Orbital Test Stand

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Team 7

Defining the Problem
Document

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1.0 PROJECT INTRODUCTION

Orbital Sciences is a US-based company specializing in the fabrication of small- and medium-class space and rocket systems. Its product line breadth includes space launch vehicles, missile defense systems, satellites, national security systems, and advanced flight systems. The project presented in this report deals primarily with a certain inefficiency--as identified by Orbital engineers--involved in the testing of Orbital launch vehicles.

Testing for Orbital's line of Antares launch vehicles occurs on a horizontal test stand located in its manufacturing and testing facility in Gilbert, Arizona. The current testing procedure is unsafe and inefficient and Orbital would like a mechanism that makes testing easier, safer, and more efficient. For the test, two payload fairings are individually loaded onto the horizontal test stand with a crane. The first payload fairing is loaded onto the top of the test stand and then Orbital engineers have to manually rotate the test stand so that a second fairing can be loaded in conjunction with the first. These payload fairings are approximately 3.9 meters in diameter and 9.9 meters in height [1]. Orbital would like to see the task of having engineers manually rotate the test stand be replaced with an automated mechanism that is capable of continuous rotation.

Figure 1: View of the horizontal test stand with one payload fairing loaded onto the test stand.

2.0 GOALS

Orbital is unsatisfied with its current testing procedure and needs a mechanism that is safer, easier to operate, and more efficient. The current procedure is unsafe because the payload fairings are substantial objects that have a lot of inertia when engineers begin rotating them on the test stand. Orbital is able to overcome this inertia by using an overhead crane as a stopgap for the rotating part of the test stand. Orbital engineers estimated that they have to manually rotate the fairing anywhere from 20 to 30 times during the setup for each test. This creates a heavy burden on the engineers who are tasked with setting up the payload fairings for testing. They have to manually rotate the payload fairing, bolt it into place at the locations that are accessible, check that the crane is in its proper place, and then manually rotate the fairing again. They repeat this until all the bolts are in place around the perimeter of both payload fairings. The payload fairings also have to be manually rotated during the test when engineers have to check the sensors that are inside each of the fairings.

Our primary goal for this project is to develop a mechanism that will allow Orbital engineers to automatically rotate the payload fairings on the test stand with no manual involvement or influence. This new mechanism should be easy to operate and easy to integrate into the current setup of the horizontal test stand. Lastly, the mechanism should be easy to manufacture and easy to maintain.

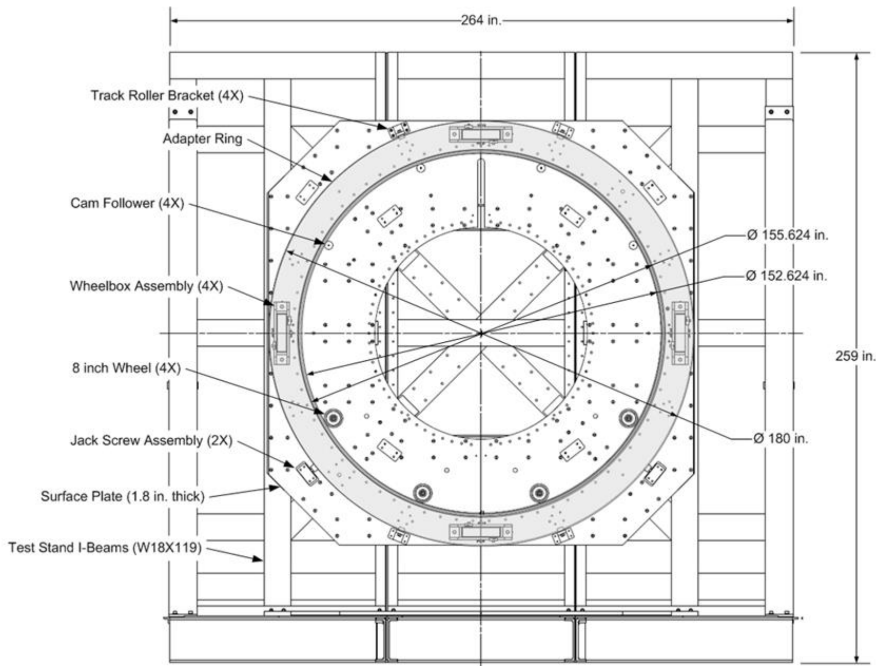

Figure 2: Schematic of Orbital's horizontal test stand.

3.0 OBJECTIVES

We identified five open-ended objectives for our test stand modification design. These objectives were derived from conversations that we had with our contact at Orbital and what they said they needed. The five objectives are to minimize the setup time, minimize costs associated with modifications, limit the amount of modifications to the current stand, support all vehicles Orbital will test, and reduce the space occupation in the testing bay.

Minimizing the setup time is an important objective because after our visit to the facility and talking with our contact and his colleagues, they were primarily interested in something that reduced setup time. The current process was described to us in detail and was tedious, time consuming, and possibly dangerous. By making our rotation device more easily setup and accessible, Orbital will be able to test their launch vehicles safely, quickly, and easily. We will quantify the success or failure of our design meeting this objective by seeing if our design can setup the vehicles for testing faster than Orbital's current process of using a crane and manpower with straps.

Minimizing the costs associated with modifying the current test stand and limiting the amount of modifications to the current setup was labeled an objective because this test stand is expensive, and it will be equally expensive to cut additional holes in it or make other modifications to it. Our design needs to be cost effective for both ourselves and for Orbital. By limiting modifications to the current test stand, Orbital will be able to resume testing faster, preventing them from losing money due to idling in their testing process. We will quantify these objectives by setting a budget and then seeing if our design ultimately falls within or exceeds the budget.

Having the design be able to handle the full catalog of Orbital vehicles is the most important objective. If our design is unable to support a vehicle, Orbital will have to build a new stand to test such a vehicle, or make further modifications to our design. By having our design meet the requirements to support all possible vehicles, Orbital will be able to use the test stand more frequently and save costs on having to build multiple stands. We will quantify this objective by seeing if our design meets Orbital's maximum bending moment criteria for supporting the test vehicles.

Finally, minimizing the space occupied in the bay is our least important objective. Space in the testing bay is slightly cramped, so it would be preferable if our design was as compact as possible, but this falls far behind being able to test all the vehicles quickly and safely. We will quantify this objective by setting a reasonable area or volume and then seeing if our design falls within or exceeds our estimated size.

4.0 CONSTRAINTS

Orbital has identified three constraints for our design modifications to their current test stand. We collaborated with our contact at Orbital to make sure that these were correct to their specifications. The three constraints that we have for this project are that the test stand must rotate +/- 360 degrees, the max RPMs cannot exceed 1, and the mechanism has to be able to support an off center load of 87,210 lbf-in.

The test stand must rotate 360 degrees in both directions to allow for specific tests to be performed on the launch vehicles as well as be able to quickly examine a specific part of the vehicle that isn't testing as expected. The launch vehicles are loaded up in halves, with the top half being loaded on, and then rotated underneath and having the second half loaded on top. The stand must be able to spin both directions to allow for the placement and removal of the test stand halves.

The rotational speed may not exceed 1 RPM because the parts are expensive and heavy and safety is a primary concern. The current method of turning the test stand with the crane is not safe, so maintaining a slow, controlled rotation is paramount to the success of our design.

Lastly, the mechanism that we design must be able to support an off center load of 87,210 lbf-in. This comes from when the top half of the launch vehicles are being rotated to the bottom, there is a point where they are perfectly off center and all the weight is trying to bend the stand and our device. Our device needs to be able to support this weight and bring the launch vehicle halves down safely without the pieces slipping and creating an extremely dangerous situation.

5.0 TESTING ENVIRONMENT

Testing for our design will consist of two stages. Stage one will begin with simple calculations. The maximum moment and strength of the material will be calculated so that they meet the requirements of our design. Since the design is on such a large scale, small scale testing will be conducted to ensure the design is safe. A small scale model will be made a tested. The results of this small scale model will relate to our actual model. The design will be altered if these tests conclude that it is necessary. Stage two will consist of computer testing. The stress and strain distribution will be simulated. The simulation will represent how it will be used by the customer. We will check for anything that does not meet our requirements. Stage two of testing will also include finite element analysis. Only after our design passes all of the tests will we allow it to proceed to be built.

6.0 QUALITY FUNCTION DEPLOYMENT

The Quality Function Deployment (QFD) is used to identify the relationship between the Customer Requirements and the Engineering Constraints of a design. Figure 3 below is the QFD that our team finalized for the Orbital Test stand.

CUSTOMER REQUIREMENTS	ENGINEERING REQUIREMENTS: Strength	Weight	Torque	Speed	Time	Continous Rotation	Cost	Power Source
Provide 360° Rotation				X	X	X		
Rotate less than 1 rpm				X	X			X
Counteract off-center load	X	X	X					
Attach to Test Stand	X	X					X	
Interface with Adapter Ring	X	X					X	
Minimal Modifications							X	

Figure 3: Quality Function Deployment.

The Customer Requirements as described in the previous section are listed along the left. The Engineering Requirements are the criteria that our team set that would satisfy the customer requirements. In the center area, is the matrix of requirement relations, note that each engineering requirement meets at least one of the customer requirements.

Material selection will have an effect on the strength, weight and torque that the test stand can handle. As mentioned earlier the modifications will need to withstand a load of 570 lbs at an offset of 153 inches. The tension and compression stresses will result from the initial load therefore the chosen material specification will need to withstand these stresses. The next criteria is speed, as a safety standard the speed of rotation cannot exceed 1 rpm. Time is a design criteria that refers to minimizing the time to rotate the vehicle and complete each test at the desired angles.

Our current QFD does not include comparisons to other competitors or designs because Orbital did not purchase the current test stand. A comparison would be added on during the next stages of design to compare the team member ideas to each other and which would best satisfy both the customer and engineering requirements.

7.0 HOUSE OF QUALITY

The House of Quality (HOQ) is used to identify the correlation between each of the team identified Engineering Requirements. Figure 4 below has plus signs indicating positive correlation and minus signs for negative correlation.

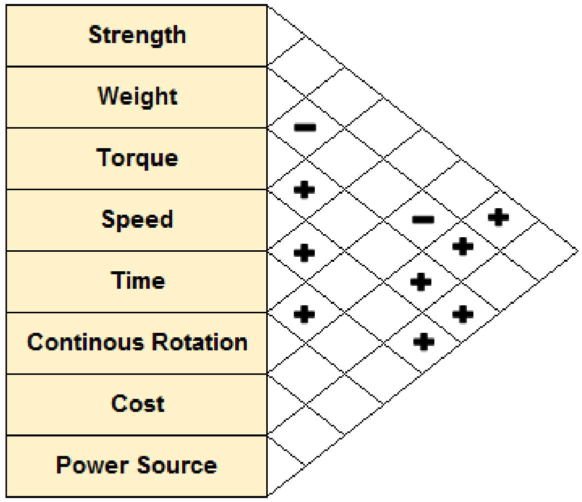

Figure 4: House of Quality.

Strength, weight, and torque have a strong positive correlation with cost. If the design is to be made from a different material than the test stand or what is available the budget will need to be increased or decreased accordingly. Speed has positive correlations with torque, time and power source. The maximum speed is an important criterion because of safety. The slow rotation will need to remain under 1 rpm as the vehicle rotates on the test stand, this will also affect the power source or motor that would be needed. Weight was identified to have a negative correlation with torque and continuous rotation. During concept generation phase this negative correction will need to be kept in mind. As the test stand continues to rotate +-360 degrees the moment arm will increase and decrease, therefore constantly changing the amount of torque, the test stand will need to maintain functionally during rotation and hold the vehicle.

8.0 SCHEDULE

The project was divided into 3 phases for Fall 2014. Phase 1 consists of defining the project goals, objects, constraints, testing environment, and QFD—the scope of this report. Scheduling for Phase 1 was based around phone interviews and email correspondence with our Orbital contacts and team meetings. The purpose of this phase was to set our project in the right direction and confirm with Orbital that we were on the same page. Phase 1 lasts approximately 3 weeks from the time the project is selected until adequate project goals, objectives, and constraints are established.

Table 1: Phase 1-Tasks list with start and end dates and duration.

1			Prepare presentation 1	2 days	Sat 9/13/14	Mon 9/15/14
2			Presentation 1	0 days	Tue 9/16/14	Tue 9/16/14
3			Prepare report 1	3 days	Tue 9/16/14	Thu 9/18/14
4			Report 1	0 days	Fri 9/19/14	Fri 9/19/14

Phase 2 is the concept generation portion of the project and lasts 2 weeks. Included in Phase 2 was a trip to Orbital Science's facility in Chandler, Arizona to see the horizontal test stand in person. From this trip we gained a higher understanding of the project through talking with our contact Ross Gentle and a few other employees. Concept generation is able to proceed after the in-person meeting once questions are answered and project scope is solidified.

Table 2: Phase 2-Task list with start and end dates and duration.

5			Orbital trip	0 days	Fri 9/26/14	Fri 9/26/14
6			Concept generation	7 days	Sat 9/27/14	Sat 10/4/14
7			Preliminary analysis	12 days	Sat 9/27/14	Sat 10/11/14
8			Prepare presentation 2	2 days	Sat 10/11/14	Mon 10/13/14
9			Presentation 2	0 days	Tue 10/14/1	Tue 10/14/14
10			Prepare report 2	3 days	Tue 10/14/1	Thu 10/16/14
11			Report 2	0 days	Fri 10/17/14	Fri 10/17/14

Phase 3 will begin with the selection of 2-3 concepts from the 10 generated in Phase 2 for further development and analysis. This phase is the longest of the 3 and will run until the end of the semester. Due to the in-depth nature of these tasks 5 weeks has been allotted for analysis and modeling of the chosen concepts. Since this will be the final presentation of the semester 7 days has been allotted for presentation preparation and 5 days for report preparation.

Table 3: Phase 3-Tasks list with start and end dates and duration.

12			Concept selection	0 days	Fri 10/17/14	Fri 10/17/14
13			Analysis/Modeling/C	27 days	Sat 10/18/14	Sat 11/22/14
14			Prepare presentation 3	7 days	Sat 11/22/14	Sat 11/29/14
15			Presentation 3	0 days	Tue 12/2/14	Tue 12/2/14
16			Prepare report 3	5 days	Sat 11/29/14	Thu 12/4/14
17			Report 3	0 days	Fri 12/5/14	Fri 12/5/14

9.0 CONCLUSION

After meeting with Ross, our team was able to determine the project objectives, goals, and restraints and thus a strong direction to take our project. Our 5 objectives for this project are to minimize the setup time, minimize modification costs, limit the amount of modifications to the current test stand, support all vehicles Orbital will test, and reduce the space occupation in the testing bay. With these design objectives in mind our team has quantifiable outcomes that can be achieved by the end of the project. The constraints associated with the objectives are a rotational freedom of +/- 360 degrees, maximum RPM of 1, and handling a maximum moment of 87,210 lbf-in when only one half of the fairing is loaded on the test stand.

10.0 REFERENCES

https://www.orbital.com/CorporateInformation/Milestones/2010-Present/