Practical Cleanroom Operations Constraints

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2007 Contamination & Coatings Engineering Workshop
Background

- Hubble Space Telescope Servicing
  - Contamination sensitive instruments
    - Wide Field Camera 3 (WFC3)
    - Cosmic Origins Spectrograph (COS)
    - Fine Guidance Sensor (FGS)
  - Large space support equipment (carriers)
    - Flight Support System (FSS)
    - Orbital Replacement Unit Carrier (ORUC)
    - Super Lightweight Interchangeable Carrier (SLIC)
    - Multi-Use Lightweight Equipment (MULE)
  - Miscellaneous refurbishment items
    - Batteries, Rate Sensor Units (RSU), New Outer Blanket Layer (NOBL)
    - Space Telescope Imaging Spectrograph (STIS) repair
    - Advanced Camera for Surveys (ACS) repair
GSFC Cleanroom Facility

- Spacecraft Systems Development and Integration Facility (SSDIF)
  - 90 feet wide by 120 feet long
  - Horizontal unidirectional flow cleanroom
  - Additional Features:
    - Access cleanroom via 25’x40’ overhead rollup door
    - Two 35 ton cranes with heights of 69’ and 80’
    - Precision Cleaning Facility
    - Hardware Storage Area
WFC3 Integration

- Instrument integration
  - Long periods of work on optical bench
  - Positioned near front of room in SSDIF (close to filter wall)
  - Restricted access to WFC3 area
  - Limited space for hardware movement
  - Extra training for contamination sensitivity
WFC3 During Integration
Operational Constraints

Why constrain cleanroom activities?

- Particle counts increase
- Potential for reactive molecular contaminants
  - During bonding activities
- Turbulent flow around hardware
  - Transport particles “upstream”
- Potential for anomalies
  - Crane
    - Light fixture impact
  - Power failure
    - Lift Operations
    - Rollup door
  - High Humidity
  - Water Leak
  - Fire
Constraint Table

- Created for consistency within Contamination Control Team
- Presented during "Refresher" Training for entire project
  - Overview only
  - Constraints added to work orders by CC team
- I&T manager requested a written copy
## Table

<table>
<thead>
<tr>
<th>Restricted Activity</th>
<th>Open (Optics or Optical Bench Exposed)</th>
<th>Closed (Draped) (Enclosure Exposed, Aperture/Optics Covered)</th>
<th>Bagged (Instrument may be draped and taped)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bonding / Staking / Lubricating</td>
<td><strong>Prohibited within 10’</strong></td>
<td>&lt; 6 g within 10’</td>
<td>&lt; 30 g within 10’ Quantity within reason</td>
</tr>
<tr>
<td></td>
<td>&lt; 6 g within 30’</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sanding / Abrading / Drilling</td>
<td><strong>Prohibited upstream</strong></td>
<td><strong>Prohibited upstream</strong></td>
<td>No Constraints</td>
</tr>
<tr>
<td>(Vacuum pickup of debris during generation)</td>
<td>&gt; 6 feet away for man-sized objects</td>
<td>&gt; 6 feet away for man-sized objects</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt;20 feet away for larger objects</td>
<td>&gt;20 feet away for larger objects</td>
<td></td>
</tr>
<tr>
<td>Crane Operations</td>
<td><strong>Prohibited</strong></td>
<td><strong>Prohibited</strong></td>
<td>No Constraint</td>
</tr>
<tr>
<td>SSDIF Maintenance</td>
<td><strong>Prohibited</strong></td>
<td>&gt;20 feet downstream</td>
<td>No Constraint</td>
</tr>
<tr>
<td>Large Structure Cleaning</td>
<td><strong>Prohibited</strong></td>
<td><strong>Prohibited upstream</strong></td>
<td>No Constraint</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;20 feet away for man-sized objects</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;40 feet away for larger objects</td>
<td></td>
</tr>
<tr>
<td>Large Structure Unbagging</td>
<td><strong>Prohibited Upstream</strong></td>
<td><strong>Prohibited upstream</strong></td>
<td>No Constraint</td>
</tr>
<tr>
<td></td>
<td>&gt;30 feet away for man-sized objects</td>
<td>&gt;20 feet away for man-sized objects</td>
<td></td>
</tr>
<tr>
<td></td>
<td>larger objects <strong>prohibited</strong></td>
<td>&gt;40 feet away for larger objects</td>
<td></td>
</tr>
<tr>
<td>Hardware Movement</td>
<td><strong>Prohibited Upstream</strong></td>
<td><strong>Prohibited Upstream</strong></td>
<td>No Constraint</td>
</tr>
<tr>
<td></td>
<td>&gt;30 feet away for man-sized objects</td>
<td>&gt;6 feet away for man-sized objects</td>
<td></td>
</tr>
<tr>
<td></td>
<td>larger objects <strong>prohibited</strong></td>
<td>&gt;20 feet away for larger objects</td>
<td></td>
</tr>
<tr>
<td>Personnel Activity</td>
<td>&lt; 5 within 10’ (SSDIF Max: 10)</td>
<td>&lt; 10 within 10’ (SSDIF Max: 40)</td>
<td>No Constraint (SSDIF Max: 40)</td>
</tr>
<tr>
<td>Air Bearing Use</td>
<td><strong>Prohibited</strong></td>
<td>&gt;30 feet downstream</td>
<td>No Constraint</td>
</tr>
<tr>
<td>(Allow 30 minutes of settle time after use)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Door Opening</td>
<td><strong>Prohibited</strong></td>
<td><strong>Prohibited</strong></td>
<td>No Constraint</td>
</tr>
<tr>
<td>(Allow 30 minutes of settle time after door closing)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Revisions

• Changed column definitions
  – Confusion between open, closed, draped and bagged
  – Defined draped
    • Cover entire instrument with sufficient material to hang along sides
  – Defined bagged
    • Llumalloy taped and fitted tightly enclosing entire instrument

• Personnel Limits
  – Contamination sensitive I&T operations for hardware besides WFC3

• Waive Constraints: Case by Case
  – Unplanned operations
  – Slight changes in Instrument Configuration
    • Mostly bagged with small openings
  – Special Visits: Astronaut Training, News Press, Tours

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More Confusion

- COS instrument
  - Moved to back of room for optical testing
  - Fixed zones did not account for move

- HFMS
  - Directly on boundary of zones
  - Approved use of man-lift work
## Activities Allowed Under Given WFC3 Condition and Activity Location

<table>
<thead>
<tr>
<th>Condition:</th>
<th>WFC3 Unbagged (Loose Drape)</th>
<th>WFC3 Bagged (Drape and Tape)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td><strong>Zone</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bonding / Staking / Lubricating</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt;6g</td>
<td>&lt;30g</td>
</tr>
<tr>
<td>Sanding/Abrading/Drilling</td>
<td>Down stream</td>
<td>&lt;6’ above floor</td>
</tr>
<tr>
<td>Crane Operations</td>
<td>WFC3 only</td>
<td>Prohibit</td>
</tr>
<tr>
<td>Air Bearing Use (Allow 30 minutes of settle time after use)</td>
<td>Prohibit</td>
<td>Prohibit</td>
</tr>
<tr>
<td>Insert/Remove Bolts</td>
<td>&lt;6’ above floor</td>
<td>&lt;6’ above floor</td>
</tr>
<tr>
<td>Door Opening (Allow 30 minutes of settle after door closing)</td>
<td>&lt;6’ high</td>
<td>&lt;6’ high</td>
</tr>
</tbody>
</table>

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SSDIF Restrictions

- SSDIF restrictions of activities are driven by condition of Science Instruments (SI)
  - Unbagged, Draped, Bagged
- 3 Major Categories of SSDIF Activities
  - Relocation of Hardware
    - Lifts, Air Bearings, Door Openings
  - Hardware Activity
    - Painting, sanding, drilling, bonding, staking, soldering
  - Contamination Control Operations
    - Maintenance, Cleaning, Hardware Bagging/Unbagging
- Types of Restrictions
  - Personnel Limits: <15 SI Unbagged, 40 max
  - Time limits before opening SI: 30 min.
  - Distance away from SI: <6 ft. from ground, >10 ft. away from SI
  - Quantity of material: <30g of staking material
Switched to decision tree
- 3 Main Categories for Constraints
  - Hardware Relocation
  - Hardware Work
  - Contamination Operation
- User Friendly
  - Answers most often asked questions
  - Provides additional new response: Call CCE
- Designed tree to support independent planning assessment by I&T manager
  - Many activities are easy to identify as ok or not ok
  - The remainder end in a “Call CCE” decision
  - Retained final authority at daily I&T meeting
Decision Tree – Hardware Relocation

Start

Is an SI open?

Yes

Are there < 10 people in the SSDIF?

Yes

Will hardware be relocated?

Yes

Will a crane be operated?

No

Is an SI open?

Yes

Postpone entry until < 40 people remain in SSDIF or SI becomes bagged or draped

No

Will a manlift be operated?

No

Is an SI open?

Yes

Will air bearings be operated?

No

Is an SI open?

Yes

Will hardware be moved by hand?
Decision Tree - Hardware Work

1. Will the work require bonding or staking?
   - Yes: Is an SI open?
     - Yes: Will the work occur > 10 ft from an SI?
       - Yes: OK with < 30 g
       - No: On SI only or < 6 g
     - No: Will the work require lubrication?
       - Yes: OK
       - No: Is an SI draped?
         - Yes: OK
         - No: Is an SI bagged?
           - Yes: Call CCE
           - No: Will the soldering occur < 10 ft away from an SI?
             - Yes: For SI only
             - No: Is the harness < 6 ft in length?
               - Yes: OK
               - No: Will the work require harness routing?
                 - Yes: IS
                 - No: Will the work require soldering?
                   - Yes: IS
                   - No: No
Decision Tree
Contamination Control Operations

1. Will contamination operations be performed?
   - No → OK
   - Yes → Will SSDIF maintenance be performed?
     - Yes → Call CCE
     - No → Will hardware be unbagged?
       - Yes → Is the object > 6 ft tall?
         - Yes → Is the object > 20 ft from an SI?
           - Yes → OK
           - No → SI only
         - No → OK
       - No → Will hardware be bagged?
         - Yes → Is the object > 6 ft tall?
           - Yes → Will cleaning be performed?
             - Yes → OK
             - No → Call CCE
           - No → No
         - No → OK
     - No → Will the cleaning be < 10 ft from an SI?
       - Yes → OK
       - No → Is the object > 6 ft tall?
         - Yes → OK
         - No → Call CCE

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Conclusion

- CCE must attend all I&T meetings
  - Need to have CC representative to address on the spot decisions
  - Schedule changes effects coordination of activities
  - CC Technicians must be informed to be prepared ahead of time
- CCE must be clear and consistent in communication to Project Team
- CC Team has to be aware of current and near future activities for all hardware
  - Coordinate with Project and adjust quickly to schedule changes
- Project is responsible for providing detail information of I&T activities
  - Personnel required
  - Type of activity
  - Specific location
  - Time duration
  - Materials, test equipment, tools