Practical Cleanroom Operations Constraints

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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

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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
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>
<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>Prohibited within 10’ &lt; 6 g within 30’</td>
<td>&lt; 6 g within 10’ &lt; 60 g within 30’</td>
<td>&lt; 30 g within 10’ Quantity within reason</td>
</tr>
<tr>
<td>Sanding / Abrading / Drilling</td>
<td>Prohibited upstream &gt; 6 feet away for man-sized objects &gt;20 feet away for larger objects</td>
<td>Prohibited upstream &gt; 6 feet away for man-sized objects &gt;20 feet away for larger objects</td>
<td>No Constraints</td>
</tr>
<tr>
<td>Crane Operations</td>
<td>Prohibited</td>
<td>Prohibited</td>
<td>No Constraint</td>
</tr>
<tr>
<td>SSDIF Maintenance</td>
<td>Prohibited</td>
<td>Prohibited upstream &gt;20 feet away for man-sized objects &gt;40 feet away for larger objects</td>
<td>No Constraint</td>
</tr>
<tr>
<td>Large Structure Cleaning</td>
<td>Prohibited</td>
<td>Prohibited upstream &gt;20 feet away for man-sized objects &gt;40 feet away for larger objects</td>
<td>No Constraint</td>
</tr>
<tr>
<td>Large Structure Unbagging</td>
<td>Prohibited Upstream &gt; 30 feet away for man-sized objects larger objects prohibited</td>
<td>Prohibited upstream &gt;20 feet away for man-sized objects &gt;40 feet away for larger objects</td>
<td>No Constraint</td>
</tr>
<tr>
<td>Hardware Movement</td>
<td>Prohibited Upstream &gt; 30 feet away for man-sized objects larger objects prohibited</td>
<td>Prohibited Upstream &gt; 6 feet away for man-sized objects &gt;20 feet away for larger objects</td>
<td>No Constraint</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>Prohibited</td>
<td>&gt;30 feet downstream</td>
<td>No Constraint</td>
</tr>
<tr>
<td>Door Opening</td>
<td>Prohibited</td>
<td>Prohibited</td>
<td>No Constraint</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
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>Zone</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Bonding / Staking / Lubricating</td>
<td>&lt;6g</td>
<td>&lt;30g</td>
</tr>
<tr>
<td>Sanding/Abrading/Drilling</td>
<td>Downstream</td>
<td>&lt;6' above floor</td>
</tr>
<tr>
<td>Crane Operations</td>
<td>WFC3 only 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
Decision Tree

- 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?

No

Are there < 10 people in the SSDIF?

Yes

Are there < 40 people in the SSDIF?

Yes

Postpone entry until < 10 people remain in SSDIF or SI becomes bagged or draped

No

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

Yes

Will hardware be relocated?

Yes

Go to hardware work flow chart

No

Will a crane be operated?

Yes

Is an SI open?

No

Will a manlift be operated?

Yes

Is an SI open?

No

Will air bearings be operated?

Yes

Is an SI open?

No

Will hardware be moved by hand?
Decision Tree
Contamination Control Operations

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

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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