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Harnessing Fusion Power Theme Workshop - Recap

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Research Needs Workshop (ReNeW)

Theme V Workshop

PPPL

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Fusion Power Theme Leaders

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

Panel Leaders

- Scott Willms, LANL
- Neil Morley, UCLA
- Rick Kurtz, PNNL
- Phil Sharpe, INL
- Wayne Reiersen, PPPL

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.

We have 5 panels under Fusion Power

- **Fusion Fuel Cycle (S. Willms):** *Learn and test how to manage the flow of tritium throughout the entire plant, including breeding and recovery.*
- **Power Extraction (N. Morley):** *Understand how to extract fusion power at temperatures sufficiently high for efficient production of electricity or hydrogen.*
- **Materials Science in the Fusion Environment (R.Kurtz):** *Understand the basic materials science for fusion breeding blankets, structural components, plasma diagnostics and heating components in high neutron fluence areas.*

We have 5 panels...(cont.)

- **Safety and Environment (P. Sharpe):** *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.*
- **Reliability, Availability, Maintainability and Inspectability (RAMI) (W. Reiersen):** *Demonstrate the productive capacity of fusion power and validate economic assumptions about plant operations by rivaling other electrical energy production technologies.*

Complete talks are posted on UCLA web site

- http://www.fusion.ucla.edu/FNST/Renew_Presentations/
- Session 1: Introductory talks by Panel leaders to describe issues, gaps and research needs
- Sessions 2-6: Contributed and stimulated talks providing more details on needs and proposed thrusts

General approach by the Panels

- Review of Greenwald issues (some modification, or recasting of issues)
- Briefly assessed state-of-the-art
- Identified gaps to demo
- Identified research needs to fill gaps
- Proposed preliminary research thrusts to fill gaps
- Some attempt at integration/cross-cutting

By the end of the presentations, we had 21 proposed thrusts

Fusion Power Theme	
Fuel Cycle Panel	
TRT-1	ITER
TRT-2	ITER TBM
TRT-3	Neutron Irr. Permeation Barrier Experiment
TRT-4	Heated Sector
TRT-5	Extraction Experiment
TRT-6	Tritium Processing Facility
TRT-7	Fuel Cycle Dev. (non-T)
TRT-8	FNSF (CTF)
TRT-9	Fuel Cycle Modeling
Power Extraction Panel	
PRT-1	Building a fusion nuclear science and technology capability: A coordinated R&D and engineering design program
PRT-2	Survive and grow in the fusion environment: Fusion break-in experiments for FW/blanket/divertor, material, and diagnostics performance
PRT-3	Feasibility and reliability of the fusion power components: establishing tritium self-sufficiency and continuous high grade power extraction for fusion (comprehensive program up to testing in a CTF)

...21 thrusts (cont.)

Materials Panel	
MRT-1	Identify and demonstrate approaches to improve the performance of existing and revolutionary materials, components and structures using a full suite of non-nuclear structural integrity benchmarking facilities, existing irradiation facilities, and a fusion-like neutron source.
MRT-2	Develop and utilize the full range of computational and modeling tools to understand and predict of the performance of materials, structures and components in the fusion environment.
Safety and Environment Panel	
SRT-1	Extension of the US Fusion Safety Standard to next-step devices and DEMO plant conceptual designs; lead an effort towards an international fusion safety framework
SRT-2	Develop recycle and clearance-based solutions to fusion's activated material stream; refine strategies of de-tritiation of materials
SRT-2'	Enhance design integration through safety in maturing designs of next-step devices and DEMO/plants
SRT-2''	Methods for monitoring/removing radioactive materials during DEMO/plant operation
RAMI Panel	
RRT-1	Initiate an integrated design activity for DEMO
RRT-2	Initiate an international RAMI data collection system through ITER that can be a pattern for existing and future experimental and test facilities
RRT-3	Design, construct, and operate a Component Test Facility/Fusion Development Facility(ies) which will provide...

An initial attempt was made to integrate these into a few large thrusts with sub-elements

DRAFT for Fusion Power Theme Comment – Not for general distribution (3/5/09)

Harnessing Fusion Power Theme

Grand Challenge: Harness magnetic fusion plasma to provide an environmentally and economically attractive carbon-emission-free energy source.

Overarching Scope: Basic research needs in material, nuclear and engineering science on the path to a fusion energy source.

Definition of Research Thrust: "An organized, multi-faceted attack on some question, or coherent set of questions, essential to magnetic fusion energy science and technology, using a combination of new and existing program elements."

Top-Level Thrusts and Key Elements:

- **Material Science and Component Engineering Thrust** to develop and qualify structural and functional materials for reliable (e.g., corrosion resistant and radiation damage tolerant), efficient (e.g., high temperature capable) and environmentally attractive (e.g., low activation) fusion energy systems:
 - o Develop and utilize experimentally validated, multiscale models for materials in the fusion environment.
 - o Establish and implement integrated, concurrent materials-structure design approach to fusion systems.
 - o Utilize non-nuclear structural testing facilities to reveal fundamental material performance properties.
 - o Establish underlying science basis for recycling and free-release of fusion materials to minimize need for disposal.
 - o Evaluate options, select and facilitate the experimental tools (e.g., intense neutron sources and large volume neutron sources (such as the FNSF described below)) needed to explore fusion relevant radiation damage to material samples and structures.
- **Fusion Nuclear Science Thrust** to establish fusion fuel self-sufficiency and develop systems to extract fusion power reliably, efficiently, safely and with minimal environmental impact:
 - o Create models and perform small-scale validation experiments for components and sub-scale systems needed for efficient (i.e., high temperature) and reliable power handling and extraction (non-nuclear experiments and facilities).
 - o Create, model and test techniques, components, and facilities needed to reliably, efficiently, and safely fuel the fusion plasma. Including tritium recovery from the plasma chamber and breeding materials.
 - o Develop and test autonomous remote maintenance approaches, techniques and equipment capable of operating in a fusion nuclear environment.
 - o Understand failure modes and conduct reliability growth program.
 - o Utilize ITER burning plasma to perform integrated experiments on first wall breeding blanket systems in a fusion environment (i.e., TBM).

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- o Address and resolve key FNS research needs in a fully integrated fusion nuclear science facility (FNSF):
 - Define research requirements and mission, evaluate alternatives through first stages of design and R&D, and select best Demo-relevant option(s).
 - Design, build and operate FNSF to mature science and technology base in preparation for Demo.
- **Cross-Cutting Modeling and Systems Integration Thrust** to help guide, support and integrate individual R&D efforts:
 - o Assess and improve key aspects of fusion energy through detailed conceptual design and systems integration activities for fusion R&D facilities (e.g., FNSF, Demo):
 - Integrated design to balance all design aspects, including performance, safety, environmental impact, availability (RAMI), and economics.
 - o Develop fully integrated, predictive modeling capability, validated by experiments, ranging from basic phenomena through synergistic physical phenomena in plasma chamber components and systems needed for fusion energy. Utilize modeling tools to optimize approaches and inform R&D priorities:
 - Integrated multi-physics simulations of nuclear components.
 - Multiscale predictive modeling of activation source term.
 - RAMI data collection and predictive modeling. (RAMI members – need words here and elsewhere?)

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Three top-level thrusts were:

- **Material Science and Component Engineering Thrust** to develop and qualify structural and functional materials for reliable (e.g., corrosion resistant and radiation damage tolerant), efficient (e.g., high temperature capable) and environmentally attractive (e.g., low activation) fusion energy systems:
 - ...
- **Fusion Nuclear Science Thrust** to establish fusion fuel self-sufficiency and develop systems to extract fusion power reliably, efficiently, safely and with minimal environmental impact:
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- **Cross-Cutting Modeling and Systems Integration Thrust** to help guide, support and integrate individual R&D efforts
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We are now re-working this to identify thrusts in a range of sizes – “small, medium and large”

- As is, the top-level thrust summary fails to provide the range of thrust sizes that is considered valuable in selling new work in bite size pieces.
- Question is how best to do this?
 - Eventually it all needs to be done (if we have the gaps and needs correct)
 - There are many “small” things that could be done. How do we chose what should be small, medium, large? Does that imply priority?
 - Also need temporal and logical connections and integration with other Themes