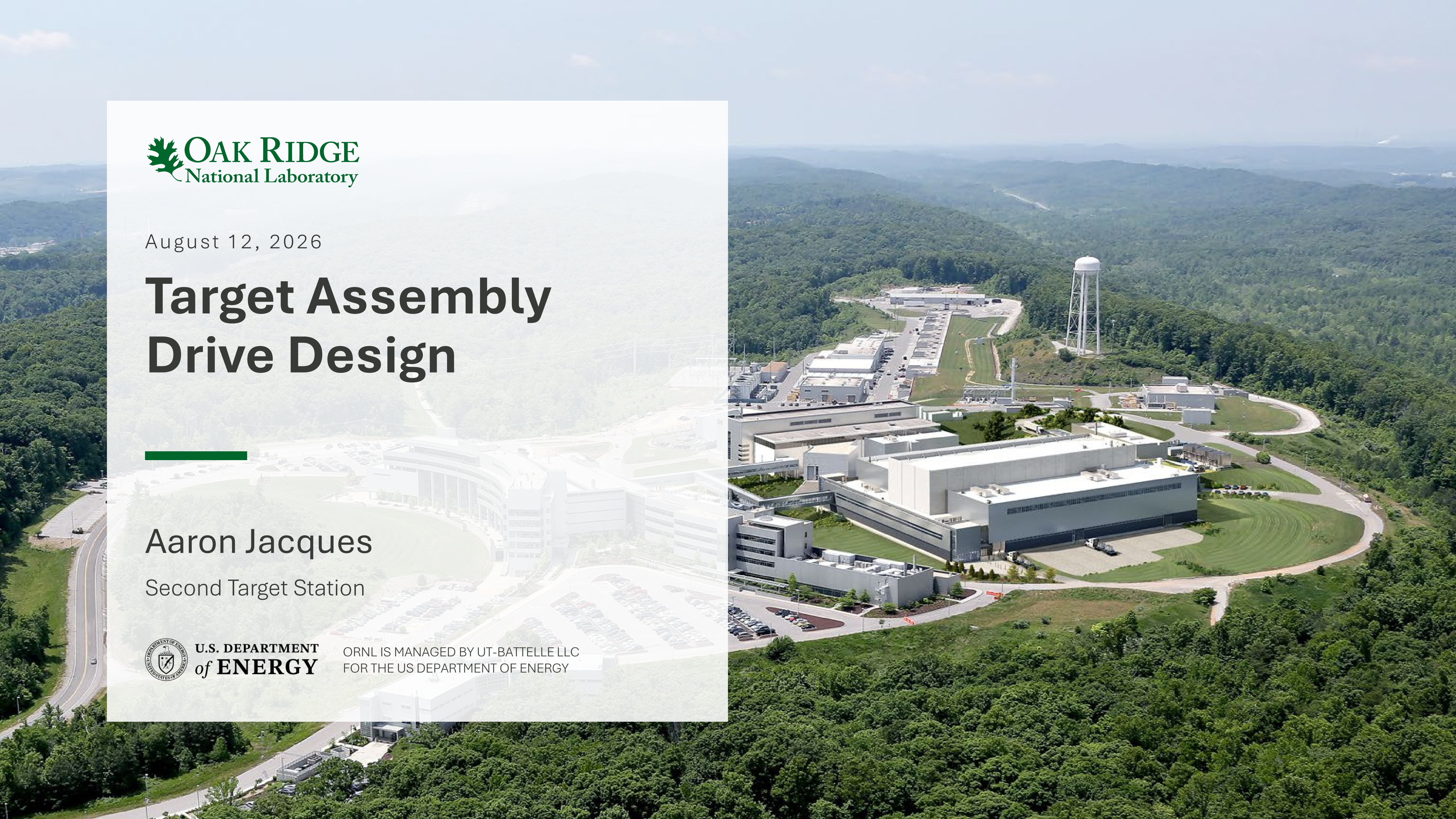

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August 12, 2026

Target Assembly Drive Design

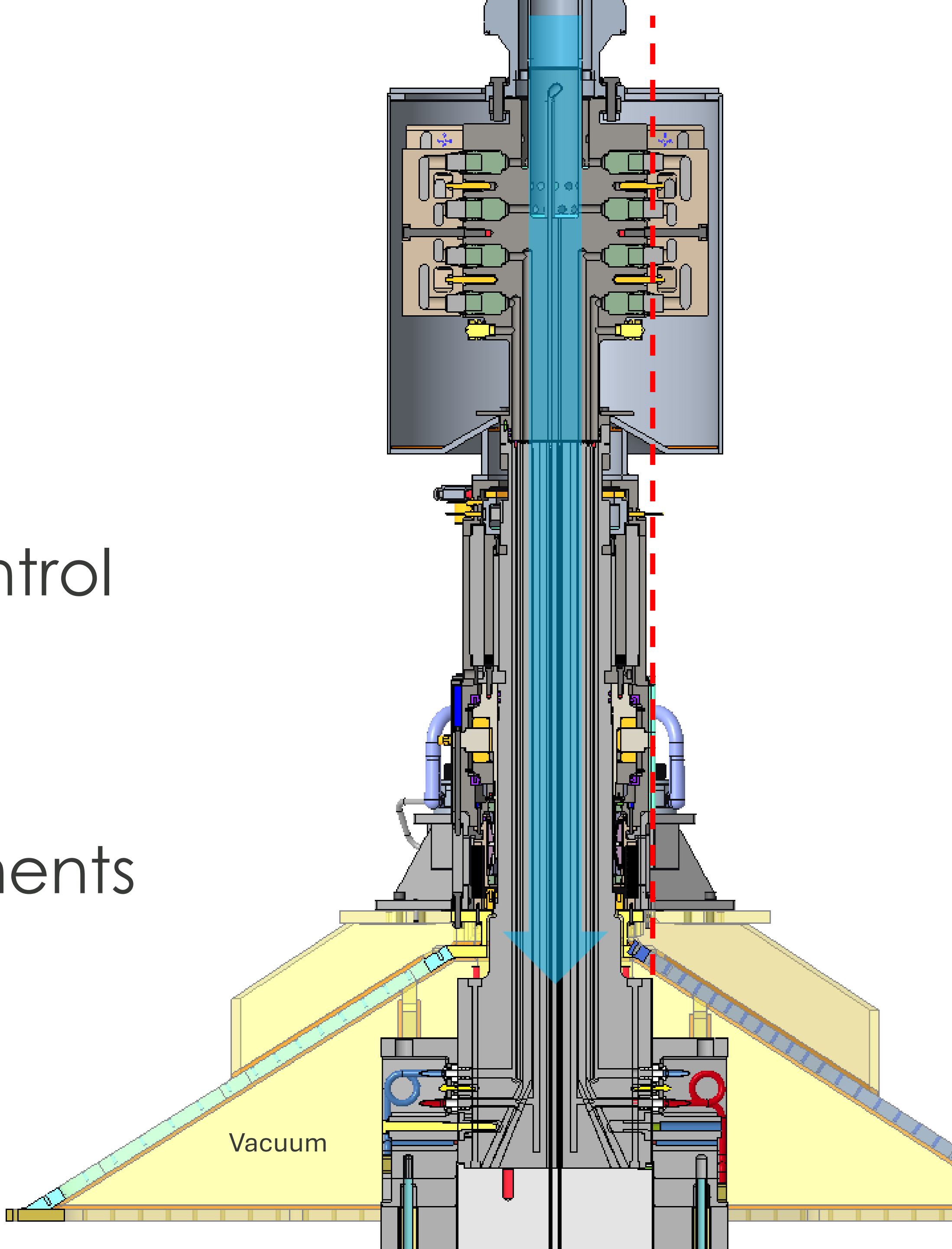
Aaron Jacques

Second Target Station

Charge Question

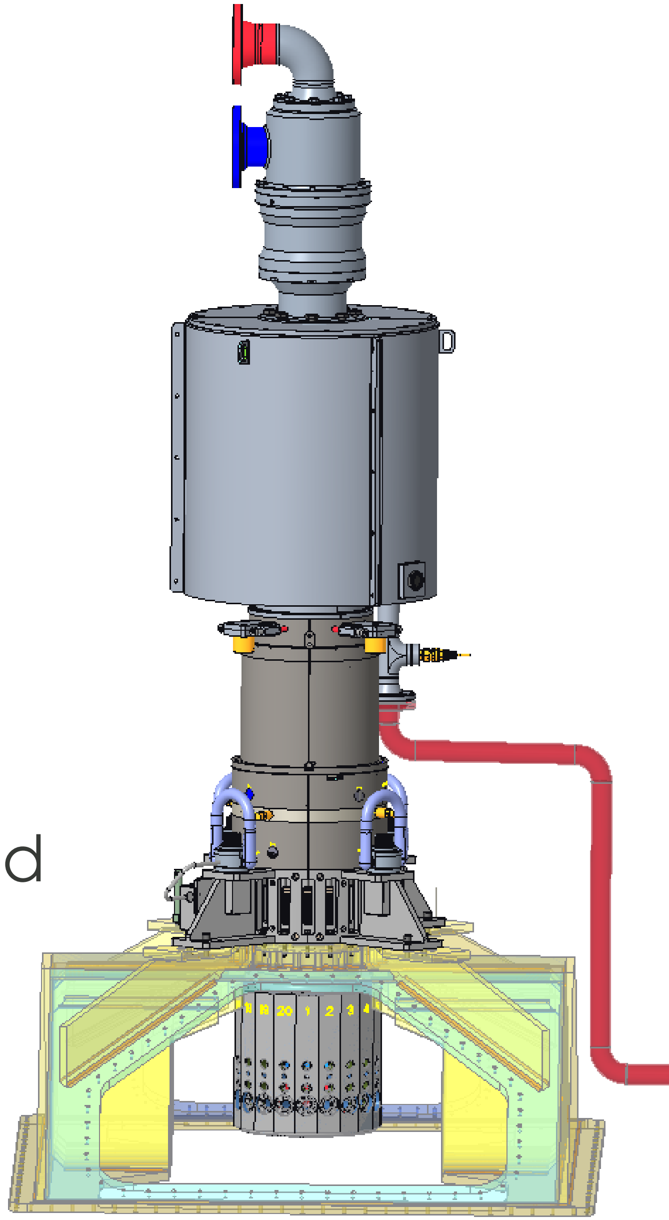
Requirements – Design Basis

- Rotates segments at 45 rpm
- Vertical segment removal
- Rotate targets
- Provides position knowledge for control system
- Shielding & seismic support
- Distribute and isolate water to segments
- Leak detection capability
- Provide fast access to components



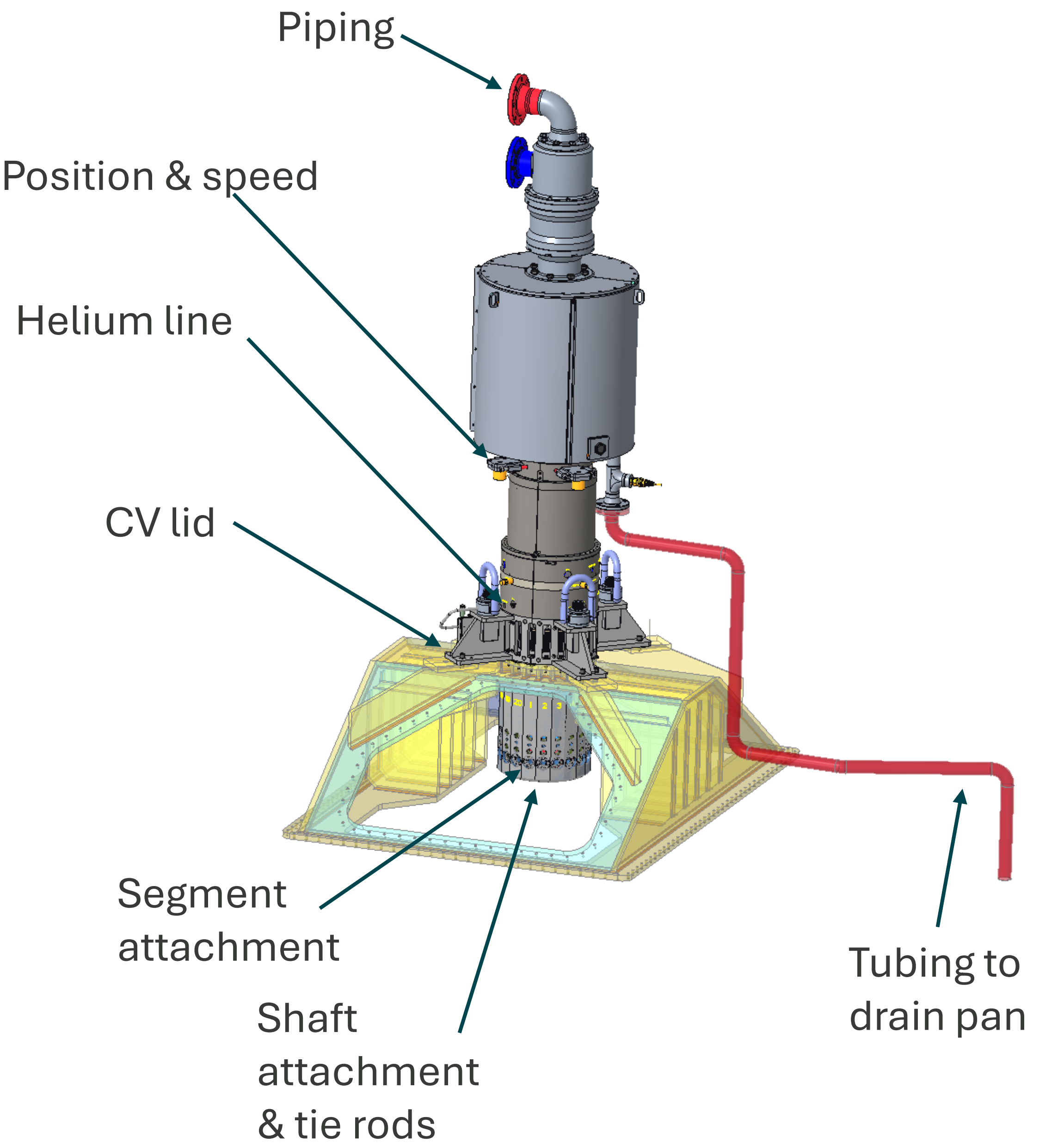
Key parameters

- Operating Speed: 45 rpm
- Torque required: 365/490 Nm
- Water flow: 158 gpm, 25 psi, 32.5°C
- Vacuum: 1 Torr
- Radiation Environment:
- Seismic role: Resist lateral forces & moment
- Replacement philosophy: fast swap in field; bench rebuild
- Alignment requirement: <1mm to STS world center
- Replacement interval: ~ Pieces every 6 years

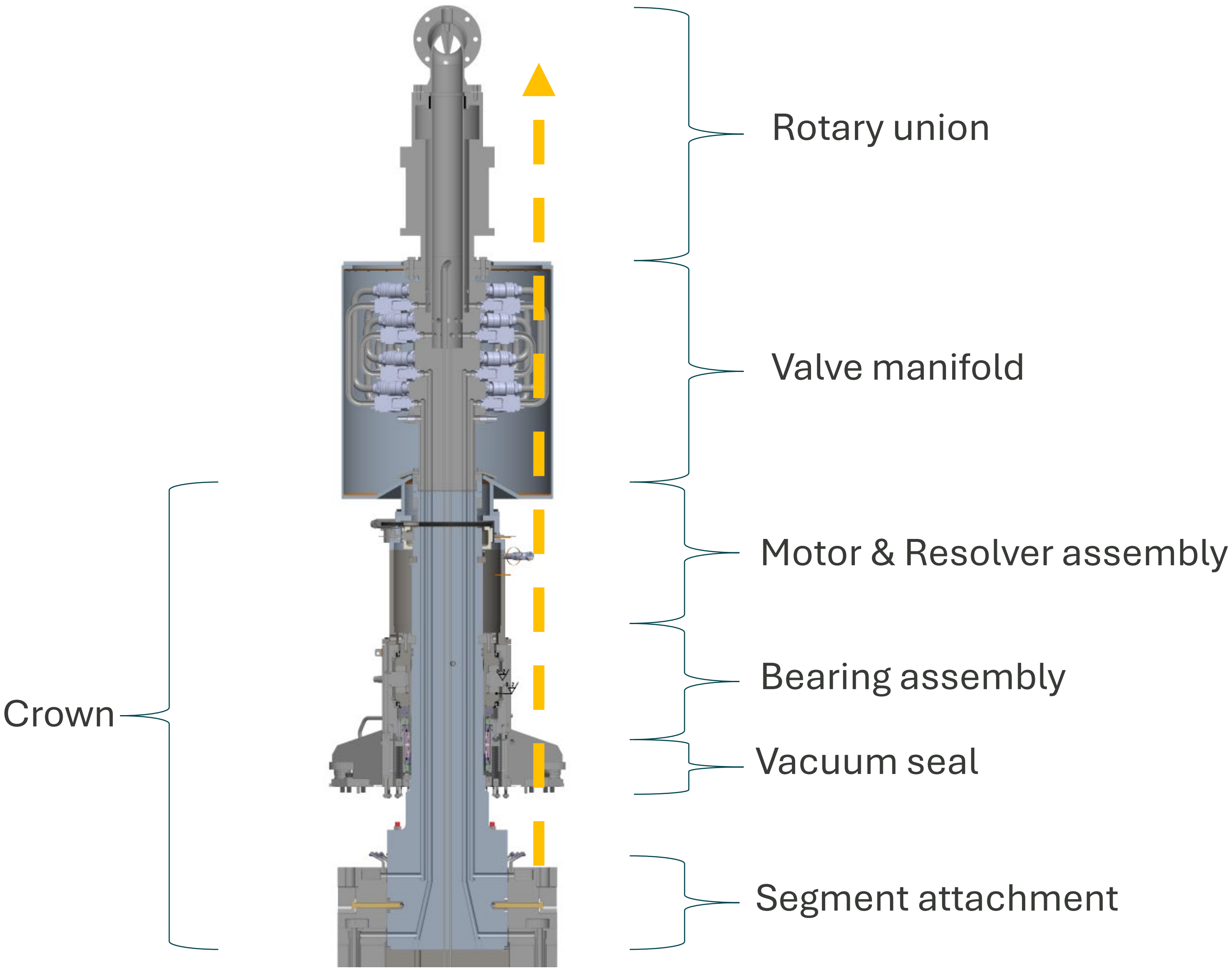


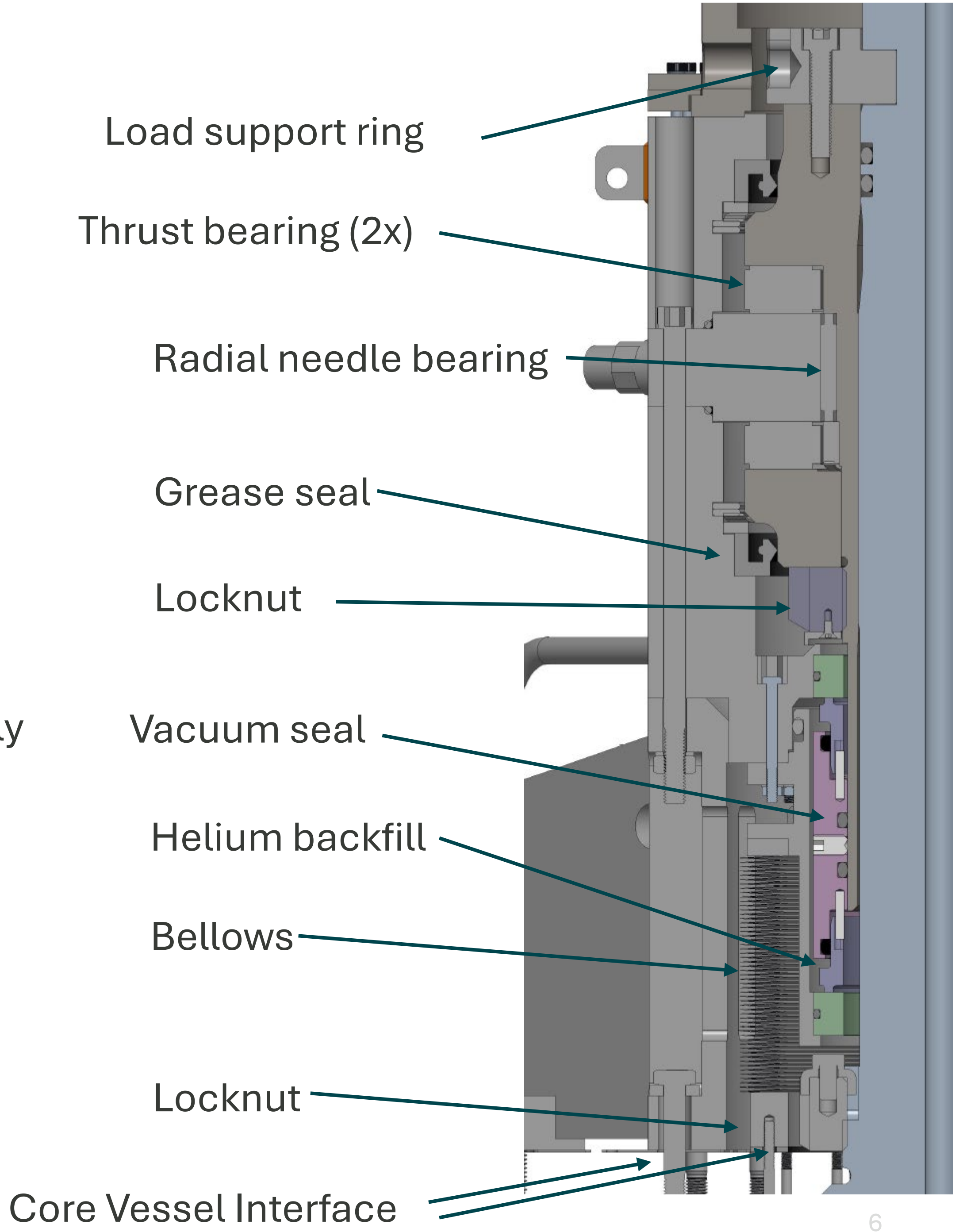
Drive Interfaces

- Shaft
- Segments
- Core Vessel Lid
- Control System
- Vacuum environment
- Maintenance personnel

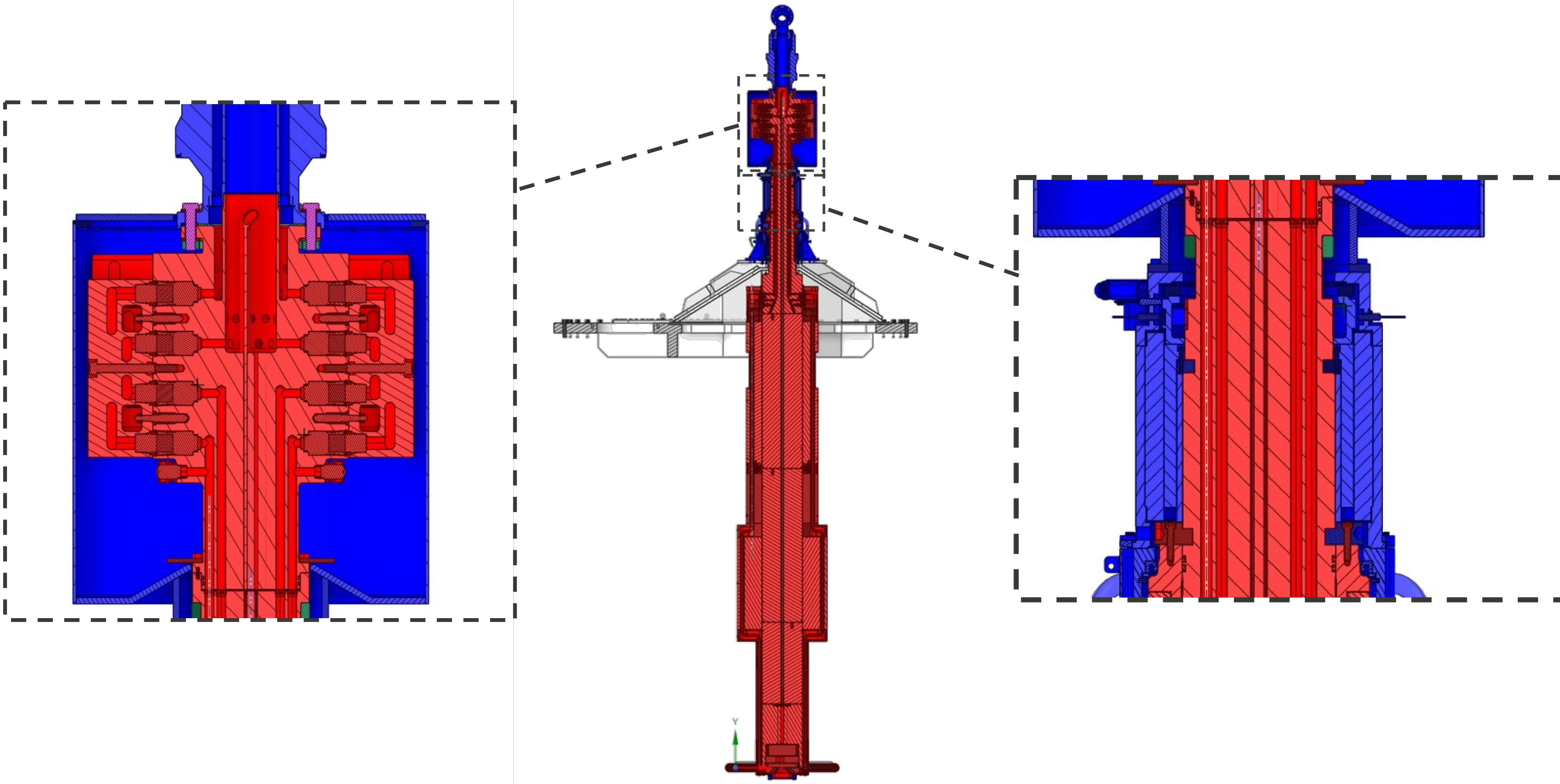


System Boundary & Architecture

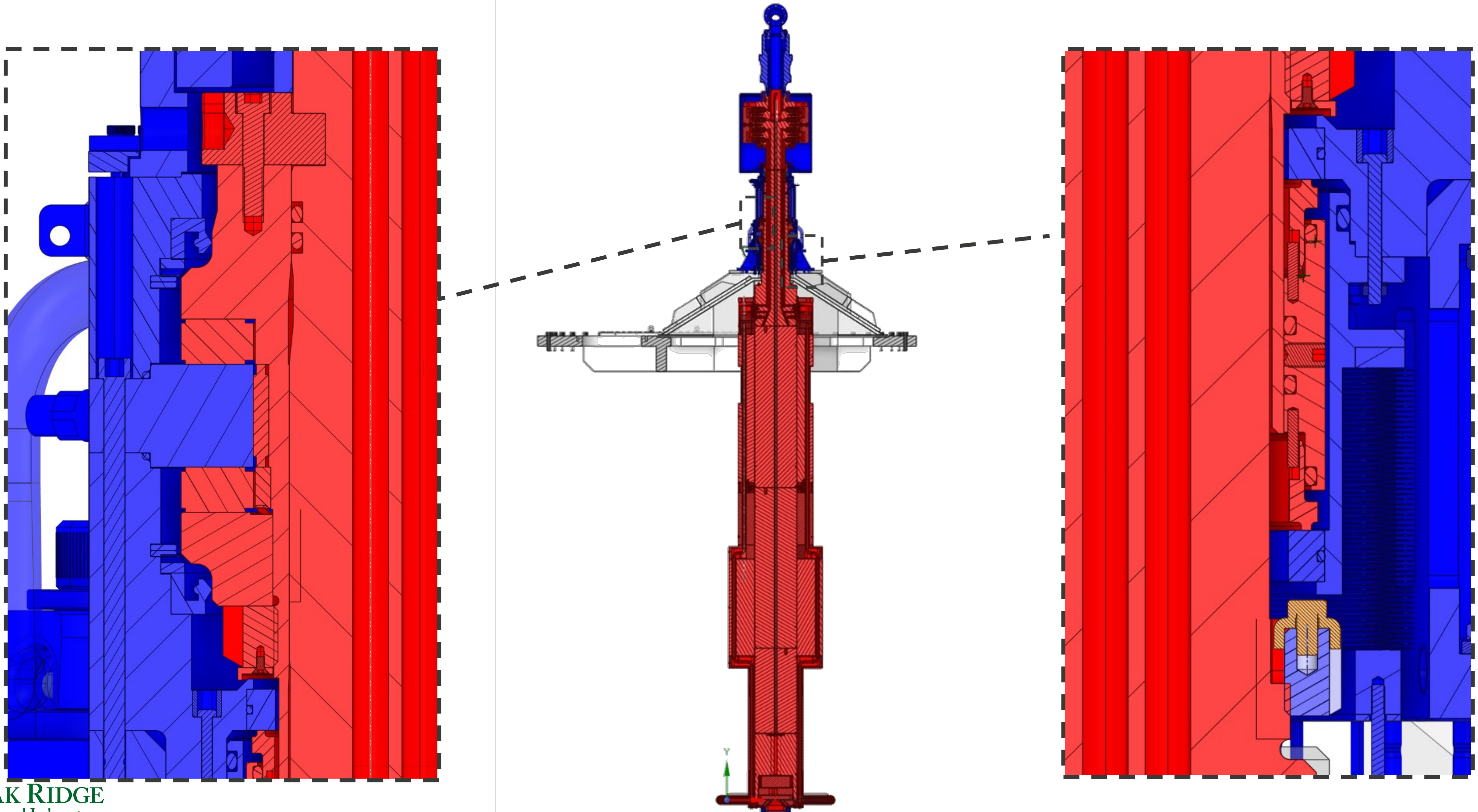




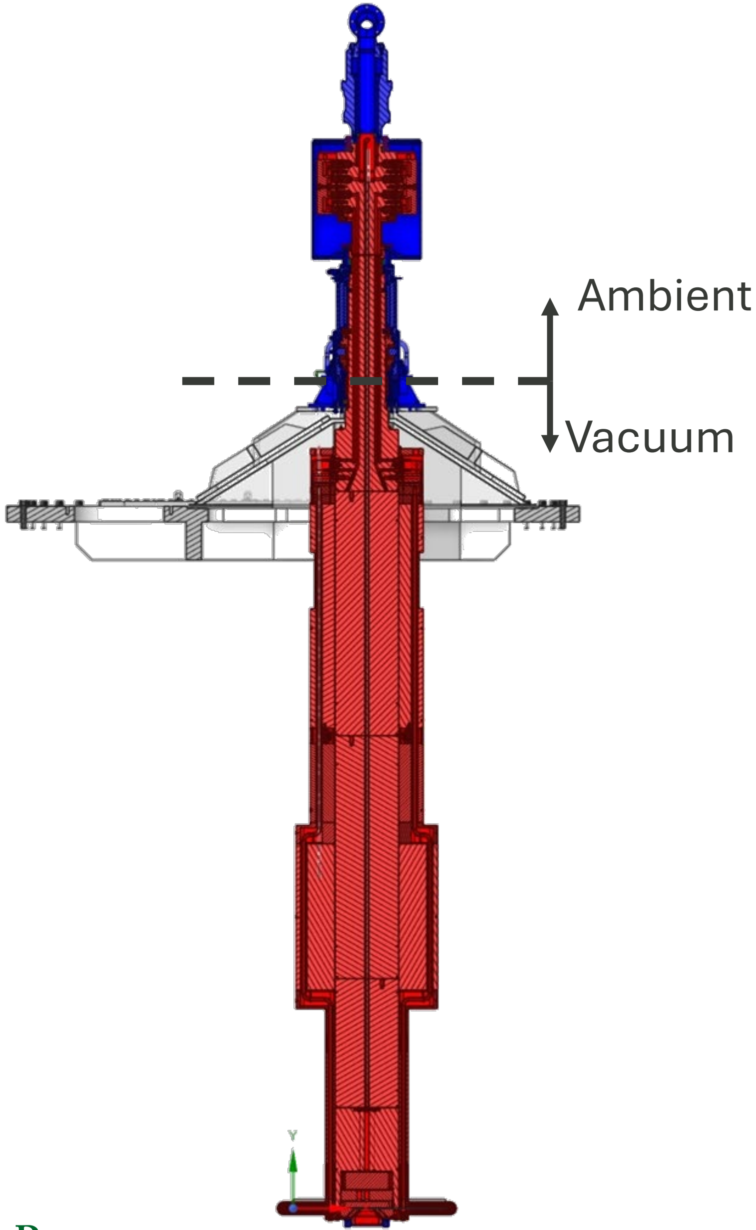
Rotating and stationary

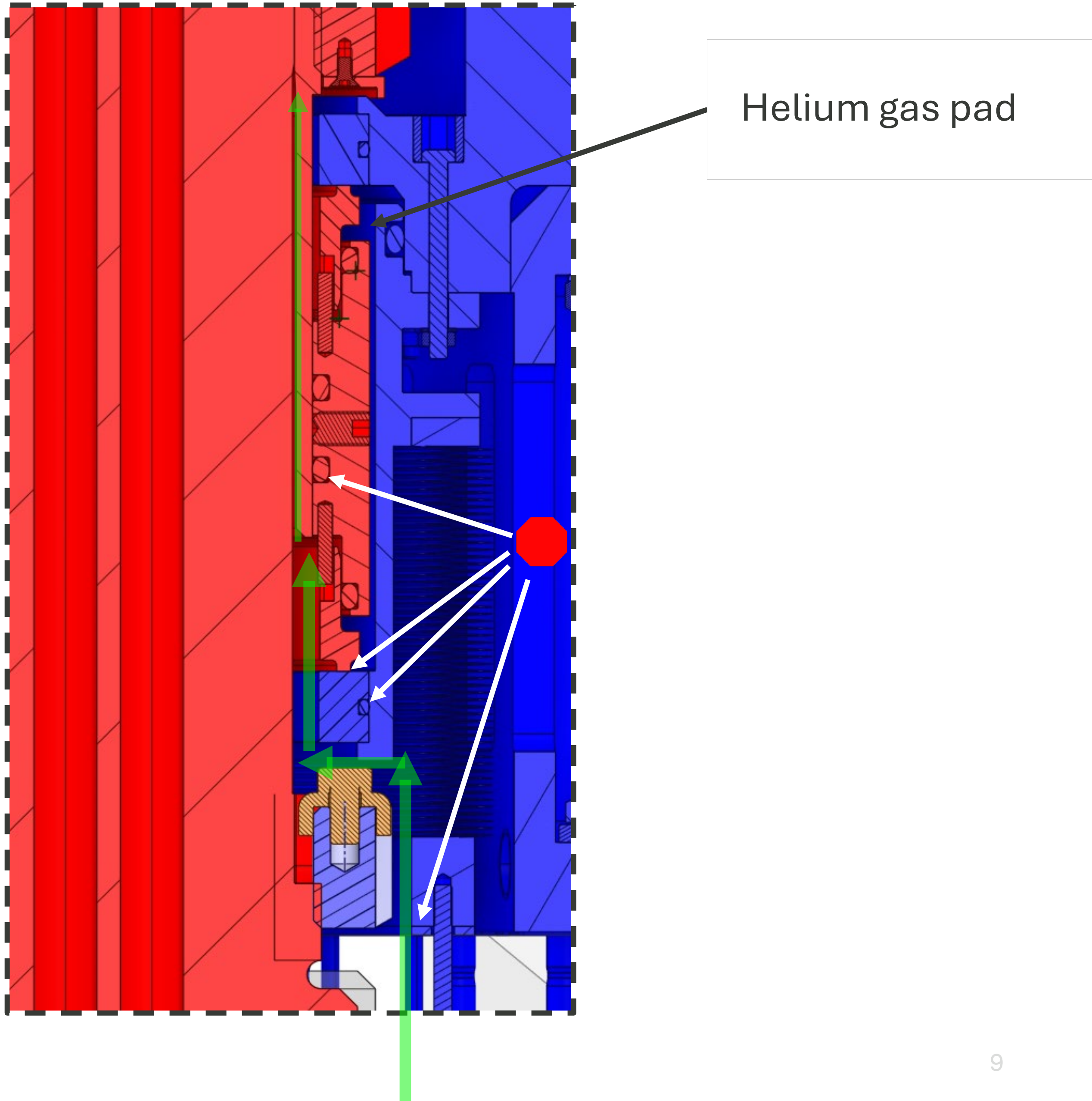


Rotating and Stationary (Continued)



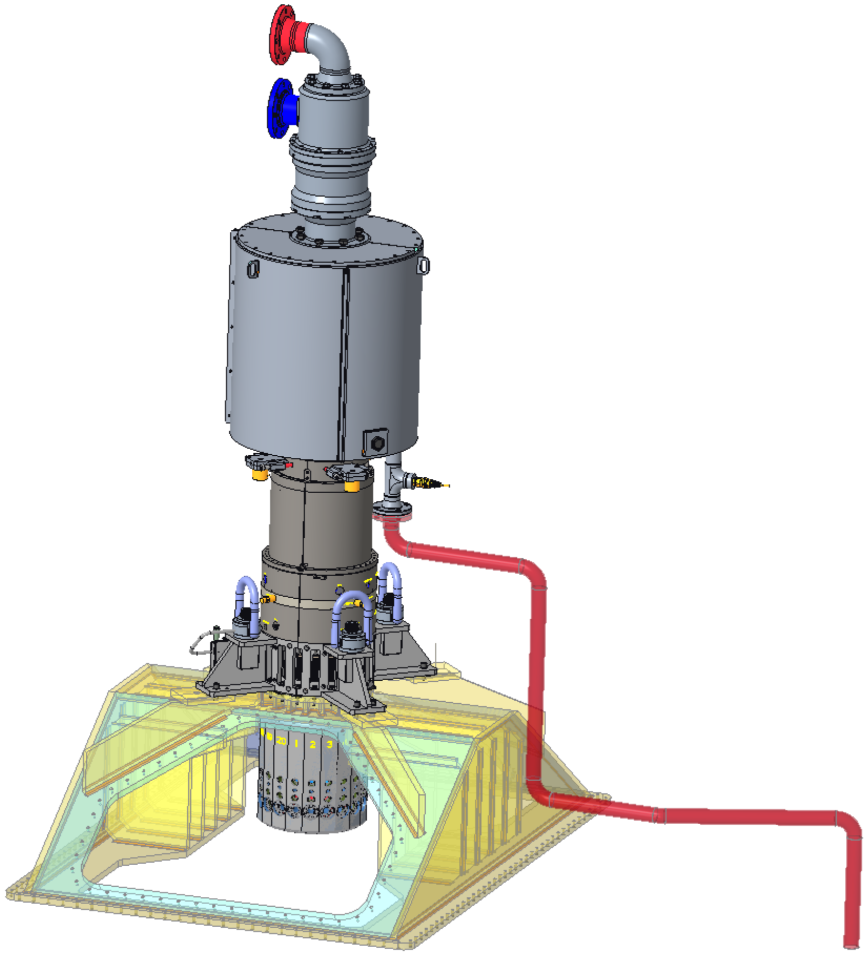
Vacuum Break



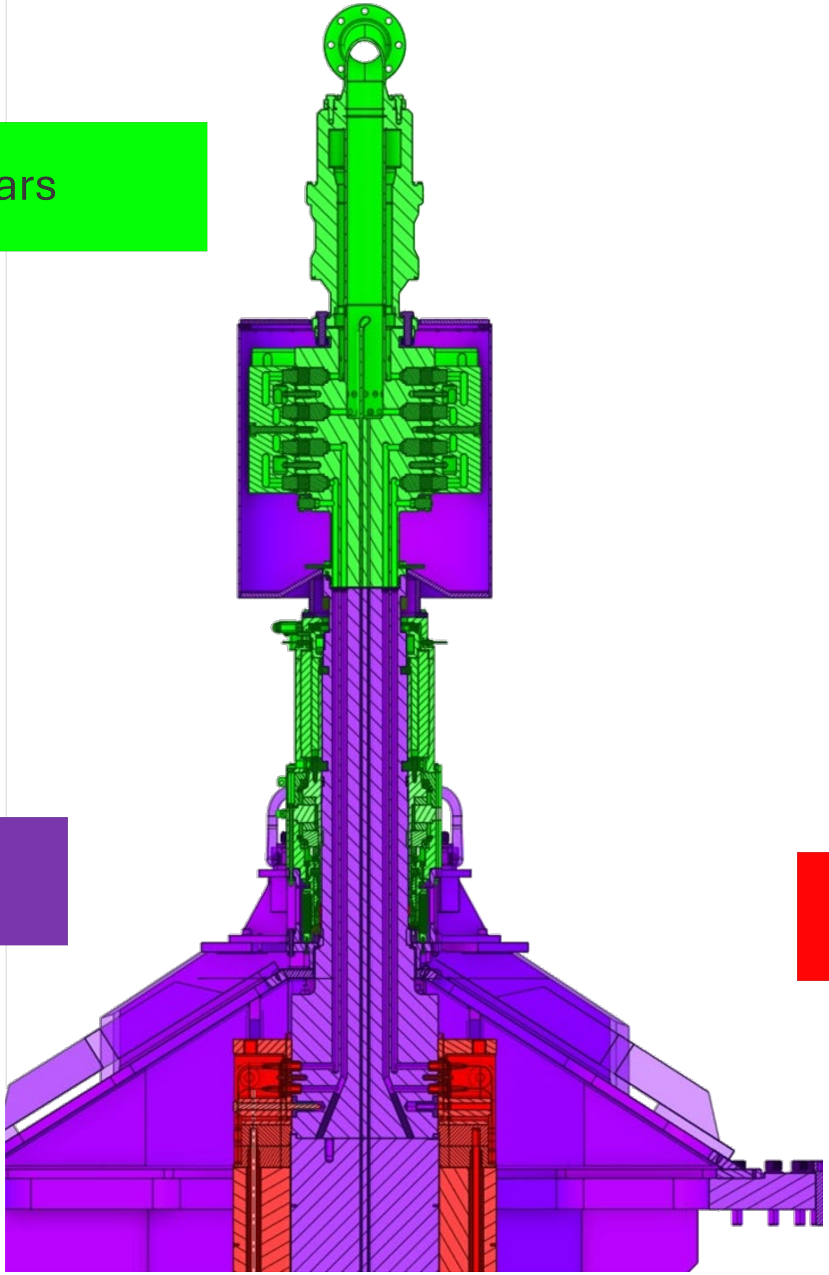


Field Replaceable Units

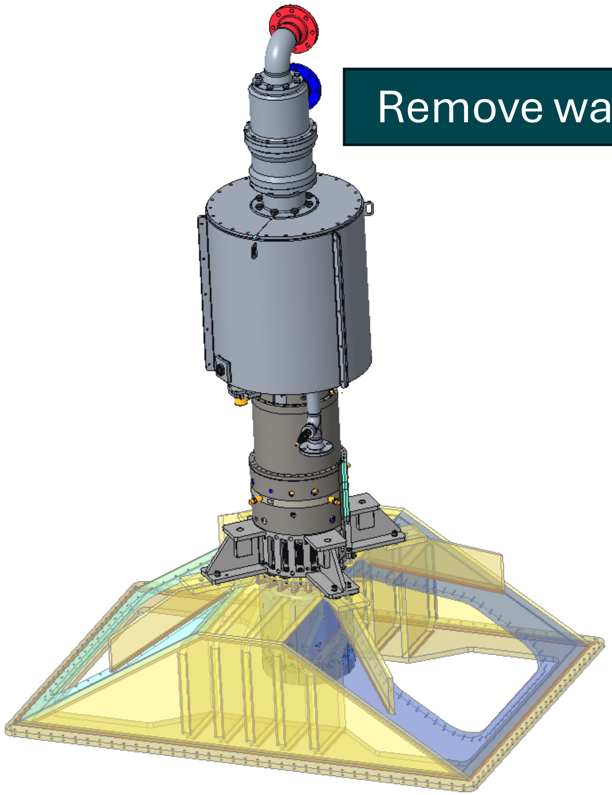
- The target drive is intended to be serviced in modules installed in the field
- Modules are built, repaired, replaced offline (bench)
- Reduces dose and downtime
- Preventative maintenance philosophy



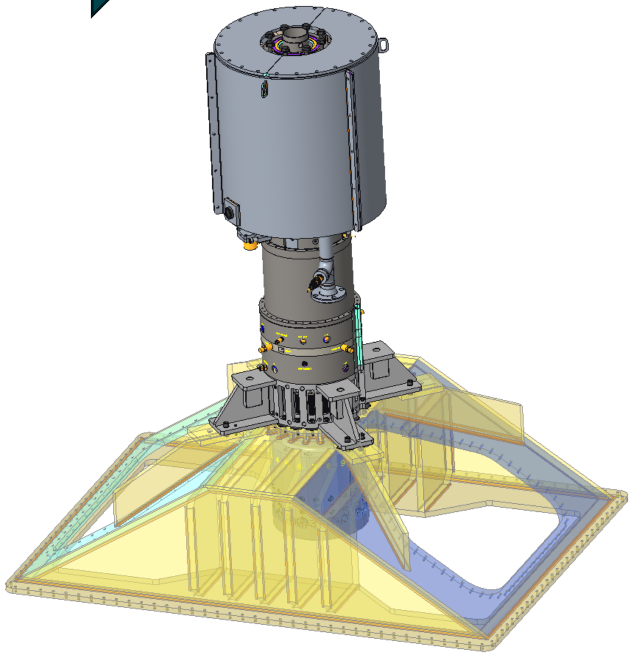
Planned Replacement Intervals



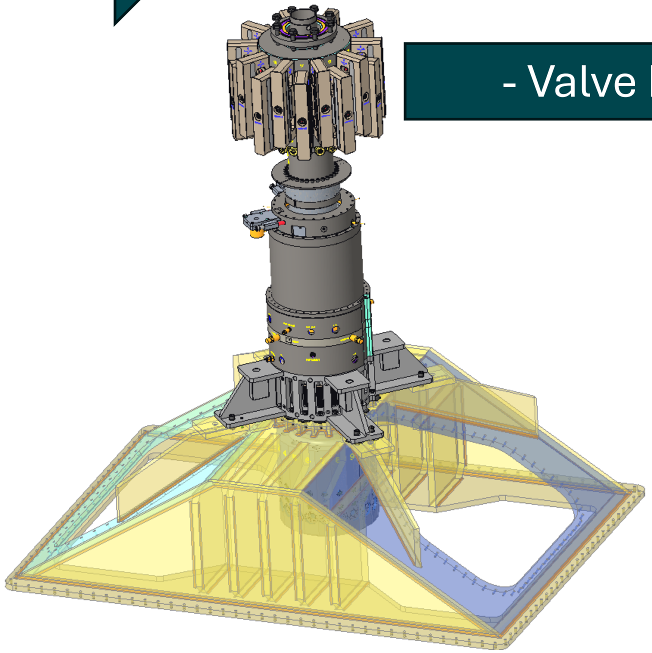
Disassembly sequence



Remove water union



Remove water shroud



- Valve Manifold

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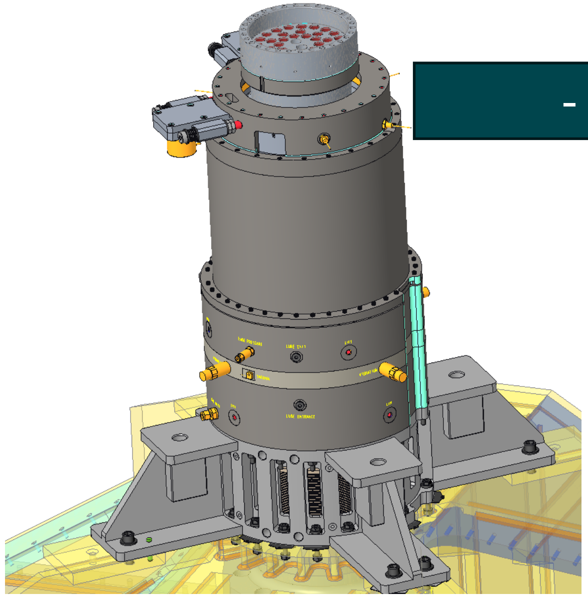
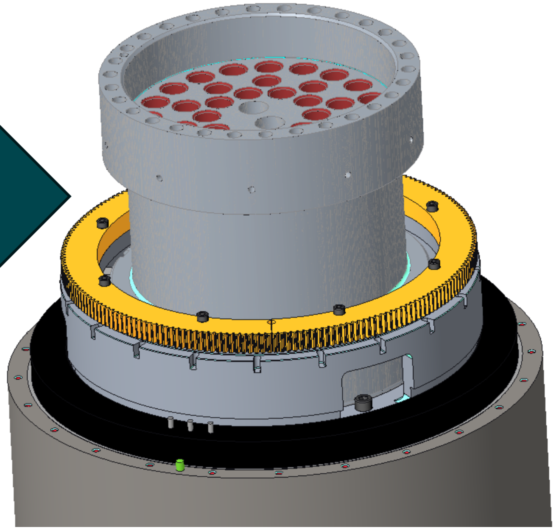
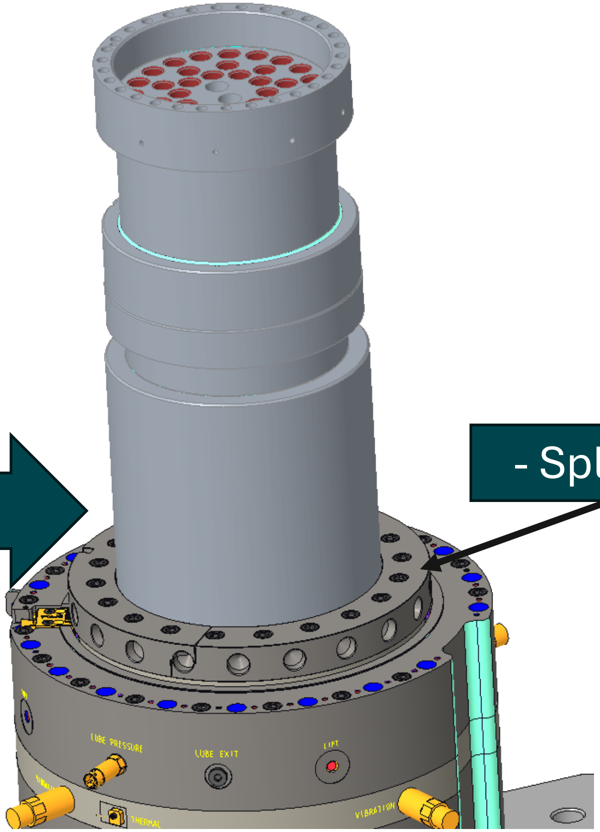
Disassembly sequence (cont)



- resolver

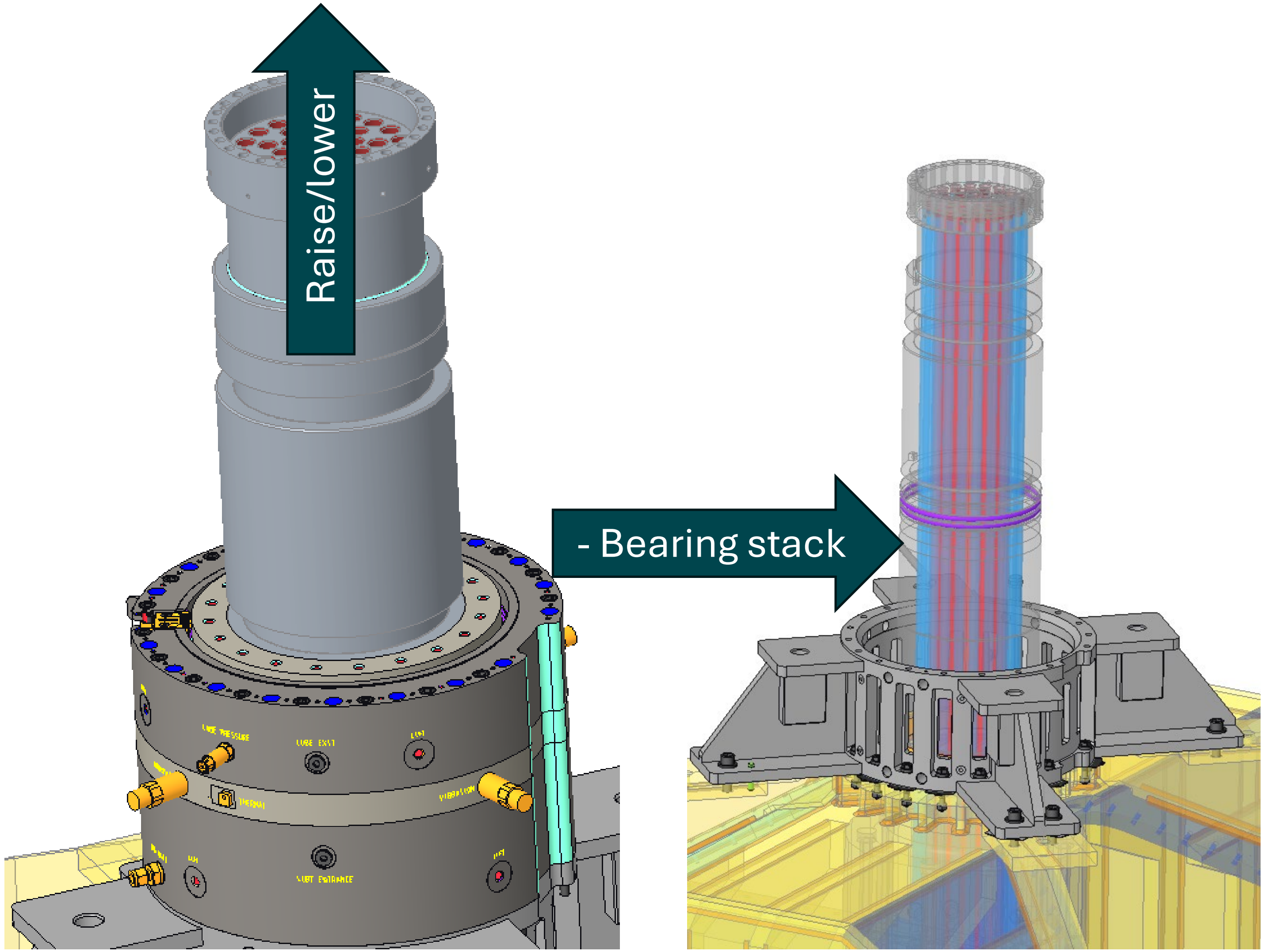


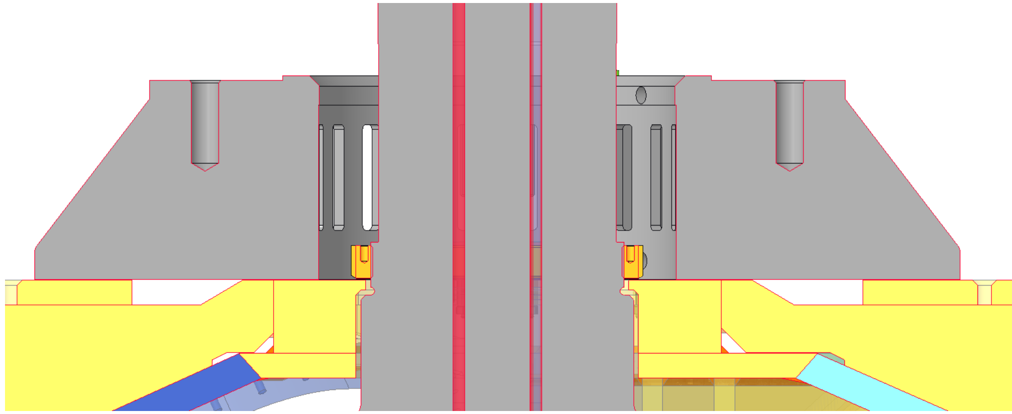
-motor



- Split ring

Disassembly sequence (cont)

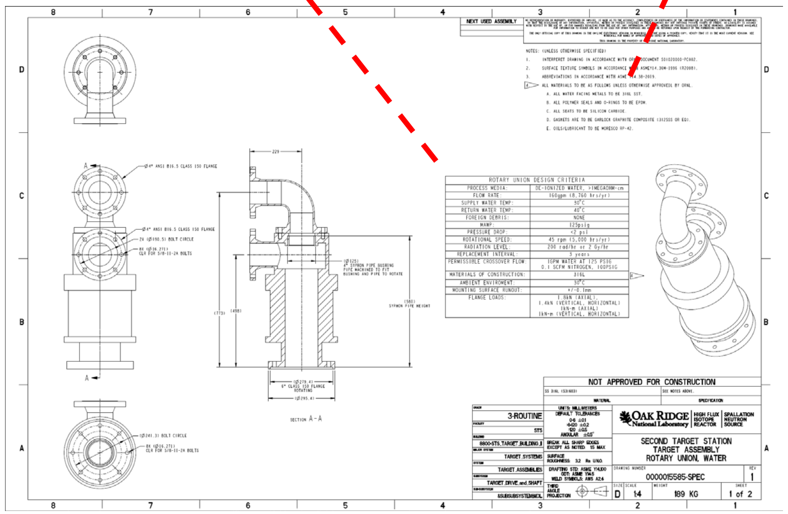


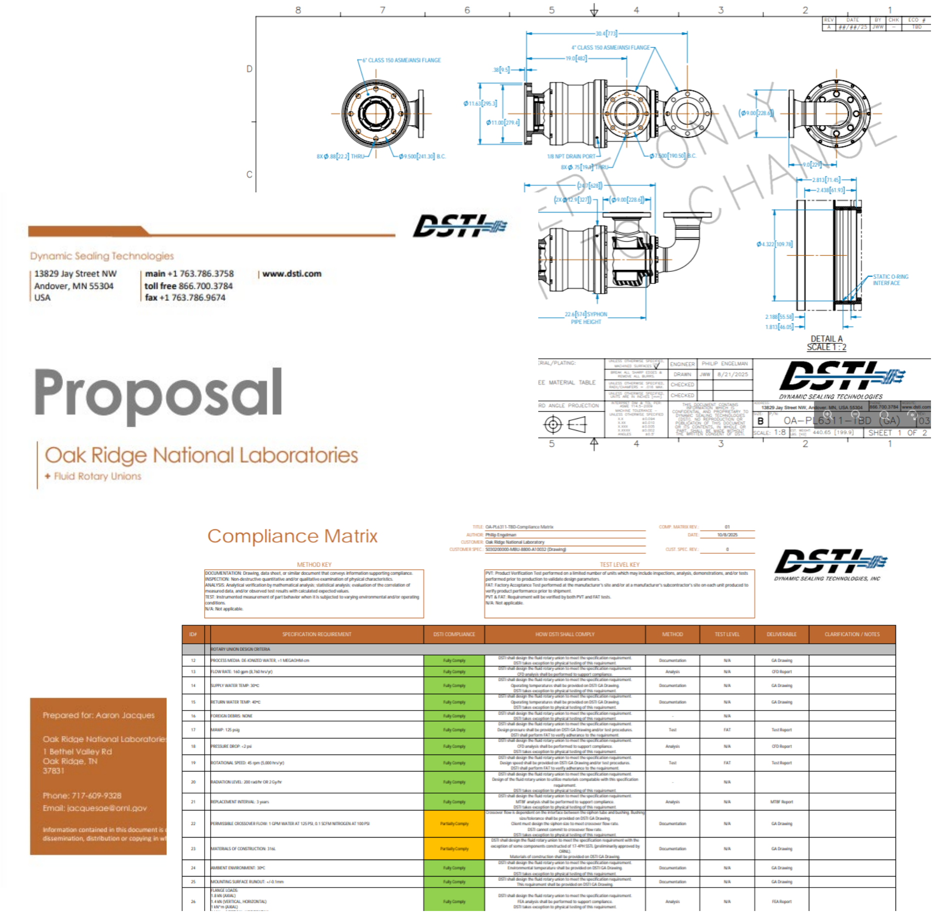


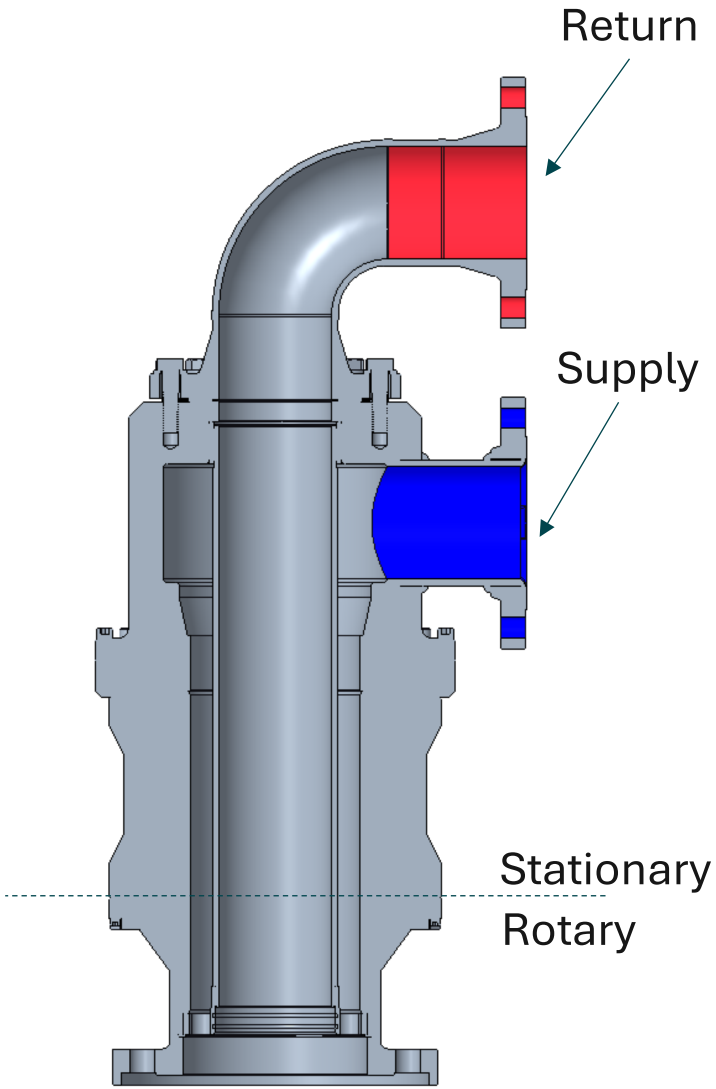
The rotary union is supplied by DSTI in a tailored configuration based upon their standard offering

ROTARY UNION DESIGN CRITERIA	
PROCESS MEDIA:	DE-IONIZED WATER, >1MEGAOHM-cm
FLOW RATE:	160gpm (8,760 hrs/yr)
SUPPLY WATER TEMP:	30°C
RETURN WATER TEMP:	40°C
FOREIGN DEBRIS:	NONE
MAWP:	125psig
PRESSURE DROP:	<2 psi
ROTATIONAL SPEED:	45 rpm (5,000 hrs/yr)
RADIATION LEVEL:	200 rad/hr or 2 Gy/hr
REPLACEMENT INTERVAL:	3 years
PERMISSIBLE CROSSOVER FLOW:	1GPM WATER AT 125 PSIG 0.1 SCFM NITROGEN, 100PSIG
MATERIALS OF CONSTRUCTION:	316L 4
AMBIENT ENVIROMENT:	30°C
MOUNTING SURFACE RUNOUT:	+/-0.1mm
FLANGE LOADS:	1.8kN (AXIAL), 1.4kN (VERTICAL, HORIZONTAL) 1kN-m (AXIAL) 1kN-m (VERTICAL, HORIZONTAL)

4. ALL MATERIALS TO BE AS FOLLOWS UNLESS OTHERWISE APPROVEDL BY ORNL.
   A. ALL WATER FACING METALS TO BE 316L SST.
   B. ALL POLYMER SEALS AND O-RINGS TO BE EPDM.
   C. ALL SEATS TO BE SILICON CARBIDE.
   D. GASKETS ARE TO BE GARLOCK GRAPHITE COMPOSITE (3125SS OR EQ).
   E. OILS/LUBRICANT TO BE MORESCO RP-42.



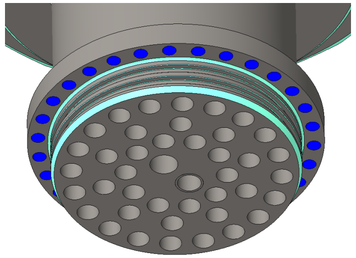


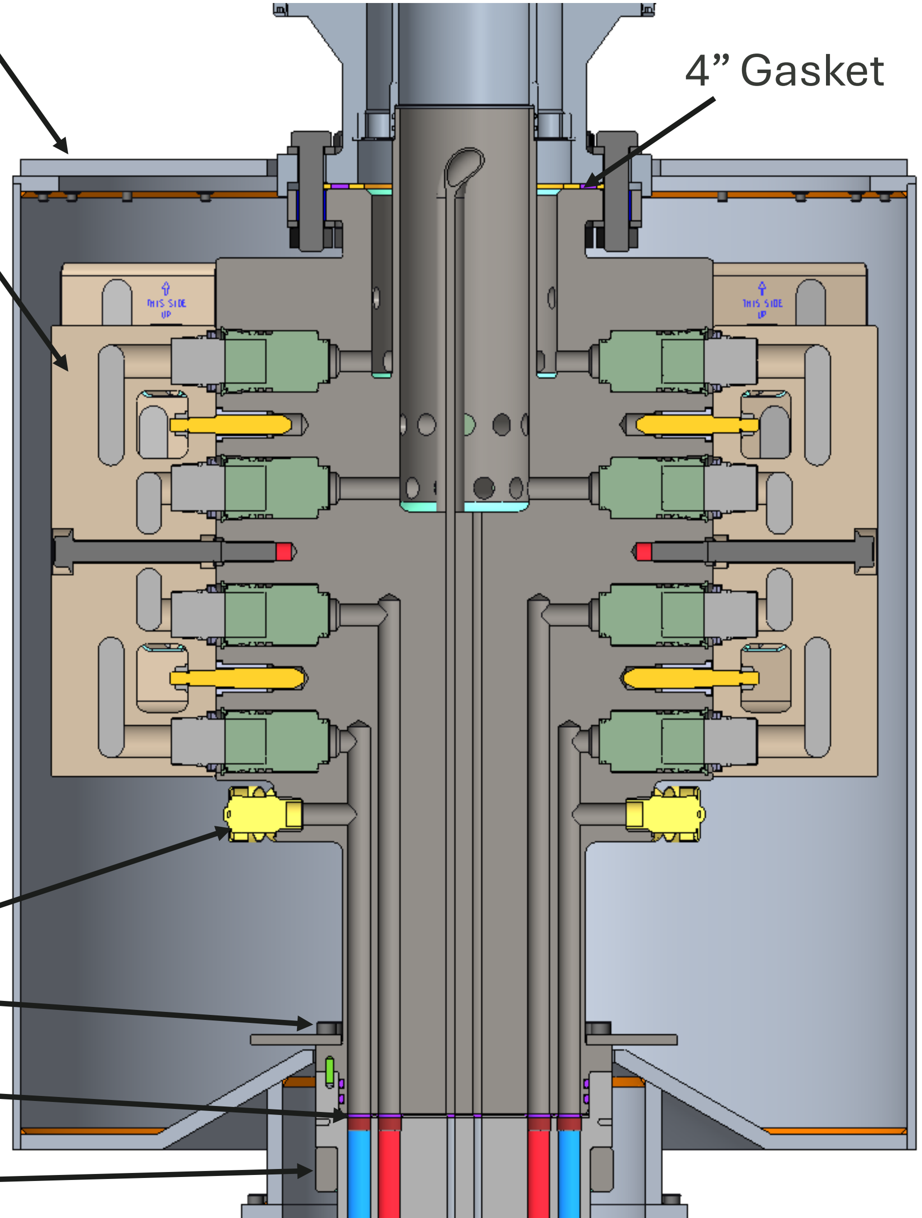


Rotational drag is reacted by the attached piping

The manifold distributes the primary flow into segment and shaft circuits

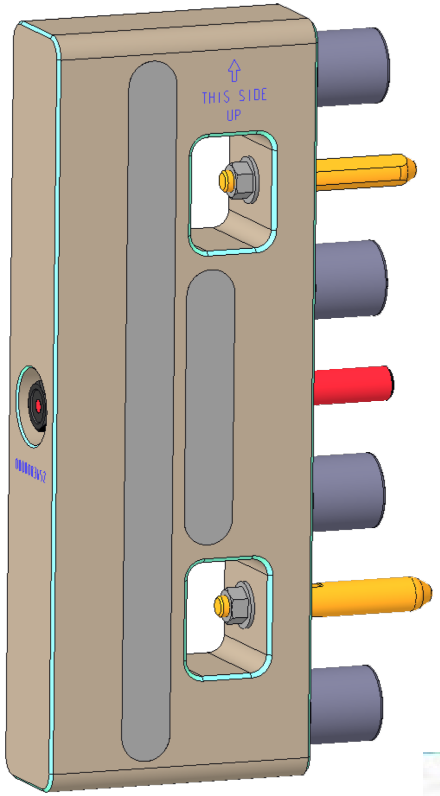
- Relief set point = 110 psi
- Material: 316L
- Bolts directly to crown (high preload to handle pipe interface loads)
- Water shroud for leak collection (to pipe pan)
- Staubli double dry break connections
- Prevents water leaks onto motor and resolver
- High clamping to prevent cross talk (diagnostics)
- Credited filter part of process systems flange
- Individual screens for circuits are used to prevent maintenance debris

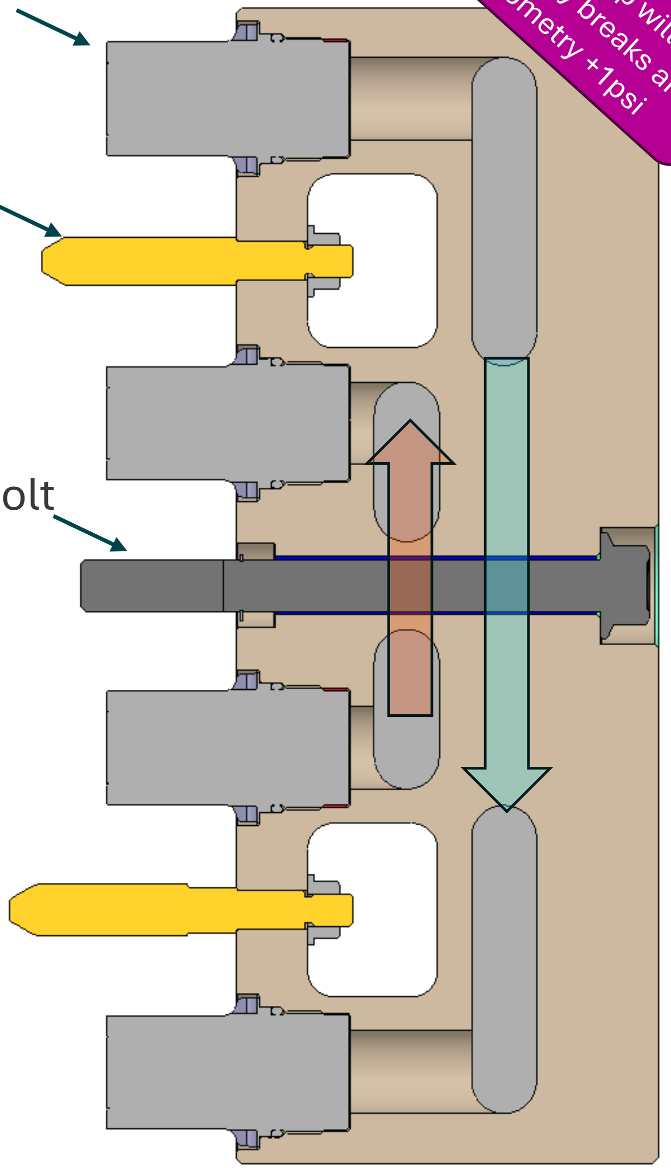




The jumper houses 4 valves and provides status of the connection

- Breaks create 0.25 psi drop (ea)
- Material: 316
- Draw bolt with indicator used to verify status
- Torque status is well beyond connection status
- Indicator only relevant at install
- Mass: 17kg
- Jumper removed to permit vertical install
- Can be rebuilt

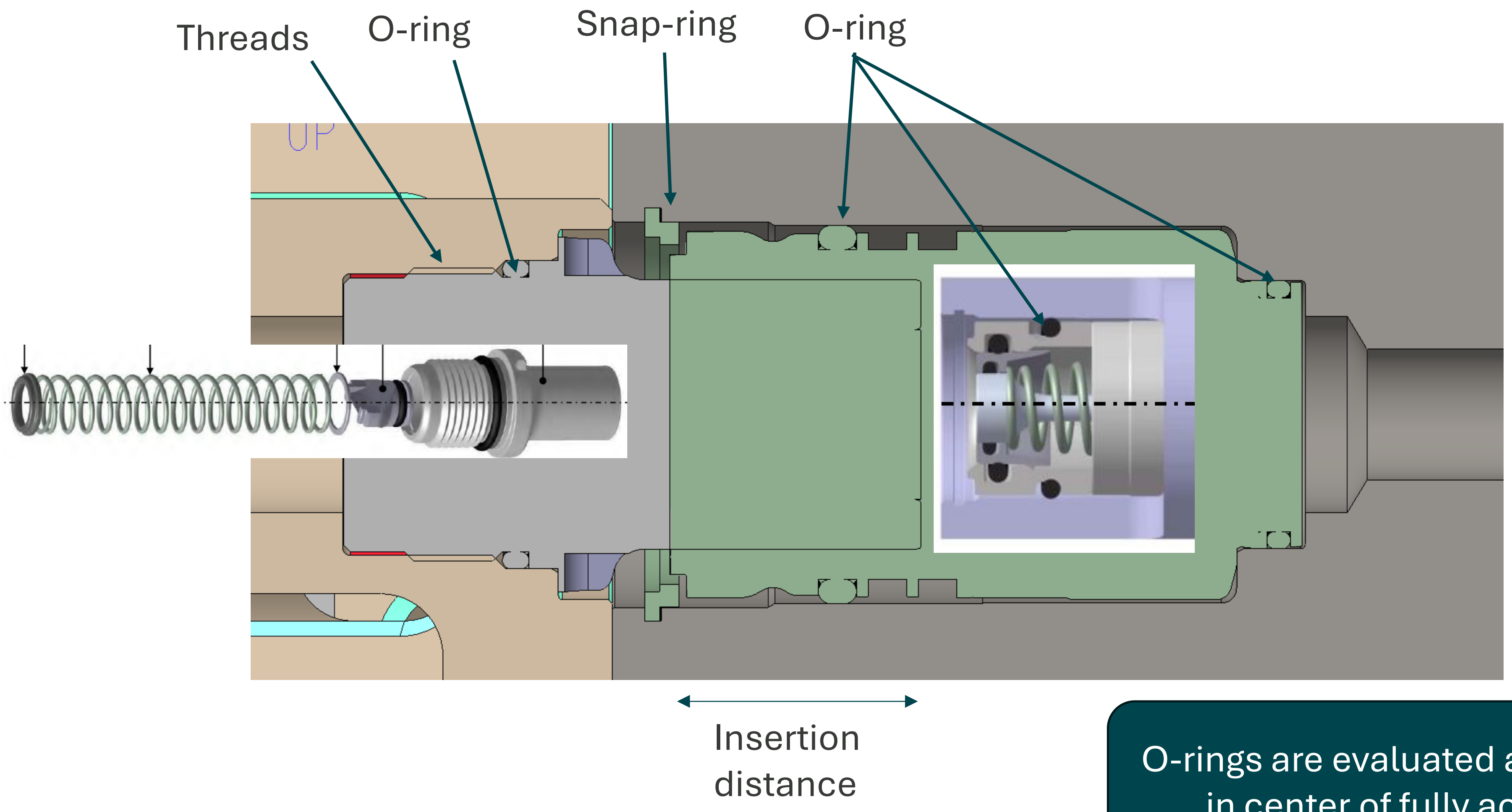




CFD pressure drop will be updated with dry breaks and jumper geometry +1psi

Maintenance jumper used for blowdown and diagnostics

The Staubli fittings are off the shelf fittings that allow flow during maintenance and can be easily replaced



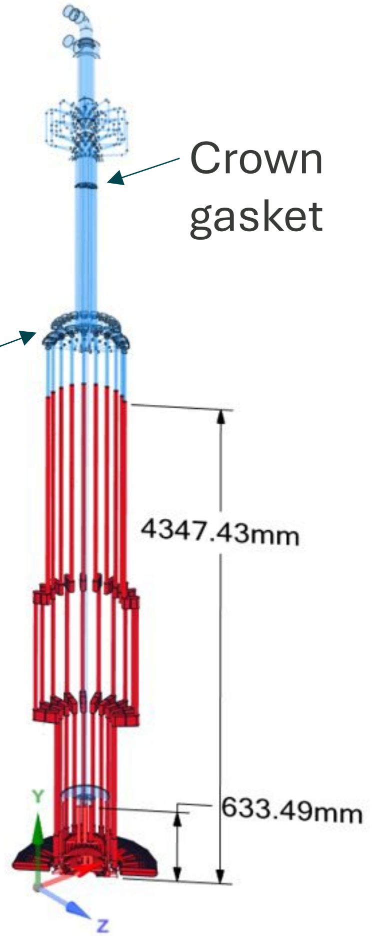
O-rings are evaluated as fully immersed in center of fully activated water

There are two blowdown procedures to remove water for maintenance safety

System blowdown

- Used for all maintenance cases
- Blowdown automated via process systems
- Water surface well below crown and segment interface

Forced air cooling to be running during and after blowdown



Crown gasket

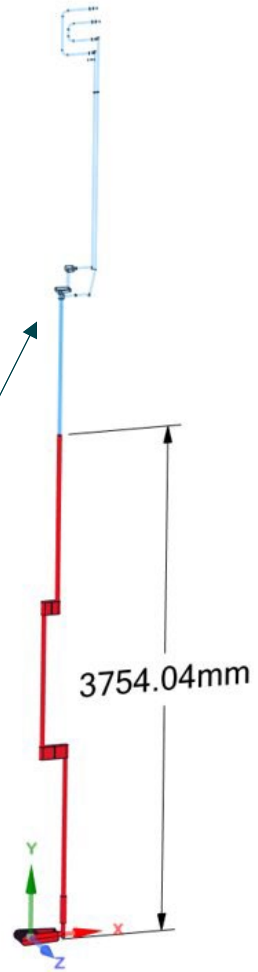
Segment Inteface

Isolated segment blowdown

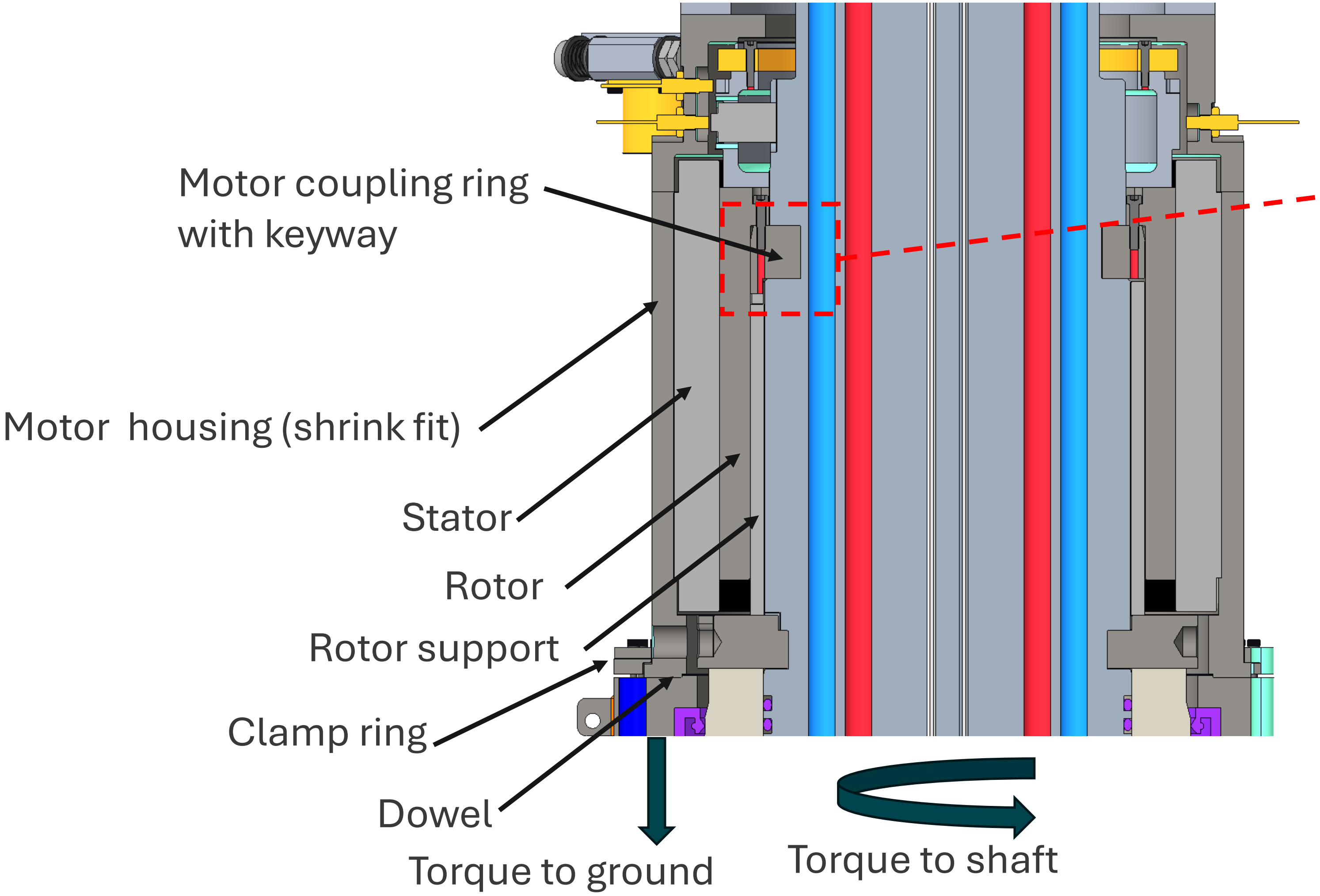
- Used for segment removal
- Removes water for safe transfer & reduces drying time*
- May be performed while water is flowing to 19 segments
- Not recommended to remove breaks with full/flowing water (re-establish after removal)

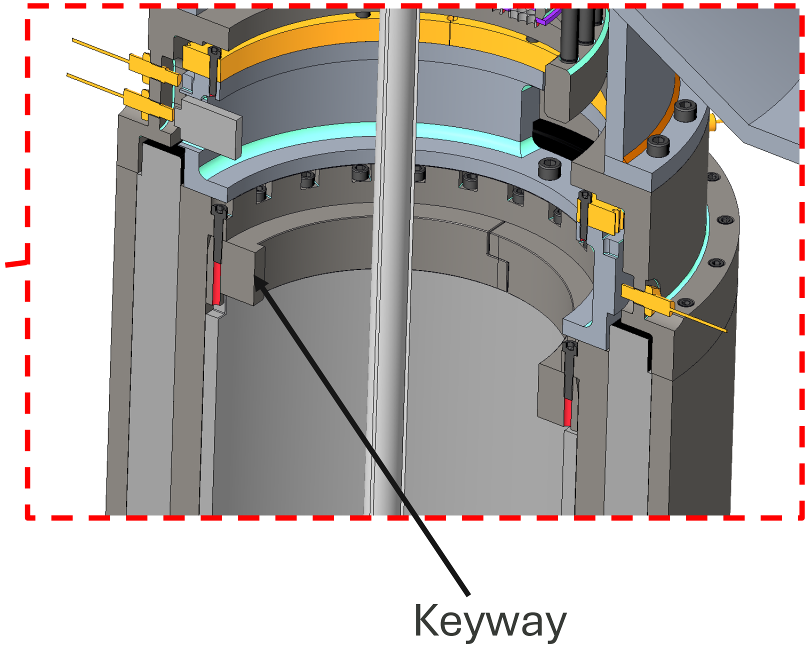
Segment Interface

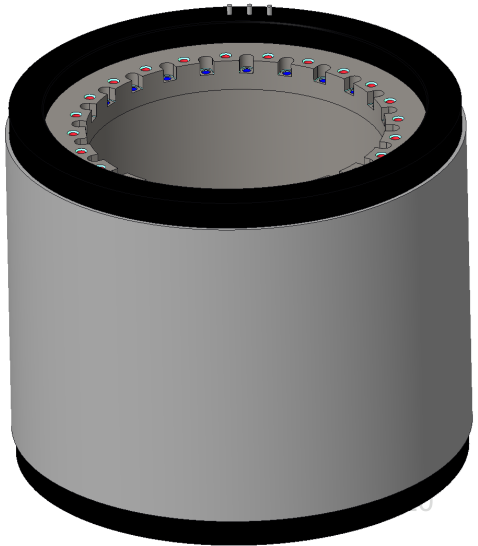
If a dry break o-ring has failed, it will manifest itself during the dynamic event of mating/demating. Jumpers to be manipulated after system blowdown



Rotational load path from the motor into the drive housing involves a keyway, shrink fit, and multiple dowels



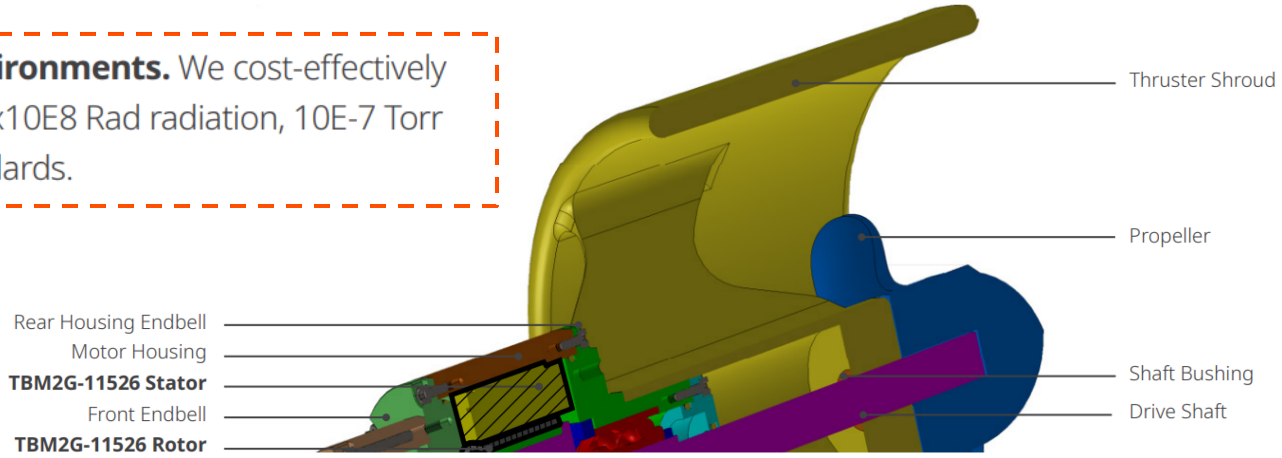




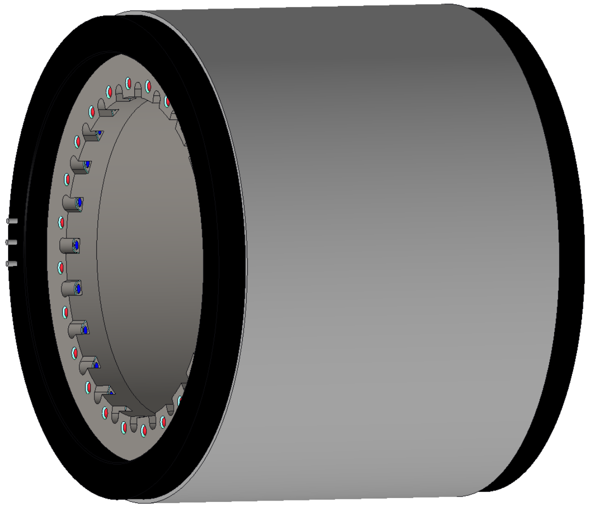
The motor is a modified variant of an off the shelf item from a vendor with experience in radiation design and materials

We offer many housed motors that are specialized for use in extreme environments — such as the submersible Goldline S Series, washdown-ready AKMA and AKMH Series, radiation-hardened motor variants and more. However, for the most compact, lightweight machine design, another compelling option is to embed a frameless motor directly within the structure of the machine.

- **Adapted for near-earth and deep-space environments.** We cost-effectively modify our standard motor platforms to meet 1x10E8 Rad radiation, 10E-7 Torr vacuum, and NASA-STD-6016A outgassing standards.



<u>Modifications:</u>
Bore diameter
Bolt circle diameter
Rad-hard materials of construction



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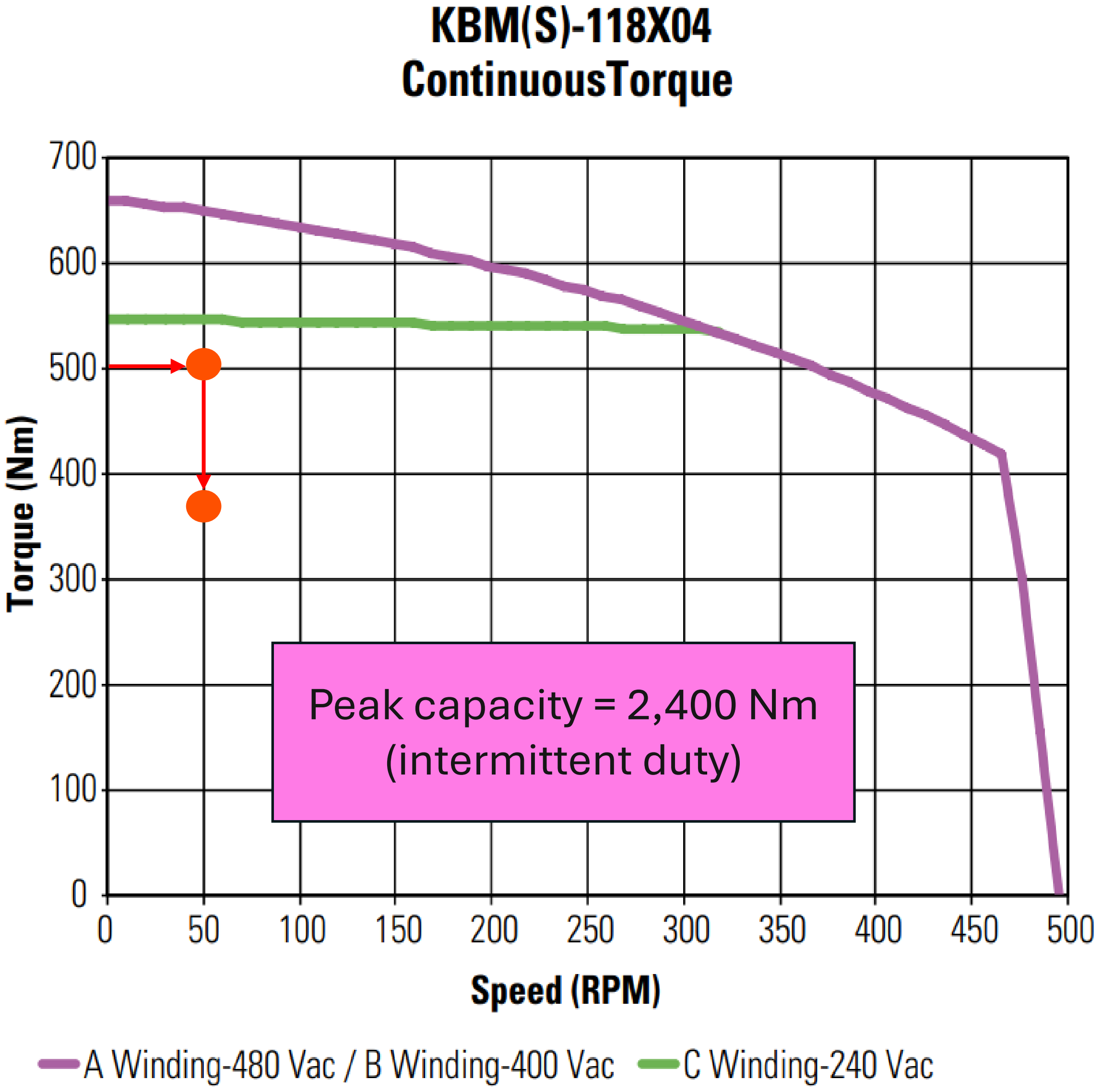
The motor has margin at steady state and startup

Friction (Nm)	Contributor
70x2=140	Thrust bearing friction (2)
5	Radial needle bearing
75	Vacuum seal
30	Grease seals
75	Water rotary union
10	Unforeseen
365	Total- Steady state
490	**Start-up**

Inertia=1.6×10^3 kg-m^2
$\alpha = 4.5$ deg/s^2 (1 minute)
=125 Nm

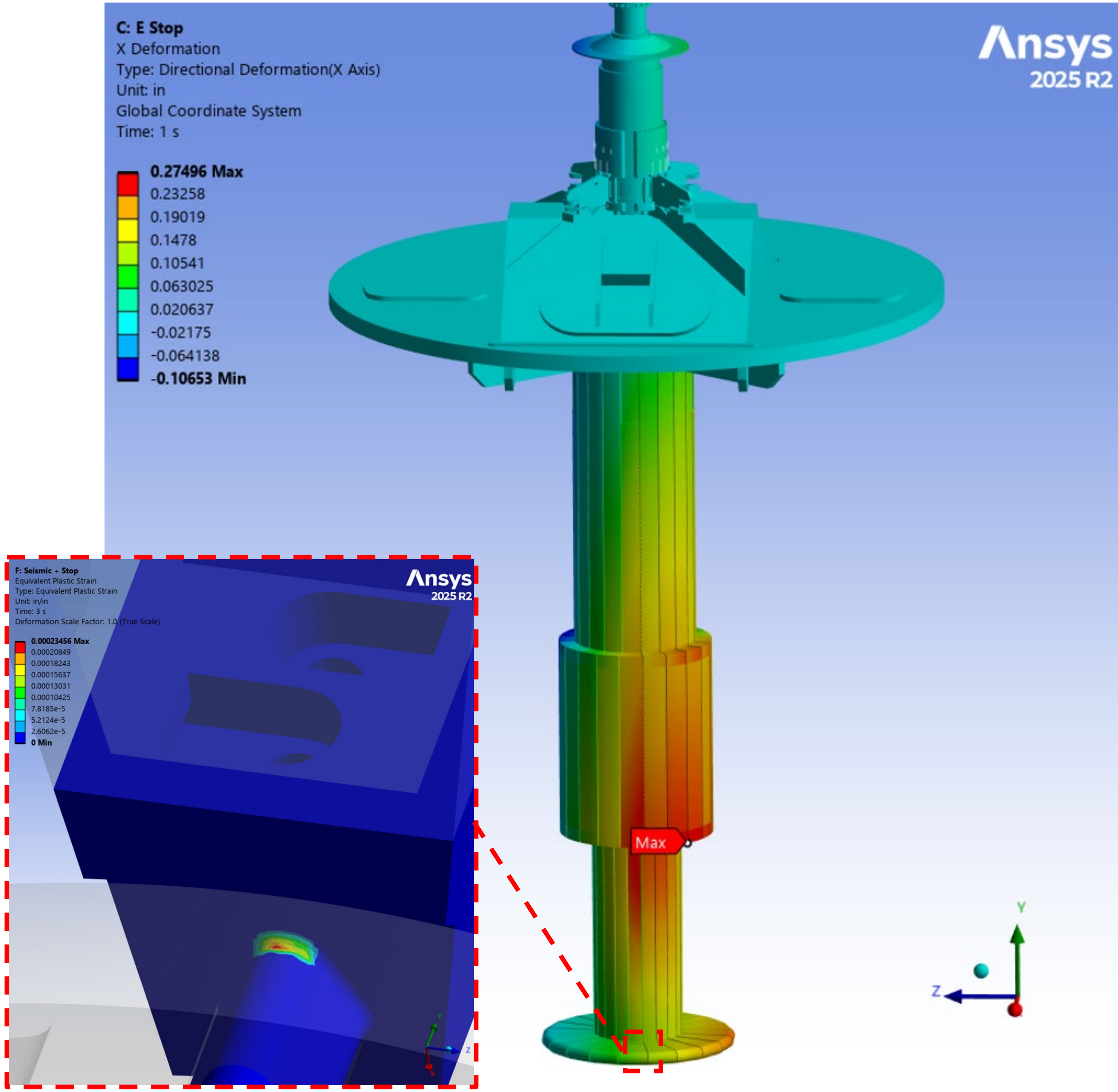


An oversized motor can also abruptly stop

<u>Items that survive a peak torque stop:</u>

- Keyways
- Shaft (S0302000-DAC10002) ✓
- Segment(S0302000-DAC10002)
- Segment pin (S0302000-DAC10002)
- Bolted connections (S0302000-DAC10002 & S03020000-DAC10005)
- Dowels (S03020000-DAC10005)

Peak capacity = 2,400 Nm
(intermittent duty)



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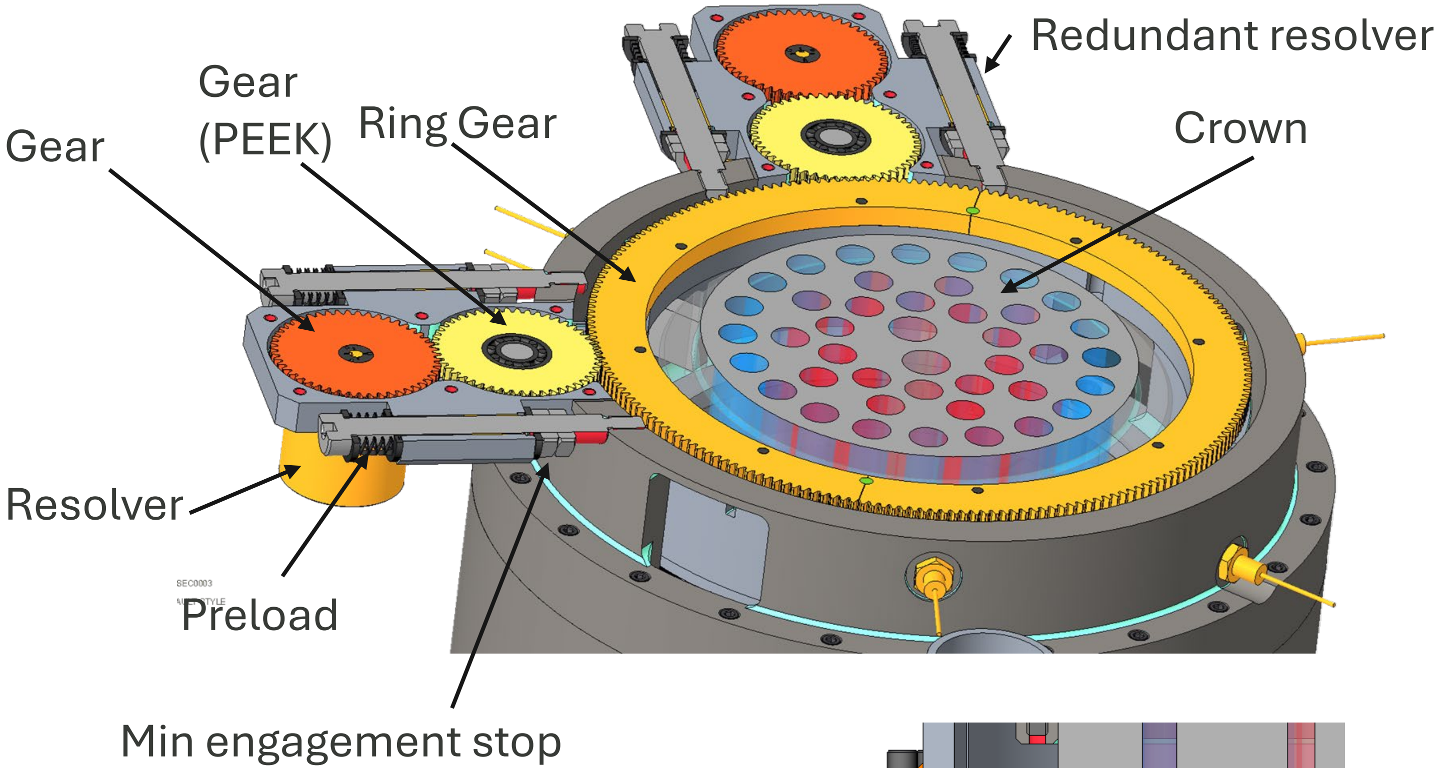
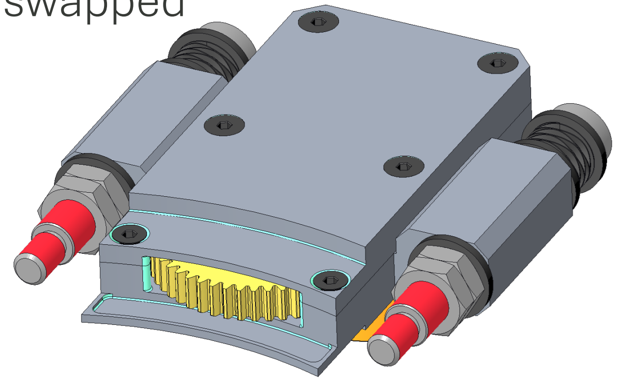
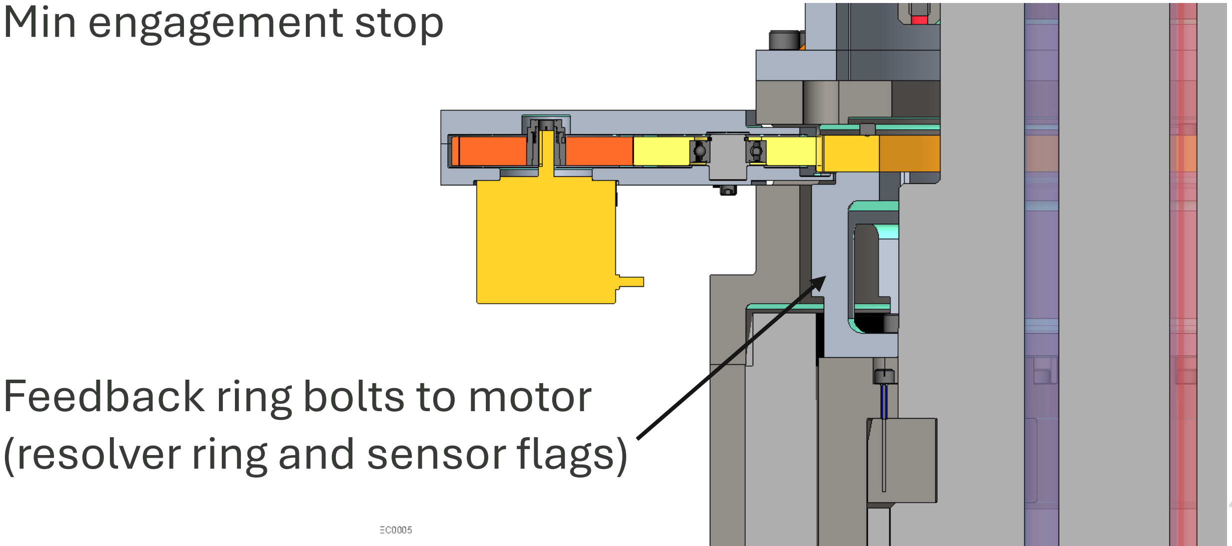
The resolver provides rotational feedback to the control system

- Resolver for radiation environment (2 Mgy)
- Accuracy: 10 arcmin (0.016 deg)
- Redundant for additional reliability
- Coupled with homing flag for precise positioning (relative & absolute position knowledge)
- Modified bushings and bores from COTS gearing
- PEEK gearing to avoid hard or magnetic schwarf from falling into rotor/stator gap
- Resolver can be easily swapped



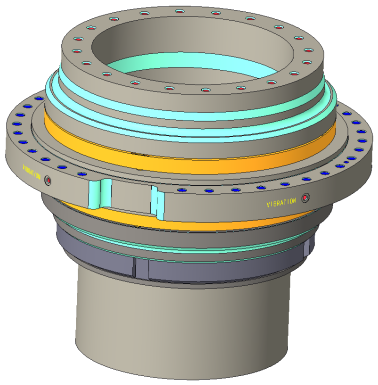




Bearings have increased in precision as the design moved into tolerancing and drawings

CAD Modeling and Analysis

- Can it carry the loads?
- Is the lifetime adequate?
- Does it fit within the envelope?
- Can it be built?
- Radiation tolerance?

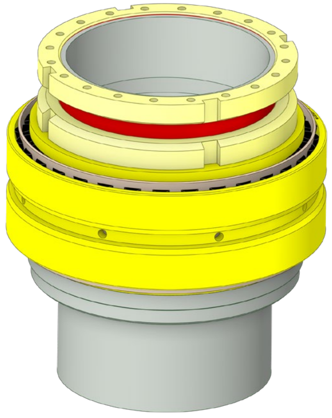


Can it be built, toleranced, preloaded, and kept lash-free with predictable stiffness?

Drawing Detailing

What are appropriate:

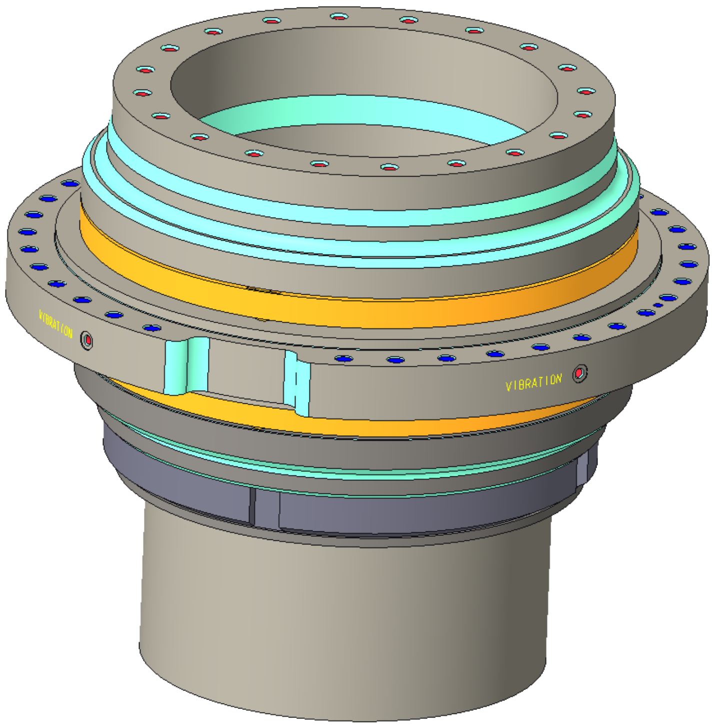
- Tolerances?
- Surface roughness?
- Fits?
- Clearances?
- Preload values?

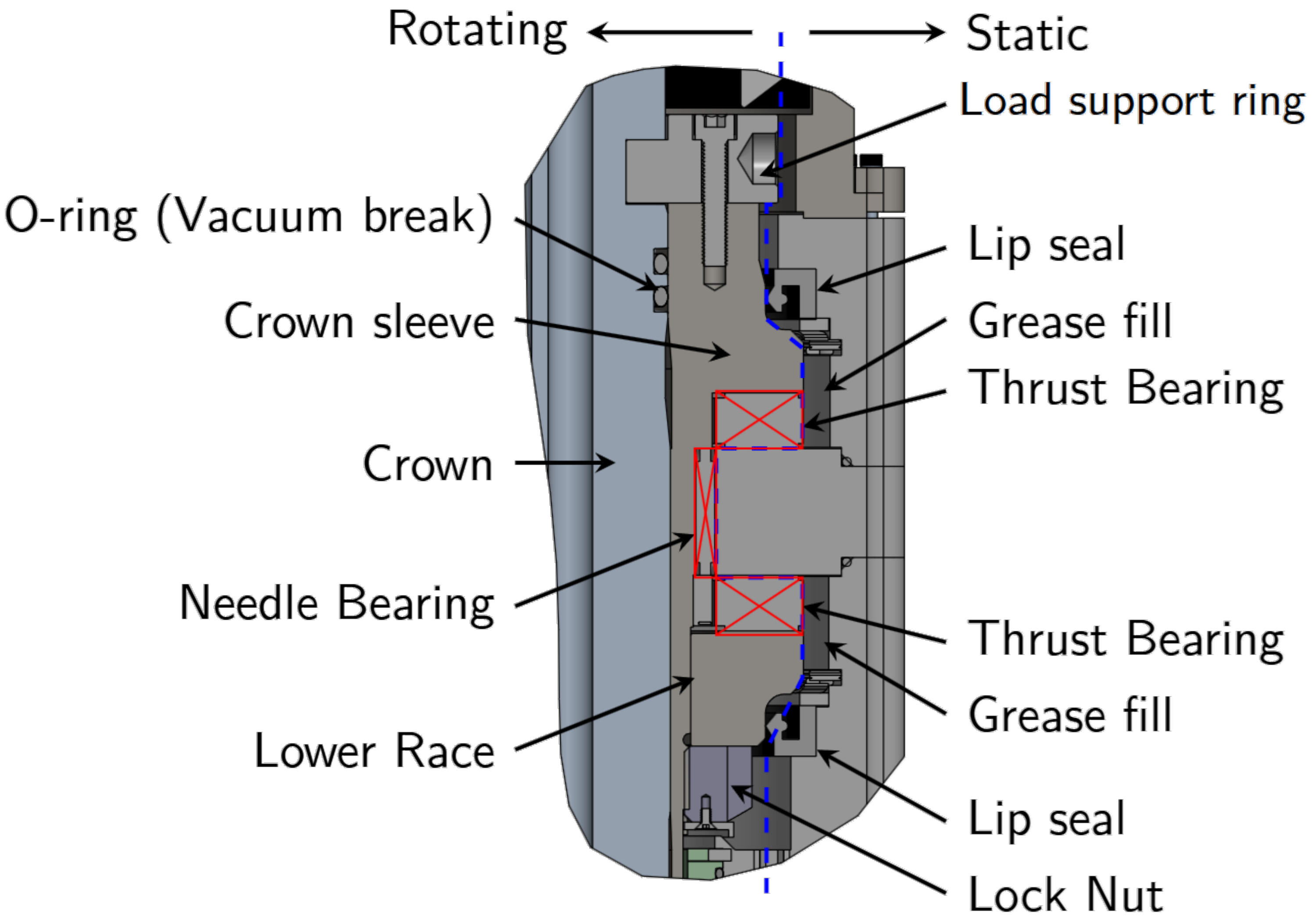


Precision occurs during drawing detailing

- **The documentation package reflects the current baseline**
- **Since that package was frozen for FDR documentation additional detailing work has been completed beyond FDR expectations**
- **Today's presentation will**
  - **Summarize what is in current documents**
  - **Present recommended update & impacts**

Baseline - Bearing General arrangement

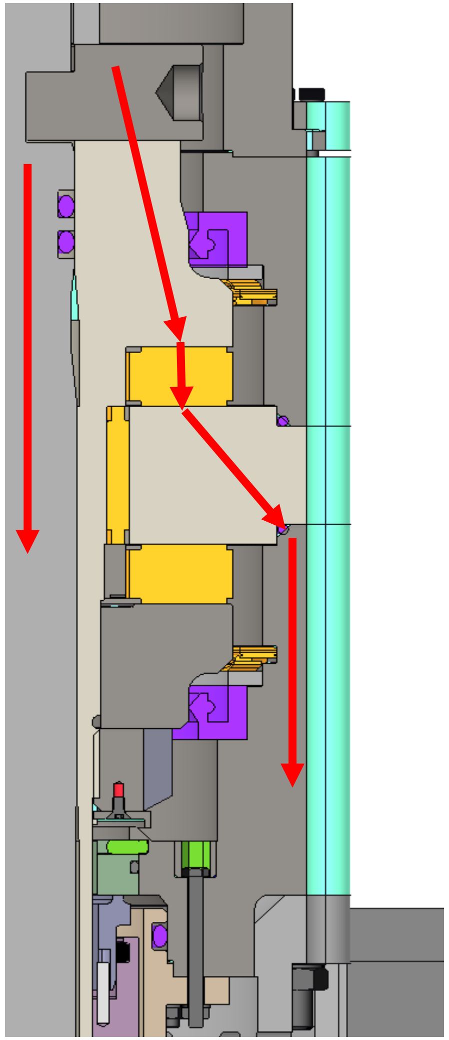




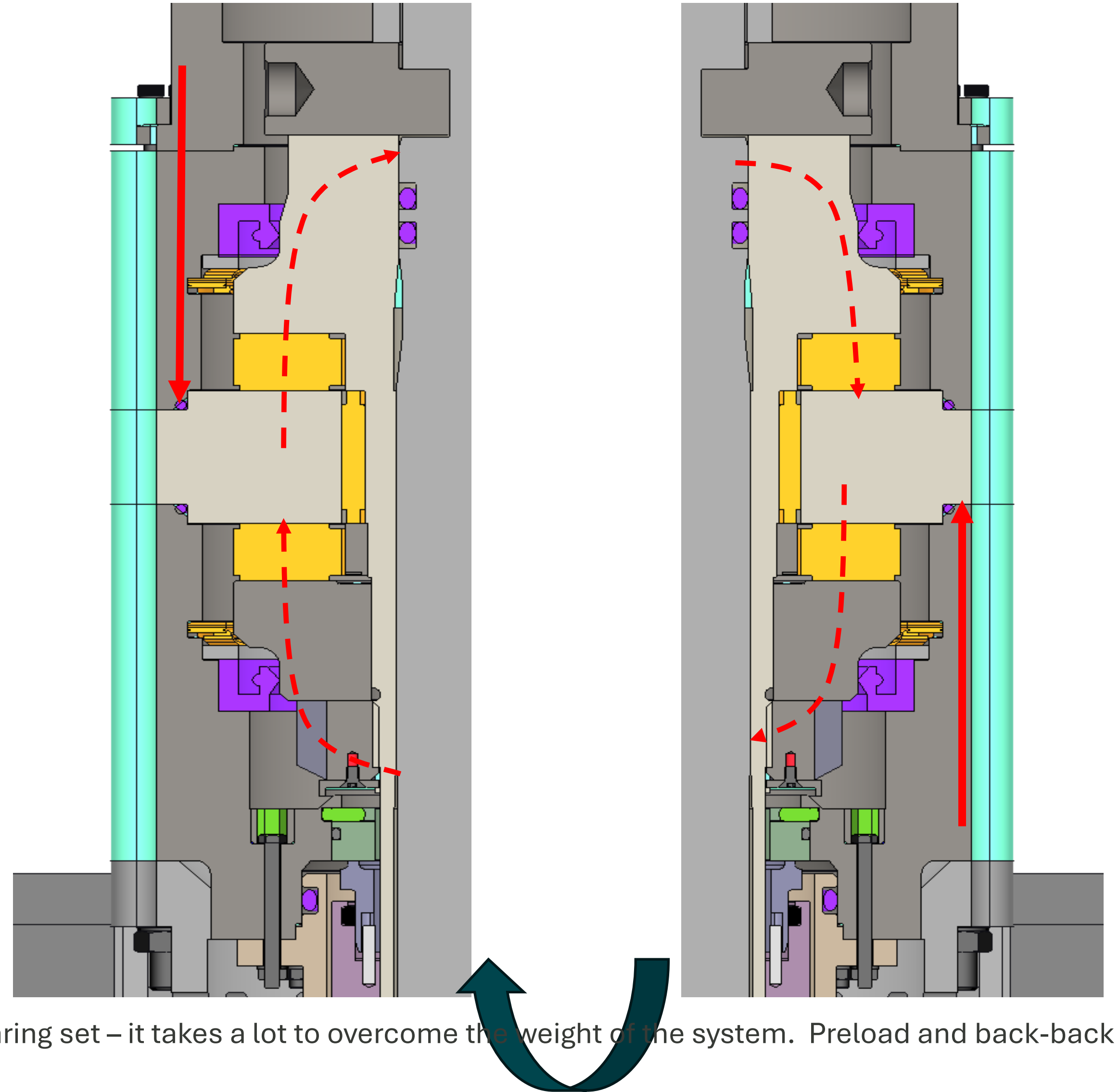
Current bearing arrangement in
- Design Description
- Machine Design Calcs
- Preliminary Drawings

Baseline - Load paths through the bearing set

Gravity (thrust load)



Couple (Imbalance & seismic)



*The external lifting force only unloads the compression in the bearing set – it takes a lot to overcome the weight of the system. Preload and back-back arrangement is important for a stiff system without lash

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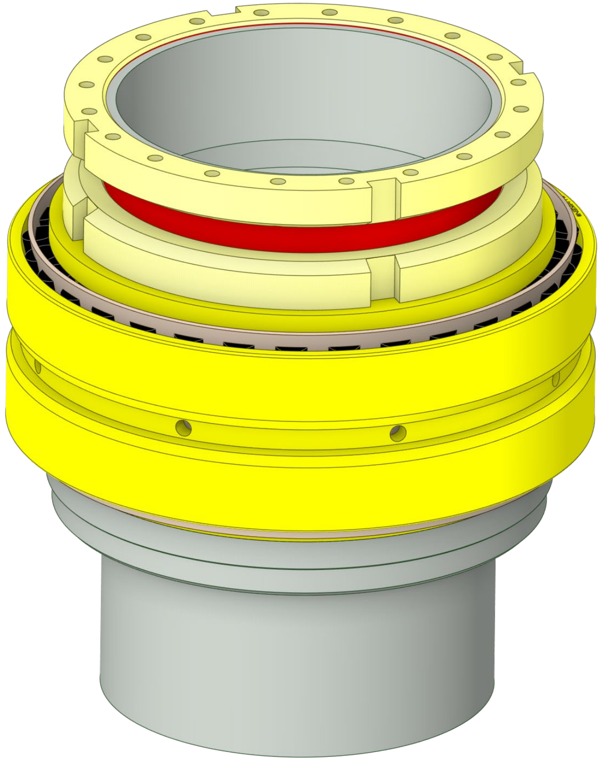
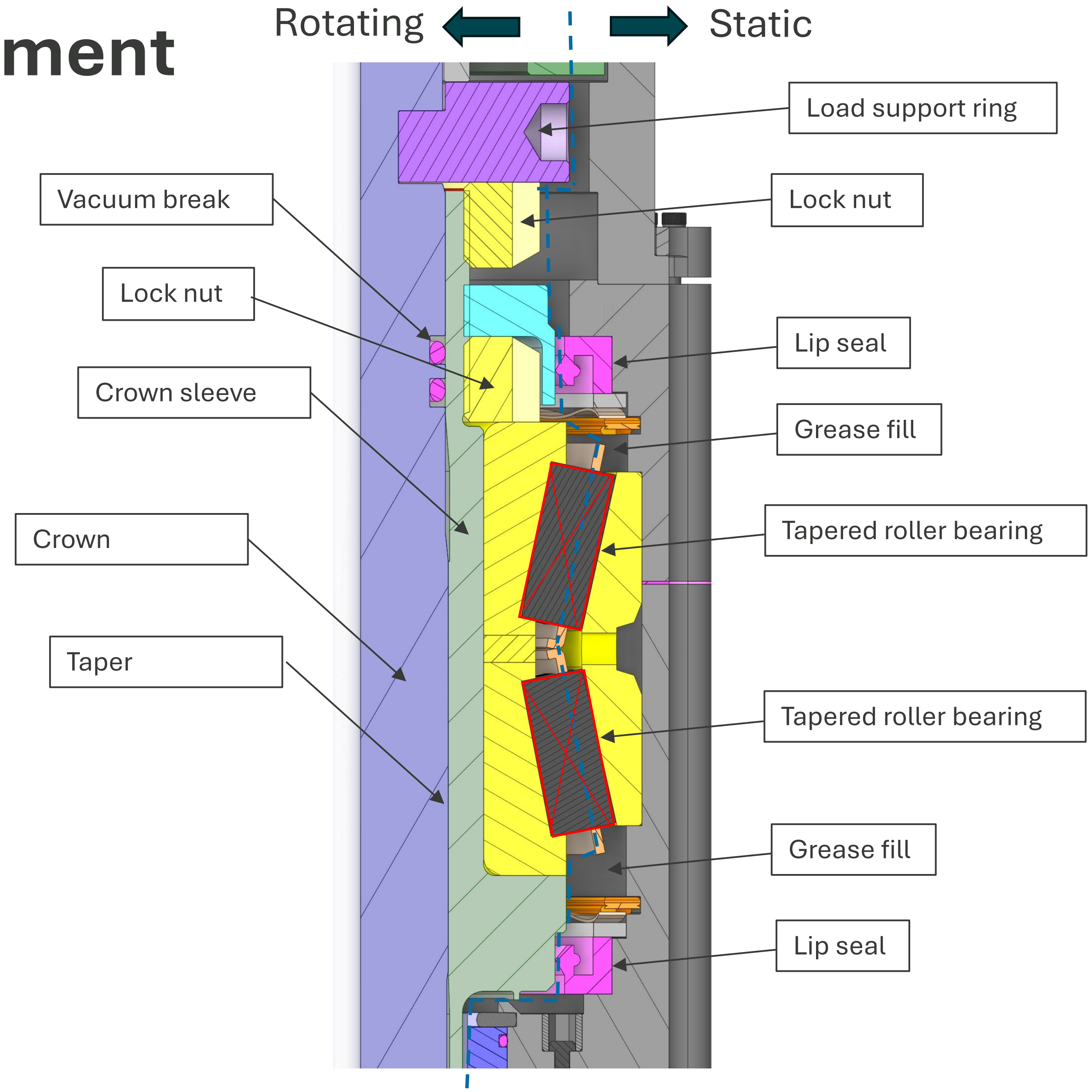
Recommended bearing arrangement for drawing release





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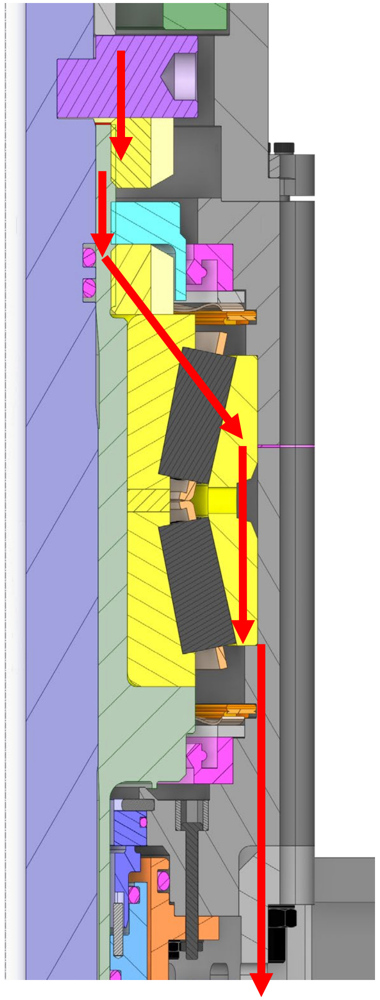
Recommended bearing improves imbalance load path and tolerances while maintaining thrust capacity

Gravity



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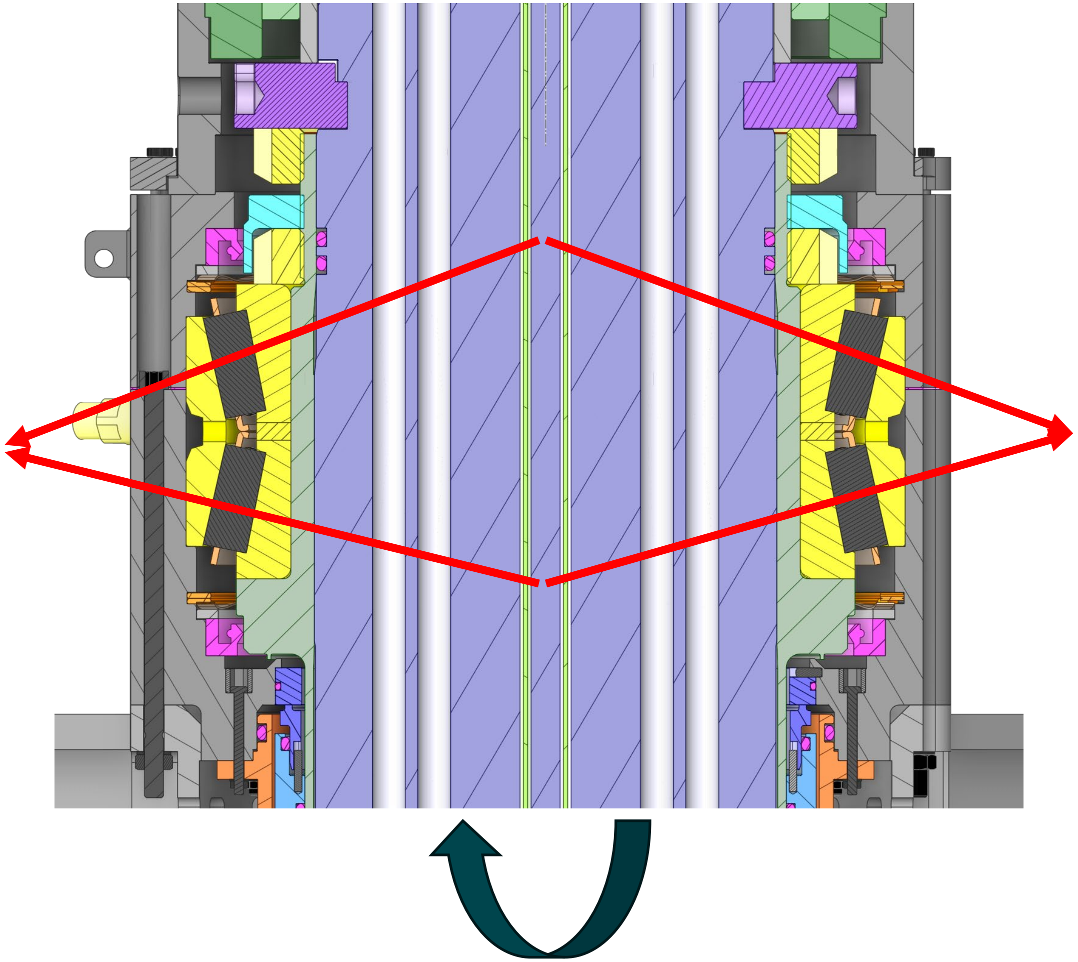
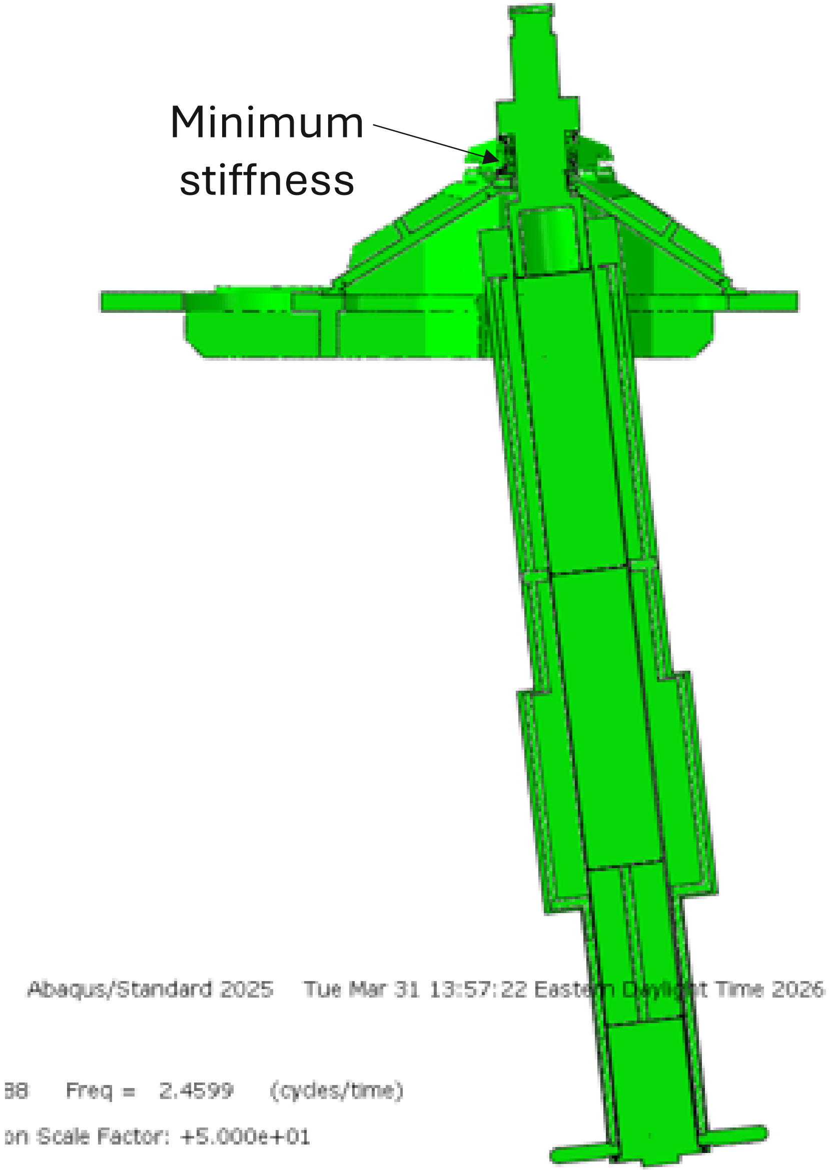


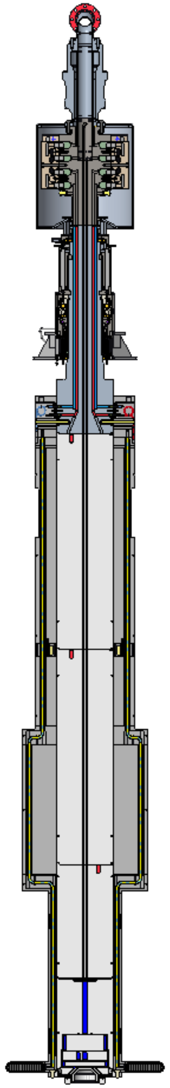
System stiffness is dominated by tolerances along load paths

Mode 1 = 2.5 Hz

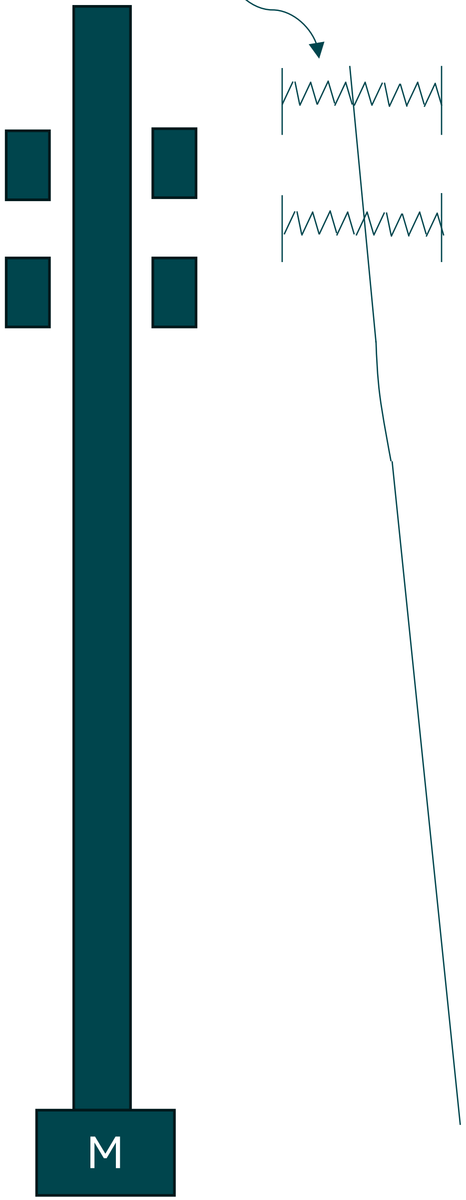
Excitation=0.75 Hz (45 rpm)

- 35 kg-m eccentric: deflection <0.5mm
- <u>Assumes bearing are perfectly rigid</u>
- Lower shaft and lid are quite stiff
- Reduction in cross section for bearings and seals reduces stiffness
- How stiff is the load path between the lid and the shaft?





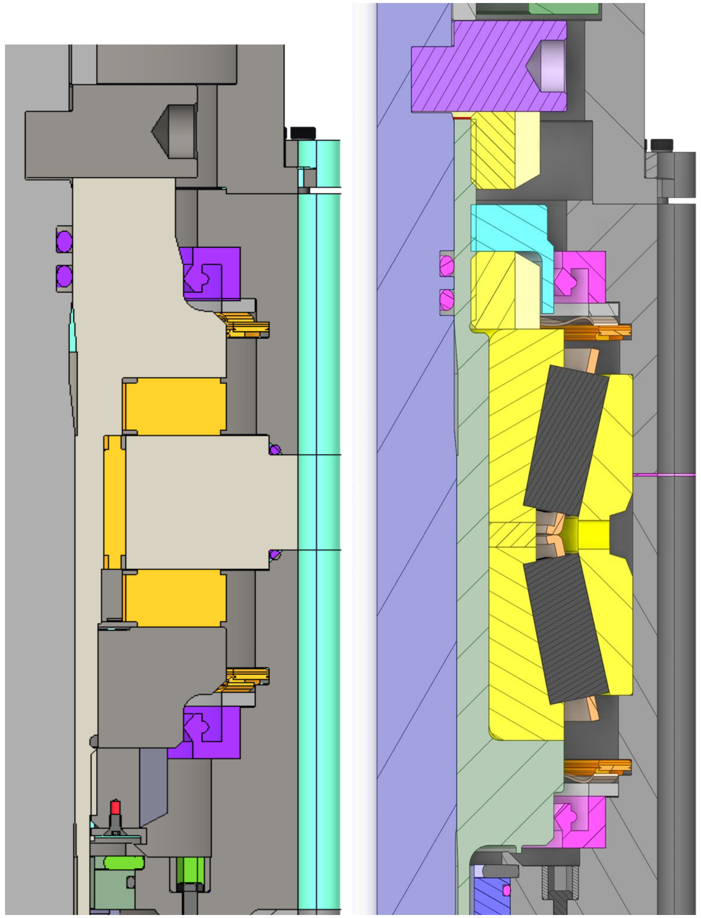
Stiffness – depends upon clearances and bearing stiffness
K_{gap}=0!



Recommended arrangement for drawing release will improve stiffness and reduce time to prepare drawings

Baseline - Thrust & Radial

- Excellent thrust capacity and axial load path
- Chosen for thrust capacity, stack height, and radial envelope
- Detailing and providing the bearing races will be an enormous task
    - Hardness & flatness of the races are difficult to specify without bearing vendor knowledge (not readily available or common conversation)
    - Deflection limits are not published or available for races (limited/no vendor support)



Not quite drop-in replacement, but close!
Both require taper

Drawing Release - Tapered Roller

- Excellent shaft stability & thrust behavior
- Assembly (w/ races) provided by bearing vendor
- Excellent vendor support for system (common bearing)
- Clear load path (thrust AND radial)
- Stiffer arrangement to resist imbalance
- Easier & faster to detail

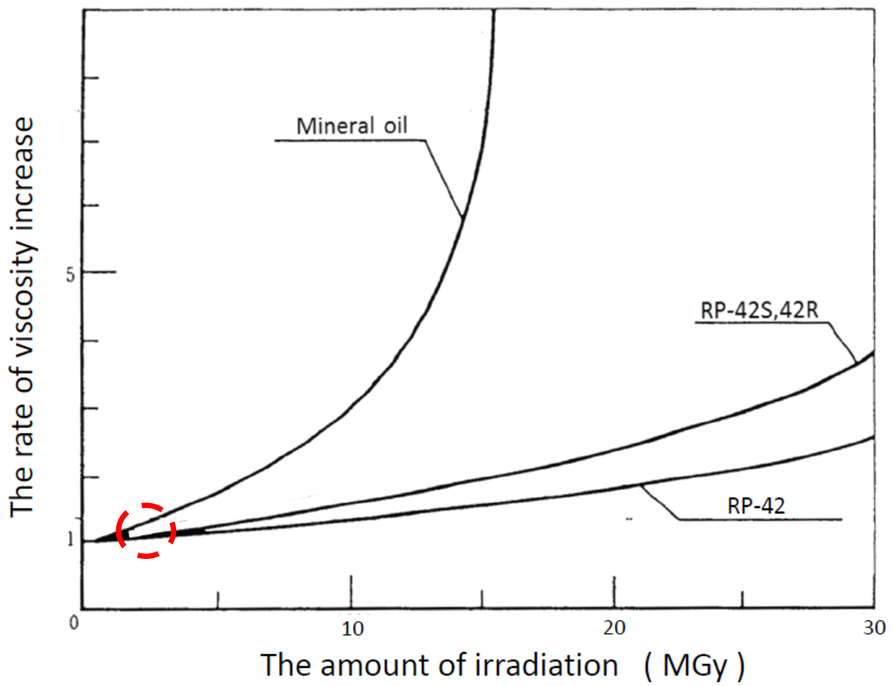
Deployment

- CAD update (off-line model)
- Machine design calcs (rough draft complete)
- Timken internal review

Grease selection

Select: Moresco RG-42-1

- Must be compatible with selected polymers
- Must have adequate viscosity for bearing protection
- Must have viscosity for reducing friction
- Must be compatible with radiation resistant seals



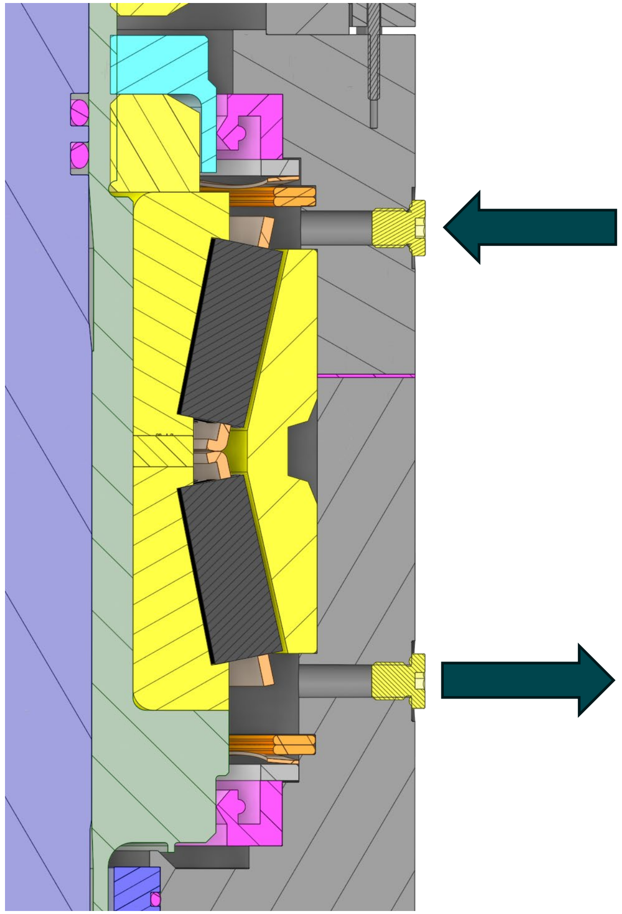
The Range of The Grease Types Products

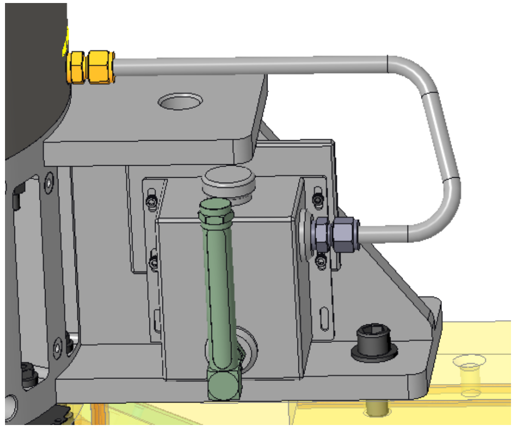
Product name	MORESCO-HIRAD RG-42-0	MORESCO-HIRAD RG-42-1	MORESCO-HIRAD RG-42-2	MORESCO-HIRAD RG-42R-0	MORESCO-HIRAD RG-42R-1	MORESCO-HIRAD RG-42R-2	MORESCO-HIRAD RG-42S-0	MORESCO-HIRAD RG-42S-1	MORESCO-HIRAD RG-42S-2
Consistency number of NLGI	0	1	2	0	1	2	0	1	2
Consistency	355～385	310～340	265～295	355～385	310～340	265～295	355～385	310～340	265～295
Oil Separation (%) 100 dC × 24 h	No data	< 4	< 1	No data	< 4	< 1	No data	< 4	< 1
Dropping point dC	No data	>300	>300	No data	>300	>300	No data	>300	>300
Base oil		RP-42			RP-42R			RP-42S	
Thickener					Inorganic				
Type of packing					1kg can				

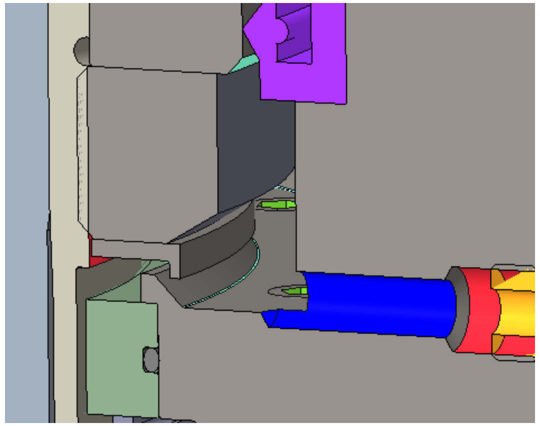
	Ethylene propylene	Nitrile	High-Nitrile	Fluorine	Chloroprene	Silicon
RP-42	○	×	×	○	×	○
RP-42R	×	○	no data	○	×	○
RP-42S	×	×	×	○	×	○
A Mineral oil (Paraffinic)	×	○	○	○	○	○
				○ = Compatible		× = Incompatible

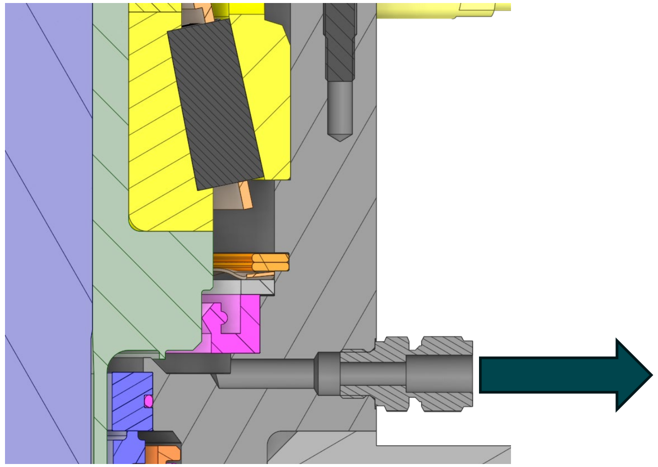
Grease containment & replacement

- Grease packed in bearings prior to install
- Push grease into housing
- Drain or Push old degrease out
- Configured for oil circulation upgrade
- Catch drain for visual monitoring and disposal
- Care must be taken during fill or purge not to exceed pressure of seals
- Oil “umbrella” prevents ingress of lubricant into vacuum seal





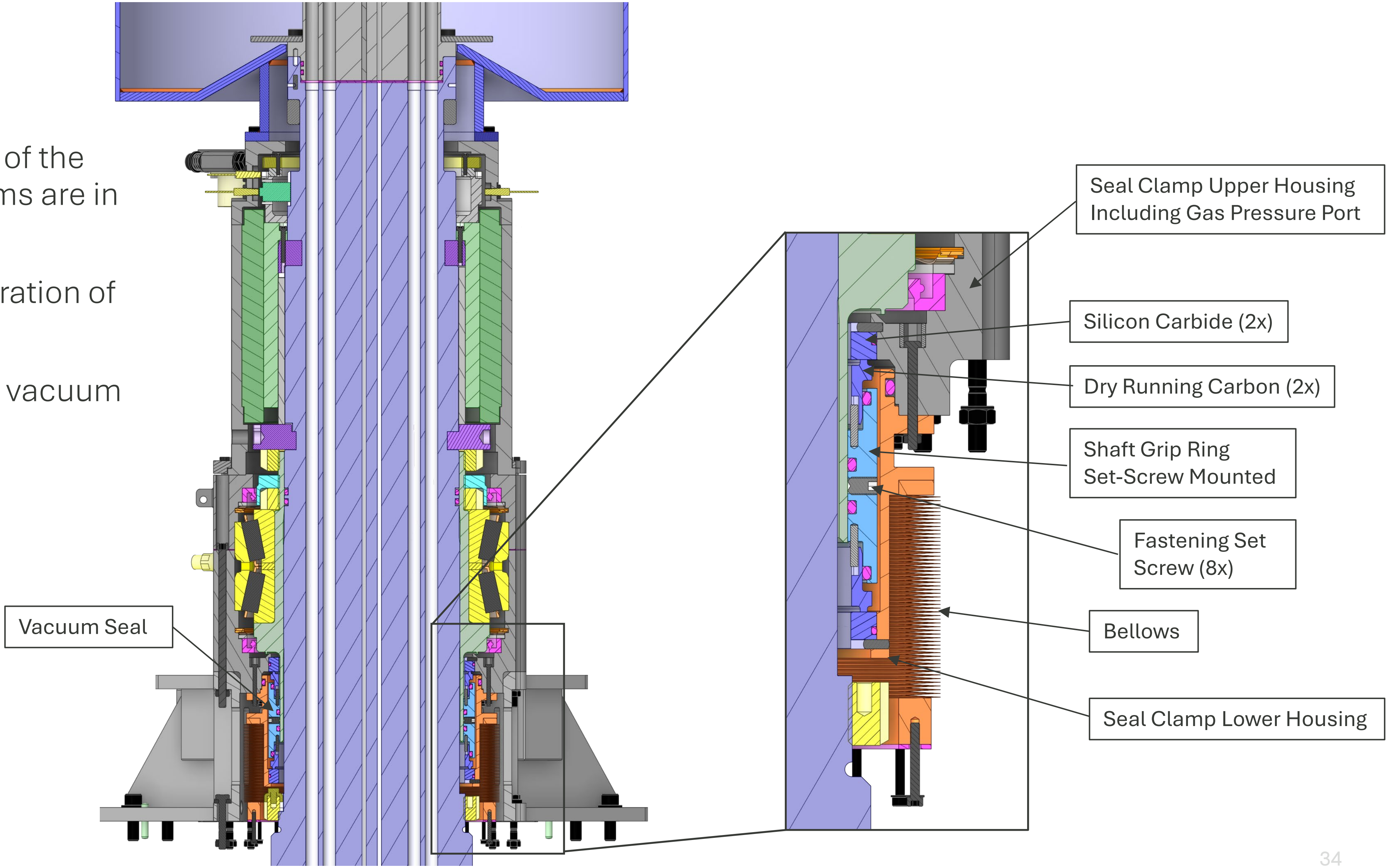




320X360X20 HMS5 V

Rotary vacuum seal – general location

- Located at the bottom of the stack to ensure all items are in ambient
- Gas pad ensures separation of grease from vacuum
- Provides seal between vacuum and rotary sections



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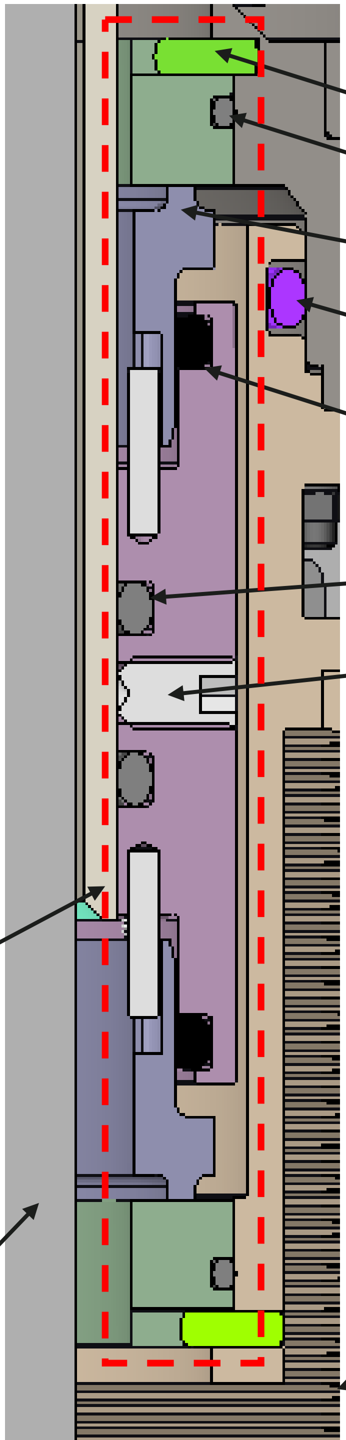
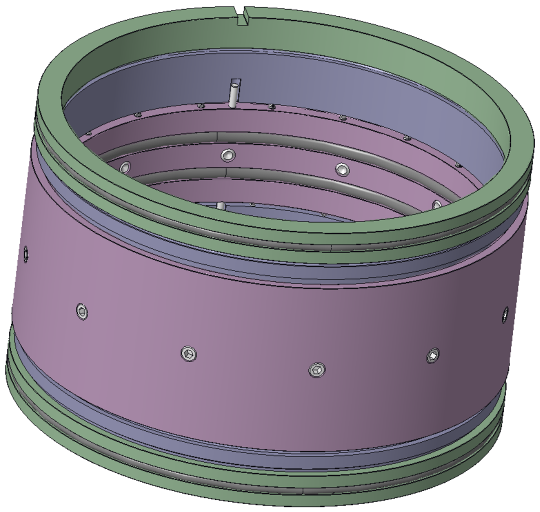
Rotary seal details

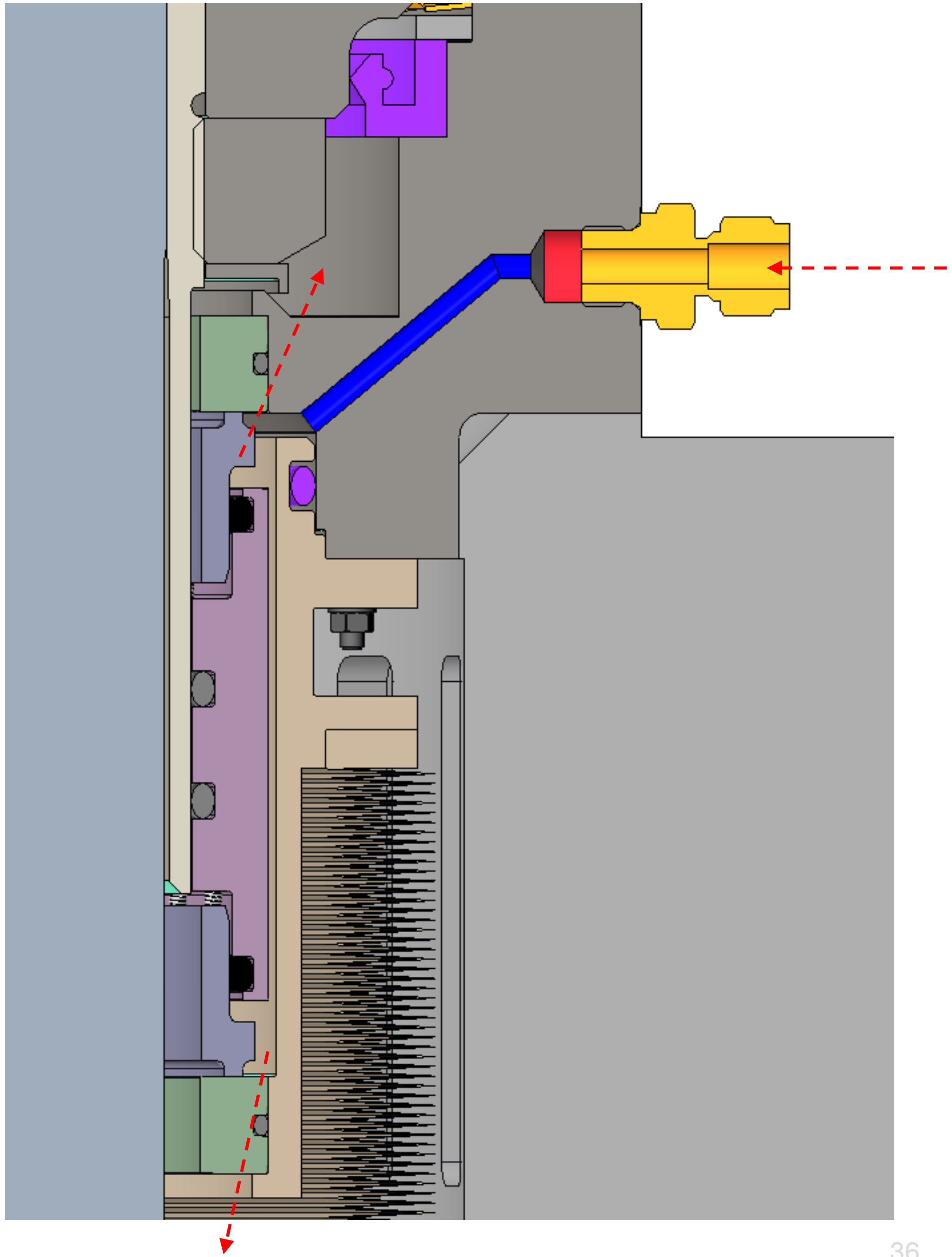
- Off the Shelf component (Chesterton)
- Dry running face seal
- Double seal to provide positive gas barrier and redundancy
- Helium gas purge to prevent grease→ vacuum
- Generous leak rate allowance: 0.1 Torr-L/s
- Installed on Crown Sleeve, bellows over





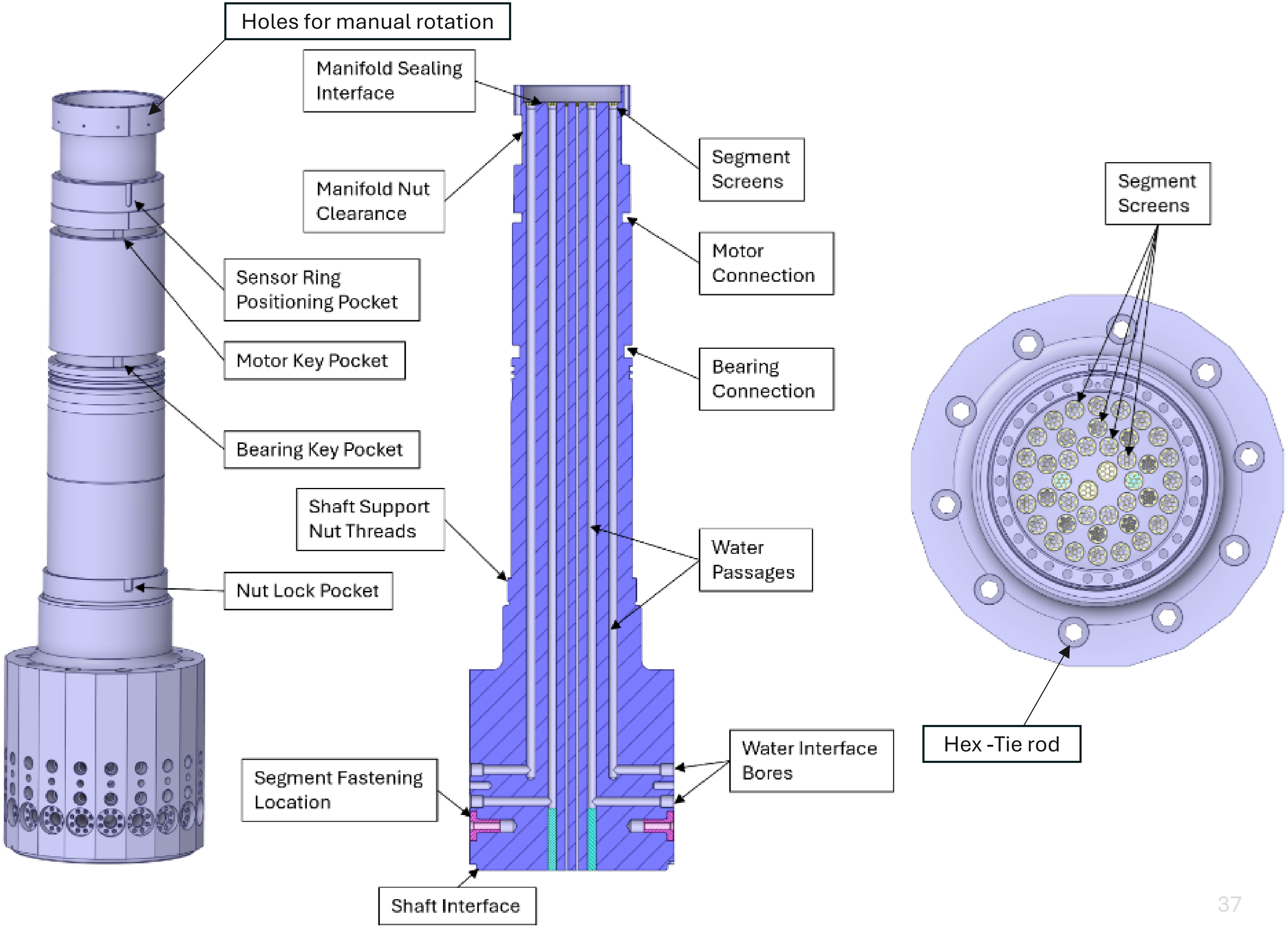
Helium pathway

- Helium pressure: 7 psig
- Control pressure; monitor mass flow rate
- Helium into drive
- Helium into core vessel
- Prevent grease into the core vessel
    - Vent if loss of helium



The crown houses multiple features for the drive and shaft

- Material: Inconel 625 (corrosion resistance & ductility)
- Involves accuracy deep drilling for water passages
- Fit-up will be important to minimize fretting during operation and maintenance
- Large turning
- Replacement possible in-situ



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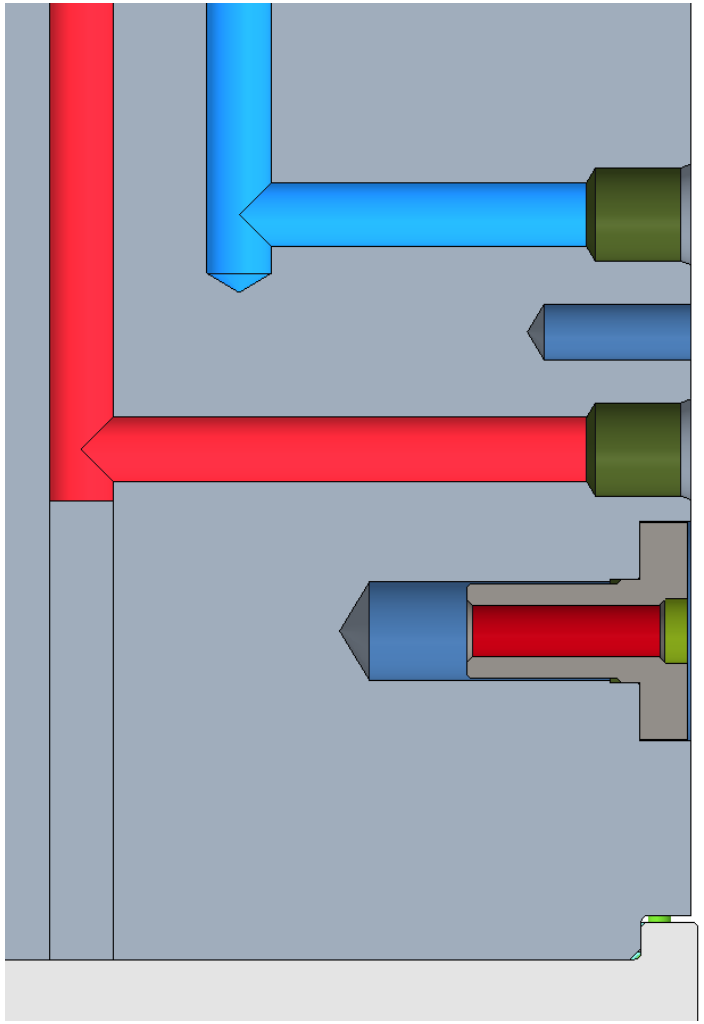
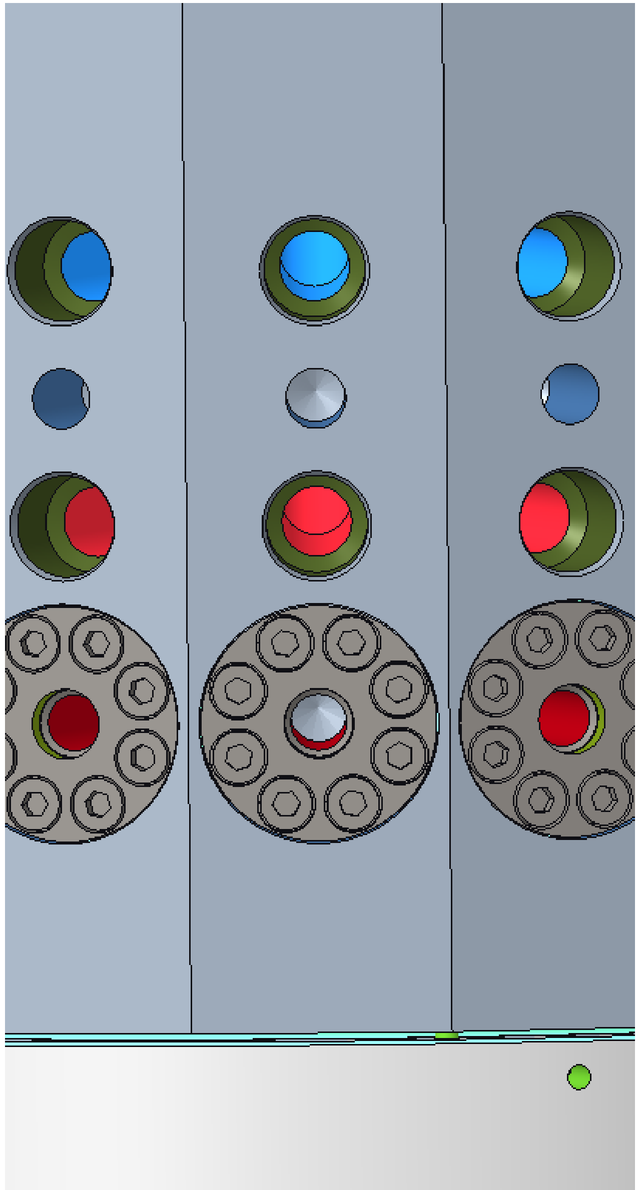
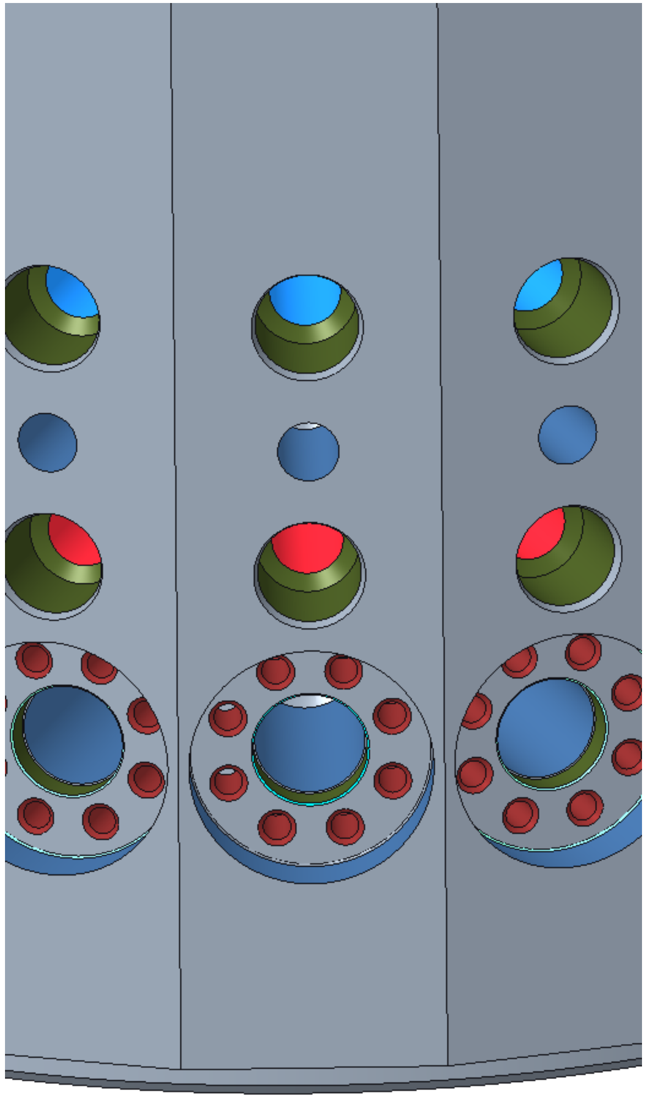
The segment attachment threads are replaceable in-situ

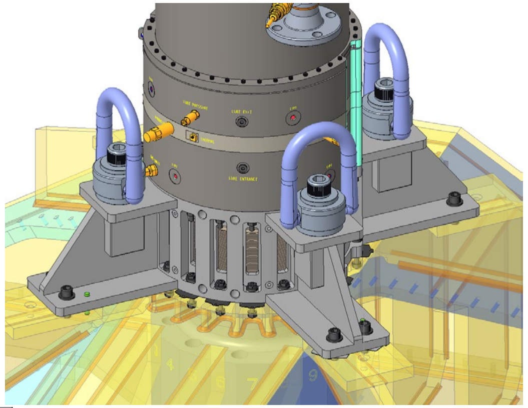


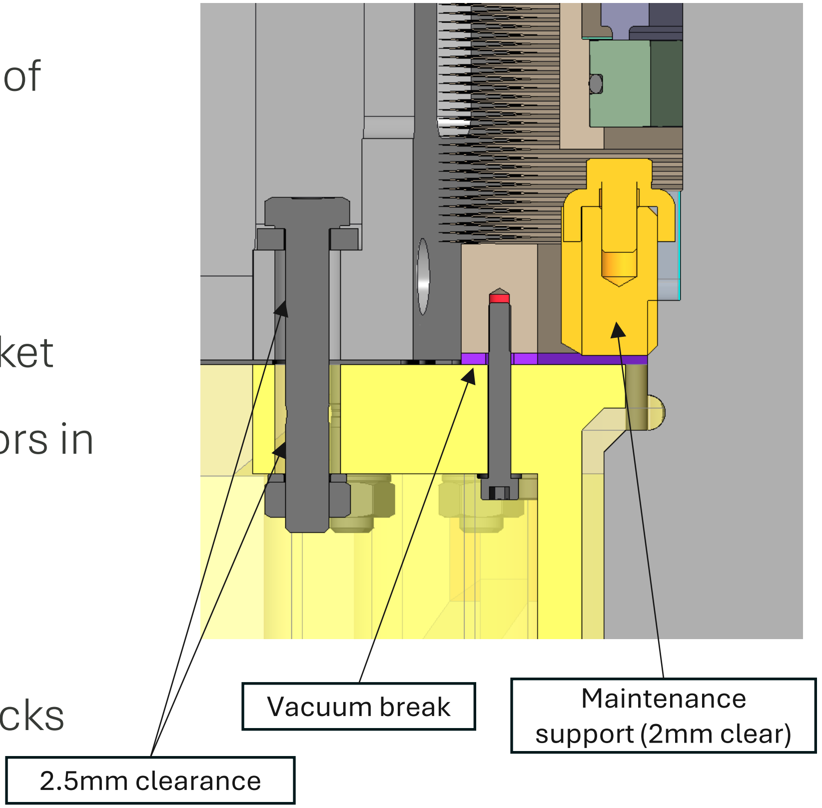


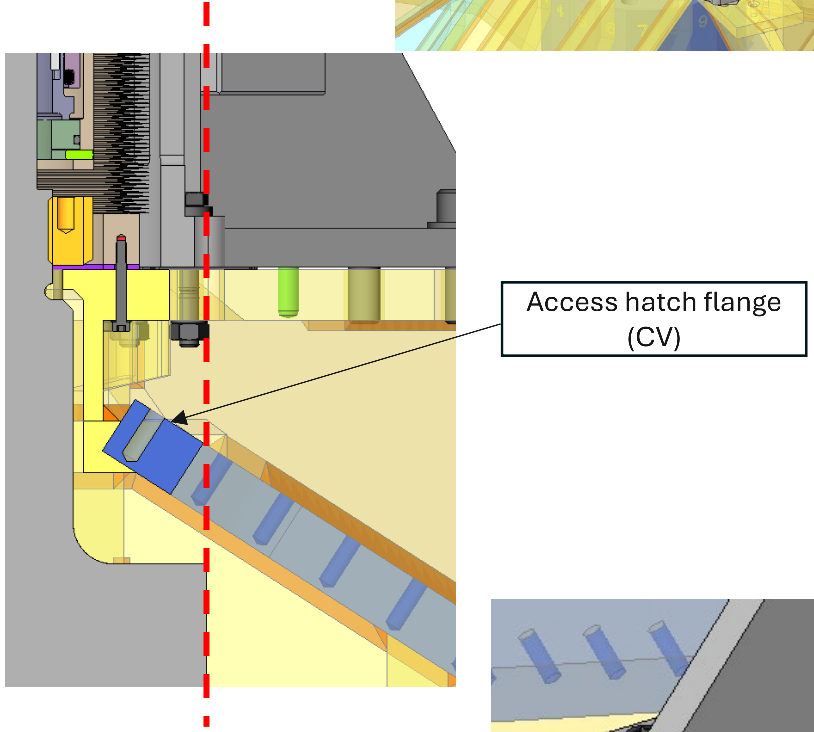


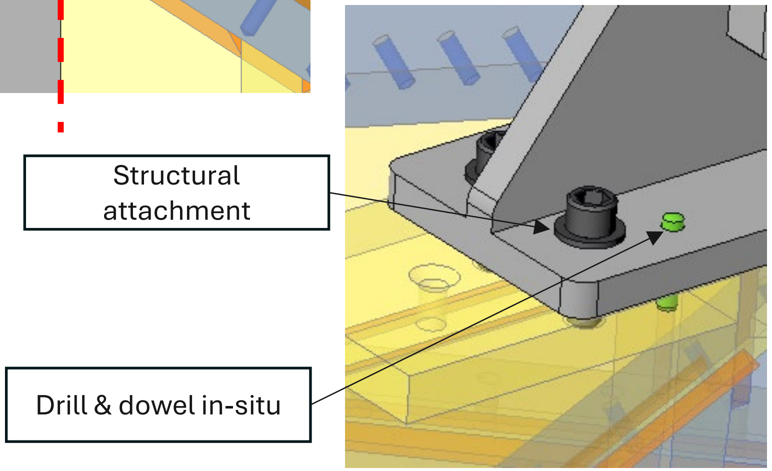
Lid – Target assembly interface

- Maintains repeatable alignment of target for maintenance events
- Ribs increase stiffness of lid (vacuum)
- Static vacuum boundary via gasket
- Must account for +/-5mm of errors in the CV lid. (all directions)
- Provides vertical support during bearing removal
- Initial alignment with pusher blocks
- Dowel in-situ
- Access hatch removal is tight!



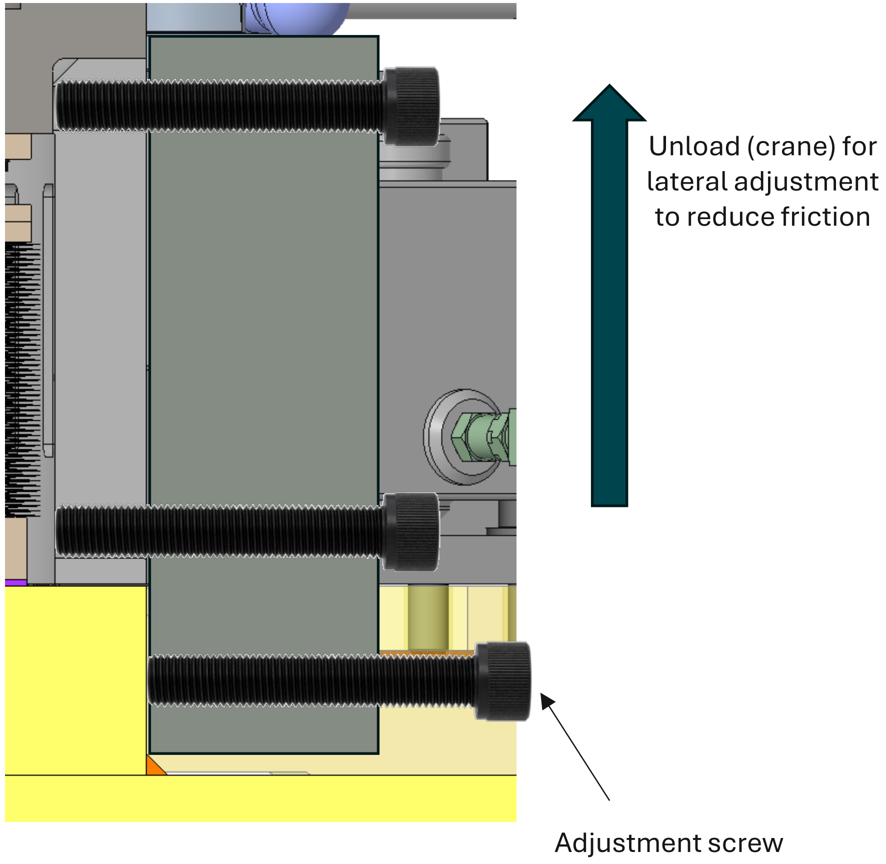


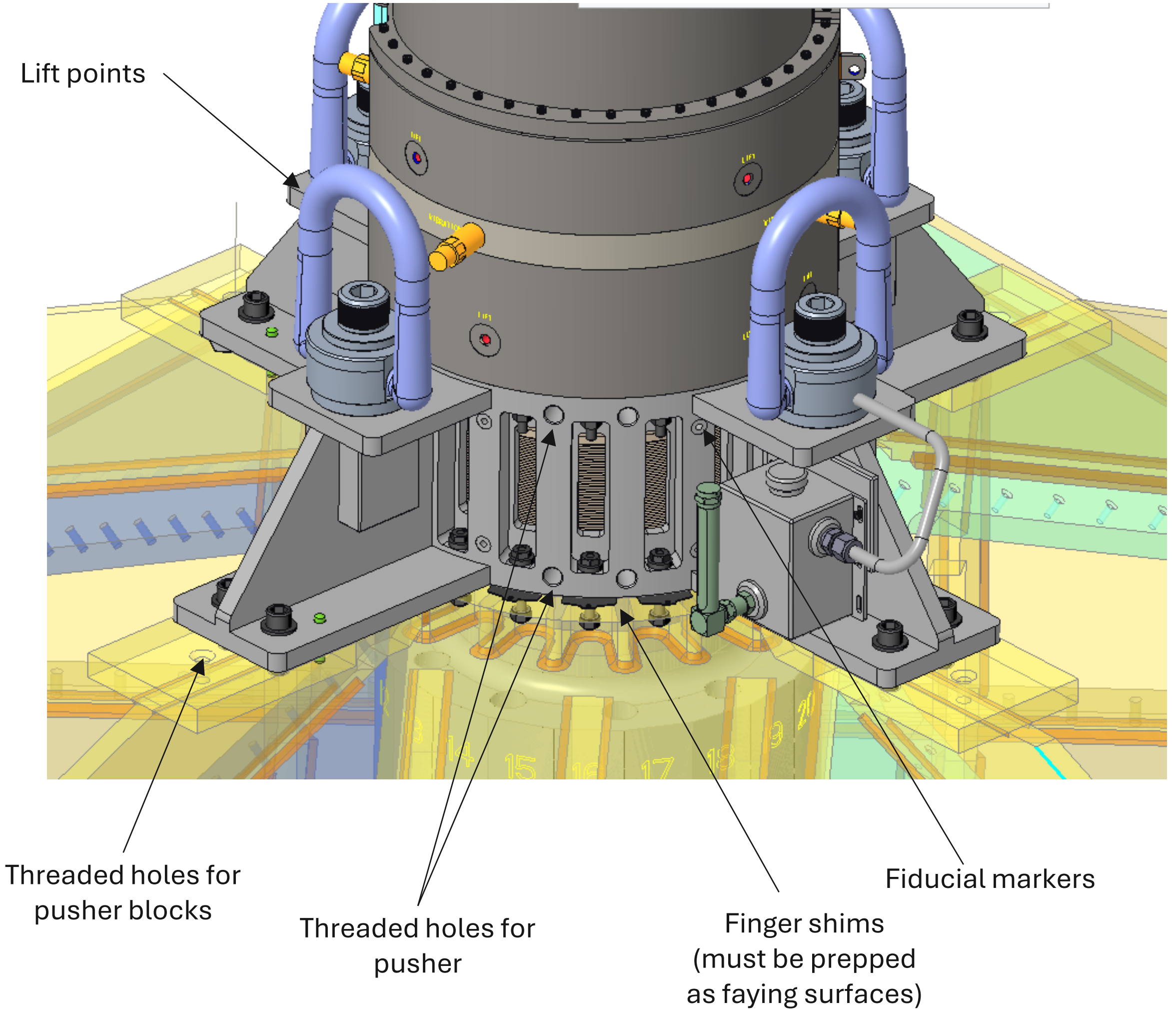




Initial positioning features – alignment within 1mm using shim and pusher blocks

Pusher block installation tool



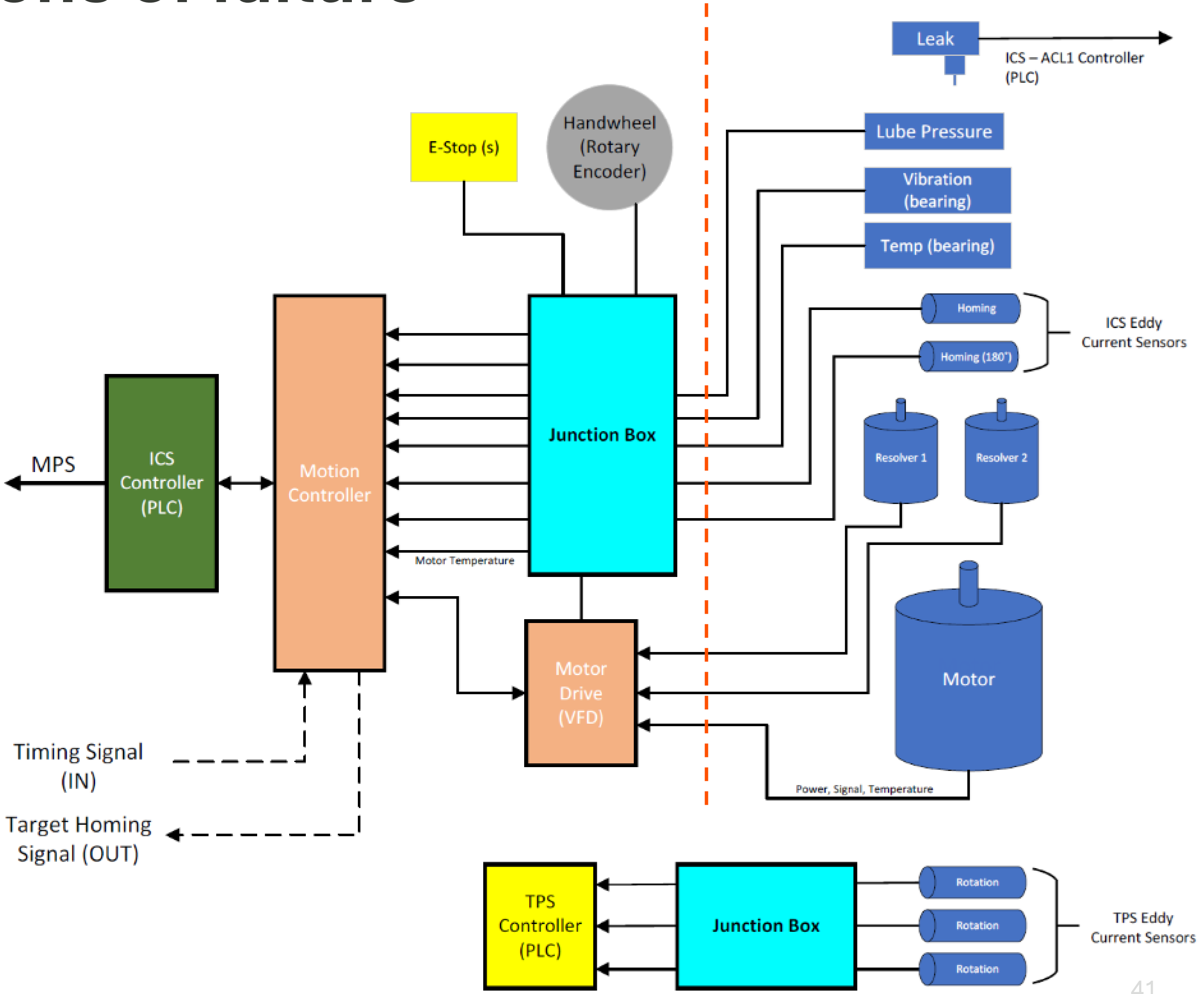


The integrated control system controls motion and monitors key parameters for indications of failure

- Motion Control loop:
  - Resolver (with homing flag)
  - Motion controller
  - Motor
- Synchronize to timing signal (TTL)
- Sequence
  - Spin to 45 rpm
  - Adjust phase
  - Lock Phase

Overall goal: position target within <1 degree offset at target face

Resolver measures 100x closer than desired precision



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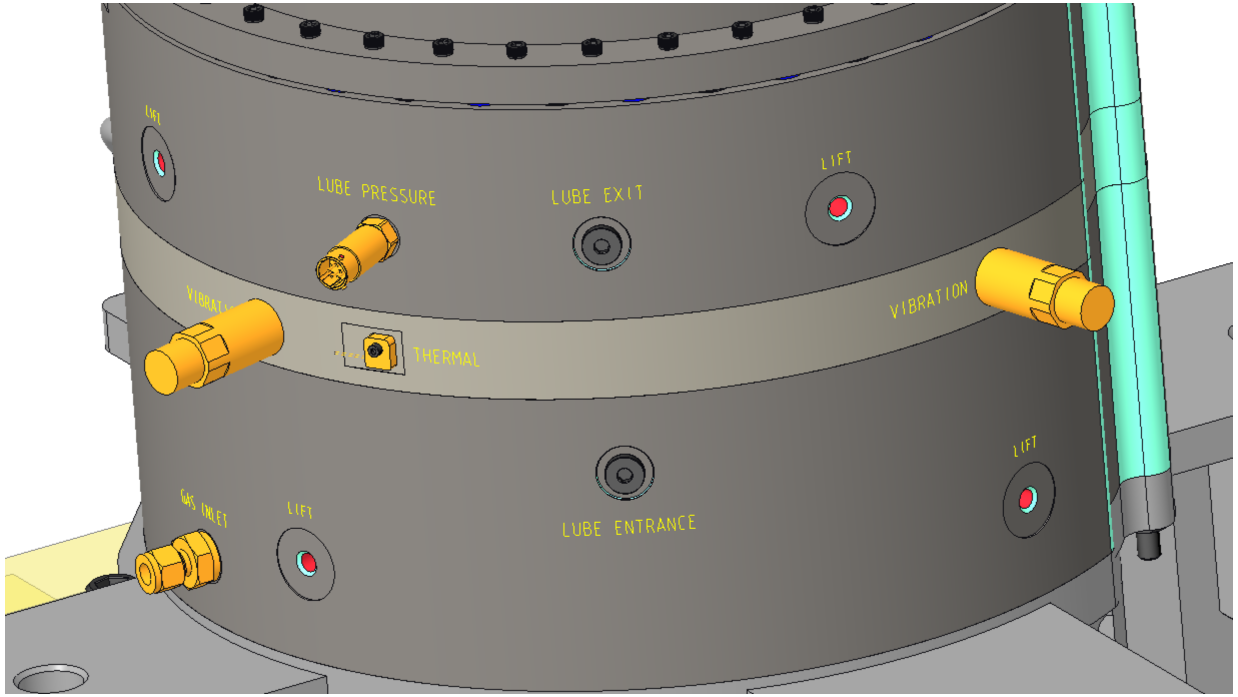
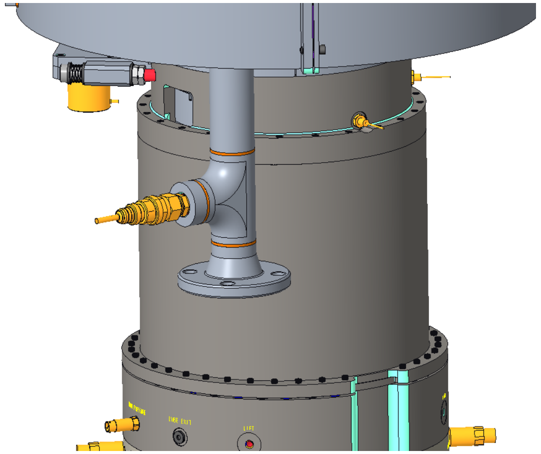
The drive and process system has several sensors for monitoring and diagnostics

- Motor drive (Torque monitoring, others)
- Bearing Vibration (Monitor for Freq – Amplitude shifts over time)
- Bearing temperature (monitor for shifts over time)
- Lubrication pressure
- Leak detection (Shroud)



- Seal gas pressure – is the gas pad on the seal adequate?
- Seal gas flow – Monitor the leak rate of the seal for degrading life
- Pressure drop across system



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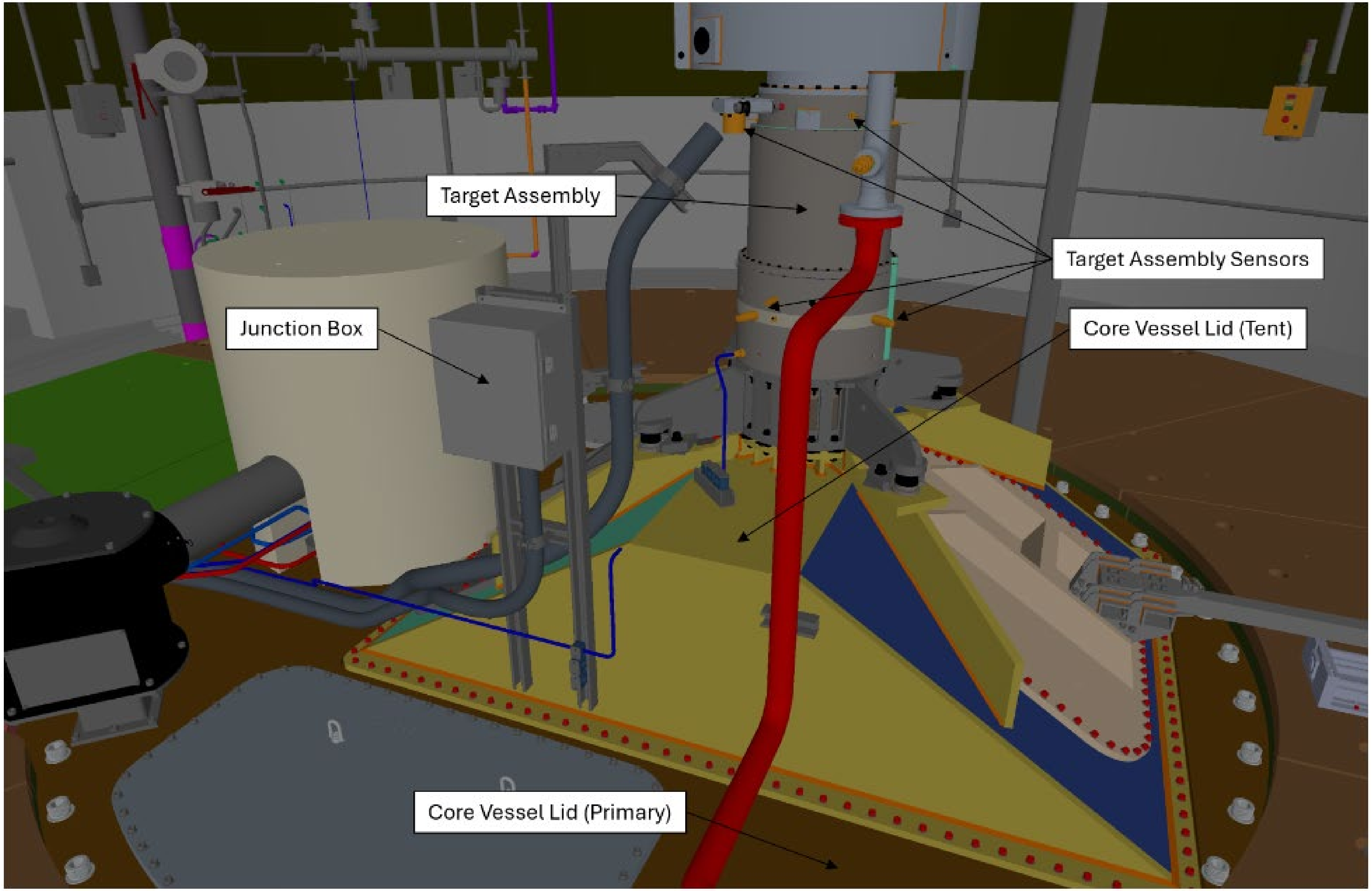
Conceptual wire routing and conduit (by ICS)



Components in the drive have high confidence of withstanding radiation levels

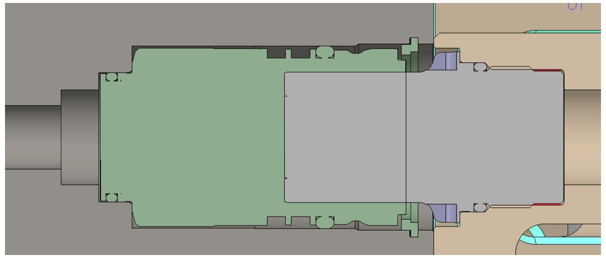
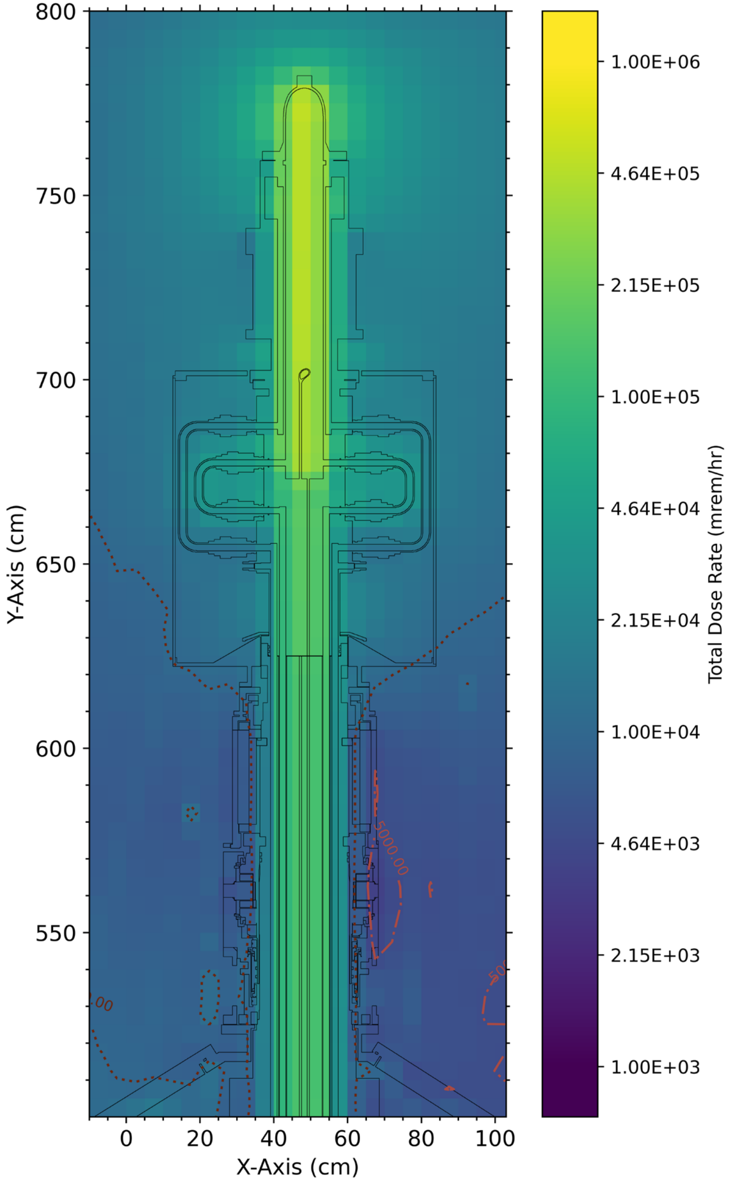


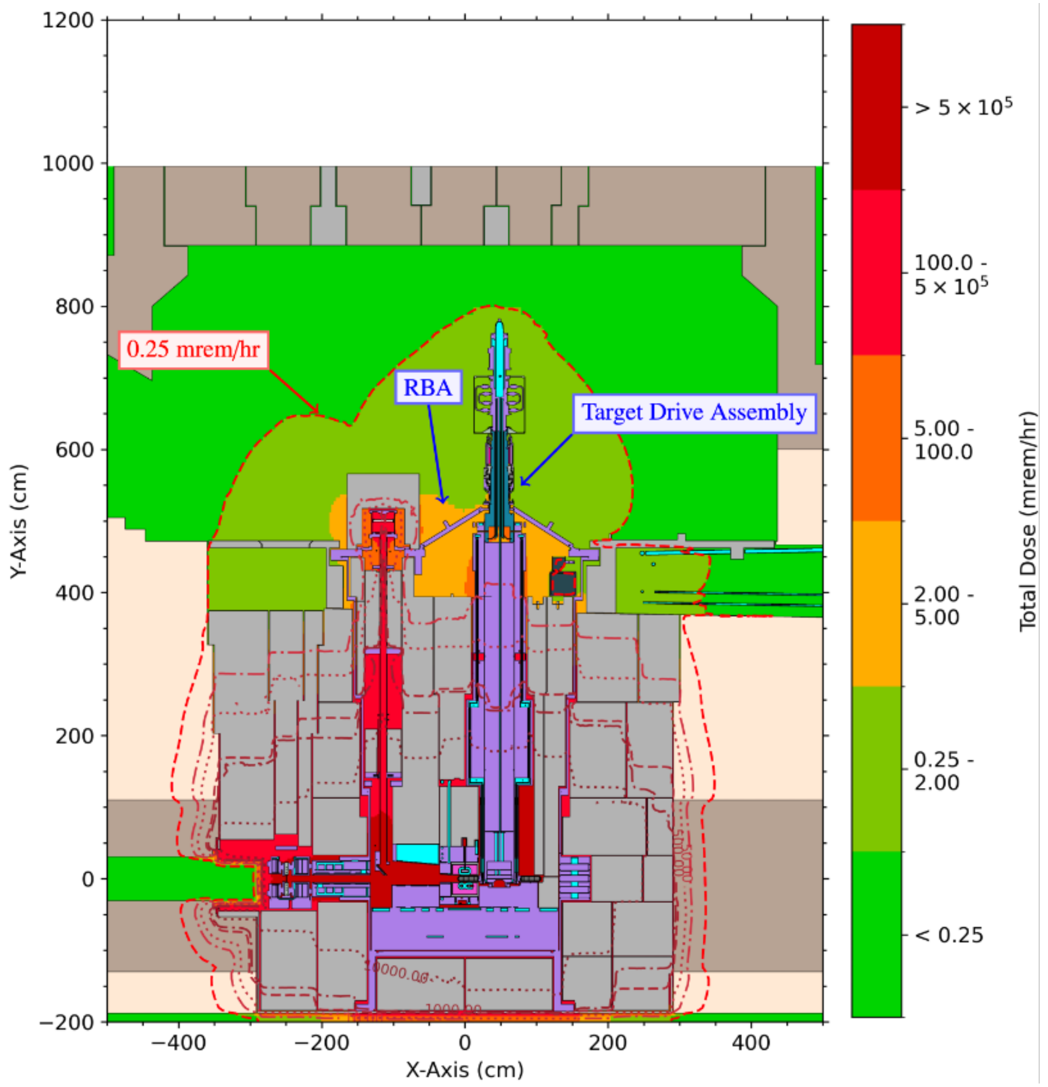
Table 13. Drive Critical Component Dose & Life

Polymer	Location	Life (kGy)	6 yr Dose (kGy)	10 yr Dose (kGy)	Factor of Life	Vendor
EPDM O-rings	Rotary Union	320	310		1.03	James Walker
EPDM O-rings	Segment Attachment	320		330[b]	0.97	James Walker
EPDM O-rings	Jumper Fittings	100 [a]	62.4 [b]		1.6 [a]	Stäubli [a]
EPDM O-rings	Bearing & Vacuum Seal	80 [a]	14.6 [c]		5.48 [a]	Generic [a]
FKM (Viton) Lip Seal	Bearing Grease Seal	20	6.8		2.9	SKF
PEEK	Motor/Resolver	2000	4.2		476	NA
Silicon Carbide	Vacuum Seal	NA	3.3		NA	A.W. Chesterton
Dry-Running Carbon	Vacuum Seal	NA	36		NA	A.W. Chesterton
RG-42-1 (grease)	Bearing	7,800 [e]	1.74		4500	MORESCO-HIRAD
Vibration Sensor	Bearing	100 [f]	4.2		23.8	Wilcoxon
Temperature Probe	Bearing	Not Listed [g]	4.2		NA	Lake Shore Cryotronics
Eddy Current Sensor	Motor/Resolver	80 [h]	6		13.3	Emerson
Resolver	Motor/Resolver	2000 [i]	4.72 [k]		424	Empire Magnetics
Motor	Motor/Resolver	1000 [j]	4.72 [k]		212	Kollmorgen
Motor Fast Neutron Fluence [m]	Motor/Resolver	1×10^{13} n/cm^2	7.52×10^{12} n/cm^2		1.33	Kollmorgen



The drive can be accessed for maintenance after 8 hours of decay.

- The drive is well shielded from activated materials
- Body dose is <3mrem/hr (Rad worker)
- All target drive components are designed to be maintained with hand tools(no remote tooling).
- Long Life products or metals trapped, plated or lodged in the drive would compromise hands-on maintenance.
- Target drive components are disposable*
- Segment maintenance involves more shielding from targets



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Drive Subsystem status

- The drive architecture, interfaces, controls, water-routing, and maintenance concepts are established.
- A **tapered roller bearing arrangement** provides a more standard, lower-risk, and more closeable release configuration.
- Remaining work includes:
    - Completing an overall drawing package
    - Updating the bearing package CAD/detailing

The remaining drawing effort is better spent closing the tapered roller configuration than trying to mature the custom bearing arrangement

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