NORTHERN ARIZONA UNIVERSITY

Payload Separation System

UGRADS Presentation

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Orbital

Overview

- Client
- Current PSS System
- Problem Formulation
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- Final Design and Manufacturing
- Testing
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- Cost Analysis
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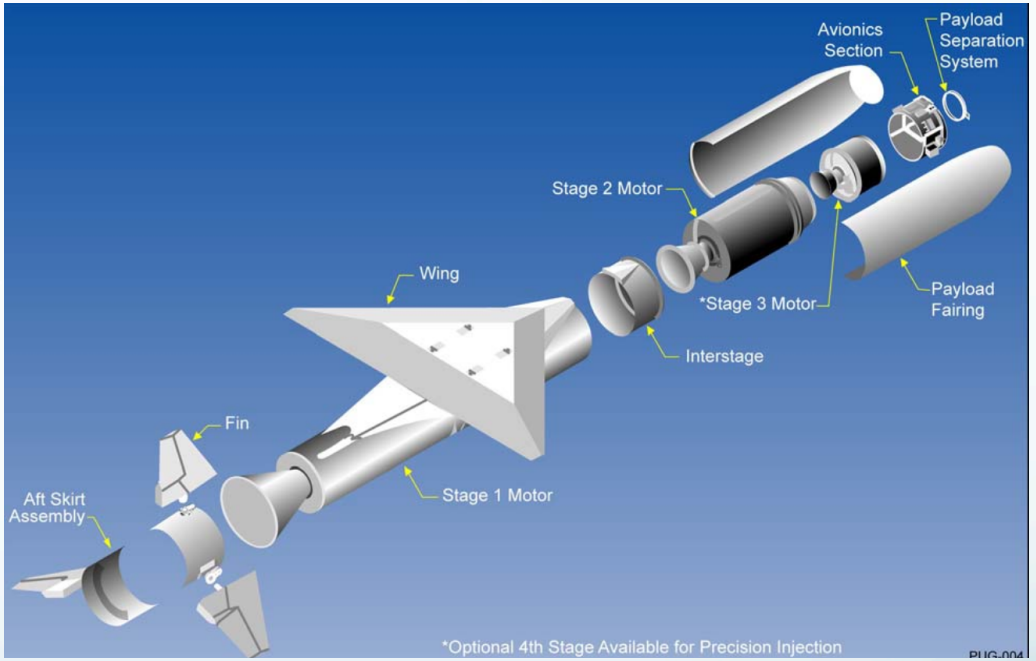
- Conclusion

Client

- Orbital Sciences Corporation
  - Lead Mechanical Engineers: Steven Hengl, Matthew Johns
  - Stakeholders: Companies/Agencies whom contract with Orbital Sciences

Current PSS System

- Launch vehicle: Pegasus
- Issues:
  - Substantial shock to payload
  - Costly
  - Subcontracting to manufacture PSS



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Problem Formulation

- Design, analyze, build, and test a less expensive payload separation system that delivers payloads into orbit with minimal shock to the payload.
- Improve:
  - Decrease number of parts while still retaining reliability
  - Decreasing cost
  - Allow for manufacturing at Orbital
  - Reduce shock to payload

Needs and Goal Statement

- Need:

The payload separation systems today are too expensive and put a large shock due to vibration on the payload.

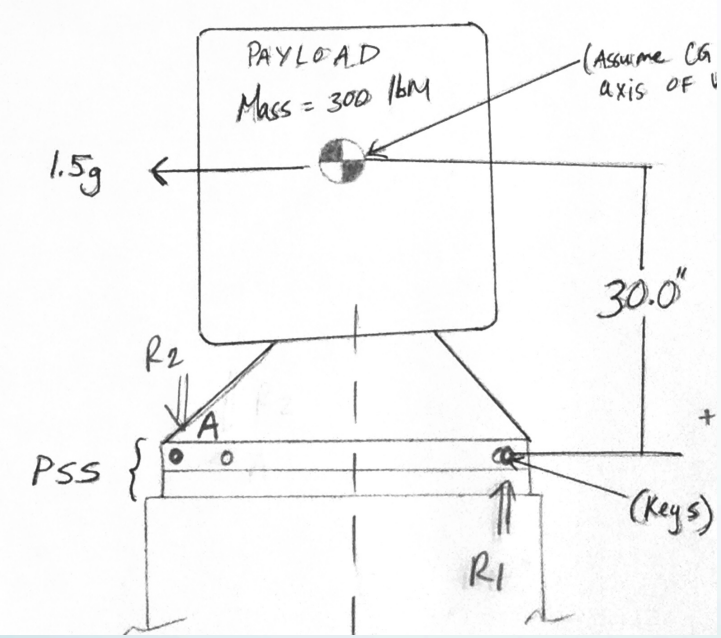
- Goal:

Design a less expensive payload separation system that can separate consistently on command with little to no impact to the payload.

Objectives

Objective	Measurement Basis	Unit
Separate Payload	Number of successful releases	%
No Debris	Number of fragmented pieces at separation	n/a
Minimal Shock	Impact force	lbf
Structural Capabilities	Material properties	n/a
No Re-contact	Push away reliably	%
Light-weight	Minimal load factor to rocket	lb
Fit Pegasus Dia.	23” or 38”	in
Ease of Assembly	Reduce man hours to assemble	hr
Special Tools to Assemble	No special tools to assemble	n/a
Mass added to Payload	Payload ring weight	lb

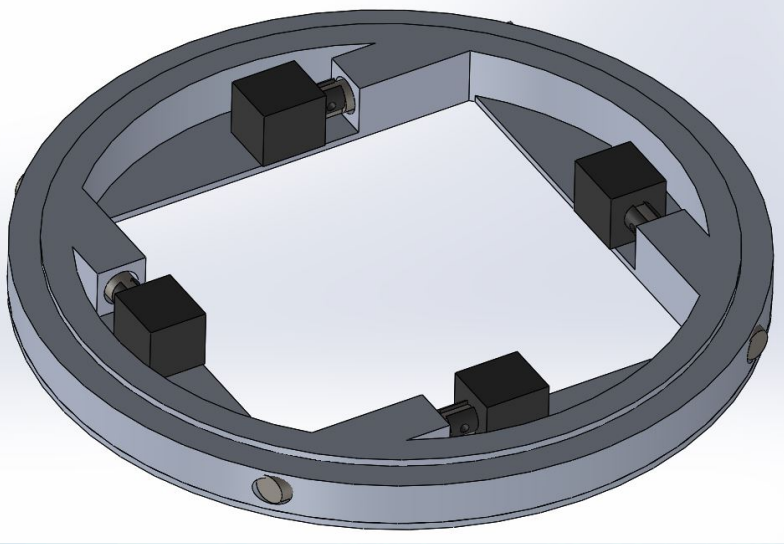
Failure Analysis



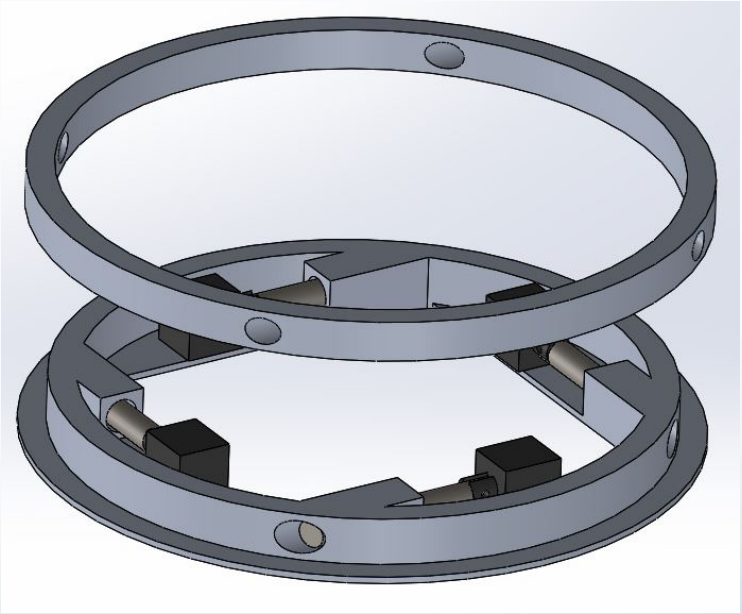
Acceleration [ft/s^2]	134.5
G's	4.2
Force/Key [lb]	313.3
Force Due to Moment/Key [lb]	1125
Shear (Keys) [lbf/in-s^2]	7325.4
Shear Yield (Key) [lb/in-s^2]	42456
Factor of Safety (Keys)	5.8
Tear Out (PR) [lb/in-s^2]	11064.1
Bearing Stress (PR) [lb/in-s^2]	4639.8

Final Design

Engaged

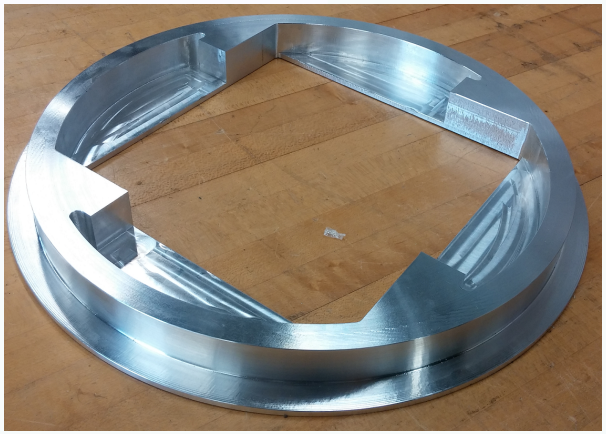


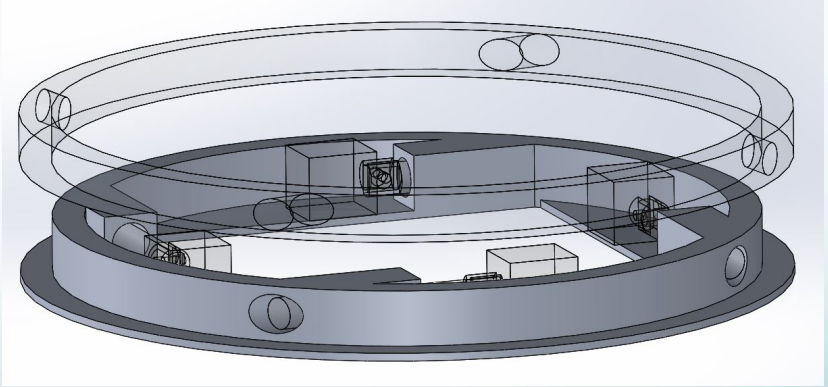
After Separation



Rocket Ring

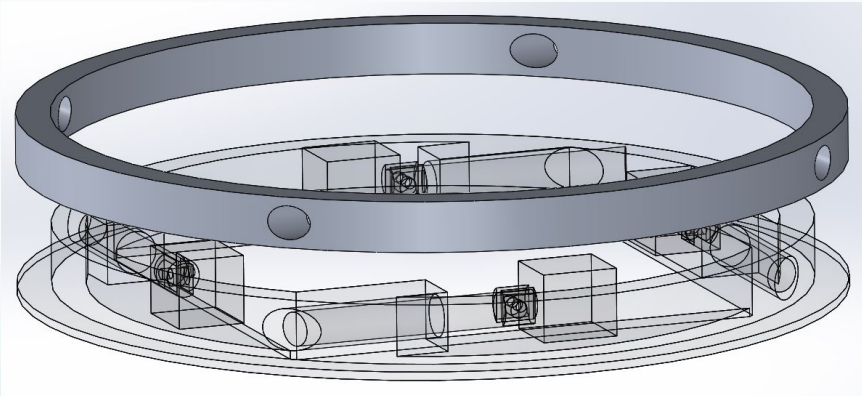
- G-code in Haas
  - Milled out center square plate with contour path
  - Milled out pockets for base plate and key housing
- Turned off ears of outer square plate with lathe
- Turned outer lip using lathe
- Hand milled key holes in the housing
- Cut shallow recess for spring using hand mill





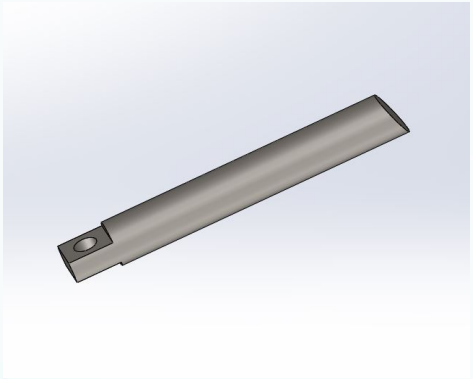
Payload Ring

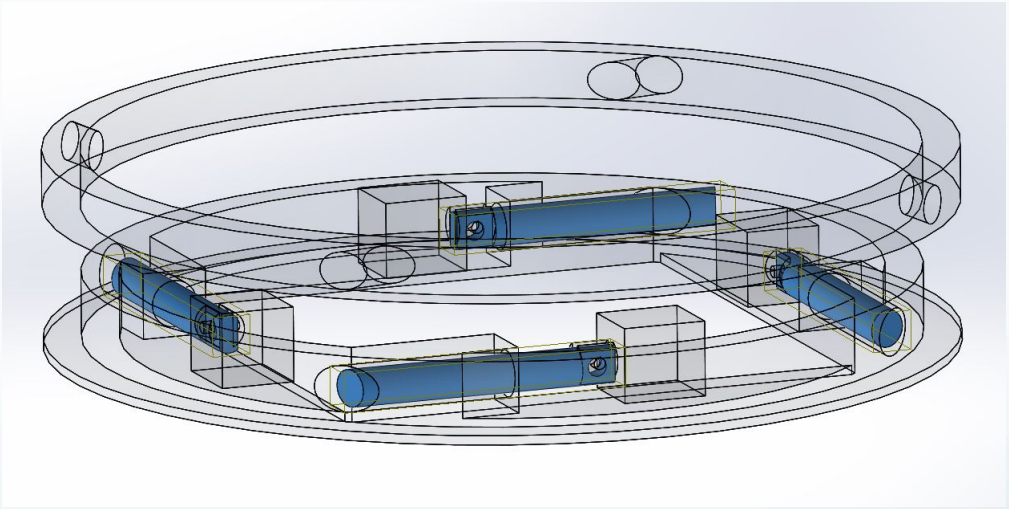
- Begin with 12” x 12” x 1” Al
- G-code generated by CAMWorks in SolidWorks
  - Contour path cuts out inner diameter
  - Outer diameter turned on a lathe



Keys

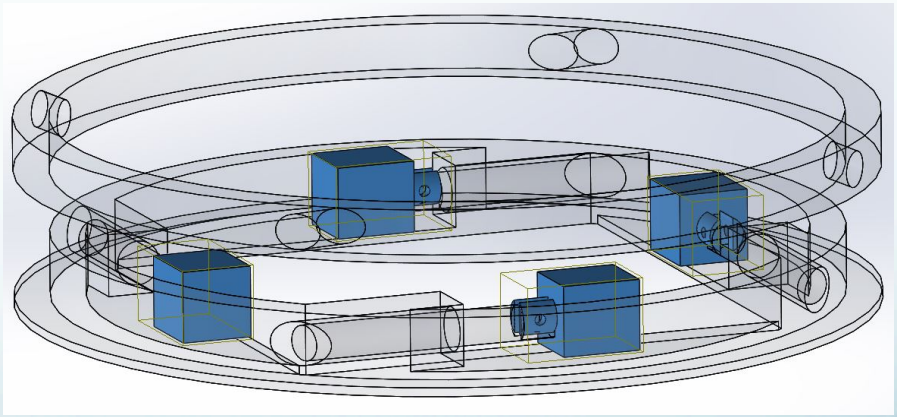
- Round 0.49’’ dia. steel stock
- Drill pin hole into tab for solenoid attachment
- Cut diagonal edge to be flush with outer payload ring





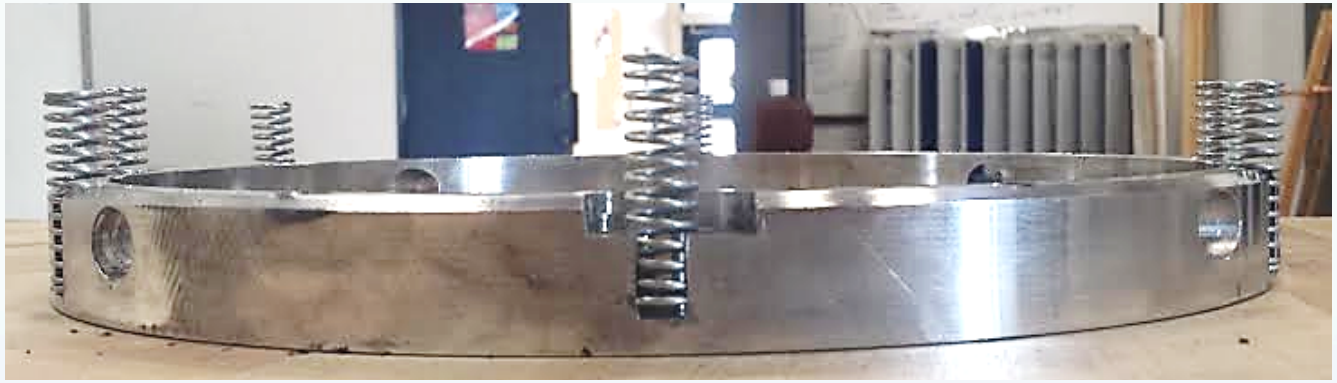
Solenoids

- Steel keys are secured to the plunger
- Fabricated mounting brackets
- Solenoids are bolted to base plate
- Wiring



Springs

- Eight Coil Springs placed symmetrically along the lip of the rocket ring
- The springs will sit in the recessed holes on the lip of the rocket ring

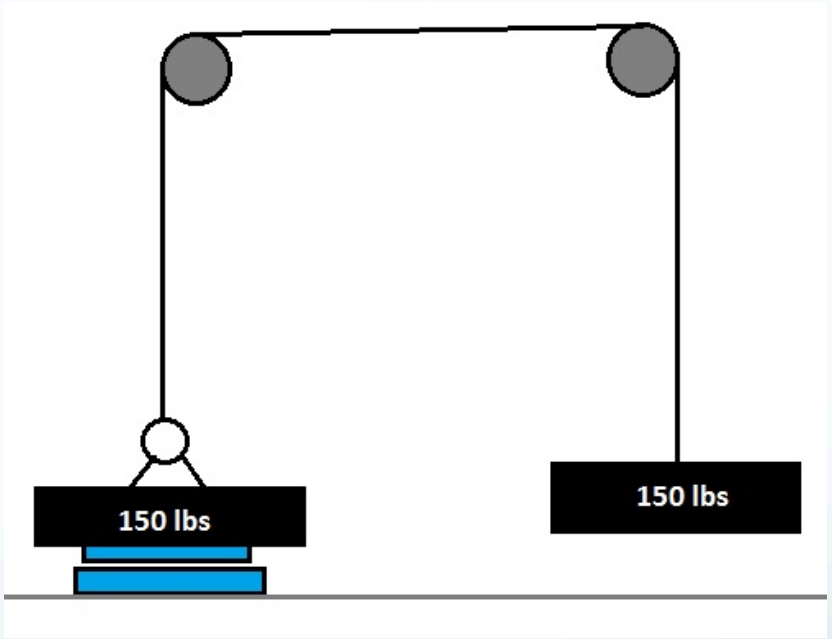


Testing

- Three situations to be tested:
  1. Prove keys can withstand max g's in longitudinal direction
  2. Prove complete separation at half scale of a 300lb load with minimal shock
  3. Ensure solenoid actuation reliability

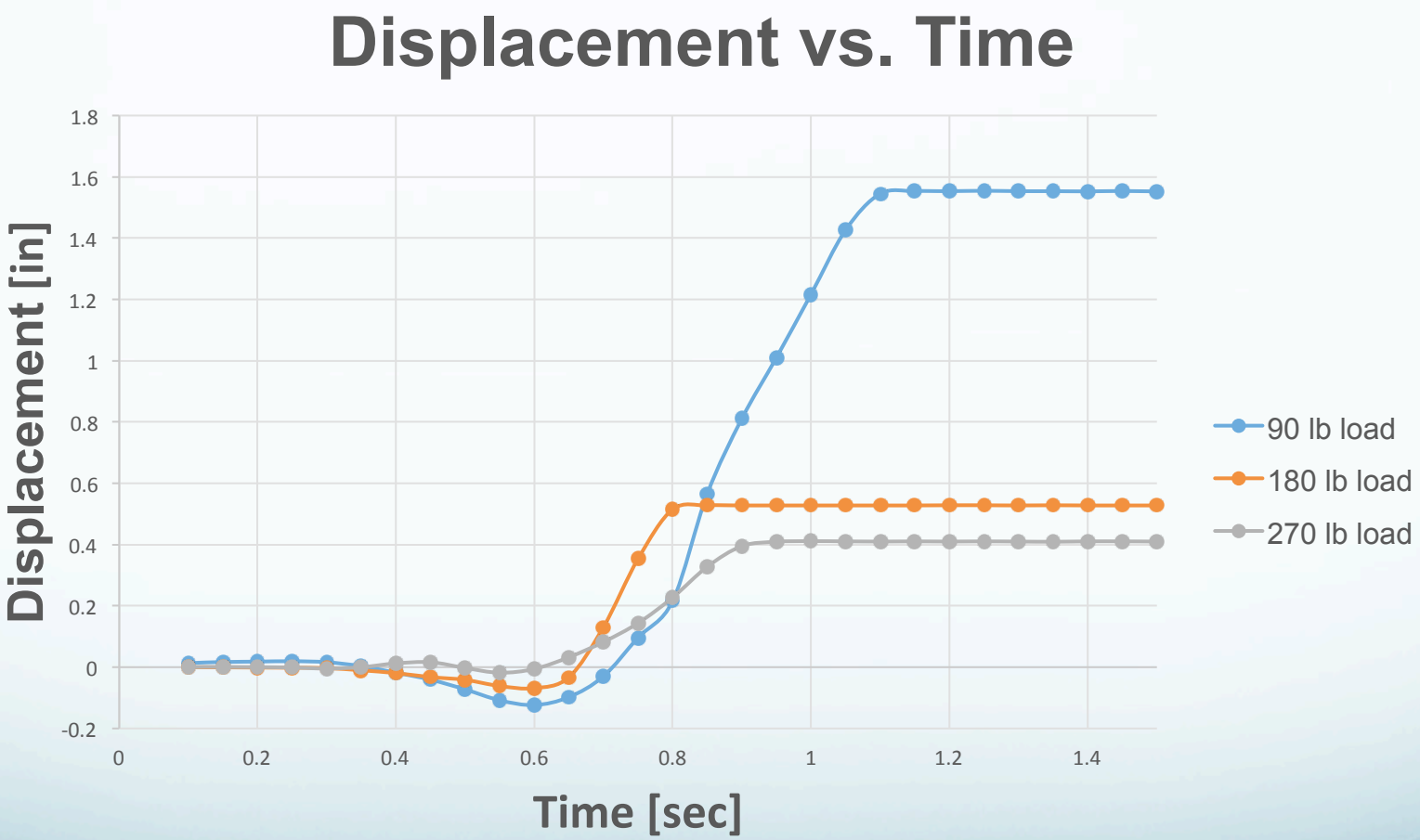
Testing Apparatus

- Pulley system attaches the P.S.S. to the equal amount of weight countering the system.
- Once balanced, the solenoids will deploy and the system will separate.

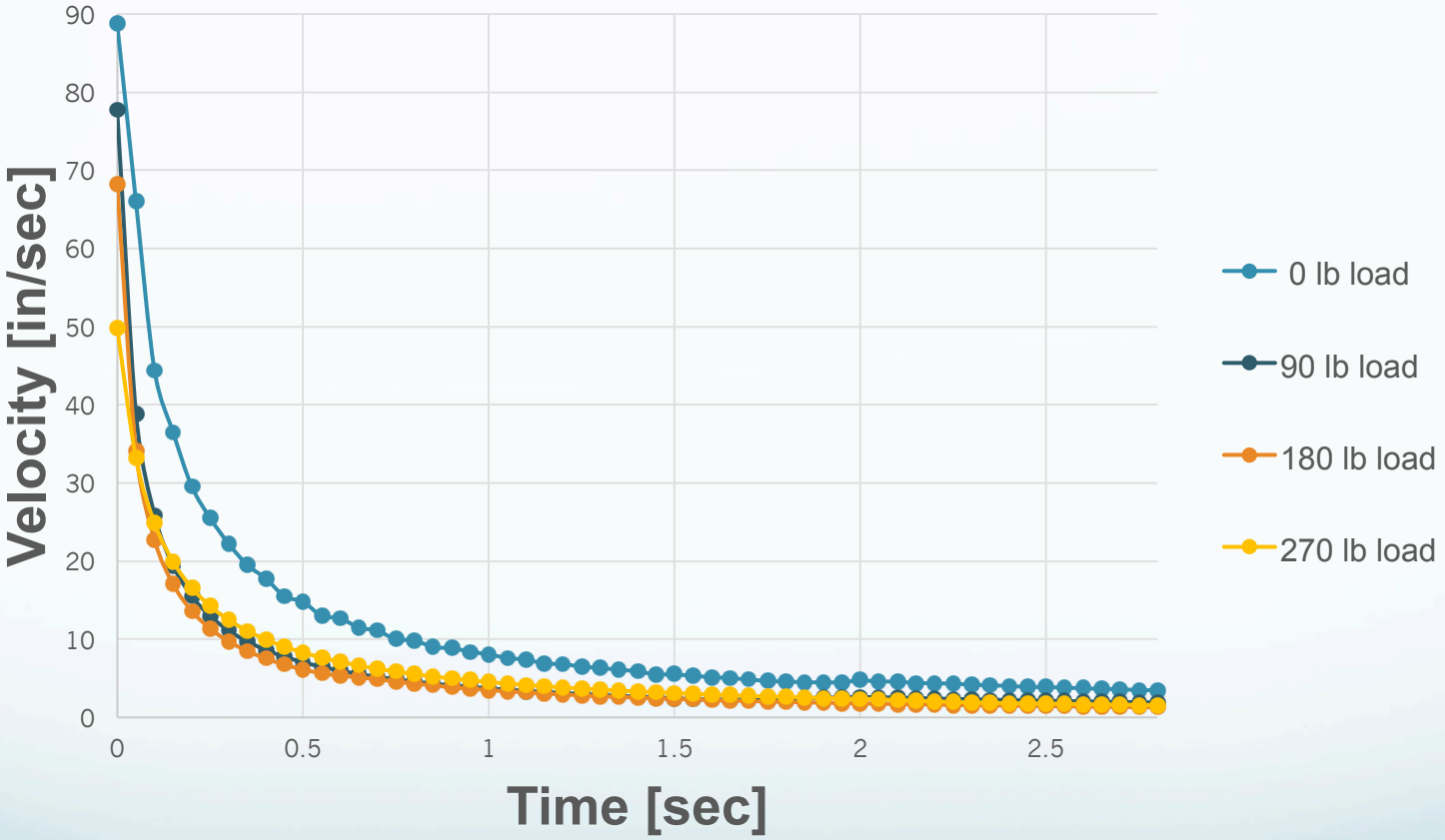


Separation & Reliability Test

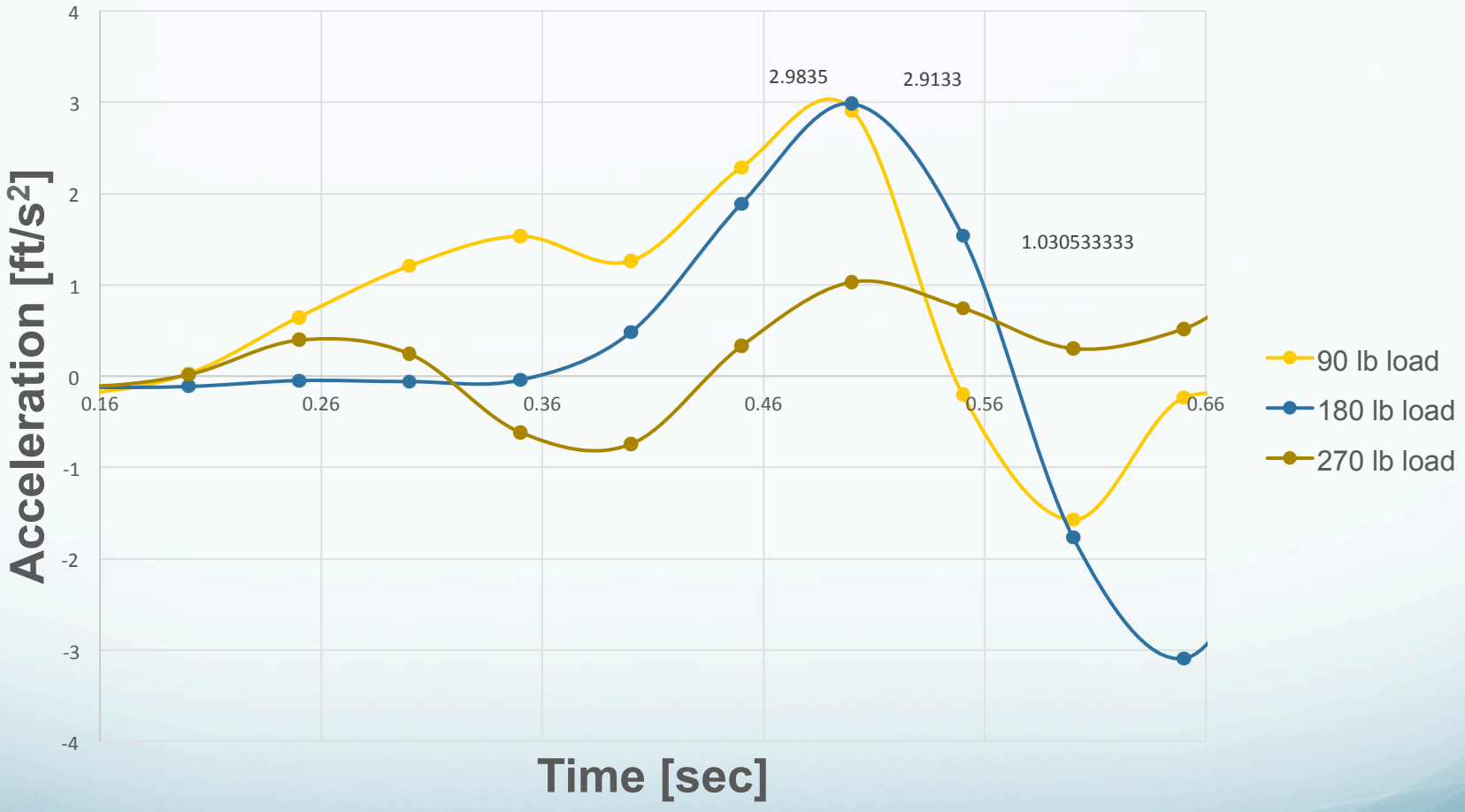
Testing Results



Separation Velocity vs. Time



Acceleration vs. Time



Bill of Materials

- For one 12’’ diameter Payload Separation System
- Budget – $1000

Material	Quantity	Unit Cost
7075 Aluminium plate 24" x 48" x 1"	1	$654.24
K & M Machine Tool Inc.	N/A	$65.00
Carbon Steel Key 0.5" dia x 48” long	1	$14.95
Solenoid	4	$28.00
Springs	8	$0.75
Testing Equipment	N/A	$266.59
Total Cost		$1118.78

Improvements

Current Payload System vs. Team Orbital's Payload System

- Weight: 40 lbs.
- Parts: 1000+
- Total Cost: $550,000
- Separation Velocity: 2.1 ft/s
- Acceleration at Separation: 5.3 g's

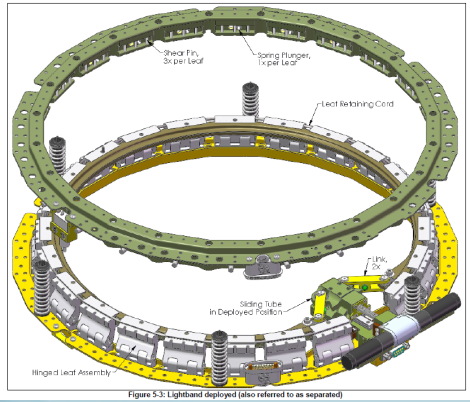


Figure 5-3: Lightband deployed (also referred to as separated)

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- Weight: 8 lbs.
- Parts: 18
- Total Cost: $3278.78
- Separation Velocity: 0.5 ft/s
- Acceleration at Separation: 0.04

Conclusion

- The mission is to design a Payload Separation System for Orbital Sciences Corp. that is reduced in price and parts while still retaining reliability.
- Manufactured a prototype at half scale to confirm reliability of proposed improvements.
- Initial tests confirmed design flaws existed in springs and keys.
- Retested to ensure successful modifications to solenoids, springs, and keys.
- Final testing results achieved successful and reliable separation while meeting design constraints and objectives.

Acknowledgements

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- Emerson Jones
- Chris Bennett
- Nick Jurik

References

[1] Kyle, Ed. "Space Launch Report 2012 Launch Stats." *Space Launch Report 2012 Launch Stats*. N.p., 29 Dec. 2013. Web. 05 Dec. 2013. <http://www.spacelaunchreport.com/log2012.html>.

[2] Philpot, Timothy A. *Mechanics of Materials: An Integrated Learning System*. 5th ed. Hoboken, NJ: John Wiley, 2011. Print.

[3] Rao, Singiresu S. *Mechanical Vibrations*. 5th ed. Upper Saddle River, NJ: Prentice Hall, 2011. Print.

[4] Baldwin, Bryan. "Pegasus User's Guide." Orbital Sciences, 1 Apr. 2010. Web. 5 Dec. 2013.

Thank you for listening,

QUESTIONS?