# SMD CDR AGENDA

<table>
<thead>
<tr>
<th>TIME</th>
<th>TOPIC</th>
<th>PRESENTER</th>
<th>CODE</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:00</td>
<td>INTRODUCTION</td>
<td>R. VASSAR</td>
<td>IN</td>
</tr>
<tr>
<td>8:10</td>
<td>SMD DESIGN OVERVIEW</td>
<td>W. FOSTER</td>
<td>OV</td>
</tr>
<tr>
<td>8:45</td>
<td>SMD REQUIREMENTS</td>
<td>A. NAKASHIMA</td>
<td>RQ</td>
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<tr>
<td>9:10</td>
<td>SMD INTERFACES</td>
<td>A. NAKASHIMA</td>
<td>IF</td>
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<tr>
<td>9:45</td>
<td>RISK AREAS/ NON-COMPLIANCE</td>
<td>A. NAKASHIMA</td>
<td>RI</td>
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<tr>
<td>10:00</td>
<td>DEVELOPMENT TESTS</td>
<td>D. READ</td>
<td>DT</td>
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<tr>
<td>10:45</td>
<td>DYNAMICS ANALYSIS</td>
<td>L. SOKOLSKY</td>
<td>DY</td>
</tr>
<tr>
<td>11:00</td>
<td>STRESS ANALYSIS</td>
<td>L. SOKOLSKY</td>
<td>ST</td>
</tr>
<tr>
<td>11:45</td>
<td>THERMAL ANALYSIS</td>
<td>D. READ</td>
<td>TH</td>
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<tr>
<td>12:15</td>
<td>EMERGENCY VENT ANALYSIS</td>
<td>D. READ</td>
<td>EV</td>
</tr>
<tr>
<td>12:30</td>
<td>LUNCH</td>
<td>D. DEAN</td>
<td>CM</td>
</tr>
<tr>
<td>1:00</td>
<td>HE CM AND SLOSH CONTROL</td>
<td>R. PARMLEY</td>
<td>TK</td>
</tr>
<tr>
<td>1:30</td>
<td>TANKS AND SUBASSEMBLIES</td>
<td>R. PARMLEY</td>
<td>VS</td>
</tr>
<tr>
<td>2:00</td>
<td>THERMAL PROTECTION SYSTEM</td>
<td>R. PARMLEY</td>
<td>PD</td>
</tr>
<tr>
<td>2:30</td>
<td>PODS SUPPORT SYSTEM</td>
<td>D. DONEGAN</td>
<td>CN</td>
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<tr>
<td>2:45</td>
<td>BREAK</td>
<td>D. FRANK</td>
<td>PL</td>
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<tr>
<td>3:00</td>
<td>CNT ASSEMBLY AND TOP PLATE</td>
<td>D. FRANK</td>
<td>MG</td>
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<td>3:30</td>
<td>PLUMBING</td>
<td>P. DINEEN</td>
<td>IS</td>
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<td>4:00</td>
<td>MASS GAUGING</td>
<td>D. Pickett</td>
<td>GS</td>
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<tr>
<td>4:15</td>
<td>INSTRUMENTATION</td>
<td>D. Pickett</td>
<td>FA</td>
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<td>4:45</td>
<td>GROUND SUPPORT EQUIPMENT</td>
<td>R. WHELAN</td>
<td>MP</td>
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<td>5:15</td>
<td>FABRICATION AND ASSEMBLY</td>
<td>K. MASON</td>
<td>CO</td>
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<tr>
<td>5:45</td>
<td>BREAK</td>
<td>R. VASSAR</td>
<td>MA</td>
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<td>6:00</td>
<td>MASS PROPERTIES</td>
<td>J. CALAHANE</td>
<td>SA</td>
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<tr>
<td>6:15</td>
<td>CONTamination</td>
<td>J. SUTY</td>
<td>RL</td>
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<tr>
<td>6:30</td>
<td>MAGNETICS</td>
<td>J. LEPETICH</td>
<td>QA</td>
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<tr>
<td>6:40</td>
<td>SAFETY</td>
<td>A. NAKASHIMA</td>
<td>VT</td>
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<tr>
<td>7:00</td>
<td>RELIABILITY</td>
<td>J. GRADY</td>
<td>OP</td>
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<td>7:15</td>
<td>QUALITY ASSURANCE</td>
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<tr>
<td>7:30</td>
<td>VERIFICATION AND SYSTEM TEST</td>
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<td>7:50</td>
<td>P/L INTEGRATION &amp; OPERATIONS</td>
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<tr>
<td>8:00</td>
<td>ADJOURN</td>
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</table>
• DETERMINE THAT THE DETAILED DESIGN OF THE SCIENCE MISSION DEWAR MEETS THE APPLICABLE REQUIREMENTS OF THE SCIENCE PAYLOAD SPECIFICATION AND THE SPACECRAFT TO PAYLOAD INTERFACE CONTROL DOCUMENT
  – SHOW CLOSURE OF ACTION ITEMS FROM EFD PDR
  – REVIEW DETAILED DESIGN
  – REVIEW REQUIREMENTS VERIFICATION STATUS
• REVIEW SCIENCE MISSION DEWAR RISK AREAS ON A TECHNICAL, COST, AND SCHEDULE BASIS
• OBTAIN CUSTOMER APPROVAL TO PROCEED WITH REMAINING SCIENCE MISSION DEWAR FABRICATION AND ASSEMBLY
DEWAR DESIGN REVIEW HISTORY

IN - 4

REVIEW

FLIGHT COMPONENT DEWAR PDR
ENGINEERING FLIGHT DEWAR PDR
SM DEWAR INTERNAL DESIGN REVIEWS
  MAIN TANK IDR
  VACUUM SHELL IDR

DATE

16 AUGUST 1991
29 & 30 JUNE 1992
27 OCTOBER 1993
15 DECEMBER 1993
THE FOLLOWING DOCUMENTS ARE BEING SUBMITTED IN FULFILLMENT THE CDR DOCUMENTATION REQUIREMENTS

LSE-01 MASS PROPERTIES REPORT
LSE-02 SCIENCE PAYLOAD SPECIFICATION
LSE-06 SPACECRAFT TO SCIENCE PAYLOAD INTERFACE CONTROL DOCUMENT
LSE-08 SMD DESIGN REVIEW DATA PACKAGE
  » CDR PRESENTATION CHARTS
  » DRAWING PACKAGE
  » ANALYSIS ENGINEERING MEMOS
  » DEVELOPMENT TEST RESULTS
  » COMPONENT SPECIFICATIONS
LSE-09 SMD VERIFICATION AND TEST PLAN
LSE-10 SMD VERIFICATION REQUIREMENTS COMPLIANCE DOCUMENT
LSE-12 SMD FAILURE MODES, EFFECTS, AND CRITICALITY ANALYSIS
LSE-13 SMD CRITICAL ITEMS LIST
LSA-02 SMD SAFETY COMPLIANCE DATA
LOP-01 PAYLOAD OPERATIONS REQUIREMENTS DOCUMENT
SM DEWAR MATURITY AT CDR

IN - 6

- DOCUMENTATION 100% DOCUMENTS COMPLETE
- DRAWINGS 34% DRAWINGS Released
- MASS PROPERTIES CONTINGENCY 55% DRAWINGS INTO CHECK
- REQUIREMENTS VERIFICATION 10% DRY SM DEWAR
- 75% ANALYSIS COMPLETE
GRAVITY PROBE-B
SCIENCE MISSION DEWAR
CRITICAL DESIGN REVIEW
MARCH 2, 1994
ACTION ITEM

AUTHOR _________________ DUE DATE ________________

PROPOSED ASSIGNEE: Stanford Lockheed

ACTION:

ACTION ITEM NUMBER ______
INDIVIDUAL RESPONSIBLE FOR CLOSURE: ______________________
OTHER INDIVIDUALS INVOLVED: ________________________________

DUE DATE: __________
SCIENCE MISSION DEWAR DESIGN OVERVIEW

BILL FOSTER
GP-B DEWAR TECHNOLOGY HERITAGE

ENG/WERING DEVELOPMENT DEWAR (EDD)

1. AXIAL LOK
2. WELL
3. CRYOPERm SHIELD
4. LEAD BAG
5. LEAD BAG RETAINER
6. AIRLOCK CYLINDER/GUIDE RODS/PISTON
7. THERMAL STOP RINGS
8. PROBE INTERFACES
9. LIQUID LEVEL SENSORS
10. COLD VALVES

SCIENCE MISSION DEWAR (SMD)

11. SFH TANK PLUS C.G. CONTROL
12. GUARD TANK
13. VCS's
14. MLI
15. PODS SUPPORTS (12 EA.)
16. VACUUM SHELL
17. SPACECRAFT INTERFACES
18. LAUNCH/ORBIT FREQUENCIES
19. AIRLOCK INTERFACE PLATE
20. TOP PLATE/BELLOWS
21. COMPOSITE NECK TUBE
22. VENT HEAT EXCHANGERS
23. POROUS PLUG
24. TANK FILL LINE
25. VENT LINE
26. WELL FILL HEAT EXCHANGER
27. COLD BUST DISCS/VENT LINES
28. FOUNTAIN EFFECT PUMP
29. FLOW METER
30. HEAT PULSE METER
31. MAIN TANK TEMP RISE RATE (GROUND HOLD)
32. TEMP SENSORS, HEATERS, LIQUID LEVEL SENSORS, ACCELEROMETERS
33. INSTRUMENTATION ON VCS'S
34. OSR
35. LIFETIME
• THE EFD WAS REPLACED WITH THE SMD

--- HAVING A BACK-UP DEWAR IS NOT PRACTICAL WITH THE FUNDING LIMITS

--- NO ADVERSE IMPACT TO PROGRAM SINCE THE EFD WAS IDENTICAL TO THE SMD EXCEPT FOR ADDITIONAL INSULATION AND FLIGHT TYPE VAPOR COOLED SHIELDS

--- COBE, IRAS, AND CLAES DEWARS DID NOT HAVE A FLIGHT BACK-UP

--- WARM SHAKE OF PROBE-B REMOVES THE DEWAR FROM THE CRITICAL PATH
EDD LESSONS LEARNED (1)

• COMPOSITE NECK TUBE ASSEMBLY

   --- RESIN SELECTION (SCI REZ 081)

   --- COMPOSITE TUBE FABRICATION PROCESS (RIB FABRICATION DEMONSTRATED ON PROBE NECK TUBE)

   --- MODULAR DESIGN

   --- LEAK TIGHT JOINT DESIGN

• HEAT EXCHANGERS (HEX)

   --- NEED HEX-0 FOR GROUND OPERATIONS

   --- SPLIT HEX DESIGN

   --- HEX FABRICATION PROCESS
• THERMAL STOP RINGS (TSR)
  --- ADJUSTABLE TSR ALLOWS WARM INSTALLATION INTO NECK TUBE
  --- REDUCED RISK

• AXIAL LOK
  --- DESIGN IMPROVEMENTS
  >> ELIMINATE WEAR PROBLEMS
  >> ADDRESS MAGNETIC PARTICLE GENERATION CONCERNS
  >> REPLACED ROLL PIN

  --- TESTING REQUIREMENTS DEFINED
• PLUMBING
  --- TANK TO WELL TRANSFER
  --- AXIAL LOK TUNNELS AND WELL PLUMBED TOGETHER
  --- IMPROVED MOTORIZED COLD VALVES

• TANK FABRICATION
  --- MACHINING AND FABRICATION SEQUENCE DEFINED
  --- CRYOGENIC STRESS RELIEVING USED TO STABILIZE PARTS
  --- CRYOPERM SHIELD FAB AND INSTALLATION

• LEAD BAG RETAINER
  --- IDENTIFIED PROBLEMS WITH BERYLLIUM COPPER RETAINER
  --- MATERIAL CHANGED AND LOWER END REDESIGNED
EDD LESSONS LEARNED (4)

- LEAD BAG INSERTION GSE
  --- VALIDATED GSE DESIGN WITH SUCCESSFUL LEAD BAG AND COLD PROBE INSERTIONS

- OPERATIONAL EXPERIENCE
  --- DEVELOPED PROCEDURES FOR LEAD BAG AND PROBE INSERTION OPERATIONS
DEWAR LAYOUT

EXTERNAL PLUMBING
MAIN SUPPORT RING

MAGNETIC SHIELD

PROTON SHIELD

BAFFLES

WELL

AXIAL LOK

FOSR COATING
(SILVER COATED TEFLEX)

ELECTRONIC BOX MOUNTING RINGS

AIRLOCK INTERFACE
ELECTRICAL FEED THRU, 5PL
PROBE INTERFACE

MULTILAYER INSULATION .5 PL

GRAPHITE/EPOXY RINGS .2 PL

PODS SUPPORTS 12 EA

COLD VALVES,
BURST DISCS LOCATION

THERMAL STOP RINGS .4 PL

VAPOR COOLED SHIELDS .4 EA

GUARD TANK VENT
(MAIN TANK VENT, 2PL ON +X AXES)

ALUMINA/EPOXY/TITANIUM COMPOSITE NECK TUBE

FOIL

GUARD TANK

2319 L MAIN TANK
• MAIN TANK BAFFLES
  --- CENTER OF MASS CONTROL BAFFLE NOT NEEDED
  --- RADIAL AND AXIAL BAFFLES USED FOR SLOSH CONTROL

• PLUMBING
  --- SEPARATE VENTS FOR MAIN AND GUARD TANKS
  --- ONLY ONE COLD VALVE NEEDS TO BE OPERATED AFTER LAUNCH
  --- ELIMINATED GUARD TANK FLEXIBLE EMERGENCY VENT LINES
  --- PYROVALVES USED FOR MAIN TANK VENT
  --- MULTIPLE TEST ORIENATIONS POSSIBLE
CHANGES FROM PDR (2)

- LEAD BAG RETAINER
  
  --- MATERIAL CHANGED FROM BeCu TO TiCu
  
  --- LOWER END DESIGNED TO FORM CLOSED DOME

- VACUUM SHELL ALLOY CHANGED FROM 8090 ALUMINUM TO 2219 ALUMINUM
  
  --- CHANGE REDUCES FABRICATION RISK AND COST
  
  --- 32Kg INCREASE IN VACUUM SHELL WEIGHT

- COMPOSITE NECK TUBE SHORTENED
  
  --- ALLOWS LONGER BELLOWS SECTION FOR REDUCED LATERAL STIFFNESS
  
  --- RESULTS IN SLIGHT INCREASE IN LIFETIME
PREDICTED LIFETIME

PREDICTED LIFETIME = CALCULATED LIFETIME / 1.3

Tshell = 220 K

Eliminated GT EV line
Disconnected EV lines from VCS
Changed He mass to 337 kg
Update EV lines dimensions
Update probe and dewar bellows dimensions
Update probe cable geometry
Changed MLI degradation factor to 2
Changed aft orbit tube length to 1.5"
Update dewar CNT thermal length

REQUIREMENT = 16.5 MO

9/1/93 10/1/93 11/1/93 12/1/93 1/1/94 1/31/94 3/3/94

DATE
DESIGN STATUS

• TOTAL DRAWING COUNT (INCLUDES GSE)
  DWGS-----356
  SHEETS----524

• RELEASED DRAWINGS
  DWGS-----120
  SHEETS----167

• DRAWINGS IN RELEASE CYCLE
  DWGS-----75
  SHEETS----127

• NUMBER OF REVISIONS
  DWGS----1

• CRITICAL PATH DRAWINGS ARE BEING WORKED TO SUPPORT THE FABRICATION SCHEDULE
DEVELOPMENT TEST STATUS

- FLEXIBLE EMERGENCY VENT LINE COMPLETE

- COMPOSITE NECK TUBE STRUCTURAL TESTS COMPLETE

- SMALL HELICOFLEX SEALS TESTS COMPLETE

- AXIAL LOK TEST COMPONENTS IN HOUSE

- COLD ELECTRICAL CONNECTORS DESIGNED AND TEST APPARATUS IN ASSEMBLY

- POROUS PLUG, HEAT PULSE METER TEST APPARATUS IN ASSEMBLY
MANUFACTURING STATUS

- MAIN TANK FORGINGS ARE ON SCHEDULE

- MACHINING OF MAIN TANK COMPONENTS (DOMES) HAS STARTED
  CHEMTRONICS IS MACHINING THE FWD DOME

- AXIAL LOK PARTS ARE COMPLETE

- COLD VALVES ARE ON ORDER

- COLD BURST DISKS ARE ON ORDER

- ASSEMBLY STAND LONG LEAD ITEMS ON ORDER
## RISK ASSESSMENT

### RISKS DUE TO NOT BUILDING THE EFD

<table>
<thead>
<tr>
<th>ITEM</th>
<th>RISK LEVEL</th>
<th>MITIGATION</th>
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</thead>
<tbody>
<tr>
<td>FABRICATION</td>
<td>MODERATE</td>
<td>PROTOTYPING BEING USED. CRITICAL VENDORS FUNDED FOR DEVELOPMENT OF PROCESSES. FABRICATION EXTRAS PURCHASED</td>
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<tr>
<td>INTERFACES</td>
<td>LOW</td>
<td>LOCKHEED BUILDING PROBE AND SPACECRAFT. INTERFACE WORKING GROUP ESTABLISHED</td>
</tr>
<tr>
<td>PERFORMANCE</td>
<td>LOW/MODERATE</td>
<td>MAJOR COMPONENTS TESTED ON IDD AND EDD AND OTHER CRYOSTATS. EARLY DEVELOPMENT TESTS ON COMPONENTS NOT PREVIOUSLY TESTED</td>
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</tbody>
</table>
## RISK ASSESSMENT

*Risks due to not building the EFD*

<table>
<thead>
<tr>
<th>ITEM</th>
<th>RISK LEVEL</th>
<th>MITIGATION</th>
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</thead>
<tbody>
<tr>
<td>SCHEDULE</td>
<td>MODERATE</td>
<td>CRITICAL PATH DEFINED FOR DESIGN, FAB, AND ASSY. WORKING CLOSELY WITH VENDORS TO MEET SCHEDULE</td>
</tr>
</tbody>
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SMD REQUIREMENTS

ART NAKASHIMA
SOURCES OF REQUIREMENTS

• SCIENCE PAYLOAD SPECIFICATION F277277 V 2.5
  – SECTION 3.7.5 DEWAR (CROSS REFERENCES SECTION 3.2)
  – SECTION 3.3 DESIGN & CONSTRUCTION
  – SECTION 3.7.4 PROBE-TO-DEWAR INTERFACE
    » DEWAR-TO-PROBE INTERFACE DRAWING, 5833117
  – SECTION 3.7.6 PROBE/DEWAR ASSY TO OTHER PAYLOAD ASSEMBLIES
    » INTERFACES OF PROBE AND DEWAR TO ELECTRONICS, GAS MANAGEMENT ASSEMBLIES
    » TOP HAT INTERFACE DRAWING, 5833116

• SPACECRAFT-TO-PAYLOAD INTERFACE CONTROL DOCUMENT F277233, V1.8
  – S/C TO P/L INTERFACE DRAWING, 5833115
<table>
<thead>
<tr>
<th>REQUIREMENT</th>
<th>HOW SATISFIED</th>
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<tbody>
<tr>
<td>PROVIDE CRYOGENIC ENVIRONMENT FOR PROBE AND SIA</td>
<td>2400 L TANK TO HOLD HE II, WELL TO HOUSE PROBE, GUARD VACUUM AND SHELL, FOSR, VCS AND MLI, CNT TO ISOLATE VAC SPACE FROM WELL, PODS TO SUPPORT TANK AND PROVIDE THERMAL ISOLATION FROM SHELL</td>
</tr>
<tr>
<td>PROVIDE ORBITAL LIFE $\geq 16.5$ MO, OPTIMIZE THERMAL PERFORMANCE</td>
<td></td>
</tr>
<tr>
<td>VENT HE BOILOFF TO S/C THRUSTERS</td>
<td>REDUNDANT VENT PATHS, VENT MODULE, POROUS PLUG FOR LIQUID/VAPOR SEPARATION, HEAT EXCHANGERS FOR THERMAL CONTROL</td>
</tr>
<tr>
<td>PROVIDE FOR GROUND OPERATIONS ALLOW 90 D GROUND HOLD WITH NO VENTING OF MAIN TANK PROVIDE FOR FILLING AND VENTING IN VARIOUS ORIENTATIONS</td>
<td>99 L GUARD TANK TO HOLD HE I, BAYONET VENT AND FILL LINES, REMOTELY ACTUATED COLD VALVES</td>
</tr>
<tr>
<td>MEET MAGNETIC ATTENUATION RQMTS</td>
<td>CRYOPERM SHIELD AROUND WELL, LEAD BAG INSIDE WELL, CONTAMINATION CONTROL OF PARTICLES</td>
</tr>
<tr>
<td>REQUIREMENT</td>
<td>HOW SATISFIED</td>
</tr>
<tr>
<td>-------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>PROVIDE PROTON SHIELD AROUND SIA</td>
<td>PROTON SHIELD</td>
</tr>
<tr>
<td>SURVIVE EXPECTED ENVIRONMENTS GROUND, LAUNCH, ORBIT</td>
<td>LOAD FACTORS DERIVED IN EM 310A USED FOR DESIGN. MARGINS BUILT INTO DESIGN. MATERIAL SELECTION, FOUNTAIN EFFECT PUMP FOR INTERNAL WELL FILL, IF REQUIRED</td>
</tr>
<tr>
<td>MEET SAFETY REQUIREMENTS</td>
<td>TWO FAULT TOLERANT AGAINST CATASTROPHIC FAILURES, POSITIVE MARGINS OF SAFETY, REDUNDANT BURST DISCS ON MAIN TANK AND SHELL, EMERGENCY VENT LINES ON MAIN TANK, BURST DISC ON GUARD TANK, FILL LINE, WELL</td>
</tr>
<tr>
<td>MEET CENTER OF MASS, SLOSH CONTROL REQUIREMENTS</td>
<td>BAFFLES FOR SLOSH, NONE REQUIRED FOR CM CONTROL</td>
</tr>
<tr>
<td>MEET MASS PROPERTIES RQMTS</td>
<td>OPTIMIZE DESIGN, MATERIAL SELECTION</td>
</tr>
<tr>
<td>PROVIDE INSTRUMENTATION</td>
<td>TEMPERATURE SENSORS, HEATERS, LIQUID LEVEL SENSORS, HEAT PULSE METER, FLOW METER, ACCELEROMETERS, PODS CONTACT SENSORS COLD VALVE MICROSWITCHES</td>
</tr>
<tr>
<td>REQUIREMENT</td>
<td>HOW SATISFIED</td>
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<tr>
<td>----------------------------------------------------</td>
<td>-------------------------------------------------------------------------------</td>
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<tr>
<td>MEET CONTAMINATION RQMTS</td>
<td>DESIGN TO CONTAMINATION CONTROL PLAN</td>
</tr>
<tr>
<td>MEET ELECTRICAL GROUNDING RQMTS</td>
<td>DESIGN WITH BONDED JOINTS FOR THERMAL LOOPS, COMPONENTS GROUNDED TO TOP PLATE</td>
</tr>
<tr>
<td>PROVIDE GROUND SUPPORT EQUIPMENT AND INTERFACES</td>
<td>SUPPORT MODULES, SHIPPING CONTAINER ASSEMBLY STAND, LIFTING DEVICE, LEAD BAG INSTALLATION EQUIPMENT, PROBE INTEGRATION EQUIPMENT, CRYOGENIC SERVICE EQUIPMENT</td>
</tr>
<tr>
<td>PROVIDE PROBE PHYSICAL INTERFACES</td>
<td>AXIAL LOK, AXIAL LOK RING, AXIAL LOK TUBES, LEAD BAG RETAINER, TOP PLATE, THERMAL STOP RINGS</td>
</tr>
<tr>
<td>PROVIDE SPACECRAFT PHYSICAL INTERFACES</td>
<td>SUPPORT RING WITH S/C SUPPORT HOLES, STAR TRACKER PEDESTALS ON GRAPHITE RINGS, BOLT HOLES FOR THRUSTERS, SOLAR ARRAYS, GPS ANTENNAE</td>
</tr>
</tbody>
</table>
LOAD FACTORS REFERENCE EM 310A / P030739A

- DERIVES COMBINED LOAD FACTORS FROM RANDOM (TRANSonic), TRANSIENT (LIFT-OFF), ACOUSTIC, AND QUASI-STATIC (MECO) LOADS (SEE DYNAMICS SECTION)
- PROVIDES SECONDARY STRUCTURE DESIGN LOAD FACTORS

ORBITAL ENVIRONMENT

- THERMAL 220 ± 10 K
- VACUUM 5 X 10⁻⁸ PA (≈ 4 X 10⁻¹⁰ TORR) @ 650 KM ALT.
- MAGNETIC 6 X 10⁻⁵ TESLA
- ELECTRON RADIATION SPEC TABLES 3.2.5-3 (MAX) AND 3.2.5-4 (INTEGRATED)
- PROTON RADIATION SPEC TABLES 3.2.5-5 (MAX) AND 3.2.5-6 (INTEGRATED)
## PERFORMANCE REQUIREMENTS (1 OF 4)

<table>
<thead>
<tr>
<th>ITEM</th>
<th>REQUIREMENT</th>
<th>PERFORMANCE</th>
<th>VERIFICATION</th>
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<tbody>
<tr>
<td>ORBITAL LIFETIME (Tshelf = 220 K)</td>
<td>≥ 16.5 MOS</td>
<td>19.8 MONTHS (TRACKED AS TPM)</td>
<td>GP-B THERMAL MODEL</td>
</tr>
<tr>
<td>He BATH TEMP</td>
<td>≤ 1.8 K</td>
<td>1.8 K</td>
<td>GP-B THERMAL MODEL</td>
</tr>
<tr>
<td>LEAD BAG TEMP</td>
<td>≤ 6.5 K</td>
<td>HE II IN WELL IS BACKUP TO VACUUM IN WELL</td>
<td>PR-B / SMD VIBRATION TEST</td>
</tr>
<tr>
<td>DEWAR MASS (DRY)</td>
<td>≤ 936 Kg (ALLOCATION)</td>
<td>850 Kg (TRACKED AS P/L TPM)</td>
<td>MASS PROP ANALYSIS, TEST</td>
</tr>
<tr>
<td>MAGNETIC SHIELDING AT SIA</td>
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<tr>
<td>STEADY STATE</td>
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<tr>
<td>CRYOPERM SHIELD</td>
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<tr>
<td>LEAD BAG</td>
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<tr>
<td>ATTENUATION FACTOR CRYOPERM SHIELD</td>
<td>≤ 3 x 10⁻⁵ TESLA, ≤ 9 x 10⁻¹² TESLA</td>
<td>MEETS RQMTS BY DESIGN TO MAGNETIC CONTROL PLAN AND PROCEDURE</td>
<td>GTU TESTING, MAGNETIC SCREENING OF CRYOPERM, WELL, LEAD BAG AND RETAINER</td>
</tr>
<tr>
<td>LEAD BAG</td>
<td>≤ 5 x 10⁻² T, LONG, ≤ 5 x 10⁻³ T, TRAN</td>
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<tr>
<td></td>
<td>≤ 1 x 10⁻¹⁰ T, LONG, ≤ 1.7 x 10⁻⁶ T, TRANS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ITEM</td>
<td>REQUIREMENT</td>
<td>PERFORMANCE</td>
<td>VERIFICATION</td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>--------------------------------------------------</td>
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<td>---------------------------------------------------</td>
</tr>
<tr>
<td>LHE CM SHIFT</td>
<td>SEE COM SECTION (90 MM, AXIAL, FULL TANK)</td>
<td>UNBAFFLED TANK</td>
<td>ANALYSIS, P088355</td>
</tr>
<tr>
<td></td>
<td>(90 MM, RADIAL, FULL@ .1RPM)</td>
<td></td>
<td>FLOW 3D- CFD CODE</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>CLOSED FORM SOLUTIONS</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>SURFACE EVOLVER PGM</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1-G SCALE MODEL TESTS</td>
</tr>
<tr>
<td>LHE SLOSH</td>
<td>MINIMIZE</td>
<td>4&quot; WIDE BAFFLES, 4 RADIAL, 3 PARALLEL</td>
<td>CFD ANALYSIS</td>
</tr>
<tr>
<td>S/V FIRST STRUCTURAL RESONANCE - LAUNCH</td>
<td>≥ 35 HZ, AXIAL</td>
<td>29.4 HZ, AXIAL *</td>
<td>LOADS ANALYSIS (EM 310A)</td>
</tr>
<tr>
<td></td>
<td>≥ 12 HZ, LATERAL</td>
<td>10.9 HZ, LATERAL *</td>
<td>PODS OPTIMIZATION ANALYSIS (EM 326)</td>
</tr>
<tr>
<td>P/L FIRST STRUCTURAL RESONANCE - ORBIT</td>
<td>≥ 10 HZ</td>
<td>15 HZ</td>
<td></td>
</tr>
<tr>
<td>HELIUM BOILOFF RATE</td>
<td>4 - 16 MG/S (GOAL 4 - 12)</td>
<td>4 - 16 MG/S</td>
<td>PRESSURE DROP ANALYSIS (GPB-100145), GP-B THERMAL MODEL</td>
</tr>
</tbody>
</table>

* NON-COMPLIANT
<table>
<thead>
<tr>
<th>ITEM</th>
<th>REQUIREMENT</th>
<th>PERFORMANCE</th>
<th>VERIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONTAMINATION</td>
<td>ZONES VIII, X (100A) ZONES IX, XI (250A)</td>
<td>MEETS RQMTS BY DESIGNING TO CONTAM CONTROL PLAN</td>
<td>TEST AT COMPONENT, SUBASSEMBLY LEVELS</td>
</tr>
<tr>
<td>SOLAR ABSORPTIVITY</td>
<td>&lt; 0.09 SOLAR ABS &gt; 0.8 IR EMISS</td>
<td>MEETS RQMTS WITH FOSR</td>
<td>ANALYSIS EM 126, VENDOR TEST</td>
</tr>
<tr>
<td>EMISSIVITY</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WELL FILL CAPABILITY</td>
<td>WITHOUT EXT PLUMBING ≤ 6.5 K</td>
<td>MEETS RQMT</td>
<td>TK TO WELL TRANSFER, FEP TESTS GTU TESTING</td>
</tr>
<tr>
<td>INLET TEMP</td>
<td></td>
<td>5 K</td>
<td></td>
</tr>
<tr>
<td>DIMENSIONAL</td>
<td>± 0.25 °, 3 AXES</td>
<td>MET BY REF AT TOP PLATE</td>
<td>TEST</td>
</tr>
<tr>
<td>REFERENCE TO SIA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FIT IN DELTA II FAIRING</td>
<td>≤ 10 FT LONG, ≤ 8 FT DIAM</td>
<td>9.937 FT LONG 6.731 FT DIAM</td>
<td>BY DESIGN</td>
</tr>
<tr>
<td>STAR SENSOR THERMAL STABILITY</td>
<td>GOAL ≤ 10 ARC-SEC</td>
<td>MET BY DESIGN USING G/E RINGS</td>
<td>ANALYSIS EM 187</td>
</tr>
<tr>
<td>ITEM</td>
<td>REQUIREMENT</td>
<td>PERFORMANCE</td>
<td>VERIFICATION</td>
</tr>
<tr>
<td>------</td>
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<td>--------------</td>
</tr>
</tbody>
</table>
| LAUNCH READY LIFE GUARD TANK MAIN TANK (NON-VENTED) | ≥ 7 DAYS  
≥ 90 DAYS | 7.85 DAYS  
90 DAYS | GP-B THERMAL MODEL |
| GROUND OPERATIONS ATTITUDES | SEE PLUMBING SECTION | MEETS RQMTS | BY DESIGN |
| PROTON SHIELDING | 20 G/CM² AL EQUIVALENT | MEETS RQMTS | STANFORD ANALYSIS |
| SAFETY FACTORS | TWO FAULT TOLERANT FOR CRITICAL FAILURES, POSITIVE MARGIN OF SAFETY  
1.5 PROOF, 2.0 YIELD, 4.0 ULT  
1.0 PROOF, 2.0 ULTIMATE  
1.25 YIELD, 1.5 ULT, 1.25 TEST  
1.5 ULT-CONT, 2.0 ULT DISC, 1.25 TEST | MEETS RQMTS | BY DESIGN, ANALYSIS PROOF PRESSURE TESTS |
<table>
<thead>
<tr>
<th>REQUIREMENT</th>
<th>HOW MET</th>
<th>VERIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONDUCTIVE LOOPS IN &quot;ISOTHERMAL&quot; ($\Delta T &lt; 5$ K) REGIONS ARE ACCEPTABLE.</td>
<td>GP-B THERMAL MODEL PREDICTS ISOTHERMAL TEMPERATURES</td>
<td>TEMPERATURES MEASURED DURING GROUND TESTS</td>
</tr>
<tr>
<td>- MAIN TANK / PLUMBING</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- GUARD TANK / PLUMBING</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- VAPOR COOLED SHIELDS, INDIVIDUALLY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BALANCED (ELEC SYMMETRIC) LOOPS REQUIRE $1 \Omega \leq R$</td>
<td>USE SIMILAR MATERIALS FROM SAME HEAT.</td>
<td>IN-PROCESS TEST</td>
</tr>
<tr>
<td>BALANCED LOOPS BETWEEN VAPOR COOLED SHIELDS REQUIRE $1 \Omega \leq R \leq 10 \Omega$</td>
<td>BONDED JOINTS WITH METAL JUMPER WIRES</td>
<td></td>
</tr>
<tr>
<td>UNBALANCED LOOPS WITH TEMPERATURE GRADIENTS &gt; 5 K REQUIRE 20 $\Omega \leq R \leq 1 \text{ M}\Omega$</td>
<td>BONDED JOINTS, AQUA DAG JOINT COATING</td>
<td>IN-PROCESS TEST</td>
</tr>
<tr>
<td>MLI IS GROUNDED IN EACH BLANKET, INNER TO OUTER SHIELD, WITH $R \leq 1 \text{ M}\Omega$ AND INNER SHIELD TO VCS $R \leq 1 \Omega$</td>
<td>TAPELED ALUMINIZED MYLAR</td>
<td>IN-PROCESS TEST</td>
</tr>
<tr>
<td>ALL CONDUCTIVE COMPONENTS SHALL BE GROUNDED TO THE TOP PLATE WITH RESISTANCE $\leq 1 \text{ M}\Omega$</td>
<td>BY DESIGN</td>
<td>IN-PROCESS TEST</td>
</tr>
<tr>
<td>DEWAR INSTRUMENTATION DOES NOT REQUIRE FILTERS OR SHIELDING</td>
<td>N/A</td>
<td></td>
</tr>
</tbody>
</table>
SMD INTERFACES

ART NAKASHIMA
DEWAR INTERFACES

• PROBE / DEWAR INTERFACES
  – MECHANICAL
  – THERMAL

• DEWAR / PAYLOAD ELECTRONICS INTERFACES
  – MECHANICAL
  – ELECTRICAL

• DEWAR / SPACECRAFT INTERFACES
  – MECHANICAL
  – VENTING
  – ELECTRICAL

• DEWAR / GSE INTERFACES
  – MECHANICAL
  – VENTING
  – FILLING
  – VACUUM
  – ELECTRICAL
DEWAR INTERFACES TO PROBE

- AXIAL LOK ON DEWAR SECURES PROBE TO DEWAR
  - AXIAL LOK DOGS LOCATED AT 120° INTERVALS CLAMP PROBE STATION 200 RING WITH INDIUM PLATING TO AXIAL LOK RING

- LEAD BAG RETAINERS PROVIDE PHYSICAL INTERFACE BETWEEN PROBE AND LEAD BAG
  - SPRING ENSURES CENTERING OF PROBE DURING INSERTION
  - PREVENTS LEAD BAG FROM FALLING DURING LAUNCH

- PROBE TOP HAT IS BOLTED TO DEWAR TOP PLATE
  - REF: PROBE/DEWAR INTERFACE TOLERANCE STUDY, F386792 / EM210

- PROBE THERMALLY GROUNDED TO DEWAR BY CONTACT OF PROBE THERMAL SHOES TO DEWAR THERMAL STOP RINGS
  - 6 PER RING AT EACH OF 4 HEAT EXCHANGER LOCATIONS
  - CLOCKED SO THAT THERE IS NO INTERFERENCE ON PROBE INSERTION
  - REF: THERMAL SHOE CONTACT CONDUCTANCE, F386748 / EM 205

- REFERENCE PROBE/DEWAR INTERFACE DRAWING 5833117
PROBE TO DEWAR INTERFACE
AT STATION 200

STANFORD

LMSC-P088357
2,3 MAR 94
CLOCKING OF
THERMAL STOP RINGS / THERMAL SHOES
ALL THERMAL stops(clocking) DIFFERENTLY TO PREVENT PROBE
THERMAL SHOE INTERFERENCE DURING INSTALLATION
DEWAR TO PAYLOAD ELECTRONICS INTERFACES

- PAYLOAD ELECTRONIC BOXES MOUNTED ON FORWARD EQUIPMENT SECTION AROUND DEWAR NECK
  - 8 PLATFORMS WITH SPACING FOR S/C ATTACHMENTS
- FEEDTHROUGH CONNECTORS P801 (TEMP SENSORS), P802 (HEATERS, PODS CONTACT SENSORS), P805 (TEMP SENSORS) ON TOP PLATE CONNECT TO PAYLOAD ELECTRONICS FOR FLIGHT OPERATION (SEE INSTRUMENTATION SECTION FOR DETAILS)
- COMMANDS TO DEWAR HARDWARE FROM PAYLOAD ELECTRONICS
  - COMMAND GUARD TANK FILL VALVE ON LAUNCH PAD THROUGH UMBILICAL
- REFERENCE TOP HAT EXTERNAL INTERFACE DRAWING 5833116
TOP PLATE INTERFACES TO ELECTRONICS

IF - 7

STANFORD

Lockheed

LMSC-P088357
2,3 MAR 94

[Diagram of top plate interfaces to electronics]
DEWAR TO SPACECRAFT INTERFACES

- 3 HOLES IN SUPPORT RING FOR SUPPORTING SPACECRAFT
  - 2 DOF TRUNNIONS SPACED 120° APART
- 2 STAR TRACKER PEDESTALS FOR SUPPORTING STAR TRACKER PLATFORMS
  - MOUNTED ON POST ATTACHED TO GRAPHITE RINGS FOR TEMPERATURE STABILITY, SPACED 180° APART
- BOLT HOLES FOR 2 THRUSTER TRUSS STRUCTURES, 2 GPS ANTENNAE, AND 4 SOLAR PANELS ON FORWARD EQUIPMENT SECTION
- VENT LINE (NOT VACUUM JACKETED) FROM VENT MODULE TO THRUSTER MANIFOLD
  - USED ONLY IN SPACE AND THERMAL VAC CHAMBER
  - REDUNDANT PATHS WITH PYROVALVES TO OPEN IN SPACE
  - MANUAL BYPASS VALVE FOR VENTING IN THERMAL/VAC
- CONNECTORS P806,P808,P809, P810 (PYROVALVES) CONNECT TO SPACECRAFT ELECTRONICS
  - P806 ON SUPPORT RING (PV1)
  - P808 ON WELL (PV3)
  - P809 AND P810 IN THRUSTER VENT MODULE (PV 4A&4B)
- S/C ALSO COMMANDS GT FILL VALVE (RAV2) TO OPEN IN ORBIT
- REFERENCE PAYLOAD TO SPACECRAFT INTERFACE DRAWING 5833115
DEWAR INTERFACES TO GSE (1 OF 2)

- SPACECRAFT ATTACH POINTS ON SUPPORT RING ARE ALSO ATTACH POINTS FOR ASSEMBLY STAND AND TILT STAND
- BAYONET (B3) FILL LINE ATTACHES TO VACUUM JACKETED TRANSFER LINE
- MAIN TANK VENT BAYONET (B1) ATTACHES TO GSE EXHAUST MODULE
- PUMPOUT PORT ON SUPPORT RING INTERFACES WITH VACUUM MODULE
- μMETAL GSE EXTENSION OF CRYOPERM SHIELD INTERFACES WITH AXIAL LOK RING
- AXIAL LOK TUBES FOR AXIAL LOK TOOL TO ROTATE DOGS
- GSE AIRLOCK ADAPTER PLATE ATTACHES TO TOP PLATE
- GSE CLOSEOUT PLATE ATTACHES TO TOP PLATE WHEN PROBE NOT INSTALLED
- GSE LIFTING DEVICE ATTACHES TO DEWAR NEAR GRAPHITE RING
- ION PUMP PORT ON SUPPORT RING ATTACHES TO ELECTRICAL MODULE FOR VACUUM SPACE MONITORING
• BURST DISCS ON VACUUM SHELL ATTACHED TO GSE RELIEF VALVES, REMOVED IN FAIRING OR IMMEDIATELY PRIOR TO ENTERING FAIRING
  – GSE FACILITY VENT LINES (PROVIDED BY S/C) ATTACHED TO BD 7A&B
• FEEDTHROUGH CONNECTORS P800 AND P803 ON TOP PLATE FOR INSTRUMENTATION READOUT ON GROUND
• FEEDTHROUGH CONNECTOR P804 ON TOP PLATE CONNECTS TO UMBILICAL FOR LAUNCH PAD GSE
• CONNECTOR P811 ON SUPPORT RING FOR VACUUM ION PUMP GSE
• REFERENCE DEWAR TO GSE INTERFACE DRAWING 5833504
RISK AREAS / NON COMPLIANCE

ART NAKASHIMA
DEWAR RISK AREAS

- SMD RISK AREAS ARE CATEGORIZED AS FOLLOWS
  - EXPERIMENT RISKS
    » THOSE RISKS FOR WHICH FAILURE WOULD JEOPARDIZE OR GREATLY COMPROMISE THE MISSION
  - GROUND SAFETY RISKS
    » THOSE RISKS FOR WHICH FAILURE COULD INJURE PERSONNEL DURING GROUND OPERATIONS
  - SCHEDULE RISKS
    » THOSE RISKS FOR WHICH FAILURE WOULD SIGNIFICANTLY IMPACT SCHEDULE
<table>
<thead>
<tr>
<th>RISK</th>
<th>APPROACH TO RISK REDUCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAUNCH VIBRATION CAUSES LEAD BAG TO WARM ABOVE ITS TRANSITION TEMPERATURE</td>
<td>DEWAR IS DESIGNED TO FILL WELL WITH HE II ON LAUNCH PAD. VIBRATION TEST WITH PROBE-B WILL DETERMINE WHETHER LIQUID IN WELL IS REQUIRED.</td>
</tr>
<tr>
<td>PODS THERMALLY SHORT IN ORBIT, DECREASING LIFETIME</td>
<td>WELL DEVELOPED TECHNOLOGY FROM ID DEWAR PROGRAM. RIGOROUS ACCEPTANCE TESTING AT PODS ASSEMBLY LEVEL. SMD VIBRATION TEST</td>
</tr>
<tr>
<td>HELICOFLEX SEAL OR ELECTRICAL FEEDTHROUGH LEAKS, INCREASING TANK VENT RATE</td>
<td>DEVELOPMENT TESTS OF SEALS AND FEEDTHROUGHS. RIGOROUS ACCEPTANCE TESTING. SMD VIBRATION TEST</td>
</tr>
<tr>
<td>POROUS PLUG BREAKTHROUGH (TOO LOW HEAT RATE) OR CHOKING (TOO HIGH VENT RATE)</td>
<td>DEVELOPMENT TESTS TO DETERMINE POROUS PLUG RANGE OF OPERATION. ANALYSIS TO DETERMINE HEAT RATE DURING ALL OPERATIONS.</td>
</tr>
<tr>
<td>RISK</td>
<td>APPROACH TO RISK REDUCTION</td>
</tr>
<tr>
<td>------</td>
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</tr>
<tr>
<td>OVERPRESSURIZATION OF MAIN TANK CAUSES BURST DISCS/EMERGENCY VENT LINES TO ACTIVATE, AND EV LINES LEAKS OR BURSTS ABOVE VACUUM SHELL CAPACITY TO VENT</td>
<td>DEVELOPMENT TESTS OF EMERGENCY VENT LINE.</td>
</tr>
<tr>
<td></td>
<td>RECENT ANALYSIS CONFIRMS LEAK BEFORE BURST OF VACUUM SHELL AND MAIN TANK</td>
</tr>
<tr>
<td></td>
<td>THOROUGH REVIEW AND CONTROL OF PROCEDURES TO PREVENT OPERATOR ERROR OF GSE AND VALVE OPERATIONS (CAUSING LOSS OF GUARD VACUUM).</td>
</tr>
<tr>
<td></td>
<td>TEMPERATURE OF MAIN TANK CAREFULLY MONITORED DURING NON-VENTING OPERATIONS</td>
</tr>
<tr>
<td>RISK</td>
<td>APPROACH TO RISK REDUCTION</td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>VIBRATION TEST WARMS LEAD BAG ABOVE ITS TRANSITION TEMPERATURE</td>
<td>GTU-2 PLANNING WOULD HAVE TO BE RE-WORKED TO ALLOW FOR 3 MO LEAD BAGS RE-EXPANSION.</td>
</tr>
<tr>
<td>VIBRATION TEST DAMAGES DEWAR, REQUIRING REMOVAL OF INSULATION SYSTEM AND PROBE</td>
<td>LOADS ANALYSIS, CONSERVATIVE DESIGN FACTORS.</td>
</tr>
<tr>
<td>COLD VALVE FAILURE AFTER ASSEMBLY COMPLETE RAV2 OPENED IN FLIGHT RAV6 (FEP) ON LAUNCH PAD RAV 1,3,5,7 FOR GROUND SERVICING</td>
<td>EXTENSIVE QUALIFICATION TESTING OF TWO VALVES. VIBRATION, THERMAL CYCLE OF FLIGHT VALVES. ACCESS PORTS IN VCS AND MLI. FAILURE OF RAV2 TO OPEN NOT CATASTROPHIC. REDUNDANT VALVES FOR RAV 6.</td>
</tr>
<tr>
<td>STRUCTURAL RESONANCE TOO LOW</td>
<td>MODIFIED S/C TRUNNION INTERFACE FOR STIFFER DESIGN. LOAD CYCLE ANALYSIS WHEN DATA AVAILABLE</td>
</tr>
<tr>
<td>WELD OR OTHER MANUFACTURING LEAKS ON TANKS OR VACUUM SHELL</td>
<td>THOROUGH TESTING DURING MANUFACTURING - LEAK CHECKS, THERMAL CYCLE, PROOF PRESSURE BONDED DOUBLERS</td>
</tr>
</tbody>
</table>
NON-COMPLIANCE

• FIRST STRUCTURAL SPACE VEHICLE MODES NOT MET
  – AXIAL: REQUIREMENT-12 HZ, PREDICTED - 10.9 HZ
  – LATERAL: REQUIREMENT - 35 HZ, PREDICTED - 29.4 HZ
• REQUIREMENTS ARE RECOMMENDATIONS BY MCDONNELL DOUGLAS TO AVOID COUPLING WITH DELTA II LAUNCH VEHICLE LOW MODES
  – REAL REQUIREMENT NOT KNOWN WITHOUT DETAILED LOAD CYCLE OF COUPLED SPACECRAFT/LAUNCH VEHICLE
  – IT IS EXPECTED THAT THESE REQUIRED VALUES ARE CONSERVATIVE
    » EXPERIENCE WITH OTHER SPACECRAFT WITH LOWER FREQUENCIES
• VERBAL AGREEMENT WITH STANFORD THAT CURRENT DESIGN IS SATISFACTORY
  – WAIT FOR DETAILED LOAD CYCLE BEFORE REACTING TO EXPENSIVE DESIGN CHANGES
DEVELOPMENT TESTS

DEAN READ
DEVELOPMENT TESTS

- COMPOSITE NECK TUBE
- HELICOFLEX SEAL
- COLD ELECTRICAL FEEDTHROUGH
- AXIAL LOK
- FLEXIBLE EMERGENCY VENT LINE
- POROUS PLUG AND HEAT PULSE METER
OBJECTIVES

- DEMONSTRATE STRUCTURAL CAPABILITY AND VACUUM INTEGRITY OF TUBE ASSEMBLY
  - EXTERNAL PRESSURE TO 37.4 PSID (2x MAXIMUM PRESSURE)
  - INTERNAL PRESSURE TO 28.5 PSID (1.5x MAXIMUM PRESSURE)
  - THERMAL CYCLE TO STRESS BOND JOINTS
  - SIDE LOAD TO SIMULATE LATERAL LOAD FROM BELLOWS
  - AXIAL LOAD TO FAILURE (DETERMINE MARGINS)
- DEMONSTRATE FABRICATION AND ASSEMBLY PROCESS
- DEVELOP ACCEPTANCE TEST PROCEDURE FOR FLIGHT ARTICLE
- PERFORM THERMAL AND STRUCTURAL PROPERTIES TESTING

STATUS

- TESTING COMPLETE (TEST REPORT EM #379)
- COUPON TESTING IN PROGRESS
COMPOSITE NECK TUBE TEST RESULTS

- THERMAL CYCLE AND LEAK CHECK OF END FLANGES
  - \(< 1 \times 10^{-8} \text{ SCC He/S FOR ALL COLD LEAK CHECKS AND AFTER THERMAL CYCLES}

- INTERNAL PRESSURE TO 28.5 PSID

- EXTERNAL PRESSURE TO 34 PSID
  - MINOR RIB DE-BONDING OCCURRED
  - REBONDED PER BONDING PROCEDURE PRIOR TO PROCEEDING

- LATERAL LOAD OF 705 LBS TO SIMULATE ULTIMATE LATERAL LOADS
  - NO STRUCTURAL FAILURE OR LEAKAGE

- EXTERNAL PRESSURE TO ULTIMATE PRESSURE ([14.7+4]\times2=37.4)
  - SIMULATES 4 PSID VACUUM SHELL BURST DISK

- AXIAL LOAD TO FAILURE
  - ONSET OF BUCKLING OCCURRED AT 9133 LBS
  - 8500 LBS PREDICTED USING $2\sigma$ KNOCK-DOWN FACTOR
COMPOSITE NECK TUBE TEST CONCLUSIONS

• COMPOSITE NECK TUBE DESIGN MET ALL TESTING REQUIREMENTS
  – LEAKAGE
  – STRUCTURAL
• DIFFERENCES BETWEEN DEVELOPMENT TEST AND ACCEPTANCE TESTING
  – EXTERNAL PRESSURE LEVELS
    » DEVELOPMENT TEST - 2 X 18.7 = 37.4 PSID
    » ACCEPTANCE TEST - 1.5 X 18.7 = 28.1 PSID
  – NO AXIAL COMPRESSION TEST
OBJECTIVES

- DEMONSTRATE LEAK TIGHT SEAL
  - $< 1 \times 10^{-8}$ SCC He/S
  - LIQUID NITROGEN THERMAL CYCLING
  - STAINLESS STEEL TO ALUMINUM JOINT REPRESENTATIVE OF TANK TOP DOME JOINT DESIGN

STATUS

- TEST OF 2" SEAL IS COMPLETE (TEST REPORT GPB-100111)
- DESIGN OF FIXTURE TO TEST 20" SEAL TO 200 K IS IN PROGRESS
HELICOFLEX SEAL TEST (2 OF 2)

DESCRIPTION

• 2" DIAMETER SEAL APPARATUS
  – REPRESENTATIVE OF THE LARGEST PENETRATION ON THE TANK DOME
  – STAINLESS STEEL FLANGE BOLTED TO ALUMINUM FIXTURE
  – 3 THERMAL CYCLES; COLD AND WARM LEAK CHECKS
  – THERMAL SHOCK TEST WITH COLD LEAK CHECK

RESULTS

• 2" SEAL TEST
  – 2 SEALS TESTED
  – NO LEAKAGE DURING THERMAL CYCLING OR THERMAL SHOCK
HELCOFLEX SEAL TEST
CONCLUSIONS

- TEST DEMONSTRATED THAT THE HELCOFLEX SEAL AND JOINT DESIGN USED ON TANK PENETRATIONS MEETS THE LEAKAGE REQUIREMENTS

- TOP PLATE TO VACUUM SHELL SEAL CONFIGURATION WILL BE TESTED
  - 20" DIAMETER ALUMINUM TO STAINLESS STEEL JOINT
  - COOLED TO 200 K IN THERMAL-VACUUM TESTING
COLD ELECTRICAL FEEDTHROUGH TEST

OBJECTIVES

- VERIFY TANK AND WELL ELECTRICAL FEEDTHROUGHS MEET LEAKAGE REQUIREMENTS (<1 x 10^-9 SCC He/S)

STATUS

- FEEDTHROUGH FABRICATION COMPLETE
- TEST FIXTURE FABRICATION COMPLETE

DESCRIPTION

- WARM LEAK CHECK
- 3 THERMAL CYCLES WITH LIQUID NITROGEN AND COLD LEAK CHECK
- WARM LEAK CHECK
- THERMAL SHOCK AND COLD LEAK CHECK
AXIAL LOK TEST

OBJECTIVES

- CHARACTERIZE PERFORMANCE OF MODIFIED AXIAL LOK DESIGN
  - LOAD VS TORQUE CHARACTERISTICS FOR BOTH WARM AND COLD OPERATION
  - BREAK-IN CHARACTERISTICS
  - VIBRATION PERFORMANCE
    » LOAD MAINTAINED DURING VIBRATION
    » TEST FOR PARTICLE GENERATION

- RESOLVE CONTAMINATION ISSUES
  - MEASURE TYPE AND QUANTITY OF PARTICLES GENERATED DURING NORMAL OPERATION
  - DEMONSTRATE THAT SEALS AND FILTERS PROHIBIT PARTICLE MIGRATION INTO THE WELL

STATUS

- AXIAL LOK PART FABRICATION COMPLETE
- TEST FIXTURE FABRICATION COMPLETE
AXIAL LOK TEST
DESCRIPTION

• WARM AND COLD (77 K) TESTING
  – MEASURE LOAD VS TORQUE OVER 20 CYCLES
  – DETERMINE IF SEALS AND FILTERS ELIMINATE POTENTIAL CONTAMINATION OF THE WELL
  – MEASURE QUANTITY AND TYPE OF PARTICLES GENERATED

• VIBRATION TESTING
  – ROOM TEMPERATURE TEST
  – MONITOR CLAMPING LOAD DURING VIBRATION
  – MEASURE QUANTITY AND TYPE OF PARTICLES GENERATED
FLEXIBLE VENT LINE TEST

OBJECTIVES

• DEVELOP DESIGN OF FLEXIBLE EMERGENCY VENT LINE TO BE USED IN SMD
  – TUBE CONSTRUCTION
  – FOLD PATTERN
  – END FLANGE DESIGN
  – VAPOR COOLED SHIELD INTERFACE
• DEVELOP ACCEPTANCE TEST REQUIREMENTS AND PROCEDURE FOR FLIGHT ARTICLES
• MEASURE LEAKAGE THROUGH VENT LINE

STATUS

• TESTING COMPLETE (TEST REPORT EM #373)
• DESIGN PARAMETERS TESTED
  – TWO END FLANGE DESIGNS TESTED
    » CONICAL AND PYRAMID
  – TWO FOLD TYPES TESTED
    » FLAT FOLD AND ACCORDION FOLD
  – DIFFERENT TUBE CONSTRUCTIONS TESTED
    » 1 PLY, 2 PLY, AND 3 PLY
    » REINFORCEMENT AT END FITTINGS

• TEST SEQUENCE
  – WARM EVACUATION AND LEAK BACK TEST
  – WARM PROOF PRESSURE AND LEAK TEST
  – RAPID PRESSURIZATION WHILE SUBMERGED IN LIQUID NITROGEN
    » LEAKAGE MEASUREMENT AT 38 PSID
  – BURST PRESSURE TEST WHILE SUBMERGED IN LIQUID NITROGEN
FLEXIBLE VENT LINE
RESULTS - TEST #11

• CONFIGURATION
  – 3 - 0.0005" MYLAR PLY CENTER SECTION
  – 5 - 0.0005" MYLAR PLY END SECTIONS
  – ACCORDION FOLD
  – CONICAL END FITTINGS
  – SIMULATED DEWAR GEOMETRY

• TEST RESULTS
  – EVACUATION AND LEAK CHECK - NO LEAKS
  – PROOF PRESSURE TO 54 PSID - NO LEAKS
  – RAPID PRESSURIZATION IN LIQUID NITROGEN - 3,000 L/HR AT 38 PSID (< 10,000 L/HR REQUIRED)
  – BURST PRESSURE TEST - ACHIEVED 200 PSID WITHOUT RUPTURE
• SMD BASELINE DESIGN
  – CONICAL END FITTING
  – ACCORDION FOLD
  – 3 MYLAR PLY CENTER SECTION; 5 PLY END CUFFS

• SELECTED DESIGN HAS LEAKAGE RATE 10 TIMES LOWER THAN THE CAPABILITY OF A SINGLE VACUUM SHELL BURST DISC

• ACCEPTANCE TEST FOR FLIGHT ARTICLES
  – 3 THERMAL CYCLES OF BOND JOINTS
  – WARM PROOF PRESSURE (54 PSID) AND LEAK CHECK
  – ADDITIONAL TESTING ON LINES FROM SAME LOT
    » RAPID EXPANSION IN LIQUID NITROGEN BATH AND LEAK CHECK
    » WARM BURST TEST TO AT LEAST 200 PSID
OBJECTIVES

- DEMONSTRATE OPERATING CHARACTERISTICS OF THE SMD POROUS PLUG
  - LOW TEMPERATURE PHASE SEPARATION
  - LIQUID BREAK THROUGH CONDITIONS
  - CHOKED FLOW CONDITIONS
- VALIDATE DESIGN AND ASSEMBLY PROCEDURES FOR THE FLIGHT ARTICLE
- DEMONSTRATE HEAT PULSE METER OPERATION

STATUS

- COMPONENTS AND INSTRUMENTATION ON ORDER
- TEST DEWAR ASSEMBLED
TEST APPARATUS

POROUS PLUG VENT

TANK FILL AND VENT

VACUUM SHELL

LHe

POROUS PLUG ASSEMBLY
DYNAMICS ANALYSIS

LARRY SOKOLSKY
• DERIVE SET OF LOADS FOR DEWAR AND PROBE DESIGN
  – RETAIN ADEQUATE CONSERVATISM
  – AVOID EXCESSIVE OVERDESIGN
• FLOW DOWN LOADS TO STRESS ANALYSIS
• MEET SPACE VEHICLE FREQUENCY REQUIREMENTS
  – 12 HZ LATERAL MODE REQUIREMENT
  – 35 HZ AXIAL MODE REQUIREMENT
• VERIFY DESIGN LOADS WITH COUPLED LOADS ANALYSIS
• DEVELOP STRUCTURAL DYNAMICS VERIFICATION PLAN
  – PROBE B, C SHAKE
  – PROBE B IN SMD COLD SHAKE
  – STATIC STRENGTH AND STIFFNESS TESTS
• BUILD PAYLOAD DYNAMIC MODEL USING SDRC-IDEAS AND MSC/NASTRAN
• COUPLE TO LMSC SPACECRAFT MODEL
• APPLY LAUNCH (TRANSIENT) TRANSONIC (RANDOM) VIBRATION INPUTS TO BASE OF SPACE VEHICLE MODEL
• APPLY ACOUSTIC LOADS WHERE APPLICABLE
• APPLY MUFs (MODEL UNCERTAINTY FACTORS) FOR CONSERVATISM
• TABULATE PAYLOAD RESPONSES FOR CRITICAL COMPONENTS
• UPDATE LOAD FACTORS WITH COUPLED LOADS ANALYSIS RESULTS WHEN AVAILABLE
• DYNAMICS AND LOADS ANALYSIS DOCUMENTED IN EM 310A
• MOTIVATION
  - COMPLETE LOAD CYCLE RESULTS WERE NOT AVAILABLE TO SUPPORT DEWAR DESIGN
  - GENERIC LOADS WOULD LEAD TO HARDWARE OVERDESIGN
• GUIDELINES
  - APPROACH MUST CONTAIN ADEQUATE CONSERVATISM
  - USE REALISTIC INPUTS TO DERIVE DESIGN LOADS
LOADS ANALYSIS
METHODOLOGY

- CREATE DETAILED FINITE ELEMENT MODEL OF PAYLOAD (DEWAR, PROBE, AND ATTACHED ELECTRONICS), COUPLE TO LMSC SPACECRAFT MODEL
- DYNAMIC LOADS FROM FSAT LOAD CYCLE
  - FSAT MASS AND CG SIMILAR TO GBP
  - LAUNCH VEHICLE DOMINATES INPUT
- ADD ACOUSTIC LOADS WHERE APPLICABLE (DERIVED FROM GPS FLIGHT DATA)
- ADEQUATE MUFs USED TO RETAIN CONSERVATISM
  - 1.5 FOR TRANSONIC ANALYSIS (RANDOM INPUT)
  - 1.75 FOR LAUNCH ANALYSIS (TRANSIENT INPUT)
- MAIN ENGINE CUT-OFF (MEO) DETERMINES AXIAL LOAD FACTORS (FROM DELTA II COMMERCIAL PAYLOAD PLANNER'S GUIDE)
- TRANSIENT ANALYSIS PARAMETERS
  - KEEP LOADS TO 200 HZ
  - 1% CRITICAL DAMPING ON ALL MODES
  - MODE ACCELERATION METHOD FOR TRANSIENT ANALYSIS
- DYNAMIC LOAD FACTOR IS MAXIMUM OF LAUNCH TRANSIENT AND TRANSONIC RANDOM
- COMBINED LOAD FACTOR = MUF*(DYNAMIC )+ACOUSTIC
- X* AND Y* LOADS RSSd TO CREATE SINGLE LATERAL LOAD FACTOR
- SSD SECONDARY STRUCTURE LOAD FACTORS USED FOR LIGHTWEIGHT HARDWARE (i.e. PLUMBING AND ELECTRONICS)
## INTEGRATED SPACE VEHICLE MODE FREQUENCIES AND MODE PARTICIPATION FACTORS TO 50 HZ

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DESIGN EFFORT TO INCREASE SPACE VEHICLE MODAL FREQUENCIES

- BASELINE DESIGN DID NOT MEET FREQUENCY REQUIREMENTS

- DEWAR STIFFENED AS MUCH AS POSSIBLE
  - FWD DOME RIB STIFFENING
  - INCREASED PODS STIFFNESS
  - OPTIMIZED SPACECRAFT INTERFACE (TRUNKNION WITH RADIAL RELEASE)

- RESULTING MODAL FREQUENCIES
  - LATERAL: 10.86 HZ
  - AXIAL: 29.45 HZ

- LATERAL FREQUENCIES OF OTHER PAYLOADS (SOURCE-MDSSC)
  - UUV < 9 HZ
  - MSX 8.5 HZ
  - MANY OTHERS IN 7-9 HZ RANGE
  - IMPACT OF LATERAL FREQUENCIES IN 10-11 HZ RANGE - NONE

- AXIAL FREQUENCIES OF OTHER PAYLOADS (SOURCE-MDSSC)
  - MOST PAYLOADS ABOVE 35 HZ
  - MSX 30 HZ
  - IMPACT: MAY INCREASE QUASISTATIC LOADS SLIGHTLY (~.25 HZ)

- CONCLUSION - CURRENT SPACE VEHICLE MODAL FREQUENCIES ARE ACCEPTABLE
QUASISTATIC AND ACOUSTIC LOAD FACTORS

- QUASISTATIC LOAD FACTORS (SOURCE: DELTA-II HDBK)
  - LIFT-OFF LOAD FACTORS (G)
    » LATERAL +/- 2.5 (G)
    » AXIAL +2.2/-0.2 (G)
  - MECO
    » AXIAL +6.3 (G)

- ACOUSTIC LOAD FACTORS (SOURCE-DELTA-II POST-FLIGHT ANALYSIS (MCD H5858)
  - LATERAL 1.6 (G)
  - AXIAL 3.5 (G)
• ENVELOPING MADE MORE CONSERVATIVE FROM PDR
• AXIAL TRANSONIC LOAD CASE NOT USED BECAUSE OF LOW INPUT LEVEL (NO SIGNIFICANT RESPONSE)
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SSD SECONDARY STRUCTURE
LOAD FACTOR CURVES

NOTES:
(1) LOADS APPLIED SIMULTANEOUSLY
NORMAL COMBINED WITH TRANSVERSE
LOADS CLOCKED THROUGH 360 DEGREES
FOR WORST COMBINATION
(2) LOADS APPLIED THROUGH C.G. OF
COMPONENT

LIMIT DESIGN LOAD FACTOR ~ \( n_g \)

COMPONENT WEIGHT ~ LBS
STRUCTURAL DYNAMICS
VERIFICATION PLANS
DY-13

• DETAILED MODAL TEST NOT PRACTICAL
  – NO MODAL TEST UNIT
  – DIFFICULT TO INSTRUMENT COLD AREAS OF DEWAR AND PROBE

• PERFORM MODAL IDENTIFICATION DURING SHAKE TESTS
  – COMMENTS APPLY TO BOTH PROBE AND INTEGRATED PAYLOAD SHAKE TESTS
    » IDENTIFY PRIMARY MODE FREQUENCIES AND DIRECTIONS
    » INSTRUMENT SPACECRAFT AND EXTERNAL DEWAR STRUCTURE TO VERIFY GLOBAL MODE SHAPES
    » FOUR INTERNAL DEWAR TRIAXIAL ACCELEROMETERS INCLUDED IN DEWAR INSTRUMENTATION

• PERFORM STIFFNESS TESTS ON PODS
  – VERIFIES STIFFNESSES IN FINITE ELEMENT MODEL
  – RELATIVELY CHEAP, SIMPLE, AND ACCURATE

• PROTOQUAL VIBRATION TESTS
  – PROBE B/C VIBRATION
  – PROBE B IN SMD VIBRATION WITH SPACECRAFT SIMULATOR
  – FULL-UP ACOUSTIC TEST
CONCLUSIONS

• SPACE VEHICLE MODAL FREQUENCIES
  – FIRST AXIAL PAYLOAD MODE 29.45 Hz (35 Hz REQUIREMENT)
  – FIRST LATERAL PAYLOAD MODE 10.86 Hz (12 Hz REQUIREMENT)
  – EXPERIENCE ON OTHER SPACECRAFT PROGRAMS INDICATE THAT THESE FREQUENCIES ARE MOST LIKELY ACCEPTABLE

• DETAILED LOAD FACTORS HAVE BEEN FLOWED DOWN TO STRESS ANALYSIS

• PRELIMINARY COUPLED LOADS ANALYSIS (IN PROCESS) NOT EXPECTED TO MODIFY DESIGN LOADS SIGNIFICANTLY
STRESS ANALYSIS

LARRY SOKOLSKY
• ANALYZE ALL STRUCTURE IN DETAIL FOR INERTIAL AND PRESSURE LOADS

• ACCOMODATE MANUFACTURING AND COST CONSIDERATIONS IN DESIGN ALTERNATIVES

• USE CONSERVATIVE ANALYSIS APPROACHES TO INSURE STRUCTURAL DESIGN
• INTERNAL PRESSURE
  – FACTOR OF 4 FOR STRESS AND BUCKLING
  – FACTOR OF 1.5 FOR PROOF PRESSURE TEST

• EXTERNAL PRESSURE
  – FACTOR OF 2 FOR STRESS AND BUCKLING

• MECHANICAL LOADS (METALLIC)
  – FACTOR OF 1.25 FOR YIELD
  – FACTOR OF 1.5 FOR ULTIMATE
  – FACTOR OF 1.25 FOR TEST

• MECHANICAL LOADS (NON-METALLIC)
  – FACTOR OF 2.0 FOR ULTIMATE
  – FACTOR OF 1.25 FOR TEST

• GROUND SUPPORT EQUIPMENT
  – FACTOR OF 3.0 FOR ULTIMATE (GROUND HANDLING EQUIPMENT)
  – FACTOR OF 5.0 FOR ULTIMATE (LIFTING EQUIPMENT)
DEWAR STRESS ANALYSIS
REQUIREMENTS - LOADS

ST-4

• INTERNAL PRESSURE
  – TANK AND PLUMBING - .26 MPA (38 PSID DESIGN - 152 PSID ULTIMATE)
  – WELL - .13 MPA (19 PSID DESIGN - 76 PSID ULTIMATE)
  – VACUUM SHELL - .06 MPA (8 PSID DESIGN - 32 PSID ULTIMATE)
  – GUARD TANK - .37 MPA (55 PSID DESIGN - 220 PSID ULTIMATE)

• EXTERNAL PRESSURE
  – TANK AND PLUMBING - .13 MPA (19 PSID DESIGN - 38 PSID ULTIMATE)
  – WELL - .36 MPA (53 PSID DESIGN - 106 PSID ULTIMATE)
  – VACUUM SHELL - .10 MPA (15 PSID DESIGN - 30 PSID ULTIMATE)

• INERTIAL LOADS
  – SEE DYNAMICS AND LOADS SECTION

• AXIAL LOK COMPRESSIVE LOAD 10889 N/CLAMP
  (2448 LB/CLAMP)
STRUCTURAL ANALYSIS APPROACH

ST-5

- USE APPROPRIATE ANALYTICAL TOOLS FOR JOB
  - PANDA FOR DESIGN, ANALYSIS AND WEIGHT OPTIMIZATION OF CYLINDRICAL SHELLS
  - BOSOR4 FOR LINEAR, MODAL AND BUCKLING ANALYSIS OF AXISYMMETRIC SHELLS
  - STAGS, DIAL, SDRC/IDEAS, MSC/NASTRAN AND NEPSAP FOR LINEAR, NONLINEAR, MODAL AND BUCKLING ANALYSIS OF GENERAL STRUCTURES USING FINITE ELEMENT TECHNIQUES
  - CLASSICAL ANALYSIS TECHNIQUES WHERE APPROPRIATE

- ALL ANALYSIS TOOLS HAVE BEEN USED AND VERIFIED ON OTHER LMSC SPACE PROGRAMS

- INERTIAL LOADS USED IN STRESS ANALYSES FROM EM 310A (DYNAMICS AND LOADS FINAL REPORT)

- MARGIN OF SAFETY > 0.0 CRITERIA FOR SUCCESS

\[ \text{MARGIN OF SAFETY} = \frac{F_a}{\sigma_a \times F.S.} - 1 \]

- \( F_a \) = MATERIAL ALLOWABLE
- \( F.S. \) = FACTOR OF SAFETY
- \( \sigma_a \) = CALCULATED STRESS
STRESS ANALYSIS DOCUMENTATION

- EM310A (P030739) 'INTEGRATED PAYLOAD/SPACECRAFT LAUNCH LOADS', 15 DECEMBER 1993, BY L. SOKOLSKY
- GPB-100126, 'STRESS ANALYSIS OF EFD CRYOPERM 10 PIN JOINT DUE TO SHEAR LOADING', BY A.G. VOGEL, 4 SEPTEMBER 1993
- GPB-100127, 'ADHESIVE-BONDED JOINTS AND THE GPB DEWAR/TANK JOINT', 1 FEBRUARY 1994, BY A.G. VOGEL
- GPB-100128, 'GP-B DEWAR AXIAL-LOK AND AXIAL-LOK COMPONENTS ANALYSIS', 18 OCTOBER 1993, BY A.G. VOGEL
- GPB-100129, 'SCIENCE MISSION DEWAR PROTON SHIELD STRESS ANALYSIS', 20 OCTOBER 1993, BY A.G. VOGEL
- GPB-100130, 'SCIENCE MISSION DEWAR GRAPHITE RING ATTACHMENT FITTINGS BOND ANALYSIS', 1 FEBRUARY 1994, BY A.G. VOGEL
- GPB-100143, 'DEWAR MAIN TANK FRACTURE AND SAFE-LIFE ANALYSIS, 7 FEBRUARY 1994, BY A.G. VOGEL
- P-0889331, 'ANALYSIS OF LOCAL STRESSES OF MAIN TANK PENETRATIONS', 17 NOVEMBER 1993, BY L.W. WANG
- GPB-100135, 'STRESS ANALYSIS OF PENETRATIONS', 4 FEBRUARY 1994, BY L.W. WANG
- GPB-100140, 'STRESS ANALYSIS OF BAFFLE PLATES', 5 FEBRUARY 1994, BY L.W. WANG
- GPB-100144, 'STRESS ANALYSIS OF FLEXURE', 8 FEBRUARY 1994, BY L.W. WANG
- GPB-100146, 'STRESS ANALYSIS OF THE ASSEMBLY STAND', 9 FEBRUARY 1994, BY L.W. WANG
- GPB-100156, 'STRESSES CALCULATED IN GP-B VAPOR-COOLED SHIELDS', 20 JANUARY 1994, BY S. McHUGH
- GPB-100157, 'BUCKLING OF GP-B COMPOSITE NECK TUBE, VAPOR COOLED SHIELDS, AND PODS', 21 JANUARY 1994, BY S. McHUGH
- GPB-100159, 'STRESS ANALYSIS OF THE SMD SFHe TANK FORWARD DOME', 17 FEBRUARY 1994, BY N.D. NGUYEN
- GPB-100160, 'STRESS ANALYSIS OF THE SMD STAR TRACKER MOUNTING PEDESTAL', 17 FEBRUARY 1994, BY N.D. NGUYEN
- GPB-100161, 'STRESS ANALYSIS OF THE SMD AFT PODS TANK MOUNTING BRACKET', 17 FEBRUARY 1994, BY L. SOKOLSKY
# MATERIAL PROPERTIES

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<th>TEMPER CONDITION</th>
<th>THICKNESS (INCHES)</th>
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<td>BE/CU-165 (C17000)</td>
<td>H</td>
<td>&gt;1.0</td>
<td>LONG</td>
<td>19</td>
<td>.30</td>
<td>85</td>
<td>75</td>
<td>51</td>
</tr>
<tr>
<td>AL 1100</td>
<td>H14</td>
<td>ALL</td>
<td>LONG</td>
<td>10.0</td>
<td>.33</td>
<td>18</td>
<td>17</td>
<td>9</td>
</tr>
<tr>
<td>TI-CU</td>
<td>1/4 HT</td>
<td>ALL</td>
<td>LONG</td>
<td>18.0</td>
<td>.30</td>
<td>80</td>
<td>100</td>
<td>N/A</td>
</tr>
</tbody>
</table>
• FORWARD DOME
  – WAFFLED CONSTRUCTION FOR STIFFNESS (DRIVES UP FIRST AXIAL MODAL FREQUENCY)
  – FINITE ELEMENT MODEL WITH PENETRATION DETAILS FOR STRESS
  – BOSOR4 MODEL FOR BUCKLING

• RIBBED CYLINDER MODELLED USING BOSOR4

• LOWER DOME
  – WAFFLED FOR WEIGHT SAVINGS
  – FINITE ELEMENT MODEL FOR STRESS
  – BOSOR4 MODEL FOR BUCKLING
  – DETAILED FINITE ELEMENT MODEL FOR LOCAL PODS STRESS

• PODS BRACKETS

• WELL
  – MONOCOQUE CONSTRUCTION
  – BOSOR4 MODEL FOR STRESS AND BUCKLING
• AXIAL LOK
  – MAJOR LOAD IS STA 200 CLAMPING LOAD
  – SCALED FLICOMP PDR ANALYSIS FOR NEW LOADS

• TANK-TO-WELL BOND JOINT
  – ORIGINALLY DESIGNED AS WELD
  – CHEMTRONICS PREFERRED BOND (LESS RISK)
  – JOINT OPTIMIZED TO REDUCE PEEL STRESSES

• CRYOPERM SHIELD
  – LARGEST LOADS ARE ON RESTRAINING PIN AT BASE OF TANK
  – STRESSES MUST BE KEPT BELOW YIELD TO PRECLUDE LOSS OF SHIELDING FROM WORK HARDENING

• PROTON SHIELD
  – LOADED INERTIALLY FROM WEIGHT OF SHIELDING MATERIAL AROUND GYRO AREA
• FORWARD DOME
  – BUCKLING MARGINS (KNOCKDOWN FACTOR = 0.67)
    » INTERNAL PRESSURE M.S. = +4.04
    » EXTERNAL PRESSURE M.S. = +0.28
  – STRESS MARGINS
    » SHELL ULTIMATE M.S. = +0.02
    » WELD AREA ULTIMATE M.S. = +0.09
    » RINGS ULTIMATE M.S. = +0.13
    » STRINGERS ULTIMATE M.S. = +0.02
TANK MARGINS OF SAFETY
(CONTINUED)

• AFT DOME
  – BUCKLING M.S. = +0.21 ULTIMATE (KNOCKDOWN FACTOR = 0.67)
  – STRESS MARGINS
    » SHELL ULTIMATE M.S. = +0.01

• WELD AREAS AREAS ULTIMATE M.S = +0.02

• AFT PODS MOUNTING BRACKET
  – STRESS YIELD M.S. = +0.10
  – STRESS ULTIMATE M.S. = +0.05

• CYLINDER
  – BUCKLING M.S. = +0.23 (KNOCKDOWN FACTOR = 0.67)
  – STRESS M.S. = +0.13

• WELL
  – STRESS ULTIMATE M.S. HIGH
  – BUCKLING M.S. > +1.01
• ANALYSIS PERFORMED IN FLAGRO
• ALLOWABLE FLAWS
  – MAX ALLOWABLE FLAW SIZE IS 1.14 MM (0.045 IN)
  – INSPECT BY DYE PENETRANT, X-RAY OR EDDY CURRENT NDE
• SAFE LIFE OF 283 LIFETIMES (REQUIREMENT IS 4)
• ANALYSIS SHOWS THAT DESIGN IS LEAK-BEFORE-BURST
TANK FORWARD DOME FINITE ELEMENT MODEL

ST-14

2, 3 MAR 94
• RESULTS SCALED FROM FLICOMP PDR FOR SMD INERTIAL AND CLAMPING LOADS

• FINITE ELEMENT MODEL MADE FOR DOG-EAR CLAMP (NEGATIVE MARGIN FOR FLICOMP ANALYSIS)

• MARGINS OF SAFETY:
  – INTERNAL PRESSURE (ULTIMATE): +8.90
  – DOG CLAMPING ON RING (ULTIMATE): +0.95
  – LATERAL ACCELERATION (ULTIMATE): +1.73
  – AXIAL ACCELERATION (ULTIMATE): HIGH
  – DOG-EAR CLAMP
    » YIELD +2.12
    » ULTIMATE +2.26
  – THREAD RETAINER (ULTIMATE): +4.18
  – SPECIAL SCREW
    » TENSILE YIELD: +0.67
    » SHEAR ULTIMATE: +1.56
  – AXIAL LOK PLUG (ULTIMATE): HIGH
  – BALL LOCK CONE (YIELD): +0.13
ANALYSIS MODEL
- MODELLED IN BOSOR4
- SHIELD MATERIAL IS 6063-T6
- BOUNDARY CONDITIONS
  » FIXED AT STA 196.67 WHERE BOLTED TO TANK
  » RADIAL RESTRAINT AT STA 125.61 AT AFT END OF TANK
- INERTIALLY LOADED DUE TO WEIGHT OF SHIELING MATERIAL

STRESS RESULTS
- MAXIMUM STRESS = 2.92 MPa (4240 PSI)
- M.S. ULTIMATE = +4.50
- M.S. YIELD = +4.85

DISPLACEMENT RESULTS
- RADIAL (INWARD/OUTWARD) DISPLACEMENT = 0.17 MM (0.0066 IN)
- AXIAL (LENGTH) DISPLACEMENT = .061 MM (0.0024 IN)
- CONCLUSION: WILL NOT STRIKE CRYOPERM SHIELD DURING LAUNCH
DEWAR/TANK BONDED JOINT STRESS ANALYSIS

• ANALYSIS PERFORMED USING THE NEPSAP FINITE ELEMENT CODE
  – HAS JOINT ELEMENT IN ITS DATABASE
  – PRODUCES SHEAR AND PEEL STRESSES

• JOINT DESIGN MODIFIED TO REDUCE STRESS IN THE ADHESIVE
  – SHEAR
    » MAXIMUM SHEAR STRESS = 6.31 MPa (915 PSI)
    » ULTIMATE M.S. = +0.01
  – PEEL
    » MAXIMUM PEEL RESULTANT = 1.2 N/MM (7.0 LB/IN)
    » ULTIMATE M.S. = +0.03
CRYOPERM SHIELD PIN JOINT STRESS ANALYSIS

ST-20

2, 3 MAR 94

- ANALYSIS OF THE CRYOPERM SHIELD WAS PERFORMED USING THE NEPSAP AND BOSOR4 COMPUTER CODES

- GEOMETRY
  - CONNECTS AFT PORTION OF THE DEWAR WELL AND CRYOPERM SHIELD TO MAIN TANK AFT DOME
  - JOINT DESIGNED TO REACT LOADS IN SHEAR AND BENDING ONLY

- DEWAR WELL STRESS RESULTS
  - MAXIMUM STRESS = 120.07 MPa (17,415 PSI)
    » ULTIMATE M.S. = +0.34
    » YIELD M.S = +0.42

- CRYOPERM SHIELD STRESS RESULTS
  - MAXIMUM STRESS = 50.25 MPa (7288 PSI)
    » ULTIMATE M.S. > 0.99
    » YIELD M.S. = +1.39
THE SMD VACUUM SHELL MUST CARRY THE PRESSURE AND ACCELERATION LOADS FROM THE EXPERIMENT

ALL SHELLS WERE ANALYZED FOR STRESS AND BUCKLING USING BOSOR4

SEALS AND MAIN SUPPORT RING WERE ANALYZED USING A DIAL FINITE ELEMENT MODEL

AFT DOME ANALYZED WITH DIAL FINITE ELEMENT MODEL BECAUSE OF POCKETED CONSTRUCTION FOR WEIGHT SAVINGS

MATERIALS CHANGED FROM 8090 TO 2219 SINCE PDR
• SUPPORT RING CARRIES HIGH POINT LOADS FROM THE TRUNNIONS AND THE AFT PODS. THE MAIN LOADS CARRIED BY THE SUPPORT RING ARE AS FOLLOWS:

• CASE 1: POD LOADS
  1091 KG (2400 LB) X 6.3 G AXIAL ACCELERATION, CARRIED BY 6 PODS TO LUGS ON SUPPORT RING

• CASE 2: TRUNNION LOADS
  \( F_z = 58240 \, \text{N} \) (13000 \( \text{Lb} \))
  \( F_\theta = 111200 \, \text{N} \) (25000 \( \text{Lb} \))
  \( M_z = 8814 \, \text{N-M} \) (78000 \( \text{in-lb} \))
  \( M_\theta = 2825 \, \text{M-M} \) (25000 \( \text{in-lb} \))

• HELICOFLEX DELTA SEAL LOAD 140.1 N/MM (800 LB/IN)
- STRESSES AND MARGINS OF SAFETY DUE TO INTERNAL PRESSURES. TABLE GIVES SHELL CAPABILITIES. ALL MARGINS ARE POSITIVE

<table>
<thead>
<tr>
<th>Region</th>
<th>DESIGN CAPABILITY (PSI)</th>
<th>ULTIMATE CAPABILITY (PSI)</th>
<th>MS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aft Dome</td>
<td>12.50</td>
<td>50.00</td>
<td>0.20</td>
</tr>
<tr>
<td>Lower Cone</td>
<td>2.96</td>
<td>11.84</td>
<td>4.07</td>
</tr>
<tr>
<td>Support Ring</td>
<td>1.05</td>
<td>4.20</td>
<td>9.00</td>
</tr>
<tr>
<td>Mid Cylinder</td>
<td>3.52</td>
<td>14.08</td>
<td>3.26</td>
</tr>
<tr>
<td>Forward Cone</td>
<td>9.04</td>
<td>36.16</td>
<td>0.66</td>
</tr>
<tr>
<td>Forward Cylinder</td>
<td>&gt;1.76</td>
<td>&gt;7.04</td>
<td>&gt;7.52</td>
</tr>
<tr>
<td>Weld 1</td>
<td>1.20</td>
<td>4.80</td>
<td>4.63</td>
</tr>
<tr>
<td>Weld 2</td>
<td>0.80</td>
<td>3.20</td>
<td>7.44</td>
</tr>
</tbody>
</table>
THE VACUUM SHELL MUST BE CAPABLE OF CARRYING AN EXTERNAL PRESSURE OF 0.10 MPa (15 PSI) WITH A SAFETY FACTOR OF 2. USING A KNOCKDOWN FACTOR OF 0.67 RESULTS IN A MINIMUM THEORETICAL BUCKLING PRESSURE OF 0.31 MPa (45 PSI). ALL MARGINS ARE POSITIVE

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>BUCKLING PRESSURE (PSI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFT DOME</td>
<td>55.0</td>
</tr>
<tr>
<td>LOWER CONE</td>
<td>52.7</td>
</tr>
<tr>
<td>MID CYLINDER</td>
<td>53.2</td>
</tr>
<tr>
<td>FORWARD CONE</td>
<td>47.6</td>
</tr>
<tr>
<td>FORWARD CYLINDER</td>
<td>&gt;48.3</td>
</tr>
</tbody>
</table>
SMD VACUUM SHELL ANALYSIS:
AFT DOME PRESSURE STRESSES

ST-26

2, 3 MAR 94
### SMD VACUUM SHELL FINAL SHELL DIMENSIONS

#### LOWER CONE | MID CYLINDER | FORWARD CONE | FORWARD CYLINDER
--- | --- | --- | ---
WALL THICKNESS (IN) | 0.080 | 0.080 | 0.090 | 0.110 (MONOOCOQUE CONSTRUCTION)
RING HEIGHT (IN) | 0.699 | 0.690 | 0.630 | 0.690
RING THICKNESS (IN) | 0.045 | 0.045 | 0.050 | 0.045
RING SPACING (IN) | 1.450 | 1.415 | 0.760 | 1.415

### AFT DOME

| WALL THICKNESS (IN) | 0.100 |
| RING HEIGHT (IN) | 0.750 |
| RADIAL STIFFENER THICKNESS (IN) | 0.052 |
| RADIAL STIFFENER SPACING (DEG) | 10 |
| RING THICKNESS (IN) | 0.040 |
| RING SPACING (IN) | 3.01 |
| OUTER BAY RADIAL STIFFENER THICKNESS (IN) | 0.110 |
• THE ONLY SIGNIFICANT ACCELERATION STRESSES ARE IN THE SUPPORT RING, WHERE THE PODS ATTACH AND AT THE TRUINION PIN.

<table>
<thead>
<tr>
<th>REGION</th>
<th>POD LOAD (KSI)</th>
<th>M.S.</th>
<th>PIN LOAD (KSI)</th>
<th>M.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td>POD LUG</td>
<td>7.8</td>
<td>+6.94</td>
<td>7.8</td>
<td>+6.94</td>
</tr>
<tr>
<td>PIN SOCKET</td>
<td>-</td>
<td>HIGH</td>
<td>28.0</td>
<td>+1.21</td>
</tr>
<tr>
<td>GUSSET</td>
<td>-</td>
<td>HIGH</td>
<td>27.0</td>
<td>+1.30</td>
</tr>
</tbody>
</table>

• RING DEFLECTION BETWEEN BOLTS DUE TO SEALS MUST NOT EXCEED .0015 IN

• 140.1 N/MM (800 LB/IN) MINIMUM LINE LOAD ON SEALS

• RESULTS:

  DEFLECTION (MIL)

  RING TO LOWER CONE:  0.0037
  RING TO MID CYLINDER: 0.0045

  ASSUMES 7117 N (1600 LB) BOLT PRELOAD

• CONCLUSION: SEAL DESIGN IS CONSERVATIVE
ELECTRONICS BOX LOADS

ST-30

- APPROX 136 KG (300) LB OF ELECTRONICS BOXES ARE SUPPORTED BY THE FORWARD CYLINDER ATTACHMENT RINGS.

- ASSUMING THAT THE MASS IS EVENLY DISTRIBUTED ABOUT THE CIRCUMRERENCE AND THE ACCELERATION IS 6.3 G AXIAL AND 6.6 G LATERAL:

- STRESS = 20.6 MPa (3 KSI) IN FORWARD CYLINDER

- MARGIN OF SAFETY = HIGH

- BUCKLING WAS NOT CONSIDERED IN THIS ANALYSIS. RISK OF REDESIGN IS LOW
SMD VACUUM SHELL FRACTURE AND LEAK-BEFORE BURST ANALYSIS

- THE ONLY SIGNIFICANT CYCLIC LOADING IS IN THE SUPPORT RING NEAR THE TRUNNION PIN AND POD LUG.
- USE THE GODDARD LAUNCH LOAD SPECTRUM
- MINIMUM OF 4 LIFETIMES IS REQUIRED
- NASA/FLAGRO USED FOR COMPUTATIONS
- THIS ANALYSIS VERIFIES THAT THE VACUUM SHELL IS LEAK-BEFORE BURST (CRACK PENETRATES VACUUM SHELL BEFORE RUNAWAY CRACK GROWTH BEGINS)

<table>
<thead>
<tr>
<th>REGION</th>
<th>CRACK CASE</th>
<th>ai</th>
<th>a/c</th>
<th>LIFETIMES</th>
</tr>
</thead>
<tbody>
<tr>
<td>POD LUG</td>
<td>CC03</td>
<td>0.05</td>
<td>1.0</td>
<td>50</td>
</tr>
<tr>
<td>PIN SOCKET</td>
<td>CC02</td>
<td>0.05</td>
<td>1.0</td>
<td>6</td>
</tr>
<tr>
<td>RING GUSSET</td>
<td>CC01</td>
<td>0.10</td>
<td>1.0</td>
<td>&gt;100</td>
</tr>
</tbody>
</table>
• INTEGRATED PAYLOAD WILL BE LIFTED BY REMOVING THREE BOLTS AT THE TOP OF THE MID CYLINDER AND INSERTING HOIST RINGS

• STRESS ANALYSIS OF MID-CYLINDER UNDER LIFTING LOADS IN PROGRESS

• LIFTING LOAD IS 1.5 G WITH FULL DEWAR WEIGHT (2000 DG/4400 LB)

• FACTOR OF SAFETY FOR DEWAR HARDWARE IS 1.5. FACTOR OF SAFETY FOR EXTERNAL LIFTING HARDWARE IS 5.0

• INITIAL ANALYSIS SHOWS THAT LIFTING STRESSES ARE LOW. EXACT MARGIN OF SAFETY TBD
GRAPHITE RING ANALYSIS

ST-33

STANFORD
Lockheed
LMSC P088357
2, 3 MAR 94

- ANALYSIS
  - THORNEL P-120S 2K HIGH MODULUS, HIGH STRENGTH FIBERS USED IN RING CONSTRUCTION, WITH FIBERS ORIENTED IN HOOP DIRECTION
  - DIAL FINITE ELEMENT MODEL CONSTRUCTED
  - RULE-OF-MIXTURES AND ASSUMPTION OF TRANSVERSE ISOTROPY USED TO DERIVE APPROXIMATE ELASTIC PROPERTIES
  - PODS LOADS DERIVED WITH DYNAMICS MODEL, THEN APPLIED TO RING

- RESULTS

<table>
<thead>
<tr>
<th>STRESS COMPONENT</th>
<th>MAX STRESS (PSI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIGX (HOOP)</td>
<td>39500</td>
</tr>
<tr>
<td>SIGY (AXIAL)</td>
<td>475</td>
</tr>
<tr>
<td>SIGZ (RADIAL)</td>
<td>1510</td>
</tr>
<tr>
<td>TAUXY</td>
<td>488</td>
</tr>
<tr>
<td>TAUYZ</td>
<td>231</td>
</tr>
<tr>
<td>TAUZX</td>
<td>1416</td>
</tr>
</tbody>
</table>

- WELL BELOW THE ALLOWABLE STRESSES OF TYPICAL Gr/Ep MATERIAL SYSTEMS

- WHILE THE STRESSES FROM THE APPLIED LOADS ARE BELOW TYPICAL ALLOWABLES, MATERIAL TESTING IS REQUIRED TO ESTABLISH FINAL ALLOWABLE STRESSES AND STRAINS
GP-B Gr/Ep Mounting Ring, Hoop Stress

(Deflected Shape is Magnified)
ANALYSIS PERFORMED USING BOTH THE NEPSAP FINITE ELEMENT CODE & CLASSICAL HAND ANALYSIS

SHEAR STRESS = 0.724 MPa 105 PSI; MS = +7.57

PEEL RESULTANT = 0.01 LB/IN; MS_{ULT} = HIGH
GUARD TANK STRUCTURAL ANALYSIS

ST-36

- ANALYSIS UPDATED TO REFLECT NEW BURST DISK SETTING
- BOSOR4 USED TO DETERMINE STRESS AND BUCKLING MARGINS FOR:
  - 0.26 MPa (38 PSI) EXTERNAL PRESSURE
  - 1.52 MPa (220 PSI) INTERNAL PRESSURE
  - INERTIAL LOADS
- BOSOR4 ANALYSES
  - 2-D AXISYMMETRIC
  - AL 2219 MATERIAL FOR TANK
  - AL 6063 STRUCTURE FOR SUPPORT STRUCTURE
  - FIXED CIRCUMFERENCE FOR CYLINDRICAL SUPPORT
  - 0.67 BUCKLING KNOCKDOWN FACTOR
- FINITE ELEMENT ANALYSIS
  - FINITE ELEMENT MODEL MADE FOR STRESS AND BUCKLING OF THE ATTACHMENT CONE AND CYLINDER UNDER INERTIAL LOADS
  - 0.67 BUCKLING KNOCKDOWN FACTOR
GUARD TANK STRESS ANALYSIS RESULTS: SAFETY MARGINS

ST-38

- INTERNAL PRESSURE ULTIMATE STRESS M.S. = +1.87
- WELD PRESSURE ULTIMATE STRESS M.S. = +0.65
- EXTERNAL PRESSURE ULTIMATE BUCKLING M.S. = +0.41
- UPPER CONE AND CYLINDER INTERTIAL LOADS
  - ULTIMATE STRESS M.S. = 2.04
  - BUCKLING M.S. = 1.83
  » ORIGINAL CYLINDER DESIGN SUFFERED FROM PREMATURE BUCKLING
     - LIGHTENING HOLES WERE REMOVED
     - INNER CYLINDER WALL WAS THEN ABLE TO BE THINNED FROM 13.9 MM (0.55 IN) TO 7.6 MM (0.30 IN)
guard tank, with buckling, external pres. =
DEFORMED STRUCTURE
BUCKLE MODE 1, N = 2, E.V. = 2.159E+00
PODS OPTIMIZATION ANALYSIS

- **DEWAR COMPUTER CODE FOR OPTIMAL DESIGN OF DEWAR SUPPORT SYSTEMS USED**
  - MINIMIZES SUPPORT SYSTEM THERMAL CONDUCTANCE, SUBJECT TO STRUCTURAL CONSTRAINTS
    - LAUNCH AND ORBIT FREQUENCIES
    - STRESS AND STRAIN OF PODS SUPPORT TUBES
    - SUPPORT SYSTEM CLEARANCE
  - USED TO DEVELOP ORIGINAL SMD DESIGN
  - RECENTLY UPDATED AND VERIFIED AGAINST DETAILED FINITE ELEMENT MODELS

- PODS DESIGN REVISED SINCE PDR TO PREVENT THERMAL SHORTING OF PODS DUE TO VACUUM SHELL COOLING DURING THERMOVAC TESTING OR ON-ORBIT COOLING

- FINAL CONFIGURATION SHOWN BELOW:

<table>
<thead>
<tr>
<th>TUBE</th>
<th>LOCATION</th>
<th>OD (MM/IN)</th>
<th>THICKNESS PER PLY (MM/IN)</th>
<th>LAYUP (DEG)</th>
<th>ORBIT TUBE LENGTH (MM/IN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAUNCH</td>
<td>FWD</td>
<td>42.8/1.69</td>
<td>0.229/0.009</td>
<td>[10,-10,10,10]</td>
<td>---</td>
</tr>
<tr>
<td>LAUNCH</td>
<td>AFT</td>
<td>42.8/1.69</td>
<td>0.381/0.015</td>
<td>[10,-10,10,10]</td>
<td>---</td>
</tr>
<tr>
<td>ORBIT</td>
<td>FWD</td>
<td>13.0/0.512</td>
<td>0.127/0.005</td>
<td>[10,-10]</td>
<td>134.6/5.30</td>
</tr>
<tr>
<td>ORBIT</td>
<td>AFT</td>
<td>18.0/0.710</td>
<td>0.127/0.005</td>
<td>[10,-10]</td>
<td>76.2/3.00</td>
</tr>
</tbody>
</table>

1) TOTAL LENGTH, FOLDED TUBE DESIGN
• CRITICAL MODES ARE PODS BUCKLING AND BOND STRESSES
  -- NO ACCOUNT FOR VCS SIDE LOADS IN DEWAR OPTIMIZATION ANALYSIS
  -- BUCKLING AS SHELL STRUCTURE AND AS COLUMN ANALYZED
  -- STRESS MARGINS FOR FITTINGS HIGH ( > 10 )

• BOUNDING LOADS USED FOR CONSERVATISM
  -- MAX. AXIAL LOADS FROM DEWAR ANALYSIS +
    MAX. SIDE LOADS FROM VCS STRUCTURAL ANALYSIS

• RESULTS
  -- BUCKLING
    | Type     | Theoretical Buckling Load Factor | MARGIN |
    |----------|----------------------------------|--------|
    | SHELL    | 19.4                             | 8.0    |
    | COLUMN   | 8.9                              | 3.2    |

  -- BOND STRESSES
    Average Bond Shear Stress = 824 psi
    Allowable Average Shear Stress = 1800 psi
    (Based on test data)
    Factor of Safety = 2.0

    MARGIN = +0.09
• 3-D DIAL FINITE ELEMENT ANALYSIS CONTAINS:
  – 4 VAPOR-COOLED SHIELDS + MLI
    » VCS-1: 23 KG (51 LB)
    » VCS-2: 26 KG (58 LB)
    » VCS-3: 27 KG (60 LB)
    » VCS-4: 39 KG (85 LB)
  – GUARD TANK
    » TOROIDAL TANK PLUS LIQUID HELIUM: 17.9 KG (39.4 LB)
  – COMPOSITE NECK TUBE WITH HEX RINGS
  – 6 FWD PODS
  – 6 AFT PODS
• CONSTRAINTS
  - NODES AT TOP OF VCS-1 AND VCS-2 EQUIVALENCED TO CNT
  - VCS-3 AND VCS-4 NOT ATTACHED TO CNT
  - INTERSECTION POINTS OF ALL VCS AND FWD PODS: ROTATIONAL DOFS EQUIVALENCED
  - INTERSECTIONAL POINTS OF VCS-1 AND VCS-2 WITH AFT PODS: ROTATIONAL DOFS EQUIVALENCED
  - INTERSECTION POINTS OF VCS-3 AND VCS-4 WITH AFT PODS: RIGIDLY ATTACHED
  - BASE OF CNT FIXED
  - TOP OF CNT: FREE IN AXIAL DIRECTION ONLY
  - ENDS OF PODS CAN ROTATE BUT NOT TRANSLATE
VAPOR COOLED SHIELDS ANALYSIS RESULTS

ST-45

• SHIELD LOADS ON PODS BELOW:

<table>
<thead>
<tr>
<th>LOAD DIRECTION</th>
<th>FAZ (LB)</th>
<th>MZZ (IN-LB)</th>
<th>MYY (IN-LB)</th>
<th>TORQUE (IN-LB)</th>
<th>SHEAR-Y (LB)</th>
<th>SHEAR-Z (LB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LATERAL</td>
<td>258.</td>
<td>241.</td>
<td>660.</td>
<td>11.</td>
<td>15.</td>
<td>39.</td>
</tr>
<tr>
<td>AXIAL</td>
<td>98..</td>
<td>212.</td>
<td>177.</td>
<td>4.</td>
<td>10.</td>
<td>11.</td>
</tr>
</tbody>
</table>

• SHIELD STRESS MARGINS OF SAFETY
  - DOMES - M.S. = LARGE
  - HONEYCOMB
    » ALL CORE MATERIAL MARGINS OF SAFETY ARE LARGE
    » FACE SHEETS
      • VCS-1 M.S. = +1.62
      • VCS-2 M.S. = -0.27 (LOCAL HIGH STRESS AT TRANSITION ZONE WILL BE ELIMINATED BY DOUBLER)
      • VCS-3 M.S. = +0.64
      • VCS-4 M.S. = +0.82

• SHIELD BUCKLING MARGINS OF SAFETY - MINIMUM M.S. = +0.15
GRAPHITE RING FLEXURE ANALYSIS

- FLEXURES DESIGNED TO TRANSFER LOAD FROM GRAPHITE RING TO VACUUM SHELL WHILE ALLOWING RADIAL GROWTH/SHRINKAGE OF VACUUM SHELL
- LATERAL INERTIAL LOAD APPLIED TO WEIGHT OF HARDWARE SUSPENDED BY FWD PODS
- SIMPLE NASTRAN BEAM MODEL OF PODS AND FLEXURES USED FOR ANALYSIS
  - MAXIMUM RADIAL DISPLACEMENT = 1.7 MM (0.066 IN)
  - ULTIMATE M.S. = 3.3
SLOSH BAFFLE STRESS ANALYSIS

ST-47

- SLOSH BAFFLES LOADED BY FLUID SLOSHING DURING TRANSPORTATION OF HALF-FULL SFHe TANK (3 G INPUT)
  - FULL RESONANCE OF FLUID ASSUMED
  - AXIAL LOAD = 0.47 N/MM (2.67 LB/IN)
  - TANGENTIAL MOMENT = 1.62 N/MM (9.27 IN-LB/IN)

- STRESS RESULTS
  - BAFFLE DISKS AND LONGITUDINAL PLATES INCREASED IN THICKNESS FROM 1.2 MM (.046") TO 1.3 MM (.050")
  - TANK CYLINDER RIBS WHERE BAFFLES ATTACH INCREASED IN THICKNESS FROM 1.2 MM (.046") TO 1.3 MM (.050")
  - SPOT WELDS WERE MODIFIED TO PROVIDE TWO ROWS OF WELDS INSTEAD OF ONE
  - BAFFLE DISKS TO BE MANUFACTURED IN 4 QUADRANTS TO ALLOW MORE OVERLAP ON RIBS
  - MINIMUM STRESS M.S. IS +0.18 AT BASE OF RIBS

- BUCKLING RESULTS
  - BAFFLE DISKS WILL BUCKLE
  - WILL STAY IN ELASTIC RANGE (WILL POP BACK INTO SHAPE WHEN LOAD IS REMOVED)
PENETRATION ANALYSIS

ST-48

- ALL REMOVABLE SEALS ARE OF HELICOFLEX DELTA DESIGN
  - HIGH SEAL LINE LOAD DUE TO DELTA FEATURE
  - VERY TIGHT REQUIREMENTS OF FLANGE RELATIVE DISPLACEMENT AND SLOPE DRIVE UP FLANGE DIMENSIONS
    » ALLOWABLE RELATIVE DISPLACEMENT DUE TO LOAD = .041 MM (.0016 IN)
    » ALLOWABLE TANGENTIAL SLOPE = 0.1%
    » ALLOWABLE RADIAL SLOPE = 1%
  - PRESSURE LOAD ADDED TO SEAL LINE LOAD

- RESULTS SHOWN IN FOLLOWING TABLE
- ALL SAFETY MARGINS ARE POSITIVE
- SOME TOP PLATE PENETRATIONS STILL TO BE ANALYZED
## PENETRATION ANALYSIS
### MARGINS OF SAFETY

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>SFHe TANK BURST DISKS, VACUUM SHELL BURST DISKS, POROUS PLUG</th>
<th>SFHe TANK WELL, ELEX, FEP</th>
<th>STAR TRACKER MOUNT</th>
<th>GUARD TANK RAV, LIQUID LEVEL SENSOR</th>
<th>MAIN MOUNTING RING FILL LINE</th>
</tr>
</thead>
<tbody>
<tr>
<td>PORT ID (IN)</td>
<td>2.00</td>
<td>1.00</td>
<td>2.75</td>
<td>0.625</td>
<td>2.5181</td>
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<tr>
<td>DISPLACEMENT AT SEAL (IN)</td>
<td>0.0012</td>
<td>0.0009</td>
<td>0.0015</td>
<td>0.0011</td>
<td>&lt;0.0015</td>
</tr>
<tr>
<td>RADIAL SLOPE (%)</td>
<td>0.29</td>
<td>0.34</td>
<td>0.33</td>
<td>0.19</td>
<td>&lt;0.33</td>
</tr>
<tr>
<td>TANG. SLOPE (%)</td>
<td>0.002</td>
<td>0.001</td>
<td>0.032</td>
<td>0.1</td>
<td>&lt;0.032</td>
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<tr>
<td>STUD YIELD M.S.</td>
<td>0.03</td>
<td>0.073</td>
<td>0.022</td>
<td>0.096</td>
<td>&gt;0.022</td>
</tr>
<tr>
<td>FLANGE YIELD M.S.</td>
<td>1.3</td>
<td>1.21</td>
<td>2.19</td>
<td>0.33</td>
<td>&gt;2.19</td>
</tr>
<tr>
<td>BOSS YIELD M.S.</td>
<td>0.47</td>
<td>0.35</td>
<td>0.33</td>
<td>1.14</td>
<td>&gt;0.35</td>
</tr>
</tbody>
</table>

¹THOSE FLANGES O.K. BY SIMILARITY TO OTHER SIZED FLANGES
DEWAR ASSEMBLY STAND
PRELIMINARY DESIGN ANALYSIS

ST-50

• LOADED BY DEWAR MOUNTED TO STAND - DESIGNED TO SUPPORT 1591 KG (3500 LB) MAX DEWAR WEIGHT

• MAXIMUM ALLOWED DISTANCE FROM CG OF DEWAR TO PLANE OF BEARING ASSEMBLY = 152 MM (6 IN)

• SAFETY FACTORS
  – GSE GROUND HANDLING EQUIPMENT ULTIMATE SAFETY FACTOR
    » ULTIMATE = 3.0
    » YIELD = 2.5
  – LIFTING EQUIPMENT SAFETY FACTOR = 5.0

• MINIMUM MARGIN OF SAFETY = +0.07

• DOLLY MUST HAVE RING INSTALLED BEFORE LOADING TO PREVENT EXCESS SAG

• LAYOUT VERIFIED - DETAIL STRESS ANALYSIS STILL NEEDS TO BE PERFORMED
COMPOSITE NECK TUBE ANALYSIS

ST-51

- ORIGINAL ANALYSIS (SEE FLICOMP PDR) UPDATED TO REFLECT REVISED VCS DESIGN AND LAUNCH LOADS

- LOADS
  - EXTERNAL PRESSURE
  - LOCAL AXIAL AND SHEAR LOADS DUE TO VCS AND MLI
  - LATERAL LOAD FROM BELLOWS

- CNT IS BUCKLING CRITICAL IN TWO MODES, DEPENDING ON LOADING
  - GLOBAL BUCKLING DUE TO EXTERNAL PRESSURE
  - LOCAL BUCKLING OF COLDEST BAY DUE TO MECHANICAL LOADS

- APPROACH
  - ASSESS STRESS STATE AT WHICH BUCKLING IS MOST LIKELY TO OCCUR
    » DIFFERENT COMBINATIONS OF AXIAL AND SHEAR STRESS
    » USE STATISTICALLY-BASED KNOCKDOWN FACTORS BASED ON EXPERIMENTAL DATA
  - ASSESS THE STRESSES RESULTING FROM THE APPLIED LOADS
  - COMPARE
• PRESSURE LOADING AND FACTORS OF SAFETY HAVE NOT CHANGED SINCE ORIGINAL ANALYSIS; NO REVISED ANALYSIS NECESSARY

• FOR A 3σ PROBABILITY OF SUCCESS, THE MAXIMUM ALLOWABLE LATERAL BELLOWS FORCE IS 1957 N (440 LB) (PREDICTED FORCE = 1514.1 N (340.4 LB))

• AN ALLOWABLE BELLOWS LATERAL STIFFNESS OF 1751 N/MM (10,000 LB/IN) HAS BEEN ADOPTED, BASED ON A 2σ PROBABILITY OF SUCCESS
  – A 3σ CRITERIA RESULTS IN INCREASED NECK TUBE THICKNESS AND UNACCEPTABLE THERMAL LOSSES
  – A 100% PROBABILITY-OF-SUCCESS WILL BE DEMONSTRATED VIA STRUCTURAL TESTING
  – THIS APPROACH WAS USED WITH SUCCESS IN OTHER CRYOSTAT PROGRAMS (CLAES, SPIRIT III, ETC.)
  – ACTUAL PROBABILITY OF SUCCESS WILL BE HIGHER THAN 2σ BECAUSE PREDICTED DEWAR BELLOWS STIFFNESS < 876 N/MM (5000 LB/IN)

• DEVELOPMENT NECK TUBE HAS BEEN SUCCESSFULLY TESTED TO ULTIMATE LOADS
• ALL DEWAR STRUCTURE HAS BEEN ANALYZED AND ALL STRUCTURAL MARGINS ARE POSITIVE

• SOME DETAIL ANALYSIS STILL NEEDS TO BE COMPLETED

• NO SIGNIFICANT STRENGTH PROBLEMS ARE ANTICIPATED
THERMAL ANALYSIS

DEAN READ / JACK GOODMAN
SM PAYLOAD THERMAL ANALYSIS OBJECTIVES

- PREDICT HELIUM LIFETIME, HEAT RATE AND VENT RATE

- PREDICT DEWAR AND PROBE TEMPERATURES (BOTH STEADY STATE AND TRANSIENT) DURING PAYLOAD OPERATIONS
  - GROUND HOLD
  - LAUNCH
  - ORBIT

- PERFORM SENSITIVITY STUDIES

- EVALUATE IMPACT OF DESIGN CHANGES ON PERFORMANCE
- **SINDA** network analyzer computer code for thermal systems which can be represented in lumped parameter form

- Steady-state model for orbit and ground boundary conditions
  
  267 nodes and 521 conductors

- Transient model is a reduced node version of the steady state model
  
  110 nodes and 333 conductors

- Thermal model is mature and is representative of current hardware design
SM PAYLOAD
THERMAL MODEL

WARM END
(VACUUM SHELL)

-----------------Heat Flow Path-----------------

Dewar

COLD END
(SFHe TANK)

-----------------Heat Flow Path-----------------

Probe

SIA

DEWAR HEAT FLOW PATHS
MLI
PODS
FILL LINE
EMERGENCY VENT LINES
WIRES
AXIAL LOCK TUBES
NECKTUBE + LINER
VENT GAS COOLING

PROBE HEAT FLOW PATHS
NECKTUBE + LINER
FIBER OPTICS
PROBE WIRES
SIA CABLES/ WIRES
PRESSURE SENSE LINE
CAGING LINES
SPINUP/EXHAUST LINES
EXPECTED PERFORMANCE *

GUARD TANK

<table>
<thead>
<tr>
<th>HOLD TIME (DAYS)</th>
<th>BOIL OFF (mg/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.85</td>
<td>15.8</td>
</tr>
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</table>

* INCLUDES 30% MARGIN
TEMPERATURE RISE OF NON-VENTED MAIN TANK ON THE GROUND

(WITH GUARD TANK FILLED)
(INCLUDES 30% MARGIN)

Time, Days

Main Tank Temperature, K

0 50 100 150 200 250 300 350

1.55 1.60 1.65 1.70 1.75 1.80 1.85 1.90 1.95 2.00
TEMPERATURE RISE OF NON-VENTED MAIN TANK ON THE GROUND

(WITH GUARD TANK EMPTY)
(INCLUDES 30% MARGIN)

Time, Days
0 1 2 3 3.5 4 4.5 5

Main Tank Temperature, K
1.75 1.8 1.85 1.9 1.95 2

Lifetime Reduction, Months (Blowdown Main Tank to 1.8K on Orbit)
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
VACUUM SHELL DECREASES FROM 300 K TO 220 K IN 24 HOURS
GUARD TANK EMPTY AT LAUNCH (INCLUDES 30% MARGIN)
REFERENCE PERFORMANCE VALUES (INCLUDES 30% MARGIN*)

LIFETIME = 19.8 Months
VENT RATE = 6.48 mg/s
WARM BOUNDARY = 220K
COLD BOUNDARY = 1.8K

HEAT FLOW PATHS
(DOES NOT INCLUDE 30% MARGIN*)

<table>
<thead>
<tr>
<th>DEWAR</th>
<th>mW</th>
<th>%</th>
<th>PROBE C</th>
<th>mW</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>MLI</td>
<td>26.6</td>
<td>22.8</td>
<td>CABLES/WIRES</td>
<td>27.9</td>
<td>24.0</td>
</tr>
<tr>
<td>TITANIUM LINER</td>
<td>1.9</td>
<td>1.6</td>
<td>TITANIUM LINER</td>
<td>1.9</td>
<td>1.6</td>
</tr>
<tr>
<td>COMPOSITE NECK TUBE</td>
<td>12.2</td>
<td>10.4</td>
<td>COMPOSITE NECK TUBE</td>
<td>11.3</td>
<td>9.6</td>
</tr>
<tr>
<td>PODS, 12 ea.</td>
<td>7.8</td>
<td>6.7</td>
<td>CAGING LINES</td>
<td>0.0</td>
<td>0.0</td>
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<tr>
<td>AXIAL LOCK TUBE, 3 ea.</td>
<td>5.6</td>
<td>4.8</td>
<td>EXHAUST LINES</td>
<td>3.1</td>
<td>2.6</td>
</tr>
<tr>
<td>FILL LINE</td>
<td>1.1</td>
<td>0.9</td>
<td>SIA SUPPORT TUBE</td>
<td>3.0</td>
<td>2.6</td>
</tr>
<tr>
<td>WIRES</td>
<td>6.8</td>
<td>5.8</td>
<td>SPINUP LINES</td>
<td>1.2</td>
<td>1.0</td>
</tr>
<tr>
<td>VENT GAS</td>
<td>-0.3</td>
<td>0.0</td>
<td>FIBER OPTICS</td>
<td>0.9</td>
<td>0.7</td>
</tr>
<tr>
<td>SFHe TANK EMG VENT LINES</td>
<td>5.5</td>
<td>4.8</td>
<td></td>
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</tr>
</tbody>
</table>

DEWAR TOTAL 67.2 57.7
PROBE TOTAL 49.3 42.3

*30% BASED ON MEASURED VS. PREDICTED LIFETIME PERFORMANCES ON OTHER DEWAR PROGRAMS
IMPACT OF FLUX FLUSHING ON MAIN TANK VENT RATE AND TEMPERATURE (QBS HEATER = 600 mW)

Time, Hours

Main Tank Rate, mg/sec

Main Tank Temperature, K

0 1 2 3 4

0 1 2 3 4
THERMAL ANALYSIS
SUMMARY

• STEADY STATE THERMAL MODEL IS UP TO DATE WITH CURRENT DESIGN

• TRANSIENT THERMAL MODEL IS BEING USED TO EVALUATE DEWAR AND PROBE OPERATIONS

• DESIGN CHANGES/TRADE STUDIES ARE EASILY INCORPORATED INTO MODEL

• THERMAL PERFORMANCE CRITERIA ARE MET WITH A HIGH DEGREE OF CONFIDENCE IN RESULTS
  • REQUIREMENTS:
    LIFETIME > 16.5 MONTHS (19.8 PREDICTED)
    VENT RATE = 4-16 mg/sec (6.48 NOMINAL)
EMERGENCY VENT ANALYSIS

DEAN READ / JACK GOODMAN
EMERGENCY VENTING ANALYSIS
OBJECTIVE

ANALYZE THE FOLLOWING VENTING SCENARIOS AND SIZE APPROPRIATE BURST DISKS AND FLOW LINES SO THAT SAFE PRESSURES ARE MAINTAINED DURING EMERGENCY VENTING

(1) MAIN TANK
   • SEAL LEAKAGE/CATASTROPHIC LOSS OF WELL OR DEWAR GUARD VACUUM

(2) GUARD TANK
   • SEAL LEAKAGE/CATASTROPHIC LOSS OF DEWAR GUARD VACUUM

(3) VACUUM SHELL
   • LEAKAGE/FAILURE OF MAIN OR GUARD TANK PLUMBING DURING CATASTROPHIC EVENT
   • BURST OF GUARD TANK BURST DISK
• DEVELOP VENTING MODEL BASED ON CONSERVATION OF MASS AND ENERGY IN THE TANKS COUPLED WITH PRESSURE DROP IN THE FLOW PATH

• USE MODEL TO PERFORM TRADE STUDIES WITH THE VARIOUS INITIAL AND BOUNDARY CONDITIONS TO CALCULATE PRESSURE HISTORIES AND DETERMINE MAXIMUM PRESSURES

• MAXIMUM ALLOWABLE DIFFERENTIAL PRESSURE:
  SFHe TANK = 0.26 MPa (38 psi)
  GUARD TANK = 0.38 MPa (55 psi)
  VACUUM SHELL = 0.055 MPa (8 psi)

• DESIGN APPROACH
  SFHe TANK
  • REDUNDANT FLOW PATHS EACH CONSISTING OF COLD BURST DISK CONNECTED TO WARM BURST DISK BY INFLATABLE VENT LINE

  GUARD TANK
  • SIZE NORMAL VENT LINE FOR EMERGENCY FLOW
  • ADD COLD BURST WHICH PROVIDES REDUNDANT FLOW PATH

  VACUUM SHELL
  • REDUNDANT BURST DISKS
• MASS AND ENERGY BALANCE ON CONTROL VOLUME (TANK) GIVES RELATIONSHIP FOR DENSITY AND ENERGY CHANGE IN TIME. THESE TWO VARIABLES ARE USED WITH THERMODYNAMIC TABLES TO DETERMINE PRESSURE AND TEMPERATURE HISTORIES.

\[
dm = -m \, dt
\]

\[
du = \frac{1}{m} \left[ Q - m(h - u) \right] \, dt
\]

\[
m_{i+1} = m_i + dm
\]

\[
u_{i+1} = u_i + du
\]
- MASS FLOWRATE IS DETERMINED BY PRESSURE DIFFERENCE ACROSS THE BURST DISK (ASSUMED AN ORIFICE WITH A DISCHARGE COEFFICIENT) OR VENT LINE
  - VAPOR FLOW ———> COMPRESSIBLE; ISENTROPIC OR FANNO
  - LIQUID FLOW ———> INCOMPRESSIBLE; BERNOULLI EQUATION
  - TWO-PHASE ———> VAPOR

- INITIAL/BOUNDARY CONDITIONS:
  TANK VOLUME AND SURFACE AREA
  FLOW PATH GEOMETRY
  BURST DISK DIAMETER
  INITIAL ULLAGE
  AIR CONDENSATION HEAT RATE
  START TIME IS WHEN TANK REACHES DISK BURST PRESSURE
• REDUNDANT FLOW PATHS; EACH FLOW PATH HAS A BURST DISK ON THE TANK AND ON THE VACUUM SHELL, CONNECTED WITH A 2" VENT LINE

• FLOW IS FROM TANK THOROUGH EMERGENCY VENT LINE; COMPLETE FLOW PATH INCLUDES RELIEF VALVE AND GSE VENT LINE

• CONDENSATION HEAT RATE IS A FUNCTION OF THERMODYNAMIC STATE IN TANK
  – LIQUID = 1.5 W/cm²
  – VAPOR OR SUPERCRITICAL = 0.5 W/cm²
  – TWO-PHASE = AVERAGED, BASED ON VOID FRACTION
VENTING OF SFHe TANK THROUGH EMERGENCY VENT LINE

BURST PRESSURE = 0.262 MPa (38 psid)
BACK PRESSURE = 0.021 MPa (3 psid)
LINE DIAMETER = 5.08 cm (2")

Diagram with time (s) on the x-axis and differential pressure (MPa) on the y-axis, showing different curves for initial fill percentages (90%, 50%, 10%) and a dashed line for maximum allowable pressure.
EMERGENCY VENTING OF
GUARD TANK

- NORMAL VENT LINE ALSO SERVES AS EMERGENCY VENT LINE
  - EMERGENCY VENTING SIZES LINE DIAMETER

- SECONDARY FLOW PATH FOR EMERGENCY VENTING IS THROUGH BURST DISK (0.46") ON TANK AND BURST DISK (2") ON VACUUM SHELL
INITIAL PRESSURE = 0.0017 MPa (0.25 psid)
BACK PRESSURE = 0.0017 MPa (0.25 psid)
VENT LINE DIAMETER = 1.90 CM (0.75")
EMERGENCY VENTING OF GUARD TANK THROUGH BURST DISK (BD-4)

TANK BURST DISK PRESSURE = 0.372 MPa (54 psid)
BURST DISK DIAMETER = 1.17 cm (0.46"")
VACUUM SHELL BURST DISK PRESSURE = 0.028 MPa (4 psid)
BURST DISK DIAMETER = 5.08 cm (2"")
# EMERGENCY VENTING SUMMARY

## Differential Pressures MPa (PSI)

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<thead>
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<th></th>
<th>Calculated</th>
<th>Requirement</th>
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</thead>
<tbody>
<tr>
<td><strong>Main Tank</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loss of Guard Vacuum</td>
<td>0.26 (38)</td>
<td>0.26 (38)</td>
</tr>
<tr>
<td><strong>Guard</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal Vent Line</td>
<td>0.27 (38.9)</td>
<td>0.38 (55)</td>
</tr>
<tr>
<td>Burst of BD-2</td>
<td>0.39 (56.0)</td>
<td>0.38 (55)</td>
</tr>
<tr>
<td><strong>Vacuum Shell</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BD-2 Burst Only</td>
<td>0.028 (4.0)</td>
<td>0.055 (8)</td>
</tr>
<tr>
<td>BD-2 Burst with Leakage from EV Line</td>
<td>TBD</td>
<td>0.055 (8)</td>
</tr>
<tr>
<td><strong>Dewar Well</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loss of Dewar Guard Vac W/O Probe</td>
<td>&lt;0.17 (24.7)</td>
<td>0.23 (34)</td>
</tr>
<tr>
<td>Loss of Probe Vacuum</td>
<td>0.13 (18.9)</td>
<td>0.23 (34)</td>
</tr>
</tbody>
</table>
EMERGENCY VENTING
CONCLUSIONS

- MAIN TANK; MAXIMUM ALLOWABLE PRESSURE = 0.26 MPa (38 PSID)
  - SINGLE 2" VENT LINE IS SUFFICIENT TO MEET THE MAXIMUM
    ALLOWABLE PRESSURE REQUIREMENT (LINES ARE REDUNDANT FOR
    RELIABILITY)

- GUARD TANK; MAXIMUM ALLOWABLE PRESSURE = 0.38 MPa (55 PSID)
  - THE 0.75" NORMAL VENT LINE MEETS THE MAXIMUM ALLOWABLE
    PRESSURE REQUIREMENT
  - VENTING THROUGH THE REDUNDANT FLOW PATH EXCEEDS THE
    MAXIMUM ALLOWABLE PRESSURE REQUIREMENT BY 1 PSID
    (GUARD TANK STILL HAS A POSITIVE STRESS MARGIN)

- VACUUM SHELL; MAXIMUM ALLOWABLE PRESSURE = 0.055 MPa (8 PSID)
  - SINGLE BURST DISK IS SUFFICIENT TO MEET THE MAXIMUM
    ALLOWABLE PRESSURE REQUIREMENT (BURST DISKS ARE
    REDUNDANT FOR RELIABILITY)
HELIUM CENTER OF MASS AND SLOSH CONTROL

DAVID FRANK
• SPACECRAFT WILL BE ROLLING BETWEEN 0.1 AND 0.5 RPM
• SPACECRAFT WILL BE IN A DRAG-FREE MODE OF OPERATION
• OFFSET IS THE DISPLACEMENT OF THE CENTER OF MASS LOCATION FROM THE POINT OF SYMMETRY OF THE TANK
CENTRIFUGAL FORCES

WEBER # (CENTRIFUGAL/CAPILLARY)

- MAXIMUM GRAVITY GRADIENT FORCE IS LESS THAN 2E-07 g₀
THE ANALYTICAL TOOLS ARE CLOSED FORM SOLUTIONS TO THE LIQUID/VAPOR INTERFACE AND A COMPUTATIONAL FLUID DYNAMIC (CFD) CODE

THE CLOSED FORM SOLUTIONS:
- PERFORMED TWO DIMENSIONAL QUASI-STATIC CALCULATIONS USING SOLUTIONS TO THE LIQUID/VAPOR INTERFACE EQUATION
- PERFORMED 3D QUASI-STATIC CALCULATIONS USING SURFACE EVOLVER TO ANALYZE THE INITIAL CONFIGURATION OF THE ULLAGE

THE CFD CODE:
- UTILIZING CFD CODE FLOW 3D WITH MODIFICATIONS PERFORMED BY LMSC AND FLOW SCIENCE
- PERFORMED TWO AND THREE DIMENSIONAL TRANSIENT AND QUASI-STATIC CALCULATIONS
- DETERMINED TRANSIENT EFFECTS DUE TO GRAVITY/ACCELERATION FIELD CHANGES
- COMPUTED FORCES AND RESPONSES TO INPUT DISTURBANCES
ULLAGE PROFILES AT ZERO RPM

- THE FOLLOWING SHOWS THE ULLAGE PROFILE FOR THE 95 AND 83% FULL TANK AT ZERO RPM
  - THE RADIAL OFFSET FOR 95% IS 2.3 CM, AND APPROXIMATELY 8.2 CM AT 83% (STEADY STATE USAGE IS 6%/MONTH)
• SPIN-UP FOR A ROLL RATE OF 0.4 RPM WITHOUT ANY GRAVITATIONAL FIELD COMPUTED WITH THE 3D CFD CODE
• COMPUTED THE INITIAL ROLL RATE REQUIRED FOR A 95% FULL TANK TO ACHIEVE AXISYMMETRIC PROFILE WITHOUT ANY GRAVITATIONAL FIELD USING THE CFD CODE

0.6 rpm  0.5 rpm  0.4 rpm  0.2 rpm

• THE RESULTS SHOW THAT A ROLL RATE OF 0.5 - 0.6 RPM IS REQUIRED TO ACHIEVE AN AXISYMMETRIC CONFIGURATION
- SURFACE EVOLVER CODE WAS UTILIZED TO ANALYZE THE ROLL RATE DEPENDENCY ON ACHIEVING AN AXISYMMETRIC PROFILE
  - THE ROLL RATE TO ACHIEVE AN AXISYMMETRIC PROFILE WAS CALCULATED
  - THE LOWER STABILITY LIMIT OF THE AXISYMMETRIC PROFILE WAS CALCULATED
  - RESULTS SHOW THAT ONCE AN AXISYMMETRIC PROFILE WAS ACHIEVED, THE ROLL RATE COULD BE LOWERED TO 0.15 RPM
SCALE MODEL SPIN TESTING

- SCALE MODEL SPIN TESTS ARE BEING PERFORMED IN 1-G TO VERIFY THE PREDICTIONS BY THE SURFACE EVOLVER CODE ON THE LOWER STABILITY OF THE AXISYMMETRIC ULLAGE
  - TESTS WERE PERFORMED BY THE SCHOOL OF AERONAUTICS & ASTRONAUTICS OF PURDUE UNIVERSITY UNDER THE SUPERVISION OF PROF. STEVEN COLLICOTT
  - TESTS WERE DONE WITH STORABLE FLUIDS (WATER & AIR)

- MODEL DESIGNS ARE BASED ON THE RELEVANT SCALING LAWS
  - WEBER NUMBER IS MATCHED
  - BOND NUMBER IS MINIMIZED
  - FROUDE NUMBER IS MAXIMIZED

- IDEAL MODE, AS FAR AS MATCHING BOND AND FROUDE NUMBERS IS CONCERNED, ARE INFINITELY SMALL, SPINNING INFINITELY FAST.
  - THUS MODELS ARE INHERENTLY A COMPROMISE

- SURFACE EVOLVER IS ADAPTED TO SIMULATE THE 1-G SPIN TESTS
Thick 1-g Test Model

- 1/27 scale model.
- Orbital Weber number range is matched.
- Stroboscopic video data acquisition.
- Glass and acrylic to contain water and air.
• TWO EXPERIMENTAL MODELS WERE BUILT AND TESTED OVER A WIDE RANGE OF GPB FILL LEVELS AND SPIN RATES
  – "THIN MODEL" - EXAMINE BALANCE OF CENTRIFUGAL AND CAPILLARY FORCES WHEN GRAVITY IS NEGLIGIBLE
  – "THICK MODEL" - EXAMINE BALANCE OF CENTRIFUGAL AND CAPILLARY FORCES WHEN GRAVITY IS NOT NEGLIGIBLE
• SURFACE EVOLVER PREDICTIONS FOR BOTH MODELS SHOWED THAT THE AXISYMMETRIC SHAPE WAS STABLE DOWN TO ZERO RPM.
  – THUS THESE 1g₀ TESTS COULD NOT MODEL A LOWER STABILITY FOR A NON-ZERO SPIN RATE
• THE HYSTERESIS PREDICTED BY SURFACE EVOLVER WAS VERIFIED BY THE EXPERIMENTAL DATA
  – STABLE AS THE SPIN RATE WAS REDUCED ALL THE WAY DOWN TO NO SPIN AT ALL
• OVER THE RANGE OF FILL LEVELS AND SPIN RATES, THE ULLAGE SHAPE AND TRENDS BETWEEN EXPERIMENT AND SIMULATIONS WERE GOOD
- Gravity gradients are such that an ullage that is only in contact with the inner wall can be pushed into different axial positions
  - This will cause center of mass displacements
- The following figure shows the profile of a 5% ullage transitioning from 0.1 to 1.0 RPM
- Determined steady state profiles with both 2D and 3D CFD code.
- Figure shows results for \( W = 0.1 \) RPM at various fill levels.
  - Approximate roll rate required to flatten the liquid/vapor interface sufficiently such that the ullage stretches the length of the tank:
    - \( > 0.5 \) RPM for 95% fill, \( 0.3 \) RPM for 83% fill, \( 0.2 \) RPM for 72% fill, \( 0.1 \) RPM for 52% fill.
UNBAFFLED TANK PERFORMANCE

- THE FOLLOWING CHART SHOWS THE AXIAL DRIFT OF THE CENTER OF MASS ABOUT THE POINT OF SYMMETRY OF THE TANK
  - RESULTS SHOW THE MAXIMUM DRIFT OF THE CENTER OF MASS IS APPROXIMATELY +/- 6.7 CM WHICH OCCURS WHEN THE TANK IS APPROXIMATELY 80% FULL AT 0.1 RPM

- THE PERFORMANCE OF AN UNBAFFLED TANK MEETS THE AXIAL DISPLACEMENT REQUIREMENTS
• NO BAFFLES ARE REQUIRED TO CONTROL THE FLUID CENTER OF MASS

• SOME OPERATIONAL CONSTRAINTS ARE IMPOSED IN THE EARLY PORTION OF THE MISSION:
  – THE FLUID MUST BE SPUN UP TO APPROXIMATELY 1 RPM PRIOR TO OPERATING IN A DRAG FREE MODE
    » HIGH ROLL RATE MUST BE MAINTAINED LONG ENOUGH TO GET THE FLUID AND TANK ROTATING AS A SOLID BODY
    » THIS IS TO POSITION THE FLUID IN AN AXISYMMETRIC CONFIGURATION

  – THE ROLL RATE CAN THEN BE LOWERED TO A MINIMUM ROLL RATE DEPENDING ON THE FILL LEVEL
    » THIS PERFORMANCE IS BASED ON THE LOWER STABILITY OF THE AXISYMMETRIC PROFILE
    » MINIMUM ROLL RATE OF 0.14 RPM IS REQUIRED WHEN THE TANK IS 95% FULL
    » THE MINIMUM ROLL RATE DECREASES AS THE FLUID IS DEPLETED (I.E. 0.1 RPM AT 91%)
DYNAMIC FLUID MOTION

- A study was performed to select a configuration that would dampen fluid motion in the tank
  - There were no specific requirements at the time of this study

- Parallel and radial baffle configurations were studied
  - Candidate designs were such that they would not interfere with an ullage whose liquid/vapor interface had not stretched the entire length of the tank

- Based on this study a configuration with four radial and three parallel baffles was selected

- The 3D CFD code was run to determine the fluid displacement and forces due to an impulse disturbance
  - Data was generated for use by the spacecraft control model
THE 3D MODEL WAS USED TO DETERMINE THE FLUID MOTION DUE TO A DISTURBANCE (0.01 g₀ FOR 10 ms) IN THE AXIAL DIRECTION.

FIGURES SHOW THE RESULTS FOR THE BAFFLED AND UNBAFFLED TANK WITH 60% REMAINING AT 0.1 RPM.

- BAFFLES PROVIDE GOOD DAMPING OF THE FLUID MOTION.
LATERAL FLUID MOTION

- The 3D model was used to determine the fluid motion due to a disturbance (0.01 g0 for 10 ms) in the lateral direction.

- Figures show the results for the baffled and un baffled tank with 60% remaining at 0.1 RPM.

  - Results are shown in body-fixed coordinates.
  - Baffles provide good damping of the fluid motion.
TANKS AND SUBASSEMBLIES

RICHARD PARMLEY
HARDWARE DISCUSSED
IN THIS SECTION

- MAIN TANK AND WELL
- MAIN TANK SUBASSEMBLIES
  - AXIAL LOK
  - CRYOPERM SHIELD
  - PROTON SHIELD
- LEAD BAG AND RETAINER
- GUARD TANK
 MAIN TANK AND SUBASSEMBLIES

- FUNCTIONS
- REQUIREMENTS
- DESIGN DESCRIPTION
- RISKS AND RISKS REDUCTION
- STATUS
MAIN TANK FUNCTIONS AND VERIFICATION

FUNCTIONS:
1) CONTAIN He II FOR SIA COOLING AND USE OF BOILOFF IN SPACECRAFT PROPORTIONAL THRUSTERS
2) PROVIDE WELL, STA 200 AND AXIAL LOK FOR PROBE SUPPORT, COOLING
3) PROVIDE LOW MAGNETIC FIELDS FOR SIA USING CRYOPERM SHIELD AND EXPANDED LEAD BAG
4) PROVIDE PROTON SHIELDING FOR SIA
5) PROVIDE CENTER OF MASS CONTROL (COM) OF He II

VERIFICATION:
1) PROOF PRESSURE TEST, WARM
2) LEAK TESTS, WARM AND COLD
3) AXIAL LOK FUNCTIONAL TEST
4) INSTRUMENTATION C/O
5) WELL MAGNETIC MAPPING, WARM
6) PROTON SHIELDING BY ANALYSIS
7) COM CONTROL BY ANALYSIS
<table>
<thead>
<tr>
<th>ITEM</th>
<th>REQUIREMENT</th>
<th>MEETS REQMT</th>
<th>VERIFICATION</th>
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<td>HELIUM LEAK RATE</td>
<td>&lt; 1 X 10^-8 SCC/S</td>
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<td>BY DESIGN</td>
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<tr>
<td>TANK MAX OPERATING PRESSURE</td>
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<tr>
<td>INTERNAL</td>
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<td>LATERAL</td>
<td>6.0 g</td>
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<tr>
<td></td>
<td>-INSTRUMENTATION</td>
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</table>
MAIN TANK DESIGN

MAXIMUM PRESSURE, MPa
- OPERATING .26
- PROOF .39

OPERATING TEMPERATURE, K 1.8

MAXIMUM LEAK RATE, <10^-8 cc/s STP GHe
MAIN TANK VOLUME (LITERS)

AT TEMPERATURE = 1.8 K

MAIN TANK, COLD  2471.9
CRYOPERM SHIELD  - 1.7
PROTON SHIELD    - 20.7
BAFFLES          - 3.3
PLUMBING, INSTRUMENTATION  - 5.0
USABLE VOLUME    2441.2
    - LIQUID  2319.1 (337 kg)
    - GAS  122.1 (5%)
CRYOPERM SHIELD DESIGN

RQMT AT SIA, STEADY STATE
\[ \leq 3 \times 10^{-5} \text{Tesla} \]

ATTENUATION FACTOR RQMT
\[ \leq 5 \times 10^{-2} \text{ T, LONG} \]
\[ \leq 5 \times 10^{-3} \text{ T, TRANS} \]

MATERIAL
SHIELD: CRYOPERM 10
PIN: \( \mu \)-METAL
PROTON SHIELD DESIGN

MATERIAL
6063 AL

SHIELDING DIMENSIONS
CALCULATED BASED ON PROTON ENVIRONMENT
AXIAL LOK MECHANISM

FUNCTIONS
- CLAMPS PROBE AT STA 200
- BREAK PROBE LOOSE, IF REQ'D. FOR REMOVAL
- EXPANDS PROBE BELLOWS AND COMPRESSIONS 24 PROBE THERMAL SHOES DURING PROBE INSERTION

VERIFICATION
- EDD / PROBE-A TESTS
- FLIGHT VERSION IN DEV.TEST (SECTION DT)

CHANGES SINCE PDR
- THREAD PITCH FROM 1/24 TO 1/40
- TEFLOM SEALS, 2 PLACES
- 2 µ FILTERS
- MATERIAL CHANGES (MAGNETIC REASONS)
  - BALL LOCKING CONE: 304 L TO BeCu #25
  - BALL BEARING: 440 CRES TO Ti 6AL-4V
- EVACUATION, PURGE OF PLUMBING/TANKS
- FILL OF MAIN TANK WITH He I OR He II
- DRAIN OF MAIN TANK
- FILL OF GUARD TANK WITH He I
- EMPTYING GUARD TANK WITH HEATERS
- COOLDOWN OF BYPASS FILL LINE
- FILL OF WELL WITH He I AT < 6.5 K FROM EXTERNAL SOURCE OR MAIN TANK
- FILL OF WELL WITH 12 TORR GHe OR He II (IF REQUIRED)
- VENTING OF TANKS, LINES TO SPACE
- OVERPRESSURE PROTECTION FOR ALL CLOSED VOLUMES
RISKS

- WAFFLE DOMES ARE COMPLICATED MACHININGS
- HIGH COST/SCHEDULE IMPACT IF FINAL WELDS NOT SATISFACTORY
- LEAKAGE OF ELECTRICAL FEEDTHRUS
- LEAKAGE OF HELICOFLEX SEALS FOR PP AND FEP

RISK REDUCTION

- C/O NC PROGRAM ON PLASTIC OR LOWER COST CASTING (DUPLICATES ORDERED)
- WELD DEVELOPMENT ON ALL WELDS, LEAK CHECKS, BONDED DOUBLER
- THERMALLY CYCLE TO 77 K AND LEAK CHECK FEEDTHRUS PRIOR TO INSTALLATION (REF DEV. TEST SECTION)
- HELICOFLEX SEAL QUALIFIED (SEE SECTION DT)
MAIN TANK STATUS

- DETAILED DWG'S. COMPLETE
- CHEMTRONICS SELECTED TO BUILD TANK
- CRYOPERM SHIELD ON ORDER (VACUUMSCHMELZE)
- FORGINGS
  - RECEIVED
    » FORWARD DOME
    » AXIAL LOK RING
    » WELL CYLINDER
    » WELL HEMISPHERE
  - ON ORDER
    » AFT DOME
    » CYLINDER
    » PROTON SHIELD
- MACHINING IN PROGRESS
  - AXIAL LOK RING
  - FORWARD DOME
  - WELL CYLINDER
LEAD BAG AND RETAINER

- FUNCTIONS, REQUIREMENTS
- PERFORMANCE
- DESIGN
- STATUS
LEAD BAG AND RETAINER
FUNCTIONS, REQUIREMENTS

• LEAD BAG
  - ESTABLISH AND MAINTAIN MAGNETICALLY SHIELDED
    REGION OF $< 1 \times 10^{-7}$ GAUSS FOR SIA IN DEWAR WELL
  - LOW FIELD ESTABLISHED THROUGH SEQUENTIAL EXPANSION
    OF SUPERCONDUCTING LEAD FOIL BAGS

• LEAD BAG RETAINER
  - PROBE CENTERING DURING INSERTION
  - ENSURE THERMAL CONTACT BETWEEN
    BAG AND WELL
  - PREVENT BAG FROM FALLING DOWN
    INTO WELL ON ASCENT
  - SUPPORT CANTILEVERED PROBE
    DURING ASCENT
  - PROBE INSERTION FRICTION
    FORCE $< 318 \text{ KG} \ (<700 \text{ LB})$
  - INTERFACE: INSERTS AT STA 200

• GSE: ALL EXISTING EQUIPMENT
LEAD BAG AND RETAINER PERFORMANCE

- AFTER INSTALLATION OF RETAINER INTO EDD, LEAD BAG MAGNETIC FIELD INCREASED FROM $1 \times 10^{-7}$ TO $4 \times 10^{-6}$ GAUSS
  - Be Cu SHEET MATERIAL THE PROBLEM
  - COUPONS PASS CRYO SCREENING, ASSEMBLY PASSES R.T. SCREENING
  - BOTTOM 35" OF SPRINGS CUT OFF AS TEMPORARY FIX FOR EDD ONLY
  - BRUSH ALLOY 199 SUBSTITUTED FOR BeCu FOR NEW RETAINER
- SURVIVAL OF LEAD BAG IN VIBRATION ENVIRONMENTS
  - PRELIMINARY ANALYSES SHOW LEAD BAG HEATING ( > 6.5 K) DURING LAUNCH MAY BE A PROBLEM
  - CONSEQUENTLY THE SMD PLUMBING WAS MODIFIED TO ALLOW EITHER GHe OR He II FILL OF THE WELL JUST PRIOR TO LAUNCH, TO FACILITATE HEAT TRANSFER
- GROUND VIBRATION TESTS OF PROBE-B IN SMD WILL DETERMINE WHETHER VACUUM OR He II IS USED DURING LAUNCH. ALSO WILL EVALUATE MECHANICAL DAMAGE.
# Material Substitution for Lead Bag Retainer Springs (Due to Unsatisfactory Magnetic Properties)

<table>
<thead>
<tr>
<th></th>
<th>Beryllium</th>
<th>Copper</th>
<th>Substitute Material</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Current Material</td>
<td>Binary*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>UNSC - 17200</td>
<td>Uns C19900</td>
<td>Brush Alloy 199</td>
</tr>
<tr>
<td><strong>Chemical Composition, %</strong></td>
<td>Be 1.82 Co 0.20 Ni 0.06 Fe 0.07 Cu BAL</td>
<td>Be 1.8 Cu BAL</td>
<td>Ti 3.0 Cu BAL Balance, 1/4 HT</td>
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<tr>
<td><strong>Test Conditions: 2K, 100G</strong></td>
<td>Sample Size, g: 6.1 x 10^-7</td>
<td>Remanent Moment, emu: 4.9 x 10^-7</td>
<td>Mass Susceptibility: 7.0 x 10^-8</td>
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<tr>
<td></td>
<td>Susceptibility, emu/G: NO</td>
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<td>Approved for Use (J. Lockhart) YES</td>
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<tr>
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<td>Modulus, 10^8 psi: 18.5</td>
<td>Yield Strength, ksi: 70</td>
<td>Tensile Strength, ksi: 80</td>
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<tr>
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<td>Tensile Strength, ksi: 107</td>
<td>Thermal Cond, w/mK: 18</td>
<td>Density, lb/in^3: 69</td>
</tr>
<tr>
<td></td>
<td>Density, lb/in^3: 0.298</td>
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</tbody>
</table>

* BINARY BERYLLIUM COPPER ALLOY WITHOUT Co, Ni, Fe HAS LARGE, HARD TO CONTROL GRAIN SIZES. SPECIAL MILL RUN REQUIRED.
ASSEMBLY DRAWING
LEAD BAG RETAINER

STANFORD
Lockheed
LMSC-P088357
2,3 MAR 94

TK - 18

CHANGES SINCE PDR
MATERIAL: BeCu to TiCu
EXTENSION OF SPRINGS TO BOTTOM OF WELL
LEAD BAG AND RETAINER STATUS

- MAGNETIC FIELD OF 1 X 10E-7 GAUSS ACHIEVED IN EDD
- FEWER EXPANSIONS REQUIRED THAN EXPECTED
- RETAINER IS PERFORMING ITS PROBE CENTERING FUNCTION WELL IN EDD
- GSE & INSTALLATION PROCEDURES HIGHLY DEVELOPED
- NEW RETAINER TO BE AVAILABLE BY JUNE 1994
GUARD TANK

- FUNCTIONS
- REQUIREMENTS
- DESIGN DESCRIPTION
- RISKS AND RISKS REDUCTION
- STATUS
GUARD TANK FUNCTIONS AND VERIFICATION

FUNCTIONS:
1) ALLOWS MAIN TANK TO BE SERVICED AWAY FROM THE LAUNCH PAD AND LEFT NONVENTED FOR UP TO 90 DAYS PRIOR TO LAUNCH
2) ALLOWS FOR UP TO TWO LAUNCH ABORTS PLUS LAUNCH SEPARATED BY 24 HOUR INTERVALS WITHOUT ANY SERVICING REQUIRED ON THE LAUNCH PAD
3) REQUIRES REFILLING ONCE A WEEK WITH He I (4.2 K, 1 ATM)

VERIFICATION:
1) PROOF PRESSURE TEST, WARM
2) VACUUM LOAD TEST (1 ATM ΔP)
3) LEAK TESTS, WARM AND COLD
4) INSTRUMENTATION C/O
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<td>TANK MAX OPERATING PRESSURE *</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>INTERNAL</td>
<td>0.38 MPa (55 PSID)</td>
<td>√</td>
<td>ANALYSIS</td>
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<tr>
<td>EXTERNAL</td>
<td>0.13 MPa (19 PSID)</td>
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<tr>
<td>TANK DESIGN LOADS</td>
<td></td>
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<tr>
<td>LATERAL</td>
<td>5.2 g</td>
<td>√</td>
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<td>AXIAL</td>
<td>6.3 g</td>
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<tr>
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<td>-ELECTRICAL</td>
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* CHANGED FROM PDR
GUARD TANK
(TANK 2219 AL, SUPPORT CYL/CONE 6063 AL)

TANK VOL, LITERS
- WARM 98.8
- COLD 97.6

MAX PRESS*, MPa
- OPERATING .38
- PROOF .57

OPERATING TEMP,K
4.2

MAX LEAK <10^-8
RATE*, cc/s STP GHe

* CHANGED FROM PDR
GUARD TANK
PLUMBING FUNCTIONS

- EVACUATION, PURGE OF PLUMBING/TANKS
- FILL OF MAIN TANK WITH He I OR He II
- DRAIN OF MAIN TANK
- FILL OF GUARD TANK WITH He I
- EMPTYING GUARD TANK WITH HEATERS
- COOLDOWN OF BYPASS FILL LINE
- FILL OF WELL WITH He I AT < 6.5 K FROM EXTERNAL SOURCE OR MAIN TANK
- FILL OF WELL WITH 12 TORR GHe OR He II (IF REQUIRED)
- VENTING OF TANKS, LINES TO SPACE
- OVERPRESSURE PROTECTION FOR ALL CLOSED VOLUMES
GUARD TANK RISKS AND RISK REDUCTION

RISK

• LEAKAGE OF SEALS

• LEAKAGE OF WELD

RISK REDUCTION

• THERMALLY CYCLE TO 77 K, LEAK TEST FEED THRU* AND SEALS*

• WELD DEVELOPMENT, BONDED DOUBLER

* SEALS HAVE PASSED THERMAL CYCLING, LEAK TEST; ELECTRICAL FEEDTHRU TESTS ARE SCHEDULED (REF DEV TEST SECTION)
GUARD TANK STATUS

- FINAL DESIGN COMPLETE
- FORGINGS ON ORDER
- FABRICATION TO START IN APRIL 94
THERMAL PROTECTION SYSTEM

RICHARD PARMLEY
MULTILAYER INSULATION,
VAPOR COOLED SHIELDS

- MULTILAYER INSULATION
  - FUNCTIONS
  - DESIGN
  - CUTTING PATTERNS
- VAPOR COOLED SHIELDS
  - FUNCTIONS
  - DESIGN
- RISK / RISK REDUCTIONS
- STATUS
MULTILAYER INSULATION

FUNCTION: REDUCE PARASITIC RADIATION HEAT LOAD TO HELIUM, INCREASE DEWAR LIFETIME

LIFETIME VERIFICATION PLAN: BOILOFF RATE MEASUREMENTS

SMD: $T_H = 300K$ (LAB)
    $T_H = 220$ (THERMAL VAC)
# SM Multilayer Insulation Design

**Radiation Shield**
15 Layers / cm (37 Layers/in)

1/4 Mil Aluminized Mylar
(3 Mil Aluminized Mylar, Access Cover Region)

**Low Conductance Spacer**
Swiss Silk Net
(Un-Sized)

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<th>UNIT WEIGHT, kg/m² (PSF)</th>
<th>1/4 MIL</th>
<th>3 MIL</th>
<th>NO</th>
<th>AVE. AREA, m²</th>
<th>WT, kg/lb</th>
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<th>AVE. AREA, m²</th>
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<td>0.00903 (0.00185)</td>
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<td>7</td>
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<td>18 (3 ea)</td>
<td>9.7 (104)</td>
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<td>0.107 (0.022)</td>
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<td>14</td>
<td>11.8 (127)</td>
<td>1.8 (3.9)</td>
<td>39 (3 ea)</td>
<td>11.8 (127)</td>
<td>4.2 (9.2)</td>
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<td>21</td>
<td>12.6 (136)</td>
<td>2.9 (6.3)</td>
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<td>4.1 (9.1)</td>
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<td>15.6 (168)</td>
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<td>113</td>
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<td>16.6 (36.9)</td>
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<td>166</td>
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<td>19.6 (43.3)</td>
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<table>
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<tr>
<th>VCS GAP cm (in)</th>
<th>MIL THICKNESS, cm (in)</th>
<th>RADIATION GAP (WARM SIDE), cm (in)</th>
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<td>TANK-VCS1*</td>
<td>1.02 (.40)</td>
<td>.48 (.19)</td>
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<tr>
<td>VCS1-VCS2*</td>
<td>1.65 (.65)</td>
<td>.96 (.38)</td>
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<td>VCS2-VCS3*</td>
<td>2.29 (.90)</td>
<td>1.45 (.57)</td>
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<td>VCS3-VCS4*</td>
<td>3.18 (1.25)</td>
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<td>VCS4-AFT DOME*</td>
<td>4.57 (1.80)</td>
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<td>7.77 (3.06)</td>
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*Each blanket electrically grounded from inner shield to outer shield with taped single aluminized Mylar strip*
CNT AREA

- VENT LINES, 3 EA
- AXIAL LOK TUBES, 3 EA
- WIRES

CYLINDRICAL AREA

- PODS, 12 EA
- EMERGENCY VENT LINES, 2 EA
- FILL LINE, 1 EA
CUTTING INSULATION PATTERNS

• ULTRASONIC KNIFE OR LASER CUTTER FACILITY WITH COMPUTER CONTROLLED X-Y TABLE, 20 FT X 6 FT ACCURATE TO 0.014 IN. LOCKHEED FUNDED INSTALLATION IN BLDG. 205. OPERATIONAL DEC 1994

• 3-D MODEL OF DEWAR ALLOWS ITERATION OF PATTERNED CUTS FOR SILK NET AND DOUBLE ALUMINIZED MYLAR (D-A-M). APPROXIMATELY 20,000 PIECES REQ'D.

• SILK NET PIECES SEWN TOGETHER

• D-A-M TAPE TOGETHER WITH ALUMINIZED MYLAR/ACRYLIC TAPE
FUNCTION:
1) CONDUCT PARASITIC HEAT LOAD COMING THRU MLI, PODS, WIRING, PLUMBING LINES TO HEX 1,2,3,4. VENT GAS CARRIES OFF HEAT EXTENDING LIFETIME.

2) SUPPORT MLI; MAINTAIN RADIATION GAPS BETWEEN SHIELDS AND MLI.

VERIFICATION:
1) PROBE B/SMD VIBRATION TEST

2) PROBE-C / SMD LIFETIME TEST
\[ T_H = 300 \text{ K AT S.U. HEPL} \]
\[ T_H = 220 \text{ K AT LMSC} \]
(THERMAL VAC)
# VAPOR COOLED SHIELD

## CONSTRUCTION AND SUPPORT

<table>
<thead>
<tr>
<th>VCS</th>
<th>CONSTRUCTION</th>
<th>SUPPORT</th>
<th>THERMAL GROUNDING</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>CONE</td>
<td>CYLINDER</td>
<td>DOME</td>
</tr>
<tr>
<td>1</td>
<td>HONEYCOMB</td>
<td>HONEYCOMB, 6 PANELS</td>
<td>MONOCOQUE</td>
</tr>
<tr>
<td>2</td>
<td>HONEYCOMB/MONOCOQUE</td>
<td>HONEYCOMB, 6 PANELS</td>
<td>MONOCOQUE</td>
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<tr>
<td>3</td>
<td>HONEYCOMB</td>
<td>HONEYCOMB, 6 PANELS</td>
<td>MONOCOQUE</td>
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<tr>
<td>4</td>
<td>HONEYCOMB</td>
<td>HONEYCOMB, 6 PANELS</td>
<td>MONOCOQUE</td>
</tr>
</tbody>
</table>

**NOTES:**

1. **HONEYCOMB CONSTRUCTION**
   
   .1 mm 1100 AL, PERFORATED FACE SHEETS
   
   BONDED WITH FM 24 RETICULATED ADHESIVE

2. **MONOCOQUE DOME**
   
   6063 AL

3. **JOINTS**
   
   VELCRO FASTENERS IN Z PLANE. BOLTED JOINTS, EPOXY BONDED IN X-Y PLANE

5052 A1 PERFORATED CORE, .56 cm THICK
MLI/VCS RISKS AND RISK REDUCTION

RISKS / CONCERNS

• THERMAL PERFORMANCE OF SM DEWAR AND PROBE ARE NOT DEMONSTRATED UNTIL LATE IN PROGRAM

• INSTALLING THE FLIGHT MLI/VCS's MAY TAKE SIX MONTHS

• IF EMERGENCY VENT OCCURS OR COLD VALVES FAIL, ACCESS THROUGH MLI/VCS IS REQUIRED

RISK REDUCTIONS

• CAREFUL THERMAL MODELLING, MEASURE THERMAL CONDUCTIVITY OF ALL MTLS ROUTED FROM COLD SURFACES TO VAC SHELL. CAREFUL THERMAL GROUNDING OF PENETRATIONS, CAREFUL INSTALLATION OF THERMAL PROTECTION SYSTEM (LAYER DENSITY, FIT AROUND PENETRATIONS)

• USE ULTRASONIC KNIFE OR CO₂ LASER, X-Y TABLE TO CUT PATTERNS ACCURATE TO ± 0.4mm, SPEED UP PROCESS

• ACCESS THROUGH MLI/VCS IS PROVIDED IN TWO AREAS (WITH FORWARD VACUUM SHELL CONE REMOVED)
MULTILAYER INSULATION

- MATERIALS, NUMBER OF LAYERS SELECTED
- CUTTING FACILITY TO BE OPERATIONAL BY DEC 1994
- 3-D COMPUTER MODEL TO BE COMPLETE BY AUGUST 1994

VAPOR COOLED SHIELDS

- DETAILED DRAWINGS TO BE COMPLETE BY APRIL 1994
- STRESS ANALYSIS IN PROGRESS
- FABRICATOR OF VCS's TO BE SELECTED BY MAY 1994
VACUUM SHELL

- FUNCTIONS
- REQUIREMENTS
- DESIGN
- RISKS AND RISK REDUCTION
- STATUS
VACUUM SHELL

FUNCTIONS:
1) PROVIDES GUARD VACUUM AND SUPPORT POINTS (THRU 12 PODS/GRAPHITE RINGS) FOR THERMAL PROTECTION SYSTEM AND CRYOGEN TANKS
2) SUPPORT INTERFACE TO SPACECRAFT, 3 PL
3) SUPPORT FOR PROBE ELECTRONIC BOXES
4) PROBE WELL SEAL AND TOP HAT/TEE FLANGE/SUN SHADE SUPPORT
5) DEWAR PLUMBING AND ELECTRICAL INTERFACES TO GSE AND SPACECRAFT
6) SUPPORT AND SEAL TO DEWAR CNT THRU BELLOWS IN TOP PLATE

VERIFICATION:
1) INTERNAL PROOF PRESSURE TEST
2) VACUUM LOAD TEST (1 ATM ΔP)
3) LEAK TEST
# Derived Vacuum Shell Design Requirements

<table>
<thead>
<tr>
<th>ITEM</th>
<th>REQUIREMENT</th>
<th>MEETS REQMT</th>
<th>VERIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Helium Leak Rate</strong></td>
<td>$&lt; 1 \times 10^{-7}$ SCC/S</td>
<td>√</td>
<td>BY DESIGN</td>
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<tr>
<td><strong>Vac Shell Max Operating Pressure</strong></td>
<td></td>
<td></td>
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<tr>
<td>Internal</td>
<td>0.05 MPa (8 PSID)</td>
<td>√</td>
<td>ANALYSIS</td>
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<tr>
<td>External</td>
<td>0.10 MPa (15 PSID)</td>
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<td>ANALYSIS</td>
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<tr>
<td><strong>Vac Shell Design Loads</strong></td>
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</tr>
<tr>
<td>Lateral</td>
<td>6.6 g (6.0 Support Ring)</td>
<td>√</td>
<td>ANALYSIS</td>
</tr>
<tr>
<td>Axial</td>
<td>6.3 g</td>
<td>√</td>
<td>ANALYSIS</td>
</tr>
<tr>
<td><strong>Interfaces</strong></td>
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<td>- Electrical</td>
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<tr>
<td>- Plumbing</td>
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<tr>
<td>- CNT</td>
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<td></td>
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<tr>
<td>- Pods</td>
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<td></td>
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<tr>
<td>- Graphite Rings</td>
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<td></td>
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<tr>
<td>- Axial Lok</td>
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<tr>
<td>- Tunnels, 3 EA.</td>
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<tr>
<td>- Probe Electronic Box Mounts</td>
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<td>- Star Tracker</td>
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<tr>
<td>- Mounts, 2 EA.</td>
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<tr>
<td>- Spacecraft Interfaces, 3 PL</td>
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</tbody>
</table>
VACUUM SHELL DESIGN

MAX PRESS, MPa
- OPERATING - 0.10 TO + 0.055
- PROOF .08

ORBIT TEMP, K 220 ± 15K
MAX LEAK RATE, < 10^-7
cc/s STP GHe
## VACUUM SHELL RISKS AND RISK REDUCTIONS

<table>
<thead>
<tr>
<th>RISKS</th>
<th>RISK REDUCTIONS</th>
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</thead>
<tbody>
<tr>
<td>VACUUM SHELL PARTS ARE COMPLICATED MACHININGS, FORGINGS ARE EXPENSIVE</td>
<td>C/O NC PROGRAM ON LOW COST MATERIAL</td>
</tr>
<tr>
<td>HIGH COST/SCHEDULE IMPACT IF VACUUM SHELL DOME AND CONE WELDS ARE NOT SATISFACTORY</td>
<td>WELD DEVELOPMENT, LEAK CHECKS, BONDED DOUBLER</td>
</tr>
<tr>
<td>LEAKAGE OF INSTRUMENTATION FEED THRUS</td>
<td>THERMALLY CYCLE TO 180 K AND LEAK CHECK FEED THRUS</td>
</tr>
<tr>
<td>LEAKAGE OF LARGE NUMBER OF SEALS</td>
<td>SMALL SEALS HAVE BEEN QUALIFIED. (SEE SECTION DT) LARGE SEALS LEAK CHECKED AT ASSEMBLY</td>
</tr>
</tbody>
</table>
VACUUM SHELL STATUS

- DESIGN STATUS
  - TOP PLATE ASSEMBLY COMPLETE
  - FORWARD CONE IN PROGRESS
  - MID-CYLINDER COMPLETE
  - SUPPORT RING COMPLETE
  - AFT DOME ASSEMBLY IN PROGRESS
- CHEMTRONICS SELECTED TO BUILD VACUUM SHELL
- FORGING STATUS
  - RECEIVED
    » SUPPORT RING
  - ON ORDER
    » TOP PLATE
    » CYLINDER
- MACHINING IN PROGRESS
  - SUPPORT RING
PASSIVE ORBITAL DISCONNECT STRUTS

RICHARD PARMLEY
FUNCTIONS

- SUPPORTS 918.7 kg (2025 lb)
  - MAIN TANK 287.9
  - GUARD TANK 16.4
  - VCS's PLUS MLI 118.7
  - CNT ASSY 13.6
  - COLD PLUMBING 16.1
  - LHe (337 + 3.8)
  - PROBE 84.2
  - SIA 41.0

- DOES NOT SHORT OUT ON THE GROUND OR IN ORBIT
- MINIMIZES PARASITIC HEAT LOAD TO MAIN TANK
- STIFFNESS MEETS LAUNCH AND ORBIT RESONANCE REQUIREMENTS
VERIFICATION

- QUALIFICATION LOADS TEST (COMP & TENSION) TO DESTRUCTION ON TWO AFT AND TWO FORWARD PODS IN TENSILE TEST MACHINE
- TENSION & COMPRESSION SHORTING AND PROOF LOADS; SPRING RATE MEASUREMENTS IN TENSILE TEST MACHINE (12 PODS, EACH TESTED SEPARATELY)
- SIDE LOAD SHORTING TEST (EA OF 12 PODS)
- COLD VIBRATION TEST OF SMD / PROBE-B
PODS V DESIGN

MATERIALS

- LAUNCH TUBE: ± 10° γ ALUMINA FIBER/SCI REZ 081 EPOXY
- ORBIT TUBES: ± 10° γ ALUMINA FIBER/SCI REZ 081 EPOXY
  (T300 GRAPHITE/SCI REZ 081 EPOXY*)
- METAL END FITTINGS: 303 CRES(INVAR*)
- ROD END FITTINGS: INCONEL 718

PODS GAP, MILS

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<thead>
<tr>
<th>NO LOAD</th>
<th>FULL TANK, COLD</th>
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<tbody>
<tr>
<td></td>
<td>GROUND (VERT)</td>
</tr>
<tr>
<td></td>
<td>TENSION COMP</td>
</tr>
<tr>
<td>FORWARD</td>
<td>4.6 4.6</td>
</tr>
<tr>
<td>AFT</td>
<td>4.6 4.6</td>
</tr>
</tbody>
</table>

* PDR MATERIALS
<table>
<thead>
<tr>
<th>RISKS</th>
<th>RISK REDUCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>PODS SHORTING,</td>
<td>WELL DEVELOPED TECHNOLOGY, EACH POD WILL BE STRUCTURALLY TESTED PRIOR TO</td>
</tr>
<tr>
<td>STRUCTURAL FAILURE</td>
<td>INSTALLATION, STRUTS LIGHTLY LOADED IN TENSION (242% MARGIN), NO FATIGUE</td>
</tr>
<tr>
<td></td>
<td>PROBLEMS</td>
</tr>
</tbody>
</table>
PODS STATUS

- FINAL DESIGN COMPLETE
- ASSEMBLY SEQUENCE DEFINED
- PARTS FABRICATION IN PROGRESS
COMPOSITE NECK TUBE ASSEMBLY
AND TOP PLATE

DAVID DONEGAN
FUNCTIONS OF COMPOSITE NECK TUBE / HEAT EXCHANGER ASSEMBLY

- ISOLATE DEWAR VACUUM SPACE FROM WELL
- INTERFACE FOR COOLING OF PROBE THROUGH TSRS
- THERMAL INTERFACE / STRUCTURAL SUPPORT FOR VAPOR COOLED SHIELDS AND GUARD TANK ON O.D. OF HEX
- SUPPORT OF GUARD TANK AND VCS#1 ON HEX #1
- SUPPORT OF VCS #2 ON HEX #2
- THERMAL INTERFACE ONLY FOR VCS
  #3 & #4 ON HEX #3 & #4
- HEX PROVIDE PARALLEL TANK VENT PATH
- HEX PROVIDE THERMAL GROUND 4 PL FOR SEPARATE GUARD TANK VENT
- OPTIMIZE THERMAL PERFORMANCE
<table>
<thead>
<tr>
<th>ITEM</th>
<th>REQUIREMENT</th>
<th>VERIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>CNT INTERNAL PRESSURE</td>
<td>0.13 MPa, (19 PSID), FOS 4.0 ULTIMATE</td>
<td>EM 219 ANALYSIS / PROOF TEST</td>
</tr>
<tr>
<td>CNT EXTERNAL PRESSURE</td>
<td>0.13 MPa, (19 PSID), FOS 2.0 ULTIMATE</td>
<td>EM 219 ANALYSIS / PROOF TEST</td>
</tr>
<tr>
<td>HEX INTERNAL PRESSURE</td>
<td>0.26 MPa, (38 PSID), FOS 4.0 ULTIMATE</td>
<td>EM 245 ANALYSIS / PROOF TEST</td>
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<tr>
<td>HEX EXTERNAL PRESSURE</td>
<td>0.13 MPa, (19 PSID), FOS 2.0 ULTIMATE</td>
<td>EM 245 ANALYSIS / PROOF TEST</td>
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<tr>
<td>ACCELERATION LOADS</td>
<td>SEE EM 310</td>
<td>ANALYSIS / TEST</td>
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<tr>
<td>END TO END ELECTRICAL RESISTANCE</td>
<td>1 TO 10 OHMS</td>
<td>DESIGN / TEST</td>
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<tr>
<td></td>
<td>CNT &amp; HEX</td>
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</table>
COMPOSITE NECK TUBE ASSY DESIGN FEATURES

- COMPOSITE TUBE/ HEX ASSY MODULAR DESIGN
  - END FLANGES AND HEX BONDED ON TUBE, ASSY. ACCEPTANCE TESTED BEFORE BONDING TO TONGUE AND GROOVE JOINTS ON DEWAR - MINOR CHANGES FROM EDD

- COMPOSITE TUBE
  - .020 WALL CYLINDER ( EDD WAS .080)
  - GAMMA ALUMINA FIBER / SCI REZ 081 RESIN PREPREGGED UNIDIRECTIONAL TAPE
  - 4-Ply BALANCED LAYUP, +/- 40 DEG WIND ANGLE TO MATCH CTE OF COPPER TSR, HEX
  - RING STIFFENED BY FILAMENT WINDING, .030 THICK, .125 HIGH, 33PL
  - PERMEATION BARRIER: 1 MIL TITANIUM FOIL (15V-3AL-3CR-3SN)
  - SAME FABRICATION TECHNIQUE / VENDOR AS PROBE CNT
  - DEVELOPMENT TUBE FABRICATION AND TEST SUCCESSFUL
• THERMAL STOP RINGS (TSRs)
  - OFHC COPPER WITH RHODIUM OVER GOLD STRIKE PLATED TABS
  - CIRCUMFERENTIALLY COLLAPSIBLE DESIGN ALLOWS INSTALLATION AT ROOM TEMP. WITH "BLUE DEATH" EPOXY
  - IDENTICAL TO EDD
COMPOSITE NECK TUBE ASSY DESIGN FEATURES

- HEAT EXCHANGERS
  - DUAL FLOW PATH - MIRROR IMAGES
  - OFHC COPPER HALF-RINGS JOINED BY .005 WALL 321 S.S. INTERCONNECT TUBING / BELLOWS BONDED IN PLACE
  - HALF-RINGS ALL BRAZED CONSTRUCTION-2 STEP HYDROGEN FURNACE BRAZE
  - "CLAMSHELL" DESIGN - EPOXY BONDED TO COMPOSITE TUBE
  - "MODULAR DESIGN" - THERMAL CYCLED, PROOF PRESSURE TESTED, AND LEAK TESTED PRIOR TO BONDING TO COMPOSITE TUBE
• END FLANGES
  - CONTINUOUS INTERLOCKING RINGS ON I.D. & O.D. OF EACH END OF TUBE (ALUM ON COLD END, S.S. ON WARM END)
  - OUTER RING FLANGED WITH BOLT PATTERN
  - CLOCKED TO TSRs AND TO EACH OTHER, "BLUE DEATH" EPOXY BONDED W/ WIRE SPACERS AND GLASS BEADS
COMPOSITE NECK TUBE / HEAT EXCHANGER ASSEMBLY AND TEST FLOW

HEX HALF RING BRAZEMENTS WARM & COLD LEAK TESTS

BELLOWS TUBES BONDED BETWEEN HEX RINGS ON FIXTURE. PROOF PRESS. TEST, WARM & COLD LEAK TESTS

BELLOWS INTERCONNECT TUBES - WELD & WARM LEAK TEST

THERMAL CYCLE BARE COMPOSITE TUBE

INSTALL TSR USING ALIGNMENT FIXTURE

BOND END FLANGES USING ALIGNMENT TOOL

INSTALL TEMPORARY HEX SIMULATORS

INSTALL TEMPORARY END PLATES TO SEAL TUBE END FLANGES WITH “C” SEALS

WARM LEAK TEST

3 COLD LEAK/ THERMAL CYCLE TESTS

INTERNAL PROOF / WARM LEAK TEST

EXTERNAL PROOF / WARM LEAK TEST

LATERAL LOAD TEST (705 LBS)

COLD LEAK TEST

BOND HEX TO CNT USING FIXTURE

WARM LEAK TEST HEX
• MANY SUCCESSFUL DEVELOPMENTS INCORPORATED FOR SMD
  – PROBE RESIN SELECTION, TUBE FAB., DEV TESTING
  – EDD HEAT EXCHANGER BRAZEMENTS, TSRs, END FLANGE CONCEPTS
  – MODULAR DESIGN, FABRICATION, ASSEMBLY AND TEST CONCEPT DEVELOPED FOR EDD
    » END FLANGES AND HEX BONDED ON TUBE, ASSY. ACCEPTANCE TESTED BEFORE BONDING TO TONGUE AND GROOVE JOINTS ON DEWAR - MINOR CHANGES FROM EDD

• COMPOSITE NECK TUBE DEVELOPMENT TESTING COMPLETE
  – DEMONSTRATED STRUCTURAL CAPABILITY, VACUUM INTEGRITY OF NEW PROTOTYPE THIN WALL TUBE
    » WARM AND COLD LEAK TESTS
    » 37.4 PSID EXTERNAL PRESSURE
    » 705 LBS LATERAL LOAD AT TOP PLATE
    » NO BUCKLING OR LEAKAGE
    » AXIAL LOAD TO FAILURE - 9311 LBS
  – VALIDATED DESIGN, FABRICATION, ASSY. AND TEST PROCEDURES
• ALL DRAWINGS RELEASED

• CHANGES FROM PDR
  – 1 MIL Ti 15-3-3-3 FOIL LINER - WAS 1/2 MIL
     ( TO EASE FABRICATION AND HANDLING )

  – LONGER BELLOWS , SHORTENED COMPOSITE NECK TUBE
     ( LONGER BELLOWS TO MEET LATERAL STIFFNESS REQUIREMENT )

  – HEX INTERCONNECT TUBES BONDED IN PLACE - WAS BRAZED
     ( BONDING INCREASES END TO END ELECTRICAL RESISTANCE )
VACUUM SHELL TOP PLATE
COMPONENT FUNCTIONS

- INTERFACE WITH PROBE
- VACUUM SEAL JOINT WITH LOWER PORTION OF VACUUM SHELL
- FACILITATE DIFFERENTIAL THERMAL CONTRACTION BETWEEN TANK AND VACUUM SHELL WITH BELLOWS JOINT AT TOP OF NECK TUBE
- OVERPRESSURE PROTECTION FOR DEWAR WELL
- MAIN TANK AND GUARD TANK VENT BAYONETS
- DEWAR ELECTRICAL FEEDTHROUGHS
- GSE INTERFACES
  - TOP PLATE HEATERS
  - LEAD BAG
  - PROBE INSTALLATION
VACUUM SHELL TOP PLATE / NECK TUBE JOINT LAYOUT

BONDED END FLANGE

.75 ID X 1.63 00
WELDED BELLOWS
SOLID L = 0.70
EXT'D L = 1.50

BELLOWS

.030
TYP

.125
TYP

.019
±.001

COMPOSITE TUBE

VACUUM SHELL TOP PLATE

.55 ID X 1.03 mm
WELDED BELLOWS
SOLID L = 0.40
EXT'D L = 1.50

1/8" MACHO CU PLATE BRAZED TO 1/2" LINES & BONDED TO 3/4" LINE

3/4" VENT LINE TO THRUSTERS

2,3 MAR 94
<table>
<thead>
<tr>
<th>ITEM</th>
<th>REQUIREMENT</th>
<th>VERIFICATION</th>
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<tbody>
<tr>
<td>LEAK RATE FOR ALL PENETRATIONS AND SEALS</td>
<td>&lt;1X10E-9 SCC/SEC</td>
<td>TEST</td>
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<tr>
<td>SUPPORTED WEIGHT</td>
<td>121 Kg EST</td>
<td>ANALYSIS</td>
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<tr>
<td>LAUNCH LOADS</td>
<td>ACCELERATION (G'S)</td>
<td>DYNAMICS LOAD MODEL</td>
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<tr>
<td></td>
<td>Z*: 9.8, RADIAL: 8.9</td>
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<tr>
<td>INTERNAL LIMIT WORKING PRESSURE MPa (PSID)</td>
<td>BELLOWS / TOP PLATE</td>
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<tr>
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<td>.13 (19) / .06 (8)</td>
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<td>EXTERNAL LIMIT WORKING PRESSURE MPa (PSID)</td>
<td>BELLOWS / TOP PLATE</td>
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<tr>
<td>BELLOWS STROKE</td>
<td>&gt; + .375 IN.</td>
<td>TEST</td>
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<tr>
<td>BELLOWS AXIAL SPRING RATE</td>
<td>&lt; 9 Kg/CM (50 LB/IN.)</td>
<td>TEST</td>
</tr>
<tr>
<td>BELLOWS RADIAL SPRING RATE</td>
<td>&lt; 1800 Kg/CM (10K LB/IN.)</td>
<td>TEST</td>
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STATUS OF VACUUM SHELL
TOP PLATE

• DESIGN STATUS
  – TOP PLATE ASSEMBLY COMPLETE
  – DETAILS IN PROGRESS
  – ELECTRICAL FEEDTHROUGH DESIGN COMPLETE, VENDOR QUOTING
• 304 STAINLESS STEEL FORGING ON ORDER
• CHANGES SINCE PDR
  – POSITION AND ANGLE OF ELECTRICAL CONNECTORS
  – SINGLE MAIN TANK VENT BAYONET - WAS DUAL
    ( WEIGHT REDUCTION )
  – ADDED SEPARATE GUARD TANK VENT BAYONET - MAIN TANK USED TO VENT THROUGH GUARD TANK ( ELIMINATE POSSIBLE TAOs )
  – ADDED BOSS FOR MOUNTING ASSEMBLY OF PAIR OF PYRO VALVES TO OPEN MAIN TANK VENT TO THRUSTERS (FLIGHT INSTALLATION ONLY)
  – MANUAL VALVE ADDED TO ISOLATE MAIN TANK GROUND VENT BAYONET FOR FLIGHT
PLUMBING FUNCTIONS

- MAIN TANK
  - FILL AND TOP-OFF WITH He-I
  - CONDITION TO He-II
  - PRE-COOLEDING OF FILL LINE
  - PROVISIONS FOR NON-VENTED OR VENTED
  - PRESSURE DRAIN

- GUARD TANK
  - FILL AND TOP-OFF WITH NBP He
  - CONTINUOUS VENT
  - EMPTY WITH HEATER

- WELL
  - FILL AND TOP-OFF WITH NBP He
    » FROM EXTERNAL SOURCE OR MAIN TANK
  - FILL WITH HE-II FROM MAIN TANK

- EVACUATE VACUUM SPACES
  - GUARD VACUUM, WELL, PLUMBING LINES

- PROVIDE PRESSURE RELIEF OF TRAPPED VOLUMES
• REDUNDANT PYRO VALVES (PV4A & 4B) ARE TO INSURE PROPER VENTING OF TANK AFTER LAUNCH

• NO REDUNDANCY FOR ON-ORBIT VENTING OF FILL PLUMBING
  – NOT CRITICAL TO LIFETIME

• NO REDUNDANCY FOR GROUND OPERATIONS EXCEPT FOR CLOSURE OF FOUNTAIN EFFECT PUMP VALVE (RAV6A & 6B)
  – REDUNDANCY INCLUDED BECAUSE VALVES CAN’T BE LEAK CHECKED PRIOR TO LAUNCH

• PLUMBING COMPONENTS ARE REMOVABLE BY USE OF HELICOFLEX SEAL

• DESIGNING FOR MAXIMIZING ACCESS TO PLUMBING COMPONENTS THRU THERMAL PROTECTION SYSTEM

• ACCEPTANCE LEAK TESTING OF COLD COMPONENTS ARE PERFORMED AT LIQUID NITROGEN TEMPERATURE

• TESTING OF MOTORIZED VALVES ARE PERFORMED BELOW 20K

• ALL PLUMBING LINES ARE METALLIC (CRES OR AL)
CHANGES SINCE PDR

- INTERFACE WITH THE SPACECRAFT CHANGED SUCH THAT PAYLOAD HAS COMPLETE CONTROL OVER CRYOGEN SERVICING PLUMBING

- MAIN TANK
  - VENT BYPASSES THE GUARD TANK
  - POST LAUNCH ACTIVATION OF VENTING CHANGED FROM OPERATING COLD VALVES TO FIRING OF PYROTECHNIC VALVES

- GUARD TANK
  - SEPARATE VENT FOR THE GUARD TANK
  - ELIMINATION OF ONE COLD BURST DISC
  - ELIMINATION OF SEPARATE EMERGENCY VENT LINES
    » NORMAL VENT LINE IS USED

- FOUNTAIN EFFECT PUMP
  - FLOW DOWNSTREAM OF PUMP GOES THRU THE HEAT EXCHANGER WITH THE MAIN (SUPPLY) TANK
LAUNCH CONFIGURATION OPERATIONS

- GUARD TANK NEEDS TO BE SERVICED EVERY 7 DAYS
  - DRAINED TO 30 LITERS PRIOR TO LAUNCH WHICH IS SUFFICIENT TO ACCOMMODATE 2 LAUNCH ABORTS

- MAIN TANK NEEDS TO BE SERVICED EVERY 90 DAYS
  - DESIGN IS SUCH THAT THERE ARE NO REQUIREMENTS FOR SERVICING ON LAUNCH PAD

- LAUNCH PAD OPERATIONS:
  - REQUIRES OPERATING OF PAYLOAD AND SPACECRAFT ELECTRONICS
  - REQUIRES USE OF UMBILICAL
  - REQUIRES ACCESS THRU PAYLOAD SHROUD

- ASCENT OPERATIONS:
  - REQUIRES FIRING OF THREE PYROTECHNIC VALVES (PV3, PV4A, PV4B)

- ON-ORBIT OPERATIONS:
  - REQUIRES OPERATION OF RAV2
  - REQUIRES FIRING OF ONE PYROTECHNIC VALVE (PV1)
GROUND OPERATIONS

• VERTICAL
  – NORMAL BOILING POINT FOR LEAD BAG AND PROBE INSERTION
  – CONDITION MAIN TANK AND WELL (OPTION) FOR FLIGHT
  – SERVICING OF GUARD TANK
  – NO LIMITATIONS ON FILLING/CONDITIONING OF TANK, WELL, AND GUARD TANK

• VERTICAL TO 57.5 DEGREES OFF VERTICAL
  – PROBE OPERATIONS
  – NO LIMITATION ON FILLING/CONDITIONING OF TANK

• HORIZONTAL
  – GYRO TESTING (+X, +Y AXIS UP)
    » FILLING CAPABILITY
  – CAGING (-X, -Y AXIS UP)
    » NO FILLING OF TANK
- DURING GROUND TESTING, THE MAIN TANK FLOWRATE IS APPROXIMATELY 9 mg/s

- **+Y, -Y, -X AXIS UP:**
  - VENT THRU POROUS PLUG BYPASS VALVE RAV3
  - CAN OPERATE TO 1.8 K

- **+X AXIS UP:**
  - VENT THRU POROUS PLUG (BYPASS IS SUBMERGED)
  - PLUG PRESSURE DROP REQUIRES THE BATH PRESSURE (i.e. TEMPERATURE) TO INCREASE
    » MINIMUM TEMPERATURE APPROXIMATELY 2 K
• THE POROUS PLUG MAY BE DRY DURING HORIZONTAL OPERATIONS WITH THE +X AXIS UP
  - VENTING THRU PLUG WILL CAUSE THE BATH TEMPERATURE TO RISE
HORIZONTAL FILL OPERATIONS

- **+X AXIS UP:**
  - VENT THRU POROUS PLUG (BYPASS IS SUBMERGED)
  - MAXIMUM FILL LEVEL IS 90%
  - MINIMUM OPERATIONAL LEVEL IS 38%
  - LIMITED FILL RATE DUE TO POROUS PLUG PRESSURE DROP
    » BATH TEMPERATURE WILL RISE

- **+Y AXIS UP:**
  - VENT THRU POROUS PLUG BYPASS VALVE RAV3
  - MAXIMUM FILL LEVEL IS 50%
  - MINIMUM OPERATIONAL LEVEL IS 38%
• HIGH VENT RATES (MANY GRAMS PER SECOND) DURING FILL OPERATIONS RESULT IN A LARGE PRESSURE DROP ACROSS THE POROUS PLUG WITH THE +X AXIS UP
  – RESULTS IN A HIGHER BATH TEMPERATURE
LOCATION OF PLUMBING ON TOP PLATE

GUARD TANK VENT

MAIN TANK VENT

THRUSTER VENT
LOCATION OF PLUMBING ON SUPPORT RING

VIEWING - X *

1" NC PYRO VALVE PV1 CONNECTOR P808
STAR TRACKER PEDESTAL 2 PL
VACUUM PUMPOUT PORT PO
BURST DISC BD3 (TANK FILL LINE)

VALVE V8
TANK FILL BAYONET B3
TANK FILL VALVE V13

VIEWING + X *

BD58 BD5A BD7A BD7B
• USED TO PREVENT OVER PRESSURIZATION OF VACUUM SPACE DURING EMERGENCY VENT OF MAIN TANK
COLD VALVES

- 0.5" STEPPER MOTOR-DRIVEN VALVE (7 RAVs)
- VENDOR: MISSION RESEARCH CORPORATION
- BASIC VALVE DESIGN HAS BEEN USED FOR NUMEROUS APPLICATIONS.
- NUMBER OF IMPROVEMENTS ARE BEING INCORPORATED:
  - HIGH RELIABILITY MICROSWITCHES
  - WIRING OF MICROSWITCHES
    » IMPROVE RELIABILITY AND DIAGNOSTIC TESTING
  - MANUFACTURING OF BALL SCREW AND NUT
  - DRY LUBRICATION OF MISC. PARTS
  - INCREASE TORQUE MARGIN TO FOUR
- TESTING:
  - EACH VALVE IS SUBJECTED TO AN ACCEPTANCE TEST
    » MOTOR AND DRIVE TRAIN CHARACTERIZATION
    » THERMAL CYCLING AND LEAK CHECK
    » VIBRATION
  - TWO VALVES ARE SUBJECTED TO QUALIFICATION TEST
    » SIMILAR TO ACCEPTANCE
    » MORE EXTENSIVE MOTOR TESTING
    » 1000 OPEN/CLOSE CYCLES
COLD BURST DISCS

- MAIN TANK (BD1A, BD1B) - 2 INCH ORIFICE, 38PSID

- GUARD TANK (BD2) - 0.46 INCH ORIFICE, 54 PSID

- VENDOR: FIKE CORP.

- ALL WELDED DESIGN

- TESTING:
  - EACH BURST DISC IS SUBJECTED TO AN ACCEPTANCE TEST
    » THERMAL CYCLING AND COLD LEAK CHECK
    » VIBRATION
  - TWO BURST DISCS ARE SUBJECTED TO QUALIFICATION TEST
    » SIMILAR TO ACCEPTANCE
    » COLD RUPTURE OF BURST DIAPHRAGM
• USED FOR TRANSFERING SFHe TO WELL PRIOR TO LAUNCH (IF REQUIRED)

• DESIGN
  - 0.5 MICRON S.S. MOTT PLUG
  - 1 WATT HEATER

[Graph showing the relationship between heater power and volumetric flowrate.]
LIQUID/VAPOR PHASE SEPARATOR

- USED FOR VENTING OF SFHe TANK
  - PHASE SEPARATION IS ACHIEVED 12 SECONDS AFTER INITIATION OF VENTING OF THE MAIN TANK DURING ASCENT

- INSTRUMENTATION
  - REDUNDANT UPSTREAM THERMOMETERS
  - DOWNSTREAM THERMOMETER
  - DOWNSTREAM LIQUID DETECTOR
PERFORMANCE OF THE PHASE SEPARATOR

\[ \Delta P \quad (\text{Torr}) \]

\[ Q \quad (\text{W}) \]

\[ \dot{m} \quad (\text{mg/s}) \]

0.5 \( \mu \)m S.S. Porous Plug

\[ D = 3.30 \text{ cm} \]

\[ L = 1.27 \text{ cm} \]
THE FOLLOWING GRAPH SHOWS THE INTERFACE PRESSURE AS A FUNCTION OF THE MASS FLOWRATE
GUARD TANK RELIEF

- USED FOR PREVENTING BACKFLOW OF AIR INTO VENT LINE AND FOR EVACUATION DURING ASCENT AND ON-ORBIT
- WEIGHT OF TUNGSTEN EXCEEDS SUM OF SPRING, MAGNET, AND 1/3 PSID FORCES FOR GROUND OPERATIONS
- TUNGSTEN RETRACTS IN ORBIT AND IS HELD OPEN BY SPRING AND MAGNETS
GUARD TANK FLOWRATE FOLLOWING LAUNCH

• FOLLOWING LAUNCH, THE GUARD TANK WILL BLOWDOWN

• THERE WILL BE UP TO 30 LITERS REMAINING AT LAUNCH

• FLOWRATES WERE CALCULATED BASED ON DEPRESSURIZING THE REMAINING LIQUID
  
  – DOES NOT ACCOUNT FOR ANY FLASHING OF LIQUID IN WARM SECTION OF PLUMBING FOLLOWING ORBIT INSERTION

• AT ONE HOUR FOLLOWING LAUNCH THE VENT RATE WILL BE 6-15 mg/s WITH 9 LITERS OF LIQUID REMAINING IN THE TANK
  
  – VENTING RATE DEPENDS ON THE PARASITIC HEAT LOAD TO THE GUARD TANK

• BASED ON THESE FLOWRATES, THE VENT RATE WILL PERSIST FOR 24 - 60 HOURS

• GAS IS VENTED THRU A THRUST NULIFIER
• PLUMBING SEALS:
  - TOTAL OF 23 SEALS INTERNAL TO VACUUM SHELL
    » ON-ORBIT SEALING: 12 SFHe, 1 GHe, 10 VACUUM
  - TOTAL OF 4 SEALS ON MAIN TANK VENT LINE EXTERNAL TO VACUUM SHELL

• WARM BURST DISCS:
  - FILL LINE (BD3) - 0.46 INCH ORIFICE, 18 PSID
  - VACUUM SHELL (BD5A, BD5B) - 2.0 INCH ORIFICE, 4 PSID
  - MAIN TANK VENT LINE (BD7A,BD7B) - 2.0 INCH ORIFICE, 4 PSID

• PYROTECHNIC VALVES:
  - VACUUM SHELL (PV1) - 1.0 INCH ORIFICE
  - WELL ( PV3) - 1/2 INCH ORIFICE
  - MAIN TANK VENT (PV4A, PV4B) - 1.0 INCH ORIFICE
MISC. COMPONENTS (2 OF 3)

• THRUST NULIFIERS:
  – GUARD TANK (TN1)
  – WELL (TN2)

• BAYONETS:
  – MAIN TANK GROUND VENT (B1) - 3/4 INCH
  – GUARD TANK VENT (B2) - 3/4 INCH
  – FILL BAYONET (B3) - 1/4 INCH

• MANUAL VALVES:
  – TANK FILL VALVE (V13) - 1/4 INCH
  – MAIN TANK GROUND VENT - THRUSTERS (V12) - 3/4 INCH - MDC
  – MAIN TANK GROUND VENT - CRYOGEN SERVICING (V9) - 1/2 INCH
  – FILL AND VENT BAYONET SEAL-OFF (V8, V10) - 1/4 INCH - NURO
MISC. COMPONENTS (3 OF 3)

• PUMP-OUT PORT:
  - VACUUM SHELL (PO) - 2.0 INCH - SAES PURE GAS

• PUMP-OUT PORT/RELIEF:
  - WELL (RV2) - 1/4 INCH

• INTERNAL 2 MICRON LIQUID LINE FILTERS:
  - INTERNAL TANK TO WELL X-FER (F1) - NUPRO
    » 10 torr DP @ 30 L/hr
  - EXTERNAL FILL (F2) - ERBE ENGINEERING
    » 50 torr DP @ 600 L/hr
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<th>RISK</th>
<th>RISK REDUCTION</th>
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<td>RELIABILITY OF COLD VALVES</td>
<td>INCORPORATE LESSONS LEARNED FROM VALVE DEVELOPMENT PROGRAMS FOR SHOOT, GPB, AND ISO</td>
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<td>POROUS PLUG</td>
<td>DEVELOPMENT TESTING</td>
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<tr>
<td>SEAL LEAKAGE FOR REMOVABLE PLUMBING</td>
<td>DEVELOPMENT TESTING</td>
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<td>BLOWDOWN OF GUARD TANK AFFECTS S/C ATTITUDE CONTROL</td>
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<tr>
<td>BLOWDOWN OF WELL (IF USED) AFFECTS S/C ATTITUDE CONTROL</td>
<td>PROVIDING THRUST NULIFIER TO MINIMIZE IMPACT</td>
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<tr>
<td>LH_{e} REMAINING IN WELL FLASHING IN WARM REGIONS</td>
<td>BURST DISC ON PROBE WILL AUGMENT PRESSURE RELIEF</td>
</tr>
</tbody>
</table>
MASS GAUGING

DAVID FRANK
OVERVIEW

- TWO METHODS OF PERFORMING MASS GAUGING ARE BEING IMPLEMENTED:
  - HEAT PULSE METER
    » MEASURES THE REMAINING QUANTITY OF HELIUM
  - THERMAL FLOW METER
    » MEASURES THE FLOW RATE

- BOTH METHODS ARE BEING UTILIZED TO GET MEASUREMENTS WITH BETTER THAN 5 PERCENT ACCURACY
  - FLOW METER REQUIRES CALIBRATION THAT CAN BE PERFORMED WITH GROUND TESTING
HEAT PULSE METER

• THE HEAT PULSE METER UTILIZES A HEATER AND TEMPERATURE THERMOMETRY
  – BOTH ARE IN GOOD CONTACT WITH THE LIQUID
    » HEATER IS LOCATED ON THE SLOSH BAFFLE INSIDE THE TANK
    » THERMOMETER IS LOCATED ON THE INLET TO THE POROUS PLUG

• UTILIZING THE TEMPERATURE RESPONSE TO A KNOWN AMOUNT OF HEAT INPUT AND LAWS OF CONSERVATION OF ENERGY AND MASS, THE QUANTITY OF FLUID REMAINING CAN BE DETERMINED
  – HEAT RAISES THE TEMPERATURE OF THE LIQUID AND VAPOR
  – HEAT IS ABSORBED IN VAPORIZING LIQUID

• THE INCREASE IN LIQUID TEMPERATURE IS LIMITED TO 5 mK
HEAT PULSE METER
OPERATION

- OPERATING AT 28 V dc AND A MAXIMUM CURRENT OF 1.2 amp TO A 33 WATT HEATER
  - HEAT FLUX IS MAINTAINED BELOW 0.2 W/cm²

- FULL TANK REQUIRES 5000 W-S OF HEAT
  - A 5 mK RISE LEADS TO A PULSE DURATION OF 151 SECONDS WHEN THE TANK IS FULL

- DATA BEFORE AND AFTER SHOULD BE RECORDED FOR A DURATION OF TIME EQUAL TO THE PULSE DURATION
  - THIS DATA IS USED TO ESTABLISH BEFORE AND AFTER DRIFTS

- ANALYSIS CAN BE PERFORMED BY ANALYZING THE ABSOLUTE CHANGE IN TEMPERATURE OR THE RATE OF TEMPERATURE RISE

- OPERATION OF THE DRAG-FREE CONTROL SYSTEM MUST BE REVIEWED SUCH THAT THAT IT'S OPERATION DOES NOT INTERFERE
ACCURACY (1 of 2)

- THE SHORTER THE HEAT PULSE, THE SMALLER ARE THE ERRORS DUE TO CHANGES IN VENTING AND PARASITIC HEAT LOAD

- THE LARGER THE HEATER POWER IN RELATIONSHIP TO THE PARASITIC LOAD, THE SMALLER ARE CORRECTIONS NEEDED TO BE MADE TO THE CALCULATIONS

- ERRORS IN THE THERMOMETRY, READOUT, HEAT DISSIPATION, AND OTHERS (SEE NEXT CHART)

- ASSUMING PREFLIGHT ASSUMPTIONS THAT THERE ARE NO CHANGES IN VENTING RATE AND NO CORRECTIONS DUE TO TEMPERATURE DRIFT, THE ERROR IN THE HEAT PULSE READING WILL BE LESS THAN 5 PERCENT
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<th>VALUE</th>
<th>COMMENTS</th>
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<td>SENSOR CALIBRATION (GR-200-1500) @ 1.8K:</td>
<td></td>
<td></td>
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<tr>
<td>- ABSOLUTE ACCURACY (dTabs1)</td>
<td>5mK</td>
<td>BASED ON TYPICAL CALIBRATION</td>
</tr>
<tr>
<td>- REPRODUCIBILITY (dTabs2)</td>
<td>0.5 mK</td>
<td>BASED ON RECOMMENDED SENSOR CHARACTERISTIC</td>
</tr>
<tr>
<td>- STABILITY (dTabs3)</td>
<td>0.28 mK</td>
<td>DRIFT OF 0.05%</td>
</tr>
<tr>
<td>- RESISTANCE (R)</td>
<td>13810 OHM</td>
<td>VENDOR CALIBRATION DATA</td>
</tr>
<tr>
<td>- SENSITIVITY (dR/dT)</td>
<td>24821 ohm/k</td>
<td>VENDOR CALIBRATION DATA</td>
</tr>
<tr>
<td>- DERIVATIVE OF SENSITIVITY (dR/dT)**2</td>
<td>68115 ohmK**2</td>
<td>EXTRAPOLATED FROM CALIBRATION DATA</td>
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<tr>
<td>THERMOMETER READOUT UNCERTAINTY:</td>
<td></td>
<td></td>
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<tr>
<td>- ABSOLUTE TEMPERATURE (%R)</td>
<td>13.8 OHM</td>
<td>0.1 % IN ABSOLUTE RESISTANCE</td>
</tr>
<tr>
<td>- RESOLUTION (DR)</td>
<td>2.5 OHM</td>
<td>0.1 mK RESOLUTION</td>
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<tr>
<td>CALCULATED TEMPERATURE UNCERTAINTY:</td>
<td></td>
<td></td>
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<tr>
<td>- ABSOLUTE TEMPERATURE (dTabs4)</td>
<td>5.1 mK</td>
<td>RMS OF dTabs 1,2,3 and [ %R/(dR/dT)]</td>
</tr>
<tr>
<td>- CHANGE IN TEMPERATURE</td>
<td>0.12 mK</td>
<td>RMS OF ERROR IN DETERMINATION OF dR/dT</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[((dR/dT)**2)*dTabs4/(dR/dT)*dThpm] and [DR/(dR/dT)]</td>
</tr>
<tr>
<td>HEATER POWER DISSIPATION UNCERTAINTY:</td>
<td>0.5 Ws</td>
<td>0.1 - 0.2 % OF ACTUAL HEAT DEPENDING ON PULSE DURATION</td>
</tr>
<tr>
<td>TANK VOLUME UNCERTAINTY:</td>
<td>23 LITERS</td>
<td>1 % OF MEASURED VOLUME</td>
</tr>
</tbody>
</table>
• FLOWMETER APPROACH
  – MEASURE THE RESPONSE OF THE FLOW STREAM WALL TEMPERATURE TO A KNOWN HEAT INPUT
  – BASED ON FULLY DEVELOPED LAMINAR FLOW WITH A CONSTANT TEMPERATURE BOUNDARY

• DEVELOPED MODELS TO PREDICT PERFORMANCE
  – CLOSED FORM SOLUTION USED TO PERFORM PARAMETRIC STUDIES TO SIZE THE FLOWMETER
    » ASSUMES CONSTANT PROPERTIES AND NO HEAT LOSSES
  – CFD AND SINDA MODELS TO PERFORM DETAILED ANALYSIS ON FINAL DESIGN
    » USES VARIABLE PROPERTIES
    » CALCULATE HEAT LOSSES (RADIATION AND CONDUCTION IN TUBING)
FLOWMETER SCHEMATIC

- DESIGN IS 0.75 INCH IN LENGTH WITH A HEAT INPUT OF 75 mW
- COPPER SLEEVE USED TO ACHIEVE AN ISOTHERMAL WALL

Inlet Temperature (Te) → Flow → Wall Temperature (Tw) → Copper

Heater
FLOWMETER PERFORMANCE

- THE FOLLOWING CURVES SHOW THE RESPONSE AND SENSITIVITY OF THE FLOWMETER

  - RESULTS SHOW THAT THE METER CAN BE LOCATED IN THE WARM OR COLD SECTION OF THE DEWAR
    - COLD - LOCATED BETWEEN Hx-0 AND Hx-1
    - WARM - DOWNSTREAM OF Hx-4

[Diagram images showing temperature difference (Tw - Te) and flowrate (Mg) curves for Helium flow with D=0.5", L=0.75", Q=75 mW]
FLOWMETER SUMMARY

- AN ERROR ANALYSIS SHOWS THAT THE ACCURACY CAN BE BETTER THEN FIVE PERCENT
  - PRIMARY ERROR IS IN THE ASSUMPTION OF THE ENTRANCE TEMPERATURE OF THE FLOWSTREAM WHICH IS NOT MEASURED

- COLD LOCATION WAS SELECTED

- FLOWMETER MUST BE ACTIVATED FOR FIVE MINUTES IN ORDER TO ACHIEVE STEADY STATE
  - 100% DUTY CYCLE RESULTS IN A 3/4 MONTH DECREASE IN LIFE

- WALL TEMPERATURE NEEDS TO BE RECORDED FOR FIVE MINUTES BEFORE HEAT IS APPLIED
  - WALL TEMPERATURE DURING THIS TIME WILL BE REPRESENTATIVE OF THE ENTRANCE FLOWSTREAM TEMPERATURE

- CALIBRATION OF THE FLOWMETER SHOULD BE PERFORMED DURING TESTS WHEN THE GUARD TANK IS FILLED
  - ACHIEVE OPERATIONAL FLOWRATES WITH USE OF THE MAIN TANK HEATER

- EVALUATION OF A WARM LOCATION OF THE METER IS STILL ON GOING
INSTRUMENTATION

PAUL DINEEN
• **LEAD BAG TEMPERATURE** - 3.7.5.4.3 OF PAYLOAD SPEC F277277
  - PROVIDE INSTRUMENTATION TO INSURE CAPABILITY TO MAINTAIN TEMPERATURE AT < 6.5K AFTER INITIAL COOLDOWN.
    » LIQUID LEVEL SENSORS LL-3L, LL-3U, LL-4L AND LL-4U; GRT'S T-20D, T-21D, T-22D AND T-23D VERIFY COMPLIANCE.

• **WELL FILL CAPABILITY** - 3.7.5.4.4 OF PAYLOAD SPEC F277277
  - PROVIDE TANK TO WELL LIQUID HELIUM TRANSFER (NORMAL/SUPERFLUID)
    » HEATERS H-6D AND H-7D ALLOW TRANSFER OF SUPERFLUID HELIUM THROUGH FOUNTAIN EFFECT PUMP
    » HEATERS H-8D AND H-9D ALLOW TRANSFER OF NORMAL HELIUM THROUGH RAV7
INSTRUMENTATION REQUIREMENTS

- HELIUM BOIL-OFF - 3.7.5.5 OF PAYLOAD SPEC F277277
  - PROVIDE HELIUM BOILOFF GAS AND THE CAPABILITY TO MONITOR BOILOFF GAS FOR SPACECRAFT OPERATIONS
    » HEATERS H-5D MONITORS FLOW OF GAS
    » HEATERS H-10D AND H-11D ALLOW THE FLOW RATE TO BE INCREASED ON ORBIT
HEATERS DESIGN

- SEE EM#339, P065938 FOR HEATER WATTAGE SIZING
- HEATERS RESISTANCE SIZED USING HEATER WATTAGE AND NOMINAL 28 VDC
- HEATER CURRENT BASED ON 35 VDC MAX
  * H8 & 9 SIZED USING 52 VDC POWER SOURCE
- HEATER FUNCTIONS REDUNDANT
- MANUFACTURER: TAYCO ENGINEERING (SAME AS PROBE B)
- CONSTRUCTION: KAPTON INSULATION W/COPPER LEAD WIRES
- ACCEPTANCE TEST: 70VDC BURN-IN TEST, 77K-5 CYCLE THERMAL SHOCK TEST AND 100V INSULATION RESISTANCE TEST
- QUALIFICATION TEST: BY SIMILARITY TO OTHER COOLER PROGRAMS AND FLIGHT DESIGNS USED IN SPACE SYSTEM DIVISION
# HEATERS DEFINITION

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<th>PIN NO.S</th>
<th>DEVICE NO</th>
<th>FUNCTION</th>
<th>LOCATION</th>
<th>POWER (W)</th>
<th>CURRENT (A)</th>
<th>WIRE SIZE, TYPE</th>
<th>COLD FEEDTHRU</th>
<th>PIN NO.S</th>
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<td>HEAT PULSE METER, MEASURE TANK RESIDUAL</td>
<td>INSIDE SFHE TANK, MOUNTED ON BAFFLES</td>
<td>33</td>
<td>1.47</td>
<td>.040 DIA MANGANIN</td>
<td>P824</td>
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<td>INSIDE SFHE TANK, MOUNTED ON BAFFLES</td>
<td>33</td>
<td>1.47</td>
<td>.040 DIA MANGANIN</td>
<td>P824</td>
<td>5,6,7, 8</td>
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<td>GUARD TANK DEPLETION</td>
<td>GUARD TANK, OUTSIDE</td>
<td>4</td>
<td>.18</td>
<td>.010 DIA MANGANIN</td>
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<td>P804</td>
<td>43,51</td>
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<td>GUARD TANK, OUTSIDE</td>
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<td>N/A</td>
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<td>MEASURE FLOW RATE</td>
<td>VENT LINE</td>
<td>.2</td>
<td>.01</td>
<td>.005 DIA MANGANIN</td>
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<td>P804</td>
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<td>WELL TRANSFER, SUPER FLUID HELIUM</td>
<td>FOUNTAIN EFFECT PUMP</td>
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<td>.05</td>
<td>.005 DIA MANGANIN</td>
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<td>WELL TRANSFER, SUPER FLUID HELIUM</td>
<td>FOUNTAIN EFFECT PUMP</td>
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<td>.05</td>
<td>.005 DIA MANGANIN</td>
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<td>P803 (GROUND)</td>
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<td>1.3</td>
<td>.040 DIA MANGANIN</td>
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<tr>
<td>P802</td>
<td>9,15,16,23</td>
<td>H-10D</td>
<td>FLOW CONTROL, INCREASE ON ORBIT FLOW RATE</td>
<td>SFHE TANK, OUTSIDE</td>
<td>.4</td>
<td>.18</td>
<td>.010 DIA MANGANIN</td>
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<tr>
<td>P802</td>
<td>12,13,19,20</td>
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<td>FLOW CONTROL, INCREASE ON ORBIT FLOW RATE</td>
<td>SFHE TANK, OUTSIDE</td>
<td>.4</td>
<td>.18</td>
<td>.010 DIA MANGANIN</td>
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# TEMPERATURE SENSORS

<table>
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<tr>
<th>TOP PLATE FEEDTHRU</th>
<th>PIN NO.S</th>
<th>DEVICE NO</th>
<th>DEVICE DESCRIPTION</th>
<th>SUPPLIERS PART NO REF</th>
<th>LOCATION</th>
<th>WIRE SIZE, TYPE</th>
<th>COLD FEEDTHRU</th>
<th>PIN NO.S</th>
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<tbody>
<tr>
<td>P801 (FLIGHT)</td>
<td>34,42,43,51</td>
<td>T-1D</td>
<td>GRT *</td>
<td>GR-200B-1500-1.4B</td>
<td>HEX0</td>
<td>.005 DIA, MANGANIN</td>
<td>N/A</td>
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<tr>
<td>P801</td>
<td>23,24,32,33</td>
<td>T-2D</td>
<td>GRT</td>
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<td>HEX0</td>
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<td>P801</td>
<td>9,15,16,22</td>
<td>T-3D</td>
<td>SILICON DIODE **</td>
<td>DT470-SD-11-1-4LS</td>
<td>HEX1</td>
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<td>P801</td>
<td>3,7,8,14</td>
<td>T-4D</td>
<td>SD</td>
<td>**</td>
<td>VCS1, MIDDLE</td>
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<tr>
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<td>P801</td>
<td>4,10,11,17</td>
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<td>P800 (GROUND)</td>
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<td>T-9D</td>
<td>SD</td>
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<td>SFHE TANK OUTSIDE, BOTTOM</td>
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<tr>
<td>P801</td>
<td>61,62,65,66</td>
<td>T-10D</td>
<td>GRT</td>
<td>SEE ABOVE</td>
<td>PP, UPSTREAM</td>
<td></td>
<td>P821 4,5,6,7</td>
<td>4,5,6,7</td>
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<tr>
<td>P801</td>
<td>21,30,31,40</td>
<td>T-11D</td>
<td>GRT</td>
<td>SEE ABOVE</td>
<td>PP, UPSTREAM</td>
<td></td>
<td>P821 8,9,10,11</td>
<td>8,9,10,11</td>
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<tr>
<td>P801</td>
<td>12,13,19,20</td>
<td>T-12D</td>
<td>GRT</td>
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<td>PP, DOWNS</td>
<td></td>
<td>P821 12,13,14,15</td>
<td>12,13,14,15</td>
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<tr>
<td>P805</td>
<td>1,2</td>
<td>T-13D</td>
<td>SD</td>
<td>SEE ABOVE</td>
<td>SUPPORT RING VAC SHELL</td>
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<td>N/A</td>
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<tr>
<td>P805</td>
<td>3,4</td>
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<td>SEE ABOVE</td>
<td>BOTTOM VACUUM SHELL</td>
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<tr>
<td>P804 (UMBILICAL)</td>
<td>10,17,18,27</td>
<td>T-15D</td>
<td>SD</td>
<td>SEE ABOVE</td>
<td>GUARD TANK, OUTSIDE</td>
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# TEMPERATURE SENSORS

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<tr>
<th>TOP PLATE</th>
<th>PIN NO. S</th>
<th>DEVICE NO</th>
<th>DEVICE DESCRIPTION</th>
<th>SUPPLIERS PART NO REF</th>
<th>LOCATION</th>
<th>WIRE SIZE, TYPE</th>
<th>COLD FEEDTHRU</th>
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<tbody>
<tr>
<td>P801</td>
<td>28,29,37,38</td>
<td>T-16D</td>
<td>SD</td>
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<td>GUARD TANK, OUTSIDE</td>
<td>&quot;&quot;</td>
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<td>P805</td>
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<td>T-17D</td>
<td>SD</td>
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<td>TOP PLATE</td>
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<tr>
<td>P801</td>
<td>46,47,54,55</td>
<td>T-18D</td>
<td>GRT</td>
<td>SEE ABOVE</td>
<td>VENT LINE</td>
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<tr>
<td>P801</td>
<td>52,53,59,60</td>
<td>T-19D</td>
<td>GRT</td>
<td>SEE ABOVE</td>
<td>VENT LINE</td>
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<td>P800</td>
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<td>T-20D</td>
<td>GRT</td>
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<td>ID OF WELL</td>
<td>&quot;&quot;</td>
<td>P823</td>
<td>1,2,3,4</td>
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<tr>
<td>P804</td>
<td>1,2,3,6</td>
<td>T-21D</td>
<td>GRT</td>
<td>SEE ABOVE</td>
<td>ID OF WELL</td>
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<td>P823</td>
<td>21,22,23 .24</td>
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<tr>
<td>P800</td>
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<td>GRT</td>
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<td>P800</td>
<td>14,15,21,22</td>
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<td>&quot;&quot;</td>
<td>P823</td>
<td>9,10,11,12</td>
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</table>

* GERMANIUM RESISTANCE THERMOMETER (GRT)
** SILICON DIODE (SD)

- MANUFACTURER: LAKESHORE CRYOTRONICS
- ACCEPTANCE TEST: THERMAL CYCLING AT VENDOR
- CALIBRATION: AT VENDOR
- CONCERNS: CALIBRATION WILL NEED TO BE REPEATED USING FLIGHT ELECTRONICS
### LIQUID LEVEL SENSORS

<table>
<thead>
<tr>
<th>TOP PLATE FEEDTHRU</th>
<th>PIN NO.S</th>
<th>DEVICE NO</th>
<th>DEVICE DESCRIPTION</th>
<th>LOCATION</th>
<th>FUNCTION</th>
<th>WIRE SIZE, TYPE</th>
<th>COLD FEEDTHRU</th>
<th>PIN NO.S</th>
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</thead>
<tbody>
<tr>
<td>P803 (GROUND)</td>
<td>9,16,23,24</td>
<td>LL-1</td>
<td>LIQUID LEVEL SENSOR</td>
<td>SFHE. TANK</td>
<td>VERIFY 95% FILL LEVEL, MONITOR FILL LEVEL DURING TESTING</td>
<td>.012 DIA CU ON SENSOR, .005 DIA MANGANIN FROM TOP PLATE TO SENSOR</td>
<td>P824</td>
<td>1,2,3,4</td>
</tr>
<tr>
<td>P803</td>
<td>2,3,7,8</td>
<td>LL-2</td>
<td>**</td>
<td>SFHE. TANK</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>P824</td>
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<tr>
<td>P804 (UMBILLICAL)</td>
<td>44,45,52,53</td>
<td>LL-3L</td>
<td>**</td>
<td>WELL</td>
<td>MONITOR WELL FILL LEVEL DURING PROBE INSERTION</td>
<td>**</td>
<td>P823</td>
<td>25,26,27,28</td>
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<td>P804</td>
<td>54,55,61,62</td>
<td>LL-3U</td>
<td>**</td>
<td>WELL</td>
<td>**</td>
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<td>P823</td>
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<tr>
<td>P803</td>
<td>1,4,5,6</td>
<td>LL-4U</td>
<td>**</td>
<td>WELL</td>
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<td>P803</td>
<td>17,25,26,27</td>
<td>LL-4L</td>
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<td>WELL</td>
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<td>P823</td>
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<tr>
<td>P804</td>
<td>56,57,58,64</td>
<td>LL-5</td>
<td>**</td>
<td>GUARD TANK</td>
<td>MONITOR GUARD TANK FILL LEVEL</td>
<td>**</td>
<td>P811</td>
<td>1,2,3,4</td>
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<tr>
<td>P804</td>
<td>25,26,35,36</td>
<td>LL-6</td>
<td>**</td>
<td>GUARD TANK</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>P812</td>
</tr>
</tbody>
</table>

- **MANUFACTURER**: AMERICAN MAGNETIC INC. SELECTED OVER KELLER PSI SENSOR
- **CONSTRUCTION**: SUPERCONDUCTING MEASUREMENT WIRE ENCASED IN 1/4" DIAMETER FIBERGLASS SUPPORT TUBE.
- **ACCEPTANCE TEST**: THERMAL CYCLING AT VENDOR
# ACCELEROMETERS

<table>
<thead>
<tr>
<th>TOP PLATE FEEDTHRU</th>
<th>PIN NO.S</th>
<th>DEVICE NO</th>
<th>DEVICE DESCRIPTION</th>
<th>LOCATION</th>
<th>FUNCTION</th>
<th>WIRE SIZE, TYPE</th>
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</thead>
<tbody>
<tr>
<td>P800 (GROUND)</td>
<td>35,36,37,44,45,46</td>
<td>AC-1</td>
<td>TRIAXIAL ACCELEROMETER</td>
<td>SFHE TANK, HEX0</td>
<td>MONITOR LOADS AT STA 200*</td>
<td>.005 DIA MANGANIN</td>
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<tr>
<td>P800</td>
<td>38,39,40,47,48,49</td>
<td>AC-2</td>
<td></td>
<td>SFHE TANK, AFT</td>
<td>MONITOR OVERALL TANK LOADS</td>
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<tr>
<td>P800</td>
<td>41,42,50,51,57,58</td>
<td>AC-3</td>
<td></td>
<td>SFHE TANK, NEAR FWD POD SUPPORT</td>
<td>MONITOR LOADS NEAR POD SUPPORTS</td>
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<tr>
<td>P800</td>
<td>16,23,24,32,33,34</td>
<td>AC-4</td>
<td></td>
<td>SFHE TANK, NEAR AFT POD SUPPORT</td>
<td>MONITOR LOADS NEAR POD SUPPORTS</td>
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</table>

- **MANUFACTURER:** KISTLER MODEL 8614A-500
- **CONSTRUCTION:**
  - THREE KISTLER MODEL 8614A-500 ACCELEROMETERS MOUNTED ON ALUMINUM CUBE
  - CONNECTION: SOLDER
- **ACCEPTANCE TEST/CALIBRATION TEST:** AT TEMPERATURE AT UTAH STATE
- **QUALIFICATION:** SPIRIT III
PRESSURE SENSORS

- VAC-ION PUMP (GROUND TEST ONLY)
  - FUNCTION: MEASURE A 10^{-7} TO 10^{-8} TORR VACUUM BETWEEN THE DEWAR MAIN TANK AND VACUUM SHELL
  - PUMP MAGNET TO BE REMOVED BEFORE FLIGHT TO REDUCE WEIGHT
  - VARIAN MODEL: 913-0032; PUMPING RATE: 2 LITER/SEC
  - INTERFACE: CONNECTOR P811, SEE VIEW C-C OF ICD 5833115
  - ACCEPTANCE TEST: LEAK TEST
  - FLIGHT QUALIFIED ON LONG LIFE COOLER, CLAES AND SPIRIT III
LIQUID POINT SENSOR

- LIQUID POINT SENSOR
  - FUNCTION: MEASURE THE PRESENCE OF LIQUID HELIUM DOWNSTREAM OF THE POROUS PLUG. VERIFIES THAT THE POROUS PLUG IS FUNCTIONING CORRECTLY BY INDICATING THAT NO LIQUID HELIUM IS PRESENT.
  - AMERICAN MAGNETICS INC MODEL: LHE-PT25
  - ACCEPTANCE TEST: THERMAL CYCLE TO LN2
  - QUALIFICATION: VIBRATION TEST PLANNED AT POROUS PLUG ASSEMBLY LEVEL
<table>
<thead>
<tr>
<th>TOP PLATE FEEDTHRU</th>
<th>PIN NO.</th>
<th>DEVICE NO</th>
<th>DEVICE DESCRIPTION</th>
<th>LOCATION</th>
<th>WIRE SIZE, TYPE</th>
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<tbody>
<tr>
<td>P801 (FLIGHT)</td>
<td>24</td>
<td>R-0</td>
<td>PODS DISCONNECT COMMON RETURN</td>
<td>TANK</td>
<td>.005&quot; DIA MANGANIN</td>
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<tr>
<td>P802 (FLIGHT)</td>
<td>34</td>
<td>R-1</td>
<td>PODS DISCONNECT</td>
<td>PODS#1</td>
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<tr>
<td>P802</td>
<td>33</td>
<td>R-2</td>
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<td>PODS#2</td>
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<tr>
<td>P802</td>
<td>43</td>
<td>R-3</td>
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<tr>
<td>P802</td>
<td>51</td>
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<td>P802</td>
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<td>R-12</td>
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<td>PODS#12</td>
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</table>

- **FUNCTION:** VERIFY THERMAL ISOLATION BETWEEN TANK AND VACUUM SHELL
- **READINGS SHOULD NORMALLY BE OPEN UNLESS PODS SHORT OUT**
- **R-0 COMMON RETURN FOR R-1 THRU R-12**
- **ACCEPTANCE TEST: CONTINUITY CHECK AT INSTALLATION USING JUMPER TO SHORT POD**
<table>
<thead>
<tr>
<th>TOP PLATE FEEDTHRU</th>
<th>PIN NO.S</th>
<th>DEVICE NO</th>
<th>DEVICE DESCRIPTION</th>
<th>LOCATION</th>
<th>CURRENT (A)</th>
<th>WIRE SIZE, TYPE</th>
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<tbody>
<tr>
<td>P800 (GROUND)</td>
<td>52,53,54,55,56,59,60,61,</td>
<td>RAV-1</td>
<td>REMOTE ACTUATED VALVE</td>
<td>SFHE TANK FILL</td>
<td>1 @ 1.5</td>
<td>1 @ .040 DIA</td>
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<tr>
<td></td>
<td>62,65,66</td>
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<td></td>
<td></td>
<td>4 @ 0.7</td>
<td>4 @ .020 DIA</td>
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<td></td>
<td></td>
<td>6 @ &gt; .001</td>
<td>6 @ .005 DIA</td>
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<td>P802 (FLIGHT)</td>
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<td>RAV-2</td>
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<td>GUARD TANK FILL</td>
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<tr>
<td>P803 (GROUND)</td>
<td>35,36,37,38,39,40,44,45,46,47,48</td>
<td>RAV-3</td>
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<td>POROUS PLUG BYPASS</td>
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<td>P804 (UMBILICAL)</td>
<td>4,5,7,8,11,12,13,14,19,20,21</td>
<td>RAV-5</td>
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<td>WELL FILL</td>
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<td>FOUNTAIN EFFECT PUMP</td>
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<td>RAV-7</td>
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<td>P806</td>
<td>1,2,3,4</td>
<td>PV-1</td>
<td>PYRO VALVE</td>
<td>EXTERNAL VACUUM SHELL</td>
<td>TBD</td>
<td>4 @ TBD</td>
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<tr>
<td>P808</td>
<td>1,2,3,4</td>
<td>PV-3</td>
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<td>EXTERNAL WELL</td>
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<tr>
<td>P809</td>
<td>1,2,3,4</td>
<td>PV-4A</td>
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<td>SFHE ON ORBIT VENT</td>
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<tr>
<td>P810</td>
<td>1,2,3,4</td>
<td>PV-4B</td>
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<td>SFHE ON ORBIT VENT</td>
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</tbody>
</table>
FEEDTHROUGH CONNECTORS

- TOP PLATE FEEDTHROUGH CONNECTORS
  - MANUFACTURER: PACIFIC COAST TECHNOLOGIES
  - TYPE: 66 PIN MIL-C-38999 TYPE III CONNECTORS
  - ACCEPTANCE TEST AT VENDOR: THERMAL CYCLE TO 220K, ROOM TEMPERATURE DC ISOLATION AND LEAK TEST
  - QUALIFICATION TEST: SMD VIBRATION TEST

- COLD FEEDTHROUGH CONNECTORS
  - MANUFACTURER: PACIFIC COAST TECHNOLOGIES
  - CONSTRUCTION: STAINLESS STEEL BODY, INCONEL PINS, CRYOFLEX SEAL, SOLDER CONNECTION BOTH ENDS
  - DEVELOPMENT TEST: SEE DEVELOPMENT TEST SECTION
  - ACCEPTANCE TEST AT VENDOR: THERMAL CYCLE TO LN2, ROOM TEMPERATURE DC ISOLATION AND LEAK TEST
  - LMSC ACCEPTANCE TEST (AFTER WELDING INTO FLANGE): THERMAL CYCLE/LEAK TEST AT LN2, ROOM TEMPERATURE 83PSI PRESSURE TEST
  - QUALIFICATION TEST: SMD VIBRATION TEST
• DEWAR INTERFACE TO PROBE - ICD DWG 5833117
  – REVISION WILL SHOW INSTALLATION OF LIQUID LEVEL SENSORS LL-3U, LL-3L, LL4U AND LL4L IN WELL AND NECK REGIONS
  – REVISION WILL SHOW INSTALLATION OF GRTS T-20D, T-21D, T-22D AND T-23D IN WELL REGION
• PAYLOAD - TO - SPACECRAFT INTERFACE - ICD DWG 5833115
  – UPDATE IN PROCESS
  – UPDATE WILL SHOW T-13D, T-14D AND T-17D INSTALLATION LOCATIONS AND WIRE ROUTING TO CONNECTOR P805
INSTRUMENTATION STATUS

• INTERNAL TANK: DETAILED DRAWINGS
  – HEATER, GRT, FEEDTHRU, FLANGE, AND WIRE DWGS COMPLETE
  – LIQUID LEVEL SENSOR AND BRACKET DRAWINGS IN PROCESS, REVISED FOR +X AND +Y HORIZONTAL FILL ORIENTATIONS
• INTERNAL TANK INSTALLATION DRAWINGS: IN PROCESS
• EXTERNAL TANK DRAWINGS/LAYOUT
  – WIRES SORTED BY DEVICE TYPE, GROUND, FLIGHT AND UMBILICAL FUNCTIONS AND ASSIGNED PIN NUMBERS
  – TOP HAT CONNECTORS INCREASED FROM 55 PINS TO 66 PINS BECAUSE OF WIRE SORTING AND AVAILABILITY OF OFF-THE-SHELF MATING CONNECTORS
  – OFF THE SHELF BENDIX CONNECTOR SELECTED AS TOP PLATE FEEDTHROUGH MATE. PREVIOUS CONCEPT SOLDER CONNECTION
  – WIRES SIZED FOR CURRENT LOADS, REF EM#338 -REV A, P065937
  – DETERMINED THAT WIRES WILL NOT NEED TO BE SHIELDED WITHIN DEWAR. TEMPERATURE SENSORS TO BE ROUTED SEPARATE FROM REMOTE ACTUATED VALVES
  – FINAL WIRE ROUTING IN PROCESS
CHANGES SINCE PDR

- Tank liquid level sensor orientation revised to monitor tank fill level with $+x$ axis and $+y$ axis pointing up.
- Selection of AMI as main tank and guard tank liquid level sensor vendor.
- Definition of number of wires needed for remote actuated valves and final number of remote actuated valves:
  - Allowed final sorting of wires by connector function (i.e., ground, flight, and umbilical).
- Selection of Pacific Coast Technologies as cold feedthrough vendor:
  - Allowed finalization of tank and axial Lok feedthrough openings.
<table>
<thead>
<tr>
<th>RISK</th>
<th>RISK REDUCTION</th>
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</thead>
<tbody>
<tr>
<td>COLD FEEDTHRU LEAKAGE</td>
<td>THERMAL CYCLED &amp; LEAK TESTED AT VENDOR AND LMSC PRIOR TO INSTALLATION. WELDED TO REMOVABLE FLANGES IF REPLACEMENT REQUIRED</td>
</tr>
<tr>
<td>FAILURE OF GRTS AND SILICON DIODES</td>
<td>THERMAL CYCLING AT VENDOR AND LMSC PRIOR TO INSTALLATION. REDUNDANT FUNCTIONS INSTALLED</td>
</tr>
<tr>
<td>FAILURE OF HEATERS</td>
<td>THERMAL SHOCK TEST PERFORMED AT VENDOR. REDUNDANT HEATER INSTALLED.</td>
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<tr>
<td>WIRE BREAKING</td>
<td>HEAVIEST POSSIBLE COATING OF POLYIMIDE INSULATION USED ON WIRES.</td>
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</table>
SUMMARY AND CONCLUSION

- INSTRUMENTATION MEETS REQUIREMENTS

- DETAILED DESIGN IN PROGRESS

- DEWAR INTERNAL INTERFACES CLEARLY DEFINED

- RISK AREAS CLEARLY IDENTIFIED AND BEING ADDRESSED
GROUND SUPPORT EQUIPMENT

DAVID PICKETT
• LEAD BAG AND RETAINER INSTALLATION
• PROBE/DEWAR INTEGRATION EQUIPMENT
• DEWAR HANDLING EQUIPMENT
• CRYOGENIC SERVICE EQUIPMENT
• DEWAR GROUND SUPPORT EQUIPMENT
• EDD/SMD COMMON INTERFACE DESIGN AND OPERATIONS APPROACH TO CAPITALIZE ON EDD SUCCESSES AND MAXIMIZE COMMONALITY OF EQUIPMENT, PROCEDURES, AND EXPERIENCE

• SUCCESSFUL LEAD BAG WORK AND COLD PROBE INSERTION SHOWS UTILITY OF MAJOR PORTION OF ALL GSE NEEDED FOR SMD
<table>
<thead>
<tr>
<th>EQUIPMENT DESCRIPTION</th>
<th>COMMENTS</th>
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<tbody>
<tr>
<td>GLOVEBOX</td>
<td>EXISTING EDD EQUIPMENT</td>
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<tr>
<td>RADIATION BAFFLES</td>
<td>EXISTING EDD EQUIPMENT</td>
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<tr>
<td>RADIATION COVER PLATE</td>
<td>EXISTING EDD EQUIPMENT</td>
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<tr>
<td>MAGNETOMETERS</td>
<td>EXISTING EDD EQUIPMENT</td>
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<tr>
<td>EXPANSION TOOLS</td>
<td>EXISTING EDD EQUIPMENT</td>
</tr>
<tr>
<td>SHUTTER</td>
<td>EXISTING EDD EQUIPMENT</td>
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<tr>
<td>DEWAR ADAPTER</td>
<td>NEW DESIGN FOR SMD</td>
</tr>
<tr>
<td>REMOVABLE MAGNETIC SHIELD</td>
<td>NEW SMD DESIGN, EDD 'BUCKING COIL' CAN 'T BE USED</td>
</tr>
</tbody>
</table>
• DEWAR ADAPTER
  - SMD TOP PLATE DESIGN IS SIGNIFICANTLY DIFFERENT FROM EDD
  - PROVIDES INTERFACE BETWEEN TOP PLATE & LEAD BAG GSE

• REMOVABLE MAGNETIC SHIELD
  - CYLINDER Mu METAL MATERIAL WHICH MATES WITH STATION 200 AND EXTENDS UP INTO THE DEWAR NECK TUBE
  - EXTENDS MAGNETIC SHIELD FURTHER UP THE NECK DURING INITIAL COOLDOWN THROUGH THE INSTALLATION OF THE 10 INCH LEAD BAG
# PROBE/DEWAR INTEGRATION EQUIPMENT

<table>
<thead>
<tr>
<th>EQUIPMENT DESCRIPTION</th>
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<tbody>
<tr>
<td>• PROBE AIRLOCK</td>
<td>MODIFICATION REQUIRED FOR PROBE B/EDD INTEGRATION</td>
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<td>• PROBE AIRLOCK SUPPORT PLATE</td>
<td>CLAMSHELL DESIGN REQUIRED FOR SMD</td>
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<tr>
<td>• AIRLOCK BARREL LIFTING MECHANISM</td>
<td>LIMITED HOOK HEIGHT REQUIRES NEW DESIGN FOR PROBE-B/EDD</td>
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<tr>
<td>• SHORT LOAD CELL/LIFTING DEVICE</td>
<td>LIMITED HOOK HEIGHT REQUIRES NEW DESIGN FOR PROBE/EDD</td>
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<tr>
<td>• DIAL INDICATOR PROBE CENTERING DEVICE</td>
<td>EXISTING EDD EQUIPMENT</td>
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<td>EQUIPMENT DESCRIPTION</td>
<td>COMMENTS</td>
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<tr>
<td>----------------------------------------</td>
<td>--------------------------------------------------------------------------</td>
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<tr>
<td>• ASSEMBLY STAND</td>
<td>180° TILT CAPABILITY, 5° ROLL POSITIONING, LOCKS IN PLACE FOR TILT OPERATIONS</td>
</tr>
<tr>
<td>• INTEGRATION AND TEST STAND</td>
<td>ASSEMBLY STAND MODIFIED FOR MOTORIZED ROLL &amp; DITHER</td>
</tr>
<tr>
<td>• LIFTING SLING</td>
<td>LIFTING DEVICE TO HOIST TANK AND DEWAR INTO AND OUT OF THE ASSEMBLY/TEST STAND (5000 LB CAPABILITY)</td>
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</tbody>
</table>
SMD ASSEMBLY STAND

Caster Mounting Plate: Ref Note 12, 14 Places

Pedestal Mounting Plate: Ref Note 12, 03 Places

DC Motor & Brake

Torque Control

Switch with 14 FT Cable Brackets. For Locating. The Cables are not shown. See Note 18

Support Shown Out of Plane

Roller Bearing Notation (W1, OW in Front View)

Usage/Optional Reference Item 30 Not Shown
SMD ASSEMBLY STAND REQUIREMENTS

- DESIGN REQUIREMENTS
  - WEIGHT CAPACITY = 2000 KG (FULLY LOADED DEWAR WITH PROBE)
  - INTERFACE WITH VACUUM SHELL SUPPORT RING AT SPACECRAFT ATTACH POINTS

- FUNCTIONAL REQUIREMENTS
  - STAND CAN BE ROLLED AROUND LAB
  - STAND CAN BE JACKED UP OFF WHEELS AND FIRMLY BOLTED TO THE LAB FLOOR
  - STAND SHOULD MAXIMIZE ASSEMBLY ACCESS
  - DEWAR CAN BE SECURED TO THE STAND EVERY FIVE DEGREES IN THE ROLL ORIENTATION
  - DEWAR CAN BE TILTED UPSIDE DOWN
  - STAND CAN BE USED FOR SHIPPING

- CAN BE MODIFIED FOR USE AS TEST AND INTEGRATION STAND
<table>
<thead>
<tr>
<th>ITEM</th>
<th>REQUIREMENT</th>
<th>BASELINE PERFORMANCE</th>
<th>VERIF</th>
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<tbody>
<tr>
<td>LOAD CAPABILITY</td>
<td>3700 LBS. (MAX AT PROBE INTEGRATION)</td>
<td>MEETS REQ.</td>
<td>AN/TEST</td>
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<td></td>
<td>@ FOS 5.0</td>
<td>(18500 LBS)</td>
<td>DES/TEST</td>
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<tr>
<td>TILT CAPABILITY</td>
<td>DEWAR VERTICAL TO HORIZ.</td>
<td>MEETS REQ.</td>
<td>DES/TEST</td>
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<tr>
<td>TILT VELOCITY</td>
<td></td>
<td>TBD</td>
<td>DES/TEST</td>
</tr>
<tr>
<td>PROFILE</td>
<td></td>
<td>TBD</td>
<td>DES/TEST</td>
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<tr>
<td>ROLL CAPABILITY</td>
<td>360 DEG. (30 MIN/REV)</td>
<td>MEETS REQ.</td>
<td>DES/TEST</td>
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<tr>
<td>ROLL MECHANISM</td>
<td>STEPPER MOTOR, CONTROL: MANUAL OR COMPUTER</td>
<td>MEETS REQ.</td>
<td>DES/TEST</td>
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<tr>
<td>ROLL VELOCITY</td>
<td></td>
<td>TBD</td>
<td>DES/TEST</td>
</tr>
<tr>
<td>PROFILE</td>
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<td>TBD</td>
<td>DES/TEST</td>
</tr>
<tr>
<td>ROLL REFERENCE MARKS</td>
<td>DETERMINE QBA ROLL TO +/- 1 DEG</td>
<td>MEETS REQ.</td>
<td>DES/INS</td>
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<tr>
<td>LEVELING ADJUST</td>
<td>SET TRUNNION HORIZONTAL</td>
<td>SEE EM 229</td>
<td>INSPIE</td>
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<tr>
<td>LEVELING CHECK</td>
<td>TBD (CHECK AT DEWAR TOP)</td>
<td>JACKS @ 4 PLCS CLINOMETER</td>
<td>INSPIE</td>
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<tr>
<td>ITEM</td>
<td>REQUIREMENT (STANFORD SO130 5/2/90)</td>
<td>BASELINE PERFORMANCE</td>
<td>VERIF</td>
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<tr>
<td>DITHER RANGE/ TOLERANCE</td>
<td>200 ARC SECONDS</td>
<td>MEETS REQ.</td>
<td>DES/TEST</td>
</tr>
<tr>
<td></td>
<td>+/- 10 ARC SECONDS</td>
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<tr>
<td>ANGULAR VELOCITY VELOCITY PROFILE</td>
<td>200 ARC SEC / 5 SEC</td>
<td>50 +/- 10 ARC SEC/SEC</td>
<td>DES/TEST</td>
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<td>TBD</td>
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<tr>
<td>CALIBRATION/ READOUT</td>
<td>MANUAL / DIAL INDICATOR</td>
<td>MEETS REQ.</td>
<td>DES/TEST</td>
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<tr>
<td>MECHANISM</td>
<td>STEPPER MOTOR</td>
<td>MEETS REQ.</td>
<td>DES/TEST</td>
</tr>
<tr>
<td>DITHER PIVOT POINT LOCATION</td>
<td>INTERSECTION PROBE C. L. &amp; SIDE MOUNT GATE VALVE FLANGE</td>
<td>MEETS REQ.</td>
<td>DES/TEST</td>
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<tr>
<td>DITHER PIVOT REF LOCATION</td>
<td>LOCATION: WITHIN .25 DEG. OF TILT PLANE</td>
<td>MEETS REQ.</td>
<td>DES/INSPECTION</td>
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<tr>
<td>EQUIPMENT DESCRIPTION</td>
<td>COMMENTS</td>
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<tr>
<td>----------------------------------------</td>
<td>---------------------------------------------------------------------------</td>
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<tr>
<td>• LIQUID HELIUM SUPPLY DEWAR (2 EACH)</td>
<td>1000 L CAPACITY, WITH MODIFICATIONS FOR SUB-ATMOSPHERIC FLUID TRANSFER AND LEVEL SENSORS</td>
<td></td>
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<tr>
<td>• SUPPLY DEWAR SIPHON</td>
<td>FEMALE LINDE TYPE BAYONETS. NEED TO REVIEW LAUNCH PAD HEIGHT RESTRICTION</td>
<td></td>
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</tr>
<tr>
<td>• TANK FILL TRANSFER LINE</td>
<td>9&quot; RIGHT ANGLE MALE BAYONET AT DEWAR. 0.5 MICRON FILTER. TRANSFER LINE LENGTHS REQUIRED IS TBD</td>
<td></td>
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<tr>
<td>• TANK EXHAUST LINE</td>
<td>MALE LINDE TYPE BAYONETS, EACH END. INTERFACES WITH MAIN TANK OR GUARD TANK AND EXHAUST MODULE</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
FUNCTIONAL REQUIREMENTS

• CAPABLE OF OPERATING AT REMOTE FACILITIES

• CAPABLE OF CONTINGENCY OPERATIONS AT THE LAUNCH PAD

• VACUUM PUMPING ON DEWAR VACUUM SPACE, TANKS, WELL, & PLUMBING

• MONITOR DEWAR STATUS (TEMPERATURE, PRESSURE, FILL LEVEL)

• SUPPORT HELIUM (NORMAL & SUPER FLUID) FILL/VENT OPERATIONS
<table>
<thead>
<tr>
<th>EQUIPMENT DESCRIPTION</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>VACUUM MODULE</td>
<td>PUMPS THE DEWAR VACUUM SPACE TO A HARD VACUUM</td>
</tr>
<tr>
<td>GAS MODULE</td>
<td>PROVIDES A CONTROLLED EVACUATION AND BACKFILL OF THE MAIN TANK AND GUARD TANK; SUPPORTS HELIUM FILL OPERATIONS</td>
</tr>
<tr>
<td>EXHAUST MODULE</td>
<td>PROVIDES HIGH CAPACITY PUMPING TO CONDITION SFHE; PROVIDES HEAT EXCHANGER TO WARM EXHAUST GAS DURING FILL OPERATIONS</td>
</tr>
<tr>
<td>EQUIPMENT DESCRIPTION</td>
<td>COMMENTS</td>
</tr>
<tr>
<td>----------------------------------------</td>
<td>----------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>• ELECTRICAL MODULE</td>
<td>CONTAINS MONITORS AND CONTROLS FOR GAS, VACUUM, AND EXHAUST MODULES. INCLUDES LIQUID LEVEL R/O, POWER SUPPLIES FOR ALL HEATERS AND CONTROL FOR CRYOVALVES. SUPPLIES POWER TO ALL MODULE GSE EXCEPT SFHE CONDITIONING PUMPS</td>
</tr>
<tr>
<td>• DATA ACQUISITION SYSTEM</td>
<td>COMPUTER, PRINTER, PLOTTER, VOLTMETER AND SCANNER FOR DISPLAYING, REDUCING, AND STORING TEST DATA</td>
</tr>
<tr>
<td>• TEMPERATURE, MONITOR AND ALARM (TMA)</td>
<td>MONITOR AND DISPLAY CRITICAL TEMPS. 115 VAC OR SELF CONTAINED BATTERIES. PORTABLE (CAN BE CARRIED). AUDIBLE ALARM FEATURES.</td>
</tr>
<tr>
<td>OPERATION</td>
<td>HELIUM SUPPLY</td>
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<tr>
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<tr>
<td>EVACUATE VACUUM SPACE</td>
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<tr>
<td>EVACUATE/BACKFILL MAIN TANK, GUARD TANK, WELL, &amp; PLUMBING</td>
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<td>SYSTEM LEAK CHECKS</td>
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<td>SYSTEM BAKEOUT</td>
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<td>MAIN TANK FILL (NBHE)</td>
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<tr>
<td>MAIN TANK FILL (SFHE)</td>
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<tr>
<td>MAIN TANK VENTING</td>
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<tr>
<td>GUARD TANK FILL</td>
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<tr>
<td>GUARD TANK VENTING</td>
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<tr>
<td>MONITOR AND OPERATE INSTRUMENTATION</td>
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## PRELIMINARY

### GSE FACILITY REQUIREMENTS

<table>
<thead>
<tr>
<th>EQUIPMENT</th>
<th>APPROXIMATE ENVELOPE (In.)</th>
<th>APPROXIMATE WEIGHT (lb)</th>
<th>POWER</th>
<th>COMPRESSION AIR (80 psi)</th>
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</thead>
<tbody>
<tr>
<td>VACUUM MODULE</td>
<td>(L) (W) (H) 30 X 36 X 60</td>
<td>600</td>
<td>N/R</td>
<td>YES</td>
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<tr>
<td>GAS MODULE</td>
<td>30 x 36 x 60</td>
<td>600</td>
<td>N/R</td>
<td>YES</td>
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<tr>
<td>EXHAUST MODULE 2 (UNITS)</td>
<td>30 X 72 X 80</td>
<td>800</td>
<td>208 V, 3 Ø 30 A</td>
<td>YES</td>
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<tr>
<td>ELECTRICAL MODULE</td>
<td>30 X 36 X 60</td>
<td>800</td>
<td>208 V, 3 Ø 30 A</td>
<td>YES</td>
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<tr>
<td>TM&amp;A</td>
<td>10 x 26 x 18</td>
<td>30</td>
<td>110 V, 10 A (OR) BATTERIES</td>
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<tr>
<td>DATA SYSTEM</td>
<td>36 x 72 x 36</td>
<td>800</td>
<td>110 V, 10, 20 A</td>
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<tr>
<td>LEAK DETECTOR</td>
<td>36 x 36 x 36</td>
<td>600</td>
<td>110 V, 10, 30 A</td>
<td>N/R</td>
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FABRICATION AND ASSEMBLY

DAVID PICKETT
# SMD Fabrication Schedule

## Activity Name

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<td>PHASE I</td>
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<td>MAIN TANK AFT DOME</td>
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<td>MAIN TANK ASSEMBLY</td>
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<td>MAIN TANK CYLINDER</td>
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<td>BAFFLE INSTALLATION</td>
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<td>CRYOPERM SHIELD</td>
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<td>MAIN TANK FORWARD DOME ASSEMBLY</td>
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<td>FORWARD DOME</td>
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<td>AXIAL LOK RING</td>
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### Diagram:

- A diagram showing the timeline and dependencies for each activity.
- The timeline is marked with dates from January to December.
- The diagram includes arrows indicating the sequence and progression of the activities.
PHASE I (MAIN TANK ASSEMBLY)

- AXIAL LOK MACHINING - IN PROGRESS
- WELL CYLINDER MACHINING - IN PROGRESS
- WELL DOME FORGING - COMPLETE
- UPPER DOME FORGING - COMPLETE
- UPPER DOME TOOL TRIAL MACHINING - IN PROGRESS
- CRYOPERM SHIELD PROCUREMENT - IN PROGRESS
- TANK CYLINDER FORGING - IN PROGRESS
- LOWER DOME FORGING - IN PROGRESS
PHASE II (SUPPORT RING, PODS, & PLUMBING INSTALLATION)

- PODS PIECE PART PROCUREMENT - IN PROGRESS
- VACUUM SHELL SUPPORT RING FORGING - COMPLETE
- VACUUM SHELL MID-CYLINDER FORGING - COMPLETE
- GRAPHITE RING PROCUREMENT - IN PROGRESS
- AXIAL LOK PIECE PART PROCUREMENT - COMPLETE
- COLD VALVE PROCUREMENT - IN PROGRESS
- COLD BURST DISC PROCUREMENT - IN PROGRESS
PHASE III (COMPOSITE NECK TUBE & GUARD TANK ASSEMBLIES)

- COMPOSITE NECK TUBE PROCUREMENT - INITIATE IN MARCH
- HEAT EXCHANGER PROCUREMENT - INITIATE IN MARCH
- GUARD TANK FORGING PROCUREMENT - IN PROGRESS

PHASE IV (VAPOR COOLED SHIELDS, MLI, & VACUUM SHELL ASSEMBLIES)

- VAPOR COOLED SHIELDS PROCUREMENT - INITIATE IN APRIL
- VACUUM SHELL NECK CYLINDER FORGING - IN PROGRESS
- FIXED ASSET PROCUREMENT OF CUTTING TABLE - INITIATE IN MARCH
PROCESS DEVELOPMENT

- AXIAL LOK TOOL FABRICATION COMPLETE
- FORWARD DOME TOOL TRIAL - IN PROGRESS
- WELD SCHEDULE DEVELOPMENT - IN PROGRESS

MAIN TANK FABRICATION

- AXIAL LOK FABRICATION - IN PROGRESS
- WELL CYLINDER FABRICATION - IN PROGRESS
- FORWARD DOME BASKET FIXTURE AND VACUUM CHUCK FIXTURE - COMPLETE
- CENTER CYLINDER TOOL FABRICATION - IN PROGRESS

VACUUM SHELL FABRICATION

- SUPPORT RING FABRICATION - IN PROGRESS
WELL, AXIAL LOK, PROTON SHIELD, & GUARD TANK SUPPORT (6063 AL)

- LOCKHEED LAC SPECIFICATION 3853-020101
  - PROCESS QUALIFICATION REQUIRED
  - X-RAY, VISUAL, PENETRANT, AND HELIUM LEAK INSPECTION REQUIRED
  - WELD FILLER MATERIAL CONTROL REQUIRED

MAIN TANK, GUARD TANK, & VACUUM SHELL (2219 AL)

- LOCKHEED LAC SPECIFICATION 3861-010000
  - PROCESS QUALIFICATION REQUIRED
  - X-RAY, VISUAL, PENETRANT, AND HELIUM LEAK INSPECTION REQUIRED
DEVELOP WELD PARAMETERS

- PREPARE WELD COUPONS
  - FLAT PLATE AT THICKNESS OF JOINT
  - FLAT PLATE WITH PROPOSED JOINT GEOMETRY

- WELD "BEAD ON PLATE" AND MACHINED JOINTS TO DEVELOP PARAMETER WINDOWS
  - CLEANING PROCEDURE
  - MACHINE PARAMETERS
  - FIT-UP REQUIREMENTS
  - BEAD SHAPE
WELD PARAMETERS QUALIFICATION

- MACHINE ADDITIONAL FLAT PLATE TO CONFIRMED JOINT GEOMETRY
- GTAW OR EB WELD
- GRIND WELD FLUSH
- VISUAL INSPECT, X-RAY INSPECT, HELIUM LEAK CHECK, PENETRANT INSPECT
- SECTION AND IDENTIFY
- METALLURGICAL EXAM
- MECHANICAL TESTING
- MACHINE FULL SIZE JOINTS FROM EXTRA FORGING MATERIAL
  - REPEAT WELDING AND THE WELD INSPECTION/TESTING ABOVE
- MAIN TANK AND WELL
- CRYOPERM
- PROTON SHIELDING
- INSTRUMENTATION AND HEATERS
- INTERNAL PLUMBING
- SLOSH BAFFLES
TANK FABRICATION SEQUENCE

5833408-101
AXIAL LOK RING
FORGING (6063-T452)

5833407-101
AXIAL LOK RING
MACHINED

DIE FORGED,
SOLUTION HEAT TREATED,
STRESS RELIEVED, AGED,
MACHINED, ULTRASONIC
INSPECTED, MAGNETIC
INSPECTED

AXIAL LOK RING
DEVELOPMENT TEST
FIXTURE

MACHINING TRIAL FOR
COMPLEX BORE AREA
TANK FABRICATION SEQUENCE

5833381-101
WELL CYLINDER
FORGING (6063-T452)

DIE FORGED,
SOLUTION HEAT TREATED,
STRESS RELIEVED, AGED,
MACHINED, ULTRASONIC
INSPECTED, MAGNETIC
INSPECTED

5833389-101
WELL CYLINDER
MACHINED

5833407-101
AXIAL LOK RING
MACHINED

REMOVE FROM STORES

5833396-101
AXIAL LOK/WELL
WELDMENT

X-RAY INSPECT,
HELIUM LEAK CHECK,
PENCETRANT INSPECT
5833464-101
WELL DOME
FORGING (6083-T652)

DIE FORGED,
SOLUTION HEAT TREATED,
stress relieved, aged,
machined, ultrasonic
inspected, magnetic
inspected

5833398-101
WELL DOME
MACHINED

5833384-102
WELL DOME WELDMENT

5833396-101
AXIAL LOK/WELL
WELDMENT

X-RAY INSPECT,
HELIUM LEAK CHECK,
PENETRANT INSPECT
5833172-101
FORWARD DOME
MACHINED

5833171-101
TANK FORWARD DOME
FORGING (2219-T852)

DIE FORGED,
SOLUTION HEAT TREATED,
STRESS RELIEVED, AGED,
MACHINED, ULTRASONIC
INSPECTED
PODS ATTACH POINTS PROVIDE BOSSES FOR THREE POINT LIFT
UPPER DOME BONDING/ALIGNMENT FIXTURE

INSTALL WELL DOME WELDMENT (5833384-102)

STATION 200 INTERFACE

PODS ATTACH POINTS INTERFACE
ATTACH UPPER DOME TO LIFTING FIXTURE

LOWER UPPER DOME OVER WELL TO BOND
5833384-101
FORWARD DOME ASSEMBLY

EPOXY BOND DOME TO AXIAL LOK, THEN HELIUM LEAK CHECK

FORWARD DOME ASSEMBLY CAN BE REMOVED FROM FIXTURE FOR PRECISION CLEANING PRIOR TO NEXT ASSEMBLY
5833196-101 MAGNETIC SHIELD ASSEMBLY

INSTALL MAGNETIC SHIELD IN SUPPORT CRADLE

WELD PER DRAWING, STRAIN RELIEVE, MAGNETIC TEST

REMOVE INNER SUPPORT PLUG FROM MAGNETIC SHIELD
5833313-101 MAIN TANK SHIELDS INSTALLATION

ALL MAIN TANK SHIELDS AND PLUMBING ASSEMBLY OPERATIONS SHALL BE PERFORMED IN A CLASS 100 CLEAN ROOM ENVIRONMENT

ALL 5833313-101 COMPONENTS SHALL BE PRECISIONED CLEANED PRIOR TO ASSEMBLY

USE FIXTURE TO HOLD FORWARD DOME ASSEMBLY IN THE HORIZONTAL

USE HOIST TO POSITION CRADLE
5833313-101
MAIN TANK SHIELDS
INSTALLATION

USE HOIST TO POSITION CRADLE. APPLY EPOXY TO WELL DOME FOR PIN BOND, THEN SLOWLY INSTALL MAGNETIC SHIELD OVER THE WELL

MAGNETIC SHIELD INSTALLATION COMPLETE
5833465-101
PROTON SHIELD
FORGING (6063-T452)

5833465-102
PROTON SHIELD
FORGING

5833466-102
PROTON SHIELD
CYLINDER

5833466-104
PROTON SHIELD
DOME

5833466-101
PROTON SHIELD
ASSEMBLY

DIE FORGED,
SOLUTION HEAT TREATED,
stress relieved, aged,
machined, ultrasonic
inspected, magnetic
inspected

X-RAY INSPECT,
penetrant inspect
5833313-101
MAIN TANK SHIELDS
INSTALLATION

USING HOIST, SLOWLY
LOWER PROTON SHIELD
OVER THE WELL

SECURE PROTON SHIELD
TO FORWARD DOME
INSTALL INTERNAL PLUMBING, LEAK CHECK AND THERMAL CYCLE BOND JOINTS

INSTALL LIQUID LEVEL SENSOR AND HEATERS

5833313-101
MAIN TANK SHIELDS INSTALLATION COMPLETE
5833175-101
TANK CYLINDER
FORGING (2219-T851)

5833176-101
TANK CYLINDER
MACHINED

5833170-101
MAIN TANK
ASSEMBLY

DIE FORGED,
SOLUTION HEAT TREATED,
STRESS RELIEVED, AGED,
MACHINED, ULTRASONIC
INSPECTED

PRECISION CLEAN

SPOT WELD SLOSH
BAFFLES INTO CYLINDER
5833170-101
MAIN TANK
ASSEMBLY

PRECISION CLEAN

TACK WELD IN PREPARATION
FOR E-BEAM PERFORMED IN
CLEANLINESS CONTROLLED AREA
5833173-101  
TANK AFT DOME FORGING (2219-T852)

5833174-101  
TANK AFT DOME MACHINED

5833390-101  
MAIN TANK CLOSURE ASSEMBLY

---

E-Beam weld
X-ray inspect,
Helium leak check,
Penetrant inspect

DIE FORGED,
SOLUTION HEAT TREATED,
STRESS RELIEVED, AGED,
MACHINED, ULTRASONIC INSPECTED

PRECISION CLEAN
THEN TACK WELD
DOME TO CYLINDER
• MAIN TANK
  – TESTS COMPLETED
    » TANK PROOF PRESSURE TEST
    » HELIUM LEAK TEST

• PODS
  – TESTS COMPLETED
    » LOADS TEST

• GRAPHITE RING
  – COUPON TESTS COMPLETED
    » MATERIAL TEST
    » LOADS TEST
• GUARD TANK
  – COMPONENTS INSTALLED
    » LIQUID LEVEL SENSOR
  – TESTS COMPLETED
    » TANK PROOF PRESSURE
    » HELIUM LEAK TEST

• COMPOSITE NECK TUBE ASSEMBLY
  – COMPONENTS INSTALLED
    » COMPOSITE NECK TUBE
    » TSR, HEX, AND END FLANGES
  – TESTS COMPLETED
    » PROOF PRESSURE TEST (INTERNAL & EXTERNAL)
    » THERMAL CYCLE/HELIUM LEAK TEST
    » BUCKLING TEST
• COLD VALVES AND COLD BURST DISCS
  – ACCEPTANCE TEST PERFORMED ON EACH COMPONENT
    » PERFORMANCE AND ENVIRONMENT TESTS

• VAPOR COOLED SHIELDS
  – PIECE PARTS INSPECTED FOR DIMENSIONAL VERIFICATION

• CRYOPERM SHIELD ASSEMBLY
  – MAGNETIC TESTING

• VACUUM SHELL
  – TESTS COMPLETE
    » HELIUM LEAK TESTS
    » COMPONENT PROOF PRESSURE TESTS
**STEP 1**

- INSTALL VACUUM SHELL SUPPORT RING IN ASSEMBLY STAND

**STEP 2**

- BOLT VACUUM SHELL TO SUPPORT RING (WITH ALIGNMENT PINS)
- SLIP LOWER GRAPHITE RING THRU VACUUM SHELL CYLINDER; TEMPORARILY TAPE GRAPHITE RING TO SUPPORT RING
- BOLT BOX/FLEXURE ASSY'S TO ID OF VACUUM SHELL CYLINDER
**STEP 3**

- FIT CHECK FWD GRAPHITE RING
- SAND, BOND, AND BOLT IN GRAPHITE RING TO ELEVEN BOX STRUCTURES

**STEP 4**

- ROTATE VACUUM SHELL CYLINDER UPSIDE DOWN USING FIXTURE
- REPEAT STEP 3 FOR AFT GRAPHITE RING
STEP 5

- ROTATE VACUUM SHELL CYLINDER RIGHT SIDE UP USING FIXTURE
- INSTALL 3 TEMPORARY SUPPORTS BETWEEN BOX ASSY'S ON AFT GRAPHITE RING AND SUPPORT RING

STEP 6

- BOLT PRECISION ALIGNMENT TOOL TO MAIN TANK AT AXIAL LOK
- LIFT TANK/TOOL WITH CRANE AND LOWER INTO THE VACUUM SHELL CYLINDER (BOLT ALIGNMENT TOOL TO VACUUM SHELL CYLINDER)
- INSTALL 12 PODS STRUTS
STEP 7

- UNBOLT FLEXURES FROM VACUUM SHELL
- UNBOLT FIXTURE FROM MAIN TANK
- UNBOLT VACUUM SHELL CYLINDER FROM SUPPORT RING
- REMOVE 9 FLEXURES FROM BOXES
- BOLT ALL VCS ATTACHMENTS TO PODS
- MEASURE, ADJUST, AND MARK VCS ATTACHMENT LOCATIONS AND CLOCKING ON PODS
- REMOVE ALL VCS ATTACHMENTS
**STEP 8**

- INSTALL VALVE AND PLUMBING MOUNTING BRACKETS
- INSTALL FEP AND POROUS PLUG
- INSTALL INSTRUMENTATION, VALVE CABLING, AND HEATER WIRES; BRING WIRE LEADS TO STATION 200
- INSTALL FLIGHT MLI ON TANK

**STEP 9**

- INSTALL COLD VALVES, COLD BURST DISCS, AND MISC. PLUMBING
- LEAK CHECK PLUMBING A/R
• INSTALL TANK BURST DISC CHECK VALVE ASSEMBLIES ON VACUUM SHELL SUPPORT RING

• CONNECT COLLAPSIBLE VENT LINES FROM MAIN TANK TO VACUUM SHELL

• CLAMP ALIGNMENT/SUPPORT TOOL TO STATION 200 WITH 3 DOGS
- Epoxy bond CNT assembly to tank using alignment tool to assure positioning
- Epoxy bond doubler
- Leak check bond joint
- Bond axial LOK tubes to tank and heat exchangers.
- Leak check bond joints

- Epoxy bond guard tank assembly to HEX 1
- Install all fill and vent interconnect plumbing. Cover all exposed plumbing w/ DAM
- Install instrumentation and route lead wires up CNT, heat sinking them to each HEX
• REATTACH VCS #1 ATTACHMENTS ON ALL 12 PODS

• HAND LIFT VCS #1 CONE ON TO THE GUARD TANK

• SCREW CONE TO GUARD TANK

• SCREW VCS #1 "B" PANELS TO VCS #1 CONE
• Hand lift lower dome in place and bolt to 'B' panels

• Bolt VCS #1 'A' panel to cone and dome

• Check spacing

• Match drill pods attachments to VCS flanges
- MATCH DRILLING OPERATIONS 18, 19, 20, & 21 FOR SHIELD # 2 ARE SIMILAR TO STEPS 14, 15, 16, & 17

- BOLT VCS #3 ATTACHMENTS ON ALL PODS

- PLACE 12 ADJUSTABLE SUPPORTS ON HEX-3

- HAND LIFT AND HOLD CONE OVER TANK

- SCREW CONE TO TEMPORARY SUPPORTS (12 PLACES)
• SCREW VCS #3 "B" PANELS TO VCS #3 CONE

• HAND LIFT LOWER DOME IN PLACE AND BOLT TO 'B' PANELS
- SCREW VCS #3 "A" PANELS TO VCS #3 CONE AND DOME
- MATCH DRILL PODS ATTACHMENTS

- MATCH DRILLING OPERATIONS 26, 27, 28, & 29 FOR SHIELD # 4 ARE SIMILAR TO STEPS 22, 23, 24, & 25
• REMOVE ALL VCS USING SPECIAL TOOLS TO SEPARATE VECRO FASTENERS

• ADD NUT PLATES TO ALL FLEXURE (EACH ATTACHMENT CUSTOM MARKED TO PODS LOCATION)

• EPOXY BOND ALL (48) FLEXURES TO PODS

• REINSTALL ALL VCS'S PER STEPS 14 THROUGH 29. EPOXY BOND ALL BOLTED JOINTS

• INSTALL MLI AND INSTRUMENTATION ON EACH VCS, AS REQUIRED

• REBOLT FLEXURES TO BOX STRUCTURE
- Rotate Dewar upside down
- Remove attachment between CNT flange and support tool
- Epoxy bond top plate to CNT and axial LOK tubes
- Leak check bond joint
- Bond doublers to axial LOK tube joints, leak check
- Rotate Dewar upright

- Place Helicoflex seal into support ring groove
- Lower vacuum shell cylinder on to support ring and bolt
- Bolt nine flexures to I.D. of vacuum shell cylinder
- Remove temporary struts
DEWAR ASSEMBLY SEQUENCE

- PLACE HELICOFLEX SEAL INTO VACUUM SHELL CYLINDER GROOVE AND TOP PLATE GROOVE
- REMOVE ALIGNMENT TOOL FROM INSIDE CNT
- USING O/H CRANE, LOWER FORWARD VACUUM SHELL WELDMENT ON TO VACUUM SHELL CYLINDER AND TOP PLATE AND BOLT AT BOTH LOCATIONS

- ROTATE DEWAR UPSIDE DOWN
- PLACE HELICOFLEX SEAL IN SUPPORT RING
- USING O/H CRANE AND VACUUM CHUCK, LOWER AFT VACUUM SHELL WELDMENT ON TO SUPPORT RING AND BOLT
• Rotate Dewar upright

• Install external valves and burst discs on vacuum shell support ring and top plate

• Dewar ready for SMD subsystem testing
SMD MASS PROPERTIES

RICHARD WHELAN
# DEWAR MASS PROPERTIES SUMMARY

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<td>849.95</td>
</tr>
<tr>
<td></td>
<td>HELIUM</td>
<td>341.50</td>
<td>0</td>
<td>341.50</td>
</tr>
<tr>
<td></td>
<td>DEWAR - WET</td>
<td>1116.93</td>
<td>7</td>
<td>1191.45</td>
</tr>
</tbody>
</table>

DRY DEWAR CONTROL WEIGHT = 936 KG; MARGIN = +86 KG
<table>
<thead>
<tr>
<th>ITEM</th>
<th>BASIC WT (KG)</th>
<th>CONT. %</th>
<th>PREDICTED WT (KG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEWAR - DRY</td>
<td>775.43</td>
<td>10</td>
<td>849.95</td>
</tr>
<tr>
<td>HELIUM</td>
<td>341.50</td>
<td>0</td>
<td>341.50</td>
</tr>
<tr>
<td>PROBE</td>
<td>176.85</td>
<td>5</td>
<td>185.69</td>
</tr>
<tr>
<td>SIA</td>
<td>39.05</td>
<td>5</td>
<td>41.00</td>
</tr>
<tr>
<td>SHUTTER</td>
<td>22.09</td>
<td>35</td>
<td>29.82</td>
</tr>
<tr>
<td>SUNSHADE</td>
<td>2.20</td>
<td>82</td>
<td>4.00</td>
</tr>
<tr>
<td>FORWARD ELECTRONICS</td>
<td>77.96</td>
<td>44</td>
<td>112.27</td>
</tr>
<tr>
<td>MAIN PAYLOAD - WET</td>
<td>1435.08</td>
<td>10</td>
<td>1564.23</td>
</tr>
<tr>
<td>AFT ELECTRONICS (ON S/C)</td>
<td>173.00</td>
<td>14</td>
<td>197.76</td>
</tr>
<tr>
<td>AFT HARDWARE (ON S/C)</td>
<td>106.34</td>
<td>37</td>
<td>145.22</td>
</tr>
<tr>
<td>SCIENCE PAYLOAD - WET TOTAL</td>
<td>1714.42</td>
<td>12</td>
<td>1907.21</td>
</tr>
</tbody>
</table>

SCIENCE PAYLOAD WEIGHT ALLOCATION = 2000 KG; MARGIN = +93 KG
This table is used to assess design maturity:

<table>
<thead>
<tr>
<th>MATURITY</th>
<th>ELECTRICAL/ ELECTRONIC COMPONENTS</th>
<th>STRUCTURE</th>
<th>MECHANISMS</th>
<th>THERMAL CONTROL</th>
<th>PROPULSION AND PYROTECHNICS</th>
<th>BATTERIES</th>
<th>WIRING AND CABLES</th>
<th>INSTRUMENTATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>CODE</td>
<td>0 TO 10 LBS</td>
<td>11 TO 30 LBS</td>
<td>31 LBS AND UP</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>NEW DESIGN OR PRELIMINARY DESIGN (SKETCHES DESCRIPTIONS)</td>
<td>30</td>
<td>25</td>
<td>20</td>
<td>20</td>
<td>25</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>J</td>
<td>MAJOR MODS TO EXISTING HARDWARE OR LAYOUT CALCULATIONS</td>
<td>25</td>
<td>20</td>
<td>15</td>
<td>15</td>
<td>20</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>L</td>
<td>MINOR MODS TO EXISTING HARDWARE OR PRERELEASED DWG CALCULATIONS</td>
<td>20</td>
<td>15</td>
<td>10</td>
<td>8</td>
<td>8</td>
<td>15</td>
<td>8</td>
</tr>
<tr>
<td>C</td>
<td>RELEASED DWG CALCULATIONS</td>
<td>15</td>
<td>10</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>X</td>
<td>EXISTING HARDWARE ACTUAL WEIGHT</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>A</td>
<td>FLIGHT HARDWARE ACTUAL WEIGHT</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>S</td>
<td>SUBCONTRACTOR HARDWARE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>CUSTOMER FURNISHED EQUIPMENT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(1) MAXIMUM SPECIFICATION WEIGHTS, "0" PERCENT CONTINGENCY
(2) REPORTED STATUS VALUES: SUBCONTRACTOR CONTINGENCY, OR AS MUTUALLY AGREED
"0" PERCENT CONTINGENCY, OR AS DIRECTED BY PROCURING AGENCY
# WEIGHT CHANGES

## CHANGES SINCE PDR:

<table>
<thead>
<tr>
<th>REPORT</th>
<th>CHANGE</th>
<th>( \Delta (KG) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEPTEMBER 93</td>
<td>MISC. PROBE &amp; DEWAR CHANGES</td>
<td>+1 KG</td>
</tr>
<tr>
<td>NOVEMBER 93</td>
<td>BAFFLE WEIGHT REDUCED</td>
<td>-61 KG</td>
</tr>
<tr>
<td></td>
<td>VACUUM SHELL MATERIAL CHANGE</td>
<td>+40 KG</td>
</tr>
<tr>
<td></td>
<td>OTHER MISC. CHANGES</td>
<td>+17 KG</td>
</tr>
<tr>
<td></td>
<td>(MOSTLY PROBE SUNSHADE CHANGE - FIXED TO DEPLOYABLE)</td>
<td></td>
</tr>
<tr>
<td>DECEMBER 93</td>
<td>PRE-RELEASED VAC. SHELL DWGS ANALYZED</td>
<td>-17 KG</td>
</tr>
<tr>
<td></td>
<td>HEX BRAZEMENT RE-ANALYSIS</td>
<td>-13 KG</td>
</tr>
<tr>
<td></td>
<td>SFHe ADDED (MAIN TANK VOLUME RE-ANALYSIS)</td>
<td>+17 KG</td>
</tr>
<tr>
<td>JANUARY 94</td>
<td>BAFFLE STRESS ANALYSIS UPDATED</td>
<td>+6 KG</td>
</tr>
<tr>
<td></td>
<td>STAR TRACKER PALTFORM -&gt; S/C</td>
<td>-5 KG</td>
</tr>
<tr>
<td></td>
<td>PLUMBING, MISC. CHANGES</td>
<td>-2 KG</td>
</tr>
<tr>
<td></td>
<td>PLUMBING, INTERFACE CHANGES</td>
<td>+7 KG</td>
</tr>
<tr>
<td></td>
<td>GUARD TANK</td>
<td>-3 KG</td>
</tr>
<tr>
<td></td>
<td>OTHER MISC. CHANGES</td>
<td>-2 KG</td>
</tr>
<tr>
<td>FEBRUARY 94</td>
<td>VACUUM SHELL HARDWARE REANALYSIS</td>
<td>-10 KG</td>
</tr>
<tr>
<td></td>
<td>MISC. CHANGES</td>
<td>+2 KG</td>
</tr>
</tbody>
</table>
Dry DEWAR Weight History

- CONTROL WEIGHT = 936 KG
- Baffle wt reduction
- Vac. Shell mat'l change (prelim. analysis)
- Vac. Shell re-analysis
- HEX Brazement re-analysis
- SFHe added

REPORT DATE:
- 2/93
- 4/93
- 6/93
- 9/93
- 11/93
- 12/93
- 1/94
- 2/94

- PREDICTED WEIGHT
- BASIC WEIGHT
- ALLOCATION
Science Payload Weight History

- **ALLOCATION = 2000 KG**

- **1907.7**
- **1915.8** (Proton Shield Added (Out-of-Scope change))
- **1914.3** (includes 17.5 kg of add'l Helium)
- **1915.4**

**REPORT DATE**
- 2/93, 4/93, 6/93, 9/93, 11/93, 12/93, 1/94, 2/94

**PROJECTED WEIGHT**
- **BASIC WEIGHT**
- **ALLOCATION**
• CENTER OF GRAVITY LIMITS:
  XCG < ±4 MM  YCG < ±4 MM
  ZCG > 4260 MM & ZCG < 4500 MM

• PRESENT STATUS:
  XCG = -4.15 MM  YCG = 4.88 MM  ZCG = 4555.87 MM

• PRODUCT OF INERTIA LIMITS:
  IXZ & IYZ < 10.50 KG-M2

• PRESENT STATUS:
  IXZ = 7.36 KG-M2
  IYZ = 6.84 KG-M2
CONTAMINATION

KARL MASON
SMD CONTAMINATION REQUIREMENTS

• GENERAL REQUIREMENT:
  CONTAMINATION (PARTICULATE AND MOLECULAR) SHALL BE CONTROLLED TO:
  – PREVENT DEWAR VALVE ASSEMBLY LEAKAGE
  – PREVENT MIGRATION OF MAGNETIC CONTAMINANTS FROM TANK TO WELL
  – PREVENT PLUGGING OF 0.5 μ POROUS PLUG

• APPROACH
  – GSE FILL LINE SHALL INCLUDE FILTER TO PROTECT AGAINST VALVE ASSEMBLY LEAKAGE
  – EACH WELL FILL LINE HAS ADDITIONAL FILTER TO PREVENT MIGRATION OF MAGNETIC PARTICLES INTO WELL
  – FILL LINES AND INTERNAL TANK SURFACES SHALL BE CLEANED TO LEVELS SPECIFIED IN THE CONTAMINATION CONTROL PLAN
  – ESTABLISH CONTAMINATION CONTROLS AT TANK(S) VENDORS
<table>
<thead>
<tr>
<th>ZONE</th>
<th>DESCRIPTION</th>
<th>LEVEL</th>
<th>RATIONALE</th>
</tr>
</thead>
<tbody>
<tr>
<td>VIII (8)</td>
<td>INTERIOR OF ALL LIQUID FILL LINES, ALL COLD VALVES</td>
<td>100 A</td>
<td>PROTECT THE REMOTE VALVES, PREVENT PLUGGING WELL FILL FILTERS</td>
</tr>
<tr>
<td>IX (9)</td>
<td>INTERIOR OF WELL, MAIN TANK, GUARD TANK, VENT LINES, AXIAL LOK, AXIAL LOK TUBING, COMPOSITE NECK TUBE</td>
<td>250 A</td>
<td>LEVEL 250 WILL PREVENT PLUGGING OF FILTERS</td>
</tr>
<tr>
<td>X (10)</td>
<td>INTERIOR OF GSE FILL LINES DOWNSTREAM OF EXTERNAL FILL LINE FILTER</td>
<td>100 A</td>
<td>PROTECT THE REMOTE VALVES, PREVENT PLUGGING WELL FILL LINE FILTERS</td>
</tr>
<tr>
<td>XI (11)</td>
<td>INTERIOR AND EXTERIOR OF VACUUM SHELL</td>
<td>VISIBLY CLEAN</td>
<td></td>
</tr>
</tbody>
</table>


FILL LINE REQUIREMENTS

- 25 µM ABSOLUTE FILTER REQUIRED IN GSE FILL LINE
- 10 µM FILTER (F-2) IN FILL LINE ON DEWAR SIDE
- WELL FILL LINE HAS 2 µm FILTER (F-1) DOWNSTREAM OF REMOTE VALVES
- FOUNTAIN EFFECT PUMP IS 0.5 µm FILTER
- FILL TUBE INTERNAL SURFACE CLEANLINESS:
  - LAC 3150 070100 / MIL-STD-1246 100A
- FILL LINE VALVES INTERNAL SURFACE CLEANLINESS:
  - LAC 3150 070100 / MIL-STD-1246 100A
### TABLE I. PARTICULATE CLEANLINESS LEVELS(a)

<table>
<thead>
<tr>
<th>Particle Size Range (microns)</th>
<th>-03XXX</th>
<th>-04XXX</th>
<th>-05XXX</th>
<th>-06XXX</th>
<th>-07XXX</th>
<th>-08XXX</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-10</td>
<td>(b)</td>
<td>(b)</td>
<td>(b)</td>
<td>(b)</td>
<td>(b)</td>
<td>120</td>
</tr>
<tr>
<td>11-25</td>
<td>(b)</td>
<td>(b)</td>
<td>(b)</td>
<td>(b)</td>
<td>500</td>
<td>55</td>
</tr>
<tr>
<td>26-50</td>
<td>(b)</td>
<td>(b)</td>
<td>(b)</td>
<td>280</td>
<td>65</td>
<td>6</td>
</tr>
<tr>
<td>51-100</td>
<td>(b)</td>
<td>(b)</td>
<td>340</td>
<td>45</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>101-150</td>
<td>(b)</td>
<td>700</td>
<td>25</td>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>151-250</td>
<td>1,230</td>
<td>175</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>251-500</td>
<td>170</td>
<td>&quot;25</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>501-750</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Over 750</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Fibers</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>0(c)</td>
<td>0(c)</td>
</tr>
<tr>
<td>Equivalent degree of cleanliness per MIL-STD-1246</td>
<td>750</td>
<td>500</td>
<td>250</td>
<td>150</td>
<td>100</td>
<td>50</td>
</tr>
</tbody>
</table>

(a) Sample size shall be 100 milliliters for liquid, or 10 cubic feet for gas, unless other volume is specified.

(b) Count not required (maximum particle size limits size and quantity of smaller particles).

(c) Statistical 0 (i.e., if two analyses are performed and a fiber is found in one analysis, count is 0).
### MIL-STD-1246
#### CLEANLINESS LEVELS

#### CLASSIFICATION OF PRODUCT CLEANLINESS LEVELS

<table>
<thead>
<tr>
<th>Cleanliness Level</th>
<th>Range Surface and Fluids</th>
<th>Quantity of Particulates</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>10</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>25</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>50</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>100</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>200</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>300</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>500</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>750</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>1000</td>
<td>10</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Level</th>
<th>Quantity NVR</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Less than 1.0 mg</td>
</tr>
<tr>
<td></td>
<td>1.0 mg to</td>
</tr>
<tr>
<td>B</td>
<td>2.0 mg</td>
</tr>
<tr>
<td>C</td>
<td>2.0 mg to</td>
</tr>
<tr>
<td></td>
<td>3.0 mg</td>
</tr>
<tr>
<td>D</td>
<td>3.0 mg to</td>
</tr>
<tr>
<td></td>
<td>4.0 mg</td>
</tr>
<tr>
<td>E</td>
<td>4.0 mg to</td>
</tr>
<tr>
<td></td>
<td>5.0 mg</td>
</tr>
<tr>
<td>F</td>
<td>5.0 mg to</td>
</tr>
<tr>
<td></td>
<td>7.0 mg</td>
</tr>
<tr>
<td>G</td>
<td>7.0 mg to</td>
</tr>
<tr>
<td></td>
<td>10.0 mg</td>
</tr>
<tr>
<td>H</td>
<td>10.0 mg to</td>
</tr>
<tr>
<td></td>
<td>15.0 mg</td>
</tr>
<tr>
<td>J</td>
<td>15.0 mg to</td>
</tr>
<tr>
<td></td>
<td>25.0 mg</td>
</tr>
</tbody>
</table>

\*Derivation of Cleanliness Levels. Each level of Table Ia was established by plotting the curves in Chart I. Chart I points are number of total particles above given size versus particle size.\*
MINIMUM PROCESS REQUIREMENTS

- CHEMICAL PRECLEAN TUBING BEFORE BENDING
- FLOW-THROUGH HIGH VELOCITY / VOLUME FLUSHING IS REQUIRED (NOT A DIP OR RINSE)
REQUIREMENTS DURING ASSEMBLY

- SPECIAL CLEANLINESS AREA REQUIRED (MINIMUM)
  - GOAL OF CLASS 300,000 AIR CLEANLINESS PER FED-STD-209
  - LMSC B/205 WILL BE CLASS 300,000 FOR DEWAR ASSEMBLY
- PROCESS REQUIREMENTS (MINIMUM)
  - CLASS 300,000 DURING OPERATION (MONITORED)
  - DEDICATED AREA
  - CLEAN ROOM GARMENTS
  - REGULAR MAINTENANCE
  - PROTECTIVE COVERS FOR HARDWARE DURING PERIODS OF NON USE. COVERS CLEAN TO LAC 3150 050100 / MIL-STD-1246 250A
- ASSEMBLY TOOLING TO BE REGULARLY DEGAUSSED AND CLEANED BEFORE USE.
• SPECIAL CLEANLINESS AREA REQUIRED (MINIMUM)
• PROCESS REQUIREMENTS (MINIMUM)
  – INITIATE NITROGEN PURGE DURING ASSEMBLY PROCESS, CONTINUE UNTIL ALL WELDS COMPLETED
• COVER FILL TUBE ENDS WITH CLEAN COVERS. CLEAN TO LAC 3150 070100 / MIL-STD-1246 100A
MAGNETICS

RICHARD VASSAR / ERNEST IUFER
DEWAR MAGNETIC CONTROL

- DEWAR WELL, CRYOPERM SHIELD, LEAD BAGS, LEAD BAG RETAINER, AND TRANSFER LINES ARE MAGNETICALLY SCREENED TO ZONE 4.

- MAGNETIC CONTAMINATION OF WELL IS PREVENTED BY TRANSFER LINE FILTERS
  - LHE ALWAYS PASSES THROUGH 2 $\mu$ FILTER F1 BEFORE WELL ENTRY
  - A 2 $\mu$ FILTER IS ABSOLUTE FOR 10 $\mu$ PARTICLES. A SINGLE, SATURATED IRON 10 $\mu$ PARTICLE CAN PRODUCE $9 \times 10^{-10}$ GAUSS AT 5 "$. A SINGLE 2 \mu$ PARTICLE CAN PRODUCE $7 \times 10^{-13}$ GAUSS.
  - LHE NEVER ENTERS THE PROBE VACUUM SHELL

- USE OF FILTERS AVOIDS NEED TO SCREEN TANK
NUMBER OF SATURATED IRON PARTICLES PRODUCING 0.1 μG

NO. OF PARTICLES PRODUCING 0.1 μGAUSS

NO. OF PARTICLES PRODUCING 0.1 μGAUSS

100000.00

10000.00

1000.00

100.00

10.00

1.00

14121 @ 2μ

113 @ 10μ

PARTICLE SIZE (μM)

2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46
CRYOPERM SHIELD TESTING

• THE CRYOPERM FERROMAGNETIC SHIELD WILL BE TESTED FOR CONFORMANCE TO REQUIREMENTS AT NASA AMES PRIOR TO INTEGRATION.

• THE FOLLOWING KEY ELEMENTS WILL BE INCLUDED IN THE TEST PROCEDURE
  - REMOVAL OF REMANENCE UPON ARRIVAL
  - MEASUREMENT OF POST DEMAGNETIZATION REMANENCE IN ZERO AMBIENT FIELD
  - MEASUREMENT OF NET FIELD AT GYRO LOCATIONS AND AT THE SHIELD MOUTH IN ZERO FIELD AND AGAIN WHILE IN AN AXIAL AMBIENT FIELD OF 600 mG
  - MEASUREMENT OF NET FIELD AT GYRO LOCATIONS AND AT THE SHIELD MOUTH IN ZERO FIELD AND AGAIN WHILE IN A TRANSVERSE AMBIENT FIELD OF 600 mG
  - MEASURE THE EXTERIOR CHARACTERISTICS OF THE SHIELD AS REQUIRED TO DETERMINE IN-ORBIT MAGNETIC TORQUES
SAFETY OVERVIEW

- SCIENCE MISSION DEWAR SAFETY COMPLIANCE DOCUMENT, GPB-100153, REFLECTS THE ASSESSMENT OF THE DESIGN AS OF THE PRINTING OF THIS CDR PACKAGE.
  - MINOR UPDATE TO THE HAZARD REPORTS REQUIRED TO REFLECT DETAILS OF THE ENGINEERING MEMORANDUMS RELEASED SINCE THIS CDR PACKAGE WAS PRINTED.

- MOST OF THE SMD SAFETY ISSUES HAVE BEEN ADDRESSED WITHIN THE SECTIONS OF THE CDR WHERE THE REQUIREMENTS APPLY.
  - STRESS ANALYSIS PRESENTED STRUCTURAL FACTORS OF SAFETY.
  - THERMAL ANALYSIS PRESENTED MAXIMUM DESIGN PRESSURES.
  - OVERALL DESIGN PRESENTED DUAL VENTING CAPABILITY.
  - REQUIREMENTS LISTED WITHIN LMSC DOCUMENT F277277 AND TRACKED BY SYSTEMS ENGINEERING.
REQUIREMENTS CHANGE

  – DETAILED COMPARISON COMPLETED BETWEEN CHAPTER 3 OF EACH DOCUMENT.
  – ADDED A WRR 127-1 CHAPTER 3 CHECKLIST AS AN ATTACHMENT TO THE LMSC SMD SAFETY COMPLIANCE DOCUMENT.
  – INPUTS MADE TO UPDATE LMSC DESIGN REQUIREMENTS SPECIFIED IN LMSC DOCUMENT F277277.
    » NO IMPACT TO THE FLIGHT HARDWARE
    » CHANGES TO THE GSE REQUIREMENTS WILL NOT IMPACT THE PROGRAM AS THE GSE DESIGN AND OPERATIONS FOR THE WESTERN RANGE HAVE NOT MATURATED TO THE LEVEL THAT A CHANGE IN THE REQUIREMENTS IMPACTS THE HARDWARE.
  – PRESENTATION, LMSC DOCUMENT GPB 100151, SENT TO THE WESTERN RANGE SAFETY OFFICE TO OBTAIN AGREEMENT THAT LEAK-BEFORE-BURST DESIGN FOR THE VACUUM SHELL REDUCES THE RISK TO ACCEPTABLE LEVELS.
HANDLING AND TRANSPORTATION

• DEFINED IN LMSC DESIGN DOCUMENT F277277;
  – LOADS FOR SMD DESIGN
  – TRANSPORTATION LOADS.

• ALERT TO SHIPPING HAZARDS TO THE HARDWARE;
  – X, Y, & Z AXIS FOR THE CONTAINER AND FOR THE SMD ARE COORDINATED AND APPROPRIATE ACTIONS TAKEN TO MITIGATE UNWANTED LOADING.
  – SHIPMENT OF PARTIAL ASSEMBLIES ARE REVIEWED FOR STRUCTURAL SOUNDNESS.
  – TRANSPORTATION LOADS ARE MONITORED.

• GROUND HANDLING FIXTURES REVIEWED FOR STABILITY, GIVEN MOVEMENT OF THE FIXTURE OR A SEISMIC EVENT.

• GROUND HANDLING FIXTURES WILL BE PROOF LOADED.
• SHIPMENT OF SMD WITH NORMAL BOILING POINT LIQUID HELIUM.
  - SHIPMENT PERFORMED WITH PRESSURES LESS THAN 40 PSIA, THEREFORE THE DEWAR DOES NOT QUALIFY AS A PRESSURE VESSEL WITHIN THE DEFINITIONS OF THE DOT.
    » COORDINATE THE TRANSPORTATION WITH A TRANSPORTATION ORGANIZATION. WITHIN CALIFORNIA THE JURISDICTION FOR ENFORCEMENT OF TRANSPORTATION REGULATIONS IS THE HIGHWAY PATROL.
  - PER DOT, LIQUID HELIUM QUALIFIES AS A CRYOGENIC GAS, HAZARDOUS CLASSIFICATION 2.2, ID # UN1963, LABELED AS A NON-FLAMMABLE GAS.
  - LIMITED TO 500 KG ON CARGO AIRCRAFT.
    » EACH CARRIER HAS THEIR OWN RULES AND PROCEDURES.
    » THE VENT LINES SHOULD BE ROUTED THROUGH AN ABSOLUTE PRESSURE REGULATOR.
    » THE EMERGENCY VENT LINES NEED TO BE ROUTED OUT OF THE AIRCRAFT.
HELium VENTING

- Establish "Keep out Zones" around burst disks during handling. Keep main tank burst disks connected to a facility vent when practical.

- Main tank has capacity to reduce the air in a 700,000 cubic foot room to less than acceptable oxygen levels (19% oxygen).

- The guard tank and vacuum shell can be considered equal risk to the 500 liter supply dewars.

  » The oxygen deficiency figure is deceptive. The vented gas will rise, displacing the air from the ceiling down. At the ceiling the oxygen level could go less than 5% while the ground level is still 21%.

  » Each facility needs to be assessed. How permeable is the ceiling, where does the gas go, are their people working at heights...

- The LMSC high bay facility, building 205, has an O2 monitor in the ceiling.

- The LMSC environmental test facility determined sufficiently large and "leaky" by occupational safety.
RELIABILITY - SMD INSTRUMENTATION AND PLUMBING

JIM SUTY
- OBJECTIVE & APPROACH

- FMECA DESCRIPTION

- STUDIES & ACTIONS SINCE PDR
  - BURST DISK RELIABILITY ANALYSIS
  - COLD VALVE/MOTOR DURABILITY ACTIONS

- RESULTS, CONCLUSIONS, RISK AREAS
OBJECTIVE & APPROACH

- DEFINE DURABILITY REQUIREMENTS
  - DESIGN LIFE ENVIRONMENTS
    » SERVICE LIFE
    » TEST & VERIFICATION
    » TRANSPORTATION AND LAUNCH

- CONDUCT FAILURE MODES, EFFECTS & CRITICALITY ANALYSIS (FMECA)

- ASSESS PLUMBING COMPONENT RELIABILITY
  - CRITICAL ITEM LIST
  - DESIGN TRADEOFFS
  - OPERATING MARGINS (PRESSURE, FORCE, TORQUE, TRAVEL)
  - RISK ASSESSMENT / MITIGATION

- PLAN FOR TRENDING / VERIFICATION OF PERFORMANCE

- LIST CONCLUSIONS / RECOMMENDATIONS
FMECA DESCRIPTION
(1 OF 2)

- A FMECA HAS BEEN CONDUCTED FOR EACH TYPE OF PLUMBING COMPONENT. THEY ARE:
  - VACUUM-JACKETED BAYONET CONNECTION
  - PYROTECHNIC VALVE
  - REMOTELY ACTUATED VALVE
  - MANUALLY ACTUATED VALVE
  - COLD AND WARM BURST DISCS
  - RELIEF VALVE
  - FOUNTAIN EFFECT PUMP
  - POROUS PLUG
  - EMERGENCY VENT LINE
  - FILTER
  - ELECTRICAL WIRING
  - TANK HEATERS
  - PASSIVE ORBITAL DISCONNECT STRUT
  - ELECTRICAL FEEDTHROUGH
  - VAC ION PUMP
  - HELICAL FLEX COLD SEAL
FMECA DESCRIPTION
(2 OF 2)

- EACH FMECA ITEM ANALYSIS CONSISTS OF:
  - END ITEM DESCRIPTION
  - ITEM DESCRIPTION
  - FUNCTION
  - NEXT HIGHER ASSEMBLY
  - FAILURE MODE AND CAUSES
  - EFFECTS
  - HOW FAILURE IS DETECTED
  - HOW FAILURE IS ISOLATED
  - HOW FUNCTION IS RESTORED
  - TIME TO RESTORE
  - ASSESSMENT
  - CORRECTIVE DESIGN AND DEVELOPMENT ACTION
  - STATUS
  - ADDITIONAL NOTES
• BURST DISK RELIABILITY
  – ANALYSIS TO CONVERT .999 RELIABILITY INTO TEST PARAMETERS
  – INCORPORATION OF PARAMETERS INTO BURST DISK SPECIFICATION

COLD VALVE/MOTOR DURABILITY ACTIONS
  – REVIEW OF PREVIOUS FAILURES IN SIMILAR HARDWARE
  – REVIEW OF PREVIOUS FAILURE ANALYSIS AND DESIGN FIXES
  – FORMULATION OF DESIGN AND FABRICATION GUIDELINES
  – INTERCHANGE WITH VALVE/MOTOR SUPPLIER
RESULTS, CONCLUSIONS, RISK AREAS

- BURST DISKS
  - SPECIFICATION
    » REQUIRES VERIFICATION OF .999 PROBABILITY THAT BURST DISKS WILL PERFORM THEIR FUNCTION BETWEEN 83% AND 117% OF NOMINAL SET POINT
    » ALLOWS ADDITIONAL MARGIN OF SAFETY OF 17 PSID FOR MAIN TANK
    » ALLOWS ADDITIONAL MARGIN OF SAFETY OF 24 PSID FOR GUARD TANK
  - RISK OF MULTIPLE LOT/DATE CODES FOR BURST DISK ASSEMBLIES
    » MITIGATED BY SPECIFICATION, CERTIFICATION OF CONFORMANCE, INSPECTION

- COLD VALVES/MOTORS
  - SUPPLIERS SUBSCRIBING TO DESIGN GUIDELINES
  - SUPPLIERS ALREADY FOLLOWING FABRICATION GUIDELINES
  - RISK OF CONTAMINATION, TOOL DAMAGE, OVERPOTTING OF COILS
    » MITIGATED BY ADHERENCE TO AGREED ASSEMBLY PRACTICES
QUALITY ASSURANCE

JIM LEPETICH
REQUIREMENTS

- IMPLEMENTATION: LMSC GP-B SAFETY, RELIABILITY, MAINTAINABILITY AND PRODUCT ASSURANCE PLAN REF: F428533 - REPRESENTS A TAILORED VERSION OF NHB5300.4(1B)

- SPECIFIC AREAS;
  - DESIGN AND BUILD
  - PROCUREMENT
  - INSPECTION
  - TESTING
  - AUDITS
  - NON-CONFORMANCES
• REVIEW AND SIGNOFF ON ALL DRAWINGS AND PROCEDURES PRIOR TO RELEASE, AND ON SUBSEQUENT REVISIONS
  – DRAWINGS / PROCEDURES ARE REVIEWED FOR INSPECT POINTS AND CONTINUITY WITH PREVIOUS DOCUMENTATION
• OPERATIONS ORDERS ARE USED FOR KITTING AND BUILD ACTIVITY; USED TO INVOKE PROCEDURES
  – OPERATIONS ORDERS ARE ALSO REVIEWED FOR INSPECT POINTS AS WELL AS BEING REVIEWED PRIOR TO FINAL CLOSURE TO VERIFY STEPS ARE COMPLETED AND TO VERIFY THAT NO ISSUES ARE LEFT UNRESOLVED
PROCUREMENT

• VENDOR CERTIFICATION
  – SURVEYED BY LMSC, PUBLISHED IN LMSC DIRECTORY OF APPROVED SOURCES (DAS)
  – BASED ON PREVIOUS R&D WORK HISTORY, VENDOR MAY BE INCLUDED IN R&D DAS
  – SPECIAL APPROVAL MAY BE GRANTED FOR A ONE-TIME PROCUREMENT BY THE QUALITY ENGINEER

• IMPOSE QUALITY REQUIREMENTS ON OUTSIDE VENDORS VIA PURCHASE ORDERS
  – IMPOSE GENERAL PROGRAM REQUIREMENTS
  – ADDITIONAL REQUIREMENTS ARE BASED ON DRAWING NOTES, STATEMENTS OF WORK, ETC.
INSPECTION

• RECEIVING INSPECTION
  - VERIFIES PROPER ITEM IDENTIFICATION AND NO SHIPPING DAMAGE
  - PERFORMS DIMENSIONAL INSPECTION; MINIMUM 100% 1 PART AND CRITICAL DIMENSIONS ON A SAMPLE BASIS OF BALANCE OF PARTS
  - VERIFIES RECEIPT OF CERTIFICATIONS (MATERIAL, PROCESS, ETC.)
  - VERIFIES RECEIPT OF SUPPLIER DOCUMENTATION (TEST DATA, FIRST ARTICLE INSPECTION REPORTS, ETC.)

• IN-PROCESS INSPECTION
  - INDEPENDENT INSPECTIONS / OPERATION VERIFICATIONS ARE PERFORMED AT KEY STEPS IDENTIFIED BY THE QE SUCH AS SOLDERING OR VERIFICATION OF CONTROLLED INTERFACE DIMENSIONS
  - UNANNOUNCED AUDITS WILL BE PERFORMED TO VERIFY CONFORMANCE TO AND MAINTENANCE OF BUILD PAPER

• SHIPPING INSPECTION
  - PACKAGING WILL BE INSPECTED TO VERIFY CONFORMANCE WITH ESTABLISHED STANDARDS
• SOURCE INSPECTION
  
  - VERIFICATION OF DIMENSIONAL AND / OR DOCUMENTATION REQUIREMENTS AT VENDOR; EITHER IN - PROCESS, OR JUST PRIOR TO DELIVERY
    
    » eg. Dewar hardware at Chemtronics
TESTING

• REVIEW AND SIGNOFF ON ALL TEST PROCEDURES PRIOR TO RELEASE, AND ON SUBSEQUENT REVISIONS
  – PROCEDURES WILL BE CHECKED AGAINST REQUIREMENTS FOR COMPLETENESS AND PROPER HANDLING OF HARDWARE
  – INSPECT / VERIFY POINTS WILL BE IDENTIFIED
• MONITORING OF IN - HOUSE TESTING
  – ACCEPTANCE TESTS WILL BE MONITORED TO ASSURE CONFORMANCE TO THE PROCEDURE
  – DATA WILL BE REVIEWED FOR CONFORMANCE TO SPECIFICATIONS
• SUPPLIER ACCEPTANCE TESTS
  – SUPPLIER ACCEPTANCE TESTS MAY BE WITNESSED AT THE DISCRETION OF THE QE AND GP - B MANAGEMENT
    » eg: Dewar Ground Support Modules
  – ALL SUPPLIER ACCEPTANCE TEST DATA WILL BE REVIEWED
AUDIT

- HARDWARE LOGBOOKS
  - LOGBOOKS WILL BE AUDITED PERIODICALLY TO VERIFY THAT THEY ARE BEING KEPT CURRENT
  - AUDITS WILL ALSO VERIFY THAT RECORDS ARE ADEQUATE AND COMPLETE

- ASSEMBLY AREAS
  - PERIODIC AUDITS WILL BE PERFORMED TO ASSURE COMPLIANCE TO IMPOSED REQUIREMENTS (IE. CONTAMINATION CONTROL)
• HARDWARE
  – DEFECTIVE HARDWARE WILL BE SUITABLY IDENTIFIED AS TO STATUS, AND IMPOUNDED AS REQUIRED
• NON - CONFORMANCE REPORTS
  – NON - CONFORMANCE REPORTS (DISCREPANCY REPORTS / DR’S) WILL BE WRITTEN TO DOCUMENT DISCREPANCIES
  – QE AND RESPONSIBLE EQUIPMENT ENGINEER DETERMINE DR DISPOSITION
  – THE QE IS RESPONSIBLE FOR MAINTAINING OPEN DR’S AND ASSURES PROPER CLOSURE ONCE OPEN ISSUES ARE RESOLVED
VERIFICATION AND SYSTEM TEST

ART NAKASHIMA
SMD VERIFICATION PROGRAM
OBJECTIVES

- VERIFY SMD COMPLIANCE WITH APPLICABLE REQUIREMENTS IN PAYLOAD SPECIFICATION F277277 V2.5 AND SPACECRAFT TO PAYLOAD INTERFACE CONTROL DOCUMENT F277233 V1.8
  - ENVIRONMENTS
  - INTERFACES WITH SPACECRAFT
  - INTERFACES WITH PROBE
  - INTERFACES WITH ELECTRONICS
  - INTERFACES WITH GSE
  - OPERATIONS
- MIL-STD-1540B "TEST RQMTS FOR SPACE VEHICLES"
  - PROVIDES ENVIRONMENTAL TEST PROGRAM GUIDANCE FOR GP-B
- MDC H3224B, "COMMERCIAL DELTA II PAYLOAD PLANNERS GUIDE"
  - PROVIDES ENVIRONMENTAL TESTS GUIDELINES FOR DELTA II PAYLOADS
- WRR 127-1, "WESTERN RANGE SAFETY REQUIREMENTS"
  - PROVIDES RANGE SAFETY TEST REQUIREMENTS
- MIL-STD-882C, "SYSTEM SAFETY PROGRAM REQUIREMENTS"
- MIL-STD-1522A, "RQMTS FOR SAFE DESIGN AND OPERATION OF PRESSURIZED MISSILE AND SPACE SYSTEMS"
  - PROVIDES PRESSURE AND STRUCTURAL TEST GUIDELINES
VERIFICATION TESTING APPROACH

- DEVELOPMENT TESTS FOR DESIGN VERIFICATION
- QUALIFICATION TESTING OF COLD VALVES, BURST DISCS, PYROVALVES, PODS
- PROTOFLIGHT TESTING AT DEWAR SUBSYSTEM LEVEL
- SYSTEM LEVEL TESTS CONDUCTED AT DEWAR, PAYLOAD, AND SPACE VEHICLE LEVELS AT SEVERAL LOCATIONS
  - DEWAR (WITHOUT PROBE) FUNCTIONAL AND HELIUM TESTS IN LMSC B/205
  - PROBE INSERTION, LEAD BAG EXPANSIONS IN STANFORD HANSEN EXPERIMENTAL PHYSICS LAB
  - SMD / PROBE-B VIBRATION (COLD) IN LMSC B/181
  - MOST ENVIRONMENTAL TESTS AT SPACE VEHICLE LEVEL, WITH FLIGHT (SMD / PR-C) PAYLOAD
    » S/C -P/L INTEGRATION (EXCEPT SOLAR ARRAYS) IN LMSC B/205
    » EMC/EMI TESTING IN LMSC B/205
    » ACOUSTIC TESTING IN LMSC B/156
    » THERMAL VAC AND LIFETIME TESTS IN T/V CHAMBER AT LMSC
    » INERTIA MEASUREMENTS IN LMSC B/104
• VERIFICATION AND TEST PLAN (LSE-09)
  – VERIFICATION MATRIX, INCLUDING PLAN FOR COMPLIANCE
  – SYSTEM TEST FLOW AND TEST PLAN
  – COMPONENTS AND ASSEMBLIES TEST PLAN MATRIX
  – UPDATE PRIOR TO TESTING
  – INTEGRATION INCLUDED IN LOP-01, NOT LSE-09

• TEST PROCEDURES
  – EACH SYSTEM TEST, COMPONENT TEST, AND DEVELOPMENT TEST WILL HAVE A TEST PROCEDURES DOCUMENT AND OPERATIONS ORDER DOCUMENTS
  – TEST RESULTS WILL BE DOCUMENTED IN THE WORKING COPY OF OPERATIONS ORDER
  – MAJOR TEST RESULTS WILL BE DOCUMENTED IN A TEST REPORT

• VERIFICATION REQUIREMENTS COMPLIANCE DOCUMENT (LSE-10)
  – PROVIDES REFERENCE SOURCES FOR VERIFICATION DOCUMENTATION, AND DEGREE OF COMPLIANCE
  – UPDATED AT ACCEPTANCE REVIEW
TABLE 1. DEWAR SPECIFICATION (Section 3.7.5 of F277277)

<table>
<thead>
<tr>
<th>Reqmt No.</th>
<th>Spec Section Number</th>
<th>Requirement</th>
<th>Method of Verif</th>
<th>Compliance Data</th>
<th>Nonconformance Data</th>
<th>Data Statement / Remarks</th>
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<tr>
<td>R-1</td>
<td>3.7.5</td>
<td>Dewar Specification reference to environments of 3.2.5.1 through 3.2.5.6, and requirements in section 3.3.</td>
<td>A, T</td>
<td>Environmental tests in (7.2), (8.1), (8.2). Loads analysis in Integrated Payload / Spacecraft Launch Loads Analysis (Rev A) EM 310A/P030739A.</td>
<td>Test 7.2 is a vibration test with Probe-B, not the flight probe. Acoustic (8.1) and thermal/vac (8.2) tests are done at the space vehicle level. Compliant. Open.</td>
<td></td>
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<tr>
<td></td>
<td>3.7.5.1</td>
<td>Dewar Definition</td>
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<td>definition</td>
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<tr>
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<td>3.7.5.2</td>
<td>Physical Characteristics</td>
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<td>header</td>
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<tr>
<td>R-2</td>
<td>3.7.5.2.1</td>
<td>Mass Properties</td>
<td>A, T</td>
<td>LSE-01, Mass Properties Status Report, P024612-X, published monthly to quarterly to update the mass properties analysis. Weight and dimensions measured of the dry SMD(5.1). Inertias are verified at the space vehicle level by the spin balance test (8.3)</td>
<td>Compliant Open</td>
<td></td>
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<td>R-3</td>
<td>3.7.5.2.2</td>
<td>Short Term Shift in Center of Gravity</td>
<td>A</td>
<td>Gravity Probe-B Fluid Management Final Report, LMSC P088355</td>
<td>Compliant. Closed</td>
<td></td>
</tr>
<tr>
<td>R-4</td>
<td>3.7.5.2.3</td>
<td>Dimensions</td>
<td>I, T</td>
<td>Verify dimensions to ICD drawings 5833115, 5833116, 5833117 during assembly and upon completion (5.1)</td>
<td>Compliant. Open</td>
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<tr>
<td>R-5</td>
<td>3.7.5.2.4</td>
<td>Probe Well</td>
<td>I</td>
<td>Inspection of Probe to Dewar Interface Drawing 5833116</td>
<td>Compliant Closed</td>
<td></td>
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<tr>
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<td>3.7.5.2.5</td>
<td>Structural Characteristics</td>
<td></td>
<td>header</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
SMD / PROBE-B VIBRATION TEST

- FACILITY IN LMSC B/181 (MSD)
  - 7' BY 7' SLIP TABLE WITH HORIZONTAL SHAKER- 28,000 LB FORCE RATING
  - 54" DIAMETER TABLE WITH VERTICAL SHAKER - REQUIRES ADAPTER PLATE

- PAYLOAD MOUNTED VERTICALLY IN S/C SIMULATOR

- MODAL IDENTIFICATION TESTS PRIOR TO VIBRATION
  - LOW LEVEL SINE SWEEPS OF VARYING AMPLITUDES
  - TANK INTERNALLY INSTRUMENTED WITH 4 TRIAXIAL ACCELEROMETERS
  - PAYLOAD WILL BE TEMPORARILY INSTRUMENTED WITH MANY EXTERNAL ACC

- SIMULATE LAUNCH CONDITIONS
  - SPACECRAFT SIMULATOR WILL INTERFACE WITH SMD AND TABLE
  - MAIN TANK APPROX FULL OF HE II, GUARD TANK TO HAVE APPROX 30 L 0F HE I
  - DUMMY MASSES FOR FORWARD EQUIPMENT SECTION BOXES
  - PROBABLY NO DUMMY MASSES FOR SUNSHADE, AFT EQUIPMENT, SOLAR ARRAYS
  - GYROS CAGED

- VIBRATION IN 3 AXES - LEVELS TBD

- SHAKE WITH VACUUM IN WELL, RETURN TO STANFORD FOR LEAD BAG EVALUATION
  - OBVIADES NEED FOR SHIPPING SUSPENSION, SPINUP AND FLUX FLUSHING GSE
  - IF LEAD BAG GOES NORMAL, BASELINE WILL BE HE II IN WELL AT LAUNCH
SMD SYSTEM TEST FLOW
WITH PROBE-B

RESPONSIBILITY CODE:
- SU W/ PL
- PL W/ SU

MAIN TANK TEMPERATURE INDICATED IN PATH:
A) AMBIENT TEMP; B) NH3 TEMP; C) SF6 TEMP

HEADER NUMBER INDICATES SECTION DESCRIBED IN VERIFICATION PLAN
SMD SYSTEM TEST FLOW WITH PROBE-C (1 OF 2)

Responsibility Code:

- S/U W/ PL Support
- PL W/ S/U and S/C Support
- S/C W/ S/U and PL Support
- S/C

Main Tank Temperature Indicated In Path:
A) Ambient Temp; B) NH3 Temp; C) SF6 Temp

Header Number Indicates Section Described In Verification Plan
SMD SYSTEM TEST FLOW
WITH PROBE-C (2 OF 2)

RESPONSIBILITY CODE:
- PL W/ SU AND S/C SUPPORT
- S/C W/ SU AND PL SUPPORT
- S/C W/ S/C, SU, AND LMSC SUPPORT
- LAUNCH BASE W/ S/C, SU, AND LMSC SUPPORT

MAIN TANK TEMPERATURE INDICATED IN PATH:
A) AMBIENT TEMP; B) NH3 TEMP; C) SFHE TEM

HEADER NUMBER INDICATES SECTION DESCRIBED IN VERIFICATION PLAN
DEWAR CONDITIONS DURING ENVIRONMENTAL TESTS

- HE II IN TANK DURING ACOUSTIC, THERMAL VAC AND SPIN BALANCE
  - LARGER TEMPERATURE GRADIENT PROTECTS LEAD BAG
  - MAIN TANK FULL, GUARD TANK EMPTY FOR THERMAL VAC AND SPIN BALANCE TESTS, 30 L FOR ACOUSTIC TEST

- VENTING OF MAIN TANK
  - VENT THROUGH BAYONET B1 TO VACUUM PUMP DURING ACOUSTIC, THERMAL VAC, AND SPIN BALANCE WAIT PERIODS
    » ACCESS PORTS REQUIRED IN ACOUSTIC, THERMAL VAC CHAMBERS
  - VENT THROUGH MANUAL VALVE V12 IN VENT MODULE TO THRUSTERS DURING THERMAL VAC TESTS
  - NON-VENTED DURING ACOUSTIC AND SPIN TESTS

- FACILITY VENT LINE FROM MAIN TANK WARM BURST DISCS (BD7A&B) REQUIRED FOR SAFETY
  - ACCESS PORTS REQUIRED IN ACOUSTIC, THERMAL VAC CHAMBERS
  - WILL BE TEMPORARILY DISCONNECTED DURING ACOUSTIC AND SPIN TEST
DEWAR CONDITIONS DURING TRANSPORTATION

- FOR EARLY TRANSPORTATION OF P/L ONLY BETWEEN B/205, STANFORD, AND VIBRATION FACILITY, USE ASSEMBLY STAND WITH P/L IN VERTICAL ORIENTATION

- AFTER S/C INTEGRATION, HORIZONTAL ORIENTATION WITH S/C PROVIDED SHIPPING CONTAINER
  - VENT THROUGH POROUS PLUG BYPASS (RAV3) WITH -X UP

- IN MOST CASES, FOR SHORT TRAVEL BETWEEN PALO ALTO AND SUNNYVALE, TRAVEL WITH HE II IN MAIN TANK TO AVOID TIME CONSUMING HE II CONDITIONING
  - NON VENTED MAIN TANK, WITH PARTIALLY FILLED GUARD TANK

- FOR TRAVEL TO BASE, HE I IN MAIN TANK TO AVOID SUBATMOSPHERIC CONCERNS
  - VENT THROUGH BAYONET B1 THROUGH CHECK VALVE TO ATMOSPHERE
PAYLOAD INTEGRATION & OPERATIONS

JIM GRADY
CLOSE COOPERATION WITH GP-B SPACECRAFT CONTRACTOR

-PAYLOAD & SPACECRAFT PEOPLE CO-LOCATED, BLDG. 253

-GP-B OPERATIONS TEAM:
  -STANFORD AND NASA
  -PAYLOAD CONTRACTOR
  -SPACECRAFT CONTRACTOR

-PAYLOAD AND SPACECRAFT OPERATIONS DOCUMENTS TO BE DEVELOPED AS ONE INTEGRATED SET (OP-01 P/L, MO-01 S/C, ETC.)

-PAYLOAD AND SPACECRAFT INTEGRATION AND OPERATIONS TIMELINE DEVELOPMENT UNDERWAY

INTERFACE CONTROL WORKING GROUP (ICWG) MEETINGS ON MISSION OPERATIONS AND DATA ANALYSIS (MO&DA)
PAYLOAD INTEGRATION & OPERATIONS PLANNING-2

• ENSURE THAT LESSONS ARE LEARNED FROM OTHER DELTA-II PROGRAMS AND PROGRAMS WITH SIMILAR MISSION REQUIREMENTS
  - MSX: POLAR (SUN SYNC), ‘94 FIRST (?) DELTA-II WTR LAUNCH
  - COBE: POLAR (90 DEG), DELTA-I WTR LAUNCH, SFHE DEWAR
  - POLAR AND RADARSAT: ‘94 & ‘95 NASA DELTA-II WTR LAUNCHES
  - IRIDIUM: SIX DELTA-II WTR LAUNCHES IN ‘96 AND ‘97
  - OTHER PROGRAMS

• PRELIMINARY PAYLOAD OPERATIONS REQUIREMENTS DOCUMENT (OP-01), DRAFT COMPLETED.
  - EMPHASIS ON SCIENCE MISSION DEWAR
  - UPDATE PLANNED FOR APRIL ‘94 TO SUPPORT ELECTRONICS RR AND BASELINE UPDATE IN JULY ‘94 TO SUPPORT PROBE-C PDR
<table>
<thead>
<tr>
<th>Seq. no.</th>
<th>Top Field</th>
<th>(Bottom Field)</th>
<th>MET (sec)</th>
<th>MET Time (start time)</th>
<th>Event Duration</th>
<th>Units</th>
<th>Event Intervention</th>
<th>Comments</th>
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<tr>
<td>1</td>
<td>Launch</td>
<td>Main engines ignition</td>
<td>0 sec</td>
<td>0 sec</td>
<td>n/a</td>
<td></td>
<td></td>
<td>On at Launch: PDU, 10 MHz Ck</td>
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<td></td>
<td>Vent guard tank</td>
<td>0 sec</td>
<td>0</td>
<td>24-60 hours (from launch)</td>
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<td>Xponder Rec. Flight computer</td>
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<td>2</td>
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<td>Solid motor ignition (6)</td>
<td>0 sec</td>
<td>0 sec</td>
<td></td>
<td></td>
<td>T - Delta</td>
<td>SRAM, CDU, GPS (2.2 g's)</td>
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<td>3</td>
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<td>Solid motor burnout (6)</td>
<td>63 sec</td>
<td>63 sec</td>
<td>0.6 g</td>
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<td>4</td>
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<td>Solid motor ignition (3)</td>
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<td>T - Delta</td>
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<td>Solid motor separation (3)</td>
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<td>67 sec</td>
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<td>T - Delta</td>
<td>T=SPC time based</td>
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<td>Solid motor separation (3)</td>
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<td>T - Delta</td>
<td>E=SPC Event based</td>
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<td>Solid motor burnout (3)</td>
<td>133 sec</td>
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<td></td>
<td>T - Delta</td>
<td>U=2nd uplink with info</td>
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<td>MECO (M)</td>
<td>265 sec</td>
<td>265 sec</td>
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<td></td>
<td>T - Delta</td>
<td>G=2nd uplink binary</td>
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<td>Blow off separation bolts</td>
<td>273 sec</td>
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<td>6.3 g's</td>
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<td>GA=Ground Analysis</td>
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<td>Stage II ignition</td>
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<td>T - Delta</td>
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<td>Fairing Separation</td>
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<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
<td>Discrete to GPS rec. (Data to Delta)</td>
<td>302 sec</td>
<td>302 sec</td>
<td></td>
<td></td>
<td>E - fairing sep</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td></td>
<td>Turn on TU, SSR, and Computer</td>
<td>303 sec</td>
<td>303 sec</td>
<td></td>
<td></td>
<td>E - fairing sep</td>
<td>H &amp; S to Recorder</td>
</tr>
<tr>
<td>14</td>
<td></td>
<td>Fire pyro valves 4A &amp; 4B: allows tank to start venting through porous plug</td>
<td>305 sec</td>
<td>305 sec</td>
<td></td>
<td></td>
<td>E - fairing sep</td>
<td>4A and 4B provide He to spacecraft interface for ACS</td>
</tr>
<tr>
<td>15</td>
<td></td>
<td>Telemetry to SSR and COMM</td>
<td>310 sec</td>
<td>310 sec</td>
<td></td>
<td></td>
<td>T</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td></td>
<td>Establish TDRSS Telemetry &amp; Tracking</td>
<td>310 sec</td>
<td>310 sec</td>
<td></td>
<td></td>
<td>T</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td></td>
<td>GPS Initialized (Check on time)</td>
<td>332 sec</td>
<td>332 sec</td>
<td></td>
<td></td>
<td>T</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td></td>
<td>SECO (S1)</td>
<td>620 sec</td>
<td>10.3 min</td>
<td>T - Delta</td>
<td></td>
<td></td>
<td>0.8 g</td>
</tr>
<tr>
<td>Seq. no.</td>
<td>(Top Field)</td>
<td>(Bottom Field)</td>
<td>MET (start time)</td>
<td>Units (sec)</td>
<td>MET (start time)</td>
<td>Units</td>
<td>Event Duration</td>
<td>Units</td>
</tr>
<tr>
<td>---------</td>
<td>---------------------------------</td>
<td>---------------------------------------</td>
<td>------------------</td>
<td>-------------</td>
<td>------------------</td>
<td>-------</td>
<td>----------------</td>
<td>-------</td>
</tr>
<tr>
<td>19</td>
<td>19 Stage II engine restart</td>
<td></td>
<td>3520 sec</td>
<td>58.7 min</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>20 SECO (S2)</td>
<td></td>
<td>3576 sec</td>
<td>59.6 min</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>21 Turn on SV equipment</td>
<td></td>
<td>3600 sec</td>
<td>1.0 hours</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>22 Flight computer begins ATC sensor processing (Control gyro, star trackers, and magnetometer)</td>
<td></td>
<td>3610 sec</td>
<td>1.0 hours</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>23 Turn on DEP and Payload Electronics</td>
<td></td>
<td>3620 sec</td>
<td>1.0 hours</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>24 Delta II spin up to 0.1 rpm</td>
<td></td>
<td>4000 sec</td>
<td>1.1 hours</td>
<td>TBD MDAC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>25 Delta cold gas orbit trim</td>
<td></td>
<td></td>
<td>sec</td>
<td>TBD MDAC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>26 Deploy Arrays when at 0.1 rpm</td>
<td></td>
<td>5500 sec</td>
<td>1.5 hours</td>
<td>300.00 sec</td>
<td>E</td>
<td></td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>27 First Contact With S.U. Ground Station Snapshot data dump to SGS using forward omni</td>
<td></td>
<td>5610 sec</td>
<td>1.6 hours</td>
<td>5 min</td>
<td>T</td>
<td>Low el. west side pass, N to S. Availability is being evaluated</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>28 Orient 2nd Stage at Guide star (MDAC)</td>
<td></td>
<td>5800 sec</td>
<td>1.6 hours</td>
<td>8.40 min</td>
<td>E - arrays out</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>29 Separate from 2nd stage</td>
<td></td>
<td>6000 sec</td>
<td>1.7 hours</td>
<td>12.00 sec</td>
<td>T - Delta</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>30 Flight computer begins attitude commands</td>
<td></td>
<td>6012</td>
<td>1.7 hours</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>31 Rate Capture</td>
<td></td>
<td>6012 sec</td>
<td>1.7 hours</td>
<td>2.00 hours</td>
<td>G</td>
<td></td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>32 Health and Status Check if TDRS SA avail</td>
<td></td>
<td>13000 sec</td>
<td>3.6 hours</td>
<td>(continuing as req.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>33 Three axis star processing</td>
<td></td>
<td>13212 sec</td>
<td>3.7 hours</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>34 1 Initiate Pressure Control @ TBD Torr</td>
<td></td>
<td>13300 sec</td>
<td>3.7 hours</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>2 2nd SGS pass (dump SSR)</td>
<td></td>
<td>39000 sec</td>
<td>10.8 hours</td>
<td>8 min</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>2 3rd SGS pass (dump SSR)</td>
<td></td>
<td>45000 sec</td>
<td>12.5 hours</td>
<td>10 min</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
GP-B SCIENCE MISSION OPERATIONS CONCEPTUAL OVERVIEW

Payload

- Payload Elect.
- SIA/Probe
- Dewar

Spacecraft

- S/C C&DH
- XPONDER
- Xmitter
- CMD
- TLM
- Comp.
- Dep
- Flt.
- Rcvr

Payload (6Kbps TBD, also "burst mode" of 16Kbps or 32Kbps TBD) for ground test and on-orbit

TDRSS

- MA or SA (multi-access or single-access, both are S-band)

MA 128bps

MA 512bps

SA 2Kbps

SA 1Kbps

WSGS

S.U.

GP-B SCIENCE GROUND STATION

2.5Mbps
PRELIMINARY TIMELINE

L+302 SEC.: JETTISON DELTA-II FAIRING

L+305 SEC.: FIRE PYRO VALVES 4A & 4B
(VENT MAIN TANK)

L+7 DAYS*: FIRE PV1
(VENT VACUUM SHELL)
FIRE PV3
(VENT WELL)
OPEN RAV2
(VENT FILL LINE)

*7 DAYS TO ALLOW FOR OUTGASSING
AND OTHER ON-ORBIT PROCESSING

(SMD HEATH AND STATUS CHECKS ON A
CONTINUOUS BASIS DURING EARLY ORBIT)
LAUNCH SITE OPERATIONS-1

- TWO STOPS FOR GP-B AT VAFB
  -(1) SPACECRAFT LAB. (BUILDING 836)
    - POST SHIPMENT AND OTHER
      INTEGRATED VEHICLE TESTS
    - CONDITION SMD TO HELIUM-II
  -(2) SPACE LAUNCH COMPLEX-2 (SLC-2)
    - INTEGRATION WITH DELTA-II
    - UMBILICAL INTERFACES
SLC-2 LAUNCH PAD OPERATIONS

- LEVEL-6 WHITE ROOM OPS
- DELTA-II INTEGRATION
- SERVICE GUARD TANK
- PAYLOAD C/O AND SERVICING, AS REQ.
- UMBILICAL INTERFACES
- 66 WIRES FOR DEWAR I/F
- CONTROL OF HEATERS AND VALVES, AND MONITOR SENSORS
- TBD EXPENDABLE GSE LOCATED AT FIXED UMBILICAL TOWER (FUT)