TYPE ONE ENERGY®

Type One Energy Update

David T. Anderson for the T1E Team

Co-founder and Engineering Fellow

ARPA-E Fusion Programs Annual Meeting

Tuesday, July 8, 2025

ARPAE

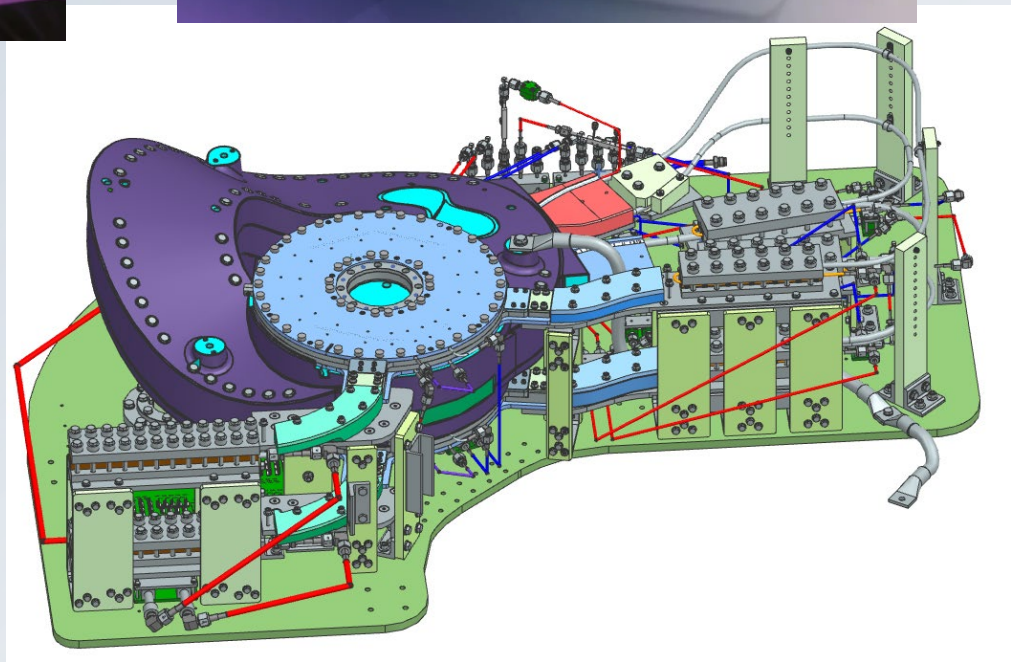
Advanced Research Projects Agency - Energy

Topics

- Type One Energy's decadal path to commercial fusion

- Physics Basis

- Magnet Zero Program

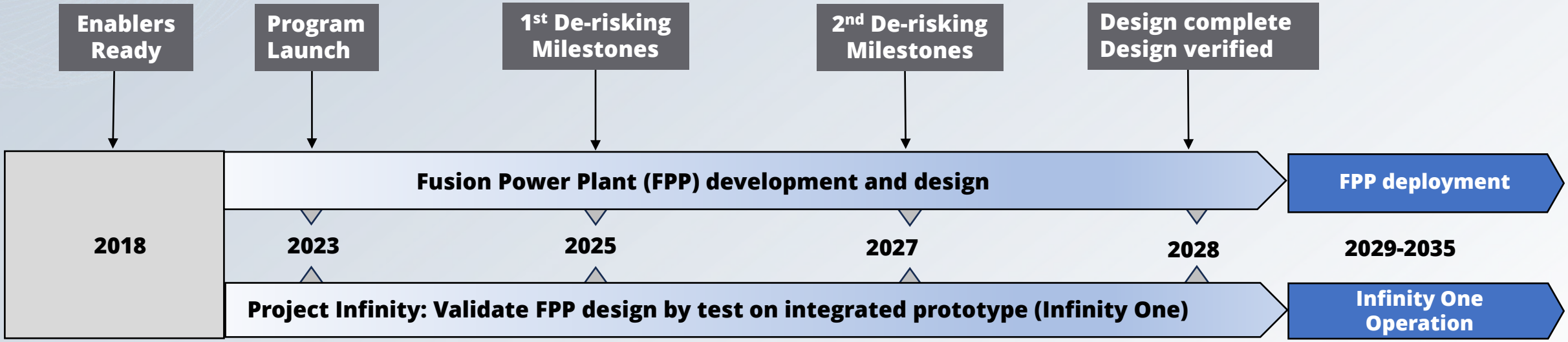


Why a Stellarator Power Plant

- Intrinsically steady-state: The plasmas can be sustained indefinitely, since the confining fields are created from the outside by superconducting coils
  - No cyclic stresses (neither thermo-mechanical nor electromagnetic)
  - 24/7 energy production (on demand)
- Very stable: the comparably low plasma currents in stellarators make them very robust against macroscopic plasma instabilities
  - Simpler control issues and increased reliability
- Can be ignited; minimal or no reinjected power into the plasma once ignited
  - Many other fusion concepts require active reinjection of powerful microwaves or neutral beams to sustain the discharge and avoid instabilities
  - Lower recirculating power ⇒ more efficient at producing electricity
    ⇒ further increases reliability

FusionDirect Stellarator Commercialization Program

A direct path to contracting the first Fusion Power Plant project before 2030



First Customer Agreement for Fusion Power Plant Project

Build Infinity One prototype in TVA Bull Run, develop TVA Infinity Two power plant project

Infinity One: Type One Energy stellarator prototype

- Integrated Project Delivery model with TVA in Bull Run power plant
- TVA responsible for site preparation, project support, utilities
- Shared supply chain, TVA provided utilities (e.g., cooling water)

Infinity Two: TVA Fusion Pilot Power Plant (350MWe)

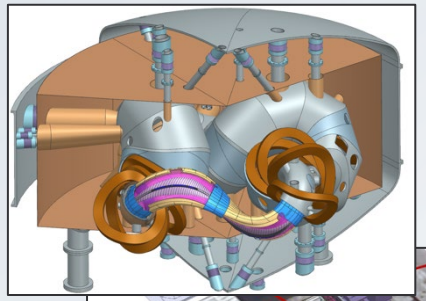
- Joint development of TVA power plant EPC project plan, siting, & licensing
- Support TVA evaluation of schedule, conditions for construction start
- Establish project consortium for financing, ownership

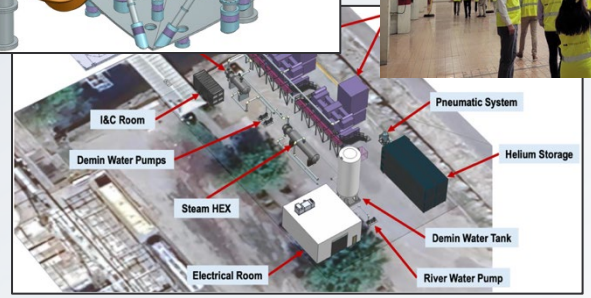
Licensing partnership

- Type One Energy
- TVA
- State of TN

Infinity One Prototype at Bull Run

- First 24/7, power plant relevant fusion machine
- Construction starts 2026, completes 2028
- 2029 verification of Infinity Two design





First industry end-customer Agreement… jointly develop TVA Fusion Pilot Plant project

Major Components of the *FusionDirect* Program

- Type One Energy's *FusionDirect* program is a milestone-based direct path to commercialize stellarator fusion within a decade using high-temperature superconducting (HTS) magnets, modern computational physics, and advanced manufacturing methods

Fusion plasma optimization
Infinity Two Physics Basis series, J. Plasma Phys. (2025)

HTS magnet R&D

- **Magnet Zero prototype**
- Further technology demonstration magnets on the path to Infinity Two

Other technology R&D (e.g., blanket, tritium cycle, divertors)
B. Goh, SOFE2025
J. Talley, SOFE2025
M. Knilans, SOFE2025

Infinity One Prototype

Infinity Two Fusion Power Plant
Infinity Two Physics Basis series, J. Plasma Phys. (2025)

Journal of Plasma Physics published Infinity Two articles

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Type One Energy has partnered with the JPP to publish the Infinity Two physics baseline design (6 peer reviewed journal articles + one editorial)

Title	Done
Editorial: Status of the Infinity Two reactor physics basis	✓
The Infinity Two Fusion Pilot Plant baseline plasma physics design	✓
Magnetohydrodynamic equilibrium and stability properties of the Infinity Two Fusion Pilot Plant	✓
Alpha-particle confinement in Infinity Two Fusion Pilot Plant baseline physics design	✓
Predictions of core plasma performance for the Infinity Two Fusion Pilot Plant	✓
Power and Particle Exhaust for the Infinity Two Fusion Pilot Plant	✓
Breeder blanket and tritium fuel cycle feasibility of the Infinity Two Fusion Pilot Plant	✓

No fundamental plasma physics barriers ✓

Infinity Two Physics Basis: Implementable today

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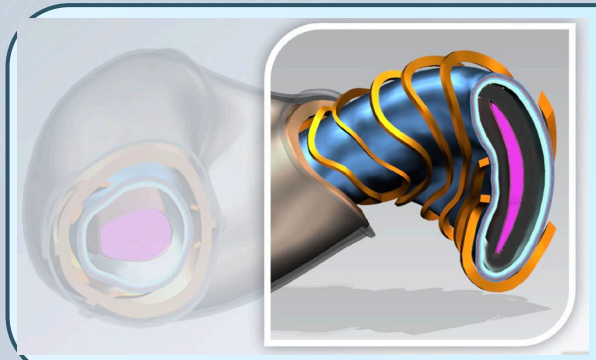
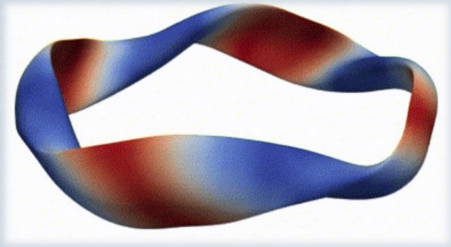


World's first implementable fusion power plant physics basis

Basis for 350 MWe power plant design derived from today's technologies

- **Unified** analysis integrates plasma, magnets, divertor, materials, and blanket
- **Robust** with conservative margins from 160,000 full-physics 3D simulations
- **Peer-reviewed** by Journal of Plasma Physics (JPP) in 7 scientific papers

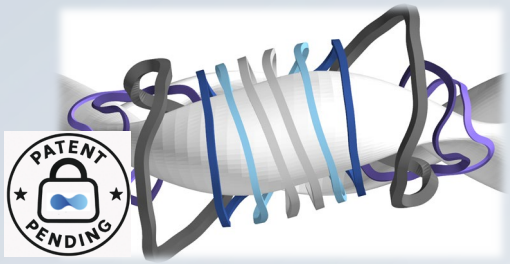
1. Fusion Plasma



QI symmetry, 4 period, A = 10

- Efficient; configuration can be ignited
- Robustly stable in all operations
- Achievable with 9T magnetic field

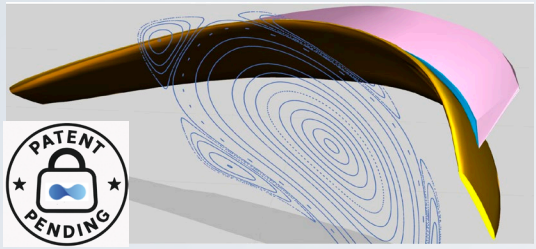
2. Magnet Set



Modular VIPER-based HTS

- Manufacturable geometry
- Supports modular maintenance
- Sufficient space for blanket

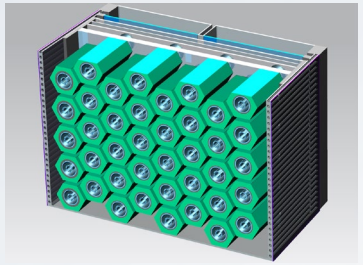
3. Divertor and First Wall



Backside Island Divertor

- Efficient exhaust technology
- Uses already qualified materials
- 4-year lifetime for limiting PFCs

4. Blanket & Fuel Cycle



Pebble Bed Blanket

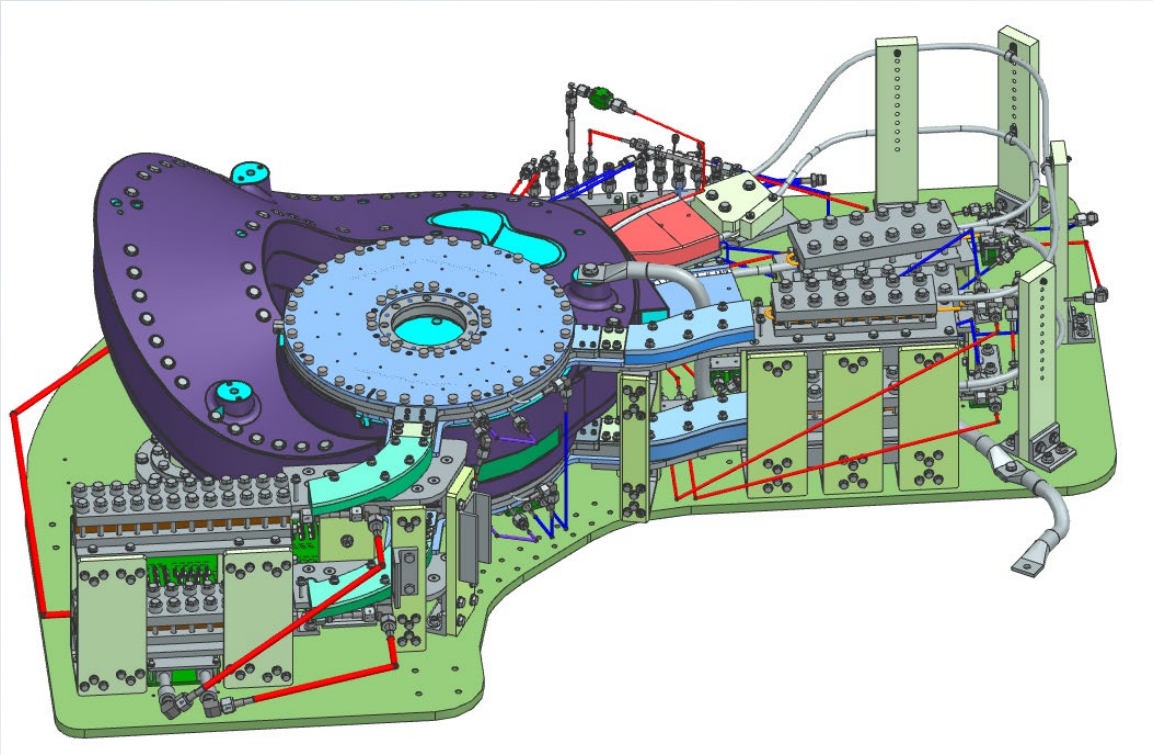
- TBR =1.3, vs 1.05 required
- Robust performance
- Operational tritium < 1 kg

"... innovative and groundbreaking ... setting the gold standard for how this is done ..." (JPP)

Physics Basis of Infinity Two Fusion Power Plant in Special Issue of JPP

Stellarator HTS magnet technology demo platform

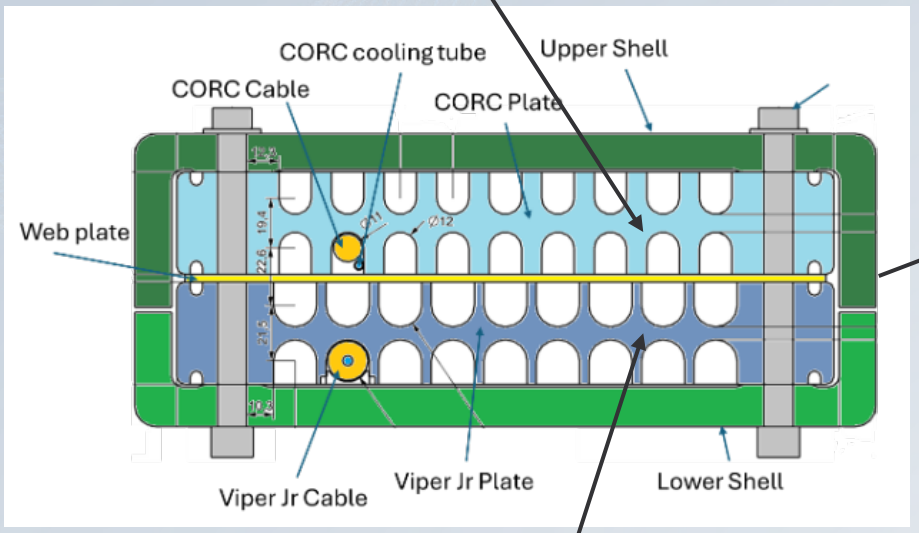
- Magnet Zero (M0) is the first non-planar, high-field, high-temperature superconducting (HTS) stellarator magnet
- Retires risks associated with bending, high field and high current
- Tests two alternative HTS cable technologies in one assembly
- Concentrates the highest field at the tightest bend region with planar auxiliary coils

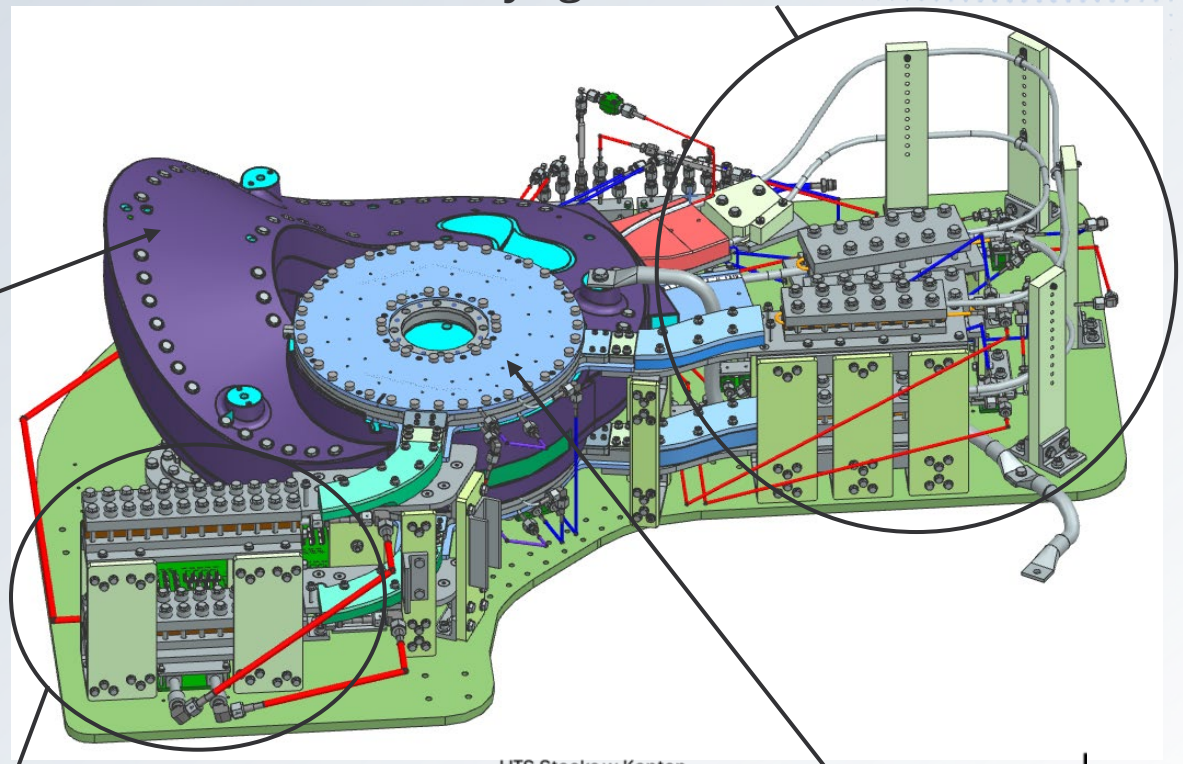


M0 comprises four distinct magnets in one

Internal electrical connections and helium cryogen lines

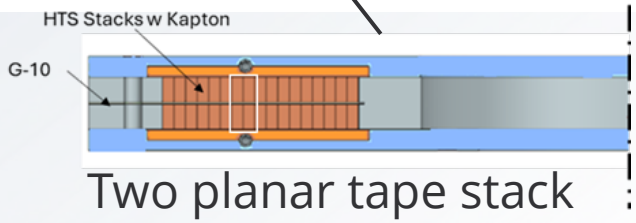
Non-planar CORC cable-in-plate





Non-planar reduced-size VIPER-derived ("VIPER Jr") cable-in-plate

Electrical terminals

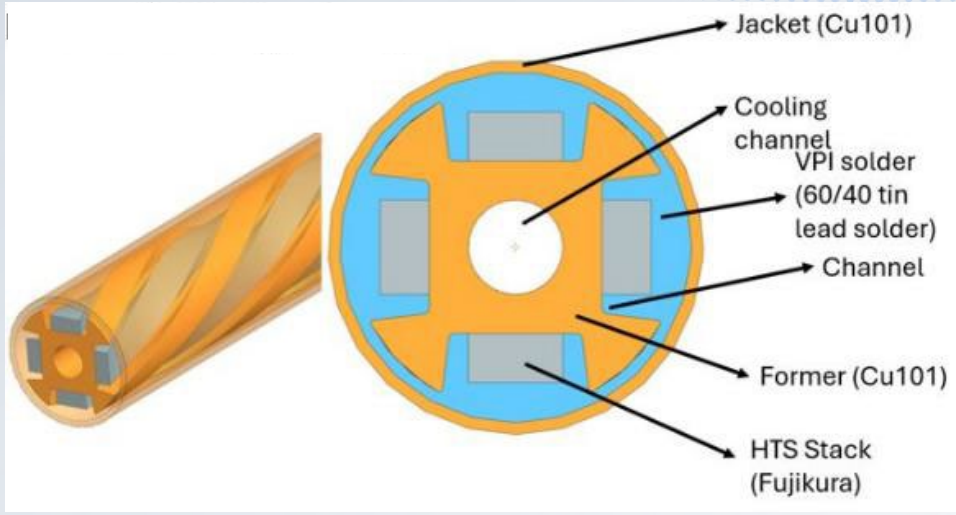


Two planar tape stack Auxiliary coils

All coils are electrically connected in series

VIPER Jr cable is a Variant of the MIT VIPER design

- VIPER Jr was developed in partnership with MIT from VIPER cable (Hartwig et al. 2020 *Supercond. Sci. Technol.*), with smaller cross section for easier bending
- VIPER Jr comprises HTS stacks in channels in a twisted copper former with a central cooling channel, enclosed in a copper jacket, bent to shape in plate grooves and vacuum pressure impregnated with solder
- VIPER-derived cables are characterized by particularly good current sharing between tapes because of soldering
- Soldering also provides good thermal connections and mechanical stability
- 32 kA predicted capability at 20 K in B=8T

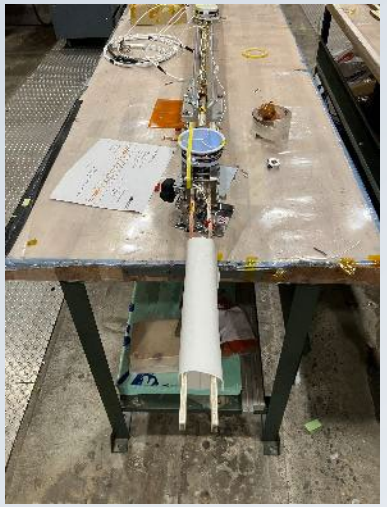


VIPER cable after bending and VPI-soldering

VIPER Jr development coils

- A series of development cables of increasing length and geometric complexity were fabricated
  - Tested the VPI soldering process when scaled down from VIPER to VIPER Jr
  - Tested cable performance after bending
- Critical currents in 77 K self-field electrical testing were within error bars of predictions (see *Granetz, SOFE2025* for some modeling techniques)
- Similar performance to bent VIPER cables previously demonstrated by Type One Energy in collaboration with MIT and the UW-Madison (Riva et al. 2023 *Supercond. Sci. Technol., ARPA-E BETHE funded project)*

"Control cable"



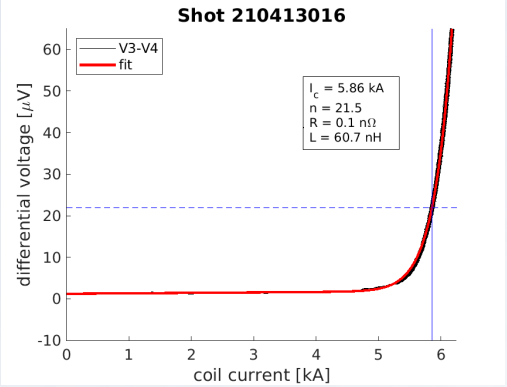
'Ash' (2 m straight cable)

"3-D bends"

'Birch' (2 m non-planar cable)

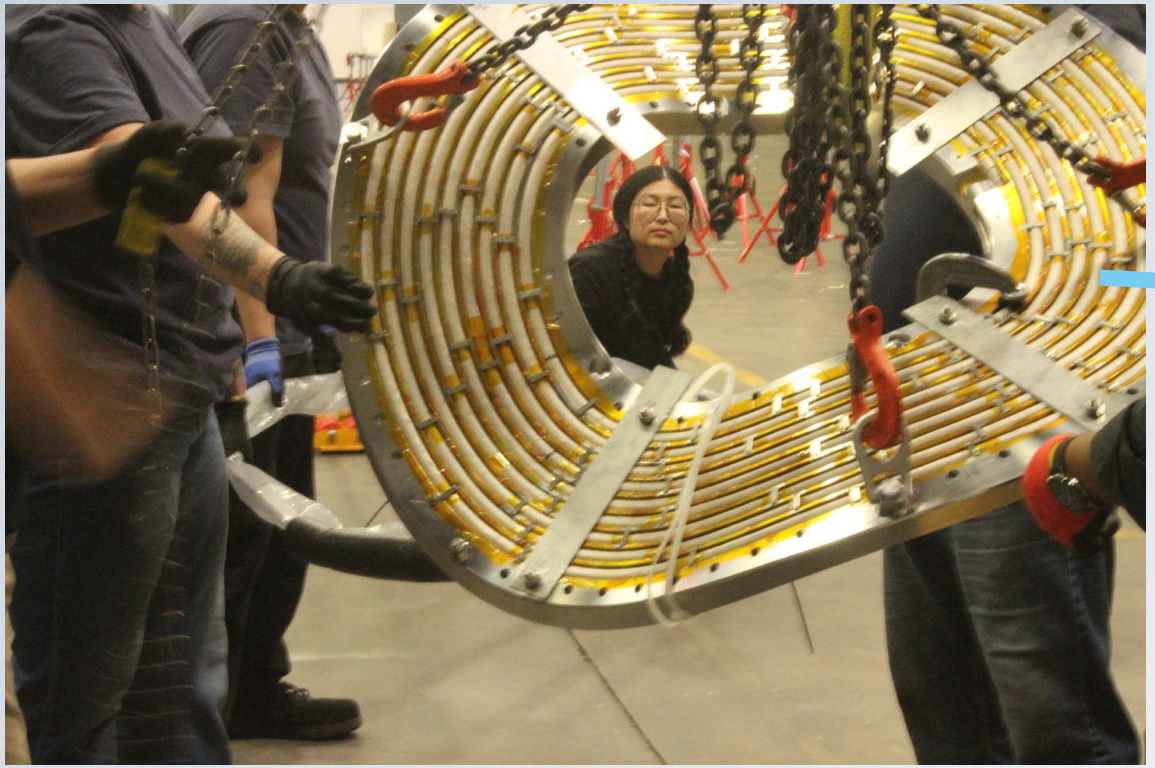
"Solder flow"

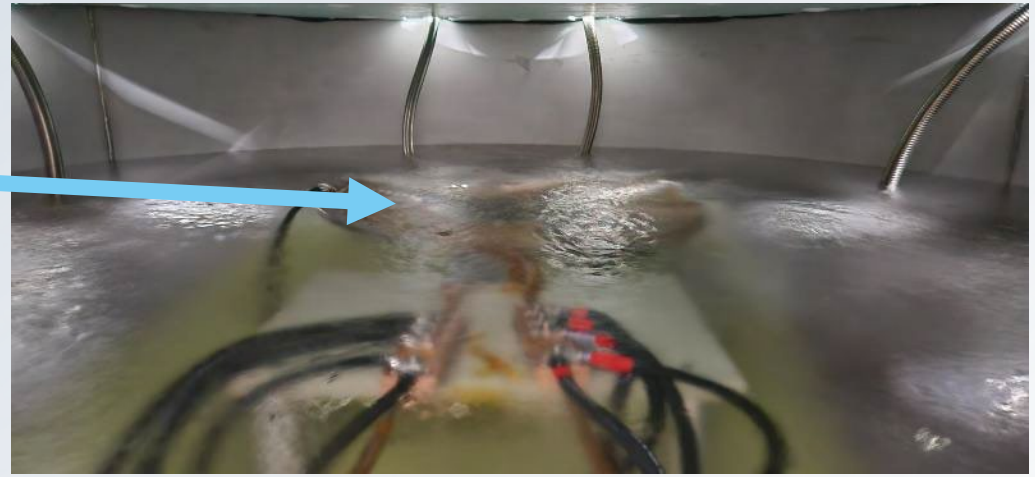
'Cedar' (6.25 m 4-turn planar coil in plate)



Magnet Zero Viper Jr Plate

- The first non-planar coil is a “VIPER Jr” cable wound into an 18-turn stainless-steel double-pancake plate
- Successfully tested at 77K (LN2) within specification

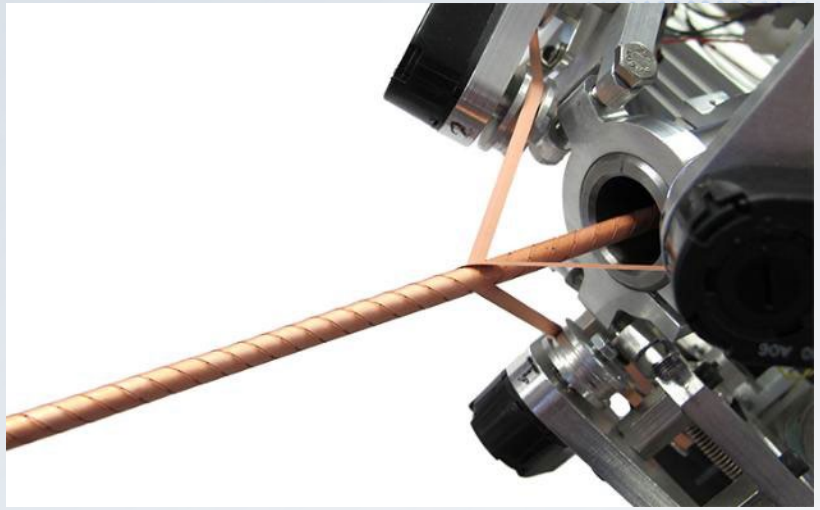




VIPER Jr coil during electrical testing in LN2

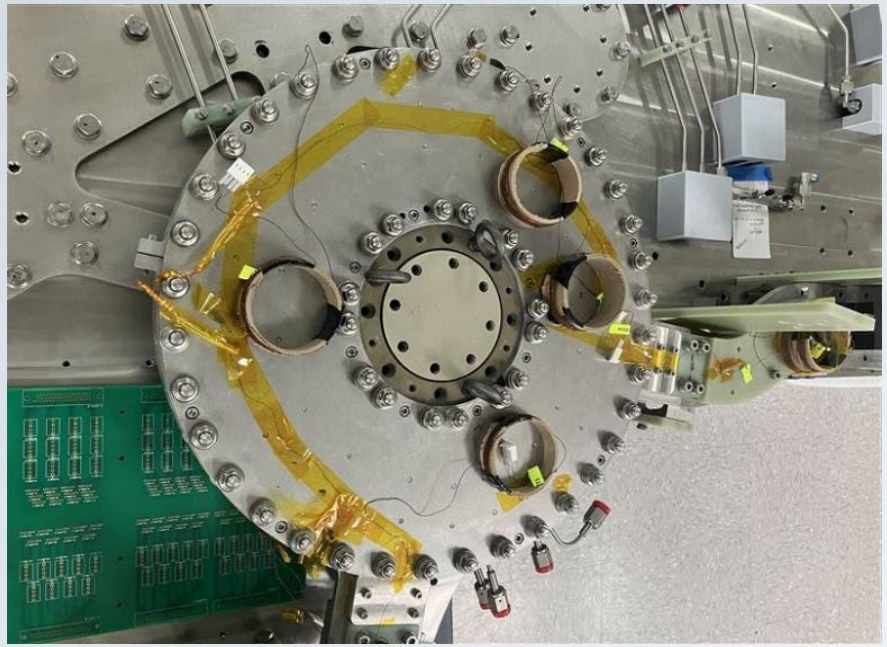
CORC coil

- The other non-planar coil is a CORC cable supplied by Advanced Conductor Technologies, wound into an 18-turn stainless-steel double-pancake plate
- The CORC cable comprises twisted HTS tapes wound on a round copper core in layers with alternating angle, bent to shape in plate grooves
- A custom-made high-tape high-current CORC cable was made for Magnet Zero
- CORC cables are characterized by particularly good bendability
- CORC plate is scheduled for LN2 test this week



Auxiliary coils

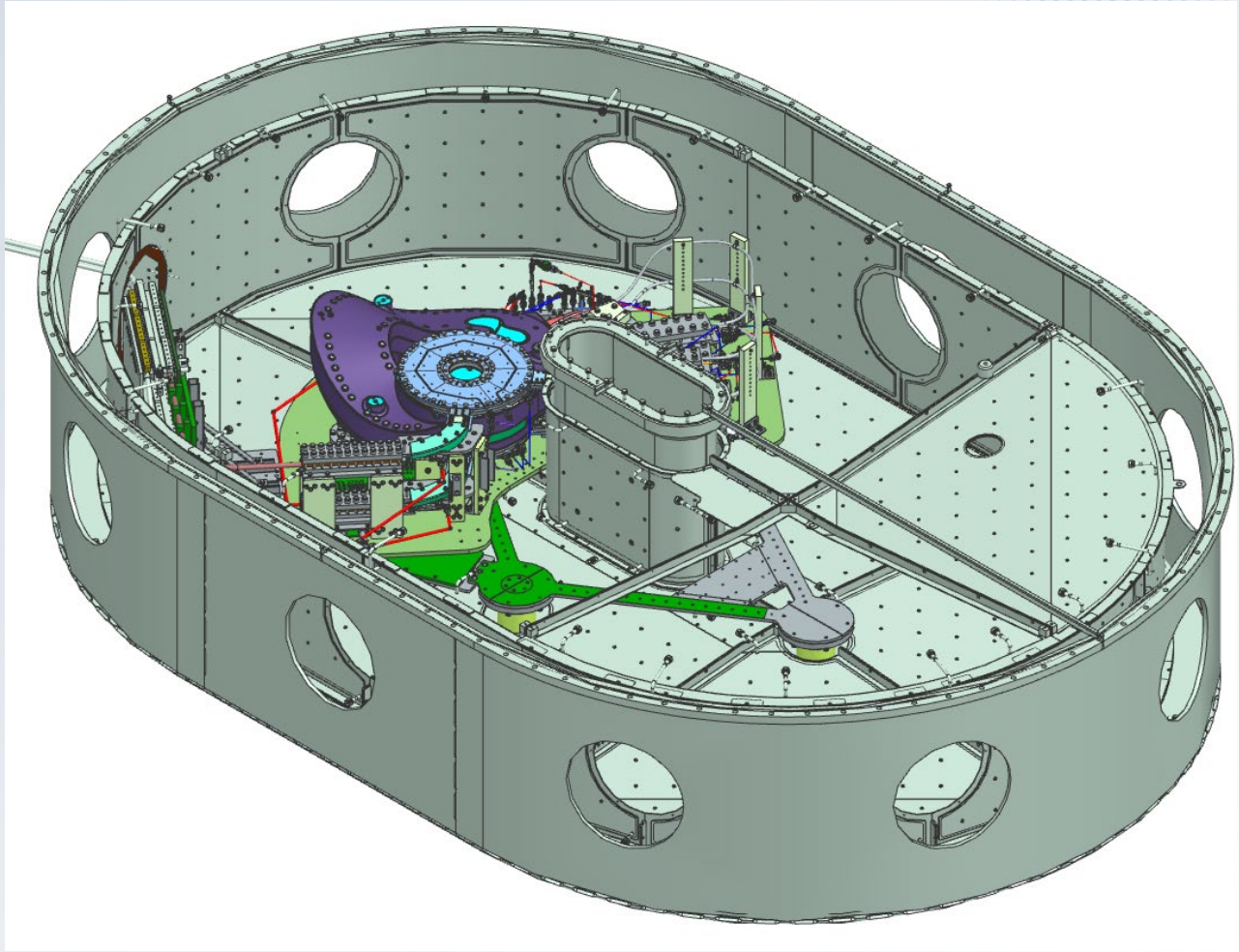
- The Auxiliary coils are insulated 30-in-hand dry-wound planar double-pancake coils
- The Aux coils sandwich the region of the non-planar coils with the tightest (12.5 cm radius) bend
  - Test the operational robustness of the non-planar coils in fields and EM loads representative of a high-field stellarator
- The Aux coils are electrically connected in series with the other coils



Aux coil during electrical testing in LN2

Upcoming integrated 20 K test at MIT

- MIT's Superconducting Magnet Test Facility will be used to test the coil in the coming months at 20 K
  - Supercritical helium cooling at 20 K
  - 32 kA operating current (test facility can reach 50 kA)
  - Aiming to reach 8 T peak magnetic field
- This will be the first such test of a high-field non-planar HTS stellarator magnet



Summary

- Type One Energy is on a direct path to commercial fusion in the next decade
- We will build Infinity One prototype in TVA Bull Run plant; demolition underway!
- First industry end-customer agreement… jointly develop TVA Fusion Pilot Plant project
- Physics basis of Infinity Two well supported by peer-review articles in the Journal of Plasma Physics
- Magnet Zero is the first high-field non-planar HTS stellarator magnet
- The constituent coils of Magnet Zero have shown good performance and the integrated magnet will be tested at MIT in the coming months at 20 K and 8 T