FUV Detector System
Environmental Qualification Overview

Dr. Barry Welsh
FUV Project Manager
FUV Detector System Test Flow

- **FUV detector Performance tests**
  - Linearity, QE, Flat Field
  - Background, stray light etc

- **Vibration Test Preparation**
  - Final closeouts
  - Harness dress
  - Staking, torquing etc

- **Pre-Vibration Functional**
  - Long-Form Detector Functional Test

- **Vibration Test**
  - Verify Mechanical Integrity Only
  - Static Acceleration
  - Random Vibration
  - Sine Survey

- **Post-Vibration Functional**
  - Long-Form Detector Functional Test

- **EMI/EMC**
  - Verify w/ HV On, Stims active, Ion Pump On
  - Conducted Emissions (HV on)
  - Conducted Susceptibility (Stims on)

- **MCP UV scrub**
  - Final Pre-Ship functional testing
  - Long-Form Detector Functional Test

- **Ship to UCo**
  - Thermal Cycles Long-Form Detector Functional (10 to 40C), Short-Form Detector Functional (-15 to 45C)
  - Turn-On Verification
  - Survival Soaks

- **Cleanliness Certification**
  - Bake-out
  - Cert at 40C with TQCM
FUNCTIONAL TEST DESCRIPTION

- Short Functional System Test (no photons)
  - Power on, record currents
  - Record housekeeping (temperatures, voltages, etc.)
  - “+28 volt” margin test (±7 volt)
  - Interface redundancy test
  - TDC settings (walks, thresholds, stretches and shifts to nominal values)
  - Acquire stims and analyze position and FWHM
  - Verify counters
  - Auxiliary power and door motor test
  - HV operation (ramp HV to safe level)
  - Power down
FUNCTIONAL TEST DESCRIPTION

- Long Functional System Test (no photons)
  - Same as short functional system test with additions
  - TDC command comprehensive test (all bits exercised)

- Long Functional System Test with Photons (in vacuum)
  - Same as above with additions
  - Exercise door motor
  - Exercise door actuator (limited life item, perform once during TV)
  - HV to nominal operational voltage
    - Acquire background image
    - Perform gain versus voltage characterization
    - Brief flat field
FUV SYSTEM ENVIRONMENTAL QUALIFICATION OVERVIEW

- FUV detector environmental test requirements specified in the COS Statement of Requirements Document (COS-08-0003). Test plan outlined in the Environmental Verification Plan (COS-UCB-007).

- Summary of Environmental Test Requirements:
  - EMI/EMC system compliance per MIL-STD-462 & MIL-STD-461C
  - Vibration test compliance per GEVS-SE
  - Magnetics test compliance per ST-ICD-02E
  - Radiation: TID and SEE requirements per ST-ICD-02E
    - Parts procured and screened by GSFC
  - Contamination/Cleanliness compliance per IN0090-111
  - Thermal operational & survival limits per COS-08-0003
# FUV ENVIRONMENTAL TEST MATRIX

## COS-UCB-007 APPENDIX A: Environmental Verification Matrix

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Description</th>
<th>Qualification</th>
<th>Assembly Level</th>
<th>Analysis/Test Description</th>
<th>Test Facility</th>
<th>Test Procedure</th>
<th>Test Report #</th>
<th>PFR #</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOR 5.1.2</td>
<td>Structural Qualification</td>
<td>X</td>
<td>DEB flight/DVA test components</td>
<td>Sine-burst vibration test in 3 orthogonal axes at 1.25 times the Limit Load, 9.7 g's</td>
<td>AMES</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>SOR 5.1.3</td>
<td>Structural Acceptance</td>
<td>X</td>
<td>DVA flight component</td>
<td>Sine-burst vibration test in 3 orthogonal axes at the Limit Load, 7.8 g's</td>
<td>AMES</td>
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<tr>
<td>SOR 5.1.4</td>
<td>Vibro-Acoustic Qualification</td>
<td>X</td>
<td>DVA qualification test components</td>
<td>1 minute exposure in 3 orthogonal axes to the random vibration environment stated in Table 5-1, COS-08-0003</td>
<td>AMES</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SOR 5.1.5</td>
<td>Vibro-Acoustic Acceptance</td>
<td>X</td>
<td>DEB/DVA flight components</td>
<td>1 minute exposure in 3 orthogonal axes to the random vibration test spectrum stated in Table 5-2, COS-08-0003</td>
<td>AMES</td>
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<tr>
<td>SOR 5.1.6</td>
<td>Stiffness</td>
<td>X</td>
<td>DEB/DVA flight components</td>
<td>Sine survey tests demonstrating natural frequency greater than the primary resonance stated in Table 5-3, COS-08-0003 (&gt;75 Hz for DEB, &gt; 125 Hz for DVA)</td>
<td>AMES</td>
<td></td>
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<tr>
<td>SOR 5.1.7</td>
<td>Shock</td>
<td>-</td>
<td>-</td>
<td>N/A</td>
<td>No shock requirements</td>
<td>N/A</td>
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<tr>
<td>SOR 5.1.8</td>
<td>Mechanical Function</td>
<td>X</td>
<td>Door assembly</td>
<td>Identical FUSE door motor mechanism was life tested &gt; 3000 cycles (Report A00605), and won't be repeated. Door function tested during assembly, &amp; verified in Thermal-Vac.</td>
<td>UCB</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SOR 5.2.1</td>
<td>Absolute Pressure</td>
<td>X</td>
<td>DVA/DEB sub-assembly</td>
<td>Proper operation verified at atmospheric pressure and at high vacuum.</td>
<td>UCB</td>
<td></td>
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</tr>
<tr>
<td>SOR 5.2.2</td>
<td>Differential Pressure</td>
<td>X</td>
<td>DEB sub-assembly</td>
<td>Components designed in accordance with conservative rule of thumb 1 in' vents 1 ft³ volume.</td>
<td>UCB</td>
<td></td>
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<tr>
<td>SOR 5.3.1</td>
<td>Magnetic Susceptibility</td>
<td>X</td>
<td>DVA sub-assembly</td>
<td>Shield design performance verified at static magnetic field of 2 Gauss and time varying component of +/- 1.8 Gauss</td>
<td>COS-990426-JV</td>
<td>COS-990426-JV</td>
<td>N/A</td>
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</tr>
<tr>
<td>SOR 5.3.2</td>
<td>Magnetic Emission</td>
<td>X</td>
<td>DVA sub-assembly</td>
<td>Strongest magnetic field strength is &lt; 0.25 Gauss at a distance of 3cm from the ion pump housing</td>
<td>UCB</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SOR 5.4.1</td>
<td>Total Dose Environment</td>
<td>X</td>
<td>DEB/DVA sub-assembly</td>
<td>Parts selected by GSFC/UCB to meet hardness &gt; 10 krad</td>
<td>GSFC</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>SOR 5.4.2</td>
<td>SEE Environment</td>
<td>X</td>
<td>DEB/DVA sub-assembly</td>
<td>Critical circuits have latch-up immunity to a LET of 37 Digital devices selected with SEU immunity of at least 28</td>
<td>UCB/GSFC</td>
<td>FMECA</td>
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<tr>
<td>SOR 5.5.1.1</td>
<td>In-Spec Temperature</td>
<td>X</td>
<td>DEB/DVA flight components</td>
<td>Thermal-Vac: Short-form functional for 3 cycles between -10C and +45C. Long-form functional between +10C and +40C @ 10 deg intervals.</td>
<td>UCB/SSL</td>
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<tr>
<td>SOR 5.5.1.2</td>
<td>Operational Temperature</td>
<td>X</td>
<td>DEB/DVA flight components</td>
<td>Thermal-Vac: Short-form functional for hot turn-on verification at +45C Short-form functional for cold turn-on verification at -20C</td>
<td>UCB/SSL</td>
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</table>

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Hubble Observatory  
HST-COS FUV  
PER 11/8/00
<table>
<thead>
<tr>
<th>Requirement</th>
<th>Description</th>
<th>Qualification</th>
<th>Analysis/Test Description</th>
<th>Test Facility</th>
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<tbody>
<tr>
<td>SOR 5.5.1.3</td>
<td>Survival Range</td>
<td>DEB /DVA flight components</td>
<td>Thermal-Vac: Hot survival soak at +50C&lt;br&gt;Cold survival soak at –25C</td>
<td>UCB/SSL</td>
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<tr>
<td>SOR 5.5.1.4</td>
<td>Non-Temperature Sensitive Items</td>
<td>DEB / DVA board level</td>
<td>Non-vacuum thermal cycles</td>
<td>UCB</td>
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<tr>
<td>SOR 5.5.1.5</td>
<td>Thermal Design Requirements</td>
<td>DEB /DVA board level</td>
<td>BASD Thermal Model</td>
<td>BASD</td>
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<tr>
<td>SOR 5.5.2</td>
<td>Thermal Monitoring and Control</td>
<td>DEB /DVA flight components</td>
<td>Heaters and thermisters controlled and monitored per Section 7.5, COS-UCB-001 (FUV Detector ICD)</td>
<td>UCB/SSL</td>
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</tr>
<tr>
<td>SOR 5.5.3.1</td>
<td>Voltage Margin Testing</td>
<td>Board or Sub-Assembly</td>
<td>+65C to -25C, Regulated Supply 1% Accuracy</td>
<td>UCB</td>
<td>Ref. in UCB/EAG Electronics Assembly and Test Flow Chart</td>
<td></td>
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<tr>
<td>SOR 5.5.3.2</td>
<td>Temperature Testing</td>
<td>Sub-Assembly, FUV Sub-System</td>
<td>Electronic Assembly: Non-Vacuum Thermal Soak at +80C max for 144 hrs, -25C min for 24 hrs. FUV Sub-System: Thermal-Vac testing (See Verification Matrix for SOR 5.5.1.1,2,3)</td>
<td>UCB</td>
<td>Ref. in UCB/EAG Electronics Assembly and Test Flow Chart</td>
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<tr>
<td>SOR 5.5.3.3</td>
<td>Non-Vacuum Thermal Cycle</td>
<td>Sub-Assembly</td>
<td>6 to 12 cycles, 2C per minute, for 96 hrs. Soak for 2 hrs at each extreme (-20C to 65C)</td>
<td>UCB</td>
<td>Ref. in UCB/EAG Electronics Assembly and Test Flow Chart</td>
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<tr>
<td>SOR 5.5.3.4</td>
<td>Thermal-Vacuum Testing</td>
<td>Sub-Assembly, FUV Sub-System</td>
<td>Electronic Assembly: Thermal Vacuum Soak +65C max for 144 hrs, -25C min for 24 hrs. FUV Sub-System: See Verification Matrix for SOR 5.5.1.1,2,3.</td>
<td>CASA</td>
<td>Ref. in UCB/EAG Electronics Assembly and Test Flow Chart</td>
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<td>SOR 6.1</td>
<td>Interface Voltage</td>
<td>DEB flight components</td>
<td>Bench Tests</td>
<td>UCB</td>
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<td>SOR 6.2</td>
<td>In-Rush Current</td>
<td>DEB flight components</td>
<td>Bench Tests</td>
<td>UCB</td>
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<td>SOR 6.3</td>
<td>Ground Location</td>
<td>FUV Sub-System</td>
<td>Single-point ground per Section 7.3, COS-UCB-001</td>
<td>UCB</td>
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<tr>
<td>SOR 6.4</td>
<td>Power Supply Specifications</td>
<td>Power Supply Board Level</td>
<td>Tests performed at Battel Engineering, documentation supplied with flight unit delivery to UCB</td>
<td>Battel Engineering</td>
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<tr>
<td>SOR 6.5.1</td>
<td>Cabling Interfaces</td>
<td>DEB /DVA flight components</td>
<td>Connector pin-outs provided in Appendix C, COS-UCB-001. Safe-to-mate test prior to connection.</td>
<td>UCB</td>
<td></td>
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<tr>
<td>SOR 6.5.2</td>
<td>Grounding</td>
<td>DEB /DVA board level</td>
<td>Grounding requirements per Section 7.3, COS-UCB-001</td>
<td>UCB</td>
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<tr>
<td>SOR 6.5.3.1</td>
<td>Conducted Emissions</td>
<td>FUV Sub-System</td>
<td>Narrowband conducted emissions tests on cabling from 30Hz to 15kHz (CE01) and from 15kHz to 50MHz (CE03). Transient tests per CE07.</td>
<td>EMCE Engineering</td>
<td>Mil-Std-462</td>
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<tr>
<td>Requirement</td>
<td>Description</td>
<td>Qualification</td>
<td>Assembly Level</td>
<td>Analysis/Test Description</td>
<td>Test Facility Date</td>
<td>Test Procedure</td>
<td>Test Report #</td>
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<tr>
<td>SOR 6.5.3.1.2</td>
<td>Radiated Emissions</td>
<td>-</td>
<td>Instrument</td>
<td>N/A at FUV Detector System level (Waived)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
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<tr>
<td>SOR 6.5.3.2.1</td>
<td>Conducted Susceptibility</td>
<td>X</td>
<td>FUV Sub-System</td>
<td>CS01/CS02 tests at 1.5V peak-to-peak from 15Hz to 50MHz</td>
<td>EMCE Engineering</td>
<td>MIl-Std-462</td>
<td></td>
</tr>
<tr>
<td>SOR 6.5.3.2.2</td>
<td>Radiated Susceptibility</td>
<td>-</td>
<td>N/A</td>
<td>Waived</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>SOR 6.6</td>
<td>Communication Interface</td>
<td>X</td>
<td>FUV Sub-System</td>
<td>Hardware Interface Test using UCB DCE and BASD MEB simulators. Software Interface detailed in Software Verification Plan</td>
<td>BASD</td>
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<tr>
<td>SOR 7.4</td>
<td>Contamination</td>
<td>X</td>
<td>FUV Sub-System</td>
<td>Component level Bakeout. System certification at 40C with TQCM at –20C.</td>
<td>CASA</td>
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</table>
FUV SYSTEM VIBRATION TESTING

- **TEST OBJECTIVES**
  - Demonstrate both the DVA & DEB are structurally sound such that their functionality is not degraded after vibration, static load & acceleration testing
  - Functionality includes system electronic performance & mechanical performance

- **TEST LEVEL DESCRIPTION**
  - Vibration test levels taken from GEVS-SE

<table>
<thead>
<tr>
<th>Item</th>
<th>SOR Requirement</th>
<th>Test Performed</th>
</tr>
</thead>
<tbody>
<tr>
<td>DVA1</td>
<td>DVA2</td>
<td>DEB1</td>
</tr>
<tr>
<td>Structural Qualification</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Vibro-Acoustic Qualification</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Structural Acceptance</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Vibro-Acoustic Acceptance</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Stiffness</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

>125Hz for DVA >75Hz for DEB
DETECTOR VIBRATION TEST PLAN

- Facilities
  - Test to be carried out at the NASA AMES test facility

- Plan/Status
  - First Subsystem vibration test to be to Qualification Levels (proto-flight)
  - Delicate DVA interior hardware passed early Qualification Level vibration:
    - Brazed Body Assembly (BBA)
    - Anode Cradle/Pogo/Bellows assembly
    - Ion Repeller Grid

- Second Subsystem vibration to acceptance levels

- Test Configuration
  - Sine survey performed before and after each axis vibration
  - Ion Pumps powered throughout testing via external HV supply
  - Units attached to shake fixture at their flight structural I/F’s
  - UCB and GSFC QA representative in attendance throughout
VIBRATION TEST PROCEDURE FLOW

- Detector System Long Functional Test performed at UCB prior to shake
  - Detector door operation verified in vacuum chamber
  - Detector electronic performance verified
- Detector system (bagged, with N₂) driven to NASA AMES on shipping plate
- DVA and DEB max dummies vibrated immediately prior to flight items
- Comparison Sine sweep before and after each shake axis
- Ion Pump current monitored throughout DVA shake (monitors DVA pressure)
- Hardware visually inspected prior to and after each axis shake
FUV DETECTOR EMI/EMC TESTING

• TEST OBJECTIVES
  – Demonstrate that the FUV system is compliant with selected conducted emission & susceptibility tests defined per MIL-STD-461C and MIL-STD-462
    • Radiated emissions & susceptibility have been deemed not applicable at the FUV Detector sub-system level by the HST project.

• TEST LEVELS DESCRIPTION
  – Conducted Emission test methods CE01, CE03 & CE07 on the 28V primary power input line
  – Conducted Susceptibility test methods CS01, CS02 & CS06 (modified) on the 28V primary power line at a test voltage of 21V
    • Voltages and currents measured as specified in the HST-COS FUV Detector EMC Control Plan & Performance Requirements Specification (UCB-COS-PLN-1137)
    • Performance susceptibility assessed from STIM data (position and FWHM)
    • Emissions assessed with HV applied to detector (at a safe level)
EMI/EMC Test Circuit & Test Levels

LISN for conducted emission testing

C1 = 19000µF
L2 = L3 = 3µH
R1 = 330, 5W
R2 = R5 = 247
R3 = R6 = 0.17
R4 = R7 = 0.37

CE 01 Narrowband Emissions

Frequency

LISN for conducted emission testing

CE03 Narrowband Emissions

Frequency

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EMI/EMC TEST PLAN

• Facilities
  – Tests to be carried out at EMCE Engineering (Fremont, CA) who performed a more extensive set of EMI/EMC tests on the FUSE detector system in 1996 (FUSE test report available for inspection)
  – LISN circuit provided by UCB

• Test Configuration
  – DVA and DEB with flight configured harnessing attached to the shipping plate
  – Ion Pumps powered throughout testing via IPGSE to maintain DVA vacuum. Power may be removed for brief periods during conducted emissions testing as required.
  – Detector HV applied only at “safe” turn-on level
  – Data logged with FUV EGSE & Assembly Travelers
  – UCB and GSFC QA representative in attendance throughout
EMI/EMC TEST PROCEDURE FLOW

- FUV “Short” Functional test performed at UCB prior to delivery to EMCE
  - Stim (X,Y) positions and FWHM
  - Housekeeping T/M values logged

- Pre-EMI/EMC “Short” Functional test performed upon arrival at EMCE
  - Compare with UCB values

- CE-01, CE-03, CE-07 performed with detector at safe HV

- CS-01 and CS-02 performed with continuous collection of stim data

- Post EMI/EMC “Short” Functional test performed at UCB after completion of testing at EMCE
• **TEST OBJECTIVES**
  
  – Demonstrate both the DVA & DEB can:
    - Survive after soaks at hot and cold temperature extremes
    - Perform nominally throughout thermal vacuum temperature cycling

• **TEST LEVELS**
  
  – Hot Survival = 50C, Cold Survival = -25C
  – Hot Operate Limit = 45C, Cold Operate Limit = -20C
  – Hot In-Spec Limit = 40C, Cold In-Spec Limit = 10C
  – Will perform 1 hot & cold survival soak cycle followed by 5 thermal cycles between 0C and 40C
FUV Thermal Vacuum Test Configuration

COS DETECTOR SYSTEM
THERMAL VACUUM QUAL TEST CONFIGURATION

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HST-COS FUV
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FLIGHT THERMAL LIMITS and PREDICTIONS

• Flight Temperature Limits *per COS-UCB-001*

<table>
<thead>
<tr>
<th>ITEMS</th>
<th>HOT SURVIVAL</th>
<th>HOT OPERATING</th>
<th>HOT IN-SPEC</th>
<th>COLD IN-SPEC</th>
<th>COLD OPERATING</th>
<th>COLD SURVIVAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>DVA</td>
<td>+50°C</td>
<td>+40°C</td>
<td>+40°C</td>
<td>+10°C</td>
<td>-20°C</td>
<td>-25°C</td>
</tr>
<tr>
<td>DEB</td>
<td>+60°C</td>
<td>+50°C</td>
<td>+40°C</td>
<td>+10°C</td>
<td>-20°C</td>
<td>-25°C</td>
</tr>
</tbody>
</table>

All temperatures are as measured at the component thermal interfaces.

**In-Spec Limits** are the temperatures within which the detector subsystem will be verified to operate within the specifications defined by COS-08-0003 *Statement of Requirements for the HST-COS FUV Detector.*

**Operating Limits** are temperatures within which the detector subsystem may be safely operated.

**Survival Limits** are the temperatures beyond which detector components may be damaged.

• Below we give the BATC predictions for in-flight temperatures (°C) of the key components of the FUV system:

<table>
<thead>
<tr>
<th>Component</th>
<th>With ACS</th>
<th>Without ACS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hot Op</td>
<td>Cold Op</td>
</tr>
<tr>
<td>DVA</td>
<td>26</td>
<td>25</td>
</tr>
<tr>
<td>Charge Amps</td>
<td>28</td>
<td>26</td>
</tr>
<tr>
<td>DVA I/F</td>
<td>21</td>
<td>20</td>
</tr>
<tr>
<td>DEB TDC’s</td>
<td>28</td>
<td>23</td>
</tr>
<tr>
<td>DEB I/F</td>
<td>17</td>
<td>13</td>
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</tbody>
</table>
FUV THERMAL VACUUM TEST PLAN

- Facilities
  - Tests to be carried out in the University of Colorado “Betty” T-V chamber at CASA
  - UCB to supply T-V mounting plate for the DEB and DVA
  - UCB to provide all EGSE and external HV supply for ion pumps
  - FUV system contains thermistors that monitor each electronics board temperature and several DVA temperatures, U of Co to provide extra thermistors for additional temperature monitoring
  - UCB to provide a UV lamp (ex-FUSE flight stimulation lamp) that will be powered in the T-V chamber to provide a UV photon stimulus to the detector
FUV SYSTEM CLEANLINESS CERTIFICATION

• TEST OBJECTIVES
  – Ensure that the FUV systems (DEB + DVA) meets the cleanliness and outgassing requirements of the COS Contamination Control Plan (IN0090-111)

• TEST LEVELS
  – Particulates
    • Meet level 150A (mil Std 1246) - interior surfaces
    • Meet level 400A (mil Std 1246) - exterior surfaces
  – Molecular
    • Outgassing rate < 4.3 x 10^{-13} g/cm^3 (TQCM at -20C, hardware at 40C)
    • Actual measured frequency change of TQCM expected from system in the certification set-up outlined in memo COS-000503-MAG
CLEANLINESS CERTIFICATION PLAN

• TEST FACILITIES
  – Certification to be carried out inside the U of Co “Betty” T-V chamber
  – Faraday Labs TQCM mounted on chamber plate, held at -20C

• TEST PLAN (Outgassing)
  – FUV system (power off) heated to 50C and baked out for 72 hours (temperature limit defined by detector door paraffin actuator)
  – Temperature lowered to 40C and TQCM certification performed

• TEST PLAN (Particulates)
  – Prior to insertion into T-V chamber, FUV system inspected for particulates using UV black lamp and tape lifts
FUV Detector Shipping Plan

- All shipment activities governed by:
  - Handling Procedures (ESD etc)
  - Contamination Control
  - Detector Safety (constant power to ion pumps to maintain vacuum)

- Transportation Configuration
  - DEB and DVA (double bagged) mounted at their flight interfaces to a shipping plate (same as the T-V mounting plate)
  - Shipping plate mounts on vibration damper supports within a shipping container
  - Require accelerometers to be mounted to frame
  - Container placed on wooden blocks and strapped to the shipping truck floor
  - EGSE and IPGSE racks padded and strapped to wall of truck
  - Other GSE shipped in crates
  - No special environmental requirements (humidity, temperature etc)
Detector Shipping Plan (cont)

- Power to detector ion pumps
  - UPS Battery supplies AC voltage to Ion Pump GSE Controllers which in turn power the detector ion pumps to maintain vacuum within the DVA
  - UPS lifetime ~ 48 hours (also powered during overnight stay)

- Truck
  - Rental truck (2 drivers)
  - Supported by car (2 drivers) in cell phone communication with truck