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FINAL REPORT
A STUDY TO DETERMINE THE

FEASIBILITY OF MODIFYING THE HIGH RESOLUTION INFRARED RADIATION SOUNDER (HIRS)

FOR
MEASURING SPECTRAL COMPONENTS OF EARTH RADIATION BUDGET

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A STUDY TO DETERMINE THE FEASIBILITY OF MODIFYING THE HIGH RESOLUTION INFRARED RADIATION SOUNDER (HIRS) FOR MEASURING SPECTRAL COMPONENTS OF EARTH RADIATION BUDGET

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1.0 SUMMARY

The Earth Radiation Budget Experiment (ERBE) will measure the shortwave (0.2-5μm) and longwave (5-50μm) radiant exitance from the top of the atmosphere. However, these broadbands will not meet the requirements of many scientists who would also like to determine the origin (e.g., H_2O, CO_2, O_3, and surface), and profile of the exitance. The current 20-channel, High Resolution Infrared Radiation Sounder (HIRS/2) provides many of the measurements that are needed to meet these requirements, particularly in the longwave spectral emission region (4-15μm). Although the HIRS/2 meets the meteorological sounding goals for which it was designed, it fails to provide needed measurements in two important radiation budget areas. First, the HIRS/2 does not provide a measurement of the water vapor rotational-band emissions in the 15-50μm spectral region. And secondly, its single visible channel (0.67 - 0.71μm) is not adequate for modeling the entire shortwave bidirectional reflectance spectrum (albedo). Four spectral channels of 0.5, 1.0, 1.6 and 18-25μm would significantly increase the capability of the HIRS instrument for earth radiation budget measurement.

This study addressed the physical features of the HIRS instrument to define components and locations for the added

channels. The placement of a pyroelectric sensor for the 18-25μm band ahead of the filter wheel permits sensing of this longwave radiation with negligible effect on the present 15μm channels. Placement of three shortwave sensors in the general location of the present visible (0.7μm) sensor is possible within the confines of the present mechanical configuration.

Performance estimates indicate capability of the new channels to meet the noise equivalent radiance goals and maintainance of all present HIRS channels at their present quality. Means for including the added data in the HIRS format are described. An on-board calibration source for the shortwave (albedo) channels is described.

The study concludes that the ERB modifications of a HIRS/2 system are feasible and could be included in a program of new instrument assembly.

2.0 INTRODUCTION

2.1 Background

The High Resolution Infrared Radiation Sounder (HIRS/2) is an operational instrument on the TIROS-N/NOAA A-G series of satellites. Its continuous operation, diurnal data collection, relatively wide scan pattern and narrow field of view provide many of the features desired for surface radiation budget data collection. The addition of selected infrared and albedo channels provides an opportunity to increase its utility in an Earth Radiation Budget role.

NOAA's recent purchase of two additional TIROS-N series spacecraft (NOAA H and I) leaves open the possibility of one or two additional ERBE follow-on missions in the late 1980's similar to the current ERBE NOAA F and G missions. HIRS/2 is a strong sounder candidate for the NOAA H and I flights.

This study was intended only to answer basic questions concerning the feasibility and practicality of adding several spectral channels to the existing 20-channel sounder. Guidelines for the study were that:

1) The performance and operating characteristics of the present HIRS/2 spectral channels shall not be degraded beyond instrument specification limits, and all optical and functional performance are to be retained without change.

2) All output data from added channels shall be incorporated into the 288-bit minor frame assigned to the present HIRS/2.

3) Specification goals for the four added channels (denoted as channels #21-24) are listed in the table below. An initial band from 18-20μm was changed to 18-25μm when it was learned that the wider band was achievable. The intent of the band re-specification for channel 24 was not per se to reduce channel NEΔN, although reduction does occur, but to provide better spectral sampling of the water vapor rotational band. Indeed, a band with flat response from 18 to 100μm would be even more desirable.

CHANNEL	CHANNEL CENTER FREQ. cm^{-1}	HALF-POWER BANDWIDTH cm^{-1}	INPUT FLUX RANGE *	NEΔN *
21	20,000	2,000	0-15	0.06
22	9,900	400	0-25	0.10
23	6,300	400	0-20	0.08
24 (initial)	∿525	∿50	30-150	0.60
24 (final)	475	150	30-150	0.60

*$mW - m^{-2} - sr^{-1} - cm$

4) An on-board calibration system shall be considered providing stable calibration sources, (1) for the present (channel #20) and added shortwave channels (#21-23), and (2) for the added longwave channel (#24).

The High Resolution Infrared Radiation Sounder (HIRS) was developed as an advanced atmospheric sounder to have both 15μm and 4.3μm sounding channels, a cloud cover sensor at 0.7μm and water vapor channels at 6.7 to 8.2μm. The instrument flew on the Nimbus 6 spacecraft in 1975, permitting evaluation of sounding algorithms based on this approach. The success of this method led to a rapid redesign of the instrument for the TIROS-N spacecraft and NOAA A-G series. In this series the first spacecraft (TIROS-N) was launched in October 1978 and the second (NOAA-6) launched in June 1979. The HIRS instrument was very successful on both flights, having shown no indication of degradation or potential failure in either spacecraft.

Extension of the NOAA series of operational meteorological spacecraft is leading toward additional instruments, with some functional changes being considered to increase the reserve cooling capacity, improve optical registration and provide a lower background noise level. The start of design modifications and fabrication of three additional instruments is anticipated in the first quarter of 1981. Need dates (delivery to the spacecraft integrator) are given as mid 1983, late 1983 and early 1984.

2.2 HIRS Instrument Summary

The HIRS/2 is a 20 channel scanning radiometric sounder utilizing a stepping mirror to accomplish crosstrack scanning, directing the radiant energy from the earth to a single, 15cm (6-inch) diameter telescope assembly every tenth of a second. Collected energy is separated by a beamsplitter into longwave (6.7 to 15μm) and shortwave (.7 to 4.6μm) components, passed through field stops and through a rotating filter wheel to cooled detectors. In the shortwave path a second beamsplitter separates and directs the visible energy to a silicon detector. An Indium Antimonide detector and a Mercury Cadmium Telluide detector mounted on a passive radiant cooler operating at 107 Kelvin sense the shortwave and longwave energy.

Radiometric data is converted to 13 bit binary data and combined with HIRS "housekeeping" data to form a single data stream for the TIROS Information Processor (TIP). Radiometric performance is monitored by periodic (every 40 scan lines) views of the on-board targets (Internal Warm Target and Internal Cold Target) and space. All important internal voltages, currents and temperatures are included in the data as well as an electronic calibration check of the amplifier strings.

Figures 2-1 through 2-5 and tables 2-1 and 2-2 provide a listing of general instrument parameters and diagrams of system operation and configuration. Table 2-3 lists the operational performance of the present instruments. The Protoflight Model unit is operating on the TIROS-N spacecraft, Flight Model 1 is on the NOAA-6 spacecraft and Flight Model 4 is presently on board the NOAA-C spacecraft. Flight Models 5, 6 and 7 are currently in fabrication and assembly. A more complete description of the instrument may be found in the HIRS/2 Final Project Report of Contract NAS5-23567, August 1979 or the Technical Description for HIRS/2 Contract NAS5-23567, October 1978.

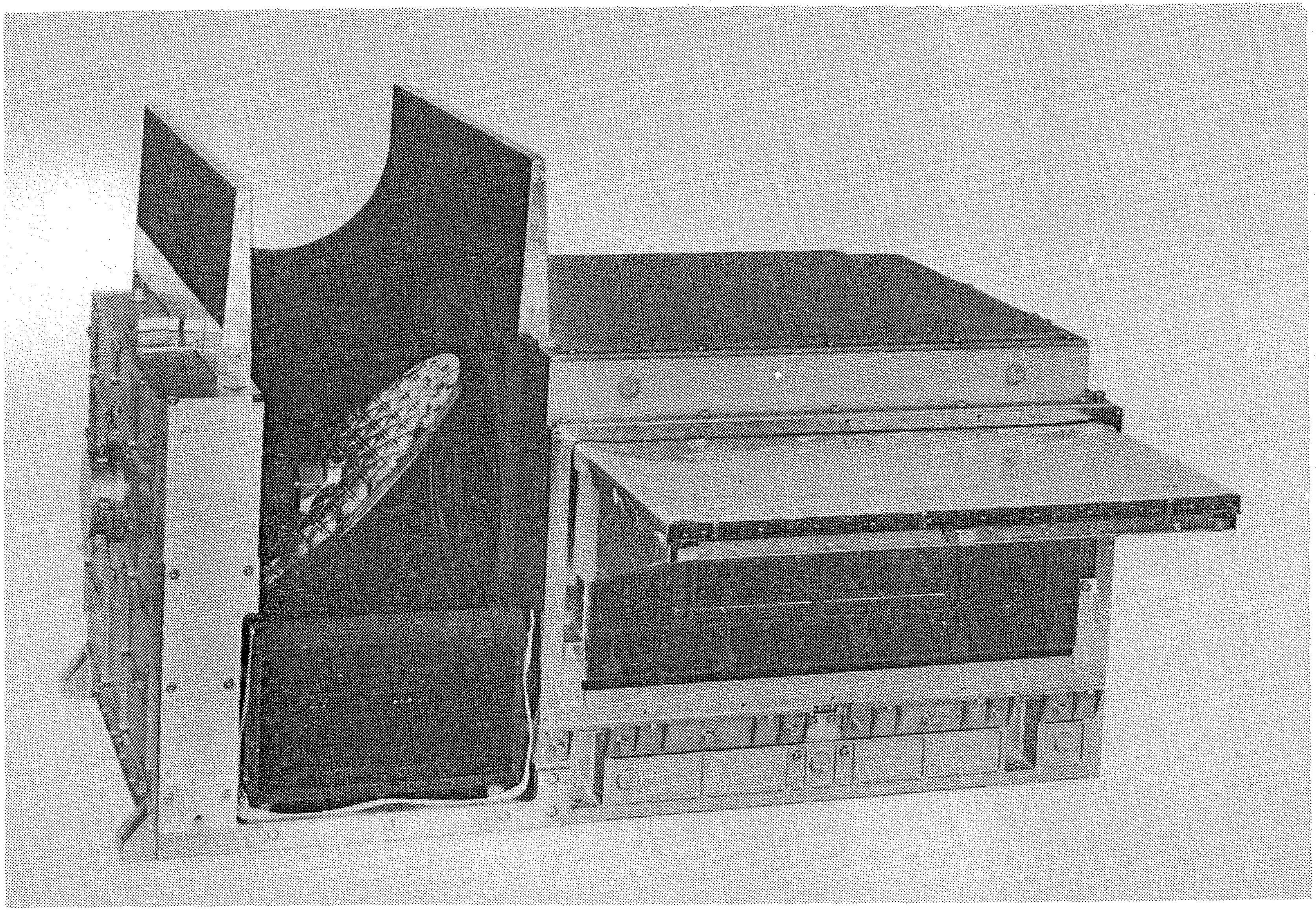


Figure 2-1. HIRS/2 Flight Model, Cooler View

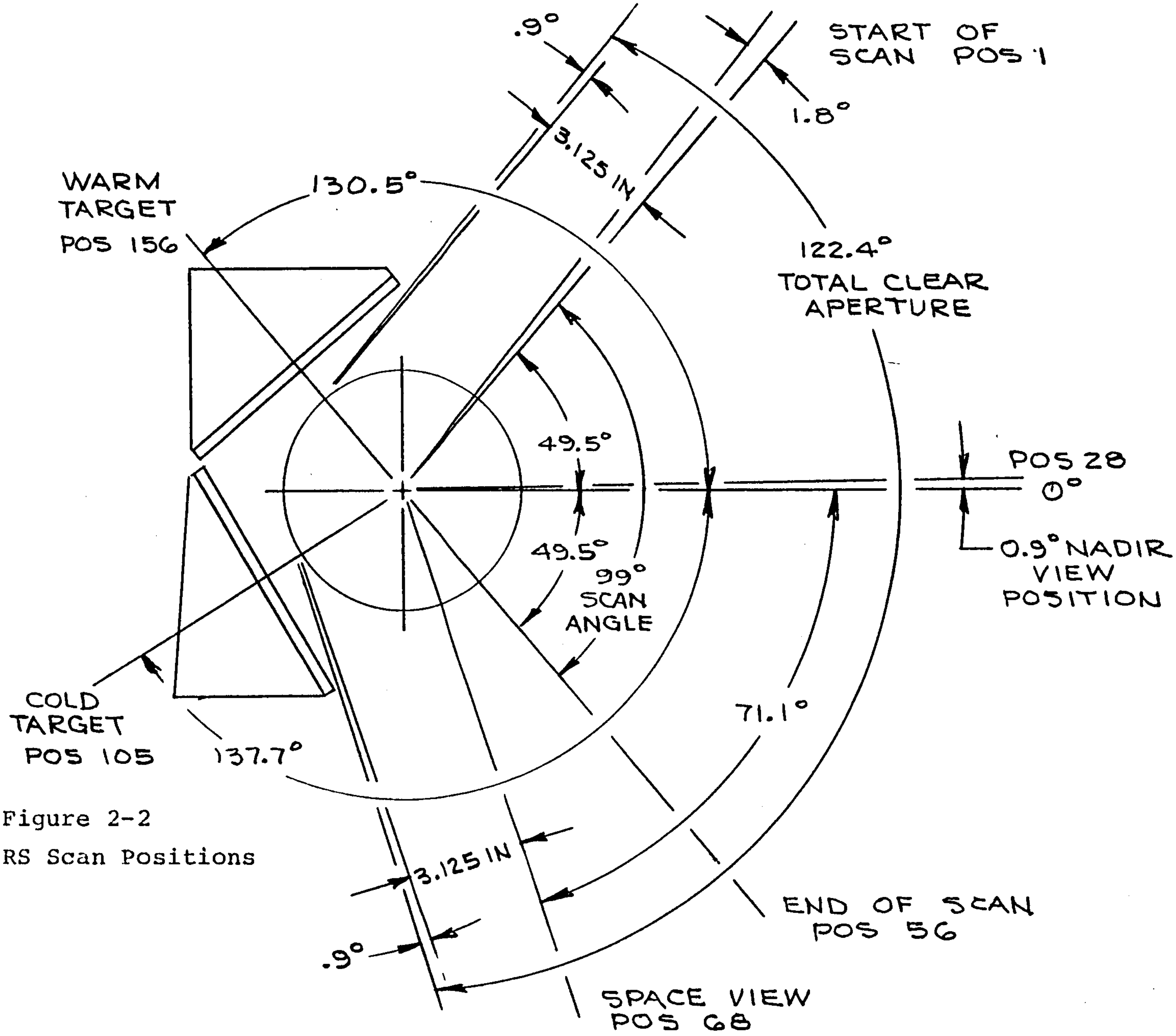


Figure 2-2

HIRS Scan Positions

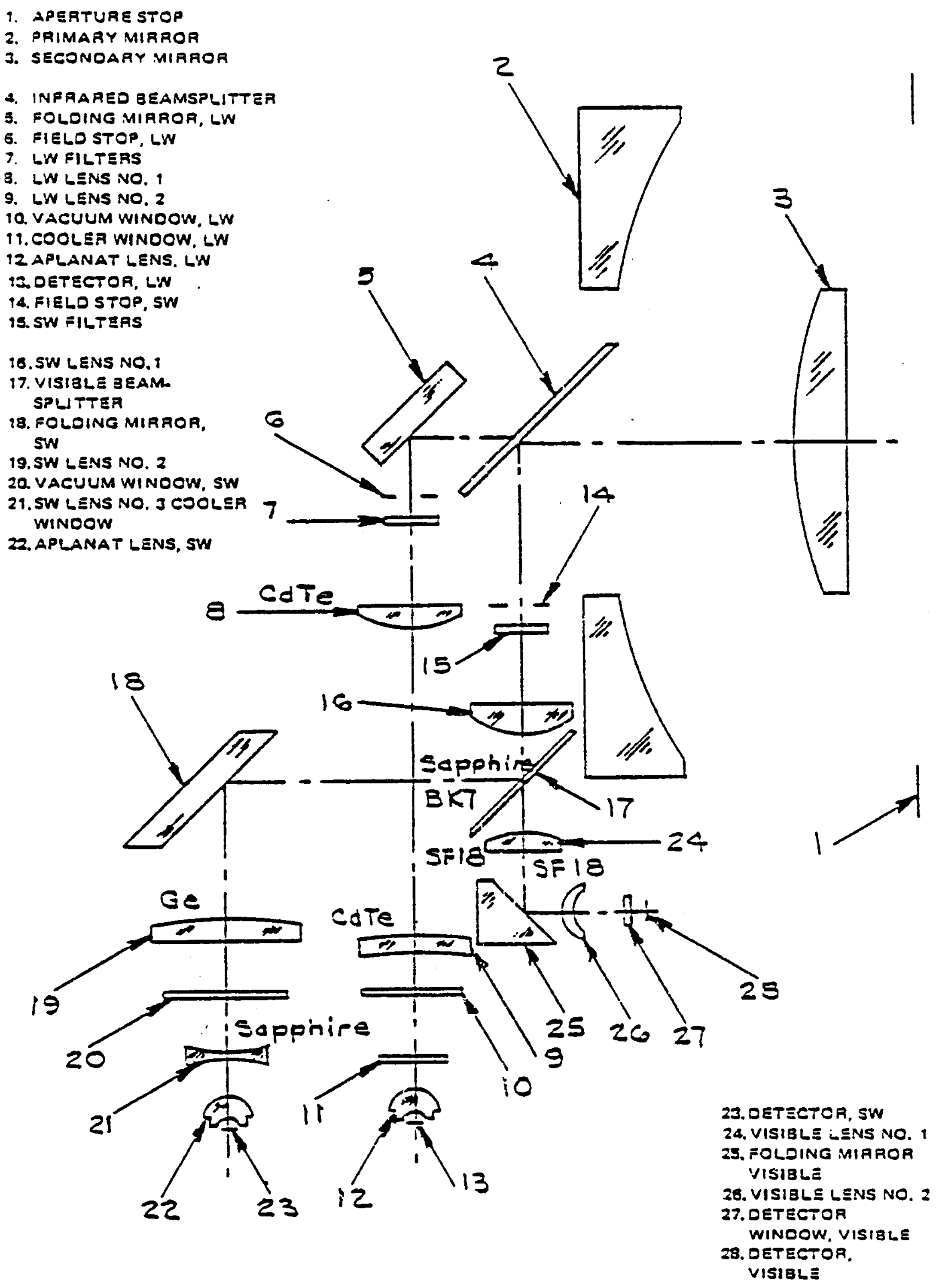


Figure 2-3 Optic Layout

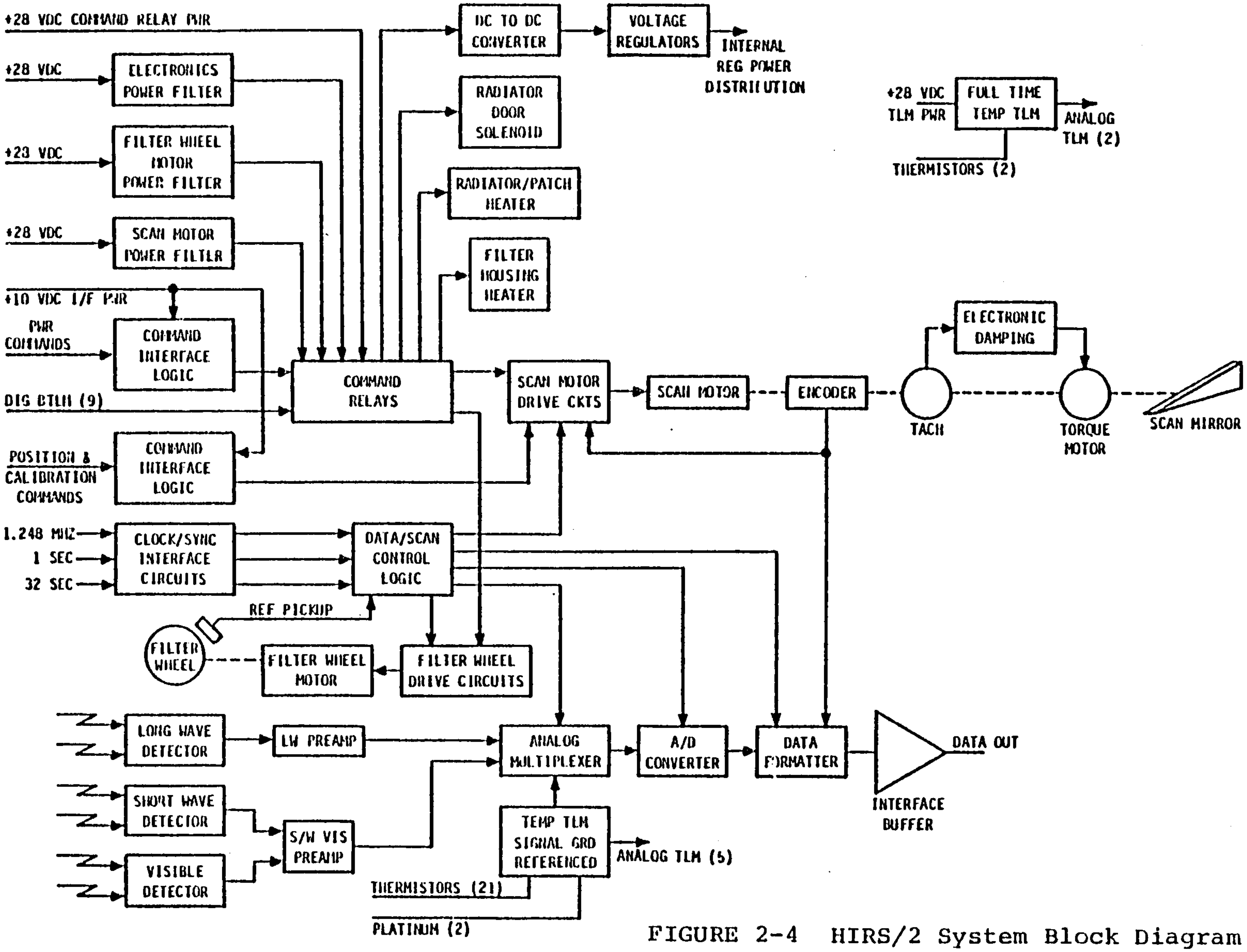


FIGURE 2-4 HIRS/2 System Block Diagram

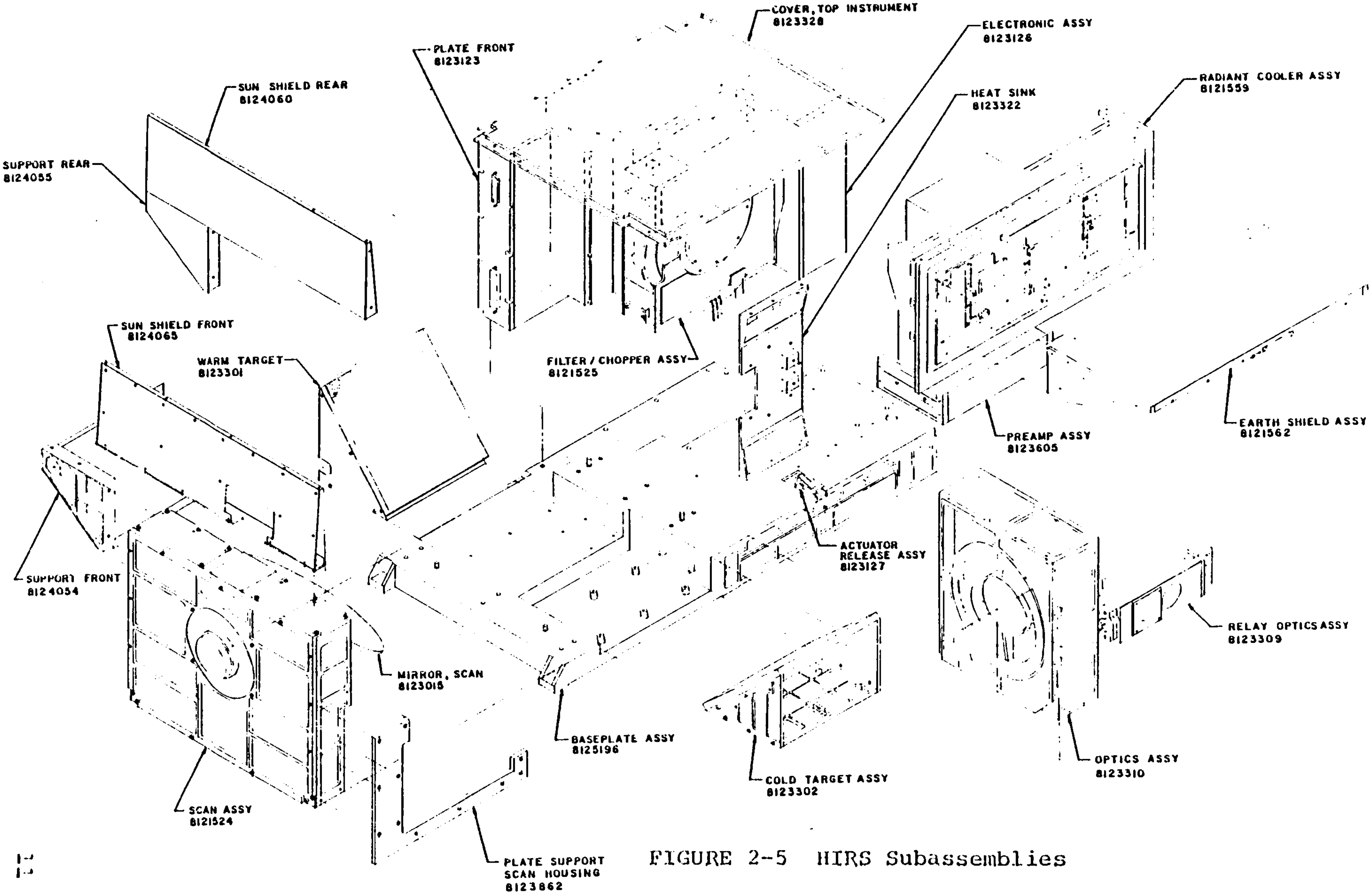


FIGURE 2-5 HIRS Subassemblies

TABLE 2-1. HIRS/2 SYSTEM CHARACTERISTICS

Optic Field of View	1.22° (17.5km) typical, (97% within 1.80°)
Channel-to-Channel Registration	
Longwave	±1.5% of FOV Width
Shortwave	±1% of FOV Width
Earth Scan Angle	99.0° (56 steps, 6.4s cycle)
Step and Dwell Time	100 ms total
Earth Swath Width (833 Km orbit)	2254 km (56 steps)
Radiometric Calibration	290K Black Body (56 samples) 265K Black Body (56 samples) Space Look (48 samples)
Frequency of Rad. Cal.	256s, (every 40 lines)
Longwave Channels	12 (Mercury Cadmium Telluride Detector)
Shortwave Channels	7 (Indium Antimonide Detector)
Visible Channel	1 (Silicon Detector)
Signal Quantizing Levels	8192 (13-bit coding)
Electronic Calibration	32 equal levels
Telescope Aperture	15.0 cm (5.9 in)
IR Detector Temperature	107K
Filter Temperature	288K
Instrument Operating Temperature	15°C nominal, louver control
Instrument Size, Max, door Closed	65 cm(25.5 in) by 40.4 cm (15.9 in) by 35.3 cm(13.9 in)
Instrument Weight	32.3 kg, (71 lb)
Instrument Power	22.5 watts

TABLE 2-2 PRESENT HIRS RADIOMETRIC REQUIREMENTS

CHANNEL NUMBER	WAVELENGTH (MICRONS)	CENTER FREQUENCY (cm^{-1})	HALF BANDWIDTH (cm^{-1})	MAXIMUM SCENE TEMPERATURE (K)	SPECIFIED NEΔN
1	14.95	668.5±1.3	$3.0^{+1}_{-0.5}$	280	3.00
2	14.71	680.0±1.8	10^{+4}_{-1}	265	0.67
3	14.49	690.0±1.8	12^{+6}_{-0}	240	0.50
4	14.22	703.0±1.8	16^{+4}_{-2}	250	0.31
5	13.97	716.0±1.8	16^{+4}_{-2}	265	0.21
6	13.64	733.0±1.8	16^{+4}_{-2}	280	0.24
7	13.35	749.0±1.8	16^{+4}_{-2}	290	0.24
8	11.11	900.0±2.7	35±5	330	0.10
9	9.71	1030.0±4	25±3	270	0.15
10	8.16	1225.0±4	60^{+10}_{-3}	290	0.16
11	7.33	1365.0±5	40±5	275	0.20
12	6.72	1488.0±4.7	80^{+15}_{-4}	260	0.19
13	4.57	2190.0±4.4	23±3	300	0.006
14	4.52	2210.0±4.4	23±3	290	0.003
15	4.46	2240.0±4.4	23±3	280	0.004
16	4.40	2270.0±4.7	23±3	260	0.002
17	4.24	2360.0±4.7	23±3	280	0.002
18	4.00	2515.0±5	35±5	340	0.002
19	3.76	2660.0±9.5	100±15	340	0.001
20	0.69	14500±220	1000±150	100% A	0.10% A

NEΔN in mW/m^2 ster cm^{-1}

	PFM ORBIT NEΔN	FM1 ORBIT NEΔN	FM2 T/V TEST NEΔN	FM3 T/V TEST NEΔN	FM4 T/V TEST NEΔN	PFM SPEC NEΔN	FM SPEC NEΔN
CH 1	3.59	1.92	3.18	1.52	.85	.75	3.00
2	.67	.506	.61	.18	.16	.25	.67
3	.56	.41	.43	.14	.12	.25	.50
4	.41	.31	.28	.097	.20	.20	.31
5	.26	.26	.19	.073	.061	.20	.21
6	.27	.295	.19	.093	.066	.20	.24
7	.18	.174	.14	.067	.059	.20	.24
8	.072	.062	.042	.026	.019	.10	.10
9	.073	.071	.055	.032	.035	.15	.15
10	.104	.137	.066	.033	.028	.20	.16
11	.21	.191	.14	.054	.059	.10	.20
12	.13	.150	.095	.040	.040	.10	.19
13	.0040	.0025	.0029	.0011	.0014	.002	.006
14	.0021	.0032	.0031	.0014	.0014	.002	.003
15	.0024	.0037	.0037	.00078	.00096	.002	.004
16	.00125	.0021	.0025	.00074	.00083	.002	.002
17	.0015	.0019	.0035	.00068	.00095	.002	.002
18	.0014	.0009	.0011	.00048	.00049	.002	.002
19	.00049	.00049	.00055	.00024	.00028	.001	.001

NEΔN mW m^{-2} sr^{-1} cm

TABLE 2-3 HIRS/2 PERFORMANCE SUMMARY

3.0 HIRS/ERB DESIGN

3.1 Optics

The ERB channels have been added to the HIRS by slight modifications to the optics. The present HIRS optical layout, shown in figure 2-3, uses a rotating filter wheel to spectrally select each channel. This arrangement will be unaffected for channels 1 through 19. The channel 20 filter will be removed from the wheel allowing the entire shortwave spectrum below 2μm to enter the visible relay optics. The visible optics will be completely redesigned to provide a beamsplitter and filter arrangement that yields channels 20, 21, 22 and 23. These four channels will each have their own detector and filter. All four channels will sample the scene simultaneously, thus providing zero misalignment between channels due to spacecraft motion. The present long wave folding mirror will be replaced by a beamsplitter allowing the channel 24 wavelengths to exit the back of the telescope to be sensed by its own chopper and detector assembly.

Figure 3-1 shows the HIRS/ERB optic design with the channel 24 modifications. Channel 24 has its own field stop allowing it to be accurately aligned to the other channels and ensuring that the out-of-field response is very small. The energy is transferred to the detector by a single lens that images the entrance aperture on the detector to eliminate uniformity and FOV problems. The energy will be chopped by teeth that are added to the existing filter wheel. There will be no modifications to the existing filter layout or the filter motor design.

The only optical changes required are the two beamsplitters that now must pass the channel 24 wavelengths. The

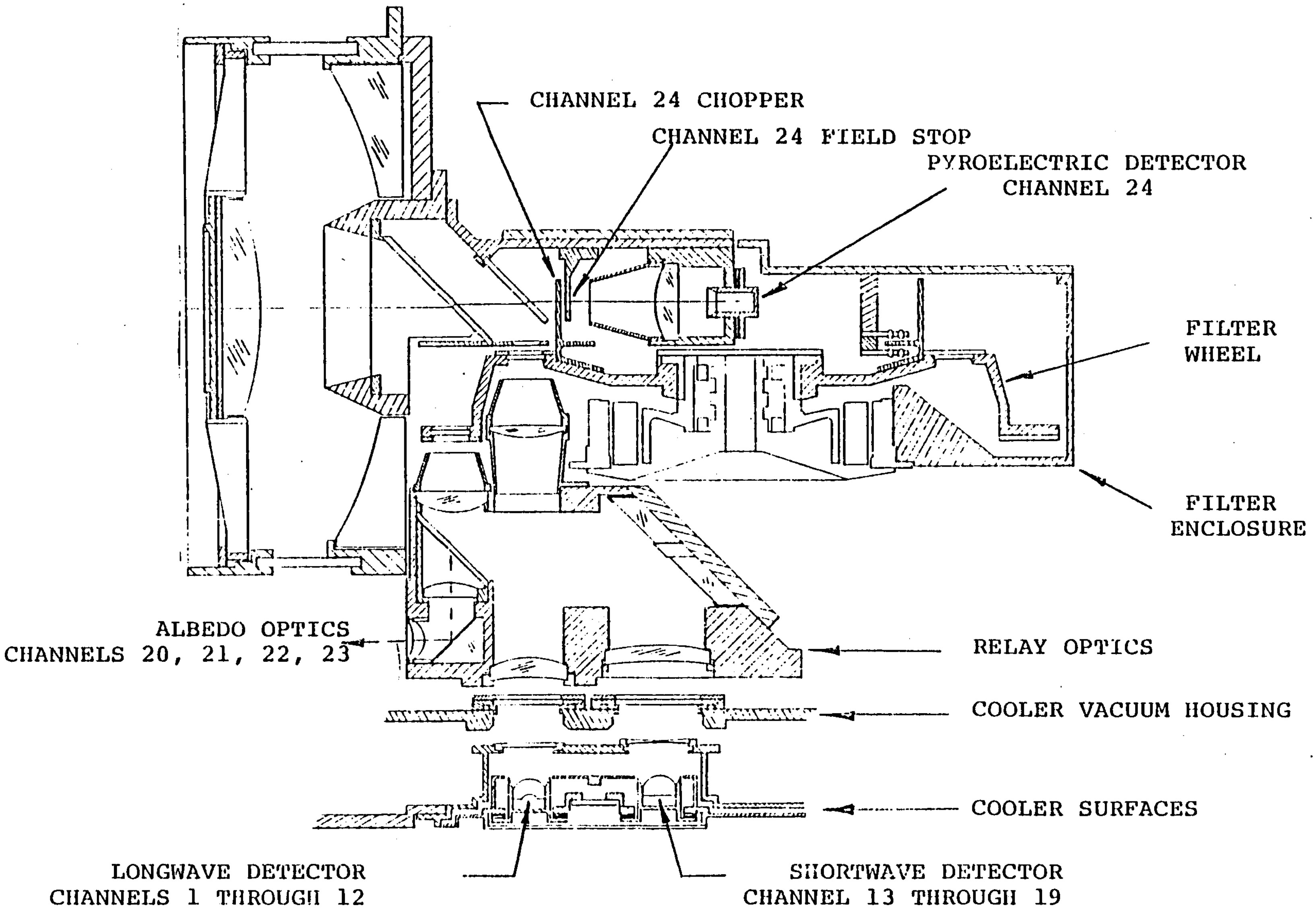


Figure 3-1 HIRS/ERB OPTICS DESIGN

first (LW/SW) beamsplitter consists of the present coatings put on a cadmium telluride (Cd Te) substrate. The computer predicted performance is shown in figures 3-2 through 3-5. Three angles of incidence and both planes of polarization are examined. Even though the coating was not designed for use beyond 15 microns it yields very useable transmissions in the 18 to 25 micron band of channel 24. During the detail design of the optics the beamsplitter coating will be revised and its performance should be improved by fine tuning the multilayer coating. The second beamsplitter is a new replacement for the L.W. folding mirror. A new coating design has been generated that will allow a direct substitution without affecting the present system. A very slight throughput loss of about 5% is anticipated but would not affect the present HIRS channel NEΔN values. The computer prediction for the new beamsplitter, as shown in figure 3-6, shows exceptionally high reflectance in the present HIRS channels and very high transmission in the channel 24 region. Figure 3-7 shows that the expected polarization characteristics should not cause problems.

The albedo optical energy is presently separated from the shortwave path by a SW/VIS beamsplitter. This beamsplitter does transmit in the .5 to 1.6 micron range and could be utilized with no changes. However, it appears possible to slightly modify the coating to improve its response in the new channels without affecting the present channels. The computer predicted response shown in figure 3-8 indicates better than required performance. Figure 3-9 shows one of the concepts for the albedo channels. This optical system will replace the present channel 20 assembly and provide for channels 20, 21, 22 and 23. The registration of these channels is determined by the shortwave field stop and

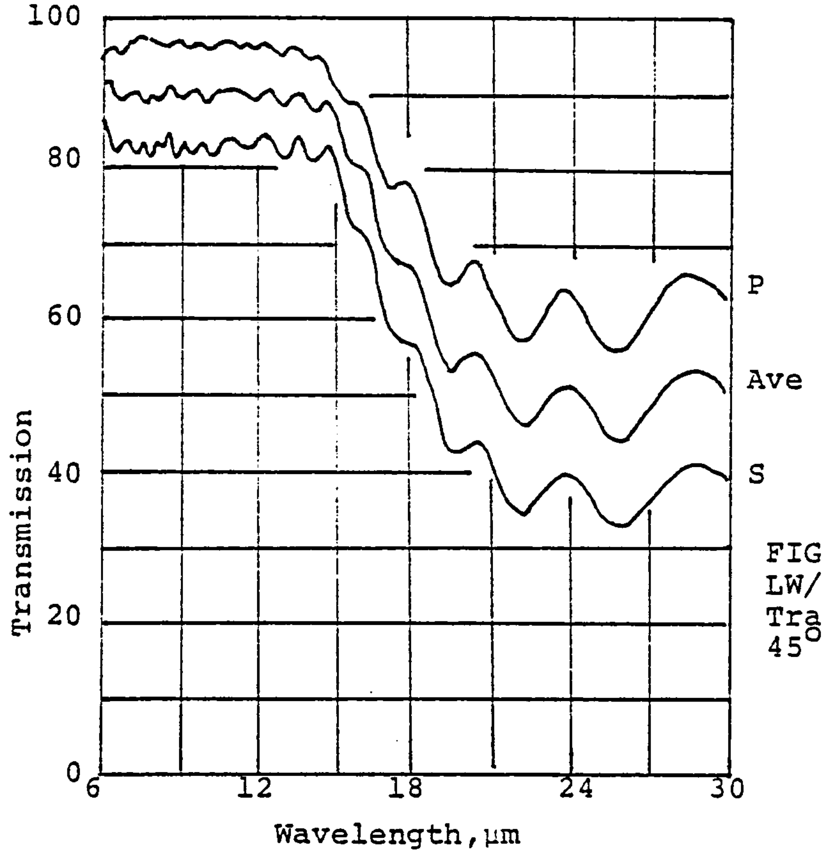


FIGURE 3-2
LW/SW Beamsplitter
Transmission at
45° Incidence Angle

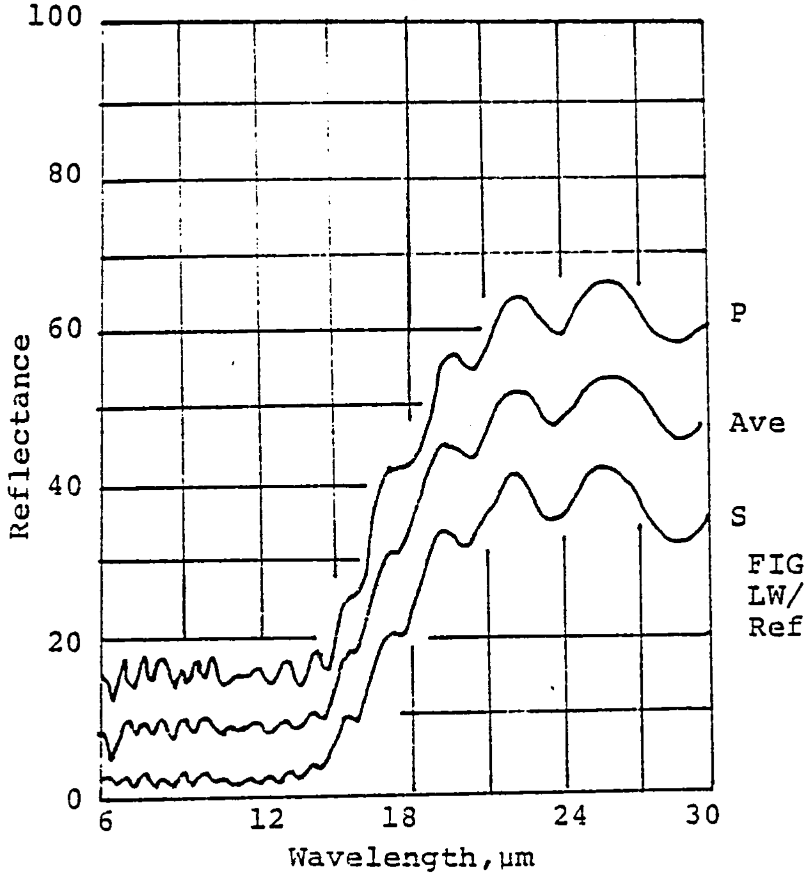


FIGURE 3-3
LW/SW Beamsplitter
Reflectance at 45°

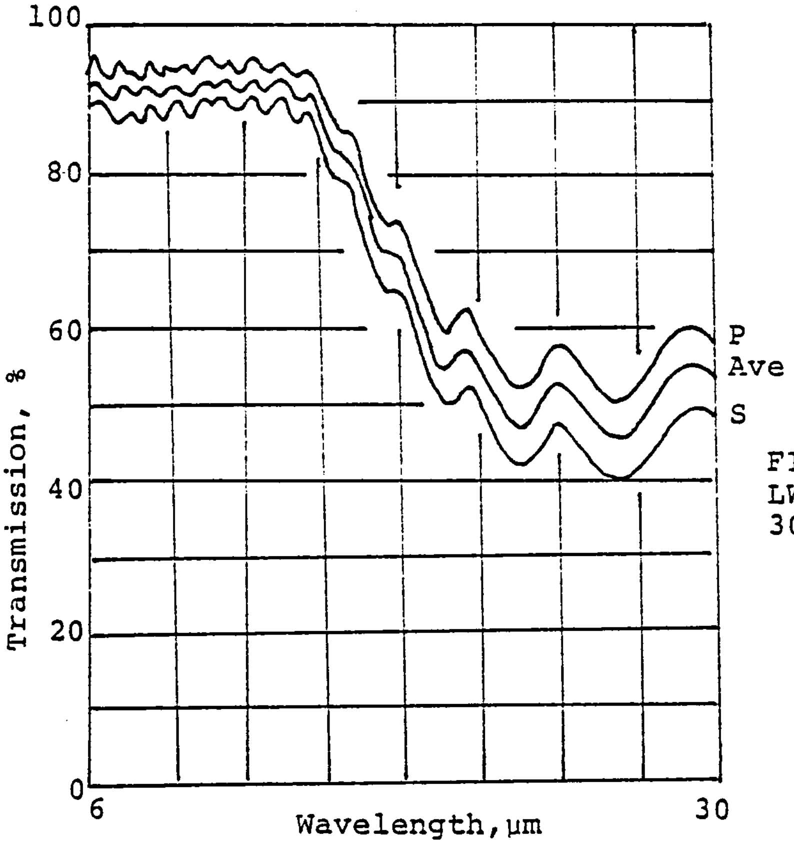


FIGURE 3-4
LW/SW Beamsplitter
30° Incidence Angle

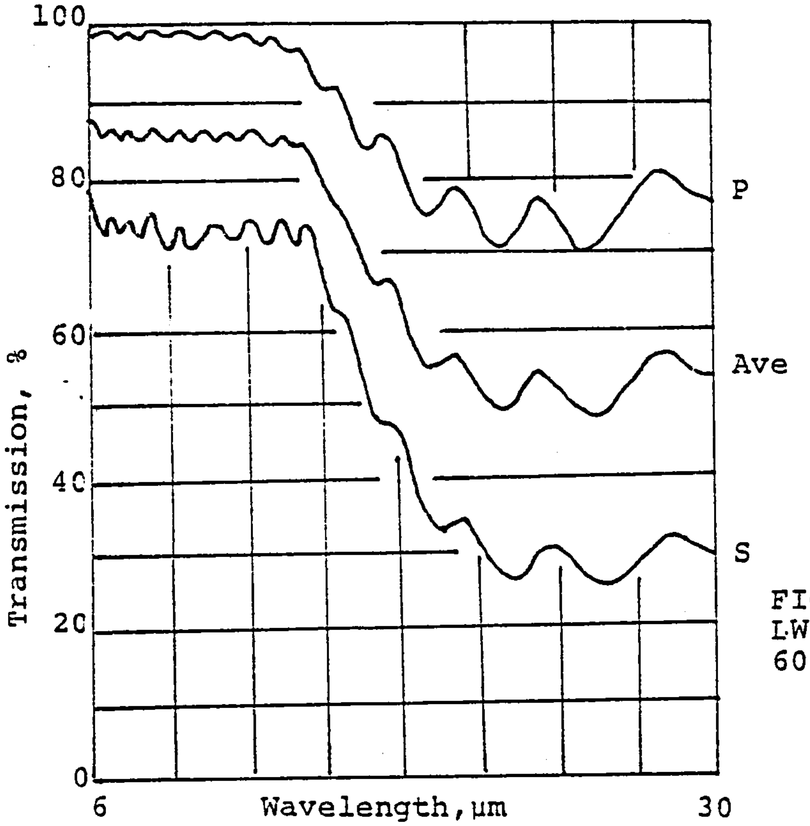


FIGURE 3-5
LW/SW Beamsplitter
60° Incidence Angle

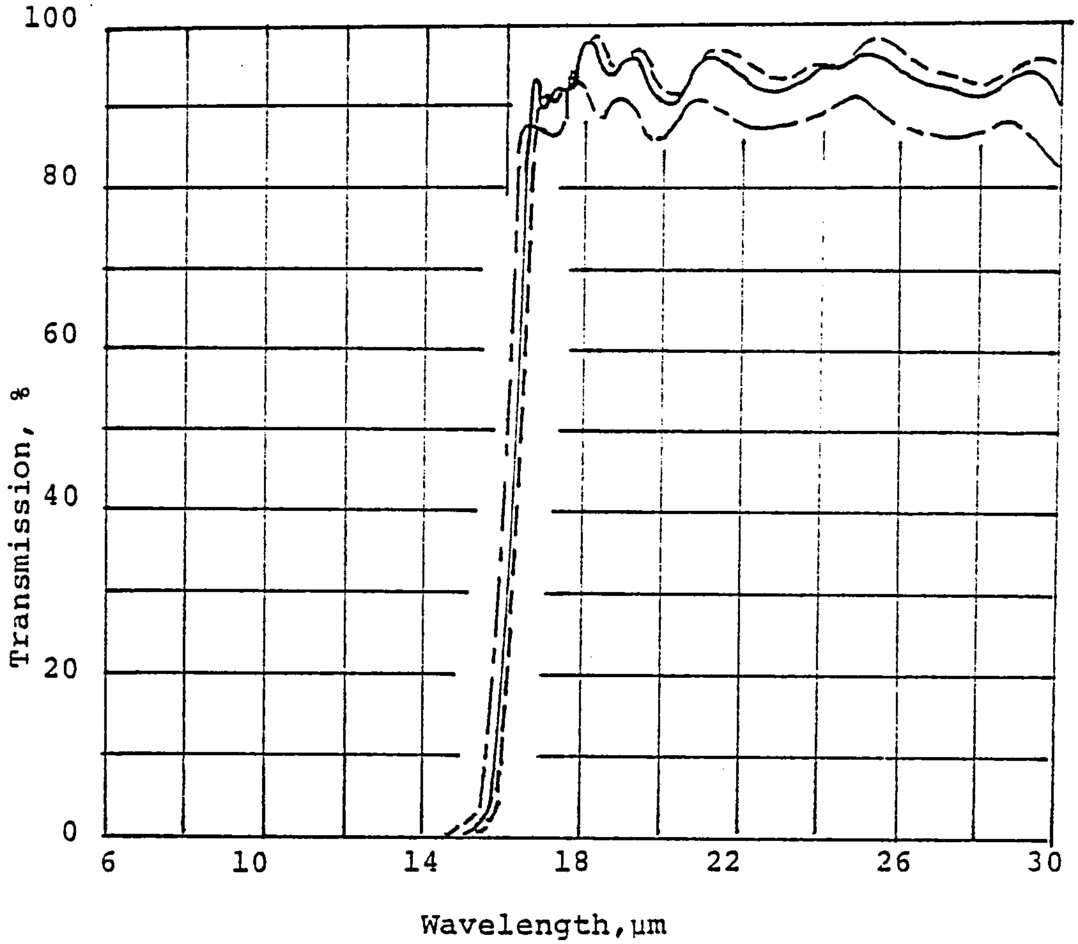


FIGURE 3-6 New LW/24 Beamsplitter Transmission at 30, 45 and 60° Incidence

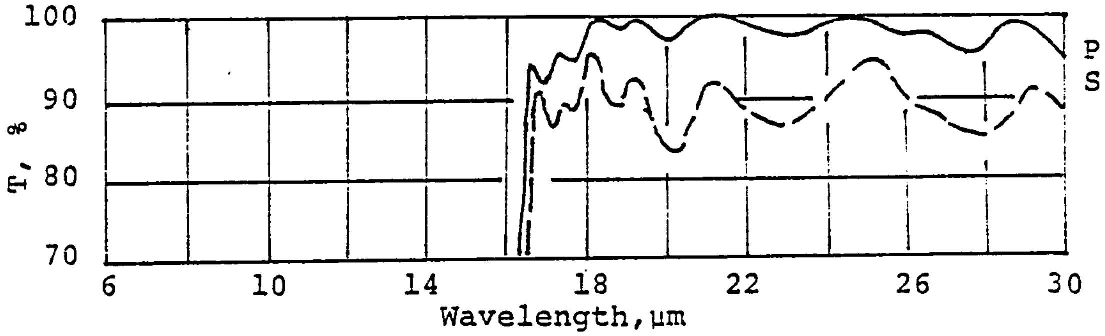


FIGURE 3-7 New LW/24 Beamsplitter Polarization in P and S planes.

should be very well aligned with the other HIRS channels. The exact configuration of the lenses and beamsplitters will depend on a detailed optical coating study and the new HIRS/2I cooler interface design, but the initial optics design shown in figure 3-9 shows that it is possible to construct a system that fits the physical limitations. The three new beamsplitters are named No. 1, No. 2 and No. 3 for convenience and the computer predicted performance is shown in figure 3-10 through 3-15.

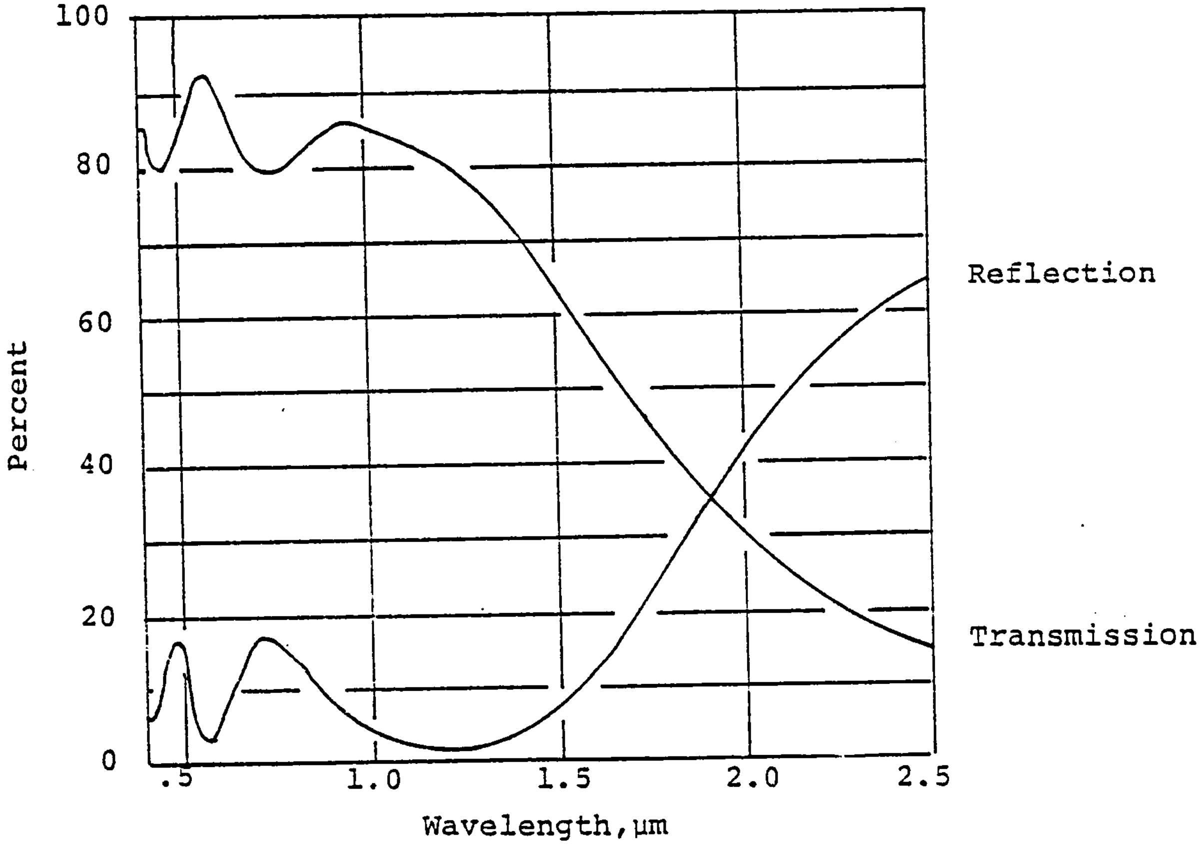


FIGURE 3-8. SW-VIS Beamsplitter

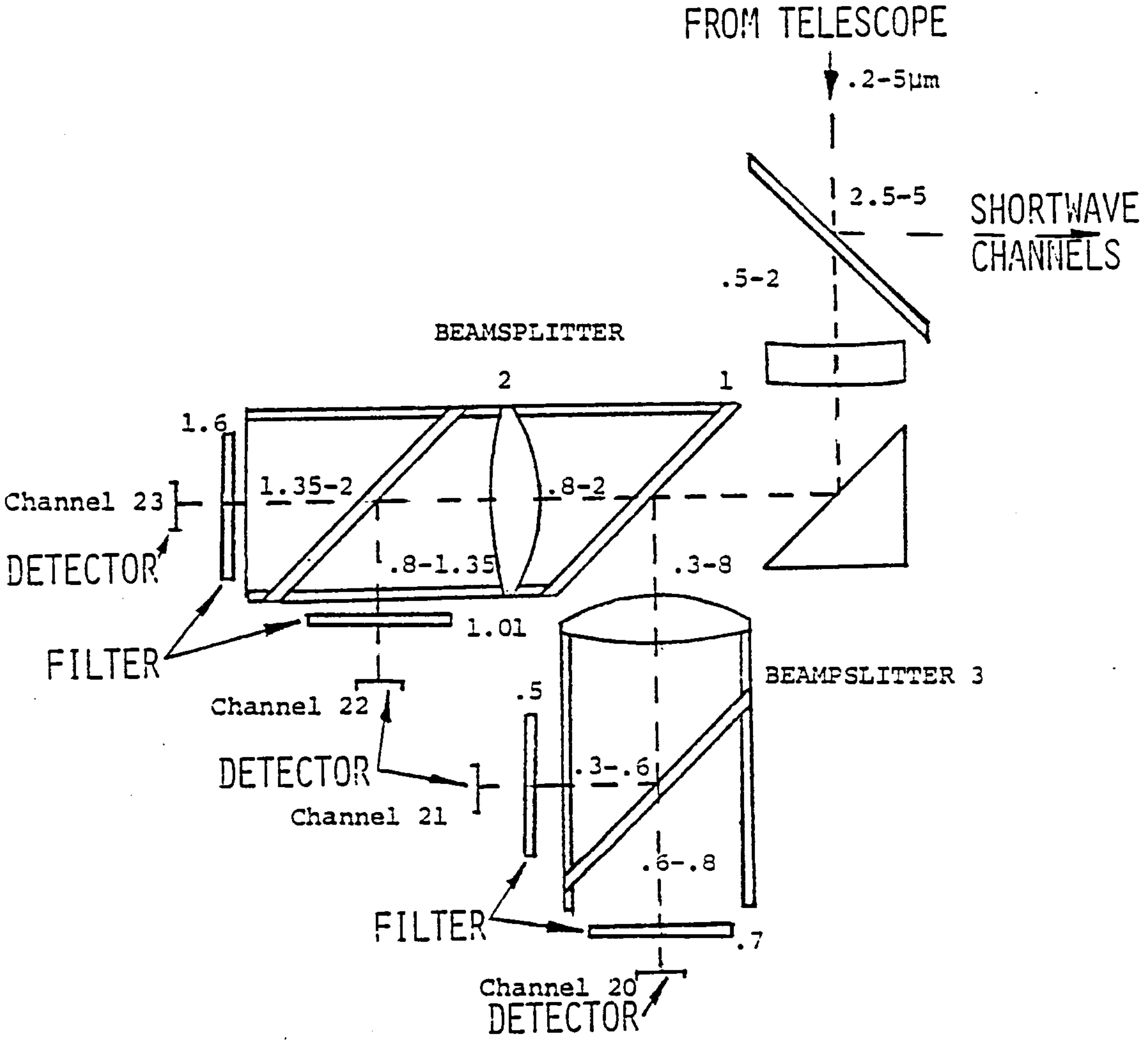


FIGURE 3-9. Albedo Optic System

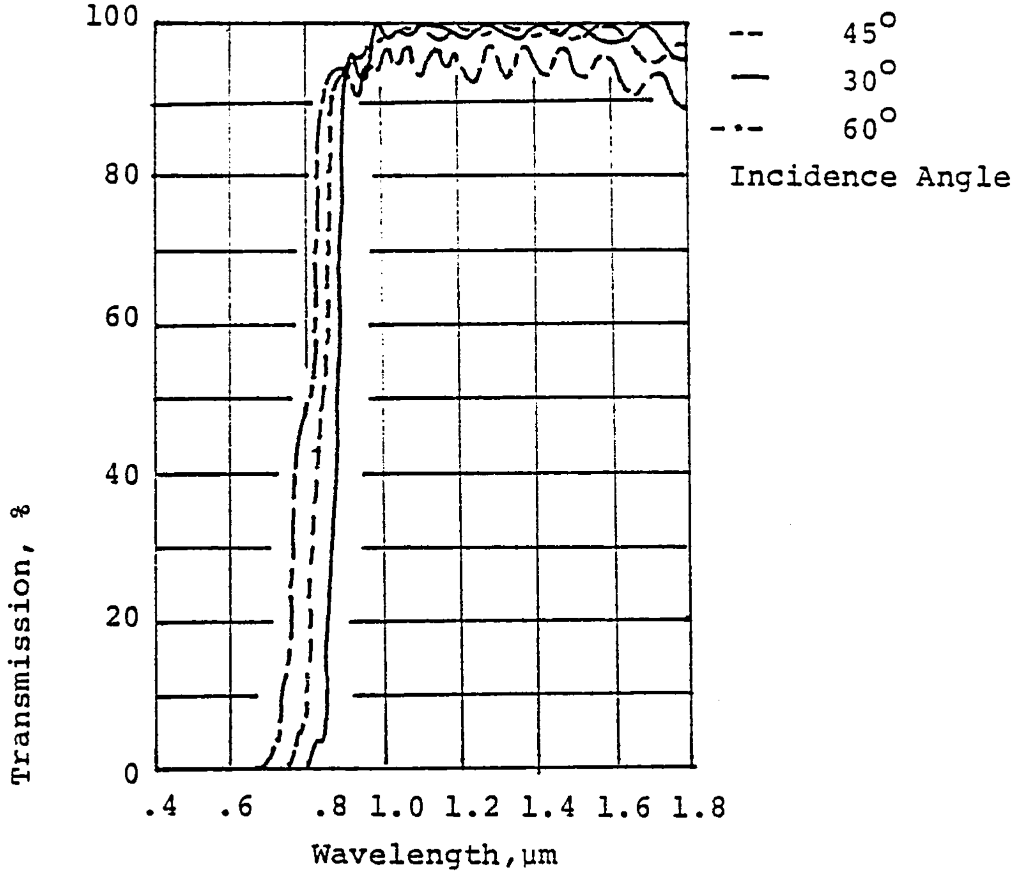


FIGURE 3-10 Beamsplitter No. 1 Transmission

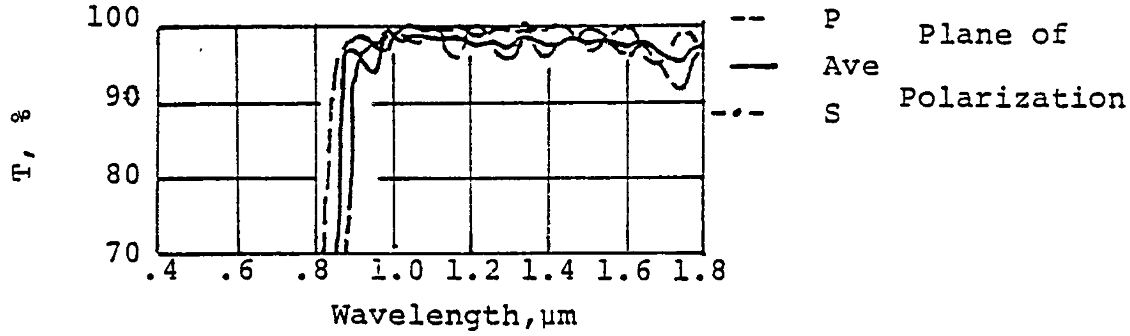


FIGURE 3-11 Beamsplitter No. 1 Polarization
(45° Incidence Angle)

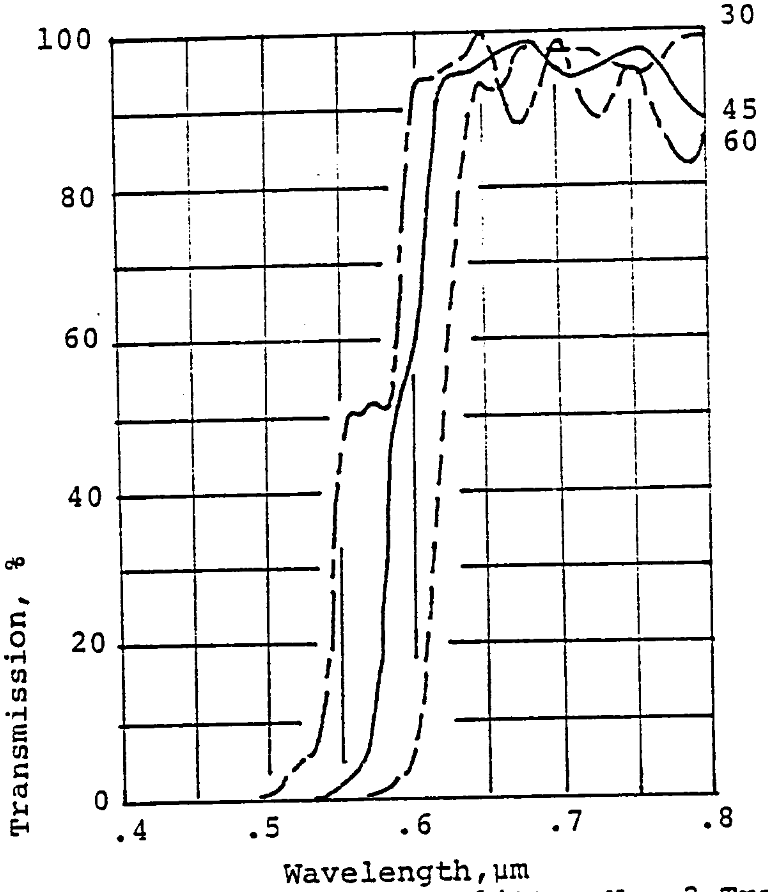


FIGURE 3-12 Beamsplitter No. 2 Transmission at 30, 45 and 60° Incidence Angles

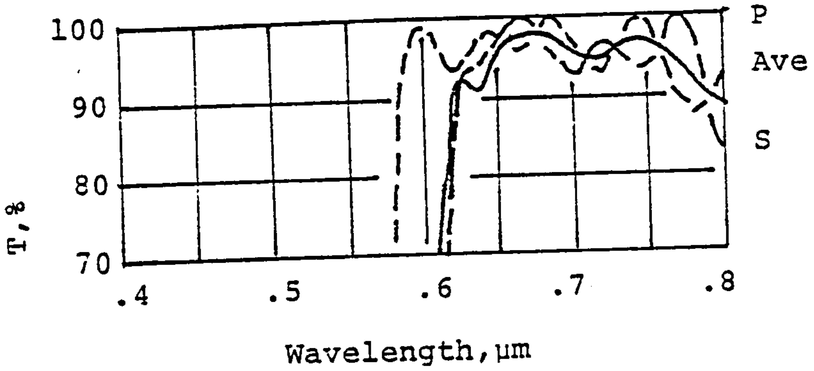


FIGURE 3-13 Beamsplitter No. 2 Polarization

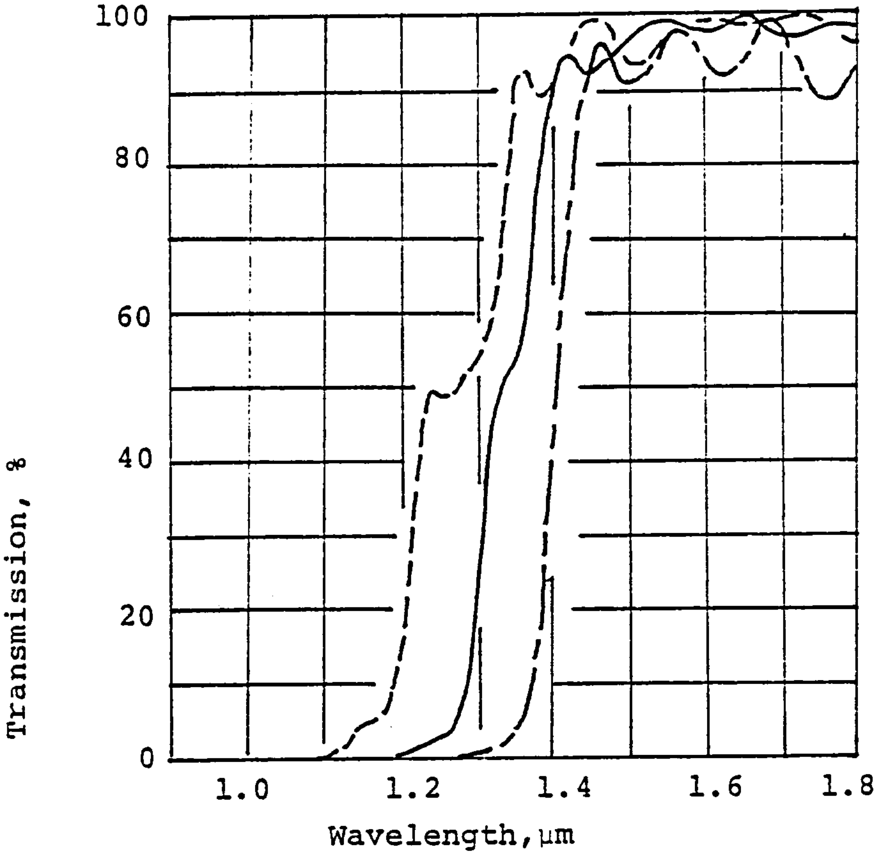


FIGURE 3-14 Beamsplitter No. 3 Transmission at 30, 45 and 60° Incidence

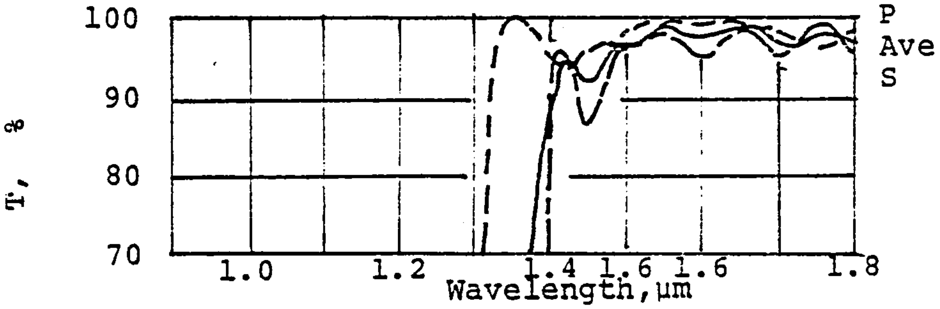


FIGURE 3-15 Beamsplitter No. 3 Polarization

TABLE 3-1 Channel 24 Optical Transmission

Optical Element	Transmission
Scan Mirror	.95
Telescope Primary	.95
Telescope Secondary	.95
LW/SW Beamsplitter	.60
LW/24 Beamsplitter	.80
Channel 24 lens	.85
Detector Window	.85
Total	.30

TABLE 3-2 Albedo Channels Optical Transmission

Optical Element	Transmission			
Channel:	20	21	22	23
Scan Mirror	80	80	80	80
Telescope Primary	80	80	80	80
Telescope Secondary	80	80	80	80
LW/SW Beamsplitter	25	25	25	25
SW Lens #1	85	85	85	85
SW/VIS Beamsplitter	80	80	70	30
Albedo Lens #1	95	95	95	90
Folding Mirror	95	95	95	95
#1 Beamsplitter	90	90	90	90
Albedo Lens #2	95	95	95	90
#2 or #3 beamsplitter	90	90	90	90
Spectral Filter	90	90	90	90
Total	.054	.054	.047	.018

The total system optical transmission can be calculated from the individual part coating curves and the substrate transmission curve shown in figure 3-16. The coated substrate will have peak transmission over 90%. The four optic elements in channel 24 will have a total thickness of near 6mm causing a limiting wavelength near 30μm. The preliminary estimate of total transmission for channel 24 is given in table 3-1 and for the albedo channels is given in table 3-2.

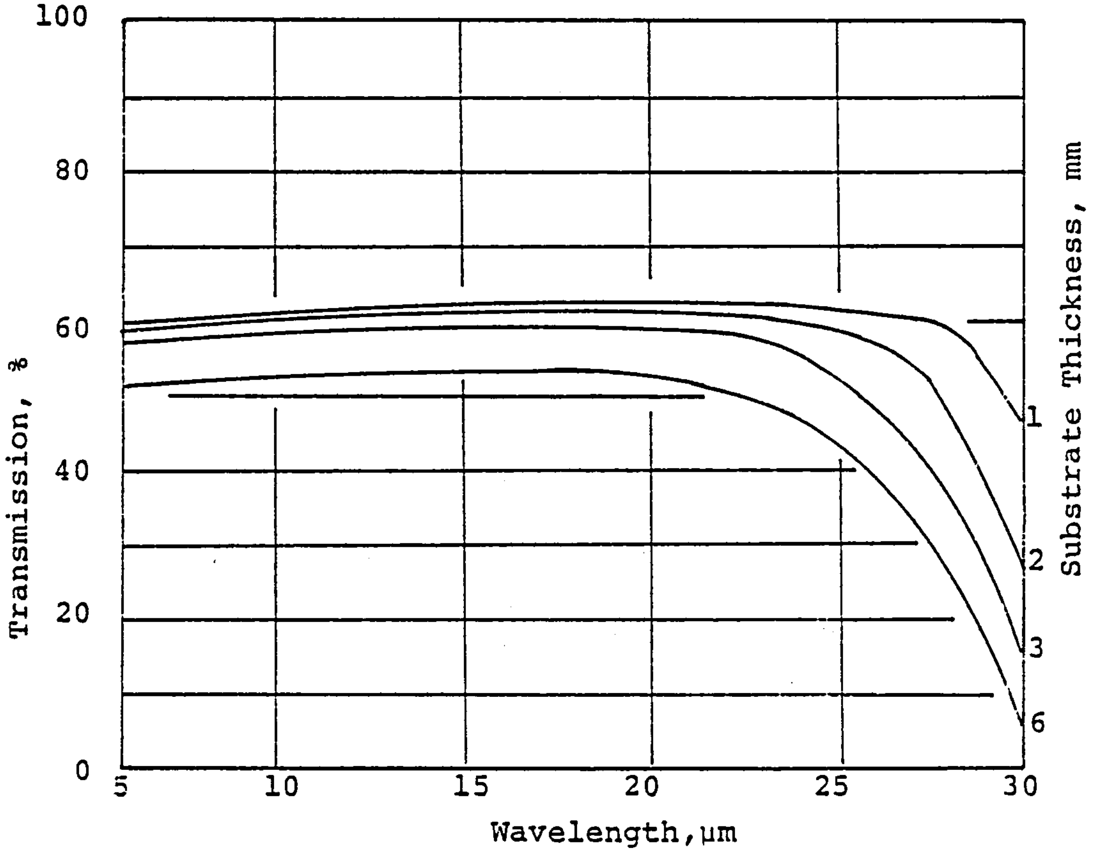


FIGURE 3-16. Cadmium Telluride Transmission, Uncoated Substrate

Coarse optical alignment of the four visible channels (number 20, 21, 22 and 23) will be done during the relay optics assembly. Fine alignment will be done on the HIRS optics bench. The optics bench is presently capable of testing all four channels with no modifications. The present test system contains all necessary electronics to align these channels directly with or without the HIRS filter wheel and electronics. The system is computer controlled and requires no modifications to hardware or software to do the alignment on a channel by channel basis.

The far IR channel (number 24) requires a field stop alignment step as well as a detector alignment step. Both can be done on the present HIRS optics bench with only slight modifications. The present field stop alignment programs will be directly applicable and should need no modifications. Depending on the arrangement used to mount the pyroelectric detector, alignment may be delayed until the optics are mounted on the baseplate. In any case, the alignment can be performed with the present computer programs and optics bench electronics.

If the new channels are to be fully integrated into the normal HIRS alignment sequence, the alignment must be checked using the instrument electronics and the data pulled out of the HIRS data stream. This can easily be done by a modification to the software field of view program. No hardware changes are required.

3.2 Detectors

A silicon detector similar to the present HIRS channel 20 detector will be used for channel 20 (.7μm), channel 21 (.5μm), and channel 22 (1.01μm). Silicon detectors provide exceptional uniformity, fast response time, low noise, good efficiency, and linearity providing NEΔN values that exceed specification. Due to the high light levels and the low noise the NEΔN will be restricted by the digitizing resolution. This condition presently exists in channel 20.

A germanium photodiode will be used for channel 23. This detector has characteristics similar to the silicon detectors of the other albedo channels except its response extends out to the 6300 cm^{-1} (1.59μm) spectral region of channel 23. This channel also has low noise and high light levels making the limiting factor the digitizing resolution. Typical spectral responses for silicon and germanium detectors are shown in Figure 3-17.

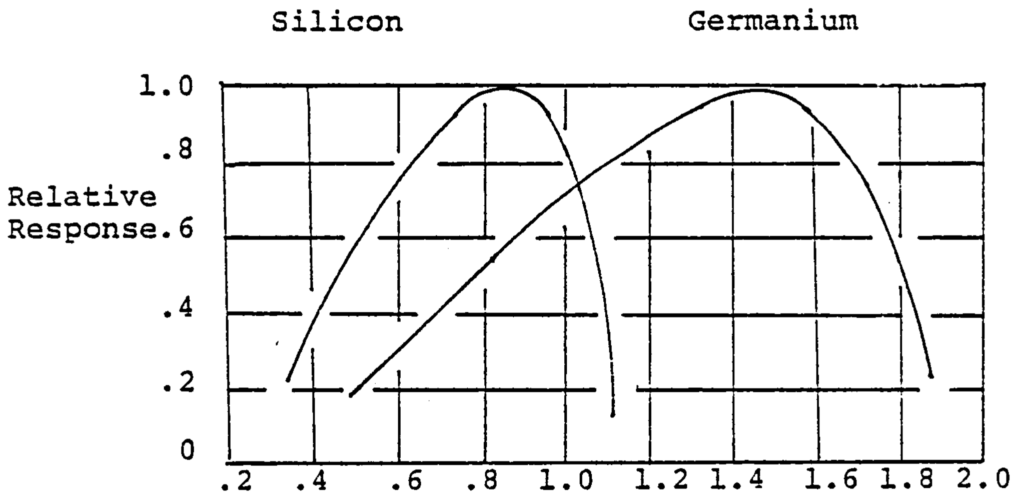


FIGURE 3-17 Photodiode Comparison

Channel 24 will utilize a pyroelectric detector to achieve the flat response needed over such a large infrared band. The telescope entrance aperture is imaged on the detector to remove any nonuniformity effects and remove the need for sharp detector edges. Channel 24 has its own field stop which will determine the FOV size, shape, and position to match the other channels. This channel has its own chopper which is placed prior to the field stop to eliminate background problems and provide a good chopped signal to the electronics. The use of a small area detector will greatly reduce vibration, a problem inherent in pyroelectrics. The detector, its relay lens, and chopper are all mounted in the thermally stable filter wheel housing to provide a stable system response.

3.3 Internal Albedo Target

The present HIRS Internal Cold Target (ICT) will be replaced with an Internal Albedo Target (IAT). The present ICT is not used at either ITT or NOAA for calibration of any of the present HIRS channels and consideration was given to removing it completely in the HIRS/2I instrument. The present target is a bolt-on subassembly that provides no major mechanical strength or thermal bias to the HIRS baseplate. This isolation makes it ideal for replacement by the new target assembly.

Figure 3-18 shows the proposed target assembly. A small integration sphere will average three lamps to provide a bright uniform source at the focal point of a seven (7) inch diameter cassagrain collimator. The system is oversized to ensure that slight scan mirror motions will not affect the reference level. The target will be designed to cover a 3.0 degree field of view to ensure the 1.5 degree HIRS instrument field of view is completely filled. For the dimensions required the efficiency of the sphere is low (approximately 30%) but the gain in reliability and uniformity are considered worthwhile. Each lamp will have its own spectral filter to provide a total target output of at least 15% albedo in channels 20, 21, 22, and 23.

Each measurement will be digitized to 13 bits while the ERB data has only 9 bits of resolution. The integrating sphere's output will be sampled by a photodiode on the collimator's secondary mirror that has a clear view directly into the integrating sphere. The entire target's output will be measured by the present HIRS channel 20 which is digitized to the 13 bit level and lies spectrally between the ERB channels. The reference diode will view the same spectrum as channel 20 (.69μm center and 0.04μm wide) giving a measure of the lamps independent of mirror reflections. If desirable, the reference diode bandwidth can be decreased or even moved to a different center wavelength, but the channel 20 position appears ideal.

In summary, the albedo target will be monitored by three independent methods which are:

1. Direct measure of lamp current
2. Radiometric measure of only the integrating sphere's light output.
3. Radiometric measure of the entire target's light output.

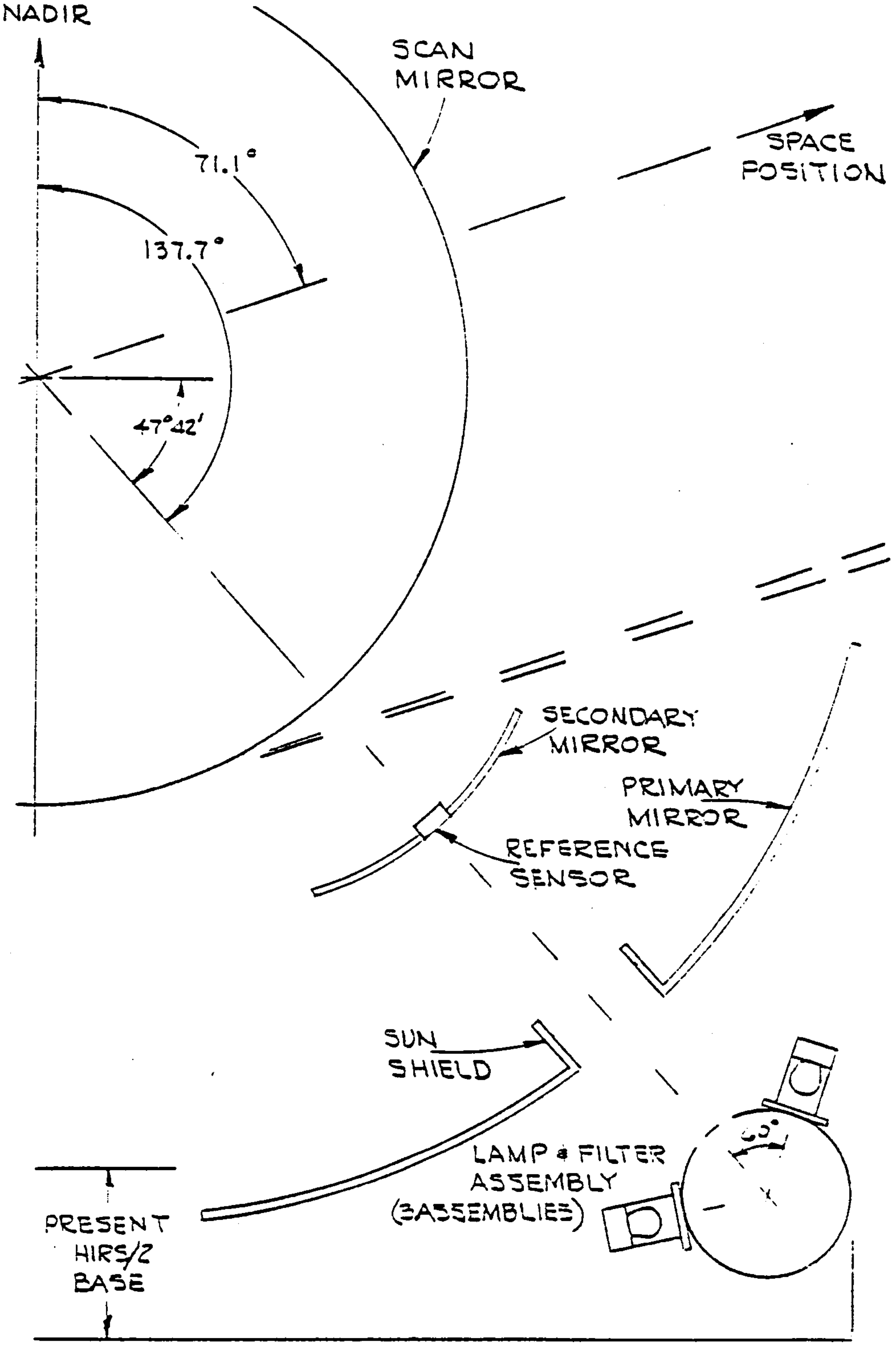


FIGURE 3-18 Internal Albedo Target

The lamps will be turned on in two steps to prevent stressing the lamps due to surge current and to preheat them for increased life, better repeatability, and more reliable operation. Turning the lamps off in two steps does not appear to be necessary but could be implemented. Thus the lamps will be off during normal system operation, run at a reduced level (approximately half power) during space view, run at full power during the albedo target view, and off during the warm target view. Each lamp will be of the vacuum type (as opposed to gas filled) and run at approximately 2200K which is less than full rated temperature. The peak power required will be approximately 4.5 watt for lamps and electronics. The orbital average is approximately 0.2 watt.

The lamps will be run in the current controlled mode to provide the long term stability required. This is preferred to controlling the lamps by the diode output as any change in the lamp current will not only change its brightness but also its spectral distribution. Thus it is possible to maintain the diode output constant in one channel yet get large variations in the other channels. An extreme example of this is if one lamp fails. Monitoring the output allows the user to adjust the albedo level if required for brightness and color temperature. The current controlled system is less sensitive to solar reflections and requires fewer parts.

The lamp power circuits will be controlled by a Lamp Enable command and a Lamp Disable command. When the Lamp Enable command is on, the albedo target will be turned on at every calibration cycle. When the Lamp Disable command is on, the albedo target will never be turned on. The reference diode and lamp current will be sampled independent of the command status.

The table below shows the output of the albedo target for the unfiltered condition, glass filter only, and with multilayer coated filters. The albedo levels provided by the target can be changed if required during the final design phase.

Internal Albedo Target

Channel Number	Unfiltered Output	Glass Filter	Multilayer Filter
20	175%	94%	50% albedo
21	18	17	17
22	975	20	20
23	3150	98	50

An initial design of the IAT collimating mirrors has been completed with the following specifications:

Primary Mirror: Diameter = 17.8cm (7.0 inch)
Radius of curvature = 14.2mm(5.6 in)
Eccentricity = -1.0

Secondary Mirror: Diameter = 5.1cm (2.0 inch)
Radius of curvature = 5.1cm (2.0 in)
Eccentricity = -2.99

Distance between Mirrors = 5.1cm (2.0 inch)

Distance from source to secondary = 7.65cm (3.0 in.)

Paraxial Focal Length = 26.8cm (10.6 inch)

The quality of the collimating target is shown in Figure 3-19 where the energy emitted by the target is seen to be contained within very low divergence angles.

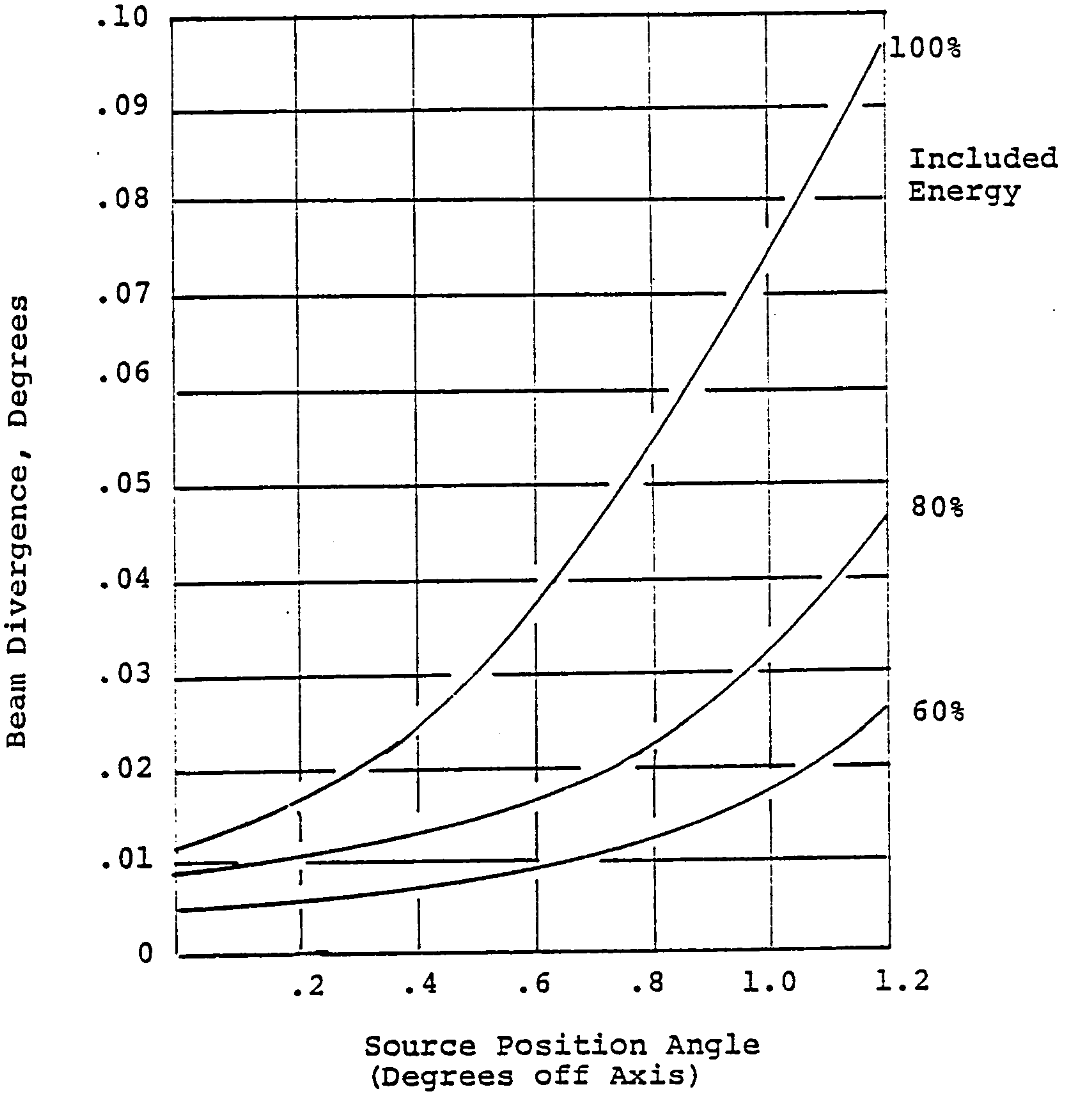


FIGURE 3-19 Internal Albedo Target Performance

3.4 Data Format

3.4.1 Modified HIRS Format

The requirements for data are based on the need to provide for the dynamic range of each channel and to collect data from at least alternate steps of the scan pattern. The four channels have specified NEΔN's that are 0.4% of the maximum anticipated radiance in each channel. This factor of 250 may be accommodated with an 8 bit system, with a 1 σ noise value of one count. In order to provide for tolerance in the dynamic range a 9 bit system will be provided.

In the present format there is much redundance where duplication was used as a convenient means of filling data slots. Table 3-3 is a data format having least impact on the initial format yet providing the 9 bit data for all 56 scan steps, space look and electronic calibration. Figure 3-20 compares the information contained in the present and new format on an element basis.

In the revision of the data format we reviewed each data item and revised the listing based on several factors:

1. The prime information is maintained in the same position as before.

2. Data is kept at the same bit position as before, if possible, so as to minimize changes in data reduction.

3. Data that is duplicated is now minimized.

4. Data (digital or analog-to-digital) that did not need to be measured in every element is given a position in elements 58 or 59.

Encoder Position is maintained in its original location in each element.

Electronic Cal Level (digital) is required only once, if at all, and is relocated in elements 58 and 59.

Channel 1 Period Monitor has been deleted from elements 0 - 57 and 60 - 63, but is given in elements 58 and 59 to provide a measure of filter wheel rotational rate stability.

Line Count Number has been relocated to elements 60 - 63.

Element Number has been deleted entirely. This number was generated only for output and was found to duplicate element identifiers presently in the TIP processor. It is our understanding that the NESS system does not rely on this number.

Filter Sync Designator has been relocated to elements 58 and 59 only, where they still verify the sync condition of the filter wheel.

Radiant Signal Output from the 20 HIRS channels appear in the same bit locations as before and retain 13 bit resolution. Radiant Signal Output from two of the new channels are added in the data of elements 0 - 57 at a 9 bit resolution. The data from the remaining two channels is stored and read out during retrace in elements 60 - 63.

Valid Data Bit remains in the same location in all elements.

Minor Word Parity Check remains as the last bit in each element.

TABLE 3-3 PROPOSED DATA FORMAT

ELEMENT 0 - 55

BIT 1 - 8	ENCODER POSITION
9 - 26	RADIANT SIGNAL, CH 21, 22, 9 BIT
27 - 286	RADIANT SIGNAL, CH 1-20, 13 BIT
287	VALID DATA BIT
288	MINOR WORD PARITY CHECK

ELEMENT 56

BIT 1 - 8	ENCODER POSITION
9 - 26	NEG ELECTRONIC CAL, CH 21, 22, 9 BITS
27 - 286	NEG ELECTRONIC CAL, CH 1 - 20, 13 BITS
287	VALID DATA BIT
288	MINOR WORD PARITY CHECK

ELEMENT 57

BIT 1 - 8	ENCODER POSITION
9 - 26	RADIANT SIGNAL (SPACE) CH 21, 22, 9 BITS
27 - 286	RADIANT SIGNAL (SPACE) CH 1 - 20, 13 BITS
287	VALID DATA BIT
288	MINOR WORD PARITY CHECK

ELEMENT 58

BIT 1 - 8	ENCODER POSITION
9 - 25	COMMAND STATUS*
26	FILTER SYNC DESIGNATOR
27 - 31	ECAL LEVEL
32 - 36	INST. S/N
37 - 48	PERIOD MONITOR (CH1)
49 - 52	FILL ZERO'S
53 - 65	INTERNAL WARM TARGET 1, 13 BITS
66 - 78	2
79 - 91	3
92 - 104	4
105 - 117	FILTER HOUSING TEMP 1, 13 BITS
118 - 130	2
131 - 143	PATCH TEMP EXPANDED, 13 BITS
144 - 156	RADIATOR TEMP
157 - 169	ALBEDO TARGET TEMP
170 - 182	PYRO TEMP
183 - 195	LAMP CURRENT 1
196 - 208	LAMP CURRENT 2
209 - 221	LAMP CURRENT 3
221 - 234	DIODE OUTPUT
235 - 247	ECAL DAC
248 - 286	SPARE
287	VALID DATA BIT
288	MINOR WORD PARITY CHECK

TABLE 3-3 CONTINUED

ELEMENT 59	
BIT 1 - 9	ENCODER POSITION
10 - 25	COMMAND STATUS
26	FILTER SYNC DESIGNATOR
27 - 31	ECAL LEVEL
32 - 36	INST S/N
37 - 48	PERIOD MONITOR
49 - 52	FILL ZERO'S
53 - 65	SCAN MIRROR TEMP
66 - 78	PRIMARY TELESCOPE TEMP
79 - 91	SECONDARY TELESCOPE TEMP
92 - 104	BASEPLATE TEMP
105 - 117	ELECTRONICS TEMP
118 - 130	PATCH TEMP-FULL RANGE
131 - 143	SCAN MOTOR TEMP
144 - 156	FILTER MOTOR TEMP
157 - 169	COOLER HOUSING TEMP
170 - 182	PATCH CONTROL POWER
183 - 195	SCAN MOTOR CURRENT
196 - 208	FILTER MOTOR CURRENT
209 - 221	+15 VDC
222 - 234	- 15 VDC
235 - 247	+7.5 VDC
248 - 260	-7.5 VDC
261 - 273	+10 VDC
274 - 286	+5 VDC
287	VALID DATA BIT
ELEMENT 60	
BIT 1 - 8	ENCODER POSITION
9 - 20	LINE COUNT NUMBER
21 - 25	FILL ZERO'S
26 - 286	CH 23 OUTPUT FROM ELEMENT 0 - 28
287	VALID DATA BIT
288	MINOR WORD PARITY CHECK
ELEMENT 61	
BIT 1 - 8	ENCODER POSITION
9 - 20	LINE COUNT NUMBER
21 - 25	FILL ZERO'S
26 - 286	CH 23 OUTPUT FROM EL 29 - 57
287	VALID DATA BIT
288	MINOR WORD PARITY CHECK

TABLE 3-3 CONTINUED

ELEMENT 62

BIT 1 - 8	ENCODER POSITION
9 - 20	LINE COUNT NUMBER
21 - 25	FILL ZERO'S
26 - 286	CH 24 OUTPUT FROM 0 - 28
287	VALID DATA BIT
288	MINOR WORD PARITY CHECK

ELEMENT 63

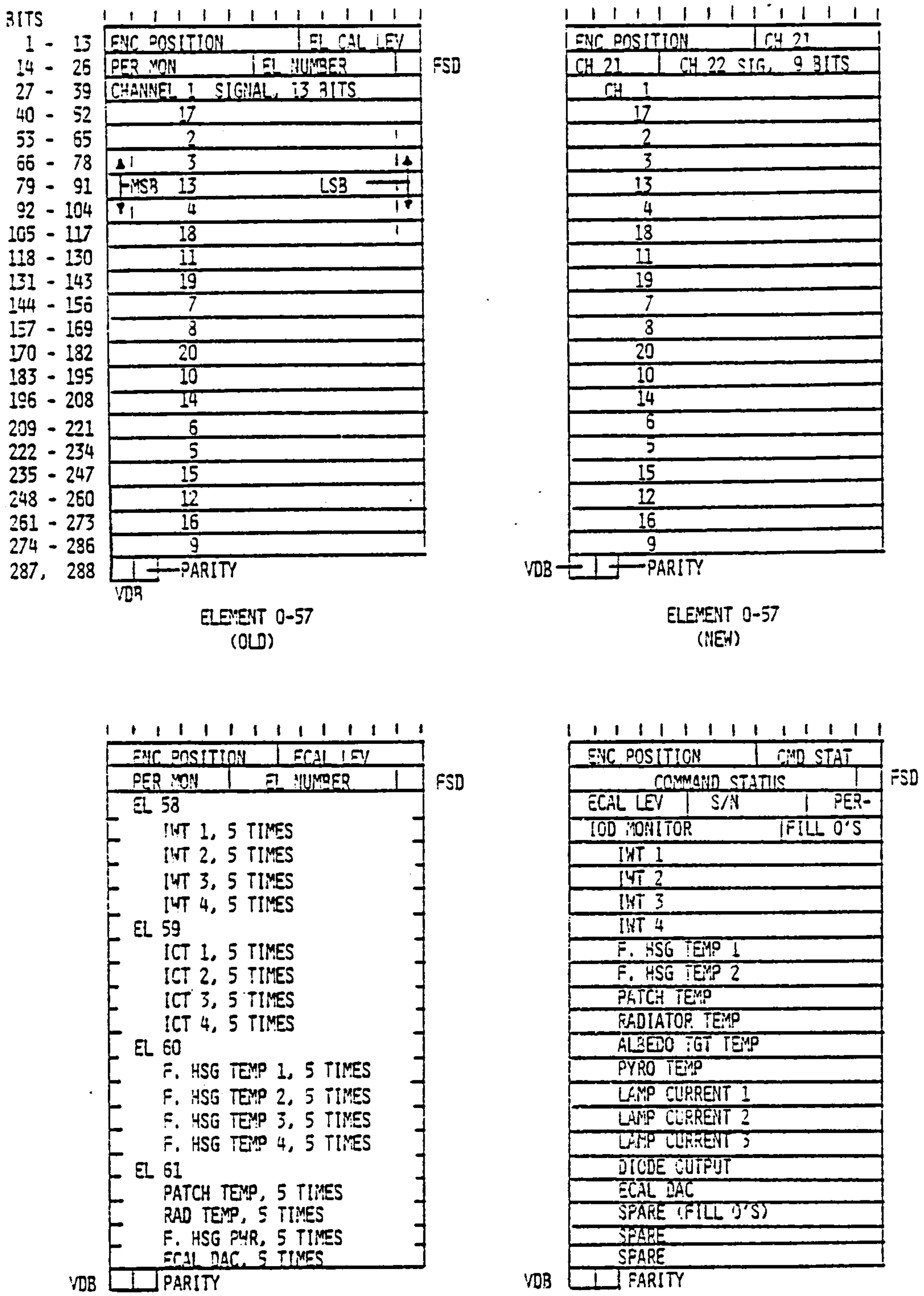
BIT 1 - 8	ENCODER POSITION
9 - 20	LINE COUNT NUMBER
21 - 25	FILL ZERO'S
26 - 286	CH 24 OUTPUT FROM ELEMENTS 29 - 57
286	VALID DATA BIT
288	MINOR WORD PARITY CHECK

ELEMENT 58

*BIT 9	Instrument ON/OFF	ON = 1
10	Scan Motor ON/OFF	ON = 0
11	Filter Wheel ON/OFF	ON = 0
12	Electronics ON/OFF	ON = 0
13	Cooler Heat ON/OFF	ON = 0
14	Internal Warm Tgt. Pos	True = 0
15	Internal Cold Tgt. Pos	True = 0
16	Space Pos.	True = 0
17	Nadir Pos.	True = 0
18	Calibration Enable/Disable	Enabled = 0
19	Cover Release Enable/Disable	Enabled = 0
20	Cooler Cover Open	Yes = 1
21	Cooler Cover Closed	Yes = 1
22	Lamp Enable/Disable	Enabled = 0
23	Patch Temp Control ON/OFF	ON = 0
24	Filter Motor Power HIGH	Normal = 1
25	Clamp Memory HOLD/RUN	HOLD = 0

*Command Status Bits

FIGURE 3-20 Data Format Modification



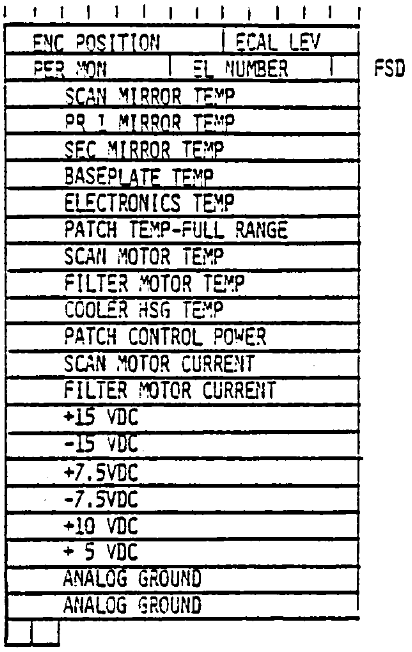
ELEMENT 0-57
(OLD)

ELEMENT 0-57
(NEW)

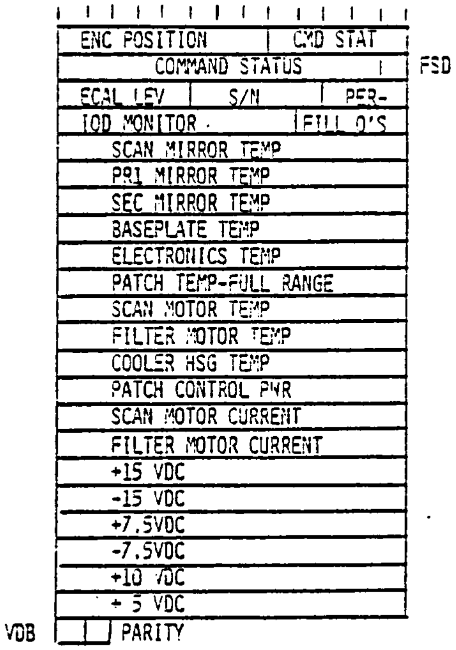
ELEMENT 58, 59, 60, 61
(OLD)

ELEMENT 58
(NEW)

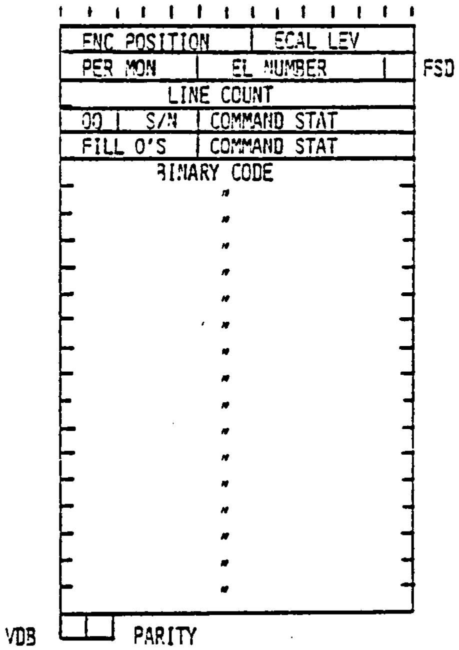
FIGURE 3-20 (Cont'd) Data Format Modification



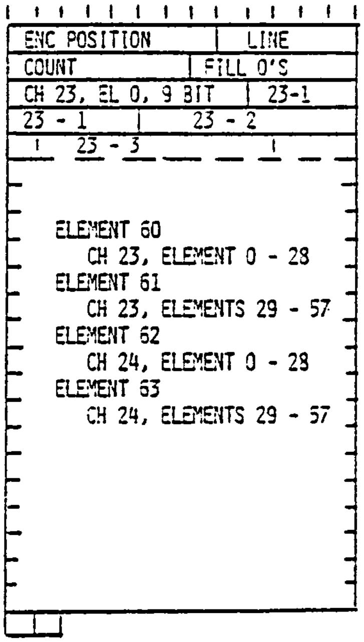
ELEMENT 62
(OLD)



ELEMENT 59
(NEW)



ELEMENT 63
(OLD)



ELEMENTS 60, 61, 62, 63
(NEW)

The data format for Elements 0 through 57 remain identical, with electronic calibration signals appearing in element 56 and the space look in element 57.

Elements 58 and 59 have a new location for the digital telemetry, with sufficient space for full resolution of each measurement. There are 39 bits unassigned in these elements, permitting addition of three analog teletry points if required. (Thirty-two analog telemetry functions are presently included).

Elements 60 - 63 will contain the stored data of Channels 23 and 24. The format of these elements is identical, with the channel and sampled element changing consecutively.

3.4.2 Alternate Format

The addition of ERB data from HIRS may be accomplished with very little change to the present format if 32 bits of data space could be made available in each TIP minor frame. Information from the four ERB channels could be processed in the HIRS instrument but assembled in a separate data formatter that would respond to a separate TIP "select" signal. The data would be retrieved coincident with the HIRS data for that element time and be as completely correlated with the HIRS data as if it were in the data stream as described in section 3.4.1. The format is shown in Table 3-4.

The 32 bits of extra data would contain the full 9 bits of channel 21, 22 and 23 for each element. Channel 24 data would be collected for two element periods, with its value read out in two successive elements since only 5 bits remain of the 32 for one element. This seems to be a reasonable compromise, permitting the present HIRS data processing to be unaffected by the added ERB capability. The quality of channel 24 may be increased to ten bits in this application.

TABLE 3-4 ERB DATA OUTPUT

Alternate Format

ELEMENT 0 - 57

Bits 1 - 9	CHANNEL 21 OUTPUT, 9 BITS
10 - 18,	CHANNEL 22 OUTPUT, 9 BITS
19 - 27,	CHANNEL 23 OUTPUT, 9 BITS
28 - 32	(EVEN ELEMENTS), CHANNEL 24, 5 MSB
28 - 32	(ODD ELEMENTS), CHANNEL 24, 5 LSB

ELEMENT 58

Bits 1 - 10	ALBEDO TARGET TEMP 1, 10 BITS
11 - 20	2, 10 BITS
21 - 30	PYROELECTRIC TEMP , 10 BITS
31 - 32	FILL ZEROS

ELEMENT 59

Bits 1 - 10	LAMP CURRENT 1, 10 BITS
11 - 20	2, 10 BITS
21 - 30	3, 10 BITS
31 -	LAMP ENABLE COMMAND STATUS ENABLE = 0
32 -	FILL ZERO

ELEMENT 60

Bits 1 - 10	DIODE OUTPUT 1, 10 BITS
11 - 20	2, 10 BITS
21 - 30	3, 10 BITS
31 - 32	FILL ZEROS

ELEMENT 61, 62, 63

Bits 1 - 32	FILL ZEROS - (SPARE)

The quality of the other data may be adjusted to simplify data conversion and processing. Using a 10 bit A/D converter for all ERB data will provide high quality measurement of all telemetry. The temperature of the components will be read to approximately 0.05°C. More positions may be included such as a lamp and a reflector temperature measurement of the albedo target. The reference diode value may be sampled more than one time, permitting averaging to reduce noise in the calculated value.

The availability of four additional 8 bit words in the TIP format is recognized as a problem. This must be considered as the complement of instruments is established for each of the NOAA satellites. The timing of the words within the TIP format and the separation of the 4 words are non-critical to the data formatting and memory that holds this information.

3.5 Electronic System

3.5.1 General

The inclusion of the added four channels will impact the electronics system by adding more circuitry but not the basic methods of data handling. The major addition will be the four detectors and signal processing chains. These are shown in Figure 3-21 with the Channel 20 signal processor chain to indicate how the systems will be combined.

3.5.2 Channel 21-23 Signal Processing

The timing of the new channels is shown in Figure 3-22, noting that the signals generated in Channels 20, 21, 22 and 23 occur simultaneously. Each of the new channels has its own analog to digital converter capable of storing the converted

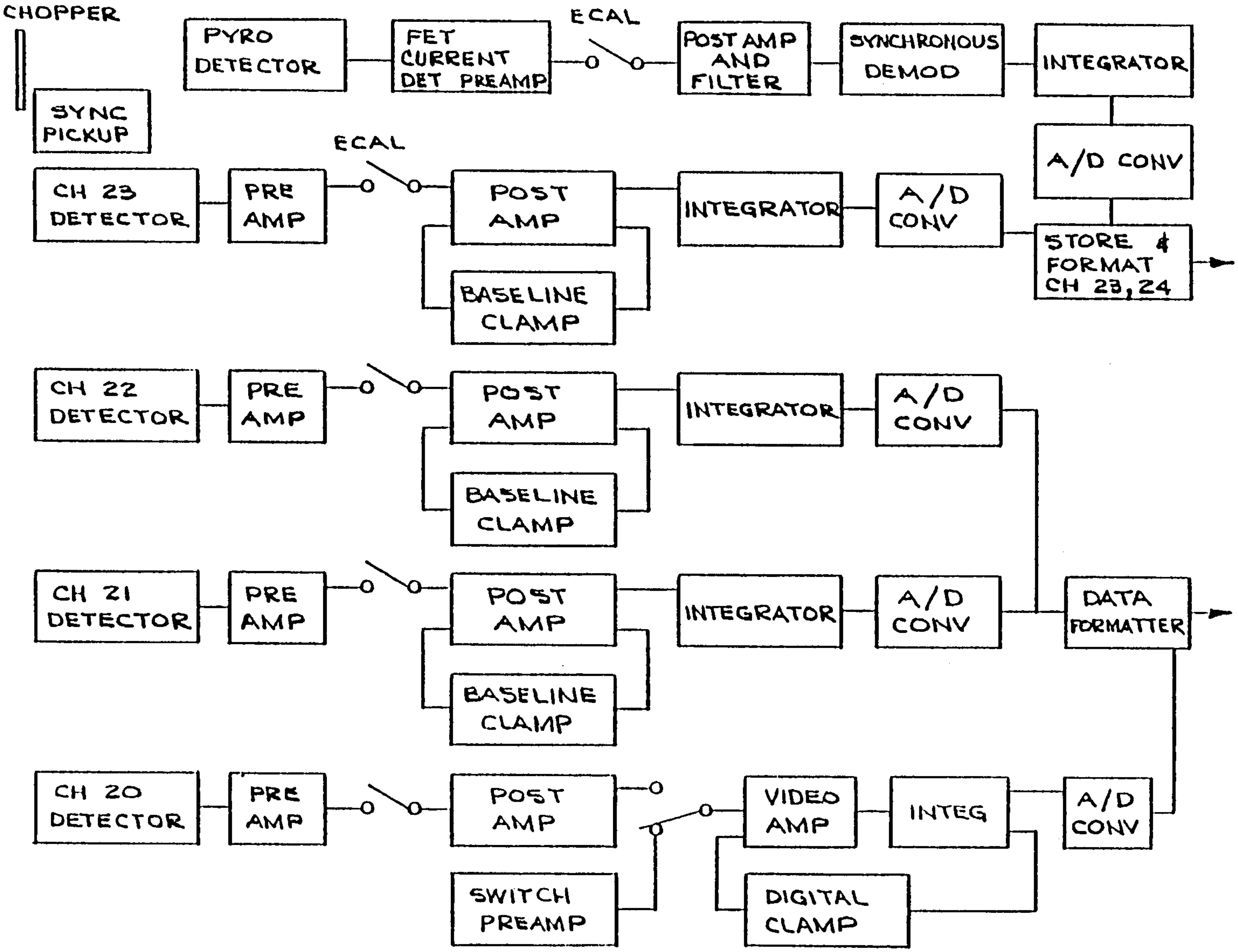


FIGURE 3-21 Electronic System

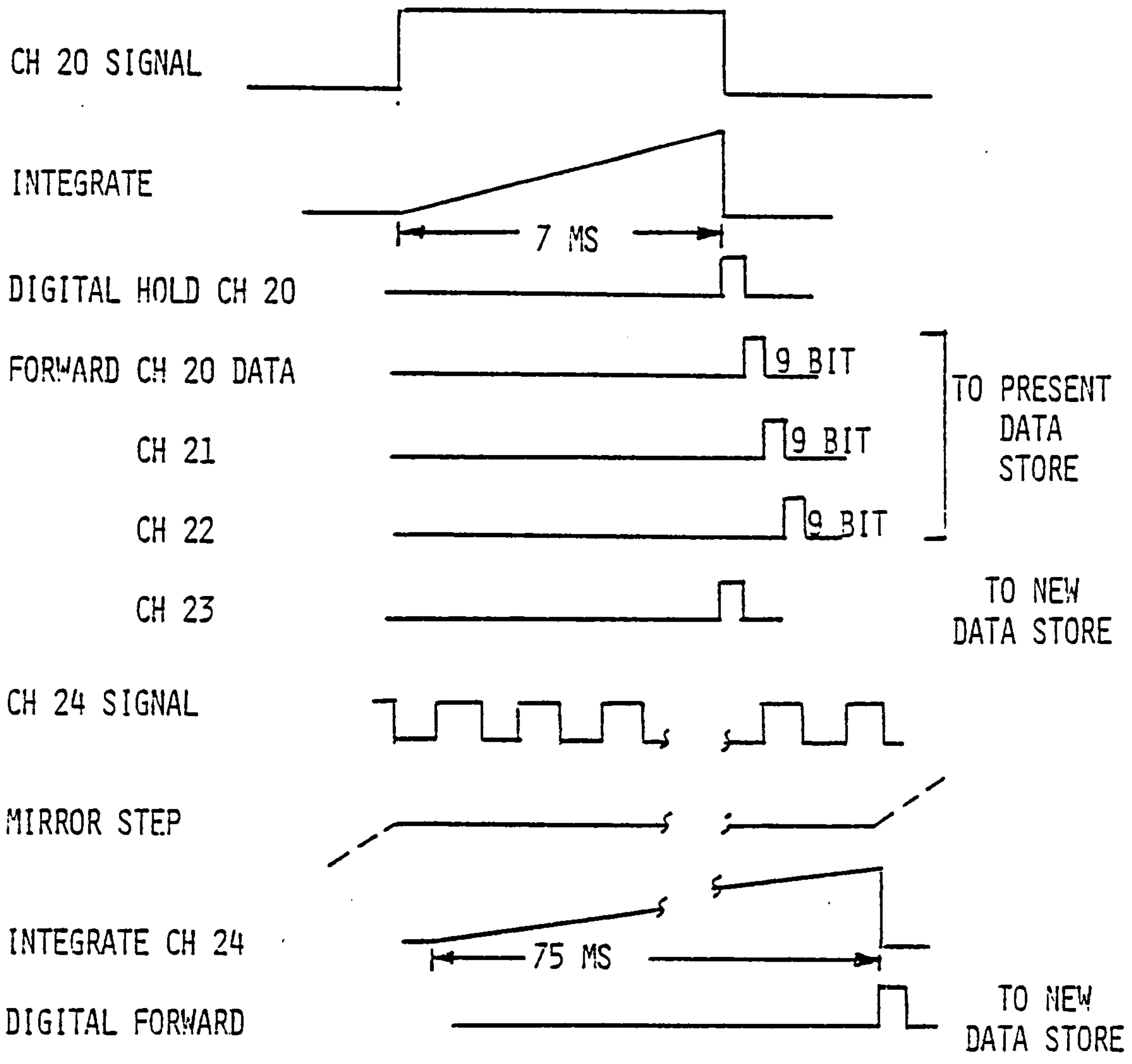


FIGURE 3-22 Signal Timing

signal to permit time multiplexing into the data formatter. The digital data from channels 21 and 22 are fed into the same data formatter now used for all of Channels 1 through 20. Data from channels 21 and 22 are read out of the system in each element time period in bits 9 - 26, and fit into the present data multiplexing system very easily.

The signal processing for channels 21-23 will be much like that of the present channel 20 in that all these channels have the same input signal timing and similar detectors. The germanium detector for channel 23 is a high-speed, high-impedance photovoltaic sensor like the silicon detectors. All preamplifiers will be nearly the same with gains adjusted for the individual detector and signal amplitudes. The three new channels will use a clamp level from the filter wheel as a baseline clamp. (There will be no space clamp for these channels).

As each signal is integrated and converted to digital form in individual converters the data is held for specific timing signals which shift the data into the proper timing slots in the data formatter. The modifications to the data format for inclusion of ERB data make the addition of channels 21 and 22 very simple, requiring no additional circuit components. For channel 23 and 24 a new data formatter and control board will be required.

Electronic calibration signals will be injected into the amplifier chain as increasing step levels just as now occuring in channel 20.

3.5.3 Channel 24 Signal Processing

The output from channel 24 is unique to the HIRS system, but is easily implemented. As a completely separate channel not using a filter in the filter wheel, the signal will be processed by conventional chopper modulation techniques. As seen earlier in Section 3.1 the optical bundle is focused after the longwave beamsplitter. This beam is chopped and relayed to the pyroelectric detector. The chopper teeth are mounted to the filter wheel, providing a constant chopping rate of 200 Hz. The signal occurs continuously, but will be sampled only during the mirror dwell time of 0.075 seconds for each element, providing a constant chopping rate of 200 Hz. The signal occurs continuously, but will be sampled only during the mirror dwell time of 0.075 seconds for each element, providing registration with the other channels.

Signal processing of the pyroelectric sensor output includes the use of a low noise current mode preamplifier optimized for the detector and frequency band. This a-c signal will be amplified and demodulated using phased pickup signals from an LED sensor on the chopper. After demodulation the signal will be integrated for the full 0.075 seconds, converted to 9 bit digital form, and passed on to the data storage circuits. At an integration time of 0.075 seconds the channel 24 signal has an effective bandpass of 6.7 Hz. This permits the a-c amplifiers to have a narrow bandpass and to reduce the effect of potential microphonics to this very narrow band at 200 Hz. Care in mechanical design can assure low mechanical vibration levels at this frequency, using well known vibration isolation methods.

Electronic calibration signals will be inserted in the data stream after the low noise preamp. This will be an increasing step level that is modulated by the phase reference pickup such that the 32 calibration levels will occur in sequence on successive lines. Since the input scene temperatures are lower than the 288K chopper temperature the signals will always be in the same polarity. The electronic calibration signal will therefore be unipolar and encompass the range of input from space to internal warm calibration target conditions.

3.5.4 Electronics Implementation

Addition of the necessary electronics for the four ERB channels requires only moderate changes to the system. All of the new circuits are low power demand, adding less than 0.1 watt to the system power budget. All of the power supplies and regulators can provide this extra load with no change in design or loss of reliability.

Shielded leads will go from the new detectors to new preamplifier boards in the electronics nest. The four amplifiers can be mounted on two new boards, shielded from the other circuitry for low noise operation. These preamplifiers will have sufficient gain that signal levels will be above circuit noise when transmitted to the signal processing boards. Two (or perhaps only one) board(s) will contain the channel 24 demodulator and all of the new integrators and A/D converters. Channel 21 and 22 digital data will be routed to the present data formatter board, requiring no added board. The channel 23 and 24 data will be routed to a new storage and data formatter board. This board must contain storage capacity for the 58 x 9 x 2 bits that will accumlate during a line scan. One board will be able to hold these components. A second board (perhaps replacing the present formatter logic) will contain the added control logic for timing and routing of the stored data. From this, in summary, we see a need to add two preamp boards and two to four signal and data processing boards.

3.5.5 Albedo Target Electronics

The albedo reference lamp and sensor assembly will require electronics for command, control and monitoring. The albedo reference, see Section 3.3, will be turned on only infrequently, by ground command. A command of Lamp Enable, when in the Calibration Enable Mode will cause the lamp to come on during the next auto-calibration cycle and repeat until Lamp Disable is sent. During scan line 0, (at space look) the lamps will be turned on to a low value, about one-fourth maximum power. This 6 second interval permits the lamps to start heating. At the time of slew to the visible target the lamp will be brought to full power. The time constant of these three small (T1-3/4) lamps is such that they reach final color temperature and current conditions within a few tenths of a second.

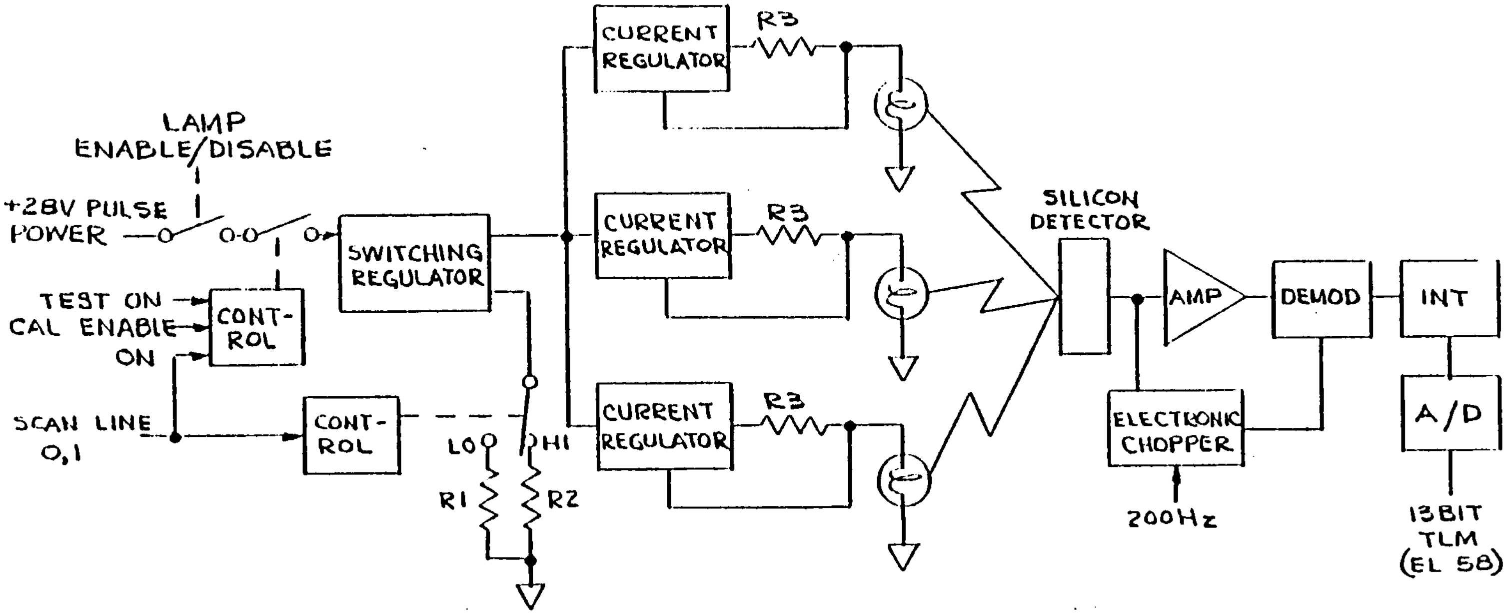
The four widely separated spectral channels being calibrated by the lamps are greatly affected by the source color temperature. This is directly related to lamp current and is not measurable from a single diode sensor. If the system were under the control of the diode output a change in output would call for more or less current to the lamps. This would change the color temperature as well as increase the total energy output. A change in color temperature would cause the calibration to be incorrect. An extreme case would occur if one of the lamps were to open. Regulating the current to the lamps may be designed to be very precise, permitting fine control of the lamp output and color temperature. If more than one light level is desired it is best to operate only one or two of the lamps, but at the same current. As a brightness monitor the detector diode would operate best if it were sensitive over a narrow spectral band. This would provide a measurement of the energy from one narrow part of the black body curve. Knowing the color temperature of the lamps and the filter characteristics it is then possible to calculate the total flux from the target. Selecting this band to be the same as that of channel 20 (0.69μm) would provide a good comparison between the source monitor and system output at a high resolution.

The lamp control system is shown in Figure 3-23 and the timing of lamp power in 3-23. A slow increase of current will prevent stress on the lamps and assure low power supply transients. The lamps will have 14 volts drop at rated current of 0.080 amperes. We plan on operating the lamps at full power to achieve the 2200K color temperature. The albedo reference assembly will be calibrated by comparison of signal output when looking at the NASA integrating sphere and at the albedo reference. The electronic circuitry for the lamp current control will consist of three LM117 current regulators having the sense resistors (R3) adjusted for 0.080 amperes in each lamp. (These are high precision, stable Vishay resistors). The voltage drop across R3 is 1.2 volts at the regulating point. The current regulator requires about 2.5V drop for proper operation. For maximum efficiency a switching regulator (as used in scan drive) will be set for a voltage output of 18.0 volts, providing nearly 75% efficiency for the current regulator electronics. The current regulators will prevent current surges in the lamps since the current will not be allowed to exceed 0.080A even under low resistance turn-on conditions. During line 0 the switching regulator will be set to a low voltage of about 10V to provide a warming current for the lamps.

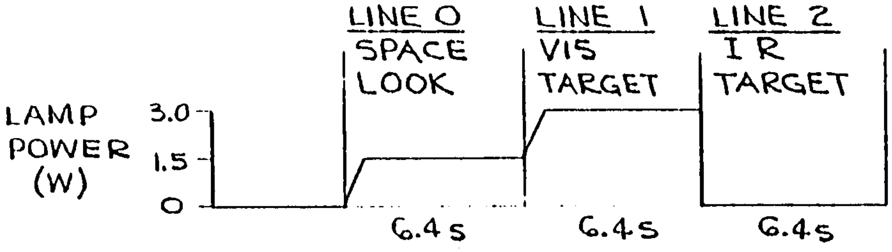
Sensing of the lamp output will be accomplished by a silicon diode looking through a narrow band spectral filter at the integrating sphere. The detector output will be electronically chopped at 200 Hz rate to provide amplifier stability. After sufficient amplification the signal is demodulated and integrated for 5.6 seconds. The integrator output is held until element 58 when it is fed to the 13 bit A/D converter used for other telemetry. The output will be included in the data stream. When the lamp is off the sensor output remains constant at a given count level (unless disturbed by sun input or noise). The sensor will measure the output during scan line 0 and scan line 1, only scan line 1 will be used for reference comparisons.

Electronics components for the Albedo Reference lamp and sensor will require additional circuit boards. Lamp control, consisting of a switching regulator and three current regulators and associated control circuitry, may be mounted on one standard 5 x 7 inch printed board with space to spare. The power dissipated in the current regulators during their peak period is in the order of 0.6 watts total and another 0.3 watts in the control resistors. The switching regulator will dissipate less than 0.25 watts for a total of 1.15 watts on this board for 6.4 seconds, and perhaps 0.5 watts for the 6.4 seconds of warming during scan line 0. This short time period reduces average power on the board to 80 mW over a 40 scan line period.

FIGURE 3-23 Albedo Lamp Control



a) ELECTRONICS



b) TIMING

Total power dissipation by the three lamps and their regulators may be determined as:

Scan Line 1;	Lamp power 3 x 14 x .08 =	3.36W
	Regulator power	1.15W
	Peak Power Demand	4.51W
Scan Line 0;	Lamp Power 3 x 7 x .04 =	.84W
	Regulator Power	.50W
		1.34W

Average power over 40 lines = 5.85/40 = 0.15W

The electronics for the sensor signal processing may be included in one of the other preamp or signal processing boards since there are perhaps seven integrated circuit parts required. The A/D converter is not a new part, being the same converter now used in all channel and telemetry conversions. A half-board will be planned for this circuit.

The registration of the new channels is controlled by the telescope field stops and thus should be aligned with the present HIRS channels and all the alignment and uniformity data presently generated will also be available for them.

4.0 HIRS/ERB PERFORMANCE

Table 4-1 shows the expected radiometric performance and the major parameters affecting the albedo channels. The NEΔN is better than the required value by 80 times in channel 23, by 100 times in channel 22, and by 150 times in channel 21. The detectors are similar to the present channel 20 detector and should be easily implemented. All the albedo channels should have NEΔN values limited by digitizing noise.

Table 4-2 shows the expected performance of channel 24 and the major parameters affecting it. The NEΔN is expected to meet the specification value but may require special consideration due to the properties of pyroelectric detectors. This channel has its own chopper and field stop to ensure as stable and noiseless performance as possible. The detector active area size does not determine the FOV size and detector nonuniformities should not distort the FOV. The entire detector and chopper assembly is mounted in the thermally isolated filter wheel to prevent any temperature problems. The optics design provides a small area detector to minimize the vibration noise term. Additional techniques are available, such as adding a detector window, if it should be required when all the contributing factors are finalized in the detail design.

The registration of the new channels is controlled by the telescope field stops and thus should be aligned with the present HIRS channels. The out-of-field response, FOV size, and FOV contours should be very close to the present channel 20 values. The additional channels will be aligned in the same manner as the present HIRS channels and all the alignment and uniformity data presently generated will also be available for them.

TABLE 4-1 ALBEDO CHANNELS PERFORMANCE

$$NE\Delta N = \frac{\alpha N_T}{A_o \ \Omega_o \ T_o \ \Delta_\nu \ R_\lambda \sqrt{2t_d}}$$

A_o = Collection Area = 1.3×10^{-2} m^2

Ω_o = Solid Angle = 4.7×10^{-4} ster

T_o = Optical transmission

Δ_ν = Optical Bandwidth cm^{-1}

R_λ = Detector Responsivity A/W

t_d = Integration time = 6.8×10^{-3} sec.

α = degradation Factor = 2.0

N_T = Total Noise Amp

NEΔN is in mW/m^2 ster cm^{-1}

		21	22	23
Optical Bandwidth	Δ_ν	2000	400	400
Optical Transmission	T_o	0.054	0.047	0.018
Detector Responsivity	R_λ	0.2	0.4	0.7
Shot Noise	$\sqrt{2eI}$	6×10^{-13}	2×10^{-12}	2×10^{-12}
Johnson Noise	$\sqrt{\frac{4KT}{R}}$	9×10^{-13}	9×10^{13}	9×10^{-13}
Amplifier Noise		3×10^{-12}	3×10^{-12}	3×10^{-12}
Total Noise		3×10^{-12}	3×10^{-12}	3×10^{-12}
Calculated NEΔN		.0004	.001	.001
Specification NEΔN		.060	.100	.080

TABLE 4-2 CHANNEL 24 PERFORMANCE

$$\mathrm{NE\Delta N} = \frac{\alpha\sqrt{A_D} \quad \sqrt{\Delta F}}{A_o \ \Omega_o \ T_o \ \Delta_\lambda \quad CSD^*}$$

A_o = Collection Area = 1.3×10^{-2} m^2

Ω_o = Solid Angle = 4.7×10^{-4} ster

T_o = Optical Transmission = .30

Δ_λ = Optical Bandwidth

C = Chopper Factor = 50%

S = Shape Factor = 0.7

D* = Detector D-Star = 1.5×10^8 cm $\sqrt{HZ}/W$

α = Degradation Factor = 2.0

A_D = Detector Area = .16 cm^2 (4mm square)

ΔF = 1/2t = Electrical Bandwidth

t = Integration time = 0.07 sec

NEΔN is in mW/m^2 ster cm^{-1}

NEΔN Calculated = .44 for initial 50 cm^{-1} optical bandwidth

= .15 for final 150 cm^{-1} optical bandwidth

NEΔN Specified = .60 for 50 cm^{-1} bandwidth (independent of $\Delta\lambda$)

5.0 IMPACT ON PRESENT SYSTEM

5.1 Radiometric

Installation of the new and revised optic elements will have little effect on the radiometric performance of each of the present HIRS channels. Longwave channel 1 is the most likely to be affected by the addition of channel 24. Changes to the substrate of the LW-SW beamsplitter and the coatings of the beamsplitter and LW folding mirror-beamsplitter were reviewed in detail in section 3.1. Information from Optical Coating Laboratories, Inc. show that the change in optical transmission at 15μm will be in the order of 5% or less. This is an estimated value from computed response of multilayer interference surfaces, however, past experience has shown these predictions to be fairly accurate. A change in transmission of 5% will result in a 2 to 3% change in NEΔN, and will be unrecognized in a measurement of system performance. It might be noted that the longwave detector collects energy coming from or through a total of ten optic elements, each having significant variation in transmission for a total throughput of only about 5%. The detector response at 15μm is changing rapidly and may vary from unit to unit by a factor of 3 or more. The slight change in throughput caused by the new elements is therefore considered negligible.

The shortwave channels (13 through 19) are not expected to be degraded by the changed LW-SW beamsplitter. The present coating is satisfactory for passing the 18-25μm energy and will be maintained for the revised system. The SW-VIS beamsplitter is now acceptable for use with the new albedo channels. If the need for more transmission at 1.6μm were to evolve, we would permit no reduction of 3.5μm reflectance below present specification. The shortwave channels are therefore to be considered completely unaffected by the proposed modification.

Addition of optic elements in the path of the channel 20 detector will cause some reduction of energy to that detector. The present signal level is high enough that a specified level of 0.1% albedo is below 0.5 count of system output. At that level the digitizing uncertainties are the limiting factor. In the modified system the video level will still be below digitizing noise level and any change will be unobservable. The impact on channel 20 output is therefore negligible.

5.2 Physical

Physical changes to the HIRS/2 system are listed in Table 5-1 and will have a significant impact on the instrument. Figure 5-1 shows the instrument and its new components. The outline configuration of Figure 5-2 shows that the only external dimensions affected are in the Z axis where the electronics nest is extended 3.1 inches. The nest is recessed for the connectors to reduce cabling extension beyond the Instrument Mounting Platform (IMP) edge. This configuration is only tentative, with options for reduction of the extended length by placing some electronics boards in other locations. There appears to be sufficient available volume for a variety of configuration selections to assure compatibility with the spacecraft.

5.3 Interface

The spacecraft interfaces will be affected by the physical, electrical and data format changes of the HIRS/ERB. The data format changes do not affect the TIP system since all information is included in the HIRS data allocation. If the alternate format were used there would be a need for new "C Select"

Table 5-1. PHYSICAL CHANGES TO HIRS ASSEMBLIES

Telescope

- Replace folding mirror with new beamsplitter
- Change beamsplitter coating & substrate
- Add pyroelectric lens
- Add field stop for CH 24

Filter Assembly

- Add CH 24 chopper to wheel
- Move CH 20 filter from wheel to relay
- Modify sync pickup ass'y
- Enlarge filter housing

Relay Optic Assembly

- Change SW-VIS beamsplitter coating
- Add CH 20-23 optic, detector parts

Electronic Assembly

- Expand housing to hold 8 more boards
- Change wiring for command, interfaces
- Change data formatter and control boards

Albedo Target Assembly

- Replace cold target with lamp/optic ass'y

Baseplate Assembly

- May require modification for IAT, new electronics housing, wiring, added mounts
- Modify thermal blankets for new outline

Cooler Assembly - No change

Scan Assembly - No change

Warm Target - No change

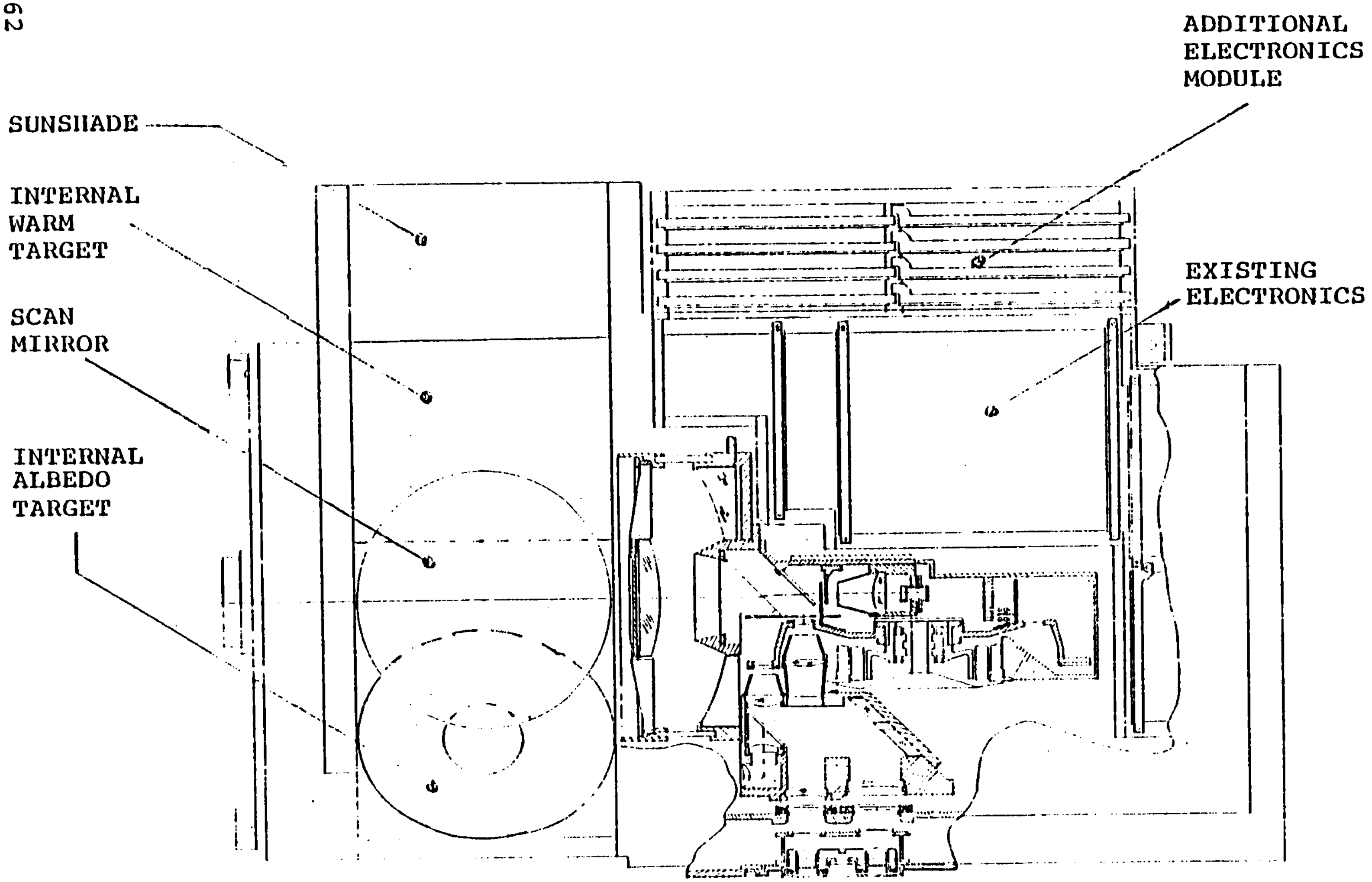


FIGURE 5-1. HIRS/ERB Instrument Design

ITT AEROSPACE/OPTICAL DIVISION
FORT WAYNE, INDIANA, U.S.A.
INTERNATIONAL TELEPHONE AND TELEGRAPH CORPORATION

HIRS/ERB Dimensions (Inches)
(HIRS/2I Dimensions)

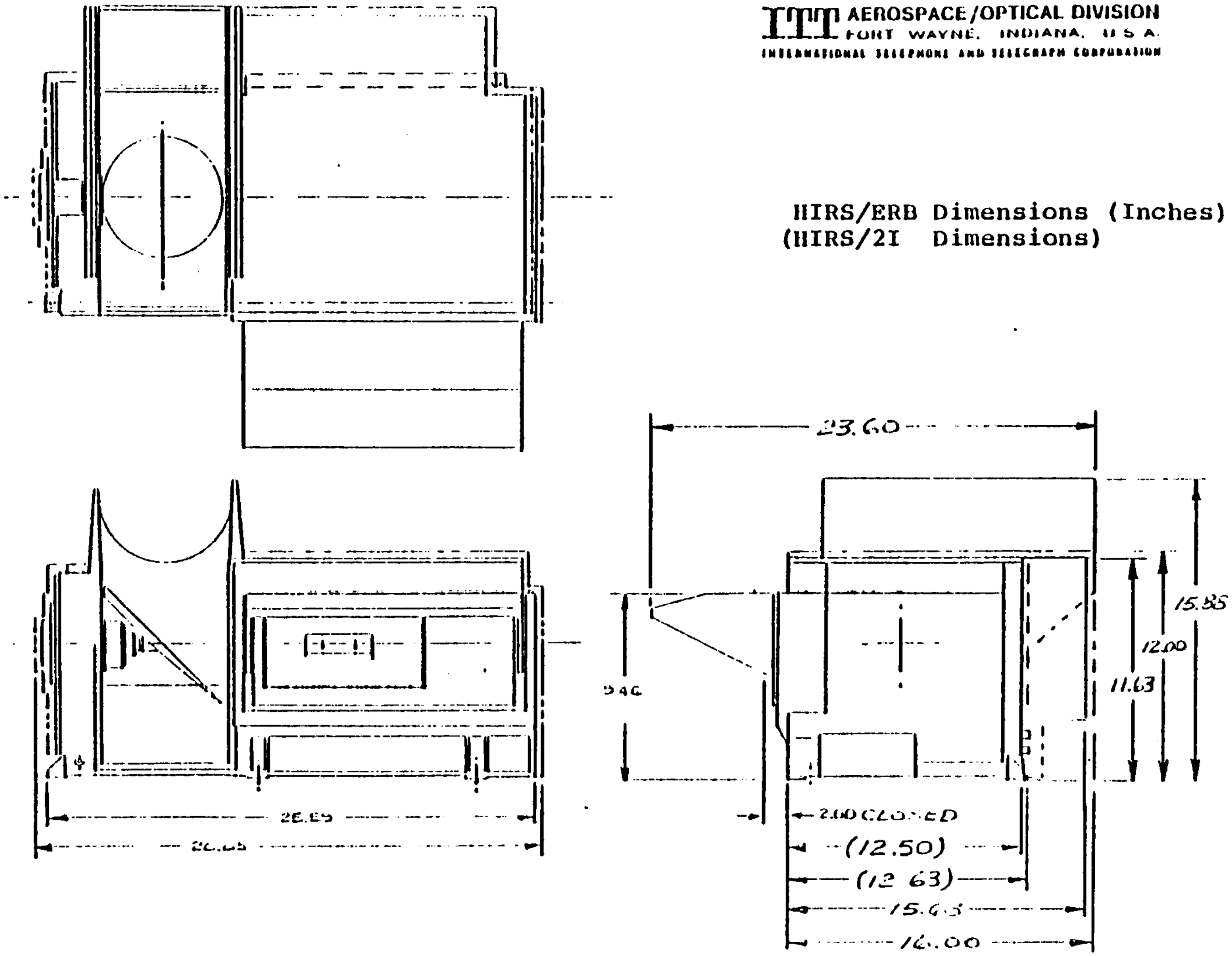


Figure 5-2 Outline Dimensions of the HIRS/ERB

pulses to call ERB data from the modified HIRS.

Command and control will have one change. A "Lamp Enable Disable" command must be added for operator control of calibration time for the albedo channels. Some changes may be made to the analog telemetry for monitoring of pyroelectric temperature.

Location of the modified instrument on the IMP is shown in Figure 5-3, where there is some possibility of interference with the solar panels in their closed position. A definition of the configuration limits may be met in a more complete layout after the true system requirements are known.

A rough estimate of the added mass of the new components increases the mass of the instrument from 32.3 kg (71 lb) to 35.2 kg (77.5 lb). The longwave optics and detector and new albedo channel optics and detectors are expected to add 0.7 kg (1.5 lb) and the added electronics will add 2.7 kg (6.0 lb). The center of gravity will shift in the +Z direction, depending on final system design.

Power for the new system components will increase the average demand from the 28 volt regulated supply by less than 0.1 watt if the albedo reference lamp is not used. This lamp may require as much as 4.5 watts when the lamp is on. Averaged over a 40 line calibration period this is only 0.15 watts. It is likely that the lamp will be used only intermittently, reducing the average power accordingly. From this we can assume little if any effect on power demand or instrument power dissipation.

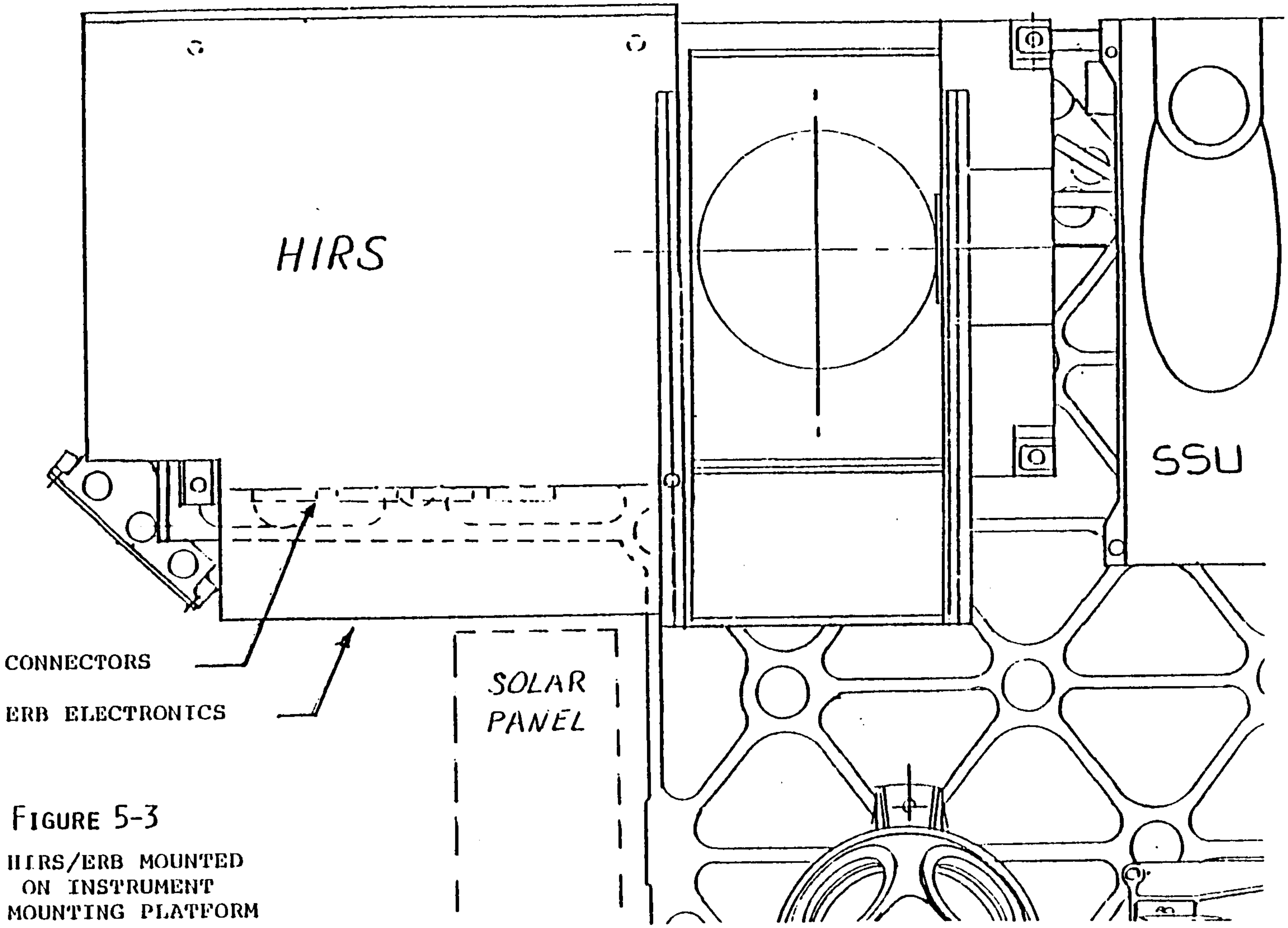


FIGURE 5-3

HIRS/ERB MOUNTED
ON INSTRUMENT
MOUNTING PLATFORM

Operating procedures for the modified instrument will not change other than control of the Lamp Enable command. Data reduction and formatting will be changed in the separation of information from the new format. None of the quality of the radiometric or telemetry information has been reduced.

6.0 SCHEDULE

A tentative schedule for the fabrication and test of two added instruments has been developed for NASA planning and reviewed for the impact of adding ERB channels. Planning is based on concurrent design detailing and common parts buys for the basic instrument and the added channel requirements. Under these conditions the added tasks will expand some consecutive efforts in assembly, alignment and test of the optical parts and new subsystems.

From this review an estimate of one month delay in the alignment and test of the system is predicted at the time of integration of the optics into the system. Another month may be expended at the system level as the complete instrument alignment and test of the new channels are performed. Delivery of the first instrument will therefore be delayed two months and the remaining two instruments delayed one to two months.

A schedule of tasks and milestones was made for Flight Models 8 and 9 as shown in Figure 6-1. The impact of the ERB may be seen as adding time to these programs. A firm schedule for the Flight Models for NOAA H, I and J will be prepared after NASA/NOAA produce a hard specification and delivery requirement for these instruments. A tentative start of activity in February 1981 is shown and is relatively important. Completion of design

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FORT WAYNE, INDIANA

PROGRAM *HIRS/2 IMPROVEMENT*
DATE *5-7-80*

Type Schedule	Number
☐ Program Master	
☐ Detail Program	
☐ Work Package	
☐ Work Package Task	

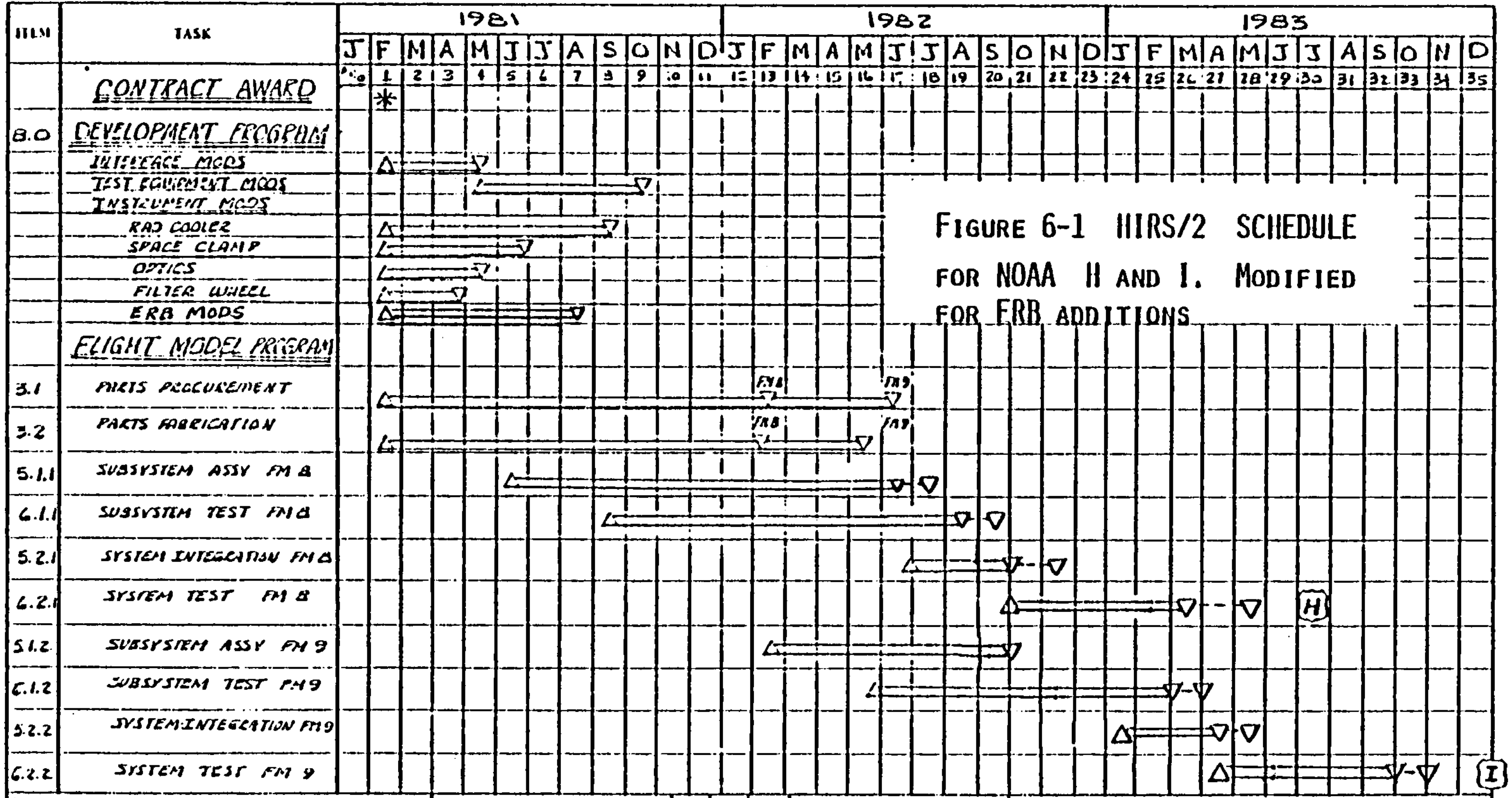

FIGURE 6-1 HIRS/2 SCHEDULE FOR NOAA H AND I. MODIFIED FOR ERB ADDITIONS

LEGEND
△ Start ◇ Intermediate Milestone ▽ Complete
▲ ◆ ▼ Actuals
△ ◇ ▽ Plan
△ ◇ ◇ ▽ ▽ Change/Slippage
▲ ◆ ▽ On Schedule
▲ ◆ ▽ Ahead of Schedule
▲ ◇ ▽ Behind Schedule

Prepared By *D. MELTON*
Dept *833B* Date *5-7-80*
Approval
Contract No
Project No
Next Higher Schedule

Rev	Date	App'd	Reason

REMARKS
⬡ NASA REQUIREMENT
--▽ ERB EXTENSION

detailing is necessary in time to permit the long lead times typical of optic parts and microcircuits. Optic design of the new components is a major task to meet the schedule. The other design details and parts requirements for the ERB channels are not more complex than those of the planned taks, so would not cause added time in the initial phase of fabrication, although the general level of design effort must be increased to perform the necessary tasks.

7.0 COST ESTIMATE

A rough order of magnitude cost estimate was prepared for the added development, detailing, fabrication and test of Flight Models 8 and 9 resulting from the ERB modification. The dollar values for this estimate have been submitted separately to the contract offices. The additional tasks are to be performed at the same time as the other projected improvements. This is the most effective approach in that physical interfaces may be established in the normal routine of engineering detailing. It is also the most efficient approach in that, as a combined operation, the engineering, support and management personnel will encompass all development tasks and all effort will proceed to an integrated system design.

As an indication of the tasks to be performed the Work Breakdown Structure for the Flight Model 8 and 9 is given in Table 7-1. The list shows the three new development tasks added to the four proposed tasks for HIRS Improvement. The proposed effort on improvement of the Internal Cold Target was not going to be supported by NASA and is automatically deleted now that the Internal Albedo Target will be physically replacing that unit. These tasks are presently under review

TABLE 7-1
WORK BREAKDOWN STRUCTURE for ERB ADDITIONS

1.0 PROGRAM MANAGEMENT
  1.1 Technical Management
  1.2 Program Reviews
  1.3 Resource Management

2.0 PRODUCT ASSURANCE
  2.1 Reliability
  2.2 Quality Assurance

3.0 FLIGHT MODEL FABRICATION
  3.1 Fab Structure
  3.2 Parts Procurement

4.0 SPARE PARTS

5.0 FLIGHT MODEL SYSTEM ASSEMBLY
  5.1 Subsystem Assembly
  5.2 System Integration

6.0 FLIGHT MODEL SYSTEM TEST
  6.1.1 FM 8 Subsystem Test
  6.1.2 FM 9 Subsystem Test
  6.2.1 FM 8 System Test
  6.2.2 FM 9 System Test

7.0 DOCUMENTATION
  7.1 Program Management
  7.2 FM 8 System Tests
  7.3 FM 9 System Tests

8.0 DEVELOPMENT
  8.1 Interface Mods
  8.2 Test Equipment Mods
  8.3 Instrument Mods
    8.3.1 Radiant Cooler
    8.3.2 Space Clamp
    8.3.3 Optics
    8.3.4 Filter Wheel
    8.3.5 Internal Cold Target
    8.3.6 Channel 21, 22, 23
    8.3.7 Channel 24
    8.3.8 Albedo Target

by NOAA-NESS and will be reflected in a revised instrument specification.

A significant cost factor in the added tasks is that of purchased materials. Electronic parts for the new circuitry add nearly 20% to the system electronics. Even more impact is added by the cost of the new optical parts which include as many as seven new beamsplitters, four new lenses and four new filters. The new detectors may require some special design and fabrication costs to meet system requirements. The optic parts and special fabricated parts for the albedo target will also include new designs.

Test equipment modifications will be relatively minor in that the new configuration can be accommodated in the bench and chamber test sets. Some changes to the optical alignment test set will be required, and, of course, the test procedures must be modified for the added alignment, functional and registration tests.

Computer programs for the reduction of data from the new format and for evaluation of the new channel data must be prepared. This effort will begin as the instruments are being assembled to assure readiness of the data system for test and evaluation.

8.0 CONCLUSIONS AND RECOMMENDATIONS

8.1 Summary of Results

The study produced a conceptual approach to achieving the goals of the program.

8.1.1 System Design

A systematic approach for adding the four additional detectors and related optics has been successful in specifying candidate parts capable of meeting the design objectives. These parts have been located in practical positions in the instrument where volume and interfaces to the other subsystems cause minimal impact on the total instrument. Optical components have been designed (on a first level basis) to meet the general characteristics of the HIRS system. Substrate materials and optical coatings have been defined that retain the high performance of the present system while supporting the new channels.

The study was limited in time and available effort, preventing a fully integrated optical-mechanical system layout. It was also limited in the level of study applied to such topics as polarization, detailed detector specification and optimum spectral requirements for the various beamsplitters and filters.

8.1.2 On-Board Calibration

An on-board calibration target has been described that will provide a reference for the albedo channels at 0.5, 1.0 and 1.6μm. The 18-25μm channel will use the Internal Warm Target for radiometric calibration. Optical design of the new target has established its general parameters. A more detailed optical - mechanical design will be necessary to fully determine the target parameters. The technique for referencing to NBS standards appears reasonable but must be considered in more detail to establish system accuracy and long term stability desired for ERB data collection.

8.1.3 Physical Configuration Changes

Physical configuration changes are mostly internal to the instrument where the optics, detectors and modified parts are located. External configuration must change to permit addition of the electronics components. The location described in the report must be reconsidered in providing sufficient clearance for the solar panels in their folded position. This is not a serious concern since the number of printed circuit boards to be added is probably less than projected for this layout. There are other volumes available for installation of preamp modules or complete board packages that will probably be acceptable. The increase in weight (3kg) and peak power (4.5W) will require additional spacecraft capacity. These figures, the weight particularly, are probably high when considering the addition of the parts as a unified system.

8.1.4 Signal Processing

Two approaches to data processing have been described. One makes use of the HIRS data allocation in the TIP program but requires significant change in the HIRS format. The other maintains HIRS format but requires some additional data space. Either system provides for high quality data collection and sufficient telemetry for information extraction. The electronic design for inclusion of either data format is direct and achievable. Standard techniques of low noise amplification and signal processing are considered available for this effort.

8.1.5 Estimated Performance

Calculations of performance of the new channels indicate achievement of the stated sensitivities in all cases. In the 0.5, 1.0 and 1.6μm channels there is a large margin within the specified value of NEΔN. The longwave channel has less margin, however the conservative values used in the calculation permit confidence in achieving the specification.

8.1.6 Impact on Present Channels

The impact on the present channels has been carefully reviewed. If actual component characteristics meet the predicted transmission and reflectance values there will be little or no noticeable change in any of the present system output. The projected performance is based on preliminary computer analysis and assumption of substrate and coating characteristics. Even so, the prospects for operation well within instrument specifications appear good.

8.1.7 Preliminary Cost Estimate

A preliminary cost estimate indicates that adding the ERB channels will increase the cost of a flight instrument by roughly 25%. The most cost effective program is one where the change is made along with the cooler and other optic changes being considered for Flight Models 8, 9 and 10.

8.1.8 Schedule of Effort

A schedule of effort has been developed for common design and fabrication of the projected improvements and ERB additions. A stretch of 2 months in first instrument delivery will accommodate the added alignment and test effort. The ERB channel design will require an intensive optical design effort early in the constract to permit final placement of parts and procurement of long lead optical elements. The program will be structured to complete the tasks in a manner that will expedite the most critical tasks. It might be desirable to consider an early start on some of the longer design phase.

8.2 Recommendations

The study indicates that the ERB channels may be added to the HIRS with a high probability of success. A combined program of development and design detailing may be prepared and completed in the same general time frame as the projected schedules for Flight Models 8, 9 and 10. It is recommended that a program be defined that includes these modifications in the instrument procurements now under consideration.

An interim effort would reduce the concentrated effort in the detailing of the modified instrument. This design study might include:

A complete optical design and layout of the new channels.

Definition of the spectral requirements for channel 24.

Completion of the specification and design of the beamsplitter elements.

Definition of the pyroelectric detector performance and configuration.

Establishment of the calibration techniques.

The information developed in the conceptual study provides the basis for adding the ERB channels to the HIRS instrument. Consideration of the scientific merits of such a change may be made with reasonable confidence that the system may be fabricated and flown in the near future.

End of Document