PM-HIP and Electron Beam Welding Development for Nuclear Applications

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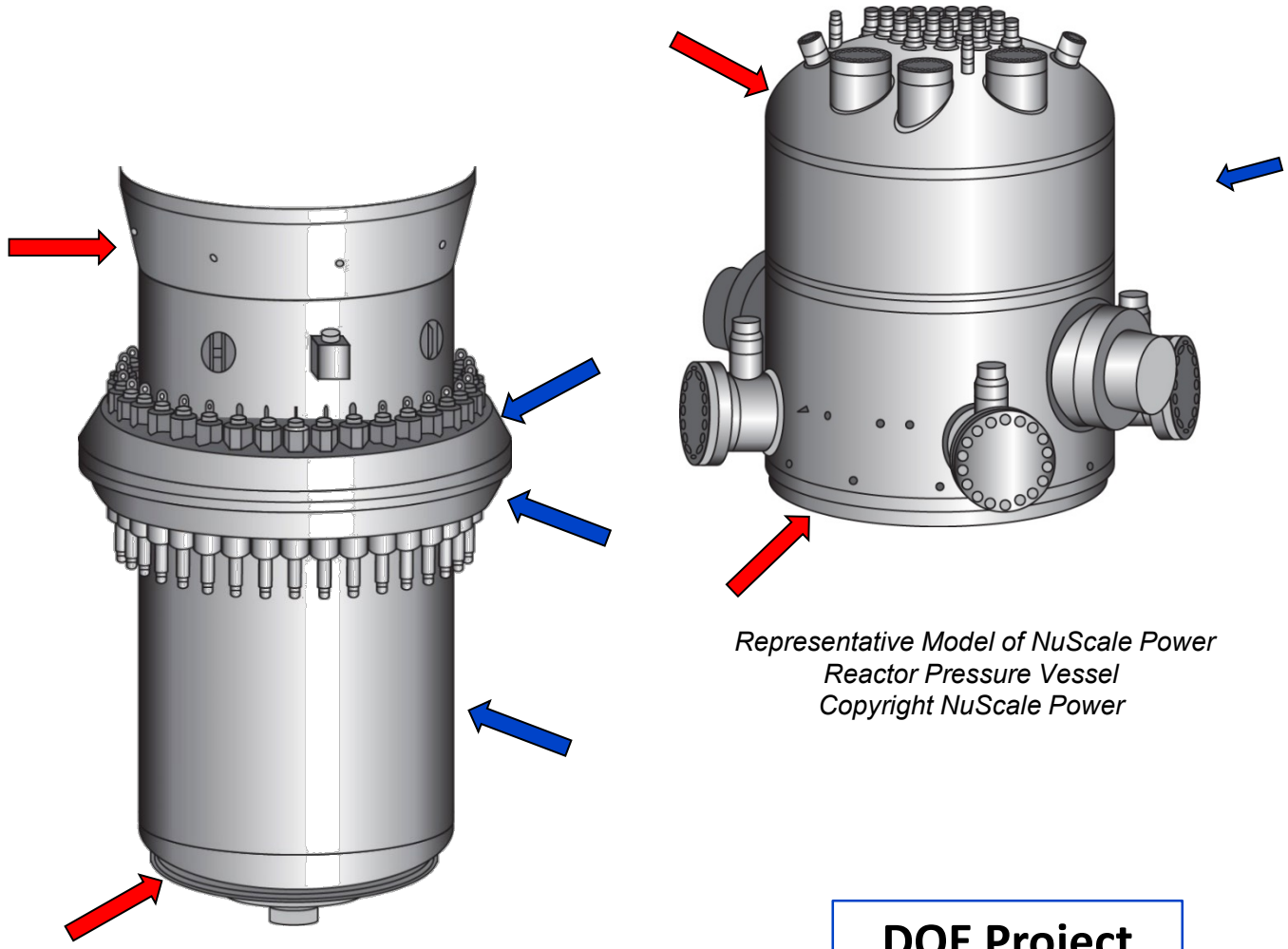
Overview

- Background
- Advanced Manufacturing/Fabrication Technologies
  - DOE Projects: **DE-NE0008629 and DE-NE0008846**
- Powder Metallurgy-Hot Isostatic Pressing
- Electron Beam Welding Development
- Modular In-Chamber Electron Beam Welding
- Summary

Objectives – SMR Advanced Manufacturing Project

- Rapidly accelerate the deployment of SMRs
- Develop/Demonstrate new methods for manufacture / fabrication of a RPV in **< 12 months**
- Eliminate 40% from the cost of an SMR RPV, while significantly reducing the schedule
- Primary Advanced Methods:
  - PM-HIP
  - Electron Beam Welding
  - Diode Laser Cladding



Representative Model of NuScale Power Reactor Pressure Vessel
Copyright NuScale Power

EPRI ELECTRIC POWER RESEARCH INSTITUTE

U.S. DEPARTMENT OF ENERGY

NUCLEAR AMRC

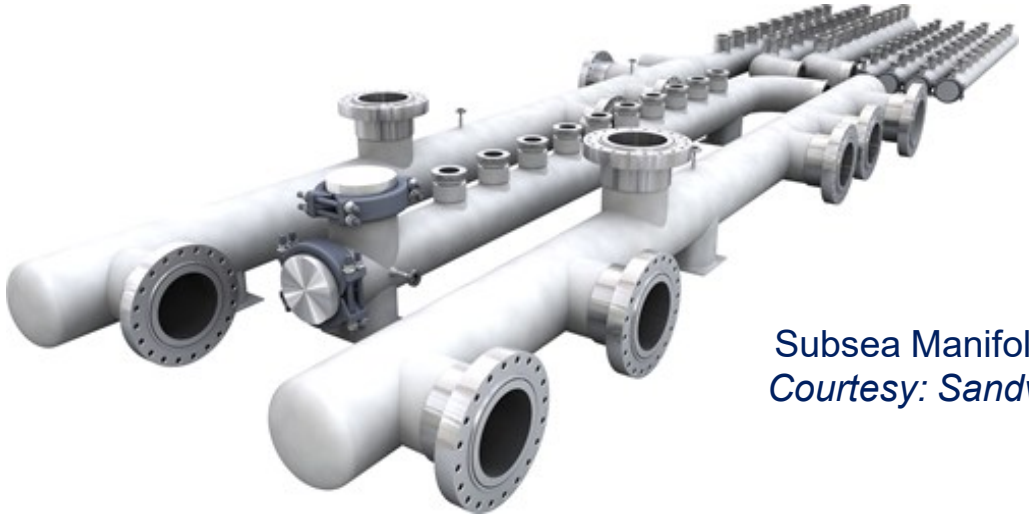
NUSCALE Power for all humankind

DOE Project DE-NE0008629

Powder Metallurgy-Hot Isostatic Pressing

Why PM-HIP?

- Near-net shaped components
- Homogenous microstructure
  - Ease of inspection!
- Elimination of welds
- 4-6 months lead times typical
- Ideal for multiple penetration applications (RPV or CNV head) vs expensive forgings

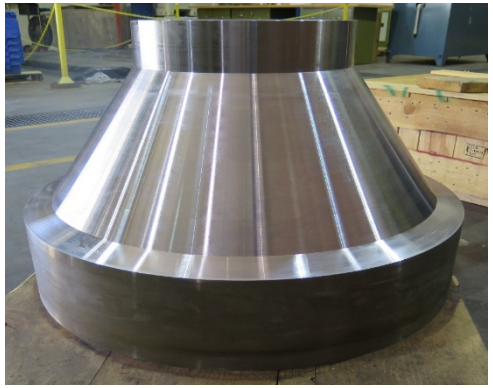


Subsea Manifold.
Courtesy: Sandvik

40” diameter HIP Vessel
Courtesy: Isostatic Forge International

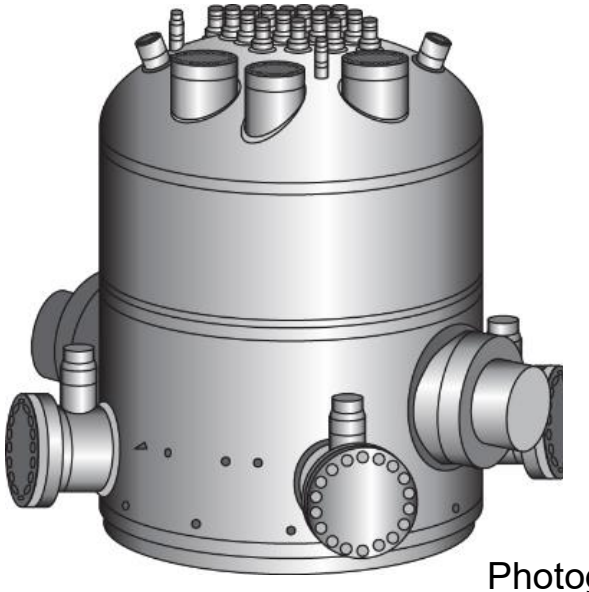
Large Bore Valve
(courtesy Roll-Royce)

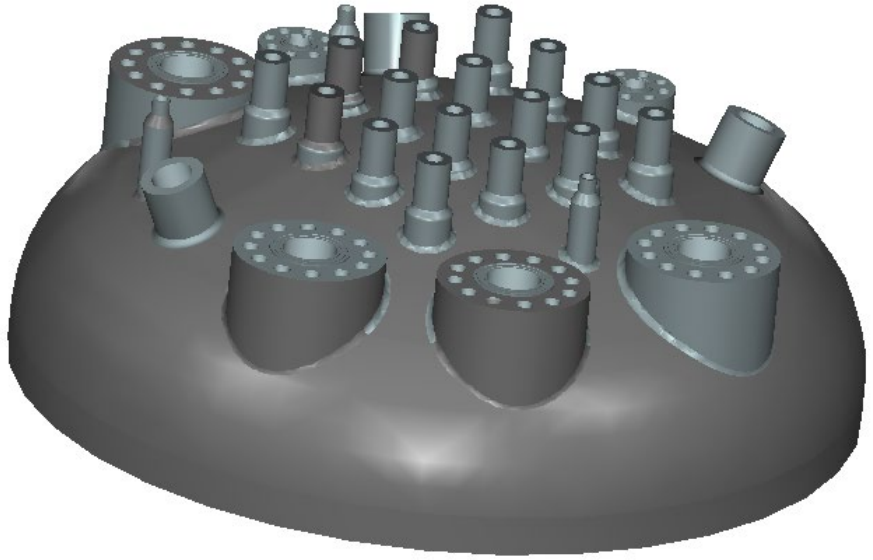
NNS Reactor Coolant Pump Impeller (courtesy Framatome and Albert & Duval)



3600lb BWR Nozzle

Small Modular Reactor Upper Head--Example



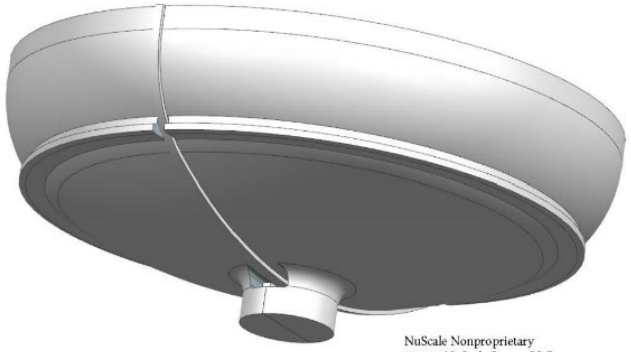


Photographs courtesy of EPRI and NuScale Power

- ~44% scale
- Single monolithic structure
- A508 Class 1, Grade 3
- 27 penetrations
- 1650kg (3650lbs); 1270mm (50 inches) diameter
- Next, 2/3-scale head
- Need larger HIP Vessel -- ATLAS

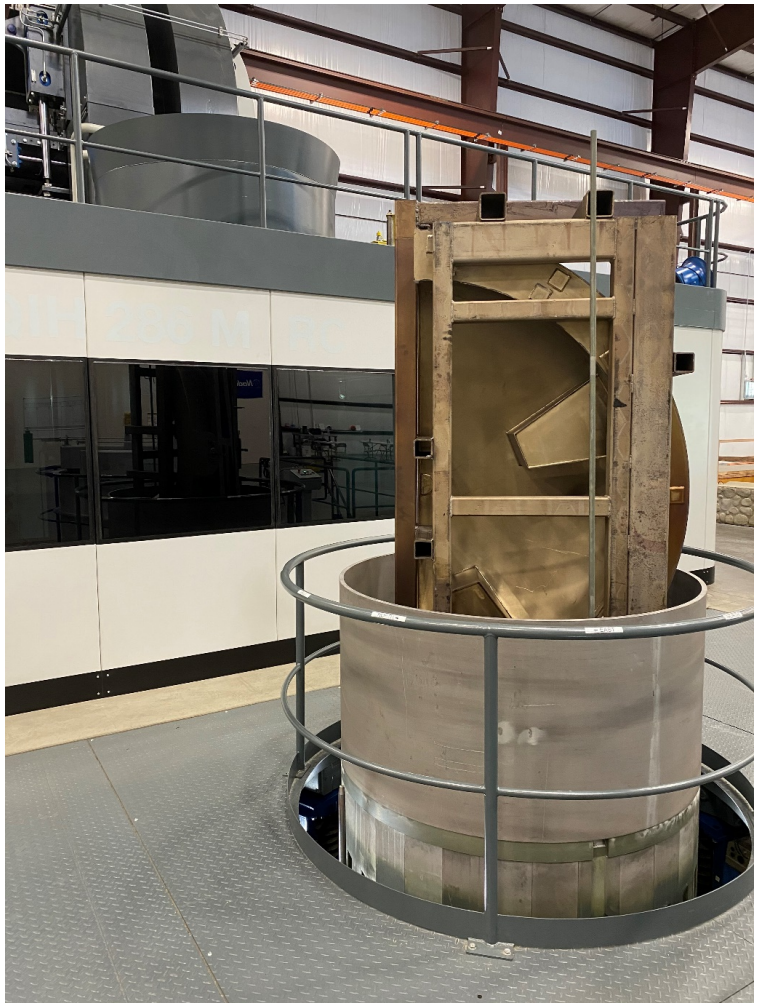
DOE Project: DE-NE0008629

One-Half Lower Head Capsule in Frame for HIP'ing



70-inches in diameter, ~6300lbs each

Capsule & Frame are inserted into HIP; Lower Head after HIP



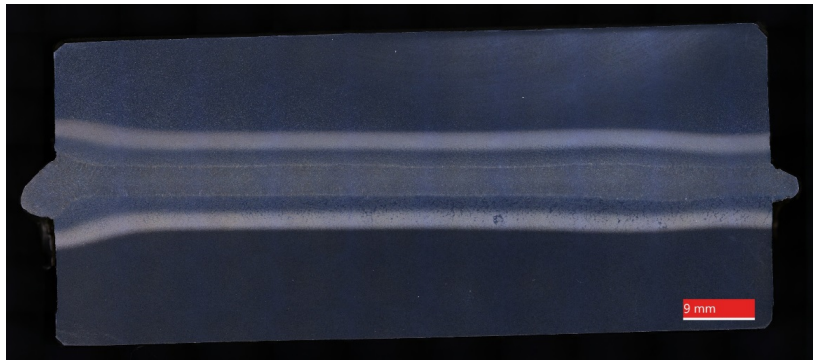
Electron Beam (EB) Welding

Why EBW?

- One-pass welding!
- No filler metal required.
- EBW can produce welds w/ minimal HAZ
- Nuclear-AMRC, TWI, Rolls-Royce & EPRI have demonstrated in-chamber and/or local vacuum on thick section alloys
  - Enables field/shop welding!
- RPV girth welds (110mm thick) in <60 min

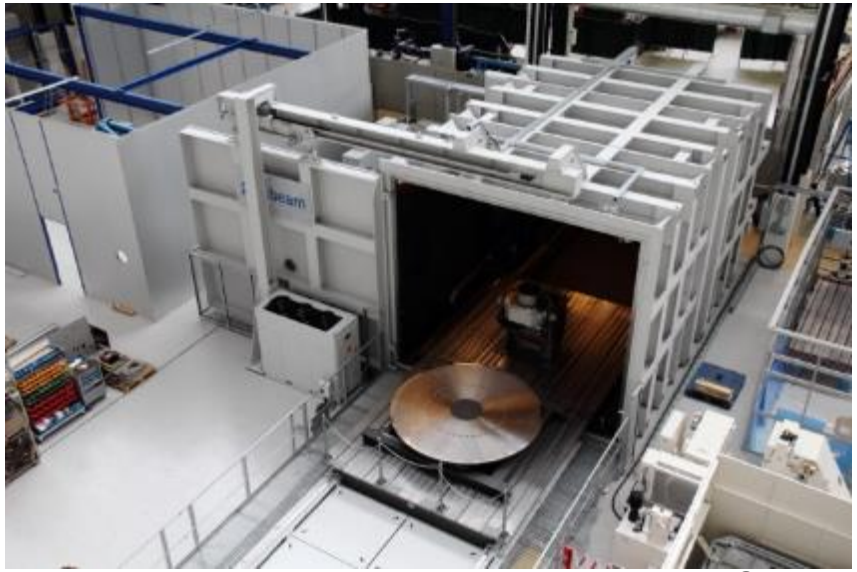
Inspection, Costs?

- Huge savings in welding costs (up to 90%)
- Potential to eliminate in-service inspection coupled with heat treatment!



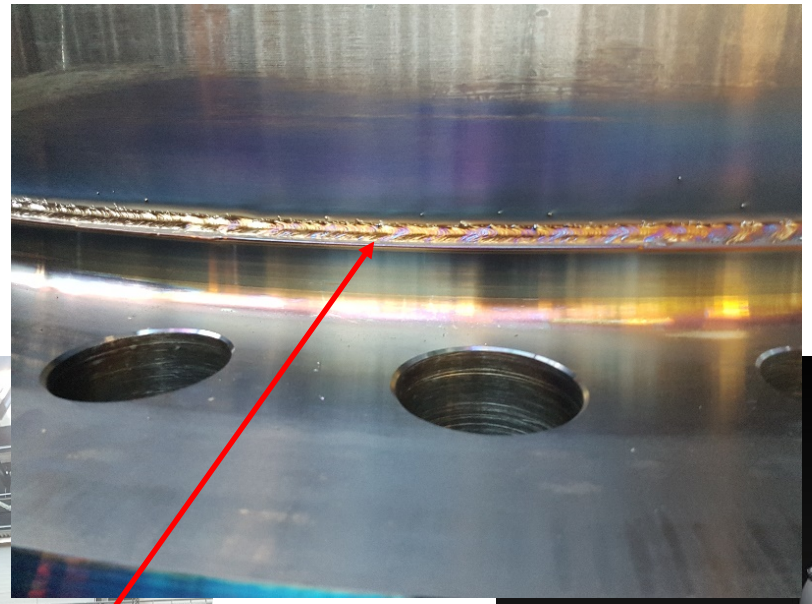
110mm (thick) EB Weld

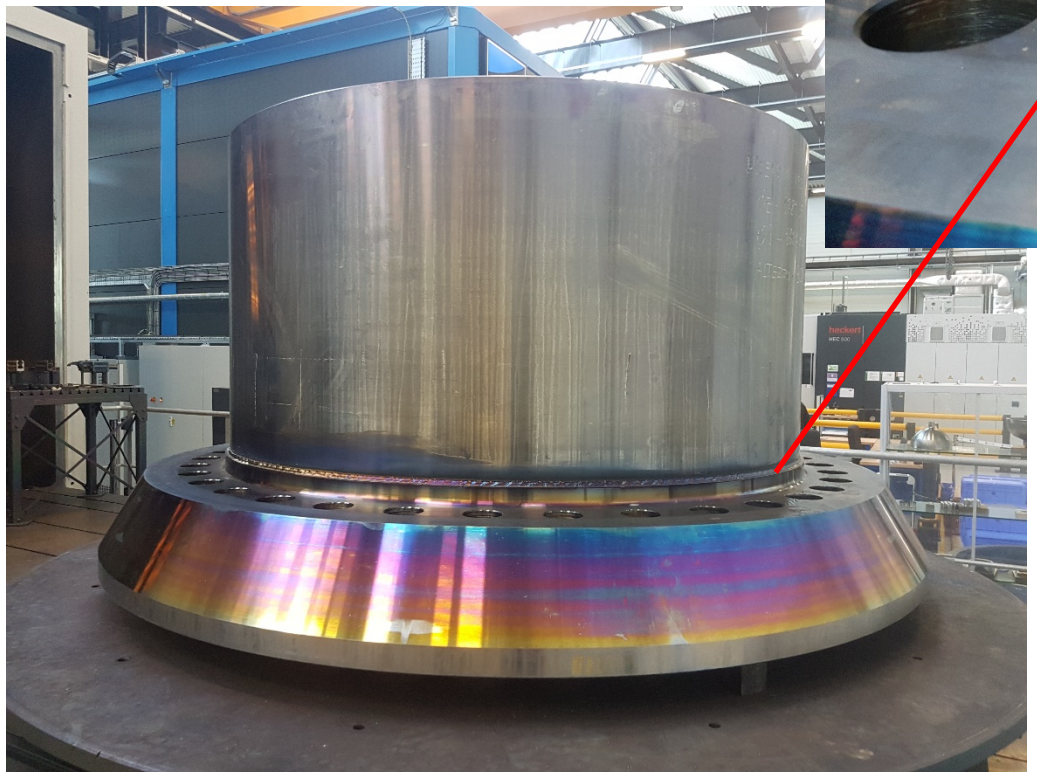
Photograph provided courtesy: Nuclear AMRC (UK)



Photograph provided courtesy: Nuclear AMRC (UK)

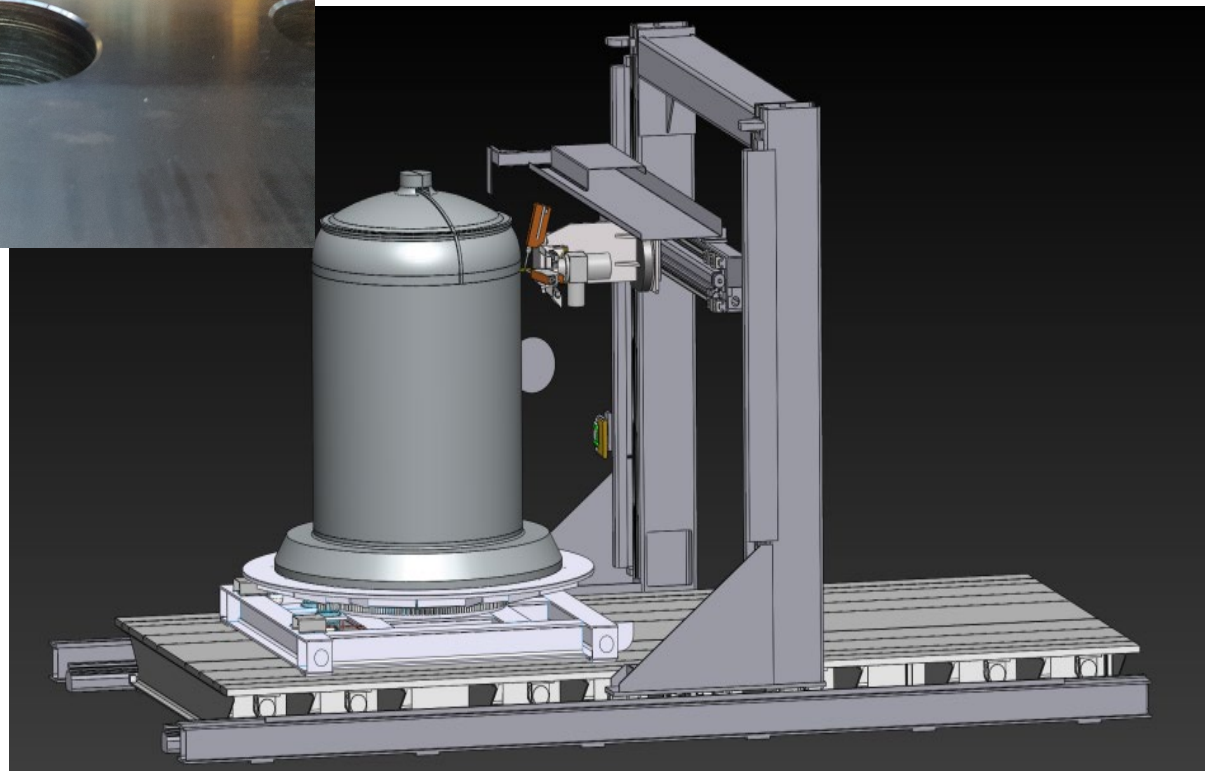
Electron Beam Welding





Lower Flange Shell Mockup EB Weld -- ~6 ft (1.82m) diameter (Note, mockup is upside down)

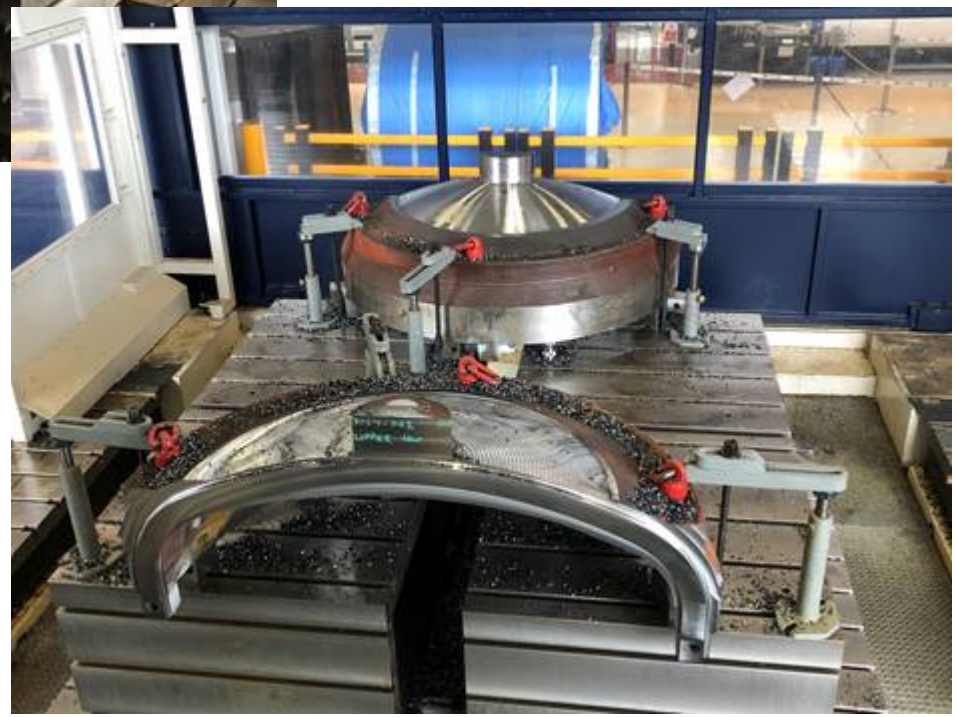
Completed in 47 minutes



Lower head to Lower Flange Shell (again, upside down)

One-half lower head—Article 4.

Each One-half Lower Reactor Head ~6500lbs (2950 kg) x 70 inches @ 2/3rds scale



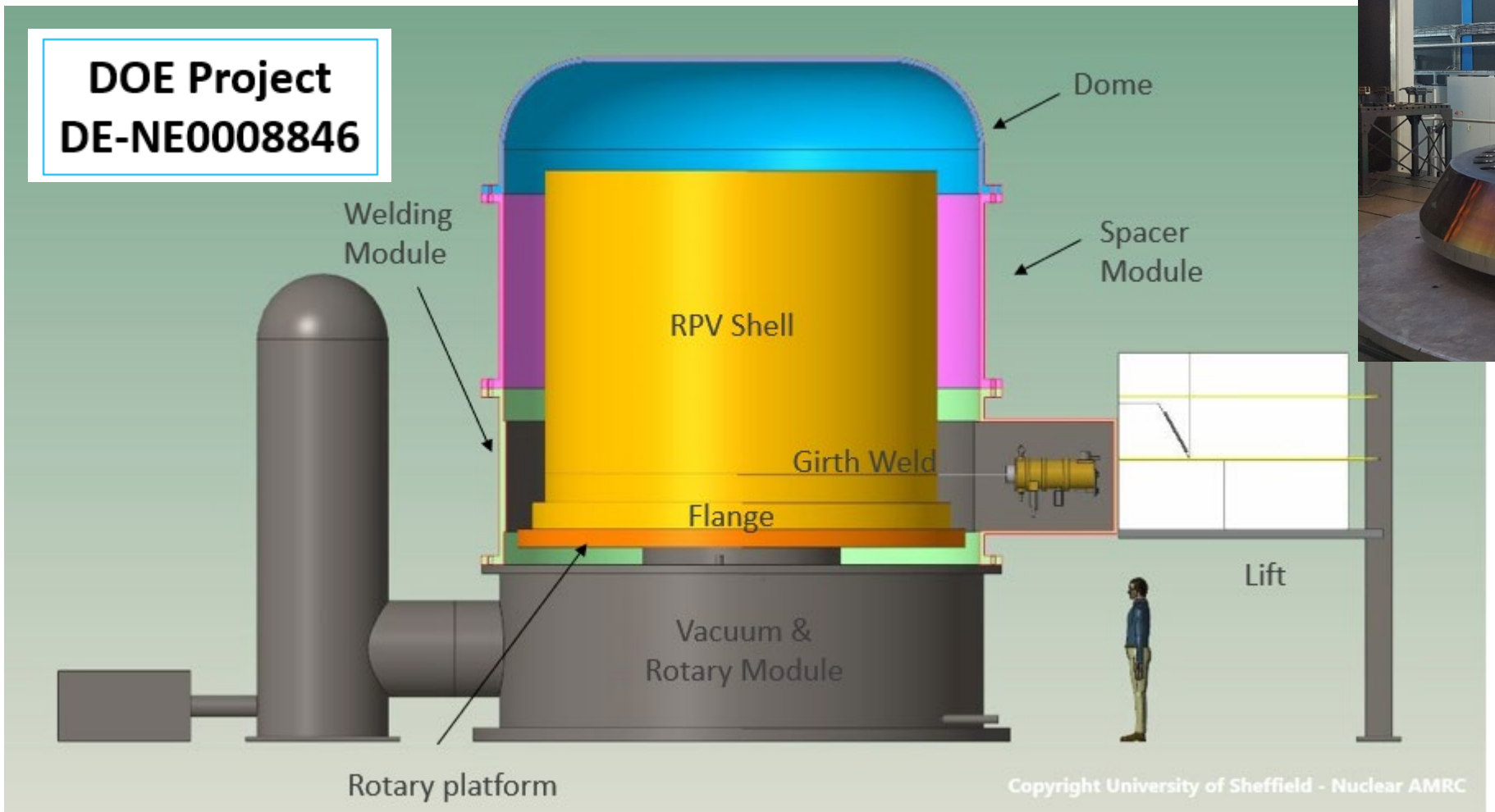
Articles 2 and 3 – EB Welding Complete

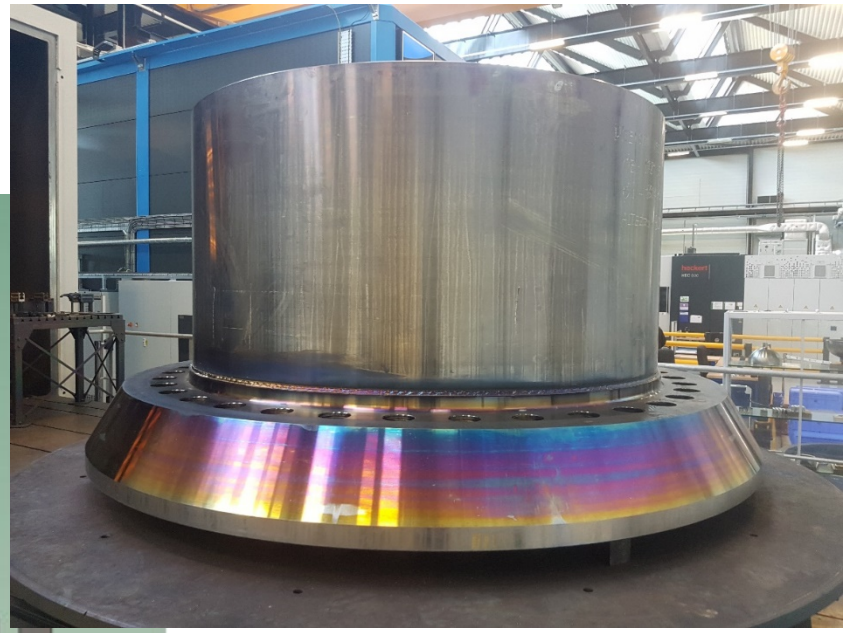
Lower Head Halves – Weld Prep for EBW

NUCLEAR AMRC

Modular In-Chamber Electron Beam Welding

RPV Shell and Flange Shown Inside of Modular EBW Chamber (in gold)

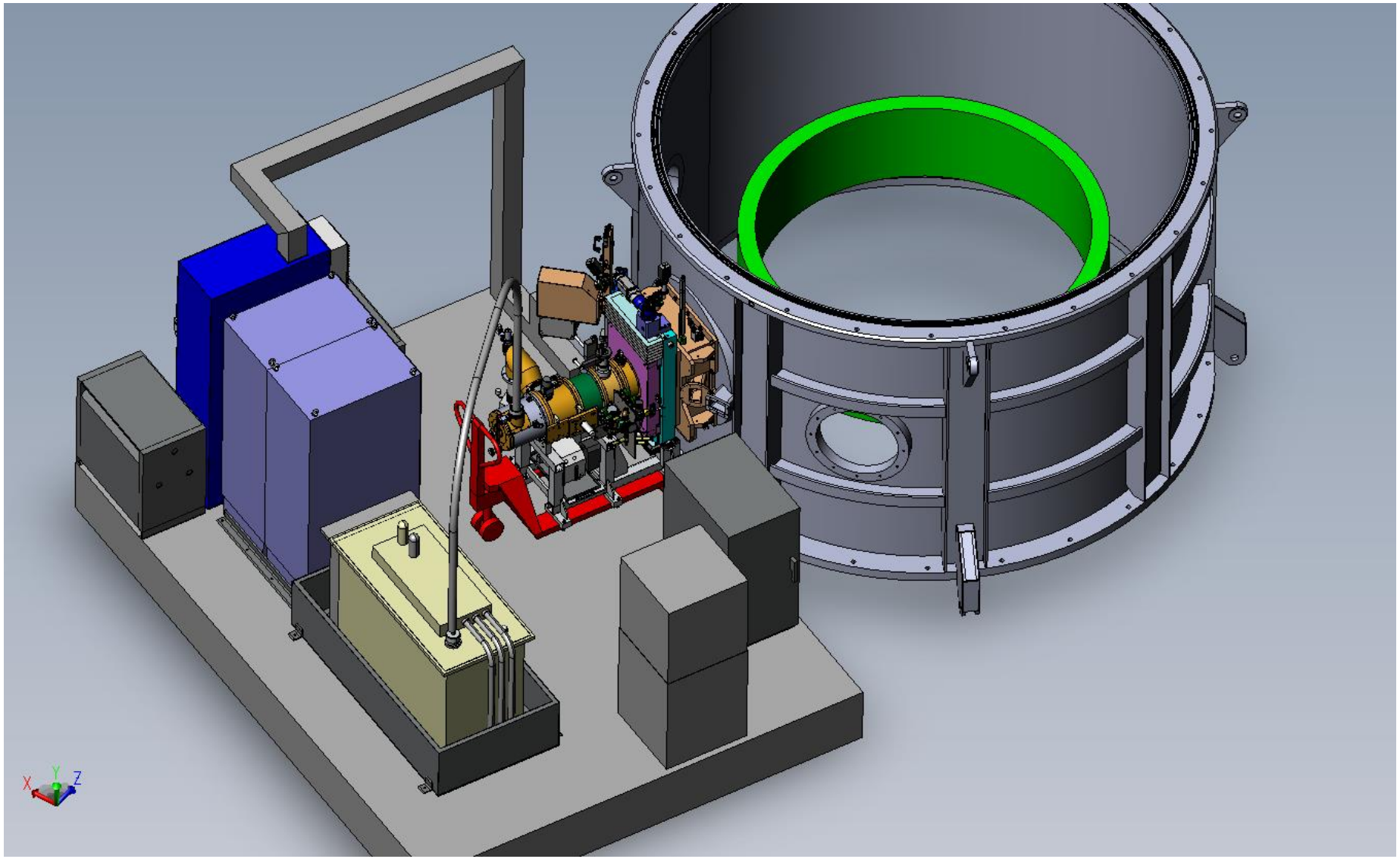




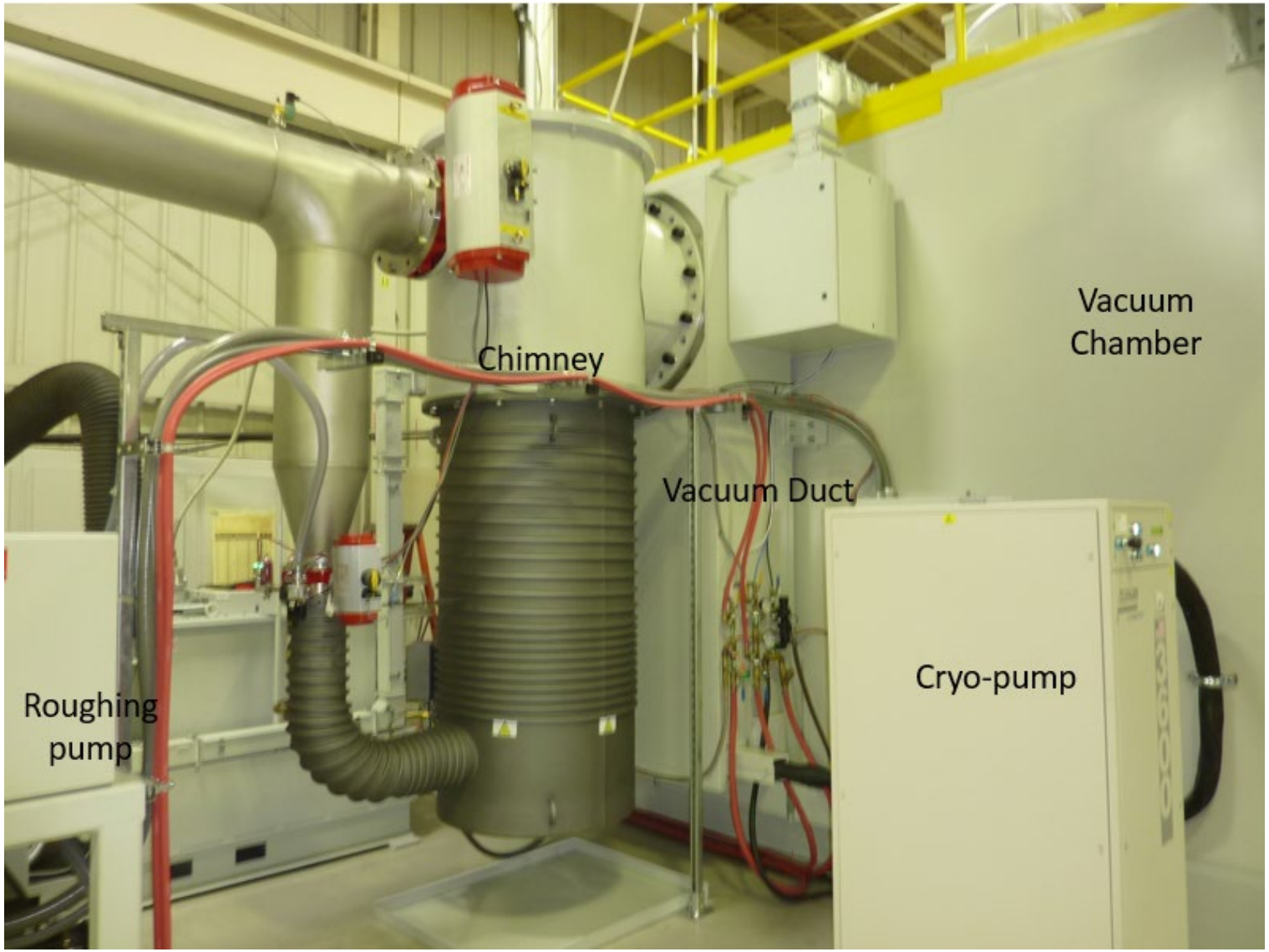
Lower Flange Shell Mockup EB Weld -- ~6 ft (1.82m) diameter (Note, mockup is upside down)

Completed in 47 minutes

Platform & System Layout

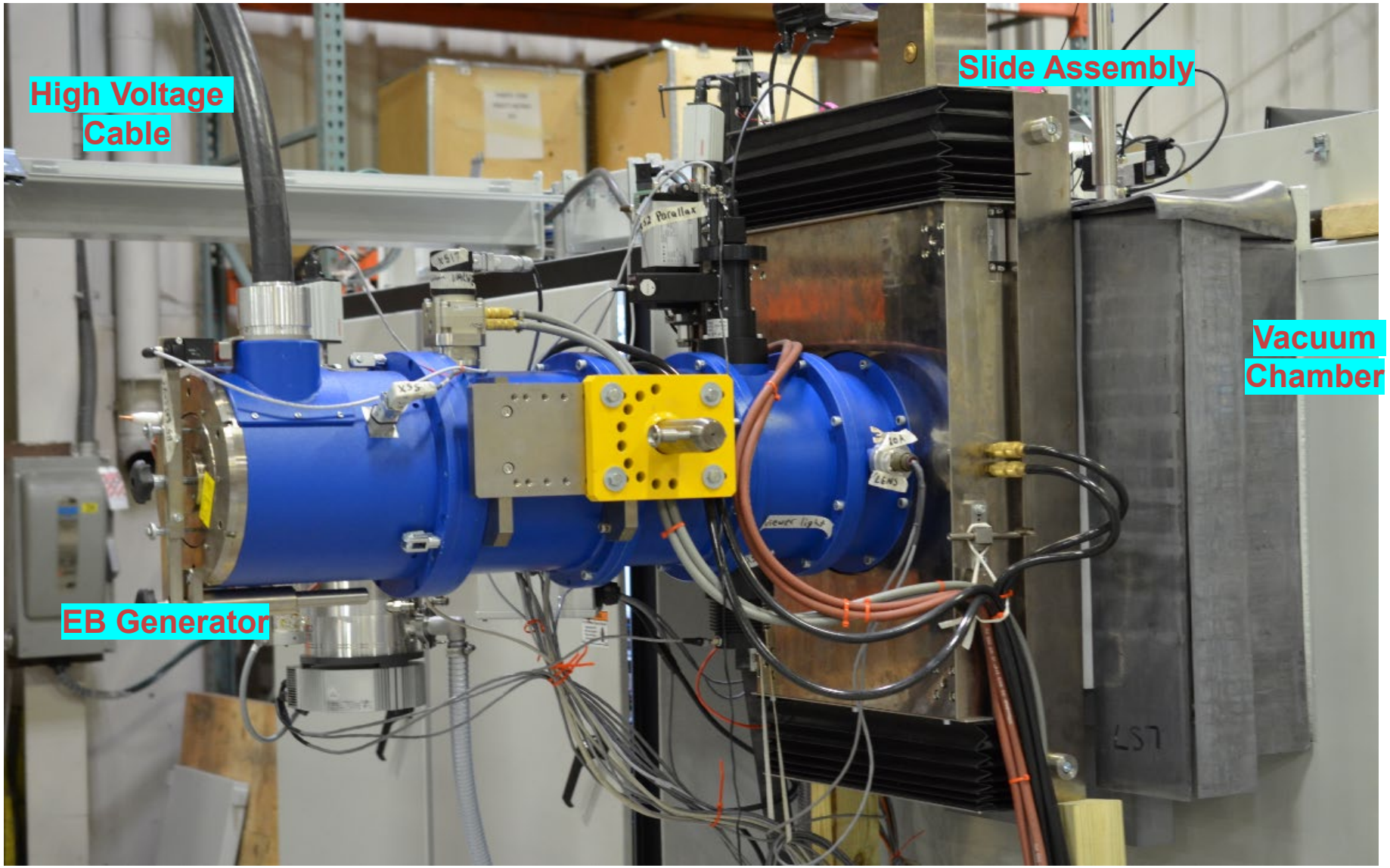


Mechanical pump package

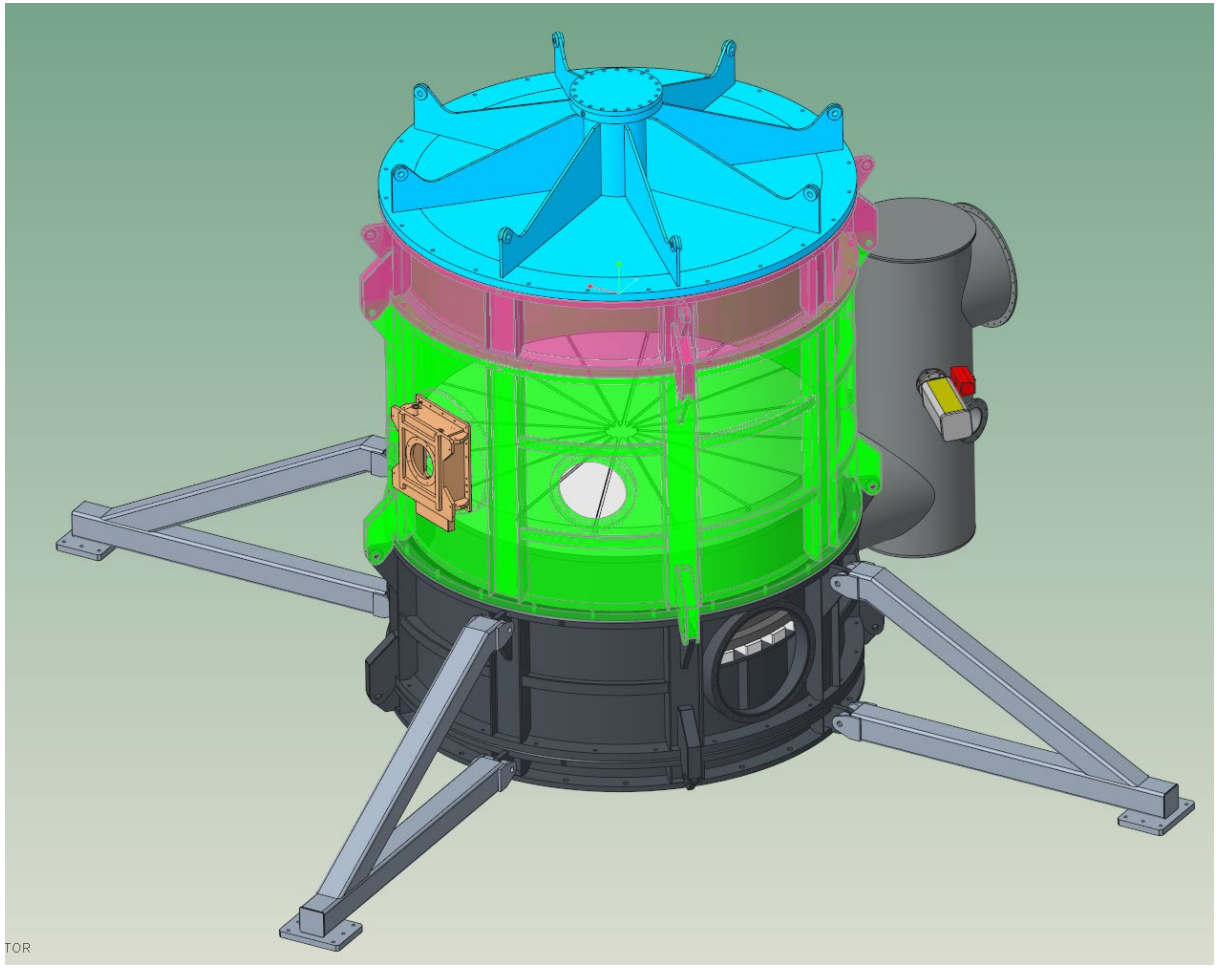


Assembly of the EB welding equipment for the MIC-EBW system

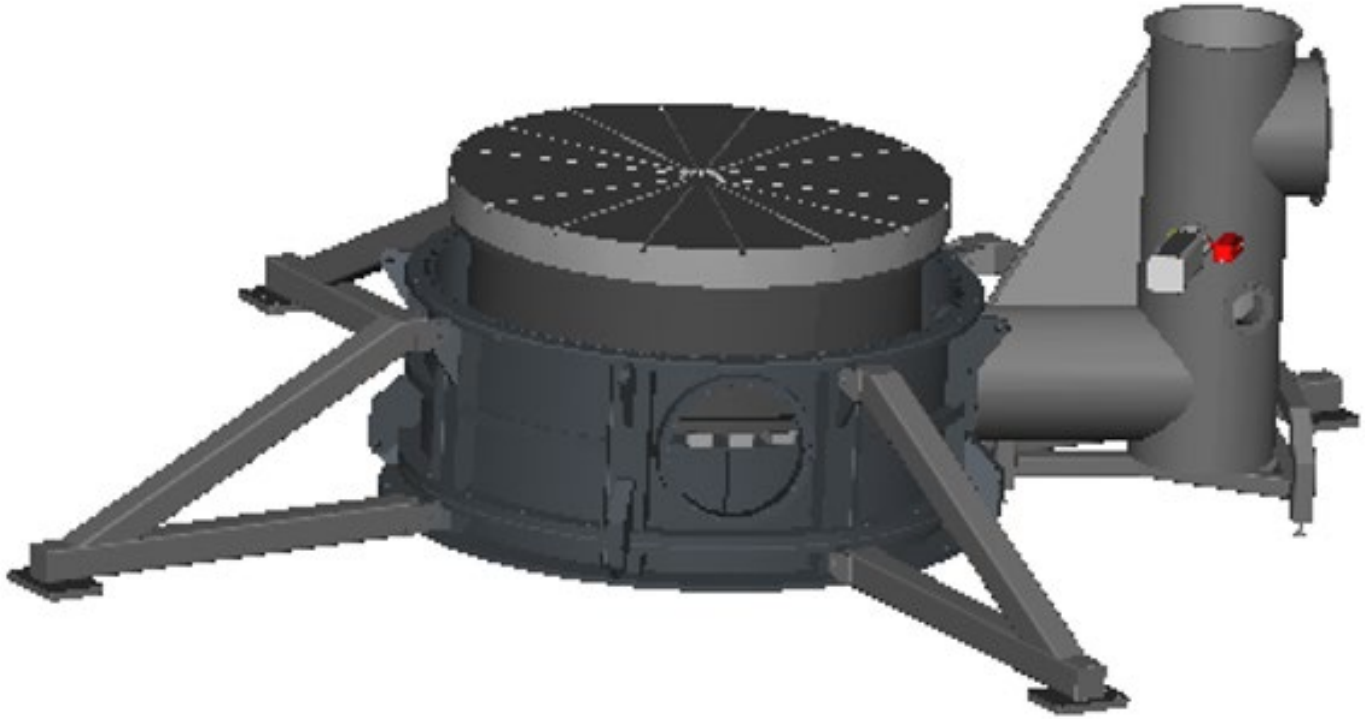
EB Generator and Slide attached to the vacuum chamber

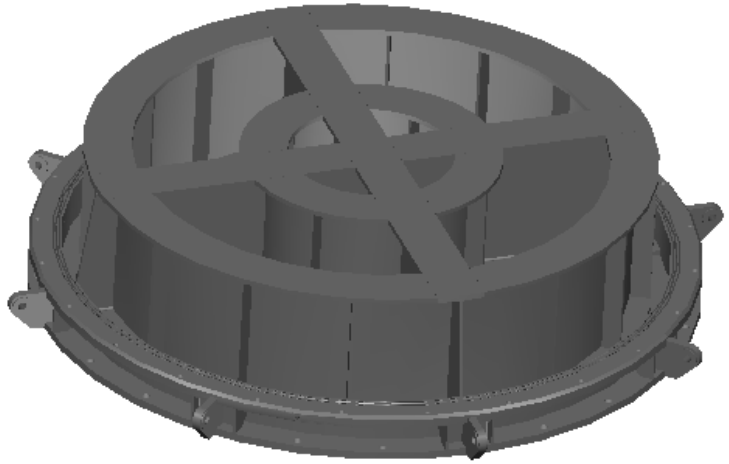


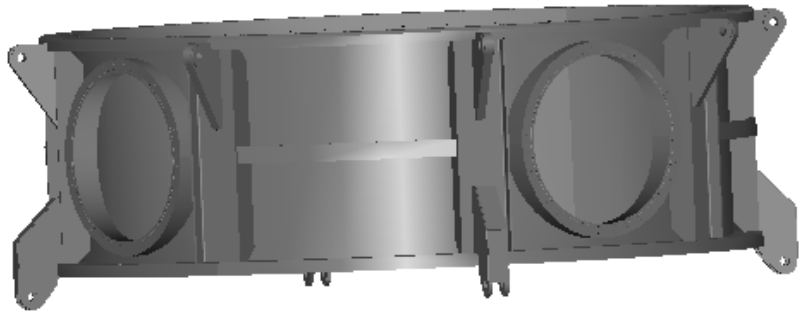
Demonstrator and Full Height EBW System



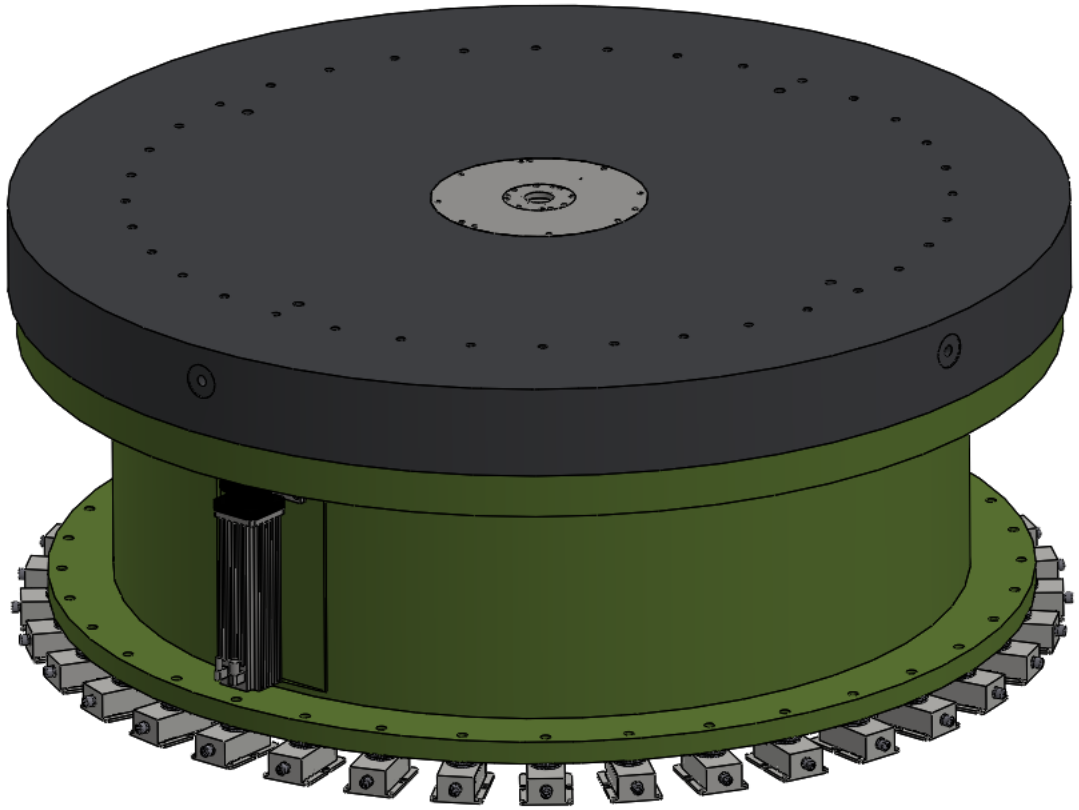
Vacuum Module Design

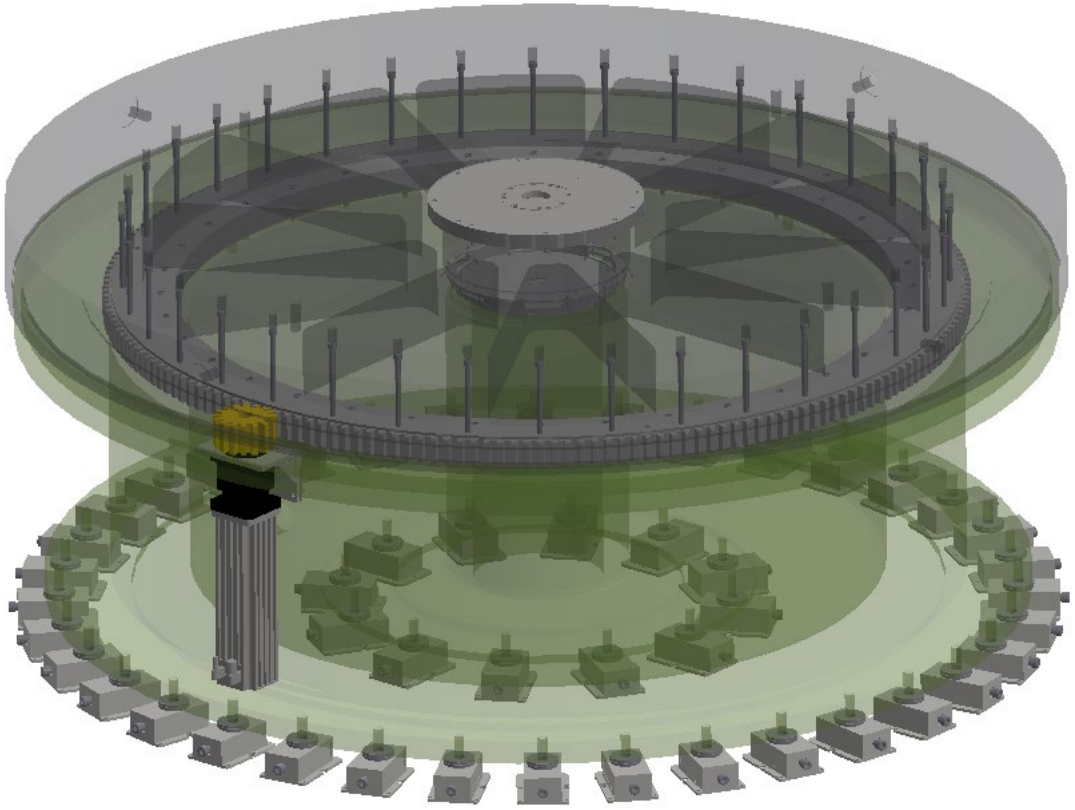




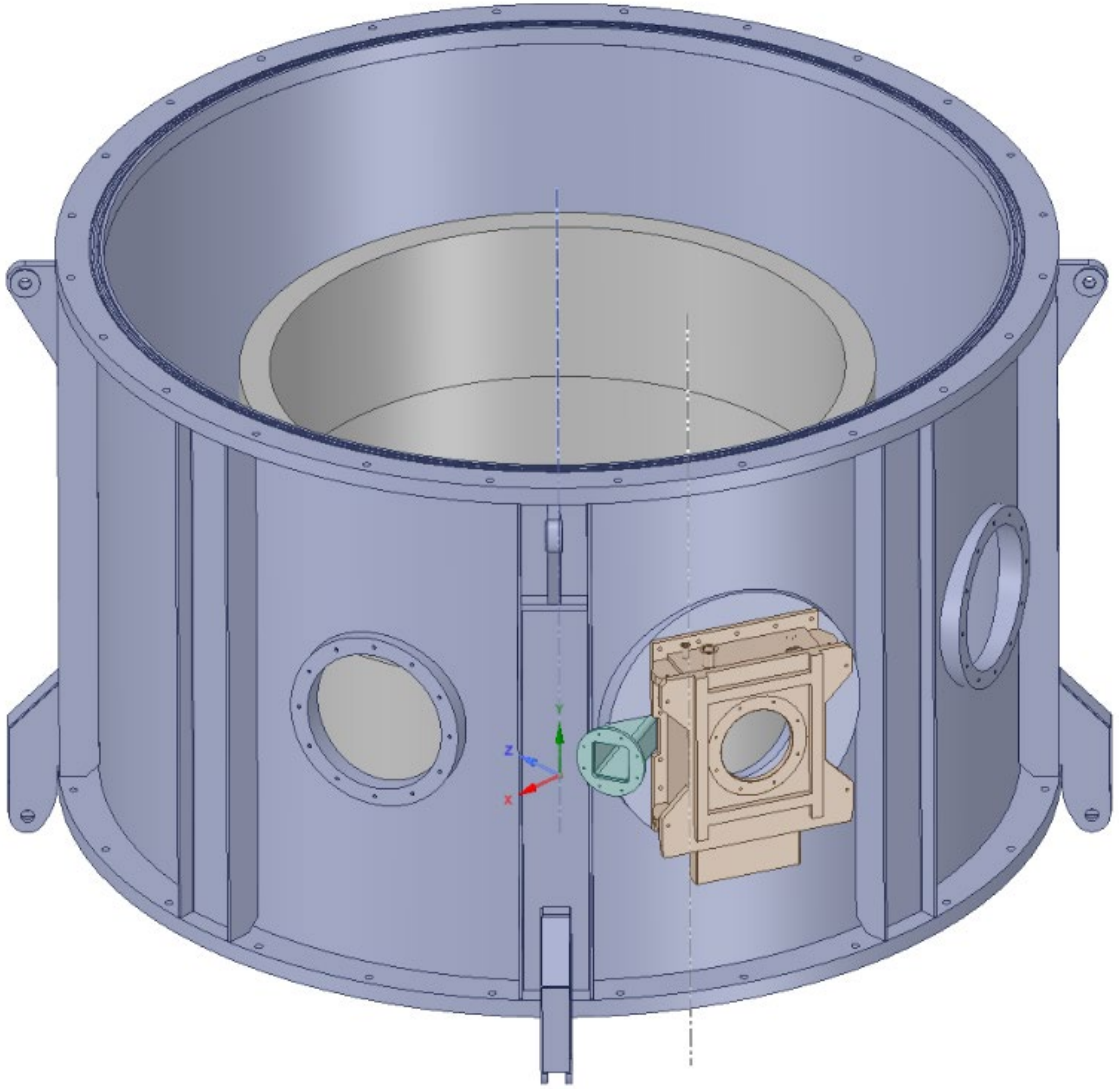


Rotary Table Design

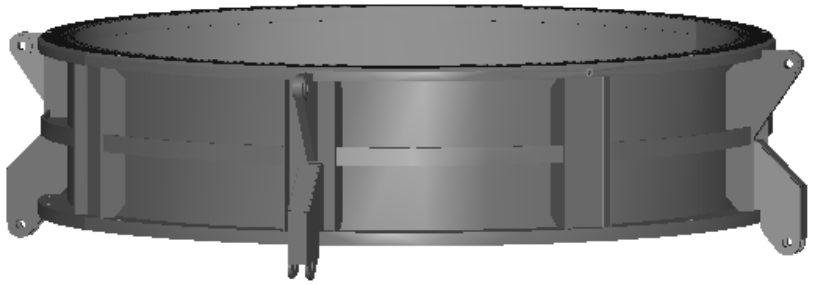




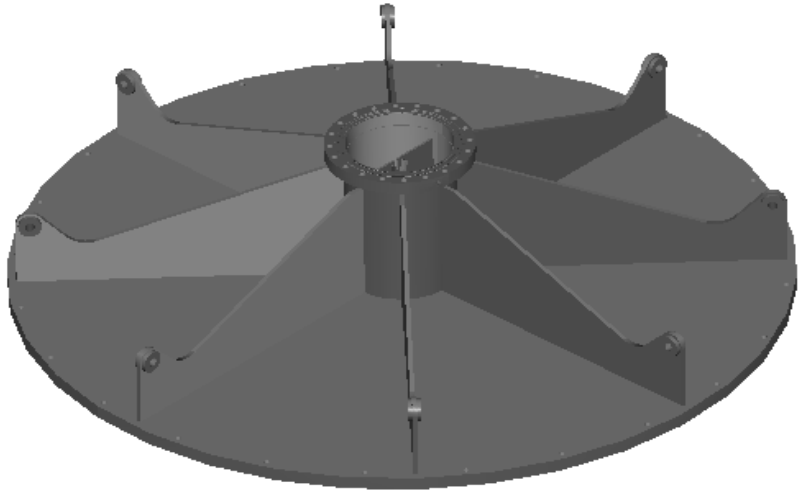
EB and Spacer Module, plus Lid



EB Module with RPV ring inside it.

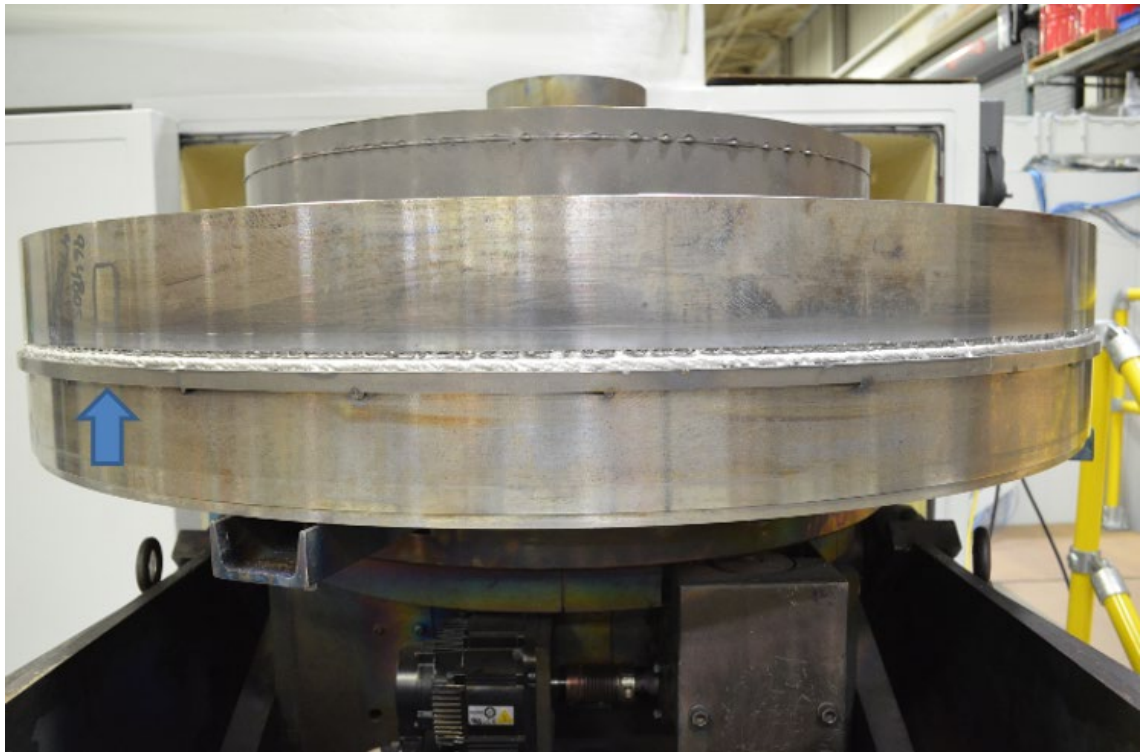


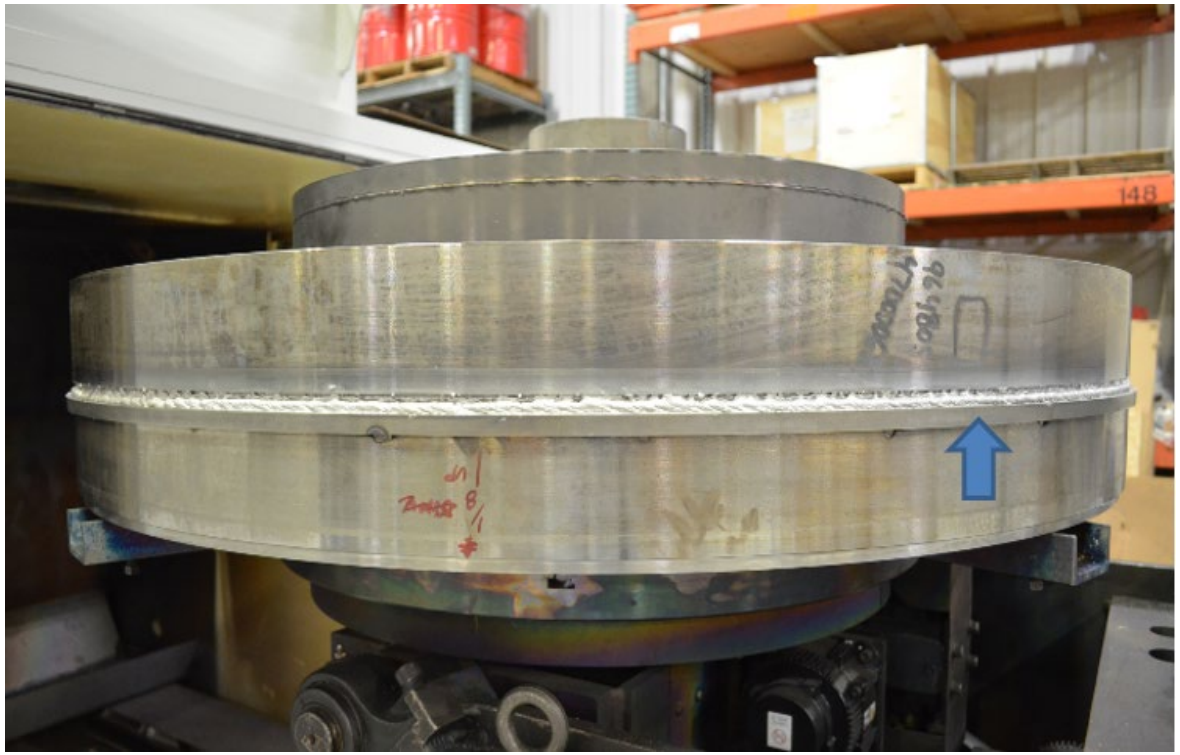
Spacer Ring



Lid

4ft Diameter x 5-inch Thick Weld Performed





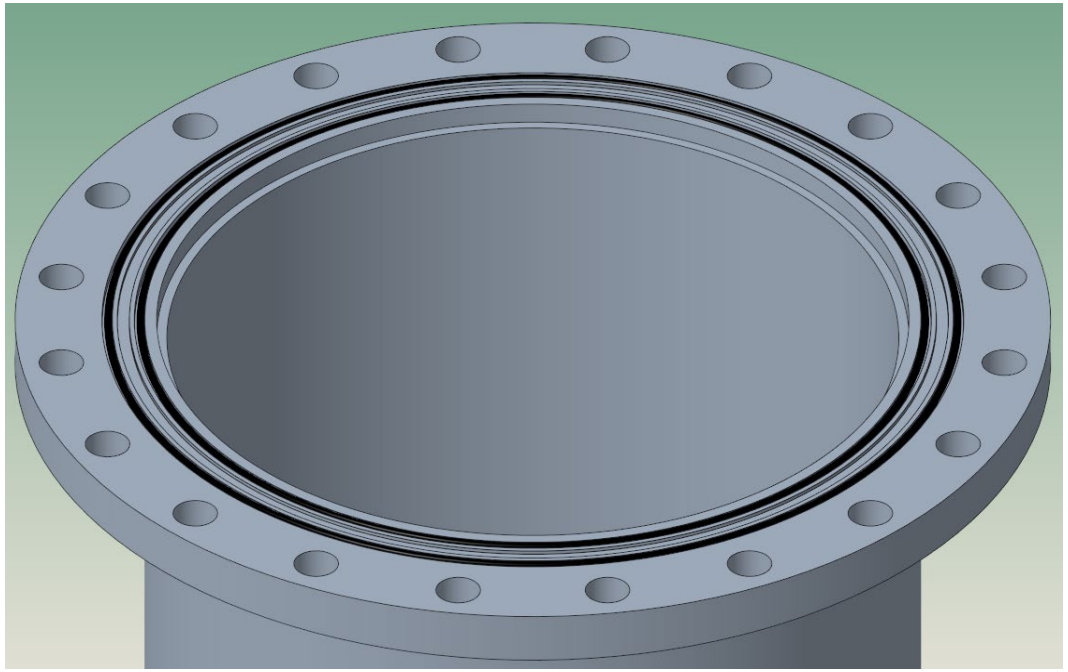
Summary

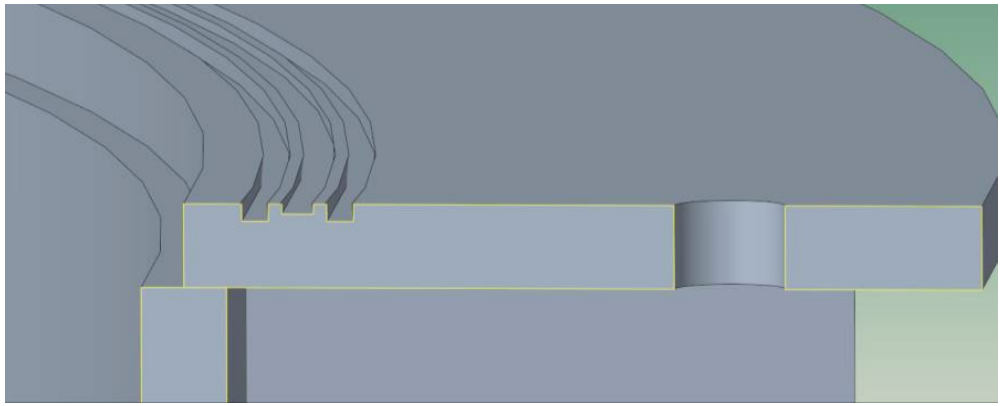
- Advanced Manufacturing/Fabrication Technologies
  - Reviewed DOE Projects: **DE-NE0008629 and DE-NE0008846**
  - Targets rapid acceleration for deployment of SMRs!
- Powder Metallurgy-Hot Isostatic Pressing
  - Near-net shaped components; ease of inspection; shorter lead times; scale to larger parts
- Electron Beam Welding Development
  - Rapid; single pass; thick section, highly repeatable
- Modular In-Chamber Electron Beam Welding
  - Establishes capability in USA; targets NuScale reactor, but applicable for other major components

Together...Shaping the Future of Electricity

Task 4--Design Vacuum Seals for Modular Ring Sections --AMRC Lead

- Individual “ring sections” will be produced (Task 6) from >1.5 in. (>38.1 mm) thick carbon steel.
- A flange will be attached to both the upper and lower extremities of the ring section via welding to achieve a good junction between two modules.
- A tight fit is achieved at the junction between the two modules through two engineered vacuum seals.
- A sensor will be positioned between the two vacuum seals to allow vacuum tightness to be checked
  - before pump-down
  - and monitoring during pumping to detect any leaks—extremely important in EBW activities.





Vacuum seals rings--example