15 JULY 1975

EXPERIMENT DEFINITION PHASE SHUTTLE LABORATORY

LDRL-10.6 EXPERIMENT

•

Fourth Quarterly Report

NASA Contract NAS 5-20018

HUGHES
HUGHES AIRCRAFT COMPANY
SPACE AND COMMUNICATIONS GROUP

Hughes Ref. No. D0824 • SCC 50232R

CONTENTS

1. INTRODUCTION

This fourth quarterly report for the Experiment Definition Phase of the Shuttle Laboratory LDRL 10.6 Micrometer Experiment (Contract NAS 5-20018) covers the period from 27 March 1975 to 26 June 1975.

During this period work was reduced to the experiment measurement of the optomechanical subsystem of the 10 μm receiver. Phase II of the program started on 1 June 1975 when the additional funding was authorized, although preliminary efforts started as early as 19 May 1975.

Fourth quarter activities included:

- Detail design of mechanisms and optomechanical structure subsystem of the shuttle terminal
- Optics drawing review for interface verification and addition of manufacture and coating notes
- Preliminary alignment procedure
- Experiment measurements of the optomechanics of the 10 μm receiver

2. MECHANISMS AND STRUCTURE

In accordance with the terms of the recent contract amendment, detail design of hardware for construction of the brassboard model has begun.

Selection of components for procurement was completed during the earlier layout phase, and these items have been placed on order. These procurements were placed with sufficient lead time to assure parts availability in time for assembly. A summary of these purchase items is given in Table 2-1.

TABLE 2-1. PURCHASE ITEMS

Item	Vendor and P/N	Promised Delivery
Motors	Inland T8902	22 September 1975
Encoders	Disc Instruments 2863	19 September 1975
Tachometers	Singer CU0-9611-032	17 September 1975
Resolvers	Singer CR 40908-034	17 November 1975
Gimbal bearings	Kaydon KA080AR0	22 August 1975
Gears	Pic Designs (several)	22 August 1975

Items are being fabricated using materials compatible with high vacuum (space) operation in close proximity to optical surfaces. Gimbal bearings and gears will be dry film lubricated at Hughes after receipt.

Limit switches for end-of-travel indication have been transferred from another program and are on hand.

Detail drawings prepared to date have concentrated on the outer gimbal telescope housing box and the motor/bearing packages. Preliminary drawings of the box have been given to the stress analysis group and to the fabrication facility for review. This box is a beryllium structure with machined steel end pieces. This combination was selected to maintain integrity of the optical alignment under varying thermal conditions and to minimize machining costs. The beryllium plate and channel stock have been transferred from another Hughes program and the 17-4 CRES stock is on order. Design of the bearing preload spring for the motor/bearing package is also under way.

An important feature of the preliminary bearing spring and box structure analysis is that the box (supported by the outer gimbal) will require caging external to the transmitter package to protect outer gimbal bearings from launch load input. Details of this caging system require a firm definition of the experiment-to-shuttle interface and, therefore, are not a part of the shuttle side of the interface for future update to a flyable experiment. For the brassboard model, four caging lugs will be provided on the box-to-bearing interface plate to pick up this future external caging system.

The inner gimbal bearing system is adequate to carry its lighter load during the potential launch environment. Therefore, the simple antirotation lock included in the brassboard design is all that is required for this secondary axis.

Preliminary drawings of the mirrors have been reviewed for interface compatibility to the box.

A procedure for optical alignment of the assembled brassboard model is in preliminary stage (see Section 4). The required features will be incorporated in the structure design to facilitate the alignment procedure. This includes provisions for boresighting, temporary attachment of mirrors, bench mounting, etc.

3. OPTICS

3.1 BERYLLIUM MIRRORS

Preliminary drawings for the nine beryllium mirrors were completed in the LDRL Phase I effort. These drawings were distributed to several vendors to determine ROM price and schedule for Phase II. Presently the drawings are being reviewed for interface verification and the addition of manufacture and coating notes. A tolerance analysis will be performed and all drawings reviewed prior to release of the RFQ scheduled for 1 August 1975. It is anticipated a vendor will be selected by 15 August 1975.

3.2 OPTICAL COATINGS

During the course of the LDRL transmitter development, attempts were made to eliminate the need for an expensive and massive germanium solar "filter" window. By maximizing the mirror reflectance throughout the spectral region of high solar energy, i.e., 0.425 to 2.00 μm, this led to an initial recommendation of protectively coated metallic silver on all mirror surfaces. In addition, high system transmittance is required at 10.6 μm and transmittance must be high enough for visible alignment. More specifically, the following considerations must be observed:

1) 10.6 μm — Requires high reflectance for efficient data transmission

2) 0.425 to 2.00 μm — Peak solar energy spectrum requires low absorption (i.e., high reflectance)

3) 0.6328 μm — Requires reasonably high reflectance for use of helium neon laser for alignment and test

4) 0.4 to 0.7 µm — Visible high reflectance (40 percent of solar energy in this spectrum) for alignment and test and nonabsorption of solar energy

5) Availability of coatings — Cost prohibitive if not readily available

Silver, aluminum, and gold reflective coatings are all readily available and easily applied to the substrate. Overcoatings are also required on these metallic films for protection against the environment (e.g., humidity, acid gasses, and cleaning). Enhanced metal coatings with thin dielectric films deposited over the reflective metal have an enhanced or "peaked" reflectance at a specific wavelength, but usually at the expense of reflectance in other wavelength bands. Thus, an enhanced 10.6 µm and visible reflectance cannot be expected without much added time and expense.

Dielectric coatings alone are also excellent for a specific wavelength and sometimes for reflective broadband applications (e.g., visible region), but requiring one dielectric coating to do both leads to time and money over and above that of metallic coatings.

The transmitting optical train from the pre-expander to the output pointing mirror consists of a total of 13 mirror surfaces. One can examine the coating tradeoffs best by considering the system transmittance for these 13 surfaces.

Table 3-1 summarizes the results of six coating combinations considered. Figure 3-1 shows the system transmittances for six different coating options. Thirteen surfaces of silver gives both the best average visible reflectance and the lowest solar absorptance of all metallic coatings. Gold, which absorbs far too much of the shorter visible wavelengths, and aluminum, with a reflectance dip at 0.85 µm, are both unsuitable for thermal reasons. Also, an option involving zinc selenide (ZnSe) pre-expander was considered. Although it maximizes transmission efficiency at 10.6 µm, it also absorbs a significant amount of the energy withing the solar spectrum. ZnSe has reduced transmittance in the visible region and, additionally, its refractive index dispersion would make system alignment difficult for the widely separated wavelength regions (visible and 10.6 µm).

On the basis of these considerations, it is recommended that silver coatings be used throughout the system. Although protected silver is recommended for the mirrors in the Phase II brassboard model, additional effort will be required in the full bore flight configuration to ensure meeting all of the stringent space environmental requirements. The possibility exists of stripping the mirrors and recoating them with appropriate coatings for future upgrading to the fully qualified flight model.

TABLE 3-1. AVAILABLE COATING COMBINATIONS

Number of Surfaces	Coating	Average Visible System Transmittance, %	10.6 µm System Transmittance, %
13	Silver	65	73
13	Aluminum	25	60
13	Gold	20	78
9 4	Silver Gold	32	74
9 4	Silver Aluminum	48	67
9 3 elements	Silver ZnSe	9	78

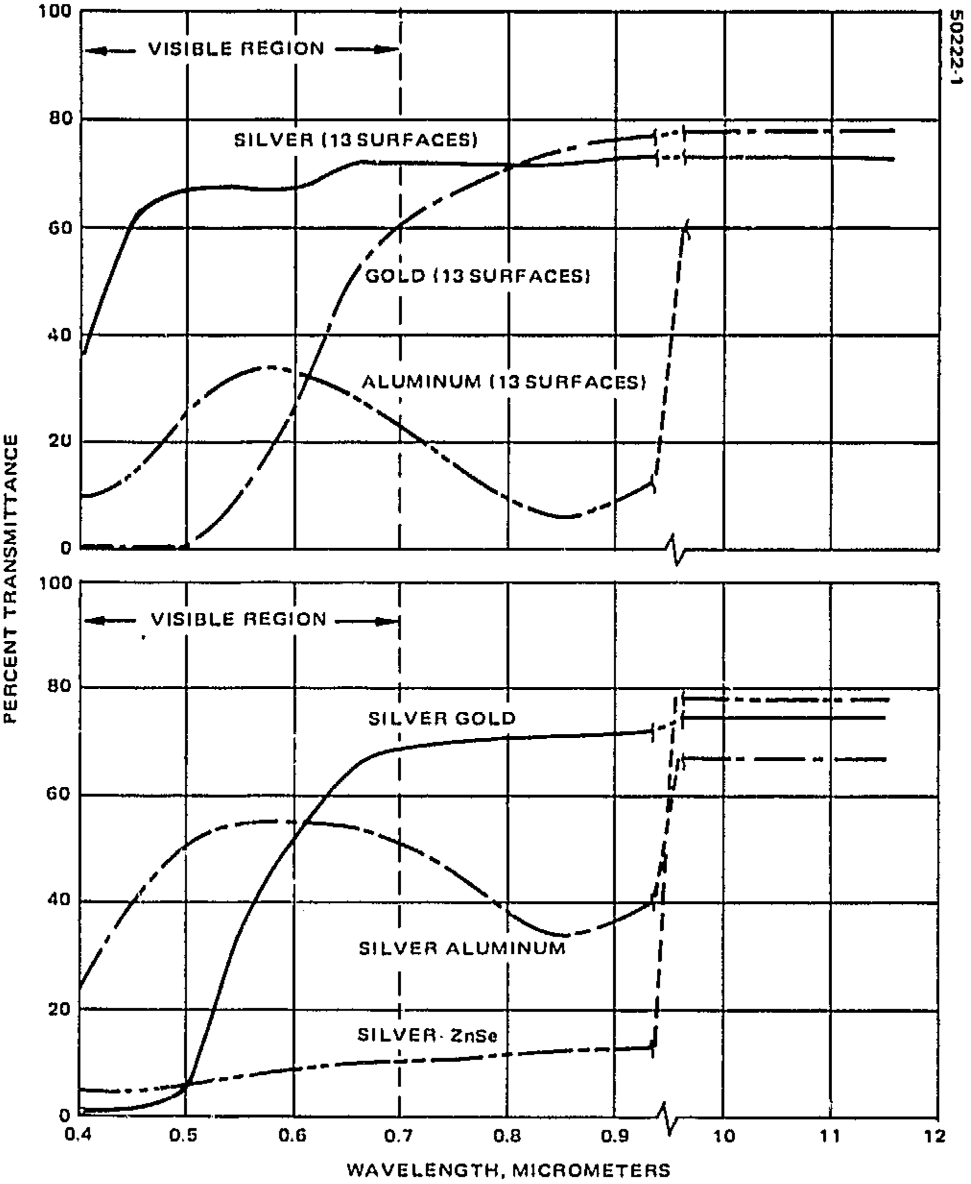


FIGURE 3-1. SYSTEM TRANSMISSION FOR COATING OPTIONS

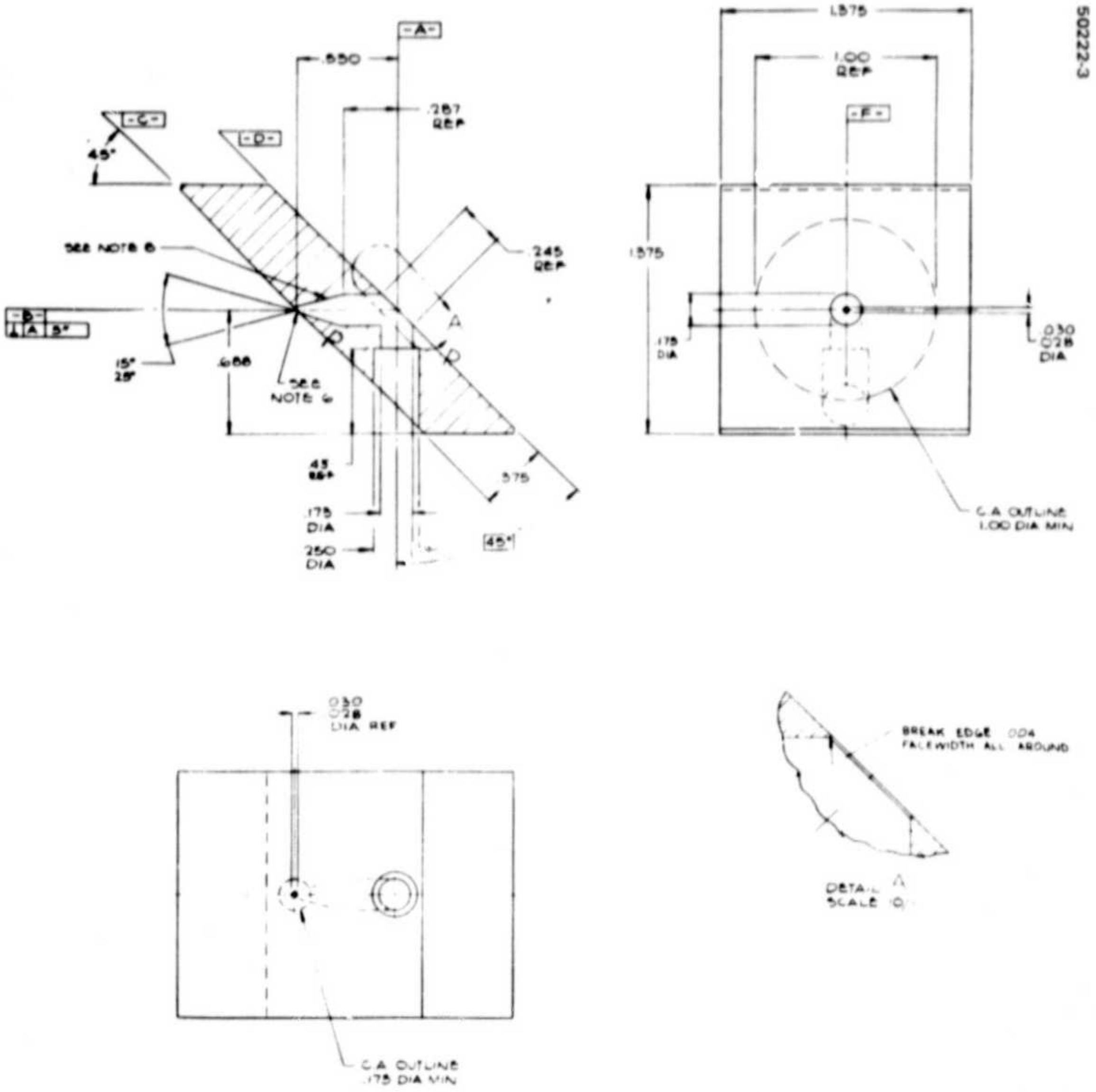
3.3 OPTICAL PRE-EXPANDER (Figures 3-2 through 3-5)

In order to maintain the philosophy of a relatively easily alignable and all reflective optical throughput for the LDRL transmitter, it was decided to design and fabricate the 5.77x pre-expander as a prealignable CERVIT mirror subassembly. The subassembly will be designed to expand the 0.44 cm diameter laser beam to 2.54 cm (1 inch). It has four polished mirror surfaces and will achieve a 1/4λ wavefront error peak-to-peak. Its figure is to be maintained over a temperature range (laboratory) of 50° to 110°F. The mirrors will have a protective silver coating providing 98 percent reflectance at 10.6 μm and greater than 96 percent reflectance at 0.425 to 2.00 μm.

The design will also feature a double sided folding mirror that greatly simplifies and improves alignment and also enables a 1 arcsec parallelism between the two mirror faces to be built into the design.

The acquisition beam will be aligned to the transmitter exit beam to within 5 arcsec. The system will be tested with a helium neon laser beam at 0.6328 μm. The subassembly will be mounted in the base compartment with adjustable expander screws for angular alignment, and the lateral alignment will be provided for by oversized screw holes on the base compartment bulkhead.

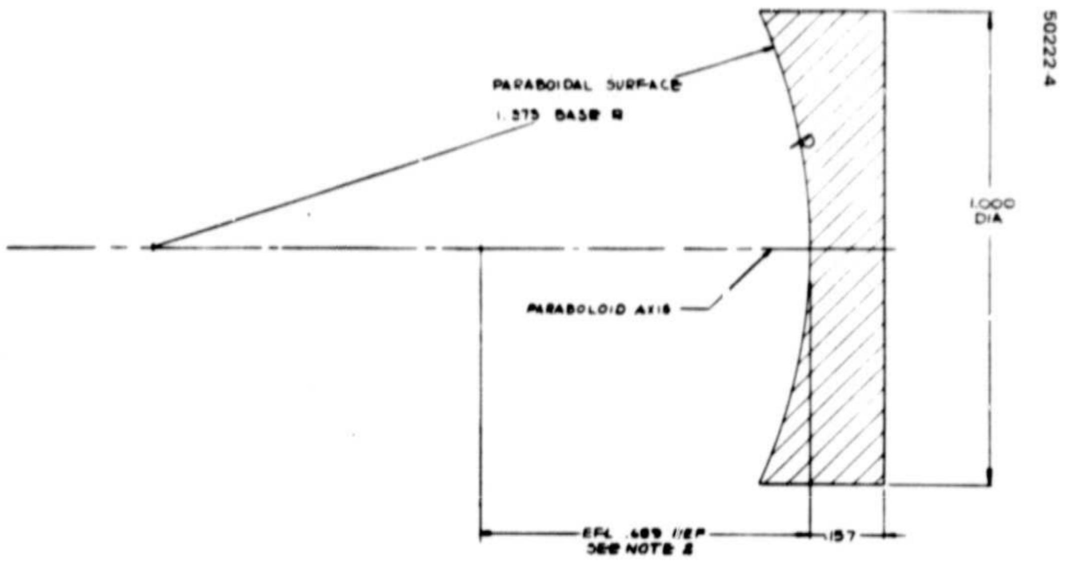
The present status of the pre-expander subassembly is that the RFQ was mailed to five different vendors on 11 July 1975, and vendor is to be selected by 15 August 1975.



NOTES: UNLESS OTHERWISE SPECIFIED

1. PART IN ACCORDANCE WITH MIL-O-13830
2. CLEAR APERTURE: AS SHOWN
3. SURFACE QUALITY: 40-20 WITHIN CLEAR APERTURE. UNSPECIFIED OUTSIDE CLEAR APERTURE
4. SURFACES -C- AND -D- PARALLEL WITHIN 1 ARC SECOND
5. REFERENCE: A PLANE DEFINED BY AXES -A- AND -B- SHALL INTERSECT SURFACE -D- ALONG AXIS -F- TO WITHIN ±5 SECONDS OF ARC AND SHALL BE PERPENDICULAR TO SURFACE -D- TO WITHIN ±5 SECONDS OF ARC
6. CHIPS AROUND HOLE SHALL NOT EXCEED THE ALLOWABLE SCRATCH-DIG SPECIFICATION. HOLE EDGE .003 R MAX.
7. CHAMFER ALL EDGES .050 FACE WIDTH x 40°/50° UNLESS NOTED OTHERWISE
8. CONICAL HOLE MAY BE FABRICATED AS STEPPED COUNTER BORE
9. COAT CLEAR APERTURE FOR GREATER THAN 80 PERCENT REFLECTANCE BETWEEN .425 AND .675 MICROMETERS AND GREATER THAN 98 PERCENT REFLECTANCE AT 10.6 MICROMETERS

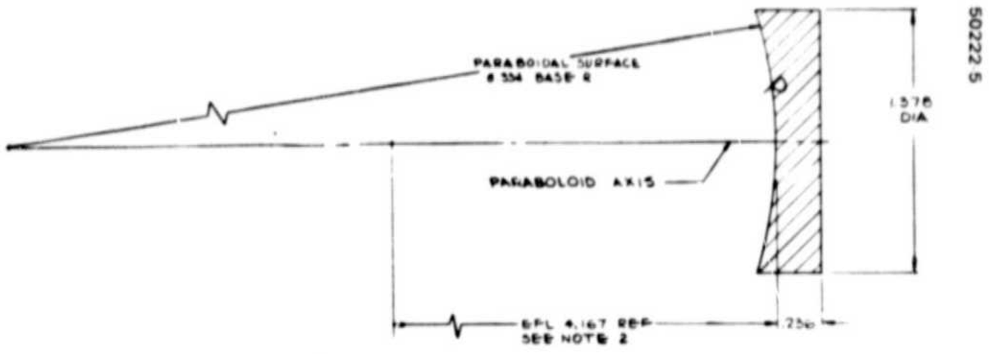
FIGURE 3-2. FOLDING MIRROR PRE-EXPANDER



NOTES: UNLESS OTHERWISE SPECIFIED

1. PART IN ACCORDANCE WITH MIL-O-13830
2. REFERENCE ONLY: THE POLISHED SURFACE FIGURE SHALL NOT DEVIATE FROM A TRUE PARABOLOID BY MORE THAN 1/4 WAVELENGTH OR AS REQD TO MEET OVERALL SUBASSY PERFORMANCE (SEE DWG 5487109) TEST WAVELENGTH: .6328 MICROMETERS
3. SURFACE MARKED "P" POLISHED. ALL OTHERS AS MACHINED
4. SURFACE QUALITY: 40-20 ON SURFACE MARKED "P"
5. CLEAR APERTURE .200 DIA
6. CHAMFER EDGES .010/.025 FACEWIDTH × 40°/50°
7. COAT CLEAR APERTURE FOR REFLECTANCE GREATER THAN 80% FROM .425 TO .675 MICROMETERS AND GREATER THAN 98% AT 10.6 MICROMETERS

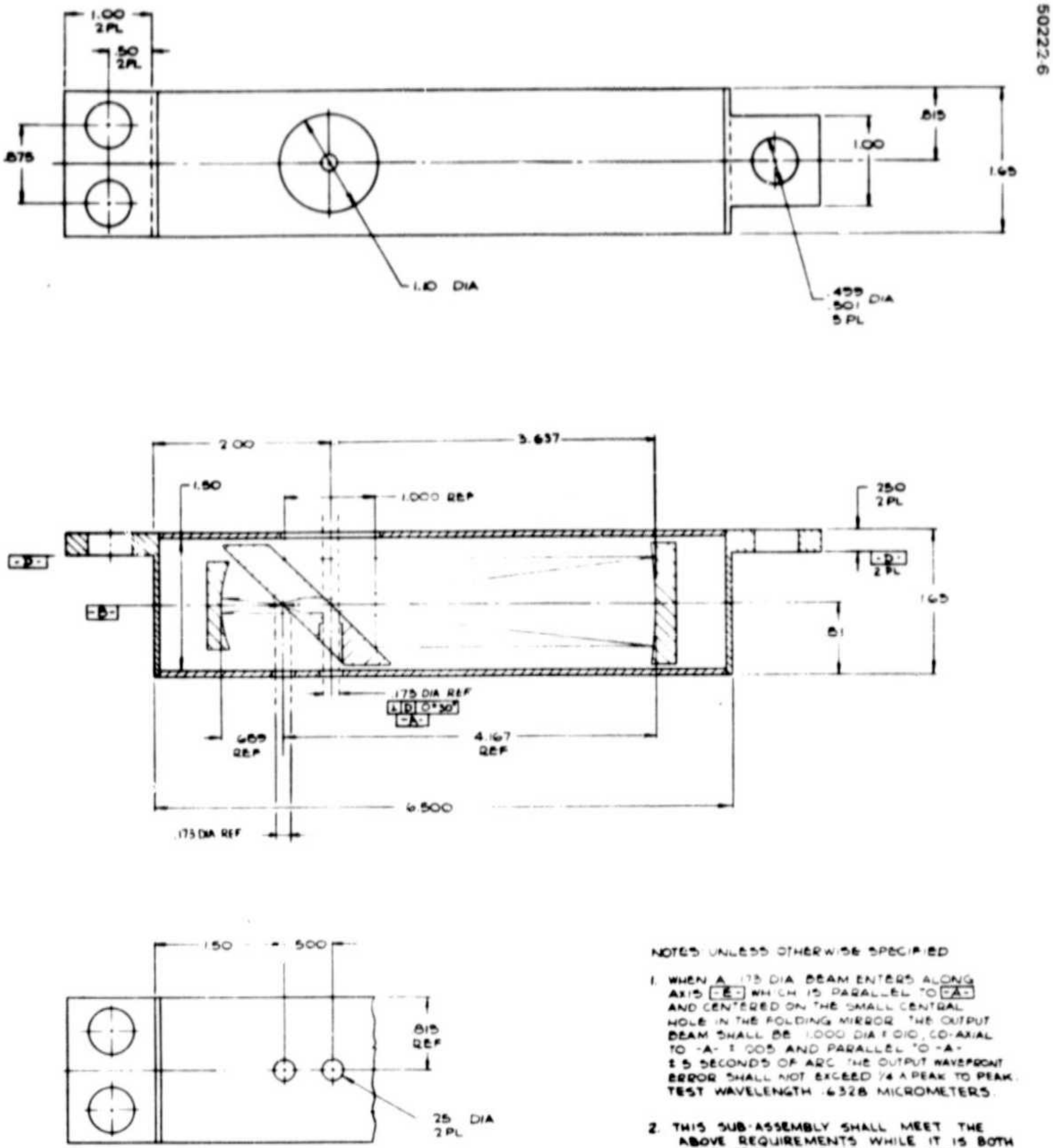
FIGURE 3-3. PRE-EXPANDER SECONDARY MIRROR



NOTES UNLESS OTHERWISE SPECIFIED

1. PART IN ACCORDANCE WITH MIL-O-13830
2. REFERENCE ONLY: THE POLISHED SURFACE FIGURE SHALL NOT DEVIATE FROM A TRUE PARABOLOID BY MORE THAN 1/2 WAVELENGTH OR AS REQD TO MEET OVERALL SUB-ASSY PERFORMANCE (SEE DWG 5482109) TEST WAVELENGTH: .6328 MICROMETERS
3. SURFACE MARKED "P" POLISHED ALL OTHERS AS MACHINED
4. SURFACE QUALITY 40-20 ON SURFACE MARKED "P"
5. CLEAR APERTURE 1.20 DIA
6. CHAMFER EDGES .010/.025 FACEWIDTH X 40°/50°
7. COAT CLEAR APERTURE FOR REFLECTANCE GREATER THAN 80% FROM .425 TO .675 MICROMETERS AND GREATER THAN 98% AT 10.6 MICROMETERS

FIGURE 3-4. BEAM EXPANDER PRIMARY MIRROR



NOTES: UNLESS OTHERWISE SPECIFIED

1. WHEN A .175 DIA BEAM ENTERS ALONG AXIS -B- WHICH IS PARALLEL TO -A- AND CENTERED ON THE SMALL CENTRAL HOLE IN THE FOLDING MIRROR, THE OUTPUT BEAM SHALL BE 1.000 DIA ± .010, CO-AXIAL TO -A- ± .005 AND PARALLEL TO -A- ± 5 SECONDS OF ARC. THE OUTPUT WAVEFRONT ERROR SHALL NOT EXCEED 1/4 λ PEAK TO PEAK. TEST WAVELENGTH .6328 MICROMETERS.

2. THIS SUB-ASSEMBLY SHALL MEET THE ABOVE REQUIREMENTS WHILE IT IS BOTH FREE FROM SUPPORT AND ALSO WHILE BOLTED FIRMLY TO A FLAT PLATE.

3. ALL INPUT & OUTPUT HOLES IN HOUSING SHALL BE COVERED TO PROTECT FROM DUST DURING SHIPPING.

4. ASSEMBLE IN ACCORDANCE WITH MIL-O-13830

FIGURE 3-5. PRE-EXPANDER SUBASSEMBLY

4. PRELIMINARY ALIGNMENT PROCEDURE

4.1 INTRODUCTION

The optical configuration of the LDRL system consists of two afocal Gregorian telescopes with a large (0.417) central obscuration. The relatively high speed (f/1.5) of the primary makes accurate alignment crucial for good performance.

There are four aspheric surfaces comprising the two telescopes, each surface having a specific optical axis and a focal point on that axis. For proper alignment, all four axes must be colinear with the system axis, and each pair of focal points for the two beam exapnders must coincide. The system axis follows a complex path as it is folded through the mechanical structure by nine flat-folding mirrors. The reference mechanical axis is the rotational axis of the outer gimbal bearing located between the two Gregorian telescopes. All optical elements must eventually be aligned to this reference axis.

4.2 SPECIAL TEST FIXTURES

Several test fixtures must be available for system alignment and test. These fixtures are described throughout this procedure. For convenience, all of the required devices are listed here:

1) Rigid mount for holding the LDRL optical structure to a standard optical table

2) Means for rigidly caging the inner and outer gimbal bearings

3) Means for reading the position of the gimbal resolvers

4) Two test mirrors and means for mounting these to the rotating portion of the inner and outer gimbals

5) Alignment fixture for IMC subassembly alignment

6) Two autocollimating telescopes with fully adjustable mounts

7) Two steerable flat mirrors, at least 7 inch diameter

8) HeNe Alignment laser

9) Collimated visible source, at least 8 inch diameter

10) Reticle for location of the center of the small folding diagonal mirror (fold 3)

11) Alignment fixtures for the primary and secondary mirrors

4.3 ALIGNMENT PROCEDURE

The system will be aligned in a step-by-step procedure. It is assumed that the pre-exapnder will be received as an aligned subassembly. Under this assumption, the large 7x beam expander will require alignment, followed by a relative alignment between the two expanders.

The first task in the alignment procedure is alignment of the 7x beam expander telescope consisting of the primary, secondary, and one folding mirror. The IMC subassembly alignment is next, followed by the alignment of the two folding mirrors following the IMCs. Next, the two large output flat-folding mirrors will be aligned. Alignment will be completed with the installation of the pre-expander telescope. Figure 4-1 is a diagram of the optical system with all mirrors labeled. These labels will be used throughout this procedure.

Two test mirrors are shown in Figure 4-1, TS1 and TS2. These mirrors must mount to the rotating portion of the inner and outer gimbals

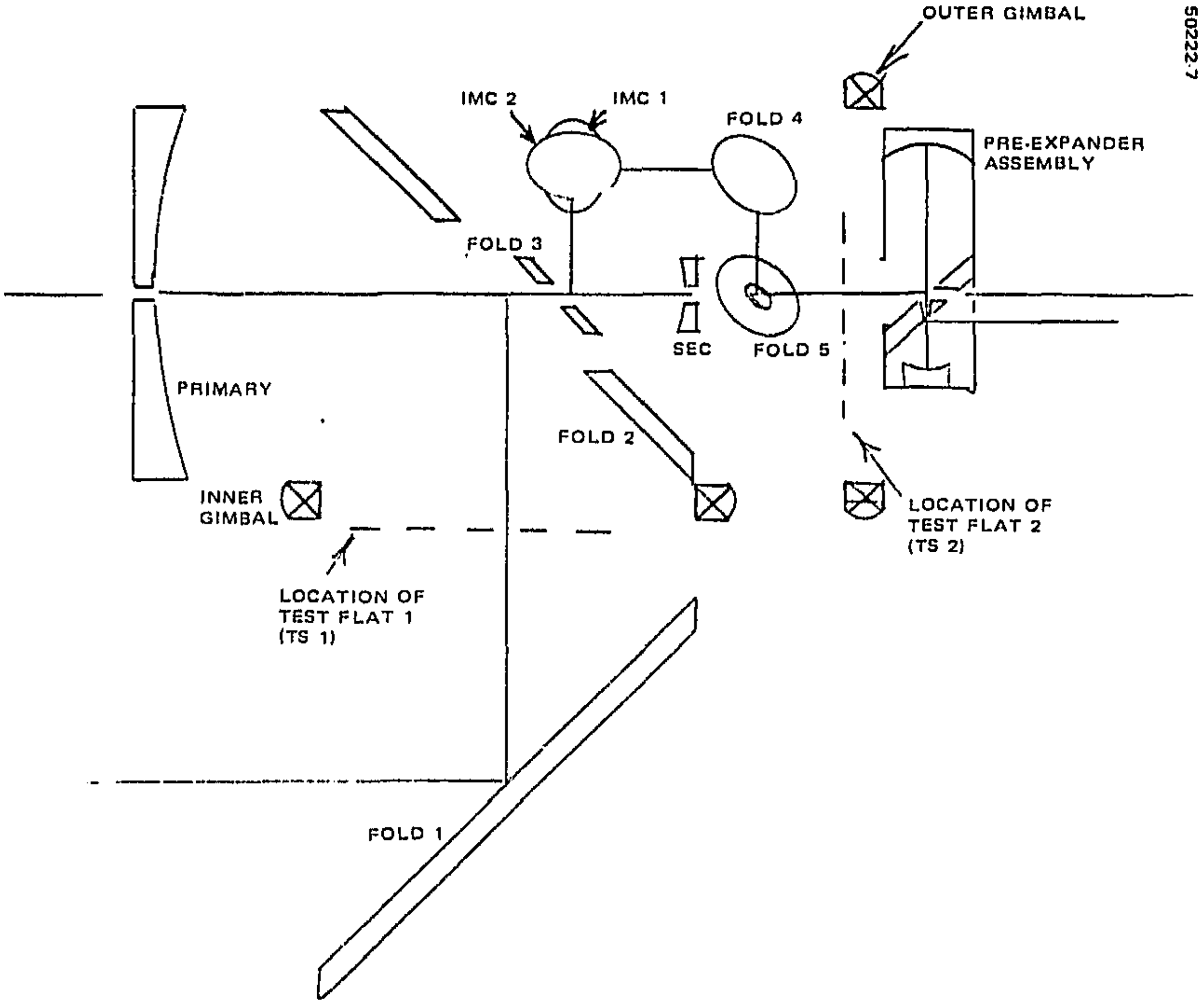


FIGURE 4-1. MIRROR LABELS

and be adjustable in angle for alignment. They should be flat, and TS1 must be about 6 inches in diameter. TS2 may be as small as 1 inch in diameter.

4.3.1 7x Beam Expander Alignment

Figure 4-2 is a schematic representation of the 7x optical beam expander, along with the optical alignment devices to be used in this procedure. Two autocollimating telescopes (AC1 and AC2) and two steerable flat mirrors (flat 1 and flat 2) are required. AC1 is used in two positions, A and B. The principal mirrors of the expander have been labeled. An alignment crosshair or reticle is required to locate the center of the opening in fold 3. Alignment will be much easier if this centering device consists of an etched crosshair pattern on a transparent substrate.

Several alignment fixtures must be available. The most important fixture will be the mount for the telescope housing. This mount must support the telescope on an optical table in a manner that will allow installation and removal of the major optical components and subassemblies without disturbing the position of the box. It must mount the box as if the view in Figure 4-1 were a top view so that the principal axis of the telescope is parallel to the surface of the table. It is not necessary that the mount be adjustable, only that it be rigid. If gimbals are installed, they must be locked.

Mounts must also be available for the two autocollimators. These mounts must be securely fastened to the table, and must be adjustable in four dimensions, two angular rotations, and two linear translations.

The three elements to be aligned are the primary, secondary, and fold 3. Fold 3 has no adjustments. The center of fold 3 thus locates a point on the reference axis. The secondary has three degrees of freedom, two angular adjustments, and a focus translation. The center of this mirror establishes a second point on the reference axis. The primary mirror has five degrees of freedom, and is adjusted to coincide with the established reference axis and focal point. The alignment procedure is as follows (refer to Figure 4-2):

50222-8

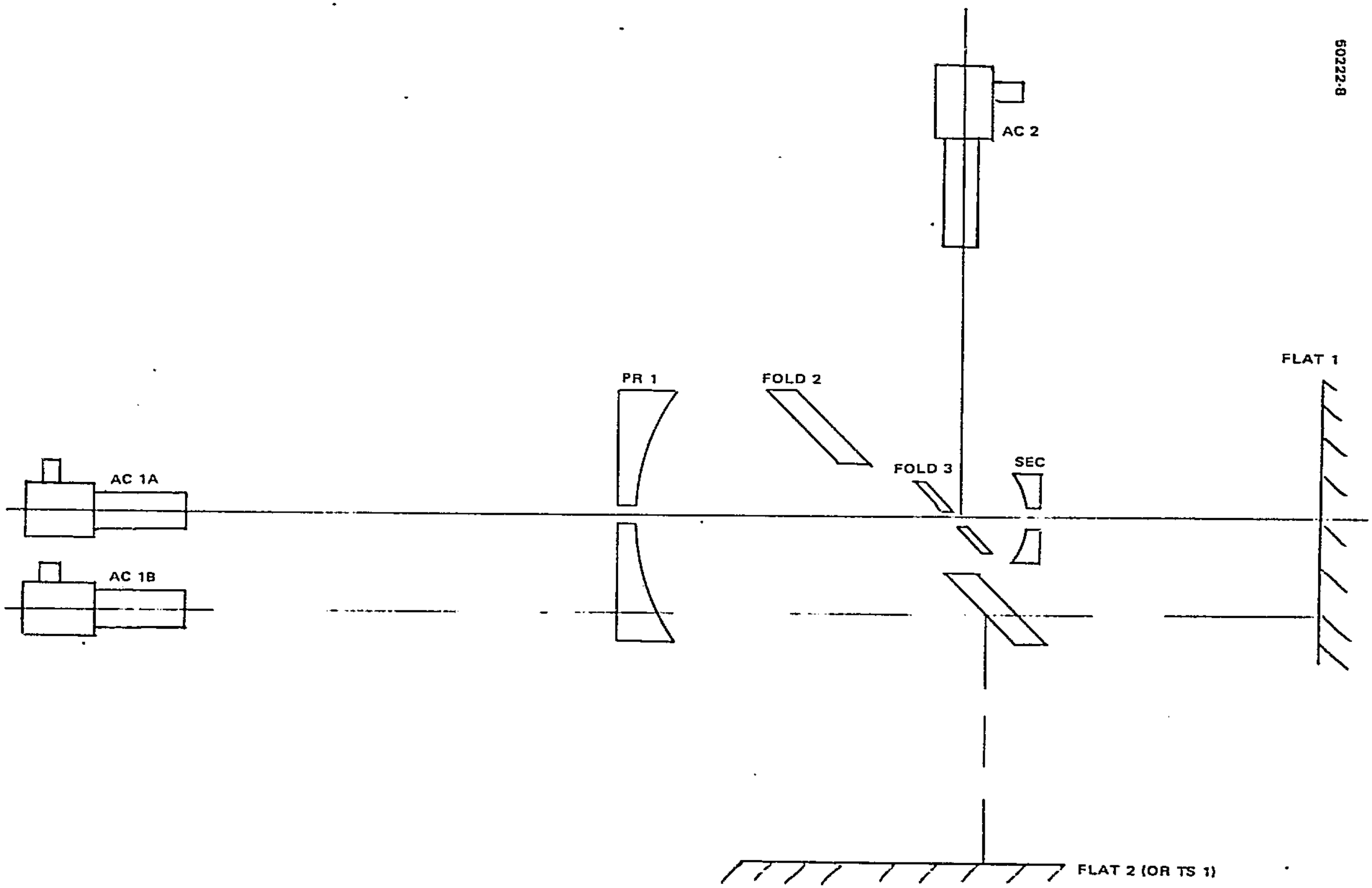


FIGURE 4-2. TEST SETUP FOR 7X BEAM EXPANDER ALIGNMENT

1) Mount the mechanical structure so it is rigid. Install fold 3 and the reticle to locate the center of fold 3. Temporarily install the secondary.

2) Mount AC2. Align AC2 so that the reticle in fold 3 and the center reference hole of the secondary are on the axis of AC2. This establishes a reference axis.

3) Mount AC1 in position A. Adjust AC1 to align its axis with the reticle in fold 3 and the center hole of the secondary.

4) Remove the secondary. Align flat 1 so that AC2 autocollimates. Check AC1 for autocollimation. Both AC1 and AC2 should autocollimate with flat 1 and coincide with the reticle in fold 3. Repeat steps 2 through 4 until this condition exists.

5) Install the secondary and its alignment fixture. Focus AC1 on the reticle in fold 3. Illuminate the target graticule in AC2. Adjust the secondary until the target from AC2 is in focus and aligned with the reticle in fold 2, as viewed through AC1. Focus may be checked by a lack of parallax between the target and the reticle.

6) Lock the secondary and remove the alignment fixture.

7) Move AC1 to position B. Adjust AC1 for autocollimation with flat 1.

8) Install fold 2 in the box. Align flat 2 so that AC1 is autocollimated.

9) Install the primary mirror. Remove the reticle from fold 3. Translate the primary until the center reference hole is aligned with AC2.

10) Focus AC2 to infinity. Adjust the primary until AC2 is autocollimating through the beam expander to flat 2 and is in focus. Alignment of the 7x beam expander is now complete.

4.3.2 Preliminary Alignment of the IMC Subassembly

The IMC assembly has not been fully designed. This procedure suggests the steps necessary for alignment. These adjustments or equivalent adjustments should be considered during final design.

Figure 4-3 depicts a suggested alignment fixture. The IMC assembly must be adjustable as a unit to compensate for tolerance buildup in the 7x beam expander. The IMC subassembly should mount to the test fixture in its nominal or centered position.

The test fixture is built up of 1/4 or 3/8 inch aluminum plates. Small holes (1/8 inch) are located as shown along the nominal optical axes of the IMC subassembly. The alignment procedure is as follows:

1) Mount the test fixture to a suitable table.

2) Align a HeNe laser through holes A and B that establish the input axis.

3) Mount the IMC subassembly with IMC 1 in place.

4) Adjust IMC 1 so that the beam from the HeNe hits the center of the mirror and exits through hole C.

5) Install the stop and adjust to center it on the HeNe beam.

6) Install IMC 2 so that the HeNe beam hits the center of the IMC mirror and exits through hole D.

4.3.3 Alignment of the IMC Assembly

Refer to Figure 4-2. It is now necessary to illuminate the primary mirror with a collimated source. This may be accomplished by the following procedure.

1) Establish the conditions shown in Figure 4-2.

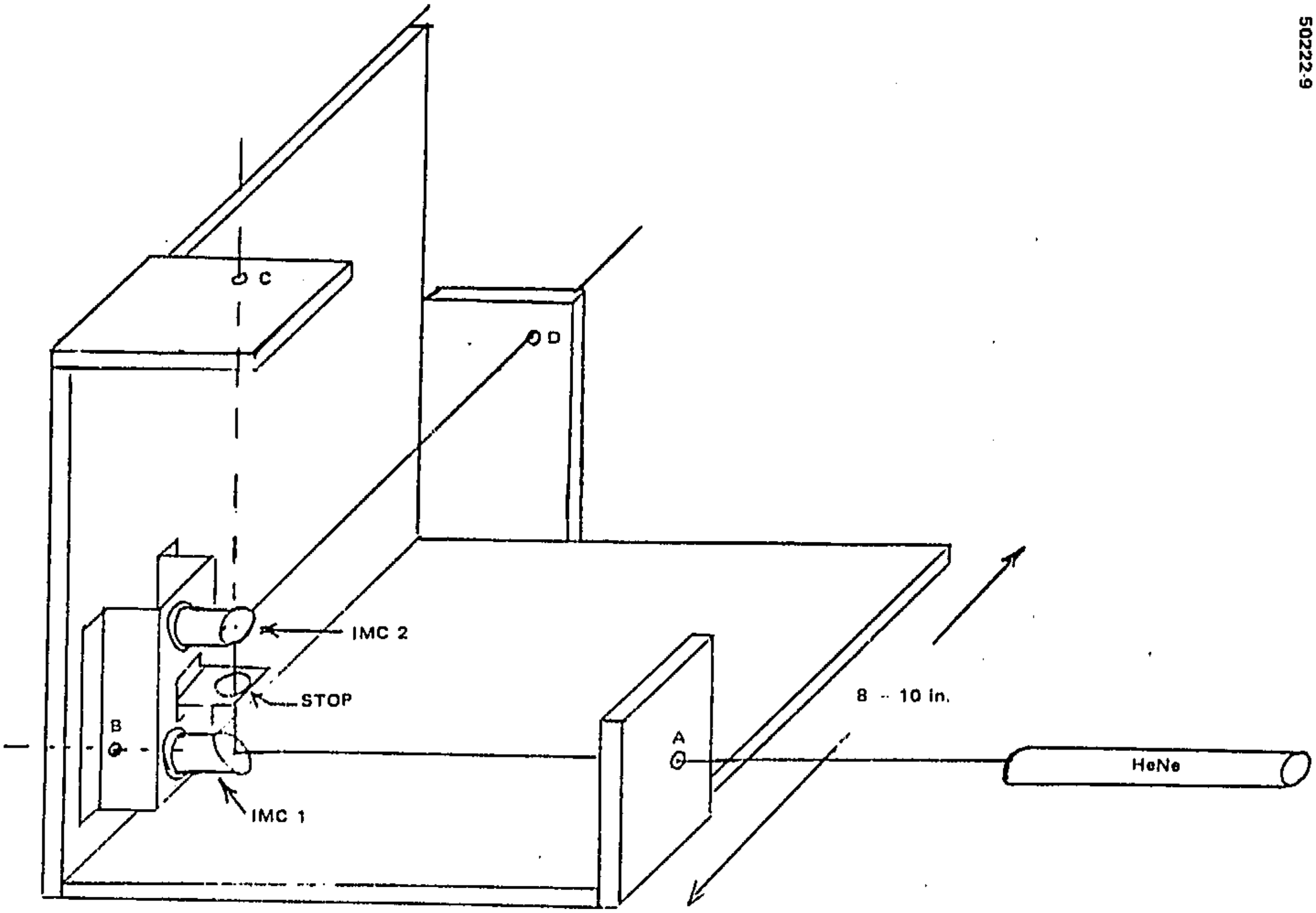


FIGURE 4-3. IMC SUBASSEMBLY ALIGNMENT

2) Position an adjustable flat mirror to reflect a collimated HeNe source onto fold 2. Adjust the angle of the flat to place a point HeNe image on the crosshair of AC2 (use eye protection if necessary).

3) Check to see that the entire primary of the system is illuminated. If not, move the flat mirror and repeat the alignment in step 2.

4) Examine the beam emerging from fold 3. A symmetrical toroid representing the primary mirror and the hold in fold 3 should emerge with no other shadows. If this is not the case, alignment to this point is not correct and must be repeated.

5) Install the IMC subassembly and again examine the emerging image. Adjust the IMC assembly until the shadow cast by the stop is symmetrical with theoutline of the primary mirror. These two circles should be very nearly identical in diameter.

4.3.4 Alignment of the Folding Mirrors Behind the IMC Assembly

Fold 4 and fold 5 following the IMCs are used to align the optic axis to the center of the outer gimbal bearing axis. Two additional alignment fixtures are required. These are the adjustable flat mirrors, TS1 and TS2, described earlier and shown in Figure 4-1. Use the following procedure:

1) Assuming the system is set up as in step 5 of the previous alignment, the 1 inch diameter HeNe beam is still exiting the system. Set up an autocollimator to accept this beam, and adjust the autocollimator until the focused HeNe beam coincides with the crosshair.

2) Turn off the HeNe. Mount alignment mirror TS1. Adjust for autocollimation through the system.

3) Move the autocollimator so that it coincides approximately with the optic axis of the telescope. Align it to view the hole in the back of the secondary mirror.

4) Install flat alignment mirror TS2. Adjust the mirror and/or the autocollimator for autocollimation. Uncage and rotate the outer gimbal through its travel range and note the motion of the target relative to the reticle. Adjust the mirror to a new position, and readjust the autocollimator for autocollimation. Repeat the rotation check. Iterate until the target remains stationary during rotation.

5) Focus the autocollimator on the mirror surface. Rotate the bearing. Note the center of rotation relative to the crosshair. (A mark placed on the mirror may make this observation easier.) Translate the autocollimator until the crosshair coincides with the center of rotation.

6) Repeat steps 4 and 5 until no motion is apparent in either step.

7) Remove the alignment mirror TS2 from the bearing center. Install fold 4 and fold 5. Install the reticle in fold 3. Adjust fold 4 and fold 5 until the autocollimator crosshair is aligned to the reticle in fold 3 and the center of the primary and secondary mirrors.

8) Focus the autocollimator to infinity. The target reflected from TS1 should be visible. Rotate the outer gimbal and note any motion of the target.

9) Adjust the fold 4 and fold 5 to obtain the best compromise between the alignment in step 7 and minimum motion in step 8. Record the angular excursion of any motion in step 8.

4.3.5 Alignment of Fold 2

The system should be set up as in step 9 of the previous procedure, with the following steps:

1) Cage the outer gimbal in a convenient position where the inner gimbal is free to rotate.

2) Check to be sure the autocollimator is still aligned to TS1.

3) Uncage and rotate the inner gimbal through its full range. Note any target motion.

4) Adjust fold 2 to a new position. Readjust TS1 for autocollimation.

5) Repeat steps 3 and 4 until there is no relative motion in step 3.

4.3.6 Alignment of Fold 1

Continue from step 5 of the previous procedure:

1) Remove TS1.

2) Rotate the outer gimbal until the line of sight emerging from fold 2 is nearly parallel to the table.

3) Set up a large flat mirror to intercept this line of sight. This mirror should be elevated above the table so that only the lower portion is used (see Figure 4-4a).

4) Adjust the flat for autocollimation.

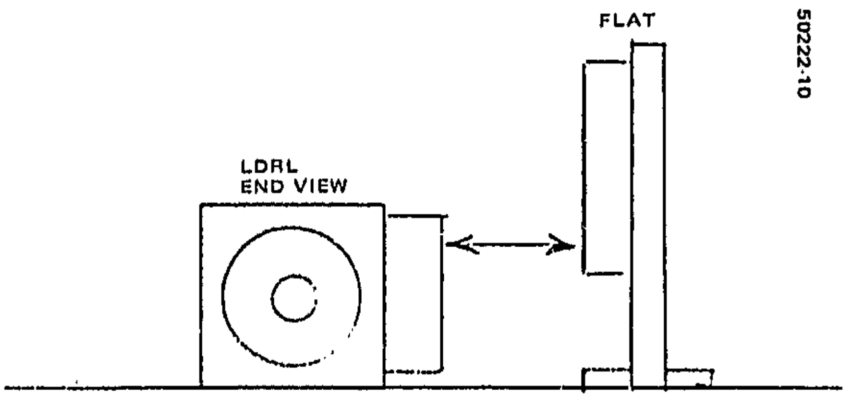
5) Using the resolver readout, rotate the outer gimbal 90° to the position shown in Figure 4-4b.

6) Install fold 1 on the inner gimbal. Rotate the inner gimbal to view the large flat, as shown in Figure 4-4b.

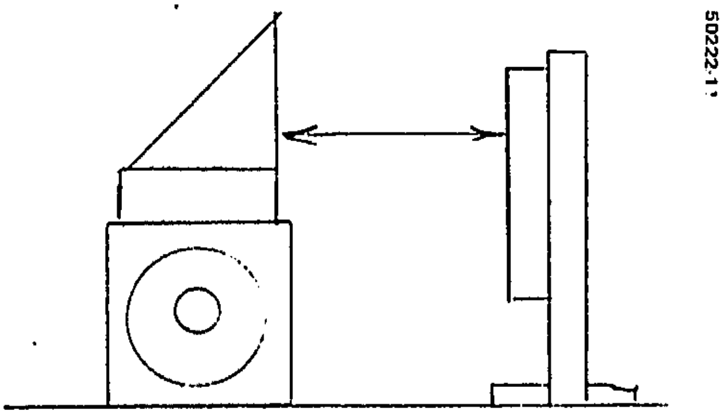
7) Adjust the inner gimbal position and shim fold 1 until autocollimation is achieved.

4.4 INSTALLATION OF THE PRE-EXPANDER

The procedure for installation and alignment of the pre-expander will be written after the design is finalized. It is unknown at this writing what alignment reference marks will be provided by the vendor.



a) INITIAL SETUP



b) AFTER 90º ROTATION

FIGURE 4-4. MIRROR ALIGNMENT

5. OPTOMECHANICAL SUBSYSTEM OF 10 MICROMETER RECEIVER MEASUREMENTS

The measurement program will integrate the waveguide local oscillator, servo drive electronics, and AIL receiver with its doppler tracking electronics into the optomechanical subsystem (OMSS). This will provide a complete optical heterodyne receiver which will then be tested and evaluated to determine its performance characteristics. The components to be integrated were developed under contracts NAS 5-21859, NAS 5-23119, NAS 5-23183, and NAS 5-23211.

During this reporting period the local oscillator subsystem, consisting of the laser, Stark cell, Stark cell electronics, power supply, starting circuit, and conditioning optics, were completed and installed in the OMSS and operation against a 10.6 μm source was attempted. Preliminary measurements of the HgCdTe mixer showed that this critical element was inoperative and in subsequent tests the receiver front end electronics had also failed. Possible reasons for these failures and corrective action and steps to prevent future recurrence are discussed in this section.

5.1 LASER WAVEGUIDE LOCAL OSCILLATOR AND STARK CELL

The laser local oscillator has been tested with the Stark cell and the final version of the Stark cell electronics. During testing, the Stark cell was found to be inoperative. It was removed and returned to Malibu for evaluation. A second cell was modified and installed on the laser, and operation was achieved. The original cell has been reprocessed and is now working. However, it will not be exchanged with the spare cell at present because of the realignment that would be required.

The stabilization circuit is working properly with a closed loop bandwidth of about 5 Hz. The acquisition and monitoring functions are all operating satisfactorily.

The laser assembly has been installed in the receiver. Two wire grid polarizers have been mounted to control the level of the laser energy. A two lens coupling arrangement has been designed and installed to relay the local oscillator energy to the detector plane. The parameters of the laser beam in the plane of the detector are:

Peak power density	8 mW/mm^2
Gaussian radius (w)	0.85 mm
Wavefront radius	133 mm
Detector area	0.04 m^2
Total power	9 mW
Detector power	0.32 mW
Wavefront error	$\lambda/250$

The optical system has been installed in the receiver and the optical path has been aligned.

5.2 DUAL WAVELENGTH COLLIMATED SOURCE

The 20 inch collimator used in the earlier servo system tests has been modified to operate at both 6328 Å and at 10.6 μm. A multiple lens beam expander is used on both the CO_2 and HeNe lasers to expand the beam to about a 1 inch diameter, then to converge the beam at a speed of f/5. The converging beams are combined using a germanium beam-splitter, then directed to a pinhole located in the focal plane of the collimator. The resulting beams are colinear within one CO_2 beamwidth. Wire grid polarizers are used to control the intensity of the CO_2 laser beam.

5.3 SIGHTING OPTICS

A major problem with the receiver has been initial alignment of the receiver with the collimator. To overcome this problem, a visible sighting arrangement has been devised. The cryostat and detector are located in position by means of three ball supports riding in two V grooves and a flat surface. The support thus constrains the detector to a single location, but still allows easy removal. A second support mechanism was fabricated, and a reticle installed in place of the detector. When the reticle is in place and an eyepiece is used, it is possible to sight back through the all reflective receiving optics. The system is then aligned by adjusting the receiver to cause the reticle to coincide with the image of the pinhole in the collimator focal plane, or with the focused image of the HeNe laser beam. The detector mount then replaces the sighting mount, and the detector is aligned to the 10.6 μm collimator source.

5.4 PRESENTATION AT CONFERENCE FOR LASER ENGINEERING AND APPLICATIONS

A report on the progress of this work was presented at the Conference for Laser Engineering and Applications in Washington, DC on 30 May 1975.*

5.5 RECEIVER FRONT END

The receiver front end, furnished by AIL through NASA, was operated with the receiver subsystem. Several catastrophic failures have occurred, all concerned with the front end. The following is a brief chronological summary of the problems encountered. The remainder of this report is a more detailed explanation of the problems, along with the planned solutions.

Initial tests on the HgCdTe detector showed that the element no longer had the characteristics of a diode, but looked more like a resistor.

---

*F. E. Goodwin and T. A. Nussmeier, "A 10.6 Micrometer Receiver Subsystem for Wideband Space Communications," paper No. 19.

The ±15 volt power supply located in the front end control panel failed. Failure mode is unknown. The power supply overheated to the point that smoke was noticed. The line fuse did not blow.

A wiring error was found in the cabling between the control panel and the preamplifier. The ground lead and bias lead were interchanged. The result was such that the preamplifier supply current (120 mA) would pass through the mixer diode if the chassis of the control unit was not attached to the chassis of the preamplifier. This condition would occur even with the bias current supply disabled.

An operational amplifier in the bias supply failed. This amplifier failed in a manner tha would cause 20 mA to flow through the detector. There was only a 100 ohm resistor in series with the detector to limit the current.

The preamplifier for the detector failed. There are six thin film integrated amplifiers in theunit, and apparently all six modules have failed. No reason for this failure is evident. It is suspected that it failed due to an overvoltage when the power supply failed.

The impact of these failures on the program is evident. Essentially, the entire front end (detector, preamplifier, bias supply, and power supply) is inoperative and must be replaced or repaired. The task is made more difficult since no schematics were furnished with this equipment.

5.6 ANALYSIS AND CORRECTIVE ACTION

5.6.1 Detector

The detector was measured on a curve tracer. The characteristic appeared to be essentially resistive with a value of 1000 ohms. The detector was illuminated with the 10.6 μm collimator. No change in the characteristic was evident on the curve tracer. An optical chopper was used with the collimator, and the detector signal was found using a lock-in amplifier. Although the signal was easily found, it was very weak. Finally, the detector was illuminated with the local oscillator, and the heterodyne signal was located with a spectrum analyzer. Again, although mixing did occur, the amplitude was far below expected values. The detector housing was opened and the detector examined. Photographs were made, but no evidence of optical damage was observed.

Corrective Action

It is recommended that the detector be returned to SAT for analysis of the failure mode. It is Hughes opinion that the detector was damaged by excessive bias current caused by a wiring error or parts failure in the bias circuit, as described in the following section. For the present, the space detector will be used for testing. This has been tested, installed, and operated in a nonheterodyne mode and is working satisfactorily.

5.6.2 Detector Bias Circuit

The detector bias circuit has been intermittent from the day it was received. It was not operated with the detector. However, the preamplifier was used to test the back end of the receiver and during these tests, the digital voltmeter used to monitor the bias current and voltage was reacting strangely, occasionally indicating an overload condition. A meter was placed across the input, and was found to read the correct voltage and current. During these tests, the digital voltmeter on the control panel also acted normally. It was assumed that the meter indicated correctly only with a load at the preamplifier input. No schematics were furnished with the unit, thus it was not possible to check this assumption. In retrospect, it is believed the regulating operational amplifier was intermittent, since it failed totally later. Failure of the operational amplifier caused 14 volts to be applied to the diode through a current sensing resistor of 100 ohms. Short circuit current under these conditions was about 20 mA.

The bias circuit was traced by hand to obtain a working schematic. The faulty operational amplifier was replaced. Several other problems were noted once the circuit was available. The circuit was arranged so that current in excess of 1.5 mA was sensed, the bias supply was shut off. This was achieved by removing a voltage supply from the input to the regulating operational amplifier. This circuit does not protect the diode if the regulating operational amplifier fails (as it did) or if the negative power supply fails (as it did). Furthermore, it was found that when the pushbutton to activate the bias supply was pushed, the positive supply was activated first, followed by the negative supply. Thus, each time the button was pushed, a 20 mA transient current passed through the diode, with the length of the transient dependent upon how fast the button was activated.

Corrective Action

The bias supply has been modified by changing the current sensing series resistor to 6.8K. This value limits the maximum diode current to less than 2 mA without the negative power supply or if the regulating amplifier fails. Input resistors to the current limit circuit were also changed so that under normal operation the current limit trips at 1.5 mA.

5.6.3 Reversed Interconnecting Leads

The problem of the reversed bias and ground lead at the preamplifier defies solution. The wiring at the preamplifier was examined closely. The lengths and arrangement of the wiring eleiminates the possibility that the reversal occurred at the preamplifier itself. The cable termination shows no evidence of modification or disassembly. The cable itself is a three wire bundle that may be installed in either direction. The cable pins are connected on a one-to-one basis and show no signs of modification. Inside the front end control panel the cable terminates at a Jones barrier terminal strip. At this point, all three wires are the same color and the same length, and could easily be interchanged. It is at this point that it is felt the error occurred. However, AIL was contacted and has said the system was working properly until it was shipped. Both NASA and Hughes personnel that have had the box since shipment deny making any modifications, and would not have had any reason to do so. It appears that this problem, which may very well have caused destruction of the diode, is unlikely to be resolved.

It is worth noting that with the wires reversed, it is still possible to achieve a correct bias current and voltage reading at the diode connector. To do this, the preamplifier would have to be isolated from the control panel ground and the preamplifier supply would have to be turned off. These are the conditions most likely to be in effect during such a measurement.

Corrective Action

The terminal strip wires have been correctly installed and labeled to preclude reversal in the future.

5.6.4 Power Supply Failure

The cause of the power supply failure is unknown. Even with the preamplifier wiring error, excessive current is not drawn. The power supply was dismantled and the transformer was found to be destroyed by overheating. It is presumed that this was a random failure caused by a faulty component.

Corrective Action

The power supply has been replaced. The bias circuit has been modified to prevent power supply failure from damaging the diode. The preamplifier circuit will be modified in the same manner.

5.6.5 Preamplifier Failure

The preamplifier consists of six Avantek wideband thin film integrated amplifiers mounted in two housings, all supplied by +15 volts. All six modules failed. Failure of all modules implies that the power supply must have put out a transient overvoltage as it failed.

Corrective Action

NASA has agreed to send Hughes another set of amplifiers to replace those that failed. A transient suppression network will be incorporated into the power supply system to preclude failure in the future.

5.7 PLANS FOR THE NEXT PERIOD

Difficulty has been encountered in aligning the local oscillator path to the signal path to assure good mixing. At present, mixing is achieved by a random search process, and optimization is then attempted by iteration of several adjustments. Since the adjustments are not orthogonal and are not repeatable, it is impossible to assure optimization. This problem will receive study and a better procedure will be developed.

Once efficient mixing is achieved, further progress will require use of the preamplifier and bias circuitry. This, in turn, is dependent upon obtaining replacement parts for the damaged components. It is expected that these will be received, and that the interface between the front end, back end, and servo system will be completed during this period.