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Gravity Probe B Relativity Mission
Payload Verification Requirement Compliance Matrix (VRCM) Part II
S0851 Rev. A

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Rev.	Section	Requirement	Change Description
A	4.1 and 3.5 5.0	3.2.5.1 Assembly and Test Environments 3.2.5.6.1 Thermal Environment	Verified requirements 3.2.5.1 and 3.2.5.6.1 and moved them from Section 4.1 to Section 3.5 Updated Tables 1 & 2 in Section 5.0.
—	All	All	Original Release

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5.0 Summary

1.0 Scope

The document covers the verification for the deferred requirements from S0493 Rev. C “Payload Verification Requirement Compliance Matrix” and does not list all of the completed verifications to date for the PLSE-12 Payload Specification. The principal requirement document for the design, construction, and performance of the Gravity Probe B Science Payload is PLSE-12, which is maintained within the Gravity Probe B Hardware and Configuration Database. Additional requirements come from T002 and T003. PLSE-12 contains 901 requirements, of which 572 require a verification. Because of the large number of requirements and the specific nature of the remaining open requirements a delta document was necessary to provide a better summary of the completed verifications. From the previous VRCM, documented in S0493 Rev. C, there was only 79 remaining PLSE-12 verifications and two T002/3 remaining verifications. This document covers those 79 PLSE-12 and two T002/3 requirements previously deferred, and any updated verifications.

2.0 Introduction

The Science Payload consists of the Science Instrument Assembly (SIA), Probe-C, Science Mission Dewar (SMD), Gas Management Assembly (GMA), Forward Equipment Enclosure (FEE), and the support electronics boxes, regardless of where this equipment is physically located. Many of the Payload units are mounted on Spacecraft structures, and some of the previously noted Science Payload subassemblies are only integrated at the Space Vehicle level. The Space Vehicle is the combination of the Science Payload and the Spacecraft (Bus). The requirements covered in this document can be broken down into three categories: Ground Support Equipment, Gas Management Assembly (GMA), and Miscellaneous. The Ground Support Equipment for the Payload supports operations for the Science Mission Dewar and the GMA. These requirements are primarily to prepare the GSE for use at VAFB or design guidelines. The GMA was built by MOOG and scheduled for delivery to Stanford after the PL AR and required testing both at the subassembly level and after integration into the Space Vehicle to verify system level performance. Finally, the miscellaneous requirements cover primarily Space Vehicle environments, and a few systems that were integrated or tested at the Space Vehicle level. Figure 1 gives a map to the requirements.

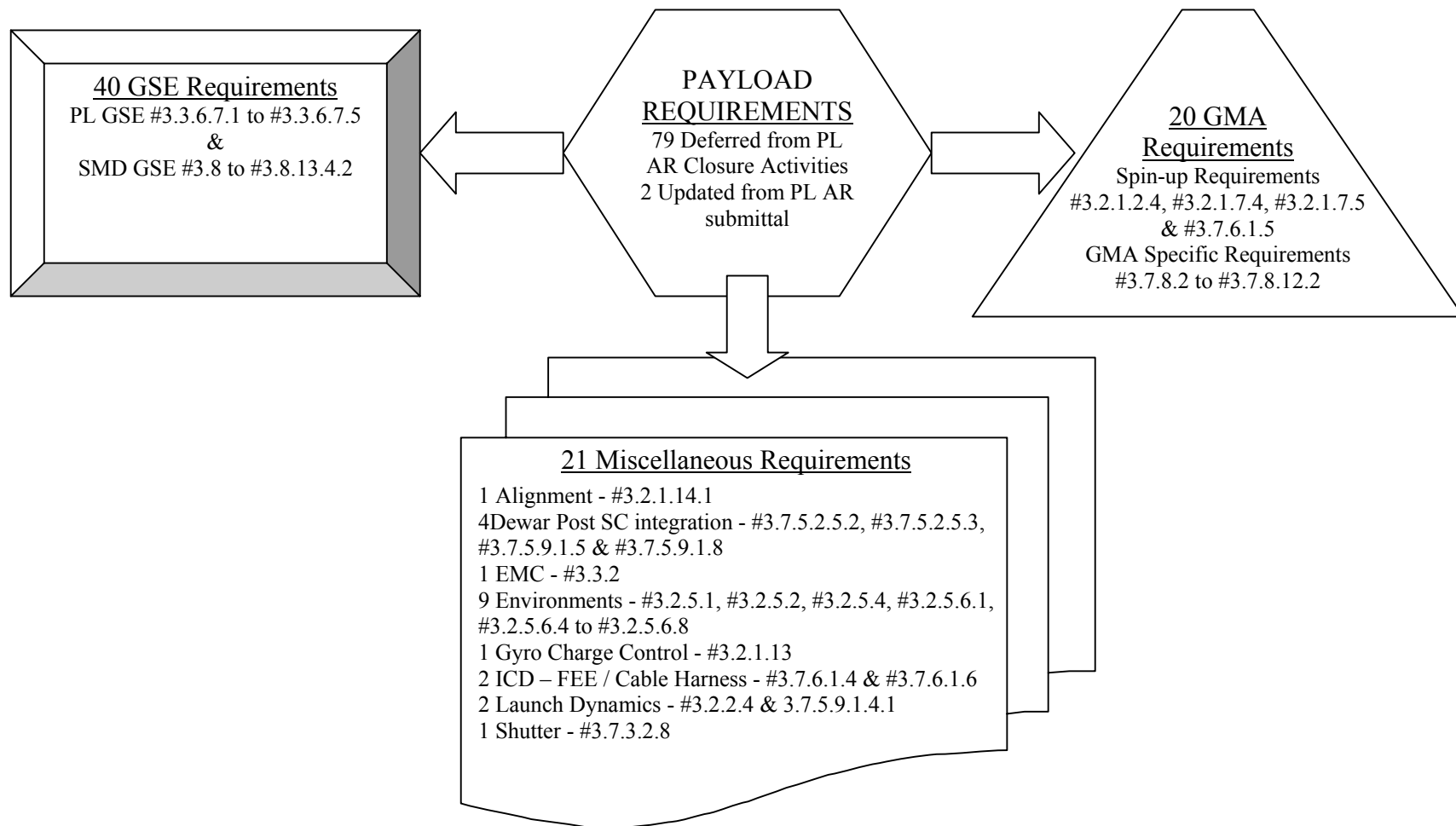


Figure 1 – Requirements Roadmap

The requirements roadmap does not show the additional requirements verified from the Payload Acceptance Review, they are noted in the revision record of S0493. The Science Payload electronic boxes are included in this report and were integrated at the Space Vehicle level. Likewise the on-orbit environments for the Science Payload are evaluated at the Space Vehicle level and include the Payload electronic boxes. In addition the lower level Payload assembly ADPs contain verifications and roll up to the Payload level. Figure 2 shows a graphical representation of the “As-Built” configuration of the payload, part number 65113-1C34292-101 Rev B, serial number: SM-01 as it was shipped to LM for PL/SC integration. Figure 3 gives a diagram of the Payload electronics, which were added to the Payload after PL/SC integration.

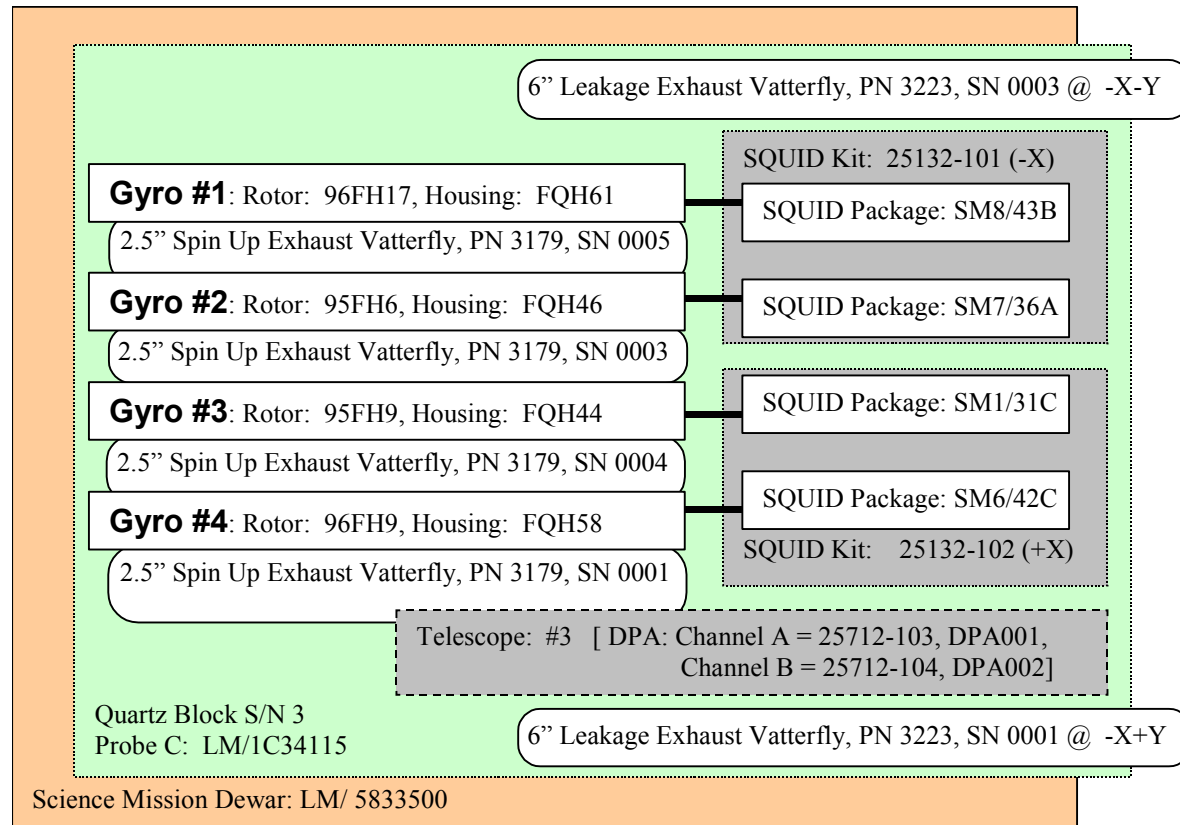


Figure 2 - Diagram of Installed Payload Hardware "As Built" Delivery to LM

Table -1 Lower level acceptance data packages:

1. SQUID Package VRCM; May 14, 1998 2. SQUID kit VRCM; Sept. 10, 1998 3. Science Telescope VRCM 10/14/98 4. DPA VRCM Feb 99 5. Gyro VRCM; FQH61, 46, 58, 44; September 25, 2001 6. QBA VRCM 4/8/99 7. SIA/ Probe Integration VRCM 7/6/99 8. SIA/ Probe Integration VRCM 7/6/99 9. Dewar VRCM, PLIT-03, GPB 100155A, 26 Feb 97. 10. Probe C AR, GPB-100269 v3, 15 May 98; final Probe C ADP, June 2001	11. Caging VRCM 4/19/99 12. FWD/AFT GSS ADP package and VRCM Vol. 1-3; January 13, 2003 13. FWD/AFT SRE ADP package and VRCM; February 5, 2003 14. FWD/AFT ECU ADP package and VRCM; September 26, 2001 15. Vattery Fly 2.5" & 6.0" VRCM; October 15, 2001 – Final ATP; February 10, 2003 16. P-9 gauge ADP package and VRCM S/N 101 & 102; September 25, 2001 17. Payload Magnetometers SN 01, 02, 03, & 04 ADP and VRCM; Sept. 28, 2001 18. Proton Monitor ADP package; September 26, 2001 19. TRE ADP Package and VRCM; November 19, 2002 - GPS Receivers/Flight Antennas ADP and VRCM; January 24, 2002
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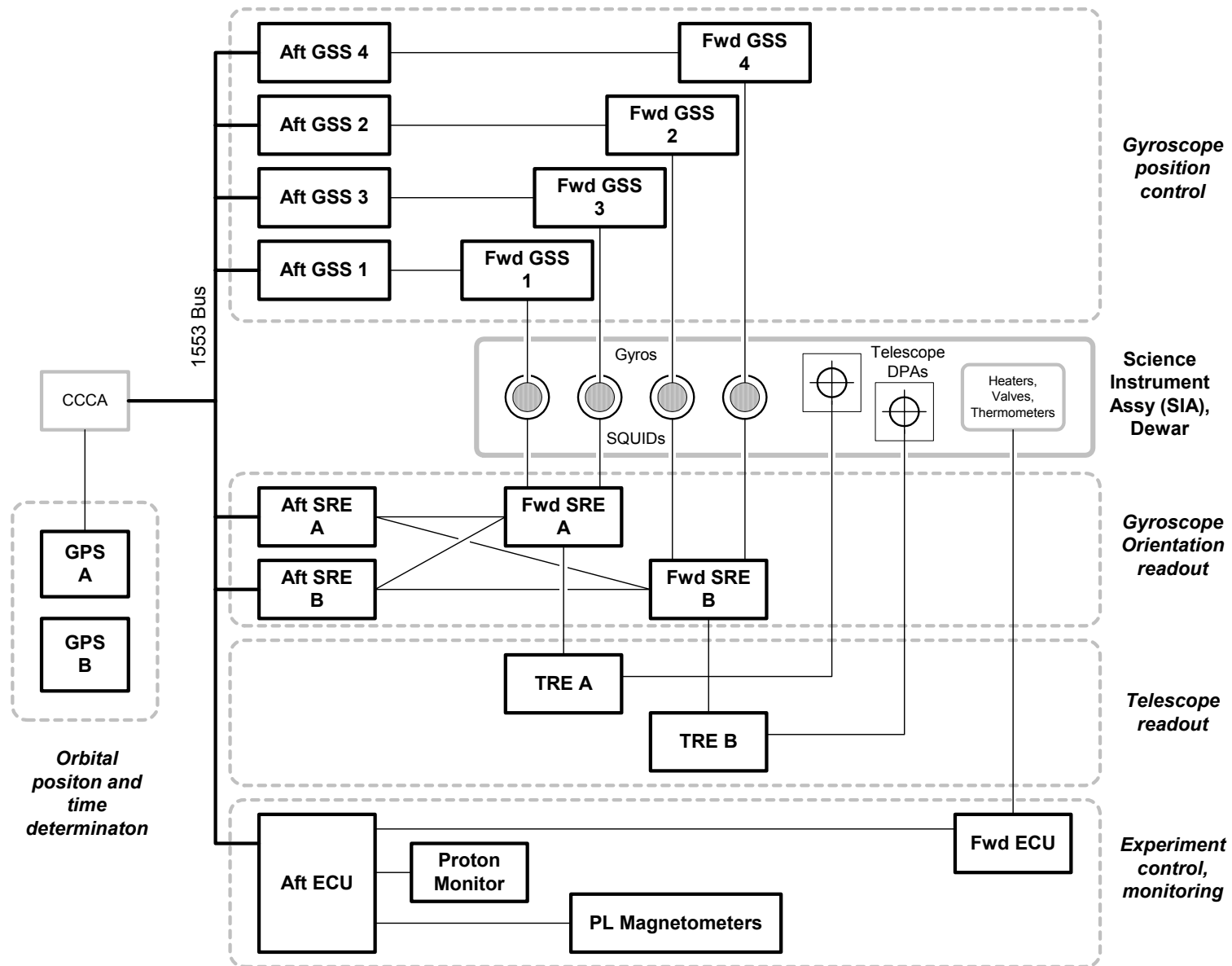


Figure 3 – Diagram of GP-B Payload Electronics suite (excluding the CCCA) showing the Science Payload connections

3.0 Requirements Verified

Verification of compliance with the requirements of PLSE-12 and T002/3 will be performed as specified in the verification column in the requirements tables of Section 3.0 under verification “method”. The methods defined below establish how each requirement will be met:

- Analysis (A): 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 (I): A visual examination of the item against the applicable documentation to confirm compliance with requirements.
- Test (T): 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 the 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.
- Similarity (S): 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; (4) and pedigree of the previous item. All in-orbit experience must be documented and available for review.
- Not Applicable (NA): Use of the term "Not Applicable" will be limited to those paragraphs/paragraph headings for which there are no requirements.

Section 3.1 T002 Payload Requirements Verified**T002 Payload Requirement**

Para #	Title	Requirement	Method	Compliance Data	Verified
6	Science Gyroscope Spinup and Alignment	The Science Gyroscope rotors shall be spun up to a speed in the range 80 to 180 Hz. After spin up, the spin axes of the gyroscopes shall be aligned in a specified direction with respect to the line of sight to the guide star with accuracy better than 10 arcsec maximum.	A, T	Tests which directly support the verification of this requirement include gyro commissioning data for FQH61, FQH46, FQH41, and FQH58 (data in their respective ADPs), PL Ver II tests P0519, P0522, and P0481 (for gas flow, gyro spin and levitations), GMA Test at Stanford P0943, and gas flow tests at the Space Vehicle level run as E28 15.10.1 and E28 15.10. Alignment portion of this requirement is verified purely by analysis / simulation. Spin Speed analysis per S0794 shows that the four gyros can attain spin speeds of 126, 151, 128, and 146 Hz respectively for G1, G2, G3, G4). S0579 (Gyro spin speed verification at probe level) and S0545 (Gas flow verification at gyro/probe interfaces) feed into S0794. S0256 shows that spin axis alignment requirement is met with an expected alignment better than 1 arcsec (as verified previously in requirement T003 #5.3).	√ VLOA written and approved

3.2 T003 Payload Requirements Verified**T003 Payload Requirement**

Para #	Title	Requirement	Method	Compliance Data	Verified
8.4	External Field	The variable (in body coordinates) instantaneous magnetic field generated by the spacecraft at the nominal position of the opening of the lead bag (in the absence of the lead bag and cryoperm shield) shall not exceed 1 e-5 T (0.1 Gauss) in addition to the Earth's field in any direction and under any operating condition.	A	S0824 contains the analysis for the spacecraft magnetic field imposed at the mouth of the lead bag. This field results from the use of the spacecraft magnetic torquers, which are limited by software to no go higher than 180 A-m ² . At this level, the worst-case magnetic field that can be imposed is 0.084 Gauss, which is the total field for all three directions. It is expected that the torque rods will only be powered to 50 A-m ² on-orbit, so there is adequate margin. 0.084 Gauss < 0.1 Gauss required, therefore requirement is met.	√ VLOA written and approved

Section 3.3 PLSE-12 GSE Requirements Verified**PLSE-12 Payload Requirement**

Para#	Title	Requirement	Method	Compliance Data	Verified
3.3.6.7.1	GSE Pressure Systems	Ground support pressure vessels services up to 3000 psi shall be designed to safety factors of no less than those identified in Table 3.3.6-2. Ground support pressure vessels may have a safety factor of 3:1 providing the requirements of ASME Boiler Code Division 2 are satisfied. Pressure system plumbing used at launch pads or missile facilities must be identified in accordance with MIL-STD-1247.	I	S0601 provides the verification inspection for the GSE pressure systems. The SMD pressure systems operate at sub-atmospheric or near atmospheric pressures, and are not applicable except for the UTS and the Helium Supply Tanks. The UTS uses an Air-Pac T-20ST Thomas Compressor at 80 psig, which is rated for 125 psig and has a relief valve set for 140 psig. The design is compliant with industry standards for pressure vessels. The Helium supply tanks are DOT certified. The GMA pressure systems operate from 5 to 2200 psig and the GDS has four supply tanks (2640 psig max) and two sample tanks (2200 psig max). These tanks are commercial products with DOT certifications. S0822 contains the verification for the pressure system plumbing connectors (Req. #3.8.13.4.1). Plumbing is label accordingly.	√
3.3.6.7.1.1	GSE Pressure Relief	Relief devices shall be provided on flight hardware or GSE to protect flight hardware against over pressurization. Launch vehicles using GSE relief devices when pressure systems are active shall have these relief devices connected as long as possible prior to launch.	I	S0601 provides the verification inspection for the GSE pressure systems. The plumbing lines from Helium supply, which operate near atmospheric pressure, to the Dewar are installed with relief valves or burst disks to protect the flight hardware. The UTS has a manufacture installed relief valve. The GDS has relief valves on the GMA supply (orange zone), sample (orange zone), and regulator supply (yellow zone) lines to the GMA.	√

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Para#	Title	Requirement	Method	Compliance Data	Verified
3.3.6.7.1.2	Pressure System Certification	Each complete system shall be pressure tested and leak-checked at its maximum operating pressure at least once and pressure relief valves operationally tested at ten percent (10%) above the maximum operating pressure prior to use in normal operations at WR. The same requirements apply for modified or repaired components. New, modified, or repaired systems and subsystems shall be functionally validated prior to acceptance for normal operational use. The user shall certify that validation tests were successfully completed and the system and subsystem are certified for use. Functional tests up to maximum operating pressure are required each time a component, such as a valve or regulator, is disassembled for repair, modification, or replacement of soft goods (valve seats) and reassembled for use.	I	S0601 provides the verification inspection for the GSE pressure systems. The SMD GSE operates at sub-atmospheric pressures and is leak tested as part of the system on a monthly basis. The GDS pressure and leak test is documented in P0917 "Gas Delivery System Certification" and successfully complete pneumatic proof testing at 1.25 MEOP. Note: The EWRR-127-1 requirement for Hydrostatic proof testing at 1.5 MEOP was waived by Range Safety to avoid contamination of the GDS and GMA, and pneumatic proof testing was approved.	√
3.3.6.7.2	Electrical GSE	Electrical and electronic systems shall meet design requirements of AFSC DH 1-6, section 4E. Electrical fuse and switch boxes shall be stenciled on the outside to show the voltage present and the functions controlled by the circuits. The discharge time for high voltage circuits and capacitors accessible to personnel shall comply with MIL-STD-454.	I	S0601 provides the verification inspection - All EGSE units have equipment labels showing the Voltage, Amperage, Phase, and number of wires. Fuses are properly labeled. High voltage circuits and capacitors are guarded by panels requiring tools to remove and are inaccessible to personnel during normal operations. These panels are marked appropriately with electrical warning labels.	√
3.3.6.7.2.1	GSE Power Switches	All GSE shall provide a main power switch on the equipment. Power switches shall be located and guarded to prevent accidental contact by personnel from activating equipment.	I	S0601 provides the verification inspection - EGSE units have main power switches that are located and guarded to prevent accidental contact. GSE units have main power switches on the equipment, except for the Electrical Module (EM). The EM main power is located in the Power Distribution Unit and is clearly labeled. The PDU is stored next to the EM because of cabling requirements and is accessible. In addition power to the EM can be turned off in an emergency by disconnecting its power cord. The GDS main power is behind a locking panel not normally accessible during operations, and can be turned off by unplugging its power cord if needed. All main power switches are labeled	√

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3.3.6.7.2.2	Critical Switches	Critical switches that can produce or induce hazardous conditions (i.e. switches that: override safety inhibits; power High Voltage Power Supplies; etc.) shall have a protective cover over them.	I	S0601 provides the list of critical switches and their method of guarded access.	√
3.3.6.7.2.3	GSE Ground Potential	All external surfaces of GSE shall be at GSE ground potential at all times.	I	S0601 provides the verification inspection for the GSE surfaces grounded to the Earth ground potential at all times.	√
3.3.6.7.2.4	Explosion-Proofing of Electrical Equipment	Electrical and electronic equipment used in areas classified as hazardous locations (e.g. flight hardware and GSE taken up in the launch tower) shall be "explosion-proof" per article 500 of the National Electrical Code (NEC, NFPA 70), or "hazard-proof" (by potting, hermetically sealing, or by positive pressurization with inert gas). Flight hardware need not be explosion-proof if it is intrinsically safe per NFPA 493. Intrinsically safe equipment, which is not "labeled, identified, or listed" shall have a national testing laboratory (e.g. UL) approval statement. The use of manual kill switches, interlocks or automatic shutdown devices in lieu of hazard proofing shall be in accordance with NFPA 496 and coordinated with the 30th Space Wing Safety Engineering Directorate (30 SPW/SE).	I	S0601 provides the verification inspection. The SMD EGSE is not intended for use in hazardous locations. If located in a hazardous area or during hazardous operations (i.e., potential or actual presence of fuel), it will be powered down using manual kill switches per approved procedures. This approach has been approved by VAFB Range Safety and covers PLSE-12 #3.8.1.1. LM Safety Engineer Harv Moskowitz verifies compliance. The SMD EGSE is labeled and built with manual kill switches and therefore complies with NFPA 496. Primary power can be turned off for the GSE from the PDU.	√
3.3.6.7.2.5	Batteries	Batteries shall comply with the requirements of sections 3.14.1.6, 3.14.3.3, 3.14.4 through 3.14.4.3 of EWRR 127-1.	I	S0601 provides the verification inspection. The TM&A and DAS contain commercial batteries with the proper labeling and safety compliance. The DAS battery is its Uninterrupted Power Source (UPS).	√
3.3.6.7.3	Accessory Hoisting Equipment	Accessory hoisting equipment is designed to meet the requirements in the following subsections.	N/A	N/A	N/A

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3.3.6.7.3.1	Design Criteria	Design and certification of accessory hoisting equipment shall be per Standard 6.3 of LMMS C-12, and standards identified in EWRR 127-1, sections 3.6.2.2, 3.6.2.3, 3.6.2.5, and 3.6.2.6. Critical hardware slings which have components that are normally disassembled shall be marked, coded, or tethered to assure proper reassembly. Disassembly or removal of any part for the purpose of lifting other items is prohibited. Components not properly identified shall invalidate certification of the entire assembly.	I	S0601 provides the verification inspection for the SMD tilt dolly with respect to the shipment of the Payload to Lockheed. Hoisting equipment for the transportation of the Payload subsystem as integrated into the Space Vehicle system to and at VAFB will be certified in accordance with SCIT-02 (P086679D) "Transportation And Handling Plan". Note: The certification of accessory hoisting equipment per LMMS C-12 has been superseded. Standard 6.3 is listed on the Occupational Safety and Health Standards - <u>LM Internal</u> website: http://opsweb.lmms.lmco.com/s&ep/Standards/Osh/Safetoc.htm	√
3.3.6.7.3.2	Nondestructive Inspections	Dye penetrant or other suitable nondestructive inspections (NDI) which can reduce the risk to high value hardware shall be performed on all accessory hoisting equipment used to lift these items. Hooks, shackles, links, eyebolts, hoist rings, and single failure point welds used for handling critical hardware at the Western Range shall receive a suitable nondestructive test annually.	I	S0601 provides the verification inspection for the SMD tilt dolly with respect to the shipment of the Payload to Lockheed. Nondestructive Inspections of the hoisting equipment for the Payload subsystem as integrated into the Space Vehicle system will be performed prior to SV transportation at VAFB and in accordance with SCIT-02 (P086679D) "Transportation And Handling Plan". Annual NDI tests are not required for use at SU or LM. A NDI test is required for lifting GSE at VAFB within a year of use, and is performed along with Proof Testing.	√
3.3.6.7.3.3	Proof Test	All slings, riggers, and lifting fixtures shall be proof-tested to 200% of the rated load prior to initial use and 200% of the rated load within a year of use at the Western Range.	I	S0601 provides the verification inspection for the SMD tilt dolly with respect to the shipment of the Payload to Lockheed. Hoisting and lifting equipment for the Payload subsystem as integrated into the Space Vehicle system will be proof tested in accordance to the SCIT-02 (P086679D) "Transportation And Handling Plan". All SMD GSE at VAFB will be lifted by a "cookie sheet" type-lifting device for getting the SMD GSE on the MST in accordance with the LSSP requirement GPB-64 "PAD Handling".	√
3.3.6.7.4	Mobile Equipment	Equipment that is mounted on casters or wheels shall have provisions for locking these casters or wheels.	I	S0601 provides the verification inspection for the locking provision of the GSE with wheels or casters. The DAS uses jackscrews to lock its wheels, the PDU is locked by restraints, the GDS uses locking casters for transport and floor jacks when stationed, and the remaining mobile GSE uses wheels with friction locks.	√

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3.3.6.7.5	Seismic Load Capability	When hardware is designed for use on the launch tower, for 24 hours or more, then the hardware or restraints shall react to accelerations equivalent to horizontal forces of two times the equipment weight applied through its center of gravity in the direction in which movement is to be restricted. As an option, calculations of force may be made in accordance with AFM 88-3, Chapter 13.	A	S0601 summaries the analysis verification of the seismic load capability. The heaviest GSE on the MST will be the Gas Module at 1178 lb. Restraints ordered are rated to 2*1500 = 3000 lbs. Most GSE weighs much less than this and will be restrained with multiple tie downs.	√
3.8.	SMD GROUND SERVICING EQUIPMENT		N/A	N/A	N/A
3.8.1	Facilities Compatibility	The applicable SMD GSE shall be compatible with the facility requirements at the following facilities: Western Range B1610 and SLC-2W Launch Tower, Lockheed buildings B205 high bay, B181 vibration facility, B156 (Spin Balance, T-V), B159 (Acoustic Chamber), and Stanford HEPL FIST Area.	D	S0822 documents the verification. The SMD GSE is compatible with the Western Range B1610 and SLC 2W as verified by the LSSP Rev. B and the VAFB approved GSE floor plan. The SMD GSE demonstrated compatibility with B205 high bay, B156 (Spin Balance, T-V), B159 (Acoustic Chamber), and Stanford HEPL FIST Area by completing the series of test and integration activities at relevant to each facility as verified by SU QA Insp. #28 Russ Leese. The SMD GSE compatibility cannot be demonstrated with B181, because the SMD will not be tested or serviced in B181.	√
3.8.1.1	Explosion Proofing	Electrical GSE shall be consistent with 3.3.6.7.2.4.	I	S0822 documents the verification. The SMD EGSE is labeled and built with manual kill switches and therefore complies with PLSE-12 #3.3.6.7.2.4. The SMD EGSE is not intended for use in hazardous locations. If located in a hazardous area during hazardous operations (i.e., potential or actual presence of fuel), it will be powered down using manual kill switches per approved procedures. This approach has been approved by VAFB Range Safety, and complies with PLSE-12 #3.3.6.7.2.4. LM Safety Engineer Harv Moskowitz verifies compliance.	√
3.8.1.2	Electrical Interface	GSE electrical equipment shall be compatible with 208 V, 3 phase, or 120 VAC, single phase, voltage source. Current requirements shall be coordinated with facilities, as required.	I	S0822 documents the verification. The SMD GSE is compatible with 208 V, 3 phase, or 120 VAC, single phase, voltage source as verified by SU QA Insp. #28 Russ Leese.	√

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3.8.3.1	Vacuum Space Evacuation	The GSE shall include a Vacuum Module, with a rated turbo pump speed ≥ 400 l/s, capable of achieving a blank-off pressure $\leq 10^{-6}$ torr, for the function of evacuating the SMD vacuum space.	I, T	S0822 documents the verification. SU QA Insp. #28 Russ Leese verifies the SMD GSE Vacuum Module turbo pump speed is rated at 530 l/s He and is capable of achieving a blank-off pressure $< 5 \times 10^{-9}$ mbar (3.75×10^{-8} torr). P0786A "Certify Vacuum Module After Transport" requires the blank-off pressure as measured by VG-1 to $< 5.0 \times 10^{-6}$, and was verified at 4.99×10^{-6} on 2/14/02.	✓
3.8.3.2	Well Evacuation	The GSE shall be capable of evacuating the Dewar well.	I, T	S0822 documents the verification. SU QA Insp. #28 Russ Leese verifies that the GSE is capable of evacuating the Dewar well. P0613D test procedure evacuates the Dewar Well, successfully ran on 12/20/02 evacuated to 3.0×10^{-4} torr as measured by PW-2.	✓
3.8.3.3	Guard Tank Evacuation	The GSE shall be capable of evacuating the guard tank to a pressure of 10 millitorr.	I, T	S0822 documents the verification. SU QA Insp. #28 Russ Leese verifies that the GSE is capable of evacuating the Guard Tank. P0916 test procedure ran on 10/05/02 evacuated the Guard Tank to 0.08 milli-torr.	✓
3.8.4	Gaseous Helium Purge	The GSE shall be capable of purging the lines and vessels with gaseous helium prior to transfer and backfill operations.	I, T	S0822 documents the verification. SU QA Insp. #28 Russ Leese verifies that the GSE is capable of purging the lines and vessels with gaseous helium prior to transfer and backfill operations. P0881A test procedure purges the lines and vessels in section G.5, successfully ran on 02/28/02.	✓
3.8.5.1	Venting of Helium Gas	The GSE shall be capable of venting 60,000 l/hr STP, with backpressure < 50 torr.	I, T	S0822 documents the verification. SU QA Insp. #28 Russ Leese verifies that the GSE is capable of venting Helium Gas. The SMD boil off rate is measured by the GSE in liquid liters/hr and not gaseous STP l/hr. A reading in excess of 100 liquid liters/hr corresponds to an external flow rate of 60,500 standard liters/hour (gaseous He). P0595B ran on 03/08/03 verifies a venting rate of 107.6 l/hr liquid He, with a backpressure of 13 torr-a (or 773 torr-g).	✓

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3.8.5.2	Warming of Exhaust Gas	The GSE shall be capable of warming 60,000 l/hr STP of vent gas from its initial temperature (approximately 5 to 45 K) to 283 K prior to its reaching the facility vent lines.	I, T	S0822 documents the verification. SU QA Insp. #28 Russ Leese verifies that the GSE is capable of warming exhaust gas. The SMD boil off rate is measured by the GSE in liquid liters/hr and not gaseous STP l/hr. A reading in excess of 100 liquid liters/hr. corresponds to an external flow rate of 60,500 standard liters/hour (gaseous He). P0595B ran on 03/08/03 verifies that the venting rate is capable of 107.6 l/hr liquid He. P0648E ran on 01/06/03 verifies that the venting rate the vented Helium was warmed to 283/282 K near 80.3 l/hr liquid He flow rate.	√
3.8.6	Leak Detection	The GSE shall be capable of providing leak detection to a level of ≤ 10 -10 scc/s He.	I, T	S0822 documents the verification. SU QA Insp. #28 Russ Leese verifies that the GSE is capable of providing leak detection ≤ 10 -10 sccs He. P0786A "Certify Vacuum Module After Transport" ran on 2/14/02 verifies that the GSE Leak Detector was successfully calibrated to 5.9E-8 sccs and measured the expected background leak rate of > 1.0 E-7 sccs.	√
3.8.7.1	Remotely Actuated Valves Electronics	The GSE shall provide power supplies and electronics for all Remotely Actuated Valves (ground and flight).	I, T	S0822 documents the verification. SU QA Insp. #28 Russ Leese verifies that the SMD EGSE is capable of providing power and electronics for all the RAVs through the four controller units built in to a patch panel that allows for multiple RAV power configurations. PLSE-12 #3.7.5.9.4 "Remotely Actuated Valves" verified the functionality of the valves in the Dewar AR, GPB-100155A, 26 Feb 97. P0648E ran on 01/06/03 verifies that the patch panel, while configured and to open/close RAV 1 & 2, provided power and control electronics.	√
3.8.7.2	Dewar Instrumentation	The GSE shall provide power supplies and signal conditioning for all SMD instrumentation (ground and flight).	I, T	S0822 documents the verification. SU QA Insp. #28 Russ Leese verifies that the SMD EGSE - primarily the PDU - provides power for all SMD instrumentation. P0773 "Certification of Electric Module, Gas Module and Data Acquisition System" verifies the GSE provides signal conditioning for all SMD ground instrumentation. P0774 "SMD "Functional Test (Abbreviated)" verifies the GSE provides signal conditioning for all SMD Flight instrumentation.	√

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3.8.7.3	Pressure Sensor Readouts	The GSE shall provide power supplies and electronics for all Dewar and GSE pressure sensor readouts.	I, T	S0822 documents the verification. SU QA Insp. #28 Russ Leese verifies that the SMD EGSE - primarily the PDU - provides power for all SMD pressure sensor readouts. Engineering test by Dave Murray provides the pressure sensor readouts by the GSE electronics. P0774 "SMD "Functional Test (Abbreviated)" verifies the GSE provides signal conditioning for all SMD Flight instrumentation.	√
3.8.8	Data Acquisition and Processing	The GSE shall provide the capability to condition, collect, reduce, and store all SMD (except accelerometers) and GSE generated data, and display desired data.	I	S0822 documents the verification. SU QA Insp. #28 Russ Leese verifies that the SMD GSE is capable of conditioning, collecting, reducing, and storing all SMD and GSE generated data, and displaying the desired data.	√
3.8.10.1	Modularity	The GSE shall be of modular construction for ease of handling, servicing, transporting, and floor configuration flexibility.	I	S0822 documents the verification. SU QA Insp. #28 Russ Leese verifies that the SMD GSE is modular in construction, noting that the SMD GSE was successfully transported to multiple LM testing facilities from SU FIST Ops.	√
3.8.10.2	Dimensions	The dimensions of the modules shall be compatible with the space allocated on the launch tower.	I	S0822 documents the verification. SU QA Insp. #28 Russ Leese verifies that the SMD GSE modules are compatible with the space allocated on the launch tower. February 2003 PMR documents that the floor layout for the MST is capable of supporting the SMD GSE. Changes in the floor layout will be document in the LSSP.	√
3.8.10.3	Weight	The weight of the modules shall be within the floor loading capability of the launch tower.	T	S0822 documents the verification. SU QU Insp. #28 measure the weight of all the Dewar GSE using B/159 scale 6/15/02. The results are documented in the LSSP and in Table 1 of this Science Document, S0822. Modules outside of the floor loading capability (75 lbs/ft^2) will be place on pallets by VAFB to distribute load within the capability.	√
3.8.10.4	Lifting and Handling Structures Factors of Safety	Lifting and handling structures shall be proof tested to 2 times the maximum expected operating load, and designed with an ultimate safety factor of 5.	T	S0822 documents the verification. For GSE lifting the SMD: Lower level verification Dewar VRCD (Dewar AR, GPB-100155A, 26 Feb 97) & EM 304/349. For lifting structures on GSE: All SMD GSE is mounted on wheels or casters and does require handling structures for movement. All SMD GSE at VAFB will be lifted by a type of "cookie sheet" lifting device provided by the launch services for getting the Cryo GSE on the MST in accordance with the LSSP requirement GPB-64 "PAD Handling".	√

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3.8.10.5	Pressure System Structures Factors of Safety	GSE pressure systems structures shall be proof tested to 1.5 times the maximum expected operating pressure, and designed with an ultimate safety factor of 4.	T	S0822 documents the verification. The SMD pressure systems operate at subatmospheric or near atmospheric pressures. The UTS uses an Air-Pac T-20ST Thomas Compressor at 80 psig, which is rated to operate at 125 psig and has a relief valve set for 140 psig. The design is compliant with industry standards for pressure vessels. The Helium supply tanks are DOT certified. Vendor certification testing provides all proof testing.	√
3.8.11	Cleanliness Requirements	The GSE interior lines shall be cleaned to Zone VI of Section 3.3.1.2.6.	I	S0822 documents the verification. SU QA Insp. #28 Russ Leese verifies that the SMD GSE is compliant to P0059 "Probe Contamination Control Plan," which specifies the Zone VI requirements. In addition SU Dewar operation procedures call out visual inspections and cleaning procedures in compliance to the contamination control plan.	√
3.8.12	Grounding Requirements	All external surfaces of GSE shall be at common ground potential at all times.	I	S0822 documents the verification. SU QA Insp. #28 Russ Leese verifies that the SMD GSE external surfaces are at a common ground potential at all times.	√
3.8.13.1	Electrical Switches	External switches shall have protective covers as required by 3.3.6.7.2.2.	I	S0822 documents the verification. SU QA Insp. #28 Russ Leese verifies that the SMD GSE has either protective covers or other manual safety locks for all critical switches.	√
3.8.13.2	Alarms for Purge Pressure	If a purge system is utilized on any GSE, an alarm audible to 200 ft shall be provided when the purge gas pressure drops below its minimum allowable pressure. A visual alarm shall be visible to 50 ft when viewing within 60 deg of normal to the front panel.	D	S0822 documents the verification. This requirement states that "if" a purge system is utilized, and implies that it is acceptable for a purge system not to be implemented. Inspection by SU QA Insp. #28 Russ Leese verified that the purge system is not utilized in the current baseline configuration. The alarm is installed, but not connected to the sensor systems.	√
3.8.13.3	Anchors	The modules shall be anchored to be seismically safe while on the launch tower.	I	S0822 documents the verification. SU QA Insp. #28 Russ Leese verifies that the SMD GSE has latches and straps to anchor the GSE while on the launch tower.	√
3.8.13.4.1	Plumbing Connectors	GSE Plumbing Connectors shall be clearly labeled with regard to mating with Dewar plumbing.	I	S0822 documents the verification. SU QA Insp. #28 Russ Leese verifies that the SMD GSE plumbing connectors are clearly labeled with regard to mating with the Dewar plumbing.	√
3.8.13.4.2	Electrical Connectors	GSE Electrical Connectors shall be clearly labeled and color-coded.	I	S0822 documents the verification. SU QA Insp. #28 Russ Leese verifies that the SMD GSE electrical connectors are clearly labeled, and were color coded prior to the flight cables installation.	√

3.4 PLSE-12 GMA Requirements Verified

PLSE-12 Payload Requirement

Para#	Title	Requirement	Method	Compliance Data	Verified
3.2.1.2.4	Allowable Permeation	The maximum amount of air allowed to enter any one of the spin-up inlet lines after the probe has been cooled to liquid helium temperatures, but while the spin-up gas is not flowing, shall be less than 540 Pa-L (5.3 Atm-cc).	A, T	S0790 documents the verification. P0886A ran on 10/13/02 after SV integration, using the GMA GDS verifies that the air entering the spinup line is less than allowed. The gas sample results from Atlantic show no air contamination at 99.9999+% pure Helium. S0701 "GMA Mitigation Plan" Section B3 provides the analysis for Cryo Contamination from the atmosphere. The mitigation plan keeps Zone V of the GMA under Helium pressure prior to and through launch. Nominally, that pressure is 300 psia. The pressure must drop below 15 psia (atmospheric pressure) while the vent line service GSE is removed, for the potential of cryo-contamination begins to exist. If that pressure should drop below 100 psia (via leakage into the probe or out the vent), then the GMA will not be considered safe to launch because the regulators could be damaged by pyro-shock events during launch, and the GMA would be re-pressurized prior to launch. Since the GMA must be kept above 100 psia, the spin-up inlet lines will be under higher than atmospheric Helium pressure prior to and through launch to preventing air contamination.	√
3.2.1.7.4	Spin-up Attempts	The Science Payload shall be capable of providing at least two complete spin-up attempts on orbit for each of the four gyroscopes.	I, A	S0790 documents the verification. S0768 verifies that science payload is capable of providing two complete spin-up attempts. P0935 "Gyro Fast Spin Test" SU QA Insp. #28 witnessed fast spin on test gyroscope with flight GMA 9/22/02. S0776 System Level validation test E28 test case ID #15.10 ran 1/10/2003	√
3.2.1.7.5	Pressurized Helium Supply	The Science Payload shall provide a reservoir of pressurized helium and the piping and gas flow conditioning components and fittings necessary to meet the requirements of 3.2.1.7.	I, A	S0790 documents the verification. S0768 verifies the helium reservoir meets the requirements of 3.2.1.7.4. QA inspection of the lower level MOOG GMA ADP VRCM Helium Gas Requirements #3.2.1.1 - 7 and GMA DWG 8A00982 verifies functionality and plumbing connections prior to installation. GMA installation OP Order INT-334, witnessed by LM & DMCA, verifies the piping and components were properly connected to the payload to meet the requirements of 3.2.1.7. S0776 System Level validation test E28 test case ID #15.10 ran 1/10/2003 verifies GMA functionality post installation.	√

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Para#	Title	Requirement	Method	Compliance Data	Verified
3.7.6.1.5	GMA Plumbing Lines Mechanical Interface	GMA plumbing lines shall be routed as defined in Spacecraft to Payload ICD, F277233.	I	S0790 documents the verification. The GMA was mounted to the Space Vehicle by OP Order INT-334 on pallet 2F3 on 10/07/02 in accordance with DWG 8A02681 (ICD) and 8A00982 (Installation). QA verified by QE #J19537 and SU Insp. #33. Note: S/C to PL ICD, F277233 V. 5.0, references the SU GMA ICD DWG 8A00323, which is replaced by the MOOG GMA ICD DWG. 8A02681.	√
3.7.8.2	Location and Envelope	The GMA pallet, with mounted components, shall be located on the spacecraft frame within the triangular truss area located at a rotation angle about +Z* of 60 degrees from the +X* axis toward +Y*. The envelope dimensions are as specified in the GMA Interface Control Drawing 8A00188.	I	S0790 documents the verification. The GMA was mounted to the Space Vehicle by OP Order INT-334 on pallet 2F3 on 10/07/02 in accordance with DWG 8A00982 at 60 degrees about the +Z axis from the +X axis towards the +Y. The ICD drawing is 8A02681. QA verified by QE #J19537 and SU Insp. #33.	√
3.7.8.3	Operating Environment	The GMA shall provide thermal control to maintain average baseplate temperature during GMA operation to 293 K +/- 10 K (20 deg C +/- 10 deg C). The temperature variation across the GMA Baseplate shall be <= 10 K (10 deg C).	A, T	S0790 documents the verification. S0791 "GMA Thermal Vacuum Summary Report" correlates the GMA temperatures to the Space Vehicle Thermal vacuum induced temperatures verifying that the GMA exercised thermal control over the baseplate by using heaters. The Space Vehicle Thermal Vacuum Test Procedure is documented in LMMS/P480647.	√
3.7.8.4	GMA Gas Output	The GMA shall provide the capability of delivering sufficient He for two gyro spin-ups and 1 spin down per gyro and 1 flux flush.	A, I, T	S0790 documents the verification. S0768 verifies that science payload is capable of providing 2 complete spin-up attempts, 1 spin-down, and 1 flux flush. P0925 Gyro Slow Spin Test - SU QA Insp. #28 witnessed GMA flow gas to test gyroscope at spin down and flux flush rates (2 sccm) 9/20/02. P0935 "Gyro Fast Spin Test" SU QA Insp. #28 witnessed fast spin on test gyroscope with flight GMA 9/22/02. S0776 System Level validation test E28 test case ID #15.10, ran 1/10/2003	√
3.7.8.4.2	Low Speed Spin-up Function	The GMA shall provide gas flow for low speed gyro spinup. The gas flow shall be between 1 and 50 sccm.	T	S0790 documents the verification. Lower Level verification by MOOG reference GMA ADP VRCM Para. #3.2.1.3. P0925 Gyro Slow Spin Test 9/20/02. S0776 System Level validation test E28 test case ID #15.10 ran 1/10/2003 flow at 2 sccm to the probe.	√
3.7.8.4.3.1	Spin-up Gas Composition	The GMA shall be capable of delivering He of purity better than 99.999% when filled with He of purity at least 99.9995% pure.	I, T	S0790 documents the verification. Gas purity verified by P0886A ran on 10/13/02 after SV integration. Gas sample results from Atlantic show 99.9999+% pure Helium. Inspected by SU QA #31 Dorrene Ross.	√

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Para#	Title	Requirement	Method	Compliance Data	Verified
3.7.8.4.4	Venting Function	The GMA shall be capable of venting its manifold to space.	T	S0790 documents the verification. Lower Level verification by MOOG reference GMA ADP VRCM Para. #3.2.1.5 Mass Flow Rate - System Purge & #3.2.2.9.4. Purging Capability. S0776 System level validation at E28 test case ID #15.10 flow at 725 sccm to vent line.	√
3.7.8.7.1	Allowable Permeation	The maximum amount of air allowed to enter any one of the spin-up inlet lines after the probe has been cooled to liquid helium temperatures, but while the spin-up gas is not flowing, shall be less than 54.0 Pa-L (.53 Atm-cc). For a 90 day hold, this corresponds to a steady state leak rate of 6.8×10^{-8} scc/s.	A, T	S0790 documents the verification. P0886A ran on 10/13/02 after SV integration, using the GMA GDS verifies that the air entering the spinup line is less than allowed. The gas sample results from Atlantic show no air contamination at 99.9999+% pure Helium. S0701 "GMA Mitigation Plan" Section B3 provides the analysis for Cryo Contamination from the atmosphere. The mitigation plan keeps Zone V of the GMA under higher than atmospheric Helium pressure prior to and through launch to prevent air contamination.	√
3.7.8.7.2	Allowable Leakage	The amount of air allowed to enter the spin-up inlet line with the helium gas shall be less than 100 Pa-L (1.0 Atm-cc).	A, T	S0790 documents the verification. P0886A ran on 10/13/02 after SV integration, using the GMA GDS verifies that the air entering the spinup line is less than allowed. The gas sample results from Atlantic show no air contamination at 99.9999+% pure Helium. S0701 "GMA Mitigation Plan" Section B3 provides the analysis for Cryo Contamination from the atmosphere. The mitigation plan keeps Zone V of the GMA under higher than atmospheric Helium pressure prior to and through launch to prevent air contamination.	√
3.7.8.8	Cleanliness and Contamination Control	The interior of the spin-up lines and valves which are in contact with the flowing gas shall be cleaned to level 100. Assembly and handling of the GMA hardware shall be in a Class 100A or better facility when the internal gas flow elements are exposed.	I	S0790 documents the verification. GP-B contamination Engineer Jim Bush visually inspected the GMA upon receipt and certified clean. Gas flow purity verified internally clean by P0886A, ran on 10/13/02 after SV integration. Gas sample results from Atlantic show 99.9999+% pure Helium. Inspected by SU QA #31 Dorrene Ross.	√
3.7.8.8.1	Particle Control	Gas flow lines shall be filtered to prevent particles from entering the SIA.	I	S0790 documents the verification. GMA fill line, feed lines, vent line, service port, and valves all contain "5-micron" filters. SU QA Insp. #33 verified with vendor supplied schematic C58800.	√

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Para#	Title	Requirement	Method	Compliance Data	Verified
3.7.8.9	GMA Instrumentation	The GMA shall provide instrumentation for evaluating performance.	D	S0790 documents the verification. S0753 "GMA Flight Monitors" presents the telemetry that the GMA provides for evaluating performance. S0776 System Level validation test E28 test case ID #15.10 ran 1/10/2003 demonstrates how the GMA telemetry is used to evaluate performance.	√
3.7.8.10	Redundancy	Redundancy of GMA valve or regulator failures shall be provided for all mission critical functions.	I	S0790 documents the verification. Lower Level verification by MOOG reference GMA ADP VRCM Para. #3.2.2.4 with GMA schematic and MOOG analysis MRR13263. SU QA #31 Dorrene Ross inspected GMA schematic - vendor DWG C58800 (ref. P0886A fig. 3) and verified redundancy in the valves and regulators.	√
3.7.8.11.1	Survival Temperature Range	The GMA shall be designed to survive a temperature range of -49 degrees C to +40 degrees C.	I, T	S0790 documents the verification. Lower Level verification by MOOG reference GMA ADP VRCM Para. #3.2.5.2.1 MRA 13238 Thermal Vacuum cycling test numbers 51-112. SU QA Insp. #33 verified MOOG "as-run" test procedure tested the GMA to -49 to + 40 degrees C. P0920 GMA functional test at SU on 9/16/02 verify GMA functionality after vendor environmental testing.	√
3.7.8.11.2	Random Vibration Environment	The GMA shall be tested to the following protoqualification vibration environment in all 3 axes: 11.1 GRMS overall	T	S0790 documents the verification. Lower Level verification by MOOG reference GMA ADP VRCM Para. #3.2.5.1.2 - MRA 13238 test no. 20 witnessed by SU QA and DCMA. P0920 GMA functional test at SU on 9/16/02 verify GMA functionality after vendor environmental testing.	√

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Para#	Title	Requirement	Method	Compliance Data	Verified
3.7.8.12.1	Structural Safety Factors	The inertial safety factors for the GMA shall be 1.25 for yield and 1.5 for ultimate for all structure except the base plate; the safety factor for the base plate shall be 2.0 for ultimate.	A	S0790 documents the verification. GMA Gamah Bracket Lower Level verification by MOOG reference GMA ADP VRCM Para. #3.2.2.3.6. MOOG analysis verifies ultimate margin of safety is +1.94. Lower level GMA ADP VRCM Para. #3.2.5.2.2 verifies GMA tank brackets, fill/drain valves analyzed to 3 times 11.1 Grms random vibration loads and brackets/tube routings/fasteners consistent with previously qualified subsystems in excess of 15 Grms. S0849 "GMA Baseplate Pull Data" verifies the fasteners to more than a 2.0 margin. EM SMS 507 "Moog GMA Pallet Stress Analysis" verifies the baseplate to 11.7 7 ultimate and 16.03 for yield, and the pallet fitting base to 1.88 ultimate and 3.27 for yield.	√
3.7.8.12.2	Pressure Safety Factors	All pressure systems shall be designed to the requirements of MIL-STD-1522A: Lines and fittings design with burst pressure factor =2.5 Pressure bottles designed and tested per section 5.2.1 of MIL-STD-1522. Components designed and tested to a burst pressure factor = 2.5	I	S0790 documents the verification. Lower Level verification by MOOG reference GMA ADP VRCM Para. #3.2.2.3.2 & #3.2.2.3.4 with MOOG analysis, test, and inspection. The MOOG requirement #3.2.2.3.2 states the burst pressure for tanks shall be 2 times the Maximum Expected Operating Pressure (MEOP). Burst pressure tested at 8,729 psig, which is more than 4 times MEOP. MOOG requirement #3.2.2.3.4 shows compliance with MIL-STD-1522A.	√

3.5 PLSE-12 Miscellaneous Requirements Verified

PLSE-12 Payload Requirement

Para#	Title	Requirement	Method	Compliance Data	Verified
3.2.1.13	Gyro Charge Control System	The Science Payload shall provide a UV photoemission based charge control system capable of maintaining the potential of each gyroscope at or below 15 mV (15pC charge). The average heating power into each gyroscope, caused by the charge control system, shall be less than 0.3 nW. No single point failure in the UV lamps and switches, or in the fiber optic system shall cause the failure of charge control to any gyroscope.	I, A, T	UV Charge Control Tests: P0565A - ran during Payload Test II P0888 - ran during SV confidence test Test Case 15.5 - ran during E28 UV Lamp Checkout S0281B documents the Charge Control Algorithm S0852 "Charge Control Verifications" provides the analysis for the UV Gyro Charge Control System, and verifies that the system is capable of maintaining a gyroscope potential that is less than 15 mV with a heating power less than 0.2 nW. S0852 shows that Charge Control System has no single point failures. SU QA Insp. #31 Dorrene Ross verified UV Gyro Charge Control System installation and that it has no single point failures as documented in S0852. UV Charge Control System was inspected on installation and the test procedures are SU QA compliant.	√
3.2.1.14.1	Initial On-orbit Uncertainty	The initial on-orbit uncertainty in the roll position sensor boresight relative to the Quartz Block/support structure interface plane shall not exceed one degree.	I, T	EM SMS 468 "Control Gyro and Star Sensor Alignments" verifies that the alignments performed have 34-arcsec error relative to the Telescope boresight and the Control Gyro reference platform. Op Orders: ALN-005, ALN-007, ALN-008 aligned the ARP to SV Coordinate frame.	√
3.2.2.4	Structural Dynamics	The Verification Loads Cycle shall yield positive margins for payload dynamic loads.	A, T	Final Coupled Loads Analysis EM SMS 467 shows that the Space Vehicle yields positive margins for the payload dynamic loads. Space Vehicle Acoustic Test, run September 25-26, 2002: EM SMS 470 "GP-B Space Vehicle Acoustic Test Report" summarizes the results of the successful test. The Acoustic test configuration and activities are documented in P480582B, "SV Acoustic TRR", 14 September 2002	√

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Para#	Title	Requirement	Method	Compliance Data	Verified
3.2.5.1	Assembly and Test Environments	1) The Science Payload shall perform as specified after exposure to the assembly and test thermal environments of 203K to 310K	A	S0848 "Payload Assembly and Test Environments Verification" shows that the Science Payload has been exposed to the assembly and appropriate assembly level test thermal environments. The 203K to 310K temperature range applies only to the SMD skin temperature and is not intended to be Payload assembly specific. The analysis was generated from box level test data and the system level Thermal Vacuum Test II - P480734, "GP-B Space Vehicle Thermal Vacuum II Test Procedure" - which verifies that the SMD was exposed to the 203K to 310 K thermal environments, and a successful post environment functional test.	√
3.2.5.2	Transportation Environments	1) The Science Payload shall perform as specified after exposure to the external thermal transportation environment of 278K to 310K. 2) The Science Payload shall perform as specified after exposure to loads of 3g axial and 2g lateral simultaneously applied.	A	Payload level Verification by EM 304/349 Space Vehicle (Integrated Payload / Spacecraft) verification by EM SMS 439 shows positive margins for: Load Case 1: 3.0 G (Fwd/Aft) + 1.0 G (Vertical) Load Case 2: 0.5 G (lateral) + 1.0 G (Vertical) Load Case 3: 2.0 G (Vertical) In these load cases "Fwd/Aft" refers to SV axial and "Vertical" refers to SV lateral with respect to the direction of gravity. The thermal environment is enveloped by the on-orbit thermal environment range and is analyzed in S0600 Rev. A.	√
3.2.5.4	Launch Vehicle Integration Environments	The Payload shall perform as specified after exposure to the Launch Vehicle integration environmental requirements at Vandenberg Air Force Base (AFB) as defined in the Delta II Gravity Probe B Mission Specification.	A	Delta II specification states the Ground Handling Environmental Requirements in Table 3-20: 1. Payload Processing Facility - B 836 (for GSE only) 2. Payload Hazardous Processing Facility B 1610 3. Handling Canister 4. Gantry White Room (doors closed) 5. Fairing and environmental shroud All of the noted locations except the Handling Canister are controlled environments. The Payload is protected from environment by a soft cover and GN2 purged as need while in the Handling Canister. Supporting analysis given in SCIT-02 (P086679D) "Transportation And Handling Plan" and SCSE-10 Part 4 P480588A "Launch Site Contamination Control Implementation Plan For a Delta II at Vandenberg"	√

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3.2.5.6.1	Thermal Environment	The Science Payload shall perform as specified while exposed to the on-orbit thermal environment specified in Stanford document P0149, "Natural Orbital Environment Specification" section 5.0 titled "Thermal Environment".	A	EM TCS 320, "GP-B Thermal Vacuum Test Model Correlation" EM TCS 310, "GP-B On-Orbit Component Temperature Predictions" P480734, "GP-B Space Vehicle Thermal Vacuum II Test Procedure" Test Completion Date: 5/21/03 The environment defined in P0149 Section 5 is the same as that of the model used to assess the GP-B hardware on-orbit and the lifetime prediction. The analysis in EM TSC 320 lead to thermal modifications on the Space Vehicle. The thermal modifications are authorized by PCB 632, approved 6/19 by MSFC CCBD GP2-00-0112, and detailed in EM TCS 310 Rev. C. The analysis in EM TCS 310 concludes that from BOL to EOL all spacecraft components are maintained within thermal limits with sufficient margin. The testing and analysis verify that the spacecraft meets the requirements of P0149 Section 5.	√
3.2.5.6.4	Radiation Environment	The Science Payload shall perform as specified while exposed to on-orbit radiation environment in accordance with Stanford document P0149, "Natural Orbital Environment Specification" section 2.0 titled "Ionizing Radiation".	A	S0610 "Radiation Environment" verifies the Payload excluding the Electronic Boxes. Documentation Referenced: EM SYS 260 - System Hardening Approaches for a LEO Satellite With Radiation Tolerant Parts EM SYS 261 - TRE and Addendum to ECU Components Recommended for Space Radiation Testing EM SYS 262 - Addendum to SRE and GSU Components Recommended for Space Radiation Testing EM SYS 263 - Revision to the SRE Components Recommended for Space Radiation Testing EM SYS 264 - Revision of the ECU Components Recommended for Space Radiation Testing EM SYS 265 - GSS Components Recommended for Space Radiation Testing Continues next page... EM SYS 266 - Shielding Calculations Against Double Bit Upsets Within One Scrub: Down to the Wire EM SYS 267 - Single Event Upset Predictions and Correlation of SRAMs and FPGAs in the Flare and Galactic Environments with Satellite Measurements EM SYS 268 - Recommended Revision of P0149 Natural Orbital Environment Specification for Gravity Probe B EM SYS 269 - Radiation Environments Inside Electronic	√ Updated

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3.2.5.6.4	Radiation Environment	Continued from previous page		Packages for GPB EM SYS 270 - System hardening approaches to SEUs in space borne applications using COTS EM SYS 271 - Radiation Assessment of the AMP-02 and SPRU Parts EM SYS 272 - Radiation assessment of the GPB GPS Receiver EM SYS 273 - Probability Calculations of Double Bit Upsets within a 72 Bit Word The Gravity Probe B radiation hardening approach for operating in an LEO environment is documented in EMS SYS 270. Preliminary designs of the payload electronics boxes were evaluated for radiation sensitivity and components requiring additional evaluation or shielding were identified. These parts are listed in EMS SYS 261, EMS SYS 262, EMS SYS 263, EMS SYS 264, and EMS SYS 265 and if additional tests are required, they were tested at the National Brookhaven Laboratory and the findings incorporated into the final electronics designs. Specific parts and their radiation sensitivities were documented in EMS SYS 267 and EMS SYS 271. To meet the 3-year total dose requirement, an evaluation of the natural environment determined the shielding requirements of the electronics assemblies. These findings are documented in EMS SYS 260, EMS SYS 266, EMS SYS 268, and EMS SYS 269. EDAC for correcting memory upsets and memory scrub requirements, which are implemented in the flight software, are defined in EMS SYS 266 and EMS SYS 273. The radiation assessment of the Trimble GPS receiver is documented in EMS SYS 272.	√ Updated

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3.2.5.6.5	Micrometeorite Environment	The Science Payload shall perform as specified while exposed to on-orbit radiation environment in accordance with Stanford document P0149, "Natural Orbital Environment Specification" section 1 titled "Meteoroid and debris strike resistance".	A	EM SYS 316B shows that the SV will meet the expected on-orbit micrometeorite and orbital debris environment. The SV has adequate shielding and redundant systems. S0694 "Reconsideration of Risk Posed by Micrometeoroid and Orbital Debris to the GP-B Relativity Mission" covers the likelihood of impact using NASA DAS calculations. S0721 "Consideration of On-Orbit Effects to Gyro Suspension" details the capability of the GSS to compensate for micrometeoroid disturbances.	√ Updated
3.2.5.6.6	EMI Environment	The on-orbit EMI environment is specified in Stanford document P0149, "Natural Orbital Environment Specification"	A, T	The analysis in S0782 "T003 15.1 Requirements Verification Report - Performance in the Ambient Environment" verifies the parent EMI requirement at the T003 level for the Orbital Environment described by T003 sec. 14 and detailed in P0149A for the target orbit defined in T003 sec. 24. The Tests are contained in the lower level Acceptance Data Packages for the payload subsystems - ECU, GSS, SRE, Probe-C, and Dewar.	√
3.2.5.6.7	Atmospheric (Neutral) Particles	The Science Payload shall perform as specified while exposed to on-orbit atmospheric particles environment in accordance with Stanford document P0149, "Natural Orbital Environment Specification" section 4 titled "Atmospheric (Neutral) particles".	A	P0149 defines the maximum atmospheric density as 1.56e-12 kg/m ³ to 3.56e-12 kg/m ³ . The requirements in P0149 are met by the analysis in SCSE-04 Part 5, section 6.1 for 1.6e-12 kg/m ³ . Since the performance requirements are 1-sigma, the 67-percentile density is sufficient. The maximum density was evaluated for the mass flow budget. Table 6.5-1 in SCSE-04, Part 5 shows that the 100-percentile density results in 1.22 mg/sec of mass flow margin. A linear increase in the pointing performance due to aerodynamic densities results in a total error of 10.5 marcs at a maximum density of 3.56e-12. This is well within the guide star invalid requirement for a telescope acquisition range of 60 arcs.	√
3.2.5.6.8	Plasma Environment	The Science Payload shall perform as specified while exposed to on-orbit plasma environment in accordance with Stanford document P0149, "Natural Orbital Environment Specification" section 6 titled "Plasma Environment".	A	P0149 (6) Plasma Environment covers three areas of concern to GP-B regarding the orbital plasma environment. These are potential optical contamination, radiation, and charging. The atomic oxygen portion of this requirement is verified in EM SYS 316B. Optical Contamination: Documentation Referenced: LMMS/P088354 GP-B Window Fluorescence Study Stanford S0347 GP-B Telescope Transmission Analysis Continued next page...	√

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Para#	Title	Requirement	Method	Compliance Data	Verified
3.2.5.6.8 Continued	Plasma Environment	Continued from previous page.		LMMS/P088354 details a study that determined the photon generation of the sapphire outer window of the GP-B spacecraft due to fluorescence induced by the electron and proton environments encountered in the polar region and in or near the South Atlantic Anomaly. Stanford S0347 shows the total transmission of IM Pegasus starlight through the GP-B telescope. A comparison of these documents shows that the fluorescence effects are within acceptable bounds. Furthermore, the effects of window fluorescence are mitigated by the ATC sanity check, which discards anomalous telescope readings, and by the excise of corrupted data in the science data analysis. Radiation: According to Dr. Gary Lum, the auroral electron flux due to the Plasma environment is nearly three (3) orders of magnitude below that produced by the natural ionizing environment (verified in PLSE-12 #3.2.5.6.4 Radiation Environment and in SCSE-12 #3.2.6.4.9) and unable to penetrate the space vehicle. The natural space environment total dose effects are much higher since the ionizing flux are from energies as high as 7 to 8 MeV as compared to the auroral electron flux with energies up to 20 KeV. Charging: Documentation Referenced: LMMS/P086899 S/C Grounding, Shielding & EMI Control Plan (SCSE-18) Compliance with the Grounding, Shielding & EMI Control Plan ensures that charging due to plasma effects does not affect the operation of the GP-B spacecraft. All metallic spacecraft surfaces are grounded to structure. Electronics assemblies are bolted directly to the pallets and each pallet is grounded through three flexible grounding straps, MS25803-2BB12 to the truss. Thermal blankets are tied to structure through grounding straps. All metal surfaces are electrically connected to the spacecraft truss providing an equipotential ground reference for the electronics system. Most spacecraft components have proven flight heritage in orbital plasma environments. These include the CCCA, IU & CTU, SSR, Star Sensor, Control Gyros, Sun Sensor, Torque rods, Transponder, and SPRU. The ACE and PDU were designed using packaging and shielding practices that have been proven effective in orbit.	√

Payload Verification Requirement Compliance Matrix Part II

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Para#	Title	Requirement	Method	Compliance Data	Verified
3.7.3.2.8	Shutter	The probe shall provide the capability to block the optical path at a location outside of the probe vacuum enclosure. The shutter shall be capable of being opened and closed once per orbit for the entire mission lifetime.	I, T	Blocks optical path by design, SU QA Dorrene Ross inspected the Sunshade source control drawing, 5050151-9, LMMS drawing 5834499 (reference Probe C VRCD - Probe C AR, GPB-100269 v4, 15 May 98). S0746 - 5-year lifetime test performed by the vendor Allied-Signal.	√
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	S0854 "Science Mission Dewar Absorptivity and Emissivity" summarizes the measurements taken on the Dewar and gives an average value of 0.05. EOL value for absorptivity of the Dewar FOSR is predicted to be less than 0.09.	√
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	S0854 "Science Mission Dewar Absorptivity and Emissivity" summarizes the measurements taken on the Dewar and gives an average value of 0.85. The EOL value for emissivity of the Dewar FOSR is predicted to be greater than 0.80.	√
3.7.5.9.1.4.1	Pyrovalve Shock	The SMD well pyrovalve shall be shock isolated as required to prevent shockwaves from being transmitted to the forward electronics.	I, T	EM SMS 510 "Well Pyrovalve Shock Isolator Characterization" analyzes the results from an engineering shock test performed on the shock isolators. Results show considerable reduction in shock input to structure output response of 30 times less on average. Results and test description inspected by SU QA Inps. #33 Ray Pressburg.	√
3.7.5.9.1.5	Guard Tank Relief Valve	A relief valve capable of opening the guard tank vent line under zero gravity shall be provided for preventing backflow of atmosphere into the guard tank vent line.	I, T	The Guard Tank Relief Valve that is capable of opening under zero gravity is known as the Thrust Nullifier. The Thrust Nullifier will be mounted on the Space Vehicle at VAFB just prior to launch. The installation will be done to DWG 8A03598, which was inspected by SU QA Insp. #33 Ray Pressburg. The flight Thrust Nullifier SN 002 was tested to Op. Orders PLU-118 Functional Test (Room Temperature) and PLU-123 Cold Test (at 78 K) to open under zero gravity. It was additionally tested to Op. Orders PLU-122 Leak Check (Room Temperature) and PLU-126 Cold Leak Test (at 231 K) for preventing backflow of atmosphere.	√

Payload Verification Requirement Compliance Matrix Part II

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Para#	Title	Requirement	Method	Compliance Data	Verified
3.7.5.9.1.8	Well Relief Valve	A relief valve near the top of the well shall provide a well vent path during ground operations when helium is in the well.	I	SU QA Insp. #31 verified that the well relief valve plumbing is in place (ref. 583350 -see sheet 5, Section D-D) on 1/30/03. This item is currently plugged off (as depicted in the assembly drawing cited above), and will additionally receive a final epoxy staking before launch.	√
3.7.6.1.4	FEE Modules Mechanical Interface	The mechanical interface between the forward equipment section modules and the probe/Dewar assembly shall be as shown in 1C34102.	I	The mechanical interface as shown in 1C34102 was completed at the Probe/Dewar assembly level. Compliance documented at Dewar level per Dewar VRCD, GPB-100155A, 26 Feb 97. The installation of the "forward equipment section modules" (i.e., Payload Electronic Boxes/Cabling) into the FEE was done to DWG 8A00631 Internal FEE Cable Mounting and FEE final closeout with the integrated Payload can be summarized by the following Op Orders: INT-259 Top FEE Cable Mtg. Installation 7/2/2002 INT-307 FEE Bottom Openings Closeout 11/25/2002	√
3.7.6.1.6	Cables Mechanical Interface	Payload cables shall be mounted to the PL/ SC in accordance with 8A02049, Cable Clamp Wire Harness Installation. Final Cable routing will be documented by photograph.	I	SU QA Insp. #31 Dorrene Ross inspected DWG 8A02049 for the Wire Harness Clamp. The PL/SC Cable ICD DWG is 8A02105. The inspection report is documented in S0882 "Cables Mechanical Interface" and provides a listing of Op Orders that verified the interfaces or installed the cables. Multiple photographs have been taken of the SV (see SV ADR photo CDs P0480741). However, final photographic verification cannot be documented in detail because of the addition of the FEE Skin, which partially blocks the view of the cable harness and final wiring configuration.	√

4.0 Requirements Pending Planned Activities

The following requirements are remaining open until the completion of planned activities. These activities are required to completely meet the requirement, however, partial verification has been provided for each requirement.

4.1 PISE-12 Miscellaneous Payload Requirements – Open

Para#	Title	Requirement	Method	Compliance Data	Verified
3.3.2	Electromagnetic Compatibility (EMC)	The payload shall comply with the EMC requirements specified in T003, Section 15.	T	EMC test procedure P0574 during payload verification II. P0833 Payload EMC Test Procedure was run in PL Phase B. Lower Level Compliance per: Dewar AR, GPB-100155A, 26 Feb 97; Probe C AR, GPB-100269 v3, 15 May 98 T003 #15.1 "Performance in the Ambient Electromagnetic" is verified, and T003 #15.2 "Payload / Space Vehicle Compatibility" is pending resolution of the SQUID noise investigation. The Space Vehicle is shown to be EMC compliant by analysis in S0782 "T003 15.1 Requirements Verification Report Performance in the Ambient Electromagnetic Environment".	Verified by various SQUID test data

5.0 Summary

The Payload Specification PLSE-12 comprises the bulk of the requirements for GP-B and many of its requirements directly relate to the top-level T002/T003 science requirements. This document only covers a small portion of those requirements, which were deferred from the PL AR because of the Space Vehicle integration schedule and the maturity of some of the lower level assemblies. The Payload VRCM S0493 should be referred to for any PLSE-12 requirements not listed here in. The following Table-1 summaries the analysis documents related to the verification effort for the deferred requirements listed in this document. Table-2 list the reference documents, drawings, and procedures that are given in this VRCM.

Table 1 – Payload VRCM Part II Analysis Documents

Analysis Document		Delivered
1.	EM SMS 439 "Vehicle Transportation and Handling"	Payload Part 2
2.	EM SMS 467 "Evaluation of Verification Coupled Loads Analysis #3"	Spacecraft ADP
3.	EM SMS 468 "Control Gyro and Star Sensor Alignments"	Payload Part 2
4.	EM SMS 470 "GP-B Space Vehicle Acoustic Test Report"	Spacecraft ADP
5.	EM SMS 507 "Moog GMA Pallet Stress Analysis"	Appendix - S0790
6.	EM SMS 510 "Well Pyrovalve Shock Isolator Characterization"	Payload Part 2
7.	EM SYS 260 - System Hardening Approaches for a LEO Satellite With Radiation Tolerant Parts	Payload Part 2
8.	EM SYS 261 - TRE and Addendum to ECU Components Recommended for Space Radiation Testing	Payload Part 2
9.	EM SYS 262 - Addendum to SRE and GSU Components Recommended for Space Radiation Testing	Payload Part 2
10.	EM SYS 263 - Revision to the SRE Components Recommended for Space Radiation Testing	Payload Part 2
11.	EM SYS 264 - Revision of the ECU Components Recommended for Space Radiation Testing	Payload Part 2
12.	EM SYS 265 - GSS Components Recommended for Space Radiation Testing	Payload Part 2
13.	EM SYS 266 - Shielding Calculations Against Double Bit Upsets Within One Scrub: Down to the Wire	Payload Part 2
14.	EM SYS 267 - Single Event Upset Predictions and Correlation of SRAMs and FPGAs in the Flare and Galactic Environments with Satellite Measurements	Payload Part 2
15.	EM SYS 268 - Recommended Revision of P0149 Natural Orbital Environment Specification for Gravity Probe B	Payload Part 2
16.	EM SYS 269 - Radiation Environments Inside Electronic Packages for GPB	Payload Part 2
17.	EM SYS 270 - System hardening approaches to SEUs in space borne applications using COTS	Payload Part 2
18.	EM SYS 271 - Radiation Assessment of the AMP-02 and SPRU Parts	Payload Part 2
19.	EM SYS 272 - Radiation assessment of the GPB GPS Receiver	Payload Part 2
20.	EM SYS 273 - Probability Calculations of Double Bit Upsets within a 72 Bit Word	Payload Part 2
21.	EM SYS 316B "The Effects of Meteoroid Debris and Atomic Oxygen on the Gravity Probe B Spacecraft"	Payload Part 2
22.	EM TCS 310, "GP-B On-Orbit Component Temperature Predictions"	SC ADP Rev. B
23.	EM TCS 320, "GP-B Thermal Vacuum Test Model Correlation"	SC ADP Rev. B

Analysis Document		Delivered
24.	S0281B "Charge Control Algorithm"	Payload Part 2
25.	S0347 GP-B Telescope Transmission Analysis	Payload Part 2
26.	S0600 Rev. A "Payload Test Corrected Lifetime Prediction"	Payload ADP
27.	S0601 "Verification of Payload Specification Section 3.3.6.7"	Payload Part 2
28.	S0610 "Radiation Environment" verifies the Payload excluding the Electronic Boxes.	Payload Part 2
29.	S0694 "Reconsideration of Risk Posed by Micrometeoroid and Orbital Debris to the GP-B Relativity Mission"	Payload Part 2
30.	S0701 "GMA Mitigation Plan"	Payload Part 2
31.	S0721 "Consideration of On-Orbit Effects to Gyro Suspension"	Space Vehicle ADP
32.	S0746 "Sunshade Shutter Actuator Life Test Verification"	Payload Part 2
33.	S0753 "GMA Flight Monitors"	Payload Part 2
34.	S0768 "Gyroscope Spin & Flux Flushing Helium Supply Volume Estimate"	Payload Part 2
35.	S0776 "15.10.1 GMA Flow Test Analysis"	Payload Part 2
36.	S0782 "T003 15.1 Requirements Verification Report - Performance in the Ambient Environment"	Space Vehicle ADP
37.	S0790 Gas Management Assembly Verification Requirements Matrix PLSE-12 Specification	Payload Part 2
38.	S0791 "GMA Thermal Vacuum Summary Report"	Payload Part 2
39.	S0822 "Science Mission Dewar Ground Support Equipment Inspection Report"	Payload Part 2
40.	S0848 "Payload Assembly and Test Environments Verification"	SV ADP Rev. A
41.	S0849 "GMA Baseplate Pull Data"	Payload Part 2
42.	S0852 "Charge Control Verifications"	Space Vehicle ADP
43.	S0854 "Science Mission Dewar Absorptivity and Emissivity"	Space Vehicle ADP
44.	S0882 "Cables Mechanical Interface"	Payload Part 2
45.	Gamah Bracket Analysis (Lower Level GMA) by MOOG	Appendix – S0790

Table 2 - Payload VRCM Part II Reference Documents/Drawings/Procedures

Verification Document		Delivered
1.	(P086679D) "Transportation And Handling Plan"	Spacecraft ADR
2.	(P086704C) SCSE-04 Control System Error Budget Part 5	Spacecraft ADR
3.	(P086899) S/C Grounding, Shielding & EMI Control Plan (SCSE-18)	Spacecraft ADR
4.	(P088354) GP-B Window Fluorescence Study Stanford	Payload Part 2
5.	(P480582B) "SV Acoustic TRR", 14 September 2002	Acoustic TRR
6.	(P480588A) SCSE-10 Part 4 "Launch Site Contamination Control Implementation Plan For a Delta II at Vandenberg"	Spacecraft ADR
7.	(P480647) Thermal Vacuum Test Procedure	Thermal Vacuum TRR
8.	(P480734) GP-B Space Vehicle Thermal Vacuum II Test Procedure	SC ADP Rev. B

Verification Document		Delivered
9.	DWG 583350 Dewar Vent Line -see sheet 5, Section D-D	Payload Part 2
10.	DWG 5834499 Sunshade source control drawing	Probe C ADP
11.	DWG 8A00631 Forward Payload Electronics Installation	Payload Part 2
12.	DWG 8A00982 GMA Installation	Appendix – S0790
13.	DWG 8A02049 Wire Harness Cable Clamp Installations	Payload Part 2
14.	DWG 8A02105 Payload Cable Interconnection and Installation Drawing	Payload Part 2
15.	DWG 8A02681 GMA ICD	Appendix – S0790
16.	DWG 8A03598 Thrust Nullifier Installation	Payload Part 2
17.	DWG C58800 GMA Schematic	Appendix – S0790
18.	O/O INT-307 FEE Bottom Openings Closeout 11/25/2002	Payload Part 2
19.	O/O PLU-126 Cold Leak Test, Flight Thrust Nullifier	Payload Part 2
20.	O/O INT-259 Top FEE Cable Mounting Installation	Payload Part 2
21.	O/O INT-334 GMA Installation	Appendix – S0790
22.	O/O PLU-118 Functional Test, Thrust Nullifier (Room Temperature)	Payload Part 2
23.	O/O PLU-122 Leak Check, Flight Thrust Nullifier (Room Temperature)	Payload Part 2
24.	O/O PLU-123 Cold Test, Thrust Nullifier (at 78 K)	Payload Part 2
25.	P0059 "Probe Contamination Control Plan"	Appendix – S0822
26.	P0565A - ran during Payload Test II	Payload ADP
27.	P0595B "Reduce Liquid Level in Main Tank-Liquid at NBP" as run 3/8/03	Appendix – S0822
28.	P0613D "Repump Well with Probe Installed" as run 12/20/02	Appendix – S0822
29.	P0648E "NBP Main Tank Fill – Guard Tank Initially Depleted and Connected to Gas Module as run 01/06/03	Appendix – S0822
30.	P0773 "Certification of Electric Module, Gas Module and Data Acquisition System" - as run 7/02	Appendix – S0822
31.	P0774 "SMD "Functional Test (Abbreviated)" - as run 7/02	Appendix – S0822
32.	P0786A "Certify Vacuum Module After Transport" - as run 02/14/02	Appendix – S0822
33.	P0881A "Verify Helium Cylinder Content/Connect Helium Supply Line" as run 02/28/02	Appendix – S0822
34.	P0886A TEST RESULTS - GMA Gas Purity Report	Appendix – S0790
35.	P0888 "UV Cable Continuity Check"	Payload Part 2
36.	P0916"Installation of FEE Guard Tank Vent Line and Leak Check with SV Vertical" as run 10/05/02	Appendix – S0822
37.	P0917 Rev. B "GDS Acceptance Test Procedure" - as run 8/19/2002	Payload Part 2
38.	P0920 GMA functional test - as run 9/16/02	Appendix – S0790
39.	P0925 Gyro Slow Spin Test - as run 9/20/02.	Appendix – S0790
40.	P0935 Gyro Fast Spin Test - as run 9/22/02	Appendix – S0790
41.	Review: GP-B Program Monthly Review February 2003	Appendix – S0822
42.	Vendor Data: GMA Verification Requirements Compliance Matrix	Stanford GMA ADP
43.	Vendor Data: MOOG Thermal Vacuum Test Data MRA 13238	Appendix – S0790

The documents listed in Table-1 and Table-2 that are listed as delivered in Payload Part 2 are include in documents package appended to the Payload ADP. This concludes the verification activities for the PLSE-12 Payload Specification with the exception of the requirements listed in Section 4.1 of this document.