Harnessing Fusion Power: Thrusts 13-15

Wayne Meier, LLNL

Rene Raffray, UCSD

Barry Sullivan, OFES

Research Needs Workshop (ReNeW)
Bethesda, MD
June 8-13, 2009

Portions of this work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344

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		

Scope of Harnessing Fusion Power

- Realizing the promise of a safe, environmentally attractive and reliable power source with an abundant fuel supply requires the development and integration of a variety of fusion chamber components and related systems.
- Thrusts 13-15 focus on this R&D.

13. Establish the Science and Technology Needed for Fusion Power Extraction and Fuel Sustainability

- A fusion plant must create the tritium fuel it uses and operate a high temperature so that the fusion energy can be converted efficiently to produce electrical power or for other possible end uses.
- This thrust develops the scientific foundation and engineering of practical, safe and reliable processes and components needed for fusion to
  1) harvest the heat produced
  2) create and extract the tritium
  3) rapidly process and contain the tritium

13. S&T for Fusion Power Extraction and Fuel Sustainability – Actions (1)

- Perform fundamental research to establish the scientific parameters necessary to address issues related to power extraction, tritium breeding and processing.

- Perform multiple effect studies to understand the combined impact of conditions and complexity more typical of a fusion environment.
  - e.g., Use ITER TBM to test tritium breeding and power extraction experiments with relevant materials, instrumentation, and designs at relevant operating temperatures.

13. S&T for Fusion Power Extraction and Fuel Sustainability – Actions (2)

- Perform integrated experiments to characterize facility performance.
  - e.g., Construct and operate a fusion nuclear science facility (FNSF) to resolve key knowledge gaps to a Demo stemming from effects of significant neutron flux and fluence in concert with all other fusion environmental conditions.

- Develop theory and predictive models, and collect reliability and safety data at all stages.

14. Materials Science and Technology Needed to Harness Fusion Power

- Fusion materials and structures must function for a long time in a uniquely hostile environment that includes combinations of high temperatures, reactive chemicals, high stresses, and intense damaging radiation.

- Ultimately, we need to establish the feasibility of designing, constructing and operating a fusion power plant with materials and components that meet demanding objectives for safety, performance and minimal environment impact.

14. Materials Science and Technology Needed to Harness Fusion Power – Actions (1)

- Improve the performance of existing and near-term materials, while also developing the next generation of high-performance materials with revolutionary properties.
  - ductility and resistance to cracking
  - high-temperature capability
  - corrosion resistant
  - technologies to fabricate and joining
  - minimum radioactive waste, maximum recycling

14. Materials Science and Technology Needed to Harness Fusion Power – Actions (2)

- Develop and experimentally validate predictive models describing the behavior and lifetimes of materials in the fusion environment.
- Establish a fusion-relevant neutron source to perform accelerated evaluation of the effects of radiation damage to materials.
- Implement an integrated design and testing approach for developing materials, components, and structures.
- Use a combination of existing and new non-nuclear and nuclear test facilities to validate predictive models and determine the performance limits of materials, components and structures.

15. Create Integrated Models and Designs for Attractive Fusion Power Systems

This thrust includes two primary aspects:

1) A science-based predictive modeling capability for plasma chamber components and related systems

2) Advanced design studies focused primarily on DEMO, but also on nearer term fusion nuclear facilities.

- Integrated models will be used to reveal important science and technology interrelationships and help interpret the results experiments and component tests.
- Detailed advanced design studies for DEMO will assess integrated safety, environmental and availability issues for fusion and develop a readily inspectable and maintainable configuration.
- Integrated modeling and design activities are also essential in evaluating alternatives for a fusion nuclear science facility (FNSF)

15. Create Integrated Models and Designs for Attractive Fusion Power Systems – Actions (1)

- Develop and validate predictive modeling capability for nuclear components and associated systems.
- Extend models to cover synergistic physical phenomena for prediction and interpretation of integrated tests (e.g., ITER Test Blanket Module).
- Develop methodologies to integrate with plasma models to jointly supply key first wall and divertor temperature, electromagnetic responses, etc.

15. Create Integrated Models and Designs for Attractive Fusion Power Systems – Actions (2)

- Assess and improve essential aspects of fusion energy through detailed advanced design and integration activities for DEMO, including:

  - optimizing the configuration, and maintenance approach to achieve the availability, maintainability, safety and environmental requirements for DEMO

  - laying out the scientific basis for fusion power and identifying research efforts to close the knowledge gap to DEMO

- Evaluate alternative configurations and designs through first stage of FNSF effort.