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Gravity Probe B Relativity Mission

S1006 Rev. –

June 3, 2004

On-Orbit Flux Reduction Decision

Prepared by

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ITAR Assessment Performed — Date

Tom Langenstein T. Langenstein ITAR Control Required? Yes/No 6·7·04

APPROVALS

Barry Muhlfelder	Program Technical Manager	June 3, 2004 Date
Gaylord Green	Program Manager	3 Jun 2004 Date
Francis Everitt	Principal Investigator	4 June 2004 Date
John Turneaure	Co-PI	6/3/04 Date
Robert Schultz	Systems Engineering ERIC KLEIN FOR BOB SCHULTZ	6/3/04 Date

Prologue

The On-orbit flux reduction decision meeting was held on 11-May-2004 from 2:00 PM to 3:00 PM in the GP-B conference room. The decision was reached to proceed with the flux reduction process (the pre-launch baseline plan). This document, written prior to the on-orbit operations reflects the discussion at that meeting. The appendix to this document contains the presentation materials from that meeting.

Several hours into this 38 hour long operation it became clear that as a result of the flux reduction process the supply pressure for the spacecraft thrusters as provided by the dewar would exceed the acceptance level for the thrusters prior to the conclusion of the flux reduction procedure. This exceedance was contrary to the prediction of the thermal subsystem team. A discussion was held with the appropriate thruster and other experts. These experts stated that while they could not guarantee performance above the acceptance level, they could see no mechanism which would cause permanent degradation to a thruster. Their technical judgment was that it was safe to proceed with the flux reduction process. The next day, a second discussion was held with a larger audience to again discuss this issue. The conclusion from that meeting was again unanimous agreement to proceed with the flux reduction procedure.

CHANGE RECORD

LIST OF ACRYONYMS AND SYMBOLS

IOC	Initial On-orbit Checkout
SQUID	Superconducting Quantum Interference Device
GP-B	Gravity Probe B
UHV	Ultra High Vacuum
SRE	SQUID Readout Electronics

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1 Introduction and Summary

A meeting to decide whether to proceed with the on-orbit flux reduction process, which is an on-orbit **baseline** process in the IOC timeline, was held on 11-May-2004 from 2:00 PM to 3:00 PM in the GP-B conference room with Francis Everitt (the GP-B principal investigator), Gaylord Green (the GP-B program manager), and specialists in gyroscope readout, gyroscope suspension, superconducting magnetic shielding, cryogenics, and GP-B science in attendance. Those in attendance included Sasha Buchman, Bruce Clarke, Francis Everitt, Gaylord Green, Dave Hipkins, Mac Keiser, Jim Lockhart, Dave Meriwether, John Mester, Barry Muhlfelder, Dave Murray, Mike Taber, and John Turneaure. After weighing the performance benefits and risks associated with a flux flushing operation, it was decided to proceed with the on-orbit flux flushing operation.

Barry Muhlfelder presented the charts that are attached to this document. He identified three issues: (1) the large noise associated with the temperature oscillations, (2) the magnitude of the trapped flux in the rotors, and (3) the SQUID bias signals at roll. We expect that the first of these issues, the large noise associated with the temperature oscillations, can be alleviated by means other than a flux flushing operation, *e.g.*, an extended UHV bakeout. The second and third issues require a flux flushing operation. A discussion of the benefits and risks associated with flux flushing are discussed in the following section.

2 Risk Discussion

There are two risks associated with an on-orbit flux flushing operation: one risk if a flux flushing operation is not performed and a second if a flux flushing operation is performed. Table 1 lists the two these risks, their probability, their impact on science, and background information. The likelihood and the severity are fairly clear for the first risk, which assumes that no on-orbit flux flushing operation is performed. The section below discusses the likelihood and severity of the risk associated with an on-orbit flux flushing operation.

2.1 On-Orbit Flux Flushing Operation

It is clear that the severity of the risk associated with an on-orbit flux flushing operation can vary between **High** to **Severe** depending on the degree to which the ambient magnetic field may have increased due to a tear or a warming of the superconducting lead bag during the final space vehicle level acoustic test or during launch.

There is strong evidence that the likelihood of the risk is Very Low. First, a successful flux flushing operation was performed after the acoustic test at the Payload level in which the gyro trapped flux met their specification of less than 9 μG. Second, a flux flushing operation was performed after the acoustic test at the Space Vehicle level. The trapped flux levels observed in the gyroscopes are the result of this flux flushing operation plus any additional trapped flux resulting from launch. Since the acoustic tests were designed to envelope the launch loads seen by the space vehicle, (i.e., the stress and heating on the lead bag during launch is expected to be more benign than for the acoustic tests) the current trapped flux level is due primarily to the SV acoustic test. The current trapped flux level demonstrates that the lead bag survived the SV acoustic test and therefore gives lead bag stress/heating margin due to launch. Further, a report, which is attached, entitled "Report on Lead Bag Heating During Ascent", 13-June-1997, prepared by Prof. Dan DeBra makes the following statement: "… there is about a 100:1 safety margin against a launch heating scenario which would lead to a reduction in the gyro accuracy during the science mission." On orbit data also indicates that the lead bag is intact. The bias signal at roll modulated by twice orbit is a measure of the magnetic ac shielding factor and is therefore an indicator of a permanent change to the lead bag integrity. The measured bias signal on gyroscopes 2 and 4 meet specification, while gyroscopes 1 and 3 are within a factor of 10 of this specification. All of the above data combined justifies the likelihood of the occurrence of this risk as **Very Low**.

Table 2-1. Risks Related to Flux Flushing Operation

Risk	Likelihood	Severity	Background
The contribution to the science error for Gyros #3 and #4 will exceed the spec. value if an on-orbit flux flushing operation is not performed	Occurred for Gyro #3 and Gyro #4	Moderate	The trapped flux level in Gyro #4 is a least 17.5 μG, which is about twice the spec. value of 9 μG. This requires the SRE to operated in Range 4. The trapped flux level in Gyro #3 is at least 8.5 μG, which is very near the spec. value of 9 μG. To provide adequate dynamic range it may be necessary for the SRE to operate in Range 3. The higher trapped flux and higher needed SRE Ranges of 3 and 4 lead to a contribution to the science error in excess of the spec. value. Also, the trapped flux level in Gyro #4 is expected to introduce linearity issues that have not been evaluated.
An on-orbit flux flushing operation may lead to higher values of trapped flux in the gyroscopes that can not be subsequently reduced leading to a greater contribution to the science error	Very Low	High to Severe	The acoustic test at the space vehicle level and/or the launch loads may have resulted in a tear in the superconducting lead bag and/or a temporary heating of the lead bag above its superconducting transition temperature, both of which can lead to an increased ambient magnetic field at the gyroscopes during flux flushing, which will be trapped by the gyroscopes during the flux flushing operation.