Blanket and First Wall Science Priority and Funding Requirements, as Part of a Broader Fusion Materials and Nuclear Science Program

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Recommendation:

Give Breeding Blanket and First Wall research a much higher priority in the US fusion program going forward, and increase annual funding by $5M in 2013.

Introduction

- The Breeding Blanket with integrated First Wall (FW) is the key nuclear component for power extraction, tritium fuel sustainability, and radiation shielding. The Blanket and FW:
  - is a single component performing multiple functions, sharing the same coolants and structure
  - must operate in an unprecedented fusion environment and dominates the potential reliability, maintainability and safety of fusion energy
  - is the prime user of, and sets the requirements for, advanced reduced activation structural and functional materials being developed for the fusion environment
  - provides the boundary to the plasma, and both influences the plasma EM and vacuum conditions as well as being strongly impacted by plasma conditions and events (e.g. disruptions)
  - requires multidisciplinary scientific expertise (e.g. neutron/photon/plasma transport and material interactions; heat, tritium and corrosion mass transfer; incompressible MHD and fluid dynamics; material science; structural and thermo- mechanics; thermodynamics; hydrogen chemistry; engineering scaling and statistical reliability methodology)

Situation Analysis

- The blanket and first wall program in the US has been chronically underfunded for >15 years; and despite major technical planning activities by the community, there is yet no official strategy to develop its scientific basis for fusion. This situation has:
  - hampered R&D efforts to advance Blanket and First Wall development and resolve scientific feasibility issues for fusion power extraction and tritium sustainability
  - limited the training and retention of young scientists even as senior experts retire
  - led to a general deterioration of facilities and capabilities in the US, who once led this area worldwide and invented most current blanket/first wall concepts.
  - prevented the US from performing experiments on US blanket concepts as part of the ITER Test Blanket Module program (only the US is not officially participating in blanket experiments in ITER)

- The recent Priorities, Gaps and Opportunities[1]; Renew[2]; FNS Pathways[3]; and FESAC Material Science and Technology Opportunities[4] studies have all emphasized that an increased priority and funding is necessary for Fusion Nuclear Science including the Blanket/FW. These studies have noted that:
  - significant challenges remain in the development of power extraction and tritium breeding components for fusion, e.g. "at present these systems are at a low technical readiness level with high uncertainty as to the performance of envisioned solutions and material systems"[4]
  - uncertainty in blanket/FW performance leads to uncertainty in physics and material requirements, design margin, failure rates and effects, achievable tritium production, and safety
  - strong linkages between engineering & materials sciences and plasma physics are essential to address difficult challenges (e.g. blanket disruption survivability, non-conformal FW heat flux)
  - the US has developed a potentially attractive family of blanket concepts based on liquid lead-lithium alloy breeder that should serve as the primary focus of a renewed US research on blanket systems, the so-called Dual Coolant Lead Lithium (DCLL) blanket being a leading example
  - the development of coupled models and predictive capabilities that can simulate time-varying temperature, mass transport, MHD, and mechanical response of blanket components and systems is a strength area for US research and should be emphasized
  - a fusion nuclear science facility is needed as an integrated, middle-life fluence test device for the blanket, first wall, divertor and plasma support technologies – commonly referred to as FNSF

Conclusions

- The proposed $5M increase in funding level for Blanket / FW is the <u>minimum</u> necessary to begin credible research on R&D priorities identified in recent community studies[3,4]. Increasing blanket R&D efforts in the US will:
  - allow examination of key feasibility issues for the lead-lithium based blanket concepts necessary to provide confidence in their continued development beyond the separate-effects level
  - address the ability of ferritc steel to accommodate highly non-uniform first wall heat flux
  - restore a viable Blanket/FW Program in the US that can interact effectively with the recently strengthened US Materials and PFC programs, the US plasma physics program, and international Blanket / First Wall and Materials programs.
  - replenish and expand the number of trained students and scientists who can understand and help resolve the competing requirements of high performance plasma operation with the material, engineering and safety limits of the Blanket/FW, as well as the production of sufficient tritium and efficient reliable energy.
    The kind of training needed to perform research and engineering within this highly constrained fusion system takes many years of education and experience.
  - mitigate the negative consequences of not leading an ITER test blanket research effort by participating as a strong collaborator with other parties.
  - gain sufficient understanding of the Blanket/FW science and engineering to enable informed decisions in the fusion program

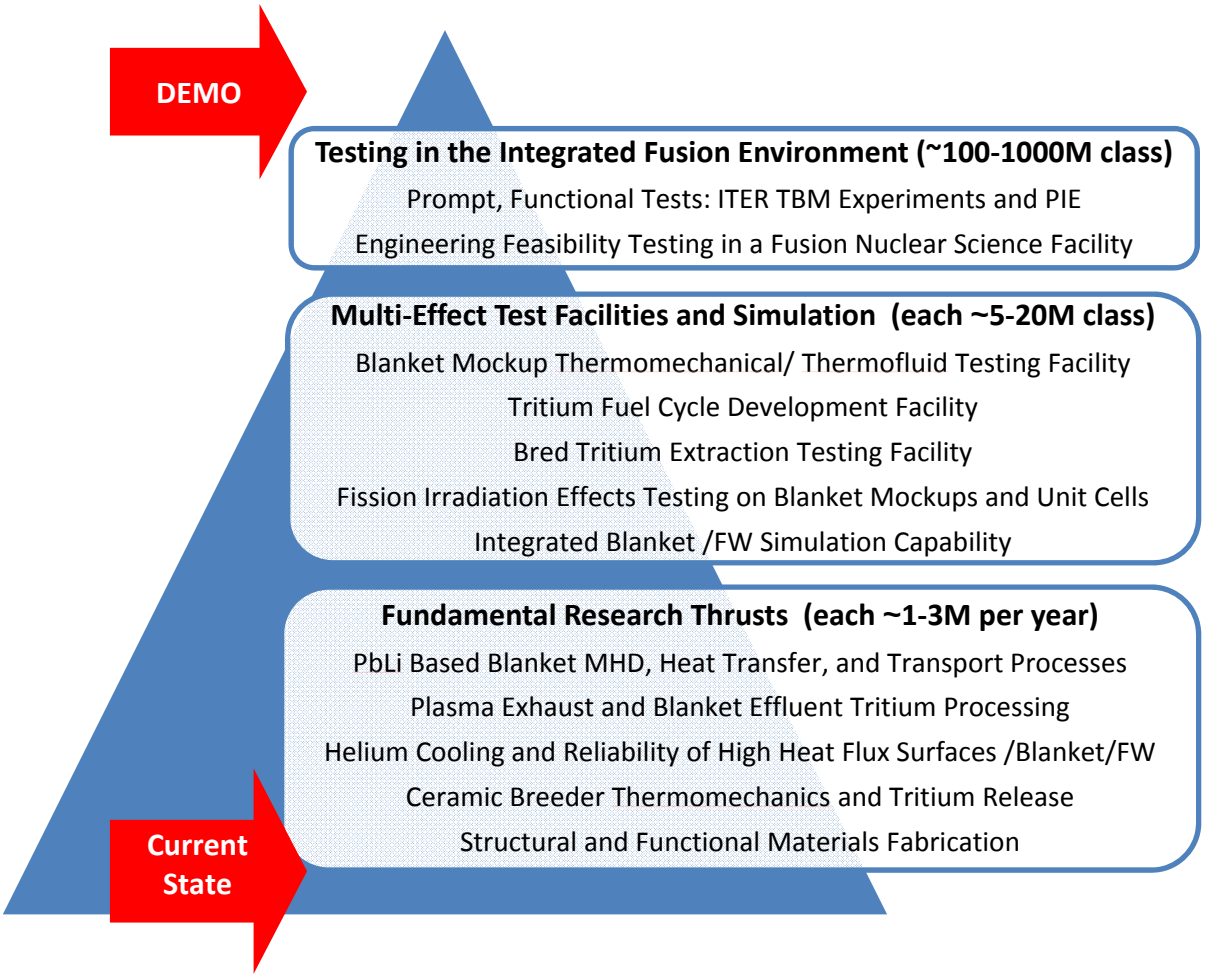

Fig. 1: Progression of essential scientific research for fusion Blanket/FW towards DEMO, proceeding from building a strong knowledge base to performing fully integrated component experiments and simulations. Tasks shown are taken from Refs. 3 & 4. Emphasis is on scientific understanding of lead-lithium based blanket systems with ceramic breeder blankets as a secondary focus.

References

[1] M. Greenwald (Chair), "Priorities, Gaps and Opportunities: Towards a Long-Range Strategic Plan for Magnetic Fusion Energy," Report to the Fusion Energy Sciences Advisory Committee, DOE/SC-102, October 2007. http://science.energy.gov/~/media/fes/fesac/pdf/2007/Fesac_planning_report.pdf

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[3] C. E. Kessel (Chair), "Fusion Nuclear Science Pathways Assessment," Princeton Plasma Physics Report PPPL-4736, February 2012. http://www.pppl.gov/pub_report//2012/PPPL-4736.pdf

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