Orbital Science Payload Separation System

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

Department of Mechanical Engineering, Northern Arizona University

NORTHERN ARIZONA UNIVERSITY

College of Engineering, Forestry & Natural Sciences

Abstract

Orbital Sciences Corporation is interested in designing a Payload Separation System (PSS) that is lighter, less expensive, less complicated, and imparts minimal vibrational shock onto the payload. It is primarily used to deliver payload into a low Earth orbit. In general, the design is a ring that must be strong enough to secure a payload to the front of the Pegasus space launch vehicle, separate on command, and release the payload into orbit. The goal of this project is to improve the current payload separation system using a simplified design, in functionality as well as fabrication. Our team came up with a design that consists of a rocket ring and a payload ring, connected together using solenoid and keys. The total weight of the design with a 23 inch diameter ring is approximately 8lb, which is significantly lower than 40lb of the current PSS. The team has fabricated and tested a proof-of-concept prototype PSS at half scale with a diameter of 12 inches. The vibrational shock on the payload at separation is also reduced by using preloaded steel mesh springs. With significant reductions in the number of parts, total manufacturing cost, and shock to payload, the proposed design is found to be very efficient compared to the current PSS design.

Problem Formulation

Needs: The payload separation systems today are too expensive and imparts 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.

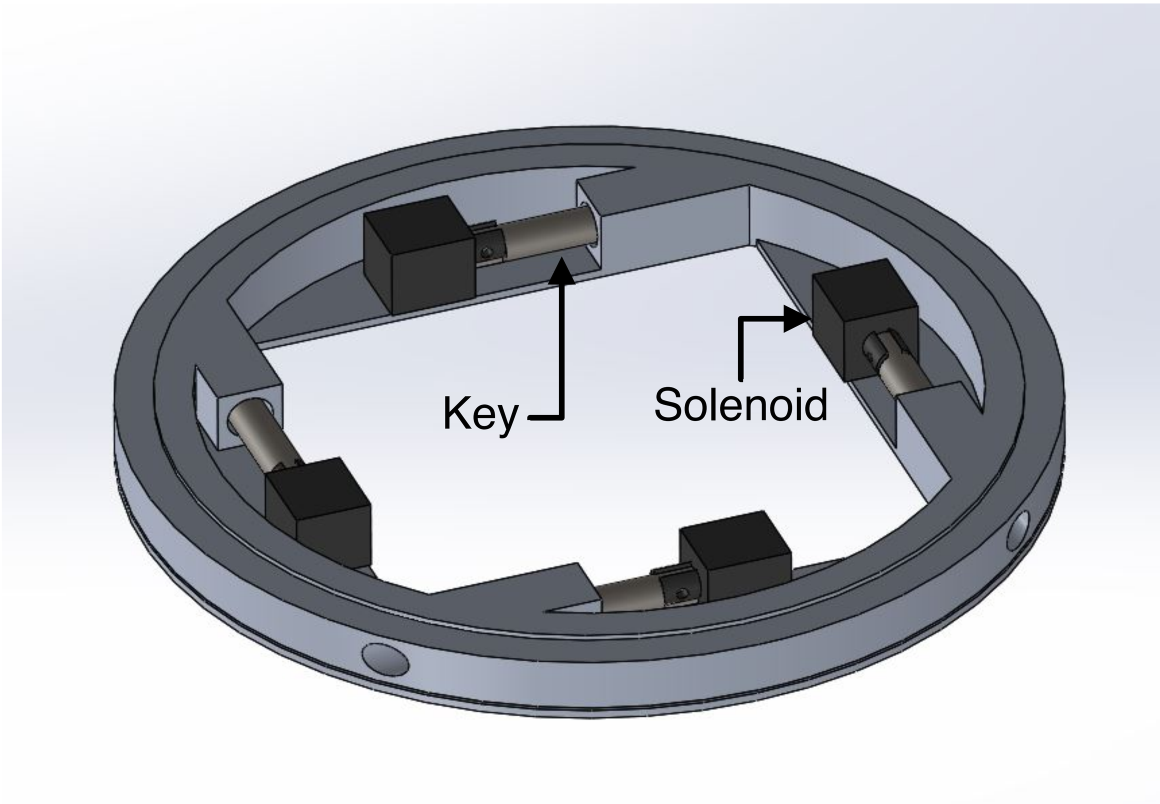
Objectives:

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	$\sigma\ \varepsilon\ \Delta$
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

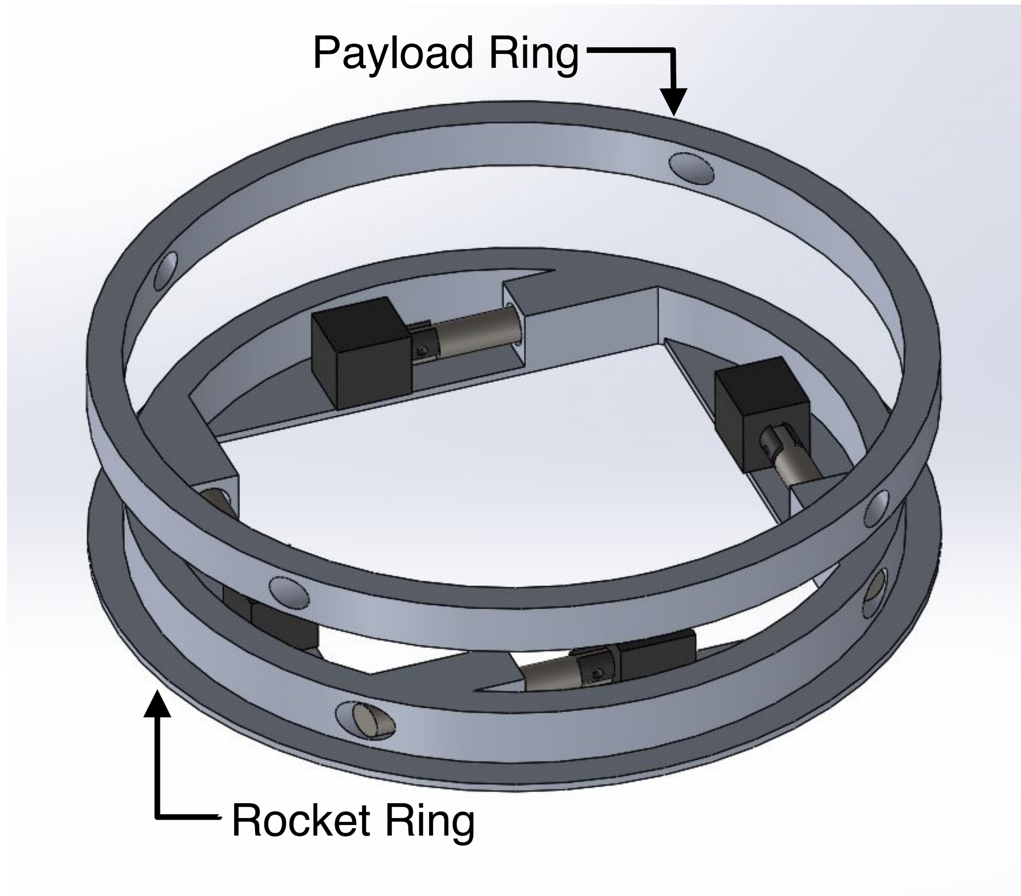
Engineering Design

Proposed Design

Fully Engaged System

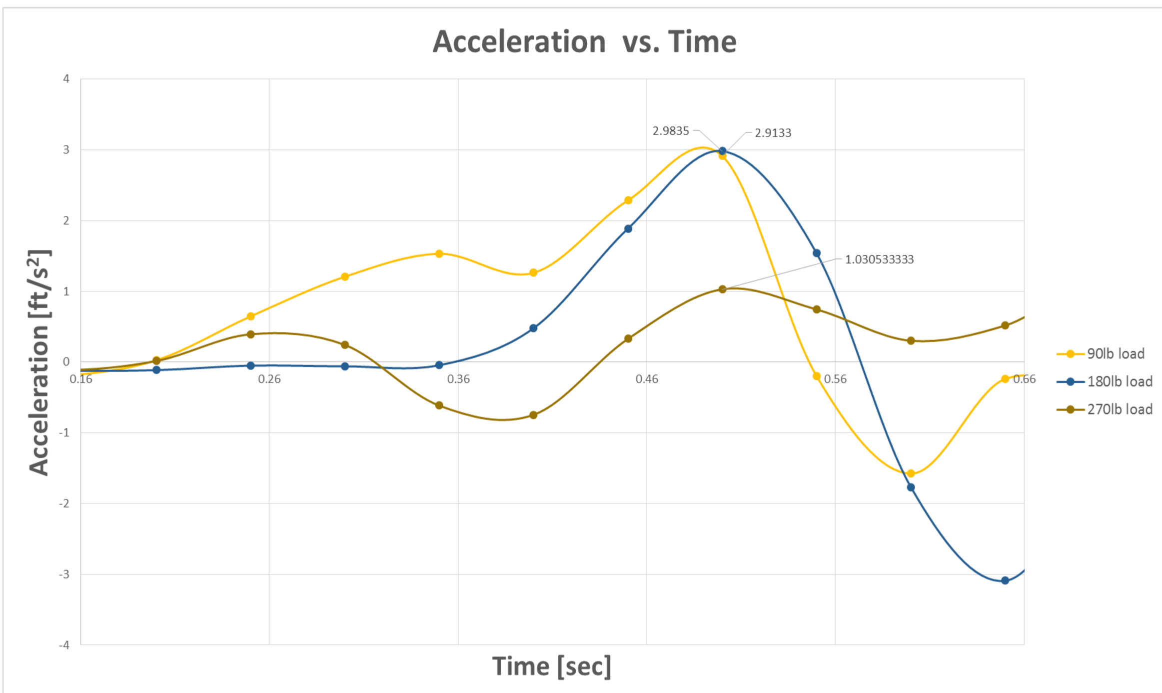


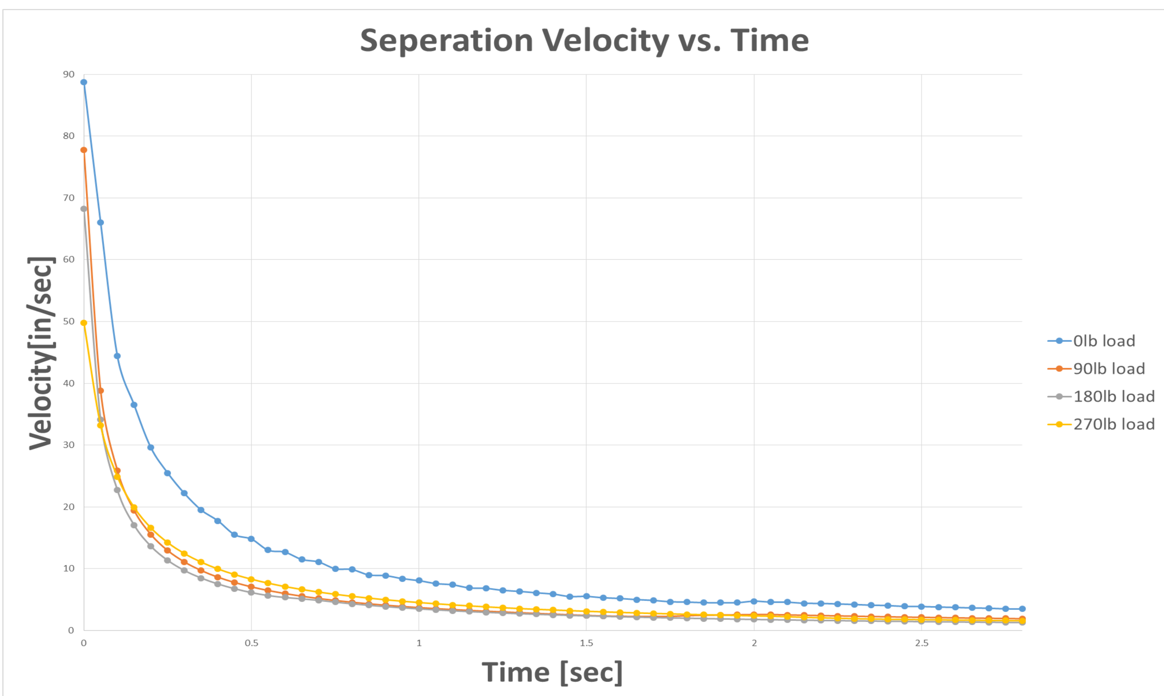
Disengaged System



Testing and Results

The payload separation system was tested with no load, 90 lbs, 180 lbs, and 270 lbs. The graphs represent the displacement of the 8 springs verse time and the velocity at separation verse time.





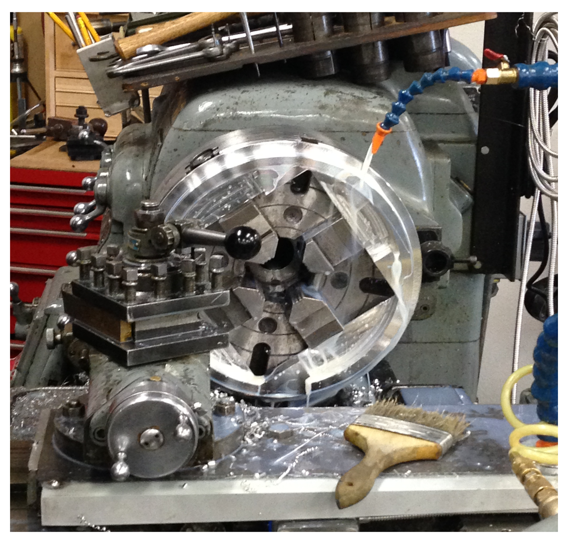
Prototype Fabrication

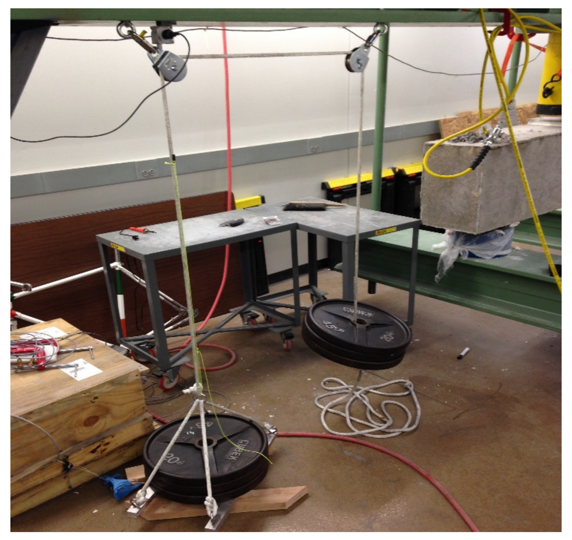
Manufacturing Process

1. Cut stock into 8 squares 12" X 12"
2. HAAS CNC: G-code generated in CAMWorks
   - Milled interior of rocket and payload ring
3. Outer diameter of both payload and rocket ring were turned on the lathe
4. Manual Mill
   - Drilled holes for keys (dia 0.5")
   - Recesses in rocket ring lip and payload ring for springs
5. Mounted solenoids, pinned keys to plungers, wired system

Testing Process

1. Create pulley system to emulate zero gravity environment, wire potentiometer to record displacement
2. Load both sides of pulley system with 150lbs to simulate 300lbs (mas payload) and engage keys
3. Power the solenoids to disengage keys, allow for spring relaxation and separate payload





Cost Analysis

Material	Quantity	Unit Cost
7075 Al Plate	1	$654.24
K & M Machine	N/A	$65.00
Steel Rod 2'	1	$14.95
Solenoid	4	$28.00
Springs	8	$0.75
Testing Equipment	N/A	$266.59
Total		**$1,118.78**

*Note: Saab PSS used currently at Orbital cost > $500,000

Conclusions

Through the course of the school year the team was able to successfully design, manufacture, and test an improved payload separation system with 99% reliability that met all client needs. Manufacturing costs and time, number of parts, and weight of the overall system were significantly reduced. The current payload separation system used by Orbital separates at 2.1 ft/s while the improved system separates at 0.55 ft/s. With a smaller separation velocity the system imparts little to no shock to the payload, reducing potential for damage. The improved payload separation system was found to be able to withstand 4.2 g's in the longitudinal direction and 1.5 g's in the lateral direction with a factor of safety of 5.8. Overall, all needs and goals were achieved and the system was a success.

References

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>.

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

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

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

Acknowledgments

Orbital Sciences Corp.
Advisers: Matthew Johns, Steven Hengl

KINETIC STRUCTURES
An Industry Leader In Wire Mesh Products

Kinetic Structures

President: Harry Artenian

K & M Machine Tool Inc.

Earle M. Jorgensen Metal
Steve Warner

NORTHERN ARIZONA UNIVERSITY
College of Engineering, Forestry & Natural Sciences

Professors to thank:
Dr. Srinivas Kosaraju, Dr. Robin Tuchscherer

Machine Shop Staff:
Tom Cothrun, Emerson Jones, Chris Bennett, Nick Jurik