Orbital Test Stand

UGRADS Presentation

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Orbital ATK

Presentation Overview

- Introduction/Problem Definition
- Design Selection
- Final Design Overview
- Manufacturing Process
- Implementation/Conclusion

Introduction

- **Client**: Orbital ATK
- **Specialty**: Small- and medium-size space and rocket systems
- **Market**: $100 billion annual global space market
- **Notable Launch Systems**: Antares, Pegasus, and Minotaur
- **Customers**: U.S. government, commercial, and international customers

Credit: Orbital

Orbital Test Stand

Orbital Test Stand with an idea of scale

Stand with one half of the launch vehicle loaded

Problem Definition

CUSTOMER NEEDS:

- Procedure for rotating launch vehicles on the test stand is inefficient and unsafe.
- Rotating launch vehicles on the test stand puts Orbital engineers in a dangerous position.
- Setup time for testing is exhausted by the need to manually rotate the launch vehicles.

Antares launch vehicle in horizontal testing position

Problem Definition

PROJECT GOALS:

- Easy to **operate**
- Easy to **implement**
- Easy to **maintain**
- Easy to **inspect**
- **Meet customer requirements**

Problem Definition

OBJECTIVES:

OBJECTIVE	MEASUREMENT BASIS	UNITS
Minimize time it takes to load launch vehicle on the test stand	Time to load launch vehicle with new mechanism compared to current procedure	minutes
Minimize costs associated with final design	Final design cost compared to maintaining current procedure and other designs	$
Limit new modifications made to test stand	Cost of material and labor for modifications	$
Handle the off-center loads of Antares fairings when loaded on stand	Strength	psi
Minimize space requirements for final design	Square footage required by new mechanism	ft^2

Problem Definition

CONSTRAINTS:

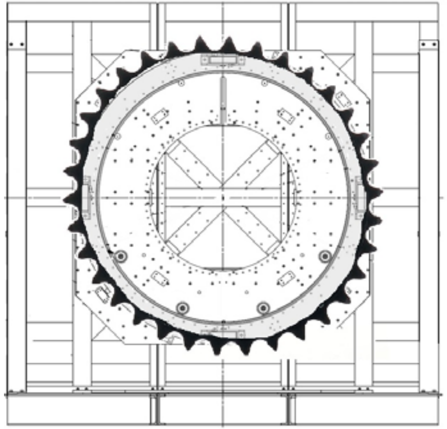
- Continuous rotation for +/- 360 degrees
- Rotational speed not exceeding 1 RPM
- Counteract off-centered load of 570 lb at 153 in
- Minimal modifications

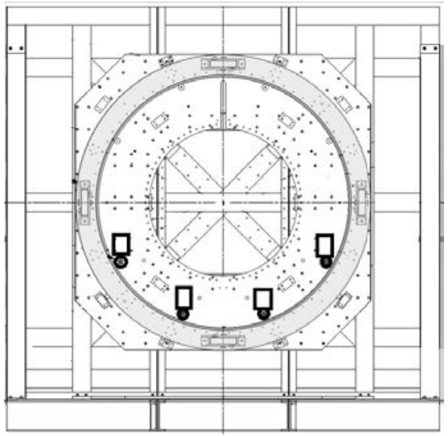
DESIGN SELECTION

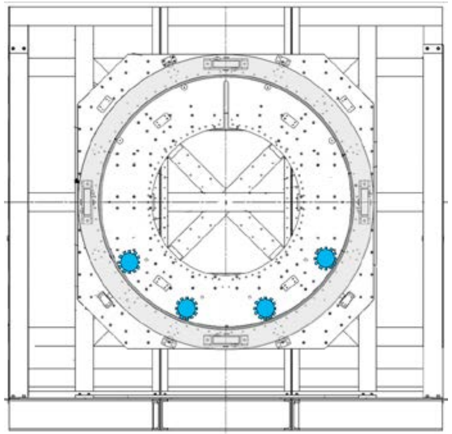
Design Selection Overview

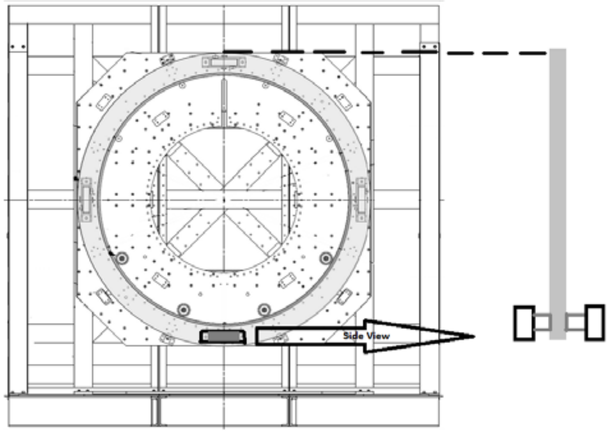
- **Initial Concept Generation**
  - 10 feasible ideas
- **Select design parameters**
  - Representative of project goals and objectives
- **Final Design Selection**
  - Presented two ideas to Orbital in November 2014

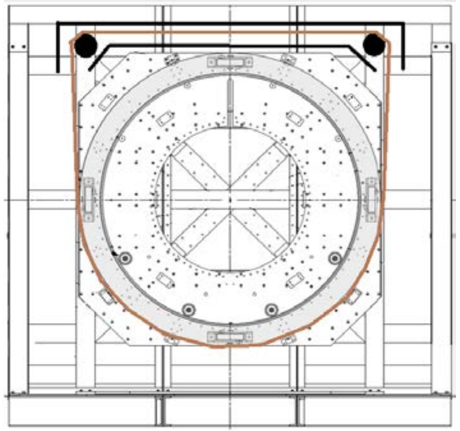
Concept Generation



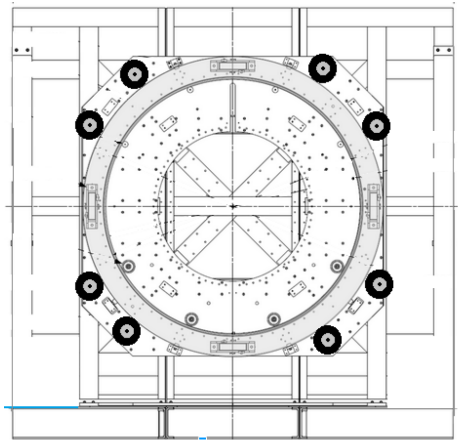


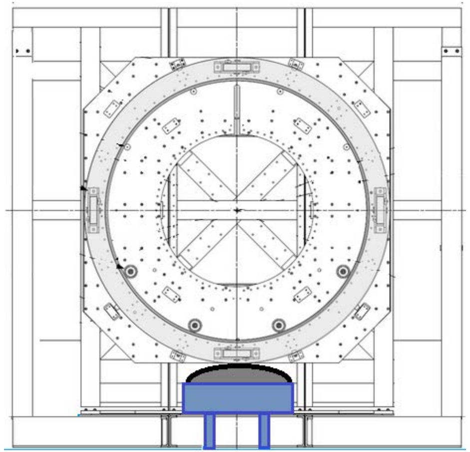


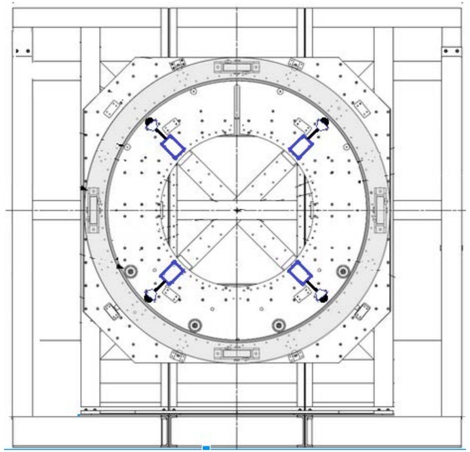


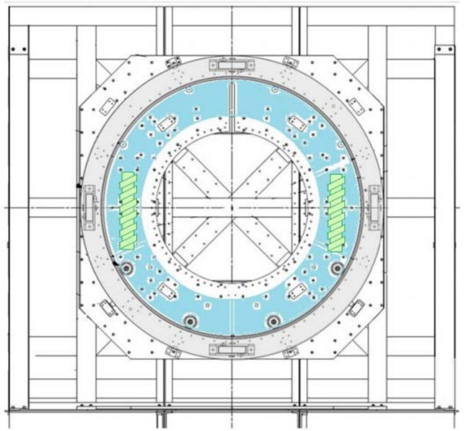


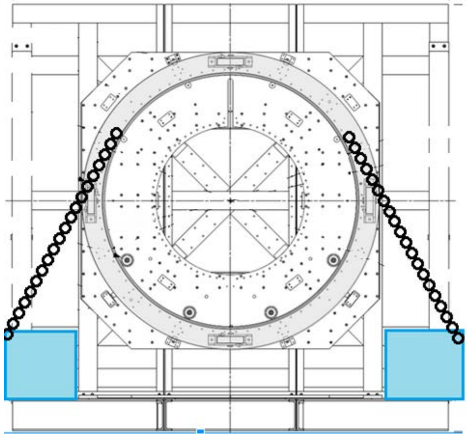
Concept Generation











Design Considerations

- Safety
- Minimal modifications
- Space requirements
- User friendly
- Easy to manufacture
- Easy to install
- Portability
- Cost
- Easy to maintain

Sample Decision Matrices

	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

Sample Decision Matrices

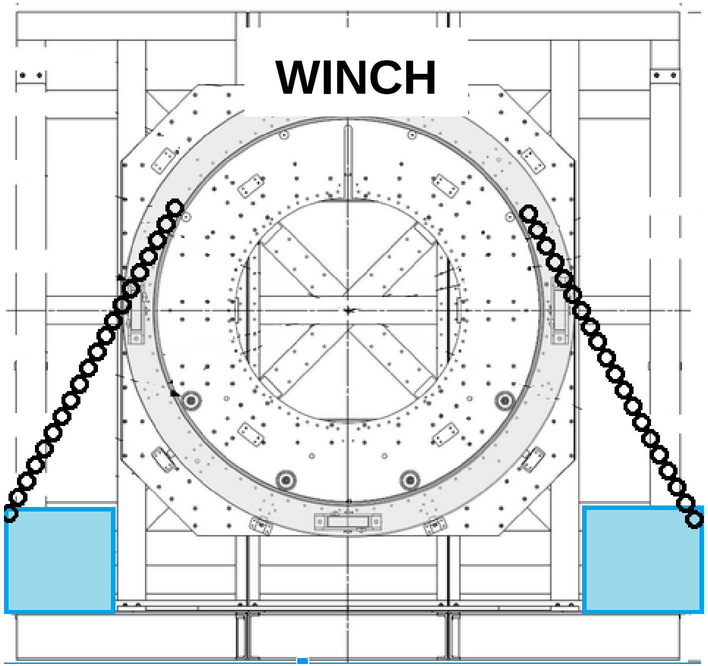
			1	2	3	4	5	6	7	8	9	10
		Weight	Chain	Winch	Exterior Wheels	Interior Wheels	Gears	Sandwich Wheels	Rope Belt	Piston	Bowling Ball Return	Worm Gears-On Ring
Design Requirements	**Minimal Modifications**	25	2	5	8	8	4	7	6	6	6	5
	Low Cost	5	4	4	7	7	6	7	6	2	5	5
	Easy Manufacture	15	2	5	7	7	5	6	5	4	3	6
	Easy Integration	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 Maintenance	15	3	4	7	7	6	6	4	6	4	6
	Total	100	295	490	695	695	495	650	535	460	430	560
	Ranking		10	7	**1**	**2**	6	**3**	5	8	9	4

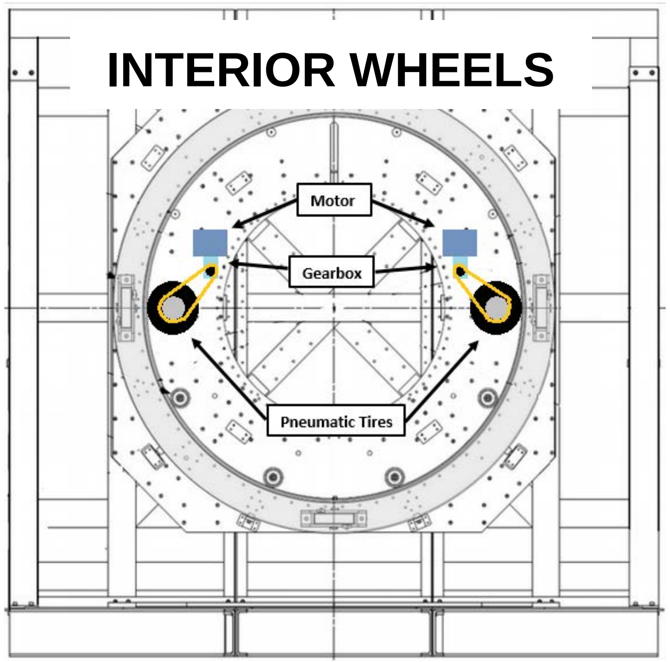
Decision Matrix Results

- Each matrix completed individually with team members having no knowledge of teammate results
- Each matrix had a different priority (i.e. weight associated with parameters)
    - Safety, Cost, Modifications, Space, Maintenance
- Standout designs:
    - **Interior Wheels** (Average Ranking: 1.4)
    - **Winch** (Average Ranking: 3.6)
    - **Rope Belt** (Average Ranking: 4.6)

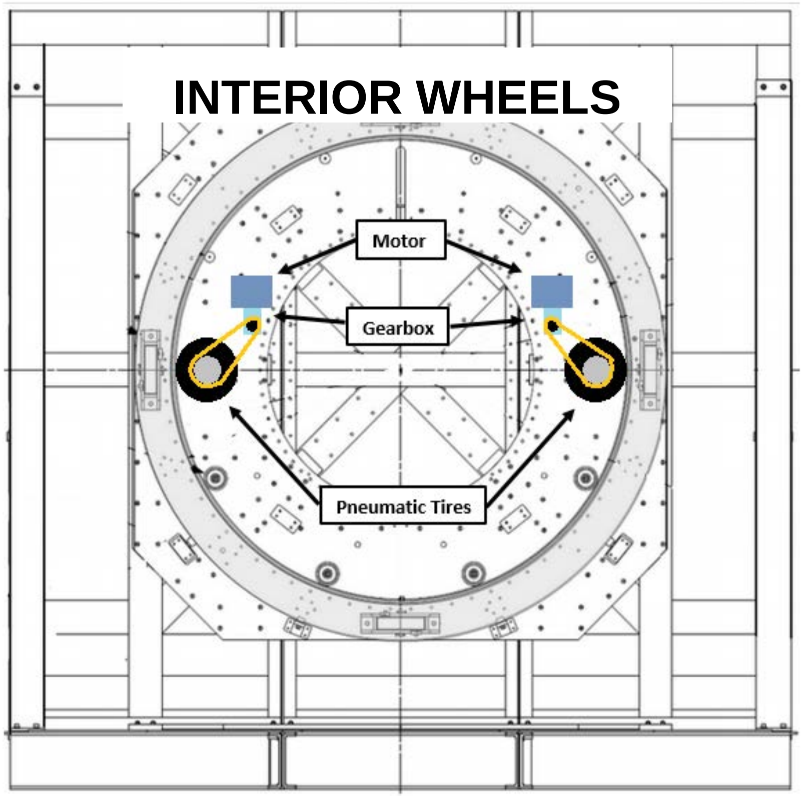
Final Design Selection

- **November 2014**: Came down to two concepts in presentation to Orbital





Orbital Selection

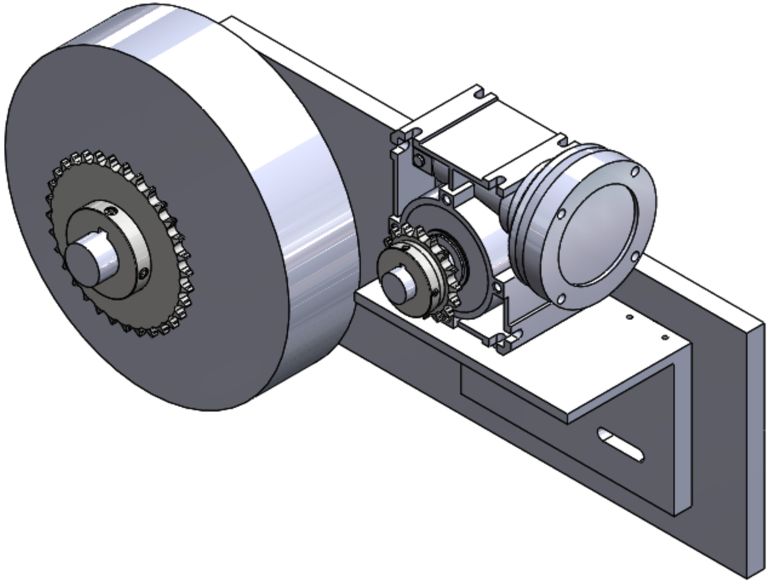


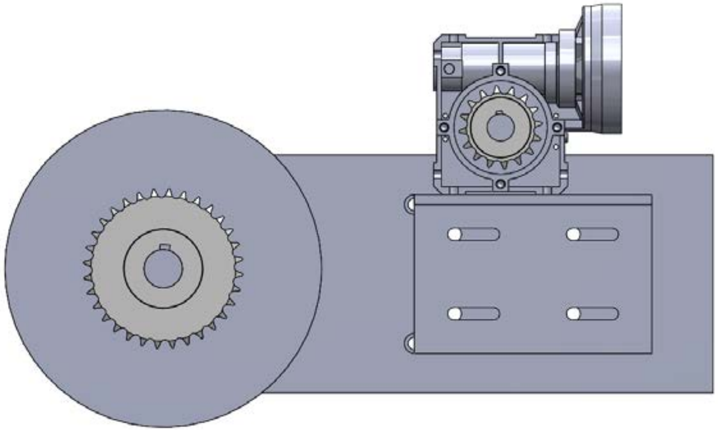
Orbital comments:

- Fits well with overall design of existing structure
- Aesthetically pleasing
- Does not require steel winch cables to be wrapped around ring
- No interference with surrounding parts or mechanisms

FINAL DESIGN

Final Design Overview

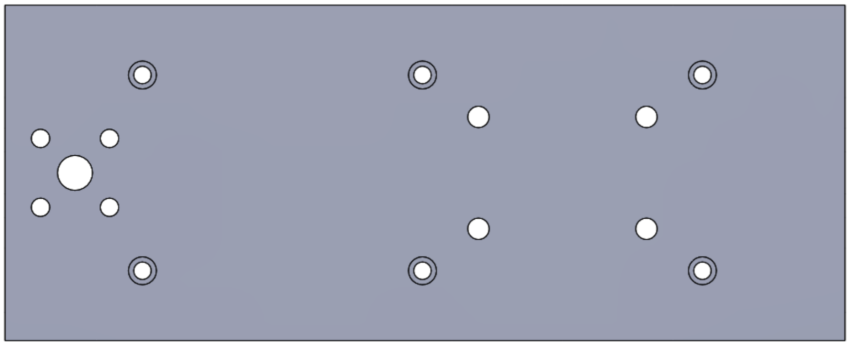


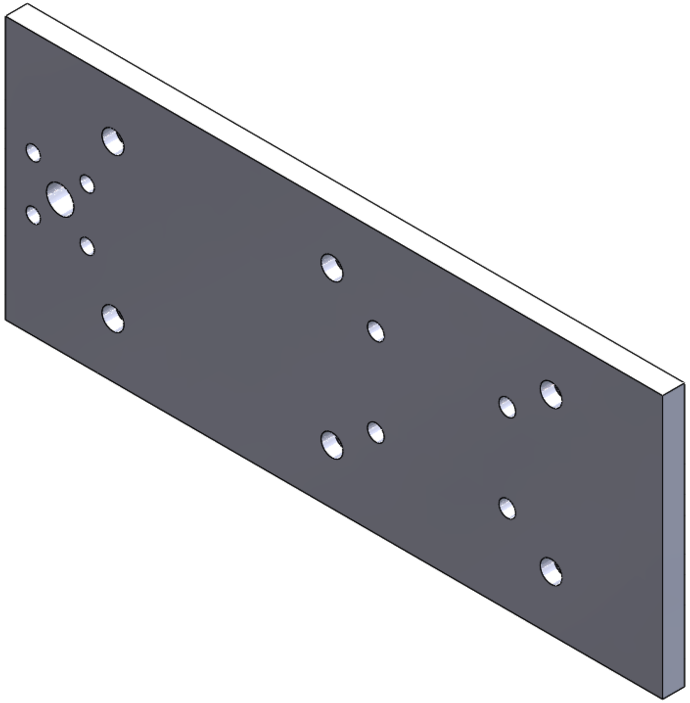


Design’s Three Main Components

- Adapter Plate
- Gearbox Mount
- Spindle Assembly

Adapter Plate



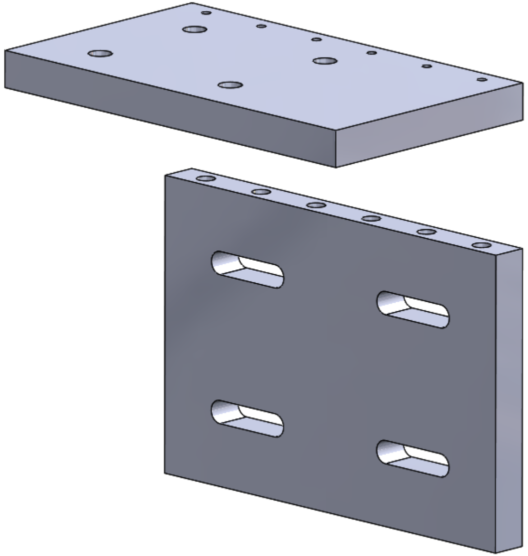


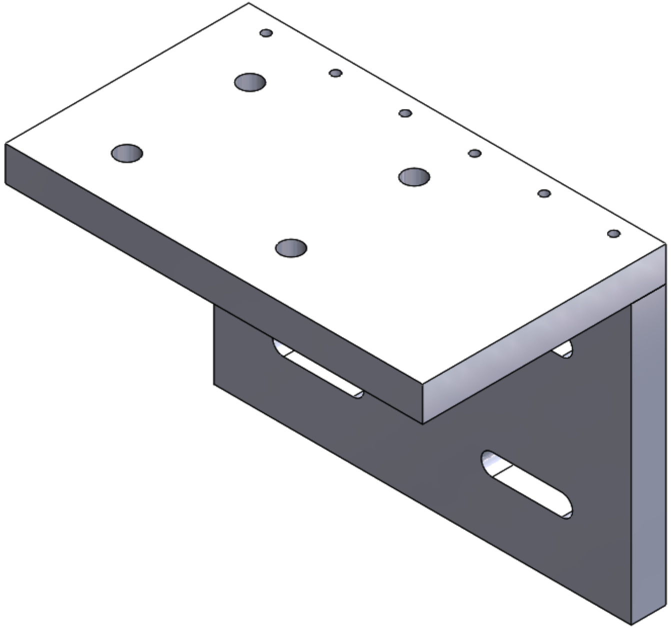
Adapter Plate

- **Purpose**: Foundation for final design that allows modular installation with minimal modifications to existing test stand

- **How it works**: Adapter plate installs directly onto the test stand via a pre-existing bolt pattern and the design's other components install directly onto the adapter plate.

Gearbox Mount



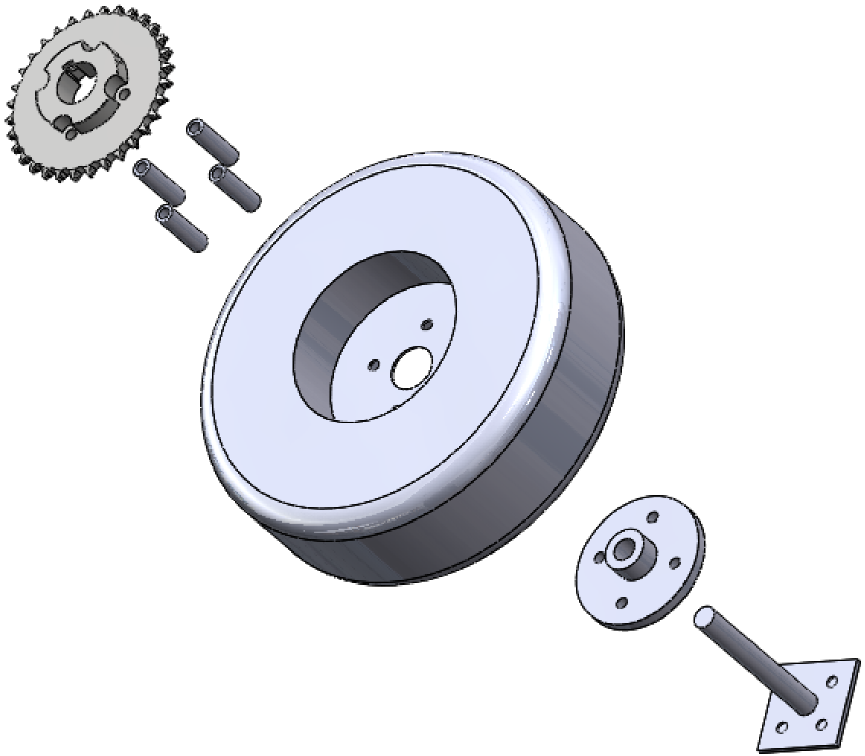


Gearbox Mount

- **Purpose**: Mounting structure for gearbox and motor assembly

- **How it works**: Two separately manufactured plates form an “L-bracket” with the gearbox mounting directly on top. The mount installs directly into the adapter plate.

Spindle Assembly



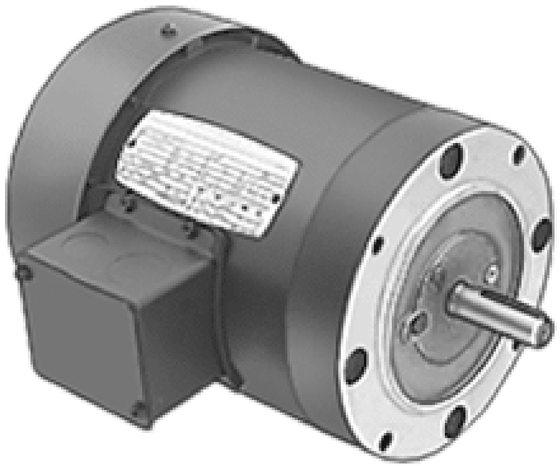
Spindle Assembly

- **Purpose**: Means of attaching wheel and sprocket to adapter plate

- **How it works**: A wheel hub slides over the spindle allowing tire and sprocket attachment via the hub’s four studs.

Motor

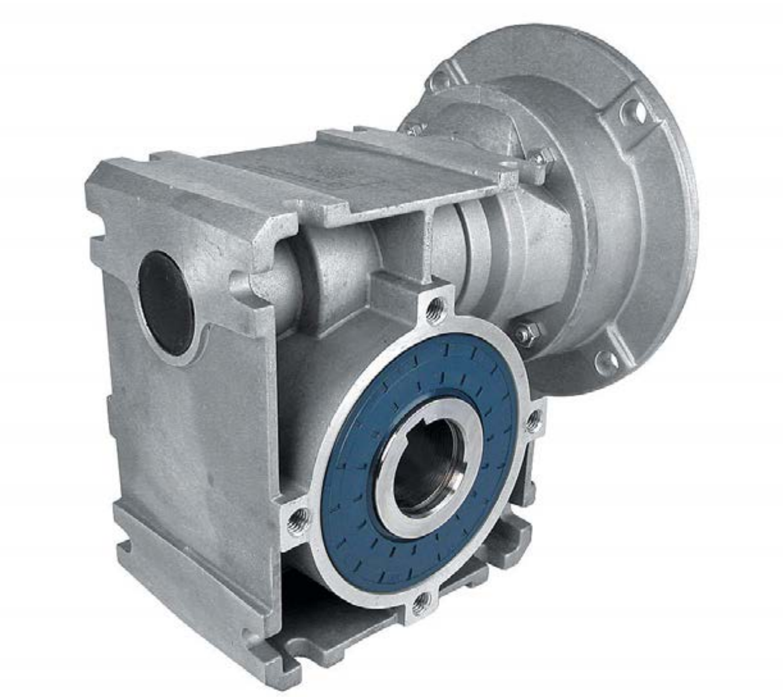
- McMaster-Carr
- 3/4 Hp
- 1725 RPM
- Steel Housing
- Motor can be mounted directly to equipment
- Heavy duty applications with high starting RPM



Credit: Mcmaster.com

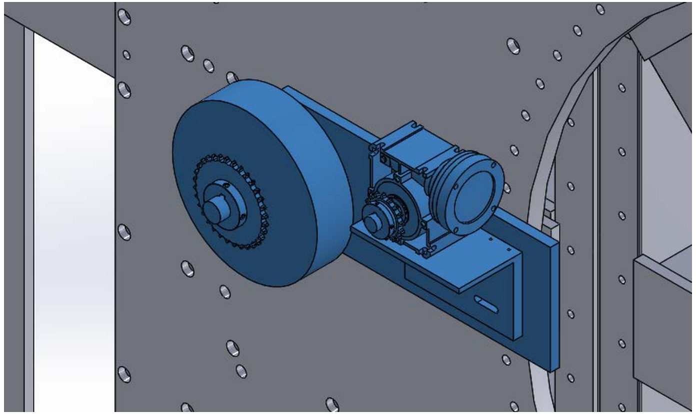
Speed Reducer

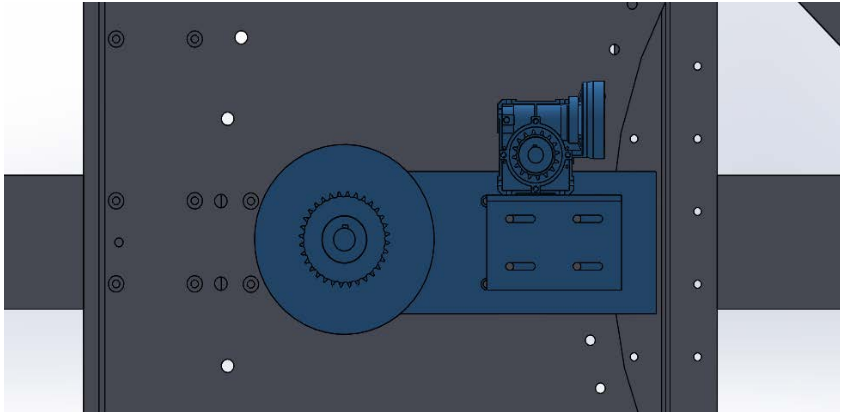
- Grainger
- 1 Stage - Reversible
- Nominal Output RPM - 18
- Max Torque - 1655 lb-in
- Aluminum housing
- Bronze alloy worm gear
- Hardened alloy steel worm pinion gear



Credit: Grainger.com

Final Design





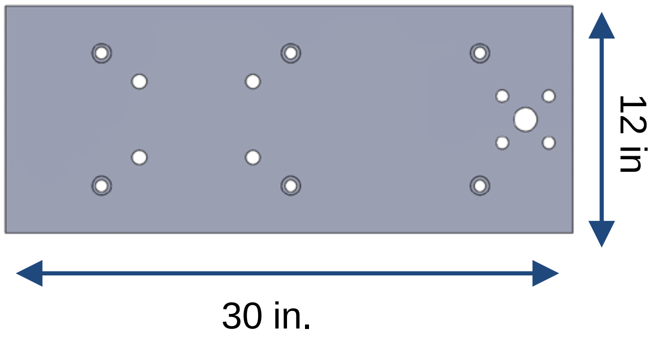
MANUFACTURING

Manufacturing Overview

- We have shown you what we planned to do. Now we are going to show you how we did it.

- Go back to the three main components
  - Adapter Plate
  - Gearbox Mount
  - Spindle Assembly

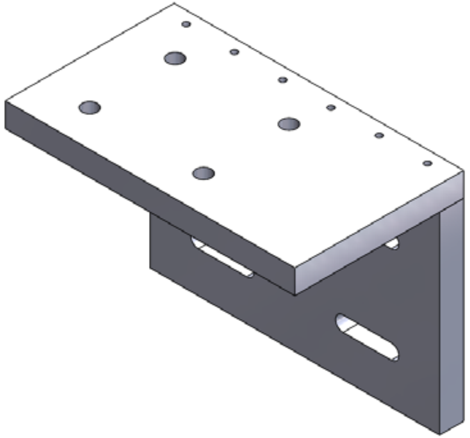
Adapter Plate



Adapter Plate

- **Material**: 6061 Aluminum
- **Dimensions**: 12 x 30 x 1 in
- **Manufacturing Process**
  - Machined using a manual mill for accurate hole placement
  - Used various sizes of drill bits and end mill to get holes and counterbores
  - For threaded inserts, holes were tapped for easier and secure installation

Gearbox Mount

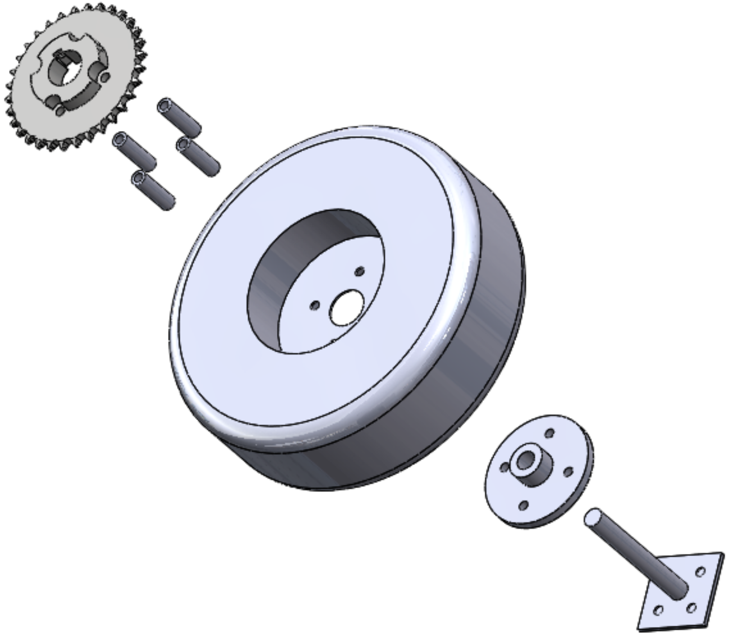


Nick Garcia

Gearbox Mount

- **Material**: 6061 Aluminum
- **Dimensions**
  - Slotted Vertical Plate: 8 x 13 x 1 in
  - Horizontal Plate: 7 x 13 x 1 in
- **Manufacturing Process**
  - Machined with a manual mill
  - Slots in vertical plate also using manual mill
  - Six threaded inserts along top of vertical plate

Spindle Assembly

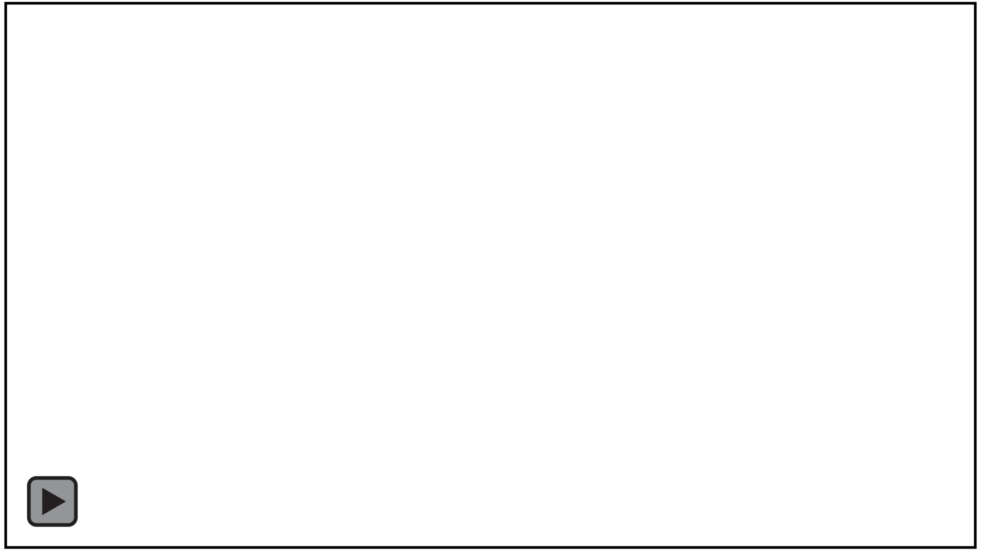


Nick Garcia

Spindle Assembly

- **Manufacturing Process**
  - Spindle welded to a steel plate for attachment to adapter plate
  - Hub studs punched out using hole press
  - Spacers/Offsets manufactured out of steel
  - Hub assembled with bearings
  - Sprocket boring via Haas

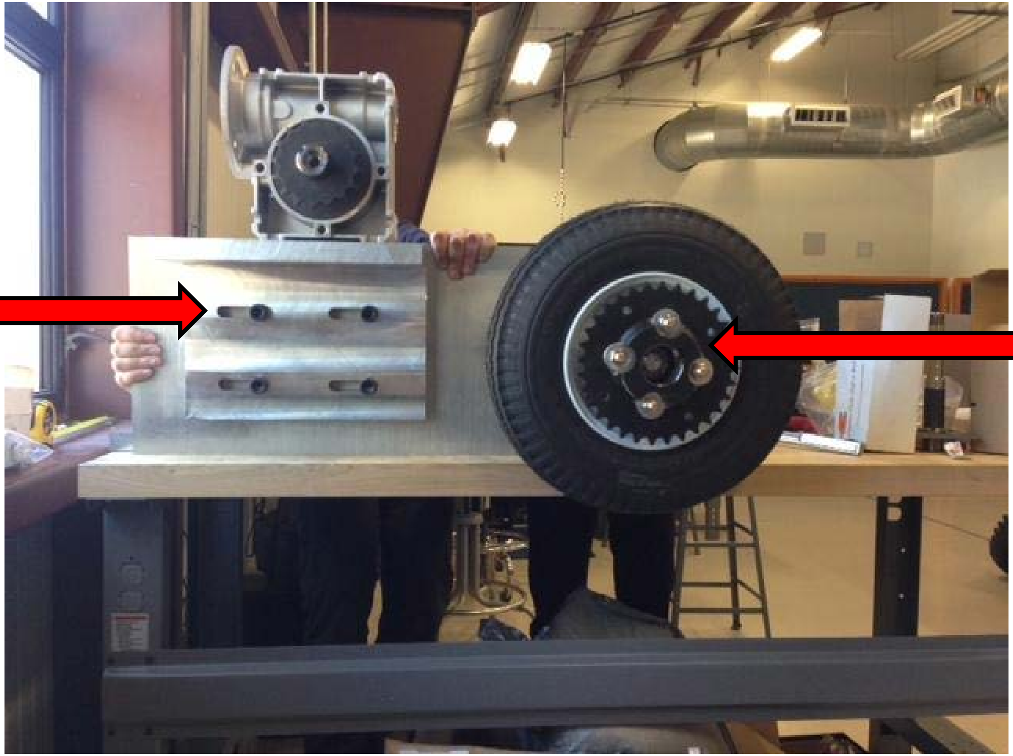
Sprocket Boring



Video: One of the 32-tooth sprockets being bored out inside the Haas machine

Two Notable Design Features

Slotted plates for chain tensioning



Sprocket boring for attachment to hub and tire

Threaded Inserts

- **Purpose**: Add strength to holes; prevent cross threading

- **Used In**: Adapter plate, Vertical plate

- **How it works**: Thread lock (red resin) activates when in contact with a metal
  - External threads screw into aluminum
  - Internal threads hold steel bolts

Nick Garcia

IMPLEMENTATION

Implementation Overview

- **Integration**
  - Initial installation process was about 2 hours, but the process could be optimized to about 15 minutes
  - This is more a credit to highly-skilled Orbital ATK technicians than our design, but our design also facilitates easy installation
- **Testing**
  - Testing on April 21-22, 2015
- **Budget**
  - Overall Cost Analysis of project

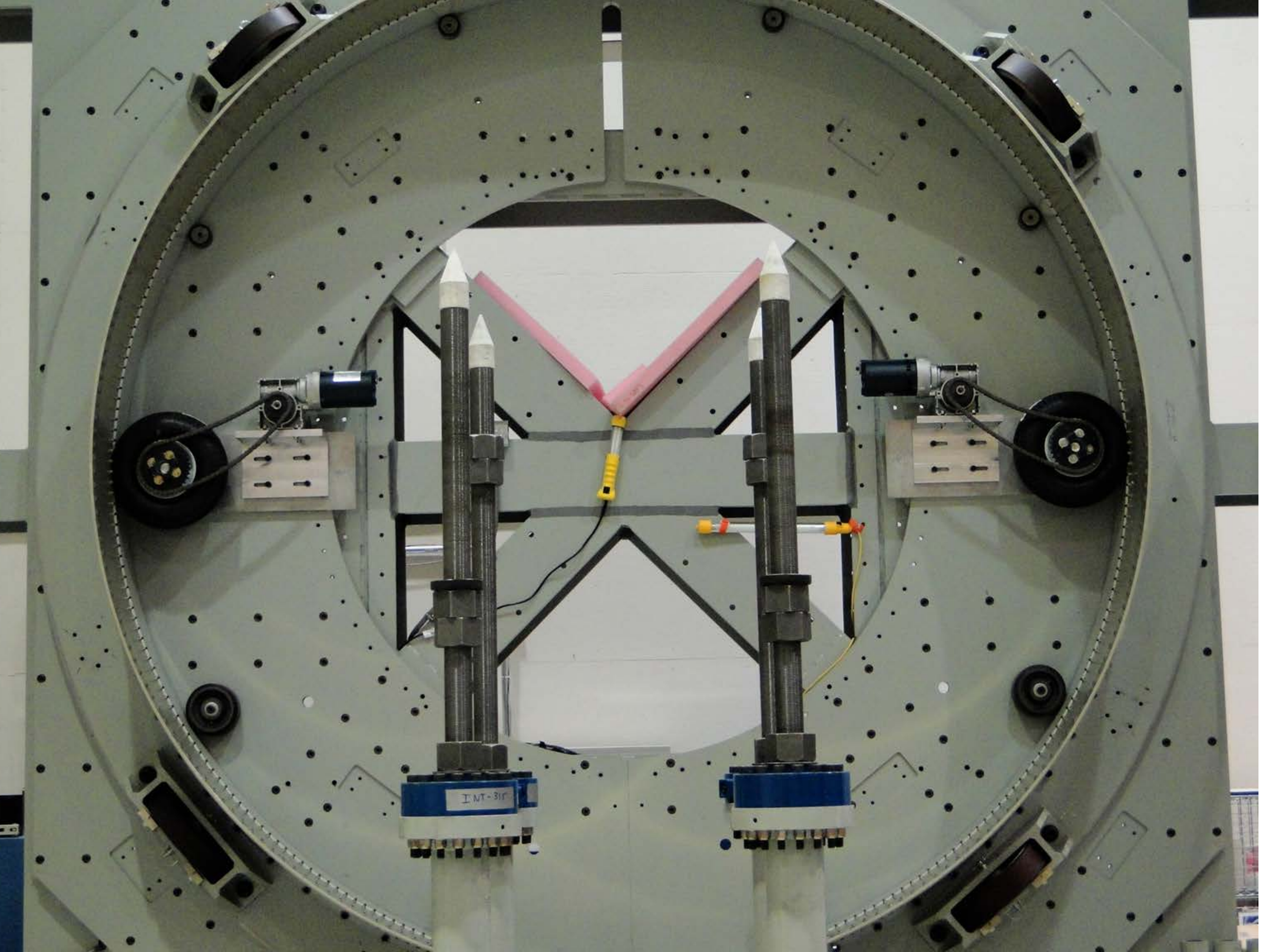


Figure: Front view showing two identical designs in the horizontal centerline of the test stand

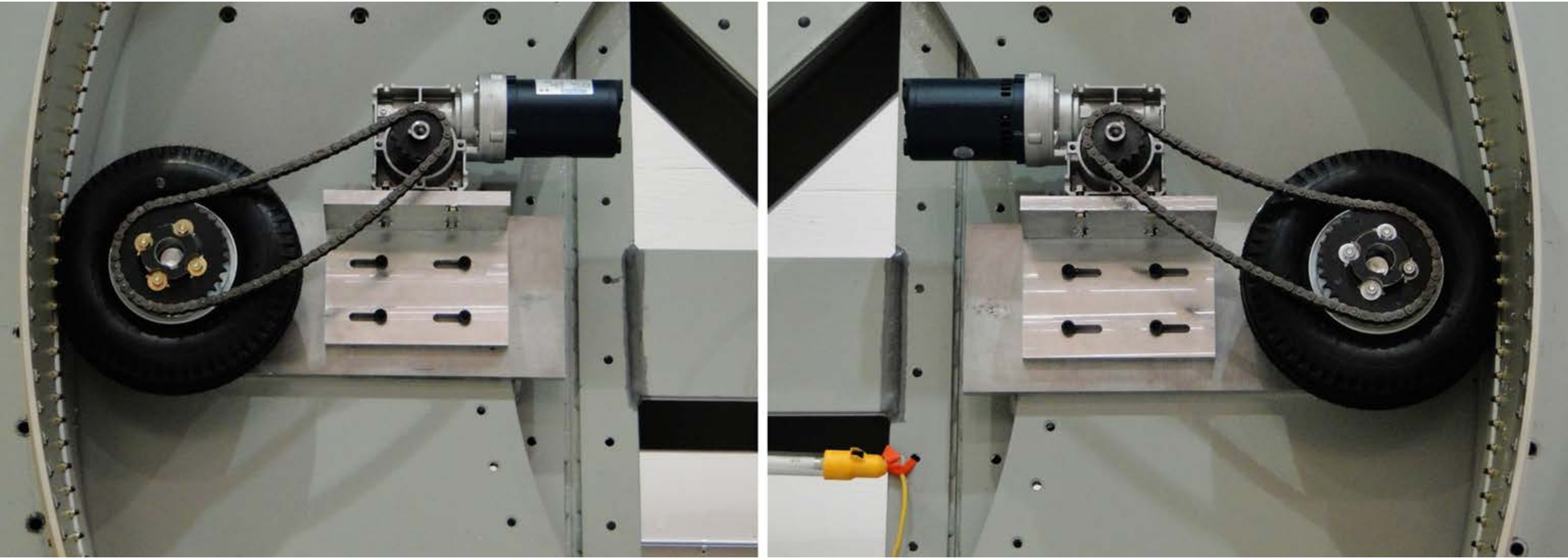
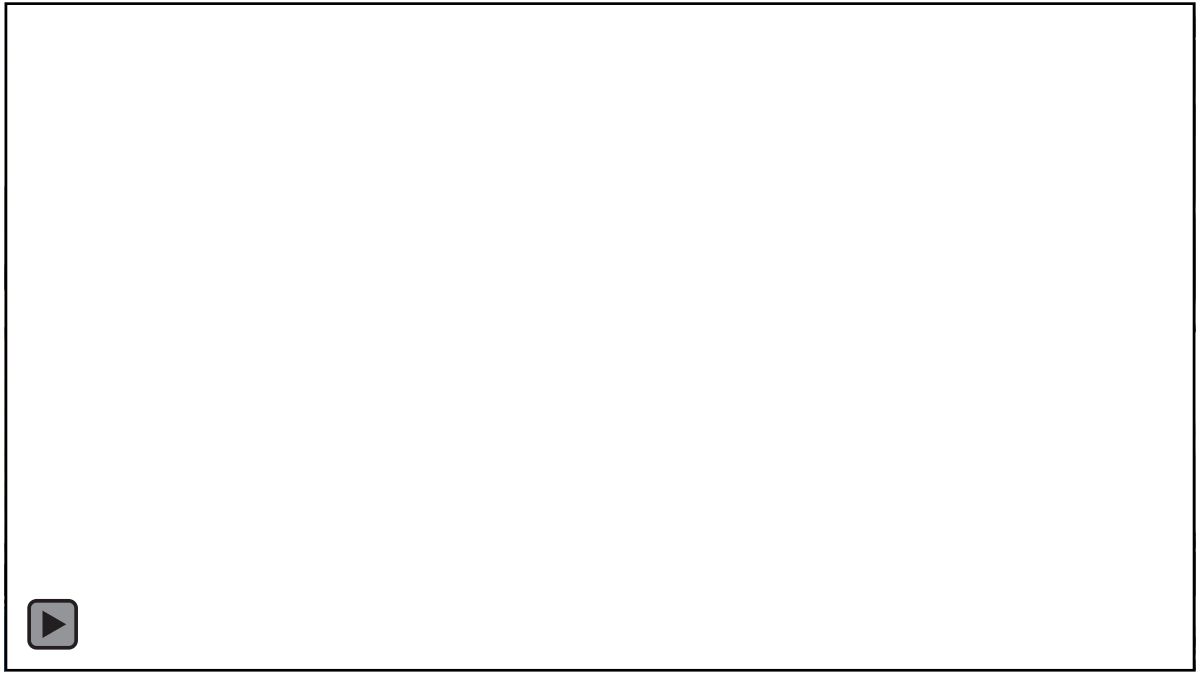


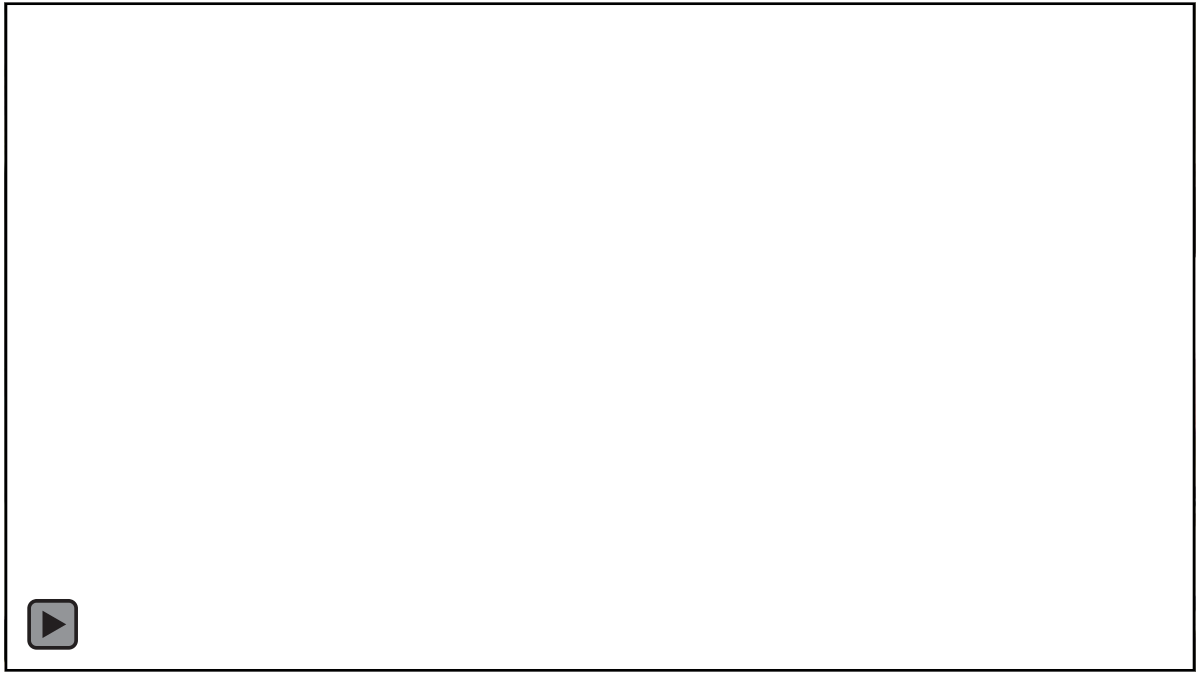
Figure: Close up view of right and left assemblies of final design, post-installation, on the test stand. Electric motor inputs directly into the gearbox and the two sprockets are connected via a roller chain. Note the contact friction between the tires and test stand.

Testing



Video: Both halves of the design working in tandem to rotate the ring

Testing



Video: Left half demonstrating the +/- capability of the design

Budget Overview

Description	Distributor	Part No.	Cost	Quantity	Line Total
Motor	McMaster-Carr	6135K77	267.18	2	534.36
Speed Reducer	Grainger	29TL65	1013.00	2	2026.00
Roller Chain	McMaster-Carr	6261K176	38.90	2	77.80
16 T Sprocket	McMaster-Carr	6280K479	37.03	2	74.06
32 T Sprocket	McMaster-Carr	6236K472	80.13	2	160.26
Trailer Wheel	McMaster-Carr	2181T31	35.78	2	71.56
Spindle-Backing-Wheel Hub	P&M Trailers	-	50.42	2	100.84
Threaded Insert, 3/8"-16 x 1"	McMaster-Carr	90248A032	12.60	8	100.80
Threaded Insert, 5/8"-18 x 11/16"	McMaster-Carr	90248A087	9.88	2	19.76
Threaded Insert, 1/2"-20 x 21/32"	McMaster-Carr	90248A086	7.88	2	15.76
Cap Screw, 1/2"-20 x 1-1/4"	McMaster-Carr	90128A842	7.26	2	14.52
Cap Screw, 5/8"-18 x 2"	McMaster-Carr	91251A402	10.54	2	21.08
Cap Screw, 1/2"-20 x 5"	Copper State	03CSFY-0500500	1.44	8	11.52
Standoff 2-3/4"	NAU Shop Stock	-	0.81	8	6.48
Bearing Grease	P&M Trailers	-	11.71	1	11.71

Total Project Cost:	$ 3,246.51
Total NAU Cost:	$ 936.15*

*Accounts for $250 in gas for trips to Orbital ATK from Flagstaff, Arizona

James Ellis

Conclusion

- **Project:** Worked as a senior design team on a project for Orbital ATK
- **Project Goal**: Design a safe, reliable, and operational system that allows for motorized rotation of launch vehicles when on the horizontal test stand
- **Final Design Concept**: Two interior wheels driving the rotating ring via a motor and gearbox mounted on a detachable adapter plate
- **Total Cost**: Orbital ATK - $3,246.51; Our Budget - $936.15
- **Objectives Met**: Minimize cost ($63.85 under budget); Minimize space requirements of design; Limit modifications to test stand

James Ellis

Acknowledgements

- Steve Hengl, Orbital
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- Roger Cundick, IMS Steel
- Jason Jacob, Grainger
- Srinivas Kosaraju, NAU
- NAU Machine Shop

QUESTIONS?