Demonstration High Temperature Superconducting Non-Planar Stellarator Magnet with Advanced Manufactured Assemblies

BETHE Kickoff Virtual Workshop
August 11–12, 2020

PI: David Anderson, Type One Energy Group

Co-PI's:

Robert Granetz, Massachusetts Institute of Technology

Lianyi Chen, University of Wisconsin-Madison

Category. B Component Technology Development

Team members and roles

TYPE ONE ENERGY

- **David Anderson** – Principal Investigator
- **Brian Matthews** – Additive Manufacturing Build, DFMA
- **Lukas Hoppe** – Additive Manufacturing Build, DFMA
- **Chris Hegna** – 3D Magnetic Field Modeling
- **Randall Volberg** – Project Director

MIT PSFC

- **Robert Granetz** – Co-PI – HTS Conductor/Testing
- **Rui Vieira** - Head Engineer
- **Amanda Hubbard** – Magnet Construction
- **PSFC Technical Team**– Magnet Construction

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

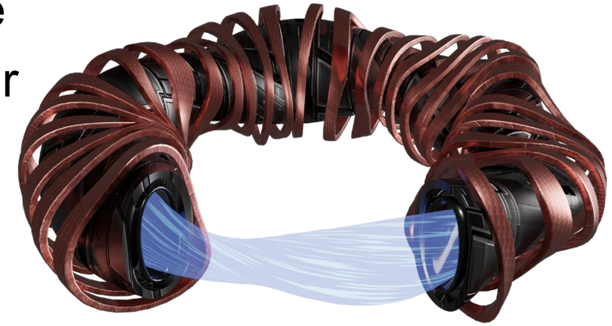
- **Lianyi Chen** – Co-PI – AM Design & Metallurgy
- **Luis Izet Escano** – Design, Testing & Analysis
- **Thomas Kruger** – 3D Magnetic Coil Modeling
- **Carl Martin** – Conductor Case Mechanical Design

Commonwealth Fusion Systems

- **Brandon Sorbom** – HTS Tape Post Processing Qualification
- **James Logan** - Engineer

Reduce the capital cost of stellarator reactors using additive manufacturing (AM) and high-temperature superconductors (HTS)

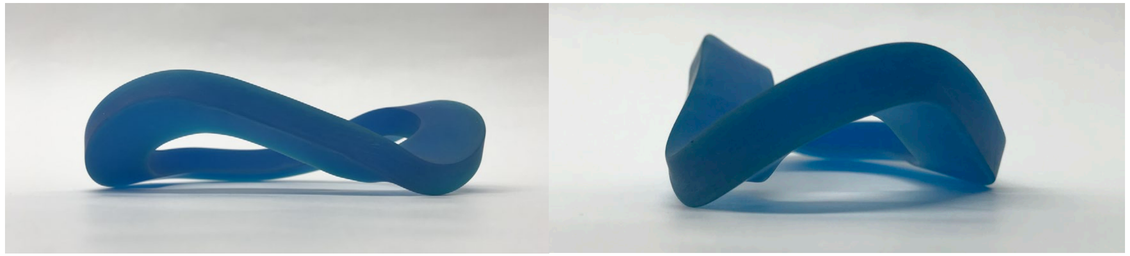
- The stellarator is second only to the tokamak in parameters achieved:
  - Recent advances point to improved confinement through magnetic design
  - Reduced turbulent and energetic ion transport
- Power plant advantages:
  - Inherently steady-state
  - Low recirculating power
  - No disruptions
  - High density limits



- Current opportunities
  - Reducing cost and time for construction at large scale and selective high precision
  - Using high magnetic fields

DELIVERABLES:

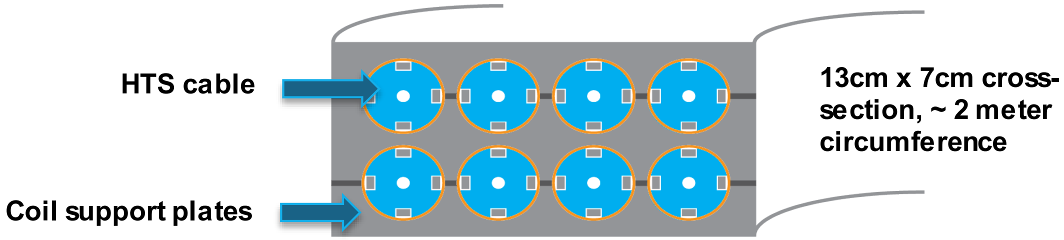
- Demonstrate that metal AM can build non-segmented HTS non-planar coil support plates with sufficient accuracy and achieve a 10X reduction in cost and time over conventional methods
- Demonstrate an HTS cable that can conform to the required non-planar coil shape (bend radii as small as 10 cm) and retain superconducting properties



Major tasks (and technical risks), milestones, and desired project outcomes

- Design and build prototype coil positioning plate (2-turn) with AM
  - Completion Jan 2021
  - Metrics:
    - +/- 0.25 mm – dimensions of coil plates
    - >99% density; low porosity
    - No detectable cracks under examination by x-ray/neutron radiography
  - Technical Risks/Mitigation
    - Build rate too slow/expensive
    - Accuracy and/or properties cannot be achieved
- Desired Outcome:
  - High deposition rate for scalable rapid manufacturing
  - 1-piece print with hybrid process to net shape

8-TURN DOUBLE PANCAKE HTS COIL IN 3D PRINTED METAL SUPPORT CASE



- Fabricate several test cables using a combination of stainless steel and HTS tapes.
- Confirm fabrication process and ability to tolerate 10 cm bends
  - Completion Feb 2021 **GO/NO GO for full coil**
  - Metrics:
    - Critical current degraded less than 20% at 77 K from virgin tape properties
  - Technical Risks/Mitigation
    - 10 cm bends result in large loss of critical current
    - Cable cannot be bent with acceptable accuracy
- Desired Outcome:
  - On completion, move to fabricate full 8-turn double pancake demo coil to achieve 1.35 kA/cm^2 at 77 K with a field of 1 tesla at the conductor (5 kA in cable) (Phase 2)

Key techno-economic metrics of the project (and, if applicable, its commercial fusion-energy application)

HTS

- Enables operation at 20 K vs. 4.2 K – large refrigeration savings
- Less Cu needed for quench protection
- No heat treatment process
- Higher critical current densities
- Higher magnetic field => smaller reactor size; more conservative plasma physics requirements
- 2nd gen REBCO tape now \$30-40 /m

AM

- Additive manufacturing efficiencies enables >10X reduction in cost and time to mass produce major stellarator components.
- OCC of <\$2 billion and <\$5 per Watt is realized (applied to ARIES-CS power plant costing).

76% Scale Coil Positioning Plate Laser-Wire AM Test Print in 316-L Stainless Steel

10 AM Mass Production Enablers