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Gravity Probe B Relativity Mission

S0356 Rev C

Payload Magnetometer Specification

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Table of Contents

DOCUMENT REVISION RECORD

Document Title: Payload Magnetometer Specification

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Authorization for change	Paragraph	Change Description
PCB0364	3.2.2.4	Changed pyroshock environment. Increased a half sine pulse duration to 0.5 millisecond from 0.25 millisecond.
PCB0371	Figure 1	Corrected Acceptance random vibration test level
PCB0378	Figure 1	Replace protoqual random vibration environment with acceptance level and add qualification level
	3.2.1.2	Removed Functional Test information from Electrical Interfaces table
	3.2.2.3	Change wording to clarify requirement (from 'shall be subjected to' to 'shall be capable of performance… after exposure to').
	3.2.3.2	Changed Field to Voltage Scale factor to 5.0 +/- 0.25 from 4.0 +/- 0.25 Volts/Gauss
	3.2.2.5.1 4.3.1.6	Changed range from 200 to 320 K to 210 to 328K and added +/- 5 degree tolerance. Modified Figure of thermal cycles (changed figure number from Fig 2 to Fig 4.3.1.6) and added a reference to the figure in paragraph 4.3.1.6
	3.2.2.5.2	Changed range from 200 to 320 K to 210 to 328K and added +/- 5 degree tolerance.
	3.2.3.1	Changed full scale measurement range from +/- 1.0 +/- 0.1 Gauss to +/- 0.7 +/- 0.1 Gauss
	3.2.3.2	Changed Field to Voltage Scale Factor from 5.0 +/- 0.25 Volts per Gauss to 4.75 +/- 0.30 Volts/ Gauss and added 'and shall be measured to a precision of 0.001 Volts/ Gauss'.
	3.2.3.7	Changed Zero Drift value from 0.1mG per degree Kelvin to 4.0 mG per degree Kelvin
	4.2.4.3	Changed Power requirement 'shall' to 'will' and 0.5 Watts to 1.5 Watts.
	Table 4.3.2 / 3.2.3.8 3.2.4.3	Added Analysis (A) to method of verification (in addition to Test (T)) for requirement 3.2.3.8 Changed method of verification from Test (T) to N/A for requirement 3.2.4.3

* Change pages are denoted by a bar line on the right margin.

1. Scope

This specification covers the performance requirements and physical characteristics of the Payload Magnetometers for the Gravity Probe-B Relativity Mission Experiment.

2. Applicable Documents

In the event of conflict between the documents referenced herein and the contents of this specification, the contents of this specification is considered a superseding requirement.

2.1 Standards and Specifications

PLSE-12	Payload Specification
P0057	Magnetic Control Plan, Science Mission
MIL-STD-461	Electromagnetic Interference Characteristics Requirements for Equipment (tailored)
P0149	Natural Orbital Environment Specification, 15 June 1994
MIL-STD-1540	Test Requirements for Launch, Upper-stage, and Space Vehicle (Tailored for GP-B)

2.2 Drawings

A900-1130APS	Payload Magnetometer Mounting Drawing

3. Requirements

3.1 Description

The Payload Magnetometers interface with the ECU to receive operating and feedback currents, and to provide three axis magnetic field data. The payload magnetometer signals consist voltages proportional to the magnetic field strength at the sensor position along three independent axes (X, Y, and Z).

Four functionally equivalent payload magnetometer units will be mounted on the dewar near Station 199 and will be connected to the forward ECU.

3.2 Payload Magnetometer Specifications

3.2.1 Interfaces

3.2.1.1 Mechanical Interfaces

The unit shall meet the mechanical interface defined in the Payload Magnetometer Mounting Drawing # A900-1130APS and EM-SMS334.

3.2.1.2 Electrical Interfaces

Each unit will have a single non-magnetic, chassis mounted, male 15 pin D connector on its side surface. The connectors will be on the right side of two units and the left side of two units. The pin assignments are as follows:

Function	PIN (HI)	PIN (LO)
TOROID DRIVE	1	9
X AXIS OUTPUT	3	11
Y AXIS OUTPUT	4	12
Z AXIS OUTPUT	5	13
SPARE	2	
HOUSING GROUND	6	
HOUSING GROUND	8	
SPARE	10	
SPARE	14	

3.2.2 Environments

3.2.2.1 Natural & Man-made External EM Environment

The unit shall meet the EMI requirements in P0149 Paragraph 3.

3.2.2.1.1 EM Pulse Shielding

The unit design shall meet performance requirement after exposure to EMI pulses up to 50 V/M in the 1-10 GHz range.

3.2.2.1.2 Conducted Emissions into Probe

No spurious signal in the frequency range of 1 MHz to 1 GHz on any conductor which connects to the probe shall be larger than 50 microvolts RMS (measured prior to tophat filtering)

3.2.2.2 Corpuscular Radiation Environment

The unit will operate in the ambient radiation environment of all parts of the GB-B orbit except the South Atlantic Anomaly (SAA). The unit will recover from passage through the SAA and will again operate by the time of the next GI-to-GV transition after an SAA passage.

3.2.2.2.1 Proton and Electron Instantaneous Flux Disturbances

The unit design shall be sufficient to reject disturbance due to Proton and Electron Instantaneous Fluxes shown in P0149 to level specified in roll and annual stability specs in its mounted configuration on the payload.

3.2.2.2.2 Galactic Cosmic Ray Flux Disturbances

The unit design shall be sufficient to reject disturbance due to Galactic Cosmic Ray Fluxes shown in P0149 to level specified in roll and annual stability specs in its mounted configuration on the payload.

3.2.2.2.3 Mission Integrated Proton Fluence Disturbances

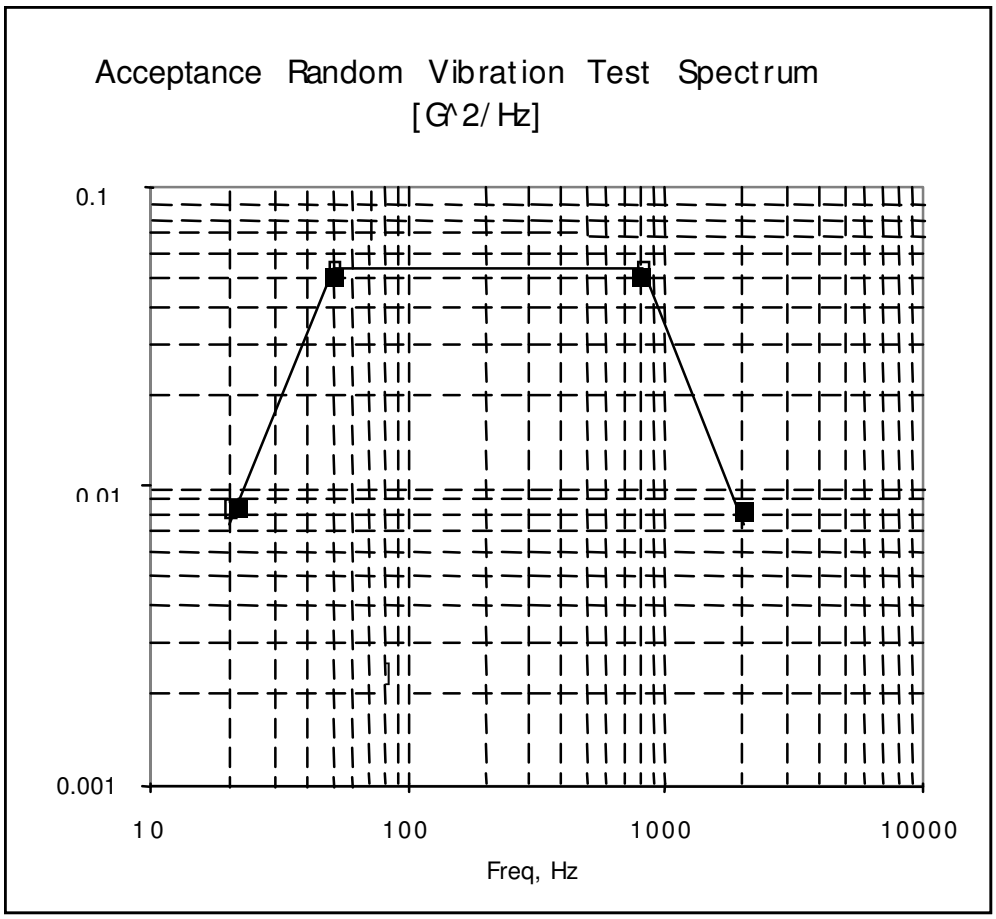
The unit design shall meet performance requirements after exposure to Mission Integrated Proton Fluence shown in P0149 attenuated by shielding due to its mounted configuration and shall meet annual stability specs.

3.2.2.2.4 Solar Flare X-Ray Instantaneous Flux

The unit shall meet performance requirements when Solar Flare X-Ray Instantaneous Flux is less than 0.001 W/m^2.

3.2.2.3 Vibration Testing Levels

The Payload Magnetometer shall be capable of performance as specified herein after exposure to the Figure 1 environment in each of 3 axes, 1 minute /axis. Test tolerance shall be as listed in Table 1.



Frequency (Hz)	Acceptance (G^2/Hz)	Qualification (G^2/Hz)
20	0.008	0.032
50	0.05	0.200
800	0.05	0.200
2000	0.008	0.032
Overall Grms	7.9	15.8

Figure 1. Acceptance Random Vibration Environment

PSD:	20 to 1000 Hz:	±1.5dB
	1000 to 2000 Hz:	±3dB
RMS:		±10% overall

Table 1. Random Vibration Test Tolerance

3.2.2.4 Pyroshock Testing Level

The Payload Magnetometer shall be capable of performance as specified herein after exposure to the protoqual pyroshock environment, which consist of a half sine pulse having duration of 0.50 milliseconds and a half sine pulse zero-to-peak amplitude of 1000 g.

3.2.2.5 Thermal Environment

3.2.2.5.1 Magnetometer Baseplate Operational Temperature Range

The unit shall meet performance requirements at the operating temperature range from 210 +/- 5 to 328 +/- 5 K.

3.2.2.5.2 Survival Test Temperature Range

The unit shall meet performance requirements after exposure to the survival test temperature range from 210 +/- 5 to 328 +/- 5 K.

3.2.3 Electrical Performance.

3.2.3.1 Full Scale Measurement Range

The payload magnetometer shall have a full scale range of +/- 0.7 +/-0.1 Gauss.

3.2.3.2 Field to Voltage Scale Factor

The magnetic field to output voltage scale factor shall be 4.75 +/-0.30 Volts/Gauss and shall be measured to a precision of 0.001 Volts/Gauss.

3.2.3.3 Scale Factor Stability

The scale factor shall change by no more than 0.02% per Kelvin of temperature change.

3.2.3.4 Noise Level

The payload magnetometer noise level shall be less than 1.0×10^{-4} Gauss RMS in a 1.0 Hz bandwidth.

3.2.3.5 Linearity

The deviation from linearity of the voltage output versus magnetic field transfer function shall be less than 0.2 %.

3.2.3.6 Initial Zero Offset

The initial zero offset shall be less than 4.0 mG.

3.2.3.7 Zero drift

The zero drift shall be less than 4.0 mG per degree Kelvin of temperature change.

3.2.3.8 Frequency Response

The transfer function shall not vary by more than 20% for signal frequencies over the range from DC to 0.1 Hz and shall be measured to a precision of 0.1 % at DC, 0.05 Hz, 0.1 Hz, 0.25 Hz, and 0.35 Hz.

3.2.4 Payload Magnetometer Mechanical Specifications

3.2.4.1 Sensor Box Maximum Dimensions

The unit dimension shall be less than 4"L X 3" W X 3.5" H

3.2.4.2 Mass/Unit

The unit mass shall be less than or equal to 0.20 Kg

3.2.4.3 Power, Max per Unit

The power consumption per unit and associated electronics, averaged over any orbit will be less than or equal to 1.5 Watts.

This power is furnished by the ECU and is included in the ECU power budget.

4.0 QUALITY ASSURANCE PROVISIONS FOR PAYLOAD MAGNETOMETERS

4.1 Overview

The quality assurance verification specified herein will be conducted to provide for acceptance of the Payload Magnetometers. These provisions ensure that the performance and design are in accordance with the requirements of section 3 of this document. Acceptance testing for this unit will be combined into a single test program entitled "Acceptance Test of the Payload Magnetometers". The unit will be considered accepted after the successful completion of all analyses, inspections, and tests defined here.

4.1.1 Responsibility for Tests

The contractor is responsible for the performance of all verification efforts specified in this document. Contractor may utilize his own facilities or any commercial or government laboratory acceptable to Stanford and NASA. Tests may be witnessed by Stanford or NASA personnel.

4.1.2 Test Conditions

4.1.2.1 Standard Ambient Test Conditions

Unless otherwise specified herein, all tests required by this specification will be conducted under the standard ambient test conditions specified in Table 4.1.2.1-1.

A	Temperature (°C):	16 to 32 °C
b	Barometric Pressure (Torr):	650 to 840 Torr
c	Relative Humidity	30-70 percent

Table 4.1.2.1-1 Standard Ambient Test Conditions

4.1.2.2 Test Connections

Unless otherwise specified herein, all power connections, measurements, and signal inputs will be made through the external connectors. Connector savers will be used during testing on all flight units.

4.1.2.3 Test Parameter Measurement Accuracy

Unless otherwise noted the measurement accuracy for all parameters will be as specified in Table 4.1.3.3-1. All measurements will be made with instruments which have been certified/calibrated.

a.	Temperature (°C):	± 3 °C
b.	Barometric Pressure (Torr):	900 to 1 Torr, ± 10%; 0.1 Torr or less, ± 1 order of magnitude.
c.	Relative Humidity	± 5%
d.	Acceleration (g):	± 5% at reference point.
e.	Vibration Amplitude or Acceleration (inches or g)	± 10% of peak level
f.	Vibration Frequency (Hz)	± 2% or ± 1 Hz, whichever is greater
g.	Random Vibration Spectral Density (g^2/Hz)	± 1.5 dB, 20 to 2000 Hz (by narrowband analysis, 25 Hz maximum below 1000 Hz and 1/3 octave above 1000 Hz).
h.	Random Vibration (rms acceleration)	± 10%
i.	Random Vibration Instantaneous Peaks	Limited to three times the rms acceleration
j.	Current	± 2%
k.	Voltage	± 0.5%
l.	Pulse Duration	± 10%
m.	Impedance	± 3%
n.	Weight	± 1%
o.	Pressure	± 1%

Table 4.1.2.3-1 Test Parameter Accuracy

4.2 Quality Conformance Inspections

4.2.1 Verification Methods

Verification of compliance with the requirements of Section 3 will be performed as specified in Table 4.2.1-1. The verification methods defined below establish how each requirement will be met:

Analysis: A process used in lieu of or in addition to testing to verify compliance with specifications. The techniques typically include an interpretation or interpolation/extrapolation of analytical or empirical data under defined conditions or reasoning to show theoretical compliance with stated requirements.

Inspection: An observation or examination of the item against the applicable documentation to confirm compliance with requirements.

Test: An action by which the operability, performance capability or other specified qualities of an item are verified when subjected to controlled conditions that are real or simulated. These verifications may require use of special test equipment and instrumentation to obtain quantitative data for analysis as well as qualitative data derived from displays and indicators inherent in the items for monitor and control. Verification by similarity may be used where applicable instead of verification by test.

Similarity: Similarity is the process of comparing a current item with a previous item, taking into consideration configuration, test data, application and environment. The evaluation must be documented and will include: (1) the test procedures/reports of the item to which similarity is claimed; (2) a description of the differences between the items; (3) and the rationale for verification by similarity. All in-orbit experience must be documented and available for review.

Not Applicable: Use of the term "Not Applicable" will be limited to those paragraphs/paragraph headings for which there is no method of verification or where verification is accomplished in subparagraphs.

Verification Legend: Analysis (A)
Inspection (I)
Test (T)
Not Applicable (N/A)

4.3 Acceptance Testing

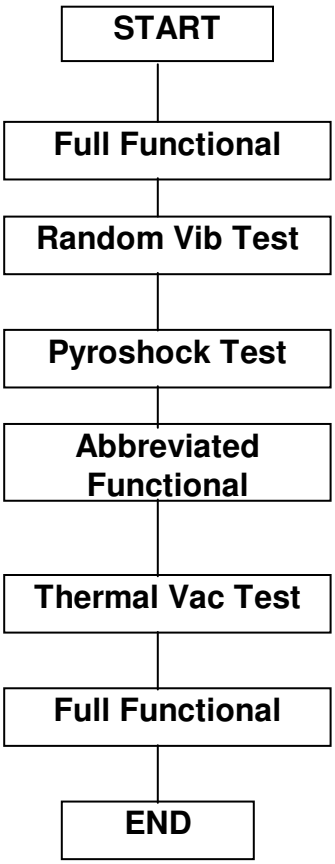
4.3.1 Acceptance Test

The payload magnetometers will be subjected to acceptance testing.

4.3.1.1 Acceptance Test Flow

An overview of the test flow is given below.

Payload Magnetometer Acceptance Test Flow



4.3.1.2 Full-Functional Tests

The Full-Functional Test will test all electrical functions of the unit completely.

4.3.1.3 Abbreviated Functional Test

The Abbreviated Functional Test is sufficient to verify basic operation and integrity of electrical functions.

4.3.1.4 Random Vibration Test

The unit will be subjected to the random vibration levels specified for Proto-Qual. The unit is not powered during vibration testing.

4.3.1.5 Pyroshock Test

For proto-qualification testing, the environment in Section 3.2.2.4 shall be applied in all three axes, at least once in each direction. The test tolerance is ±6

dB. The half-sine wave form will be recorded. Wide band recording of the test is not required.

4.3.1.6 Thermal-Vacuum Testing

The unit will be subjected to thermal-vacuum testing. The test will cover the operating temperature range specified and provide a minimum range of 100 K as a workmanship check. The unit will be powered on all the time during thermal-vacuum testing. See Figure 4.3.1.6 for temperature profiles.

4.3.1.7 EMI/EMC Testing

The payload magnetometers will be subjected to EMI/EMC testing in conjunction with the ECU. The test will be designed to test requirements as stated in the tailored Mil-Std-461 (see list of applicable documents).

In addition to the requirements in Mil-Std-461 there is an additional specifications that will be verified. A test will be designed to verify rejection of primary power variation at roll-rate by slowly varying the primary power.

4.3.1.8 Aliveness Test

This test will verify that the Payload Magnetometers have not experienced a catastrophic failure.

4.3.2 Verification Matrix

		Verification			
Para	**Title**	**A**	**I**	**T**	**N/A**
3.2	Payload Magnetometers				X
3.2.1	Interfaces				X
3.2.1.1	Mechanical Interfaces		X		
3.2.1.2	Electrical Interfaces				X
3.2.2	Environment				X
3.2.2.1	Natural & Man-made External EMI Environment	X			
3.2.2.1.1	EM Pulse Shielding	X			
3.2.2.1.2	Conducted Emissions into Probe	X			
3.2.2.2	Corpuscular Radiation Environment				X
3.2.2.2.1	Proton and Electron Instantaneous Flux Disturbances	X			
3.2.2.2.2	Galactic Cosmic Ray Flux Disturbances	X			
3.2.2.2.3	Mission Integrated Proton Fluence Disturbances	X			
3.2.2.2.4	Solar Flare X-Ray Instantaneous Flux	X			
3.2.2.3	Vibration Testing Levels			X	
3.2.2.4	Pyroshock Testing Level			X	

		Verification			
Para	**Title**	**A**	**I**	**T**	**N/A**
3.2.2.5	Temperature Environment				X
3.2.2.5.1	Magnetometer baseplate Operating Temperature Range			X	
3.2.2.5.2	Survival Test Temperature Range			X	
3.2.3	Electrical Performance				X
3.2.3.1	Full Scale Measurement Range			X	
3.2.3.2	Field to Voltage Scale Factor			X	
3.2.3.3	Scale Factor Stability			X	
3.2.3.4	Noise Level			X	
3.2.3.5	Linearity			X	
3.2.3.6	Initial Zero Offset			X	
3.2.3.7	Zero Drift			X	
3.2.3.8	Frequency Response	X		X	
3.2.4	Payload Magnetometer Mechanical Specifications (per box)				X
3.2.4.1	Box Maximum Dimensions		X		
3.2.4.2	Mass/Unit		X		
3.2.4.3	Power, Max per Unit				X

Table 4.3.2 Verification Matrix

Figure 4.3.1.6 Thermal-Vacuum Profile