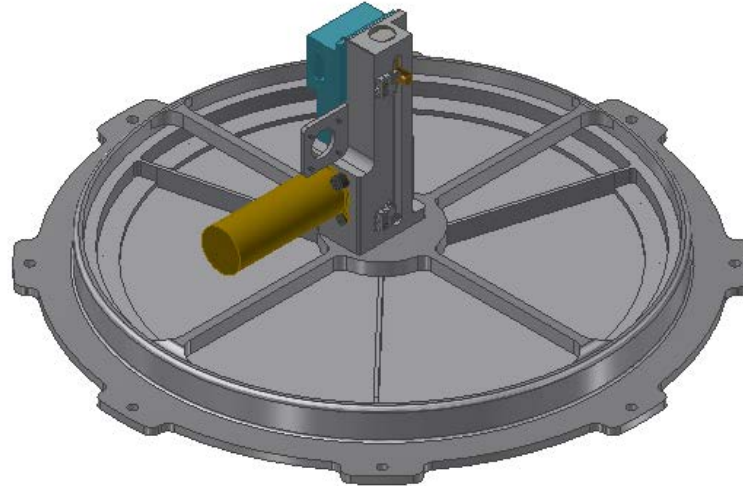




# Helium Valve Improvement



By: Lindsey Seo

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Wallops Flight Facility (WFF)

Code 548 Mechanical Systems Branch

Structures, Loads, and Mechanical Systems (SLaMS)



# Introduction



- Hometown
  - Salisbury, MD
- Graduated NC State (2017)
  - B.S. Aerospace Engineering
- NASA Journey
  - Internships
    - ❑ National Space Club Scholars (2009)
    - ❑ Science Technology Engineering Pipeline for Under-served Populations (Step Up) Internship (2010-2011)
    - ❑ NASA Sounding Rocket Operations Contract (NSROC) Internship (2012-2013)
  - Pathways Program (2014-2017)
  - PREP I- Aerothermal Heating
  - PREP II- Helium Balloon Valve Design



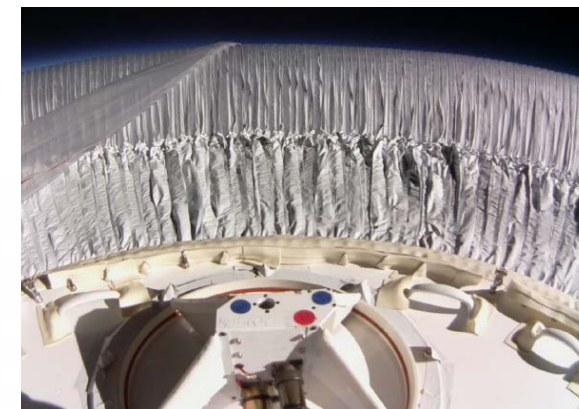
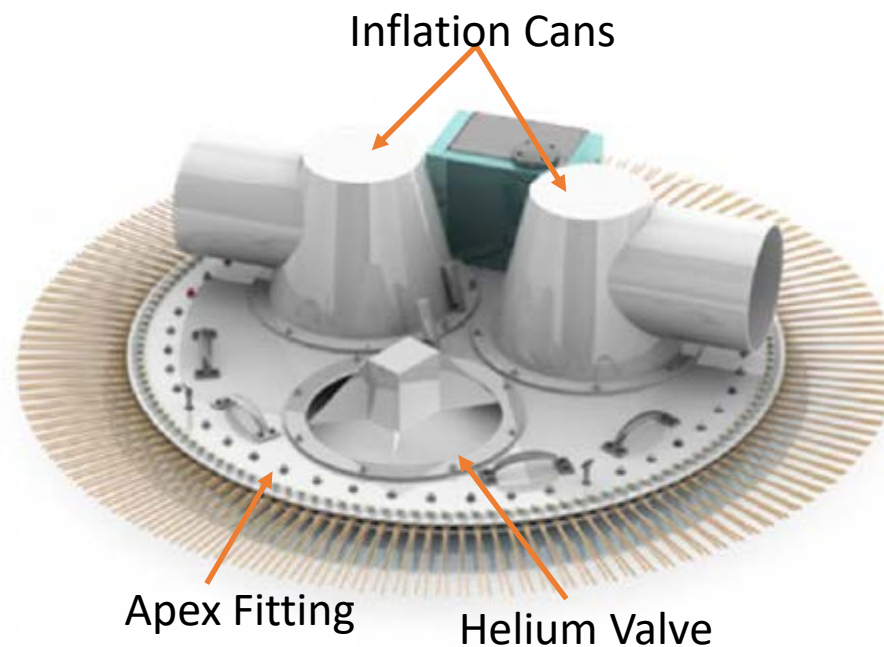
# Overview



- Background
- Objective
- Current Design
- Mechanical Design Change
- Analysis
- Forward Work
- Challenges & Lessons Learned



# Background



- Super Pressure Balloon (SPB)
  - Closed system, pressurized with excess gas to maintain altitude
  - Three valves on apex fitting
    - ❑ Two for inflation
    - ❑ One for venting
- Zero Pressure Balloon (ZPB)
  - Open system, more leak tolerant
  - One valve on apex fitting for venting



# Objective



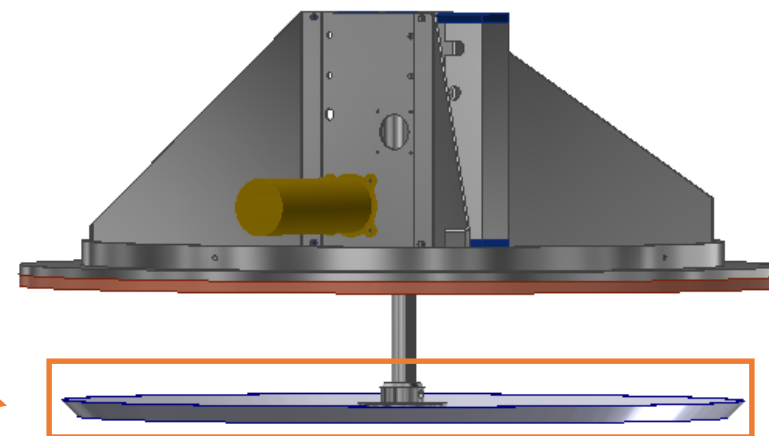
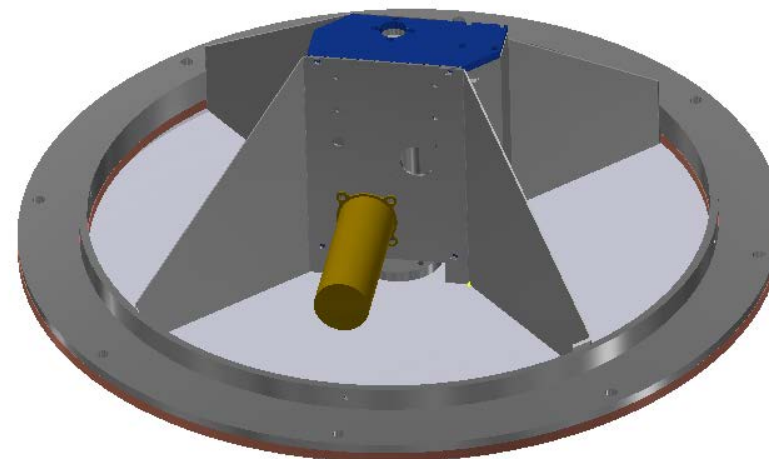
- The Engineering Review Team anomaly investigation of the April 24, 2017 SPB mission determined that the valve was a potential source of helium leakage.
- Tasks initially requested by Balloon Program Office (BPO):
  - Stiffen the valve plate to increase rigidity/stiffness.
  - Increase stiffness of the metal brackets supporting the motor/electronics.
  - Explore use of a silicon gasket.
  - Perform ground tests representative of flight environment.
- Additional requirements
  - Valve shall have the same bolt pattern as apex fitting.
  - Valve shall provide the same interface to the inflation cans.
  - Valve shall weigh 7lbs or less.



# Current Design

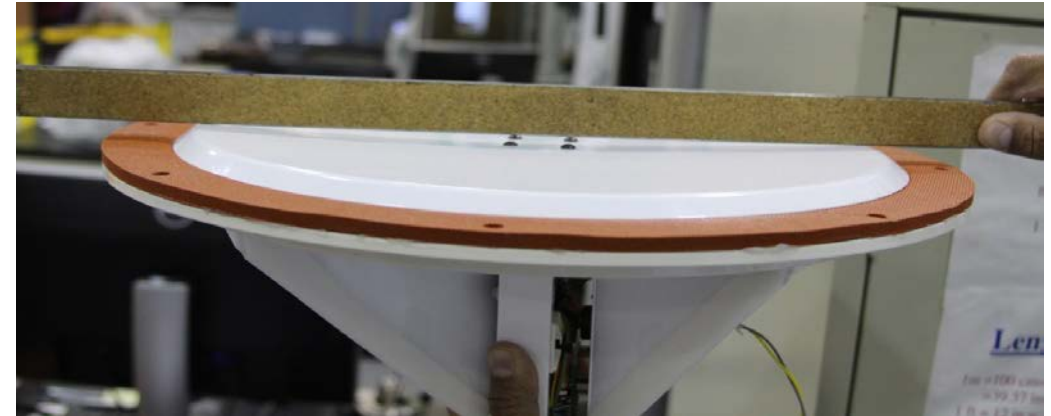
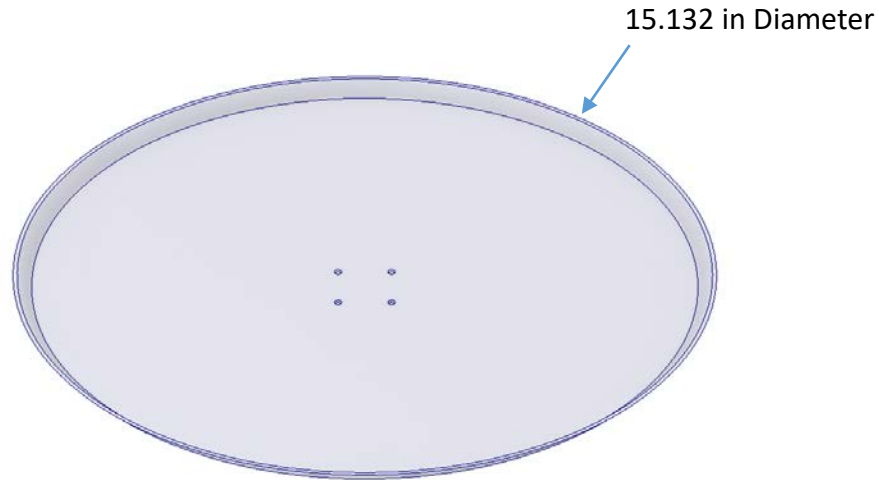


- Helium gas valves have been standard on large scientific balloon systems since the 1960's
- Design was mainly unchanged since the early 1990's and uses the following components:
  - Apex interface ring (6061-T6)
  - Modified Globe motor (24V)
  - Rack & pinion with open/close limit switches
  - Single gasket seal: closed cell silicone
  - Valve plate ("pie plate")
  - Electronics Housing
  - Sheet Metal Gussets (5052- H34)





# Current Design - Pie Plate

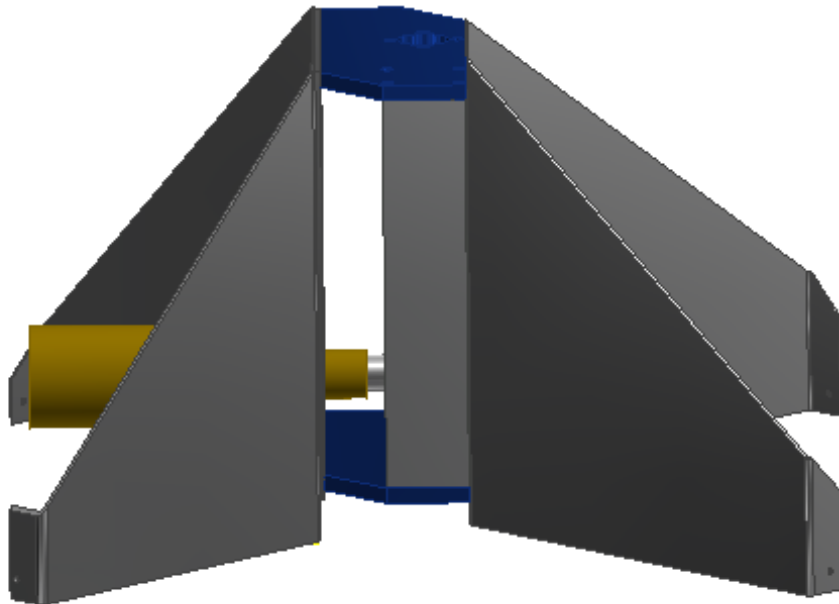


- Material: Al 5052-AHC
- Thickness: 0.0625 in.
- Design Concerns
  - When closing, the plate deflects and gaps at the edge, under the force from the motor
  - Holes are thru, which is a potential leak path





# Current Design - Gussets

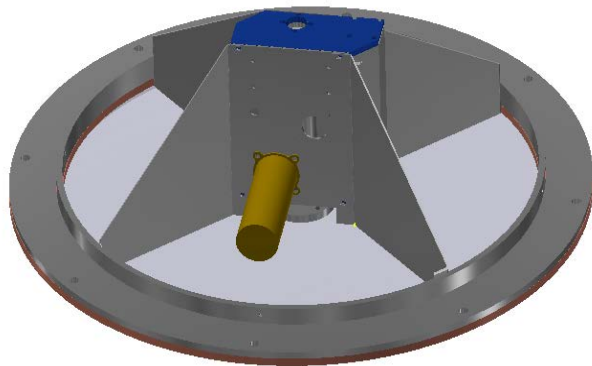


- Material: Al 5052-H34
- Thickness: 0.032"
- Design Concerns
  - Gussets aren't of a common design
  - Multiple components for assembly
  - Easily deflects under small amount of torque

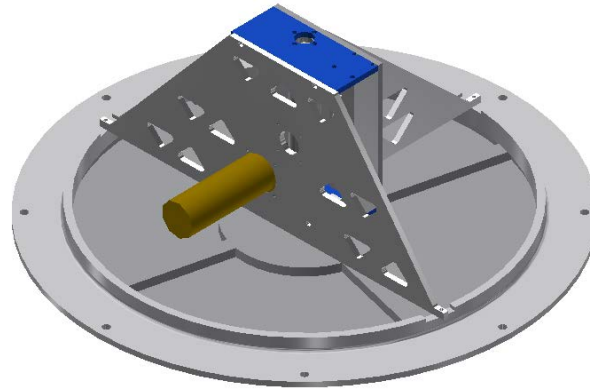




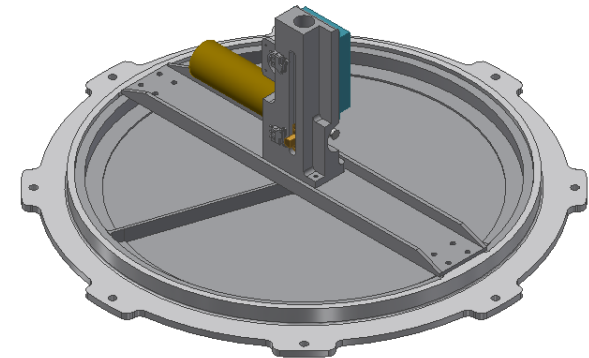
# Mechanical Design Changes



Existing  
Design



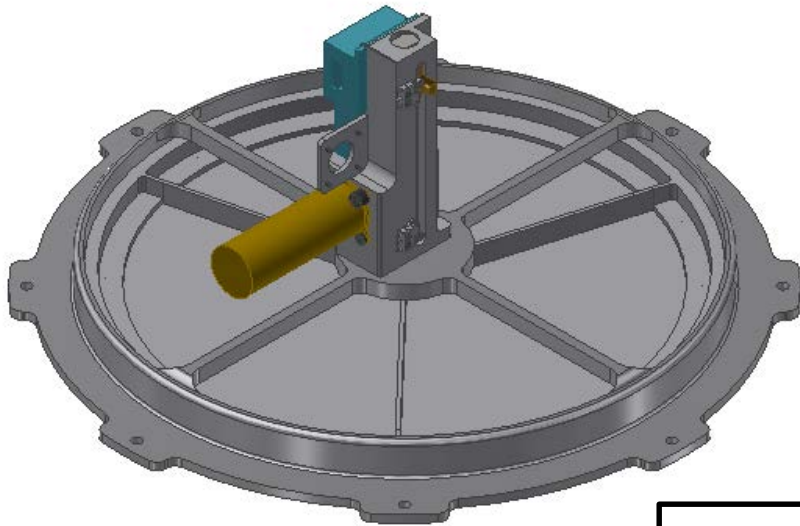
Design Review (Dec. 2018)



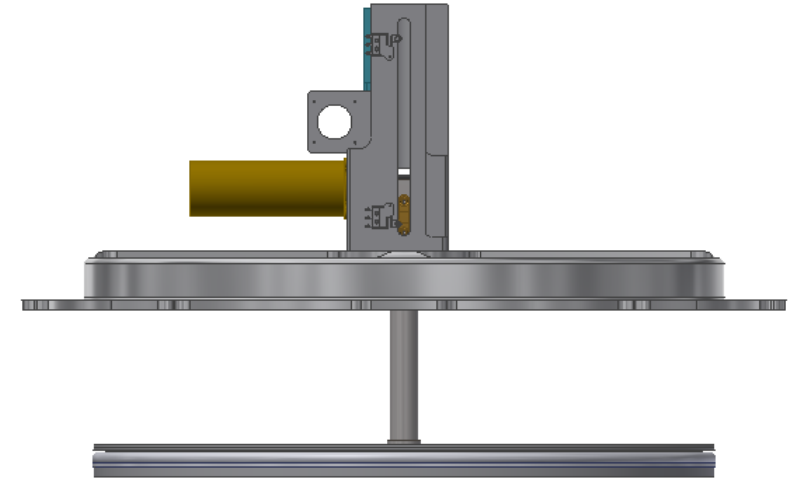
Delta Design  
Review (May 2019)



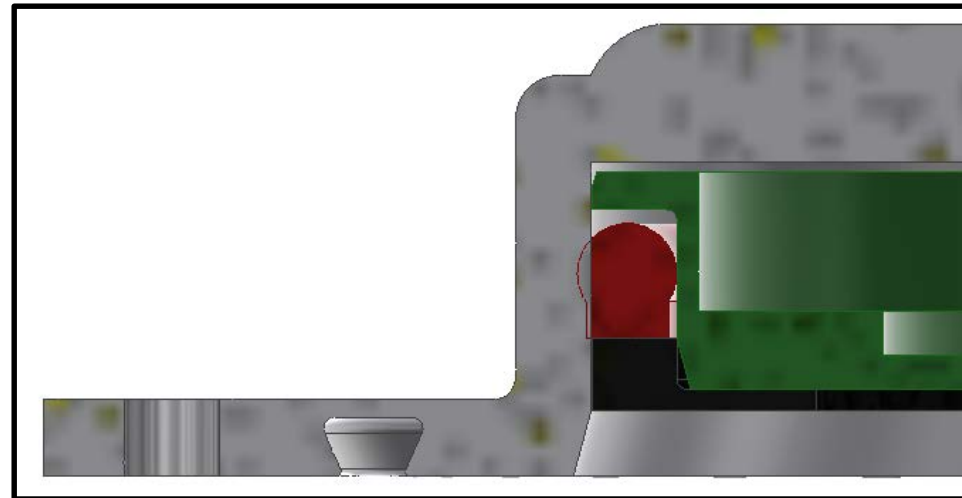
# Final Design



**Closed**



**Open**



**Section View**

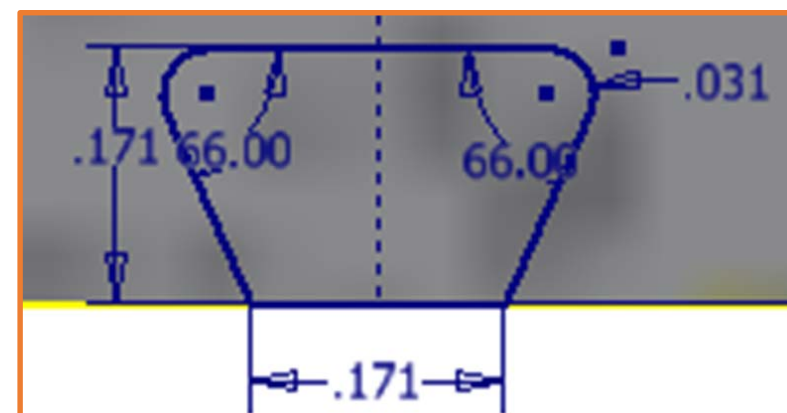
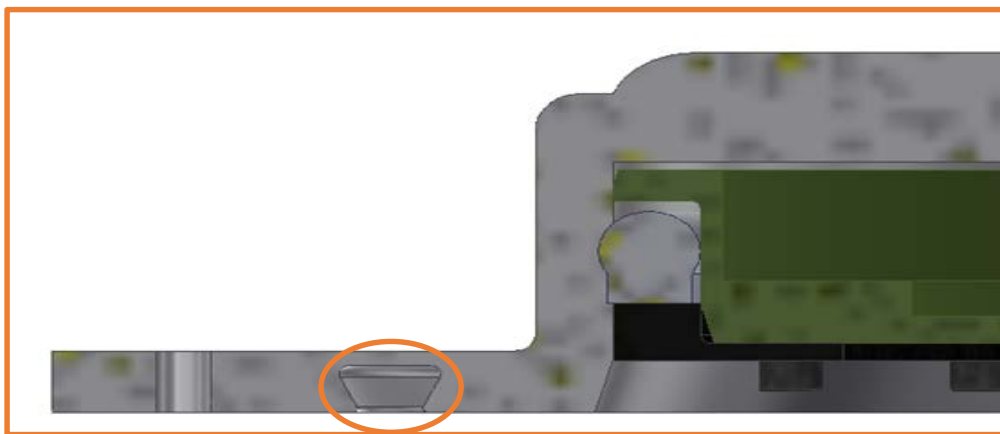
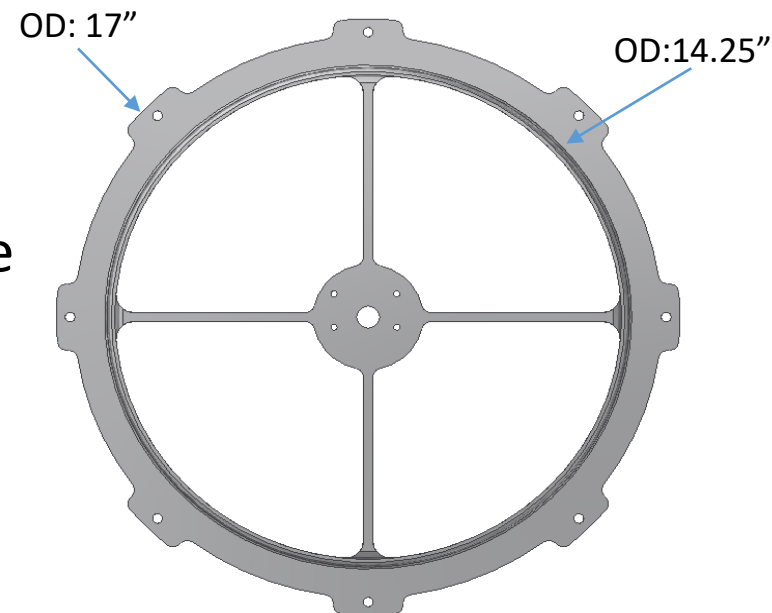


# Ring



## Changes from Original:

- Removed side mounting holes for gussets
- Ribs and a mounting surface for the electronics package
- Maintained outside diameter of ring for inflation cans and original mounting holes for apex plate
- Scalloped the outside diameter to reduce weight
- Dovetail O-ring groove to seal the flange: 0.188" width, silicone rubber



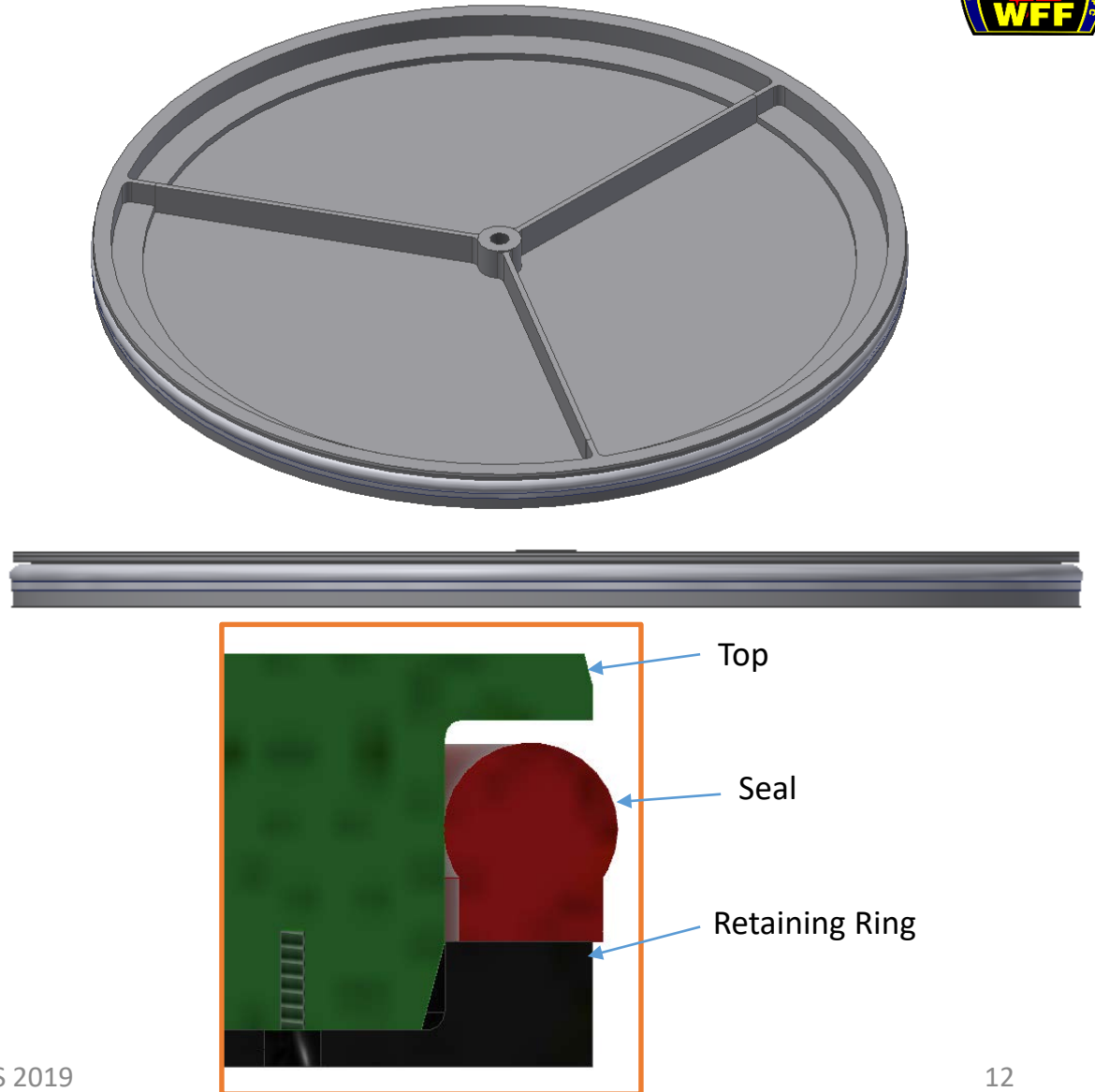


# Piston



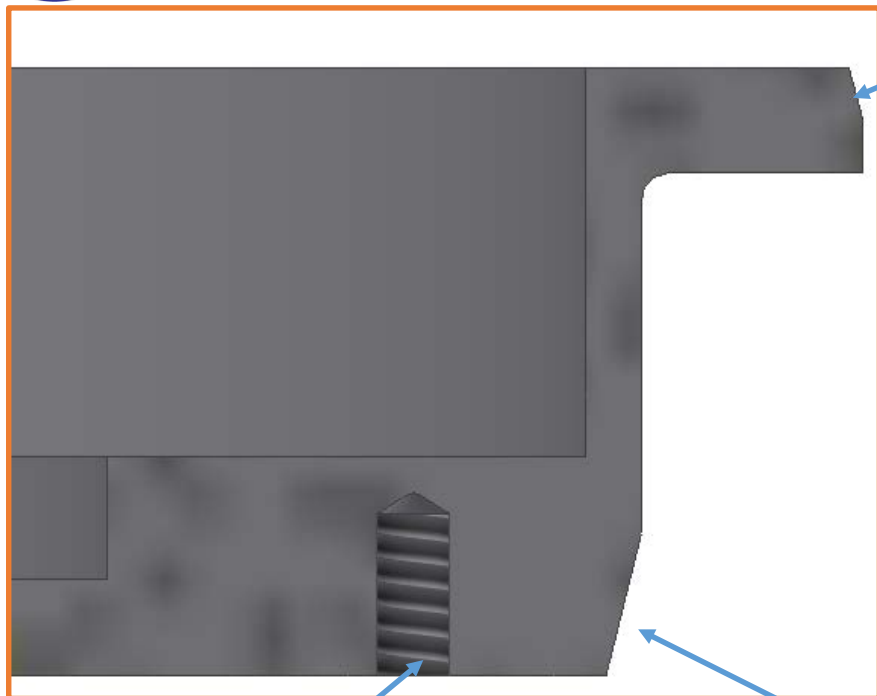
## Changes from Original:

- Material: Al 6061-T6
- Three-piece piston assembly
  - Top plate
  - Retaining ring
  - Seal: Spring-energized seal by Marco Rubber
    - ❑ Forms seal between piston and bore.





# Piston Top Plate



Chamfer for guiding piston into valve ring bore to seal

- Material: Al 6061-T6
- Designed features for ring and top plate according to Marco Rubber design guide
- Designed for weight savings and stiffness
- Threaded center hole with thick wall to provide stability to gear rack
- All holes are blind to minimize leak paths

16 #4-40 threaded holes for retainer ring

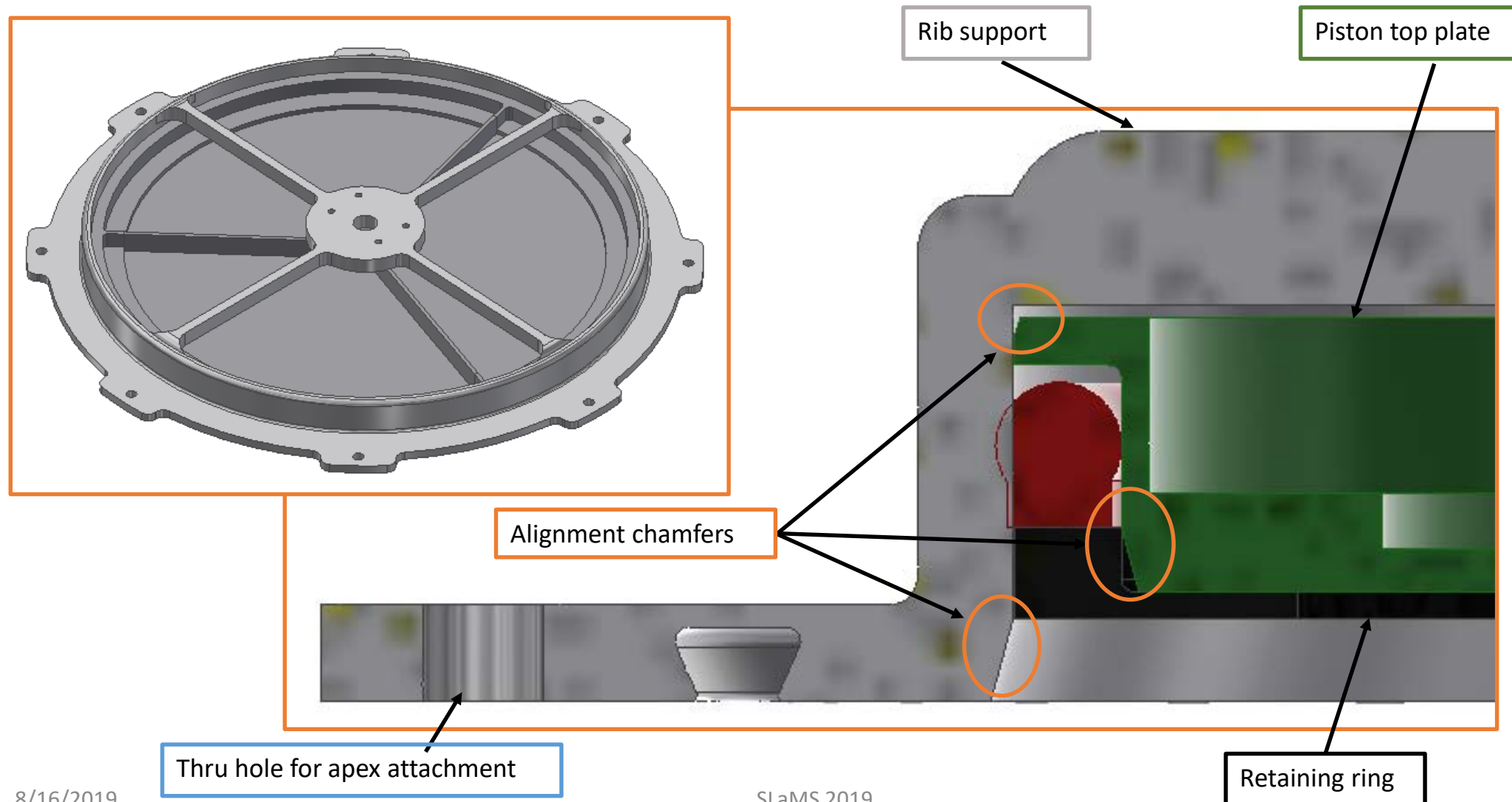
Chamfer for spring seal

3/8 - 24 Hole Thread



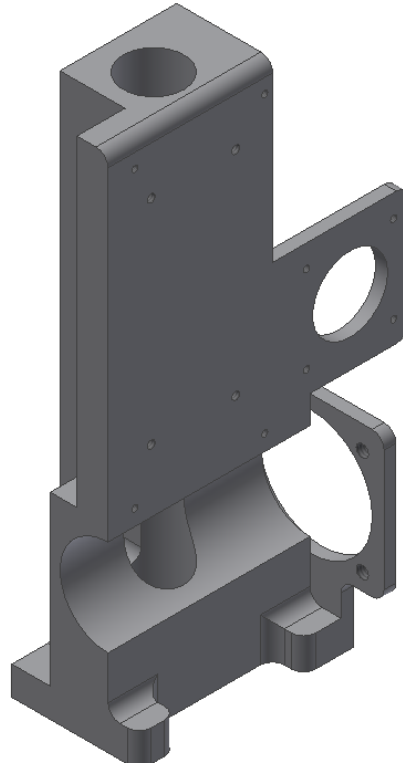
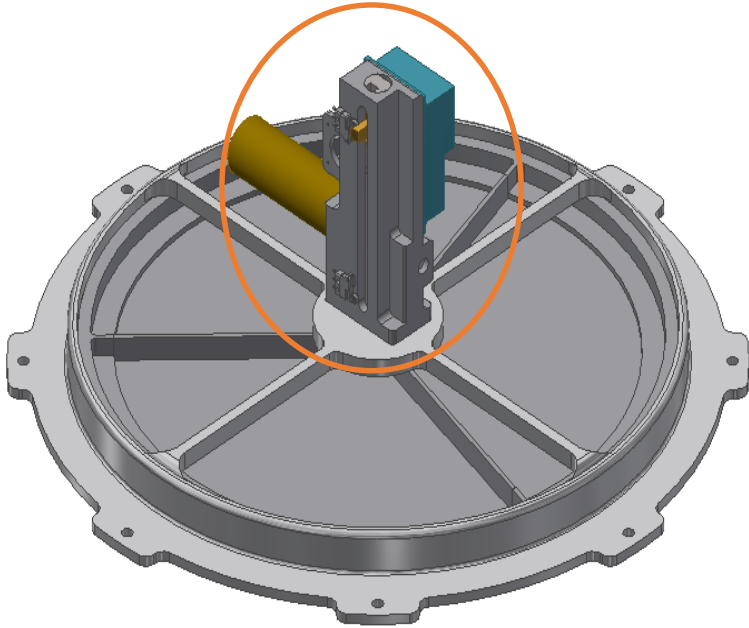


# Assembly Overview with New Parts





# Electronics Mount

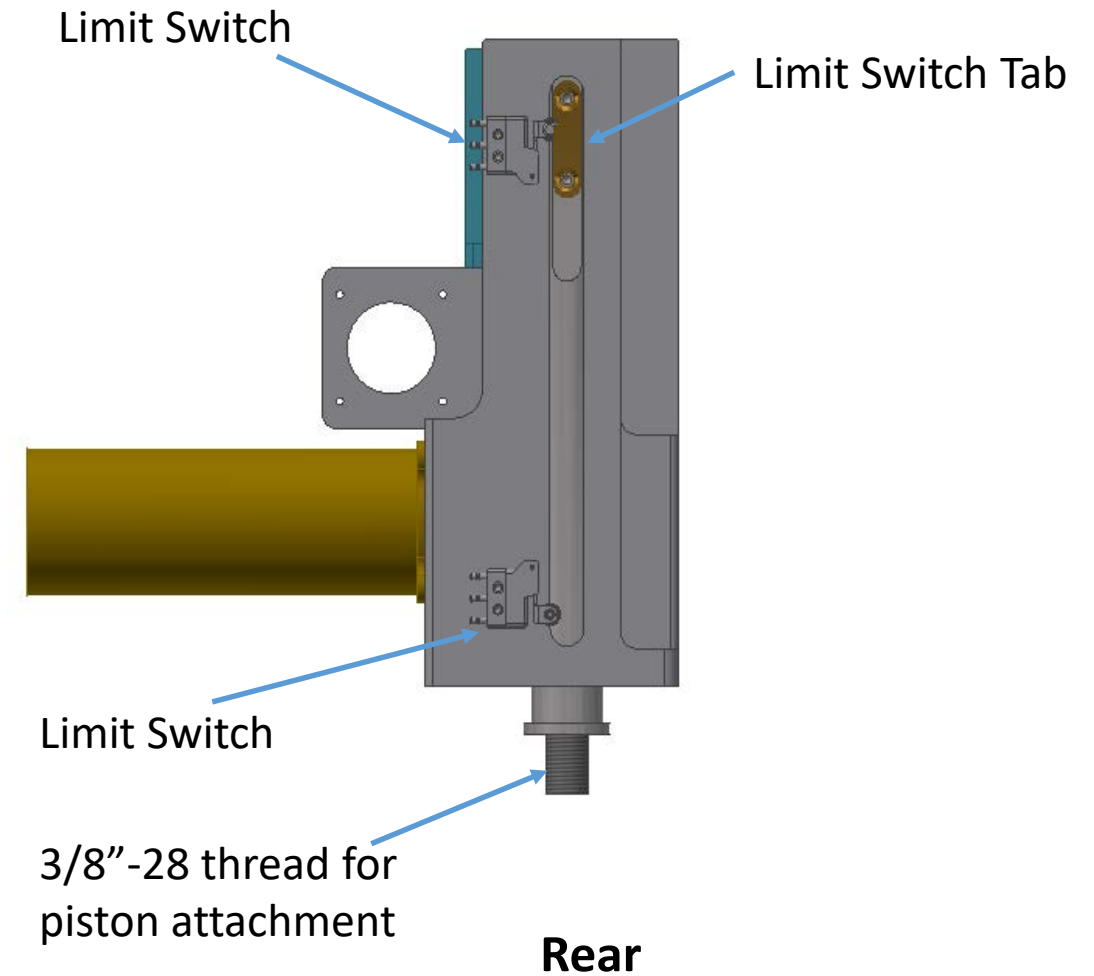
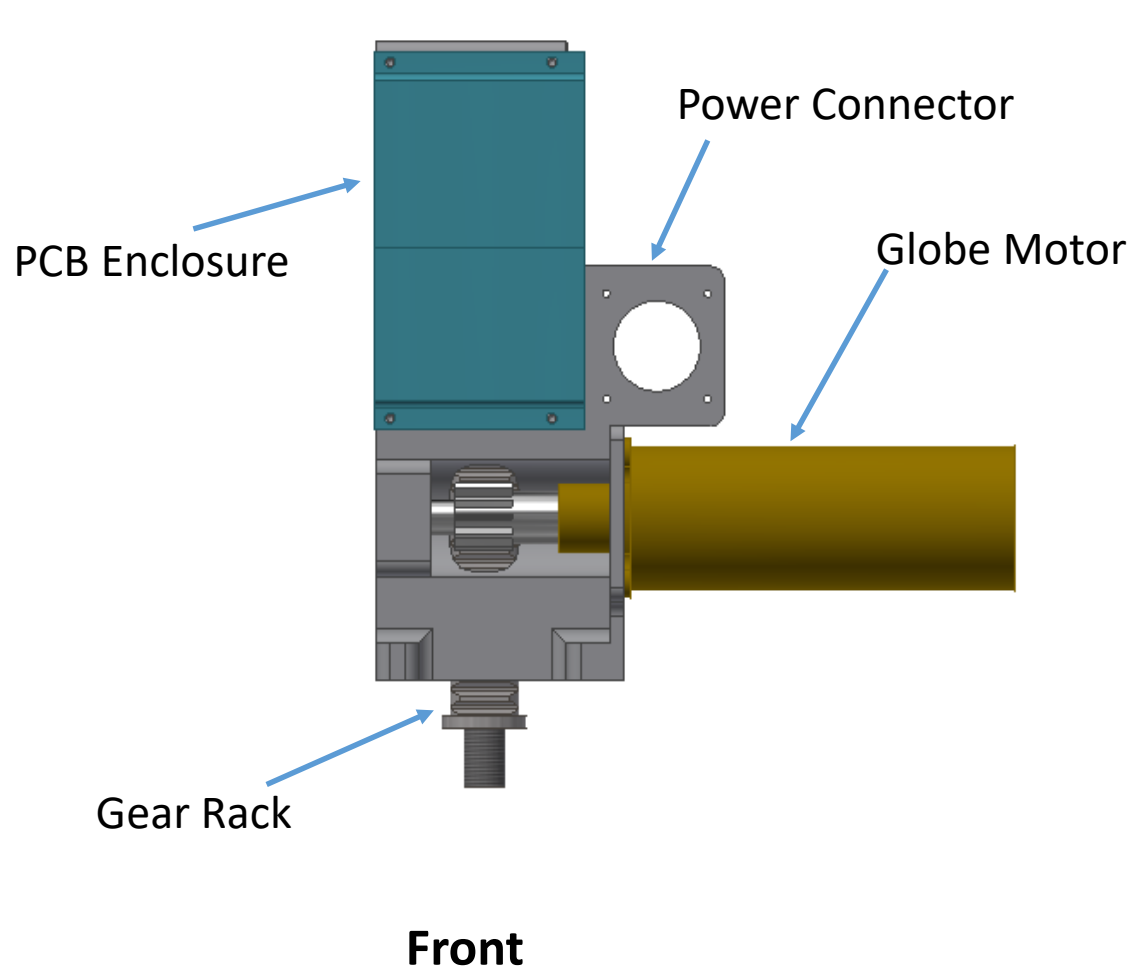


- Not in the original design
- Provides interface for the electronics and motor package
- Material: Al 6061-T6
- Custom design
- Height: 5.40", width: 3.13", depth: 1.77"





# Electronics Mount Continued

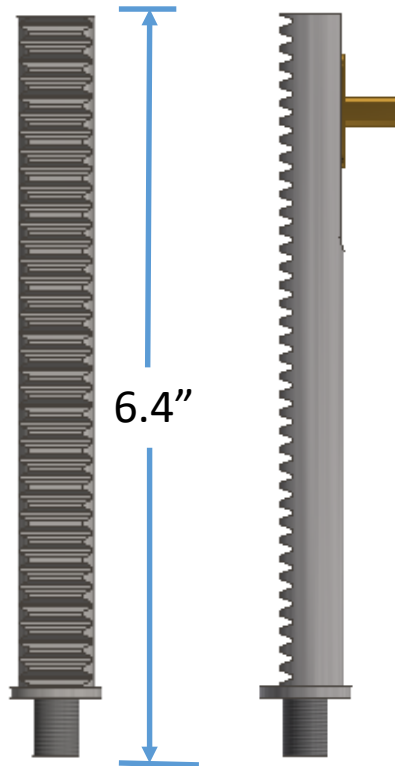




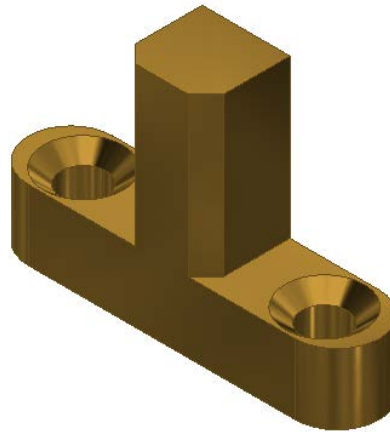
# Components of Electronics Mount



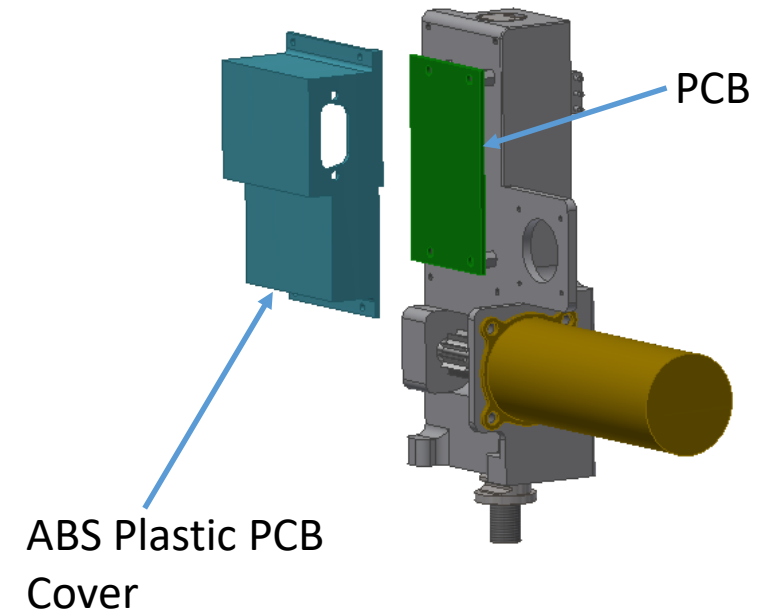
Gear Rack



Limit Switch Tab



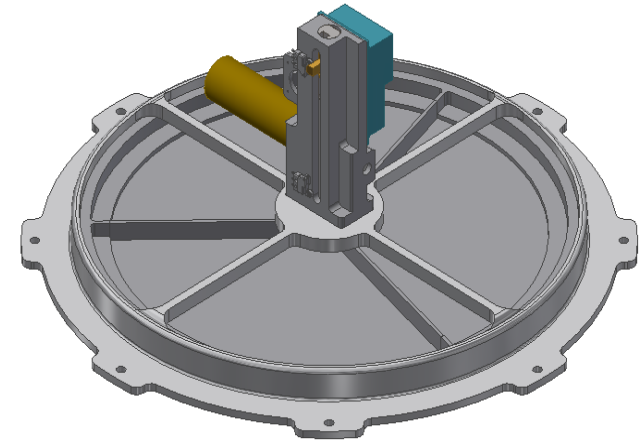
Electronics



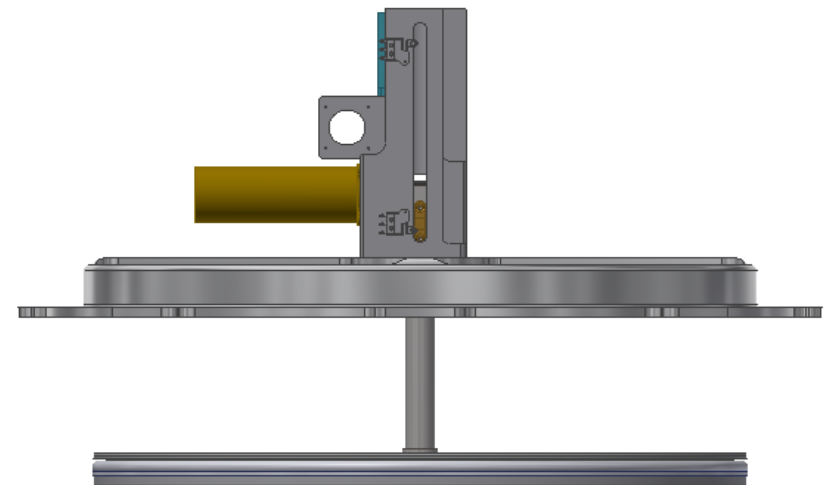


# Final Product

- ✓ Improved seal function
- ✓ Wider positional tolerance of piston seal
- ✓ Improved verification of seal with apex fitting
- ✓ Streamlined electronics package
- ✓ Maintained same bolt hole pattern
- ✓ Maintained mating surface for inflation cans
- ✓ Internal holes are blind to reduce a leak risk
- ✓ Weighs 6.7 lbs. (CAD estimate)
- ✓ Can be standardized for SPB and ZPB
- ✓ Keeps similar open area for helium flow into balloon
- ✓ Utilizes the same electronics interface except smaller limit switches



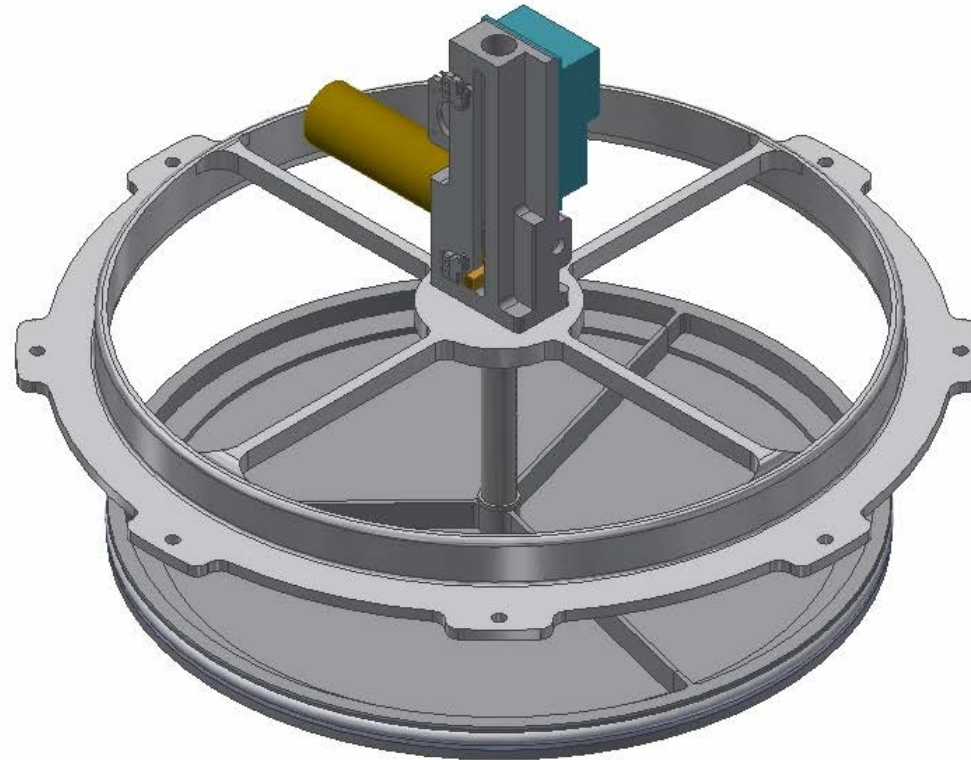
**Closed**



**Open**



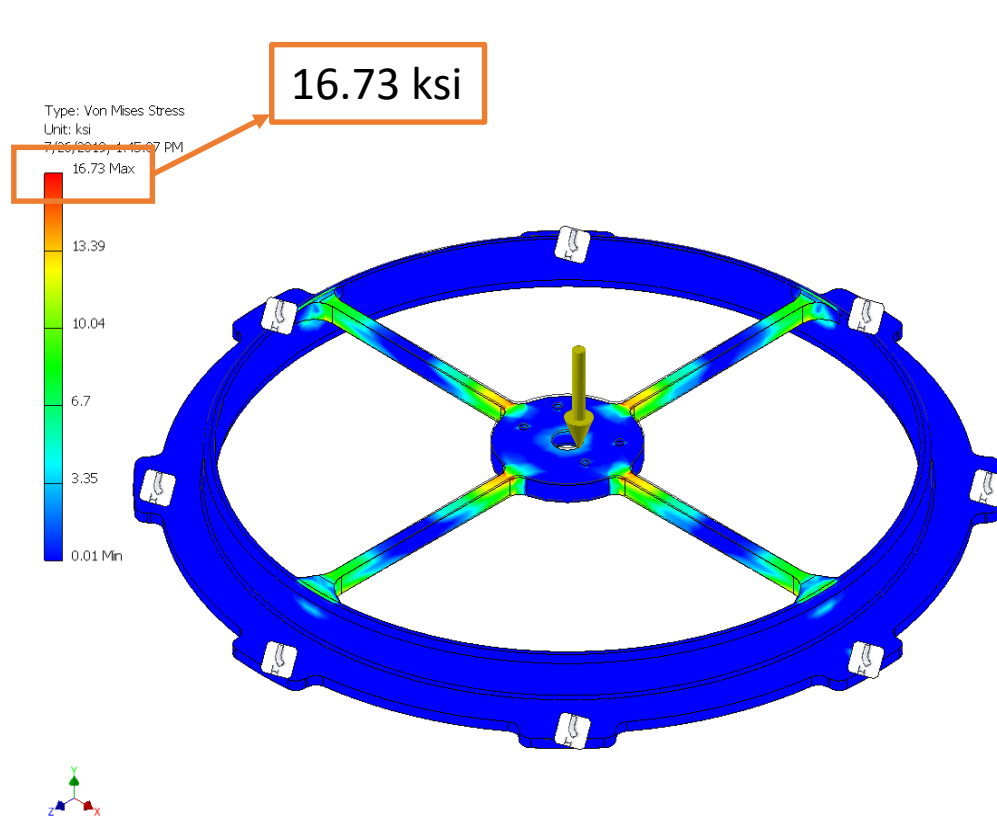
# Helium Valve Animation



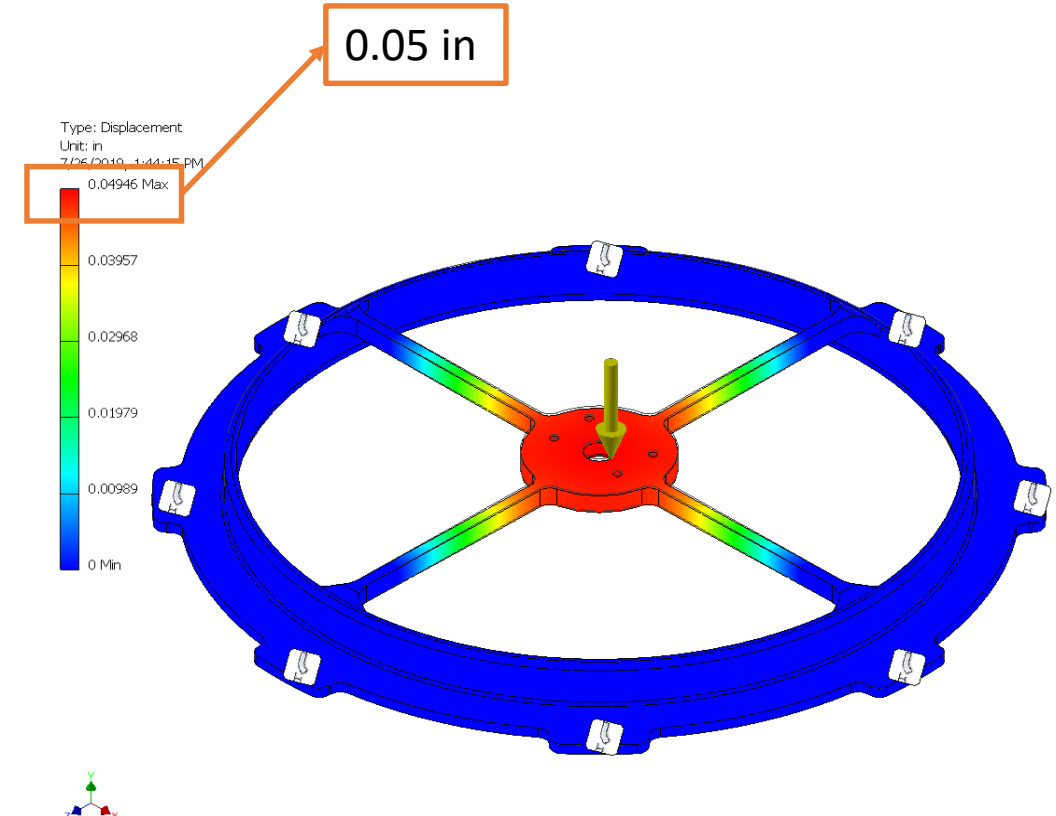


# Ring Mount Assembly Analysis

- Condition: 140 lb. applied to center hole



Von Mises Stress (ksi)



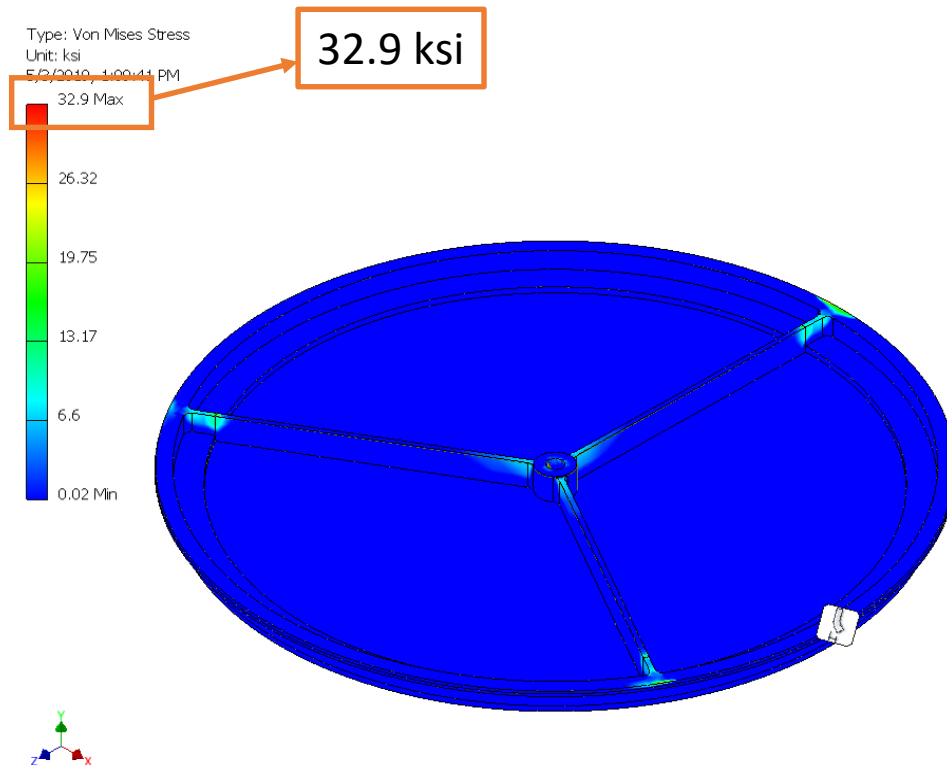
Displacement (in)



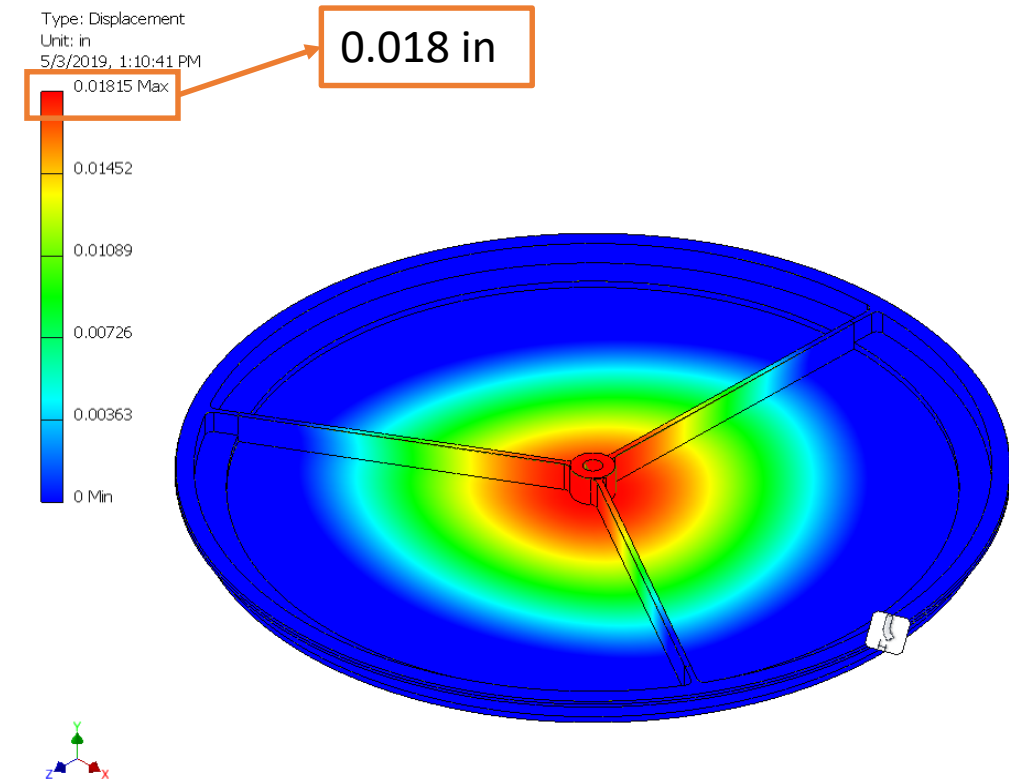
# Piston Top Plate Analysis



- Condition: 140 lb. applied to piston center



Von Mises Stress (ksi)



Displacement (in)



# Analysis Summary

Item	Material	Standard	Safety Factor (Ultimate Tensile)	Stress from FEA (ksi)	Stress at Failure (ksi)	Margin of Safety
Ring	Aluminum 6061-T6	MMPDS-12	1.4	16.73	42	1.51
Piston Top Plate	Aluminum 6061-T6	MMPDS-12		32.90	42	0.28

Item	Material	Standard	Safety Factor (Yield Tensile)	Stress from FEA (ksi)	Stress at Failure (ksi)	Margin of Safety
Ring	Aluminum 6061-T6	MMPDS-12	1.25	14.94	35	1.34
Piston Top Plate	Aluminum 6061-T6	MMPDS-12		29.27	35	0.20

MMPDS-12, Table 3.6.2.0(d). Design Mechanical and Physical Properties 6061 Aluminum Alloy Rolled, Drawn, Cold Finished Bar, Rod, and Shapes





# Future Work



- Complete drawings
- Fabricate prototype parts
- Develop assembly procedure
- Assemble parts
- Testing: Working closely with Balloon Research and Development Lab (BRDL) to use facility to conduct environmental testing
  - Develop test plan and procedure for each test
  - Operation in multiple mission environments



# Challenges & Lessons Learned



- Challenges

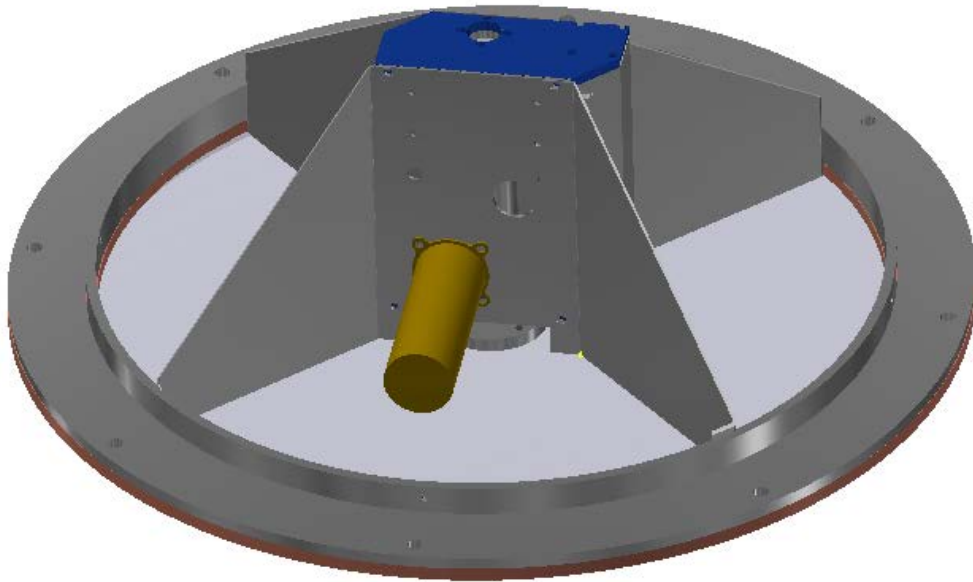
- Communication between design team and customer
- Determining the right path forward during design phase
- Finalizing design requirements

- Lessons Learned

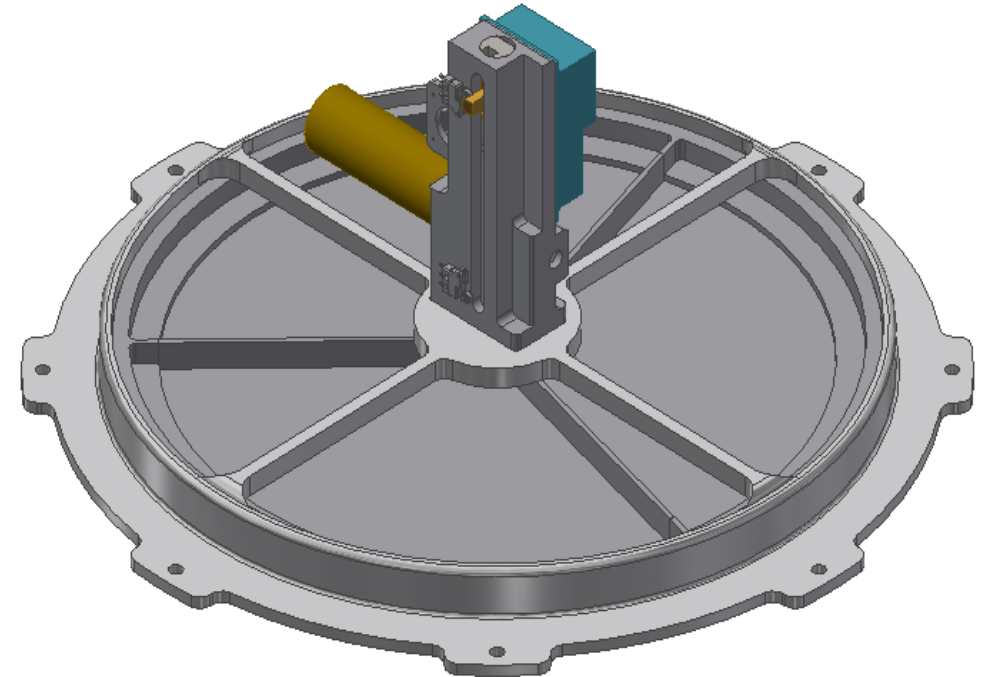
- Improved CAD skills
- Better understanding of mechanical designs
- Learned more about the NASA Balloon Program
- Professional development when communicating among team and others



# Questions ?



Current Design



New Design



# Acronym List

BPO	Balloon Program Office
BRDL	Balloon Research and Development Lab
CAD	Computer Aided Design
CSBF	Columbia Scientific Balloon Facility
DR	Design Review
DRR	Delta Design Review
in	inch
ksi	kilopound per square inch
lb	Pound
OD	Outside Diameter
PCB	Printed Circuit Board
SPB	Super Pressure Balloon
WFF	Wallops Flight Facility
ZPB	Zero Pressure Balloon



# Back Up





# Requirements



- 3.4 - The helium valve shall be designed to fit within the static and dynamic envelope of the current standard helium valve.
- 3.5 - The weight of the helium valve assembly not be greater than 7.0 lb.
- 3.6.2 - The valve shall be designed to meet all strength and performance requirements when subjected to ambient pressure between 1,013 millibar and 2 millibar.
- 3.6.3 - The valve shall be designed to meet all strength and performance requirements when subjected to a differential pressure between 0 – 200 Pa.
- 3.7 - The fittings shall be designed to show positive margins of safety when exposed to temperatures within the range -70°C to +65°C.
- 3.11.5 - The valve shall have a mating surface on its outside perimeter for attaching a CSBF fill can.



# Performance Requirements



## Mechanical

- 4.1.1 - A test plan shall be implemented to demonstrate that the valve will perform desirably without damage when subjected to a minimum of 200 open/close cycles.
- 4.1.2 - The valve shall provide confirmation of closure.
- 4.1.3 - The valve shall demonstrate that the duration full travel to open or close is less than or equal to 22 seconds.
- 4.1.4 - At room temperature, the flight configured fitting shall maintain seal at all interfaces with detectable gas loss of no more than  $1.44 \times 10^{-4}$  g/s.
- 4.1.5 - When fully open, the valve shall have a helium gas flow rate equal to or greater than the flow rate of the current helium valve.

## Electrical

- 4.2.1 - The valve shall maintain the same electrical interface to CSBF equipment as the current valve.
- 4.2.2 - The valve shall operate acceptably over a voltage range of 22 VDC to a maximum of 29.5 VDC.
- 4.2.3 - The valve shall have a maximum power consumption of 15 watts when operating.





# Weight Breakdown

Part	Weight (lb)
Ring	2.427
Piston Top	1.974
Piston Bottom	0.316
Seal	0.154
Electronics Mount	0.674
Gear Rack	0.36
Motor	0.8
PCB	TBD
Limit Switch	0.003
Limit Switch	0.003
Power Connector	TBD
PCB Enclosure	0.023
Total	6.734



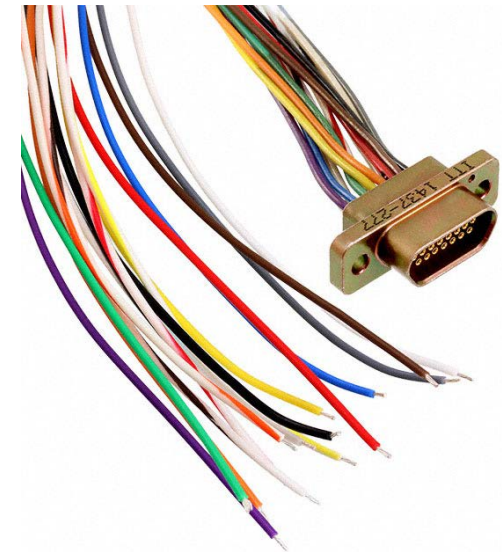
# Estimated Mechanical Cost

Item	Cost for single prototype	Cost per unit for set of 8
Ring	\$1764.82	\$631.60
C-Channel	\$533.98	\$201.70
Top Piston Plate	\$1242.99	\$420.39
Retaining Ring	\$1059.01	\$215.77
Electronics Mount	\$704.38	\$253.01
Gear Rack	\$1347.05	\$360.07
Limit Switch Tab	\$213.57	\$57.42
Spring Energized Seal	\$600	\$600.00
Hollow O-Ring	TBD	TBD
Total	\$7465.80	\$2739.96



# Electrical Design Changes

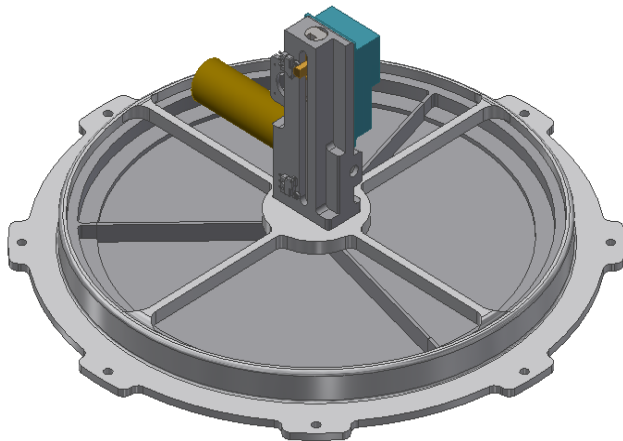
- No changes to original PCB
  - Will be housed in enclosure
- Additional interface adapter cable from PCB enclosure to CSBF interface, switches, and motor
  - No change to original CSBF interface (MS3102A-14S-2P)
  - PCB enclosure interface – MDM-15S
- Replace mechanical limit switches with smaller, lower profile switches (Honeywell 311SX64-H58)
  - 28VDC, 5A
  - SPDT
  - -53/+121C



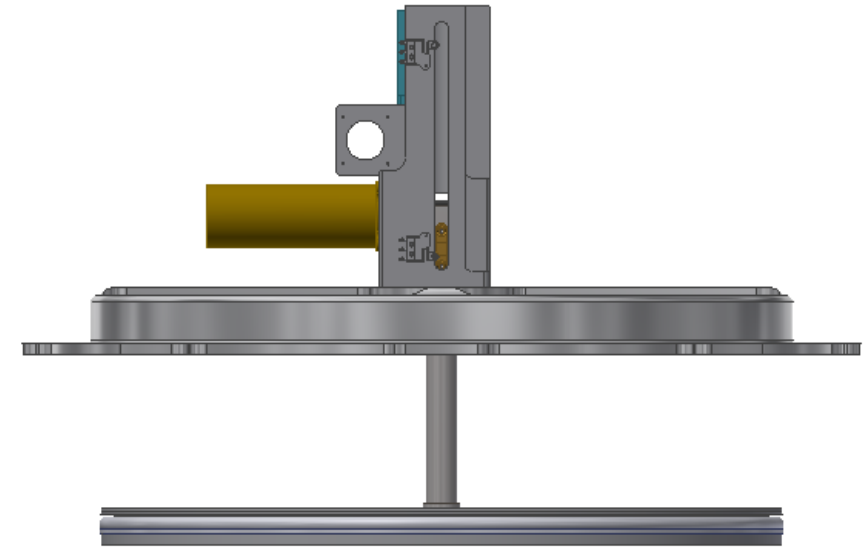


# Final Product

- Number of custom parts is less than current valve
- Piston seal design allows the same electrical interface with wider positional tolerance
- The original seal function and DR design made seal confirmation over-complicated and would change the electrical interface
- Open area for flow is  $133.3 \text{ in}^2$ , compared to  $138.5 \text{ in}^2$  from the current valve.
- Weighs 6.73 lbs. according to CAD



**Closed**



**Open**