Orbital Test Stand

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Team 7

Concept Generation
Document

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1.0 INTRODUCTION

Phase Two of the project involved the group sourcing of 10 concepts to be used to solve the problem. Each member was required to pitch two ideas to the group explaining the concept, pros, and cons. Once all concepts were pitched each member was responsible for creating their own decision matrix, assigning weights to the categories they deemed important for this project. The only standardization for this step was concept naming to ensure the proper concepts were graded accurately. Decision matrix categories included: cost, safety, maintenance, modifications/integration, user-friendly, and size although ultimately it was left to each member to decide which categories would be scored. All members worked independently of each other on this task to ensure that each individual's decision matrix was not influenced by other scores.

Once the decision matrices were completed, three concepts were chosen for further development. The interior wheels, rope/belt system, and the sandwich wheels designs were selected based on matrix results. The 10 designs were presented to Dr. Kosaraju at which point we announced the three designs we would be continuing with. These three concepts will be split amongst the team to conduct modeling and analyses to determine, ultimately, which design will move into the final development stage. By the end of November we will travel to Orbital Sciences' facility in Chandler, AZ to present the three concepts and their analyses to the senior staff who will provide feedback and approval on the final design chosen.

2.0 CONCEPT GENERATION

2.1 Chain

The chain concept takes the form of a large sprocket mounted to the rotation ring akin to a bicycle and driven by a chain. Power would be input through a second motor-powered cog. This design yields the torque and control need to rotate the off-center load and resist the high moment. Two main drawbacks exist for this design: amount of modifications and cost. Since one does not exist on the test stand a sprocket would need to be installed in sections on the rotating ring whether it be bolted or welded on. The drive motor and sprocket would also need to be mounted onto the stand. This exhibits a large amount of modification compared to other concepts. The other drawback is cost. Modification costs excluded the size of the chain needed would be expensive.

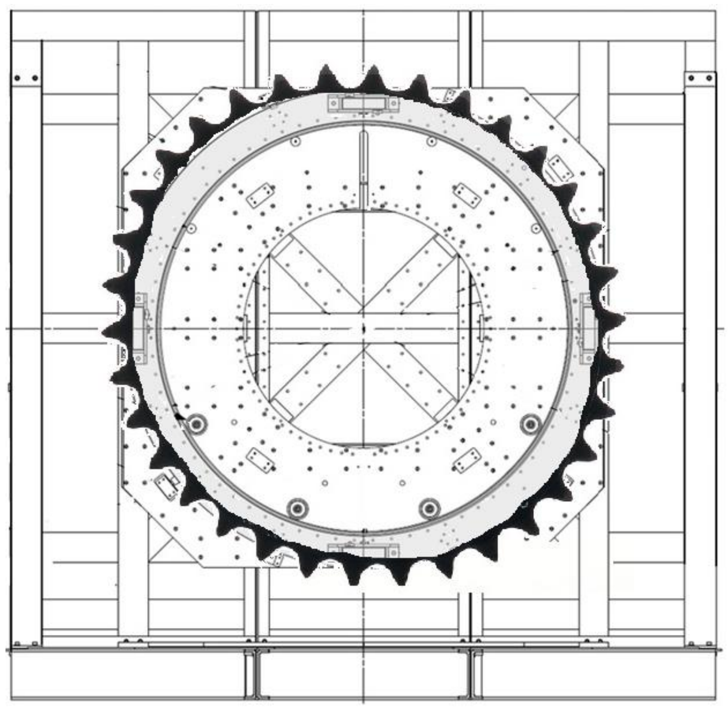

Figure 1: Chain Concept

2.2 Winch

The winch concept is based around using two winches on opposite sides of the apparatus to facilitate rotation in the test stand ring. The design works by having chains/ropes attached to the winches and then wrapped around the circumference of the ring twice and fixed in place. The left winch can retract its cable and rotate the ring counter clockwise, while the right winch can retract its cable and rotate the ring clockwise. This design is effective because it provides the full +/- 360 degrees of rotation that will be required as well as significantly increasing safety by using slow, controlled movements. One downside to this design is the cost of the winches as well as modifying the ring to allow the winch to attach properly.

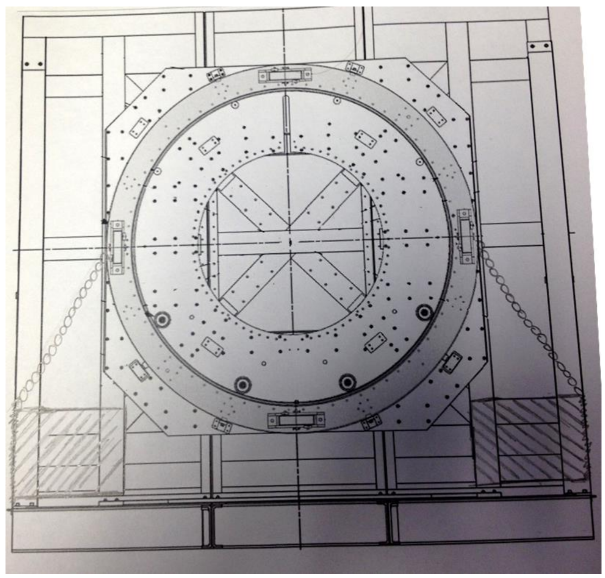

Figure 2: Winch Concept

2.3 Exterior Wheels

The exterior wheels design concept uses eight symmetrically placed wheels located along the exterior perimeter of the rotating ring. These wheels will be individually powered via motors and drive shafts coming through the back side of the plate which supports the ring. This design is effective because the wheels will provide contact friction, allowing slow, controlled movements of the rotating ring with the fairings mounted on it. One of the drawbacks to this design is the cost of the 8 motors, as well as the cost of drilling holes through the plate for the drive shafts.

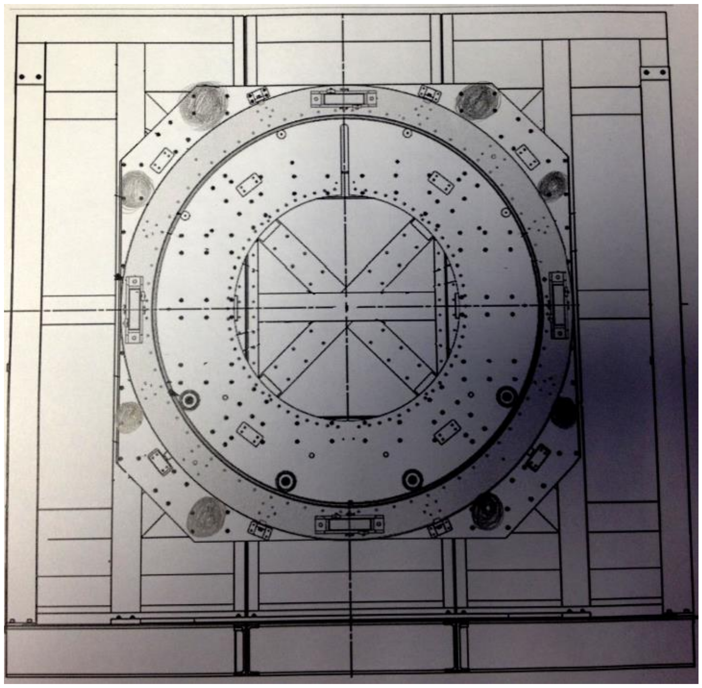

Figure 3: Exterior Wheels Concept

2.4 Interior Wheels

The interior wheels concept utilizes a number of powered wheels mounted to the inside of the rotating ring. Each wheel would be constructed from a material with a high friction coefficient to obtain the turning power needed to rotate the ring in all of its loading conditions. Worm gears would be used to provide the high torque need to move the structure and to prevent the ring from rotating the drive wheels. This design takes up a minimal amount of space and is located in an easy-access area. In addition to minimal space, minimal modifications and cost would be required to integrate this design.

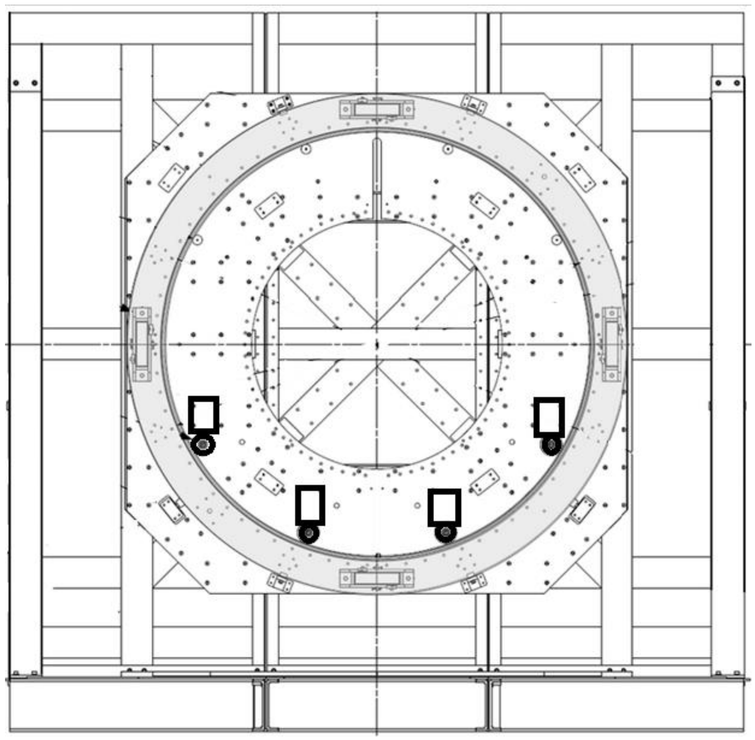

Figure 4: Interior Wheels Concept

2.5 Gears

The Gear concept consists of replacing the four bottom wheels with motorized gears. The existing wheels currently do not provide an effective function, therefore incorporating gears would be beneficial for an effective test stand. Along with modifying the wheels the inner rotating ring will need to be modified. Grooves must be incorporated into the ring to allow meshing of the teeth and thus rotation of the ring. Four gears would are needed to carry force generated by the offset load. Additionally, four gears would be easier to maintain. In the event a gear needed to be replaced, the test stand would maintain its functionality.

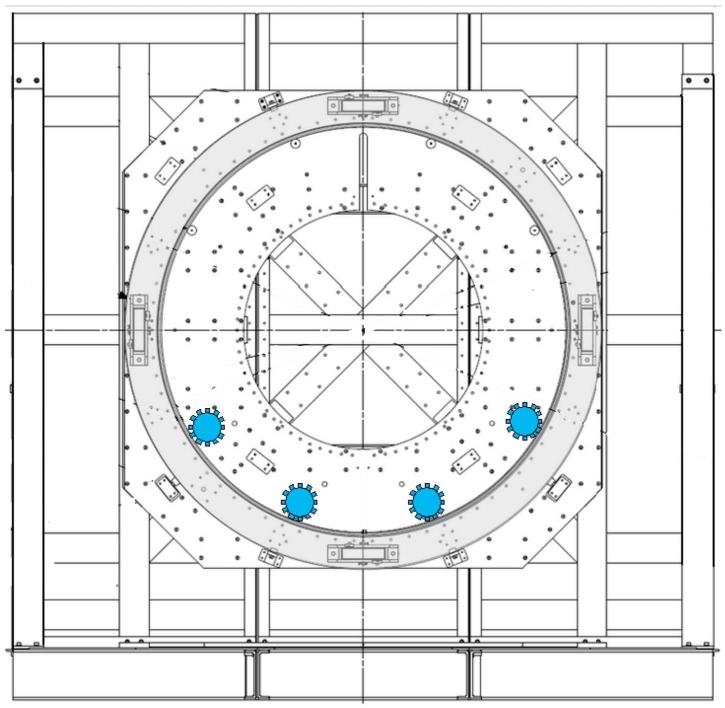

Figure 5: Gear Concept

2.6 Sandwich Wheels

The sandwich wheels concept includes two wheels placed against the front and back of the rotating ring. Both wheels will be pressed against the rotating ring to create enough friction to rotate and stabilize the loaded test ring. The wheels will be powered by an engine placed in the space behind the test stand. This design will take up minimal space and provide the rotation needed. A drawback to this design is the amount of modification needed to secure the wheels in place.

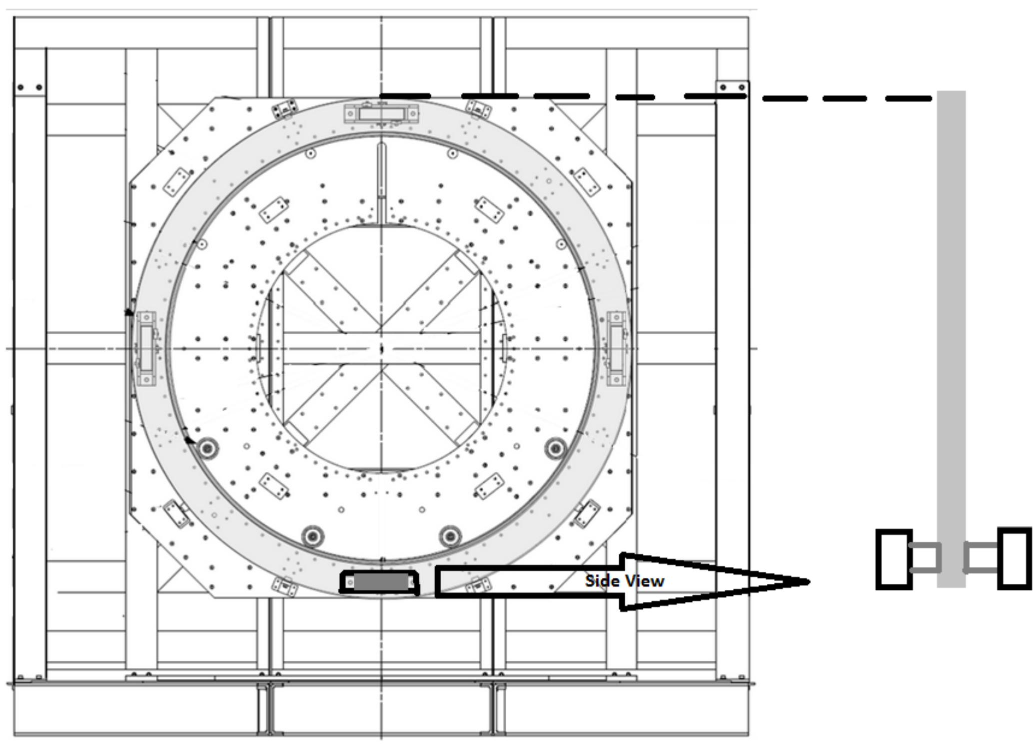

Figure 6: Sandwich Wheel Concept

2.7 Rope Belt

The rope belt design includes a belt driven by an overhead motor. The belt will be in tension between two wheels and the rotating ring. The motor will drive the wheels and belt which will rotate the ring. Clockwise and counterclockwise rotation and easy rotation of the test ring will be achieved through this method. A drawback to this design is the modification required to accommodate the motor being placed above the rotating ring.

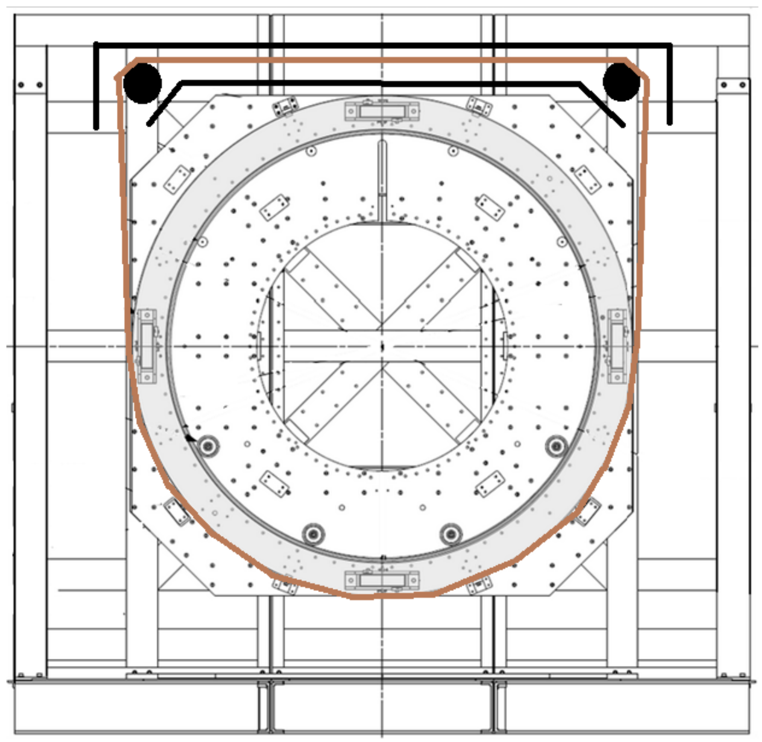

Figure 7: Rope Belt Concept

2.8 Piston

The concept for the piston design combines pneumatic and electrical elements in a design that allows for the achieved objective of continuously rotating the test stand. The design involves four pistons attached with journal bearings around the interior perimeter of the rotating ring on the horizontal test stand. Attached to the ends of each of the four pistons are electrically-driven wheels. The piston, when actuated, allows the wheels to be pressed against the interior panel of the rotating ring so that when the wheels rotate, it creates enough torque to facilitate the desired motion in the test stand. One of the advantages of this design is that it matches the overall design concept in the Orbital testing facility because pistons are used for other tests in the facility. Also, this design would not disrupt other tests because it would have a minimal physical presence on the test stand itself. It is important that the incorporated design not disrupt the operations of Orbital or require substantial modifications to the test stand as it currently sits. Since this design could be designed, tested, and modified without modifying the test stand in any way, the testing and evaluation procedure for this design can also be considered as advantageous.

The disadvantages for this design, however, outweigh the advantages. This design is highly involved and requires substantial research and development into piston-actuated, electrically-driven wheel systems. The two options for this design are that it can either be purchased from a third-party provider, or it could be designed by the team. Either option is a disadvantage whether it be the monetary considerations for a purchased design, or the extended timeline for designing this system ourselves.

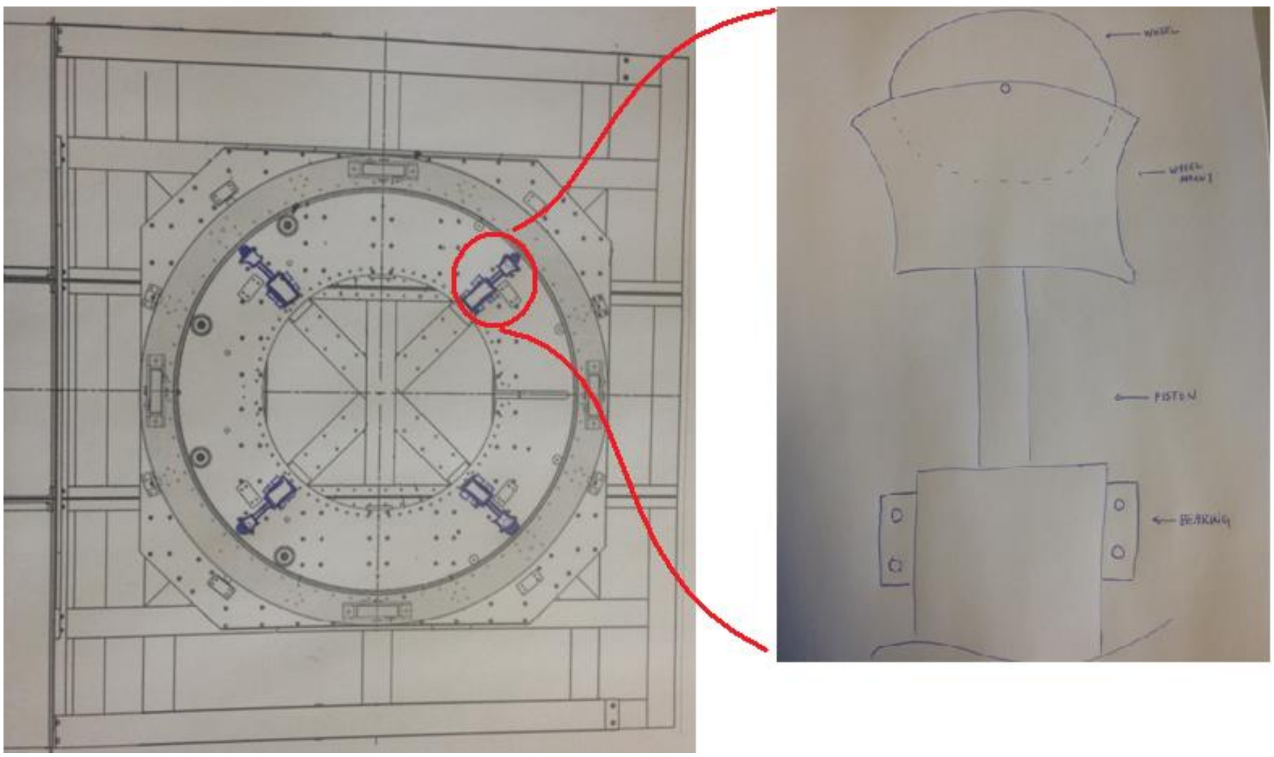

Figure 8: Piston Concept

2.9 Bowling Ball Return

The concept for the bowling ball design mimics that of the ball return in a bowling alley. The design involves a motorized rubber belt deployed below the test stand so that when the belt rotates it allows for the achieved objective of rotating the test stand. The design would be enclosed in a stand-alone box so that it would require no modifications to the test stand. The box enclosing the motorized belt system would have adjustable legs so that the belt can be positioned directly below and directly against the rotating ring. With enough friction against the rotating ring, the rotation of the belt would facilitate test stand rotation.

The advantages of the bowling ball return design are that no modifications would need to be made to the test stand, which is one of the primary objectives of this project as stated by Orbital. It can be designed, tested, evaluated, and redesigned without having to visit the testing facility multiple times. The stand-alone nature of this design allows us to test and design in Flagstaff. Another advantage is that a lot of research and literature is available for a design like this. Automatic bowling ball returns and automatic pitching machines could serve as inspiration. Using the service department of a company that develops automatic pitching machines would be a strong resource for parts for a design like this. The primary disadvantage of this design is that it would need to be designed with variable controls for speed and direction, which make it a more complex design than a standard automatic ball return or pitching machine. Another disadvantage is having to modify the rotating ring with sand paper, or a similar material to create more contact friction between the motorized rubber belt and the ring. Although this could be overcome, it still is considered a disadvantage.

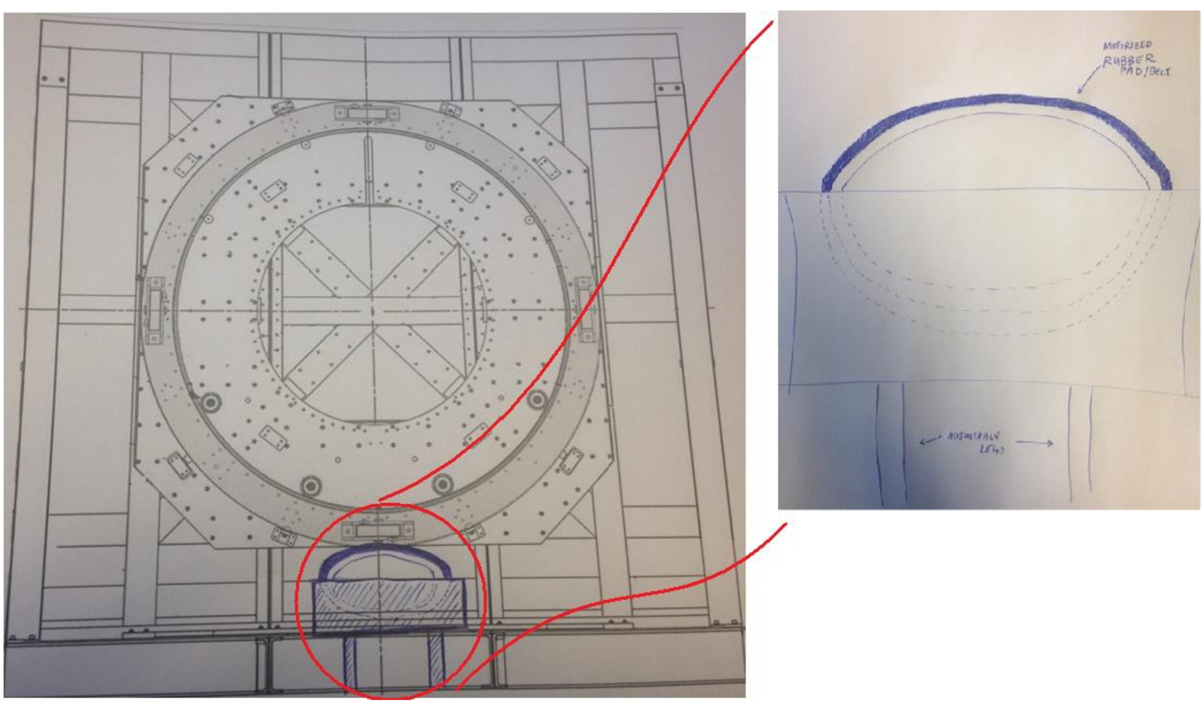

Figure 9: Bowling Ball Return Concept

2.10 Worm Gears

The Worm Gear concept consists of two worm gears to be mounted on the back of the test stand. Modifications will be needed on the ring which includes attaching an inner plate with slits made to allow the worm gear to rotate the ring. This concept does require major modifications but allows for controlled ±360° rotation. The worm gears would easily provide a safe speed of 1 rpm and the offset weight would be controlled and the forces would be dispersed between two worm gears.

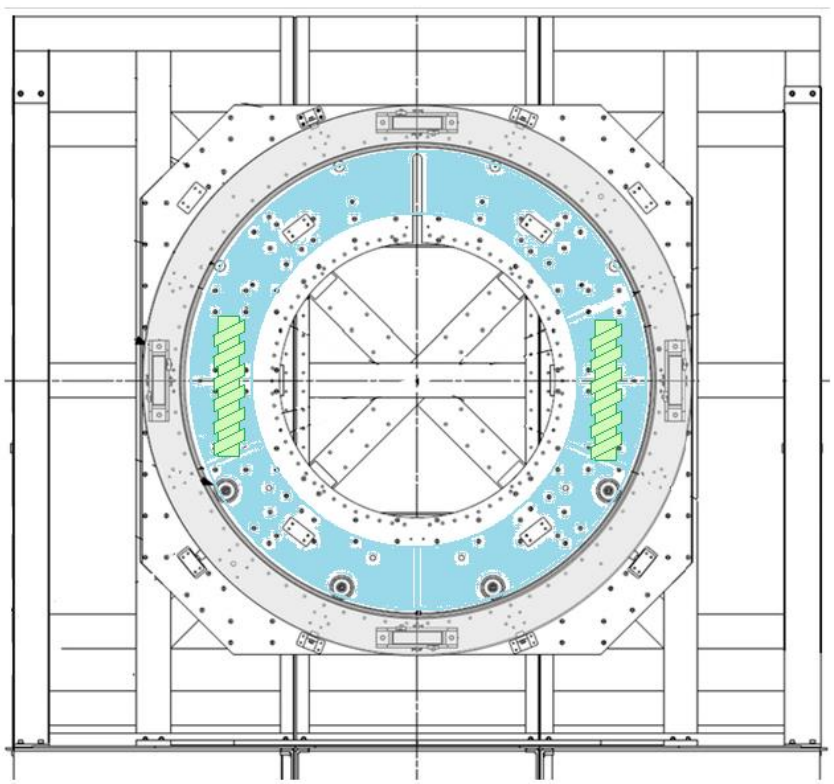

Figure 10: Worm Gear Concept

3.0 CONCEPT SELECTIONS

In order to reduce and finalize the selection of concepts each team member created a decision matrix. Each matrix was completed individually and each member came up with their own design criteria and weighed them accordingly. The matrices needed to be completed separately to eliminate favoritism and persuasion of a certain concept. The five decision matrices are listed in Appendix I and identify the priority that each member set during selection. Each member revealed to the team their top three ranked concepts. The concepts were discussed and the team averaged the rank values to determine the top three overall concepts. Table 1 lists the average rank for each concept.

Table 1: Selection by Average Ranking

	Average Rank
Chain	6
Winch	5.6
Exterior Wheels	3.4
Interior Wheels	1.4
Gears	7.6
Sandwich Wheels	3.6
Rope Belt	4.8
Piston	9.6
Bowling Ball Return	6.6
Worm Gears	6.2

Table 1 highlights four concepts but only Interior Wheels, Sandwich Wheels and Rope Belt will be the concepts that we will move forward with analysis. Exterior Wheels is higher ranked than Rope Belt but we believed the concepts of Interior and Exterior Wheels can be considered the same and interchangeable.

4.0 CONCLUSION

Our team successfully completed the concept generation phase by coming up with two ideas each. This provides our team various creative options to modify Orbital's test stand. By working on individual decision matrices we were able to easily finalize the three concepts that our team will continue with analysis and development. Before finalizing a single design our team will meet with Orbital and present a similar Concept Generation presentation to that given to Dr.

Kosaraju and receive feedback to continue. The next step after meeting with Orbital would be to assign individual member tasks to analyze each of the designs to determine an optimal concept.

5.0 APPENDIX I: DECISION MATRICIES

Table 2: James Ellis's Decision Matrix – Priority: Maintenance, Cost, Easy Use

James Ellis	maintenance	cost	ease of use	manufacture	safety	Total	Rank
Design	0.2	0.2	0.2	0.1	0.3	1	
Chain	4	6	8	6	8	6.6	9
Winch	8	8	7	8	9	8.1	5
Exterior Wheels	8	9	9	7	8	8.3	4
Interior Wheels	8	8	9	8	9	8.5	1
Gears	5	7	8	4	8	6.8	8
Sandwich Wheels	8	8	9	7	9	8.4	3
Rope Belt	7	9	9	8	9	8.5	1
Piston	4	2	6	4	7	4.9	10
Bowling Ball Return	7	7	7	6	8	7.2	7
Worm Gears	7	7	9	8	9	8.1	5

Table 3: Mary Begay's Decision Matrix – Priority: Min. Modifications

			1	2	3	4	5	6	7	8	9	10
		Weight	Chain	Winch	Exterior Wheels	Interior Wheels	Gears	Sandwich Wheels	Rope Belt	Piston	Bowling Ball Return	Worm Gears-On Ring
Design Requirements	**Minimal Modifications**	25%	2	5	8	8	4	7	6	6	6	5
	Low Cost	5%	4	4	7	7	6	7	6	2	5	5
	Easy Manufacture	15%	2	5	7	7	5	6	5	4	3	6
	Easy Integration	20%	3	5	6	6	5	7	6	4	4	6
	Minimal Materials	10%	3	6	7	7	4	6	5	3	3	5
	Portabiltiy	10%	6	5	6	6	6	6	5	4	4	6
	Easy Mainenance	15%	3	4	7	7	6	6	4	6	4	6
	Total	1	3	4.9	7	7	5	6.5	5.4	4.6	4.3	5.6
	Ranking		10	7	**1**	**2**	6	**3**	5	8	9	4

Table 4: Brett Booen's Decision Matrix – Priority: Space Req., Modifications

	Brett Booen	Space Req.	Modifications	Power Source	User Friendly	Safety		
	Decision Matrix	25%	25%	20%	15%	15%		
		0.25	0.25	0.2	0.15	0.15	TOTAL	RANK
1	**CHAIN**	3	10	9	9	4	**7**	②
2	**WINCH**	1	9	10	10	6	**6.9**	③
3	**EXTERIOR WHEELS**	9	6	4	5	7	**6.35**	⑤
4	**INTERIOR WHEELS**	10	5	6	4	10	**7.05**	①
5	**GEARS**	7	3	3	3	3	**4**	⑧
6	**SANDWICH WHEELS**	8	7	5	6	8	**6.85**	④
7	**ROPE BELT**	2	8	8	8	5	**6.05**	⑦
8	**PISTON**	5	1	1	1	1	**2**	⑩
9	**BOWLING BALL RETURN**	6	4	7	7	9	**6.3**	⑥
10	**WORM GEARS**	4	2	2	2	2	**2.5**	⑨

Table 5: Calvin Boothe's Decision Matrix – Priority: Cost

	Calvin Boothe	Cost	Modifications	Space Required	Maintenance	Safety		
	Decision Matrix	25%	15%	20%	15%	25%		
		0.25	0.15	0.2	0.15	0.25	TOTAL	RANK
1	**CHAIN**	4	7	9	9	8	7.2	1
2	**WINCH**	1	9	10	10	6	6.6	4
3	**EXTERIOR WHEELS**	9	6	4	5	7	6.45	5
4	**INTERIOR WHEELS**	4	6	8	7	10	7.05	2
5	**GEARS**	6	2	5	2	4	4.1	9
6	**SANDWICH WHEELS**	8	7	5	6	8	6.95	3
7	**ROPE BELT**	5	6	7	6	7	6.2	6
8	**PISTON**	7	2	1	2	2	3.05	10
9	**BOWLING BALL RETURN**	5	4	4	5	8	5.4	8
10	**WORM GEARS**	8	3	2	4	9	5.7	7

Table 6: Nicholas Garcia's Decision Matrix – Priority: Modifications, Maintenance, Easy Use

	Nicholas Garcia	Space Req.	Modifications/ Integration	Maintenance	Ease of Use	Cost	Safety		
	Decision Matrix	15%	20%	20%	20%	10%	15%		
		0.15	0.2	0.2	0.2	0.1	0.15	TOTAL	RANK
1	**CHAIN**	5	4	6	8	3	7	5.7	⑧
2	**WINCH**	5	5	5	6	6	6	5.45	⑨
3	**EXTERIOR WHEELS**	7	8	7	9	8	9	8	②
4	**INTERIOR WHEELS**	8	8	7	9	8	9	8.15	①
5	**GEARS**	8	4	6	7	2	8	6	⑦
6	**SANDWICH WHEELS**	6	7	6	9	7	9	7.35	⑤
7	**ROPE BELT**	6	8	7	8	8	8	7.5	④
8	**PISTON**	3	6	4	5	4	5	4.6	⑩
9	**BOWLING BALL RETURN**	8	8	7	8	7	8	7.7	③
10	**WORM GEARS**	8	6	7	7	5	7	6.75	⑥