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Gravity Probe B Relativity Mission

Science Mission Dewar Absorptivity and Emissivity Analysis

S0854, Rev.-
April 11, 2003

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ITAR Assessment Performed Tom Langenstein

ITAR Control Req'd? ☐ Yes ☒ No 4.23.03

Purpose:

This document verifies the PLSE-12 #3.7.5.2.5.2 *Dewar Solar Absorptivity* and #3.7.5.2.5.3 *Dewar Emissivity* for the surfaces of the Science Mission Dewar (SMD) tested on the ground and expected on-orbit degradation. The optical properties of the Dewar surfaces are important for evaluating the thermal performance with respect to the heat input from solar radiation, Earthshine, and albedo compared to the Dewar heat radiated to space. These properties determine the temperature at which the Dewar will be in equilibrium on-orbit. The verification method "Similarity" is added to cover the entire surface of the Dewar from taking representative samples.

Introduction:

The Dewar and Pallets were optically evaluated by test services on April 3, 2003. Measurements were taken at seven different locations on the Dewar. Because the Dewar is symmetrical and covered in the same type of FOSR the seven different locations are representative of the entire Dewar Surface. In addition the pallets were measured, but this does apply to the requirements for the SMD. The measurements were taken using a TEMP 2000 optical device built by AZ Technologies.

Requirement

PLSE-12 Requirement

Para	Title	Requirement	Method
3.7.5.2.5.2	Dewar Solar Absorptivity	The average absorptivity of the external surfaces of the SMD at the time of delivery shall be < 0.09 and < 0.12 at the end of operational life as specified in section 3.2.1.10.	A, T, S
3.7.5.2.5.3	Dewar Emissivity	The average infrared emissivity of the external surfaces of the SMD at the time of delivery shall be > 0.80. The average infrared emissivity shall not degrade below this value in orbit.	A, T, S

Reference Only – Operational Lifetime Requirement

PLSE-12

Para	Title	Requirement	Method
3.2.1.10	Orbital Life	The Science Payload shall have an orbital operating lifetime of >= 16.5 months after initiation of launch. The lifetime includes operations such as spinup, flux flushing, and low temperature bakeout. The 16.5 mo requirement is reduced on a pro-rata basis for any increased helium flow rate required by the spacecraft helium thrusters for attitude control, translation control, or orbit trim.	A, T

Acronyms and Abbreviations

GP-B – Gravity Probe B
LM – Lockheed Martin (by various current and old names)
PLF – Payload Fairing
SMD – Science Mission Dewar

Optical Test Results:

The results of the measured solar absorptance give a value of 0.05 for all locations, and naturally 0.5 is also the average value. The normal emittance measurement was 0.90 for all locations, and 0.90 is also the average value. The normal emittance is the amount of emittance measure at 90 degrees from the surface with the incident light also at 90 degrees. The hemispherical emittance is a measurement of the average emittance and includes the effect of scattered light caused by the shape and diffusivity of the surface. The TEMP 2000 device obtains this value when placed in Hemispherical Mode by comparing the emitted light to a gold and black standard. A value of 0.85 was measured for the hemispherical emittance for all seven locations, and this gives 0.85 as the average value. Table 1 provides a summary of the results and the required values.

TABLE 1 – Optical Properties of the Science Mission Dewar

Measurement Type	Average Value	Required Value	Pass/Fail
1. Solar Absorptance	0.05	< 0.09	Pass
2. Normal Emittance	0.90	> 0.80	Pass
3. Hemispherical Emittance	0.85	> 0.80	Pass

From the results it is clear that the SMD meets the Solar Absorptivity and Emissivity requirements at the time of shipping. There are no planned activities to mount additional FOSR or other surface material to the Dewar form the time of the measurements.

Degradation Analysis:

There are two primary sources of degradation for the Solar Absorptivity, which are atomic oxygen and micrometeoroid impacts. Other sources include debris from the Payload Fairing caused by the pyrotechnic release mechanisms and particle contamination from out gassing. While debris from the Payload Fairing can be modeled, it is difficult to predict the exact amount that will be released and actually remain on the surface of the Dewar. Because of the strict contamination requirements for the mission, evaluation of Payload Fairing contamination by Boeing shows that it will not impact the mission. Because the contamination sensitivity of the mission, the materials selected have low out gassing rates. In addition all assemblies have under gone Thermal Vacuum Testing at both box and Space Vehicle levels reducing the overall affects of out gassing on-orbit. The two primary sources of degradation were evaluated in EM SYS 316B [Ref 1]. The atomic oxygen degradation is based on the erosion level of the material. The SMD is coated with 3014 FOSR [Ref 2], with the exposed surface being made of Teflon FEP film 0.0100 +/- 0.0015 inch thick. Beneath the outer layer of FEP is the silverized metal film. From the table for "Predicted

Oxygen Induced Erosion of GP-B Surface Materials" in EM SYS 316B the expected erosion level is 0.0054 mil (0.0000054 inch) for two years. This value is less than variability of the surface due to production uncertainties, and is clearly negligible. The effects of orbital debris and micrometeoroid impacts are likewise negligible as seen by the table "Summary of Solar Absorptance Changes due to Impacts of Micrometeoroid and Orbital Debris" in same engineering memo, which gives a $\Delta\alpha_s$ of 4.3x10-7 for two years. The operational life as specified by 3.2.1.10 is only 16.5 months, and given that the effects of degradation of the FOSR surfaces are negligible for two years the requirement is met with margin for 16.5 months.

The change in the Dewar Emissivity over the operational life is dependent on the material radiating to space and not the changes in the quality of the surface coating. Since the entire Dewar is covered with FOSR this would mean that enough of the FOSR was damage or removed to expose the underlining silverized surface or bare aluminum. From the discussion above it was shown that the atomic oxygen environment does not affect the FEP coating enough to be noticeable over the mission life. The remaining orbital environmental factor that can damage the coating is micrometeoroids and orbital debris. Because the impacts are at high velocity even minute impacts will damage the FOSR and the effects must be view at the overall level provided by the average value. Since impacts from orbital debris and micrometeoroids have the same outcome on the optical surfaces (i.e., it damages them), it can be assumed that the same delta to the solar absorptivity will also be applied to the emissivity. The hemispherical emittance was measured at 0.85 and if the change for two years in the absorptance due to the micrometeoroid and orbital debris is applied it can be assumed that the average Dewar Emissivity will not degrade below 0.80. The change in Dewar Emissivity over the mission life is negligible and meets the requirement.

Conclusion: Dewar Solar Absorptivity & Emissivity

In accordance with PLSE-12 #3.7.5.2.5.2 and #3.7.5.2.5.3 and using the data in the Table 1 the Science Mission Dewar meets the requirements for solar absorptivity and emissivity at the time of shipping. The degradation for the Dewar solar absorptivity and emissivity is minimal and primarily driven my micrometeoroid and orbital debris impacts. These values are expected to be less than 0.09 for absorptivity and greater than 0.80 for emissivity over two years and meet the on-orbit operational life requirement.

Reference:

1. Jim Bush, Chien Chang, and Anthony Logan, EM SYS 316 Rev. B "The Effects of Meteoroid Debris and Atomic Oxygen on the Gravity Probe B Spacecraft", revised March 31, 2003.
2. J. J. Spaulding, S.S. Vylasek, and H. A. Costes, LAC 42-4437 W, November 7, 2001.

Appendix (Next Page):

1. Jerry W. Sullivan, Laboratory Report "Optical Evaluation of Gravity Probe B Space Vehicle – Equipment Pallets and Dewar (FOSR Surfaces), April 3, 2003.

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Lab Request/Job: AK0705
MPL File: 547874
Received: 3-APR-2003
Authorized: 4-APR-2003

Laboratory Report

Optical Evaluation of Gravity Probe B Space Vehicle - Equipment Pallets and Dewar (FOSR Surfaces)

Prepared for J. Bush O/L450, B/255, (650)424-2297 Fax: (408)742-0290

Charge No. F1-WMFR-AAAA
Information Requested Measure Solar Absorptance, Normal and Hemispherical Emittance
Items to Return 0

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AK 0705				
GRAVITY PROBE B SPACE VEHICLE, B/156E				
EQUIPMENT PALLETS AND DEWAR (FOSR SURFACES)				
SOLAR ABSORPTANCE				
NORMAL INFRARED EMITTANCE				
HEMISPHERICAL INFRARED EMITTANCE				
		SOLAR	NORMAL	HEMISPHERICAL
IDENTITY	LOCATION	ABSORPTANCE	EMITTANCE	EMITTANCE
PALLET	345 DEG, TOP	0.11	N/A	N/A
	345 DEG, BOTTOM	0.05	0.91	0.85
	300 DEG	0.11	0.83	0.79
	270 DEG, TOP	0.11	0.84	0.79
	270 DEG, BOTTOM	0.05	0.90	0.85
	210 DEG, TOP	0.05	0.89	0.84
	210 DEG, BOTTOM	0.05	0.90	0.85
	150 DEG, TOP	0.05	0.89	0.84
	150 DEG, BOTTOM	0.05	0.90	0.84
	90 DEG	0.05	0.90	0.85
	90 DEG	0.05	0.89	0.84
	60 DEG	0.05	0.90	0.84
	60 DEG	0.05	0.89	0.84
DEWAR	LOCATION #1	0.05	0.90	0.85
	LOCATION #2	0.05	0.90	0.85
	LOCATION #3	0.05	0.90	0.85
	LOCATION #4	0.05	0.90	0.85
	LOCATION #5	0.05	0.90	0.85
	LOCATION #6	0.05	0.90	0.85
	LOCATION #7	0.05	0.90	0.85

SAMPLE	*212894*		

Description **Gravity Probe B Space Vehicle Equipment Pallets and Dewar**

Date Received 3-APR-2003 13:37 *Lot* Unknown *Quant. Submitted* 20 EA

Sampled Date 3-APR-2003 13:37

Info. Requested Measure Solar Absorptance, Normal and Hemispherical Emittance

COMMENT_; Comment

Test Date 3-APR-2003 *Analyst* J. Sullivan *Book/Page* 4190/120