Payload Separation System

Progress Report

Benjamin Dirgo, Mark Majkrzak, Jason McCall, Matthew Mylan, Kate Prentice, Alen Younan

January 30, 2014
Overview

- Review
- Objectives
- Design Manufacturing
- Final Design and Components
- Engineering Analysis Alterations
  - Solenoids
  - Shear on Keys
  - Kick off Springs/Magnets
- PSS Testing
- Costs
- Gantt Chart
  - Spring 2014
- Conclusion
- References
Problem Statement:
- Design, analyze, build, and test a less expensive payload separation system that delivers payloads into orbit with minimal shock to the payload.

Client:
- Orbital Sciences Corporation
  - Mary Rogers: Electronic Packaging and Actuators Manager
  - Stakeholders: Companies/Agencies whom contract with Orbital Sciences

http://www.orbital.com
### Design Manufacturing

<table>
<thead>
<tr>
<th>Components to be Manufactured</th>
<th>Team Members</th>
</tr>
</thead>
<tbody>
<tr>
<td>Payload Ring (PR)</td>
<td>Jason, Alen, Ben</td>
</tr>
<tr>
<td>Rocket Ring (RR)</td>
<td>Kate, Mark, Matt</td>
</tr>
<tr>
<td>Keys</td>
<td>Jason, Alen, Ben</td>
</tr>
<tr>
<td>Solenoid (+mounting)</td>
<td>Mark, Matt</td>
</tr>
<tr>
<td>Springs/Magnets (+mounting)</td>
<td>Kate</td>
</tr>
</tbody>
</table>

The sub-scale model is half the original 24” diameter and all analyses are altered accordingly.
Final Design

Engaged

After Separation
Payload Ring

- Begin with 12” x 12” x 1” Al
- Drill 10 adaptor holes
- Inner diameter with CNC end mill
- Outer diameter with CNC end mill
Rocket Ring

- Similar to Payload Ring
- Drill key holes into Al block
- End mill the inner surface with one CNC run
  - Key housing
  - Base plate
- End mill outer diameter keeping lip
- Cut shallow recess for spring or magnets
Solenoid

- Steel keys will be secured to the plunger
- Solenoid will be secured to base plate
Manufacturing Keys

- Round 0.5” dia. steel stock
- Mill male tab to one end
- Drill hole in to tab for solenoid attachment
- Cut diagonal edge to fit into 0.5” hole
Metallic Mesh Kickoff Springs

- 3 Kick off Springs placed symmetrically along the lip of the rocket ring
- Will be purchased
- The springs will sit in the recessed holes on the lip of the rocket ring
Engineering Analysis
Alterations

- Solenoid Analysis
- Shear Force on cylindrical Keys
- Metallic Mesh Kickoff Springs OR Magnets
Solenoid Analysis

- Solenoid requirements:
  - DC Power
  - 1” minimum stroke
  - Overall dimensions < 1” x 1” x 2”
  - Pull force > 14 N
  - Easily mountable
Failure Due to Shear Forces on Keys

- Note: $Q = 0$ once left earths atmosphere

- $Q_{\text{max}} = \frac{1}{2} \rho V^2$
  - $\rho$ = local air density [m$^3$/kg]
  - $V$ = vehicles velocity [m/s]

- $Q_{\text{max}}$ [N/m$^2$]
  - 70383.6

- $Q_{\text{max}}$ per Key [N/m$^2$]
  - 17595.9

- Top Surface Area of Key [m$^2$]
  - 0.000507

- Cross Sectional Area [m$^2$]
  - 0.000127

- Force due to $Q_{\text{max}}$ [N]
  - 8.91

- Force due to $M_{\text{payload}}$ [N]
  - 6169.21

- Shear Strength [Pa]
  - $4.88 \times 10^7$

- Shear Strength Failure [Pa]
  - $215 \times 10^6$

- Factor of Safety
  - 4.41

The stainless steel keys will not fail due to shear force caused by the first stage ignition process.

http://www.orbital.com/

Mark Majkrzak

1/30/2014
Metallic Mesh Kickoff Springs

- Material: AISI 304 Stainless Steel
- Temperature range: -90°C to +400°C
- Rocket Ring Lip: ½”
- Max Load of damped spring: 500 N
- Max Payload (300lb): 1334.47 N
  - Need 3 springs
- Static Deflection: 5.5 mm
- Weight: 7 g

<table>
<thead>
<tr>
<th>D [mm]</th>
<th>22</th>
</tr>
</thead>
<tbody>
<tr>
<td>d [mm]</td>
<td>6.3</td>
</tr>
<tr>
<td>H [mm]</td>
<td>15.5</td>
</tr>
</tbody>
</table>

Mark Majkrzak


1/30/2014
Metallic Kickoff Springs Continued

- Natural Frequency \( (f_n) \): 15 – 20 Hz
- Stiffness per damped spring \( (k) \): 110.54 N/m
- Mass of payload: 600 lb = 272.15 kg

### Separation Velocity vs. Time

<table>
<thead>
<tr>
<th>[Hz]</th>
<th>[rad/s]</th>
<th>m [kg]</th>
<th>k [N/m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>125.7</td>
<td>45.36</td>
<td>716283.24</td>
</tr>
<tr>
<td>ζ [ul]</td>
<td>[Ns/m]</td>
<td>c [Ns/m]</td>
<td>x [m]</td>
</tr>
<tr>
<td>1.914213562</td>
<td>11400.00198</td>
<td>21822.0384</td>
<td>0.0055</td>
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<tr>
<td>F [N]</td>
<td>V [m/s]</td>
<td>a [m/s²]</td>
<td></td>
</tr>
<tr>
<td>3939.56</td>
<td>0.69</td>
<td>0.067</td>
<td></td>
</tr>
</tbody>
</table>
Neodymium Magnets

- Easy to manufacture into rings
- Allows for no gap between rings
- Up to 7lb force per 0.5” magnet

P.S.S. Testing

- Two Situations that need to be Tested:
  1. Prove keys can withstand max dynamic pressure (Q)
  2. Prove complete separation of a 600lb load with minimal shock

- Possible Testing Environments:
  - Submerge in Water
    - Pros: Reduces gravity
    - Cons: Solenoids aren’t waterproof
  - Hang from a spring
  - Use a liquid more dense than water
  - Free fall

- Future Challenges:
  - Load 300lb?
  - Absence of Gravity
# Bill of Materials

- For one 12” diameter Payload Separation System

<table>
<thead>
<tr>
<th>Material</th>
<th>Quantity</th>
<th>Unit Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stainless Steel Key 0.5'' dia x 2’ long</td>
<td>1</td>
<td>$9.00</td>
</tr>
<tr>
<td>7075 Aluminium plate 24'' x 48'' x 1''</td>
<td>1</td>
<td>Donated</td>
</tr>
<tr>
<td>Solenoid</td>
<td>4</td>
<td>$32.75</td>
</tr>
<tr>
<td>Nuts/ Bolts/ Misc.</td>
<td>TBD</td>
<td>$50.00</td>
</tr>
<tr>
<td><strong>Total Cost</strong></td>
<td></td>
<td><strong>$190.00</strong></td>
</tr>
</tbody>
</table>

For one 12” diameter Payload Separation System
## Man Power Cost

<table>
<thead>
<tr>
<th>Team Members</th>
<th>Pay ($/hr)</th>
<th>Rocket Ring Fabrication (hr)</th>
<th>Payload Ring Fabrication (hr)</th>
<th>Key Fabrication (hr)</th>
<th>Spring Assembly (hr)</th>
<th>Solenoid Assembly (hr)</th>
<th>Assembly (hr)</th>
<th>Total Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Matthew Mylan</td>
<td>20</td>
<td>10</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>20</td>
</tr>
<tr>
<td>Mark Majkrzak</td>
<td>20</td>
<td>10</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>20</td>
</tr>
<tr>
<td>Kate Prentice</td>
<td>20</td>
<td>10</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>20</td>
</tr>
<tr>
<td>Alen Younan</td>
<td>20</td>
<td>10</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>16</td>
</tr>
<tr>
<td>Ben Dirgo</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>15</td>
</tr>
<tr>
<td>Jason McCall</td>
<td>20</td>
<td>10</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td></td>
<td>2</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>Total Cost ($)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$2,160</td>
</tr>
</tbody>
</table>

Kate Prentice
## Manufacturing Costs

- All manufacturing will be in building 98C machine shop
- Part cost + man hours

<table>
<thead>
<tr>
<th></th>
<th>Pay ($/hr)</th>
<th>Man Power (hr)</th>
<th>Part Cost ($)</th>
<th>Manufacturing Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RR</td>
<td>20</td>
<td>30</td>
<td>donated</td>
<td>600</td>
</tr>
<tr>
<td>PR</td>
<td>20</td>
<td>42</td>
<td>donated</td>
<td>840</td>
</tr>
<tr>
<td>Keys</td>
<td>20</td>
<td>6</td>
<td>9</td>
<td>129</td>
</tr>
<tr>
<td>Solenoids</td>
<td>20</td>
<td>9</td>
<td>32.75</td>
<td>212.75</td>
</tr>
<tr>
<td><strong>Total ($)</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>1781.75</strong></td>
</tr>
</tbody>
</table>
Gantt Chart: Spring 2014

- Purchasing: 1/28/14 - 2/28/14
- Research: 1/28/14 - 3/8/14
- Testing: 2/28/14 - 3/13/14
- Analysis: 3/10/14 - 3/14/14
- Testing II: 3/14/14 - 3/26/14
- Analysis II: 3/24/14 - 3/28/14
- Testing III: 3/28/14 - 4/15/14
- Final Analysis: 4/15/14 - 5/2/14

Dates:
- 1/28/14
- 2/2/14
- 2/9/14
- 2/16/14
- 2/23/14
- 3/2/14
- 3/9/14
- 3/16/14
- 3/23/14
- 3/30/14
- 4/6/14
- 4/13/14
- 4/20/14
- 4/27/14
Conclusion

- Reviewed the problem statement, contact with Orbital, and client objectives
- Used SolidWorks models to effectively communicate the final Design
- Explained how the team will ultimately manufacture each component of the PSS
- Initial separation caused by retracting the four keys using four Solenoids and metallic mesh kickoff springs to completely separate
- Performed additional analysis due to alterations of the keys, solenoids, and springs
- Re-calculated and recorded manufacturing costs, a bill of materials, and man power cost
- Explained current and future plans using a Gantt Chart
References


Thank you for listening,

QUESTIONS?