International Space Station Reliability Analysis

Melissa Bartush
The University of West Florida, Pensacola Florida
Department of Earth and Environmental Sciences

NE/171 Safety Panels Group
International Space Station Division
Safety and Mission Assurance Directorate
Position

- Graduate Student Intern
- ISS Reliability and Maintainability
- Provide reliability data to the ISS program for risk based decisions
  - BPA and EMU Projects
Brine Processing Assembly (BPA)
Qualitative Reliability Analysis

Problems:
• Class 1E flight hardware for use on the ISS
  ➢ Means no reliability requirements
• Fault Detection, Isolation, and Recovery (FDIR) debate
Failure Mode and Effects Analysis (FMEA) Brine Processing Assembly

Benefits:
- Identified risk areas
- Input on FDIR discussion
- Co-Mentor will use results to drive design

Analysis:
- Failure Modes and causes
- Effects of Failure
- Corrective actions
- Criticality of system
Statistical Analysis
Extravehicular Mobility Unit (EMU)

• Action: Use statistical tools to test the EMU failure data for any trends that are present
• Developed analysis to determine failure rate comparison between maintenance intervals
Analysis Steps

1. Failure Data Classification
2. Normalized by EMU usage hour
3. Two Sample T-Test
4. Weibull Curve
Results

• T-Test:
  - Failure Rates (FR) between the two groups are different
  - 6 Year EMU decreasing FR

• Weibull Plot:
  - Overall the EMU has a decreasing FR
  - Each EMU has its own failure curve
  - Insufficient data for individual component analysis

• Reported data and results to EVA Chief Engineer
Professional Growth and Accomplishments

Technical Skills:
• Performing FMEA’s to aid in FDIR analysis
• Real world statistical analysis
• Weibull Analysis

Interpersonal Skills:
• Testing knowledge in professional setting
• Confidence by doing meaningful work
• Conflict resolution
The JSC Experience

- Astronauts
- Tours
- русский язык
Forward Work

• Apply for NASA Pathways Internships
• Complete Masters degree
• Scout for NASA careers
MANY THANKS

Mentor
Van Keeping

Co-Mentor
Nicholas Meyer

Advisors
Mesha Keuss
Alan Currie
Bill McAllister

Internship Coordinators
Veronica Seyl
Missy Matthias
Melissa Corning

...And all of my ‘Safety’ family!
Contact information

Melissa Bartush
melissabartush@yahoo.com
850-449-5009
Backup Slides
Normalizing the Data

Without Precise maintenance times, the following formula was used to estimate approximate usage hours:

Approximate Usage Hours = Total time on EVA
+ Base Maint/Year *(#EMUs on orbit)
+ Maint/EVA *(#EMUs on orbit)

Assumption:
• 20 Hours Base Maint/Year
• 20 Hours Maint/EVA
EMU Backup

**Probability Plot for Failures per Usage Hour (1998-2008)**

- Equation: $y = 32.895x - 0.865$
- $R^2 = 0.8291$

**Probability Plot for EMU Failures per Usage Hour (2009-2015)**

- Equation: $y = 181.39x - 1.7971$
- $R^2 = 0.9014$

Normalized non-MEGA and MEGA data
## Two Sample t-Test/Hypothesis Test

**t-Test: Two-Sample Assuming Unequal Variances**

<table>
<thead>
<tr>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td><strong>Mean</strong></td>
<td>0.033</td>
<td>0.012</td>
</tr>
<tr>
<td><strong>Variance</strong></td>
<td>0.00096</td>
<td>0.000038</td>
</tr>
<tr>
<td><strong>Observations</strong></td>
<td>11</td>
<td>7</td>
</tr>
<tr>
<td><strong>Hypothesized Mean Difference</strong></td>
<td>0</td>
<td></td>
</tr>
<tr>
<td><strong>df</strong></td>
<td>11</td>
<td></td>
</tr>
<tr>
<td><strong>t Stat</strong></td>
<td>2.219</td>
<td></td>
</tr>
<tr>
<td>P(T&lt;=t) one-tail</td>
<td>0.024</td>
<td></td>
</tr>
<tr>
<td>t Critical one-tail</td>
<td>1.796</td>
<td></td>
</tr>
<tr>
<td>P(T&lt;=t) two-tail</td>
<td>0.048</td>
<td></td>
</tr>
<tr>
<td>t Critical two-tail</td>
<td>2.201</td>
<td></td>
</tr>
</tbody>
</table>

Note: if t-Stat > t-Critical, reject Null Hypothesis

**Result:** t-Stat > t-Critical, therefore, at 95% confidence, the test shows that the failure rates between non-MEGA and MEGA EMU's is different. It appears that the failure rate actually decreases for MEGA EMU.
Scrub criteria:

• Failures that happened in flight or in a flight-like atmospheric situation (such as chamber runs for specific serial numbers in preparation for a specific flight).

PART filter: JSC GFE PRACA, IFI, PRACA

Scrubbed:

NBL Testing
Acceptance Testing
Build-Up
SSER
Battery
PIA, UIA
Glove
Functional test
Usage, Expired, Limited Life

Receiving
NVR Testing
EMI
Paperwork
BIO-MED
Vibration Test
Qual Testing
Manufacturing
METOX
# EMU Flight Failures 1998-2008

<table>
<thead>
<tr>
<th>Year</th>
<th>Failures/Year</th>
<th>Total EVA's/Year</th>
<th>Avg Failure/EVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>5</td>
<td>3</td>
<td>1.67</td>
</tr>
<tr>
<td>1999</td>
<td>8</td>
<td>1</td>
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<tr>
<td>2000</td>
<td>10</td>
<td>9</td>
<td>1.11</td>
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<tr>
<td>2001</td>
<td>14</td>
<td>16</td>
<td>0.88</td>
</tr>
<tr>
<td>2002</td>
<td>16</td>
<td>18</td>
<td>0.89</td>
</tr>
<tr>
<td>2003</td>
<td>7</td>
<td>2</td>
<td>3.50</td>
</tr>
<tr>
<td>2004</td>
<td>4</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>2005</td>
<td>2</td>
<td>4</td>
<td>0.50</td>
</tr>
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<td>2006</td>
<td>8</td>
<td>11</td>
<td>0.73</td>
</tr>
<tr>
<td>2007</td>
<td>19</td>
<td>21</td>
<td>0.90</td>
</tr>
<tr>
<td>2008</td>
<td>17</td>
<td>15</td>
<td>1.13</td>
</tr>
</tbody>
</table>
# EMU Flight Failures 2009-2016*

<table>
<thead>
<tr>
<th>Year</th>
<th>Failures/Year</th>
<th>Total EVA's/Year</th>
<th>Avg Failure/EVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>12</td>
<td>19</td>
<td>0.63</td>
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<tr>
<td>2010</td>
<td>13</td>
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<td>5</td>
<td>1.00</td>
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<tr>
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<td>3</td>
<td>2.33</td>
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<tr>
<td>2015</td>
<td>8</td>
<td>6</td>
<td>1.33</td>
</tr>
<tr>
<td>2016</td>
<td>2</td>
<td>3</td>
<td>0.67</td>
</tr>
</tbody>
</table>

Note: 2016 data included as of end of FY16
Flight EMU

Weibull Plot of EMU system as a whole
Beta indicates increasing failure rate. It is likely this failure mode is driving the higher beta for 3011.