Oak Ridge National Laboratory

August 2026

S.03.02 - Target Assembly Design

Aaron Jacques

Second Target Station

U.S. DEPARTMENT of ENERGY

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Charge Question 5: Is the design sufficiently mature to proceed with finalizing the procurement package?

Document Status

FDR (per S01020500-PCD10001)

Deliverable Title	Document Number	In Process	Draft Complete	In Review	Backcheck	Recheck	Review Complete	EDRM Signatures
Target Assembly CAD model	0000004343.asm							
Interface Documents								
Process Systems Interface	S01020500-IST10211	X	X	X	-	-	X	X
Core Vessel Interface	S01020500-IST10209	X	X	X	-	-	X	X
TVP interface	S01020500-IST10212	X	X	X	-	-	X	X
Controls Interface	S03020000-IST10000	X	X	X	-	-	X	X
Target Protection Systems Interface	S01020500-IST10104	X	X	X	-	-	X	X
Remote Handling Interface	S01020500-IST10208	X	X	X	-	-	X	X
MRA Interface	S01020500-IST10207	X	X	X	-	-	X	X
Proton Beam Interface	S01020500-IS0002	X	X	X	-	-	X	X
Conventional Facilities Interface	S01020500-IST10069	X	X	X	-	-	X	X
Systems Requirements Document								
Target Assembly Requirements	S03020000-SR0001	X	X	X	-	-	X	X
Target Drive Requirements	S03020300-SRD10000	X	X	X	-	-	X	X
Target Shaft Requirements	S03020300-SRD10001	X	X	X	-	-	X	X
Target Segment Requirements	S03020400-SRD10000	X	X	X	-	-	X	X
System Design Description								
Design Description Document	S03020000-DES10001	X	X	-	-	-	-	
Configuration Level Determination								
Target Assembly Configuration and Quality Le	S03020100-CMT10000	X	X	X	X	X	X	X
Design Analysis Calculations								
CALC - Energy Deposition & DPA Report	S00000000-CAC10001	X	X	X	X			
Clearance Budget	S03000000-CAC10000	X	X					
Fatigue Assesment (incl. Offset beams)	S03020400-DAC100000	X	X	X	X	X	X	X
Material Models	S03020000-DAC100000	X	X	X	X	X	X	X
Structural Analysis	S03020000-DAC10002	X	X	X				
Neutronics - Beam On doses	S03120100-TRT10017	X	X	X	X	X		
Neutronics Analysis - Beam off Dose	S03120100-TRT10015	X	X	X	X	X		
Neutronics Analysis - Decay Heat & radionucl	S03120100-TRT10025	X	X					
PHAR - Loss of Cooling Analysis (No beam, No	S03020000-DAC10001	X	X	X	X	X	X	X
Maintenance Stress Analysis (Debond)	S03020400-DAC10001	X	X	X	X	X	X	X
Seismic Design Loads	S03020000-CAC10001	X	X	X	X	X	X	X
Trittium exposure dose during maintenance a	S03020000-TRT10000	-	-	-	-	-	-	-
Blow Down Assesment	0000019063	-	-	-	-	-	-	-
CFD - Assembly, Segment, Drive, Shaft	S03020000-DAC10003	X	X	X	X			
ESH&Q Analysis - Transportation Assessment	S03020000-ESH10000							
ESH&Q Analysis - Disposal Assessment	S03020000-ESH10001	X	X	X	X	X	X	X
Drive - Machine Design	S03020000-DAC10005	X	X					

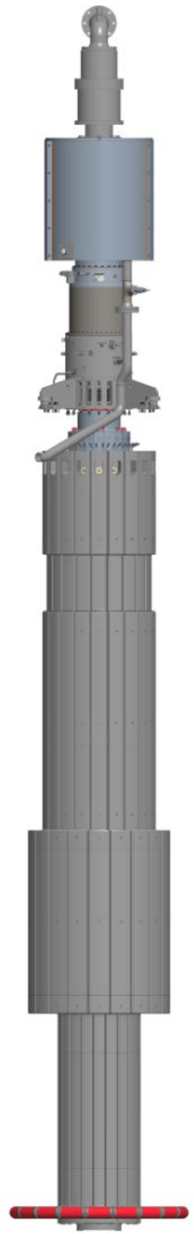
Final Design (PRR) (per S01020500-PCD10001)

Deliverable Title	Document Number	In Process	Draft Complete	In Review	Backcheck	Recheck	Review Complete	EDRM Signatures
Plans								
Target Manufacturing & Acquistion Strategy	S03020000-PLN10000	X	X	-	-	-	-	
Target Assembly Installation Plan	S03020000-TDO10000	X	X	-	-	-	-	
Target Assembly Verification Plan	S03020000-TAC10000	X	X	-	-	-	-	
Drawings								
Target Assembly Drawings	0000004343	X						
Segment & Foot Drawings	000005039	X						
Foot Drawings	0000077806	X						
Drive Assembly Drawings	000001787	X						
Shaft Drawings	000004930	X						
Technical Specifications								
Tungsten material specification	0000001253	X						
inconel, Forged, Target	0000020000 (S03020000-T	X	X	X	-	-	X	X
HIP Joining specification	S03020100-TS0002	X	X	X	-	-	X	X
HIP Cleaning specification	0000001356 (S03020100-T	X	X					
VHP joining specification	0000020001 (S07030100-T	X	X					
Electron Beam Welding	0000017745	X						
General Cleaning	0000017725	X						
Welding, General	0000017743	X						
Machining, General	0000017673	X						
Leak testing, General	0000017680	X						
Acceptance Criteria List								
Acceptance Criteria List, Segment								
Acceptance Criteria List, Drive								
Acceptance Criteria List, Shaft								
Statements of Work								
Target Drive Statement of Work		X						
Target Segment Statement of Work		X						
Target Foot Statement of Work		X						
Target Lower Shaft Weldment Statement of Work		X						
Target Shaft Forgings Statement of Work		X						
Factory & Site Acceptance Testing								
Factory Acceptance Test, Drive		X						
Site Acceptance Test Plan								

Outline

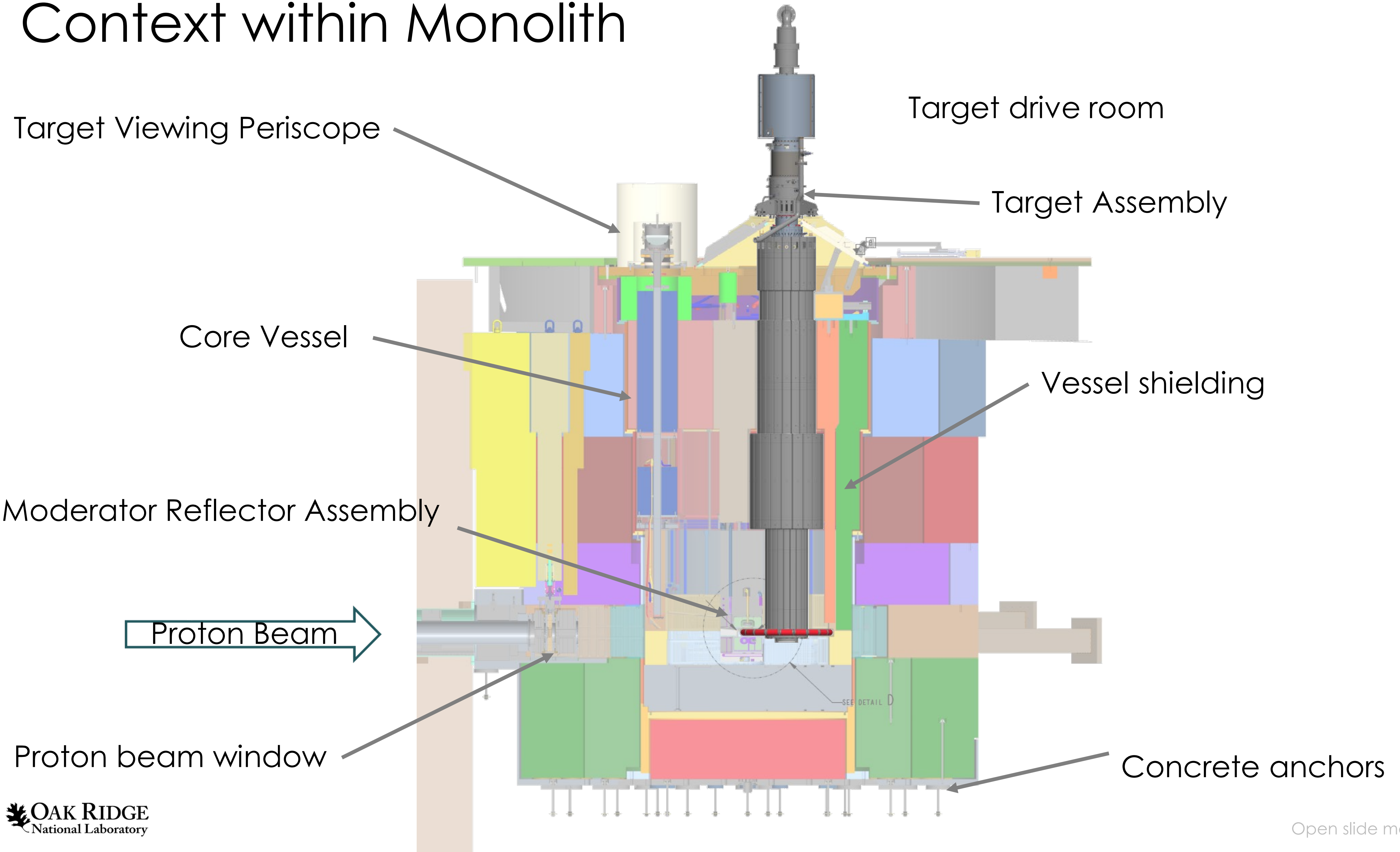
- Context
- Architecture
- Reliability approach
- Segmented approach
- Segment failure indication
- Loss of cooling
- Drive architecture
- Seismic considerations
- Streaming & radiation safety

Provides general context for more detailed design and analysis presentations



Target Assembly Context

Context within Monolith



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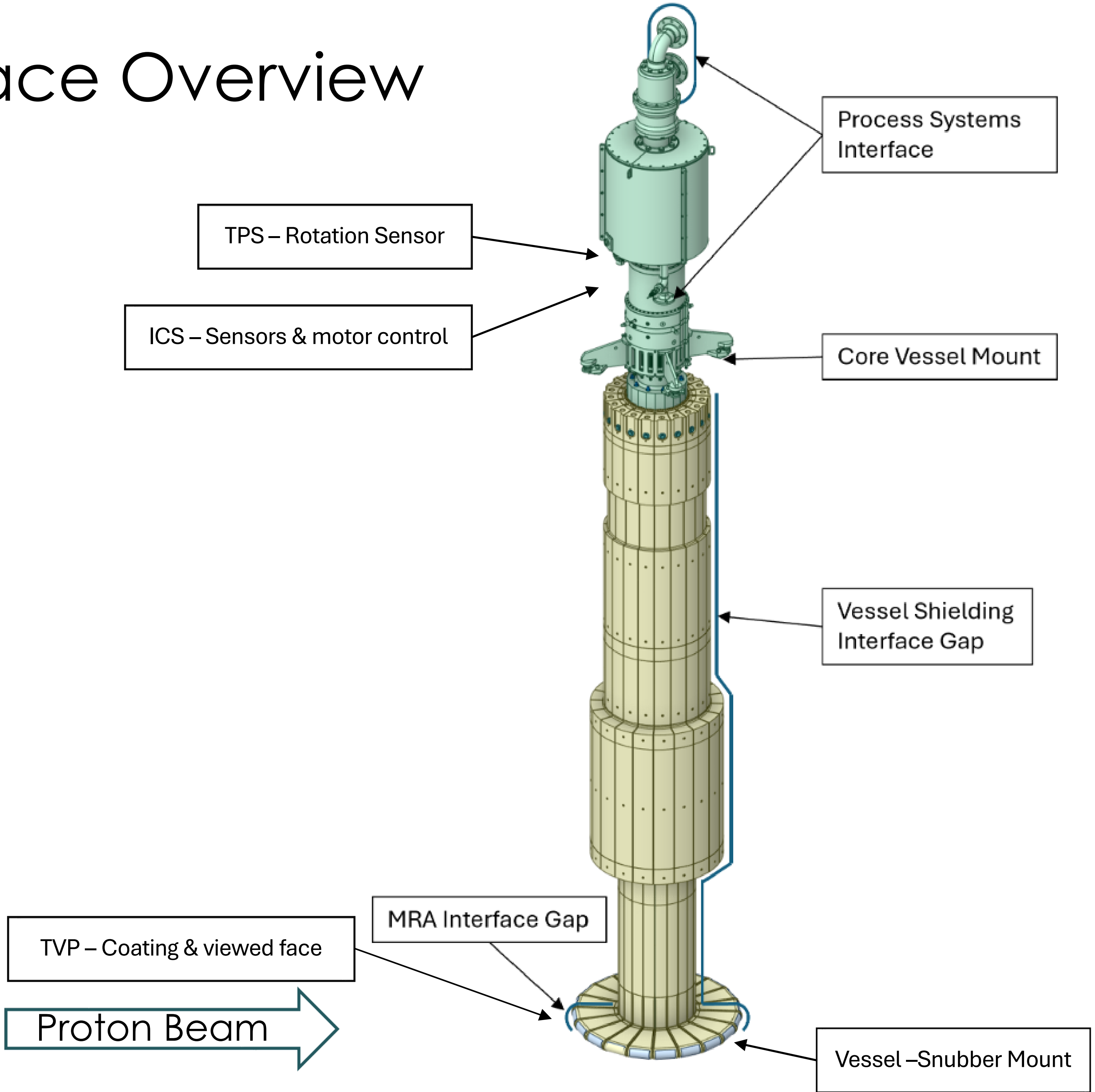
Interface Overview



RH – Segment lift points & disposal prep criteria

CF – Crane access & openings

Details in presentation by L. Bearden on Interfaces

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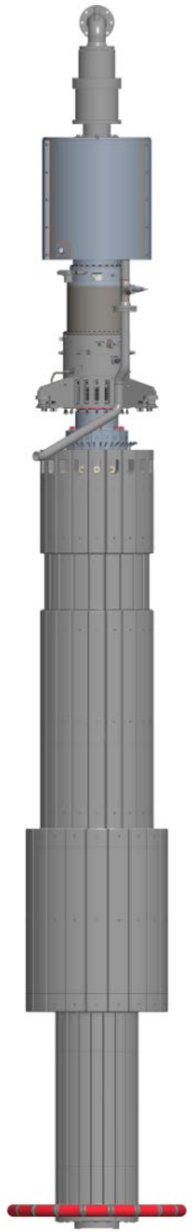
Key Parameters

- **System Mass:** ~19,000 kg
- **Segment Mass:** 577 kg
- **Rotating Mass:** 17,385 kg
- **Core Vessel vacuum:** 1 Torr
- **Vacuum Leak Rate (rotary seal):** 0.1 Torr-L/s
- **Water Leak Rate:** 1x 10^{-5} mbar-l/s
- **Speed:** 45 rpm
- **Height:** 7.9m
- **Wheel Diameter:** 1.2m
- **Flow:** 158 gpm, 32.2°C, 25 psig
- **Beam focus:** 60-90 cm^2



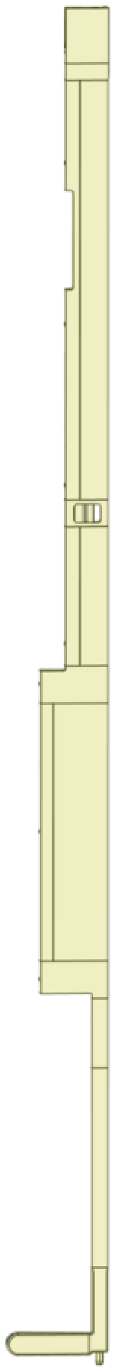
Key Requirements Refresher

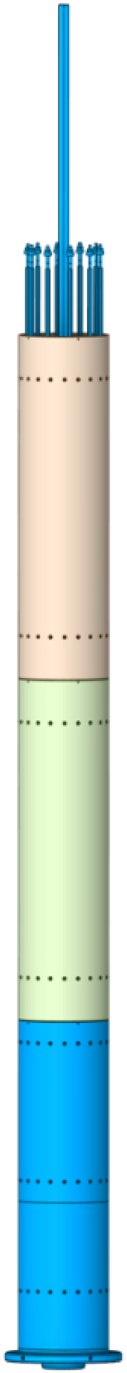
ID	Requirement statement
1452	The target assembly should have a high level of availability. (95% or better)
1446	Downsizing or reduction techniques (outside of the PIE cell) of activated components at ORNL shall minimize production of chips/swarf, small particulate matter, or liquid contamination.
1449	All items with lifetime less than the facility shall include a replacement scheme and disposal path
1454	Target Assembly geometry and materials of construction must match those referenced in the calculations used to verify requirement # 1017
1455	The Target Assembly shall match the key geometry and parameters for the model documented in S030400000-DAC10010, used to verify the requirement 1029 - Peak Brightness and 1010 - Time Average Brightness.
10947	The accumulated radiation dose (or damage) for each segment component and its constituent materials, evaluated at that component's end of life (i.e., at the planned replacement or retirement point), shall not exceed the applicable limits specified in the STS Materials Handbook (S03010300-TDO10000) or in manufacturer-published radiation tolerance data.
Credited controls	Keep the target below 800°C
1478	Prevent the target from colliding during normal or seismic interactions

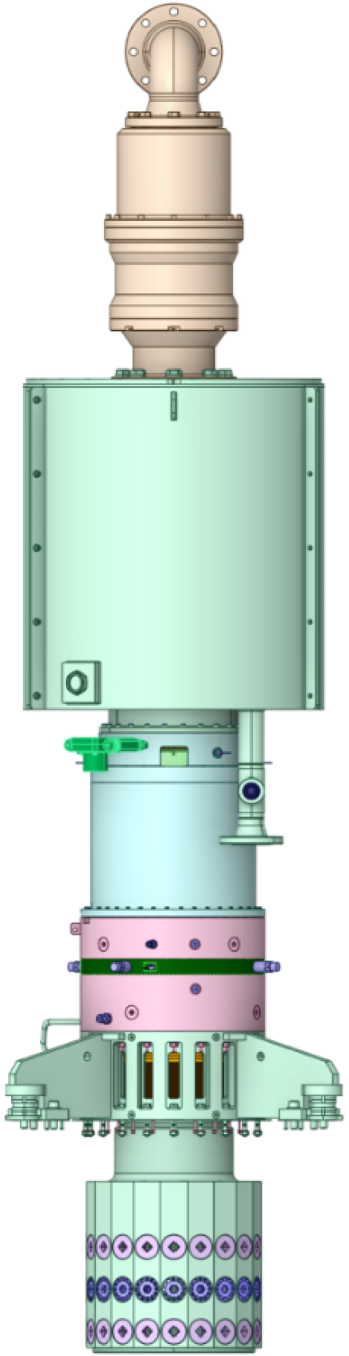
Architecture

Scope of subsystems

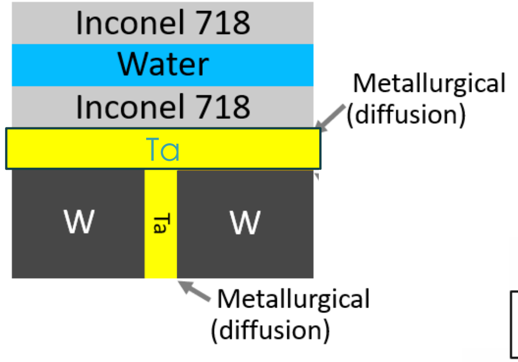
- Target Segment
- Target Shaft
- Target Drive



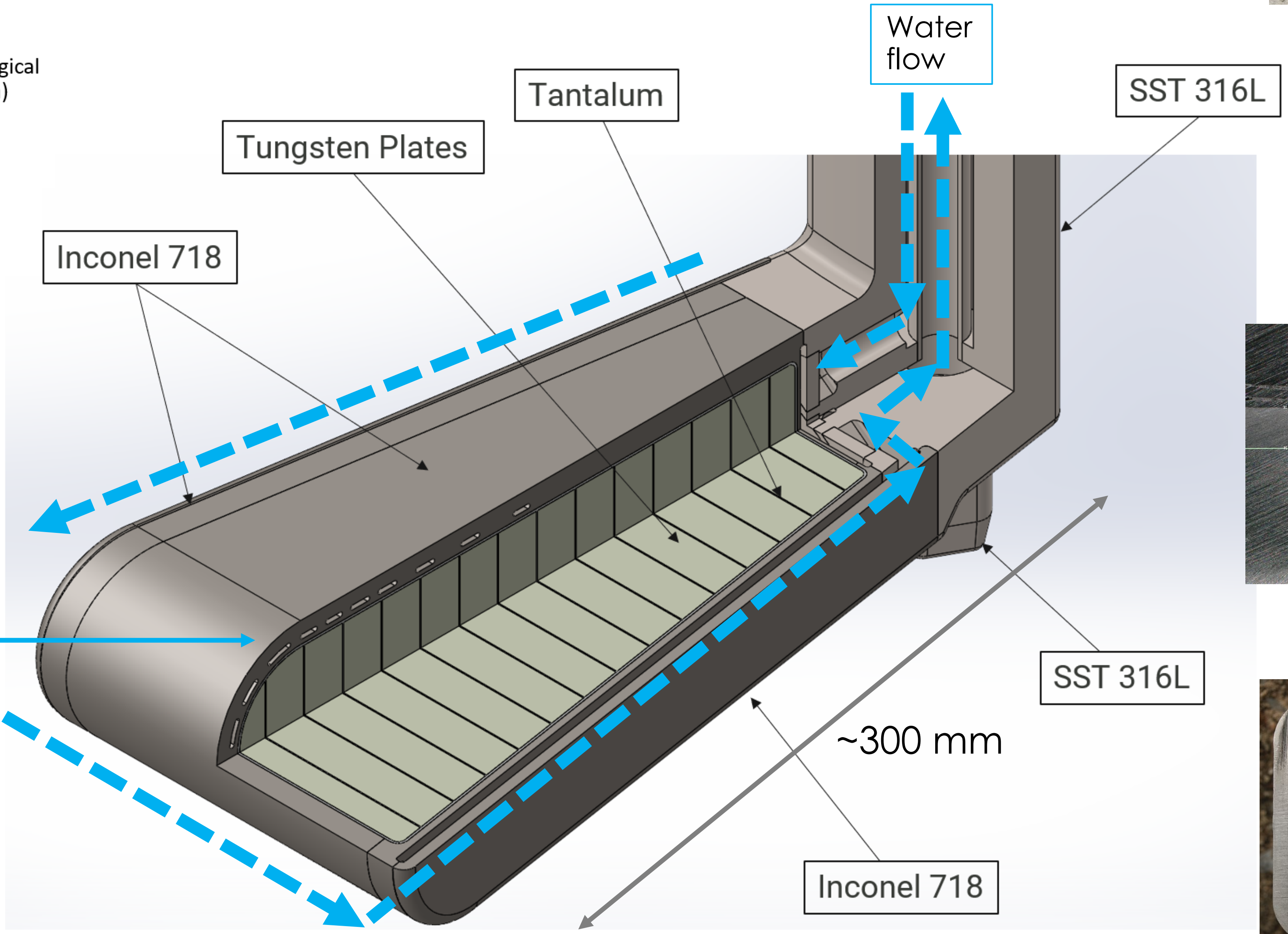


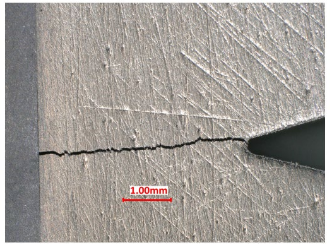


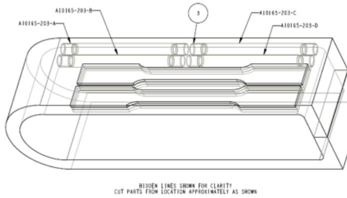
Target segment

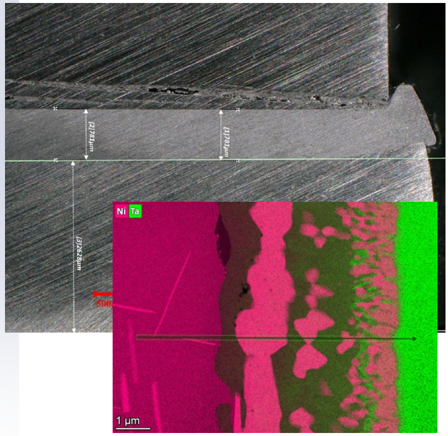


3x CTE mismatch from 718 to W









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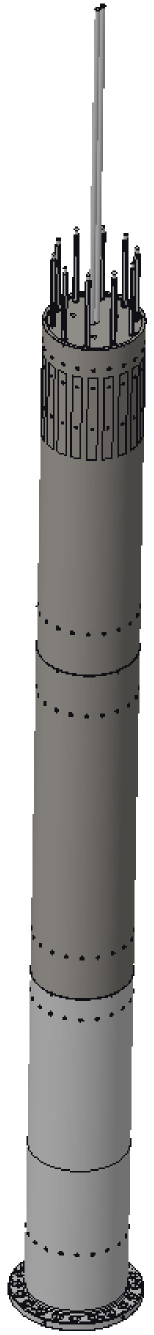
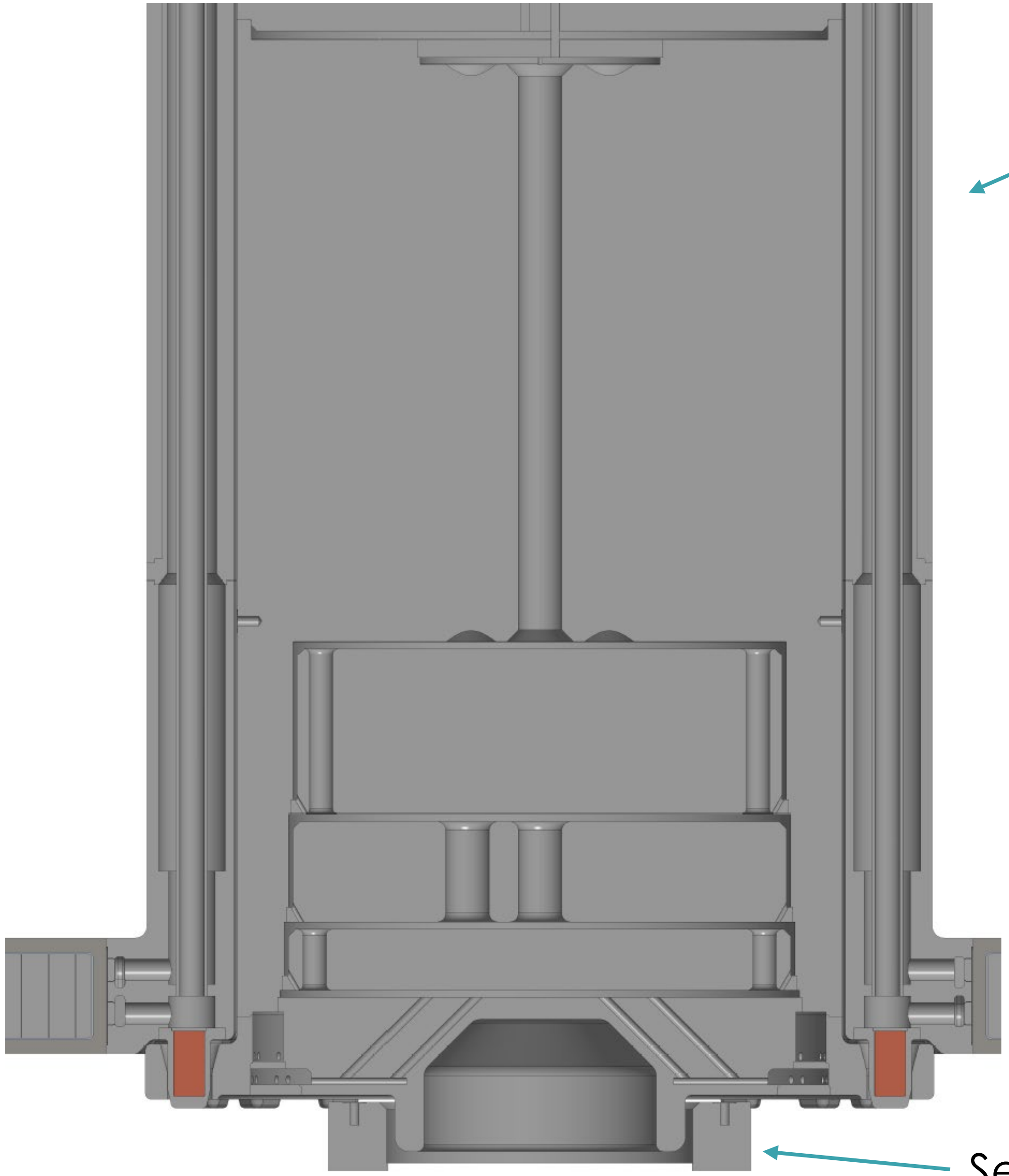
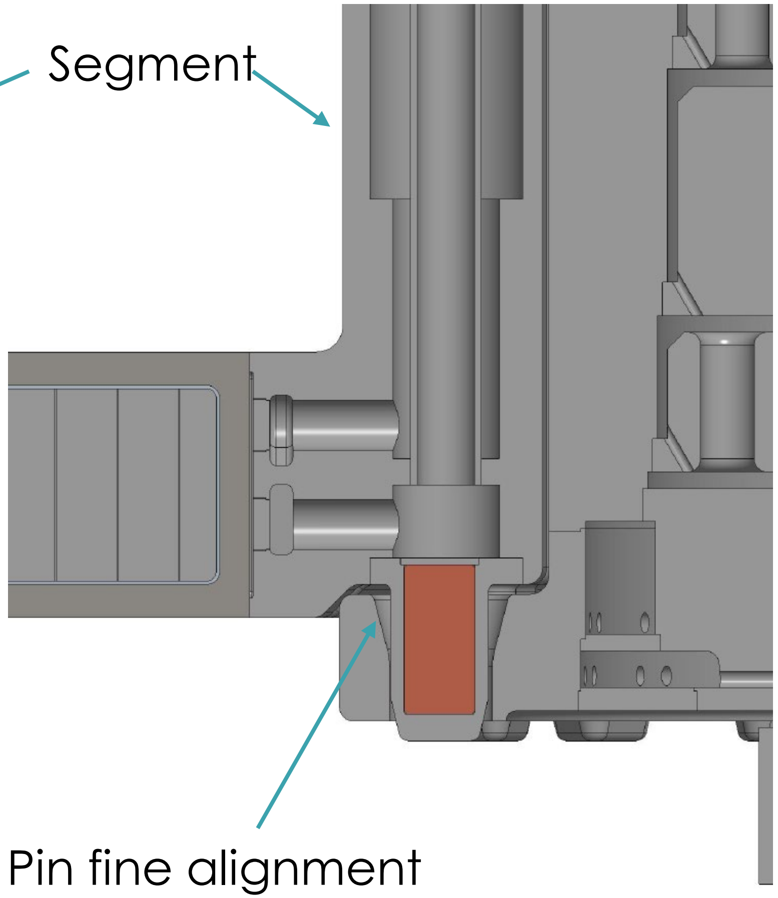
Target Shaft





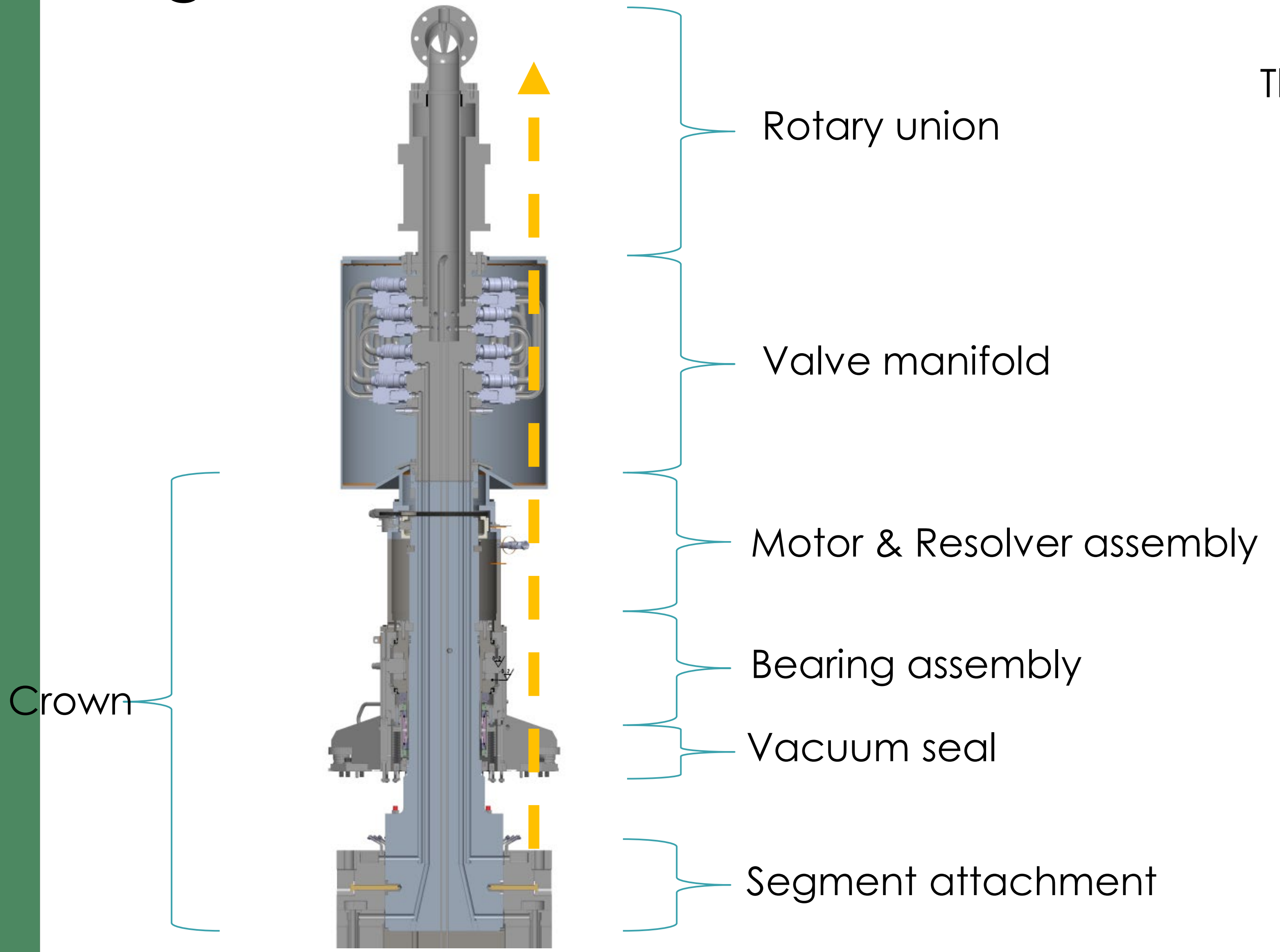


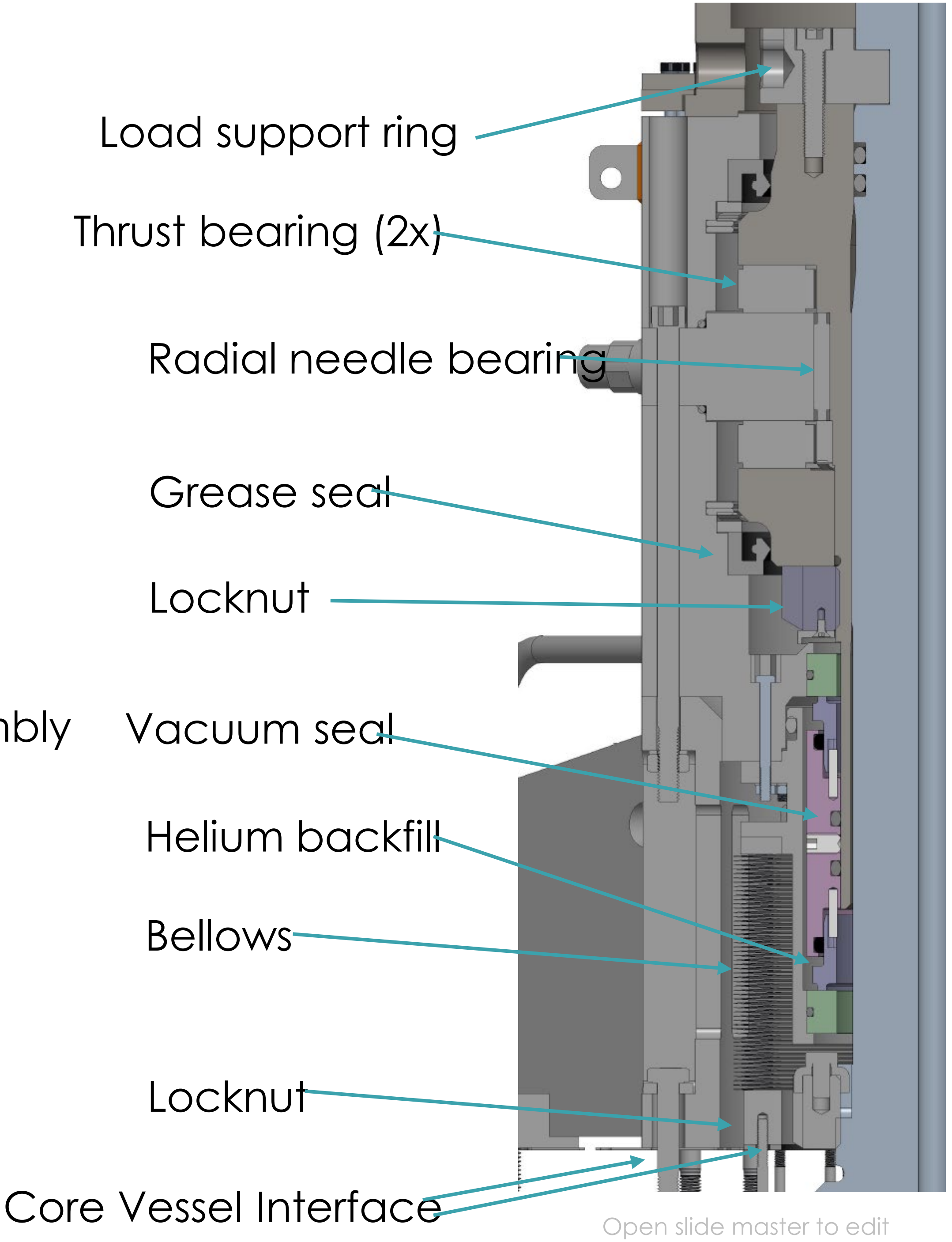
Segment

Pin fine alignment surface

Seismic restrain ring (supported from CV)

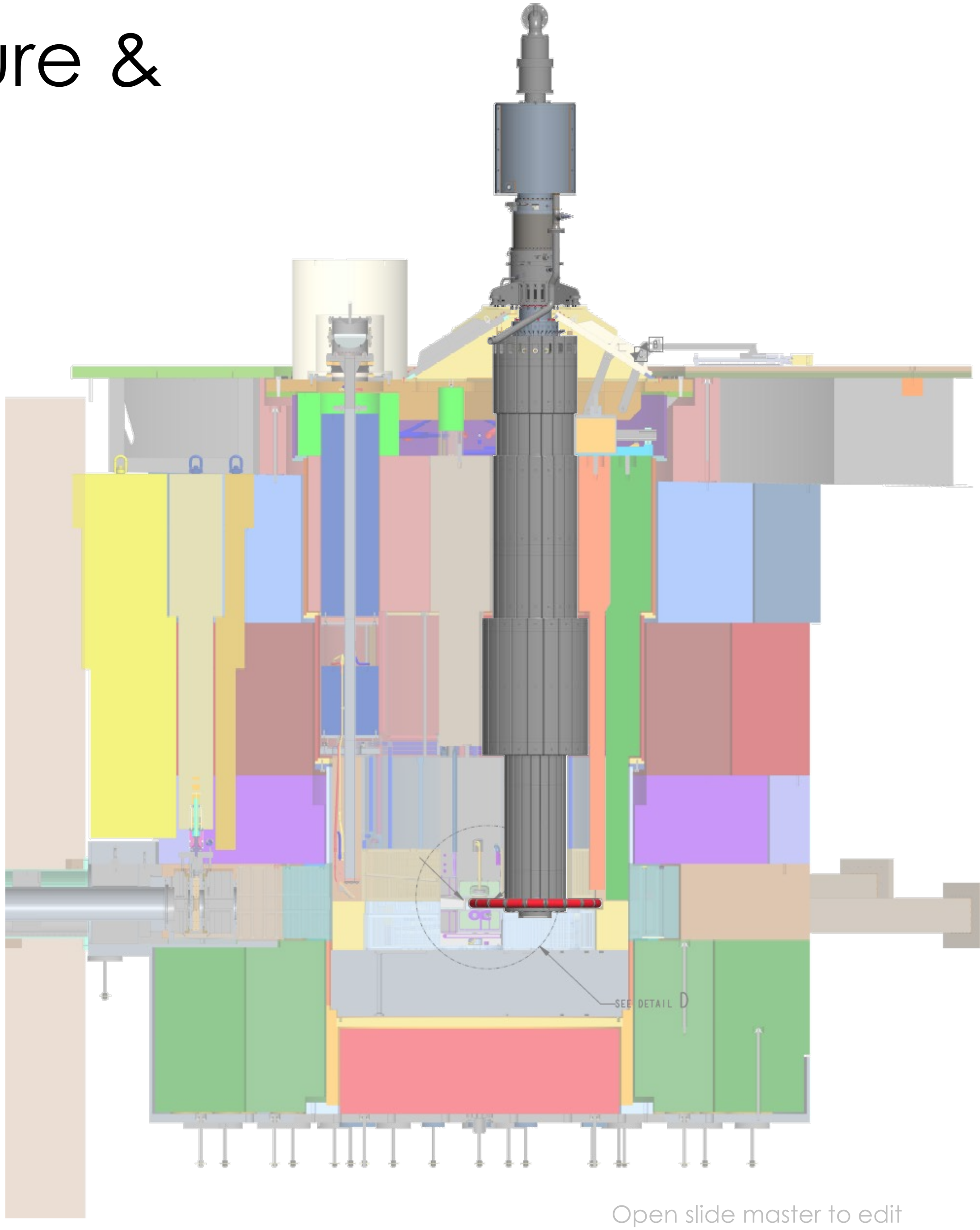
Target Assembly - Drive





Key decisions have driven structure & architecture

- Target Decisions
  - Reliability
    - Robust Design
      - Edge cooled target
      - Drive outside
      - COTS/proven hardware
    - Fast Maintenance
      - Segmented approach
        - Vertical Removal
        - Failure detection
      - Drive outside
  - Safety
    - Rotating Target
    - Seismic deflection
    - Loss of cooling
    - Radiation streaming
  - Disposal
    - Segmented approach
    - Shear cutter



Reliability Approach

Target philosophy for high availability

- Make systems as reliable as possible
- Perform preventative maintenance
- Components expected to fail, must be replaced quickly
  - Drive system must be out of vacuum with hands-on access to all components
  - Target must be exchanged quickly (segment leg provides remote manipulation)
  - Shaft must be life of facility & maintain alignments
- Utilize off the shelf items & conditions where possible
  - Bearings in ambient (no specialty vacuum greases)
  - Seal arranged below bearings
  - Motor, resolver, valves, etc. in ambient atmosphere
- Locate the drive as far from spallation as possible (COTS parts out of vac & rad environment)

Formalizing the philosophy into traceable requirements to meet the facility availability requirement

1 Ensure that all parts can be replaced in an outage window (or within allowed downtime)

2 Make systems as reliable as possible

3 Desire that all parts fail with warning and survive into an outage

- Philosophy captured as Requirement #3198

Table 7. Component Lifetime Selection

Component	Group	Replacement Time[c]	Lifetime[c]	Failure Indication
Target Drive	**Drive Requirement - 3199 Maintenance & Lifetime Criteria [d]**			
Segment	Group B	1504	1574	1499
Shaft [a]	LOF	N/A	1677	N/A

[a] Includes the crown

[b] Requirements for individual components are not formally captured as requirements but are managed by the design team; presented for clarity

[c] Hours

[d] Requirement: 3199 - Maintenance and Lifetime Criteria in subparagraph C.3.0.0.8 captures the requirements for the drive assembly in the same manner as Requirement: 3198 - Maintenance and Lifetime Criteria in subparagraph 6.2.0.0.2 does for the Target Assembly

Period	Quantity	Duration, each (h)
Run Time	2	2,500
Large Outage	2	1,400
Medium Outage	4	72
Small Outage	12	16

Target replacement =10 days

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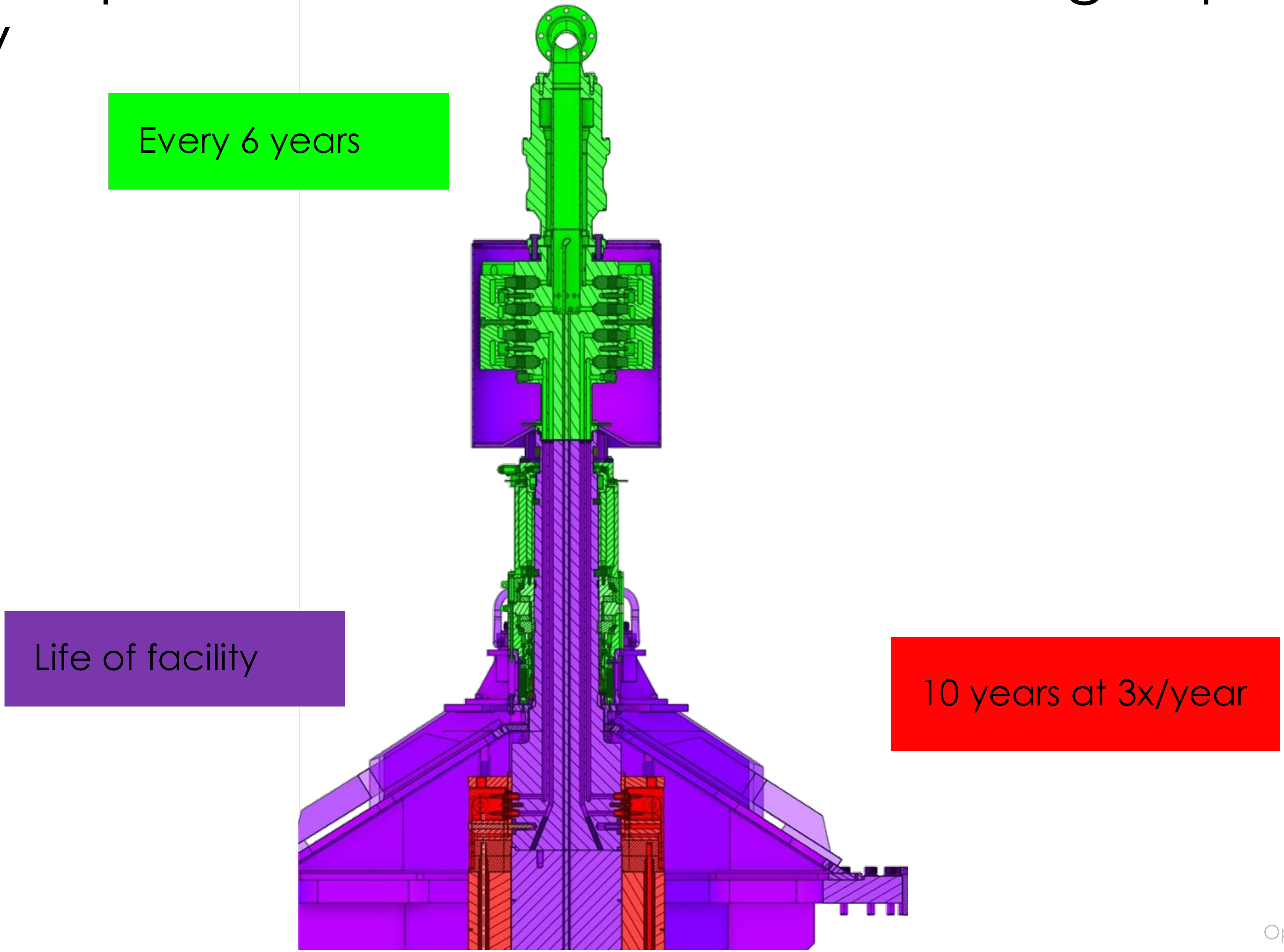
Planned Replacement Intervals are an integral part of reliability



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Segmented Target

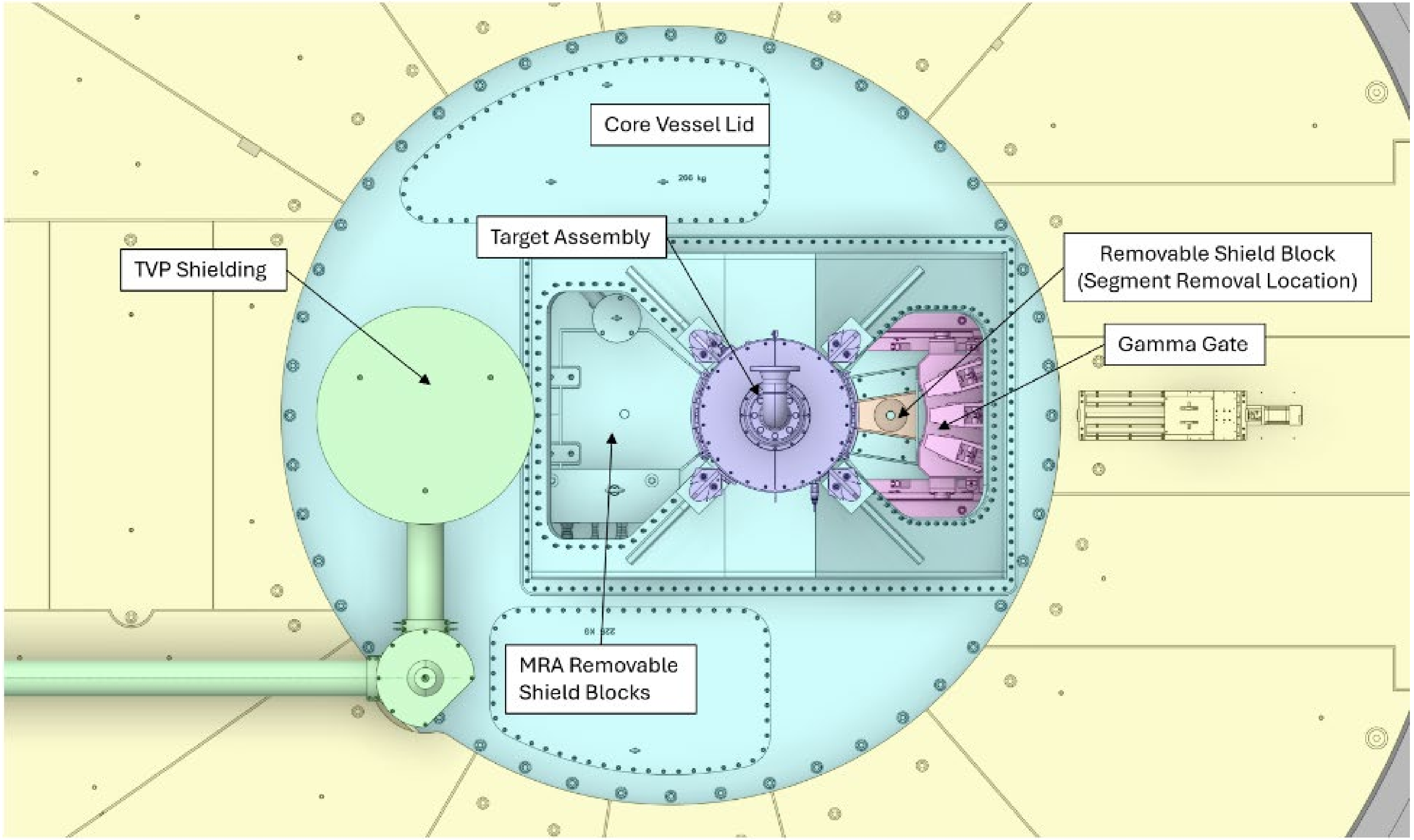
A key means to maintain a high availability facility

Segmenting the target meets availability requirements

Segment	Wheel
• Replacement is limited to failed objects • Replacement dose rates are collimated • Spares can be kept on hand • Preventative maintenance • Constrained drive geometry • More complicated sealing and water passages	• Simplified fabrication • Robust water circuits • Small failure requires replacement of full wheel • Removal requires significant dis-assembly • Exposed Core Vessel shine would be challenging • $$ Expensive Replacement $$$ • Long lead time for unexpected failures • Complicated MRA replacement

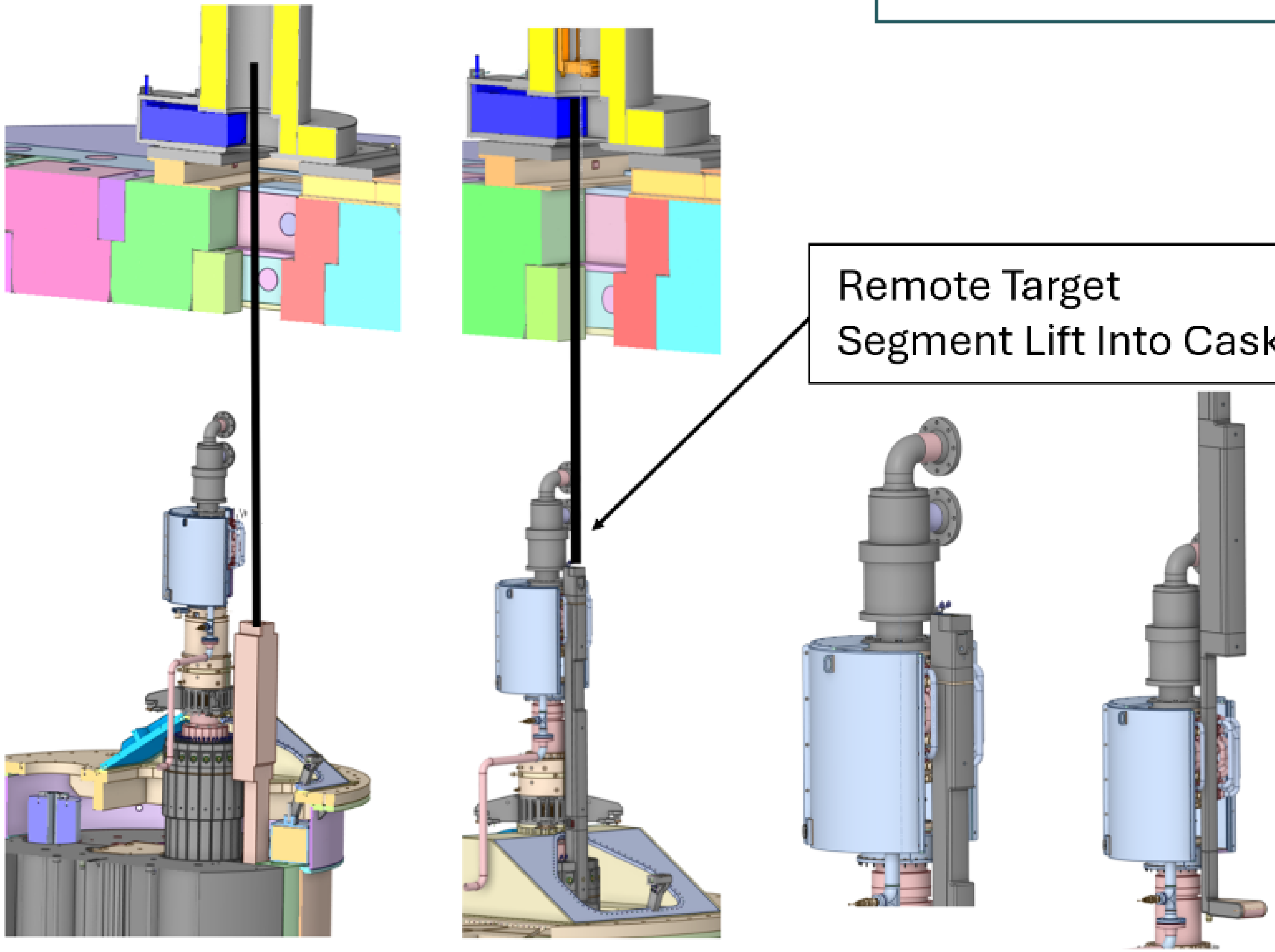
Segment Removal – Overhead view

BEAM



Segment Removal Sequence

Recall – “Target & MRA Remote Handling” presentation by S. Schrick



Remote Target Segment Lift Into Cask

Shielding Removal

Segment Removal

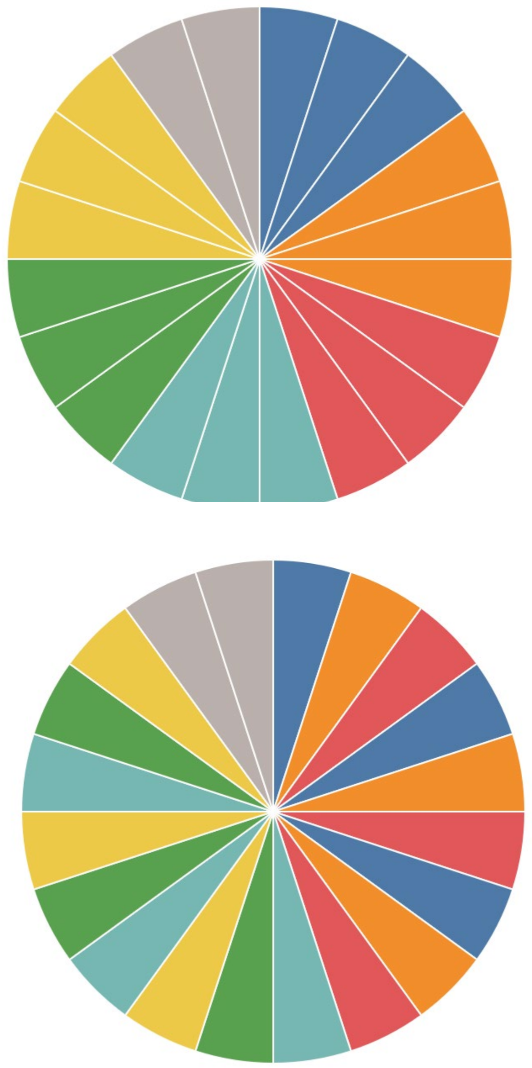
To meet availability, targets are to be replaced 3x/year to meet lifetime and availability requirements

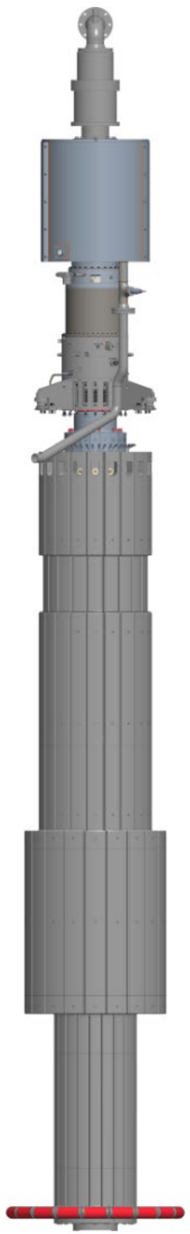
- Replacing 3 segments per year staggers lifetimes and avoids synchronized end-of-life across the wheel

- Replacement scheme matches MRA replacement intervals

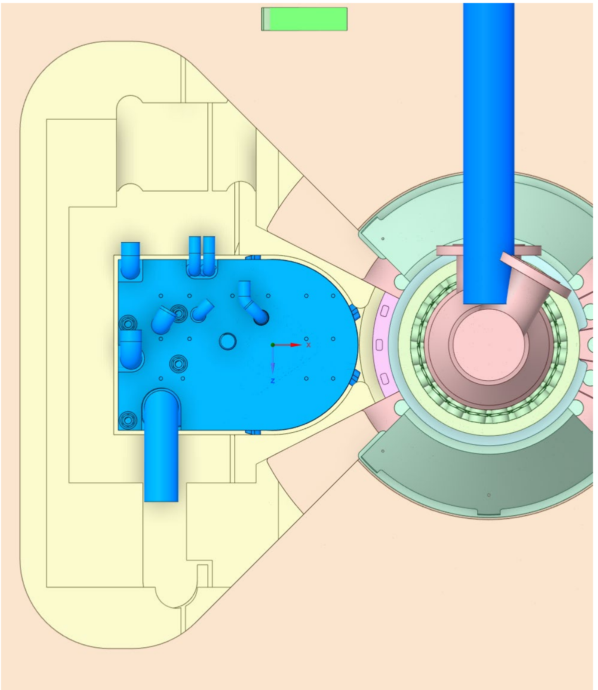
- Run-to-failure guarantees downtime…

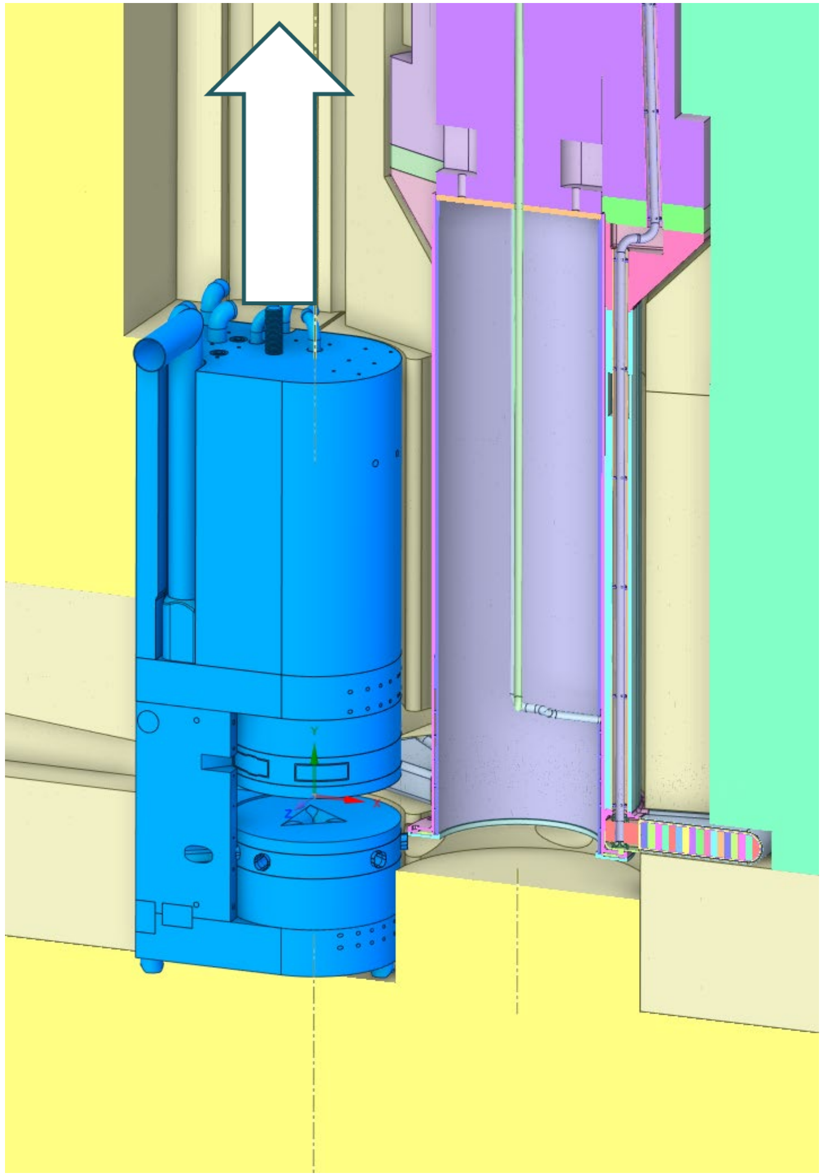
- Scheduled replacements >>> Unscheduled replacements





MRA Removal



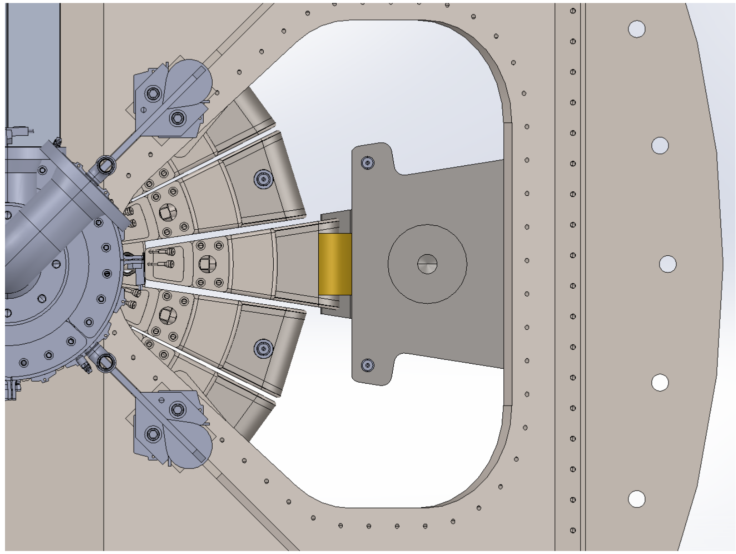


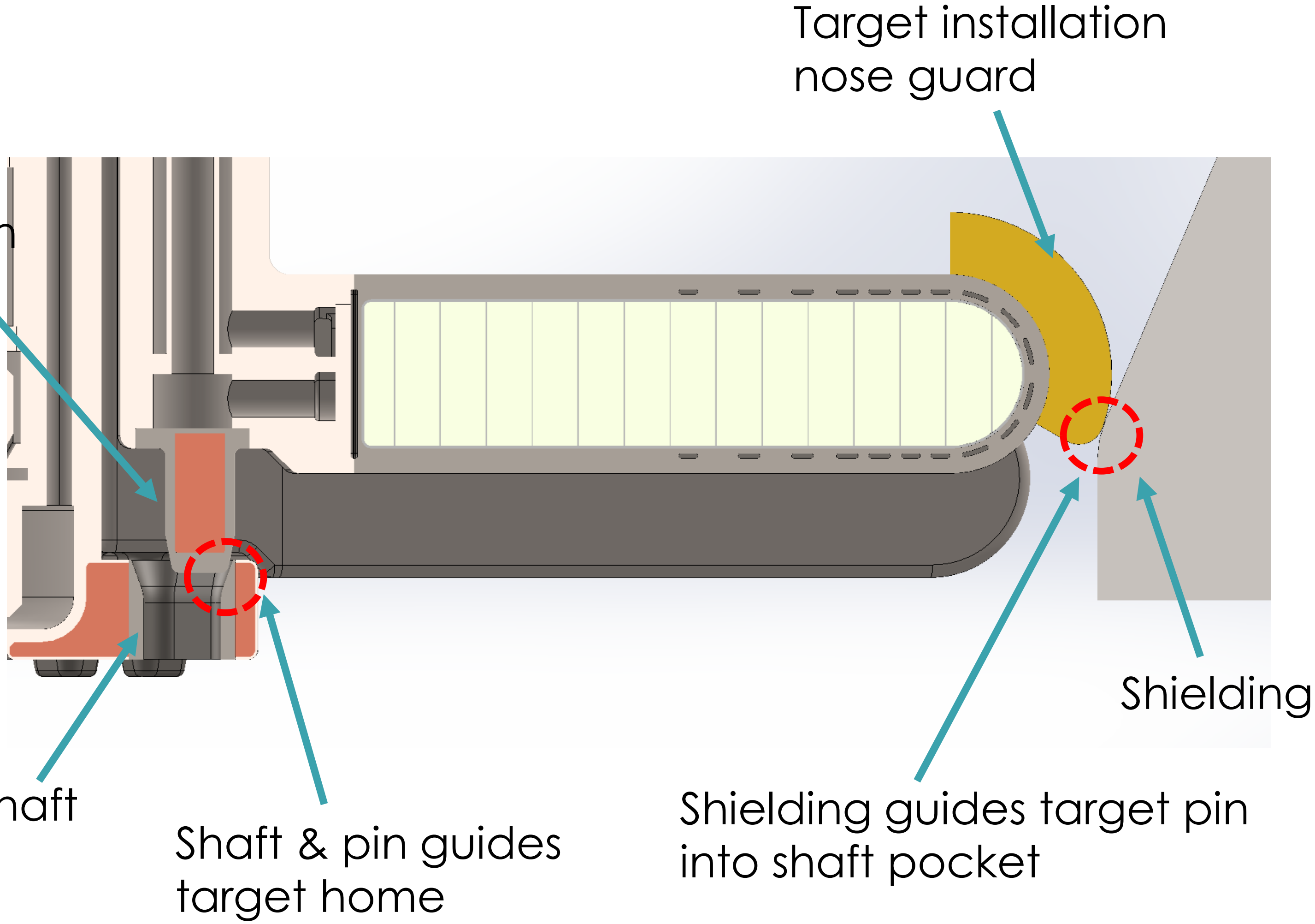
- Vertical MRA removal
- Gap rotated under MRA
- 3 Segments removed
- 3 segments align with maintenance scheme
- Vertical installation onto alignment spheres

Segment Installation

The segmented design permits replacement of individual segments through a dedicated hatch in the core vessel

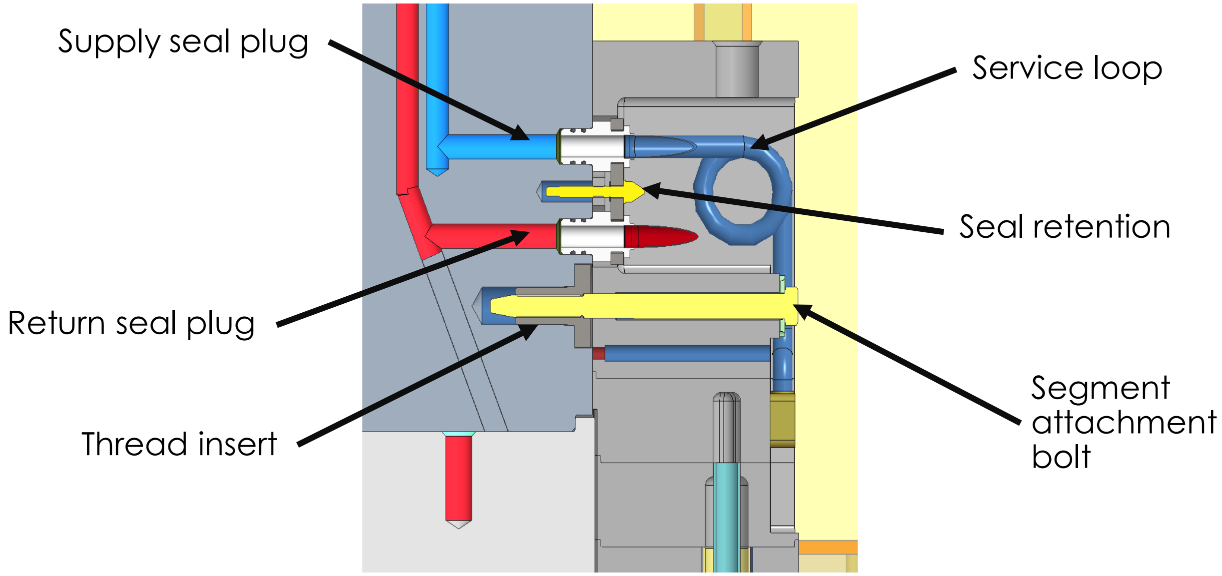
- Robust installation method
- Reduced radiation exposure
- Increased uptime
- Planned maintenance
- Life of facility shaft

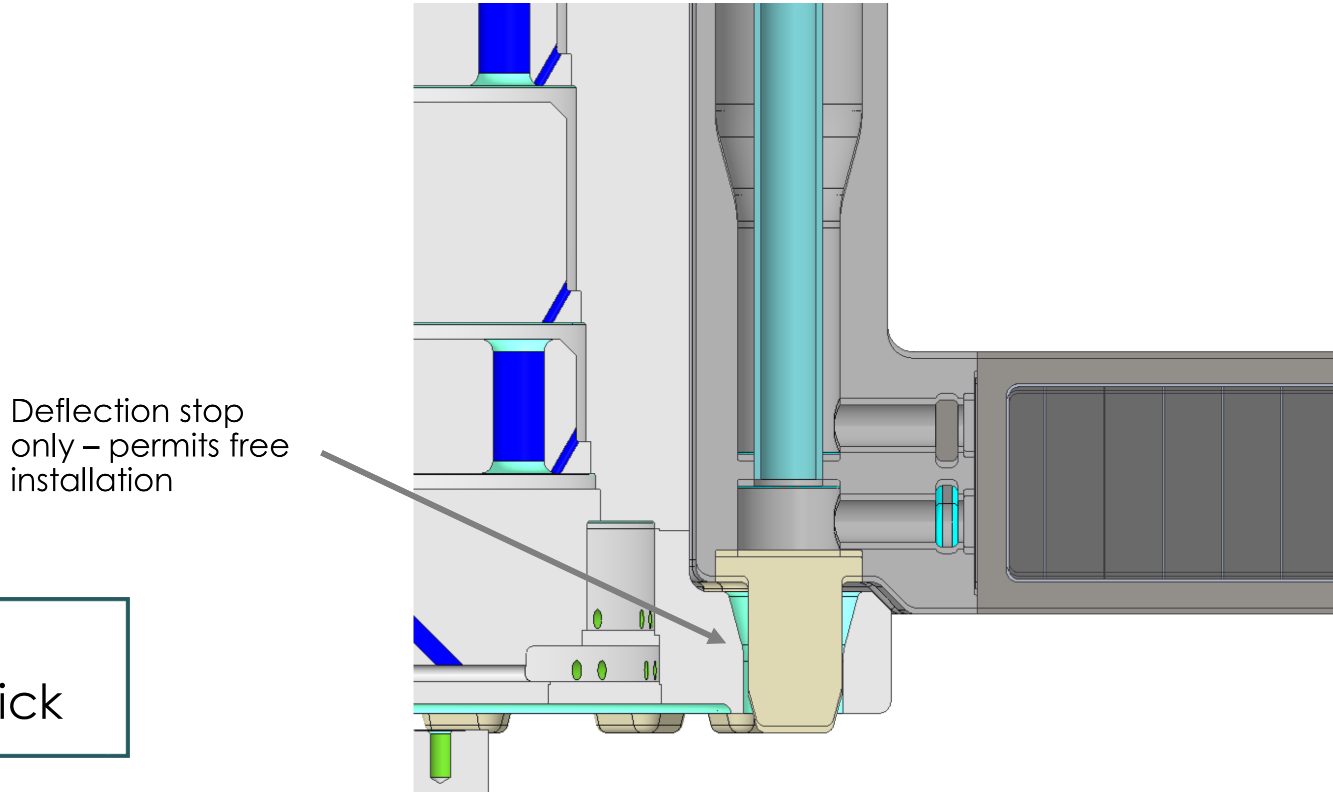




Segment Connection

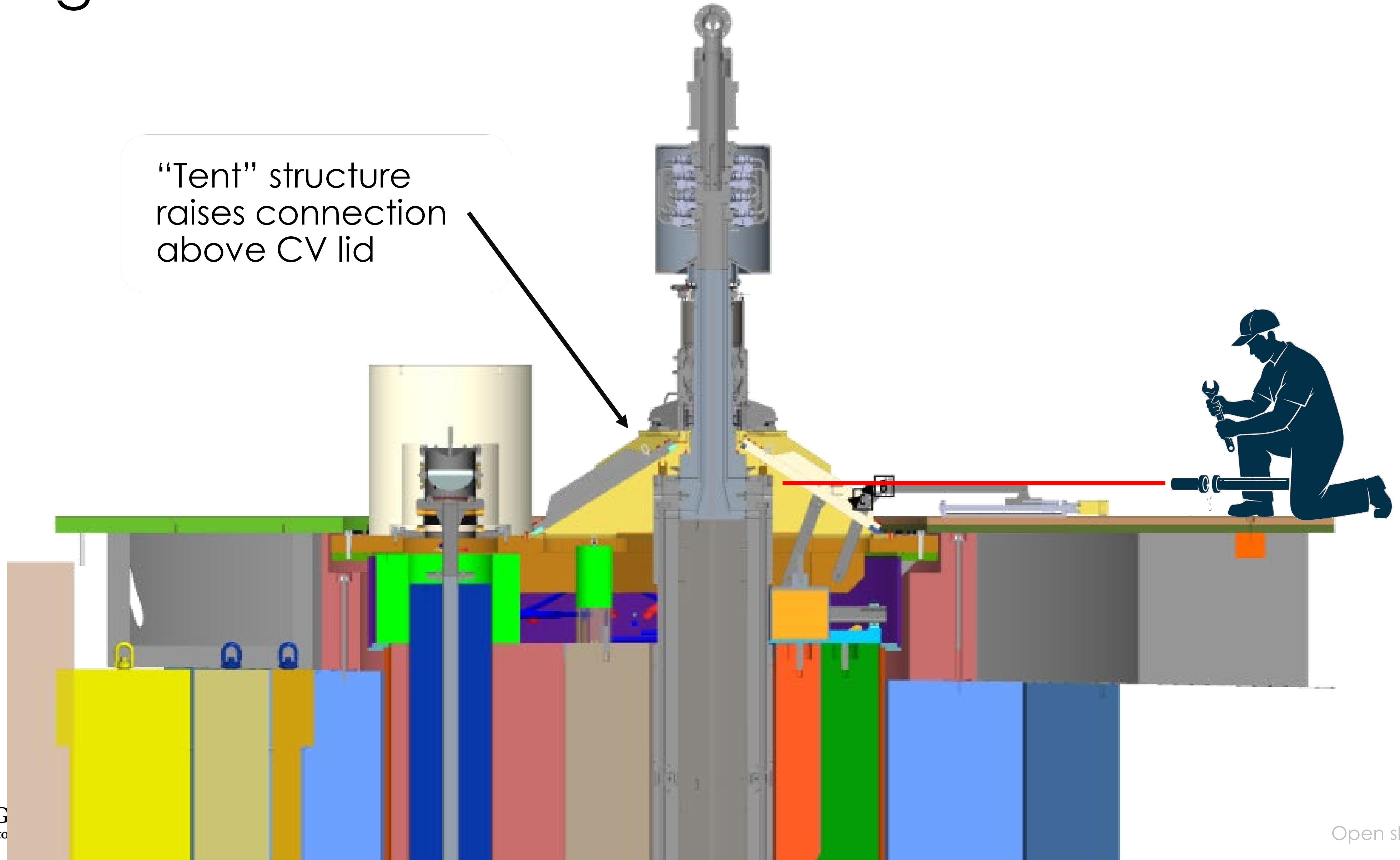
- Segment lowered vertically
- Segment fully constrained at crown (rigid body), above shield stack
- Radial deflection limited at beam elevation by pin
- Installation guided by shielding
- Bolt holes align when the segment pin is in the pocket





Recall – "Target & MRA Remote Handling" presentation by S. Schrick

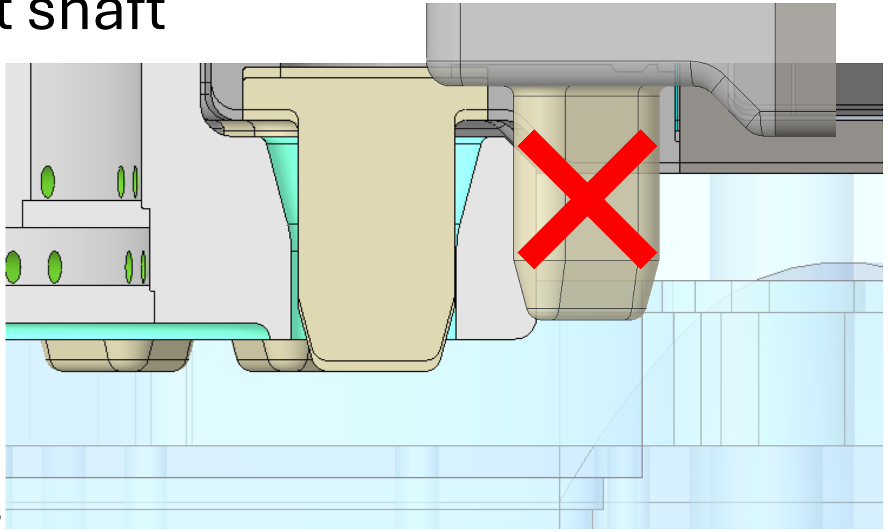
Segment bolt remote handling access sets the height of the segment connection above the Core Vessel lid.

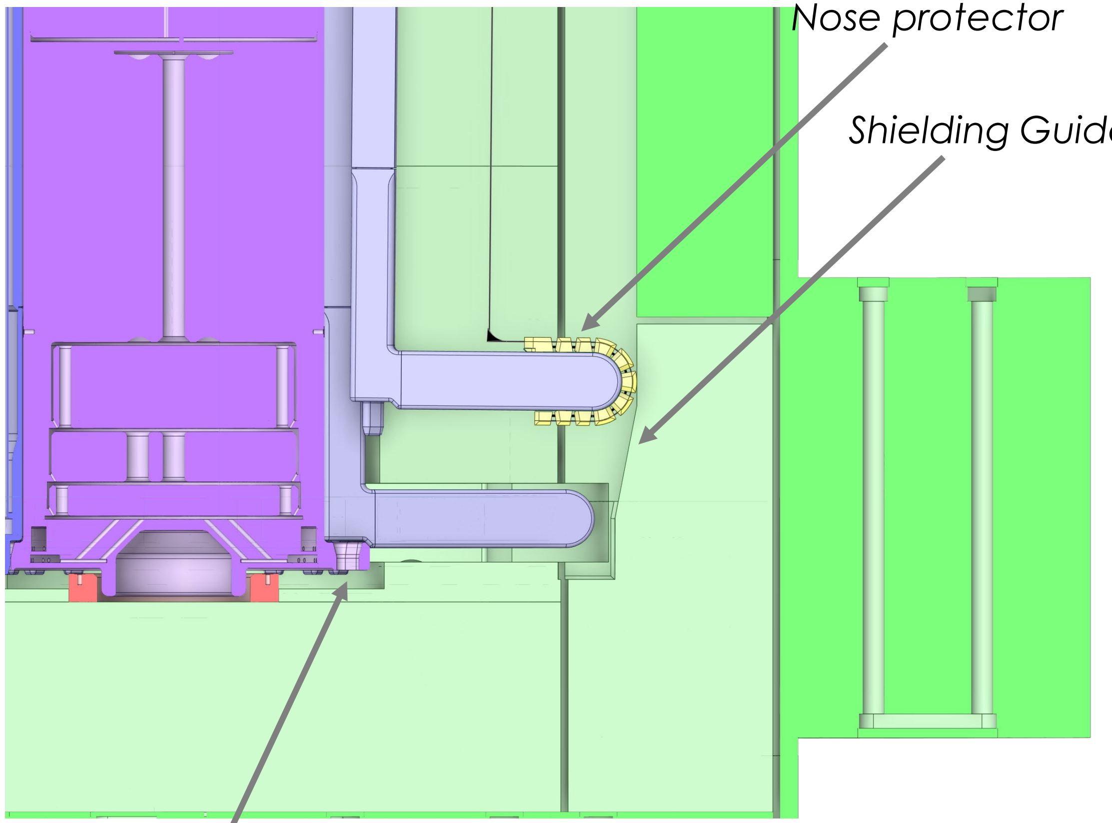


“Tent” structure raises connection above CV lid

Shielding Guides the segment into the shaft pocket

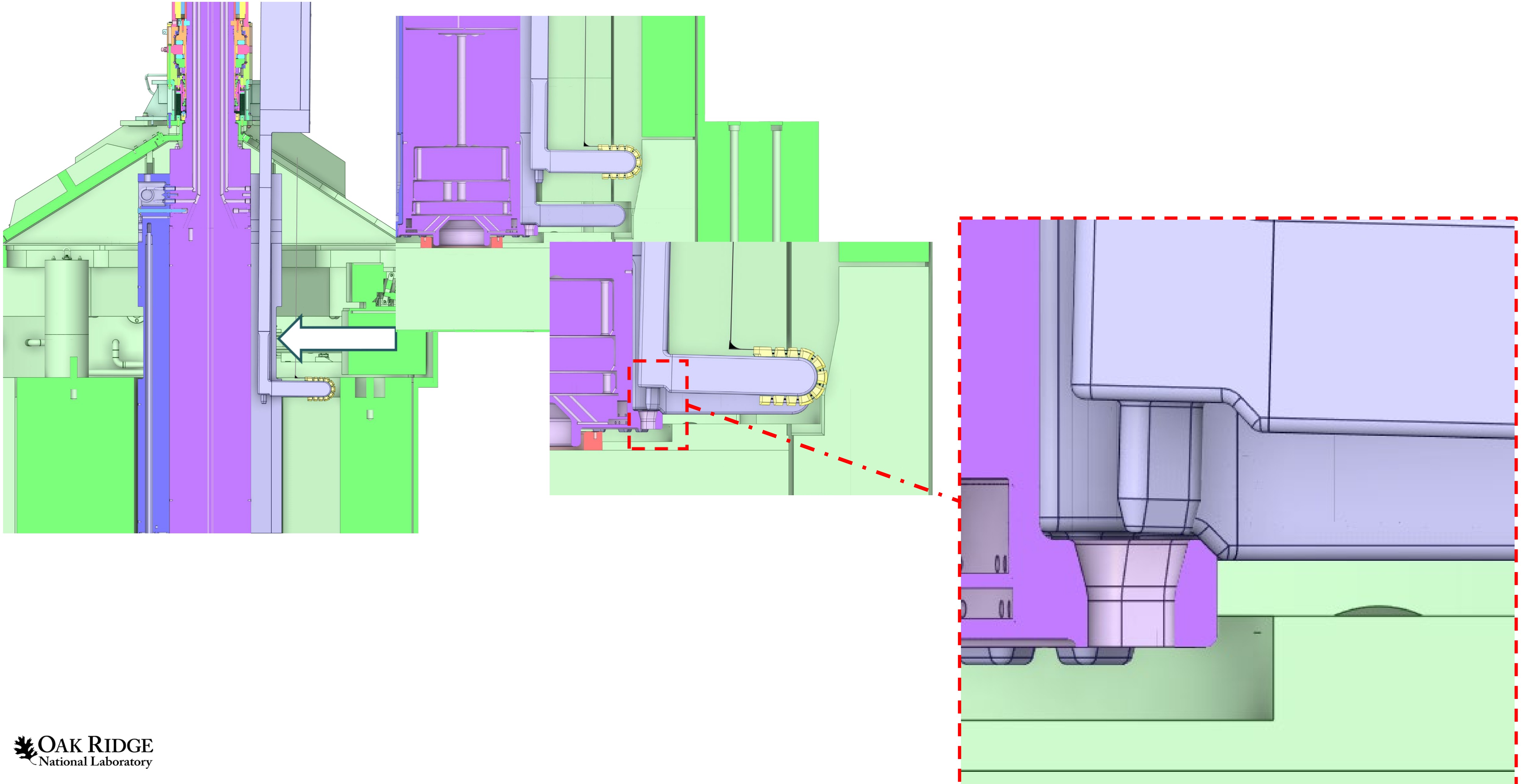
- Target segment is installed by vertically lowering into the core vessel
- Core vessel shielding assists in angular alignment of target segment as it lowers through the shielding stack
- Shielding ramp assists in aligning the target segment with the bottom of the target shaft





Shielding design & images by C. Anton (S03.06)

Installation sequence



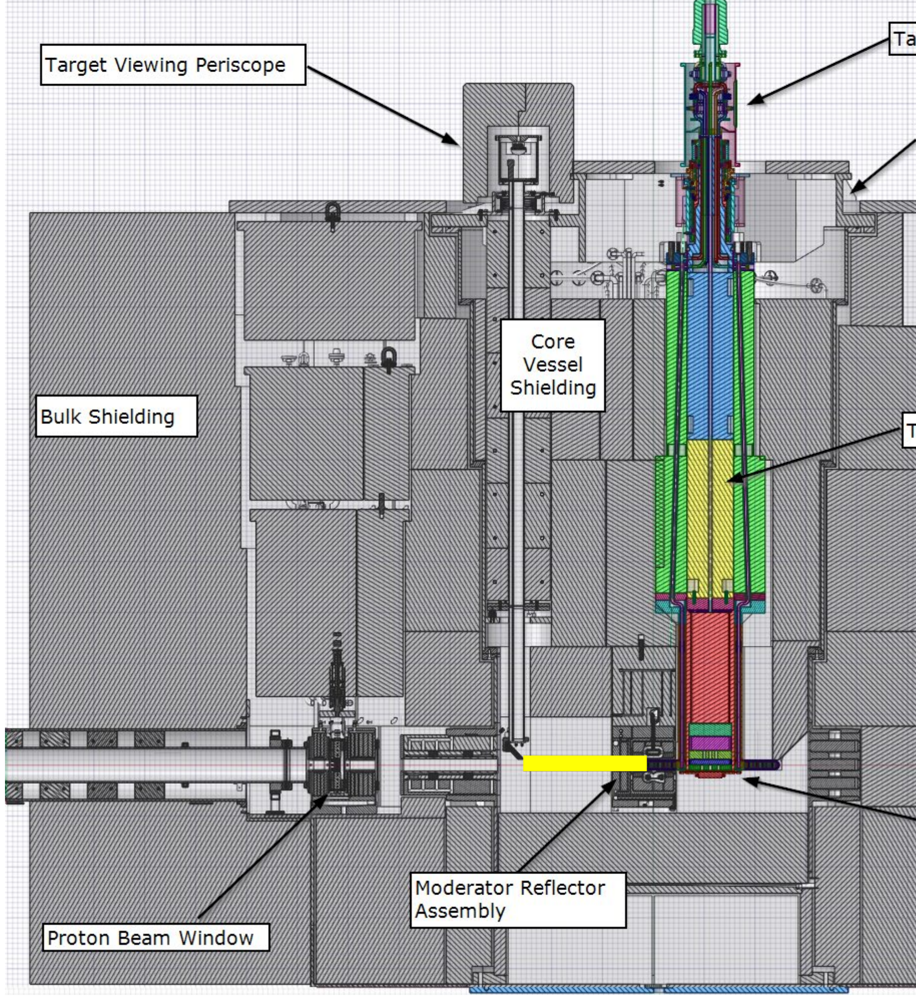
Segment Failure Indication

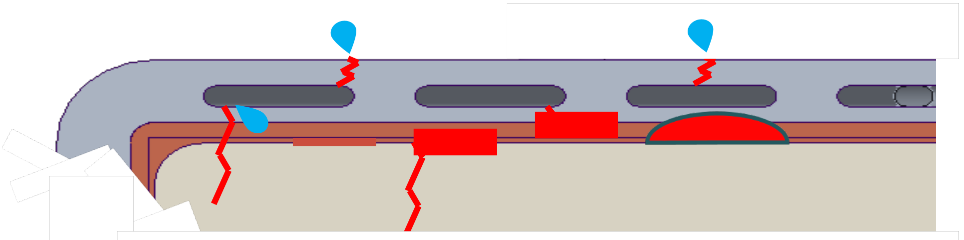
Segment Failure Sensing

- Segment replacement is only effective if you know which segment to replace
- Replacement is needed when:
  - Hands-on - Activated W/Ta accumulates in the drive (the foot design reduces this risk)
  - Water leak in the core vessel

Visual check via TVP

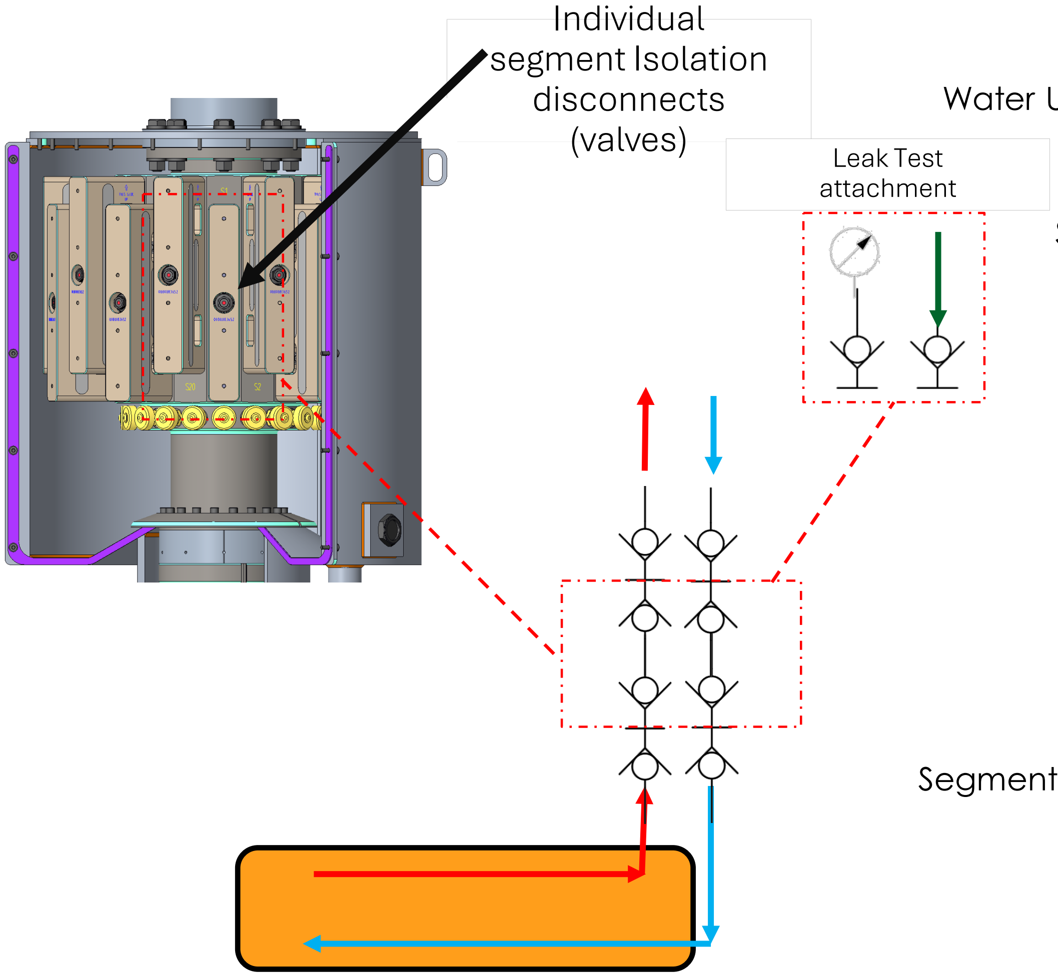
Segment circuit leak down test

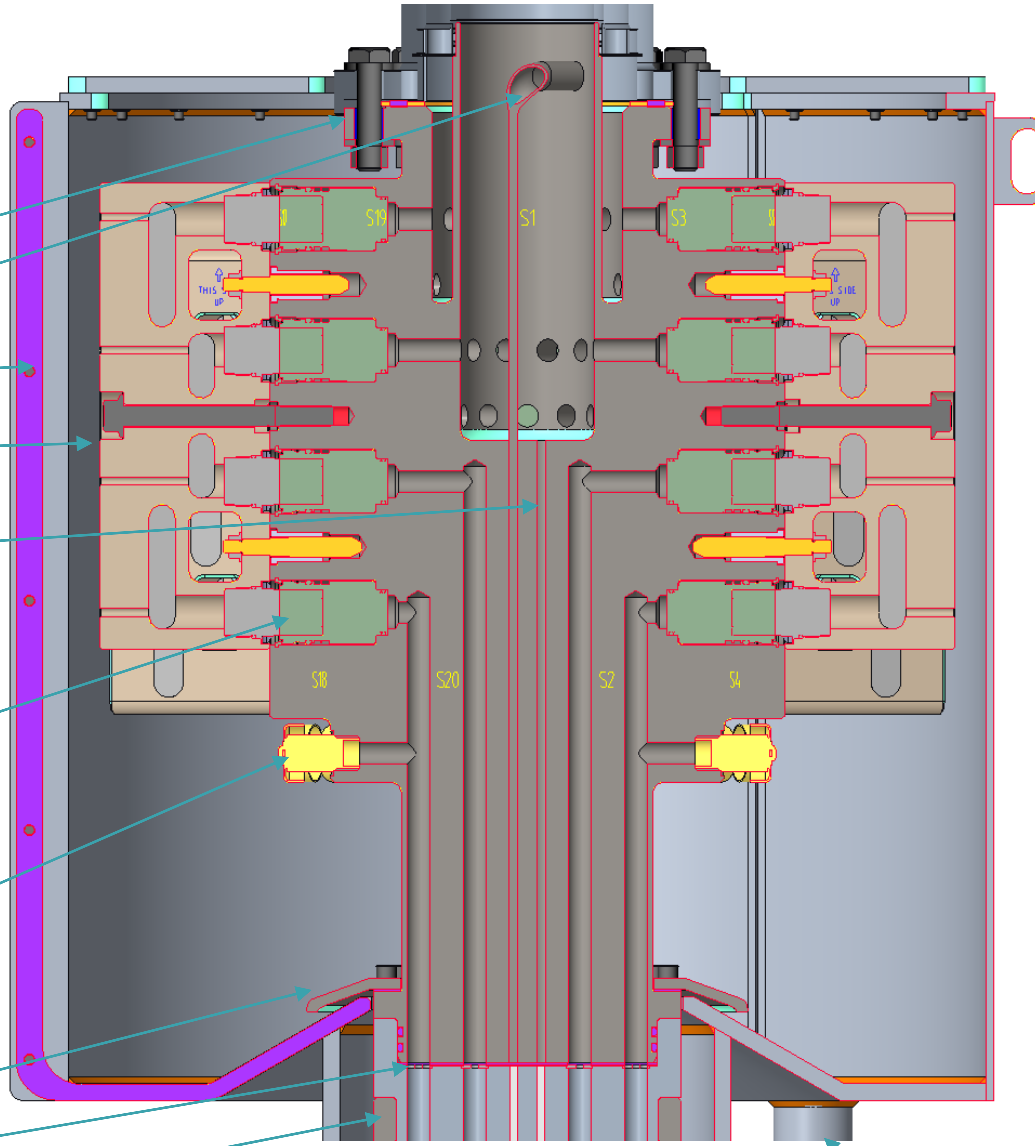




Failure modes covered in Segment Design presentation

Method #1 - The valve manifold provides segment isolation and diagnostics for 20 segments



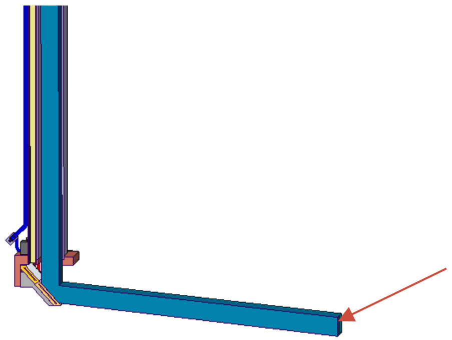


Method #2 - Target Viewing Periscope (Segment Status Indication)

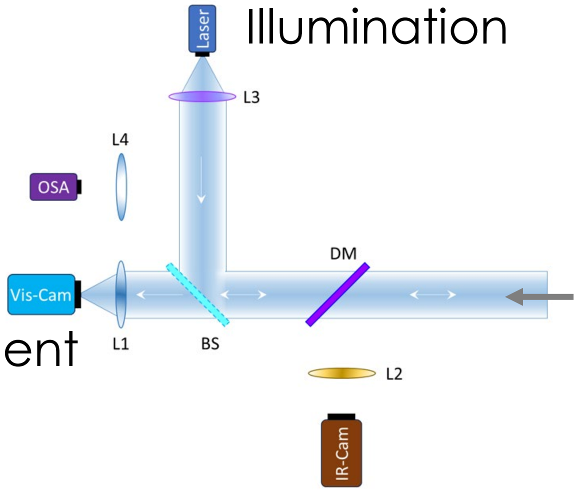
TVP provides three measurements

- Illumination : Illuminates the target face when needed
- PB Profile
  - Measures PB Profile on Target Face using a Luminescent coating material
  - This is a measurement in the visible light spectrum
- Temperature : Measures the temperature profile on the front face of the target

TVP functionality is part of the TVP scope



Views Front face of target



Slide courtesy of N. Pradham

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Loss of Cooling

A clarification about "Loss of cooling" nomenclature

Credited in HAR

- Loss of cooling
  - No flow
    - Beam on
    - Beam off
      - Maintenance
      - Unintended
  - With flow
    - Slow/loss of rotation
    - blockage

TPS in Process system:
-Sensor: Total mass flow rate
-Sensor: Differential temperature
-Sensor Differential pressure

Target Assembly:
-Valve jumper status indicator
-Poke-a-yoke segment install

TPS: Rotation sensor

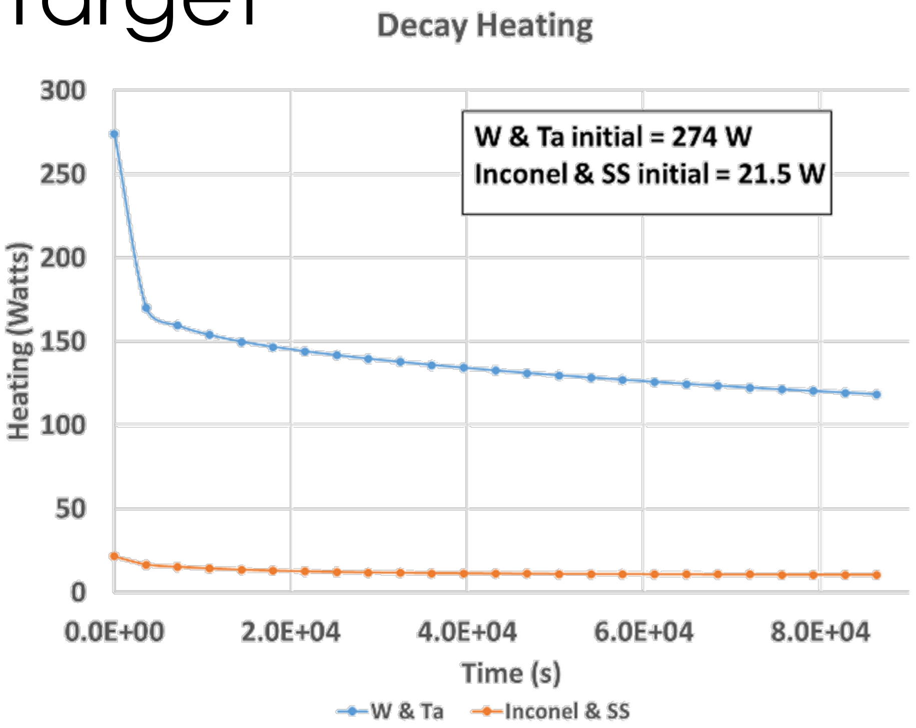
S030204000-CAC10001
-Credit inlet screen
-2 blocked tubes <800°C

TS: passive heat rejection

Presentation by L. Bearden "Decay heat – Maintenance"

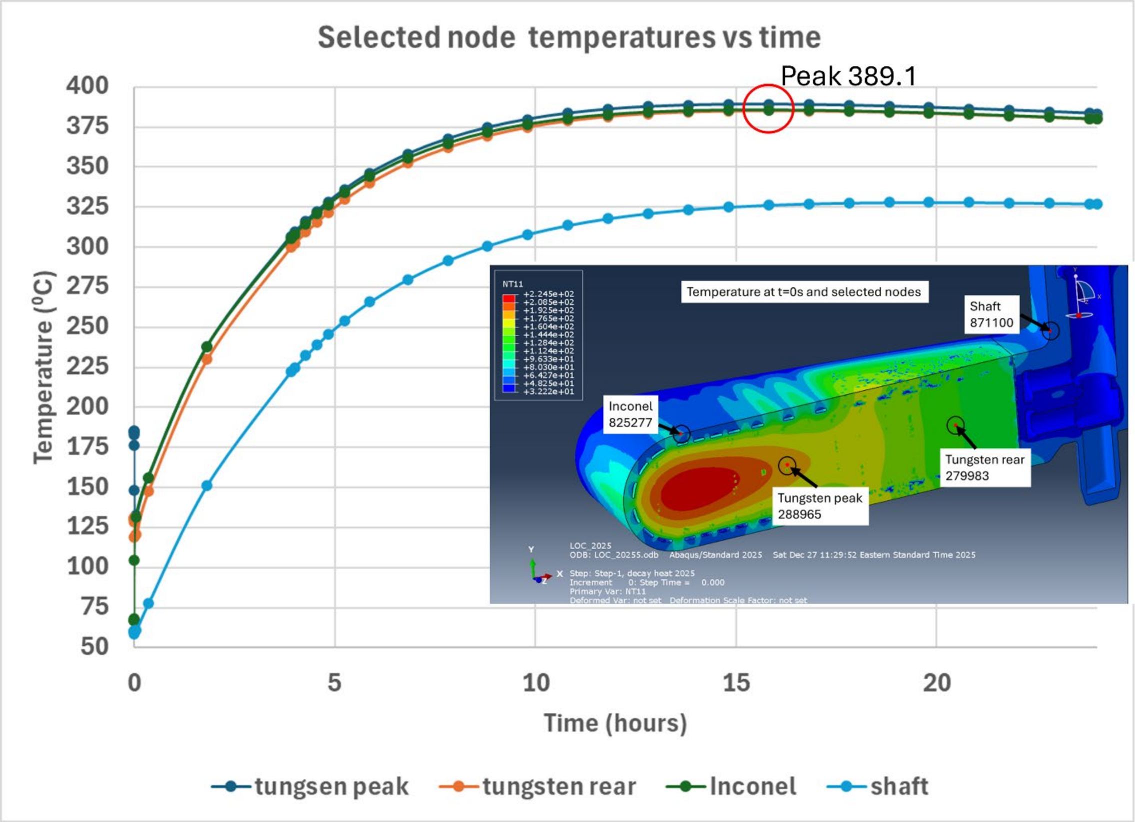
Tungsten - Loss of Cooling & Rotary Target

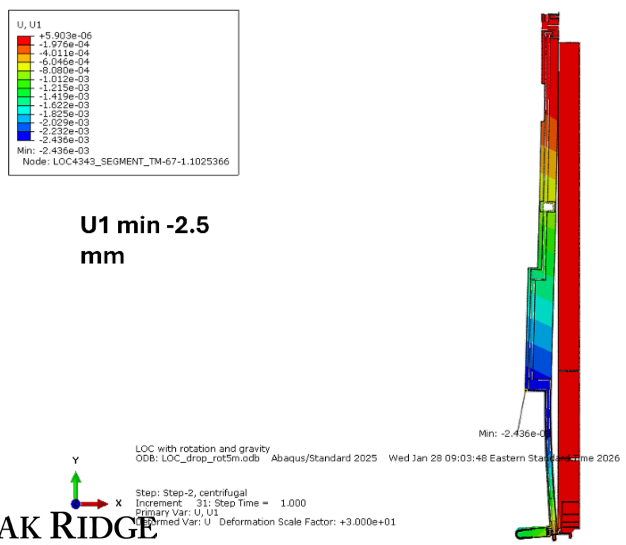
- Maintain tungsten below 800°C (ESS Toast & others)
- Prevent drooping contact at elevated temperatures
- Requires radiation/conduction heat transfer
- Large surface area provided by wheel
- Wheel also reduces steady state heat loads
- Has been extensively considered in Conceptual Design Report & other documents
- Maintained as requirement

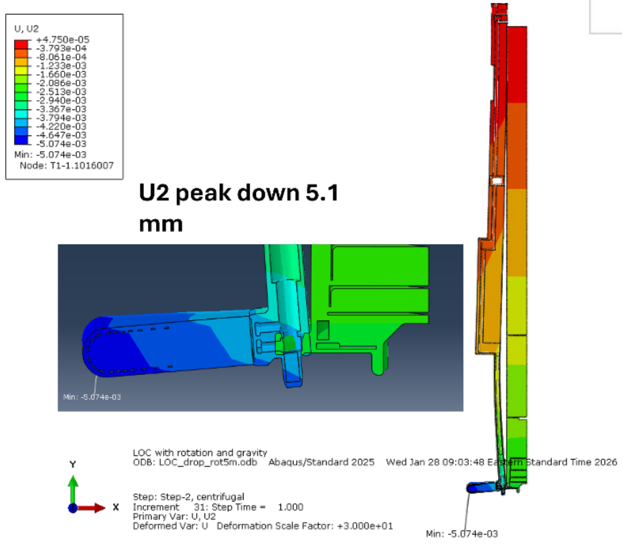


Loss of Cooling Analysis

- Decay heat only (no beam)
- Worst case – no water, vacuum
- Peak ~400°C after 8 hours
- Does not droop into shielding
- Safety analysis

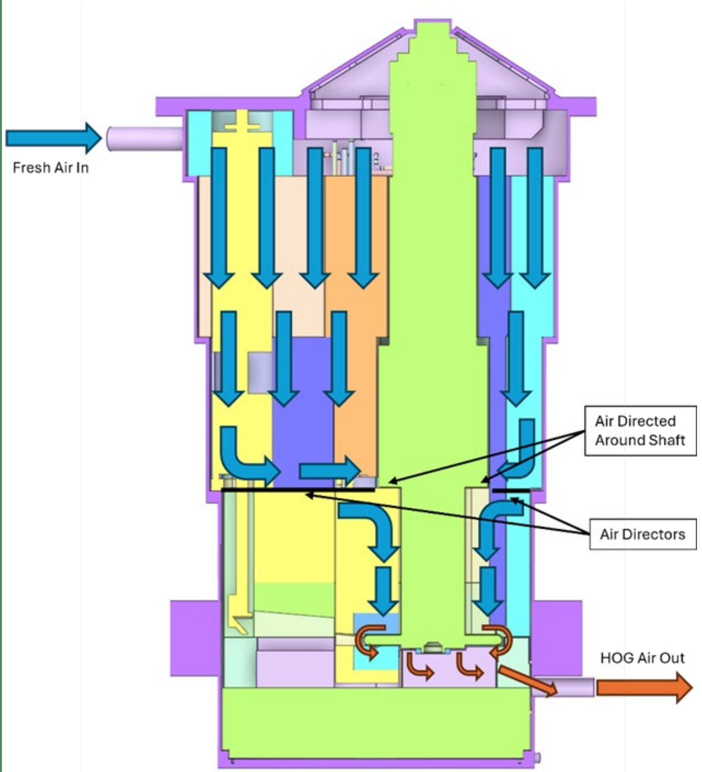




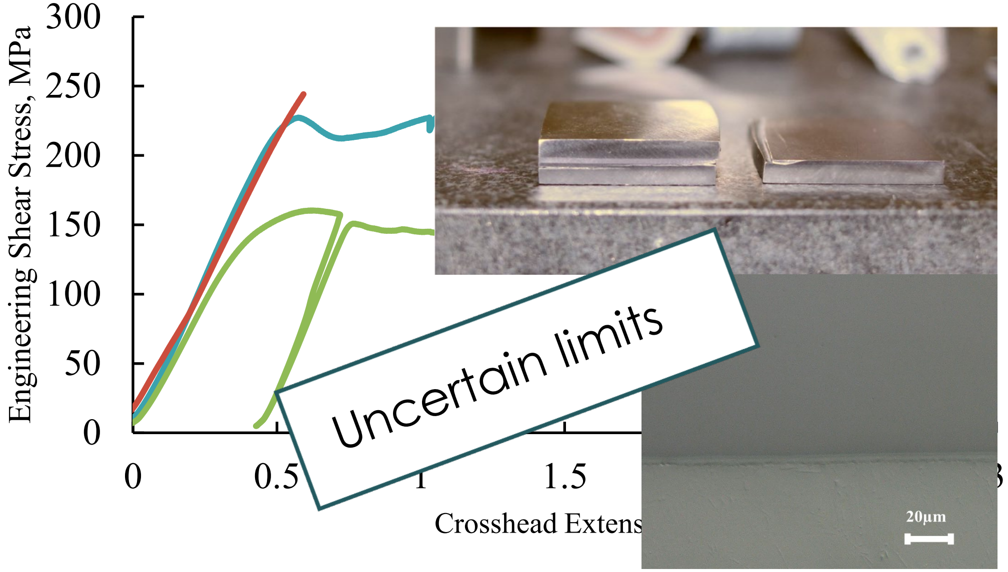


Talk by T. McManamy – "Loss of cooling – Safety"

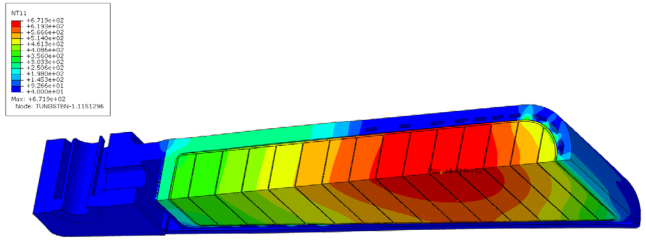
Decay heat during maintenance is a three-way risk reduction

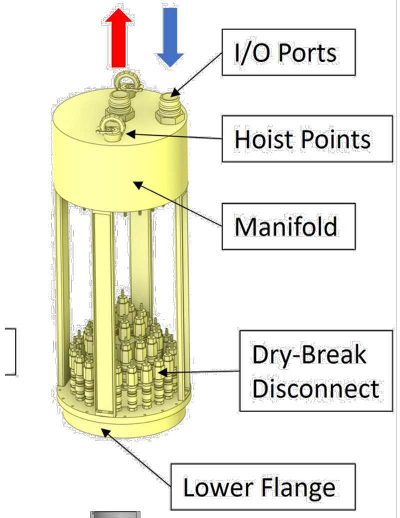


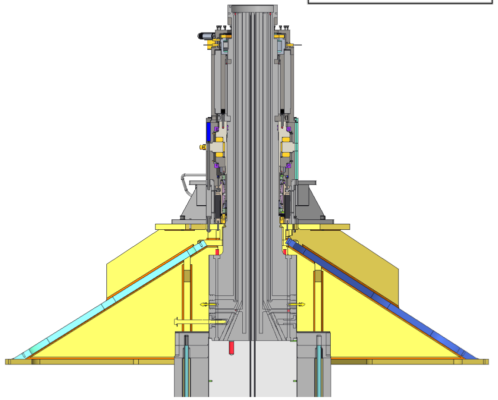
Air Cooling
-Likely used for all maintenance
-Seal & gasket maintenance
-Process system maintenance



Operation after debonding
-Increased tungsten temp (670°C)
-Acceptable Inconel fatigue life
-increased cracks in W





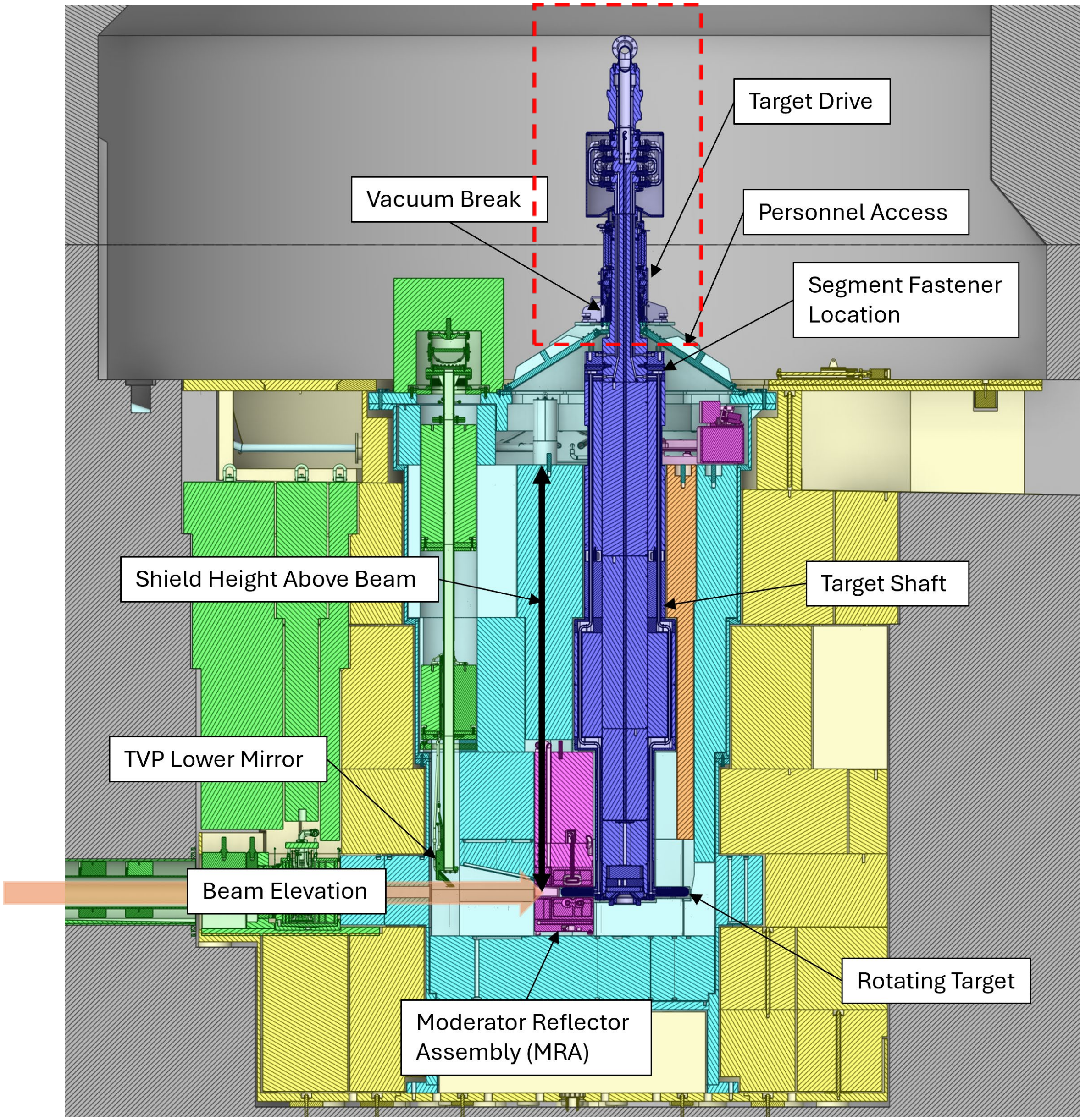


Maintenance manifold
-Low flow, attaches to crown
-Bearings & motor pass over

Drive Architecture

Reliability sets drive location

- Fast access to failed components
- Compact for vertical removal
- Off the shelf components where possible
- Above vacuum break
- Above shielding
- Low radiation field provides for hands on maintenance



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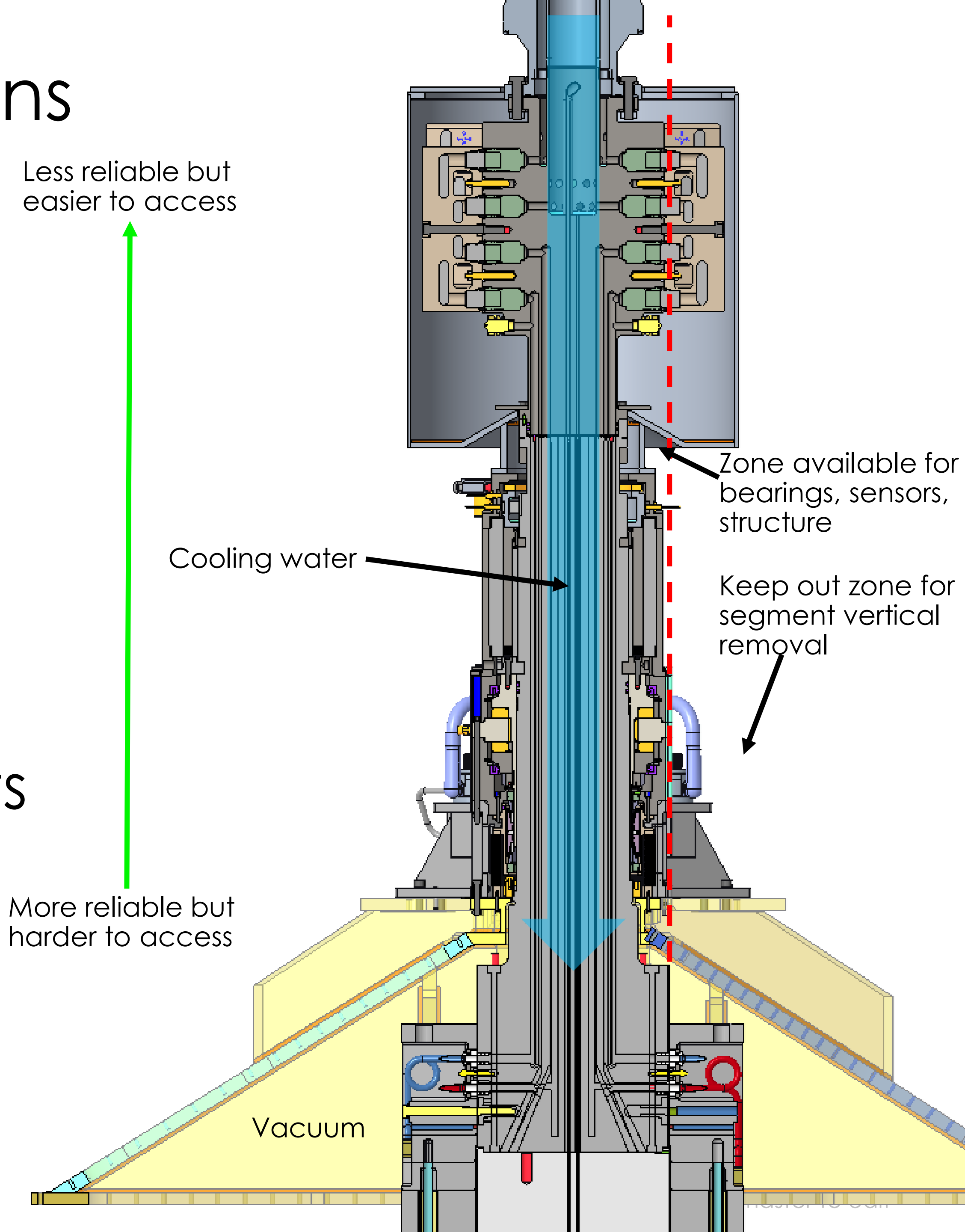
Drive Assembly – Primary functions

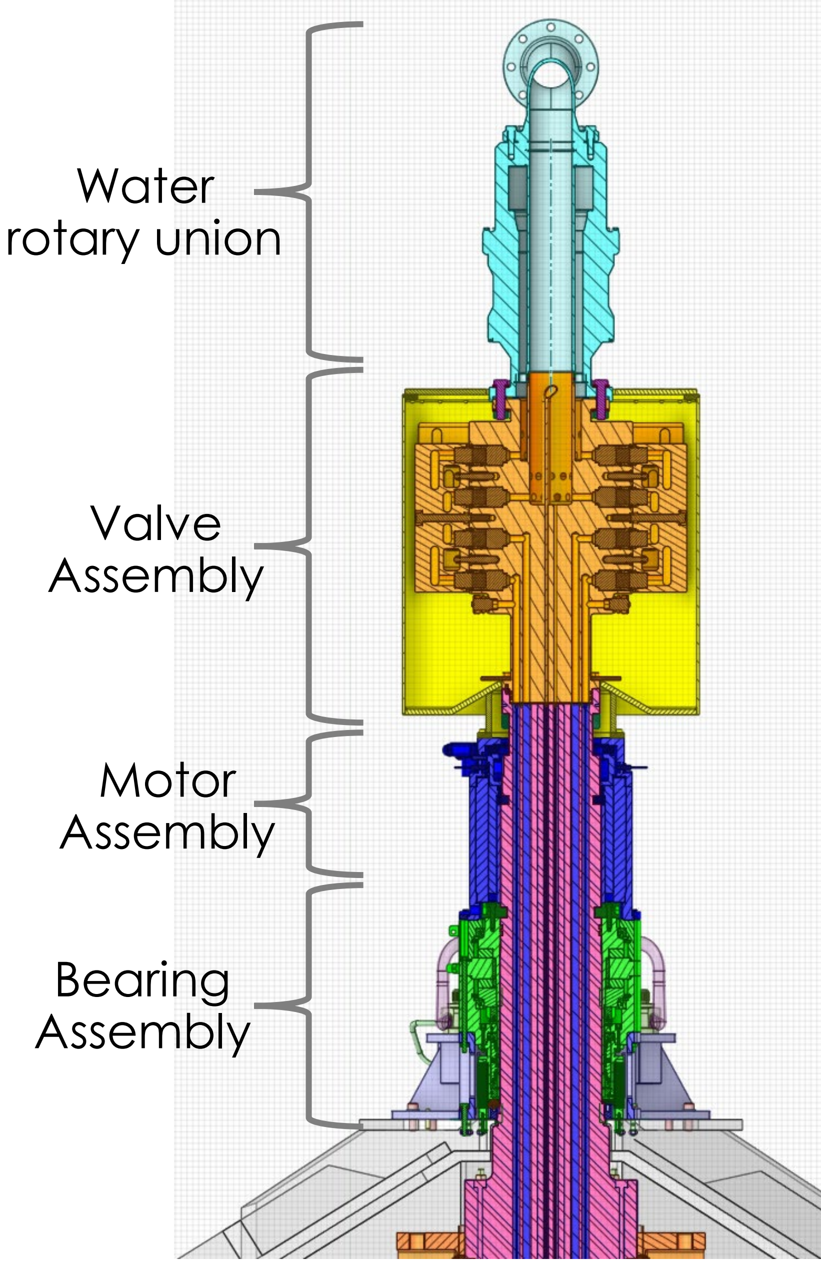
- Vertical segment removal
- Rotate targets
- Shielding & seismic support
- Distribute and isolate water
- Leak detection capability
- Provide fast access to components

Vertical arrangement of bearing, seals, and components

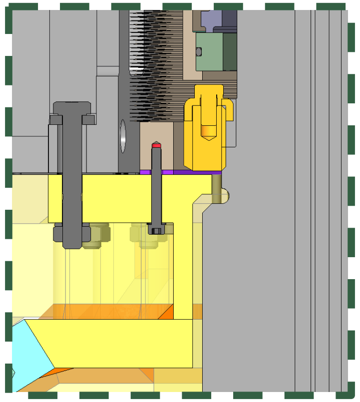


Drive assembly replacement units

- Most frequent required access → top
- Least frequent required access → bottom
- Hands on access for removal and replacement
- Nested vertical arrangement
- Arrangement also governed by loads and sizing (Must be narrow at the top for removal)

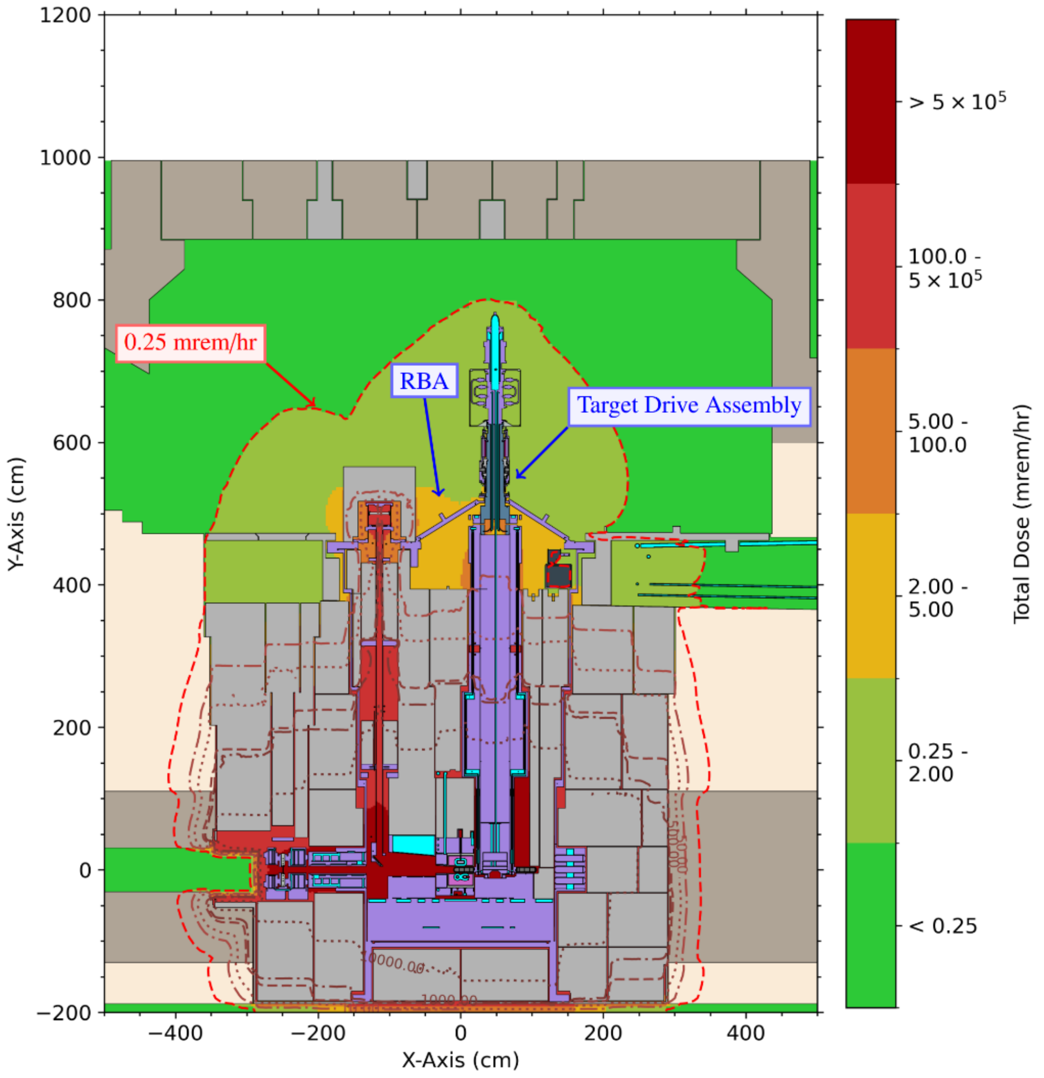


Shaft rests upon lid during bearing replacement



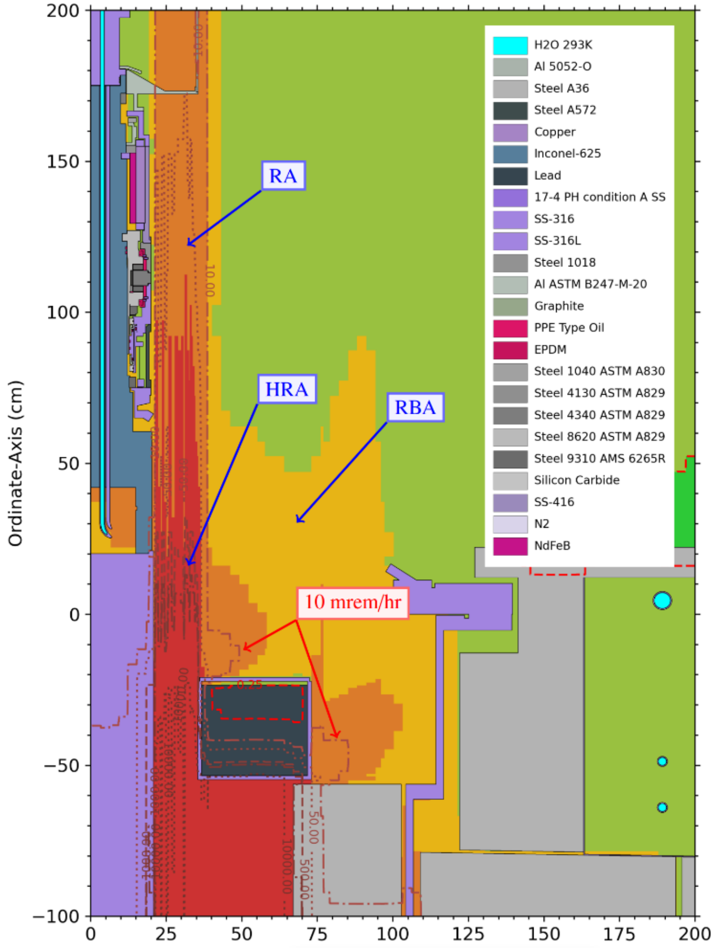
Drive Maintenance dose rates are < 2mrem/hr

- Acceptable for hands on maintenance of drive components
  - No remote tooling needed
  - More robust operation and maintenance possible
- Materials accumulated in the drive may increase dose rates
  - W/TA (minimized by target foot design)
  - Beryllium 7

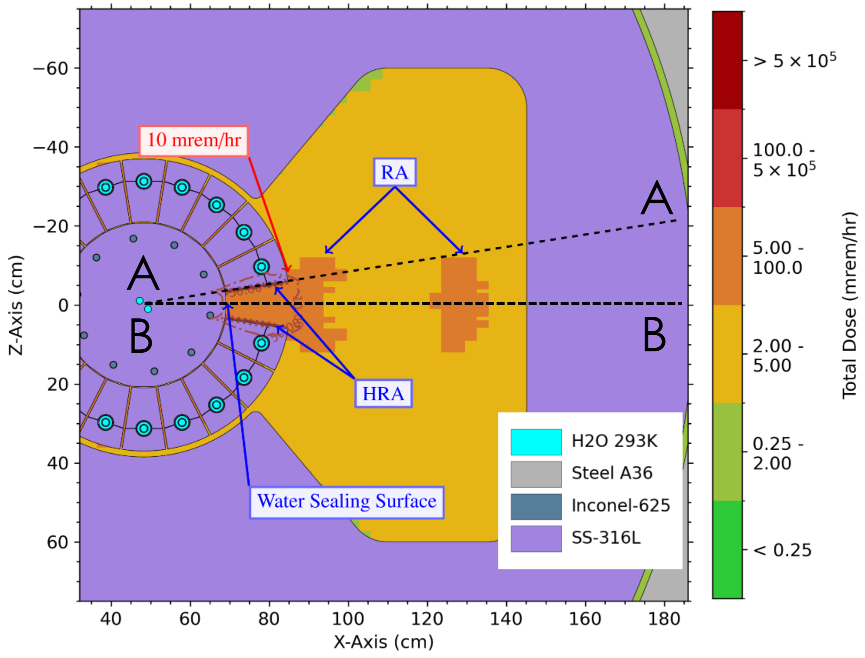


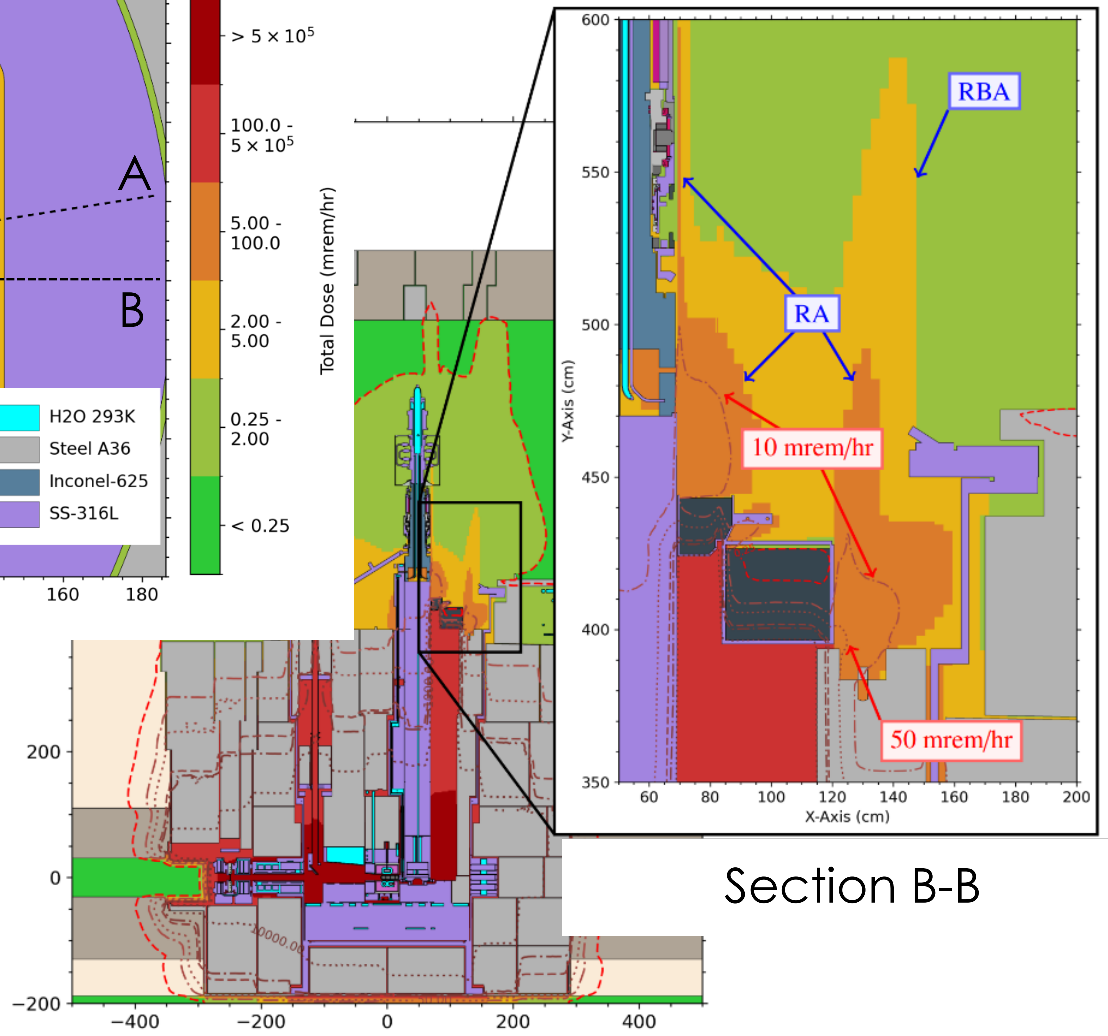
S03120100-TRT10015 - Analysis & figure by T. McClanahan
Details of Analysis to be presented in Neutronics – Prompt Streaming & Maintenance Doses

Segment attachment work is shielded through a deployable radiation shield (S.03.06)



Section A-A



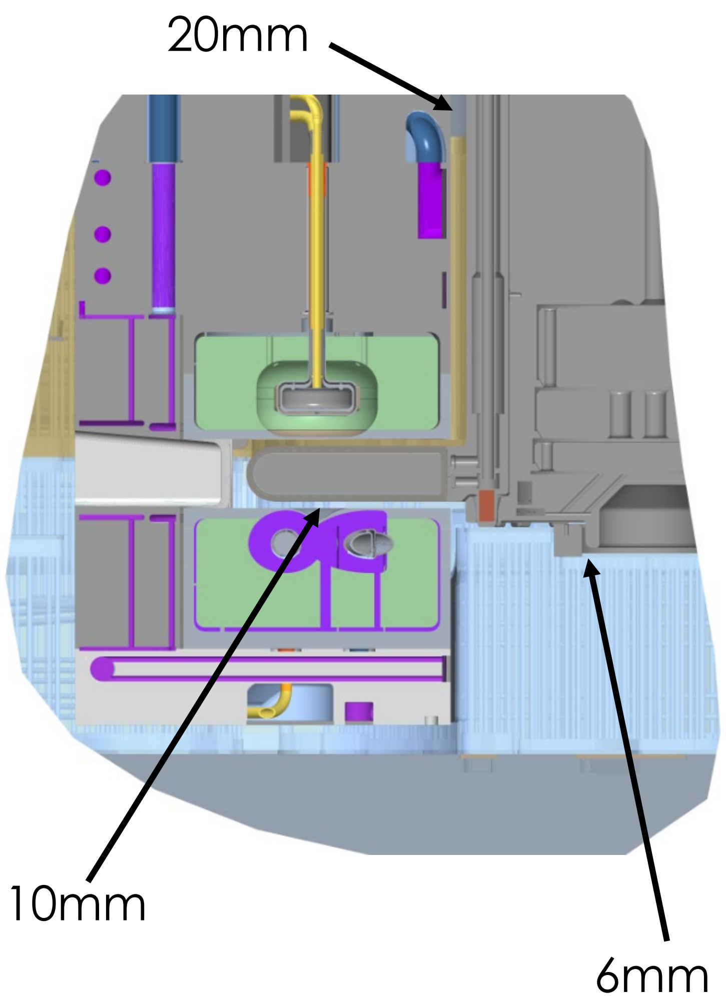


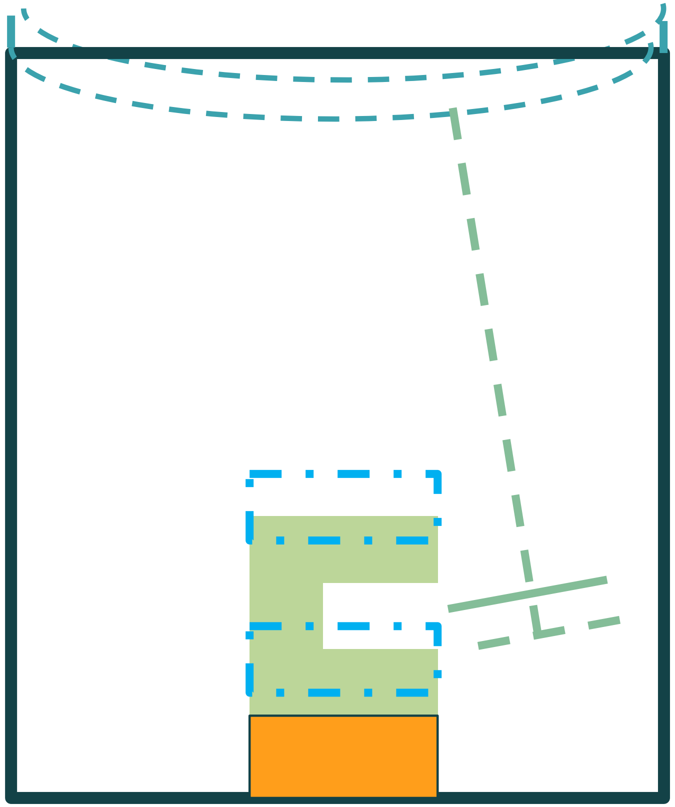
Section B-B

Recall Presentation by T. McClanahan "Maintenance Dose Rates"

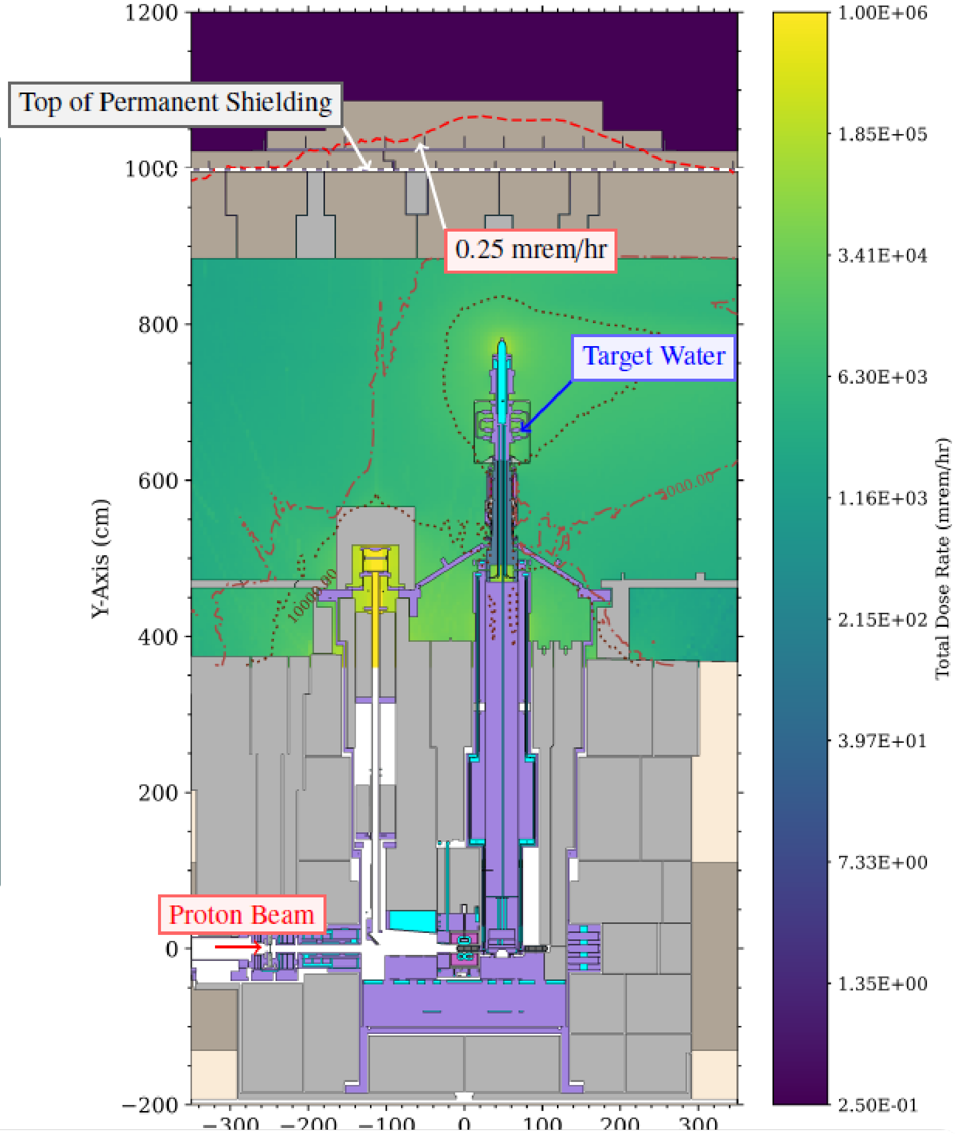
Seismic Considerations

Seismic, radiation streaming, and operational deflections are competing constraints.





Features:
- Snubber
- Segment donut
- Stiff CV lid
- Water jogs
- Stiff shaft



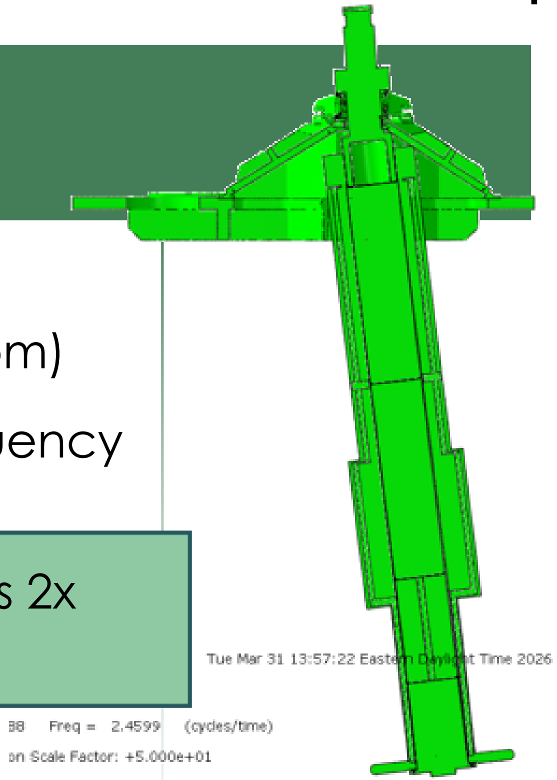
Recall Presentation by A. Jacques on " Allocation of requirements for the Clearance Budget between MRA, CV, TA"

The shaft is well above resonance and does not need to be balanced – but does require precise drive machining

Second Target Station

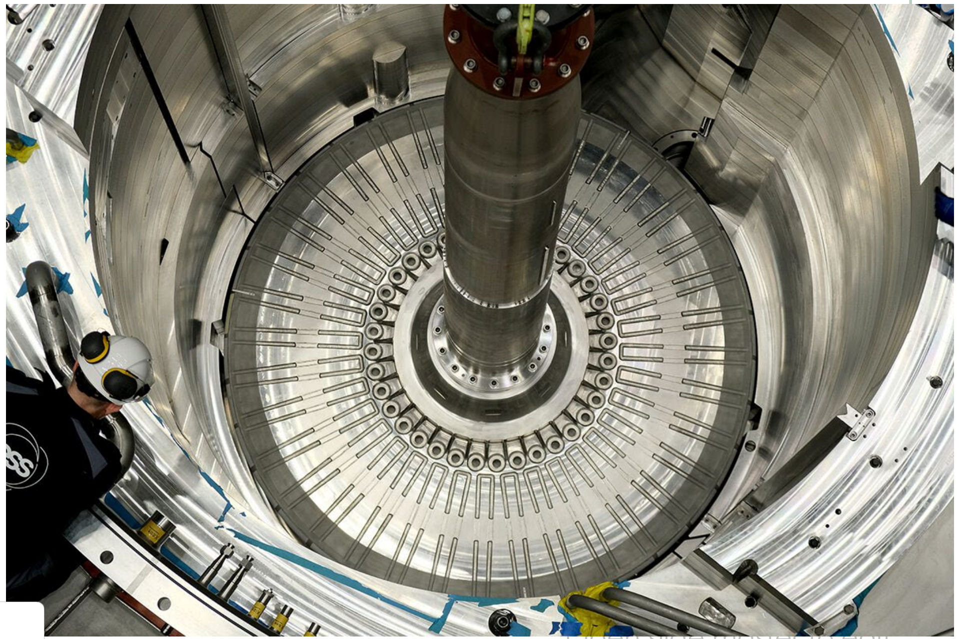
- Mode 1 = 2.5 Hz
- Excitation=0.75 Hz (45 rpm)
- 3.3x above driving frequency

Typical “Rule of thumb” is 2x above driving frequency



European Spallation Source

- Mode 1 = 2.2 Hz
- Excitation=0.383 Hz (23 rpm)
- 5.7 above driving frequency



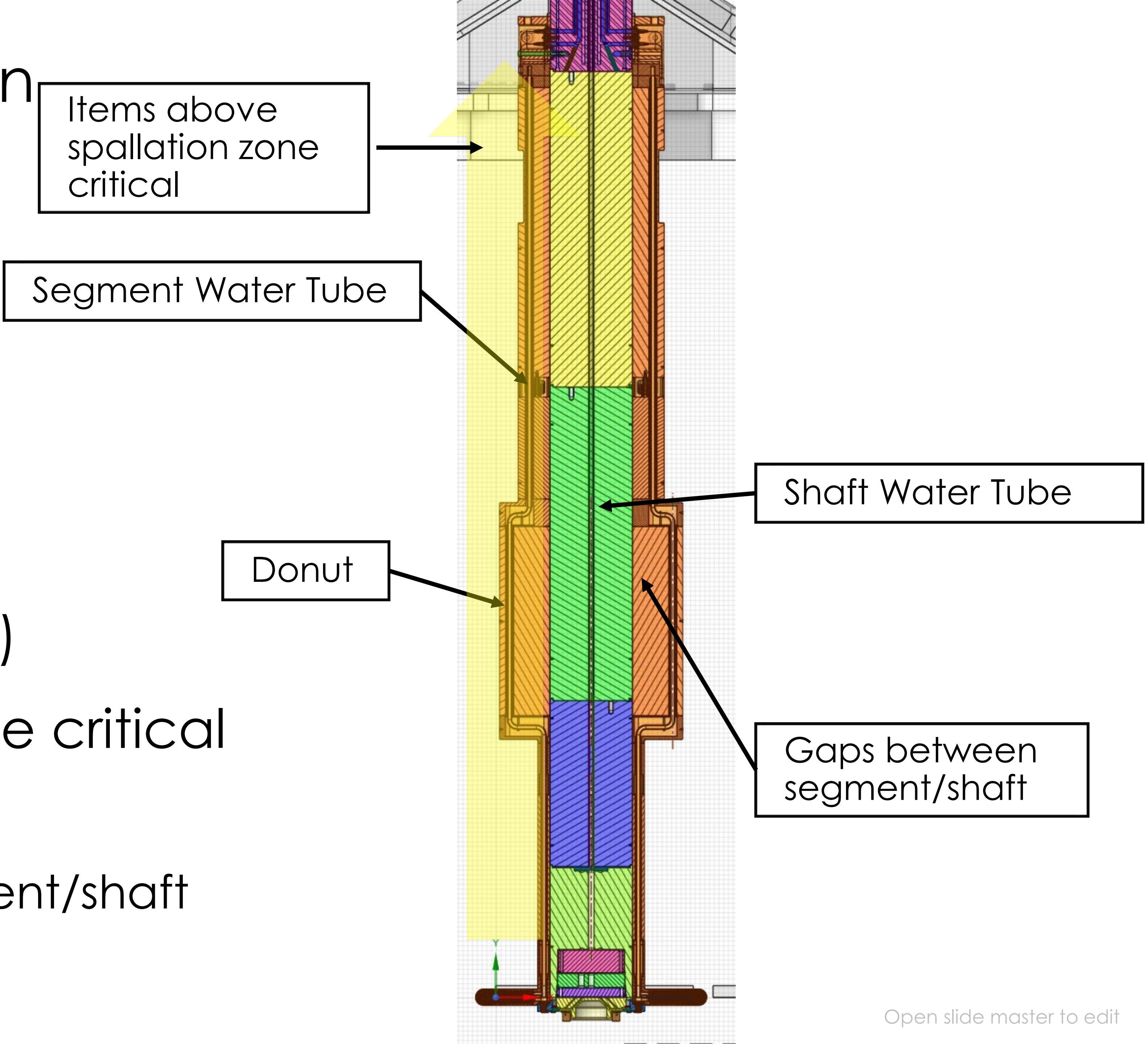
- The system cannot be balanced for segment replacement
- Deflection analysis conservatively assumed a 35kg-m eccentricity (equivalent to 1 missing target foot)
- 1mm eccentricity → Shaft motion <0.5mm

Future Presentation by A. Jacques on "Target Drive Design"

Streaming – radiation safety

Streaming Reduction

- Donut
  - Diameter
  - Length above
  - Length below
  - Angled water tubing
- Length of shaft
- Gaps (previous topic)
- Above spallation zone critical
- Low effect:
  - Gaps between segment/shaft
  - Water in shaft



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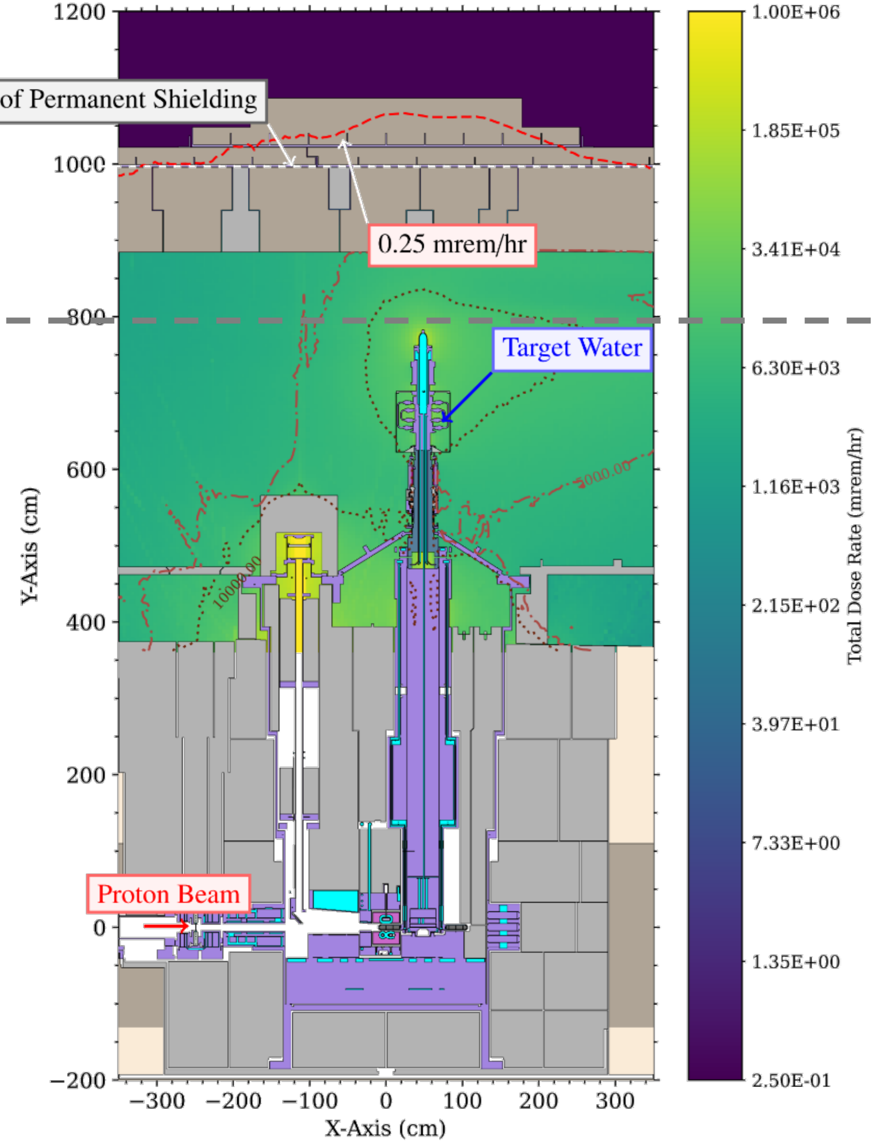
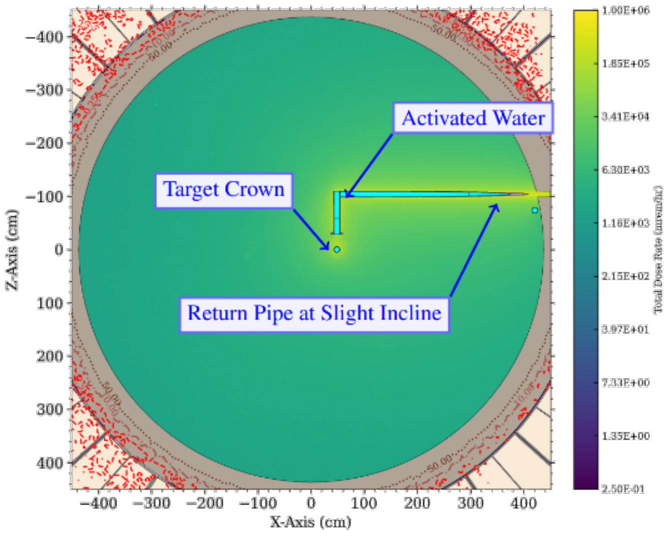
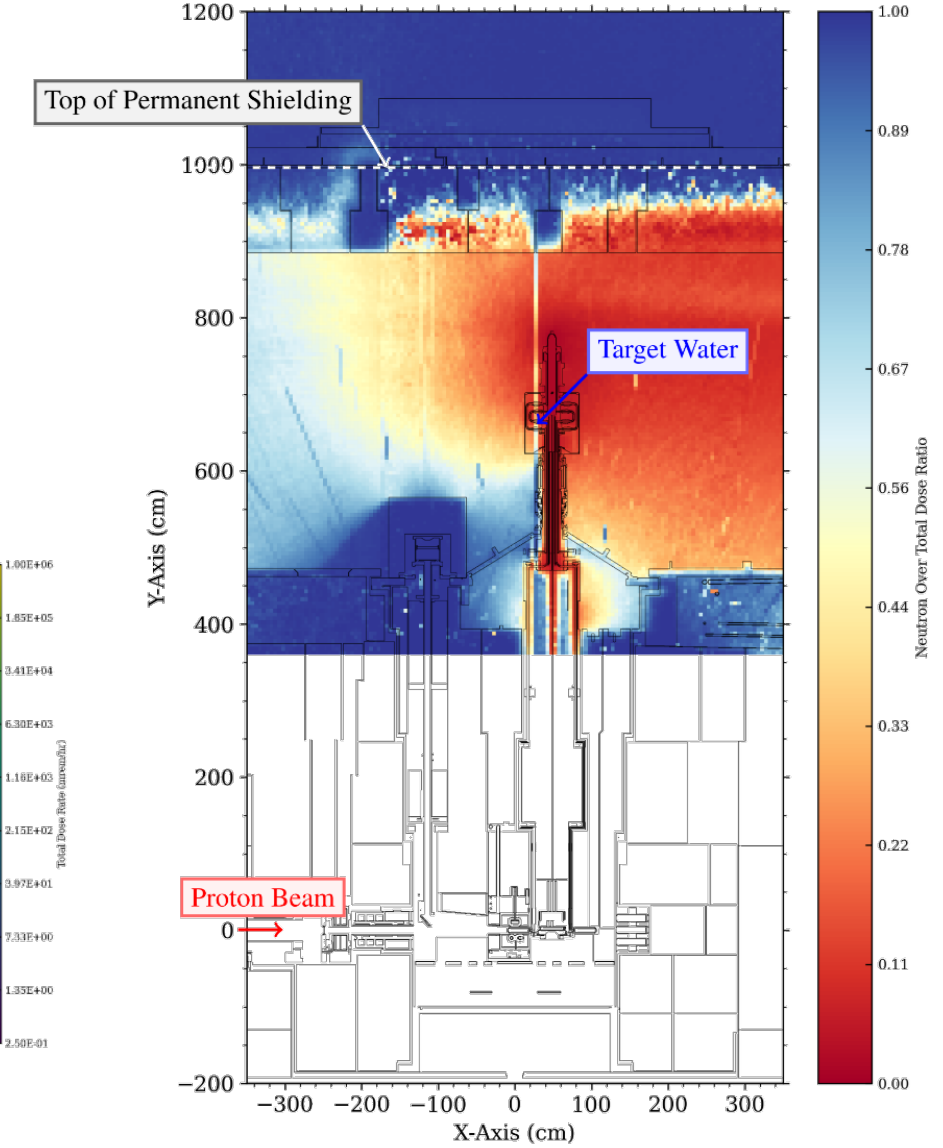
Streaming (Beam On) is both neutron and photon dose

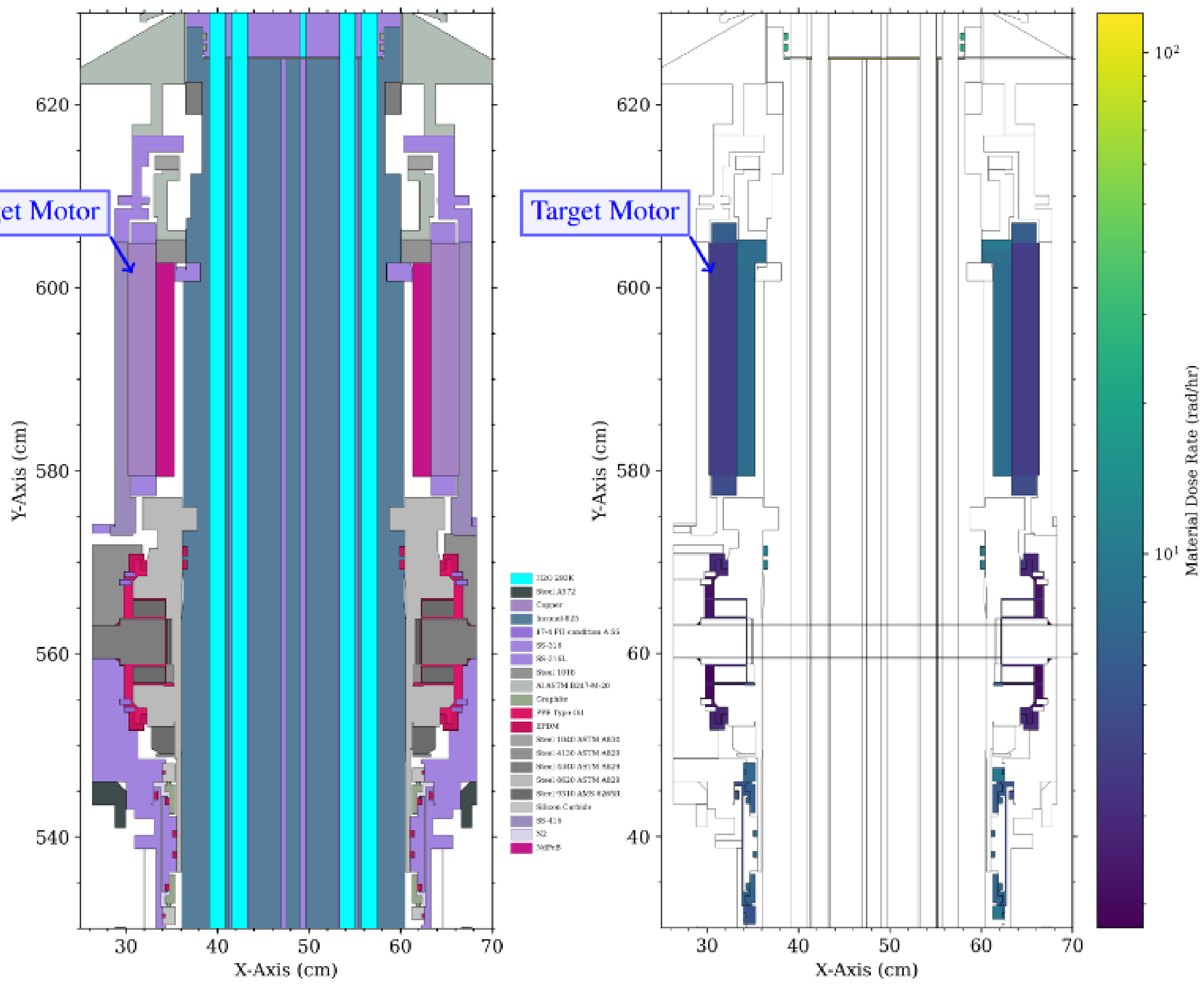






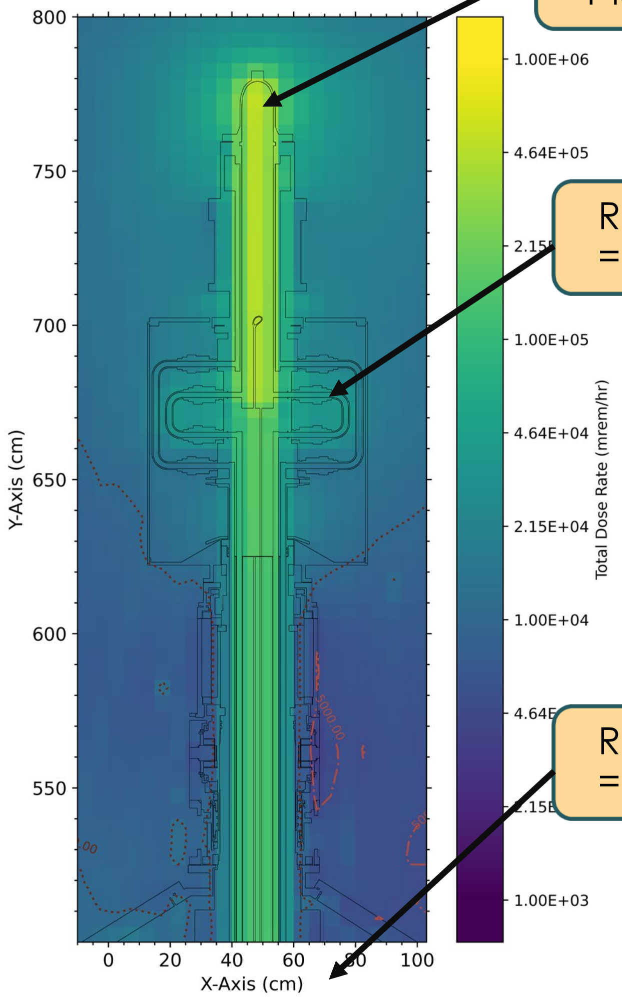
Tucker McClanahan. Evaluation of Second Target Station Target Streaming for the Preliminary Design of the Target Assembly. Tech. rep. S03120100-TRT10017. Oak Ridge National Laboratory, July. 2026..

The drive crown and drive provide some level of shielding from (water) photon doses to items of interest.



(a) Geometry

(b) Total absorbed dose rates in materials



Return water dose = 1 krem/hr

Return water dose = 100 rem/hr

Return water dose = 660 rem/hr

Charge Question 5: Is the design sufficiently mature to proceed with finalizing the procurement package?

- Key requirements are well understood and addressed (future presentations)
- The architecture of the system is sound and well suited for the needs of the facility
- Large trade-offs have been closely evaluated and well understood
- The design of the system around the mechanical design (maintenance, streaming, disposal, MRA removal) is mature
- The design itself is mature (CAD) with attention to ancillary details
- The design package clearly meets the expectations for Final Design Review as outlined in STS Engineering Policy S01020500-PCD10001
- **The design is ready for the next step towards fabrication: drawing detailing for Procurement Readiness Review**

Questions