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PAYLOAD TRANSPORTATION AND HANDLING PLAN

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1 SCOPE

This document incorporates all plans for moving, transporting, handling, and storing the Relativity Mission / Gravity Probe-B payload, including the Science Instrument Assembly (SIA) at Stanford. In conjunction with LMMS/P086679, "Transportation and Handling Plan" (IT-02), it is intended to satisfy NAS 8-39225 Contract Data Requirement 802IT-02, Transportation and Handling Plan.

This document establishes overall policy and implementation procedures to guard against damage or compromise of program critical hardware (PCH). Program critical hardware is defined as those items whose loss would result in a potentially catastrophic setback to the program, in terms of schedule and/or cost. Specifically, the PCH items are the Science Mission Dewar, Probe-C, Quartz Block, Telescope, Science Instrument Assembly, and the Integrated Payload. Smaller hardware such as the Gyros, SQUIDS, Detector Package Assemblies, although critical, are not specified PCH, since a) they are small, b) there is a history of moving these items, and c) there are spares.

The following topics are covered in this document:

1) shipping the Science Mission Dewar (SMD) from LMMS to Stanford (post facto, delivered 11/96)
2) shipping Probe-C from LMMS to Stanford (post facto, delivered 4/98)
3) moving and handling the SMD at Stanford
4) moving and handling Probe-C at Stanford
5) moving and handling the Quartz Block at Stanford
6) moving and handling the Science Telescope at Stanford
7) moving and handling the Science Instrument Assembly at Stanford
8) shipping the integrated Science Payload from Stanford to LMMS Building 205

1.1 Acronyms

The following acronyms are used in this document

GPB	Gravity Probe-B
PCH	Program Critical Hardware
ONR	Office of Naval Research
DCMC	Defense Contract Management Command
DOT	Department of Transportation
LMMS	Lockheed Martin Missiles and Space
HEPL	Hansen Experimental Physics Lab
QA	Quality Assurance
GSE	Ground Support Equipment
SMD	Science Mission Dewar
Pr-C	Probe C
SIA	Science Instrument Assembly
QB, QB/T	Quartz Block, Quartz Block/Telescope Assembly
RM, RM Cart	Quartz Block Roller Mechanism, Roller Mechanism Cart

QB/T/RM	Quartz Block/Telescope Assembly in Roller Mechanism
FIST-OPS	First Integrated System Test - Operations (HEPL High Bay, where SMD resides)
P/N	Part Number
FEE	Forward Equipment Enclosure
GSS	Gyro Suspension System
NBPHe	Normal Boiling Point Helium
TM&A	Temperature Monitor and Alarm

2 APPLICABLE DOCUMENTS

2.1 Government Documents

Data Requirements Description 802IT-02	Transportation and Handling Plan
MMI 6400.2	Packaging, Handling, and Moving of Program Critical Hardware
NHB 6000.1	Packaging, Handling, and Transportation for Aeronautical and Space Systems
NMI 6000.5	Transportation Management

2.2 Operations Orders and Procedures

GPB-100629	2/7/96 Payload Transportation Meeting Minutes
5835036, Vol.1	SMD System Level Acceptance Tests SMD Acceptance Data Review Charts, 11/11/96
Op Order PRC 0619	Delivery of Probe C to Stanford
LMMS/P480054	Probe C Acceptance Data Review Charts, 4/2/98
Op Order SMD 632	Unload Probe-C from Shipping Container
P0133	Preparations for Probe/Airlock Integration
P0134B	Airlock/Dewar Integration
P0135B	Probe Insertion into SMD
P0136B	Probe-C Removal from SMD
P0188	Move SMD
P0198 (SM)	Cleaning the Quartz Block
P0205	Mounting Probe onto Precision Manipulator
P0270 RevA	Transfer the QB from RM Cart to X-Y Cart
P0200(SM)	Bonding the Telescope to the QB
P0371B	Post Probe-C Removal from SMD
P0394	Transfer the QB/T Assembly from X-Y Cart to RM Cart
P0395	Transfer the QB/T/RM Unit from RM Cart to Optical Table
P0397	Transportation of Telescope Between Clean Room Facilities
P0282	GPB Telescope/IDA, General Alignment and Bonding Procedures
P0221	Integration of Telescope Test Probe and Test Dewar with Artifical Star #2
P0251	Integration of Science Telescope and Telescope Test Probe for Cryo Focal Test
P0253	De-integration of Science Telescope and Telescope Test Probe after Cryo Focal Test
P0244	De-integration of Science Telescope from Test Probe
P0057	Magnetic Control Plan, Science Mission
P0147	GPB Relativity Mission Contamination Control Plan, Master
P0059	Probe-C Contamination Control Plan
P0363	Quartz Block No.3 Transportation Plan

3 GENERAL POLICIES

3.1 Procedures

All movement and handling of critical hardware are to be conducted to approved released procedures or operations orders. QA and Safety are to have approval signatures for these documents.

3.2 Personnel

Engineers and technicians participating in the movement and handling of program critical hardware shall be experienced and skilled for performing these tasks. Only personnel knowledgeable with the specific hardware are allowed to handle and move that hardware. Pre-operation reviews are to be held among those performing the work, including QA and Safety Engineering.

LMMS Transportation, Organization 48-40, who is responsible for transporting the SMD, Pr-C, and the Integrated Payload, is the department of LMMS which handles transportation of all large flight hardware for LMMS. They ensure that all flight transportation and handling requirements are met, lifting equipment meet proof loading requirements, and only certified operators and equipment are used. Pre-operation meetings are held, and run through rehearsals are conducted.

Certified personnel only are allowed to handle cranes, forklifts, and other lifting GSE.

3.3 Safety

Safety Engineering is to be notified prior to any major movement of PCH (i.e., any movement other than rotations or minor adjustments). Safety Engineering is to provide a "Safety Manager" for each major movement of critical hardware. The Safety Manager shall insure that the movement is completely thought through, and to provide emergency physical assistance, if necessary, during movement.

3.4 Quality Assurance

Quality Engineering is to be notified prior to any major movement of PCH (i.e., any movement other than rotations or minor adjustments). Quality Engineering is to provide guidance regarding quality assurance.

3.5 Cleanliness

The Contamination Control Plan is described in P0147 and P0059. These plans describe bagging and packaging, cleanliness requirements, and clean room policies. Caution shall be taken to avoid potential contamination sources during transportation and handling.

3.6 Magnetics

The Magnetic Control Plan is described in P0057. Caution shall be taken to avoid any potential for strong external magnetic fields during transportation and handling.

4 SMD TRANSPORTATION TO STANFORD (11/96)

The SMD, P/N 5833500, is delivered in its Assembly Stand, P/N 5834050, from LMMS B/205 to Stanford HEPL. The plan is described below, in the future or present tense. The SMD/Stand was delivered on the morning of 13 November 1996. All of the bullets were completed as stated. Reference GPB-100629 for the pre-transportation meeting minutes, and 5835036 Vol.1, for the shipping procedure. Additionally, the shipping plan was reviewed at the Acceptance Data Package Review, held on 11 Nov 96.

- The dewar is cold but empty for this trip. All plumbing lines are closed, and the dewar is unvented. Without cryogen in the tank, the dewar/stand is a piece of hardware, containing no hazardous material. Thus it does not have DOT hazardous container requirements to meet.
- LMMS Transportation, Organization 48-40, is responsible for providing the truck, crane, equipment, and personnel for loading, transporting, and unloading the SMD.
- The truck is an 8' wide by 40' long air-ride flat bed trailer. To optimize the air-ride, counter weights are used to balance the load.
- The Assembly Stand is 12' by 14', with inside width 7'6" (i.e., between the width of the long sides). The stand is jacked up and its wheels inserted for the move.
- The dewar is oriented vertically in the stand, and bagged for cleanliness.
- The SMD in Assembly Stand is pulled and rolled out of the B205 Hi Bay through the Hi Bay doors, using a tug and forklift. This is done with spotters on both sides, since there is approximately an inch clearance on each side.
- Once outside B205, the SMD/Stand is lifted over the fence with a crane, and placed onto the truck in the driveway. The crane lifts the SMD/Stand using 7 straps (4 on Assembly Stand, 3 on lifting hooks on Mid-cylinder).
- Each long side of the Stand rests on the trailer on blocks. The cross beams of the Stand (with spacers to level the bottom with the long sides) rests on the truck.
- Tie down to the truck is with 6000 lb nylon straps, standard chains and binders.
- The load is escorted to Stanford by a truck and van in front, and a truck in back. The van has an OVERSIZED LOAD sign on it. No police escort is used.
- The route to Stanford is Page Mill to Junipero Serra to Campus Drive West -to Panama to Via Ortega to Parking Lot to End Station Loading Dock.
- A run through of the route about a month before the delivery date is taken to ensure against low trees, road holes, or other hazards.
- Maximum speed is < 25 mph. An impactograph is placed on the truck for measuring loads during the trip.
- Unloading is done by crane, reversing the procedure the SMD/Stand is lifted onto the truck. The crane places the stand right at the foot of the rollup doors in the End Station receiving dock.
- The SMD/Stand is rolled through the HEPL door using a forklift onto an air ride floor inside the HEPL building.

- A DD Form 1149 is used for documentation of shipment. It is signed by the LMMS program manager, Quality Assurance, and DCMC. Signature for receipt is by Tom Langenstein of Stanford.
- Dewar GSE Modules are transported on a separate trailer. They are transported on the same day, in order to monitor the cold dewar. Transportation of GSE does not require any special procedures.

5 PROBE-C TRANSPORTATION TO STANFORD (4/98)

Probe-C, P/N 1C34115-101, is delivered in its custom Cradle and Crate, P/N 1C34602, from LMMS B/202 to Stanford HEPL. The plan is described below, in the future or present tense. Probe-C was delivered on the morning of 14 April 1998. All of the bullets were completed as stated. Reference Operations Order PRC 0619 for the shipping procedure. The shipping plan was reviewed at the Pr-C Acceptance Data Package Review, held on 2 April 98. The probe did not include any of its windows, and blank-off plates were inserted on Window 4 and the two 6 inch Vatterfly Valve cavities on the Cross Flange. These items are to be installed in the HEPL Class 10 Cleanroom prior to Probe integration with the SIA.

- LMMS Transportation, Organization 48-40, is responsible for providing the truck, and personnel for loading, transporting, and unloading the dewar.
- The truck is an 8' wide by 40' long air-ride flat bed trailer. To optimize the air-ride, counter weights are used to balance the load.
- The Probe is backfilled with pure GN_2 through the P1 line to an overpressure of approximately 1 psig . All plumbing ports are capped with blankoffs, and all external valves closed.
- The Probe is completely double bagged.
- The Probe is inserted into its Shipping Cradle by lowering the probe in its Genie stand onto the Cradle with the Yoke installed. The Probe is supported in the Cradle at 3 support points: (1) at the probe spool, which is bolted onto the cradle plate; (2) the Station 200 Ring Yoke, which rests on a support arc, and (3) the bottom of the vacuum shell, which rests on a ring stand with upper and lower halves. Once supported in the Cradle, the Probe is disconnected from the Genie.
- The Probe in Cradle is rolled out of the cleanroom to the B202 dock.
- A forklift is used to lift the Cradle from the dock and lower it into the Shipping Crate. Prior to inserting into the Crate, the casters are removed from the Cradle.
- The Cradle is placed into the Shipping Crate with the forklift, through the Crate's removable side wall, and secured with bolts. The removable wall is re-installed, and the Crate lifted onto the flatbed truck with the forklift.
- Tie down to the truck is with 6000 lb nylon straps, standard chains and binders.
- The Genie Stand, P/N 5859767-102, is lifted onto the truck and secured.
- The load is escorted to Stanford by a van in front, and a truck in back. The van has an OVERSIZED LOAD sign on it. No police escort is used.
- The route to Stanford is Page Mill to Junipero Serra to Campus Drive West to Panama to Via Ortega to Parking Lot to End Station Loading Dock.
- Maximum speed is < 25 mph. An impactograph is placed on the truck for measuring loads during the trip.
- Unloading is done by forklift.
- The container is placed through the HEPL dock door using a forklift, onto the floor inside the HEPL building. Once inside, the Cradle is removed from the Crate using the forklift.

- A DD Form 1149 is used for documentation of shipment. It is signed by the LMMS program manager, Quality Assurance, and DCMC. Signature for receipt is by Tom Langenstein of Stanford.

6 MOVING AND HANDLING OF THE SMD AT STANFORD

- Upon delivery to HEPL, the SMD/Assembly Stand is moved on air ride casters to its semi-permanent location in the FIST-OPS lab, in accordance with P0188 (Op Order SMD 048).
- The SMD/Assembly Stand stays in this position throughout the period from delivery to Stanford through shipment of the Integrated Payload back to LMMS Building 205.
- The reverse of moving into place with the air ride casters is used in moving the Payload through the HEPL doors for transportation to LMMS.

7 MOVING AND HANDLING OF PROBE-C AT STANFORD

- Upon delivery to HEPL, a forklift is used to lift Pr-C in its Cradle out of its shipping container (Op Order SMD 632). Casters are installed on the Cradle, for rolling into the lab. The probe is then transferred from the Cradle to the Genie Stand, in accordance with P0133 (Op Order SMD 633)
- The probe is transferred from the Genie Stand to the Probe Airlock Piston, in accordance with P0133, Task Module 80 (Op Order SMD 644)
- The probe is inserted in the SMD for the purpose of performing a fit check using procedures P0134B and P0135B.
- After completion of the fitcheck, the probe is removed from the dewar using procedure P0136B and ultimately transferred to the Gurney.
- The probe is moved on the Gurney from the FIST-OPS lab to the Cleanroom area as specified by a TBS op order.
- The probe is transferred from its Gurney to the Precision Manipulator in accordance with procedure P0205.
- The probe remains on the Precision Manipulator throughout SIA to Probe integration. Upon completion, the integrated Probe-C is transferred back to its Gurney through the reverse process of that described in P0205. This latter procedure is to be completed.
- The Gurney is rolled out of the Class 10 Room into the adjacent Class 1000 Room. It remains on the Gurney throughout warm vacuum, suspension, spinup and spindown tests, conducted using GSE. Upon completion, the Probe is rolled into the FIST-OPS lab for insertion in the SMD.
- The probe is then transferred from the Gurney to the Genie Stand, in accordance with P0133 (or updated version).
- The probe is transferred from the Genie Stand to the Probe Airlock Piston, in accordance with P0133, Task Module 80 (or updated version).
- The probe is integrated into the SMD using procedures P0134B and P0135B (or updated versions thereof).

8 MOVING AND HANDLING OF THE QUARTZ BLOCK

- The Quartz Block, P/N 22770-101, is delivered to HEPL from Speedring in its custom padded shipping container, in accordance with P0363. It is received and inspected in the QA/Inspection area.
- **For all movements of the QB, two people are required, one on each end of the QB to lift or move the QB. The polished surfaces can only be touched with great care and only when absolutely required. Cleanroom gloves are to be worn when handling the QB.**
- The QB is transported to LMMS Building 202 in its Shipping Container for interferometric inspection It is transported by jeep, with the shipping container tied down with rope to tie points in the jeep, then returned to HEPL in the same way. The QB is returned to the QA/Inspection area in its Shipping Container.
- The QB is then placed in a non-magnetic jig, and carted over to the Magnetic Screening Lab in the HEPL building, where it is magnetically screened. This is done in accordance to procedure, to be supplied. After screening, it is returned to the QA/Inspection area in its Shipping Container.
- The QB is transferred to the Class 1000 Cleanroom by transferring it from the shipping container to the cleanroom cart, in accordance with P0198(SM).
- Once inside the Class 1000 Cleanroom, the QB is transferred from the cleanroom cart to the Roller Mechanism in its roll around cart, in accordance with P0198(SM).
- The QB is cleaned sequentially by aqueous cleaning in the Crest ultrasonic cleaning tank, alcohol rinse, and finally freon cleaning in the Quadrex, in accordance with P0198(SM).
- The QB is transferred from the RM/RM Cart to the X-Y Cart, in preparation for bonding to the Telescope, in accordance with P0270 RevA.
- The QB is bonded to the Telescope, in accordance with P0200(SM) RevA.
- The QB/T Assembly, P/N 23521-101, is transferred from the X-Y Cart to the RM Cart, in accordance with P0394
- The QB/T/RM Unit is transferred from the RM Cart to the Optical Table, in accordance with P0395. It is then ready for SIA integration.

9 MOVING AND HANDLING OF THE SCIENCE TELESCOPE

- The Science Telescope, P/N 25091-101, is assembled in the Telescope Class 1000 Cleanroom in the HEPL building.
- **In handling the telescope, cleanroom gloves are to be worn. Optical and bonding surfaces (which are polished to very high tolerances) can only be touched with great care and only when absolutely required.** Reference P0282 for details.
- The assembled telescope is moved to the Class 10 Cleanroom for integration with the Telescope Test Probe, in accordance with P0397. It moves between cleanrooms in its custom carrier box, a high impact polyethylene carrier box with custom formed polyurethane foam lining. When moving the telescope in its carrier box, two people are required.
- The telescope is integrated with the Telescope Test Probe, in accordance with P0251. The Test Probe is installed on the Precision Manipulator, and lowered onto the Telescope, much as the Science Probe is integrated with the SIA.
- The integrated Telescope/Test Probe is carted out of the Class 10 Cleanroom into the Artificial Star #2 Lab, in accordance with P0251.
- In the lab, the Test Probe is inserted into the Test Dewar, and Artificial Star #2 is installed, in accordance with P0221.
- After Telescope cryogenic characterization tests are completed, the Test Probe is detached from Artificial Star #2 and removed from the Test Dewar, in accordance with P0253.
- The Test Probe/Telescope is carted back to the Class 10 Cleanroom, where the Telescope is de-integrated from the Test Probe, in accordance with P0244.
- The Telescope is returned to the Telescope Cleanroom, in accordance with P0397.
- After final preparations are completed in the Telescope Cleanroom, e.g., the flight DPAs are installed and characterized, the Telescope is returned to the Class 10 Cleanroom, in accordance with P0397, for bonding to the QB.
- For bonding the telescope to the QB, refer to P0200(SM) RevA.

10 MOVING AND HANDLING OF THE SIA

- Upon completion of SIA integration in the Class 10 Cleanroom, the SIA, P/N 23170-101, is ready for integration with Probe-C.
- The SIA is transferred from the Roller Mechanism on the Optical Table to the X-Y cart, in accordance with P0404.
- The SIA is integrated with Probe-C, by lowering the Probe on the Precision Manipulator onto the SIA, in accordance with P0177(SM).
- Once integrated, the Probe-C/SIA is handled as described earlier in Section 7.

11 PAYLOAD TRANSPORTATION FROM STANFORD TO B/205

The Science Payload is to be delivered in the SMD Assembly Stand from Stanford HEPL to LMMS B/205 in mid 1999. The Payload will include the flight SIA, Probe-C including windows, flight payload electronics (with the possible exception of the GSS units) which reside in the Forward Equipment Enclosure (FEE), the FEE, and the SMD. The Sunshade is not be included in this delivery. The Science Gyros are in their caged configuration.

The SMD Main Tank is partially filled with Normal Boiling Point Helium (NBPHe), approximately to the 70% level. Venting is through Bayonet B1 to a Vent Cap Assembly with relief valve to the ambient atmosphere. The Guard Tank is backfilled with slightly over one atmosphere of gaseous helium, perhaps with some liquid helium to maintain overpressure. It vents through Bayonet B2 to a separate Vent Cap Assembly with relief valve to the ambient atmosphere.

With cryogen in the tank, the shipment contains hazardous materials, and requires a DOT exemption or a government issued Certificate of Equivalency for shipment. These exemptions basically state that the container meets or exceeds requirements of the DOT specified container. A Certificate of Equivalency is issued by the sponsoring government agency, in this case NASA, and takes 2 to 3 months to acquire. A DOT exemption typically takes about a year. The Certificate of Equivalency is good only for one year, while the DOT exemption covers all moves of the same container.

Because this is the only move in the Payload configuration, a Certificate of Equivalency will be acquired for the Payload trip. All future moves of the Payload will be as an integrated Space Vehicle, and a DOT exemption will be acquired for the Space Vehicle.

The Payload trip is similar to the SMD delivery to Stanford in that it is shipped in the SMD Assembly Stand, vertically oriented in a flatbed air-ride truck. However, because the dewar will have liquid helium in the tank, and be integrated with the probe, SIA, electronics, and FEE, trip requirements have more complexity. Following are further details of the plan:

- LMMS Transportation, O/48-40, is responsible for providing the truck, crane, equipment, and personnel for loading, transporting, and unloading the dewar.
- The truck is an 8’ wide by 40’ long air-ride flat bed trailer. To optimize the air-ride, counter weights are used to balance the load.
- The Payload is in the dewar Assembly Stand and secured on the truck as before.
- The Payload is vertically oriented in the stand, and completely bagged for cleanliness.
- The Payload/Stand is rolled to the HEPL dock door on air ride casters inside the HEPL building. Since the Payload is a few inches taller than the rollup doors, it will be tilted slightly to exit the lab and HEPL. It is carefully pulled and rolled out of the HEPL rollup door using a forklift. This is done with spotters on both sides.

- Once outside HEPL, it is lifted with a crane, and placed onto the truck in the driveway. The crane lifts the SMD/Stand using 7 straps (4 on Assembly Stand, 3 on lifting hooks on Mid-cylinder)**.**
- Each long side of the Stand rests on the trailer on blocks. The cross beams of the Stand (with spacers to level the bottom with the long sides) rests on the truck.
- Tie down to the truck is with 6000 lb nylon straps, standard chains and binders.
- The load is escorted to B205 by a truck and van. The van has an OVERSIZED LOAD sign on it. Police escort will probably be used.
- The Temperature Monitor and Alarm (TM&A) is on the truck to monitor Lead Bag, Main Tank and Guard Tank temperatures via Connector J800. An alarm will sound if a problem is detected, and a plan for responding to the alarm will be generated. The travelers are to include Mike Taber and/or Dave Murray to respond to an emergency.
- Dewar GSE Modules are transported on a separate trailer at the same time. They are connected to the SMD as soon as possible if an emergency arises en-route, or if no emergency arises, as soon as possible after establishing residence in B205. Transportation of GSE does not require any DOT exemptions.
- The route to B205 is from HEPL End Station Loading Dock through Parking Lot to Via Ortega to Panama to Campus Drive West to Junipero Serra to Page Mill to Hanover to B205 driveway.
- A run through of the route about a month before the delivery date is taken to ensure against low trees, road holes, or other hazards.
- Maximum speed is < 25 mph. An impactograph is placed on the truck for measuring loads during the trip.
- Unloading is done by crane, reversing the way the SMD/Stand is lifted onto the truck. The crane places the stand right at the foot of the rollup doors of B205. A careful measurement of height and width is made to ensure clearance through the doors. If necessary, the doors will be extended to accomodate the payload.
- A DD Form 1149 is used for documentation of shipment, with signatures of the Stanford hardware manager, Stanford Quality Assurance, and ONR. Signature for receipt will be by Hugh Dougherty of LMMS.
- Upon entering B205, the exact locations of the Payload and GSE will be strategically mapped out prior to the move. A plan will be made to connect GSE to the dewar as soon as practically possible.