Payload Separation System

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Team 11

Problem Formulation and Project Plan

Document

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Contents

Background

Launch vehicles that place payloads into orbit require mechanisms to release the payload into orbit. The payloads are typically fragile and are composed of various optical components that can be harmed when transported. Due to this problem, companies have designed various payload separation systems that have become too expensive and complicated. Mary Rodgers, the Electronic Packaging and Actuators Manager from Orbital Sciences Corporation, has requested for a new design of the payload separation system. This new design of the system must be reduced in cost, impart minimal shock to the payload, and be less complicated by reducing the number of parts. The team will design, analyze, and possibly build a sub-scale model of the payload separation system for testing for ME 476 Capstone Senior Design by May of 2014.

Problem Statement

Orbital Sciences Corporation, located in Phoenix Arizona, is interested in designing a Payload Separation System (PSS) that is lighter, less expensive, less complicated, and imparts minimal vibrational shock levels onto the payload. The primary interest of this senior design project is to deliver a payload into polar orbit around the Earth. Generally, 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 is to improve the current payload separation system today while making sure the design is simple so that it can be manufactured at Orbital.

Introduction

Current payload separation systems are generally composed of some cylindrical ring that is mounted on the tip of a launch vehicle just before the payload. The ring needs to be able to withstand the weight of the payload, and the forces and properties at Mach speeds when launched into orbit. Some of the forces that need to be considered are extreme temperatures, accelerations, vibrations, and various other material stresses caused by the environment. The project will entail trade studies, design, analysis, and possible sub-scale models and testing.

Some payloads that might be used in industry today include: satellites, telecommunication systems, optical systems, and experimental projects. These payloads can be delicate due to the nature of the mechanisms they carry. The payload and the launch vehicle are extremely expensive, although by reducing the number of parts the cost will be reduced as well.

Needs Identification

The client Mary Rodgers contacted Northern Arizona University with a need for a payload separation system. Currently the 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 re-design a payload separation system that is less expensive, and imparts as little shock to the payload as possible.

Project Goal

Orbital Sciences Corporation is interested in a payload separation system that is lighter, less expensive, less complicated, and imparts minimal shock to the payload. The goal is to improve the system so that it can break apart consistently on command with little impact to the payload. Mary Rogers has also requested that the new design be able to be machined in-house by Orbital Sciences, so to eliminate sub-contracting.

Objectives

The objectives are quantifiable expectations of performance. See Table 1 for information regarding measurement basis and units for each objective. Following the table is a brief description of what each objective means.

Table 1: List of Objectives with units

Objective	Measurement Basis	Unit
No Debris	Number of fragmented pieces at separation	n/a
Reliable	Percent complete separation during test trials, with timely separation	%
Manufacturability	Realistic feasibility of manufacturers	n/a
Minimal Shock	Impact force	N
Remain Intact	Material properties	eds
Light-weight	Minimal load factor to rocket	kg

Simplicity	Number moving and stationary parts	n/a

The payload separation system must:

1. Have no Debris – So to eliminate space trash and debris falling back into Earths atmosphere.
2. Be reliable – The payload separation system must work correctly the first time because there will only be one chance and the launch is extremely expensive and labor intensive.
3. Be easy to manufacture – Orbital wants to machine these systems in house rather than sub-contracting them to reduce cost.
4. Impart minimal or no shock – The payloads can be fragile and the shock can cause damage.
5. Remain intact – The payload separation system will need to be able to withstand extreme environment conditions and still release the payload on command.
6. Be light-weight – The payload separation system needs to be as light weight as possible to decrease the overall weight and possibly allow for the launch vehicle to carry a heavier payload.
7. Be simple – With a more simple design, there will be less parts, a decrease in cost and easy manufacturability.

Requirements

After meeting with the client, Mary Rogers, the team was able to narrow a vast list of requirements to the following. Mary made this defined list based on what she feels most needs attention.

1. Weight- With respect to current PSS the new design should be less weight overall. Simple economics dictate this were, weight means more rocket fuel, and more rocket fuel inevitably means higher cost. While it may not be possible to cut the weight in half, every ounce matters on a project of this detail.
2. Cost- Current payload separation systems can cost upwards of $500,000 per unit. For a non-recoverable system this is enormous. The complexity of modern PSS systems lends itself to these high costs. To solve this the solution is most easily defined as simplicity.
3. Parts **-** Current payload separation systems are complex beyond what is humanly recognizable. Reducing the gross number of components will help to simplify, lessen in weight, increase reliability, and lower cost overall.
4. Separation Capability- Never should there be an example where the PSS fails to separate. The opportunity for failure is non-existent. The great cost of each mission does not allow room for failure by non-separation.
5. Material Properties- The payload separation system will undergo one airline takeoff, one in-air belly release, and three separate burn sessions. Each will impose some stress on the system. It is imperative that the PSS does not fail at

this point, before separation. This means that material analysis will be had to ensure the reliability of material selection.

6. Damage (deflection) - While building a rigid and tough system overall the team must also account for the fragility of the payload. Most payloads will have very delicate instruments calibrated to very high precision. It is important to protect this cargo, preventing any extra jarring motions.

Constraints

There are several key constraints that we as a team will need to consider based on the needs specified by our client, Mary Rogers. Below are listed material constraints that need to be considered. The material needs to withstand compressible air at supersonic speeds, when Mach number is greater than 1. This ties into the velocity that the launch vehicle needs to endure. At its highest speed, the system reaches 24,550 ft/s. In order for the design to fit the specifications of the rocket sizes, it will need a bolt circle diameter that is between 23” - 38”. Furthermore, the material needs to withstand a height of 400 nautical miles into the air. This is because at 400 nautical miles microgravity starts its process that will last around 6 min, and can possibly affect the surface tensions of the materials. Furthermore, the payload separation system material will need to survive temperatures which can reach upwards of 3000°F. Other major constraints include a less expensive mechanism, and a low profile so the launch vehicle can hold more of the payload and less of the mechanism. The weight of the payload is also significant because the max load it can withstand would be 485 kg. In addition, we have to design a device that can hold more than 126kg. This system will also need to endure vibrational stresses and a lateral frequency of 20 Hz. Since our client was looking for a lower cost design, the simplicity and manufacturability of the design will be considered a constraint as well.

Quality Function Deployment

The Quality Function Deployment, or QFD, can be found in Appendix A. The purpose of a QFD is to find what is most important to the client and relate it to the requirements to identify which requirement will need the most attention further along in the design process. To further explore what objective is most important to the client, the team set up a conference call with Mary Rogers and weighted each objective using a scale of 1 to 9, 9 being most important. The rows on the left of the QFD were then scaled by the team in relation to its importance to the requirement columns. As a result, each column was multiplied by the customer weight and then summated in the bottom rows labeled raw score. This process shows that the team will need to focus the most attention on the parts and separation capability of the payload separation system. This is because the parts are related to reliability, manufacturability, and simplicity, which were weighted the highest by the client.

Working Environment

When leaving Earth's atmosphere and traveling at Mach speeds, a variety of properties change as explained in the constraints section of this report. Due to such extreme velocities and temperatures, the materials tend to be manipulated on a molecular level that can cause failures in the system. Orbit Sciences is interested in reaching heights as high as 35, 785 km, or also known as geocentric orbit. Geocentric orbit is the most common height that satellites orbit around Earth as shown in Figure 1 as the dotted black line on the outer surface. To further explain the environment of the launching process see Figure 2. First the launch vehicle, in this case the Pegasus, is belly launched from an airplane at around 39,000 feet above sea level. After the first stage ignition and burnout, the second stage begins at 229,900 feet. The payload separation system must undergo a third stage and finally separates the payload at a height of 400 nmi. The system must be designed to withstand all of these environmental conditions.

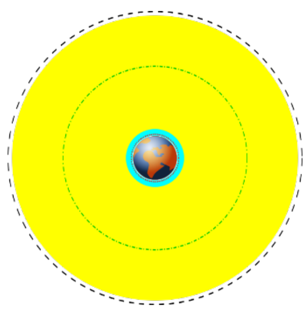

Figure 1: Geocentric orbit

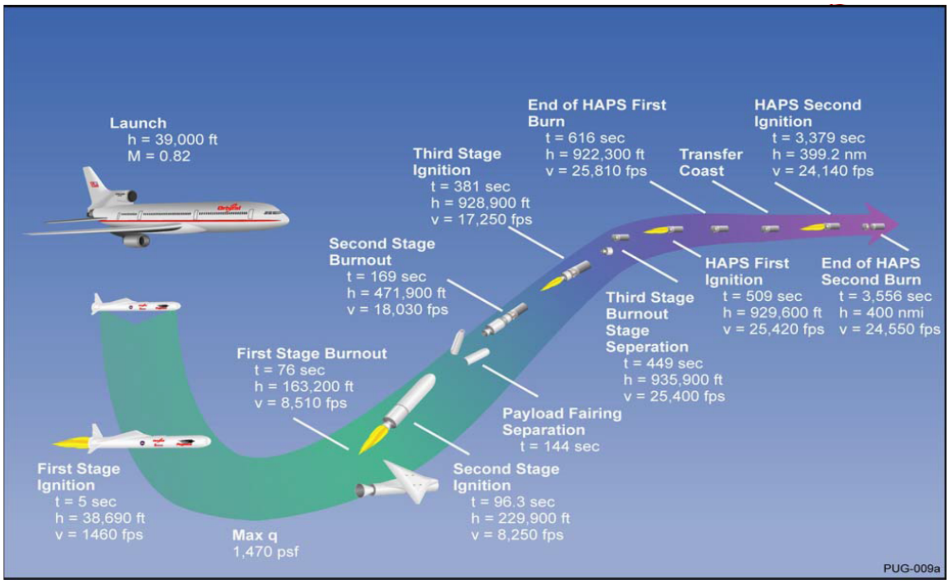

Figure 2: Mission profile launching payload into polar orbit

Project Plan

The Gantt chart shown below does a great job illustrating what the upcoming months will be like for our team. There are eight main tasks in which we will follow before we can get to the finalized payload separation system. The month of October alone has five of the main tasks that will be accomplished. Those tasks will include the research and brainstorming for the new and intelligent ideas, creating the design sketches to go with the CAD drawings, as well as choosing between a few designs that will later be narrowed down to just one using our decision matrix. In order to be on schedule some of the tasks will be running 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 three 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

Much planning has gone into the beginning of a process in developing a payload separation system. We will need to follow the Gantt chart accurately in order to be successful in making changes or modifying our first prototypes. Once we do begin our first ideas we will make changes accordingly until we have a few designs that we can work off. All in all, planning and brainstorming are crucial at this point.

As mentioned above the objectives of No Debris, Reliability, Manufacturability, Shock, Remain intact, Lightweight, and simplicity have lend themselves to be a guide for the entirety of the project. We will focus to meet the objectives, while ensuring we do meet the requirements. Those being weight, cost, parts, separation capability, material properties, and damage to the payload. These requirements are the most imperative as defined by the client Mary Rodgers of Orbital Sciences.

Future iterations of the project as defined by the Gantt Chart will soon include possible solutions as well as a top pick. We will use decision matrices weighted against the Objectives and Requirements to find our top choice.

References

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2. Baldwin, Bryan. "Orbital." *Orbital Pegasus Guide*. Orbital, n.d. Web. 7 Oct 2013. <http://www.orbital.com/NewsInfo/Publications/Pegasus_UG.pdf>.
3. Wikipedia. “Satellite.” Web. 7 Oct 2013. <http://en.wikipedia.org/wiki/Satellite#Orbit_types>

Appendix

A. QFD

Scale 1, 3, 6, 9 (best)	Ojectives	Customer Weights	1. Weight	2. Cost	3. Parts (PSS)	4. Separation Capability	5. Material Properties	6. Damage (deflection)
			Engineering Requirements					
	1. No Debris	6			3	6	6	9
	2. Reliability	9			6	9	9	9
	3. Manufacturability	6	3	9	9			
	4. Shock	9				9		6
	5. Remain Intact	6			9			
	6. Light Weight	3	9		3		3	
	7. Simplicity	6		9	9	3		
		Raw Score	45	108	**243**	**216**	126	189
		Relative Weight [%]	4.85%	11.65%	**26.21%**	**23.30%**	13.59%	20.39%
		Unit of Measure	lb	$	**ul***	**ft**	lb/ft^2	in
		*ul = unitless						

B. Gantt Chart