W. W. Hansen Experimental Physics Laboratory
STANFORD UNIVERSITY
STANFORD, CALIFORNIA 94305 - 4085

Gravity Probe B Relativity Mission

Verification of Payload Specification Section 3.3.6.7

S0601, Rev. A

April 18, 2003

Prepared by: P. Shestople 4/22/03 Date

Co-Prepared by: A. Logan 4/18/2003 Date

Approved by: R. Whelan 4/21/2003 Date

Approved by: D. Ross 4/30/03 Date

Approved by: H. Moskowitz 4-21-2003 Date

Approved by: B. Muhlfelder 4/30/03 Date

ITAR Assessment Performed Tom Langenstein 4.30.03

ITAR Control Req'd? ☐ Yes ☒ No

Purpose:

This document details verification of the PLSE-12 Payload Specification GSE safety requirements for the Gravity Probe B science payload. Although the Science Payload contains both Probe -C and the Science Instrument Assembly, the primary purpose of the GSE is to support Dewar operations and does not apply to the functionality of the Probe/SIA. The MOC and Space Vehicle control stations are responsible for the testing and monitoring of the Probe/SIA, and is outside the scope of this document.

The intent of this document is to provide safety verification of the GSE used to support the payload while at the Lockheed Sunnyvale facility and Vandenberg Air Force Base.

Acronyms and Abbreviations Used:

A Analysis
I Inspection
N/A Not Applicable
MEOP Maximum Expected Operating Pressure
DOT Department of Transportation

Applicability (√ = Applicable, N/A = Not Applicable)

Table–1 PLSE-12 Requirements

Paragraph	Title	Method	Applicability
3.3.6.7	Ground Support Equipment (GSE)	N/A	N/A
3.3.6.7.1	GSE Pressure Systems	I	√
3.3.6.7.1.1	GSE Pressure Relief	I	√
3.3.6.7.1.2	Pressure System Certification	I	√
3.3.6.7.2	Electrical GSE	I	√
3.3.6.7.2.1	GSE Power Switches	I	√
3.3.6.7.2.2	Critical Switches	I	√
3.3.6.7.2.3	GSE Ground Potential	I	√
3.3.6.7.2.4	Explosion-Proofing of Electrical Equipment	I	N/A
3.3.6.7.2.5	Batteries	I	√
3.3.6.7.3	Accessory Hoisting Equipment	N/A	N/A
3.3.6.7.3.1	Design Criteria	I	√
3.3.6.7.3.2	Nondestructive Inspections	I	√
3.3.6.7.3.3	Proof Test	I	√
3.3.6.7.4	Mobile Equipment	I	√
3.3.6.7.5	Seismic Load Capability	A	√

Note: These requirements are not GSE specific. Table 3 covers the applicability of the GSE requirements to the actual GSE units.

Table 2- Ground Support Equipment Requirement Compliance Summary

Section & Title	Description	Method	GSE Compliance	√
3.3.6.7 Ground Support Equipment (GSE)		N/A		
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	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. S0822 contains the verification for the pressure system plumbing (Req. 3.8.13.4.1). 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. Plumbing is label accordingly. Compliant – See Table 3 H. A. Moskowitz Harv Moskowitz	√
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	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. See Figure 1. The GDS has relief valves on the GMA supply (orange zone), sample (orange zone), and regulator supply (yellow zone) lines to the GMA. Compliant – See Table 3 & Fig 1. H. A. Moskowitz Harv Moskowitz	√

Section & Title	Description	Method	GSE Compliance	√
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	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. Compliant – See Table 3 for details H. a. Moskowitz Harv Moskowitz	√
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	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. Compliant – See Table 3 H. a. Moskowitz Harv Moskowitz	√
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	All 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 Compliant – See Table 3 H. a. Moskowitz Harv Moskowitz	√

Section & Title	Description	Method	GSE Compliance	√
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	Compliant – See Table 4 for details H. a. Moskowitz Harv Moskowitz	√
3.3.6.7.2.3 GSE Ground Potential	All external surfaces of GSE shall be at GSE ground potential at all times.	I	Compliant – See Table 3 for details H. a. Moskowitz Harv Moskowitz	√
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	N/A – GSE will NOT be used during hazardous operations (See S0822 Req. #3.8.1.1 for more detail)	√
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	The TM&A and DAS contain commercial batteries with the proper labeling and safety compliance. The DAS battery is its Uninterrupted Power Source (UPS). Compliant – See Table 3 H. a. Moskowitz Harv Moskowitz	√
3.3.6.7.3 Accessory Hoisting Equipment	Accessory hoisting equipment is designed to meet the requirements in the following subsections.	N/A		
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	Hoisting equipment for the transportation of the Payload subsystem as integrated into the Space Vehicle system at VAFB will be certified in accordance with SCIT-02 (P086679D) "Transportation And Handling Plan". The certification of accessory hoisting equipment per LMMS C-12 has been superceded. Standard 6.3 is listed on the Occupational Safety and Health Standards - LM Internal website: http://opsweb.lmms.lmco.com/s&ep/Standards/Osh/Safetoc.htm Compliant – See Table 3 H. a. Moskowitz Harv Moskowitz	√

Section & Title	Description	Method	GSE Compliance	√
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	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. Compliant – See Table 3 for details H. A. Moskowitz Harv Moskowitz	√
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	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 GPB-64 PAD Handling. Compliant – See Table 3 for details H. A. Moskowitz Harv Moskowitz	√
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	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. Compliant – See Table 3 H. A. Moskowitz Harv Moskowitz	√
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	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. Compliant – See Table 3 H. A. Moskowitz Harv Moskowitz	√

Table 3 GSE Specific Requirements Applicability

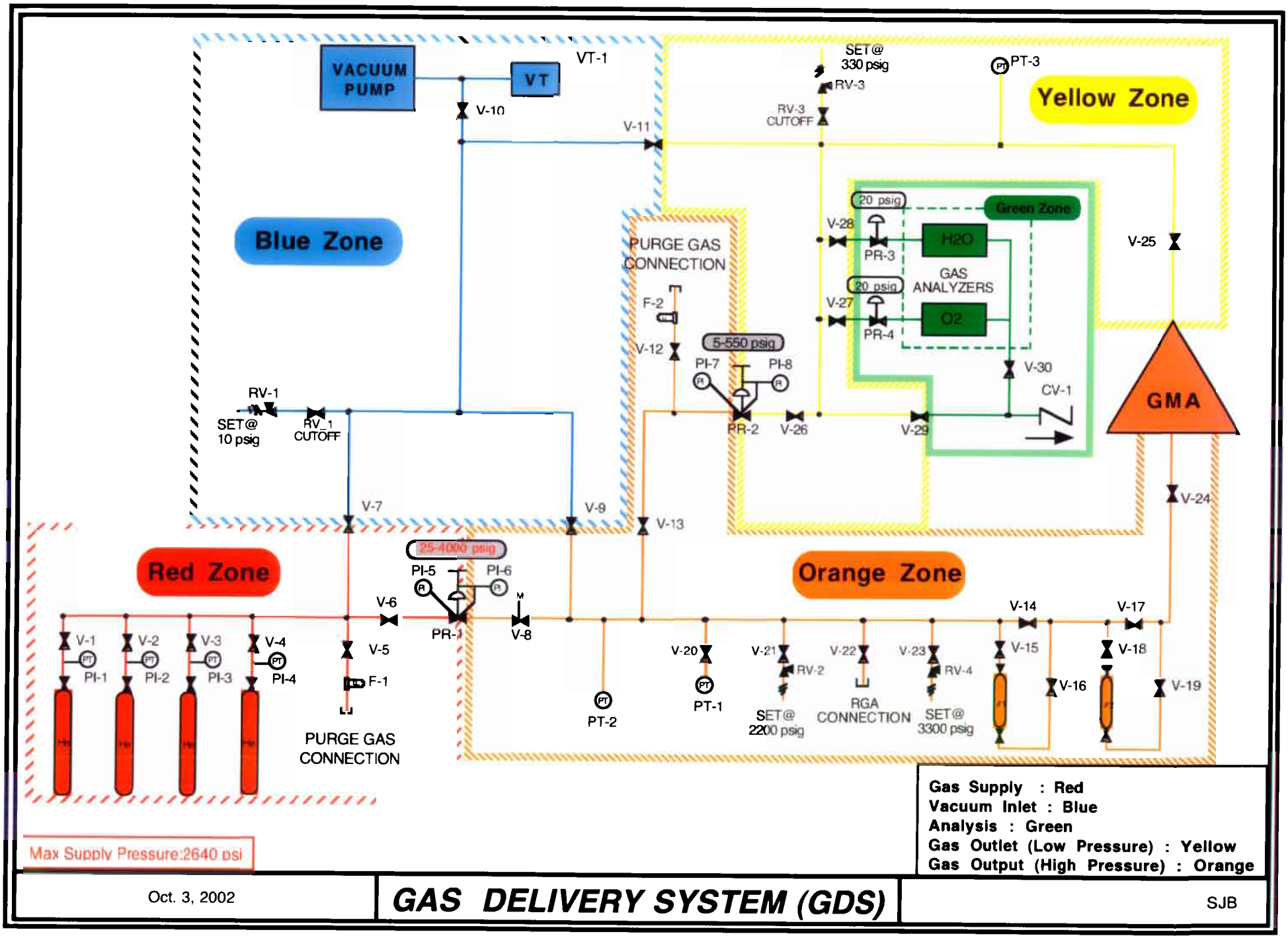
Section & Title	Gas Delivery System	Vacuum Modules	Electrical Module	Gas Module	Temperature Monitor & Alarm	Data Acquisition System	Power Distribution Unit	Utility Turbo System	Pumping Module	Leak Detector	Tilt Dolly	Generic Helium Cylinder
Used for Ground, Tower, or Both	Ground See Note 4	Both	Both	Both	Ground	Ground	Both	Both	Ground	Both	Ground	Both
3.3.6.7.1 GSE Pressure Systems	√	N/A	N/A	N/A	N/A	N/A	N/A	√	N/A	N/A	N/A	√
3.3.6.7.1.1 GSE Pressure Relief	√	N/A	N/A	N/A	N/A	N/A	N/A	√	N/A	N/A	N/A	√
3.3.6.7.1.2 Pressure System Certification	√	N/A	N/A	N/A	N/A	N/A	N/A	√	N/A	N/A	N/A	√
3.3.6.7.2 Electrical GSE	√	√	√	√	See Note 2	√	√	√	√	√	N/A	N/A
3.3.6.7.2.1 GSE Power Switches	√	√	√	√	See Note 2	√	√	√	√	√	N/A	N/A
3.3.6.7.2.2 Critical Switches	√ See Table 4	√ See Table 4	√ See Table 4	√ See Table 4	N/A	N/A	√ See Table 4	√ See Table 4	N/A	√ See Table 4	N/A	N/A
3.3.6.7.2.3 GSE Ground Potential	√	√	√	√	See Note 2	√	√	√	√	√	N/A	N/A
3.3.6.7.2.4 Explosion-Proofing of Electrical Equipment	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3.3.6.7.2.5 Batteries	N/A	N/A	N/A	N/A	See Note 2	√	N/A	N/A	N/A	N/A	N/A	N/A
3.3.6.7.3 Accessory Hoisting Equipment	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3.3.6.7.3.1 Design Criteria	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	√	N/A
3.3.6.7.3.2 Nondestructive Inspections	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	√	N/A

Section & Title	Gas Delivery System	Vacuum Modules	Electrical Module	Gas Module	Temperature Monitor & Alarm	Data Acquisition System	Power Distribution Unit	Utility Turbo System	Pumping Module	Leak Detector	Tilt Dolly	Generic Helium Cylinder
3.3.6.7.3.3 Proof Test	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	√ See Note 1	N/A
3.3.6.7.4 Mobile Equipment	√	√	√	√	N/A	√	√	√	√	√	N/A	N/A
3.3.6.7.5 Seismic Load Capability	√ See Note 3	√ See Note 3	√ See Note 3	√ See Note 3	N/A	N/A	√ See Note 3	N/A	N/A	√ See Note 3	N/A	N/A

Notes:
1) Tilt Dolly was proof tested before initial use and will not be tested again, per SU-WR agreement.
2) The Temperature Monitor & Alarm is being modified into a tower configuration in order to fit securely into the space allow by the Super Guppy and will be compliant by design.
3) Provisions for adequate restraint have been made.
4) The Gas Delivery System required for servicing the GMA is too large for use on the MST. The Vent Service Cart (VSC), a simplified compact version of the GDS, will be used to service the GMA on the MST. The VSC is currently being assembled to EWRR 127-1 specifications or to approved Range/NASA variances and will be inspected for compliance with VAFB safety requirements when completed.

Table 4 – GSE Critical Switches

GSE Unit	Switch Description	Method of Protection
Gas Delivery System	Helium Supply Outlet Valve and Regulator Locking Pressure Outlet Valve	Valves have lockout devices installed to prevent accidental opening
Vacuum Module	Turbo Controller	Interlocked – Gate valve closes if turbo turned off
Electrical Module	Exhaust Gas Valve Switches (EV)	Behind lockable doors
	Auxiliary Gas Valve Switches (AV)	Behind lockable doors
	RAV Controllers	Behind lockable doors and requires multiple actions to activate valves
	Heater Controllers	Behind lockable doors
Gas Module	Power Switch	Recessed / Behind Plexiglas panel
Power Distribution Unit (PDU)	Power Switch	Behind lockable door
Utility Turbo System (UTS)	Turbo Controller	Interlocked – Gate valve closes if turbo turned off
	Forline Valve Switch	Locking Switch
Leak Detector	Vent Switch	Must be held approx. 2 seconds to vent. Also, a separate, vent disable switch is used during critical operations to prevent venting of the leak detector


VACUUM PUMP
VT
VT-1
V-10
V-11
SET@ 330 psig
RV-3
RV-3 CUTOFF
PT-3
Yellow Zone
Blue Zone
PURGE GAS CONNECTION
20 psig
Green Zone
V-28
PR-3
H2O
GAS ANALYZERS
20 psig
V-27
PR-4
O2
V-25
F-2
V-12
5-550 psig
PI-7
PI-8
PR-2
V-26
V-29
V-30
CV-1
GMA
RV-1
SET@ 10 psig
RV_1 CUTOFF
V-7
V-9
V-13
V-24
Red Zone
25-4000 psig
PI-5
PI-6
PR-1
V-8
Orange Zone
V-14
V-17
V-1
V-2
V-3
V-4
PI-1
PI-2
PI-3
PI-4
V-6
V-5
F-1
PURGE GAS CONNECTION
PT-2
V-20
PT-1
V-21
RV-2
SET@ 2200 psig
V-22
RGA CONNECTION
V-23
RV-4
SET@ 3300 psig
V-15
V-16
V-18
V-19
Max Supply Pressure:2640 psi
Gas Supply : Red
Vacuum Inlet : Blue
Analysis : Green
Gas Outlet (Low Pressure) : Yellow
Gas Output (High Pressure) : Orange
Oct. 3, 2002
GAS DELIVERY SYSTEM (GDS)
SJB