Perspectives on

- US program support of FNSF and ITER in coming decade
- Role of spherical tokamak in fusion energy science

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Perspective on Fusion Nuclear Science Program and Facility

- U.S. aspires to lead development of Fusion Nuclear Science Program (FNSP) and Facility (FNSF)
  - FNSF mission: Provide nuclear environment prototypical of reactor to develop, test, understand fusion materials and components needed for fusion energy development
- FNSP/FNSF could be world-leading capability (if done soon enough) and transformational for materials and plasma science
  - U.S. could play strong and unique role in world program
- Is U.S. well prepared for this?
  - My answer: **probably not** - starting FNSF design in ~10 years (operation by ~2030) likely inconsistent with present trajectory
    - On flat (or reduced) funding, significant physics, technology, design R&D would not be carried out to level sufficient for viable FNSP/FNSF
  - Answering this question more carefully would be very useful activity for U.S. fusion community

U.S. research community participation and input to FNSP / next-step planning should be broadened and strengthened

- ITER is and should be very high priority in U.S. research program
  - ITER has world-wide research program (much of it pro-bono, e.g. ITPA) dedicated to achieving the ITER mission – U.S. very strong contributor
- ReNeW (2009) focused on gaps from present to DEMO
  - FNSP/FNSF proposed as means to narrow/close many gaps
  - But there are also many gaps from present to FNSP/FNSF
- FNSF would likely cost at least as much as U.S. contribution to ITER
- Should have follow-up to ReNeW → ReNeW-2/Snowmass-2 focusing on goals, needs, priorities for U.S. next-step, including:
  - Consideration of viability of such a program given present funding
  - Less expensive leadership alternatives (e.g. long-pulse PMI, stellarator)
- U.S. Burning Plasma Organization could also expand beyond ITER to incorporate FNSP/FNSF research needs and support

Developing the basis for FNSP/FNSF is an exciting, necessary, extremely challenging research enterprise

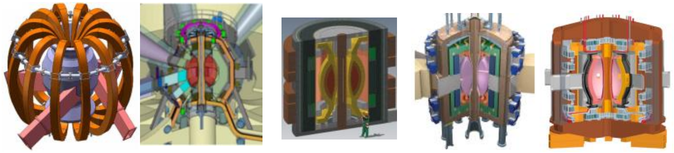
- ITER physics basis development still ongoing in key areas:
  - Disruptions, ELM control, divertor detachment, H&CD, …
- The physics basis for FNSF remains to be developed:
  - Requires steady-state (~10^6s) scenario with plasma performance sufficient to provide > 1MW/m^2 neutron wall loading (Abdou)
  - Necessary FNSF-equivalent plasma performance and power and particle exhaust handling have only been accessed transiently
- Further, FNSF would ultimately be fully nuclear device
  - Most long-pulse actuators/diagnostics/components (NBI, RF, PFCs) are being developed outside of U.S.
  - Only modest U.S. efforts on FNSF maintainability, structural materials, first-wall components, remote handling, blankets, …
    - Smaller programs (e.g. India) have ITER TBM program, U.S. does not…
    - Who will design/fabricate materials and components we aim to test?

Enhancement of design activities and focused R&D needed to enable development of U.S. FNSF

- To have viable FNSP/FNSF program, conceptual design + engineering analysis should be strengthened:
  - Physics requirements obviously drive facility parameters, design, but…
  - Facility design also strongly influences achievable plasma performance (heating & current-drive, stability, confinement, …)
  - Choice of materials also strongly influences physics and performance (e.g. high-Z PFCs, ferritic steel in blankets)
  - Example questions that can only be addressed with design support:
    - Can one facility support a staged approach? (PMI → FNSF → CTF → Pilot?)
    - Which ITER physics and technology can be leveraged for FNSF?
    - Could stellarators offer attractive alternative approach to FNSF?
  - It costs $ to estimate of how much an FNSF would really cost
- U.S. tokamak facilities should be explicitly charged with goal of developing scalable integrated scenarios for FNSF
  - Leverages U.S. strengths: workforce, diagnostics, control, simulation
  - Synergistic with developing scenarios for ITER, ITER-AT, Demo

Role of spherical tokamak (ST) in fusion program

- The high beta, increased toroidicity (low-A) of ST broadens toroidal physics understanding, enhances predictive capability
  - Can also access/overlap many parameters of conventional aspect ratio
  - **Strong contributor to ITER**: fast-ion instabilities, e-transport, H-mode access, ICRF, error-field/rotation physics, ELM mitigation, detachment
- ST strong candidate as steady-state fusion neutron source
  - Many ST FNSFs proposed - small → large:
  - See FESAC toroidal alternates report (2008), ReNeW (2009) for ST priorities



  - Substantial progress made since 2008/9 on key ST issues: plasma start-up (CHI, guns), electron transport (ETG, μ-tearing), exhaust (snowflake)
  - NSTX-U will significantly extend non-inductive current drive studies, access lower collisionality, test novel PMI solutions for FNSF and Demo
- Japan: low-A=2-2.5 SC Demo attractive: lower mass/cost/waste
- See ST whitepaper for more info on NSTX (past) and NSTX-U (future) plasma and materials science for ITER, FNSF, Demo