Comparative Mirror Cleaning Study

"A Study on Removing Particulate Contamination"

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Introduction
- Optical Devices
- Contamination Effects of Optical Surfaces

Experimental Design
- Test Plan
- Cleaning Procedures
- Verification Instrument

Design of Experiments (DOE) Software
- Jump/Statistical Analytical Software (JMP/SAS)

Results

Conclusions

Recommendations

Future Work
Introduction

Optical Devices
- Mirrors and telescopes
- Microscope and lenses
- Lasers and interferometers
- Prisms and optical filters

Optical Industry
The cleanliness of optical surfaces is recognized as an industry wide-concern for performance of optical devices:
- No established standard for optical cleaning
- No standard definition of a "clean" optical element

Advantages of Experimental Study…
- It evaluates the effectiveness of commonly used optical cleaning techniques based on wafer configuration, contamination levels, and the number and size of removed particles
- The results can help ensure mission success to flight projects developed for the NASA Origins Program (JWST, SAFIR, etc.)
Contamination Effects

1. **Molecular Contamination:** Accumulation of submicron particles (i.e. Water, hydrocarbons, and silicones)

   a. Absorptive Effects (Transmissive Surface)
   b. Absorptive Effects (Reflective Surface)

2. **Particulate Contamination:** Conglomerate of visible sized particles (e.g. Dust)

   a. Obscuration Effects
   b. Scattering Effects
Experimental Objective:
To compare the effectiveness in removing particulate contamination from coated and uncoated silicon wafers with commonly used optical cleaning methods.

Technical Objectives:
- Determine the cleaning ability of each method based on the number and size of removed particles
- Assess the risk of surface damage for each cleaning procedure
- Evaluate each method as a function of its initial contamination level ("fairly clean", "dirty, "very dirty")

Experimental Process:
- Contaminate wafers
- Characterize surface (Measure and count number of particles)
- Clean wafers
- Characterize surface
Experimental Design

Cleaning Methods
- Detergent Bath
- Solvent Rinse
- CO₂ Snow Cleaning

Wafer Configuration
- (12) - Silicon (Si)
- (12) - Gold coated silicon wafer (Si+Au)
- (12) - Gold coated silicon wafer with a silicon oxide coating (Si+Au+SiOx)

Table 1: Wafer Specifications

<table>
<thead>
<tr>
<th>Wafer Properties</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness</td>
<td>500 μm</td>
</tr>
<tr>
<td>Diameter</td>
<td>4&quot;</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Coating Thickness</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Gold Coating</td>
<td>2000 Å</td>
</tr>
<tr>
<td>Silicon Oxide Coating</td>
<td>1000 Å</td>
</tr>
</tbody>
</table>

Exposure Times
- 1 day, 3 days, and 5 days (Building 7 Highbay)
Design of Experiments (DOE) Software

Sample Size (Total Sample Size = 36 wafers)
- Calculated by specifying a 95% Upper Confidence Level
  - 13 DOF: Number of values in final calculation that are free to vary

Randomization Table
- Randomly paired cleaning methods with wafer configurations and exposure time
- Divided into 9 blocks
  - Each block has 4 wafers

Table 2: Example of Block Format

<table>
<thead>
<tr>
<th>Cleaning Method</th>
<th>Wafer Configuration</th>
<th>Exposure Time</th>
<th>Y (Response)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rinse</td>
<td>Si+Au+SiOx</td>
<td>3</td>
<td>·</td>
</tr>
<tr>
<td>CO2</td>
<td>Si+Au</td>
<td>5</td>
<td>·</td>
</tr>
<tr>
<td>Bath</td>
<td>Si+Au+SiOx</td>
<td>1</td>
<td>·</td>
</tr>
<tr>
<td>Bath</td>
<td>Si</td>
<td>5</td>
<td>·</td>
</tr>
</tbody>
</table>

JMP/Statistical Analytical Software
- Simultaneously compares input variables

July 17, 2007

2007 Contamination and Coatings Workshop
Mirror Cleaning Procedure (1)

Detergent Bath

Direct contact method that uses an aqueous based, nonionic detergent to remove contamination

Pre-Clean Preparation\(^1\):

1. Alconox Solution
   a. 5 grams of Alconox detergent
   b. 4 cups of distilled water
2. Rinse Solution - 2 cups of distilled water at 120 °F

Cleaning Process:

1. Wafer submerged in Alconox Solution
2. Q-tip placed directly on wafer at a 20°; Surfaces cleaned using a multi-directional wiping technique for 1 minute
3. Wafer rinsed 10x’s in distilled water
4. Water vertically positioned (at a 10-15° angle) for drying (~15 min)

\(^1\) NASA/GSFC Optical Component Cleaning (551-WI-8072.1.7B)

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Mirror Cleaning Procedure (2)

Solvent Rinse

Direct contact method that uses an aqueous based, nonionic detergent and an acetone rinse to remove contamination

Pre-Clean Preparation¹:
1. Alconox Solution
   a. 5 g of Alconox detergent
   b. 4 cups of distilled water
2. Rinse Solution - 2 cups of distilled water at 120 °F

Cleaning Process:
1. Wafer submerged in Alconox Solution
2. Q-tip placed directly on wafer at a 20° angle; Surfaces cleaned using a multidirectional wiping technique for 1 minute
3. Wafer rinsed 10x’s in distilled water
4. Water vertically positioned (at a 10-15°angle) for drying
5. Wafer rinsed with 4fl. oz of IPA grade acetone in a top-bottom, left-right pattern

¹ NASA/GSFC Optical Component Cleaning (551-WI-8072.1.7B)
Mirror Cleaning Procedure (3)

CO₂ Snow Cleaning

Non-contact method that uses a high velocity stream of CO₂ gas and snow pellets to remove contamination

Pre-Clean Preparation:
1. Place vacuum chuck on hot plate; turn hotplate on “High” setting (120 °F). Let warm-up for 15-20 minutes

Cleaning Process:
1. Place wafer on vacuum chuck; power on motor
2. Open pressure valve on CO₂ cylinder tank
3. Position nozzle at the upper right hand corner (30° angle; 2” from surface)
4. Open CO₂ circuit using footswitch
5. Clean entire wafer surface using 7 vertical strokes; surface cleaned in a top-bottom, right-left pattern

July 17, 2007
Image Analysis (IA) is a verification instrument that incorporates the use of a microscope, camera, and computer to measure the size, shape, and number of particles.

**IA Specifications:**
- Leica camera/CCD
- Olympus microscope (5X Obj; 50 Mag)
  - Detects 0.3μm particles at 95% certainty
- Robotic stage

**Facility Specifications:**
- Building 84 Cleanroom
- Class 10,000
- Avg. RH: 44%
- Average Temp: 69 °F
- Laminar Flow: 135-150 ft/min

\[
PAC = \frac{\text{Total Area of Particles}}{\text{Total Surface Area}} \times 100
\]

Figure 1: IA Reading Area
### Results - Detergent Bath

Table 3: PAC Removal Percentage of Detergent Bath Samples

<table>
<thead>
<tr>
<th>Wafer Configuration</th>
<th>Exposure Time</th>
<th>PAC (Before Cleaning)</th>
<th>PAC (After Cleaning)</th>
<th>Efficiency Removal %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Si</td>
<td>5</td>
<td>0.23924</td>
<td>0.08072</td>
<td>66</td>
</tr>
<tr>
<td>Si+Au</td>
<td>3</td>
<td>0.09553</td>
<td>0.01502</td>
<td>84</td>
</tr>
<tr>
<td>Si+Au+SiOx</td>
<td>5</td>
<td>0.09312</td>
<td>0.01560</td>
<td>83</td>
</tr>
<tr>
<td>Si+Au+SiOx</td>
<td>1</td>
<td>0.08290</td>
<td>0.01974</td>
<td>76</td>
</tr>
<tr>
<td>Si</td>
<td>5</td>
<td>0.07863</td>
<td>0.03506</td>
<td>55</td>
</tr>
<tr>
<td>Si+Au</td>
<td>3</td>
<td>0.06028</td>
<td>0.02268</td>
<td>62</td>
</tr>
<tr>
<td>Si</td>
<td>3</td>
<td>0.04832</td>
<td>0.04448</td>
<td>8</td>
</tr>
<tr>
<td>Si+Au+SiOx</td>
<td>3</td>
<td>0.04033</td>
<td>0.05241</td>
<td>----</td>
</tr>
<tr>
<td>Si+Au+SiOx</td>
<td>1</td>
<td>0.02070</td>
<td>0.01017</td>
<td>51</td>
</tr>
<tr>
<td>Si</td>
<td>1</td>
<td>0.01020</td>
<td>0.01460</td>
<td>----</td>
</tr>
<tr>
<td>Si+Au</td>
<td>1</td>
<td>0.00454</td>
<td>0.01077</td>
<td>----</td>
</tr>
<tr>
<td><strong>Average Removal %</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>61</strong></td>
</tr>
</tbody>
</table>
Table 4: Particle Count for Sample B5_23_Si.Au_3D (67% PAC Reduction)

<table>
<thead>
<tr>
<th>Range of Particle Sizes (microns)</th>
<th>Total # of Particles (Before Cleaning)</th>
<th>Total # of Particles (After Cleaning)</th>
<th>Removal Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 ≤ x ≤ 1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1 ≤ x ≤ 5</td>
<td>54</td>
<td>1770</td>
<td>-</td>
</tr>
<tr>
<td>5 ≤ x ≤ 10</td>
<td>482</td>
<td>782</td>
<td>-</td>
</tr>
<tr>
<td>10 ≤ x ≤ 25</td>
<td>656</td>
<td>326</td>
<td>50</td>
</tr>
<tr>
<td>25 ≤ x ≤ 50</td>
<td>542</td>
<td>231</td>
<td>57</td>
</tr>
<tr>
<td>50 ≤ x ≤ 100</td>
<td>420</td>
<td>29</td>
<td>93</td>
</tr>
<tr>
<td>100 ≤ x ≤ 150</td>
<td>211</td>
<td>2</td>
<td>99</td>
</tr>
<tr>
<td>150 ≤ x ≤ 250</td>
<td>235</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>250 ≤ x ≤ 500</td>
<td>245</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>500 ≤ x ≤ 750</td>
<td>125</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>≥ 750</td>
<td>146</td>
<td>1</td>
<td>99</td>
</tr>
<tr>
<td>Total No. of Particles</td>
<td>3116</td>
<td>3141</td>
<td>-</td>
</tr>
<tr>
<td>PAC (Cleanliness Lvl)</td>
<td>0.06 (375)</td>
<td>0.02 (300)</td>
<td>67</td>
</tr>
</tbody>
</table>
Figure 2: Average Particle Distribution for the Detergent Bath Samples
Results – Solvent Rinse

Table 5: PAC Removal Percentage of Solvent Rinse Samples

<table>
<thead>
<tr>
<th>Wafer Configuration</th>
<th>Exposure Time</th>
<th>PAC (Before Cleaning)</th>
<th>PAC (After Cleaning)</th>
<th>Efficiency Removal %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Si+Au</td>
<td>5</td>
<td>0.12063</td>
<td>0.00815</td>
<td>93</td>
</tr>
<tr>
<td>Si+Au+SiOx</td>
<td>3</td>
<td>0.08629</td>
<td>0.02234</td>
<td>74</td>
</tr>
<tr>
<td>Si+Au</td>
<td>5</td>
<td>0.07477</td>
<td>0.01800</td>
<td>76</td>
</tr>
<tr>
<td>Si</td>
<td>5</td>
<td>0.06177</td>
<td>0.00013</td>
<td>100</td>
</tr>
<tr>
<td>Si</td>
<td>3</td>
<td>0.06071</td>
<td>0.00718</td>
<td>88</td>
</tr>
<tr>
<td>Si+Au</td>
<td>3</td>
<td>0.04662</td>
<td>0.01021</td>
<td>78</td>
</tr>
<tr>
<td>Si+Au+SiOx</td>
<td>5</td>
<td>0.04414</td>
<td>0.01301</td>
<td>71</td>
</tr>
<tr>
<td>Si+Au+SiOx</td>
<td>5</td>
<td>0.04271</td>
<td>0.00171</td>
<td>96</td>
</tr>
<tr>
<td>Si</td>
<td>1</td>
<td>0.03862</td>
<td>0.03458</td>
<td>10</td>
</tr>
<tr>
<td>Si+Au</td>
<td>3</td>
<td>0.03226</td>
<td>0.00582</td>
<td>82</td>
</tr>
<tr>
<td>Si+Au+SiOx</td>
<td>1</td>
<td>0.02965</td>
<td>0.01254</td>
<td>58</td>
</tr>
<tr>
<td>Si+Au+SiOx</td>
<td>1</td>
<td>0.01209</td>
<td>0.00497</td>
<td>59</td>
</tr>
<tr>
<td><strong>Average Removal %</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>74</strong></td>
</tr>
</tbody>
</table>
Particle Count – Solvent Rinse

Table 6: Particle Count for Sample B1_5_Si.Au.SiOx_3D (74% PAC Reduction)

<table>
<thead>
<tr>
<th>Range of Particle Sizes (microns)</th>
<th>Total # of Particles (Before Cleaning)</th>
<th>Total # of Particles (After Cleaning)</th>
<th>Removal Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 ≤ x ≤ 1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1 ≤ x &lt; 5</td>
<td>2026</td>
<td>2596</td>
<td>-</td>
</tr>
<tr>
<td>5 ≤ x ≤ 10</td>
<td>1409</td>
<td>660</td>
<td>53</td>
</tr>
<tr>
<td>10 ≤ x ≤ 25</td>
<td>995</td>
<td>278</td>
<td>72</td>
</tr>
<tr>
<td>25 ≤ x ≤ 50</td>
<td>418</td>
<td>58</td>
<td>86</td>
</tr>
<tr>
<td>50 ≤ x ≤ 100</td>
<td>119</td>
<td>33</td>
<td>72</td>
</tr>
<tr>
<td>100 ≤ x ≤ 150</td>
<td>13</td>
<td>11</td>
<td>15</td>
</tr>
<tr>
<td>150 ≤ x ≤ 250</td>
<td>12</td>
<td>11</td>
<td>8</td>
</tr>
<tr>
<td>250 ≤ x ≤ 500</td>
<td>14</td>
<td>12</td>
<td>14</td>
</tr>
<tr>
<td>500 ≤ x ≤ 750</td>
<td>6</td>
<td>2</td>
<td>67</td>
</tr>
<tr>
<td>≥ 750</td>
<td>8</td>
<td>4</td>
<td>50</td>
</tr>
<tr>
<td>Total No. of Particles</td>
<td>5020</td>
<td>3665</td>
<td>-</td>
</tr>
<tr>
<td>PAC (Cleanliness Lvl)</td>
<td>0.086 (415)</td>
<td>0.022 (310)</td>
<td>74</td>
</tr>
</tbody>
</table>
Figure 3: Average Particle Distribution for the Solvent Rinse Samples
### Results – CO₂ Snow Cleaning

Table 7: PAC Removal Percentage of CO₂ Snow Cleaning Samples

<table>
<thead>
<tr>
<th>Wafer Configuration</th>
<th>Exposure Time</th>
<th>PAC (Before Cleaning)</th>
<th>PAC (After Cleaning)</th>
<th>Efficiency Removal %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Si+Au</td>
<td>5</td>
<td>0.19466</td>
<td>0.00716</td>
<td>74</td>
</tr>
<tr>
<td>Si+Au+SiOx</td>
<td>5</td>
<td>0.07471</td>
<td>0.00555</td>
<td>93</td>
</tr>
<tr>
<td>Si</td>
<td>3</td>
<td>0.06550</td>
<td>0.00261</td>
<td>96</td>
</tr>
<tr>
<td>Si+Au</td>
<td>1</td>
<td>0.06086</td>
<td>0.00414</td>
<td>93</td>
</tr>
<tr>
<td>Si+Au+SiOx</td>
<td>1</td>
<td>0.03851</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Si+Au</td>
<td>5</td>
<td>0.03823</td>
<td>0.00554</td>
<td>86</td>
</tr>
<tr>
<td>Si+Au+SiOx</td>
<td>3</td>
<td>0.03606</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Si</td>
<td>5</td>
<td>0.03522</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Si+Au+SiOx</td>
<td>3</td>
<td>0.03380</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Si+Au</td>
<td>1</td>
<td>0.01034</td>
<td>0.00284</td>
<td>73</td>
</tr>
<tr>
<td>Si</td>
<td>3</td>
<td>0.01139</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Si</td>
<td>1</td>
<td>0.00317</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Average Removal %</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>86</strong></td>
</tr>
</tbody>
</table>
### Table 8: Particle Count for Sample B4_19_Si.Au_5D (86% PAC Reduction)

<table>
<thead>
<tr>
<th>Range of Particle Sizes (microns)</th>
<th>Total # of Particles (Before Cleaning)</th>
<th>Total # of Particles (After Cleaning)</th>
<th>Removal Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0 \leq x \leq 1$</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>$1 \leq x \leq 5$</td>
<td>1184</td>
<td>1126</td>
<td>5</td>
</tr>
<tr>
<td>$5 \leq x \leq 10$</td>
<td>997</td>
<td>1028</td>
<td>-</td>
</tr>
<tr>
<td>$10 \leq x \leq 25$</td>
<td>739</td>
<td>942</td>
<td>-</td>
</tr>
<tr>
<td>$25 \leq x \leq 50$</td>
<td>277</td>
<td>901</td>
<td>-</td>
</tr>
<tr>
<td>$50 \leq x \leq 100$</td>
<td>46</td>
<td>7</td>
<td>85</td>
</tr>
<tr>
<td>$100 \leq x \leq 150$</td>
<td>10</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>$150 \leq x \leq 250$</td>
<td>10</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>$250 \leq x \leq 500$</td>
<td>5</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>$500 \leq x \leq 750$</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>$\geq 750$</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total No. of Particles</strong></td>
<td><strong>3272</strong></td>
<td><strong>4004</strong></td>
<td>-</td>
</tr>
<tr>
<td><strong>PAC (Cleanliness Lvl)</strong></td>
<td><strong>0.038 (335)</strong></td>
<td><strong>0.006 (225)</strong></td>
<td><strong>84</strong></td>
</tr>
</tbody>
</table>
Figure 4: Average Particle Distribution for CO2 Snow Cleaning Samples
Control Wafers

Environmental Controls
Monitors particulate fallout from surrounding air during image analysis reading

Table 9: PAC Values for Environmental Controls

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>IA Reading Time (Hrs:Min)</th>
<th>PAC Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block 2</td>
<td>4:47</td>
<td>0.006615</td>
</tr>
<tr>
<td>Block 5</td>
<td>4:43</td>
<td>0.006966</td>
</tr>
<tr>
<td>Block 3</td>
<td>5:10</td>
<td>0.009732</td>
</tr>
<tr>
<td>Block 4</td>
<td>5:43</td>
<td>0.009523</td>
</tr>
</tbody>
</table>

Each Block includes 4 wafers

Cleaning Controls
Determines amount of introduced contamination from the cleaning materials

Table 10: PAC Values for Cleaning Controls

<table>
<thead>
<tr>
<th>Cleaning Process</th>
<th>PAC$_{Before}$</th>
<th>PAC$_{After}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detergent Bath</td>
<td>0.000</td>
<td>0.011494</td>
</tr>
<tr>
<td>Solvent Rinse</td>
<td>0.000</td>
<td>0.009231</td>
</tr>
<tr>
<td>CO$_2$ Snow Cleaning</td>
<td>----</td>
<td>----</td>
</tr>
</tbody>
</table>
Figure 5: Regression Plot of Effective Removal Percentage
Conclusions

- Cleaning method and exposure time plays a significant factor in obtaining a high removal percentage.
  - The detergent bath and solvent rinse method displayed an increase in effective removal percentage as the contamination exposure increased.
  - CO\textsubscript{2} snow cleaning showed a relatively consistent cleaning effectiveness.

- For optimal removal of particulate contamination, the following settings should be used:
  - CO\textsubscript{2} Snow Cleaning
  - Si+Au+SiO\textsubscript{x}
  - 1 Day Exposure Time
## Conclusions –cont–

### Table 11: Advantages and Disadvantages of Optical Cleaning Methods

<table>
<thead>
<tr>
<th>Cleaning Method</th>
<th>Description</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
</table>
| Detergent Bath        | Direct contact method that uses an aqueous based, nonionic detergent to loosen contaminants from the surface. | • "Free Rinsing" capability  
• Reduces "creep" contamination | • N/A to large/complex optics  
• Excessive handling  
• Direct contact increases risk of surface damage  
• Cleaning materials could introduce contamination |
| Solvent Rinse         | Direct contact method that uses an aqueous based, nonionic detergent and solvent rinse to loosen contaminants from the surface. | • "Free Rinsing" capability  
• Reduces "creep" contamination  
• Rapid/spot free drying  
• Removes some molecular contamination | • N/A to large or complex optics  
• Excessive handling  
• Direct contact increases risk of surface damage  
• Cleaning materials could introduce contamination  
• Excessive use of solvent could create water spots |
| CO₂ Snow Cleaning      | Non-contact method that uses a high velocity stream of CO₂ solid and gas; removing contamination through momentum transfer. | • Reduced risk of surface damage  
• Removes fingerprints  
• No waste  
• Quick cleaning process | • Requires controlled environ.  
• Electrostatic charge  
• Introduction of gas constituents |

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Recommendations

Detergent Bath
- Select low or non-particulating cleaning materials
- Use a nitrogen purge gas during drying process

Solvent Rinse
- Select low or non-particulating cleaning materials
- Use a nitrogen purge gas during drying
- Use filtered solvents
- Use a certified clean storage method for solvent

CO$_2$ Snow Cleaning
- Perform cleaning in a dry box or with a nitrogen purge
- Develop a working instruction for the CO$_2$ cleaning procedures
Future Work

- SPIE Optics and Photonics Conference in San Diego, CA (August 2006)
- Perform a repetitive mirror cleaning study
- Develop a cleaning procedure for JWST’s Optical Telescope Element
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THANK YOU!
References


Back-Up Slides
James Webb Space Telescope
Optical Telescope Element

Secondary Mirror Support Structure (SMSS)
- Boron/M55J for thermal stability
- Simple four-bar linkage deployment

WFS&C Subsystem
- Simple steps
- Deterministic
- Four ISIM weak lenses and DHS

Aft Optics Subsystem
- Fixed tertiary
- Fine steering mirror
- PM baffle
- ISIM bench radiator

OTE Clear Aperture: 25 m²

ISIM Enclosure
- ISIM Instrument Suite
  - NIRSpec
  - NIRCam
  - MIRI
  - FGS
- ISIM radiators

Secondary Mirror Assembly (SMA)
- Light-weighted, rigid Be mirror
- Hexapod actuator configuration
  - Six-DoF control for alignment
- Stray light baffle
- Rigid delta frame support w/simple interface to SMSS

Primary Mirror Segment Assemblies (PMSA)
- Light-weighted, semi-rigid segments
- 18 modular units make up PM
- Separable rigid body and RoC figure control
  - Hexapod rigid body actuation, one RoC actuator
- Simple, accessible interface to Backplane

Deployment Tower Subsystem
- Simple, two-piece telescoping tube
- T300 for low conductivity
- Bi-sterm deployed
  - Slenderness ratio <60

BackPlane
- Chord-fold deployment
  - Minimizes mechanisms
  - Maximizes thermal connectivity
- Boron/M55J hybrid material
  - CTE <0.1 ppm/K
  - High stiffness
  (near Be, 2X M55J)

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Contamination Requirements

JWST Mission Requirements Document
JWST-RQMT-000634

- MRD-51 Observatory Sensitivity (particulate)
- MRD-121 Stray Light (particulate)
- MRD-211 Optical Transmission (molecular, water ice)

Derived End-of-Life (EOL) Requirements

- Particulate (1.0 PAC for PM, SM; 0.32 PAC TM, FSM)
- Molecular (400 angstroms)
- Water Ice (400 angstroms)

JWST Observatory Contamination Control Plan
(JWST-PLAN-002028)

Contamination Allowances
I&T Budget Observatory Elements and Subsystems

Implementation
Design, Facility, Personnel, MGSE & Operational Controls

Verification
Contamination Monitoring Plan, D40608
I&T Particulate Budget

Predicted PAC (%) for Worst Case PM Segment
Assumes Cup Up I&T, No Cleaning, Facilities Currently Baselined,
Idealized (requested in DUA) and Conservative (more realistic) Launch Phase Particle Redistribution

- PAC per Phase, per NGST CCP (JWST-PLAN-002028, 12-22-06) and ArianeSpace DUA Reqt
- PAC per Phase + exp time margin + added launch conservatism
- PAC accumulation, per NGST CCP and DUA Reqt
- PAC accumulation, with exp time margin & launch conservatism

1% PAC EOL Requirement

PAC (%) Due to Particulates

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2007 Conta...
Predicted PAC (%) for Worst Case PM Segment
Assumes Cup Up I&T, No Cleaning, Facilities Currently Baseline,
Idealized (requested in DUA) and Conservative (more realistic) Launch Phase Particle Redistribution.