Implementing Six Sigma Tools in ADEST
Bill Ricci
Aerial Delivery Engineering Support Team
Warfighter Protection and Aerial Delivery Directorate
OUR COMPANY HAS DECIDED TO TRY SOMETHING NEW.

NEW SIX SIGMA WAS DEVELOPED IN THE 80s.

IT'S NEW TO US.

WHY DON'T WE JUMP ON A FAD THAT HASN'T ALREADY BEEN WIDELY DISCREDITED?

THAT WAY THE FALSE HOPE MIGHT SUSTAIN US.

THERE'S NOTHING WRONG WITH SIX SIGMA. ALL IT DOES IS REDUCE DEFECTS!

LET'S SEE... FORTUNE MAGAZINE SAYS... BLAH, BLAH... MOST COMPANIES THAT USED SIX SIGMA HAVE TRAILED THE S&P 500.

SORRY I'M LATE. WHAT DID I MISS WHILE I WAS INNOVATING?
Six Sigma - Why we do it

- Communication
  - within the team
  - with the customer
  - with our suppliers
- Data driven decisions
  - Defining the problem
  - Confirming we have a solution
  - Monitoring the health of the process
• During a training exercise, several loads rolled over due to the M-1 Canopy Release not activating
• A General Officer was present and issued a memorandum directing the design of a replacement release
Failure Mode Occurrence
(% of Total Heavy Equipment Drop Malfunctions 1994-2006)

- Drogue Jettison/Loss of Extraction (No Drop): 36.34%
- Loss of Parachute(s): 33.06%
- M-1 Failure: 7.65%
- Over Rotation: 4.64%
- Non-Release Related Rollover: 1.91%
- Other: 3.55%
- Extraction by Mains: 1.37%
- Delayed Extraction: 11.48%

<table>
<thead>
<tr>
<th>Description</th>
<th>Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drogue Jettison/Loss of Extraction (No Drop)</td>
<td>133</td>
</tr>
<tr>
<td>Loss of Parachute(s)</td>
<td>121</td>
</tr>
<tr>
<td>Delayed Extraction</td>
<td>42</td>
</tr>
<tr>
<td>M-1 Failure</td>
<td>28</td>
</tr>
<tr>
<td>Over Rotation</td>
<td>17</td>
</tr>
<tr>
<td>Other</td>
<td>13</td>
</tr>
<tr>
<td>Non-Release Related Rollover</td>
<td>7</td>
</tr>
<tr>
<td>Extraction by Mains</td>
<td>5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>366</strong></td>
</tr>
</tbody>
</table>
Do we Need an Improved Canopy Release?

Pareto Chart of Malfunction Modes
(Heavy Equipment Drop Malfunctions 1994-2005)

Failure Mode Occurance (%)
Cummulative Percentage

- Drogue Jettison/Loss of Extraction (No Drop)
- Loss of Parachute(s)
- Delayed Extraction
- M-1 Failure
- Over Rotation
- Other
- Non-Release Related Rollover
- Extraction by Mains

0% 5% 10% 15% 20% 25% 30% 35% 40%
0% 20% 40% 60% 80% 100%
Do we really need to redesign from scratch? Is it a quality issue?

Pareto Chart of M-1 Malfunction Modes
(Heavy Equipment Drop Malfunctions 1994-2006)
MISSION: Improve helicopter sling load (HSL) operations in adverse environmental conditions.

Item Characteristics

- Length: 50 ft
- 15,000-pound capacity
- Constructed from loops of braided VECTRAN
- Improved sand resistance (extruded cover)

Problem

- Initial production lot failed to meet strength requirement – 75 kip
- Critical need for 101st during current deployment
Summary for Break Strength

Anderson-Darling Normality Test
- A-Squared: 0.47
- P-Value: 0.206

- Mean: 85465
- SDev: 15373
- Variance: 236325003
- Skewness: -0.12041
- Kurtosis: -1.43331
- N: 13

- Minimum: 60330
- 1st Quartile: 72930
- Median: 85770
- 3rd Quartile: 101075
- Maximum: 106330

95% Confidence Interval for Mean
- Lower: 77175
- Upper: 95734

95% Confidence Interval for Median
- Lower: 73076
- Upper: 101047

60% Confidence Interval for StdDev
- Lower: 11024
- Upper: 25577

Test Facility Gage R&R

Interval Plot of SWOS, OPR, TMT
95% CI for the Mean
• Early Production
  – Mean: 85,176 lbs
  – SD: 7,096 lbs
  – Confidence (breaking strength > 75,000 lbs): 91.17%
  – Cpk = 0.48

• After implementing improvements
  – Mean: 98,550 lbs
  – SD: 3,746 lbs
  – Confidence (breaking strength > 75,000 lbs): 99.44%
  – Cpk = 2.10
Go Argue with the Data

Histogram of T11 Fabric Cover, T11 Girth hitch and T10 Metal Cover - Regular Pull

Normal

<table>
<thead>
<tr>
<th>Variable</th>
<th>Fabric Cover - correct</th>
<th>Girth Hitch</th>
<th>Metal Cover</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>8.852</td>
<td>12.37</td>
<td>9.891</td>
</tr>
<tr>
<td>StDev</td>
<td>2.411</td>
<td>2.518</td>
<td>0.6574</td>
</tr>
<tr>
<td>N</td>
<td>40</td>
<td>40</td>
<td>40</td>
</tr>
</tbody>
</table>

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.
Old CRA vs. New CRA Statistics

<table>
<thead>
<tr>
<th></th>
<th>Total Jumps</th>
<th>Failures</th>
<th>Reliability at 95% Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Old CRA Design</td>
<td>2855</td>
<td>1</td>
<td>99.834%</td>
</tr>
<tr>
<td>New CRA Design</td>
<td>308</td>
<td>2</td>
<td>97.970%</td>
</tr>
</tbody>
</table>

Two-Sample Proportion Test

<table>
<thead>
<tr>
<th>Sample 1</th>
<th>Sample 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample Size</td>
<td>2855</td>
</tr>
<tr>
<td>Failures</td>
<td>1</td>
</tr>
<tr>
<td>Proportion</td>
<td>0.00035</td>
</tr>
</tbody>
</table>

Null Hypothesis: P1 = P2
Alternative Hyp: P1 <> P2
Difference: -0.00614
SE (diff): 0.00185
Z (uncorrected): -3.33 P 0.0009
Z (corrected): -2.35 P 0.0186

What This Means

There is a Statistical difference between the Old CRA and the New CRA design.

Even though testing has shown that it is more likely for the Old Fabric cover to come off. The New CRA is more likely to fail.
• to multiple manufacturers
  – Ensure that all manufactures can build the part
  – Ensure that all parts from all manufactures look, function and perform the same
  – Once in production - need to make sure the process stays in control
• Data from:
  • Multiple vendors
  • Measured by 3 sources
    – Where and How to Measure non-rigid Textile items
    – Hand tension vs. load cell
### Overall System: Drawing 11-1-7407, SF-10A Main Parachute Assembly

### Sub System: Canopy Assembly

<table>
<thead>
<tr>
<th>Drawing</th>
<th>Sheet</th>
<th>Zone</th>
<th>Description</th>
<th>Dimension</th>
<th>Location</th>
<th>Tension</th>
</tr>
</thead>
<tbody>
<tr>
<td>11-1-7401</td>
<td>3</td>
<td>F5</td>
<td>Skirt Band</td>
<td>Inside Edge of Seam to Outside Edge of Seam for Gores 1, 11, 18, 22 and 26</td>
<td>Hand Tension</td>
<td></td>
</tr>
<tr>
<td>11-1-7401</td>
<td>4</td>
<td>F3</td>
<td>Basic Gore Main Seam</td>
<td>180 ± 2 1/2</td>
<td>Outside Edge of Vent to Outside Edge of Skirt, Pairs Shall be Within 2 inches of Each Other</td>
<td>3 ± 1/2 lbs</td>
</tr>
<tr>
<td>11-1-7401</td>
<td>5</td>
<td>G5</td>
<td>Slotted Gore Main Seam</td>
<td>180 ± 2 1/2</td>
<td>Outside Edge of Vent to Outside Edge of Skirt, Pairs Shall be Within 2 inches of Each Other</td>
<td>3 ± 1/2 lbs</td>
</tr>
<tr>
<td>11-1-7401</td>
<td>5</td>
<td>C6</td>
<td>Drive Vent Gore Main Seam</td>
<td>179 1/8 ± 2 1/2</td>
<td>Outside Edge of Vent to Outside Edge of Skirt, Pairs Shall be Within 2 inches of Each Other</td>
<td>3 ± 1/2 lbs</td>
</tr>
<tr>
<td>11-1-7401</td>
<td>6</td>
<td>D5</td>
<td>Blank Gore Main Seam</td>
<td>178 5/8 ± 2 1/2</td>
<td>Outside Edge of Vent to Outside Edge of Skirt, Pairs Shall be Within 2 inches of Each Other</td>
<td>3 ± 1/2 lbs</td>
</tr>
<tr>
<td>11-1-7401</td>
<td>6</td>
<td>D4</td>
<td>Blank Gore Main Seam</td>
<td>180 ± 2 1/2</td>
<td>Outside Edge of Vent to Outside Edge of Skirt, Pairs Shall be Within 2 inches of Each Other</td>
<td>3 ± 1/2 lbs</td>
</tr>
<tr>
<td>11-1-7401</td>
<td>6</td>
<td>D1</td>
<td>Braking Gore Main Seam</td>
<td>179 1/4 ± 2 1/2</td>
<td>Outside Edge of Vent to Outside Edge of Skirt, Pairs Shall be Within 2 inches of Each Other</td>
<td>3 ± 1/2 lbs</td>
</tr>
<tr>
<td>11-1-7401</td>
<td>11</td>
<td>D8</td>
<td>Overall Brake Slot Length</td>
<td>Within 1 inch of Each Other</td>
<td>End of Tape to End of Bartack. Record both lengths and subtract for length difference.</td>
<td>Hand Tension</td>
</tr>
<tr>
<td>11-1-7401</td>
<td>13</td>
<td>D1</td>
<td>Suspension Line Length</td>
<td>256 1/2 ± 2 1/4</td>
<td>Top of Connector Link to Match Mark for Gores 1, 11, 18, 22, and 26</td>
<td>14 lbs</td>
</tr>
<tr>
<td>11-1-7401</td>
<td>14</td>
<td>C3</td>
<td>FN 42 - FN 46 Control Line Grouping Length</td>
<td>See Table</td>
<td>See Table</td>
<td>Hand Tension</td>
</tr>
<tr>
<td>11-1-7401</td>
<td>14</td>
<td>B7</td>
<td>Control Line Routing</td>
<td>See Detail E</td>
<td>See Detail E</td>
<td>Hand Tension</td>
</tr>
<tr>
<td>11-1-7401</td>
<td>18</td>
<td>E3</td>
<td>Extended Gore Trailing Edge (Dimension &quot;B&quot;)</td>
<td>134 1/2 ± 1 1/4</td>
<td>Inside to Inside of Horizontal Tapes</td>
<td>Hand Tension</td>
</tr>
</tbody>
</table>
• Production lot sampling
• CTQ data recorded
• Control Charts
• Just another tool in our toolbox
• Appreciate all the efforts of our suppliers
• Will be used in other programs, e.g. T11, JPADS, etc.
• Company X
  – $C_p = 0.67$
  – $C_{pk} = 0.5$
  – $P = 0.170$
  – $StDev = 1.253$

• Company Y
  – $C_p = 0.9$
  – $C_{pk} = 0.61$
  – $P = 0.039$
  – $StDev = 0.930$