Thoughts on Fusion Competitiveness Initiative

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What can we do to compete worldwide?

- Large-scale Confinement Device: We will not be able to compete with Asian Superconducting tokamaks and ITER in a timely manner. What is left from the mix is a “super” advanced-tokamak DT burning device with long-pulse (capability for days of operation). Note that this will be a nuclear machine.

- We can consider instead a series of programs (maximum of 5) which are packaged under one University Fusion Initiative and are executed in parallel. These programs are aimed at:
  - Addressing the critical issues for fusion at a substantial level of resources, thus leap-frog the rest of the world in many areas;
  - Educating next generation of scientists to work on ITER and follow-up devices.
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Greenwald Panel: Top-rated issues are fusion engineering related.

- High-rate issues include Material, PMI, PFC, …are mainly fusion engineering sciences issues.

- It is not necessary to use a fusion and/or a high-temperature plasma as a test bed to resolve these issues:
  - Our level of scientific understanding in these field is not mature.
  - Developing engineering knowledge through extensive testing and experimental correlations is costly and is NOT practiced anymore.
Science-based approach to engineering of components

A major shift to modeling and simulation to minimize testing requirements and development costs in engineering disciplines.

- Relying on 3-D multi-physics codes which are based on first principle to analyze components.

This approach, however, requires a different development approach:

- Accurate understanding of fundamental physics principles (single effect issues)
- Experiment planning such that it highlights multi-physics interaction (instead of traditional approach of testing integrated systems to failure repeatedly).
- Final validation in an integrated, prototypical environment.
Example of modern engineering development

- Aircraft companies now design the aircraft through CAD/CFD/Structural analysis codes with verification in wind tunnel and actual flight.

- “Conventional” alloy development is a slow and expansive process
  - e.g., 55°C improvement in upper operating temperature of steel after 40 years of development.
  - Computational thermodynamics calculations can lead to composition and heat treatment optimization, drastically reducing the time and expenses (See S. Zinkle presentation at 2007 FPA meeting posted on fire Web site).
Addressing feasibility of high heat transfer capability of gas-cooled high-heat-flux components

- A T-tube design for divertor modules capable of > 10MW/m² of heat load was developed (ARIES/FZK collaboration).
- $80k university experiment at Georgia Tech (2 Master Students) was funded under the ARIES program to test this concept.
Scientific basis for the concept was tested under similar dimensionless parameters.

- Experiments confirmed the predicted high heat transfer coefficient.
- Found better coolant routings and illuminated difficulties in manufacturing.
Example of Initiatives to address fusion engineering sconces issues

- **Plasma facing components and plasma material interaction**
  - University based groups to develop and test high-heat flux component concepts
  - Linear plasmas device with capability of several MW/m² heat and relevant particle flux on “component-size” test articles.

- **Radiation-resistant material**
  - User facilities based on existing neutron sources (e.g., SNS) with extensive university participation to define experiments.
Example of Initiatives to address fusion engineering scones issues

- **Fusion Nuclear Engineering**
  - 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).
  - 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.
In summary …

We suggest that we consider a series of programs (maximum of 5) which are packaged under one University Fusion Initiative and are executed in parallel. These programs are aimed at:

- Addressing the critical issues for fusion at a substantial level of resources, thus leap-frog the rest of the world in many areas;
- Educating next generation of scientists to work on ITER and follow-up devices.
- Both aims directly address American Competitiveness Initiative!

Three such initiatives in fusion engineering sciences are identified.