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PHOTOHELIOGRAPH FUNCTIONAL VERIFICATION UNIT TEST AND OPERATIONS PLAN

August 12, 1968

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Photoheliograph Task

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FOREWORD

This report covers work on one phase of the photoheliograph development task, NASA Code 945-84-00-01-00, for the period November 1967 through June 1968. The photoheliograph has been proposed to NASA for the Apollo telescope mount (ATM) by Caltech, with Professor Harold Zirin as the principal investigator and Dr. Robert Howard of Mt. Wilson and Palomar Observatories the co-investigator (see TM 33-369, November 1967). The objective of the investigation is to obtain high resolution cinematographs in white light near ultraviolet and narrow band hydrogen alpha. Because of the ATM program uncertainties, emphasis has been placed on areas of technology that are somewhat mission-independent, but the ATM spacecraft has been used to establish design constraints.

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PHOTOHELIOGRAPH FUNCTIONAL VERIFICATION UNIT
TEST AND OPERATIONS PLAN

SCOPE AND PURPOSE

Scope

This document covers the testing to be performed on the Functional Verification Unit (FVU) Photoheliograph in the telescope test facility. Excluded (at this time) are performance or environmental tests conducted prior to instrument buildup in the test facility. The test facility description, a general instrument description and a general discussion of the optical test method are also included.

It is not a test procedure; it is comprehensive in that all test activities are described, but each activity description covers "what and why" thoroughly, with only a general discussion of "how".

Purpose

This document is to put under one cover comprehensive descriptions of all applicable FVU testing plans and the facility for those tests. The reader will have the FVU description, an explanation of the test technique selected as most appropriate for that instrument, the plans for implementation of that test technique, and the design/design requirements of the facility for implementation of those test plans.

This document, periodically updated, will be part of the reference material in the RFP, as it conveys valuable information to bidders on the standards expected in the proposed test program.

It currently is scoped to the testing in the optical test facility, but it will be expanded and thereby become more valuable by including the entire FVU test program.

The document shows how the stringent telescope design leads to unique requirements on test technique and test facility. Because the facility does not yet exist, and because the selected optical test technique has not yet been mechanized, some discussion of alternates is presented; these discussions of alternates are to give the reader a better understanding of the plans by illustrating the consequences of the alternates considered.

1.0 INTRODUCTION

The following material is redundant with other documentation concerning the Photoheliograph, but is inserted here to give the reader some general information under the same cover as the test plans. Since it is redundant, it is not always current, hence, differences between these instrument descriptions and other design documentation may well occur, and should be settled by the writer of the design document.

1.1 Description of the Telescope Optical System

A modified Gregorian optical design has been chosen for the ATM Photoheliograph on the basis of thermal considerations. A schematic representation of the telescopes optical system is shown in Figure 1. The primary mirror clear aperture for the f/50 design is 65cm. The secondary obstruction ratio is only 0.2 of the diameter. Assuming no surface errors, the telescope would give essentially diffraction-limited performance across the 3.2 arc-minute field. Alignment and surface errors are expected to reduce performance to a Strehl ratio of approximately 0.8. (See Figure 2).

The theoretical performance of the Gregorian telescope will be 0.19 arc-seconds of resolution (Strehl ratio = 1). Surface errors of the mirrors will degrade the performance especially since there are four mirrors in the image forming portion of the telescope. However, two of these mirrors are small flats, and it is felt that the random surface errors of these flats can be held to perhaps a 1/100th wave thus opening up the tolerance on the random surface

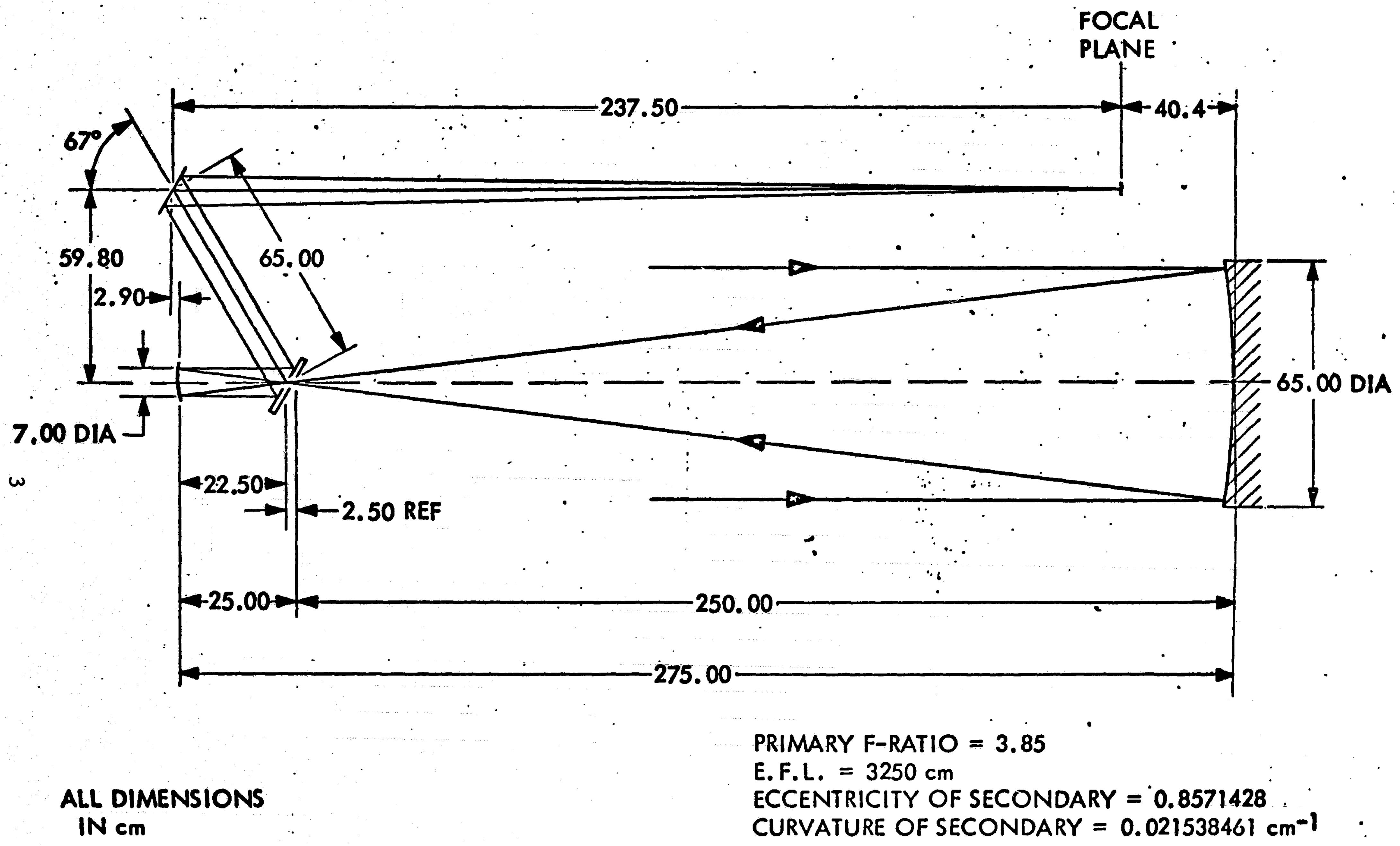

Figure 1. F/50 Gregorian Telescope With Magnification = 1.3

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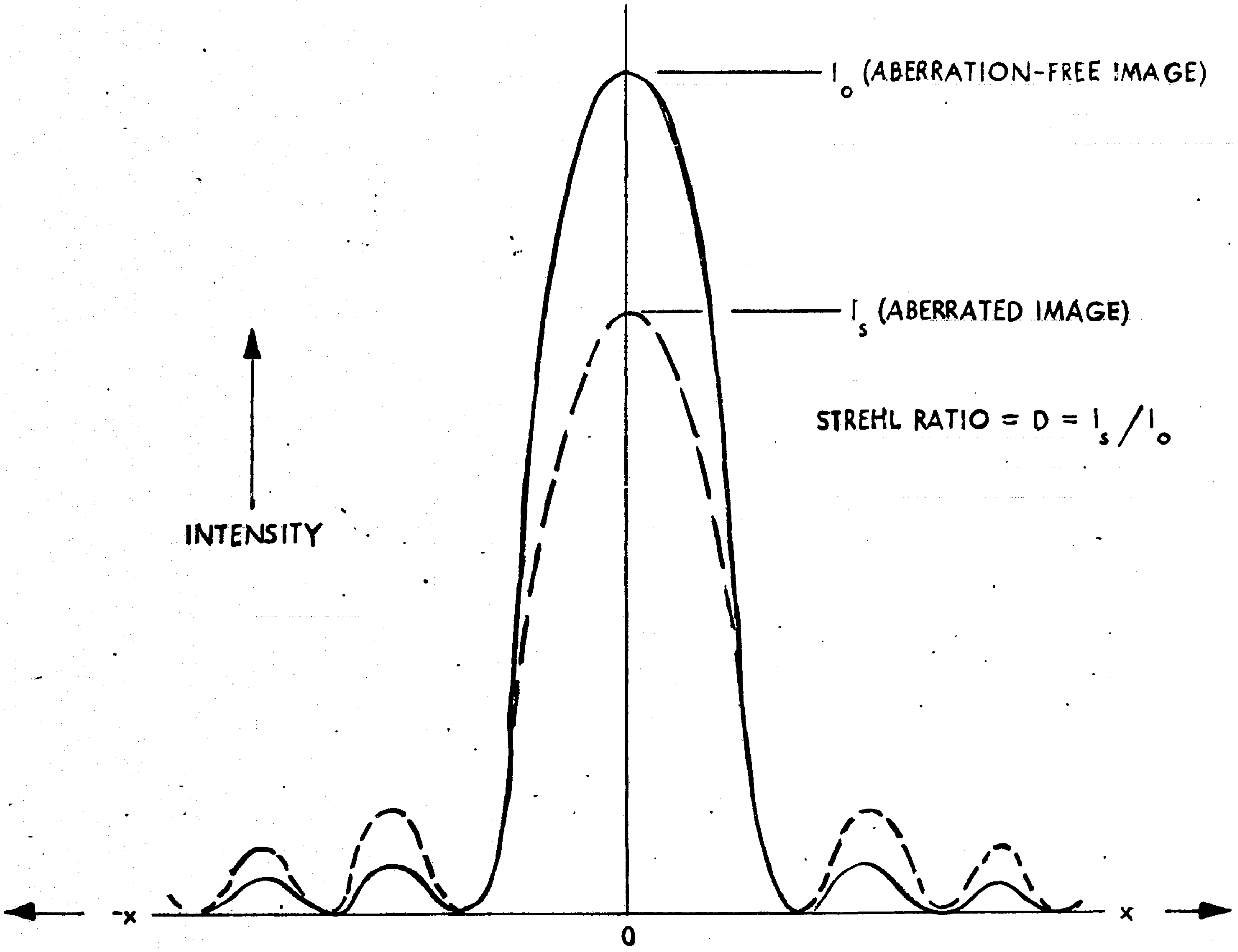


Figure 2. Strehl Ratio, D

errors on the two curved mirrors (primary and secondary mirrors). The manufacturing tolerance systematic wavefront error of the optical system should be held to approximately 1/15th to 1/20th wave. Systematic thermal distortions of approximately 1/20th wave are anticipated which, combined with the manufacturing tolerance, should lead to approximately 1/10th wave performance. It appears possible through tight control on random and systematic surface errors to achieve a Strehl ratio in the order of 0. 8 (a Strehl ratio of 0. 8 is equivalent to the Rayleigh quarter-wave criteria). Measurement sensitivity must accordingly be in the range of 1/20th wave for accurate determination of optical performance.

1. 2 Evaluation of Performance

Optical performance of a nearly diffraction-limited system depends upon the quality of the optical elements and the relationship in which they are mounted with respect to each other. To succesfully evaluate the performance of the telescope, measurements of the wavefront errors of the system must be made to within 1/20th wave. The Rayleigh criteria of 1/4 wave optical path difference in the image (Strehl ratio = 0. 8) is the expected operating point for the optical system. However, the accuracy of measurement is required to systematically evaluate each contributed error.

The performance will be evaluated then by Strehl ratio and the acceptable limit will be 0. 8 or better. The Strehl ratio is also defined as the ratio of the volume under the 3 dimensional MTF curve to the volume under the 3 dimensional MTF curve for an aberration free system.[1] The MTF will be the parameter by which the Strehl ratio is determined and the MTF will be computed from the measured optical path difference of the system. The PAGOS computer program (Program for the Analysis of General Optical Systems) and a program yet to be written will use the measured OPD to compute MTF using a technique described by H. H. Hopkins and J. L. Rayces.[2]

[1] W. J. Smith, Modern Optical Engineering, page 311

[2] H. H. Hopkins, The Application of Frequency Response Techniques in Optics Numerical Evaluation of the Frequency Response of Optical Systems
J. L. Rayces, Theory of a Numerical Method for the Computation of Optical Transfer Curves Based on Diffraction

Characteristics of the telescope that will affect the optical performance as measured by the Strehl ratio are mechanical effects of thermal gradients, misalignment and defocussing.

1.3 Schedules

2 YEAR

JET PROPULSION LABORATORY
APPROVAL RESPONSIBILITY H. G. TROSTLE
ACHIEVEMENT RESPONSIBILITY J. D. ALLEN

PHOTOHELIOGRAPH DEVELOPMENT

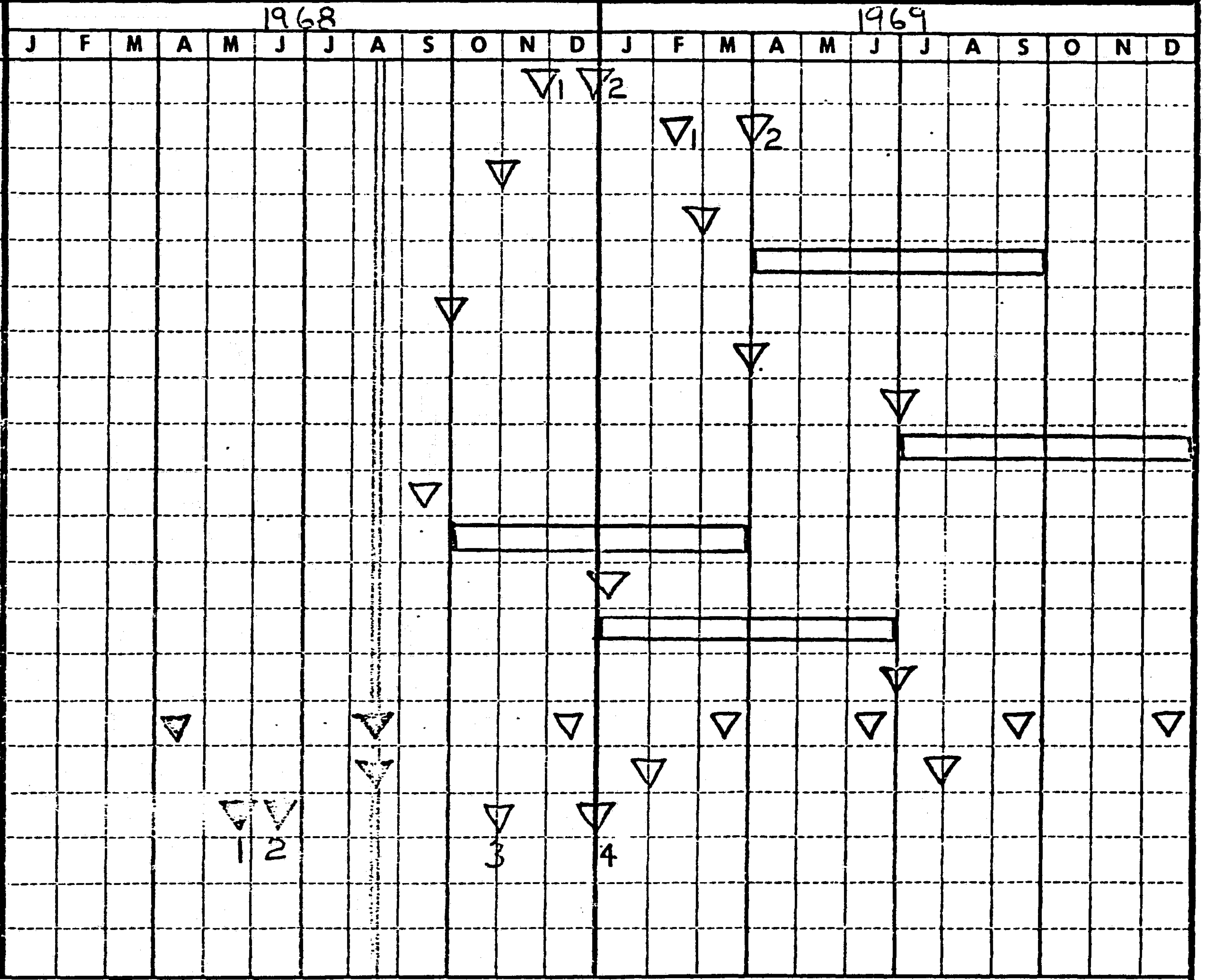
LEVEL

CONTRACTOR
NO.

ORIGINAL SCHEDULE APPROVAL
(DATE)
LAST SCHEDULE CHANGE
(DATE) (NO) (INITIALS)
STATUS AS OF AUG 5, 1968 JDA
(DATE) (INITIALS)

MILESTONES

1 PRIMARY MIRROR BLANKS RECEIVED ⇨
2 PRIMARY MIRROR FIGURING COMPLETE
3 PRI MIRROR CELL DESIGN COMPL.
4 PRI MIRROR CELL FAB COMPL.
5 PRI MIRROR ASSY. TESTING
6 INTERFEROMETER RECEIVED
7 OPTICAL TEST LAB COMPLETE *
8 SOLAR/VACUUM CHAMBER DES COMPL.
9 SOLAR/VACUUM CHAMBER FAB **
10 ALIGNMENT ASSEMBLY DES. COMPL.
11 ALIGNMENT BDBD. & TESTING
12 ZEISS H_α FILTER RECEIVED
13 FILTER TESTING
14 PRELIM FUNC, REQ. DOC. COMPLETE
15 QUARTERLY STATUS REVIEWS
16 SEMI-ANNUAL REPORTS
17 DESIGN REVIEWS ***
18
19
20



NOTES * BASED ON SEPT 1 GO AHEAD
** FY 70 FUNDS
*** DESIGN REVIEWS
1. PRI. MIRROR
2. OPTICAL SYSTEM
3. PRIMARY MIRROR CELL
4. ALIGNMENT ASSY

MILESTONE ▽ MILESTONE COMPLETE ▼
MILESTONE SLIPPED ▽
ACTIVITY SCHEDULED ▭
ACTIVITY COMPLETED ▨

SCHEDULE NO.

PAGE

2 YEAR

JET PROPULSION LABORATORY

APPROVAL RESPONSIBILITY J. D. Allen

ACHIEVEMENT RESPONSIBILITY C. J. Chocol

Test Plan for Proposed Photoheliograph

CONTRACTOR

NO.

ORIGINAL SCHEDULE APPROVAL

LAST SCHEDULE CHANGE

STATUS AS OF July 20, 1968

	MILESTONES	1968 J	F	M	A	M	J	J	A	S	O	N	D	1969 J	F	M	A	M	J	J	A	S	O	N	D
1	Buy Interferometer			XXX	XXX	XXX	XXX	X00	000	000	000														
2	Buy Test Optics					XXX	XXX	X00	000	000	000	0													
3	Prepare Optical Test Plan						XXX	X00	000	000															
4	Write Data Reduction Program						X	XX0	000	000	000														
5	Modify Computer Program							X00			000	00													
6	Calibrate Interferometer											000	000												
7	Calibrate Test Optics												000	000											
8	Verify Data Reduction System												00	000											
9	Calibrate Primary Mirror														00	000									
10	Thermal-Vacuum Test (Primary Mirror)																000								
11	Recalibrate Primary Mirror																	00							
12	Solar Flux Study (Primary Mirror)																	00							
13	Coolant Pressure Study (Primary)																		000						
14	Coolant Vibration Study (Primary)																		000						
15	Recalibrate Primary Mirror																			00					
16	Vibration-Shock Test Primary Mirror																			00	00				
17	Calibrate Optical System FVU																					00			
18	Thermal-Solar-Vacuum Test FVU																					0	000		
19	Alignment System Analysis FVU																							00	
20	Test Report																			000	000	000	000	000	000

NOTES

Activity Scheduled 00000

Activity Completed XXXXX

This is an idealized test schedule which has not been reconciled with the task overall schedule.

SCHEDULE NO.

PAGE

2.1 Test Program Planning

The following information is on test technique, test objectives, and brief test methods. In future revisions to this document, the test plans will be made more comprehensive.

2.1.1 LUPI vs Other Test Methods

The single most important quantity for specifying the performance of an optical imaging system is the complex amplitude distribution produced in the plane of the exit pupil by a point source object. The importance of this quantity inheres in that every other performance characteristic of the optical system can be calculated from it. Because this function is complex, it has both magnitude and phase. In practice, it is commonly assumed that the magnitude is constant everywhere within the boundary of the exit pupil and zero outside. It is also taken to be zero within the image of the central obstruction in folded reflecting systems. The assumption of constant magnitude is generally justified for image points near the axis of symmetrical optical systems of relatively low numerical aperture. Image points at large field angles and fast aberration-free optical systems require that polarization effects be considered; in these cases, the magnitude is not constant and an effective apodization occurs. The phase of the exit pupil complex amplitude distribution characterizes the shape of the image forming wavefront. Because the magnitude of the pupil function is nearly constant, the phase function is strongly dominant in determining the image plane intensity distribution produced by a point source object. On the basis of geometrical optics, it is immediately obvious that perfect image formation occurs only when the emergent wavefront is spherical. All optical systems test methods are based upon measuring either the shape of the emergent wavefront or its deviation from spherical.

The most direct method of measuring the shape of the wavefront emerging from the exit pupil is to use interferometry. This test involves recording the interference pattern produced by the emergent wavefront with a reference wavefront. If the reference wavefront is spherical, the interference pattern is a direct indication of the deviation of the emergent wavefront from spherical. All other optical system performance charcterizations or figures-of-merit are then directly calculable from the interferogram. A significant advantage of this method in this particular application is that the shape of the entire wavefront is measured in the time of a single photographic exposure. This is particularly important in measuring the transient response of the optical system to simulated solar heating. A further advantage which results from using a laser source in interferometric testing is that the quasi-monochromatic plane polarized light permits investigation of polarization effects.

Other test methods which were considered for this application include the Foucault test and the Ronchi test. In both of these tests, parts of the emergent wavefront are occluded in order to detect a departure from spherical. The measurement of the exact shape of the wavefront requires probing with the knife-edge in the case of the Foucault test and with the grating in the case of the Ronchi test of the region near the focus. The probing must be done in a precisely measurable and repeatable way in order for the test data to be interpretable in terms of the shape of the emergent wavefront. The time required to make these probing measurements causes these test methods to be incompatible with the requirement for characterizing the transient response of the optical system to solar heating. Both of these tests require the acquisition of a considerable amount of data, all of which is equivalent to a single interferogram.

The Hartmann test and the caustic test are immediately rejected because they require masking of the primary mirror when it is tested alone. An aperture mask would interfere with the solar heating simulation.

Of all the considered test methods, the use of the interferometer alone offers advantages without offsetting disadvantages.

2.1.1.1 Isolation Requirements

To be furnished

2.1.2 Optical Test Procedures

2.1.2.1 Calibration. Calibration of the Laser Unequal Path Interferometer and the associated test optics will follow a schedule such that all systematic errors inherent to the test optics can be eliminated. First the LUPI will be evaluated using an internal calibration flat. An interferogram from this test can be used during data processing to remove errors from the data originating in the LUPI. A general schematic of the LUPI is shown in Figure 3.

Similarly, the diverger lenses, which generate the diverging spherical wavefront, will be calibrated against the LUPI and a test sphere. The remaining test optics (i. e., autocollimating flat, diagonal flat, and folding flats) will all be calibrated using the LUPI, a test sphere and one of the diverging lenses. This type of test (for flat surfaces) is called a Ritchey test and is shown in Figure 4. All systematic errors for each element will then be known and can be subtracted from the test data.

2.1.2.2 Primary Mirror. Complete analysis of the primary mirror may be accomplished using the LUPI in the arrangement shown in Figure 5. This method will analyze a parabolic mirror at the focal point using an autocollimating flat. Changes in the optical performance will be correlated with thermal control of the mirror (under solar simulation) and mechanical mounting. The resultant primary mirror performance, in terms of MTF and Strehl ratio, can then be used as a base for complete system testing of the telescope.

An alternate method of analyzing the primary mirror has also been considered. This method would require the mirror to be figured to a sphere and testing would be done at the radius of curvature. This technique would not require the autocollimating flat, but the sensitivity will be halved as the system is only single pass. The system described above with the autocollimating flat is double pass.

Both of the above described test methods may be used on the mirror either in a vacuum or in air. Testing the mirror in a vacuum will allow complete analysis including Thermal deformation due to solar input, coolant fluid pressure study, thermal gradients due to coolant fluid, coolant fluid vibration study, and mechanical mounting. Tests that can be performed on the mirror while in air include coolant fluid pressure study, coolant fluid vibration study,

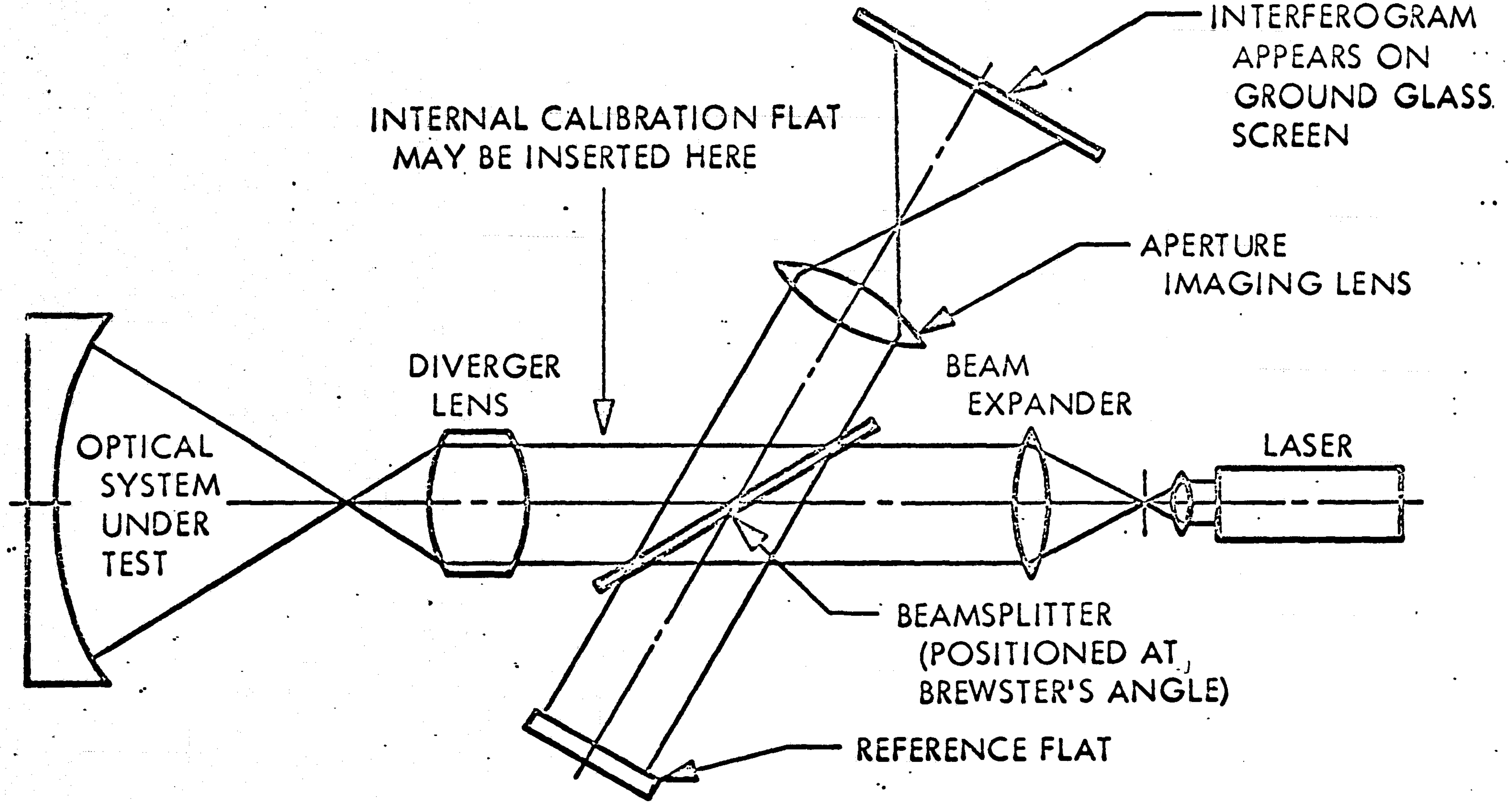


Figure 3. Optical Schematic of Laser Unequal Path Interferometer

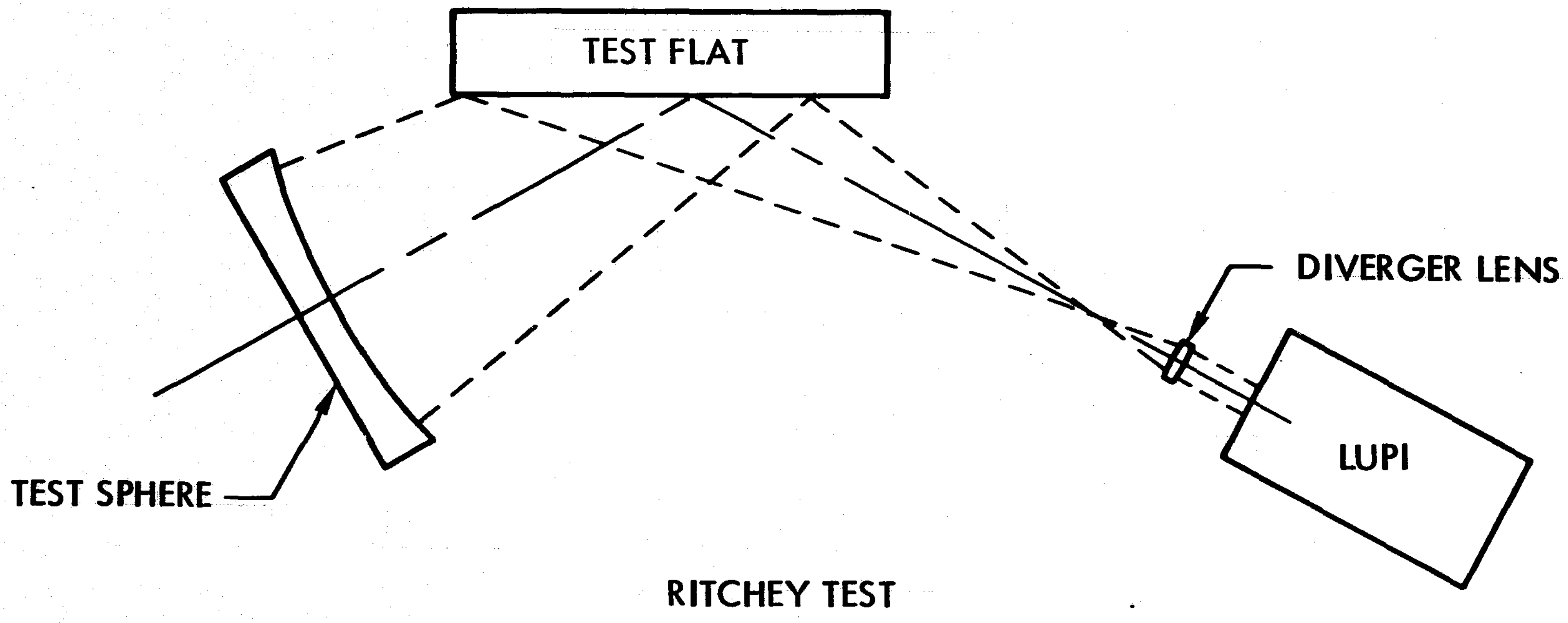


Figure 4. Ritchey Test

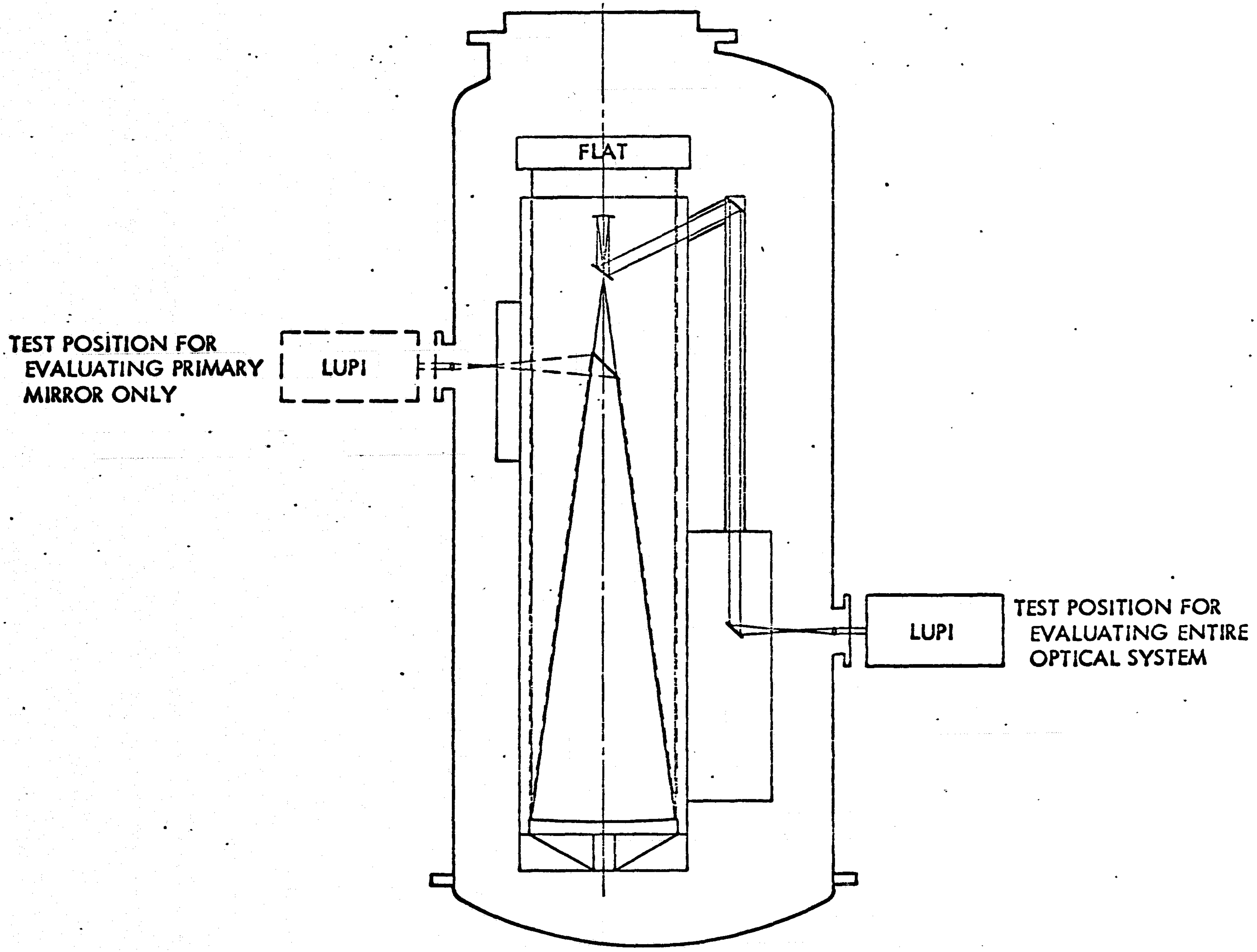


Figure 5. Optical—Thermal—Vacuum Test Chamber, ATM-Photoheliograph

and mechanical mounting. Tests with thermal inputs may be difficult to do in air due to the turbulances that would be generated.

2.1.2.3 Telescope System. All the tests performed on the primary mirror will be repeated in the telescope system tests in addition to optical misalignment and defocussing (see Figure 5). Interferograms taken for each test on the telescope system will determine experimentally the allowable limits of thermal gradients and their mechanical effects, optical misalignment and defocussing. A complete simulated mission with the telescope operating will be performed to determine the length of time required after entering full sunlight to become operational within the optical performance tolerances.

2.2 Temperature Control System Performance Tests

2.2.1 General

The current design of the Photoheliograph incorporates an active temperature control system to dissipate the excess energy that the primary mirror absorbs when it is solar illuminated. This system utilizes channels in the mirror, together with connecting lines, pumps, accumulators, radiator plates and a coolant fluid to transport the energy from the mirror to the radiators.

While the current design for the primary mirror cooling has been outlined here, it is conceivable that some other method may be used, particularly if a different boost vehicle is used and the telescope is un-manned. The current design also includes a similar system for the secondary and the heat dump mirrors to that used for the primary.

These systems must be tested under conditions which simulate, as nearly as possible, the environments to which the telescope will be subjected during flight.

Two approaches to the testing can be taken. The system can be subjected to the proper environment and the following situations can exist:

(1) The mirror can be well instrumented; therefore, the temperature distributions can be compared with that predicted from analysis. It will then be assumed that the optical characteristics are identical to the analytical results for the particular temperature distribution.

(2) The mirror can be tested in the prescribed environment with an optical monitoring system. When an acceptable optical condition results then it will be assumed that the temperature distribution is approximately that which was predicted by analysis.

Neither approach is straightforward, both having unique and therefore compromising problems.

The first approach would, of course, be preferred from the temperature control point of view. The test prescribed is directed toward temperature control interests. Unfortunately meaningfull instrumentation of the mirror is almost impossible due to the characteristics of thermocouples on or in quartz. Even if this problem did not exist or was not so severe, the fact that there will only be one mirror means that all precautions must be taken to protect it and this would also mean very limited handling.

The second alternative, although not resulting in a temperature map which can be directly compared with analytical results, does result in the final answer desired, the optical characteristics of the mirror.

Some of the problems which have existed in thermal vacuum testing similar to the one proposed are that hardware is placed in a position where it affects the results and then these affects must be backed out somehow. The optical monitoring system will require that the solar beam pass through an optical element which would cause a change in the characteristic of the spectrum depending on the material used. There also may be a problem controlling the temperature of the optical element. Hardware required in the chamber to support the monitoring system would alter the results unless the facility were large enough to allow the hardware to be outside the boundary simulators for the test. In particular, any beams of the vertical optical bench which support the flat mirror between the solar source and the mirror in test should be external to any hardware which simulates the ATM canister.

Most of the problems associated with the second alternative can be designed around the either eliminated or minimized. The first alternative presents problems which approach the impossible. Neither alternative is desirable, but the second is the more satisfactory.

The current analysis does not have boundary conditions that are compatible with the actual chamber environment. The back surface of the mirror can be enclosed in a super insulation type wrap which approaches the condition of an adiabatic surface. When the boundary conditions for the front surface are known some re-analysis will be required before the test predictions can be made.

2.2.2 Environment Required

The test environment which will be required for thermal tests will necessitate a vacuum chamber with a solar simulator, and temperature controlled walls to simulate the ATM canister. Since heat transfer by conviction would alter the temperature distribution of the telescope significantly it is necessary that any temperature control tests be performed in a vacuum of at least 10^{-3}mm Hg.

In order to monitor the optical characteristics of the mirror during testing no heaters can be placed on the front surface of the mirror or in front of it to simulate the sun. An IR heater would have to have a temperature of approximately 500°F to be an effective solar simulator. In addition, if the heater plate were placed in a position so that the front surface is not obstructed from view the heat input would not be uniform. For these reasons a solar simulator with a known spectrum for vacuum deposited aluminum will be required.

The telescope, in relation to the ATM, will have to reject heat from its radiators to the ATM canister which is to be maintained at 50 ± 3°F. Also the supporting structure will have to be maintained between 55 and 62°F to be compatible with the boundary conditions as given by the ATM system specification No. 50 MO 2417, "Performance and Design Requirements Apollo Telescope Mount (ATM) System General Specifications for." Thus, the current design allows the boundary conditions to be effected quite easily.

The structure required in the chamber to support any test hardware should be kept outside the volume which simulates the canister quadrant. If there is any violation of this requirement, the hardware will have to be finished in a manner called out by the temperature control group.

2.2.3 Instrumentation Required

The instrumentation required for the Solar-Thermal-Vacuum (STV) testing will consist of the following:

(1) Thermocouple Support Equipment

(2) Solar Intensity Monitor

(3) Chamber Pressure Monitor

Thermocouples will be utilized in any thermal testing and except for the shroud or other chamber hardware, which is usually monitored by the facilities group, the item which is being tested will have thermocouples attached when delivered to the chamber. But the peripheral equipment necessary to support the thermocouple instrumentation will be required at the chamber. Items such as reference junctions, leads, feed-throughs, and a calibrated data scanning system, such as a Datex scanner and digital printer, will be required.

In all tests it will be required that the intensity of the solar simulation be one solar constant at the plane of the front surface of the mirror. In the past this has been monitored with black flat plates, solar cells, and radiometers. The monitoring unit will be required in the chamber and may require special modifications for these tests. Most of these devices would not require as elaborate a modification while testing the mirror only as they will require for the entire telescope tests. The reason for this is that more hardware will be in the chamber at some temperature other than that of the shroud temperature and therefore will require shielding from direct IR and reflected solar.

These solar monitors will also require leads and calibrated read-out equipment, and in the case of the radiometers may require lines for water cooling.

The chamber pressure is ordinarily monitored by the facilities support group, but periodic readings should be recorded in the operations log.

2.2.4 Pretest Checkout and Calibration

After any unit is installed the instrumentation must be checked out and the solar intensity sensing devices must be calibrated.

The thermocouples can be checked out just prior to closing up the chamber. Using ambient temperature as a reference, a scan can be made and all thermocouples should be indicating approximately room temperature. Following this a heat source can be applied and the direction of the response noted, or if there is any response at all. If there is a response, this shows that the sensor is not open circuited, and if it is in the right direction, the polarity is correct.

The solar intensity sensor response and calibration must be obtained prior to closing the chamber for testing. The sensing elements can be checked with a standard sensor when the solar simulation is turned on. The characteristic of the standard in air compared to vacuum must be known.

Pressure lines for the coolant loops must be checked to ascertain that no leaks exist. The pumps must be operated to be sure they are properly installed and operate correctly.

During this period of checkout, and preferably immediately before closing the chamber, all test hardware should be checked for general cleanliness.

2.2.5 Thermal Control Tests to be Performed

This section will be broken up into two sections. The first section will outline the tests which would be performed on the mirror only; the second will be concerned with the telescope testing.

Mirror Tests

The tests which are of interest to thermal control are as follows:

(1) Transients (All mirror tests will start with an approximately 70° uniform temperature.)
   (a) Solar illumination with fluid flowing
      1. Full capacity pumping
      2. Half capacity pumping
   (b) Solar illumination with stagnant fluid
(2) Steady State

As stated, all tests are to start with an approximate 70°F bulk temperature. Due to the problems associated with instrumenting the mirror, this may be difficult to ascertain, but some representative measurements will be possible. This is compatible with the temperature of the fluid circulating and, therefore, the coolant can be circulating to help obtain the initial temperature. Once these conditions are accomplished, the mirror can be solar illuminated and the transient response monitoring begun. This same test can be done with the coolant rate flow cut in half when the solar illumination is started.

In a third test the initial conditions should be accomplished and then, two to four minutes after solar illumination has started, the coolant pumping should be stopped. This test is necessary only if it is found that the vibrations due to the coolant flowing is not acceptable. Since this is a test of the mirror only the proper coupling of the pumps cannot be simulated; therefore, the pumps should be isolated so that this vibration input does not get into the mirror.

The steady state test is not a simulation of flight conditions, but serves two other purposes. One is to get a check on the time constant of the mirror and the other is to check the analytical results.

Telescope Tests

The tests which are to be done with the telescope as a unit will not differ greatly from those which have been called out for the mirror except there will be additional tests required. The additional tests are the ones which will be discussed in this section.

The pump vibrational affects must be obtained during the telescope unit test. This data can be accumulated simultaneously with the transient testing. The results from this will indicate whether or not a stagnant fluid test is required.

With this unit a simulation of several orbits to achieve the cyclic quasi-steady state condition is a desirable test. The validity, of course, depends on the ability to simulate the shadow conditions. This may not be possible and, therefore, could invalidate any such test. Further studies of this condition are required.

3.0 PROPOSED AND ALTERNATE FACILITIES

3.1 JPL, Building 183, Complete Facility

A test chamber has been designed for testing of the ATM-Photoheliograph. Performance of the optical system and the temperature control system will be verified while subjecting the telescope to a simulated equatorial orbit solar input with appropriate S/C interfaces simulated.

Chamber Design Requirements

The Test Chamber described herein, will provide a Thermal Vacuum Environment with Solar Radiation for performing optical system and temperature control system tests of the Photoheliograph. The vacuum requirement is twofold: eliminate the effects of heat transfer by conduction and convection from the test results, and eliminate distortion of the optical path length caused by air. The thermal requirement is also twofold: simulate the S/C boundary conditions of the telescope and simulate the solar thermal input. Another requirement for this test chamber is vibration isolation. This is necessary to reduce the seismic and man-made vibrations such that the relative motions of the optical elements are comparable to their design tolerances (twentieth wave) and we can therefore verify that design tolerances were achieved and are maintained in test.

The test instrument to be used is a Laser Unequal Path Interferometer (LUPI). This instrument will be used as in a two-pass autocollimating configuration. In this configuration the laser beam is introduced into the telescope at the image plane and emerges from the entrance as a collimated beam. This is reflected from a return flat back in the direction of actual solar energy flow. This beam emerges from the image plane and re-enters the LUPI, where an interferogram is produced. This configuration will magnify the optical path errors by a factor of four. The LUPI must be located outside of the vacuum tank with an optical window provided for transferring energy through the tank wall, because it requires adjustment during use and because the interferogram is formed inside the LUPI. For the short duration while the interferogram is being recorded, the solar beam and pumping will be interrupted in order to provide better resolution of the interferogram. The upper surface of the return flat is 1° off normal to the telescope axis, so that it won't send a return beam back through the telescope; for the same reason, windows between the chamber and solar source are also tipped.

Two classifications of tests will be performed in the Test Chamber. The first consists of the primary mirror only, in its support. As it is the energy gathering device its thermal optical properties are very critical. The second classification of tests consists of the entire optical system, with the exception of the filters and cameras, in its assembled configurations. There are many other types of tests that could be performed in this chamber, however, presently only these two have been defined.

The design requirements of the test chamber are:

1. Vacuum. A pressure level of 1×10^{-4} torr or less. This is sufficient to reduce the conduction and convection losses to essentially zero and reduce the optical distortion to an acceptable value for the laser use. Valving is such that pumps can be stopped while the interferogram is formed. A very important consideration of the vacuum environment is contamination by foreign materials. Since there are exposed optical surfaces present and optical testing of extreme accuracy is being done, deposition of any material on these optical surfaces must be avoided. Hence, cold-trapping is required.

2. Solar Radiation. One solar constant (133 watts/ft.^{2}) at the primary mirror surface, with characteristics as close to the actual sun as possible.

3. Thermal. To provide a simulated spacecraft interface at its appropriate temperature. The ATM main spar is to be maintained at +70°F and the canister is to be maintained at +50°F.

4. Vibration. As low a vibration environment that will produce a stable interferogram. A numerical value of 2×10^{-4} inches per second (at any frequency) has been established, based on the experience of the Itek Company facility; they form satisfactory interferograms in such a test environment. Effort is currently continuing to evolve a requirement based on our design, by use of twentieth wave relative displacement criteria and dynamic analysis of telescope/facility structure.

Chamber Description

We plan to implement these requirements in the test chamber in the following manner:

1. Vacuum. A Roots type pump was selected as it has the lowest backstreaming of any pump that meets the requirements of pumping speed and operating pressure range. A mechanical backing pump is also required for initial roughing down and then backing the Roots when it begins operation. A liquid nitrogen cooled trap will also be used to insure that no oil vapor can enter the chamber from the pump and also act as a collector for any residual water vapor.

2. Solar Radiation. The system is basically the same as is used in the 10 and 25-ft Space Simulators at JPL except the beam diameter is only 3-ft. Many of the components were made available to us from another project which was not completed. A 20 KW xenon arc lamp will be used as the energy source, instead of the original 5 KW xenon lamp, to provide the required one solar constant at the primary mirror. Our system has been analyzed using a computer program developed for the large space simulators, and the results show that our system will have a collimation angle of ±1° and a uniformity of intensity across the beam of ±6 percent.

3. Thermal. Temperature controlled shrouds surrounding the photoheliograph will provide the simulated S/C interface. Due to the lack of detailed information of the exact configuration of the spacecraft and thermal requirements we have not proceeded with the detailed design of the thermal control system.

4. Vibration. A pneumatic vibration isolation system will be used to isolate the test chamber from the building. All attachments, with the exception of instrumentation wiring, will be disconnected from the chamber during interferometer testing. The Solar Simulation System will not be attached to the test chamber but will irradiate the Photoheliograph through a fused silica window. The test chamber will be rigidly mounted to an inertial mass of concrete below it, and this assembly will then be supported on the vibration isolators. The inertial mass lowers the center of gravity of the test chamber/mass so that attaching the isolators at the center of gravity of the combination minimizes the susceptibility of the assembly to rocking motion.

The following instrumentation will be provided:

1. Pressure. Continuous pressure measurement below 1 torr using a hot filament Ionization gauge

2. Contamination. Continuous measurement of deposited mass on a cooled quartz crystal. This crystal is in an oscillator circuit whose frequency is determined by the mass of the crystal. As deposition occurs, the change in frequency is recorded, with a variation in the rate of change being an abnormal condition.

3. Solar Radiation Intensity. A solar cell will be located in the test chamber which can be remotely positioned to a repeatable location to read the intensity of the beam during a test.

4. Solar Radiation Uniformity. A solar cell will be mounted so it can be remotely positioned in the beam at various locations and obtain intensity vs. location prior to installation of the test item.

5. Temperature. Provision will be made for bringing sufficient thermocouple leads out of the tank to measure the required temperatures of all the appropriate components.

6. Vibration. We have available to use, on a loan basis, a single-axis seismometer, which has been used to measure the vibrations in various candidate buildings for housing the test chamber. If experience dictates, a permanent installation will be made.

The test chamber, as it has been described here, actually consists of two chambers, one above the other. For vibration isolation reasons the two chambers will not be in physical contact. The Solar Simulation System is a source of many vibrations which would create an impossible situation for interferometer testing, were everything contained in a single chamber. The upper chamber and a pumping system for it exists, as part of the equipment made available to us. The vacuum level is not critical, the reasons for evacuating are to prevent the formation of ozone which would degrade the collimating mirror and to reduce heating due to any absorption. As there are two fused silica windows with a pressure differential across each for the solar energy to pass from one chamber to the other, an implosion shield will be provided as a matter of safety. The upper chamber and all its necessary auxiliaries, which are attached, will be moveable to provide clearance for raising the lower tank shell during Photoheliograph installation or modification. The lower chamber will house the Photoheliograph and provide the thermal vacuum environment. This chamber will contain an internal structure to which all the optical components, including the Photoheliograph, but excluding the LUPI, will be attached. This structure, in turn will be rigidly mounted to the inertia mass. The tank shell surrounding this structure will not be used as a structural member for supporting any of the optical components. This will eliminate any deflections due to pressure load experienced in pumping down from atmosphere to vacuum. It will also permit the alignment of the complete optical system prior to lowering the tank shell. The LUPI will be mounted on its own structure, external to the tank shell, also rigidly attached to the inertia mass. Provision will be made for some remote adjustments of the optical elements to compensate for thermal expansion should this be experienced during the test. Provision will also be made for testing the optical components individually in their actual position on the structure.

3.2 Building 183, Seismic Mass Only (Partial Facility)

This configuration will consist of the same vibration isolation system and seismic mass described previously, but will not include either of the chambers. A steel tower, instead, will be mounted on the seismic mass and will support the LUPI and a turning flat at its upper end. The primary mirror, in its mounting cell, will be attached at the base of the tower. The tower structure will be enclosed to minimize convection currents and stratification of the air.

The intent of this partial facility is to give a capability to do limited testing and perfect data analysis routines, while deferring chamber cost to the next fiscal year. Therefore, the mass and building are designed to accept the chambers, so that they will be installations, not modifications.