Payload Separation System

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Team 11

Concept Generation and Selection

Document

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Introduction

Orbital Sciences Corporation, located in Phoenix Arizona, is interested in a less complicated and less expensive payload separation system for their Pegasus launch vehicle. The team's contact with Orbital is Mary Rogers, the Electronic Packaging and Actuators Manager. The goal is to design a low shock and low profile payload adapter system that is light weight. Due to the amount of money that it takes to launch a payload into space, it is extremely important that the payload separation system is reliable and releases the payload the first time. In addition, the current payload separation systems are too expensive and do not account for the vibrational shock of the separation, causing damage to the payloads. The need of this project is to redesign a payload separation system that is less expensive, and imparts as little shock to the payload as possible.

On October 25, 2013, the team met with Mary and decided to change the Quality Function Deployment objectives and requirements. The change clarified the needs of the client and thus narrowing down initial design ideas that the team had been pursuing. In addition, the purpose of this report is to compare five initial design concepts using a decision matrix. The decision matrix uses assigned weights to measure which initial design best fits the needs and requirements of our client, Mary Rogers. The design that is most economical and reliable will be the foundation of the final design. Although there is a final design, the team plans to keep an open mind and make necessary changes when available.

Updated Quality Function Deployment

The Quality Function Deployment, also known as the QFD, has been modified over the past few weeks. Most of these changes were made after the team met face to face with the client, Mary, gaining valuable insight. The layout of the QFD, however, is exactly the same. The left hand side contains the 11 objectives and a customer weight of 1, 3, 6, or 9 was assigned to each of the objectives. Most of the weights are 9's because the client made it evident that the highly weighted goals are a must to have a successful payload separation system. These new objectives include:

- Separate Payload - The main goal is to separate the payload at a predetermined altitude.
- Structural Capabilities - Material properties built as per the specifications will meet the loading and force factors involved when in transit
- No Re-Contact - This will occur after the rocket has been separated from the payload. The payload cannot make contact with the delivery vehicle after separation.
- Fit Pegasus Dimensional Constraints - We are designing our system to fit the Pegasus rocket, therefore, it will need to meet Pegasus specifications.
- Ease of Assembly - This objective branched out from simplicity. Although this was not one of the major requirements made by our client, it would still be a benefit to reach this objective.
- Special Tools to Assemble - This objective branched out from simplicity as well. It is much like the previous objective where it is not one of the major areas we need to focus on.
- Mass Added to System and Payload - There are certain weight restrictions that our overall system can be as well as weight that will remain on the payload after separation.

Along the top of the QFD are four engineering requirements which was a reduction from the previous six. Part count and cost stayed the same, while minimal tolerances and lead time were added. The goal is to design a system that can withstand small scale tolerances to increase the reliability of the overall payload separation system. Lead time is the final engineering requirement. Due to limited building time plus the complexity of the project, it is necessary to make sure that the time spent ordering parts and materials is minimized. All of the objectives and requirements can be seen in the QFD in Appendix A.

Initial Design Concepts

Five initial design concepts were created and flushed out into simple sketches. Below is a paragraph explaining each design concept including advantages and disadvantages of the design.

Concept 1 is an interlocking design that is made up of a top and bottom ring. The bottom ring is actuated by a driving gear which will pull the arms inwards, releasing the payload from the rocket. At this point, springs on the outside of the ring will push the payload away causing no re-contact. See Figure 1 for a simple sketch of the design. The main advantage of this interlocking design is simplicity. The disadvantage to this design is the shock impact. Since it is an instant release, the shock value is large.

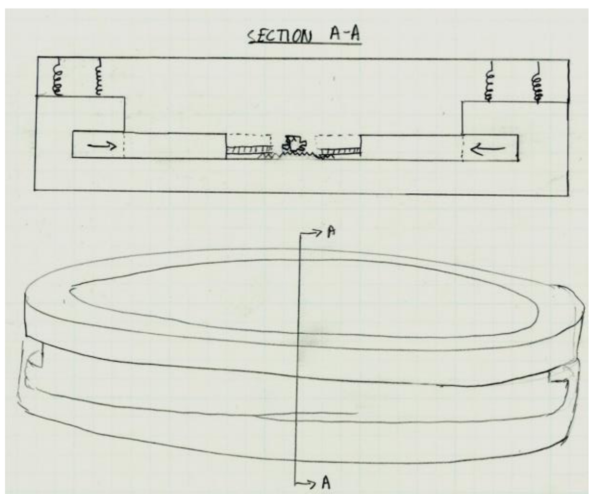

Figure 1: Concept 1, the Interlock Design

Concept 2 is a spring loaded gear system that is locked in place similar to a blender locked into the base rotor. A large gear with four teeth will rotate to a position. The gear is powered by a programmed servo motor. Once the big gear reaches the designated angle, the payload adaptor will be pushed away by kick off springs mounted underneath the four teeth. The four teeth will rotate into voids where they will not obstruct the kick off springs and ultimately cause the separation. See Figure 2 for a sketch of the design.

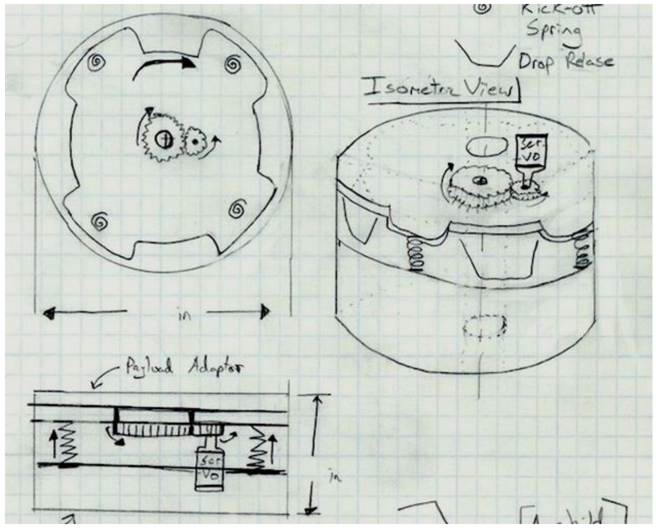

Figure 2: Concept 2, the Blender

Concept 3 is a worm screw powered by a programmed servo motor that will unthread a double sided bolt. This double sided bolt will be threaded into both female ends of the launch vehicle adaptor as well as the payload adaptor. Once separation process is initiated, the bolt will be rotated until it's free of the payload and farther into the rocket side. Once free, the payload will then be pushed away by kick off springs. See Figure 3 for a sketch of the worm design.

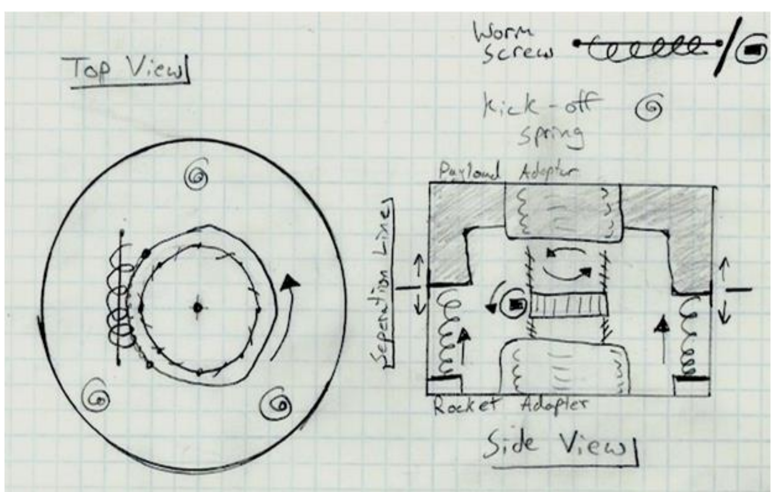

Figure 3: Concept 3, the Worm

Concept 4 uses a servo motor to turn a centered shaft. The shaft will have three spokes equally spaced apart with hinges. Similar to a bike tire, the spokes will travel along slots on the perimeter until the plate has rotated enough for the kick off springs to pop up through the holes. Once the springs are free from the plate, the payload adaptor separates from the launch vehicle. See Figure 4 for a sketch of the tangent spoke design.

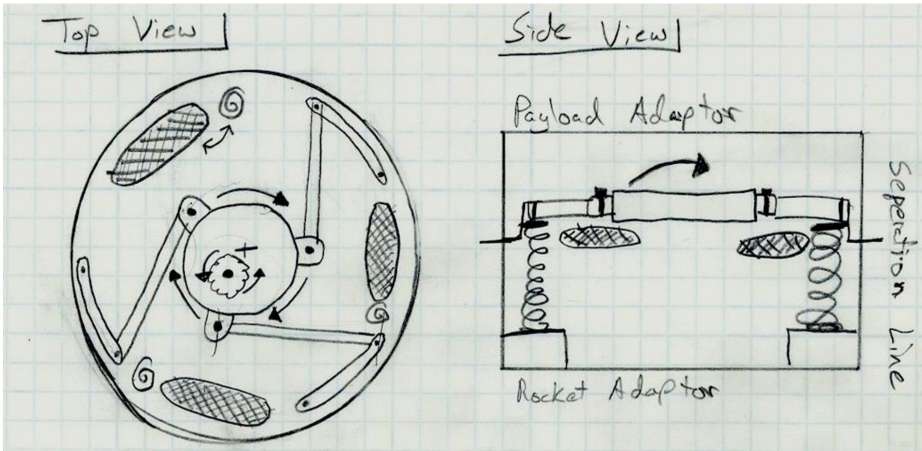

Figure 4: Concept 4, the Tangent Spoke

Concept 5 was inspired by a BNC connector that is most commonly used in lab. The simple design is made of two cylinders, a male and female end that connects via two pins. The male cylinder is connected to the payload while the female cylinder rotates inside the launch vehicle similar to a large bearing. Once a motor rotates the female end, the cylinders disconnect, and a floor that is preloaded with springs pushes away the payload to avoid re-contact. The advantage of this design is the simplicity and minimal number of parts. Although simple, the cylinders are heavy and can cause weight problems further along in the design process. See Figure 5 for a sketch of the BNC design idea.

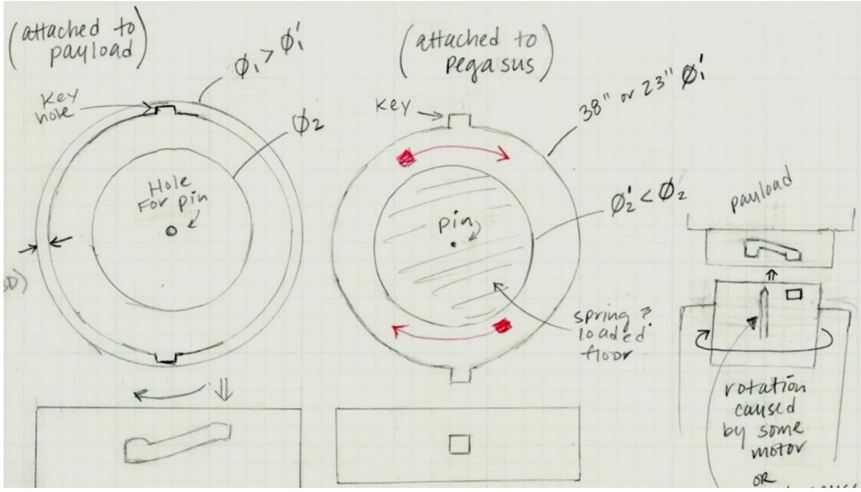

Figure 5: Concept 5, the BNC Connector

Decision matrix

The decision matrix helped to narrow down the best design concept. See appendix B for the decision matrix. A scale of 1, 3, 6, and 9 were used to weigh the design criterion listed in the rows. The columns are a list of the 5 initial design concepts. The team weighed the criterion based on what the client thought was most important, 9 being the best. Minimal shock, debris, separate payload, structural capability, and mass added to the payload all received 9's for most important design criterion. It is essential that the payload separation system deliver the payload into orbit with minimal shock. Therefore there must be zero failures in the structural design and cause zero debris so to minimize space trash or re-contact with the payload. Part count, cost, and manufacturability received a 6, deemed second most important design criterion. The number of parts needed is related to the cost and ease of manufacturability. With less parts, Orbital Sciences Corporation can manufacture the payload separation system on site, saving money overall. Weight and ease of assembly were weighted with least importance because Orbital is willing to sacrifice some weight and time for a reliable system. After each solution was compared and weighted by the designs ability to satisfy the criterion, each column was summed and the Interlock solution 1 had the highest score. The matrix shows that design concept 1 would best fit the client's needs and design requirements. The interlock was chosen as an outline for the final design.

Final Design

The final design will be a modification of design concept 1. The design will use two 'T' shaped keys. These keys combine to encompass approximately 300deg, leaving the 60deg for motion of the keys. To provide locking the keys will fit into two identical female versions of the keys, on the payload side of the system. Using compression the keys will provide for the locking of the system. The keys, built on the rocket side will force a lock, when they are pulled toward the center of the ring they will release. Two computer animated electrical motors on a rack and pinion gear system where used to initiate the unlocking process. This is simply shown in Figure 6 and 7 for demonstrative purposes.

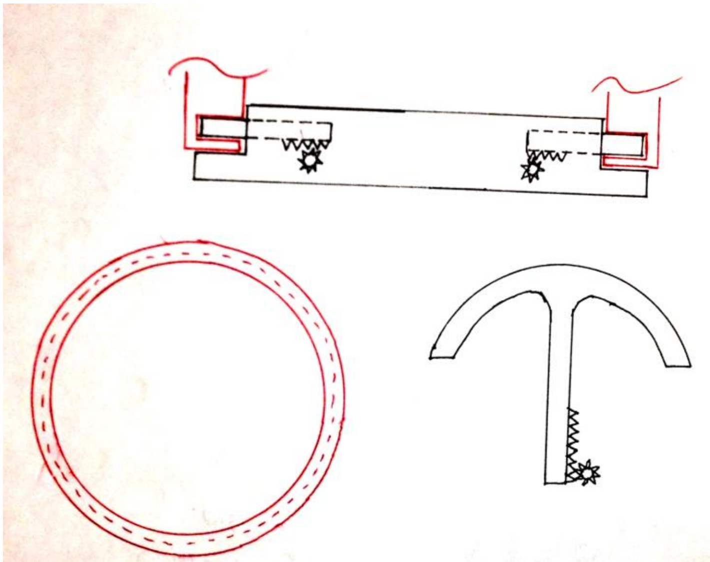

Figure 6: Final design sketch

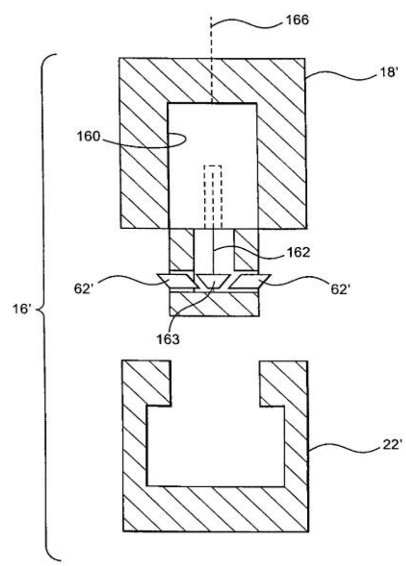

Figure 7: Final design sketch

Project Plan

The Gantt chart, shown in appendix C, illustrates what the upcoming months will be like for the team. Minor changes were made to the Gantt chart. CAD drawings were pushed back as well as a final design deadline. There are nine main tasks in which we will follow before we can finalize a payload separation system. The month of October alone has five of the main tasks that will be accomplished. Research, brainstorming, creating five initial design sketches, and a decision matrix have now been complete. CAD drawings and refinement of the final design will now be the next step in the design process. In order to be on schedule some of the tasks will run jointly. There will also be subtasks that go along with the main tasks as soon as those points are reached in this project. This goes along with two future reports and presentations over the span of two months. The date in which our team will have a completed and final design will be on December 2nd.

Conclusion

Orbital Sciences Corporation has asked the team to design, build, test, and analyze a less expensive payload separation system with minimal shock to the payload. The meeting on October 25, 2013 with the client, Mary Rogers, helped to update the Quality Function Deployment and clarify the needs and requirements. With an updated QFD, the team was able to effectively develop five initial design ideas. With the use of a decision matrix, the Interlocking solution 1 was chosen for further final design analysis. The final design had been modified slightly for optimization. Although the team has developed a final design, nothing is entirely final. As shown in the Gantt chart, there is still time for refinement of the overall design due to the complexity of the payload separation system.

References

1. Baldwin, Bryan. "Orbital." *Orbital Pegasus Guide*. Orbital, n.d. Web. 7 Oct 2013. <http://www.orbital.com/NewsInfo/Publications/Pegasus_UG.pdf>.

Appendix:

A. 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	
11.	Mass of Entire System	9		3		
		Raw Score	270	333	204	63
		Relative Weight [%]	31.03%	38.28%	23.45%	7.24%
		Unit of Measure	+/- mm	$	ul*	min
		*ul = unitless				

B. Decision 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

C. Gantt Chart