Payload Separation System

Engineering Analysis

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

November 19, 2013

Overview

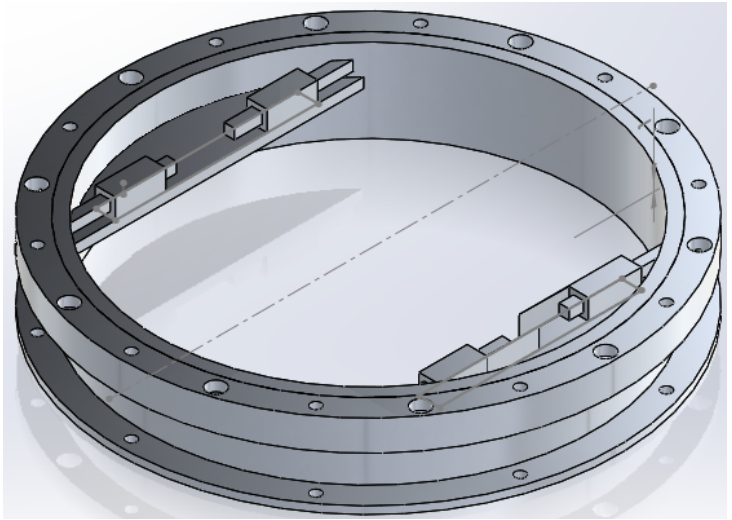
- Payload Separation System
- Top Down View
- Side View
- Dimensions of Key and Payload Ring
- Failure Due to Shear Forces on Keys
- Kick off Jets
- Servo Motor Assembly
- Improvements
- Gantt Chart
- Conclusion
- References

Payload Separation System

- 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

Isometric View:

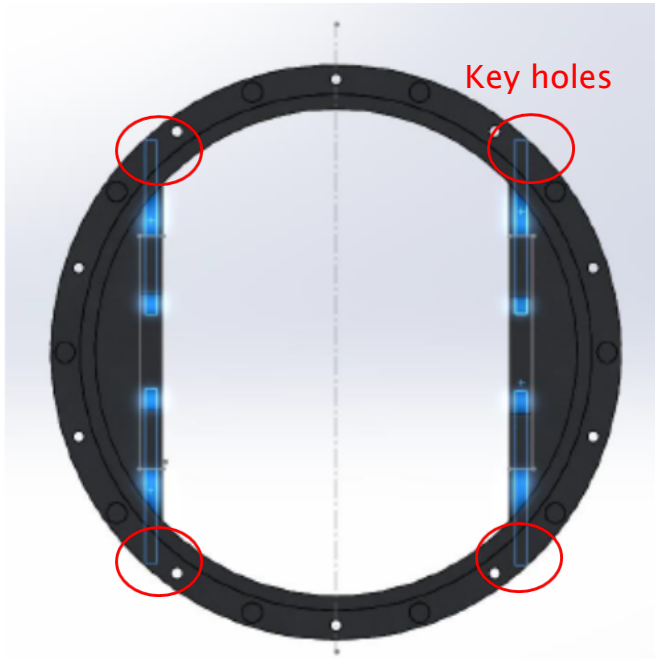


Separated Payload Side View:

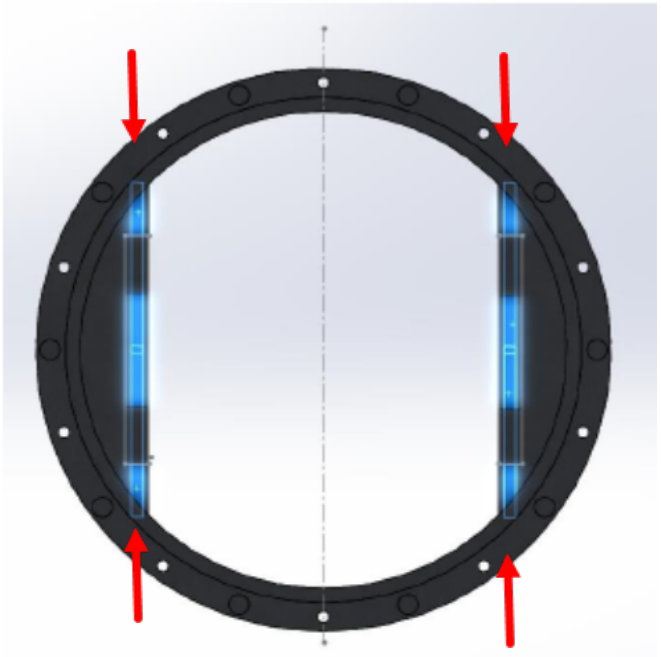
Jason McCall

Top Down View

Fully Engaged



After Separation



Alen Younan

Side View

Final Design consists of four keys that lock the payload to the rocket.

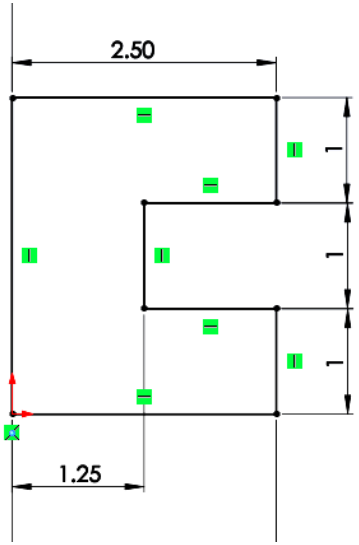
A servo motor for each key will rotate pulling each key inward simultaneously

Once the keys reach their final resting position the payload will be released from the rocket.

Alen Younan

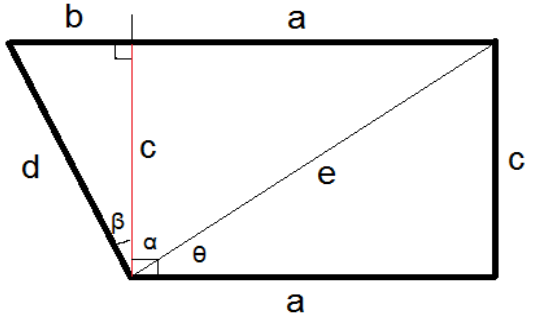
Dimensions of Key and Payload Ring

Section cut



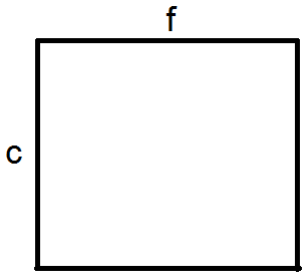
t [m] (ring wall thickness)
0.0125
r [m] (ring lip thickness)
0.025

Top



e [m]	a [m]	θ [rads]	θ [Deg]	α [Deg]	β [Deg]
0.0125	0.0075	0.927	53.1	36.8	50.1
d [m]	β [rad]	b [m]			
0.0156	0.874	0.011			

Front

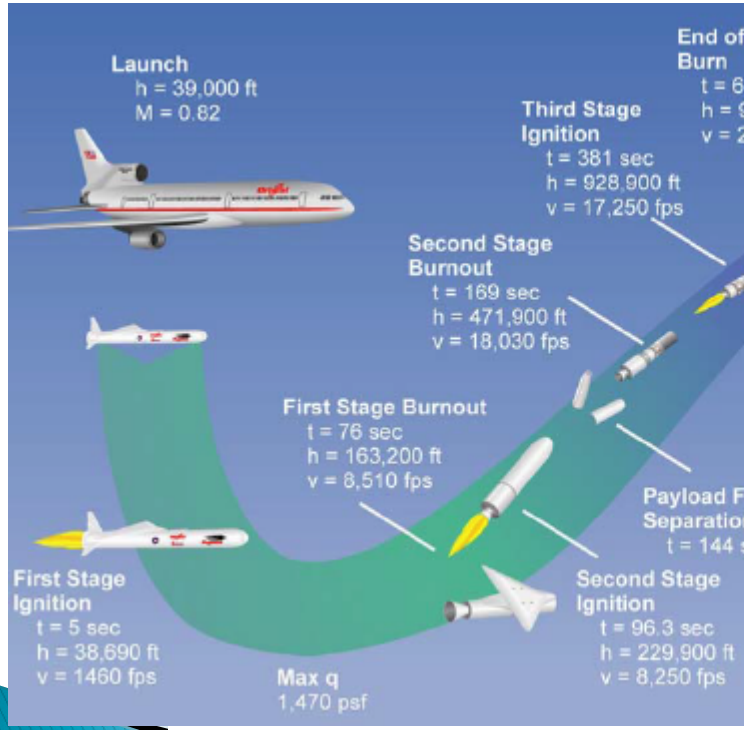


c [m] (thickness)	f [m] (width)
0.01	0.0156

Kate Prentice

Failure Due to Shear Forces on Keys

- Note: Q = 0 once left earths atmosphere
- $Q\downarrow max = 1/2\ \rho V\uparrow 2$
  - ρ= local air density [m^3/kg]
  - V= vehicles velocity [m/s]



http://www.orbital.com/

Q_{max} [N/m^2]	Q_{max} per Key [N/m^2]
70383.6	17595.9
Top Surface Area of Key [m^2]	**Cross Sectional Area [m^2]**
0.000134867	0.000156
Force due to Q_{max} [N]	**Force due to $M_{payload}$ [N]**
2.37	6169.21
Shear Modulus [Pa]	**Shear Modulus Failure [Pa]**
5.93×10^7	3.31×10^8
Factor of Safety	
5.58	

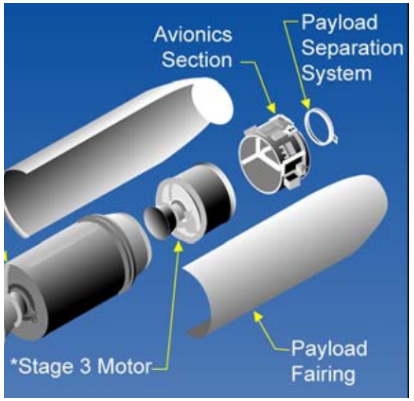
The 7075 Aluminum keys will not fail due to shear force caused by the first stage ignition process.

Kate Prentice

Kick-Off Jets

Compressed CO_2 will propel the payload away from the rocket.

Assume:
- Payload + Payload ring = 600lb
- PSS + Avionics section + stage 3 motor = 600lb
  - (Note: Total mass = 1200lb,
    Acceleration of 1 section = 50% of Net acceleration)



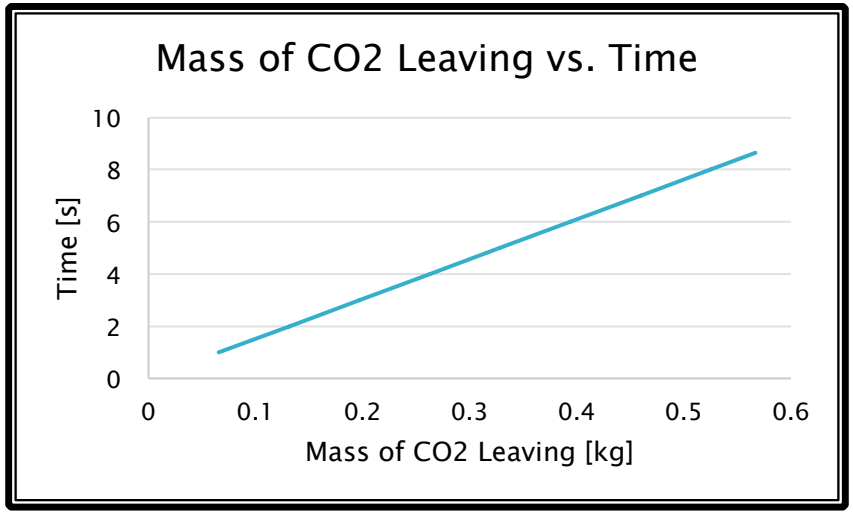
http://www.orbital.com/

20 oz CO_2 Tank
- 20 oz = 0.5667 kg
- Height 27 cm
- Diameter 8 cm

http://www.walmart.com/

Release Time
- 8.63 s

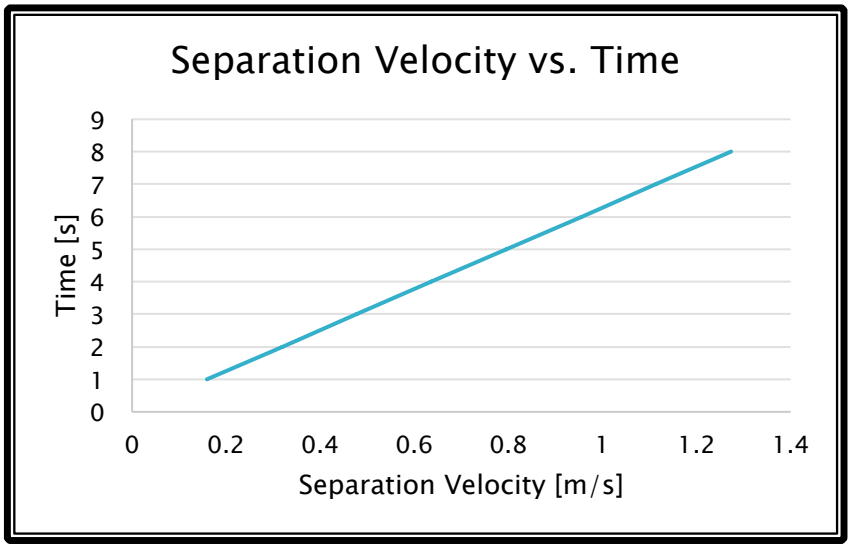
Mass flow rate
- 0.0657 kg/s

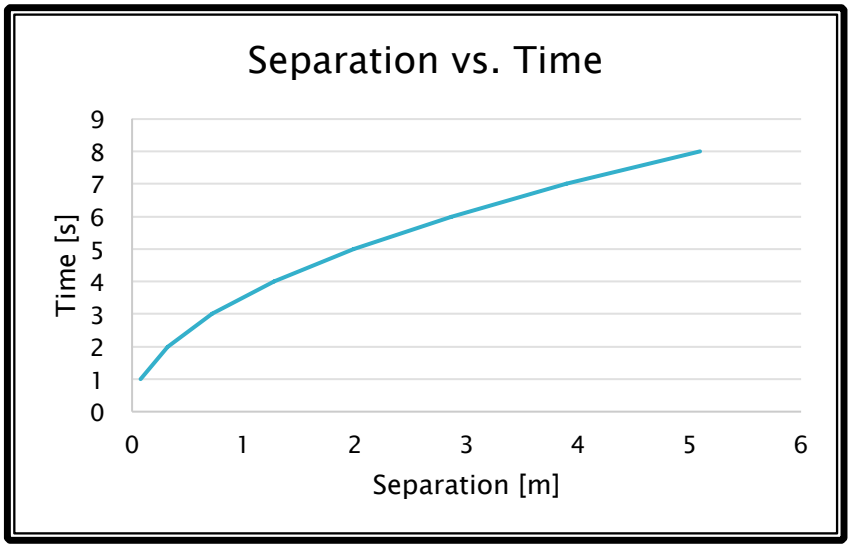


Mark Majkrzak

Kick-Off Jets Continued…

Density CO_2 [kg/m^3]	
1.98	
Pressure [psi]	**Pressure [Pa]**
1000	6894757.29
Nozzle Dia. [m]	**Nozzle A [m^2]**
0.004	1.26 E-05
Velocity of System [m/s]	**Velocity Exit [m/s]**
24550	2639.02
Mass Flow Rate [kg/s]	**Thrust [N]**
0.0657	173.3
Mass of Total System [lb]	**Mass of Total System [kg]**
1200	544.3
Net Acceleration [m/s^2]	**Accel. of Each System [m/s^2]**
0.318	0.159

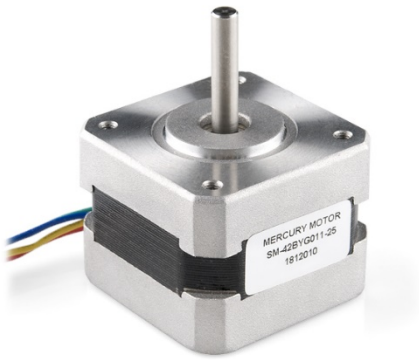




Mark Majkrzak

Servo Motor Assembly

- Horizontal forces found to be negligible, due to the fact that there will be constant velocity and little gravitational force.
- Therefore the most reliable stepper motor will be chosen for this system.



https://www.sparkfun.com/products/9238

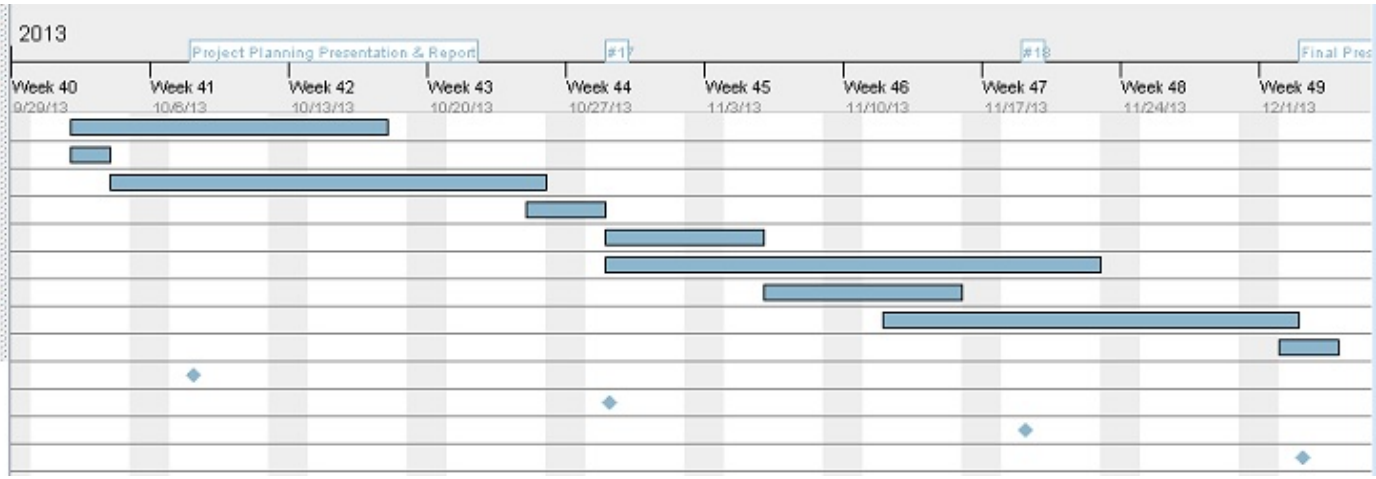
Improvements

- Make payload ring flush with rocket ring
  - Keys will only have one shear direction

- Back ups
  - Existing PSS
    - Double up current PSS
    - Marmon Clamp
    - Exploding Bolt

Gantt Chart

Name	Begin date	End date
Research	10/2/13	10/17/13
Brainstorming	10/2/13	10/3/13
Design Sketches	10/4/13	10/25/13
Decision Matrix	10/25/13	10/28/13
CAD Drawings	10/29/13	11/5/13
Engineering Analysis	10/29/13	11/22/13
Prototype	11/6/13	11/15/13
Final Design	11/12/13	12/2/13
Bill of Materials	12/2/13	12/4/13



Ben Dirgo

Conclusion

- We are designing a Payload Separation System for Orbital Sciences and Mary Rogers is our contact.
- The final design has been drawn in SolidWorks.
- The team analyzed the payload separation system and confirmed that the material chosen will not fail under the given takeoff conditions.
- Springs have been changed to kick off jets.
- The final design is tentative and will be changed as further analysis is confirmed.

References

- Baldwin, Bryan. "Orbital." *Orbital Pegasus Guide*. Orbital, n.d. Web. 7 Oct 2013. <http://www.orbital.com/NewsInfo/Publications/Pegasus_UG.pdf>.
- Anderson, John D. Fundamentals of aerodynamics. New York: McGraw-Hill, 2011. Print.
- Budynas, Richard G., J K. Nisbett, and Joseph E. Shigley. Shigley's mechanical engineering design. New York: McGraw-Hill, 2011. Print.
- Hibbeler, R. C. Mechanics of materials. Boston: Prentice Hall, 2011. Print.

Thank you for listening,

QUESTIONS?