Mechanics of Granular Materials

(MGM)

Experiment Flight Hazard Analysis
and
Safety Compliance Data

Laboratory for Atmospheric and Space Physics
University of Colorado at Boulder
September 20, 2000

EXECUTIVE SUMMARY

The enclosed report and associated documents represent the Safety Compliance Data Package (SCDP) for the Mechanics of Granular Materials (MGM) Experiment that has been manifested on STS-107 / SPACEHAB currently planned for June 2001. This mission is the third flight for MGM and will hereafter be identified as MGM-III. The first experiment, MGM-I, was flown on STS-79 / SPACEHAB / MIR-04 in September 1996. This mission is presently considered for safety hazard reverification purposes to be the “baseline mission”. The second experiment was flown on STS-89 /SPACEHAB / MIR-08 in January 1998. The present report, "MGM Experiment Flight Hazard Analysis and Safety Compliance Data," is based upon the same-titled report for MGM-I, which was authored by Sandia National Laboratories (SNL) and the report for MGM-II, authored by the Laboratory for Atmospheric and Space Physics (LASP) of the University of Colorado at Boulder (UCB). The MGM-I experiment hardware, software, and auxiliary hardware were designed, built, and tested by SNL. Subsequent to the MGM-I flight in September 1996, responsibility for MGM missions has been assumed by LASP. Dr. Stein Sture is the MGM Principal Investigator (UCB) and Dr. Nicholas C. Costes is Co-Investigator (UCB). Marshall Space Flight Center (MSFC) continues in the role of NASA sponsorship and overseeing the MGM program. Dr. Khalid Alshibli is the MGM Project Scientist(MSFC, University Alabama Huntsville (UAH).)

As was the case for the SCDP for the MGM-I and MGM-II missions, the present MGM-III report authored by UCB/LASP includes a narrative MGM description with illustrations in 6 sections covering the MGM Experiment Overview, Flight Hardware, Thermal Control System, On-Orbit Operations, Safety Assessment, and Hazard Analysis. The Hazard Analysis section of the SNL MGM-I report included the detailed Payload Hazard Reports (PHRs), recorded on JSC 542B forms, for each applicable hazard in hazard groups defined by NSTS 1700.7B, paragraph 209.1. Since the STS-107 mission is a reflight for MGM, the MGM-III flight hardware has been evaluated as series hardware in accordance with Section 9 of NSTS 13830 REV C, items A through N. In place of PHRs, the MGM-III Reflight Hazard Analysis comprising Section 6.0 of the present report submits the 'unique data for series/reflown elements' by addressing the items A-N inclusive. Item E in 6-E provides an Assessment of Verification Methods through the Hazard Control Reverification Status Matrix for MGM-III (Series Hardware). Safety verification methods for each hazard item in Payload Hazard Reports of the baseline mission are tabulated to allow assessment of the status of corresponding MGM-III safety reverification items and monitoring their submittal to the Safety Verification Tracking Log.

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LIST OF ACRONYMS

A/D	Analog-to-Digital
CCD	Charge-Coupled Device
CCTV	Closed-Circuit Television
CEU	Combined Electronics Unit
DC	Direct Current
DP	Differential Pressure
EEPROM	Electrically Erasable Programmable Read Only Memory
EMI	Electro-Magnetic Interference
ES	Embedded System
JSC	Johnson Space Center
kPa	Kilo-Pascal
PHR	Payload Hazard Report
LASP	Laboratory for Atmospheric and Space Physics
LED	Light-Emitting Diode
MDP	Maximum Design Pressure
MGM	Mechanics of Granular Materials
mm	millimeter
µ	micro-meter
MUA	Material Usage Agreement
MSFC	Marshall Space Flight Center
NDE	Non-Destructive Evaluation
NSTS	National Space Transportation System
P1	Water Jacket Absolute Pressure Sensor
PGSC	Payload General Support Computer
PIP	Power Interface Panel
PRV	Pressure Relief Valve
psia	pounds per square inch absolute
psid	pounds per square inch differential
psig	pounds per square inch gauge
QD	Quick-Disconnect
RAM	Random-Access Memory
S/MM	Shuttle/MIR Mission
STS	Space Transportation System
SVTL	Safety Verification Tracking Log
TDLA	Twin Double-Locker Assembly
UCB	University of Colorado at Boulder
UI	User Interface
VDC	Volts Direct Current
VSU	Video Switching Unit

MECHANICS OF GRANULAR MATERIALS

1.0 MGM EXPERIMENT OVERVIEW

The Mechanics of Granular Materials (MGM) experiment is designed to study the behavior of cohesionless granular materials at low confining pressures in a microgravity environment. Quantification of material constitutive behavior such as load-deformation, stress-strain, instability and failure modes, and ultimate strength will advance the understanding of interactions between solid particles and interstitial fluids. These interactions can contribute to catastrophic events in geologic granular material deposits, such as landslides, dam failures, soil liquefaction caused by earthquakes or wave action, and land erosion.

The MGM-III flight experiment will consist of 9 displacement-controlled, axial compression / extension tests performed at very low differential confining pressures (< 0.075 psid) on right cylindrical specimens of approximately 75 mm diameter and 150 mm in length. Test specimens consisting of solid granular particles enclosed in a thin, linearly elastic latex membrane are prepared under controlled compaction methods and environmental conditions. The specimens are water saturated, with the interstitial water kept at 2 psig pressure. Each end of the specimen incorporates a rigid circular platen by which axial loading is applied. The specimen is enclosed in a larger, water-filled prismatoid, which is pressurized at approximately 15 psig during transportation and storage. The cell is reduced in pressure to provide low differential confining pressure during on-orbit experiment operations. The combined specimen / prismatoid plus associated sensors, cables and connectors, etc., comprise a "test cell". The 9 experiments will be performed on 3 separate, but essentially identical, test cells during the STS-107 mission. Each test cell will be re-used twice, for a total of 3 experiments per test cell. The ninth experiment will not be completed, but instead saved in a re-used, pre-test configuration for post-flight examination.

The Phase III Flight Safety Review for the first and second flights of MGM were held on May 9-10, 1996 and September 16, 1997, respectively. There were no action items levied against MGM-I or MGM-II by the Phase III Flight Safety Review Panel, and both were considered to be safe for flight.

A series of nine displacement-controlled triaxial compression experiments were performed in the SPACEHAB module of the Orbiter, during STS-79 and STS-89 missions to MIR. The experiments were conducted on a total of nine right cylindrical specimens 75 mm in diameter and 150 mm in length at confining pressures ranging from 0.189 psi to 0.007 psi (1.30 kPa to 0.05 kPa) at relative densities of 85% (STS-79) and 65% (STS-89). The displacement-controlled test configuration was chosen to maintain overall specimen-apparatus stability as well as local material stability in the event of continuous or discontinuous bifurcation instability. All MGM-I and MGM-II experimental test cells, axial load testing, fluid pressure control, and data recording elements performed such that scientific return was 100% for the overall missions.

In-flight anomalies on STS-79 occurred during the deactivation phase of both the first and third experiments, and a hardware grounding anomaly was noted post-flight. In-flight anomalies also occurred on STS-89 during one experiment. None of these anomalies had any impact on safety or science, as described in detail in Section 6-I, where resolution of the anomalies to prevent recurrence on the presently manifested mission is also presented. For safety reverification of MGM flight hardware and experimental procedures for the STS-107 reflight mission, STS-79 (MGM-I) is considered the baseline mission.

2.0 MGM FLIGHT HARDWARE

2.1 General

MGM hardware is composed of two double-locker assemblies that provide structural support and equipment mounting. For the first MGM-I flight on S/MM-04 the twin double lockers held three test cell assemblies during ascent, descent, and in on-orbit storage before and after experiment runs. This was also the case for MGM-II / SPACEHAB / S/MM-08. However, three additional test cells were flown and carried in separate SPACEHAB stowage. For MGM-III on STS-107 the three test cells will all be carried in separate SPACEHAB stowage. Each test cell consists of a test sample, sample confinement, compressing mechanism, plus associated sensors, cables, and connectors. Experiment operations are controlled by internal microprocessors and operated though a user-interface on an external computer. Additionally, MGM has three locker-mounted CCD video cameras, whose signals are multiplexed and interface with an external camcorder. This allows for recording the sample displacement and deformation as revealed by motion of grid patterns printed on the elastic latex membrane.

MGM hardware has been designed for compatibility with the Orbiter Middeck as well as the SPACEHAB module. For STS-107, MGM-III will be mounted on the aft bulkhead of the SPACEHAB module. The experiment utilizes a self-contained viewing stage into which experiment test cells are inserted on orbit for testing. MGM video cameras are pre-adjusted so that additional focusing and alignment are not required. An STS-provided Payload General Support Computer (PGSC) provides the crew interface to the experiment control system. New to MGM, telemetry (both commanding and data) will also be used on STS-107. An STS-provided camcorder records video data to document test results. An experiment system functional block diagram is shown in Figure 1. Flight hardware operational configuration is illustrated schematically in Figure 2. The following paragraphs provide further hardware description.

2.2 Twin Double-Locker Assembly

The Twin Double-Locker Assembly (TDLA) and test cell comprises the heart of the MGM flight hardware. The TDLA consists of two horizontally adjacent, aluminum double locker structures as illustrated in Figure 3. The locker structures interface with the SPACEHAB aft bulkhead by way of double experiment mounting plates that are provided by SPACEHAB. The TDLA incorporates integral mounting / stowage provisions for most MGM experiment components. Three stowage drawers are required for storage of three test cells and miscellaneous small items.

2.3 Test Cell

The test cell is a water-filled prismatoid of triangular cross section that contains the experiment sample and compressing mechanism. Figures 4 and 5 present several views and details of the test cell. The sample consists of “Ottawa F-75 Silica” sand, a uniformly sized (0.2 ± 0.1 mm) granular material, pre-tumbled with particles smaller than US Sieve No. 200 (i.e., smaller than 0.074 mm) removed. The sand is tumbled, washed and dried before being closely packed, using a standardized dry pluviation technique, into a 75 mm diameter by 150 mm tall cylindrical mold that holds and shapes the latex sleeve. A vacuum is applied allowing release of the mold, and the sample (including the latex sleeve) is installed in the test cell between circular end platens, one of which is fixed and the other moveable. The outside of the test cell is then assembled around the specimen, filled with water and pressurized, confining the sand and allowing the release of the vacuum. The internal voids in the sand are then filled with water. (On previous missions, the voids contained only air.) The fixed platen is integral with one of the test cell end caps. The moveable platen is driven axially by means of a lead screw mechanism powered by a stepper motor affixed to the opposite end platen of the test cell. The test cell stepper motor operates continuously at a predetermined rate and dissipates 2.0 Watts electrically. The motor shaft output is connected to an integral reduction gear train, which drives the moveable sample end platen. Sample end platens have polished tungsten-carbide wear surfaces.

The two test cell end caps are triangular and made of aluminum. They provide fluid boundaries, fluid interfaces and ports, and structural support for the end platen drive mechanism. They also provide electrical connection accommodation, and mounting features for launch, landing, and on-orbit operation.

The test cell end caps are separated by three stainless steel rods, which also serve as alignment guide rods for the moveable end platen. Each rod has a threaded portion at both ends and two machined shoulders that assure precise spacing between the two end caps. The rods provide test cell structural integrity in the axial direction and ensure precise pre-loading of elastomer seals between the end caps and the Lexan outer shell of the test cell.

The lateral water boundaries are provided by a hollow Lexan outer shell, machined to a triangular cross section as shown in Figure 4. Lexan is optically transparent to permit video recording of the sample during experiment operations. Redundant O-rings installed in each test cell end cap provide a water-tight seal between the Lexan shell and the end caps as shown in Figures 4 and 5.

Each flight-configured test cell contains approximately 150 cubic inches (2.5 liters) of deionized, distilled water. The void space within the sand is saturated with water stored at 2 psig. In addition, test cell water contained by the water jacket surrounds the sample and is pressurized at approximately 15 psig during transportation and storage to maintain mechanical stability of the sample during these periods. The closed-loop fluid system is filled before launch and does not require any makeup or removal of water. On STS-79 and STS-89, water was removed from the system following each test. For STS-107 water will be transferred, through the test cell, between accumulators. On orbit, the test cell water pressure is reduced by way of the experiment fluid control system (described below) to just over 2 psig before applying axial loads to the sample. The test cell water is re-pressurized to 15 psig following sample axial loading operations. Three bellows-type fluid accumulators, mounted on the moveable end platen, maintain the applied 15 psig test cell water pressure during transportation and storage by accommodating small fluid volume changes resulting from ambient temperature and pressure excursions.

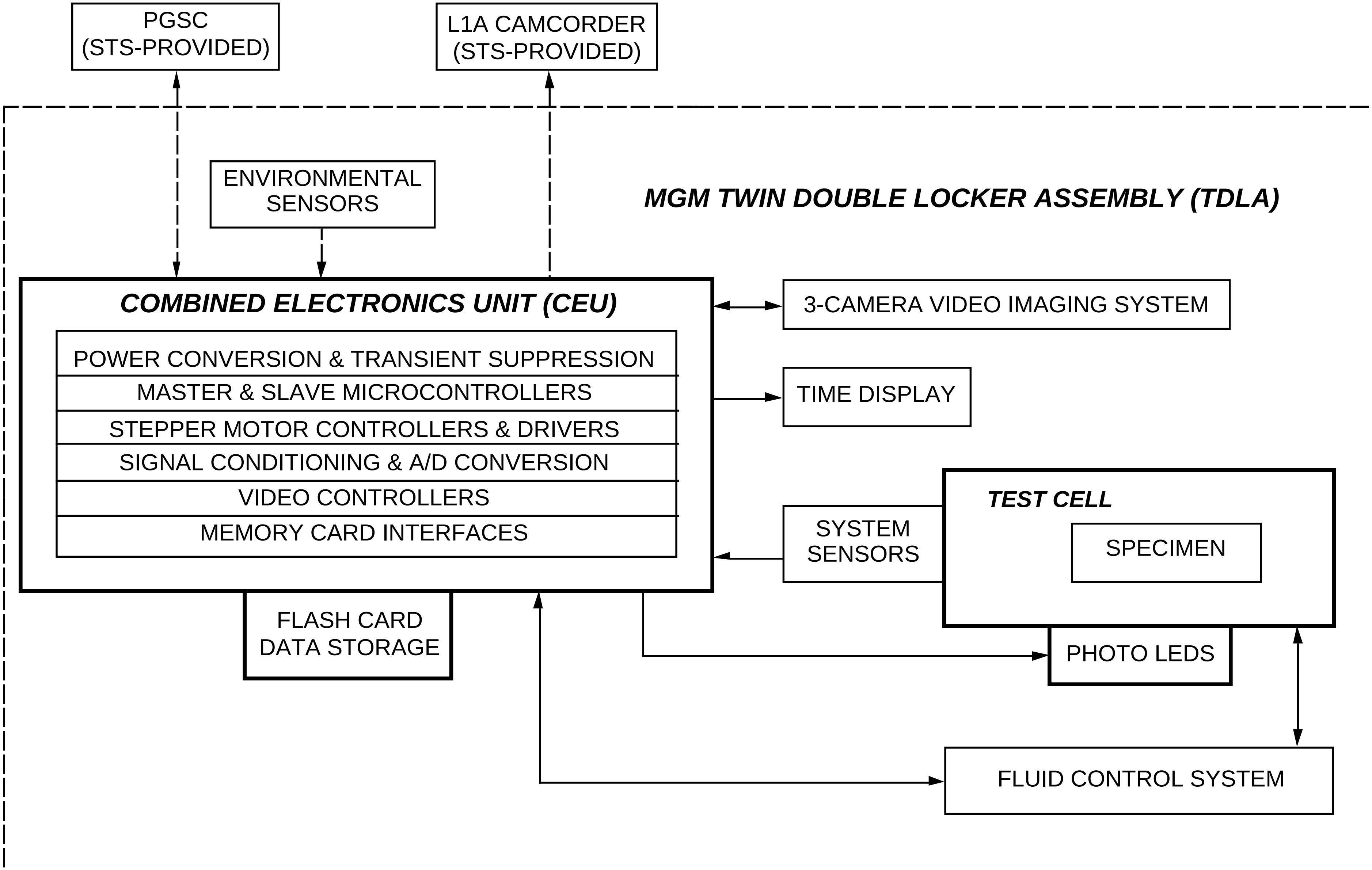

Figure 1. MGM System Functional Block Diagram

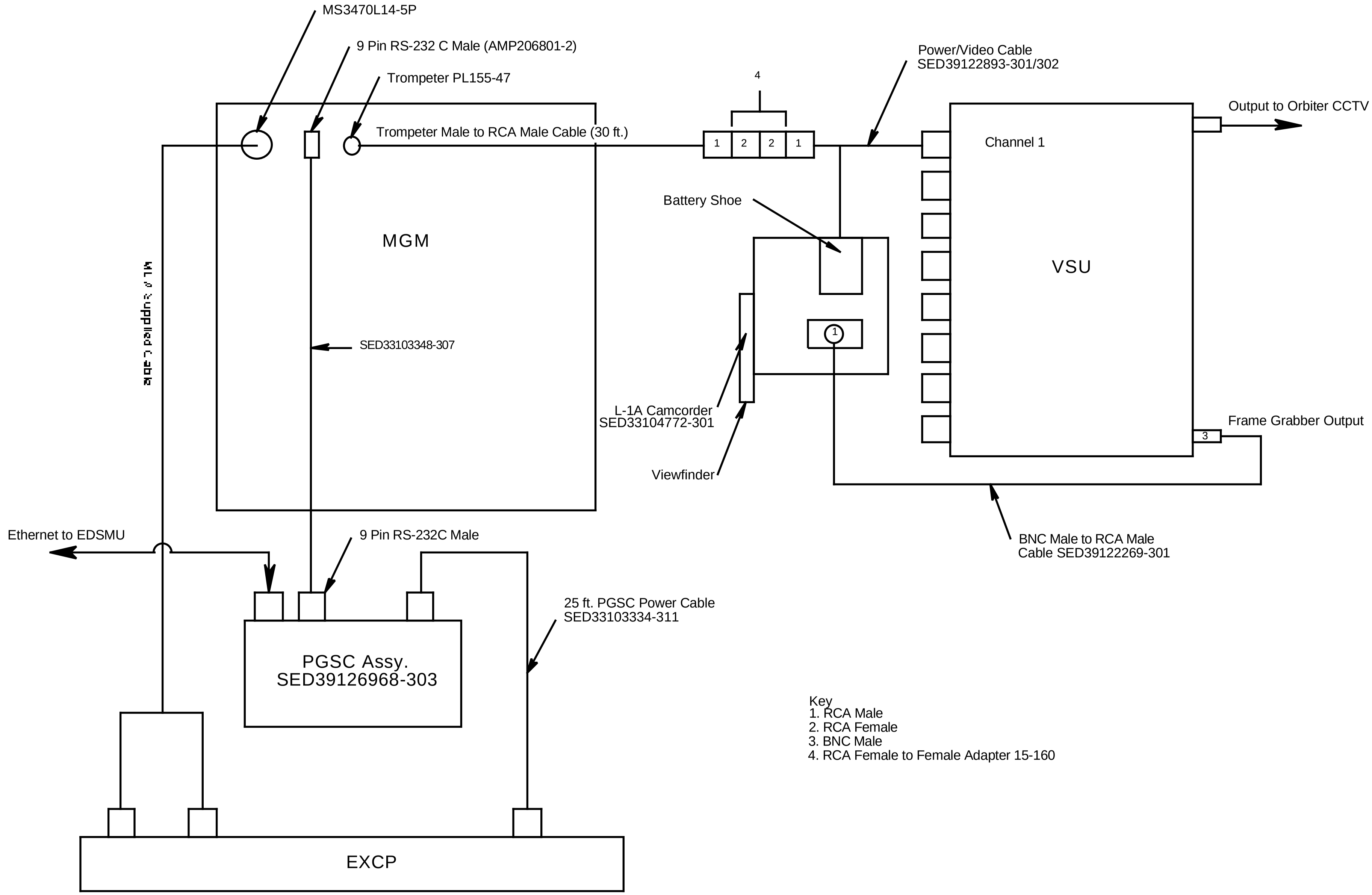

Figure 2. MGM Flight Hardware Operational Configuration

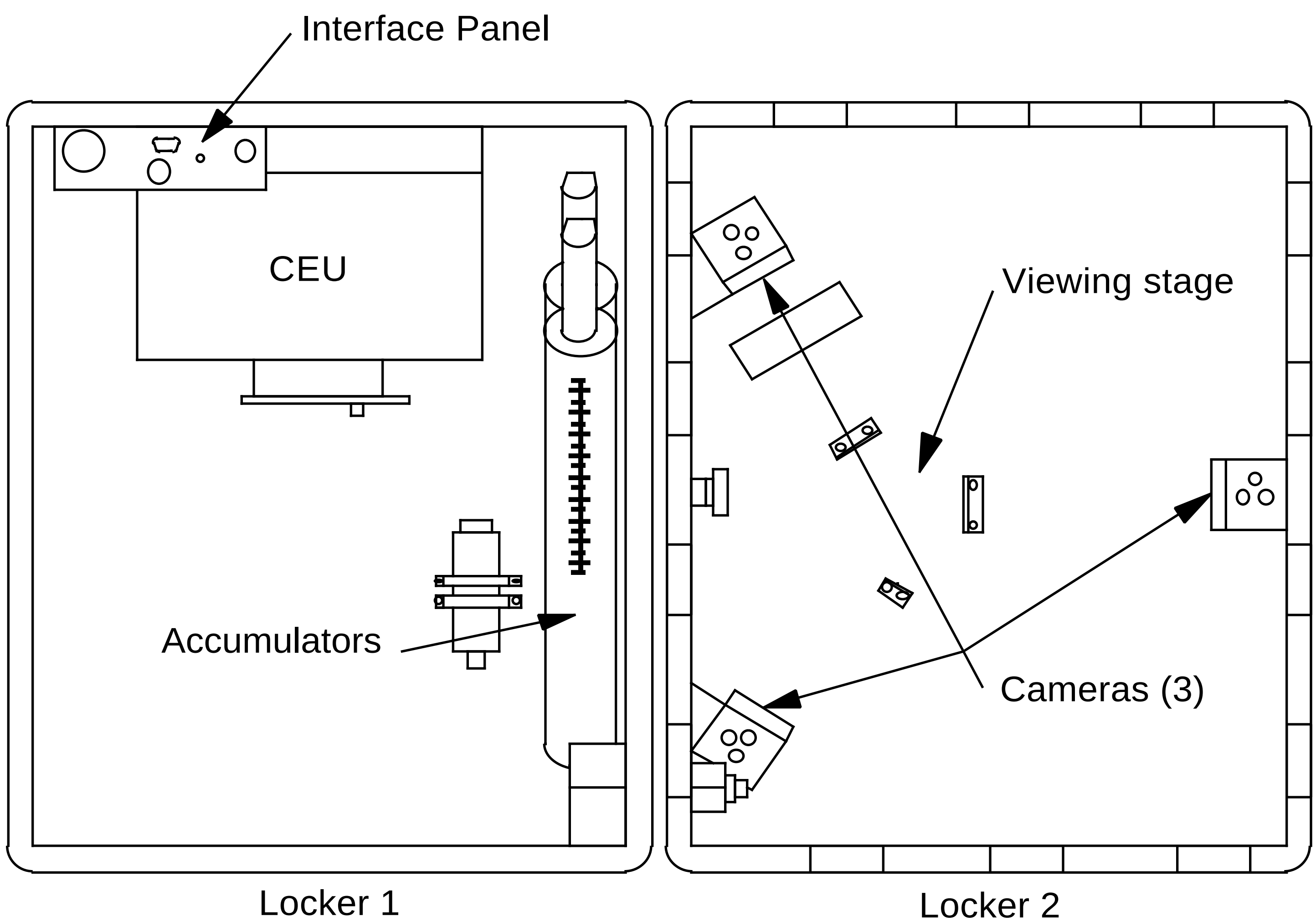

Figure 3. MGM Twin Double Locker Assembly

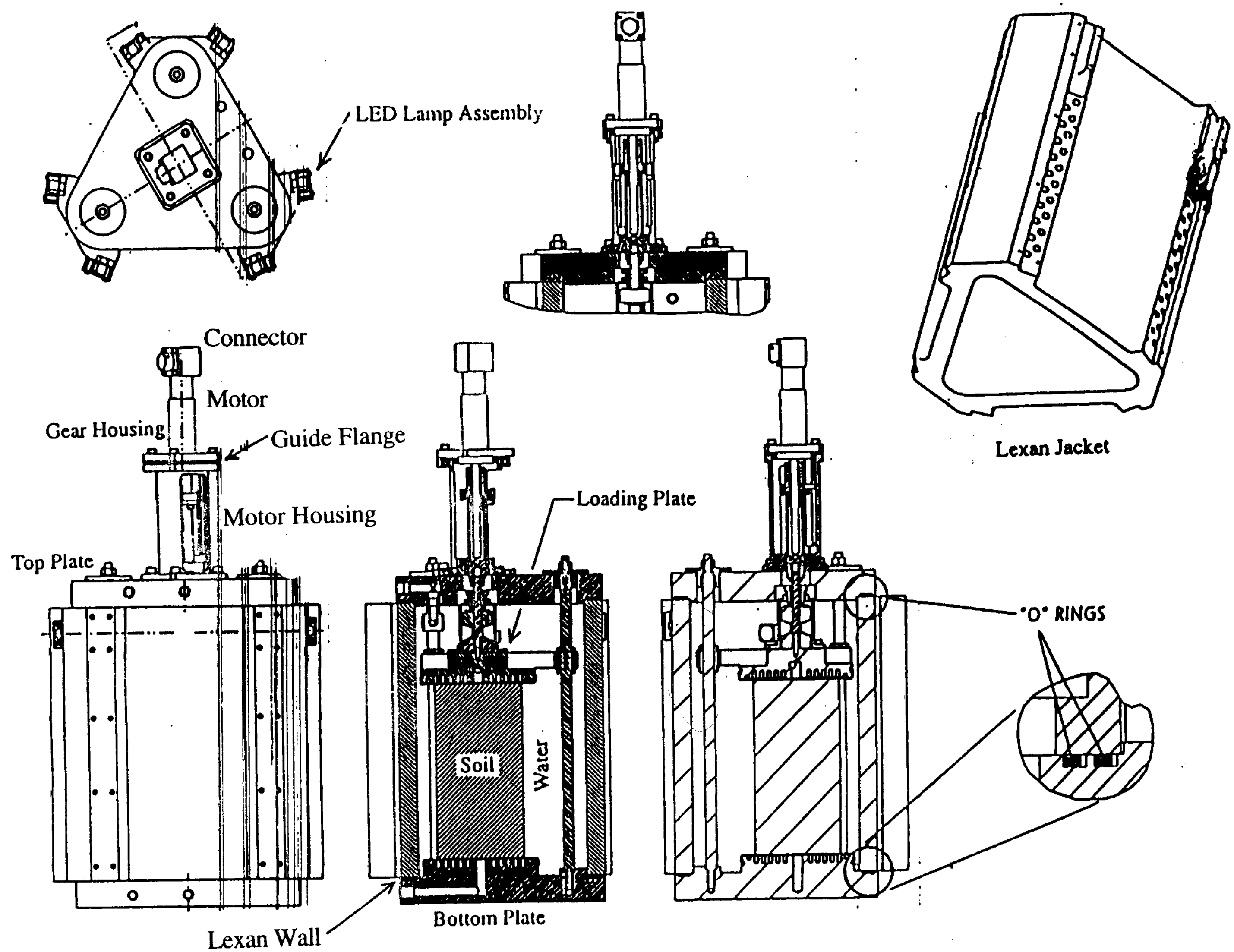

Figure 4. MGM Test Cell

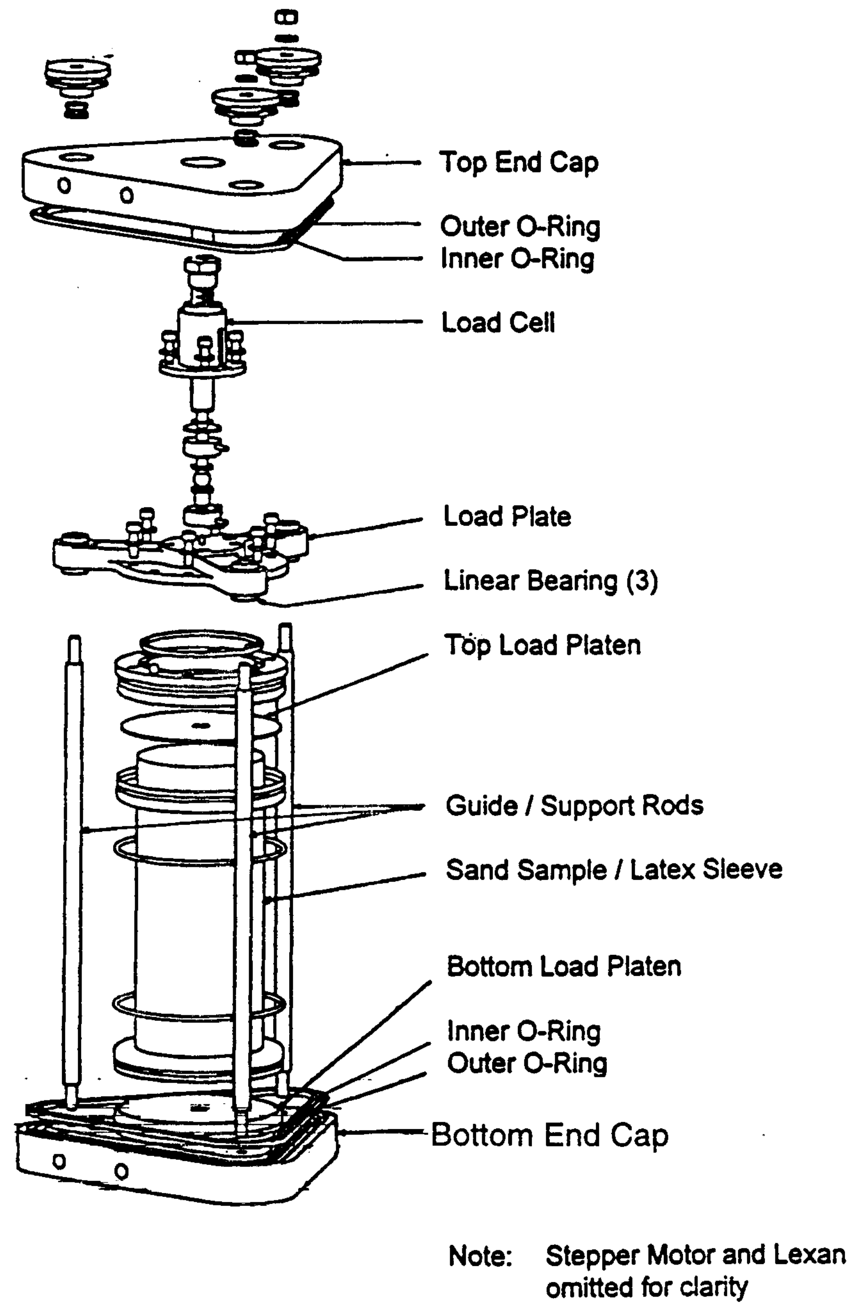

Figure 5. MGM Test Cell Expanded View

2.4 Fluid Control System

The MGM Fluid Control System, depicted schematically in Figure 6, is a closed-loop system that regulates both the test cell water jacket pressure and the specimen fluid pressure before, during, and after on-orbit axial loading operations. It interfaces with each test cell by means of low-loss quick-disconnects.

Water pressure control is accomplished with two electronically controlled piston-type fluid accumulators, illustrated in Figure 7. Each accumulator piston is driven by a stepper motor that operates at a nominal 600 steps per second. The angular motor shaft rotation is 15° per step, and each motor dissipates 4.5 Watts electrically. The motor shaft output is connected to an integral 360:1 reduction gear train, which drives the accumulator piston. Each accumulator stepper motor is driven independently as is required to produce or maintain the desired differential pressure between the water jacket and the test sample.

The water jacket accumulator, which initially contains only a small amount of water, is used to reduce test cell water jacket pressure before on-orbit testing. This is accomplished by withdrawing water from the water jacket until the desired differential test pressure is achieved. That accumulator maintains the desired differential test pressure (under software control) as the sample is compressed during the test. At the end of the test and before removal of the test cell, the water jacket pressure is raised to 15 psig by the reverse process.

For STS-79 and STS-89 (MGM-I and MGM-II) the sample accumulator contained air since all the specimens were tested under dry conditions. For MGM-III on the STS-107 mission, the sand voids and corresponding sample accumulator contains water. The accumulator, stepper motor, and related hardware used for the sample is essentially identical to the water jacket hardware, which has been proven safe when containing water. The specimen accumulator is used to regulate the interior water pressure of the sample at 2 psig to help maintain the differential pressure between the sample interior water and the exterior water jacket. During drained tests, the sample accumulator moves to maintain the 2 psig pressure. During undrained tests, the sample accumulator is initially positioned such that the sample pressure is 2 psig. During undrained specimen compression this accumulator does not move, allowing the specimen pressure to vary.

No water will need to be added or taken away from the accumulators during the mission. However, water will need to be transferred between accumulators. This will be performed using the closed-loop system. When all four QDs are connected to the test cell the balance valve can be opened to transfer water between water and specimen accumulators. In this process, the sample accumulator is moved in the appropriate direction, and P1, the absolute pressure sensor corresponding to the water jacket accumulator, maintains a low gauge pressure (16.7 psia), resulting in the water jacket accumulator moving at the same rate but in opposite direction and taking in the water from the sample accumulator.

Set point differential pressure regulation is implemented by experiment Embedded System (ES) control of the accumulator drive motors in response to inputs from absolute pressure sensors (P1 and P2) that monitor various system pressures, and vented pressure sensors (DP1 and DP2), which read the gauge pressures in the water jacket and the test sample. The difference between the gauge sensors is used to read the differential pressure between the water jacket and the test sample. This arrangement is different from STS-79 and STS-89: previously, two differential pressure sensors directly read pressure difference. The change included a change of sensors. The Tavis brand sensor (0-0.01 psid) is replaced by a Lucas-Schaevits brand sensor (0-5 psig) which has the same electrical requirements. The Validyne sensor type was not replaced, though one pressure port is now open to the atmosphere to read gauge pressure, and the exchangeable sensing diaphragm was replaced to change the sensing range.

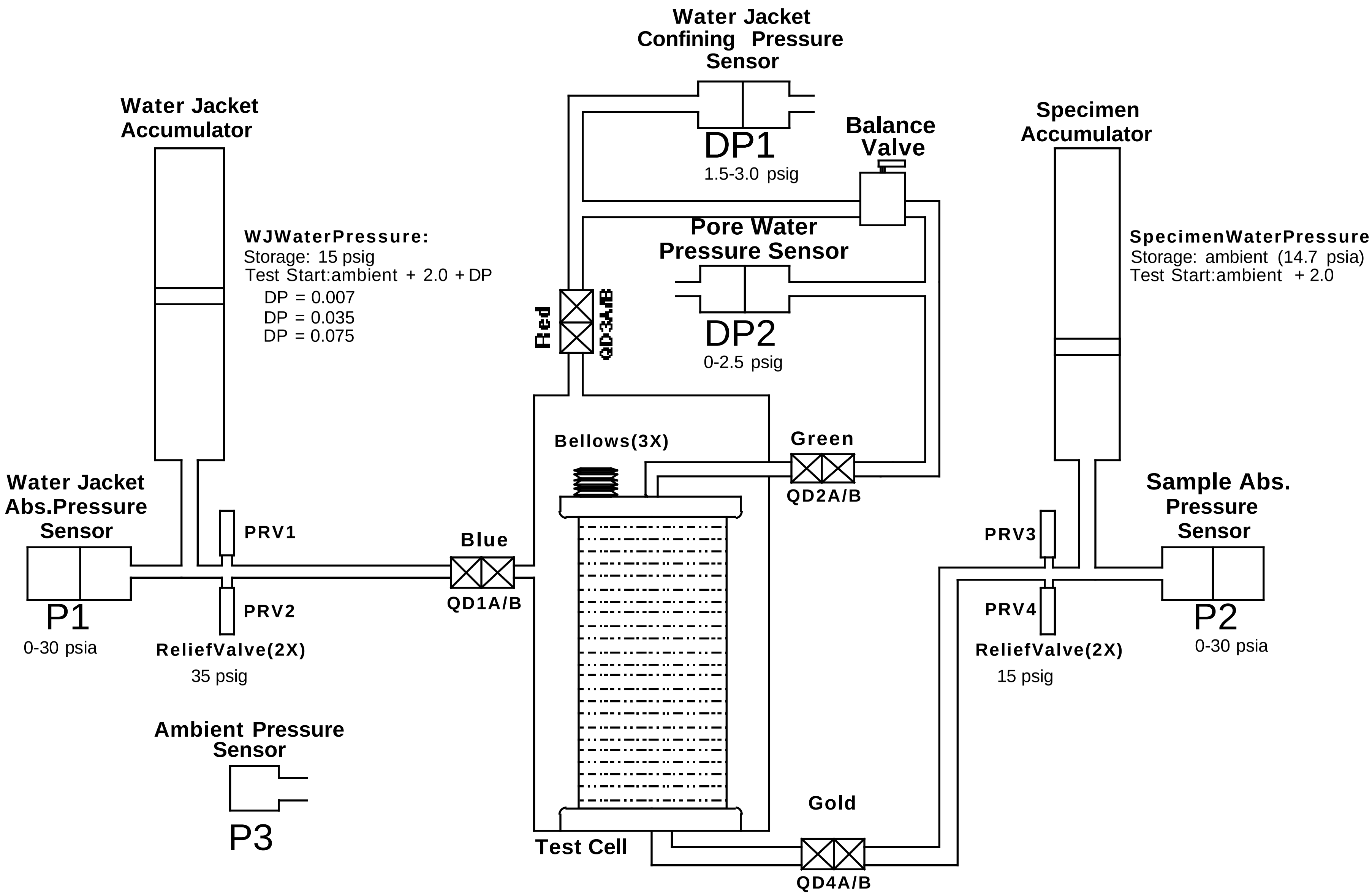

Figure 6. MGM Fluid System Schematic

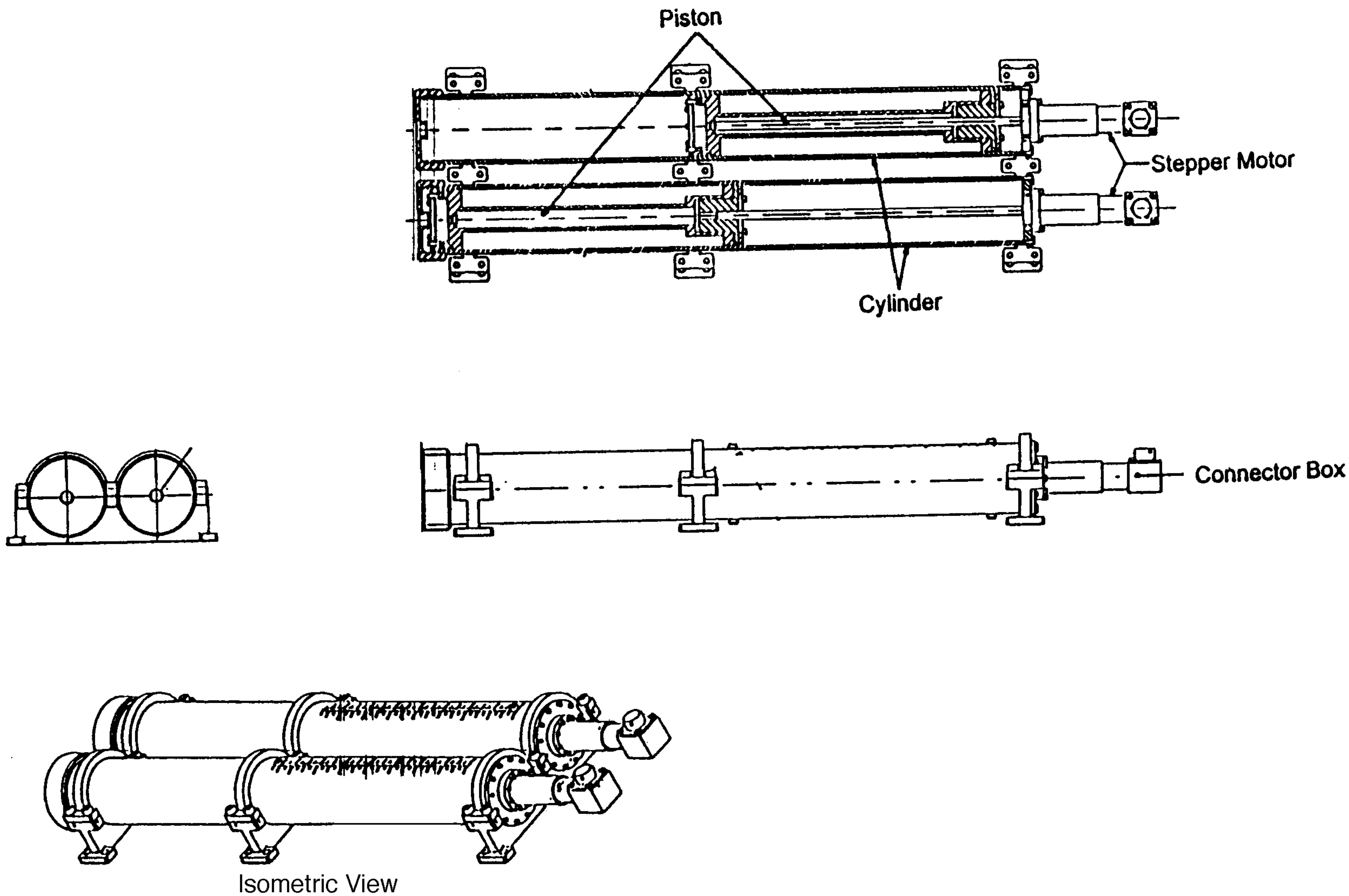

Figure 7. MGM Fluid System Accumulators

2.5 Payload General Support Computer (PGSC)

The PGSC is an STS-provided, laptop computer using Windows operating system that provides the crew interface to the MGM ES. It processes and transmits user commands, receives and displays data from the experiment microcontrollers, requests crew inputs when needed, and receives and displays advisory messages. MGM-provided software, consisting of object oriented code written in C++, is used toward this end. The PGSC will also have an ethernet connection to provide downlink telemetry and receive uplink from MGM ground software, written in LabVIEW.

2.6 Combined Electronics Unit (CEU)

The CEU provides experiment power, control, monitoring, and data management and storage. MGM utilizes SPACEHAB-provided 28 VDC electrical power. Individual CEU components are described in the following paragraphs.

2.6.1 Master and Slave Microcontrollers (Embedded System or ES)

A block diagram illustrating the two embedded microcontrollers (80C196 family) and related interface, timing, and memory functions appears in Figure 8. Microcontrollers receive commands from and transmit data / messages to the PGSC, control the sample stepper motor to achieve the specified load profile, control the Fluid Control System accumulator motors to maintain the desired confining pressures, and format / store data on “flash” memory cards. Microcontrollers use MGM-developed code written in C and Assembly Language and function as a slave to the PGSC-provided user interface. The code has been updated for the STS-107 experiment configuration.

2.6.2 Stepper Motor Controllers and Drivers

A stepper motor is an electromechanical device that converts electrical pulses into mechanical movements. The output shaft of a stepper motor rotates in discrete step increments when electrical pulses are applied to it in the proper sequence. The sequence of the applied pulses is directly related to the direction of the shaft’s rotation. The rotation speed of the shaft is directly related to the frequency of the input pulses, and the total angular rotation is directly related to the number of input pulses applied.

Stepper motors with integral gear-reduction drives are used in the test cells and fluid system accumulators. Each test cell stepper motor and integral gear reduction provides the drive mechanism to compress the test sample at a 35 mm per hour compression rate. Each accumulator stepper motor with a 360:1 gear reduction operating at a nominal 600 steps per second drives the accumulator piston at a rate of 320 mm per hour. Stepper motor controllers and drivers function under the control of the MGM slave microcontroller. This provides properly conditioned and scaled inputs to the stepper motors that drive the Fluid Control System accumulators and the sample loading mechanism.

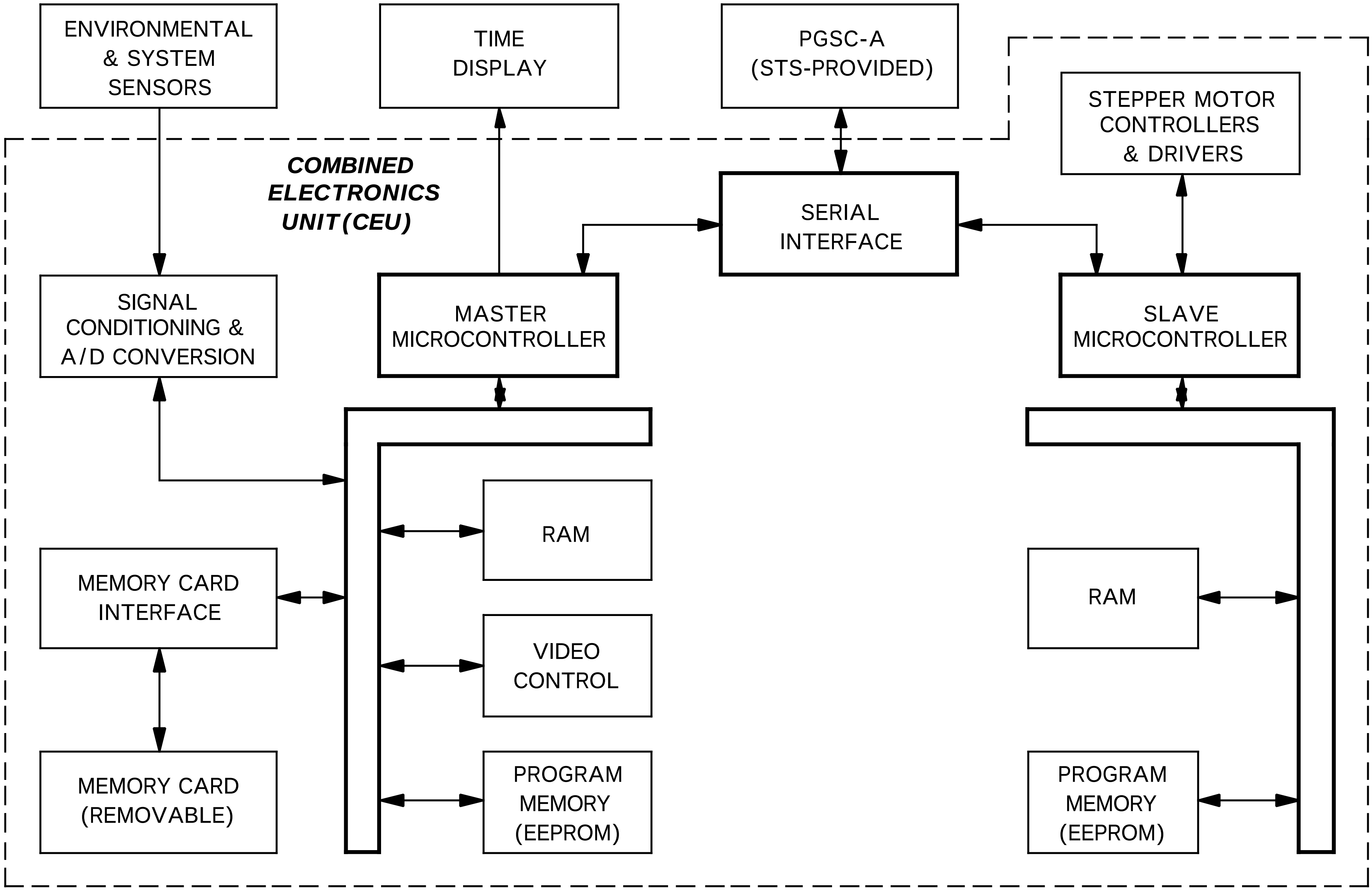

Figure 8. MGM Embedded System Block Diagram

2.6.3 Power Conversion and Transient Suppression

The power converter provides conditioned DC power at the proper voltage levels to the experiment electronics assemblies. It also provides voltage and current limiting, transient suppression, and circuit protection consistent with Memo TA-92-038. Each DC-to-DC converter incorporates a temperature sensor that monitors the respective converter board temperature and provides a signal to the CEU, which can shut off the experiment if there is thermal overload. A block diagram of the experiment power distribution is shown in Figure 9.

2.6.4 Sensors, Signal Conditioning, and A/D Conversion

A block diagram of the MGM sensors, signal conditioning, A/D conversion, and memory card interface is shown in Figure 10.

2.7 Sample Imaging and Video Data Storage

Video photography is performed on orbit using three experiment-provided CCD video cameras, which provide 360-degree video coverage around the cylindrical sand sample. The three locker-mounted cameras view the sample through the Lexan sleeve at 120-degree angular separation, recording displacement and deformation of the sample as registered on 3 grid patterns printed on the latex membrane. Multiplexing circuitry integral to the MGM electronics permits storage of video data from all three cameras on a STS-provided L1A camcorder, which is manually started before the test and continues to run until the test is complete. Illumination of the test sample for imaging and videotaping activities is provided by six linear arrays of light-emitting diodes (LEDs) mounted at the corners of the test cell Lexan jacket.

3.0 MGM THERMAL CONTROL SYSTEM

Thermal analysis has determined that MGM can rely on internal thermal mass and natural ambient air movement for thermal control. That analysis is part of the Verification Data Package and, therefore, is not included here.

4.0 MGM ON-ORBIT OPERATIONS

MGM is not powered during pre-launch, ascent, or descent phases of the mission. On-orbit crew procedures are detailed in SPACEHAB Experiment Operations Checklist MGM, document MDC2000W5808.

Experiment operations begin with the crew attaching the PGSC cable to the MGM Interface Panel and ethernet cable from the PGSC to the EDSMU for command and telemetry. The MGM input power cable and output video cable are connected to the MGM before launch. The MGM Interface Panel is illustrated in Figure 11.

The Beta Cloth light-blocking fabric screen is removed from the right-hand double locker The PGSC and L1 camcorder are removed from stowage and configured. One of the three MGM test cells in SPACEHAB stowage is selected and installed in the right-hand double locker viewing stage, and connected to the experiment electrical system by mating three electrical connectors.

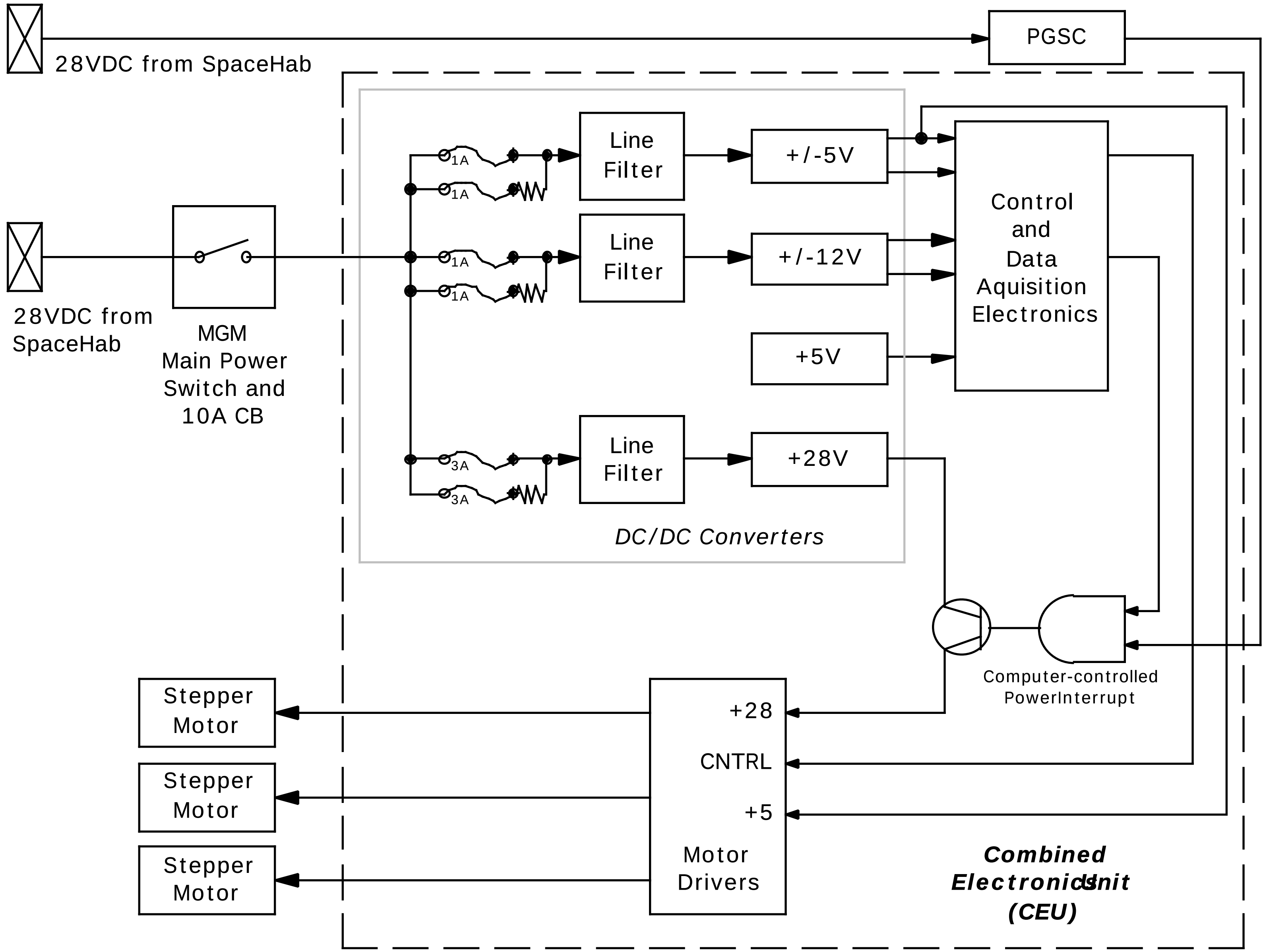

Figure 9. MGM Power Distribution Block Diagram

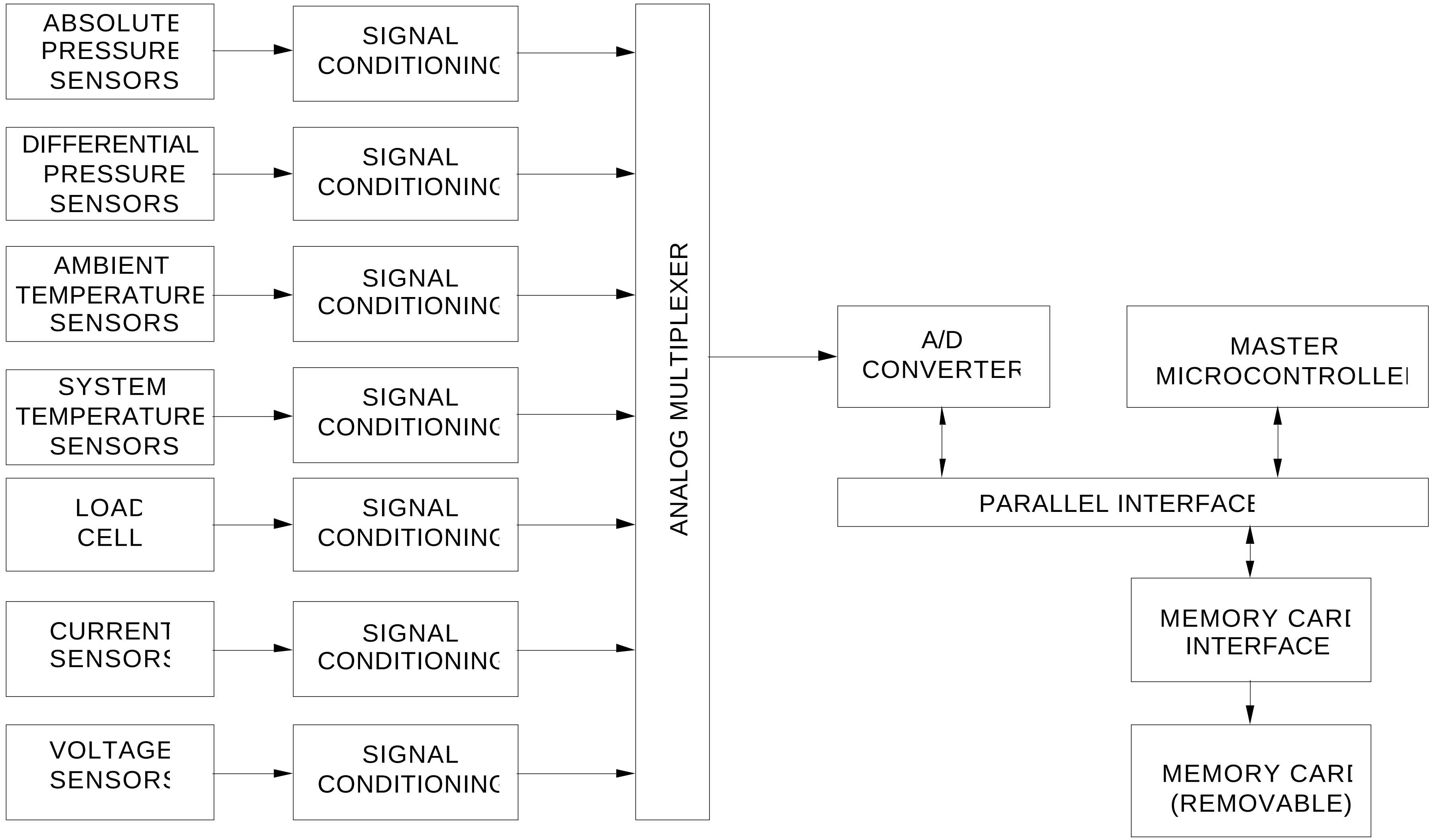

Figure 10. MGM SENSORS, SIGNAL CONDITIONING, A/D CONVERSION AND DIGITAL DATA STORAGE BLOCK DIAGRAM

The electrical assemblies are powered on. User Interface (UI) software is opened in the PGSC. The crew then initiates an automated self-test to verify proper interconnection and operation of the experiment apparatus. Steps are performed to initiate the system, including setting the MET and identifying the test cell. The test cell is connected to the experiment fluid system by mating two quick-disconnects. The video image is checked to verify operation of the cameras and multiplexing, and video recording is manually initiated.

The desired experiment protocol is initiated by the crew through the PGSC. The ES decreases pressure inside the test cell water jacket to approximately 3 psi above ambient, and differential pressure between the test cell water and the sample interior water is equalized by the Experiment Fluid System under control of the experiment microcontrollers acting as slaves to the PGSC. Two more fluid system quick-disconnects are mated and the ES decreases pressure inside the test cell water jacket to slightly above 2 psi above ambient. During this sequence the balance valve is temporarily opened for automatic sensor calibration. The Beta Cloth light-blocking fabric screen that covers the right-hand double locker is reattached with Velcro, and the experiment begins. The crew checks on the progress of the experiment at 15 minute intervals. Following the experiment stage 1 of a 2-part reformation procedure (for specimen re-use) is initiated. Stage 2 is performed during setup of the next test. Three tests will be performed on each test cell.

Upon completion of the third experiment on a single test cell, the fabric screen is removed from the front of the right side double locker. Through the UI, pressure in the test cell is raised slightly and two fluid system quick-disconnect is demated. The pressure is then raised to 15 psig storage pressure. The remaining two fluid system quick-disconnects are demated. The system is then powered off and all applicable electrical interfaces are disconnected. Between tests on the same test cell, the equipment will be powered off, but pressures will not be raised to 15 psig and fluid and electrical lines to the test cell will not be removed. As a result, the connection of fluid lines will not be performed at the beginning of the two subsequent tests on a test cell. [Note: Water from the water jacket accumulator is transferred to the sample accumulator through the balance valve following two of the nine experiments.]

Applicable portions of the above sequence are repeated for successive test cell protocols. Experiment electrical apparatus is powered down between runs. Following the third test of a test cell, the test cell is restowed. The PGSC and camcorder may be restowed between experiments and are restowed following final experiment deactivation.

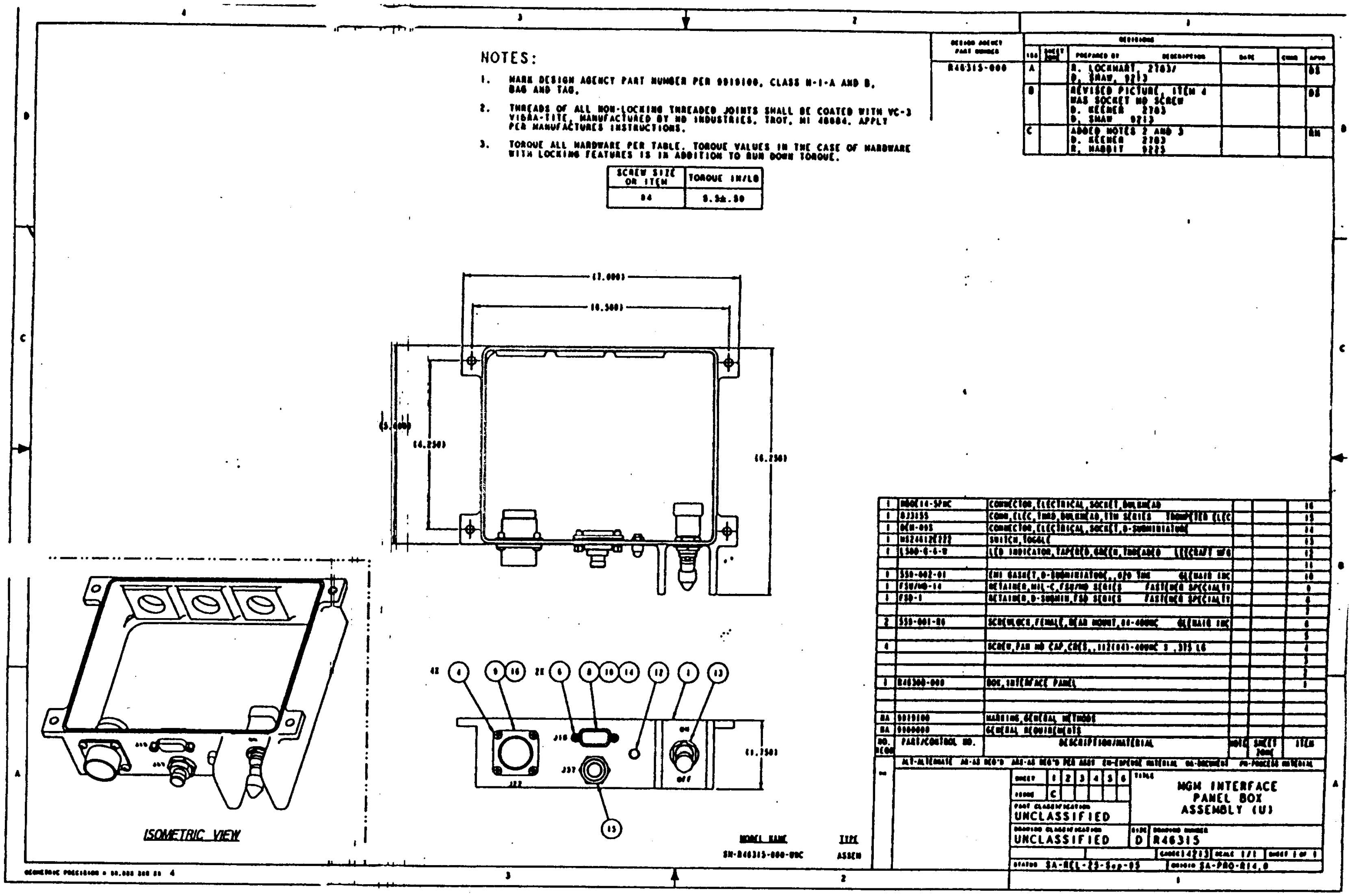

Figure 11. Interface Panel

5.0 MGM SAFETY ASSESSMENT

MGM experiment hardware and flight operations comply with requirements of NSTS 1700.7B. STS-supplied items used in support of MGM are previously flown and flight qualified, and will be used within the envelope of their accepted performance capabilities and qualification limits. Specific safety considerations relevant to MGM are summarized in the following paragraphs. These considerations reflect the safety issues specific to the present manifested MGM-III mission on STS-107. They are the same as the assessed safety items for the STS-79 baseline mission since the reflight hardware is essentially identical to the MGM-I hardware.

5.1 Electrical Shock

MGM electronics utilize low voltage (≤ 28 VDC) power. All energized conductors and components are enclosed, insulated, or otherwise isolated to preclude crew contact. Accessible conductive surfaces are electrically bonded to a grounded structure in accordance with MIL-B-5087B. MGM circuit protection complies with the requirements of Memo TA-92-038. The Payload Safety Review Panel has established policy (TA-94-029) which eliminates the need for a Payload Hazard Report on Electrical Shock for incidental contact with voltages less than 32 VDC.

5.2 Touch Temperature

Color-changing indicators visually identify crew-accessible surfaces whose temperatures can exceed 49 °C (120 °F). The indicator surfaces are located on the test cell and pressure accumulator stepper motors. The motors also incorporate thermistors that provide continuous temperature monitoring on the PGSC display.

5.3 Emergency Module Egress

Each flight-configured MGM test cell weighs approximately 30 lb. Test cells are stowed when not in use. One test cell is clamped in Locker 2 viewing stage during use and between subsequent tests. Test cells, however, are not considered to be penetrators, as determined from Figure 3-27 of the SPACEHAB Experiment Interface Definition Document, dated October 1994, using MGM Test Cell weight of 37 pounds and minimum perimeter of 23.4 inches. That determination is documented in Analysis Verification Report, MGM-AN-2.04.10.

5.4 Smoke Detection/Fire Suppression

Smoke detection for MGM powered equipment is provided by smoke detectors in the SPACEHAB cabin air loop. The MGM Combined Electronics Unit is constructed with aluminum that will not sustain a flame and does not have any penetrations that could allow flame to propagate.

5.5 Rotating Equipment

MGM rotating equipment includes stepper motors used for sample compression and fluid accumulators. Rotating equipment is configured to preclude crew access. Rotating components are low-speed, low-mass, low-power items that are considered exempt from formal assessment in accordance with JSC Memo TA-94-05.

5.6 Materials Selection

Wherever possible, MGM nonmetallic materials have been selected in accordance with MSFC-HDBK-527. In cases where MGM uses materials whose composition is either unknown or not “A”-rated, Material Usage Agreements (MUAs) have been prepared. Metallic materials used in structural applications have been selected in accordance with MSFC-SPEC-522. All material usage will be approved and certified by the MSFC Materials and Processes Laboratory.

5.7 Frangible Materials

Frangible materials are associated only with the video camera lenses that are protected with shatterproof Lexan covers.

5.8 Rupture of Test Cell or Fluid System Components

Rupture of the test cell or Experiment Fluid System components could release distilled water and possibly sand into the SPACEHAB module necessitating unplanned cleanup activity. The test cell, however, is leak-before-burst design. Maximum normal test cell internal pressure is approximately 15 psig (transportation and storage). Three bellows-type fluid pressure regulators mounted inside each test cell accommodate fluid expansion / contraction due to changes in ambient temperature and limit corresponding pressure excursions.

Four mechanical pressure relief valves are installed in the plumbing and set and tested to open at 35 psig on the water jacket accumulator loop and 15 psig on the sample accumulator loop to further prevent pressure buildup. A vent rate analysis has shown that, in the event of a very smart failure mode in which the water jacket accumulator stepper motor drives the accumulator piston at a rate of 320 mm per hour, the vent rate is 0.5 cubic inches per minute, or approximately 4 fluid ounces (118 cc) in the 15-minute intervals during which the experiment is unattended by the crew.

The Experiment Fluid System has limited potential to over-pressurize the test cell. The motor-driven water jacket accumulator is initially nearly empty, and the bellows-type test cell fluid pressure regulators can accommodate small volume changes without significant pressure increase. The volume of the sand sample increases (up to 18 percent maximum) during the axial loading operation, so the major possibility of exceeding intended test cell pressure occurs during the sample compression operation. As the volume of the sand sample increases, the differential pressure of the confining water jacket would increase rapidly if water were not withdrawn by the water jacket accumulator. However, as the differential pressure of the confining water jacket increases, the compressive strength of the sand sample rises approximately 8 times as rapidly, and stalls the compressing stepper motor very quickly before the confining water jacket pressure exceeds approximately 14 psid. During the compression, the sample expands, and water must be moved into the sample in order to prevent a decrease in pressure. As a result, potential to overpressure the sample fluid system is limited. However, if such a case were to occur, the latex membrane separating the water jacket and fluid systems within the test cell would expand and the water jacket system would control the pressure of both the water jacket and sample. As a result, the bellows and other safety mechanisms in the water jacket fluid system would also apply to the sample fluid system.

The Experiment Fluid System incorporates absolute and vented pressure sensors and an embedded microcontroller system that removes (via the embedded microcontroller) power to accumulator and sample compression stepper drive motors if water jacket accumulator or test cell pressure exceeds approximately 35 psia or if the specimen accumulator exceeds approximately 27 psia. [Note: The PGSC serves as a “watchdog” to the embedded microcontroller by monitoring response to a health status query at fixed intervals; lack of a response results in a PGSC-initiated removal of power from all three stepper motors.]

Pressurized components have been designed to factors of safety of 4.0 (lines/fittings) and 2.5 (other pressurized components) based on ultimate allowable and maximum design pressure (MDP), as listed in Table 1. As illustrated in Figure 6, the MGM Fluid System has two main branches and a third fine-sensing branch: 1) components connected to P1 (includes water jacket accumulator, pressure relief valves PRV1 and PRV2, lines, fittings, and quick-disconnect QD1); 2) components connected to P2 (includes sample water accumulator, pressure relief valves PRV3 and PRV4, lines, fittings, and quick -disconnect QD2); 3) vented pressure sensors DP1 and DP2, lines, fittings, quick-disconnects QD3 and QD4, and balance valve). The fine-sensing branch will be considered part of the main branch of components connected to P2 for pressure, safety, and verification purposes.

The MDP of components connected to P2 is 20 psig, as listed in Table 1, which is driven by the maximum allowable common line pressure for differential pressure gauges DP1 and DP2. Since DP1 and DP2 are capable of sensing extremely small (<0.01 psid) gauge pressures, they cannot withstand common line pressures above 20 psig without permanent damage to the sensor diaphragm and subsequent loss of calibration. For proof test purposes, therefore, the MDP of all components connected to DP1 and DP2 (and hence, P2 as during testing they are interconnected through the sample side of the test cell) is 20 psig. This is a change from STS-79 and STS-89, where the MDP was 40 psig. To adjust for the lower MDP, PRV 3 and 4 and microcontroller monitoring response were adjusted accordingly.

The MDP of components connected to P1 is 40 psig, which is derived from the nominal value of the pressure relief valves (35 psig) and allows for some tolerance in opening pressures of those valves. Table 1 gives a list of the approved Maximum Design Pressures for the various components. There is no change from STS-79 for these components.

Table 1. MGM-III Sealed Volume Component List

Acronym	Component, Manufacturer, P/N	Material	MOP (psig)	MDP (psig)	Required Proof Pressure (psig)	Rated Maximum Working Pressure (psig)	Ultimate Pressure Rating (psig)	Required FOS, Ultimate to MDP	Actual FOS, Ultimate to MDP
DP2	Pressure Sensor, Lucas PSI0063-004-5PV	SS	12	20	20	25	50	2.5	2.50
DP1	Pressure Sensor, Validyne DP15	SS	12	20	20	3200	12800	2.5	640.00
	Test Sample Accumulator, SNL R46035	Aluminum	12	20	20	30	120	2.5	6.00
P2	Pressure Sensor, Lucas P953	SS	12	20	20	150	600	2.5	30.00
QD2, QD3, QD4	Quick-Disconnect, Symetrics 155504-400	SS	12	20	20	30	120	2.5	6.00
PRV3, PRV4	Pressure Relief Valve, Nupro SS-4CPA2-DR-3-15, 15-psig crack	SS	12	20	20	3000	12000	2.5	150.00
	Swagelok, Plug Valve SS-4P4T	SS	12	20	20	150	3000	4.0	150.00
	Fittings, 1/4”	SS	12	20	20	6200	24800	4.0	1240.00
	Fluid Lines, 0.250” OD, 0.035” wall	SS	12	20	20	5100	20400	4.0	1020.00
	Fluid Hoses, 1/4”	SS	12	20	20	3000	12000	4.0	600.00
	Test Cell Assembly, SNL R44920	Aluminum, Lexan	20	40	40	40	100	2.5	2.50
	Water Jacket Accumulator, SNL R46036	Aluminum	20	40	40	40	122	2.5	3.00
P1	Pressure Sensor, Lucas P953	SS	20	40	40	150	600	2.5	15.00
QD1	Quick-Disconnect, Symetrics 155504-400	SS	20	40	40	40	120	2.5	3.00
PRV1, PRV2	Pressure Relief Valve, Nupro SS-4CPA2-DR-3-35, 35-psig crack	SS	20	40	40	3000	12000	2.5	300.00
	Fittings, 1/4”	SS	20	40	40	6200	24800	4.0	620.00
	Fluid Lines, 0.250” OD, 0.035” wall	SS	20	40	40	5100	20400	4.0	510.00
	Fluid Hoses, 1/4”	SS	20	40	40	3000	12000	4.0	300.00

6.0 NSTS 13830C SECTION 9.0 SERIES/REFLIGHT SAFETY ASSESSMENT

The MGM-III flight hardware for STS-107 is series hardware with no new modifications impacting safety since S/MM-04 (STS-79/MIR-04) and S/MM-08 (STS-89/MIR-08). For MGM-III hardware reverification purposes the STS-79 mission is considered as the baseline mission and Payload Hazard Reports from STS-79 will be used. Any anomalies / changes resulting from the STS-89 flight will be assessed before flight on the STS-107 mission.

The hazards associated with the MGM hardware are controlled through design and by eliminating the hazards or by reducing them to an acceptable risk level.

For the present manifested mission, the MGM-III flight hardware has been evaluated as series hardware in accordance with paragraph 216 of NSTS 1700.7 and section 9 of NSTS 13830 REV C, items A through N inclusive. The verification methods from STS-79 have been reviewed and found to be acceptable. A reverification status matrix is provided to identify safety verification requirements / methods for the baseline mission as recorded in the STS-79 Payload Hazard Reports, and corresponding safety reverification requirements for the reflight of MGM.

A. Identification of all series/reflown payloads, payload elements, and GSE to be used and the baseline safety analyses by document number, title, and release date. If chemicals are used, provide a new list, even though the chemicals are the same as those used previously.

The baseline safety analysis (MGM-I, STS-79/MIR-04) for STS-107 safety is "Mechanics of Granular Materials (MGM) Experiment Flight Hazard Analysis and Safety Compliance Data" authored by Sandia National Laboratories, Albuquerque, New Mexico and submitted March 28, 1996. A description of the MGM-I hardware and Payload Hazard Reports can be found in the MGM Flight Hazard Analysis and Safety Compliance Data for STS-79/MIR-04 that is on file at JSC. The MGM-III series/reflight elements for the SPACEHAB module are described in Section 2 of this document and include 3 experiment test cells, the Twin Double Locker Assembly (TDLA) that houses the pressure control system and associated plumbing, and video cameras during flight ascent and descent. During STS-107 ascent / descent the 3 MGM-III test cells will be carried in separate SPACEHAB stowage and remain there on-orbit except during experimentation in the MGM test locker.

B. Assessment of each series/reflown payload, payload elements, and GSE to indicate that the proposed use is the same as that currently approved (analyzed and documented).

The usage of all MGM-III reflight elements during STS-107 will, apart from details in on-orbit experimental protocol, be identical to usage of the MGM-I elements for experiments performed on the STS-79 baseline mission.

C. New or revised hazard reports, additional data, and identification of hazard reports that are no longer applicable based on the reflight application. Identification and assessment of changes in hardware/software and operations that have any safety impact, including on-orbit verifications/ reverification of hazard controls.

The verification methods from the STS-79 hazard reports were assessed for adequacy and validity and were found to be acceptable for controlling the hazards identified; therefore, no new hazard reports are required. Minor changes pertinent to PHR MGM-1 do exist and are described below. In brief, these changes do not affect or decrease the applicability of hazard controls and verification methods.

Below are descriptions of changes to the hardware, software, and operations of the MGM equipment for STS-107.

Specimen Fluid Change

> The fluid in the specimen and associated plumbing has been changed from air to de-ionized de-aired water. The water is from the same source as the water used in the water jacket and associated plumbing, which was approved for use in STS-79 and STS-89. Pressure release valves were added to the specimen-associated plumbing to account for this change (described separately below.)

Undrained Testing Added

> A new test capability has been added to MGM-III for STS-107. Previous experiments have all been "drained," where both internal specimen and external water jacket *pressures* are controlled during experimentation. During the new "undrained" testing, the internal specimen *volume* will be controlled and the external water jacket *pressure* will be controlled. Other aspects of the experiment perform the same in both drained and undrained experiments. This protocol is a new combination of system capabilities: No new core functions have been added to the system.

Reforming Procedure Added

> A new reforming procedure has been added to re-use specimens. After an experiment, the top platen will be raised back to the initial position, and an amount of water (approximately 25-50 cc) will be pushed into the specimen from the sample accumulator. The extraneous water (approximately 25 cc) will then be transferred back to the sample accumulator. This protocol is a new combination of system capabilities: No new core functions have been added to the system.

Quick-Disconnect Filter Change

> The filter size inside the quick-disconnects has been changed from 10 micron to 17 micron. The filter is the same type, with the only change being the micron size.

Quick-Disconnect Addition

> A fourth QD has been added to the TDLA and test cells. The QD is the same part number as the current QDs, with exception to the color/keying (the QDs come in different colors and keyings, to avoid accidental mismating.) The nipple-side of the QD is added to the lower sample port on the test cells. The coupling-side of the QD is added on a direct line from DP2.

Dummy Connector Addition

> A dummy connector to stow the coupling-side of the fourth QD during ascent and descent is added to Locker 2 in the TDLA. The dummy connector is the same as the original 3 dummy connectors, with exception to the color coding.

Balance Valve Addition

> A Swagelok brand plug valve (part number SS-4P4T) has been added to the plumbing associated with the specimen accumulator. It has been added to the MGM-III Sealed Volume Component List. The balance valve has analyzed and does not change the MDP or proof pressure of the system.

Pressure Sensor Modification

Pressure sensor DP1 (Validyne DP15) has been modified. The interchangeable diaphragm which determines the sensing range was replaced with one of the same type, but wider range. The modification has no change on the pressure rating or electrical behavior of the sensor. Also, the pressure sensor is now used as a gage sensor: one pressure port is connected to the water jacket pressure, the other is open to the shuttle environment. The sensor will be rechecked during leak testing.

Pressure Sensor Exchange and MDP Decrease

Pressure transducer DP2 has been exchanged. The Tavis P108 has been replaced with a Lucas Schaevitz PS10063-0004-5PV in order to increase the sensing range. The new transducer is a gage sensor and is connected only to the specimen plumbing and not the water jacket plumbing (as was the case in STS-79 and STS-89.) The new transducer was chosen because it has the same power requirements as the sensor it is replacing, and thus requires no electrical modifications to be made. However, the ultimate pressure rating and rated maximum working pressure are lower for the new sensor (see Table *, below). This has been considered, and as its pressure ratings are the lowest of all components in the sample-side plumbing it is now the controlling factor on the MDP for the specimen plumbing and in turn MDP for the specimen plumbing must be lowered, equal to the MDP of the new sensor. The system has been adjusted for proper functioning of the two-fault tolerant system: both the setpoint control via the embedded microprocessor and the crack point on pressure release valves for the sample plumbing are altered in response to this change. The sample-side pressure that will prompt the embedded microprocessor to stop all motors has been lowered to 10 psig, and the pressure at which the sample-side PRVs will crack is 15 psig. As a result, the new MDP is 20 psig after allowing for tolerance in opening pressures of those valves. Additionally, these checks will be tested for proper functioning. Also, leak test reverification according to methods in PHR MGM-1 will be performed on all plumbing systems (both water jacket and specimen) and the 3 test cells. No change has been made on the water jacket plumbing, and thus the setpoint control via the embedded microprocessor and the crack point on pressure release valves is unchanged for that plumbing loop.

Table 2. Pressure Transducer/Sample Plumbing Pressure Changes

Mission	Manufacturer	MOP (psig)	MDP (psig)	Required Proof Pressure (psig)	Rated Max. Working Pressure (psig)	Ultimate Pressure Rating (psig)	Actual FOS, Ultimate to MDP
STS-79, STS-89	Tavis	0.5	40	30	30	600	15.00
STS-107	Lucas Schaevitz	12	20	20	25	50	2.50

Plumbing Modifications

A new plumbing configuration is implemented with different pressure sensors, and newly added balance valve, pressure release valves and fourth QD. The plumbing for STS-79 and STS-89 was as follows: The first plumbing group consisted of a water jacket accumulator was connected with an absolute pressure sensor and one QD, which connected to the water jacket side of the test cell. This plumbing was water-filled. A second plumbing group consisted of a sample accumulator connected with and absolute pressure sensor and two differential pressure sensors and one QD, which connected to the sample side of the test cell. The plumbing was air-filled. A third plumbing group had connections to the other side of the two differential pressure sensors and a QD, which connected to the water jacket side of the test cell during low pressure situations.

The new plumbing for STS-107 is as follows: The first plumbing group is not altered. The second plumbing group is filled with water, and the two differential pressure sensors are removed and pressure release valves added. The third plumbing group is now divided into two halves, separated by a balance valve. In one half, there is a QD which connects to the sample side of the test cell and a gage pressure sensor. In the other half, there is another QD which connects to the water jacket side of the test cell and another gage pressure sensor. This third plumbing group is connected to the test cell only during low pressure situations. This third plumbing group will be treated as part of the second plumbing group for safety verification, and are subject the proof pressures and MDP as the second plumbing group.

The items in Table 1. MGM-III Sealed Volume Component List reflect this modification.

Software Change

The UI software has been updated from DOS to Windows 95/98. The UI, Master and Slave software has been updated to accommodate the new type of experiments. Command and telemetry functions have been added.

Pressure Release Valve Addition

Two pressure release valves (PRVs) were added to the specimen plumbing in response to the addition of water to the specimen. The valves are identical to the pressure release valves in the water jacket plumbing (Nupro SS-4CPA2-DR-3-15) with a different set crack pressure (15 psig.) The flow rate for the lower crack pressure is lower than for the Water Jacket Accumulator PRVs (1,2), but analysis indicates that the lower flow rate will still prevent the equipment from reaching the MDP. It is noted that PHR MGM-1 indicates the use of only two PRVs: all four PRVs will be subject to the same safety considerations as the two currently cited in PHR MGM-1, however.

No Accumulator Purge Required

The accumulator purge sequence used on STS-79 and STS-89 will not be required on STS-107. This step pushed water from the water jacket accumulator into a drink bag at the end of each experiment. Associated hardware (2 handles, drink bags) will not be included in MGM stowage. This sequence is replaced with an accumulator reposition routine which allows the transfer of water from the specimen to water jacket accumulator while remaining fully contained within the TDLA plumbing. The process is also simpler for the crew; the description will replace previous purge procedures in the EOC, and the crew will be trained accordingly.

MGM PIP Modification

The RS232 serial cable internal to the MGM PIP has been modified so that the TDLA DCD signal is connected to the PGSC CTS signal. This allows hardware handshaking with the Windows program using a standard SPACEHAB RS232 serial cable.

Analog to Digital Converter Modification

The MGM analog to digital converter card has been modified to optimize the scaling for pressure sensors DP1 and DP2. This change involved replacing seven scaling resistors. The resistors are of the same model with different resistance value. These changes involve modifications to sensor signal circuitry only. Power distribution circuits were not affected.

Signal Conditioning Card Modification

The MGM signal conditioning card was modified to improve the stability of sensors DP1 and DP2. This change involved replacing six resistors of same model with different resistance values. These changes involve modifications to sensor signal circuitry only. Power distribution circuits were not affected.

Bracket Exchange

The bracket which held DP2 (Tavis P108) for STS-79 and STS-89 will be changed out with a new bracket to hold the new DP2 (Lucas Schaevitz PS10063-0004-5PV.) The new drawings have been submitted.

New Drawings

Four new drawings have been submitted for STS-107. They are listed in Table 2 below.

Table 3. New drawings submitted for MGM-III STS-107.

Drawing Number	Description
20540-1-0001	Bottom Bracket
20540-1-0002	Top Bracket
20540-1-0003	Valve Handle
20540-1-0004	Deflection Cap

Quantity of Memory Cards

Due to an increase in the number of experiments to be performed, 22 Flash memory cards will be carried in stowage. For STS-79 and STS-89, 6 and 12 memory cards were carried, respectively.

Quantity of Video Tapes

Due to an increase in the number of experiments to be performed and a change of format in video cameras (digital), the number of video tapes used during experimentation will increase.

Offgasing

The TDLA will be tested for offgasing.

Test Cells Not Mounted in TDLA

No test cells will be mounted in the TDLA for ascent or descent on STS-107. In response to this change, the procedures for removing the test cells from the TDLA will be removed and the ball driver used for this purpose will not be included in MGM stowage. The effect on structural analysis will be inspected.

D. A copy of the approved baselined phase III hazard reports (attachments not required).

The approved baseline phase III hazard reports for STS-79 are presented in Appendix A.

E. Report on the completion and results of applicable safety verifications. Submission of safety verification tracking log (JSC Form 764) that identifies all safety verifications from the applicable baselined hazard reports that must be

reverified for the reflight mission. In addition, open reverification from new hazard reports must be included as appropriate.

Table 3 presents the Flight Safety Reverification Status Matrix for the MGM-III payload on STS-107 (Series Hardware) by listing the PHR Title and Safety Verification Methods recorded on each PHR documented in the Experiment Safety Data Package for flight hardware on the baseline mission that is on file at JSC. The current reverification status for each corresponding hazard item for MGM-III reflight on STS-107 is recorded for assessment of results and status monitoring for ultimate submittal to the Safety Verification Tracking Log. All open verification issues will be transferred to the STS-107 flight safety Verification Tracking Log (VTL) after the Phase III review is complete. All safety verifications to be completed for STS-107 are listed on the attached reverification matrix.

TABLE 4 HAZARD CONTROL REVERIFICATION STATUS MATRIX FOR MGM-III (SERIES HARDWARE) (Sheet 1 of 3)

HAZARD REPORT NO.	BASELINE MISSION	HAZARD REPORT TITLE	SAFETY VERIFICATION REQUIREMENTS FROM BASELINE MISSION		SAFETY REVERIFICATION REQUIREMENTS FOR MGM-III	
MGM-1	STS-79	Failure of Sealed / Pressurized System and Subsequent Loss of Containment	1.	Review of system design for incorporation of wet mate/demate quick disconnects and color coding	1.	REINSPECT and provide certification
			2.a.	Stress Analysis; failure analysis to determine MDP	2.a.	REANALYZE
			2.b.(1).	Certification of as-built hardware	2.b.(1).	REINSPECT and provide certification
			2.b.(2).	Leak testing at Proof Pressure	2.b.(2).	RETEST
			2.c.	Leak and functional testing	2.c.	RETEST
			3.a.	Functional test of fluid control system	3.a.	RETEST
			3.b.(1).	Flight hardware will be inspected to verify installation of two relief valves	3.b.(1).	REINSPECT and provide certification
			3.b.(2).	Relief valves will undergo independent functional testing to verify proper operation / setting	3.b.(2).	RETEST
			3.b.(3).	Relief valves will undergo a vent rate analysis to verify that the provisions for pressure relief effectively preclude the system from reaching MDP	3.b.(3).	REANALYZE
			3.c.	Functional test of malfunction cutoff feature	3.c.	RETEST
			3.d.	Review of crusher motor capability assessment	3.d.	REANALYZE
			4.a.	Review of system design for incorporation of wet mate/demate quick disconnects	4.a.	REINSPECT and provide certification
			4.b.	Review of PFDF	4.b.	RECERTIFY crew procedures

TABLE 4 HAZARD CONTROL REVERIFICATION STATUS MATRIX FOR MGM-III (SERIES HARDWARE) (Sheet 2 of 3)

HAZARD REPORT NO.	BASELINE MISSION	HAZARD REPORT TITLE	SAFETY VERIFICATION REQUIREMENTS FROM BASELINE MISSION		SAFETY REVERIFICATION REQUIREMENTS FOR MGM-III	
MGM-2	STS-79	Excessive Touch Temperature	1.a.1	Thermal analysis based on worst-case environments	1.a.1	CLOSED by similarity to baseline mission
			1.a.2	Certification that as-built hardware conforms to approved design drawings	1.a.2	REINSPECT and provide certification
			1.a.3	Inspection to verify presence of warning patch	1.a.3	REINSPECT and provide certification
			1.b.	Review of Crew Procedures	1.b.	REINSPECT
			1.c.	Review of Crew Procedures	1.c.	REINSPECT
G-1	STS-79	Electrical Shock	—	DELETED (TA-94-029)	—	DELETED (TA-94-029)
G-2	STS-79	Overheating of Electrical Wiring	1.a.	Circuit analysis	1.a.	REASSES waiver
			1.b.	Inspection of as-built hardware	1.b.	REINSPECT
G-3	STS-79	Exposure of the STS Electrical System of Other Payloads to EMI	1.	Test for radiated and conducted emissions in accordance with MSFC SPEC-521B	1.	REASSES waiver
G-4	STS-79	Exposure of Crew to Sharp Corners, Edges or Protrusions	1.a.	Drawing review for inclusion of requirements to remove sharp corners and edges or to provide protective covers	1.a.	REINSPECT and provide certification
			1.b.	QA certification that as-built hardware conforms to approved drawings	1.b.	REINSPECT and provide certification
G-5	STS-79	Toxic Offgasing in Habitable Areas	1.a.	Review / approval of materials usage by MSFC Materials and Processes Laboratory	1.a.	RECERTIFY
			1.b.	Certification that as-built configuration is in accordance with approved design drawings and parts lists	1.b.	RECERTIFY
			1.c.	MSFC evaluation / approval of offgas test data	1.c.	RETEST and provide certification

TABLE 4 HAZARD CONTROL REVERIFICATION STATUS MATRIX FOR MGM-III (SERIES HARDWARE) (Sheet 3 of 3)

HAZARD REPORT NO.	BASELINE MISSION	HAZARD REPORT TITLE	SAFETY VERIFICATION REQUIREMENTS FROM BASELINE MISSION		SAFETY REVERIFICATION REQUIREMENTS FOR MGM-III	
G-6	STS-79	Use of Flammable Materials	1.a.	Materials Lists and MUAs to be submitted to MSFC Materials and Processes Laboratory for approval	1.a.	RECERTIFY
			1.b.	QA certification that the as-built configuration is in accordance with design drawings and parts lists	1.b.	REINSPECT and provide certification
G-7	STS-79	Structural Failure due to Launch, Flight, and Landing Environments or Stress Corrosion Cracking	1.a.	Structural analysis to verify positive margins against specified factors of safety and static loads tests for safety factors <2.0 ultimate	1.a.	REASSESS based on STS-107 couple loads (provided by Boeing.)
			1.b.	MSFC Fracture Control Board review fracture mechanics approval of fracture control plan and analysis (including NDE)	1.b.	REASSESS based on STS-107 couple loads (provided by Boeing.)
			1.c.	Inspection verifying positive locking devices are in place, or vibration testing showing no fastener backoff in accordance with JA-418 criteria	1.c.	REINSPECT and provide certification
			2.	Approval of Metallic Materials List and. MUAs by MSFC Materials and Processes Laboratory	2.	RECERTIFY
			3.	QA certification that the as-built hardware in accordance with design drawings and parts	3.	RECERTIFY
			4.	Review of MSFC NASA Advisorys screening/response program and interface fastener testing program	4.	Alerts continuously reviewed by PM, PE, UCB PM
G-8	STS-79	Exposure of Crew to Frangible Materials		Review of design for adequate containment		CLOSED by similarity to baseline mission

F. Assessment of all noncompliances.

No safety deficiencies / noncompliances for MGM-III have been identified. There are no safety waivers or deviations applicable to MGM-III.

G. Assessment of limited life items for reflown hardware.

PHR G-7 will be revisited due to the re-use of equipment, considering hardware lifetime.

Several o-rings are required in the MGM equipment, and the limited lifetime of o-rings used in MGM-II would expire prior to the MGM-III launch date. For MGM-III, all o-rings were replaced with new o-rings. In addition, the Symetrics brand QDs were sent to the manufacturer for replacement of internal o-rings, and the PRVs with internal o-rings were replaced with identical new components.

H. Description of maintenance, structural inspections, and refurbishment of reflown hardware and assessment of safety impact.

The MGM-III flight hardware for STS-107 is classified as series hardware. Activities for MGM-III hardware will include inspections, certifications, and other verification procedures to assure the safety, workmanship quality, and functionality of the MGM-III reflight hardware.

I. Assessment of all testing or ground/flight anomalies and failures previous usage of the series/reflown payload or payload element along with corrective action taken and rationale for continued use.

I.1

During the deactivation phase of MGM-I Experiment 1 on STS-79, an anomaly occurred during execution of a new deactivation procedure made necessary by delays in other scheduled crew activities. An omitted step in the procedure caused the water jacket accumulator motor to run opposite to the expected direction, causing the pressure in the water jacket system to increase. The pressure relief valves functioned properly, and a small amount of water (<120 cc) was vented into MGM-I Locker-1 before the procedure was halted. The Mission Specialist performing the procedure cleaned up the water without incident. Post-flight investigation of the anomaly showed the MGM team omitted the execution of a user-interface “Stop Motors” command that was believed to be superfluous under the circumstances. This omission was in error, and caused the anomaly. The procedure has been corrected by adding the “Stop Motors” command. The corrected procedure will be used if a similar situation arises on the next flight.

I.2

During the deactivation phase of MGM-I Experiment 3, the water jacket absolute pressure sensor was observed to be producing erroneous readings. The sensor readings fluctuated by 5-10 psi in response to very small (± 0.005 psi) changes in the actual pressure. The system depends on these readings during experiment deactivation to control the two-step process in which the pressure in the test cells is raised from the test pressure first to 0.5 psid, then to the storage pressure of 15 psid. While the system was able to raise the test cell pressure properly, the fluctuations in the sensor readings made it difficult for the system to determine success and terminate the process. The process was terminated manually with a software command. At the time of termination the test cell had been returned to its final, stable storage condition. The remaining steps in the deactivation procedure configure the TDLA for the following experiment. Since this experiment was the final MGM experiment of the mission, the MGM team decided to terminate the deactivation phase at that point.

For the MGM-II mission the water jacket absolute pressure sensor was producing erroneous readings. The readings fluctuated by 5 - 10 psi in response to very small (±0.005 psi) changes in actual pressure. The system depends on these readings during experiment activation and deactivation to control the pressure in the test cells. While the system was able to lower and raise the test cell pressure properly, the fluctuations in the sensor readings made it difficult for the system to determine success and terminate the process. The source of the anomaly has been identified to be a Symetrics quick-disconnect (QD) assembly. The sensor, which is connected on the plumbing between the water jacket accumulator and the QD connecting the plumbing to the test cell, sensed momentary increase in pressure when the accumulator is moved. The increase is sensed because the QD provides too much of a constriction of flow. The constriction is related to the small filter inside the QDs which are intended to prevent any objects in the test cell (such as sand grains) from entering the plumbing and the accumulator. The problem has been corrected by replacing the 10-micron filter screens with a 17-micron filter.

I.3

During post-flight testing for MGM-I, McDonnell Douglas/SPACEHAB personnel performed measurements indicating that the TDLA violated the single-point grounding scheme for the Orbiter 28V power. Measurements at UCB/LASP confirmed this. The Orbiter 28V return and Orbiter chassis ground were connected in the MGM electronics via the Power Interface Panel (PIP). The cause was design error, rather than assembly error or malfunction. The verification inspection procedure performed at delivery did not include a check for this condition. Resolution of this anomaly has been achieved by reworking the PIP to enforce the required single-point grounding scheme for the next mission.

I.4

For each experiment , science and engineering data are recorded on two memory cards which create a duplicate set that contains the same information on each card. After return of the memory cards for MGM-II, the data was examined and it was detected that the memory card sets were not exact duplicates. Post-flight testing showed that the anomaly was caused by incomplete erasure of some of the cards. For STS-107 all memory cards will be erased and checked before launch.

J. For flight reviews: a list of all pyrotechnic initiators installed or to be installed on the payload. The list will identify for each initiator the function to be performed, the part number, the lot number and the serial number.

There are no pyrotechnic initiators or pressure vessels in the MGM-III hardware.

K. **Ionizing and non-ionizing radiation forms for each source within the flight hardware or GSE.**

There are no radiation sources or materials in the MGM-III reflight hardware.

L. **For payloads that flew and were assessed for safety on either the shuttle or the ISS and are being reflown on the other vehicle: Results of the assessment of the payload with respect to the safety requirements of the new host vehicle (Flight safety only: current versions of NSTS 1700.7 for the shuttle and the NSTS 1700.7 ISS Addendum for the ISS).**

Not applicable.

M. **A final list of procedures for ground processing (ground only).**

Not applicable.

N. **Certificates of NSTS Payload Safety Compliance**

Certificate of NSTS Payload Safety Compliance for Payload Design and Flight Operations to be submitted.

APPENDIX A: BASELINE HAZARD REPORTS

This Appendix is a compilation of the Payload Hazard Reports and associated documents submitted by Sandia National Laboratories in the Safety Compliance Data Package for MGM-I that was flown on STS-79/SPACEHAB/MIR-04 in September 1996.

TABLE 1 (Sheet 1 of 1)

EXPERIMENT SAFETY PACKAGE COVER SHEET			
EXPERIMENT Mechanics of Granular Materials (MGM)	PAYLOAD SH / MIR-04	PHASE III	DATE 3/96

NO.	HAZARD TITLE	REMARKS	DISPOSITION
	UNIQUE HAZARD REPORTS		
MGM-1	Failure of Sealed / Pressurized System and Subsequent Loss of Containment	Table 2-1	CLOSED
MGM-2	Touch Temperature	Table 2-2	CLOSED
	GENERIC HAZARD REPORTS		
G-1	Electrical Shock		DELETED (TA-94-029)
G-2	Overheating of Electrical Wiring	Table 3-1	CLOSED
G-3	Exposure of the STS Electrical System or Other Payloads to EMI	Table 3-2	CLOSED
G-4	Exposure of Crew to Sharp Corners, Edges, or Protrusions	Table 3-3	CLOSED
G-5	Toxic Offgasing Materials In Habitable Areas	Table 3-4	CLOSED
G-6	Use of Flammable Materials	Table 3-5	CLOSED
G-7	Structural Failure due to Launch, Flight and Landing Environments, or Stress	Table 3-7	CLOSED
G-8	Exposure of Crew to Frangible Materials	Table 3-8	CLOSED

GENERAL COMMENTS

APPROVAL	
PAYLOAD ORGANIZATION	STS

TABLE 2-1 (Sheet 1 of 2)

PAYLOAD HAZARD REPORT			NO.: MGM-1
PAYLOAD: Mechanics of Granular Materials (MGM)			**PHASE:** III
SUBSYSTEM: Fluid	**HAZARD GROUP:** Contamination		**DATE:** 5/96
TITLE: Failure of Sealed / Pressurized System and Subsequent Loss of Containment			

APPLICABLE SAFETY REQUIREMENTS:		HAZARD CATEGORY	
NSTS 1700.7B, paragraph 200.1a	RUPTURE	X	Catastrophic
	LEAKAGE	X	Critical

DESCRIPTION OF HAZARD:

Leakage of water or sand from experiment test cell or fluid control system could contaminate surrounding payload or carrier equipment and necessitate contingency cleanup / safing procedures.

HAZARD CAUSES:

1. Improper installation of test cell by crew
2. Defective design, assembly, or component

(See continuation)

HAZARD CONTROLS:

1. Quick-disconnect design precludes leakage during mate/demate; Q/Ds will be color coded to preclude cross-mating.
2.a. Design factors of safety of 4.0 (ultimate; lines and fittings) and 2.5 (ultimate; other pressurized components including test cell and accumulators) based on MDP.
2.b. Assembly will be accomplished per approved design drawings.
2.c. Non-defective components will be employed.

(See continuation)

SAFETY VERIFICATION METHODS:

1. Review of system design for incorporation of wet mate/demate quick disconnects and color coding
2.a. Stress analysis; failure analysis to determine MDP
2.b.(1). Certification of as-built hardware
2.b.(2). Leak testing at Proof Pressure
2.c. Leak and functional testing

(See continuation)

STATUS OF VERIFICATION:

1. CLOSED (Transferred to SVTL)
2.a. CLOSED (Transferred to SVTL)
2.b.(1). CLOSED (Transferred to SVTL)
2.b.(2). CLOSED (Transferred to SVTL)
2.c. CLOSED (Transferred to SVTL)

(See continuation)

APPROVAL	PAYLOAD ORGANIZATION	STS
PHASE I		
PHASE II		
PHASE III	[signature] 5/1/96 [initials] 5/1/96	[signature] 5/4/96

TABLE 2-1 (Sheet 2 of 2)

PAYLOAD HAZARD REPORT CONTINUATION SHEET	NO.: MGM-1
PAYLOAD: Mechanics of Granular Materials (MGM)	PHASE: III

HAZARD CAUSES (cont.):

3. Equipment overpressurized by malfunction
4. Improperly conducted accumulator purge

HAZARD CONTROLS (cont.):

3. The fluid control system is two-fault tolerant to overpressurization via the following:
3.a. Fluid control system will provide setpoint control within prescribed limits via embedded microcontroller. (See Attachment 1 to HR MGM-1.)
3.b. Accumulator plumbing will incorporate two pressure relief valves to preclude accumulator-induced pressure exceeding MDP. (See Attachment 2 to HR MGM-1.)
3.c. PGSC will remove power to stepper motors (independent of embedded microcontroller) if health status communication is lost. (See Attachment 1 to HR MGM-1.)
3.d. Crusher motor will not produce sufficient force to induce excessive pressure in water jacket due to increased sample volume.
4.a. Quick disconnect design precludes leakage during mate/demate.
4.b. Crew procedures will prescribe proper accumulator purge operation.
NOTE: Test cell is LBB design.

SAFETY VERIFICATION METHODS (cont.):

3.a. Functional test of fluid control system
3.b.(1). Flight hardware will be inspected to verify installation of two relief valves.
3.b.(2). Relief valves will undergo independent functional testing to verify proper operation / setting.
3.b.(3). Relief valves will undergo a vent rate analysis to verify that the provisions for pressure relief effectively preclude the system from reaching MDP.
3.c. Functional test of malfunction cutoff feature
3.d. Review of crusher motor capability assessment
4.a. Review of system design for incorporation of wet mate / demate quick disconnects
4.b. Review of PFDF

STATUS OF VERIFICATION (cont.):

3.a. CLOSED (Transferred to SVTL)
3.b.(1). CLOSED (Transferred to SVTL)
3.b.(2). CLOSED (Transferred to SVTL)
3.b.(3). CLOSED (Transferred to SVTL)
3.c. CLOSED (Transferred to SVTL)
3.d. CLOSED (Transferred to SVTL)
4.a. CLOSED (Transferred to SVTL)
4.b. CLOSED (Transferred to SVTL)

Table 1. MGM Sealed Volume Component List*

Acronym	Component, Manufacturer, P/N	Material	MOP (psig)	MDP (psig)	Required Proof Pressure (psig)	Rated Maximum Working Pressure (psig)	Ultimate Pressure Rating (psig)	Required FOS, Ultimate to MDP	Actual FOS, Ultimate to MDP
DP2	Pressure Sensor, Lucas PSI0063-004-5PV ~~Tavis P108~~	SS	12~~0.5~~	20~~40~~	2030 ~~(Note 1)~~	25~~30~~ ~~(Note 1)~~	50~~600~~	2.5	2.50~~15.00~~ ~~(Note 1)~~
DP1	Pressure Sensor, Validyne DP15	SS	12~~0.5~~	20~~40~~	20~~30~~	3200	12800	2.5	640.00~~320.00~~
	Test Sample Accumulator, SNL R46035	Aluminum	12~~0.0~~	20~~40~~	20~~30~~	30	120	2.5	6.00~~3.00~~
P2	Pressure Sensor, Lucas P953	SS	12~~20~~	20~~40~~	20~~30~~	150	600	2.5	30.00~~15.00~~
QD2, QD3, QD4	Quick-Disconnect, Symetrics 155504-400	SS	12~~20~~	20~~40~~	20~~30~~	30	120	2.5	6.00~~3.00~~
PRV3, PRV4	Pressure Relief Valve, Nupro SS-4CPA2-DR-3-15, 15-psig crack	SS	12	20	20	3000	12000	2.5	150.00
	Swagelok, Plug Valve SS-4P4T	SS	12	20	20	150	3000	4.0	150.00
	Fittings, 1/4"	SS	12~~20~~	20~~40~~	20~~30~~	6200	24800	4.0	1240.00~~620.00~~
	Fluid Lines, 0.250" OD, 0.035" wall	SS	12~~20~~	20~~40~~	20~~30~~	5100	20400	4.0	1020.00~~510.00~~
	Fluid Hoses, 1/4"	SS	12~~20~~	20~~40~~	20~~30~~	3000	12000	4.0	600.00~~300.00~~
	Test Cell Assembly, SNL R44920	Aluminum, Lexan	20	40	40	40	100	2.5	2.50
	Water Jacket Accumulator, SNL R46036	Aluminum	20	40	40	40	122	2.5	3.00
P1	Pressure Sensor, Lucas P953	SS	20	40	40	150	600	2.5	15.00
QD1	Quick-Disconnect, Symetrics 155504-400	SS	20	40	40	40	120	2.5	3.00
PRV1, PRV2	Pressure Relief Valve, Nupro SS-4CPA2-DR-3-35, 35-psig crack	SS	20	40	40	3000	12000	2.5	300.00
	Fittings, 1/4"	SS	20	40	40	6200	24800	4.0	620.00
	Fluid Lines, 0.250" OD, 0.035" wall	SS	20	40	40	5100	20400	4.0	510.00
	Fluid Hoses, 1/4"	SS	20	40	40	3000	12000	4.0	300.00

*Changes marked to indicate plumbing changes for STS-107.

~~Note: 1. Common Line Mode (same pressure on both ports, i.e., no differential pressure across sensor diaphragm.)~~

TABLE 2-2

PAYLOAD HAZARD REPORT		NO.: MGM-2
PAYLOAD: Mechanics of Granular Materials (MGM)		PHASE: III
SUBSYSTEM: Human Factors	HAZARD GROUP: Injury / Illness	DATE: 3/96
TITLE: Excessive Touch Temperature		

APPLICABLE SAFETY REQUIREMENTS:	HAZARD CATEGORY	
NASA-STD-3000, paragraph 6.5.3		Catastrophic
SPAH (SLP 2104), paragraph 7.3	X	Critical

DESCRIPTION OF HAZARD:

Extreme temperature of exposed surface could cause injury to crew upon contact.

HAZARD CAUSES:

1. Inadequate thermal design/heat dissipation results in surface temperature exceeding 113°F.

HAZARD CONTROLS:

1a. Color-change warning patches will be installed on crew-accessible surfaces whose temperatures exceed 113°F.

1b. Crew procedures to provide adequate cooldown prior to handling

1c. Crew procedures to prevent power application prior to handling.

SAFETY VERIFICATION METHODS:

1.a.1 Thermal analysis based on worst-case environments

1.a.2 Certification that as-built hardware conforms to approved design drawings

1.a.3 Inspection to verify presence of warning patch

1b. Review of Crew Procedures.

1c. Review of Crew Procedures.

STATUS OF VERIFICATION:

1.a.1 CLOSED (Transferred to SVTL)

1.a.2 CLOSED (Transferred to SVTL)

1.a.3 CLOSED (Transferred to SVTL)

1b. CLOSED (Transferred to SVTL)

1c. CLOSED (Transferred to SVTL).

APPROVAL	PAYLOAD ORGANIZATION	STS
PHASE I		
PHASE II		
PHASE III	5/1/96; 5/1/96	6/4/96

TABLE 3-1

PAYLOAD HAZARD REPORT		NO.: G-1
PAYLOAD: Mechanics of Granular Materials (MGM)~~USML-2 Integrated Payload~~		**PHASE**: III
SUBSYSTEM: Electrical	**HAZARD GROUP**: Injury / Illness	**DATE**: 2/95
TITLE: Electrical Shock		

APPLICABLE SAFETY REQUIREMENTS:	HAZARD CATEGORY	
NSTS 1700.7B, paragraphs 206 and 213		Catastrophic
~~Note: See sections 2, 3, 4, 5, 6, 8, 9, 11, 12, 13, 14, 15, 16 for reflown hardware items~~	X	Critical

DESCRIPTION OF HAZARD:

Electrical shock to the flight crew could result from contact with energized electrical components.

~~Applicable to MGM, GFFC, MPE (HI-PAC DTV), GBXI (CDOT, FSDC)~~

HAZARD CAUSES:

1. Defective components, wires, or insulation coupled with inadequate bonding/grounding results in shock potential.
2. Exposed terminals or high-voltage sources accessible to the crew during operations.

HAZARD CONTROLS:

1. Bonding and grounding will be accomplished in accordance with MIL-B-5087B.
2. High voltage sources will be inaccessible to crew by design.

SAFETY VERIFICATION METHODS:

1. Test of bonding/grounding per MIL-B-5087B.
2. Design review and inspection of as-built equipment.

STATUS OF VERIFICATION:

1. VRDS 1.08.09 submitted 1-11-96~~OPEN~~
2. OPEN

APPROVAL	PAYLOAD ORGANIZATION	STS
PHASE I		
PHASE II		
PHASE III		

TABLE 3-1

PAYLOAD HAZARD REPORT				NO.: G-2
PAYLOAD: Mechanics of Granular Materials (MGM)				PHASE: III
SUBSYSTEM: Electrical	HAZARD GROUP: Fire			DATE: 3/96
TITLE: Overheating of Electrical Wiring				
APPLICABLE SAFETY REQUIREMENTS:			HAZARD CATEGORY	
NSTS 1700.7B, paragraphs 206 and 213			X	Catastrophic
				Critical

DESCRIPTION OF HAZARD:

Overheating of electrical wiring results in evolution of toxic or noxious products at elevated temperatures or damage to critical payload or spacecraft circuitry.

HAZARD CAUSES:

1. Wiring/fusing size improper to protect downstream wiring from overheating in the event of a short or partial short circuit.

HAZARD CONTROLS:

1. Wiring and circuit protection will comply with JSC memo TA-92-038. (See Attachment 1 to HR G-2.)

SAFETY VERIFICATION METHODS:

1.a. Circuit analysis
1.b. Inspection of as-built hardware.

STATUS OF VERIFICATION:

1.a. CLOSED (Transferred to SVTL)
1.b. CLOSED (Transferred to SVTL)

APPROVAL	PAYLOAD ORGANIZATION	STS
PHASE I		
PHASE II		
PHASE III	Buddy N. Guynes 5/1/96 MS 5/1/96	[signature] 4/4/96

TABLE 3-2

PAYLOAD HAZARD REPORT		NO.: G-3
PAYLOAD: Mechanics of Granular Materials (MGM)		PHASE: III
SUBSYSTEM: Electrical	HAZARD GROUP: Radiation	DATE: 3/96
TITLE: Exposure of the STS Electrical System ot Other Payloads to EMI		

APPLICABLE SAFETY REQUIREMENTS:	HAZARD CATEGORY	
NSTS 1700.7B, paragraphs 208 and 212.2		Catastrophic
	X	Critical

DESCRIPTION OF HAZARD:

Payload generated EMI in excess of allowable limits interferes with Orbiter and/or other payload operations.

HAZARD CAUSES:

1. Radiated or conducted EMI from payload elements caused by electrical switching and/or equipment operation.

HAZARD CONTROLS:

1. Payload equipment will comply with the radiated and conducted emission requirements of MSFC-SPEC-521B.

SAFETY VERIFICATION METHODS:

1. Test for radiated and conducted emissions in accordance with MSFC-SPEC-521B.

STATUS OF VERIFICATION:

1. CLOSED (Transferred to SVTL)

APPROVAL	PAYLOAD ORGANIZATION	STS
PHASE I		
PHASE II		
PHASE III	5/1/96	6/4/96

TABLE 3-3

PAYLOAD HAZARD REPORT		NO.: G-4
PAYLOAD: Mechanics of Granular Materials (MGM)		PHASE: III
SUBSYSTEM: Human Factors	HAZARD GROUP: Injury / Illness	DATE: 3/96
TITLE: Exposure of Crew to Sharp Corners, Edges, or Protrusions		

APPLICABLE SAFETY REQUIREMENTS:	HAZARD CATEGORY	
NASA-STD-3000, Volume I, paragraph 6.3.3		Catastrophic
	X	Critical

DESCRIPTION OF HAZARD:
Injury to personnel caused by contact with sharp edges, corners, or protrusions.

HAZARD CAUSES:
1. Hardware designed and/or manufactured with sharp edges, corners, or protrusions.

HAZARD CONTROLS:
1. Hardware will comply with the intent of NASA-STD-3000 Volume I, paragraph 6.3.3.

SAFETY VERIFICATION METHODS:
1.a. Drawing review for inclusion of requirements to remove sharp corners and edges or to provide protective covers.
1.b. QA certification that as-built hardware conforms to approved drawings.

STATUS OF VERIFICATION:
1.a. CLOSED (Transferred to SVTL)
1.b. CLOSED (Transferred to SVTL)

APPROVAL	PAYLOAD ORGANIZATION	STS
PHASE I		
PHASE II		
PHASE III	[signature] 5/1/96	[signature] 6/4/96

TABLE 3-4

PAYLOAD HAZARD REPORT			NO.: G-5
PAYLOAD: Mechanics of Granular Materials (MGM)			PHASE: III
SUBSYSTEM: Materials	HAZARD GROUP: Injury / Illness		DATE: 3/96
TITLE: Toxic Offgasing in Habitable Areas			
APPLICABLE SAFETY REQUIREMENTS: -		HAZARD CATEGORY	
NSTS 1700.7B, paragraph 209.3		X	Catastrophic
			Critical

DESCRIPTION OF HAZARD:

Toxic constituents of offgasing materials used in habitable areas cause temporary or permanent crew injury / illness.

HAZARD CAUSES:

1. Use of materials which offgas toxic gases or other byproducts.

HAZARD CONTROLS:

1.a. Materials will be selected in accordance with MSFC-HDBK-527 / JSC 09604. A Materials Usage Agreement (MUA) will be submitted for materials having less than an "A" or "K" rating as defined in MSFC-HDBK-527 / JSC 09604, or these materials will otherwise be dispositioned in accordance with MSFC-PROC-1301.

1.b. Equipment / hardware will conform to approved drawings / materials lists.

1.c. Payload assemblies will be offgas tested per test 7 of NHB 8060.1.

SAFETY VERIFICATION METHODS:

1.a. Review / approval of materials usage by MSFC Materials and Processes Laboratory.

1.b. Certification that as-built configuration is in accordance with approved design drawings and parts lists.

1.c. MSFC evaluation / approval of offgas test data.

STATUS OF VERIFICATION:

1.a. CLOSED (Transferred to SVTL)

1.b. CLOSED (Transferred to SVTL)

1.c. CLOSED (Transferred to SVTL)

APPROVAL	PAYLOAD ORGANIZATION	STS
PHASE I		
PHASE II		
PHASE III	[signature] 5/1/96	[signature] 6/4/96

5/1/96

TABLE 3-5

PAYLOAD HAZARD REPORT		NO.: G-6
PAYLOAD: Mechanics of Granular Materials (MGM)		PHASE: III
SUBSYSTEM: Materials	HAZARD GROUP: Fire	DATE: 3/96
TITLE: Use of Flammable Materials		

APPLICABLE SAFETY REQUIREMENTS:	HAZARD CATEGORY	
NSTS 1700.7B, paragraph 209.2	X	Catastrophic
		Critical

DESCRIPTION OF HAZARD:

Fire with heat and smoke causes injury / illness of crewmember and possible damage or malfunction.

HAZARD CAUSES:

1. Use of flammable materials.

HAZARD CONTROLS:

1. Nonmetallic materials will meet the requirements of NHB 1700.7B and NHB 8060.1 as required. Materials will be selected in accordance with MSFC-HDBK-527 / JSC 09604, Table 2. For each material having less than "A" rating, a Materials Usage Agreement (MUA) will be submitted to the MSFC Materials and Processes Laboratory for approval, or these materials will otherwise be dispositioned in accordance with MSFC-PROC-1301.

SAFETY VERIFICATION METHODS:

1.a. Materials Lists and MUAs to be submitted to MSFC Materials and Processes Laboratory for approval.
1.b. QA certification that the as-built configuration is in accordance with design drawings and parts lists.

STATUS OF VERIFICATION:

1.a. CLOSED (Transferred to SVTL)
1.b. CLOSED (Transferred to SVTL)

APPROVAL	PAYLOAD ORGANIZATION	STS
PHASE I		
PHASE II		
PHASE III	[signature] 5/1/96	[signature] 6/4/96

AS 5/1/96

TABLE 3-6 (Sheet 1 of 6)

PAYLOAD HAZARD REPORT		NO.: G-7
PAYLOAD: Mechanics of Granular Materials (MGM)		PHASE: III
SUBSYSTEM: Structures	HAZARD GROUP: Collision	DATE: 3/96

TITLE: Structural Failure due to Launch, Flight, and Landing Environments or Stress Corrosion Cracking

APPLICABLE SAFETY REQUIREMENTS:	HAZARD CATEGORY	
NSTS 1700.7B, paragraphs 208.1, 208.2, and 208.3	X	Catastrophic
		Critical

DESCRIPTION OF HAZARD:

Failure of payload structural elements or attachment hardware results in unrestrained objects in the Spacehab module ~~or Orbiter middeck~~ which could impact Orbiter, Spacehab, or other payloads.

HAZARD CAUSES:

(See continuation)

HAZARD CONTROLS:

(See continuation)

SAFETY VERIFICATION METHODS:

(See continuation)

STATUS OF VERIFICATION:

(See continuation)

APPROVAL	PAYLOAD ORGANIZATION	STS
PHASE I		
PHASE II		
PHASE III	[signature] 5/1/96	[signature] 6/4/96

HAS 5/1/96

TABLE 3-6 (Sheet 2 of 6)

PAYLOAD HAZARD REPORT CONTINUATION SHEET	NO.: G-7
PAYLOAD: Mechanics of Granular Materials (MGM)	PHASE: III

HAZARD CAUSES (cont.):

1. Structural elements or payload equipment lack structural strength to withstand launch, landing and emergency landing loads, on-orbit environments (including depressurization and repressurization), or fail because of pre-existing flaws.
2. The use of structural materials which are susceptible to stress corrosion cracking.
3. Structural elements improperly manufactured or manufactured using unacceptable materials.
4. Inadvertent use of counterfeit fasteners.

HAZARD CONTROLS (cont.):

1.a. Safety-critical structure design will be based on worst-case mission induced loads with no negative margins of safety. Metallic structure design will be based on factors of safety of 2.0 ultimate and 1.25 yield on untested structure. All design and tests will be in accordance with JA-418A. (Reference attached General Discussion, Strength Verification.)
1.b. The design will be based on fracture control procedures for safety-critical structures in accordance with NHB 8071.1. (Reference the attached General Discussion, Fracture Control Verification.)
1.c. Positive locking for threaded fasteners in safety-critical structures for open rack and center aisle mounted equipment will be provided.
2. Materials will be selected in accordance with MSFC-SPEC-522B. Table 1, or a Material Usage Agreement (MUA) will be submitted to MSFC Materials and Processes Laboratory for approval.
3. Safety-critical structures will be built in accordance with approved design drawings and parts lists.
4. Qualified standard fasteners, fabricated from approved materials and procured from approved sources, will be used.

SAFETY VERIFICATION METHODS (cont.):

1.a. Structural analysis to verify positive margins against specified factors of safety and static loads tests for safety factors <2.0 ultimate.
1.b. MSFC Fracture Control Board review approval of fracture control plan and fracture mechanics analysis (including NDE).
1.c. Inspection verifying positive locking devices are in place, or vibration testing showing no fastener backoff in accordance with JA-418 criteria.
2. Approval of Metallic Materials List and MUAs by MSFC Materials and Processes Laboratory.
3. QA certification that the as-built hardware is in accordance with design drawings and parts lists.
4. Review of MSFC GIDEP ALERT screening/response program and interface fastener testing program. (Reference attached General Discussion, Elimination of Counterfeit Fasteners.)

STATUS OF VERIFICATION (cont.):

1.a. CLOSED (Transferred to SVTL)
1.b. CLOSED (Transferred to SVTL)
1.c. CLOSED (Transferred to SVTL)
2. CLOSED (Transferred to SVTL)
3. CLOSED (Transferred to SVTL)
4. CLOSED (Transferred to SVTL)

TABLE 3-6 (Sheet 3 of 6)

PAYLOAD HAZARD REPORT CONTINUATION SHEET	NO.: G-7
PAYLOAD: Mechanics of Granular Materials (MGM)	**PHASE:** III

General Discussion

1. STRENGTH VERIFICATION:

All metallic structural elements within MGM will be analyzed to safety factors of 2.0 ultimate and 1.25 yield for untested structures, and 1.4 ultimate and 1.1 yield for tested structures. There are no structures being tested in order to use the lower factors of safety.

PAYLOAD HAZARD REPORT CONTINUATION SHEET	NO.: G-7
PAYLOAD: Mechanics of Granular Materials (MGM)	**PHASE:** III

General Discussion

2. FRACTURE CONTROL VERIFICATION:

Payload element fracture control is accomplished in accordance with NHB 8071.1. The following paragraphs summarize the fracture control practice.

All structural components are evaluated to determine their fracture criticality and classified accordingly. Any structure with failure modes that could cause damage to the STS or crew injury is identified as fracture sensitive and is subjected to a fracture mechanics evaluation, the results of which determine which parts will be placed under fracture control. All pressure vessels and rotating machinery are considered inherently fracture critical. Fracture control selection logic is illustrated in Figure G7-1.

All structural components identified as fracture sensitive are dispositioned by rigorous analysis and/or test as one of the following:

1. Low mass: structural element ≤0.25 lb whose release or functional loss due to structural failure will not cause a catastrophic event.

2. Contained/restrained: structural failure of element will not result in separation from STS or catastrophic event.

3. Fail-safe: structural redundancy exists to the extent that structure remaining after element failure can sustain the resulting limit loads with an ultimate factor of safety ≥1.0 and has sufficient fatigue life to complete the mission. Element failure shall not release fragments in excess of low mass requirements (Item 1 above).

4. Damage tolerant (applicable to composites or nonmetallics other than glass): it has been demonstrated by test that the largest undetected flaw that could exist in an element will not grow to failure when subjected to cyclic and sustained loads/environments encountered in four complete mission (or multimission) lifetimes. Nondestructive evaluation (NDE) to the level determined by testing is required for these elements.

5. Safe life (applicable to metallics and glass): it can be shown that the largest undetected flaw that could exist in an element will not grow to failure when subjected to cyclic and sustained loads/environments encountered in four complete mission (or multimission) lifetimes. This approach requires fracture mechanics analysis and NDE.

Fracture-sensitive elements that cannot be dispositioned as one of the above are subjected to redesign and subsequent reevaluation.

TABLE 3-6 (Sheet 6 of 6)

PAYLOAD HAZARD REPORT CONTINUATION SHEET	NO.: G-7
PAYLOAD: Mechanics of Granular Materials (MGM)	PHASE: III

General Discussion

3. MODEL DYNAMIC VERIFICATION

All items in the integrated payload are represented either statically or dynamically. Those items that have all mode shapes and frequencies above 75 Hz may be represented statically. As a minimum, the static representation must contain the mass, CG, moment of inertia, and attachment interface. Items that do have mode shapes and frequencies below 75 Hz must be modeled dynamically such that all of the mode shapes and frequencies below 75 Hz are represented. All finite element models used in he final verification coupled loads analysis (CLA) for any item/component/assembly with a minimum natural frequency less than 35 Hz or weight greater than 40 lb must be verified by test. The following table represents the verification methodology for NASTRAN models:

Equipment Item	Model Verification
1. Weight < 40 lb and f1 > 25 Hz	Analytical Model Only
2. Weight < 40 lb and f1 < 35 Hz	Nastran Model verified by Modal Survey
3. Weight > 40 lb and #f1 > 35 Hz and #f1i > 75 Hz	Nastran Model with F1 and F2 verified by sine sweep test
4. Weight > 40 lb and f1l > 35 Hz and f2i < 75 Hz	Nastran Model verified by Modal Survey
5. Weight > 40 lb and f1 < 35 Hz	Nastran Model verified by Modal Survey

#f1i, f2i, when I = x,y, or z directions

Models that require modal survey testing must have sufficient instrumentation to identify mode shapes of frequencies in the range or interest (0-75 Hz).

Pretest analytical model results must be correlated with modal survey test results for verification of the structural model to be used in the final CLA. Acceptable correlation for the fundamental frequency in each principal axis is ± 8%.

4. ELIMINATION OF COUNTERFEIT FASTENERS

All PEDs for MSFC-managed Spacelab missions are required to participate in the GIDEP ALERT screening/response program. All GIDEP ALERTS are reviewed by MSFC for potential applicability to a aerospace and/or payload applications. Potentially applicable ALERT are forwarded to payload hardware developers where they are reviewed against payload hardware inventory and/or as-built flight hardware. All full ALERTs relating to structural and materials considerations require a definite response (positive or negative) from the PEDs prior to approval of hardware shipment to KSC.

Additionally, MSFC provides all safety-critical payload/carrier interface fasteners. These fasteners are provided from an inventory of standard fasteners that are fabricated from approved materials and procured from approved vendors. Lot sample tensile testing is performed on each fastener lot procured prior to release of the lot to flight hardware inventory.

TABLE 3-7

PAYLOAD HAZARD REPORT				NO.: G-8
PAYLOAD: Mechanics of Granular Materials (MGM)				PHASE: III
SUBSYSTEM: Envir. & Control	HAZARD GROUP: Injury / Illness			DATE: 3/96
TITLE: Exposure of Crew to Frangible Materials				
APPLICABLE SAFETY REQUIREMENTS:		HAZARD CATEGORY		
NSTS 1700.7B, paragraph 209.1			Catastrophic	
		X	Critical	

DESCRIPTION OF HAZARD:
Breakage of glass releases fragments into the habitable areas resulting in injury to the crew.

Applicable items: Video camera lenses (3 each)

HAZARD CAUSES:
1. Inadequate design or pre-existing flaws result in breakage of glass components.

HAZARD CONTROLS:
1. Each of the three glass lenses is contained within the body of the video camera lens holder and has an external Lexan cover which will contain any fragments resulting from a broken glass lens.

SAFETY VERIFICATION METHODS:
1. Review of design for adequate containment.

STATUS OF VERIFICATION:
1. CLOSED (Transferred to SVTL)

APPROVAL	PAYLOAD ORGANIZATION	STS
PHASE I		
PHASE II		
PHASE III	[signature] 5/1/96	[signature] 6/4/96

MS 5/1/96