INTERFACIAL-ENGINEERED MEMBRANES FOR EFFICIENT TRITIUM EXTRACTION

GAMOW Kickoff Meeting
January 21–22, 2021

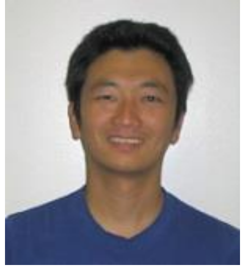
Colin Wolden, Colorado School of Mines

Doug Way (CSM), Tommy Fuerst (INL), Masahi Shimada (INL), Chase Taylor (INL), Paul Humrickhouse (INL)

Team members and roles

- Colorado School of Mines
- Professor Colin Wolden:
  - Interfacial engineering
  - Plasma processing
- Professor Doug Way:
  - Dense metal membranes
  - TEA/T2M for H_2 processing
- 2 PhD Candidates
- Undergraduate research assistants


- Idaho National Laboratory
- Dr. Thomas Fuerst: Membrane characterization and project coordination with CSM
- Dr. Masahi Shimada: PEAS, TPE, MFP, plasma-material interactions
- Dr. Chase Taylor: TEX, PEAS, radiation-material interactions
- Dr. Paul Humrickhouse: System design TEA/T2M for fusion applications

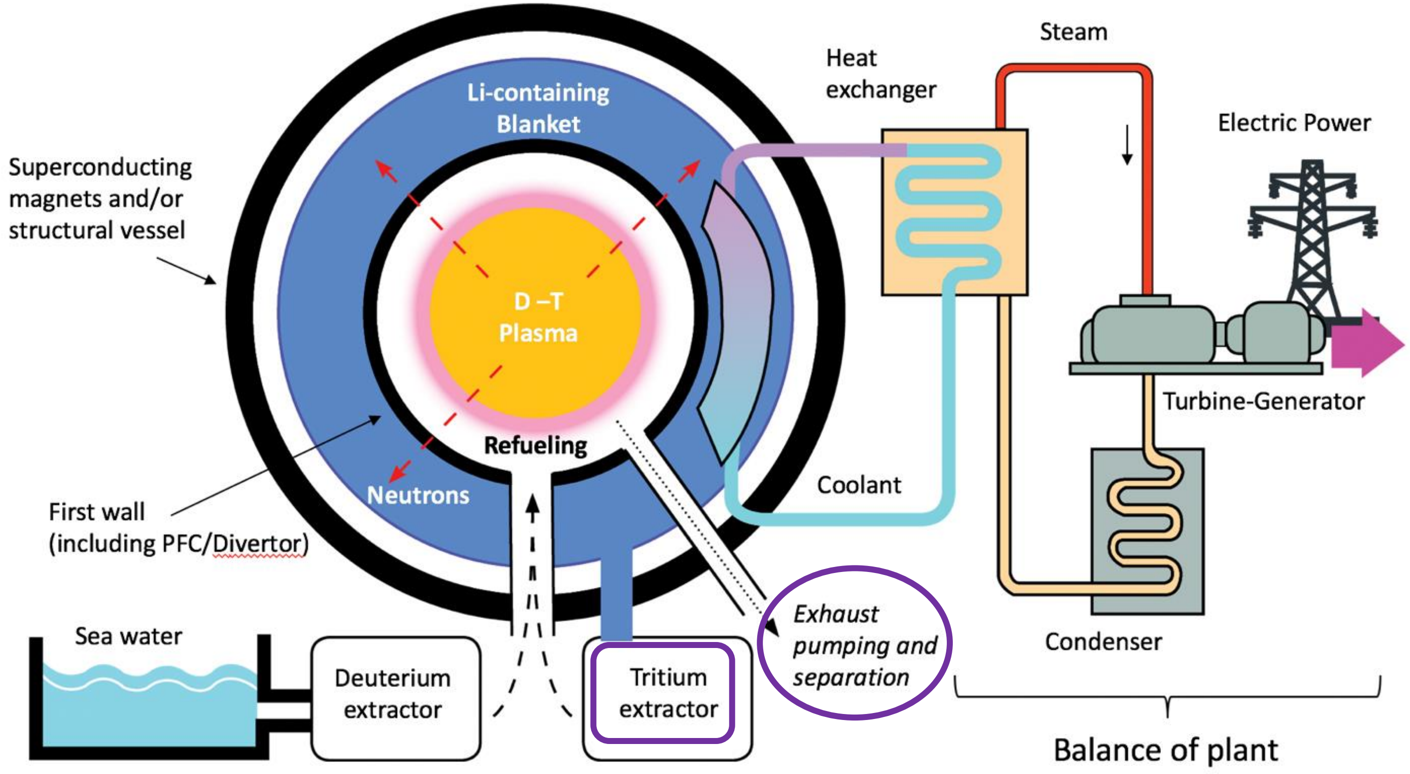
arpa·e
CHANGING WHAT'S POSSIBLE

COLORADOSCHOOLOFMINES
EARTH • ENERGY • ENVIRONMENT

INL
Idaho National Laboratory

Efficient Tritium Extraction Systems

- Challenge
  - Require >90% efficiency to ensure losses <10 g/year
  - State of the Art: Expensive Pd-Ag Foils
  - Gas liquid contactors, Cryopumps



- Exhaust Processing
  - ~1-5% DT burnup
  - T, D captured, enable direct recycle
  - Metal foil pumps (MFP)
- Breeding Blanket
  - Vacuum Permeator (VP)
  - Ceramic Breeders (He/T)
  - Liquids (e.g. PbLi, FLiBe)

arpa·e CHANGING WHAT'S POSSIBLE

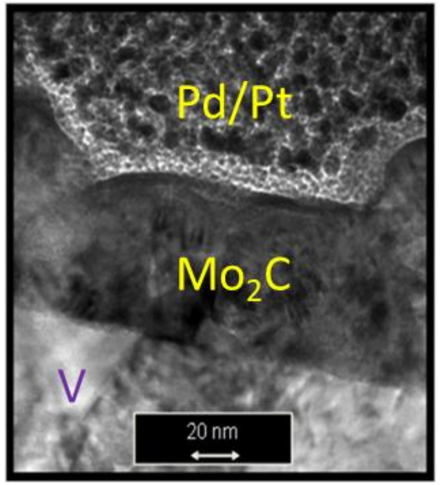
COLORADO SCHOOL OF MINES EARTH • ENERGY • ENVIRONMENT

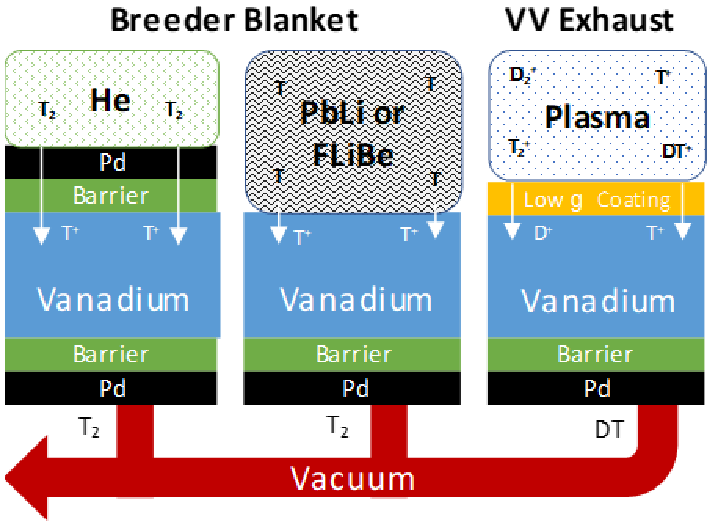
INL Idaho National Laboratory

Approach and Innovation: Composite Membranes

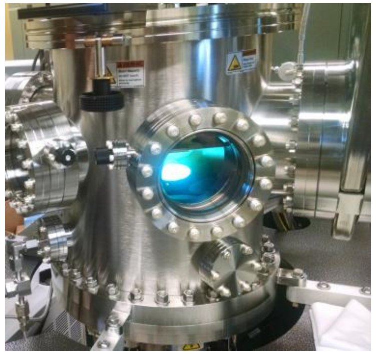
- Base: Dense Vanadium Foils
  - Permeability >10^{-7} mol.m/m^2.s.$Pa^{0.5}$
  - Thermally stable, neutron tolerant
  - 100% selectivity for H isotopes

- Interfacial Engineering
  - Impart performance & stability
  - Nanometer scale coatings





- Membrane Fabrication
  - Semiconductor precision
  - ALD, sputtering, RTP



- Advanced Characterization
  - Membrane performance
  - Characterization: TEM, XRD, XPS, TOF-SIMS, etc.
  - Accelerated lifetime testing
  - Plasma permeation

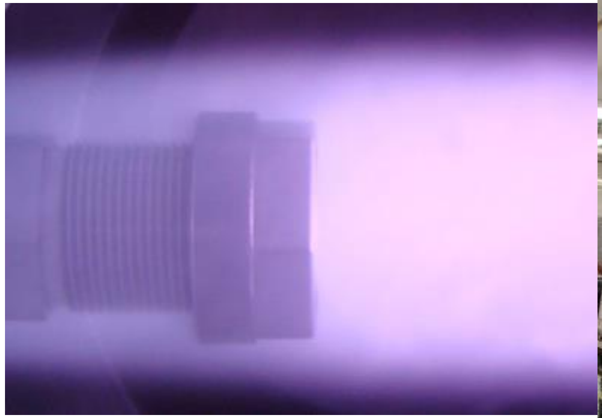
arpa·e CHANGING WHAT'S POSSIBLE

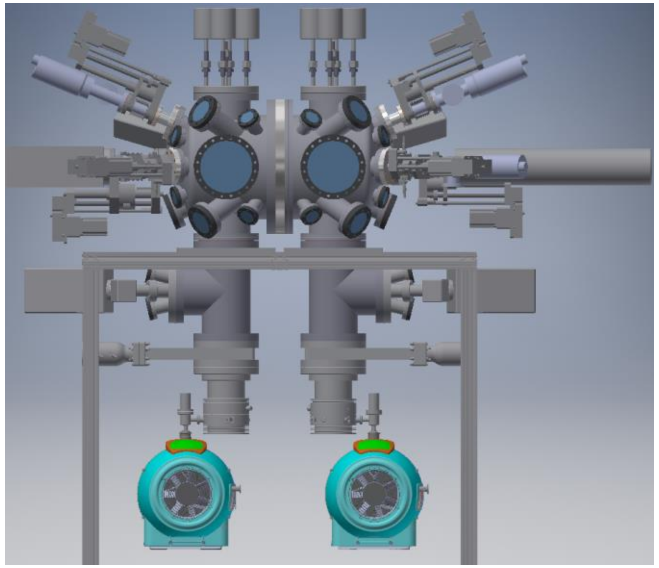
COLORADO SCHOOL OF MINES EARTH • ENERGY • ENVIRONMENT

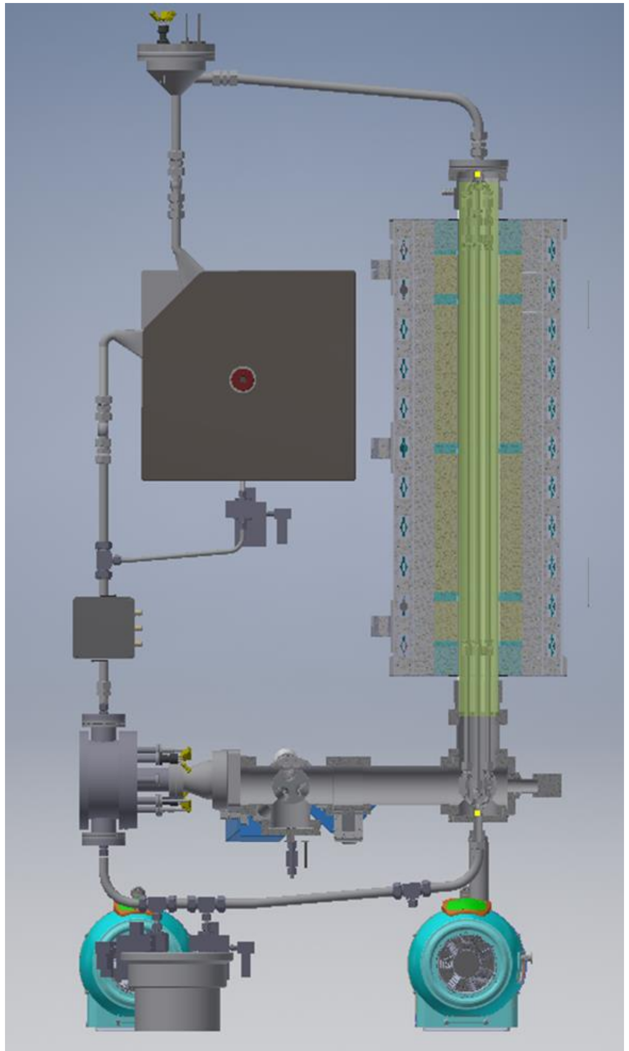
INL Idaho National Laboratory

Validation: INL

- Safety & Tritium Applied Research (STAR) Facility
  - Tritium Gas Absorption and Permeation (TGAP)
  - Tritium Plasma Experiment (TPE)
  - Permeation Experiment for Asymmetric Surfaces (PEAS)
  - Tritium Extraction eXperiment (TEX)
  - Material Capabilities: Tritium, PbLi, FLiBe
  - Design and systems analysis







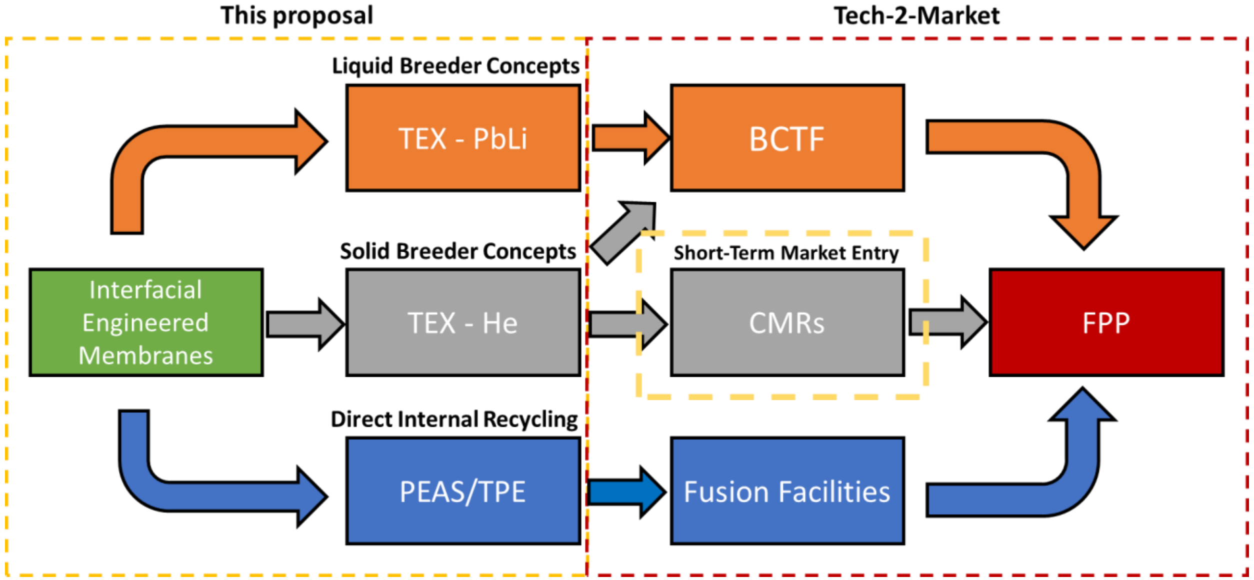
Major tasks, milestones, risks, and desired project outcomes

- Breeder Blanket (He/H_2)
  - Intermediate: $\pi > 10^{-8}$ mol m^{-1} s^{-1} $Pa^{-0.5}$
  - Final: Stable $\pi > 5x10^{-8}$ mol m^{-1} s^{-1} $Pa^{-0.5}$
- Metal Foil Pumps
  - Intermediate: $S > 2$ m^3 s^{-1} m^{-2}
  - Final: $S > 10$ m^3 s^{-1} m^{-2}
- Isotope Validation
  - Isotope Effects: TGAP, TPE, TEX
  - PbLi Extraction: >80% recovery
- Design & Analysis
  - Evaluate requirements for 200 MW_e scale
  - Assess techno-economics

- Technical Risks & Mitigation
  - Achieving target permeance & stability
  - Achieving target pumping speeds
- Technical Mitigation
  - High throughput screening
  - Accelerated lifetime testing
- Scale-up Challenges
  - Transition to tubular geometry
  - Supply V tubes

T2M and aspirational follow-on plans

- Techno-economic metrics
  - Standard: PdAg Foil
  - Reduce from \$700K to <\$5K/m^2
  - Plant: Reduce \$26M to <\$1M
- Efficient Exhaust Processing
  - Cryopump technology can't scale
  - Continuous pumping with MFP
  - Reduce burden on tritium plant by 90%
- Test & deployment plans/aspirations
  - Adaptable to different breeder concepts
  - Potential partnerships with private sector
  - Translation from planar to tubular format



- Bridge: Conventional H_2 Separation
  - Hydrogen for FCEVs
  - H_2 Production: Steam methane reforming
  - Various hydrogenation/dehydrogenation processes, separations

arpa·e CHANGING WHAT'S POSSIBLE
COLORADO SCHOOL OF MINES EARTH • ENERGY • ENVIRONMENT
INL Idaho National Laboratory