Payload Separation System

Final Proposal

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

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Overview

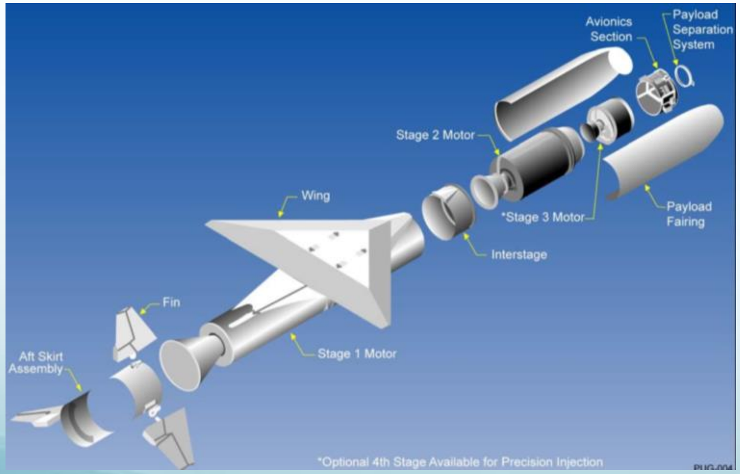
- Review
- Objectives
- Quality Function Deployment
- Concept Generation
- 5 Initial Designs
- Design Matrix
- Final Design and Components
- Analysis
  - Solenoids
  - Shear on Key
  - Kick off Springs
- Costs
- Gantt Chart
  - Fall 2013
  - Spring 2014
- Conclusion
- References

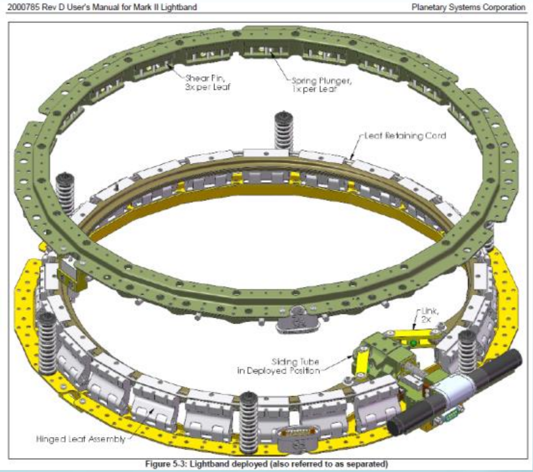
Review

- 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

Need and Goals 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.
- Payload Separation System Today:





http://www.orbital.com

http://www.planetarysystemscorp.com

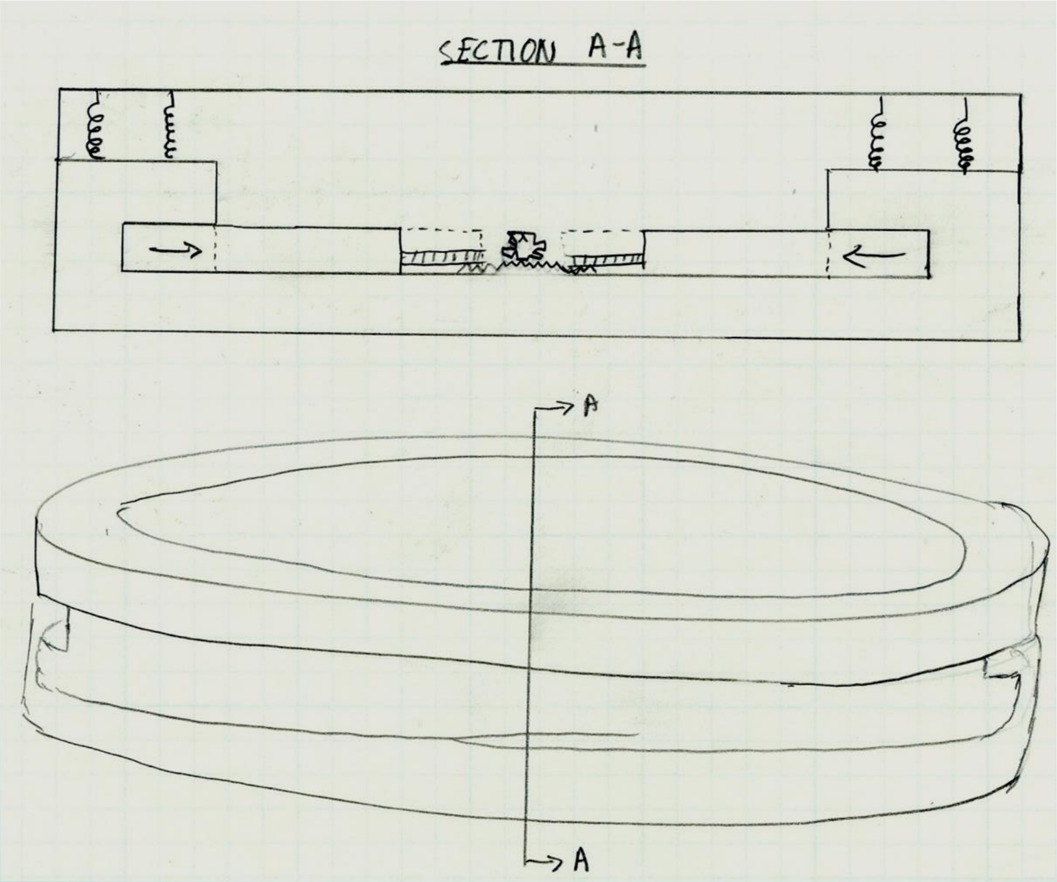
Objectives

Objective	Measurement Basis	Unit
Separate Payload	Number of successful releases	n/a
No Debris	Fragmented pieces after separation	n/a
Minimal Shock	Impact force	N
Structural Capabilities	Material properties	$\sigma\ \varepsilon\ \Delta$
No Re-contact	Push away reliably	n/a
Light weight	Light weight materials added to rocket	kg
Fit Pegasus dia.	23” or 38”	in
Ease of Assembly	No extra man hours to assemble	hr
Special Tools to Assemble	No special tool to assemble	n/a
Mass added to payload	Payload ring weight	kg

Quality Function Deployment

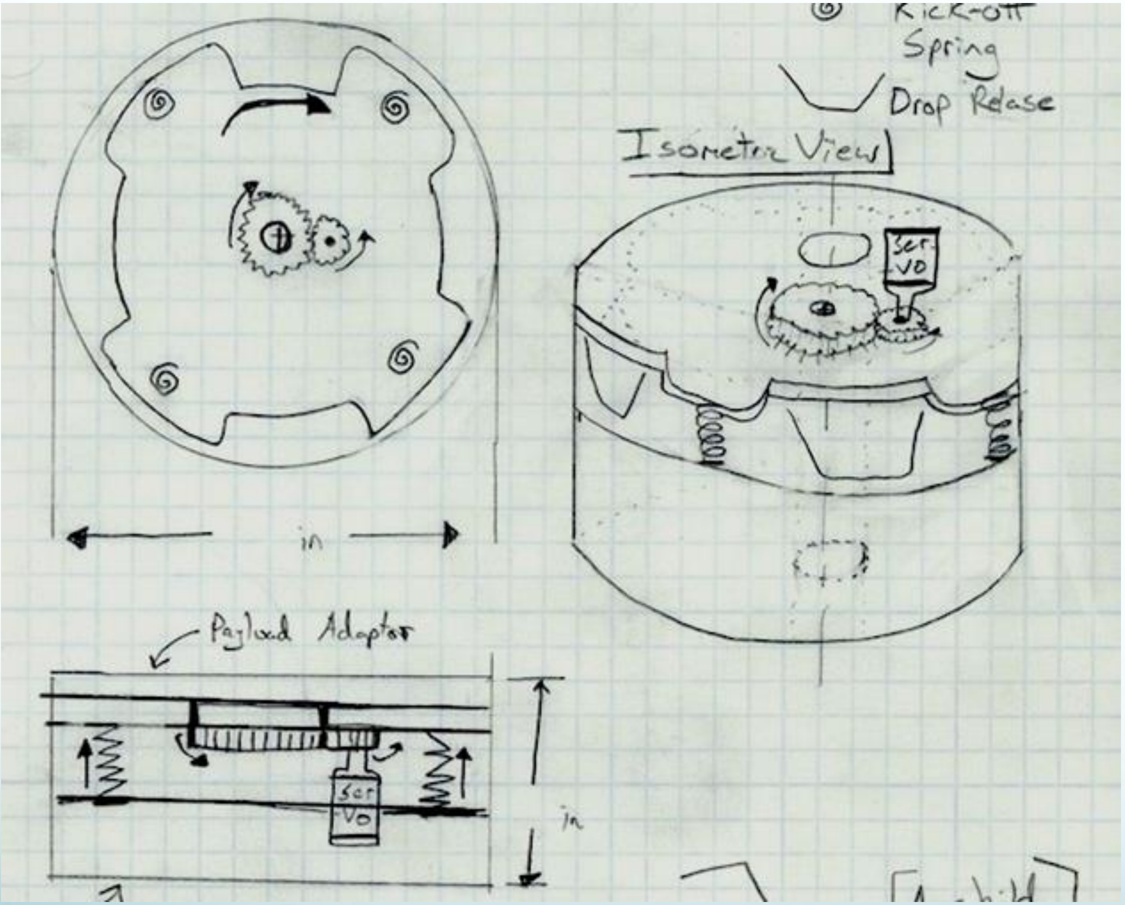
			Engineering Requirements			
Scale 1, 3, 6, 9 (best)	Ojectives	Customer Weights	1. Minimum Tolerances	2. Cost	3. Part Count	4. Lead Time
1.	Separate Payload	9	9	9	3	
2.	No Debris	9			6	
3.	Minimal Shock	6		9	1	
4.	Structural Capabilities	9	6	6		
5.	No Re-contact	9		3		
6.	Light Weight	6		6	9	1
7.	Fit Pegasus Demensional Constraints	9	9	1	3	3
8.	Ease of Assembly	3	9	6	9	1
9.	Special Tools to Assemble	3	9	9		9
10.	Mass Added to Payload	9			1	
		Raw Score	**270**	**306**	204	63
		Relative Weight [%]	**32.03%**	**36.30%**	24.20%	7.47%
		Unit of Measure	**+/- mm**	**$**	ul*	min
		*ul = unitless				

Interlock Concept



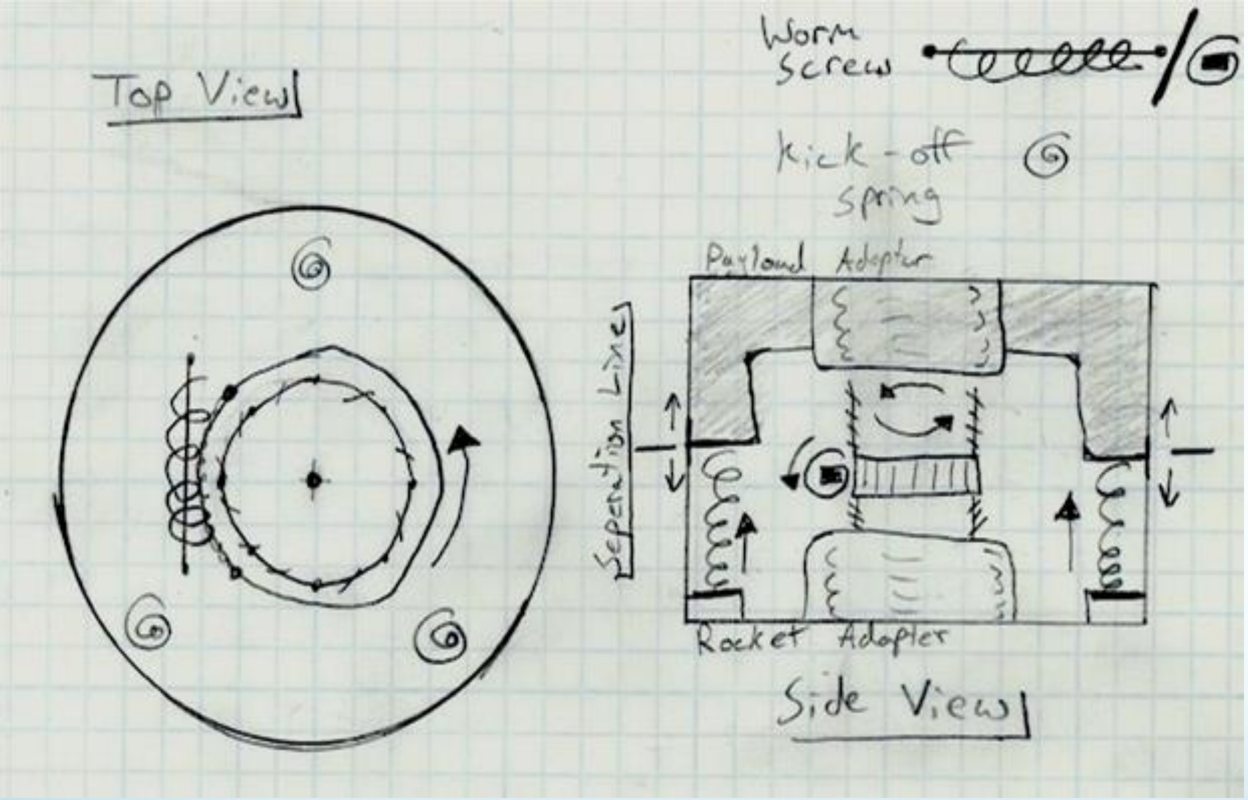
- Servo driven interlock panels
- Spring Loaded
- Relatively light weight

Blender Concept



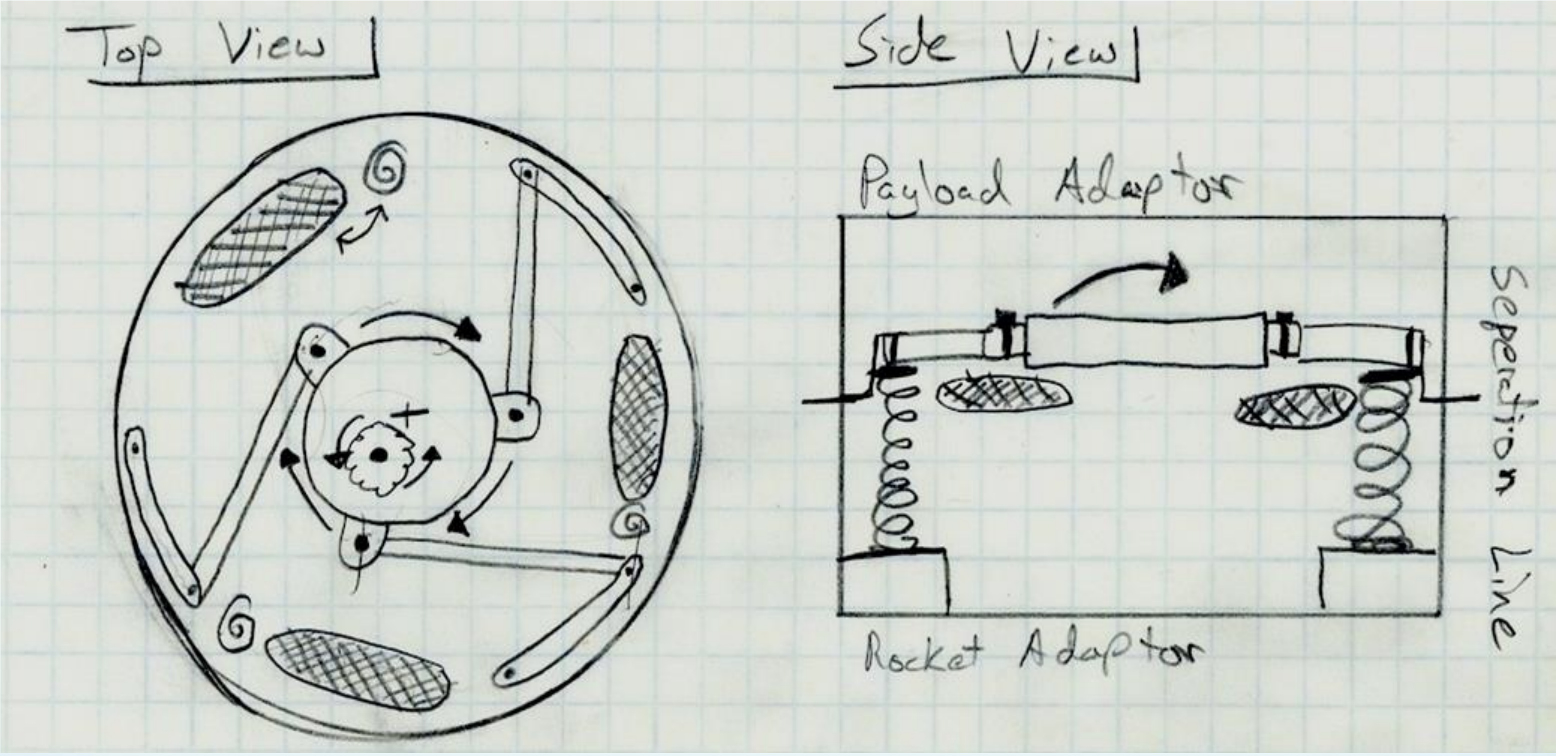
- Four toothed gear rotates via servo motor
- Once gears are in unlock position the springs are free to separate payload

Worm Concept



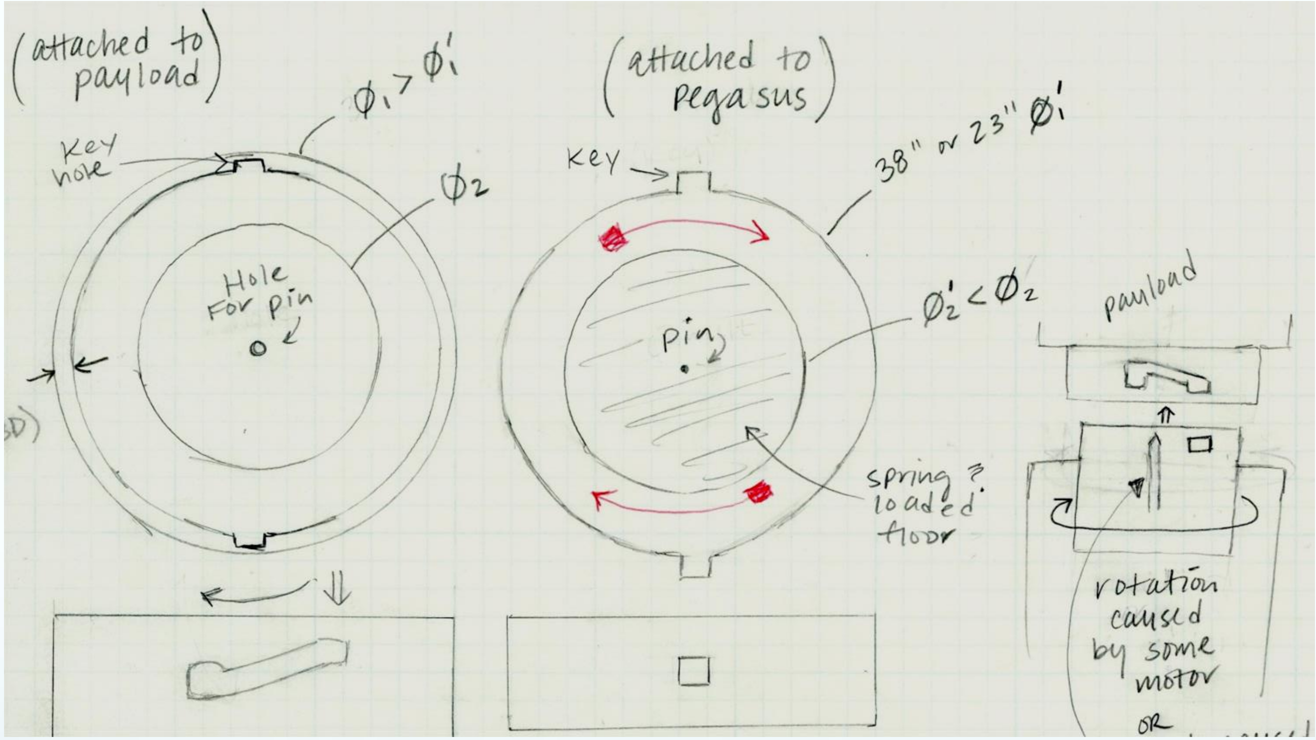
- Through bolt holds payload to rocket
- Worm bolt rotates until payload is free

Tangent Spoke Concept



- Servo motor turns center shaft
- Spokes travel along slots until the plate has rotated in position for the springs to separate payload

BNC Concept



- Motor rotates inner cylinder releasing larger cylinder attached to the payload
- Preloaded springs under floor push away the payload

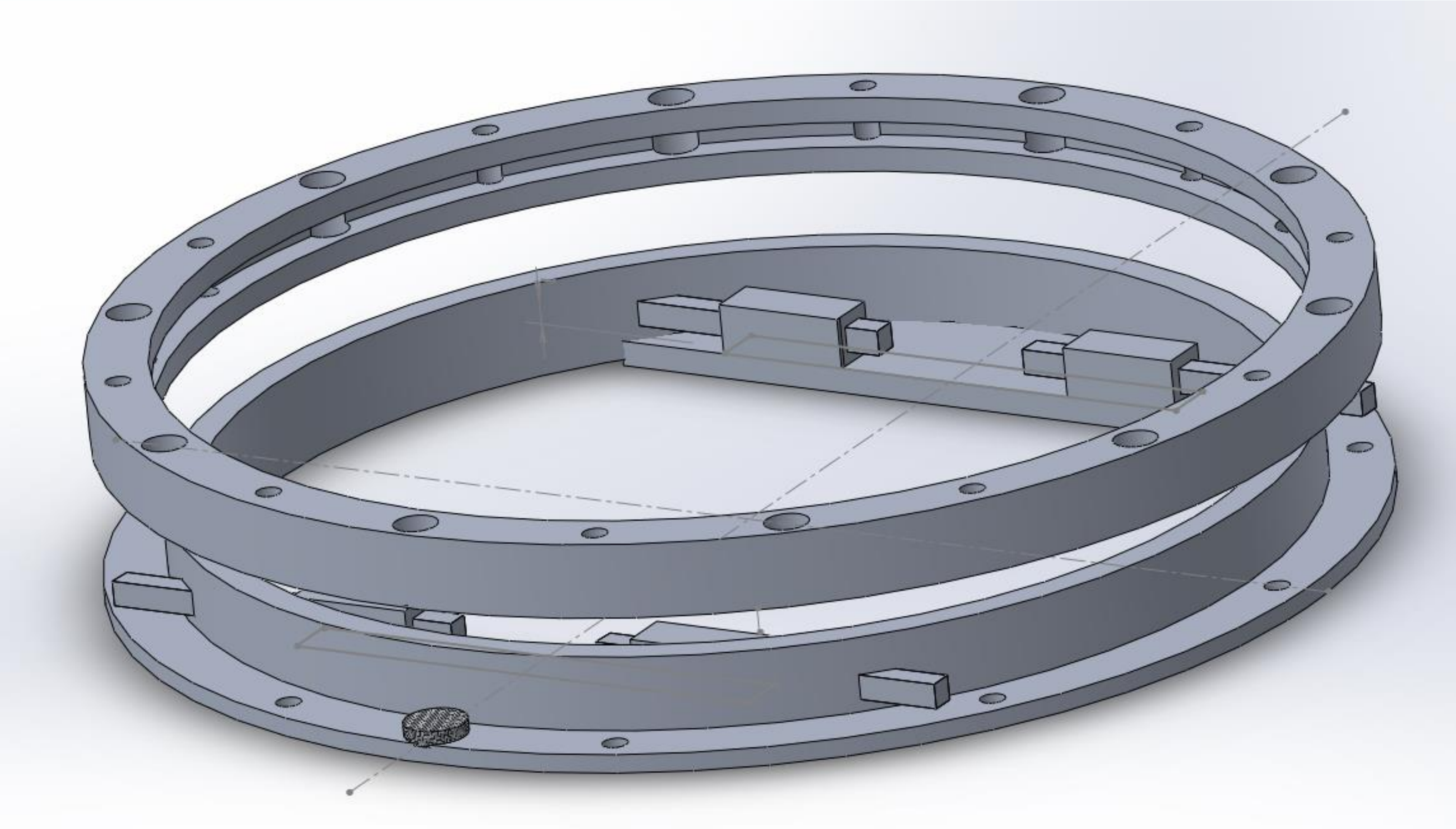
Design Matrix

scale 1, 3, 6, 9 Best	Weight	Interlock Solution 1	Blender Solution 2	The Worm Solution 3	Tangent Spoke Solution 4	BNC Solution 5
Part Count	6	6	9	3	1	9
Minimal Shock	9	3	3	6	1	1
Cost	6	6	3	1	3	6
Manufacturability	6	9	9	1	1	9
Debris	9	9	9	6	9	9
Separate Payload	9	9	3	9	6	9
Weight	3	6	1	6	6	3
Ease of Assembly	3	6	9	6	3	6
Structural Capability	9	6	6	6	6	6
Mass Added to Payload	9	9	1	3	9	1
	Score	**486**	354	336	336	405

Final Design Overview

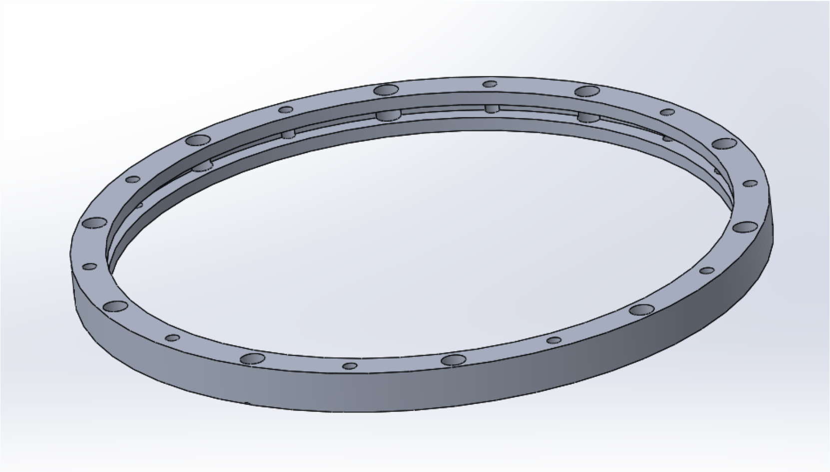
- Payload Ring (PR)
- Rocket Ring (RR)
- Keys
- Solenoids
- Metallic Mesh Kickoff Springs

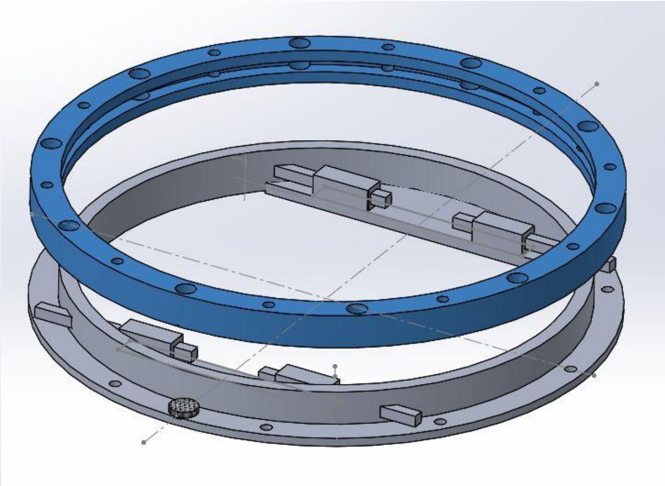
Final Design



Payload Ring

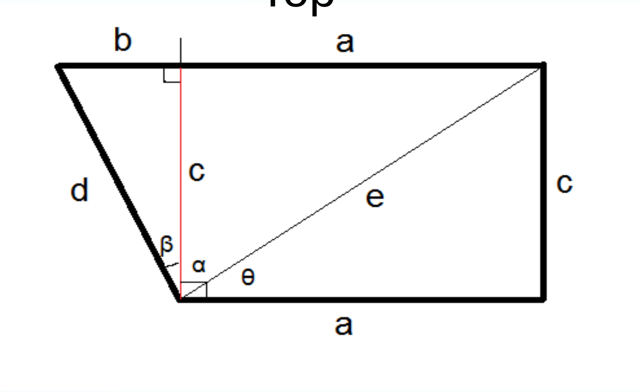
- Ring with channel on interior surface
- ~2400g = 5.29lb
- Holes drilled to reduce weight
  - Will increase manufacturing time
- Manufactured from one solid Aluminum plate





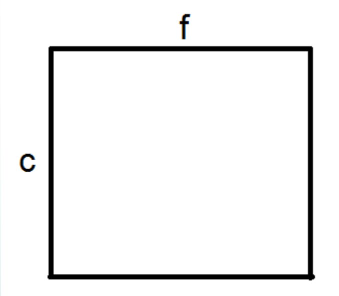
Keys

Top

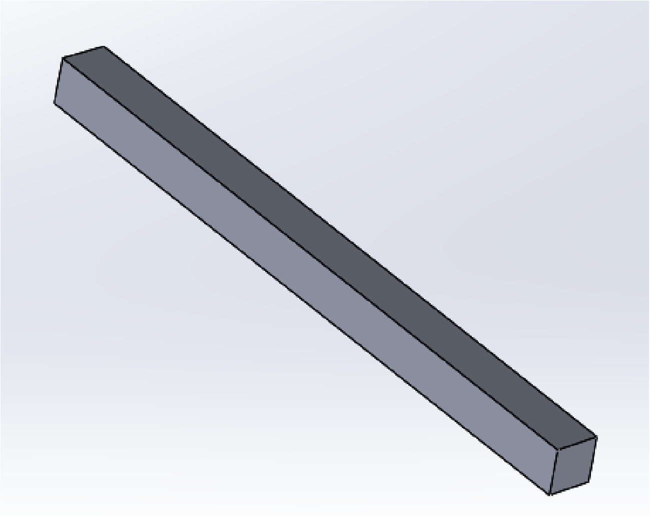


e [m]	a [m]	θ [rads]	θ [Deg]	α [Deg]	β [Deg]
0.0125	0.0075	0.927	53.1	36.8	50.1
d [m]	**β [rad]**	**b [m]**			
0.0156	0.874	0.011			

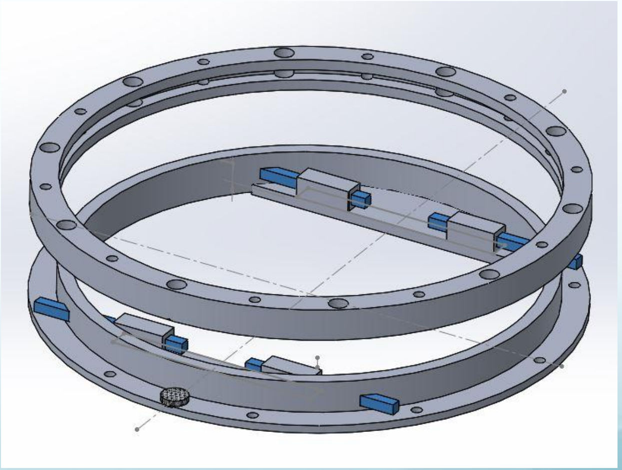
Front



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

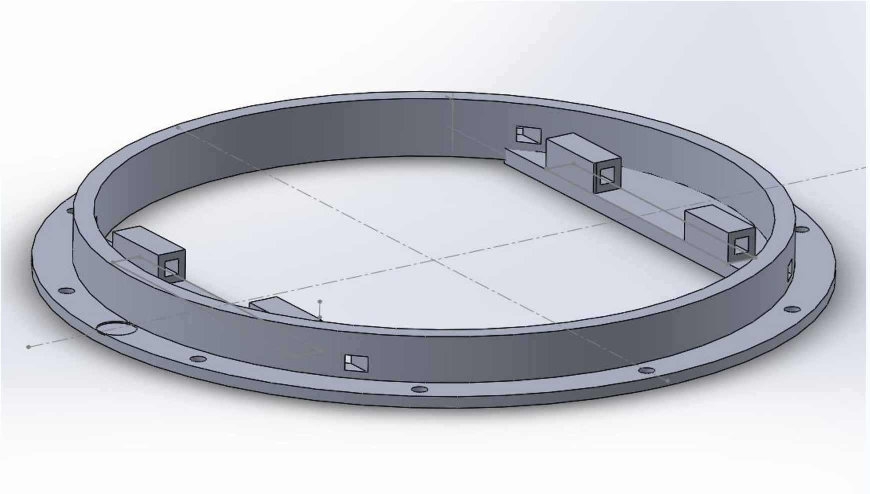


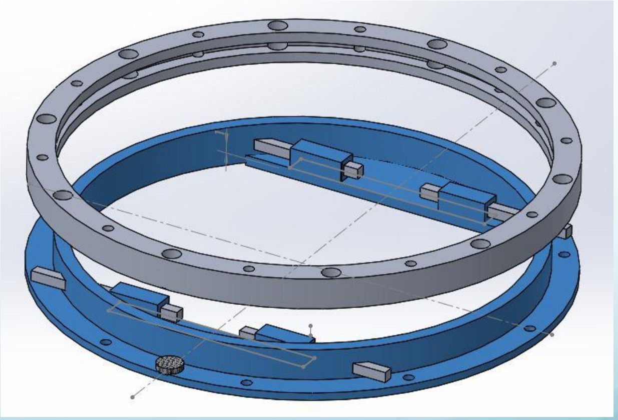
Mass = 42grams = .09lb



Rocket Ring

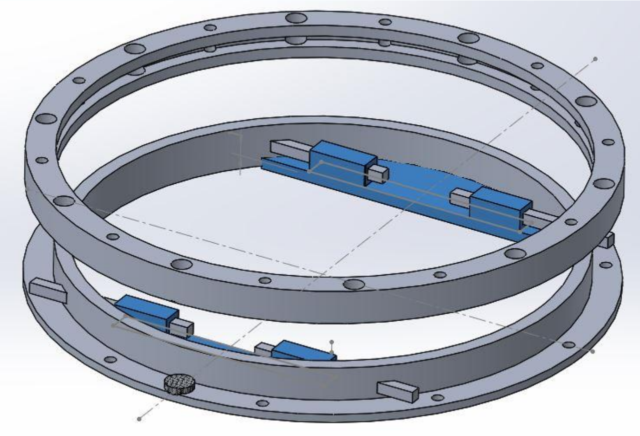
- Ring with two mounting plates
- ~3300g = 7.27lb
- Hollow housing for keys
- Cut from one solid plate of aluminum
- Recess' cut to house kickoff springs

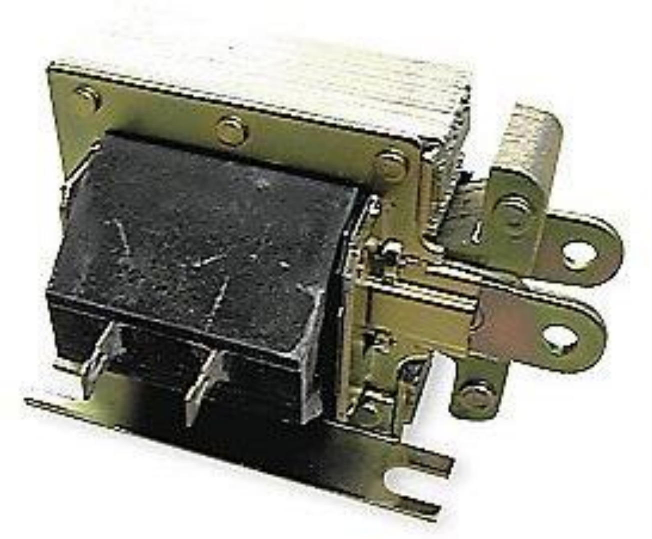




Solenoid

- Mass: 1 lb
- Pull force range: 64 – 128 oz
- Stroke range: 1/8" – 1"

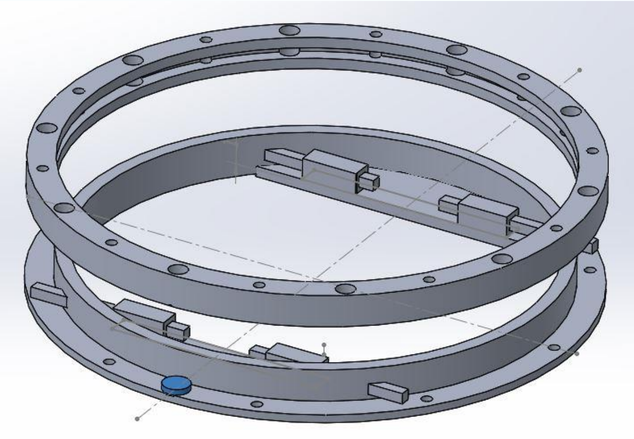




http://www.grainger.com/category/mechanical-solenoids/solenoids/electrical/ecatalog/N-8f3

Metallic Mesh Kickoff Springs

- 6 Kick off Springs placed symmetrically along the lip of the rocket ring



Bill of Materials

- For one 23’’ diameter Payload Separation System

Material	Quantity	Unit Cost
7075 Aluminum Key 3/8" x 3/8" x 24"	1	$2.52
7075 Aluminium plate 24" x 48" x 1"	1	$654.24
Solenoid	4	$32.75
Nuts/ Bolts/ Misc.	TBD	$50.00
Total Cost		**$837.76**

Man Power Cost

Team Members	Pay ($/hr)	Rocket Ring Fabrication (hr)	Payload Ring Fabrication (hr)	Key Fabrication (hr)	Assembly (hr)	
Matthew Mylan	20	10	10	2		
Mark Majkrzak	20	10	10		1	
Kate Prentice	20	10	10			
Alen Younan	20			4	1	
Ben Dirgo	20			4	2	
Jason McCall	20	10	10			
	Total Cost ($)	800	800	200	80	**1880**

Manufacturing Costs

- All manufacturing will be in building 98C machine shop
- Costs will only include:
  - Bill of materials
  - Cost of man power

Engineering Analysis Overview

- Static
- Dynamic
- Material Selection
- Machine Design

  - Solenoid Analysis
  - Shear Force on Keys
  - Metallic Mesh Kickoff Springs

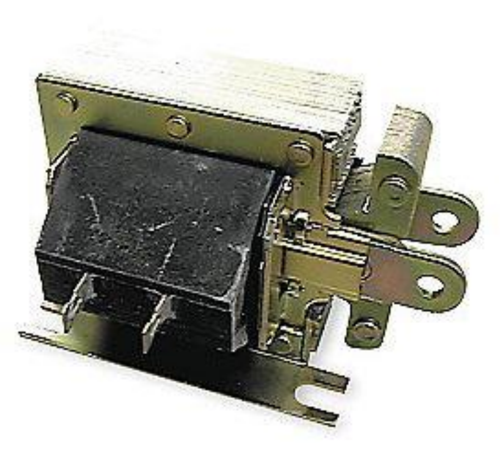
Solenoid Analysis

1 Solenoid for each Key

- 4 keys

Cost per Solenoid: $32.75

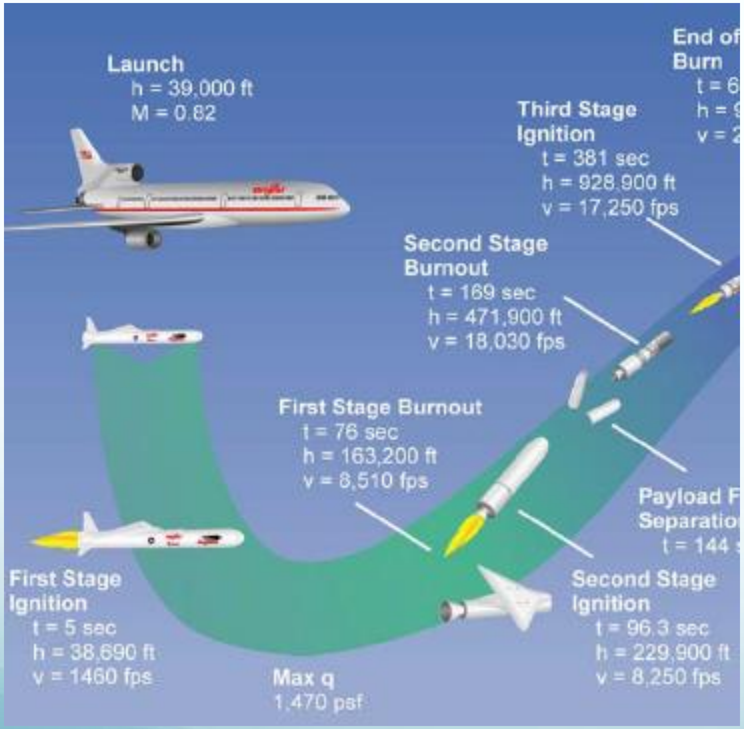
Key	Solenoid
Key Weight [lb]	**Solenoid Weight [lb]**
0.09	1
Needed Key Pull Force [oz]	**Solenoid Pull Force Range [oz]**
1.4815	64 - 128
Key retraction [in]	**Stroke Range [in]**
0.394	0.125 - 1



http://www.grainger.com/category/mechanical-solenoids/solenoids/electrical/ecatalog/N-8f3

Failure Due to Shear Forces on Keys

- Note: Q = 0 once left earths atmosphere
- $Q_{max} = \frac{1}{2}\rho V^2$
  - ρ= local air density [m³/kg]
  - V= vehicles velocity [m/s]



http://www.orbital.com/

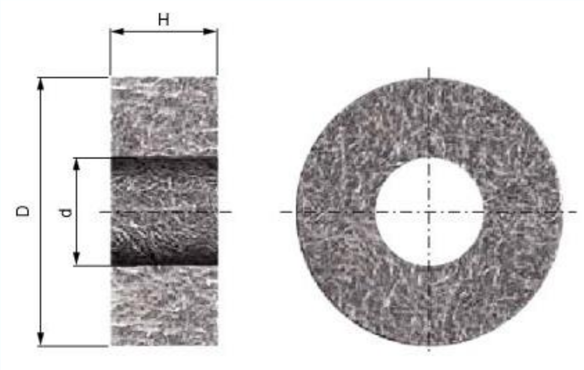
Q_{max} [N/m²] 70383.6	**Q_{max} per Key [N/m²]** 17595.9
Top Surface Area of Key [m²] 0.000134867	**Cross Sectional Area [m²]** 0.000156
Force due to Q_{max} [N] 2.37	**Force due to $M_{payload}$ [N]** 6169.21
Shear Modulus [Pa] 5.93×10^7	**Shear Modulus Failure [Pa]** 3.31×10^8
Factor of Safety 5.58	

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

Metallic Mesh Kickoff Springs

- Material: AISI 304 Stainless Steel
- Temperature range: -90°C to +400°C
- Rocket Ring Lip: 25 mm
- Max Load of damped spring: 500 N
- Max Payload (600lb): 2640 N
  - Need 6 springs
- Static Deflection: 5.5 mm
- Weight: 7 g

D [mm]
22
d [mm]
6.3
H [mm]
15.5



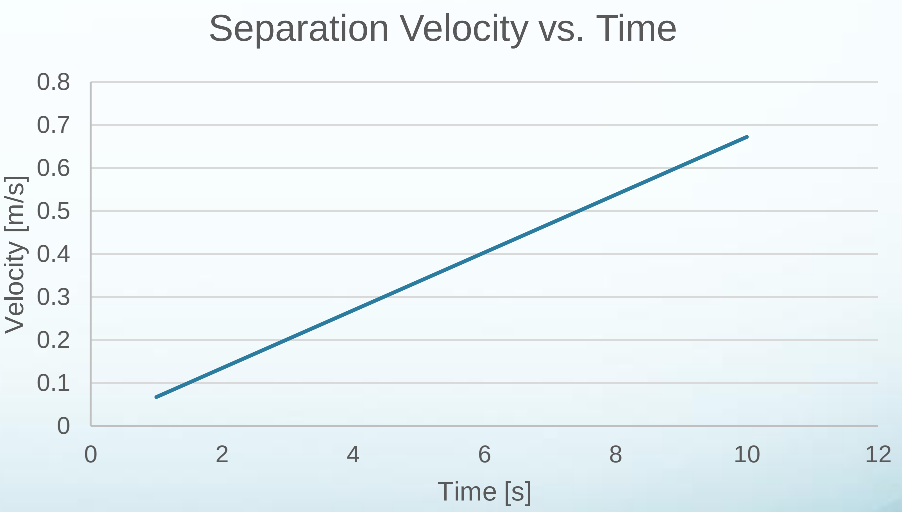
http://www.weforma.com/fileadmin/pdf/1213/Weforma-Metal-Cushions-12-13.pdf

http://www.weforma.com/fileadmin/pdf/1213/Weforma-Metal-Cushions-12-13.pdf

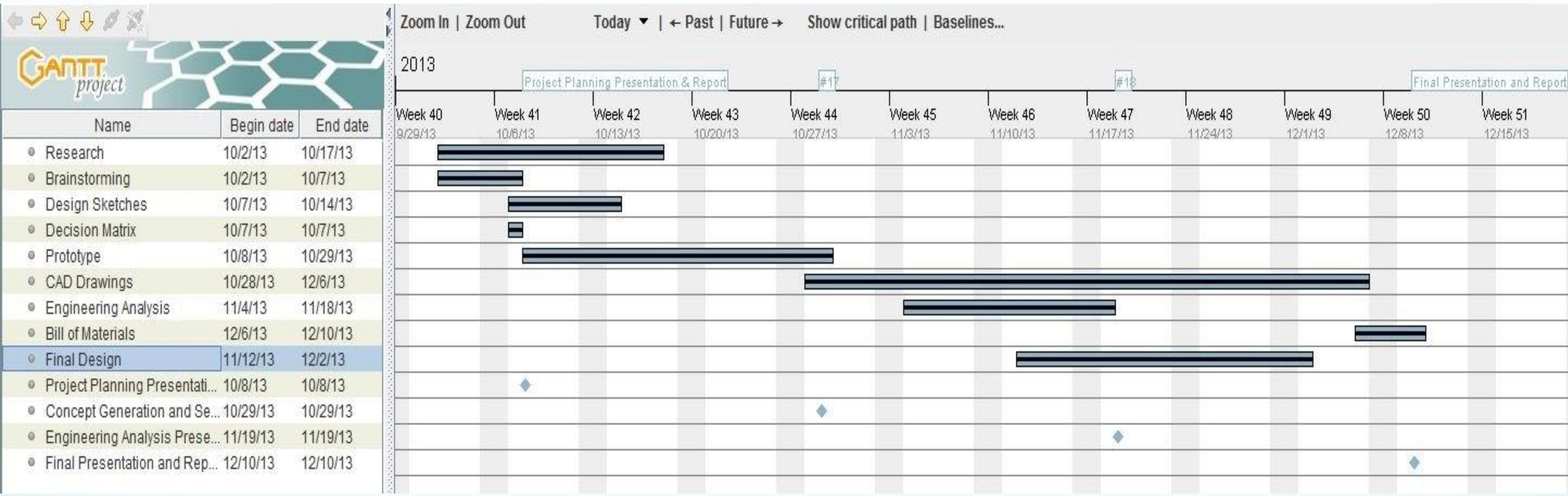
Metallic Kickoff Springs Continued

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

[Hz]	[rad/s]	m [kg]	k [N/m]
20	125.7	45.36	716283.2 4
ζ [ul]	**[Ns/m]**	**c [Ns/m]**	**x [m]**
1.91421356 2	11400.00198	21822.0384	0.0055
F [N]	**V [m/s]**	**a [m/s^2]**	
3939.56	0.69	0.067	

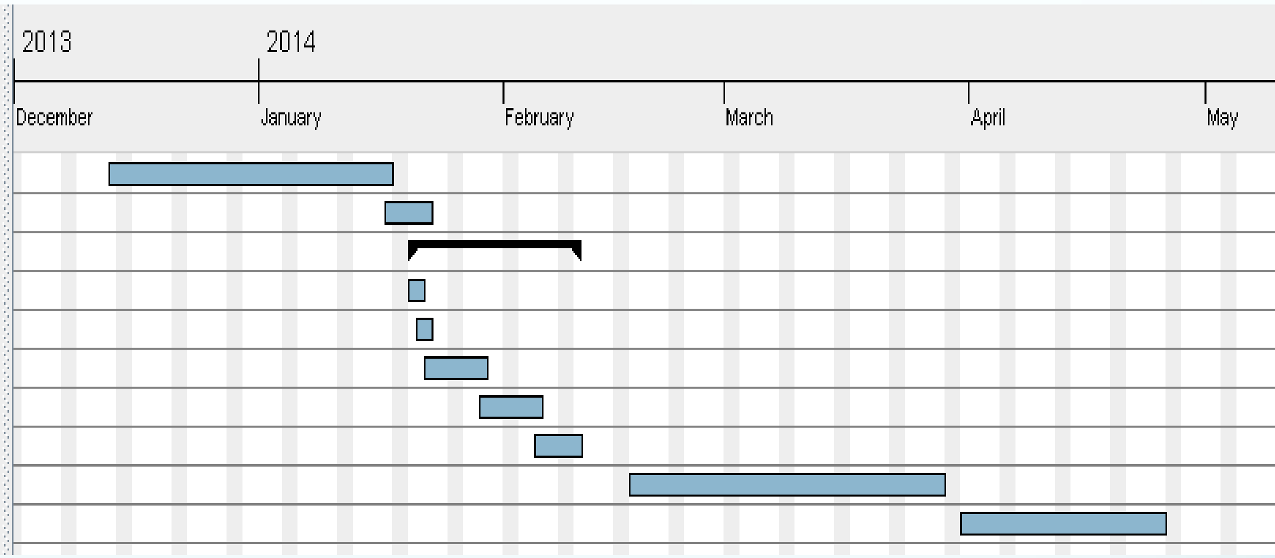


Gantt Chart: Fall 2013



Gantt Chart: Spring 2014

Name	Begin date	End date
Purchase Parts	12/13/13	1/17/14
Practice with Plywood in Machine Shop	1/17/14	1/22/14
Assembly	1/20/14	2/10/14
Measure once	1/20/14	1/21/14
Measure twice	1/21/14	1/22/14
Cut out the two rings	1/22/14	1/29/14
Mill out housings and channel	1/29/14	2/5/14
Cut out keys	2/5/14	2/10/14
Testing	2/17/14	3/29/14
Possible Alterations	3/31/14	4/25/14



Conclusion

- Reviewed the problem, need, and goal statement as well as the client
- Covered the Quality Function Deployment and why the objectives were important
- Reviewed Concept Generation and 5 initial design concepts
- Finalized the design using a design matrix
- Used SolidWorks models to draw and effectively communicate the final Design
- Initial separation caused by retracting the four keys using four Solenoids and metallic mesh kickoff springs to completely separate
- Performed an analysis on the keys, solenoids, and metallic mesh
- Calculated a recorded manufacturing costs, a bill of materials, and man power cost
- Explained the past, present, and future plans using Gantt Charts

References

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Thank you for listening,

QUESTIONS?