Thoughts on Fusion Nuclear Technology Development and the Role of ITER TBM

Farrokh Najmabadi
Prof. of Electrical Engineering
Director of Center for Energy Research
UC San Diego

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Plans for the ARIES “Pathways” Program

- What are the remaining major R&D areas?
  - What are the data base needed to field a commercial power plant (e.g., licensing, operation, reliability, etc.)?
  - What is the impact of each R&D item on the attractiveness of the final product. (metrics for prioritization of R&D).

- Which of the remaining major R&D areas can be explored in existing devices or simulation facilities (i.e., fission reactors)?

- What other major facilities are needed (CTF, Fast track, etc.)
  - What are the possible embodiments for CTF and what are the their cost/performance attributes.
MY thoughts on the Role of ITER TBM
A Decision Tree Approach for TBM

- Is ITER TBM absolutely necessary?
  - If Yes → We should get on with it regardless of the cost.

- My answer is No. Then, the question divides into several categories:
  - The need for a US test blanket (technically and programmatically)
  - The value of information generated by fielding a test blanket
  - The cost of fielding a test blanket
  - The timeliness of information from a test blanket.
The Need: is a blanket test module required to enable the US to make technical progress in FNT development?

- No. Current progress is not hindered by the absence of an ITER TBM. Current progress is limited by manpower and funding.
  - The US program has been stalled in the concept development stage with very few single-effects experiments;
- Artificial down-selection motivated by ITER will prematurely restrict design choices and innovation.
- Numerous fundamental uncertainties exist in FNT; the majority of them can be explored in non-nuclear facilities or fission reactors.
- Numerous partially integrated tests can be constructed which can be fielded in multiple steps providing projects with clear milestones (ITER TBM is NOT the only possible project).
The Need: is a blanket test module program required to make a programmatic case for getting on with FNT development?

- US fusion community and government should support the need for FNT development.

- Absence of such a support:
  - It is not clear where funds for ITER TBM will come from.
  - The FNT funding will be limited only to the minimum needed to field the ITER TBM. All other FNT research will be eliminated.
  - Probable cost over-runs in ITER TBM may lead to the cancellation of not only the ITER TBM but all FNT programs, putting FNT research back for many years (recall US leaving ITER in 1990s).
The Value: Does ITER provide an adequate platform for integrated nuclear testing of blankets?

- The fidelity of tests in ITER is far from optimal.
- ITER conditions (FW heat flux, P/R, neutron flux, fluence) are well below an attractive power plant. Thus, ITER TBM results cannot be taken as prototypical (i.e., if it works on ITER, it does not mean it works on CTF and power plants or vice versa).
- Impact of ITER non-breeding blanket on the TBM response is not known – What is the “signal-to-noise ratio?”
- It is not clear what diagnostics can be fielded, what information these diagnostics would provide, and how this information can be used to reduce uncertainties and/or build a predictive capability.
The Cost: Will the data obtained in ITER justify the cost?

- Without detailed and quantified information on the extent by which ITER TBM improves our predictive capability:
  - It is hard to make a case that blanket testing in ITER reduces the cost, schedule or risk of blanket development (or CTF).
  - It is hard to make a case that ITER TBM data will justify the cost.

- There are other major cost-related issues:
  - Are the costs realistic?
  - Is the money available?
  - What are the contingency plans in case of overruns?
The Timeliness: Is the US fully prepared to develop a TBM?

- **Issues:**
  - expertise (scientific workforce)
  - Test facilities
  - Industrial involvement
  - Funding

- Considering the current state of FNT in the US, we need 5-10 years of program growth before the elements of a balanced program are in place.

- The US has a better chance for a leadership role in concept innovation and non-nuclear and fission reactor tests. Our lack of readiness to accelerate the development of blanket modules puts us at a competitive disadvantage.
The Cost: Could the money be better spent elsewhere?

- A T-tube design for divertor modules capable of > 10MW/m² of heat load was developed (ARIES/FZK collaboration).
- $40k university experiment at Georgia Tech was funded under the ARIES program to test this concept.
The Cost: Could the money be better spent elsewhere?

- Experiments confirmed the predicted high heat transfer coefficient.
- Found better coolant routings and illuminated difficulties in manufacturing.
An Alternative Approach for building up the FNT research in US

- Address the man-power and limited single-effect data base immediately by starting a program to fund university-based research in FNT (RFP for 3-4 proposals totaling $1M/y, build to $3M/year in 3 years).

- Develop a detailed plan for FNT development with a focus on short term goals (5-7 years). Define experimental facilities with clear milestones, detailed research plan, diagnostics development, etc. This is an essential ingredient for selling the FNT research to the rest of fusion community.

- Start planning for user-facilities in national labs for proof-principle and multi-effect test in national labs (e.g., He loop, LiPb loop, heat sources, etc.) to be constructed in 3-4 years time.

- It would be “good” to have the option (in ~7 years) to participate in ITER TBM if the above program is put in place.
A role-back approach of missions of various facilities

- Demo: Build and operated by industry (may be with government subsidy), Demo should demonstrate that fusion is a commercial reality (different than EU definition)
  - There should be NO open questions going from Demo to commercial (similar physics and technology, …)

- CTF: Integration of fusion nuclear technology with a fusion plasma (copious amount of fusion power but not necessarily a burning plasma). At the of its research program, CTF should have demonstrated:
  - Complete fuel cycle with tritium accountability.
  - Power and particle management.
  - Necessary date for safety & licensing of a fusion facility.
  - Operability of a fusion energy facility, including plasma control, reliability of components, inspectability and maintainability of a power plant relevant device.
  - Large industrial involvement so that industry can attempt the Demo.