ENHANCED Shield
A Critical Materials Technology Enabling Compact Superconducting Tokamaks

GAMOW Kickoff Meeting
January 21–22, 2021

Lance Snead, Stony Brook University
Steve Zinkle, University of Tennessee-Knoxville
Jacopo Buongiorno, Massachusetts Institute of Technology

Enhanced Shield Team members and roles

A program of iterative Materials and Fabrication R&D guided by Analysis

GAMOW Management
PI. Lance L Snead, SBU
PM, Mary Botha, SBU

Shield Fabrication and Properties
Thrust Lead, Jason Trelewicz, SBU

- Hydride Stability and Modeling – Steve Zinkle, UT-K
- Composite Shield Forming Studies – Jason Trelewicz, SBU
- Characterization and Data-basing – David Sprouster, SBU

TECO and Market Outreach
Mary Botha, SBU

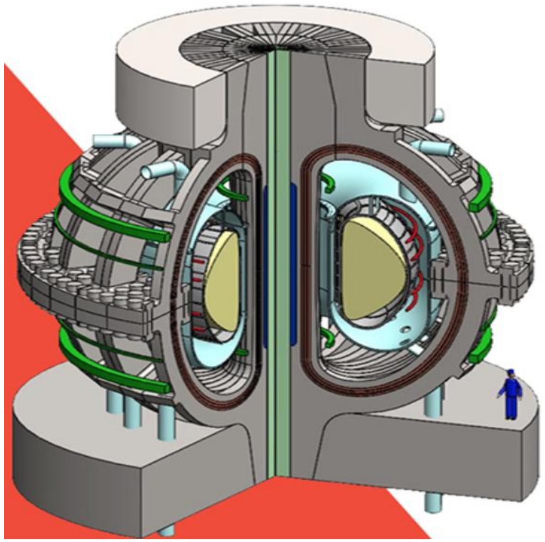
Independent Review Team
Commonwealth Fusion Systems
Tokamak Energy
St. Gobain Ceramics, North America

Shield Analysis & Performance
Thrust Lead-Lance Snead , SBU/MIT

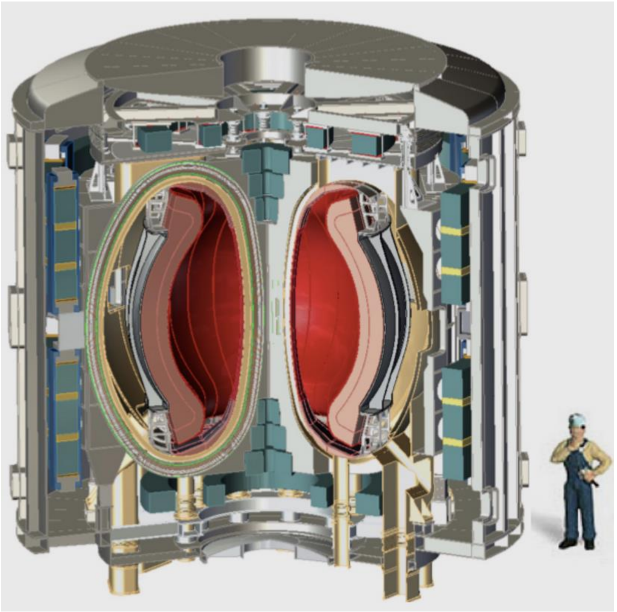
- Fusion System and Shield Neutronics – Ethan Peterson, MIT
- Compact Tokamak Economic Impact – Ethan Peterson, MIT
- Irradiation and Environmental Performance – Lance Snead, SBU

High-level motivation, innovation, and goals of the project

- Compact high-temperature superconducting fusion reactors offer promise of high performance though are limited by current magnet shield.

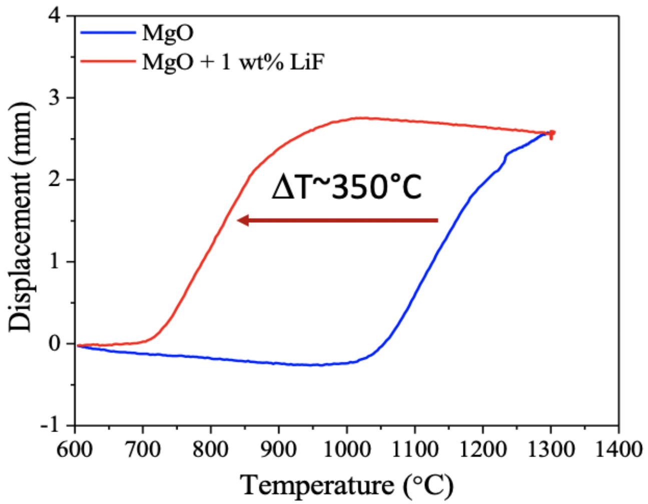


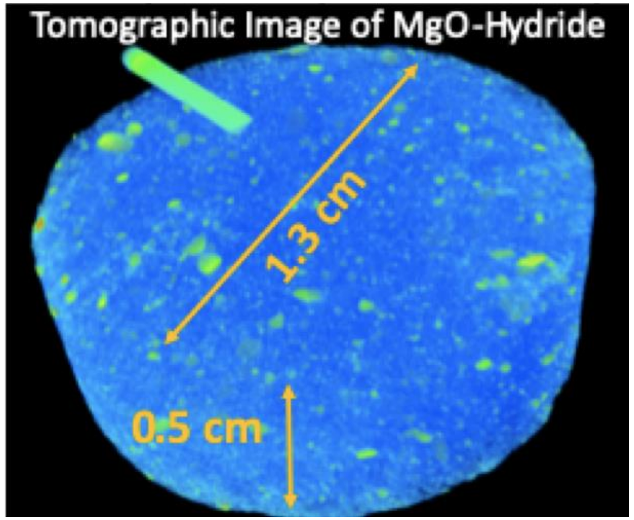
CFS-ARC Reactor



TE ST-40 Reactor

- While hydrides are attractive neutron shields, safety and H-mobility preclude their use. Here we advance composites that entrains neutron absorbing hydrides in stable ceramic and metal-matrix composite forms.





- Goal of reducing both nuclear heating and material damage (neutron dose) by >>10x in a practical composite shield.

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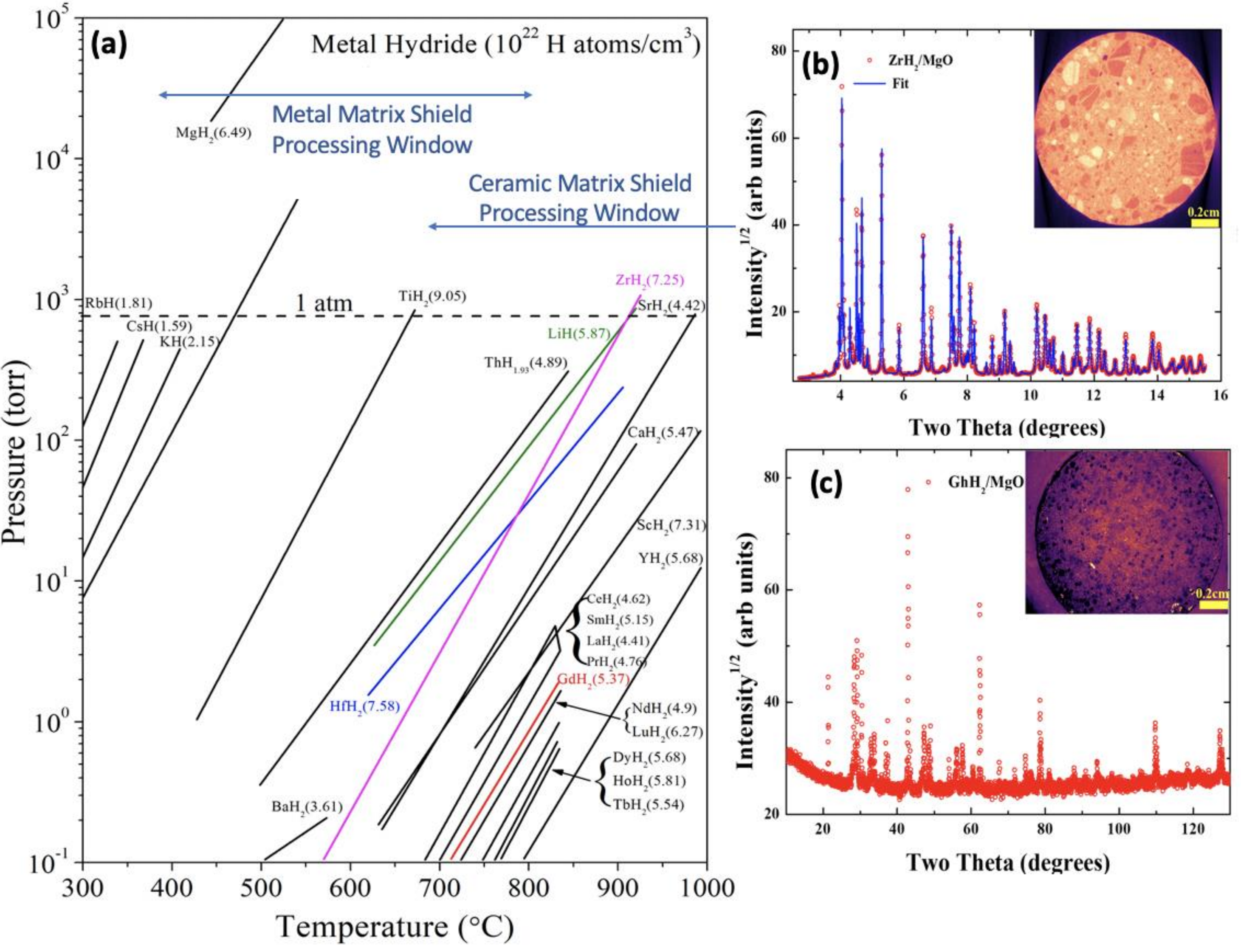
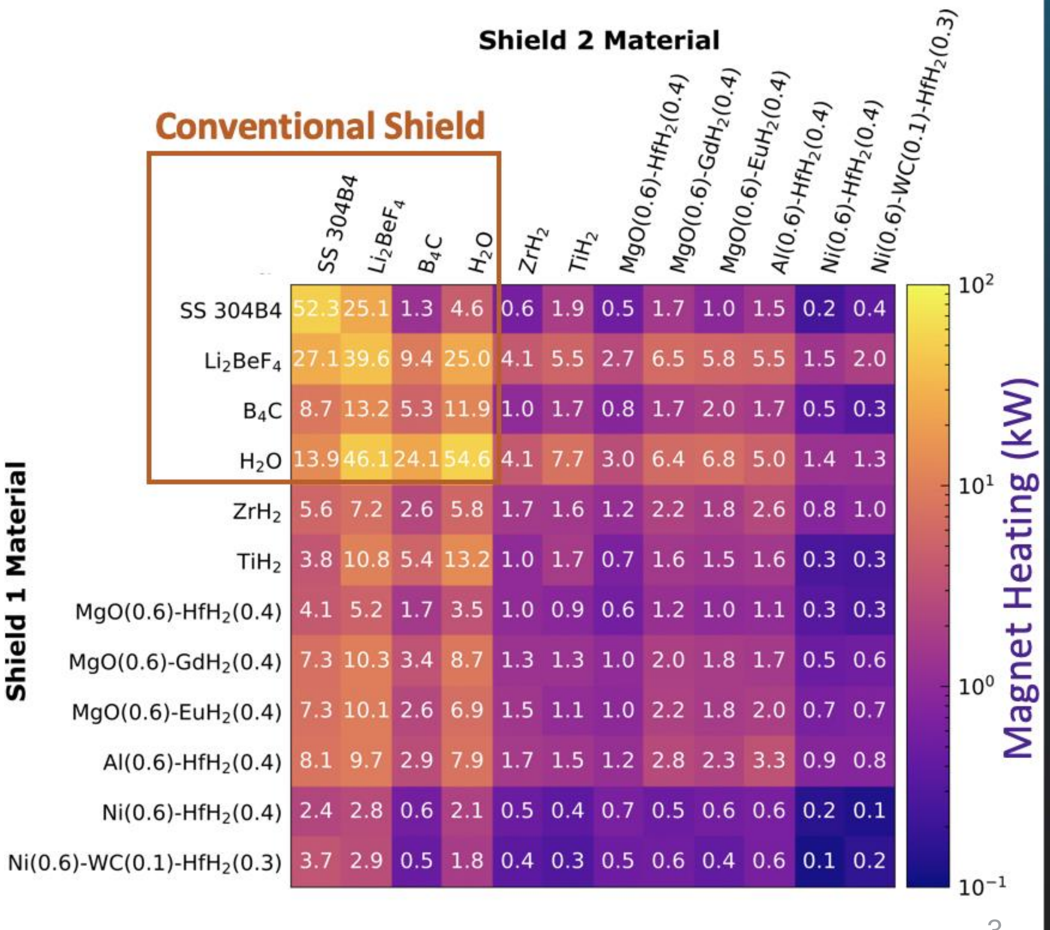
CHANGING WHAT'S POSSIBLE

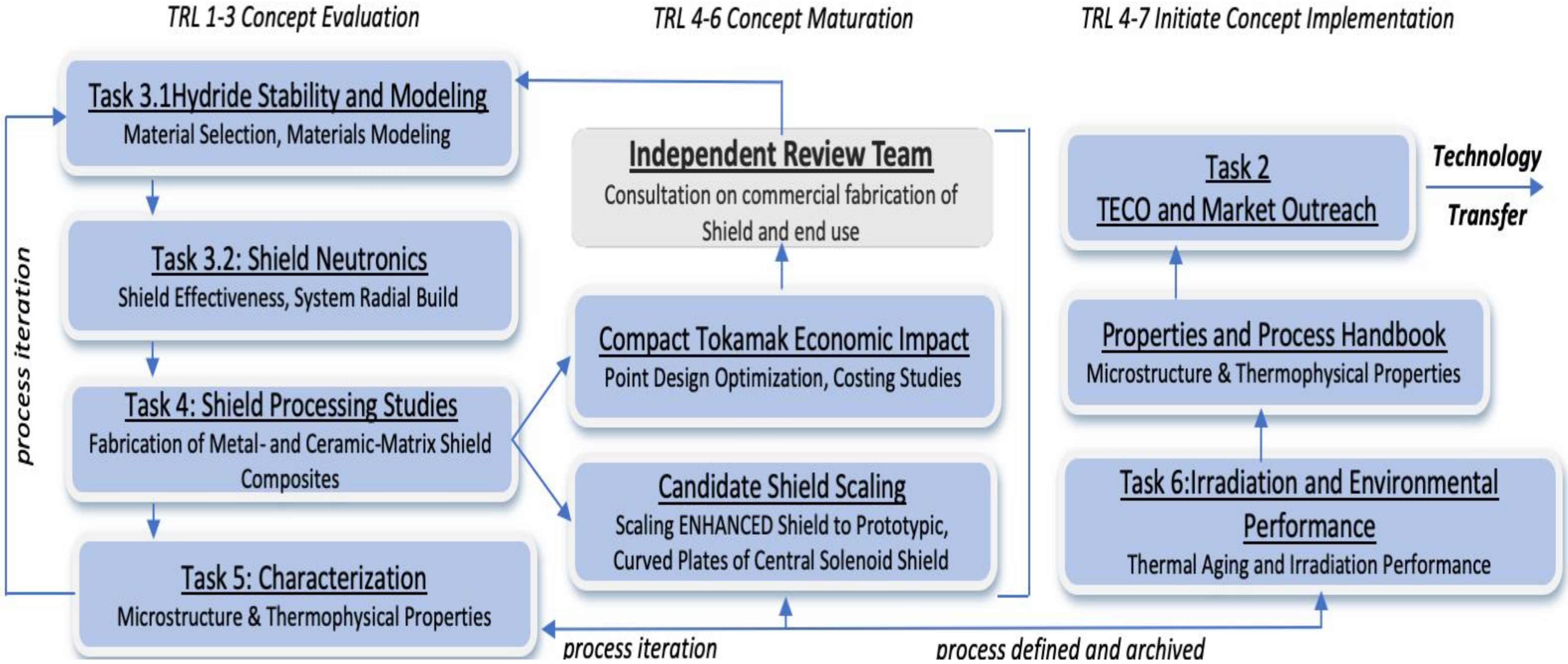
High-level motivation, innovation, and goals of the project





Major tasks, milestones, risks, and desired project outcomes

- Major milestone is the demonstration of a fabricable composite of adequate absorbing metal hydride density
- Major risks include loss of hydrogen at required processing temperature and under irradiation.



TECO and desired project outcomes

	State of the Art	Reactor	Milestone Metrics*
Technical Metrics			
1: Compact HTS Fusion Reactor Lifetime Inboard Shield	Current designs based on Steel, Boron Compounds, Tungsten bulky and require scheduled replacement.	CFS ARC Reactor TE-ST-40	ENHANCED Shield yielding <3E18 n/cm^2 fast in 30 years Heat deposit < 50 W/m^3 To inboard HTS TF Coil Matrix H/T diffusivity <10^{-10} cm^2/s Operating Temp. to 200°C H Loss/Redistribution < 15%
2: Compact HTS and Normal Conducting Outboard Shield	Use of Borated Steel, H_2O Assumed.	EU Demo HCPB	**-As above, with…-** Operating Temp. to 600°C Stretch Operating Temp 800°C H Loss/Redistribution < 20%
3: Scale Fabrication of Metal and Ceramic Matrix-Neutron Absorbing Hydride Shield	Scaling MgO-ZrH_2 in ARPA-E MEITNER. No other similar tech.	CFS ARC Reactor Inboard Shield	Curved Plates 10 x10 cm^2 Uniform H-content <15% Uniform density & K_{th}, <20%
Cost Metrics			
1: Reduced radial build & overnight construction cost	Assume current SPARC W/Steel/B_4C	CFS ARC Reactor TE-ST-40	>25% reduced shield thickness >20% reduced plant capital cost
2: Increased plant availability	n/a		>5% increase

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Aspirational follow-on plans

- Demonstration of Commercial Viability
  - Scale to repeatable large block.
  - Engage commercial fabricator to transfer technology.
  - Expand engagement with reactor designers.
- Improving understanding and TRL
  - Expanded modeling and performance information under irradiation.
  - Define limits of thermal performance.
  - Complete understanding of effect of hydrogen transport, redistribution, and loss.

Independent Review Team

Commonwealth Fusion Systems

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