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Harnessing Fusion Power Theme Summary

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Fusion Power Theme Leaders

- Chair: Wayne Meier, LLNL
- Vice-chair: Rene Raffray, UCSD
- OFES Champion: Barry Sullivan

Panel Leaders

- Fusion Fuel Cycle - Scott Willms, LANL
- Power Extraction - Neil Morley, UCLA
- Materials - Rick Kurtz, PNNL
- Safety and Environment - Phil Sharpe, INL
- RAMI - Wayne Reiersen, PPPL
  (Reliability, Availability, Maintainability, Inspectability)

Harnessing Fusion Power panel members

Fusion Fuel Cycle	Materials	Safety and Environment
Scott Willms, LANL	Rick Kurtz, PNNL	Phil Sharpe, INL
Larry Baylor, ORNL	Mike Mauel, Columbia	Laila El-Guebaly, UW
Jim Klein, SRNL	Michael Nastasi , LANL	Catherine Fiore, MIT
Martin Peng, ORNL	Bob Odette, UCSB	Kofi Korsah, ORNL
Dai-Kai Sze, UCSD	Shahram Sharafat, UCLA	Jim Mara, SRNL
Alice Ying, UCLA	Roger Stoller, ORNL	Nermin Uckan, ORNL
	Steve Zinkle, ORNL	
Power Extraction	**RAMI**	
Neil Morley, UCLA	Wayne Reiersen, PPPL	
Charlie Baker, Self Emp	Mohamed Abdou, UCLA	
Pattrick Calderoni, INL	Tom Burgess, ORNL	
Richard Nygren, SNL	Lee Cadwallader, INL	
Arthur Rowcliffe, ORNL (ret)	John Sheffield, UT	
Mohamed Sawan, UW	John Smith, GA	
Ron Stambaugh, GA	Les Waganer, Boeing Conslt	
Grady Yoder, ORNL		

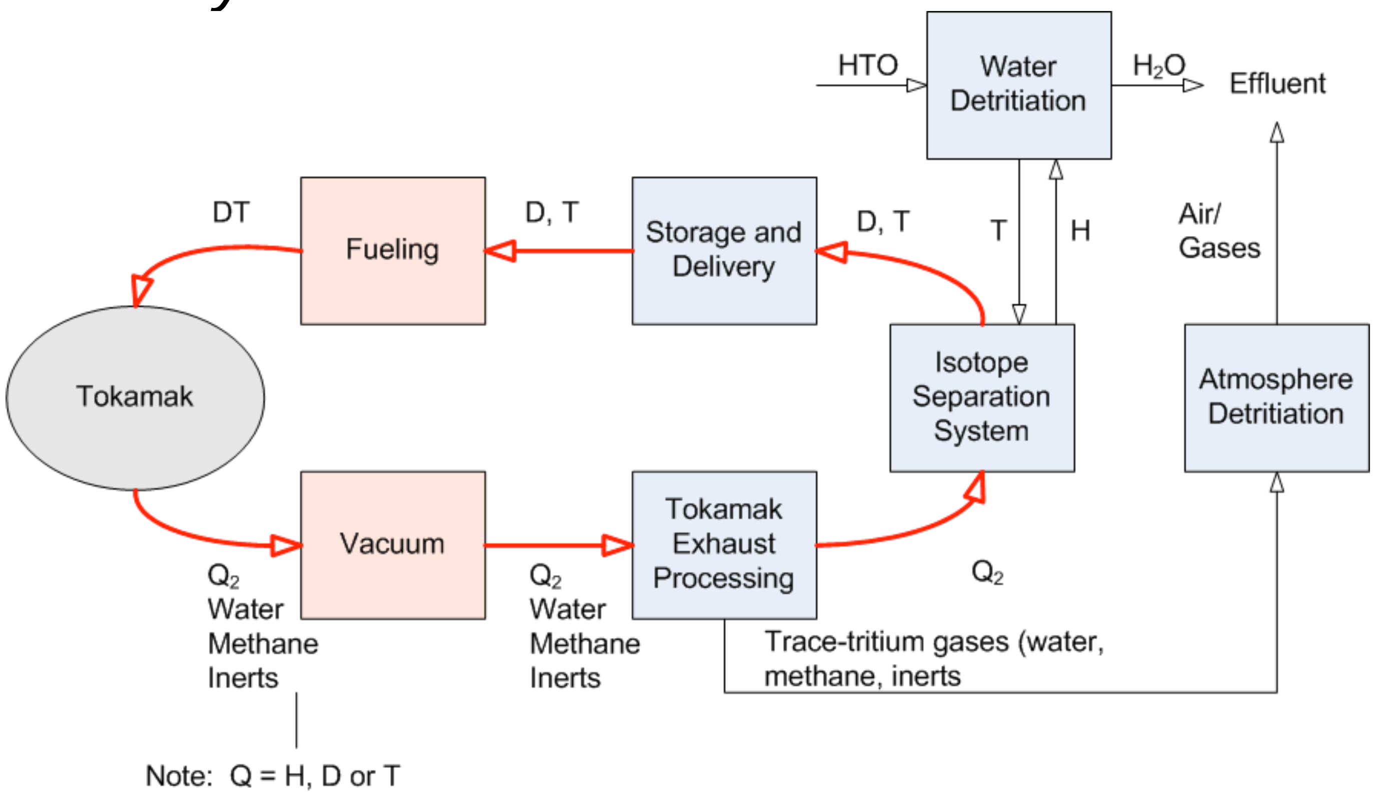
Top Level Issue from Greenwald

Harnessing Fusion Power:

The state of knowledge must be sufficient to design and build, with high confidence, robust and reliable systems that can convert fusion products to useful forms of energy in a reactor environment, including a self-sufficient supply of tritium fuel.

Fusion Fuel Cycle - Top level issue

- *Learn and test how to manage the flow of tritium throughout the entire plant, including breeding and recovery.*



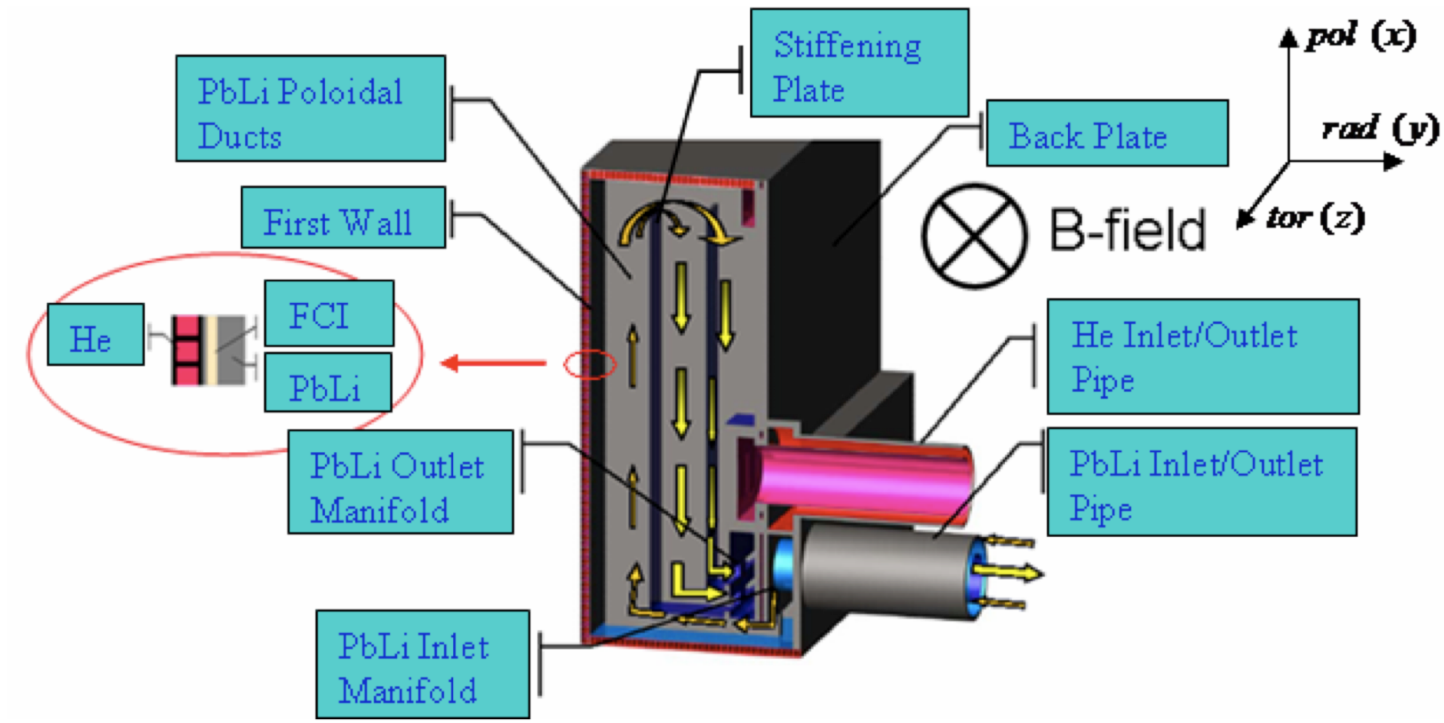
Fuel Cycle – Research requirements

Many of the fusion fuel cycle requirements for a DEMO are orders of magnitude greater than demonstrated capabilities. New or different technologies and approaches or significant scale-up of existing technologies will be needed to:

- Process fusion fuel
- Provide vacuum and recover DT from vacuum system
- Inject DT fuel (fueling)
- Breed adequate tritium (T), i.e., tritium breeding ratio > 1
- Extract tritium from the breeding system
- Characterize, recover and handle in-vessel tritium
- Contain/confine tritium
- Perform tritium accountability and nuclear facility operations

Power Extraction (PEx) - Top level issue

- *Understand how to extract fusion power at temperatures sufficiently high for efficient production of electricity or hydrogen.*



Power Extraction - Research requirements

Human resources, modeling, analyses, and experiments are needed to:

- Determine spatial and temporal temperature variations, coolant flow, and transport phenomena at fusion relevant parameters
- Develop techniques for control of coolant chemistry and impurities
- Understand synergistic phenomena in PEx components resulting from multi-field, multi-material, or multi-function effects
- Develop knowledge and ability to fabricate, maintain, and diagnose complex PEx components and systems with fusion relevant materials
- Integrate knowledge base into models capable of predicting PEx component behavior beyond parameters of the experimental database and acceptable to design/license components for Demo
- Carry out design and R&D on alternatives to mainline concepts for divertor and FW/Blankets (e.g. with different materials or feasibility issues, improved margin or performance)

It is not possible to decouple PEx research from other elements of Fusion Power Theme

- **Power extraction is a driver of component temperature**
  - Higher temperature is better for power conversion efficiency or process heat
  - Temperature in turn influences/drives many phenomena: thermal stress, creep, tritium permeation/recycling from PFCs, corrosion processes, etc.
- **It is clear that the fuel cycle and power extraction are directly linked**
  - Blankets and supporting systems must perform both functions of power extraction and tritium breeding/extraction.
  - The FW and divertor can be sites for tritium holdup as well as blanket materials (such as breeders and multipliers)
- **Materials, Safety, RAMI help set the boundaries of what is possible and what is acceptable for power extraction component designs**

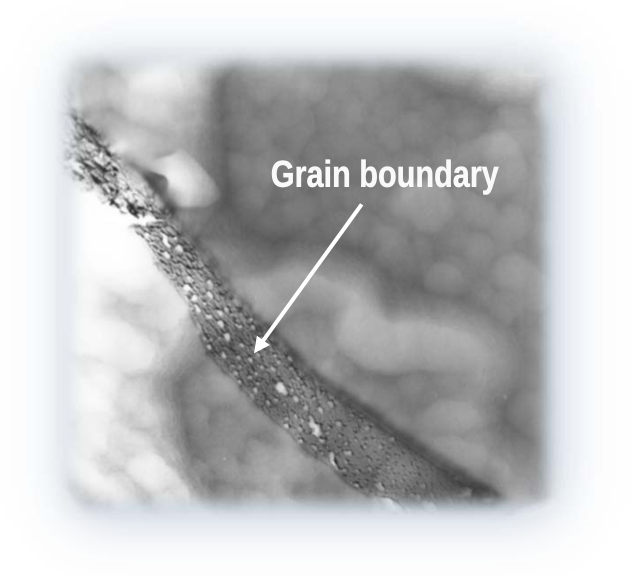
PEx research requirements must be developed in an integrated manner

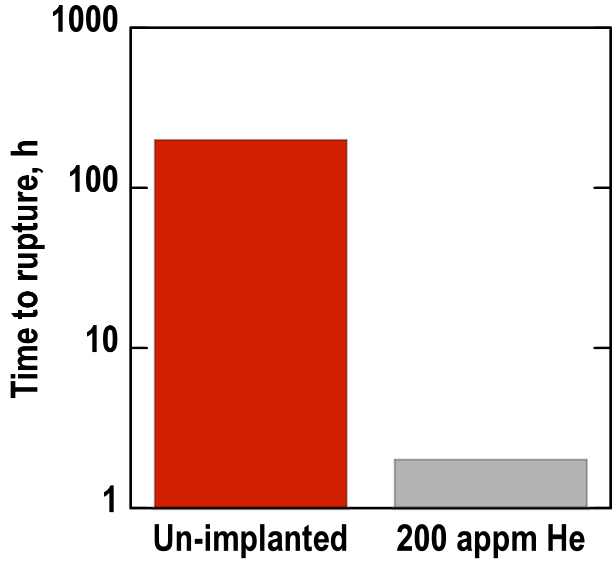
The requirements of PMI, Magnetic Configuration, Plasma Control and Off-normal events have to be developed in concert with real PEx components, material requirements, and operation temperatures.

- PFC is really a special case of power extraction -- interfacing power extraction with PWI and particle pumping
- Configuration and control schemes must be developed with knowledge of power extraction requirements
- Integrated solutions needed for fusions most difficult problems
- Power extraction is an enabling technology for all long pulse and DT plasma experiments in the future, including ITER

Materials - Top level issue

- *Understand the basic materials science for fusion breeding blankets, structural components, plasma diagnostics and heating components in high neutron fluence areas.*





Materials – Research requirements

- The overarching scientific challenge facing structural materials for DEMO is microstructural evolution and property changes (mechanical and physical) that may occur for neutron doses up to ~200 dpa and ~2000 appm He.

- Development of high-performance alloys and ceramics including large-scale fabrication and joining technologies is needed.

- Current understanding of strength-ductility/toughness relationships is inadequate to simultaneously achieve high-strength and high-ductility and toughness.

Materials – Research requirements (cont.)

- Better mechanistic physical models of thermo-mechanical degradation are needed for development of advanced materials and science-based high-temperature structural design criteria.

- The mechanisms controlling chemical compatibility of materials exposed to coolants and erosion of materials due to interaction with the plasma are poorly understood.

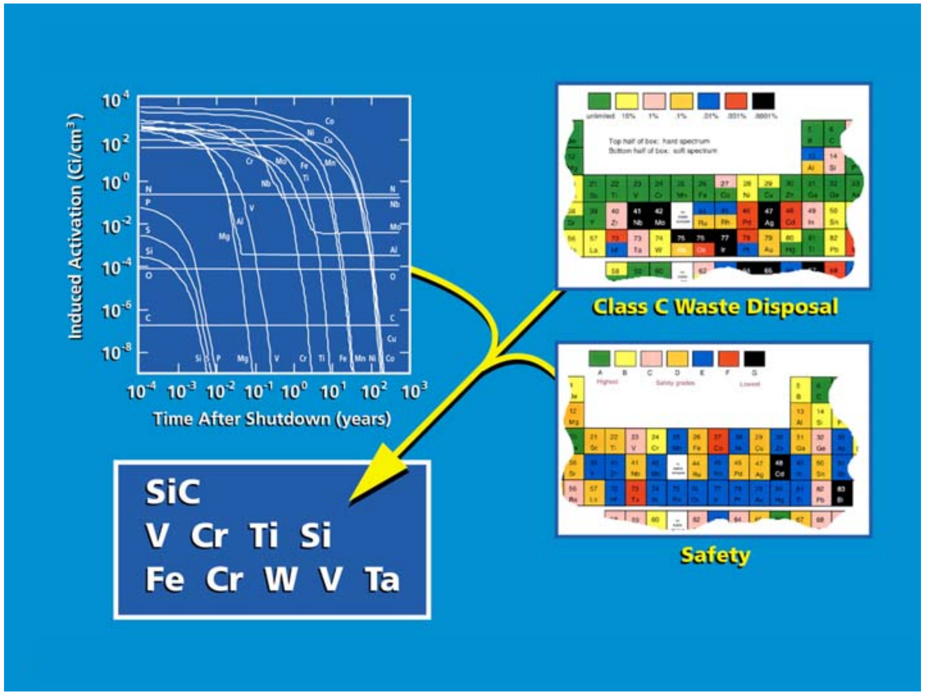
- Better understanding of radiation-induced and thermo-mechanical property changes in high-heat flux materials (tungsten), magnet, and a host of functional materials is required.

Materials – Resource needs

- Research Scientists and Engineers
- Materials Science Facilities
- Non-Nuclear Structural Integrity Benchmarking Facilities
- Extensive computational resources
- Fission Reactors
- Intense Neutron Source

Safety and Environment – Top level issue

- *Demonstrate the safety and environmental potential of fusion power to preclude the technical need for a public evacuation plan, and to minimize the environmental burdens of radioactive waste, mixed waste, or chemically toxic waste for future generations.*

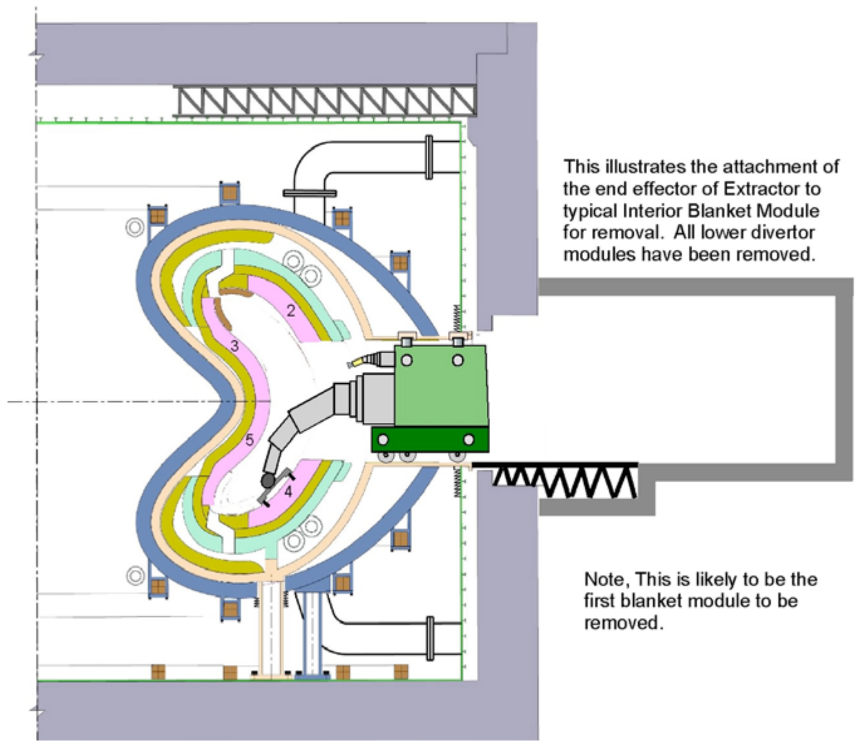


S&E - Research needs

- Need to extend US Fusion Safety Standard to next-step devices and DEMO plant conceptual designs and lead an effort towards an international fusion safety framework.
- Credible safety analyses require continued development of computational tools and database of materials responses to postulated off-normal or accident conditions.
- Develop recycle and clearance-based solutions to fusion's waste stream; refine strategies for de-tritiation of materials.
- Methods for monitoring/removing radioactive materials during facility (e.g. ITER, FNSF, DEMO) operation.
- Longer term, component qualification is need to validate facility design and functionality of key safety components (e.g. primary confinement boundary) and passive features.

RAMI – Top level issue

- *Demonstrate the productive capacity of fusion power and validate economic assumptions about plant operations by rivaling other electrical energy production technologies.*



RAMI – Research needs

The availability for DEMO much be adequately high (>50%) for the power producers to commit to building a commercial fusion plant.

To achieve this goal, DEMO must feature:

- An integrated design with component reliability, maintainability and lifetime characteristics, which promote high availability;
- An effective inspection and maintenance system that is proficient in monitoring equipment health, detecting and isolating failures, providing spares, effecting and verifying repair, refurbishing failed components, and processing radwaste.
- Tolerance for any disruptions or off-normal events that could occur.

RAMI – Research needs (cont'd)

This will require R&D activities in the following areas:

- Testing components in test facilities and monitoring in-service performance in present-day and future machines to develop needed reliability and lifetime data.
- Initiating an aggressive reliability growth and maintainability improvement program which builds on what we learn from testing and operating components.
- Initiating an integrated design activity for DEMO that will process what we learn from ITER, test facilities, and future CTF/FDF-class machines and develop a credible, low risk, attractive design for DEMO.
- Developing the design of an efficient remote handling system and hot cell facility as part of the integrated design activity, performing preparatory RH R&D, and prototyping RH on CTF/FDF-class machines.

Three thrusts have been proposed

13. Establish the Underlying Science and Technology Needed for Fusion Power Extraction and Fuel Sustainability (to be presented by Neil Morley)

14. Materials Science and Technology Needed to Harness Fusion Power (Rick Kurtz)

15. Create Integrated Models and Designs for Attractive Fusion Power Systems (Rene Raffray)