NASA Technical Memorandum 104117

P-18

THERMAL DESIGN AND TEST RESULTS

FOR SUNLITE ULTRA-STABLE REFERENCE CAVITY

Ruth M. Amundsen

August 1991

NASA

National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23665-5225

Thermal Design and Test Results for SUNLITE Ultra-Stable Reference Cavity

Ruth M. Amundsen
NASA Langley Research Center
Hampton, Virginia 23665

Introduction

The SUNLITE[1] instrument is being developed by NASA Langley Research Center to validate the fundamental linewidth and frequency stability limits of a Nd:YAG laser oscillator, locked to a high finesse reference cavity, in the microgravity and vibration-free environment of space. The narrowest laser linewidth of a diode-pumped solid-state laser oscillator achieved to date has been 3 Hz; this is 20 times higher than the shot noise limit.[2] (Ref 1) Efforts to stabilize lasers in earth-based laboratories have been limited by sensitivity of the apparatus to vibrational noise and by distortions in the reference cavity induced by gravity. A free-flying experiment in the microgravity and vibration-free environment of space would greatly reduce these limitations. The SUNLITE program will provide an automated and self-contained stabilized terahertz oscillator and will characterize the operation of this oscillator system in space. The low vibrational noise in the space environment will enable the linewidth to approach the shot noise limit of the system. Among the many applications of such an ultra-stable laser in space are deep space coherent communications, astrometry, laser radar for location and docking, and laser-gyro rotation sensors. Ultra-narrow linewidth lasers will also enable investigations such as the detection of gravity waves and tests of the theory of relativity. (Ref 2)

The lasers on the SUNLITE instrument are stabilized by a frequency-modulation technique. This technique uses a cavity with ultra-high reflectance mirrors on each end to tune the laser wavelength by locking to the resonance frequency of the reference cavity. The resonance frequency is determined by the cavity length; thus the frequency and linewidth of the laser beam are extremely sensitive to small changes in the length of the cavity. Performing this experiment in space avoids gravitational and vibrational distortions in the cavity. Once in space, the dominant effect on the cavity length will be thermal changes. These thermal changes are due to fluctuations in the spacecraft temperature during an orbit, and also to optical bench heating produced by power dissipations of SUNLITE components. The cavity is fabricated from a material with a low coefficient of thermal expansion (CTE) to minimize the thermal effects, but the limit on the temperature change of the cavity is still a demanding one. A practical limit is established by requiring that the thermal noise not contribute more to linewidth than the photon shot noise. For the inherent 150 kHz linewidth of this cavity, this limits the length growth to less than 0.025 nanometers/minute which results in a maximum thermal gradient of 0.025°C/min.[3] This limit is close to the resolution of the thermal measurement system that will be used to verify that this requirement has been met. However, the design goal is to produce performance much more stable than this requirement, and the predictions from analysis support this expectation.

---

[1]Stanford University - NASA Laser In-Space Technology Experiment

[2]*Shot noise limit*: a physical limit induced by the discrete nature of the photons within the light beam; i.e. the photons are detected as distinct events rather than a continuous and steady phenomenon.

[3]CTE (α) = 2 x 10^{-8} m/m°C, L = 50 mm, ν = 3x10^{14} Hz.

In the laboratory environment, this level of thermal stability is often achieved by using either a series of thermal shields around the cavity to buffer the reaction to external changes, or thread-like isolating supports to minimize input from the external environment. For the SUNLITE experiment, mass and volume limitations make the first method impractical, and the requirement to survive launch environment vibrations entails modification of the second method. The final design must provide sufficient thermal isolation to meet the temperature gradient requirement, with adequate structural support to maintain the position and alignment of the cavity during testing and launch. The design of the passive cavity mount has been accomplished using an isolation technique to limit the heat transfer between the optical bench and the cavity, while maintaining a low mass and stable alignment. A thermal balance test was performed to evaluate the performance of the original cavity mount design. This paper will describe that thermal vacuum test, and outline some of the improvements suggested for similar thermal tests which require this degree of accuracy and stability.

Cavity Mount Design

The cavity mount design incorporates several features to improve thermal isolation. As shown in Figure 1, the inner spacer is a Zerodur* cylinder with mirrors at each end. Zerodur is a low expansion glass manufactured by Schott Glass Technologies. The "spider" which supports this is fabricated of Kel-F*, a thermoplastic by 3M with low thermal conductivity. The cylindrical case into which the spider slips is made of Super Invar*, a low thermal expansion iron-nickel alloy. The mounting feet, mount and yoke which attach the case to the optical bench are also fabricated from Kel-F. The mounting feet have a small area of contact with the optical bench and a small effective conductance area to the main portion of the mount. For the prototype used for this test, mirrors were not incorporated since they (a) would not be used in the thermal test, (b) have negligible thermal effect and (c) are extremely expensive. For the final cavity design, high-reflectance mirrors will be attached at the ends of the spacer and the cavity will have a finesse[4] of over 20,000. Also, the inner spacer was manufactured from fused silica rather than Zerodur in order to get similar thermal characteristics at lower cost. The low expansion qualities of Zerodur were not necessary for this prototype since there was no optical performance test.

The Zerodur which will be used for the spacer was selected for low CTE; a special grade is available for the flight unit which has a vendor-claimed CTE value of 2×10^{-8} m/m°C over the range 5 to 35°C. The thermal changes in length between the mirrors, however, will be determined by the sum of the material which connects the mirrors. The mirrors themselves are fused silica, which has a higher CTE than Zerodur, but the mirrored surfaces are on the front face of the silica block where it connects to the spacer; thus the expansion of the silica will not change the distance between the mirrors. The preferred method for connecting the mirrors to the spacer is an optical bond: a bond directly between the glass surfaces. If this is not feasible, it may be possible to lay an adhesive layer between the surfaces that is sufficiently thin so as not to substantially increase the overall CTE. Another option is to compensate for the CTE that the epoxy bonds add to the assembly. This can be accomplished by mounting the mirrors on the back surfaces, so that the thermal growth of the mirror substrate is in the opposite direction to the thermal growth of the spacer. By controlling the thickness of the fused silica block of the mirror, the CTE's can be balanced exactly, leading to a perfectly stable length between the mirrors under thermal changes. The exact materials and method of bonding have not been chosen at this time; the thermal requirements presented here assume that an overall spacer CTE value of 2×10^{-8} m/m°C is achievable.

The development of the reference cavity will be an iterative process and several designs will be analyzed, built and tested. Thermal testing on initial designs will be performed to characterize the thermal performance of the mount and to correlate it with analytical models. Later tests will incorporate

---

[4]*Finesse*: a figure of merit approximately equal to the number of times a light beam will bounce between the mirrors before being scattered or absorbed.
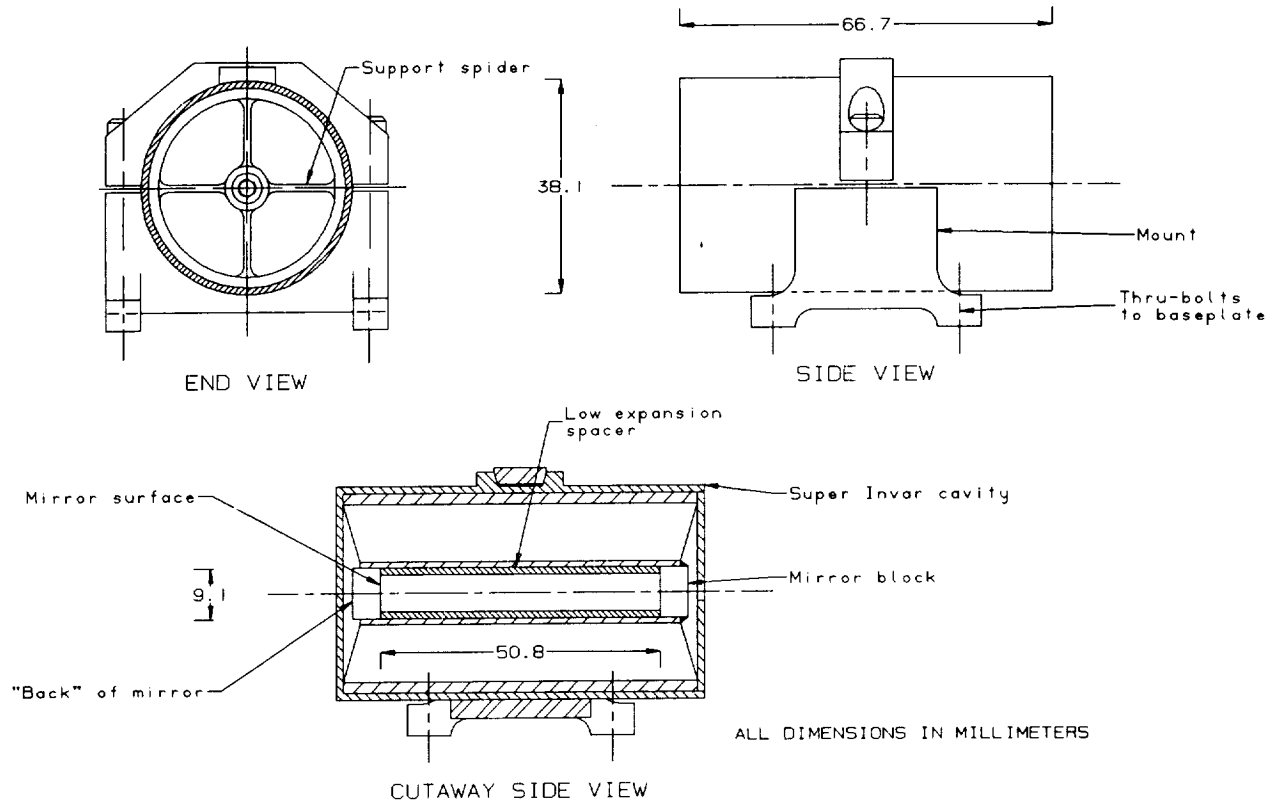
END VIEW

SIDE VIEW

CUTAWAY SIDE VIEW

ALL DIMENSIONS IN MILLIMETERS

Figure 1. Preliminary Passive Cavity Design

a functioning cavity and laser to evaluate the effects of the laser beam heating and ensure that the analytical model is accurate.

Test Objectives

The thermal stability is essential to the successful operation of the instrument and is severe enough to challenge the limits of analytical predictions. Testing of the prototype design provides confidence in the design technique, and yields data that can be used to correlate the analytical model. The main objectives of this primary test are to verify that the isolation technique will limit the thermal input to the cavity for a sufficient length of time and to gather data that can be used in correlation of the analytical thermal model.

The gradient requirement of 0.025°C/min imposes a requirement on the temperature measurement technique to read temperatures to 0.025°C, or be able to interpolate the measurements to this accuracy. The length of time for which the cavity needs to remain stable is roughly one hour after the temperature of the baseplate begins to change. This is the time period during which science data will be taken when the experiment is on-orbit. During this test thermal data was taken for much longer time periods than one hour to allow better correlations of the analytical thermal model.

Test Set-up

The SUNLITE thermal vacuum test consisted of four days of testing, with a different thermal cycle performed each day. The thermal response of the prototype reference cavity was measured by 15 temperature sensors (Omega AD590). The sensors were placed on the reference cavity as shown in

Figure 2 using RTV as a bonding agent. The sensor #1 reading is referenced most often since it represents the temperature of the spacer, which is the critical temperature in determining thermal growth between the mirrors. Two sensors were used to monitor the temperature of the baseplate near the cavity mount. The cavity was bolted to the baseplate, which simulated changes in temperature of the optical bench. The test was conducted in a vacuum to eliminate gas conduction and convective effects. The cavity was blanketed with MLI to minimize radiative thermal effects on the cavity and more closely simulate a flight environment. The temperature of the baseplate was computer-controlled to match the desired profile. The temperature of the baseplate was controlled by four infrared heat lamps directed at the side opposite the cavity and by LN_2 lines with a computer-controlled valve attached to the baseplate. Thermal profiles of the baseplate for each day were chosen to give a wide range of rates and ranges, in order to gather as much data as possible for correlation of an analytical thermal model.

The AD590 temperature sensors are current output devices which deliver a current proportional to their temperature. These currents were transformed to proportional voltages through a transconductance amplifier. The voltages were read and corresponding temperatures calculated by a Fluke data-logger. An automated program saved all test temperatures to three decimal places at two minute intervals.
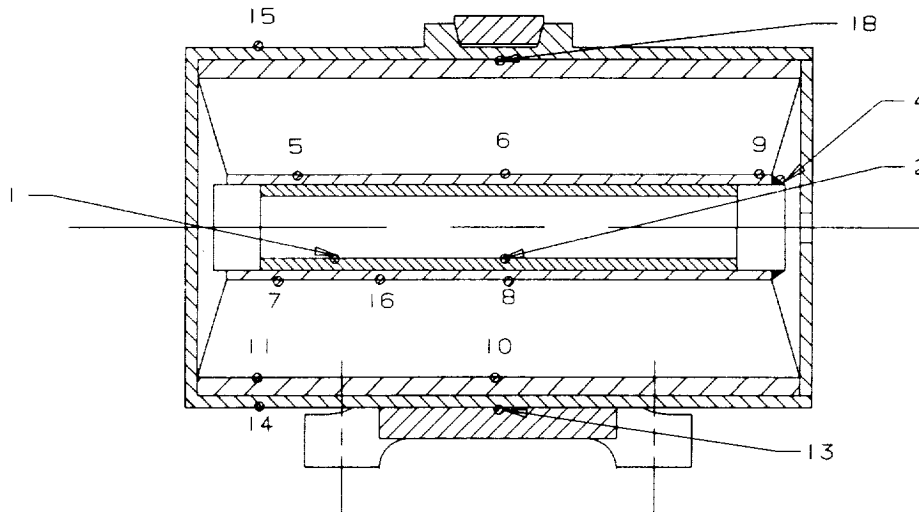

Figure 2. Temperature Sensor Placement

The temperature sensors have a maximum absolute error rating of 2°C, and a maximum repeatability error of 0.1°C/month. The potential absolute errors are not cause for concern since what is being measured is a change over time of each sensor reading; the error from some absolute temperature is not crucial. The sensors were also chosen because of their high degree of linearity (0.8°C maximum non-linearity). The conclusions section contains a discussion of potentially preferable sensor choices for later tests. To minimize the absolute errors between the sensor readings, each cycle was initiated with a steady state during which all sensors would be stable and at or near the same temperature. The calculated reference temperature was an average of all sensor readings at the initial time. This temperature was subtracted from each sensor's initial reading to give a correction factor used for that sensor on that test day. Due to the long stabilization time constant inherent in the isolation of the spacer within the cavity, either active or passive stabilization of the cavity temperatures was a lengthy procedure. Active stabilization before a run would have occupied over half the working day. Active stabilization of the cavity temperatures during overnight operation was not possible due to laboratory regulations. Instead, the test set-up was allowed to equilibrate in a passive mode overnight, so that temperatures would be stable and uniform over the entire cavity by the start of the test day. The use of an average temperature as the reference to correct the sensor readings did incorporate slight errors, since the sensors were not at

precisely the same initial temperature, but these were less than the potential 2°C absolute error. This correction does not affect the crucial parameters of stability and resolution for each sensor.

Data Evaluation

The values that are generated here for the cavity thermal drift should be over-estimates of the rate of drift for several reasons. First, the sensors used had an internal heat dissipation of 1.5 mW. It is difficult to determine what fraction of the 1.5 mW sensor power is affecting the junction temperature. The sensor data sheet suggests methods of calculating the effect, but not for any thermal environment similar to this (reference discussion in concerns section). This power is responsible for a small portion of the sensor-indicated rise in temperature, especially for Day 2, when the sensors were powered up not long before the start of the test. In the analytical model this power dissipation is accounted for by heat sources at each sensor. Another factor is the thermal impact of the wires that connect the sensors to the ambient environment. Long sections of 30 gauge wire were used to minimize thermal input and impact on the thermal rate of change. These wires, being connected to the external environment, add a thermal path that does not exist in the flight configuration; thus they add a conservative factor to the values for temperature change measured here.

The drift rates for Day 1 & Day 2 were positive before the start of the test, as shown in Table 1. This value was not subtracted from the total temperature rise, so that some of the observed temperature rise is due to drift. The Day 4 drift slope is negative before the test, and this value was added to the measured increase so that the corrected data would not show a misleadingly low temperature rise.

This data analysis method of taking the worst of all cases may seem over-conservative, but in fact there are mitigating factors. The sensors are each mounted on a small slab of RTV adhesive, so that there is some thermal isolation between the sensor and the associated structure of the cavity. Thus there could be a slight time lag between the increase of the cavity temperature and the increase in the sensor temperature; in other words, the actual temperature rise could be faster than the recorded temperature rise. The variation in the thickness of these pads of adhesive could lead to errors between sensor readings. Measurements of physical gradients along the spacer must be scrutinized to ensure that they reflect a real gradient and not a pseudo difference induced by the measurement technique. This may ultimately require extraction of spatial gradient predictions from the analytical thermal model, rather than using the values from the actual testing.

The reference correction performed to eliminate the variability error between sensors can introduce small relative errors due to initial differences in temperature. This potential error, and that due to the variation in adhesive bonds, make the relative values between the sensors less reliable than the change in one sensor reading with time. For this reason, the analytical model will be correlated using the changes in each sensor with time, and not differences between sensor readings.

The following table shows the initial stability of sensor #1 as well as the averaged reference temperature on each day of testing.

Table 1. Initial Test Conditions

Test Day	Stability (°C/min)	Average Temp. (°C)	Initial Rate Applied (°C/hr)
1	0.00075	24.815	+30
2	0.0075	23.842	+60
3	-0.0028	23.109	-15
4	-0.006	22.924	+3.6

Test Results

The test profiles for each of the four days are shown in Figures 3, 4, 5 and 6. The baseplate temperature and the reading of sensor #1 on the spacer are plotted. It can be seen from these graphs that the isolation is reducing the ramp rate observed at the cavity spacer by a factor of approximately 20, and the steady-state plateau of the spacer is far removed from the baseplate plateau. This is indicative of highly effective thermal isolation of the cavity spacer.

The thermal ramp for Day 1 (30°C/hr) is much more severe than anything that the cavity will see in flight and yet the thermal drift within the first ten minutes is still within the 0.025°C/min requirement. This is very encouraging. The data can be interpolated to reflect flight-like results using the rough guideline that the ramp will have a linear effect on the spacer change in temperature. A reasonable ramp value for worst-case flight conditions derived from preliminary optical bench modeling is 6°C/hr. This exact value was not used as a test ramp due to the fact that preliminary modelling was not complete when the ramps were selected. Thus, the results from each test must be interpolated to match predicted flight conditions. Within the nominal operation time of one hour, the cavity shows an interpolated average thermal rate of 0.011°C/min and a maximum rate of 0.017°C/min at the one-hour mark, both of which are within the requirement. This approximation factor cannot be used in lieu of detailed modeling, but it gives a preliminary idea of the temperature rise for flight-like conditions. Later optical bench modelling has indicated that the worst-case flight conditions will not be as severe as 6°C/hr; a maximum of 2°C/hr is anticipated. Thus the interpolated results presented here are extremely conservative.

The results from Day 2 show a roughly doubled increase in heating at the cavity over that of Day 1 which is reasonable since the ramp rate is twice that of Day 1. The heating at the one hour mark is not proportional due to the leveling off of the Day 2 temperature ramp at 50°C before 1 hour. The factored value for the flight-equivalent gradient over one hour is 0.006°C/min, well below the 0.025°C/min limit.

SUNLITE THERMAL VACUUM TEST: DAY 1
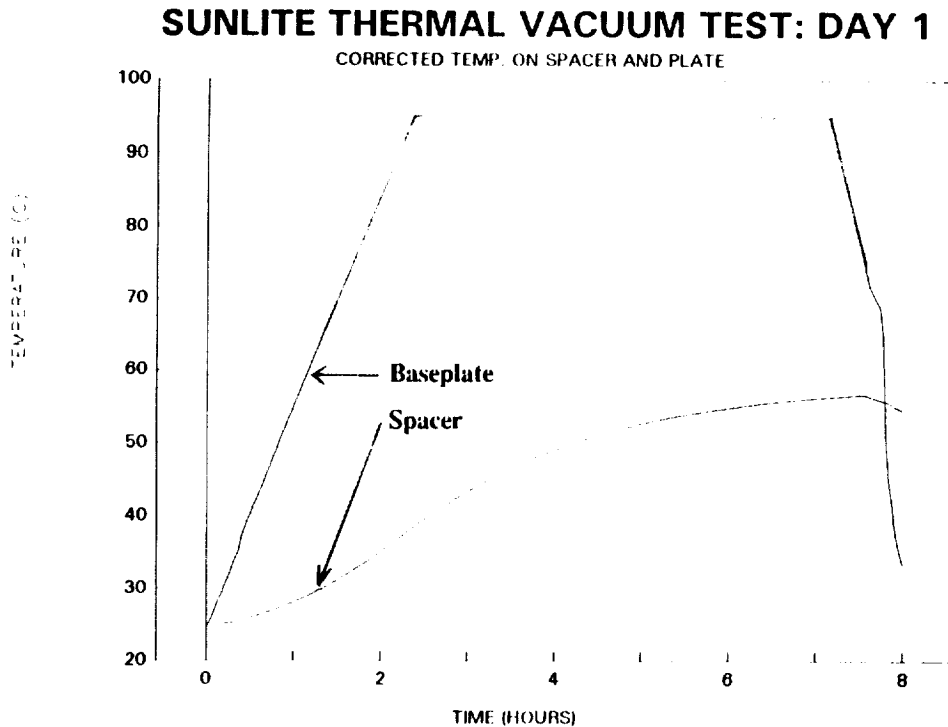CORRECTED TEMP. ON SPACER AND PLATE

Figure 3. Temperature Profile for Baseplate and Spacer for Test Day 1

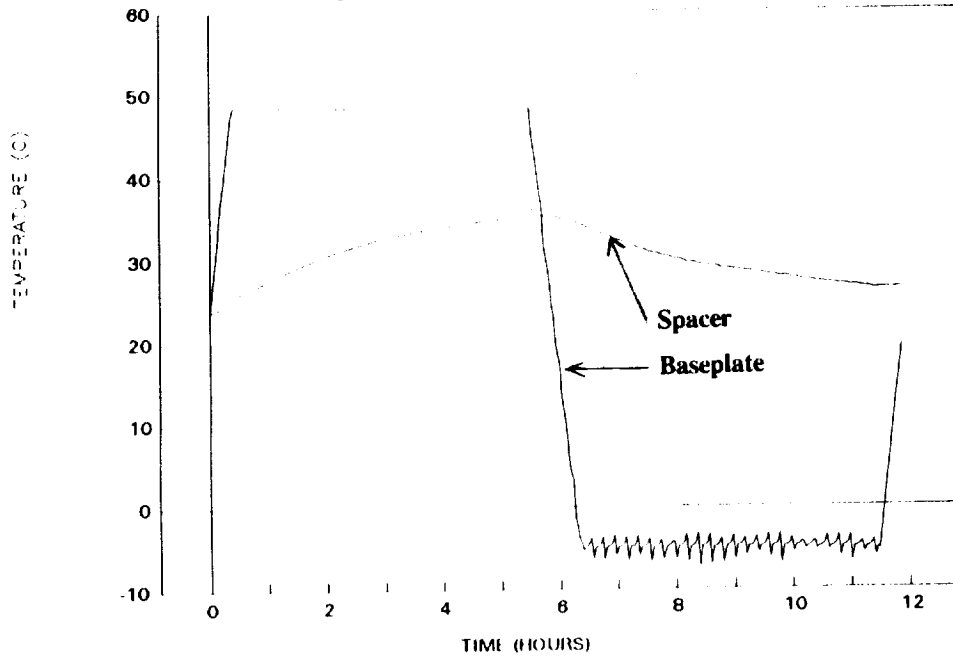# SUNLITE THERMAL VACUUM TEST: DAY 2

CORRECTED TEMP. OF SPACER AND PLATE

Figure 4. Temperature Profile for Baseplate and Spacer for Test Day 2

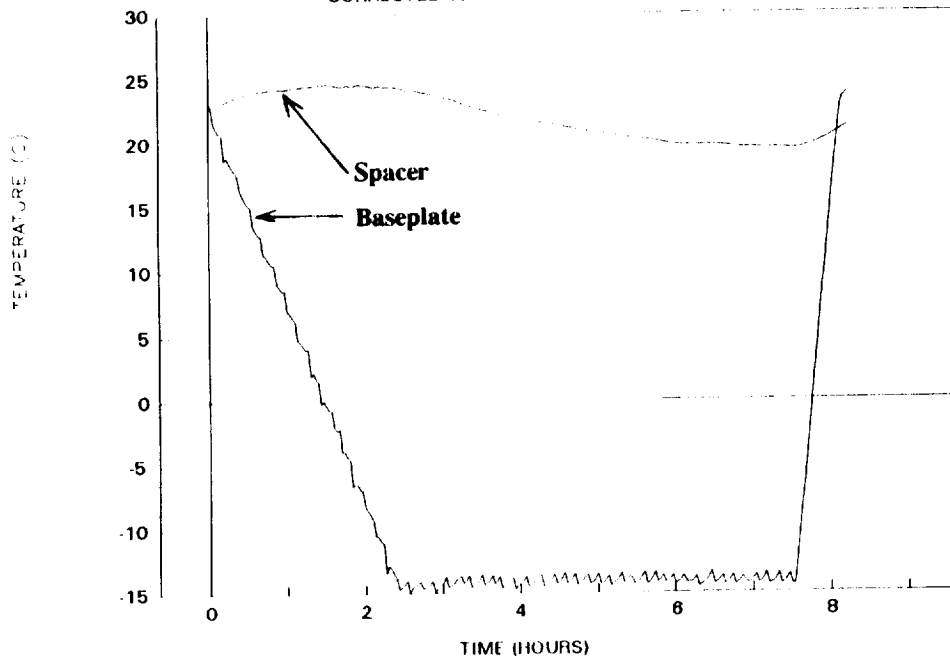# SUNLITE THERMAL VACUUM TEST: DAY 3

CORRECTED TEMP. FOR SPACER AND PLATE

Figure 5. Temperature Profile for Baseplate and Spacer for Test Day 3

SUNLITE THERMAL VACUUM TEST: DAY 4

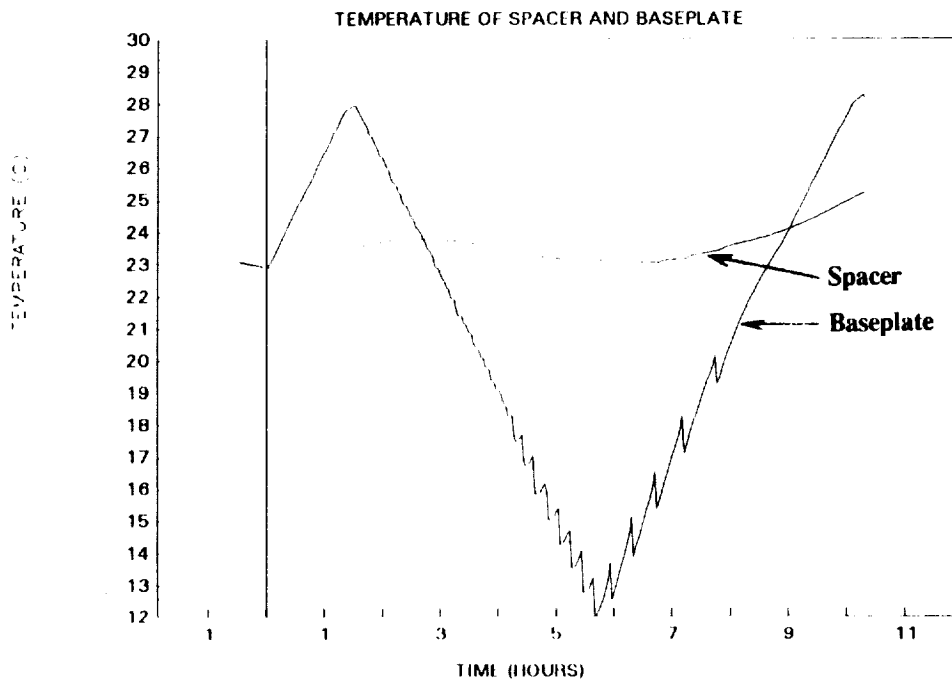## TEMPERATURE OF SPACER AND BASEPLATE

Figure 6. Temperature Profile for Baseplate and Spacer for Test Day 4

The results from Day 3 have not been interpolated in the same manner because the initial temperature deviation of the cavity is upward, even though the baseplate temperature is decreasing at 15°C/hr. This may be explained by some of the factors mentioned earlier such as the sensor self heating (see discussion below). The thermal ramps of 3.6°C/hr during Day 4 were much closer to what would be expected from the flight environment. The average change over a one-hour period was 0.008°C/min. When this is interpolated for a 6°C/hr ramp, the resultant average rate would only be 0.013°C/min and maximum rate 0.014°C/min; both are well below the stability requirement.

As shown in Table 2, the interpolated results for each test day show that this initial design would easily meet the imposed practical limit on the thermal rate even with worst-case conditions on the optical bench. The values for Day 2 are lower because of the leveling of the heating ramp before one hour.

Table 2. Interpolated Thermal Rates On Spacer for Equivalent 6°C/hr Ramp
(Requirement 0.025°C/min)

Test Day	Maximum Rate at 1 hr (°C/min)	Average Rate over 1 hr (°C/min)
1	0.017	0.011
2	0.009	0.006
4	0.014	0.013

The pre-test stability curves for each day of testing are shown in Figures 7, 8, 9 and 10. More sensor values are shown for Day 3, since it is interesting to see that all the sensors are going through the same slight temperature decrease before the downward ramp begins, at which point they all deviate upward. This provides evidence that some factor at the beginning of the test caused the upward deviation. This was the only test to initiate with a downward ramp; when the LN_2 lines begin full flow

to start the cooling and the IR lamps are activated to vaporize the liquid in the lines, there could be some anomalous radiative heating effect into the cavity. Another possible cause for this effect would be that the warping of the baseplate was the worst at the start of this test due to the combined effects of lamps and LN$_2$. This could cause the feet of the cavity to lose contact with the baseplate and reduce conduction from the cavity so that the self-heating of the sensors dominated.

A selection of sensors encompassing the main positions on the cavity assembly for Day 1 is shown in Figure 11. The main point to be elicited from these curves is that the major portion of the isolation is evidently being accomplished between the baseplate and the foot of the cavity mount, since the sensors are all showing a similar large temperature delta from the baseplate. The small conductive area of the Kel-F feet is effective in reducing the heat flow into the cavity mount. This should be considered when the design is modified for flight.

Problems and Concerns

Stability

The thermal stability of the testing building itself is not normally very high, and added to this was the fact that during the test the thermal control in the building was turned off for maintenance reasons. There was open air flow through the building from the outside during much of each day. For this reason, the stability before testing each day was not as good as could be expected. On the first day of testing the assembly was completed, power applied to the sensors, and pump-down to vacuum initiated. A three-hour period was necessary before sufficient stability was achieved to start the test ramp. For the second day of testing the vacuum system had been left operating in order to avoid the thermal impact of evacuation, but the sensors had been turned off. Powering up the sensors added the impact of self-heating to the quiescent system, and thus even after an hour delay the system was still changing. After Day 2, the sensor power and vacuum system were left on continuously for the duration of the test.
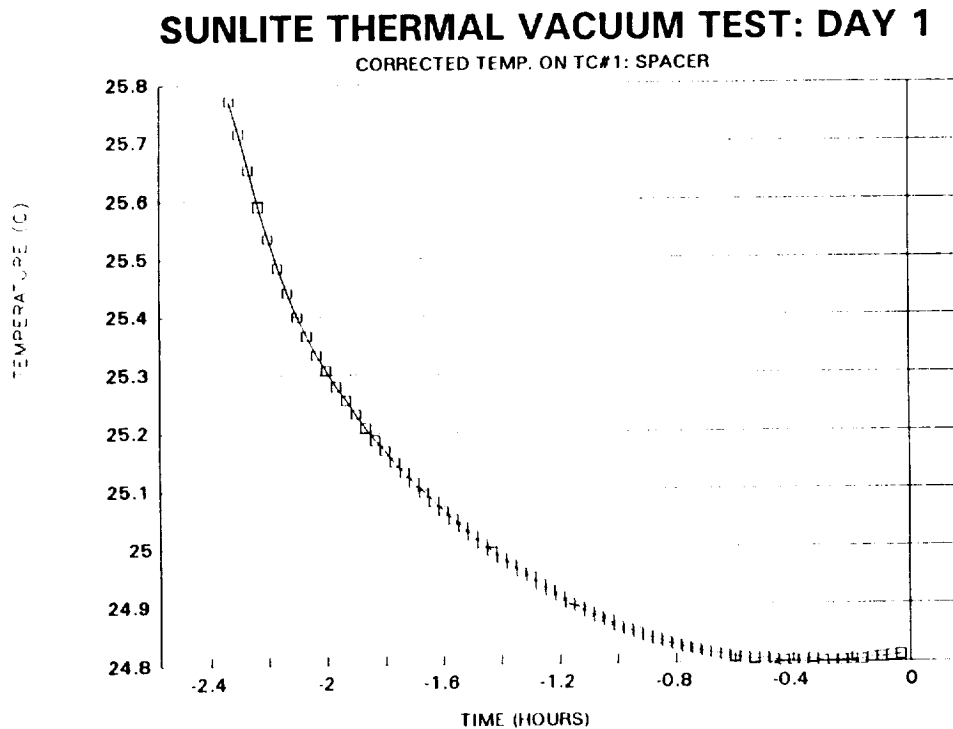
SUNLITE THERMAL VACUUM TEST: DAY 1
CORRECTED TEMP. ON TC#1: SPACER

Figure 7. Pre-Test Temperatures on Spacer Sensor (1) for Day 1

SUNLITE THERMAL VACUUM TEST: DAY 2

CORRECTED TEMP. OF TC #1 & #2: SPACER
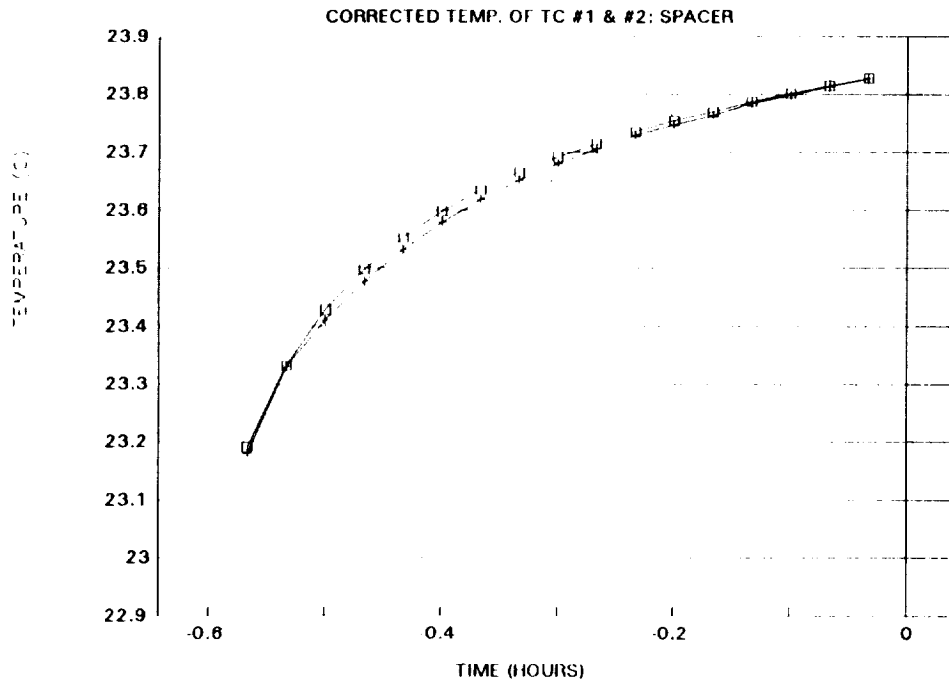
Figure 8. Pre-Test Temperatures on Spacer Sensors (1,2) for Day 2

SUNLITE THERMAL VACUUM TEST: DAY 3

CORRECTED INITIAL TEMPERATURES

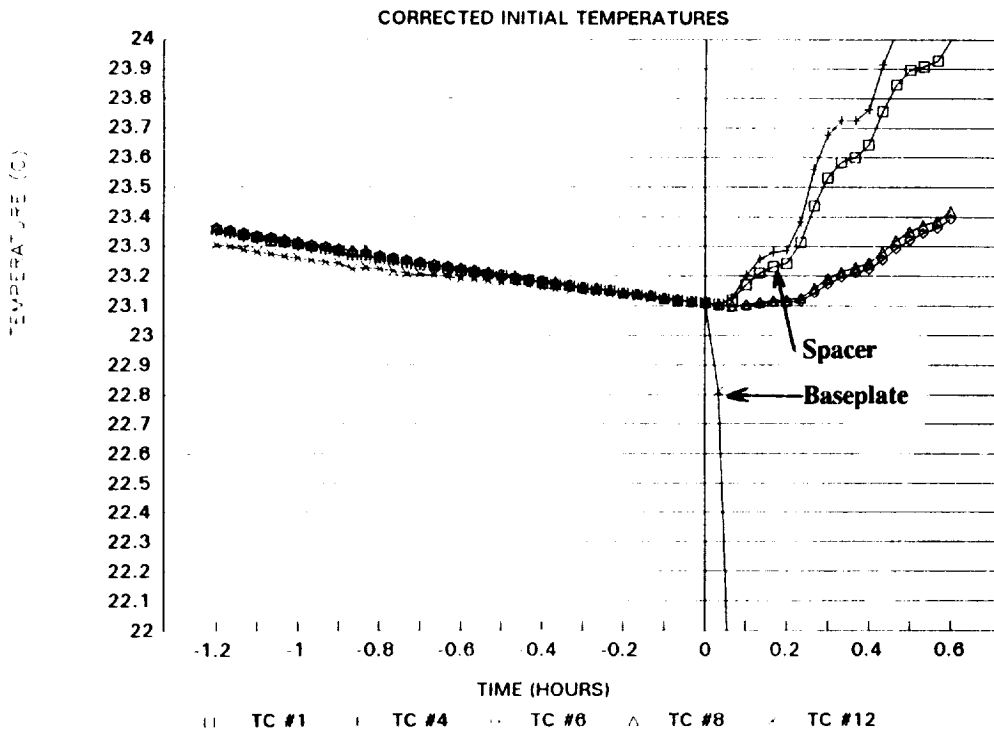| TC #1 | TC #4 | TC #6 | TC #8 | TC #12 |

Figure 9. Pre-Test Temperatures for Day 3

SUNLITE THERMAL VACUUM TEST: DAY 4

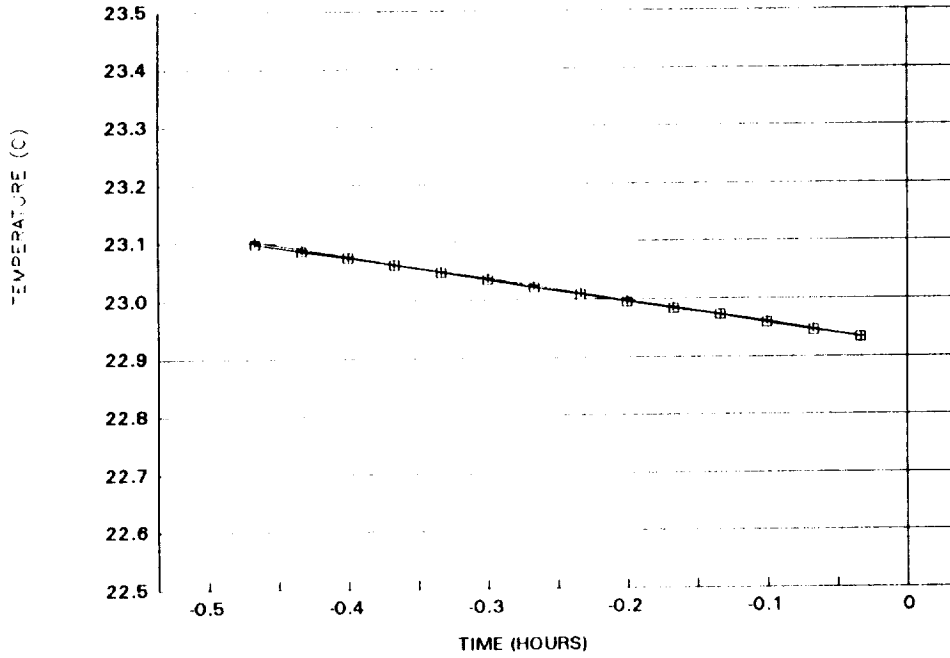## CORRECTED TEMP. OF TC #1,2: SPACER

Figure 10. Pre-Test Temperatures from Spacer Sensors (1,2) for Day 4

SUNLITE THERMAL VACUUM TEST: DAY 1
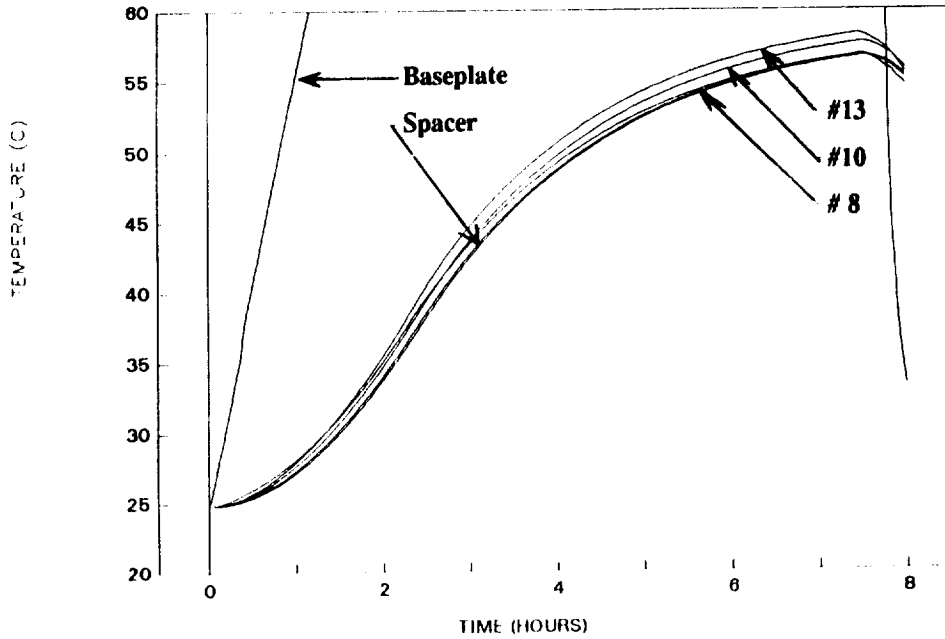
CORRECTED TEMP. ON SELECTED SENSORS

Figure 11. Selected Sensor Temperatures for Day 1

In general, for any future tests, every effort should be made to maintain active thermal control of the baseplate continuously throughout the test. One reason (in addition to time constraints) this was not done was because of the "noise" inherent in any thermal control system; it was felt that a passively stable baseplate temperature was more valuable than a continuously-controlled, slightly oscillating baseplate temperature. For this experiment, because of the isolation of the critical part (i.e. the spacer), the slight oscillation of an actively controlled baseplate would probably be more acceptable than the long-term drift.

The liquid nitrogen system used an "on-off" control, which produced large swings in the baseplate temperature at the lower temperatures. The effect of this can be seen in the jagged baseplate temperature profile in Figures 2 through 4. These variations at the low temperatures would not have affected the spacer temperature change, since there is such a long inherent time constant between the baseplate and spacer.

Sensor selection and attachment

The sensors chosen for this test were Omega AD590 monolithic integrated circuit high-sensitivity, high stability sensors. The current output aspect of these sensors is advantageous for vacuum test use, since they can be attached with little regard for the temperatures and materials at each electrical joint. However, they were not fully calibrated before the test due to technical difficulties. The correction of all sensor readings based on an initial average temperature affects only the absolute reading of each sensor and the comparison of the sensors to each other. The relative reading of each sensor (i.e. the change in the reading of one sensor over time) is still highly accurate. From the specified stability over one month, it can be seen that the stability over an 8-hour test day is at the 0.001 °C level. The extrapolations to flight conditions were made using the changes in single sensor values. Correlation of the analytical model also used the change in each sensor reading over time.

The main concern with these sensors in terms of using them for this type of test is that they dissipate heat. The heat dissipation of 1.5 mW per sensor may not seem substantial, but it produces a total of 22.5 mW within the cavity. From the analytical model, heating on the order of tens of micro-watts can be seen to change the spacer heating rate significantly. Since each sensor was mounted on RTV to attach it to the cavity, its thermal environment was highly resistive. The sensor self-heating is only guaranteed not to affect the results when the thermal environment is a highly conductive one such as a stirred oil bath. For other environments, the rise in the junction temperature above the ambient must be calculated. Unfortunately, this environment (vacuum with no heat sink) is not one for which the calculation parameters are given by the vendor, nor will all of the sensors have exactly the same environment. Differing amounts of RTV adhesive under each sensor, as well as the different substrates (Invar, Kel-F), will produce dissimilar thermal environments at each sensor. The self-heating of the sensors can be included in the analytical model, but without a detailed analysis of the thermal environment of each sensor, the determination of the actual temperature at each sensor location over time is an almost impossible task. In general, when temperatures are to be measured to this resolution and accuracy, it would be recommended to use passive sensors that dissipate little or no power. There may be some loss in the specified sensitivity of the sensor, but this will be more than compensated by the increased confidence in the data with no self-heating effects.

- 12 -

Conclusions

Cavity mount performance

The cavity thermal isolation performance was better than the requirement of 0.025°C/minute in all cases. This was true even when unrealistically worst-case conditions were assumed. The mount is damping the effect of external temperature change rates by at least a factor of 20. The main isolation is being accomplished in the Kel-F mounting feet and mount; the thermal isolating effect of the spider is outweighed by the effect of the small thermal conductance through the mounting feet.

Test system performance

The thermal stability of the test system was not satisfactory. For future tests, the baseplate will be kept under active thermal control during the entire testing period, as well as being actively stabilized for at least 12 hours before the start of the first test. The LN_2 line performance has already been improved since this test. Rather than using an on-off valve to add LN_2 to the plate and vaporizing it with IR lamps, the LN_2 flow is now controlled by a digital valve, which can allow units of flow from one-eighth to full flow depending on need. This will produce a much smoother temperature decrease ramp, and more stable soaks at low temperatures.

Some other options which could assist in correlation of the model and transfer of the information to a flight configuration are: to use a baseplate ramp which is as close as possible to the nominal flight ramp, and ramps slightly more and less severe; to run ramps which are symmetrical in increasing and decreasing temperature to ensure that there is no thermal bias in the test set-up; to ramp only the radiative environment in order to directly evaluate this effect; and to use MLI around the cavity which is as close as possible to the flight configuration. One severe ramp would be useful for providing a quick, rough correlation, and the remaining flight-like ramps could be used to attain the degree of accuracy needed.

Sensor selection

The sensors chosen for future tests should be ultra-low power, calibrated and repeatable to 0.01°C. The ultimate low-power sensor is a thermocouple; unfortunately thermocouples with a calibration of 0.01°C could not be located. The sensor currently proposed is a newly available miniature thermistor which claims a calibration of 0.01°C traceable to NIST. These are miniature thermistors with a room temperature resistance of about 10 kW and exceptionally steep resistance versus temperature properties. With suitable measurement techniques, the dissipated power can be kept below 0.1 mW per sensor. As few as possible of these sensors should be within the cavity, since power dissipated within the cavity will have the most impact on the spacer temperature.

Sensor attachment

As discussed in the results and concerns sections, the RTV adhesive bond between each sensor and the cavity may have affected the temperature readings. For this reason, if thermal testing or monitoring is performed in the future it would be desirable to have a more conductive bond between the sensors and the portion of cavity structure to be monitored. The optimum attachment from a thermal point of view would be a thermally conductive epoxy, such as one that is metal filled. Metallic tape or a metal mesh pad within the adhesive are also possibilities. If this is not feasible, more rigorous controls on the size of the bonding pad below the sensor would be helpful, to equalize the thermal resistance environment of each sensor. This would provide more uniform readings between sensors, as well as allowing simpler correlation of the thermal model. The suggested epoxy for future tests is a thin-film conductive adhesive used for electronic hybrids which has a uniform thickness of 0.13 mm (0.005 inches).

Acknowledgement

References

1. E. L. Dereniak and D. G. Crowe, *Optical Radiation Detectors*, John Wiley and Sons, 1984.

2. *Project Plan for the Stanford University - NASA Laser In-Space Technology Experiment (SUNLITE)*, NASA Langley Research Center, Hampton, Virginia, September 1990.

Appendix: Listing of Acronyms

CTE	Coefficient of Thermal Expansion
IR	Infrared
LN_2	Liquid Nitrogen
MLI	Multi-Layer Insulation
Nd:YAG	Neodymium Yttrium Aluminum Garnet
NIST	National Institute for Science and Technology
RTV	Room Temperature Vulcanization
SUNLITE	Stanford University - NASA Laser In-Space Technology Experiment

PAGE INTENTIONALLY BLANK

NASA	Report Documentation Page	

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA TM-104117		

4. Title and Subtitle		5. Report Date
Thermal Design and Test Results for SUNLITE Ultra-Stable Reference Cavity		August 1991
		6. Performing Organization Code

7. Author(s)	8. Performing Organization Report No.
Ruth M. Amundsen	
	10. Work Unit No.
	589-01-11-02

9. Performing Organization Name and Address	11. Contract or Grant No.
NASA Langley Research Center Hampton, VA 23665-5225	
	13. Type of Report and Period Covered

12. Sponsoring Agency Name and Address	Technical Memorandum
National Aeronautics and Space Administration Washington DC 20546-0001	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

SUNLITE (Stanford University – NASA Laser In-Space Technology Experiment) is a space-based experiment which uses a reference cavity to provide a stable frequency reference for a terahertz laser oscillator. Thermal stability of the cavity is a key factor in attaining a stable narrow-linewidth laser beam. The mount which is used to support and align the cavity will provide thermal isolation from the environment. The baseline requirement for thermal stability of the cavity is 0.025°C/minute, but the design is directed toward achieving stability well beyond this requirement to improve the science data gained. A prototype of the cavity mount has been fabricated and tested to characterize the thermal performance. The thermal vacuum test involved stable high-resolution temperature measurements and stable baseplate temperature control over long durations. Based on test data, the cavity mount design satisfies the severe requirement for the cavity thermal stability. Improvements to the cavity design will be made and additional prototypes will undergo thermal tests in the future. Lessons learned in this thermal test can be applied to future testing to improve the resolution and reliability of the results.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
thermal test, thermal stability, temperature measurement, reference cavity, laser, frequency modulation	Unclassified-Unlimited Subject Category 18

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of pages	22. Price
Unclassified	Unclassified	17	A03

NASA FORM 1626 OCT 86