the flight crew will be slightly more active if the Orbiter is out of contact with the ground. These periods of loss-of-signal (LOS) are assumed to be negligible by the time of the IRT reflight, so crew interaction will be further reduced. However, should contingency operations be necessary, it is vital that the Mission and Payload Specialists understand the goals and procedures of the IRT experiment.

Approximately one day of training time will be needed to develop an understanding of the scientific goals and how they relate to experiment operations. This training should take place soon after the crew is assigned.

Several days of operating experience will be required for the crew to become familiar with the various command routines, when they should be used, what instrument responses to expect, and what to do in various types of anomalous situations. The best time for this segment of crew training will be during final instrument trials at MSFC, just prior to shipment to KSC. An alternative would be during Level IV, if time is available.

The final segment of crew training, requiring about a day, is familiarization with AFD displays and related keyboard commands. Level IV is the appropriate place for this activity; it is assumed that previous sessions on the simulator will have readied the crew for specific IRT experience at Level IV.

No training manuals are planned. IRT personnel will review manuals prepared by NASA.

No EVA is planned for experiment activities during Spacelab 2. If contingency EVA is planned for the reflight mission, the IRT team should consider a small equipment modification that would permit a crew member to open the IRT vacuum cover, should it become stuck. In this case another day or two of crew training will be needed for learning when an EVA is necessary and how it is to be performed.

12.0 SHIPPING

All shipments will be via GBL issued by the GSFC Transportation Office. The following shipments are anticipated:

12.1 CRYOSTAT TO UA FROM MSFC

1 Box 3 x 4 x 8 feet; TBD pounds

1 Box 2 x 4 x 8 feet; TBD pounds

Air-ride van is required.

12.2 CRYOSTAT TO MSFC FROM UA

Same as 12.1.

12.3 DGSE TO UA FROM SAO

1 Box 4 x 6 x 8 feet; TBD pounds 10 Boxes approx. 2 x 2 x 2 each; TBD pounds 1 File cabinet; TBD feet; TBD pounds 1 Small console stand; TBD feet; TBD pounds Air-ride van is required.

12.4 DGSE TO MSFC FROM UA

Same as 12.3.

12.5 DGSE TO KSC FROM MSFC

Same as 12.3.

12.6 FLIGHT SYSTEM TO KSC FROM MSFC

All information TBD.

12.7 GSE TO KSC FROM MSFC

All information TBD.

12.8 DGSE TO JSC FROM KSC

Same as 12.3.

12.9 FLIGHT SYSTEM TO MSFC FROM KSC

Same as 12.6.

12.10 GSE TO MSFC FROM KSC

Same as 12.7.

12.11 DGSE TO SAO FROM JSC

Same as 12.3.

12.12 MISSION MATERIALS TO JSC FROM SAO

TBD Boxes Data Tapes TBD Boxes Recorder Paper 1 Box

Recorder Supplies TBD Boxes Documentation

12.13 MISSION MATERIALS TO SAO FROM JSC

Same as 12.12.

13.0 SCIENTIFIC DATA ANALYSIS AND POSTFLIGHT REPORTING

See Appendix B to this document:

IRT-210A, "Scientific Goals of IRT Data Analysis"

The IRT team plans to support Spacelab postflight reporting such as an Engineering Report, 30 days after landing, and a preliminary scientific report, 90 days after landing.

The team also plans a final report, to be issued twelve months postmission. Data will be transmitted to the NSSDC at that time.

14.0 OTHER PLANS

14.1 RELIABILITY AND QUALITY ASSURANCE

Reliability and quality assurance planning requires careful study in conjunction with appropriate GSFC staff. This effort will be mounted in FY 1982.

At the start of the IRT Program everyone assumed that Spacelabs would fly frequently, that integration costs would be modest and that it was more economical to build experiments with a minimum of reliability effort and virtually no quality assurance. Failure rates would be higher but repair and reflight would be quick and cheap.

Part way through the development of the IRT it was realized that these assumptions were not entirely valid and quality assurance became more important. However primary emphasis was placed on validation rather than process control. Some belated efforts were also put forth in the materials area, but in general the various subsystems were built on a "best effort" basis without elaborate in-process inspections or extensive documentation.

Subsystem interfaces were "formally" controlled by an internal ICD, but close communications among the participating organizations was the operant system. In some cases dummies were used for fit checks but these operations were neither controlled nor documented.

In general, electronics parts were purchased to a JAN-TX (or equivalent) level, but there were some exceptions necessitated by delivery schedules. In-process inspections were performed and documented.

14.2 SOFTWARE DEVELOPMENT

14.2.1 NASA-Provided Software -

Software run in the EC and during Spacelab integration will be written by NASA (or its contractor) to meet jointly negotiated requirements. The impact upon this requirement caused by the addition of a DEP will be studied in FY 1981 and included in IRT-119, "A DEP for the IRT System."

14.2.2 Experimenter-Provided Software -

The IRT has four separate software systems. All will have been developed by the launch of Spacelab 2 and all will undoubtedly require modifications for the reflight. A fifth system will be written for the DEP if one is added to the flight system.

The first software system runs on the CGSE, and is used to issue commands and to receive and display housekeeping prior to Level IV.

The second system runs on the DGSE for receiving, decoding, recording, and displaying of HRM data.

The third system, composed of a multitude of subsystems, is used for the reduction of IR data. Basically it removes unwanted signals from the data stream and transforms the data into intensity maps of the sky in several infrared "colors."

Finally there are a number of programs developed and used by the scientific staff for interpretation of the data. These programs deal not only with astronomical studies but also with the cryogenic, environmental and zodiacal work being conducted by the IRT Team.

Modifications to the CGSE system will be specified soon after the start of Spacelab-2 Level IV. The reworked system must be debugged and operating by the time the refurbished flight system is ready for reassembly. Modifications to the DGSE will be specified at the conclusion of the SL-2 mission; the system must be operational in time for detector checkout at UA prior to flight system reassembly. Changes to the data reduction and analysis systems will be implemented whenever they do not impact the treatment of data for SL-2. Of course they must be ready for processing reflight data as soon as it is available.

14.3 VERIFICATION

IRT-121, "IRT Verification Matrix," (Appendix C to this document) provides a cross reference to the verification of the flight system for SL-2. Subsystems that are newly built for the reflight or that undergo major rework will be verified by the appropriate means. Similarity and analysis will be used whenever possible.

14.4 SYSTEM SAFETY

The entire IRT system will have passed through all phases of safety review prior to the SL-2 mission. We expect that all hazards will have been appropriately dispositioned.

Any changes, modifications or rework on any areas related to the SL-2 hazard analysis will be carefully monitored and will be reported to GSFC. Hazard elimination or reduction techniques will be presented for review and will be implemented thereafter. All SL-2 IRT safety materials will be available for review at the various reflight checkpoints.

Figure 14-1 shows the Safety Matrix.

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PAYLOAD: SL-2 IRT (Exp. No. 5)
PAYLOAD ORGANIZATION:
DATE:
PAGE:

HAZARD GROUP SUBSYSTEM	COLLISION	CONTAMINATION (TOXICITY, ETC)	CORROSION	ELECTRICAL SHOCK	EXPLOSION	FIRE	INJURY AND ILLNESS	LOSS OF ENTRY CAPABILITY	RADIATION	TEMPERATURE EXTREMES								
Biomedical																		
Hazard Detection and Safing*																		
Cryogenics										2								
Electrical						3			5									
Environmental Control																		
Human Factors																		
Hydraulics																		
Materials						6												
Mechanical	4						9											
Optical																		
Pressure Systems					1													
Propulsion																		
Pyrotechnics							8											
Radiation																		
Structures	7		7															

Figure 14-1. Spacelab-2 Payload Safety Matrix

14.5 CONFIGURATION MANAGEMENT

Since the IRT will be built and previously flown, configuration management can be minimized. The configuration management system used for the SL-2 mission will be continued. It will meet the requirements of S-420-10 and the Class 1 Change Request form requirements of DR-1-79.

14.6 CONTAMINATION CONTROL

Probably more than any other type of system a cryogenic device is sensitive to contamination. Virtually nothing evaporates from a surface at liquid helium temperature; few if any molecules rebound when they strike such a surface. A helium-cooled telescope is a cryopump, capturing anything that impinges upon it.

Knowing this, the IRT team is particularly keenly aware of contamination problems at a level well beyond the requirements of the STS or Spacelab. The more critical parts of the IRT will be cleaned and assembled on a laminar-flow bench in a clean room of class 100 or better. Solvent residuals will be completely removed; non-outgassing materials have been selected or baked and pumped out. Thereafter the cold surfaces of the IRT are contained in the sealed cryostat under hard vacuum until the cover is opened on orbit. All external surfaces of the IRT flight system will be wiped clean to standards equal to or better than Spacelab standards. The IRT team plans to take a leadership role among the experimenters to urge and assist with self-imposed cleanliness standards.

In addition to using low outgassing materials and being extremely concerned with maintaining cleanliness standards, it is imperative to have all continuously vented gases (not necessarily those from infrequent scheduled purges) from all the experiments vented overboard, since the gases will produce an unpredictably varying IR background. This is particularly true of IR active molecules such as H_2O, CO_2 and CH_4.

To the greatest extent possible, on-orbit water dumps and flash evaporator operations should be scheduled for the sunlit side of the orbit. This will prevent water from freezing on Orbiter surfaces and later subliming into a surrounding cloud.

The IRT emits a steady but low-level flow of room-temperature gaseous helium. This should be ducted overboard via suitable mission-peculiar plumbing provided by the integrator. Detailed specification should be negotiated prior to the R&R Phase for duct size and shape are of critical importance.

APPENDIX A

IRT-119, "A DEP for the IRT System"

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IRT-119

Small Helium-Cooled Infrared Telescope

A DEP FOR THE IRT SYSTEM

R. Watts

May 18, 1981

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18 May 1981

1.0 INTRODUCTION

The IRT as flown on Spacelab 2 contains no dedicated experiment processor (DEP). For any reflights of the experiment there may be advantages to adding a DEP, primarily in simplifying the interface between the Spacelab and the IRT. A simplification could reduce cable and connector costs, save integration time, and streamline checkout procedures.

This report summarizes the situation prior to the Spacelab-2 mission and provides a non-technical assessment of potential DEP advantages.

2.0 BACKGROUND

In the fall of 1977 the IRT was selected for the Spacelab-2 mission planned for December 1980, some 40 months later. Funding was limited; time was short. SAO had no in-house processor expert and there was no readily available, space-proven processor on the market. As a result, the IRT team decided not to try to develop an IRT processor, but to rely on Spacelab facilities as much as possible.

As the design for the Experiment Computer (EC) evolved, less and less capacity was left to act as an IRT processor. Discrete signals and analog readouts became more and more necessary. As IRT design tradeoff decisions were made still more demands were made on the interface to save costs, to increase reliability and flexibility, and to cope with technical problems within the experiment. For example, more commandable valves were needed, heaters were added, and backup modes were added to the cover mechanism and scan drive.

3.0 THE RAU INTERFACE

Details of the resulting RAU interface are given in IRT-109, "Command and Housekeeping Definition." That document lists 32 discrete commands, 16 discrete housekeeping lines, and 32 analog lines. There are four serial command words and seven serial housekeeping words, one of which is a timing delay.

In addition the RAU supports instrument power and three high rate multiplexer channels. In all, there are five connectors, 335 pins.

4.0 OPERATIONS

The IRT is commandable from the ground (POCC) or from the aft flight deck (AFD). In addition, a few commands are generated by the EC software. Except for self protection in case a bright object encroaches upon the field of view, the experiment changes state only in response to external commands. Under certain circumstances it may be necessary to issue a command every two seconds for several minutes. Such a high command density severely taxes the STS uplink capability or burdens the crew with more extensive monitoring of the IRT to determine when and if such commanding is required.

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5.0 A DEP AS AN ALTERNATIVE

With the range of well proven processors available today, simplification of the electrical interface between Spacelab and the IRT becomes attractive. Nearly all the discrete and analog lines could be replaced by a few serial messages. It will be necessary to retain a few discrete commands such as Power On.

A DEP would relieve some of the load on the EC. Some routines now in ECAS, such as exception monitors that require combinations not available in ECOS, could be transferred to the DEP. Further study is necessary to determine whether the transfer of BOAA is feasible and cost effective.

Another area that could yield substantial savings is automated testing. Command sequences and appropriate responses could be executed and verified, respectively, saving time during integration. Such sequences might also enhance remote trouble-shooting should an on-orbit failure occur.

SAO plans to undertake a study of performance and cost tradeoffs that should lead to a recommendation for or against a DEP for the IRT system.

APPENDIX B

IRT-210A, "Scientific Goals of IRT Data Analysis"

IRT-210
Rev. A 11/08/79

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Small Helium-Cooled Infrared Telescope

SCIENTIFIC GOALS OF IRT DATA ANALYSIS

G. Fazio and D. Koch
Smithsonian Astrophysical Observatory

and

W. Hoffmann and G. Rieke
University of Arizona

13 August, 1979

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SCIENTIFIC GOALS OF IRT DATA ANALYSIS //IRT-210A// 11/8/79

Preface

Much has been assumed and said in the past about the scientific goals of this experiment and Koch has produced many iterations of the data reduction system, all of which have been based on the general objectives stated in our various proposals and individual discussions. However, on 11 June, 1979, Fazio, Hoffmann, and Koch met to discuss the specific goals which are to be the agreed-upon basis for implementation of our data reduction software. The goals contained herein define specifically what the data products are to be. In addition, the specific approach to these goals is also provided. The detailed implementation will evolve as the programs are developed to meet these agreed-upon goals.

For clarity the specific approach does not include all of the details such as identifying how the various tapes are merged and justified in time, how error recovery is performed, when and how an equation of motion is derived, how to detect discrete events, what the intermediate data products are to be, etc.

SPECIFIC GOALS OF THE SPACELAB-2 IRT EXPERIMENT

In general, the principal objectives of the IRT experiment on Spacelab-2 are:

1. mapping of extended cosmic infrared sources, including the zodiacal light.
2. investigation of the induced Space Shuttle environment, specifically water vapor, carbon dioxide, and particulates.
3. investigation of the performance and management of a large volume of superfluid helium in space.

Specifically, the postflight data reduction program at SAO will have the following goals:

1. Production of all-sky intensity maps in the 60-120, 18-30, 9-16, and 4-8 micron wavelength bands as well as an all-sky map of the ratio of the intensities between the 60-120 and 18-30 micron bands (the ratio being determined from the instantaneous data). This will be done on an orbit-by-orbit basis and then combined. The data bins for 60-120 and 18-30 micron wavelength band maps will be 0.2 x

0.2 degrees; bins no larger than 1.0 x 1.0 degree will be used for the other bands. The maps will not contain point cosmic sources, scans with excessive water vapor will not be used (see Item 2 below), and all spurious events will be nulled out (see Item 4 below). As desired, specific maps of the following regions will be produced: (a) galactic plane, (b) clusters of galaxies, and (c) other TBD extended low surface brightness regions, e.g., supernova remnants, etc. To the extent allowed by time and resources, maps will be analyzed to determine the distribution and color of extended galactic emission.

Complementary to each map will be a catalog containing information related to each point cosmic source that has been removed from the scans comprising each map.

2. Understanding of the Space Shuttle environment. To do this we will produce plots in Shuttle coordinates of the intensity of the 6-7, 4-8, and 9-16 micron detectors, the sum of the three 18-30 micron detectors and the sum of the three 60-120 micron detectors, and the instantaneous ratio of the 6-7 micron to the 4.5-8.5 micron detector as a function

of the scan angle. The data will be plotted in 3-degree intervals (0.5 seconds) over a 90-degree band in the scan direction for the following conditions:

a. data without thruster firings, water dumps and flash evaporator contamination;
b. data during thruster firings;
c. data during and/or after water dumps;
d. data during and/or after flash evaporator operation.

Each and every scan will be assessed as to its usability in the cosmic maps. Specifically, the minimum infrared flux level on each scan will be logged, as well as the telescope position at the minimum. The data used in plotting will be supplied to ARC for interpretation of the induced environment.

3. The all-sky maps defined in Item 1 will be used by ARC to generate a model of the zodiacal light intensity and to search for any density fluctuations. To facilitate removal of discrete cosmic sources by ARC, a list of such sources (Item 4) will be included with the above maps.

4. Identification of cosmic discrete events after despiking and compression. A selected sample of non-cosmic events will be classified where possible and will be sent to ARC for further analysis. Cosmic events above a given threshold will be listed with their coordinates for TBD further analysis.

5. Recording of the cryogenics data on the RAU data tapes and processing at MSFC after receipt of the tapes from GSFC.

APPENDIX C

IRT-121, "IRT Verification Matrix"

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Small Helium-Cooled Infrared Telescope

IRT VERIFICATION MATRIX

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October 8, 1980

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IRT-121

IRT VERIFICATION MATRIX

Note: The following matrix is for form only, not content.

IRT VERIFICATION PLAN Rev.A 6/11/80

JA-061 No.	NA	Plan-ning	MSFC-RQMT -612	IRT DOC	Other	Date Planned	Resp. Org.	Verification Method & Comments
4.1.1			1.1,1.7			3/15/81	Test Lab	T Mass properties of subsystems being measured earlier. SAO responsible EL-1 and EL-2.
4.1.2.1			1.1			3/15/81	Test Lab	I
4.1.2.2			1.1			3/15/81	Test Lab	I
4.1.2.3			1.1			3/15/81	Test Lab	I
4.1.2.4			1.1			3/15/81	Test Lab	I
4.1.2.5	X							
4.1.2.6			1.1			3/15/81	Test Lab	I
4.1.2.7	X							
4.1.2.8			1.8			6/30/81	Test Lab	T
4.1.2.9			1.9.1			6/30/81		A/T Relatching not required but is desirable
4.1.2.10				TBD		3/30/80	SSL	A Completed (Ref. Urban's tech. memo)
4.1.2.11	X							
4.1.2.12	X							
4.1.2.13	X							
4.1.2.14	X							
4.1.2.15				TBD			SAO	
4.1.2.16			1.1.1			9/30/81	Test Lab	
4.1.2.17				TBD		9/30/81	SAO	
4.1.2.18	X							
4.1.2.19	X							
4.1.2.20	X							

JA-061 No.	NA	Plan-ning	MSFC-RQMT -612	IRT DOC	Other	Date Planned	Resp. Org.	Verification Method & Comments
4.1.2.21	X							
4.1.2.22	X							
4.1.2.23				TBD		9/30/81	SAO	T
4.1.3.1		X					MSFC	A Memo to be issued by J. Verble
4.1.3.2		X					Test Lab	T
4.1.3.3		X					Test Lab	A Memo to be issued by J. Verble
4.1.3.4	X							
4.1.3.5	X							
4.1.3.6	X							
4.1.3.7	X							
4.1.4.1	X							
4.1.4.2				TBD				A SAO is developing materials lists
4.1.4.3							SPPO	SAO will submit materials list
4.1.4.4							SPPO	SAO will submit materials list
4.1.4.5	X							
4.1.4.6	X							
4.1.4.7		X						
4.1.4.8	X							
4.2.1.1			2.0				Test Lab	
4.2.1.2			2.0				Test Lab	SAO & EC&C Lab will provide inputs
4.2.1.3		X					E&C Lab	A/I
4.2.1.4		X					E&C Lab	I
4.2.1.5			2.0			3/15/81	Test Lab	I
4.2.1.6			2.0			3/15/81	Test Lab	I

JA-061 No.	NA	Plan-ning	MSFC-RQMT -512	IPT DOC	Other	Date Planned	Resp. Org.	Verification Method & Comments
4.2.1.7				TBD		6/30/81	SAO	T/A
4.2.1.8	X							
4.2.1.9	X							
4.2.1.10	X							
4.2.2		X	TBD			6/30/81	Test Lab	T
4.3				TBD		6/30/81	SAO	
4.4.1	X							
4.4.2	X							
4.4.3	X							
4.4.4		X						A/T
4.4.5	X							
4.4.6	X							
4.4.7		X						T SAO may want to take exception
4.4.8	X							
4.4.9	X							
4.5.1		X					SAO	A/T Inputs will be provided by E&C
4.5.2		X					SAO/SSL	A/T
4.5.3		X						
4.5.4		X						

Notes and Explanations

Column	Comments
JA-061 No.	Paragraph in Section 4 of JA-061.
NA	An "X" in this column indicates that the requirement does not apply to the IRT.
Planning	An "X" in this column indicates that the IRT team intends to meet the requirement, but has not completed its plans.
MSFC-RQMT-612	Paragraph in the cited document that defines the requirement. In due course Test Lab will write a test procedure superseding "612."
IRT DOC	Verification activities not covered by "612" will be defined in IRT Documents listed here.
Other	Verification activities not covered by "612" or "IRT DOC."
Date Planned	The date when the requirement is to be met.
Resp. Org.	The organization responsible for meeting the requirement.
Verification Method and Comments	Self evident.