OAK RIDGE National Laboratory

August 2026

Target Assembly: Maintenance Decay Heat

Lukas Bearden

Second Target Station

U.S. DEPARTMENT of ENERGY

ORNL IS MANAGED BY UT-BATTELLE LLC
FOR THE US DEPARTMENT OF ENERGY

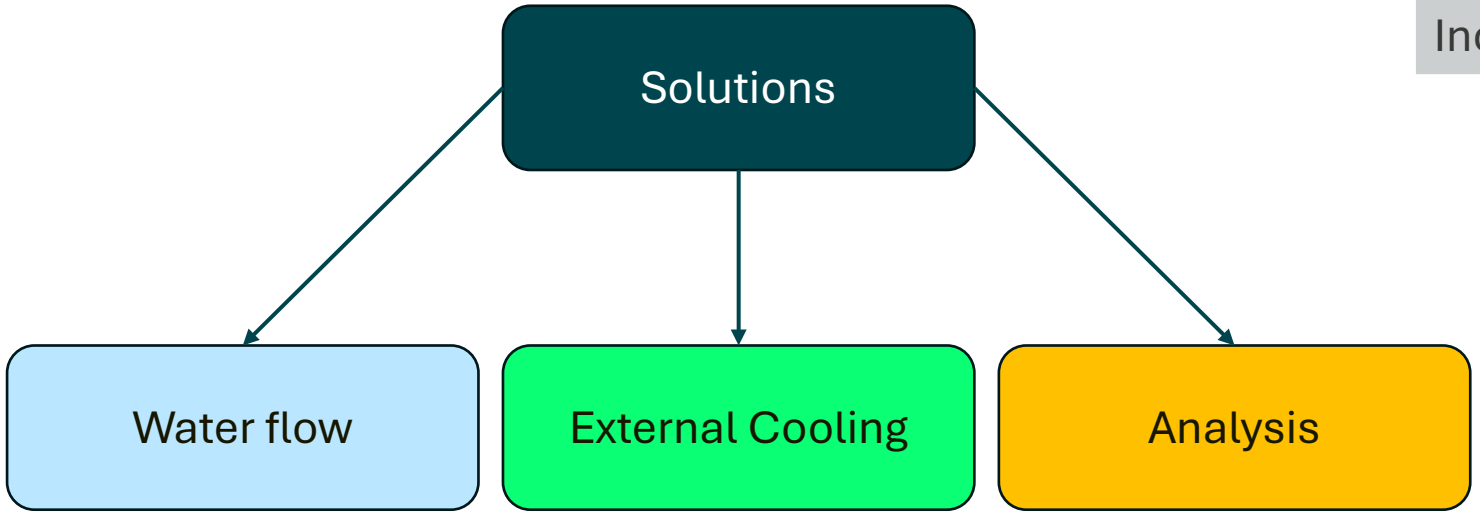
Charge Question 3: Do DACs and other supporting documentation adequately support the final design?

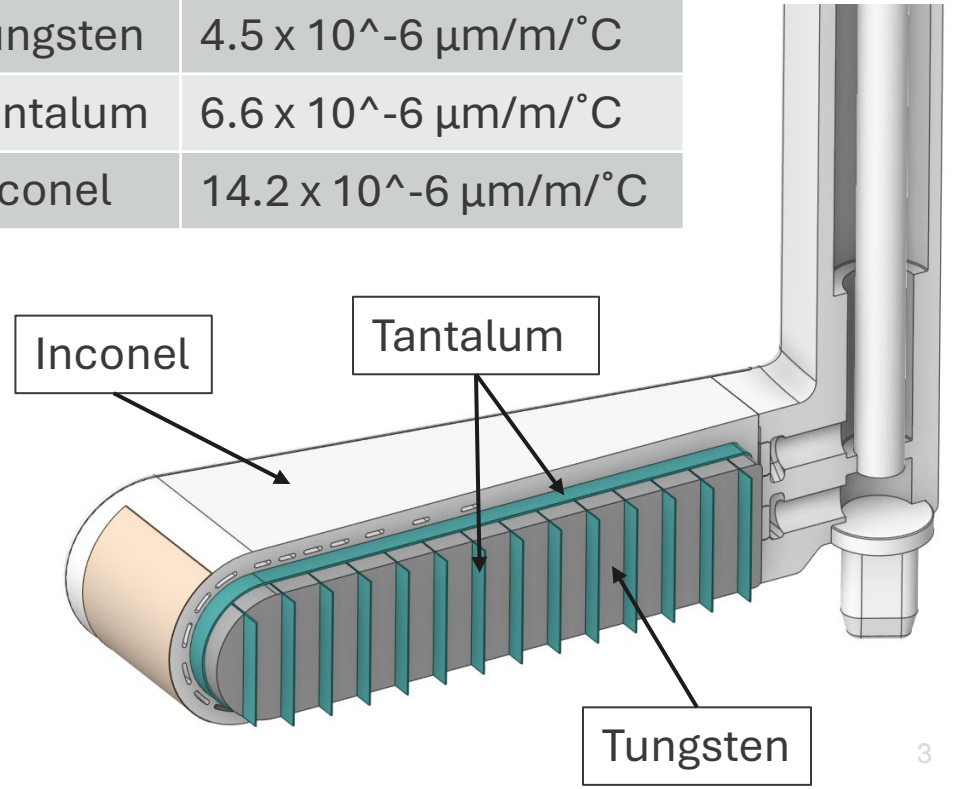
Charge Question 5: Is the design sufficiently mature to proceed with finalizing the procurement package?

Target Assembly – Maintenance Cooling

- The target block consists of tantalum and tungsten that both emit significant decay heat
- Decay heat is estimated to start to spoil the interface bond within 1 - 2 hours
- This would lead to robustness of target and expected life to decrease.
- The scenario of stopped cooling is not a safety concern
  - it is an operations and financial concern

Material	CTE
Tungsten	4.5 x 10^-6 µm/m/˚C
Tantalum	6.6 x 10^-6 µm/m/˚C
Inconel	14.2 x 10^-6 µm/m/˚C





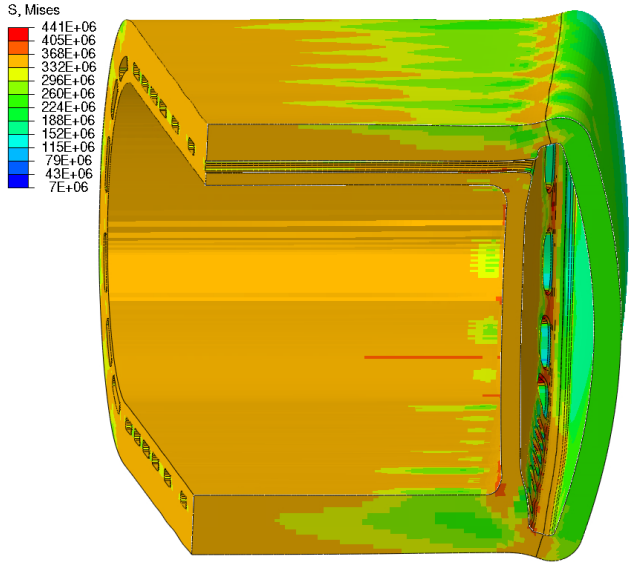
Prediction of bond “release” temperature is not fully known and more appropriately handled with design than R&D & analysis

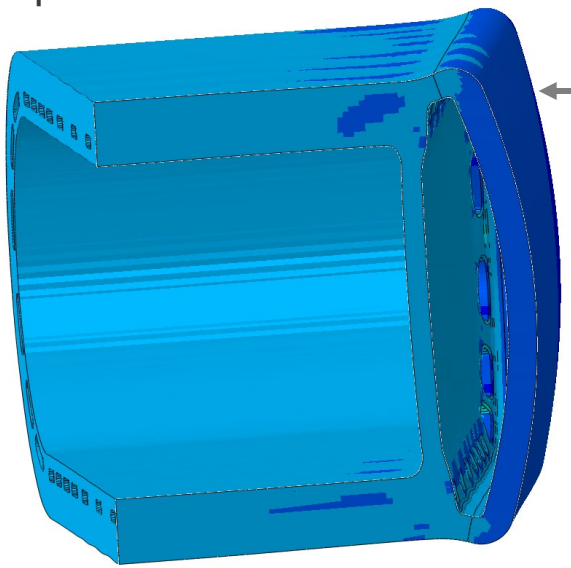
Case	Temp [°C]	IN718SA [MPa]	SS316 [MPa]	Ta [MPa]	W [MPa]
WOL	200	550	~200	280	300
WOL	100	570	~150	240	290
EOL	200	440	~180	160	430
EOL	100	385	~160	160	275

- For EOL 200°C, tungsten principal stress is above irradiated ultimate (430 > 350 MPa).
- Future work:
  - Incorporate knowledge of bond strengths
  - Analyze using ASME BPVC incl. low cycle fatigue

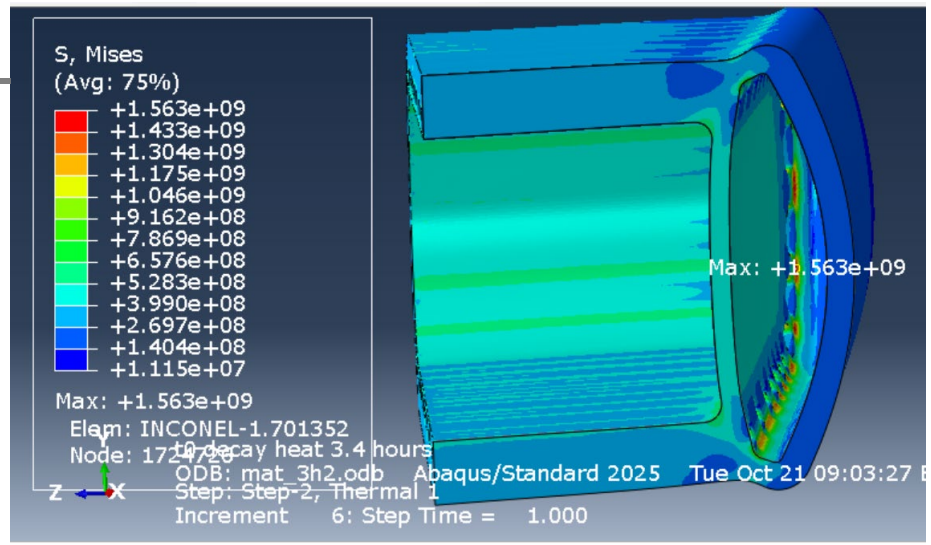
EOL 200°C Comparison

HEX elastic-plastic





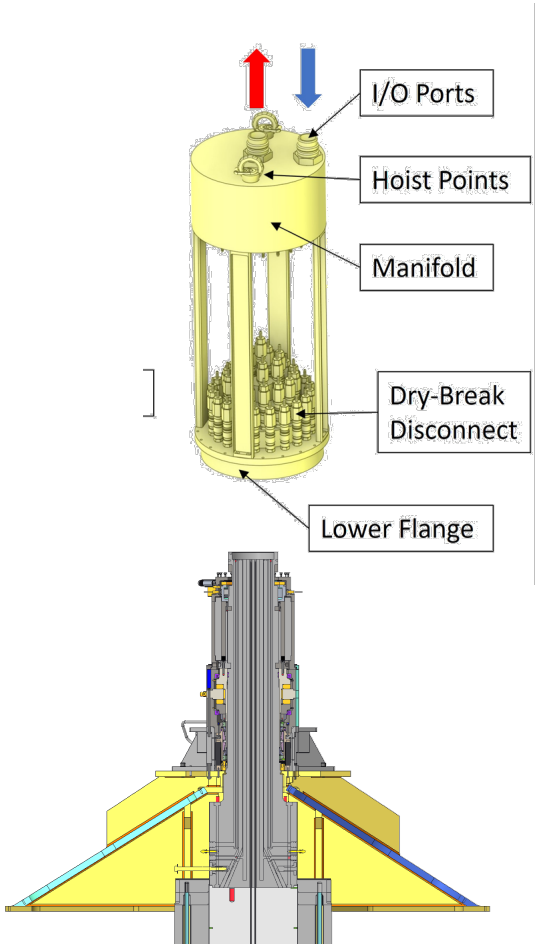
TET elastic



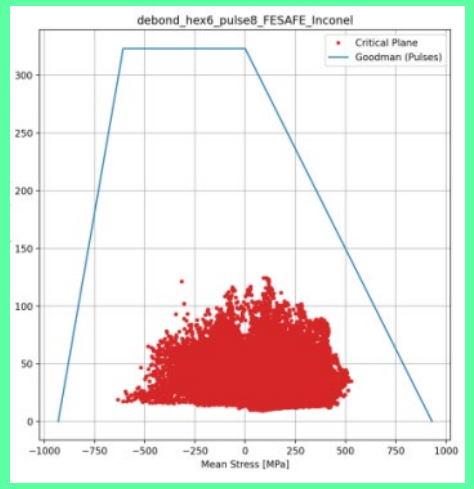
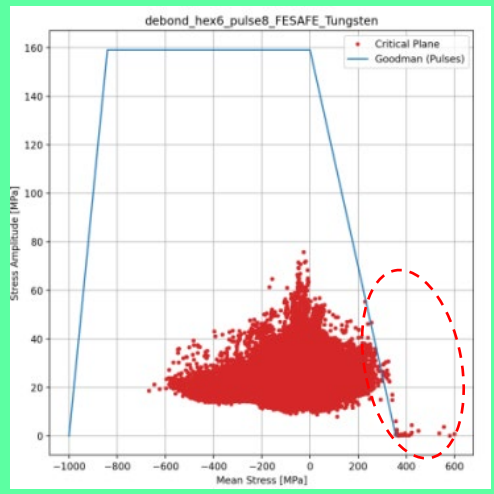
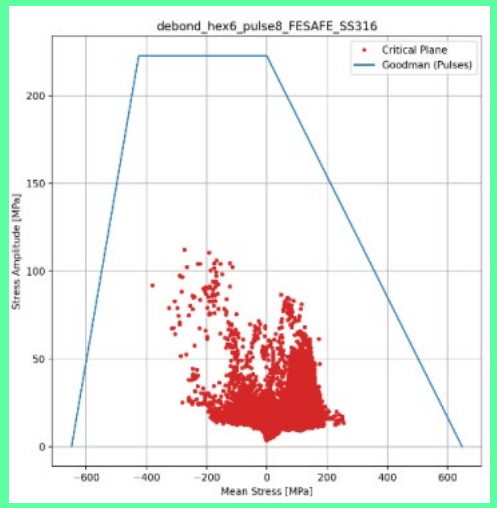
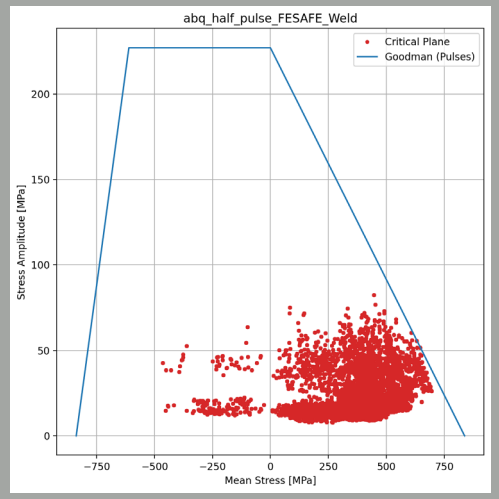
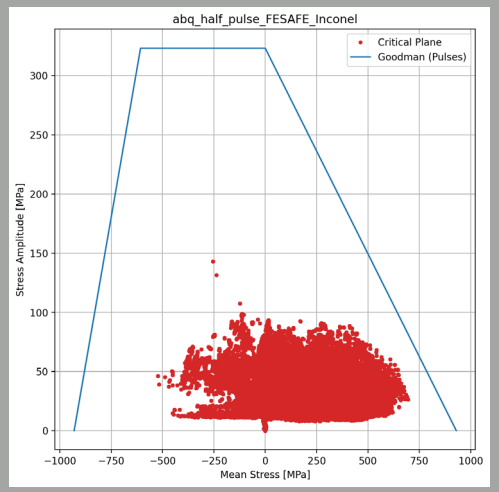
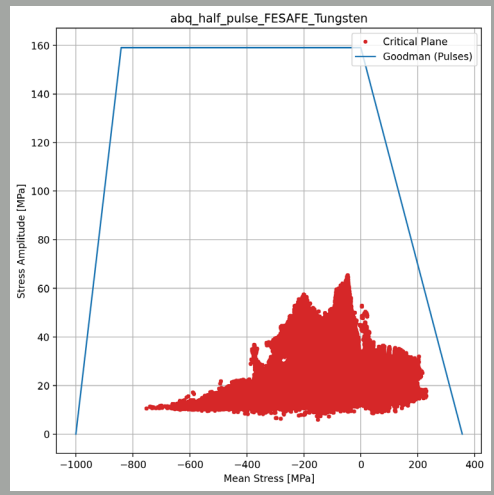
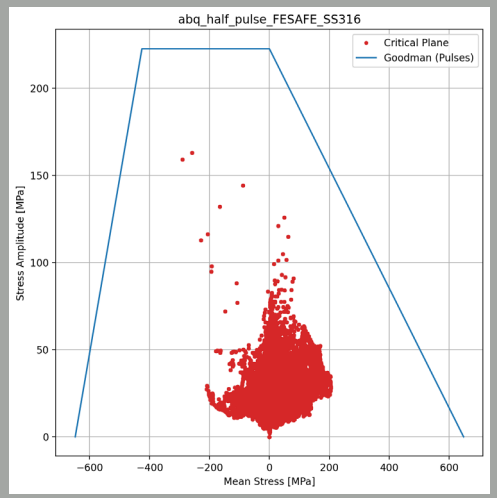
OAK RIDGE National Laboratory

Approach 1 - Water cooling adapter

- Water manifold installed for low flow associated with decay heat removal (<5gpm)
- Small diameter to permit bearing, motor, resolver, etc. to be removed
- Bolts to crown with same interface as valve manifold
- Quick disconnects to “unthread components”
- Reliable cooling, but not appropriate for all maintenance
- Can double as diagnostic device (individual circuit testing)

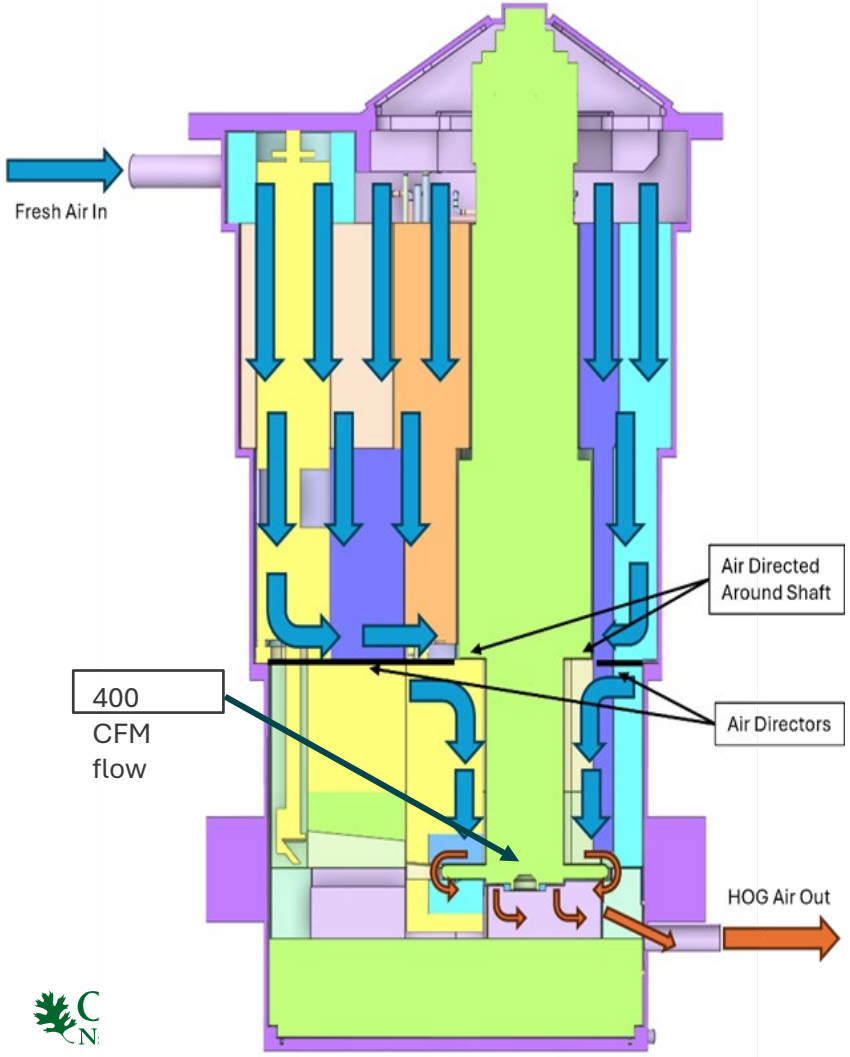


Approach 2 - Debonded fatigue results are acceptable (with cracked tungsten)

	Inconel Side Weld	Inconel 718 (SA)	Tungsten	SS316L
Debond				
Bonded				

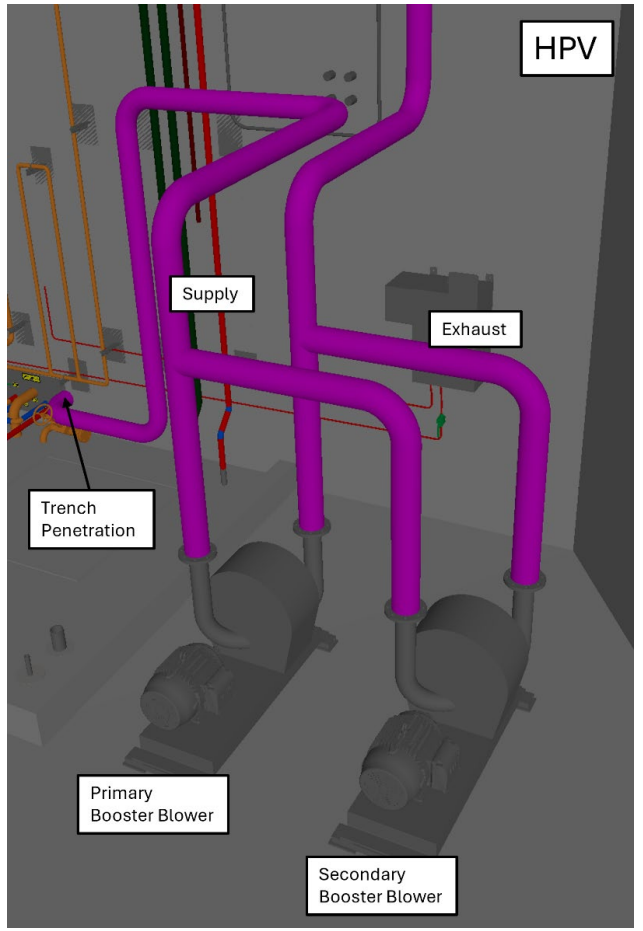
Approach 3 – Forced airflow over the target wheel

Air cooling of Target wheel is utilized during maintenance when water must be turned off to keep the Target at or below ~150C



- Suck air out the lower Core Vessel
- Draw air from upper Core Vessel
- Air baffled through CV shielding and routed around Target wheel
- Blower and backup located in HPV to increase pressure drop capability of HOG system

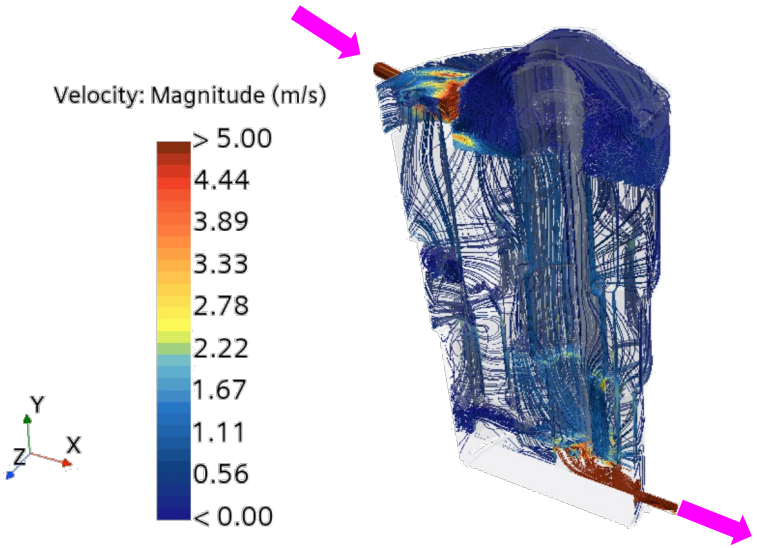
Added benefit of drawing air from lower CV in all hatch-open maintenance scenarios. Increases worker safety.

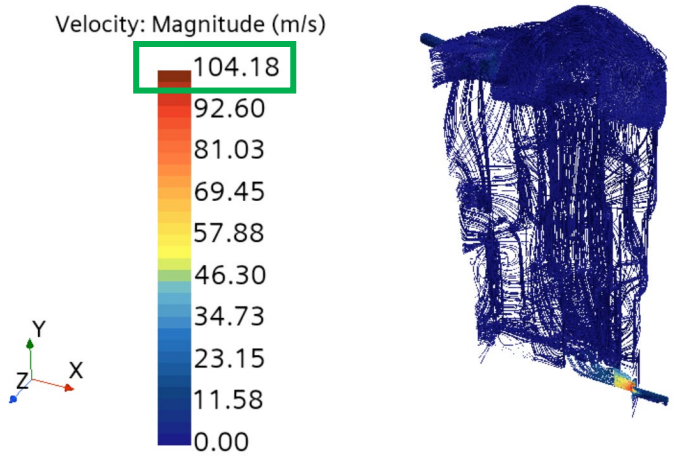


Forced Air Flow for Decay Heat Removal (8 hrs, 150W*20 Segments = 3 kW)

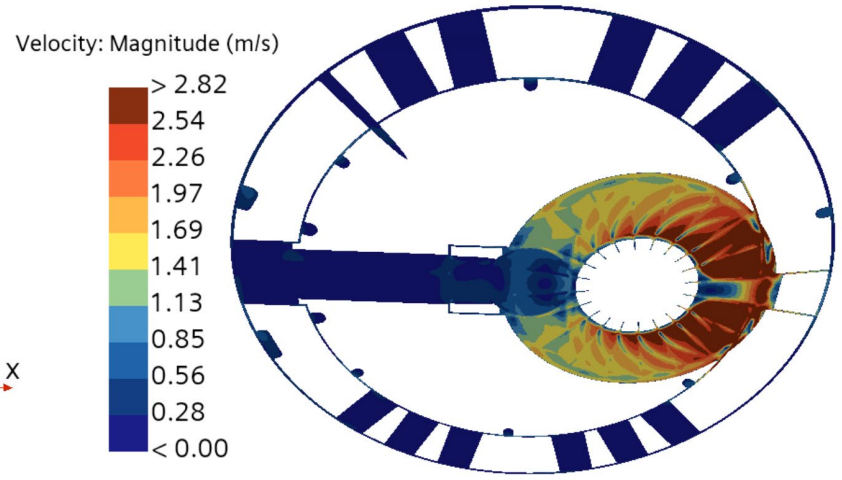
Air flow Rate = ~526 cfm , pressure drop = 1.0 psi

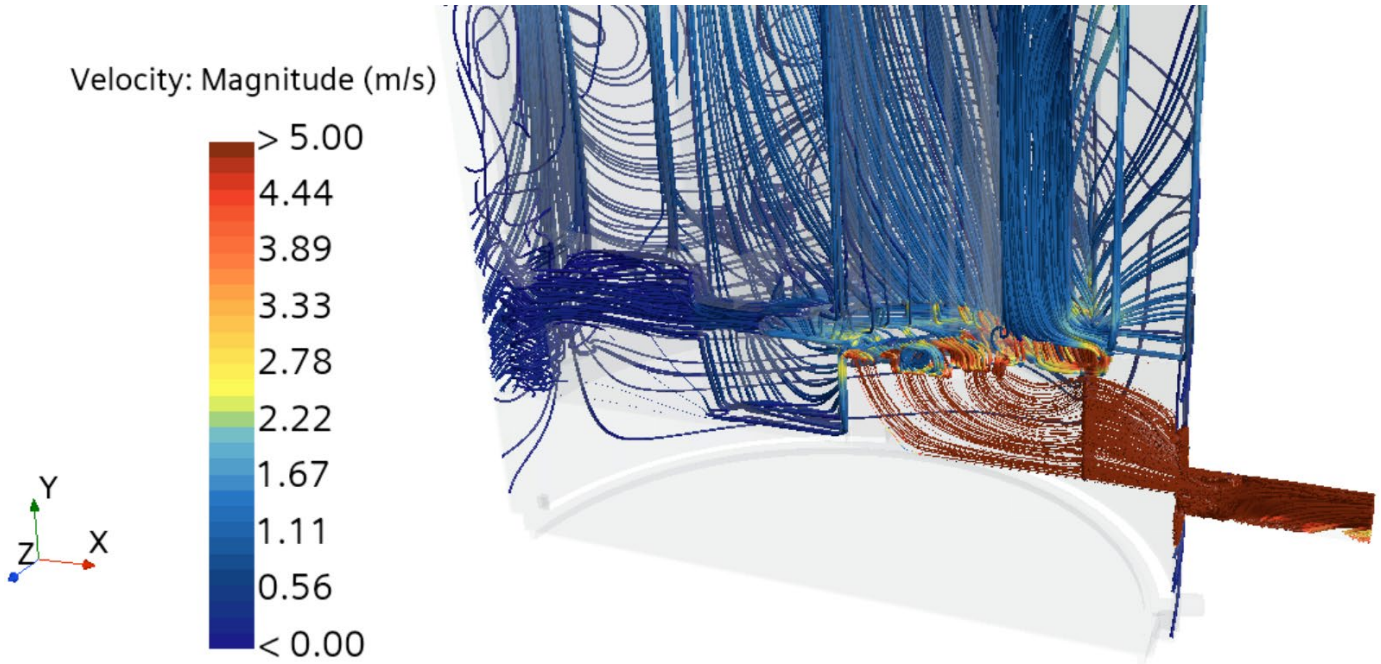
Geometry: 01/2026



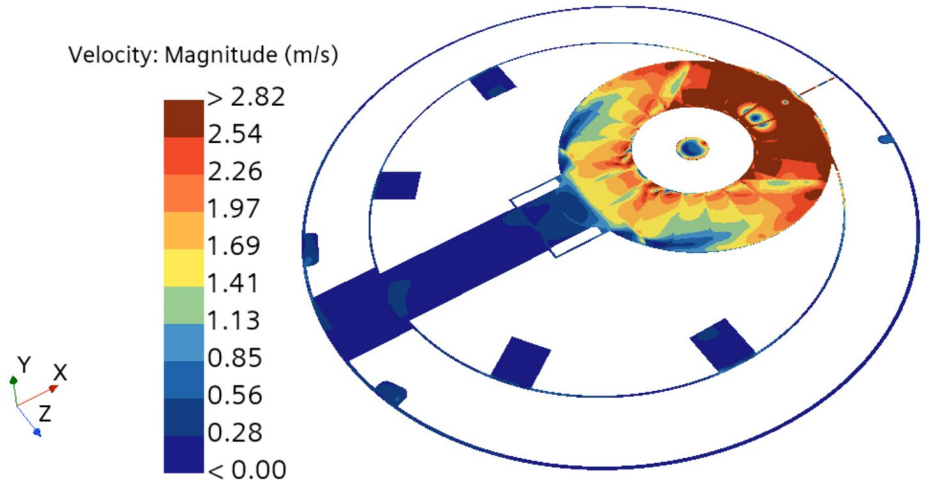


Velocity profile: Top of Target Segments





Velocity profile: Bottom of Target Segments



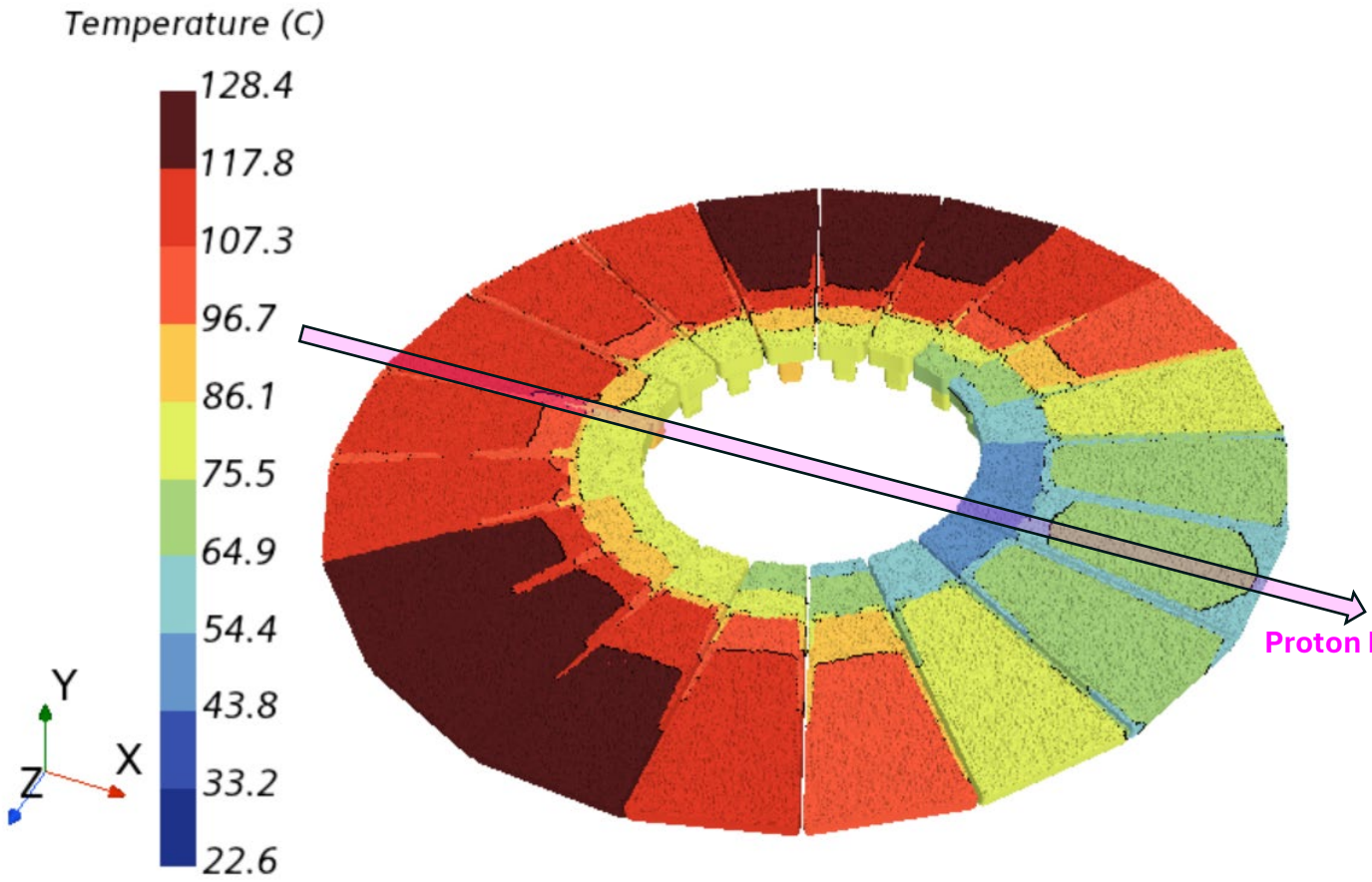
Credit: Min-Tsung Kao

Forced Air Flow for Decay Heat Removal (8 hrs, 150W*20 Segments = 3 kW)

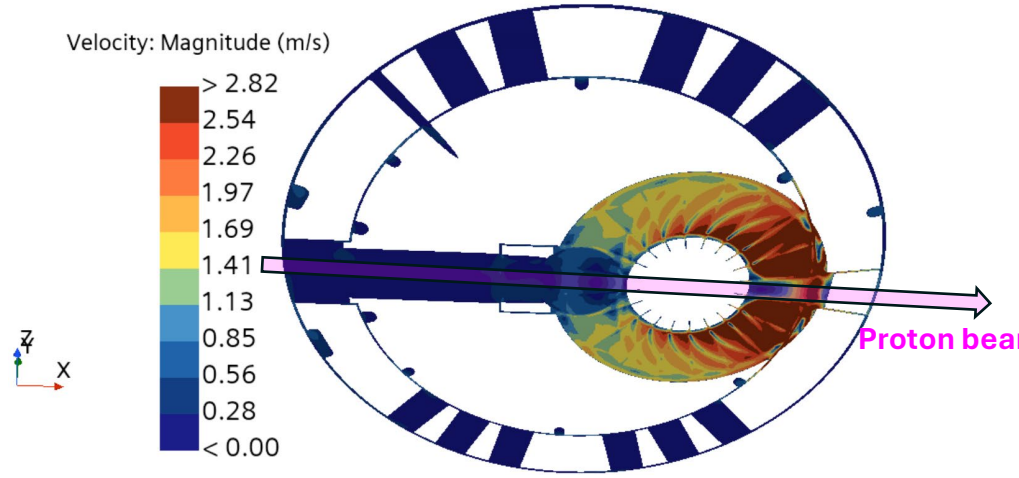
Air flow Rate = ~526 cfm , pressure drop = 1.0 psi

Geometry: 01/2026

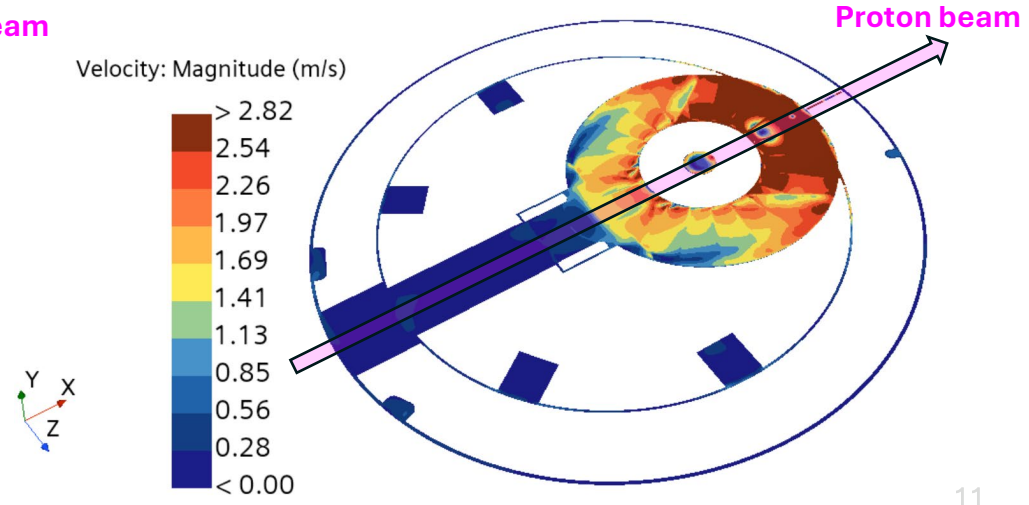
Preliminary Result, Not Fully Converged Yet



Velocity profile: Top of Target Segments



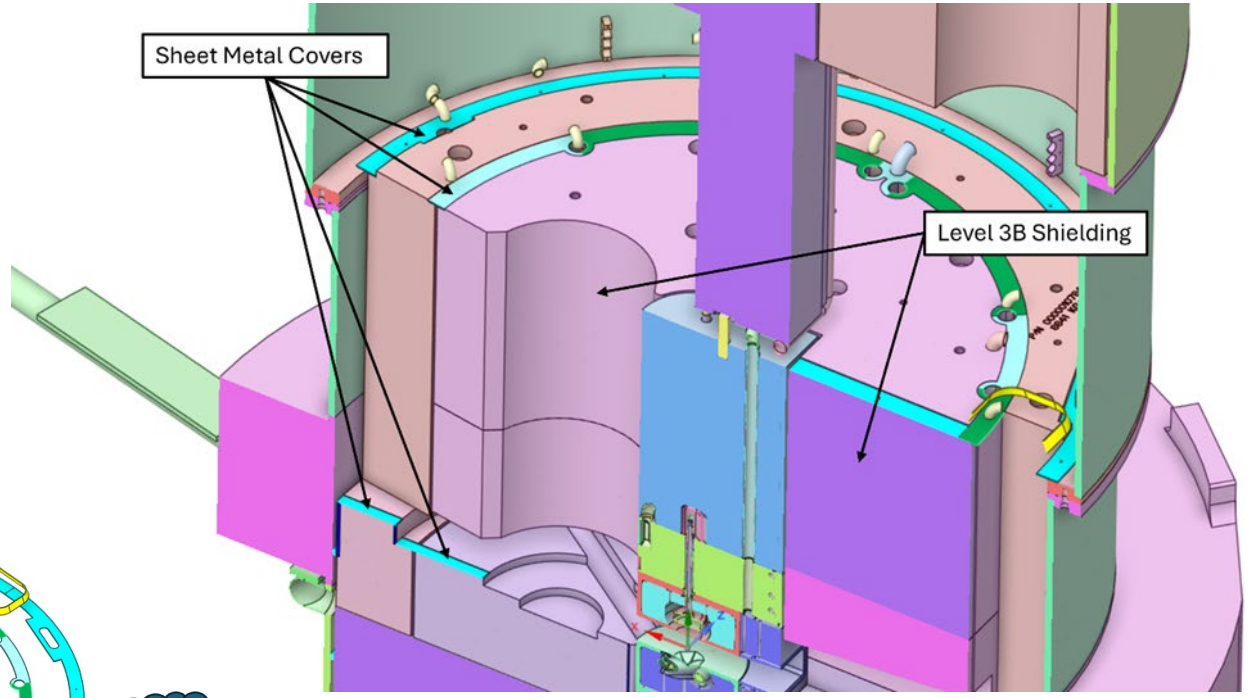
Velocity profile: Bottom of Target Segments

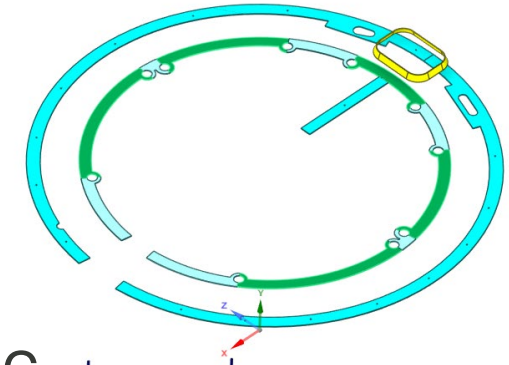


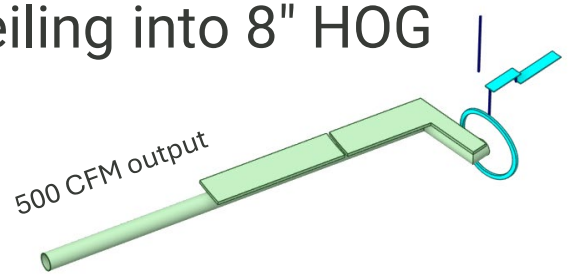
Credit: Min-Tsung Kao

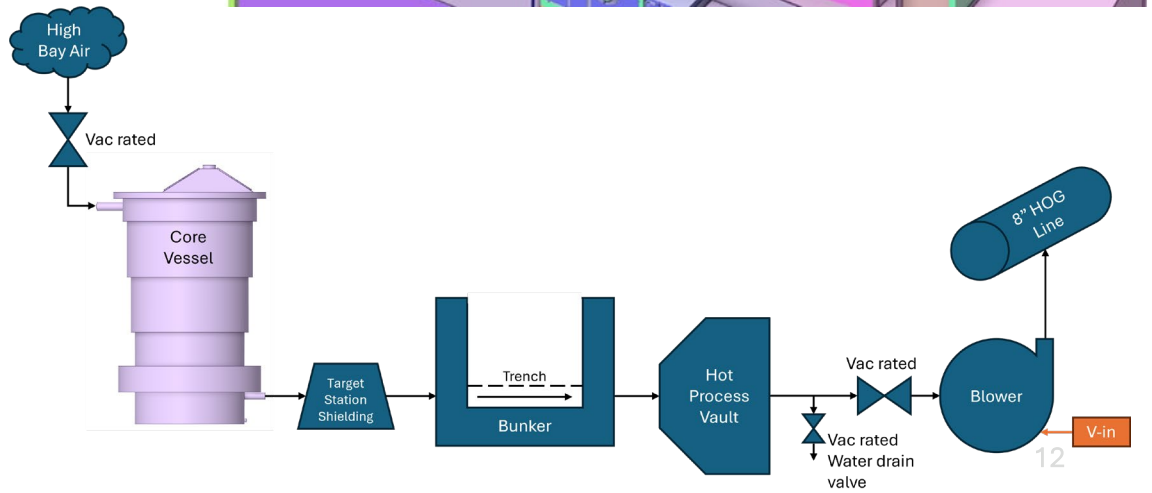
Hot Off Gas system has been modified to pass through the core vessel and around the target (was across top of CV)

- Fill select gaps in CV level 3B shielding
- Close gap between CV and shielding near exit.
- 6" duct pipe exit
- Pass through TSS & Monolith wall @ 15º
- Through trench in Bunker
- Into HPV
- Through booster blower(s)
- Up to HPV ceiling into 8" HOG line

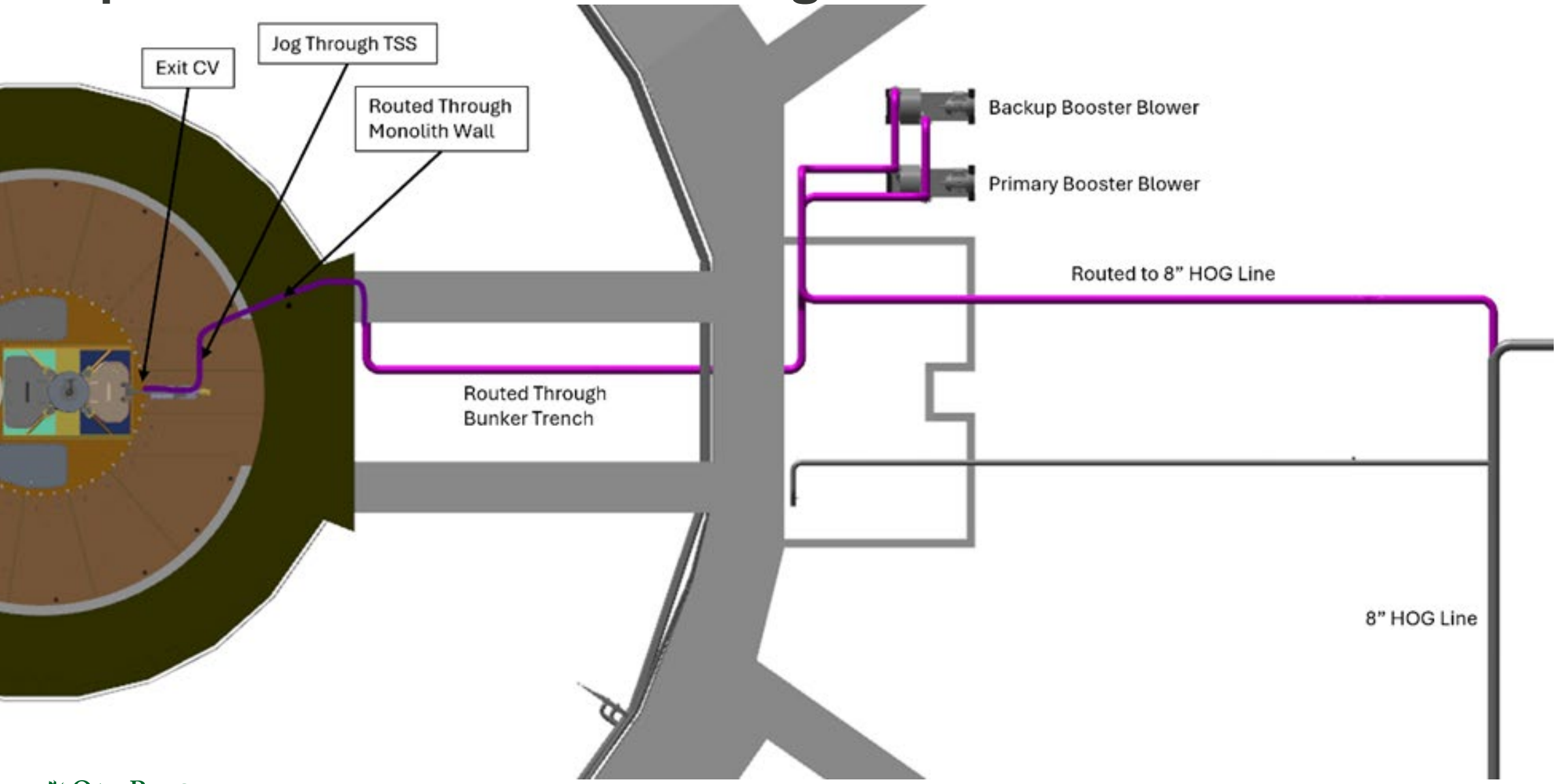




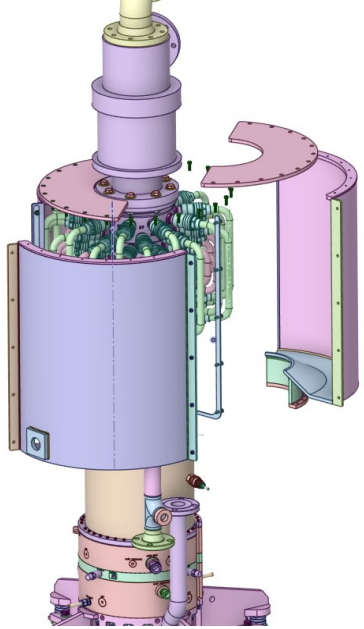




Top View – 6” Vent Line Routing from CV to 8” HOG Line



Examples of maintenance operations that require suspended cooling



S1: Motor Replacement

- Required every 6 years
- >2hr down-time windows
- Does not consider bolt stripping/breaking, mating face damage, etc.

S2: Water System Maintenance

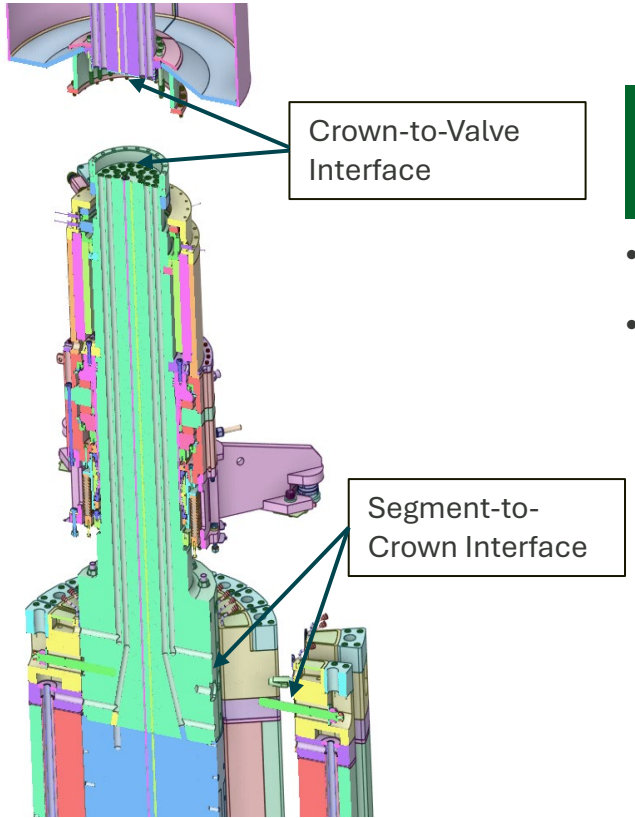
- Required periodically
- > 2hr down time

S3: Water Valve Leak

- Identified Failure scenario
- Do not turn off water
- > 8hr down-time without water

S4: Damage to Crown-to-Valve Interface or Segment-to- Crown Interface

- Identified Failure Scenario
- Crown-to-Valve interface: Only source of water to all segments
- Segment-to-Crown interface: Only source of water to a single segment
- Marring a face: likely >2hr down-time to repair



S5: Unknown failures or outages

- Unidentified Failure Scenarios
- Details unknown, but likelihood high over life of facility

Possible result: replacing individual segment, or all 20 segments

Implications of Maintenance with and without Air Cooling

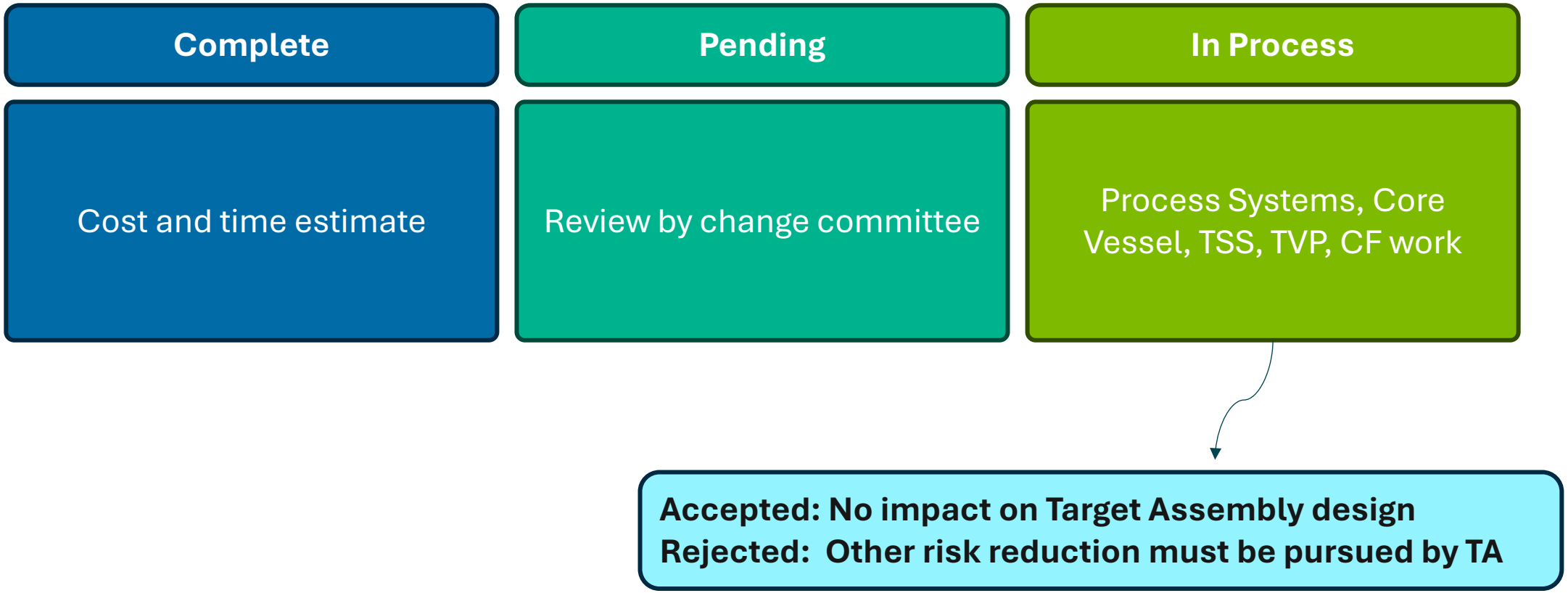
	Without Air Cooling	With Air Cooling
Manifold leak (In TDR)	Allow radioactive water to leak for >>> 2 weeks while target decay falls below an acceptable level, turn off water, make repair Damage	No Damage Turn off water immediately, waiting 8 hr for TDR to be safe to enter, make repair
Water System Maintenance	Allow target foot to cool down with water, without beam for >>> 2 weeks, Turn off water for maintenance Damage	Turn off water immediately, perform maintenance No Damage
Damage to seal interface between Crown and Manifold, or between Crown and Segment	Keep water off (already off for maintenance) and work as quickly as possible, Damage Likely damage internal bonding of 20 segments, Cost $10 - $15 million & time to MFG targets	No Damage Continue air cooling and make seal face repair
Unknown/Unforseen events	Water off for longer than 2hr time, Damage Likely damage internal bonding of 20 segments, Cost $10 - $15 million & time to MFG targets	Continue air cooling and make repair or restart system No Damage

Maintenance Air Cooling Specs

- Provide external air-cooling during maintenance; 400 CFM across target
- Booster blowers in HOG system to accommodate pressure drop in CV
- Impacts:
  - CF
  - CV
  - TSS
  - Bunker
  - Process Systems
  - Controls
  - TVP
  - Remote Handling
  - Neutronics
  - ESH&Q
- Coordination provided by Target Assembly

- Calculated to be a >1 PSI pressure drop through the Core Vessel
- Current HOG system provides 1.07 PSI of pressure drop capability
- Booster blower increases the pressure drop capability
- Sit north of beamline in HPV along Bunker wall
- Vacuum valve between CV and blowers
- Water drain between CV and vacuum valve
- Blowers on backup diesel UPS to maintain operation in event of a power failure

Status of Change Process



Solutions Considered, but Rejected

Flood Lower Core Vessel

- Damage luminescent coating on Target Segment nose
- Corrosion risk for beam port windows
- Large amount of irradiated water to dispose of

Blow Pressurized Air Directly on Target

- Major Vessel Systems shielding design impact to implement
- Still need to exhaust air
- Risk of over-pressurizing Core Vessel

Release Liquid Nitrogen Below Target

- Risk of over-pressurizing core Vessel
- Nitrogen rich environment when CV covers removed
- Unknown thermal shock risk to Target Segments

Suck Air from Lower CV without Baffling

- Path around outer edge of CV is path of least resistance, starving Target of air

Further analysis discussed in following presentation

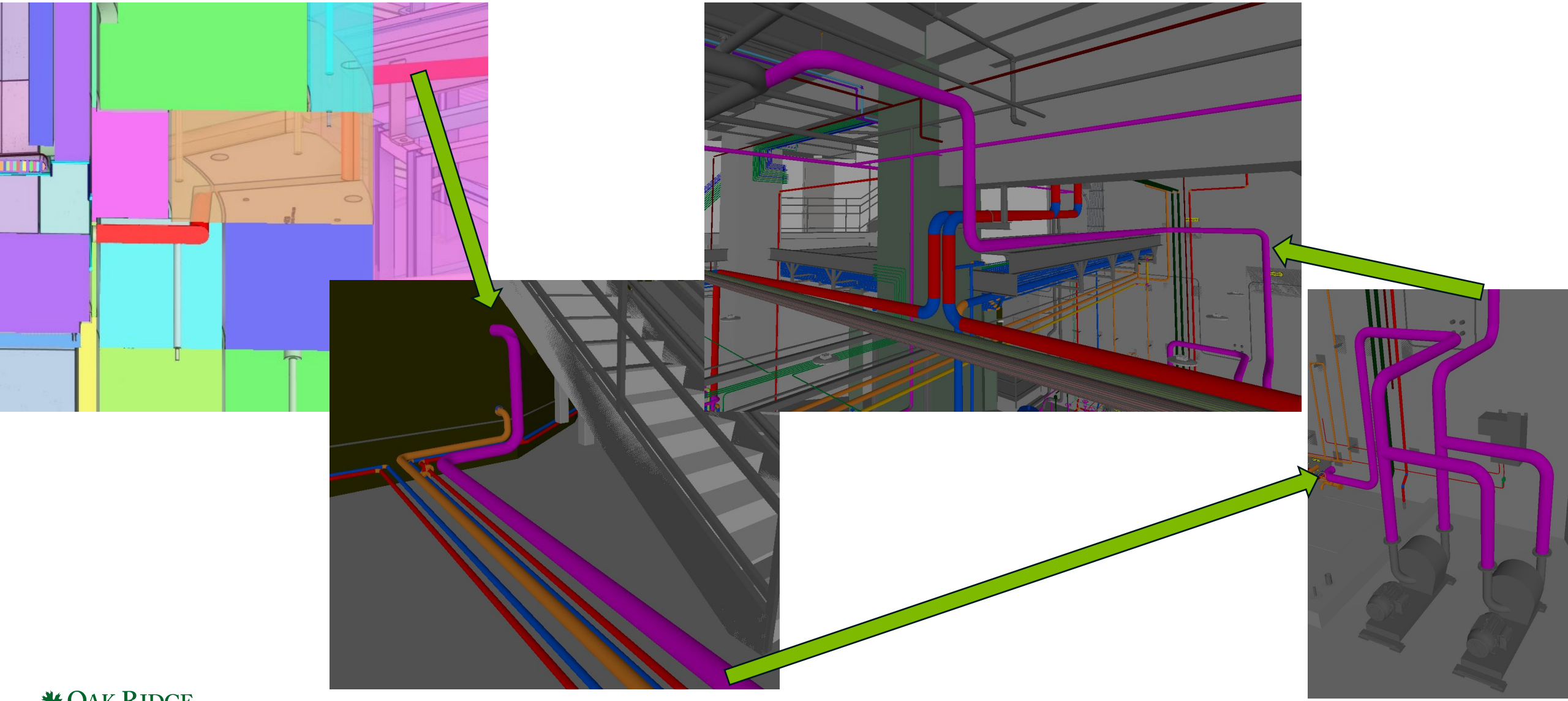
OAK RIDGE National Laboratory

U.S. DEPARTMENT of ENERGY

ORNL IS MANAGED BY UT-BATTELLE LLC
FOR THE US DEPARTMENT OF ENERGY

Backup Slides

6” Vent Line Routing from CV to 8” HOG Line



Impact per Group

System	Impact
Vessel Systems	Integration of air blocking components in CV
Target Station Shielding	Routing of exhaust pipe through Shielding
Acceleration Interface Components – TVP	Air-blocking skirt below lower shielding
Process Systems	Routing HOG pipe through booster blowers to 8" HPV HOG pipe
Bunker	Additional trench width and routing of 6" exhaust line from Monolith wall to HPV wall
Controls	Remote control of valves and blowers
CF	Routing of exhaust pipe through Monolith wall
	Widening Bunker trench
	Widening penetration from Bunker to HPV
	Tie in 6” exhaust line to 8" HOG line in HPV
	Provide electrical drop in HPV for 2 blowers (size TBD)
Neutronics	Analysis of exhaust pipe routing impact
ESH&Q	Verification of safety cases
Remote Handling	Maintenance/Remote Handling Verification
Target Assembly	Coordinating