FUSION NUCLEAR SCIENCE PROGRAM & SUPPORTING FUSION NUCLEAR SCIENCE FACILITY (FNSF):

UPDATE ON DEVELOPING THE MISSION & RESEARCH GOALS

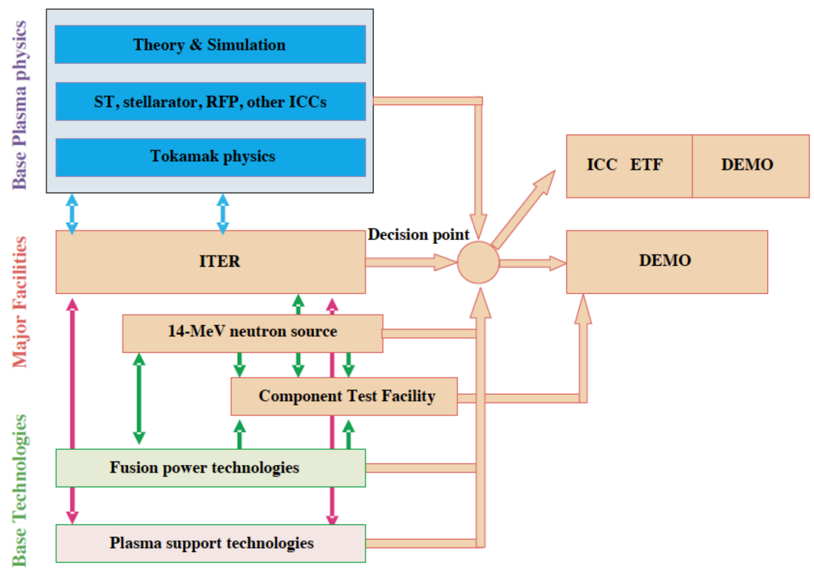
Gerald A. Navratil
Columbia University

Fusion Power Associates
32st Annual Meeting and Symposium
14-15 December 2011
Washington, DC

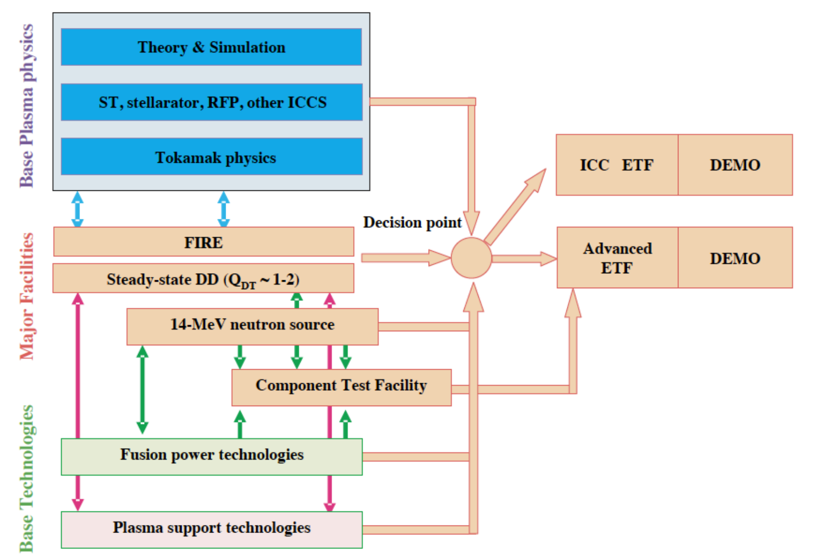
FNSP/FNSF: Some Historical Context

When MFE community was last focussed on "Pathways" planning the burning plasma experiments in 2002

FESAC/Snowmass Report: ITER-Based Development Path



FESAC/Snowmass Report: FIRE-Based Development Path



- **It was well recognized there were also critical materials and technology issues that needed to be addressed in order to apply the knowledge we gained about burning plasma state**

FUSION NUCLEAR SCIENCE PROGRAM

– FNSF STEERING GROUP WHITE PAPER 2010–

The critical R&D challenges that the FES program must address to develop a practical fusion power source … can be grouped into the following four key challenge areas:

1. **Demonstrating and exploring the burning plasma state**
   Creating and controlling a fusion plasma that releases several 100 MW of power and understanding the effects of very energetic fusion-created particles is a grand challenge of fusion science research.
2. **Creating predictable, high-performance, steady-state plasmas**
   A continuously burning plasma that behaves predictably and is highly efficient is needed for economical fusion power plants
3. **Taming the plasma-material interface**
   Magnetic confinement sharply reduces the contact between the plasma and the containment vessel walls, but such contact cannot be entirely eliminated. Advanced wall materials and magnetic field structures that can prevent both wall erosion and plasma contamination are required.
4. **Harnessing Fusion Power**
   Fusion energy from deuterium-tritium (D-T) reactions appears in the form of very energetic neutrons. The understanding of the effects of these neutrons on the surrounding materials and the fusion plasma, and the means of capturing this energy while simultaneously breeding, processing, and safely handling the tritium needed to maintain the fuel supply, must be developed.

FNSF/FNSP MISSION&GOAL DEVELOPMENT MEETING
31 AUGUST 2011

Mohamed Abdou (University of California – Los Angeles)
Jean Paul Ailain (Purdue University)
Jeff Brooks (Purdue University)
Vincent Chan (General Atomics)
Ray Fonck (University of Wisconsin)
Stan Milora (ORNL)
Gerald Navratil (Columbia University)
Martin Peng (Oak Ridge National Laboratory)
Roger Stoller (ORNL)

ORNL Invited Contributers:

Steffi Diem, Jess C. Gehin, Yutai Katoh, Bradley D. Patton,
A. L. Qualls, Aaron Sontag, John C. Wagner

Fusion Nuclear Science Program

DEVELOPMENT OF ELEMENTS OF THE FUSION NUCLEAR SCIENCE PROGRAM

Mission

FNSP: Develop the science and technology for producing energy from a magnetic fusion plasma

FNSF: Provide the unique physical environment to develop the science and technology of harnessing fusion power

Mission Elements

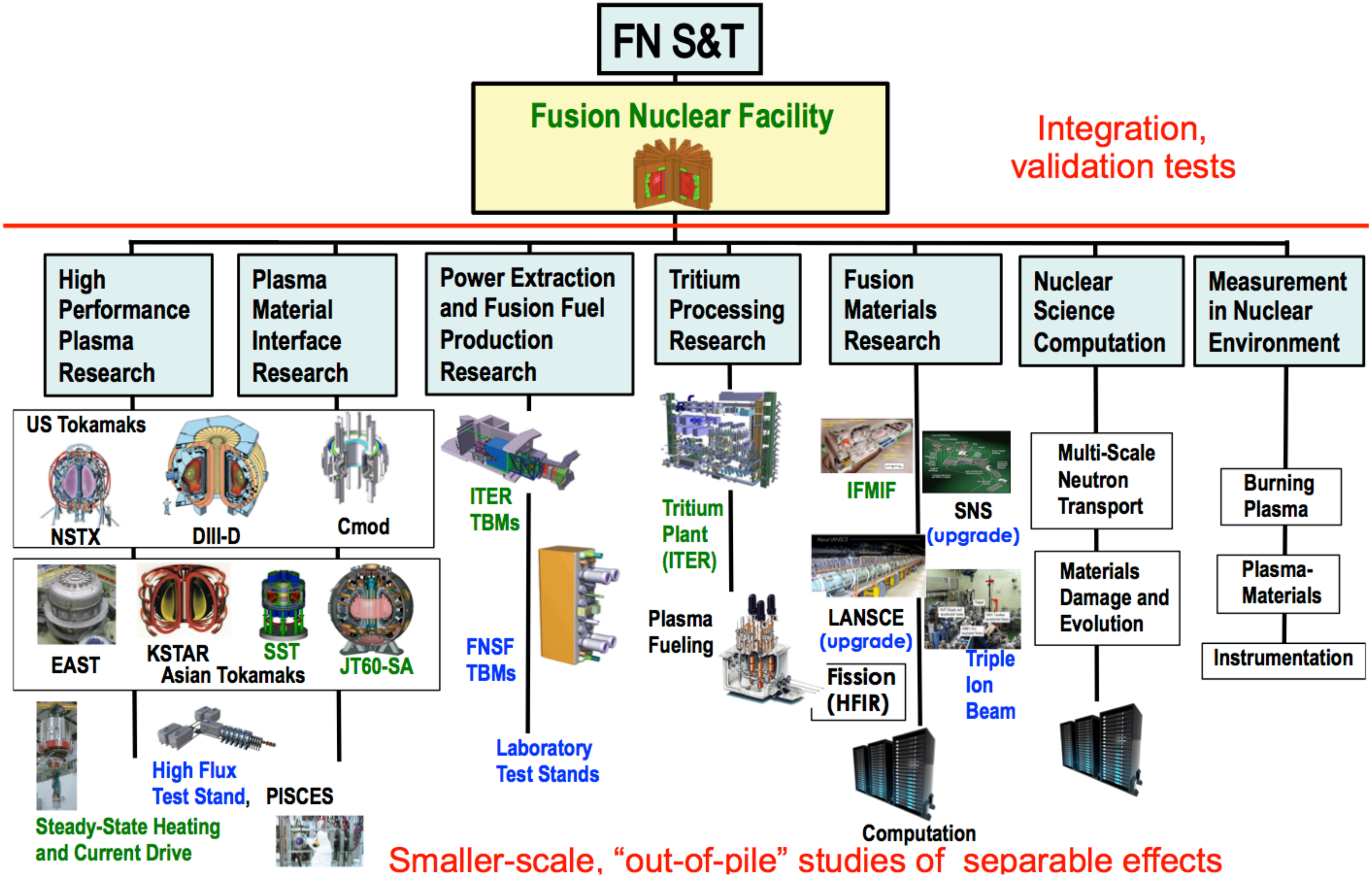
Taming the plasma-material interface

- Plasma surface material interactions and coupling with irradiation effects
- Plasma facing components and coupling with irradiation effects
- Fusion neutron irradiation effects on materials

Harnessing Fusion Power

- Fusion power extraction and tritium breeding
- Tritium self-sufficiency
- Dynamics and control of driven steady-state volumetric fusion plasma

Tools for the Fusion Nuclear Science & Technology Program



FUSION NUCLEAR SCIENCE PROGRAM

FUSION NUCLEAR ENVIRONMENT

Mission

FNSF: Provide the **unique physical environment** to develop the science and technology of harnessing fusion power

From: 2007 BES Workshop on Materials Under Extreme Environments:

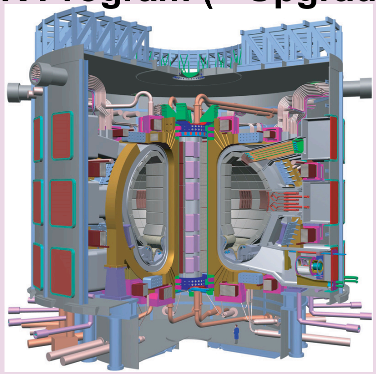
- **High Temperature**: 400 to 1000 ˚C
- **Steady-State Heat Flux**: 1 to 10 MW/m^2
- **D-T (14-MeV) Neutron Irradiation**: ~10 appm He/dpa (vs 0.1 appm He/dpa for fission neutron spectrum)
- **Irradiation Damage Exposures**: 30 to 200 dpa

FNSF Unique Physical Environment is a driver for discovery and feasibility: advances our understanding of material science, plasma/material interaction and fusion technology essential to the design of a practical fusion energy DEMO facility.

Aggressive MFE Via Fusion Nuclear S&T and one Integrative Step in ITER Timeframe

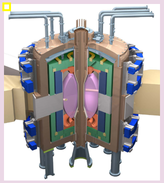
Plasma Confinement Sciences

ITER Program (+ Upgrades?)



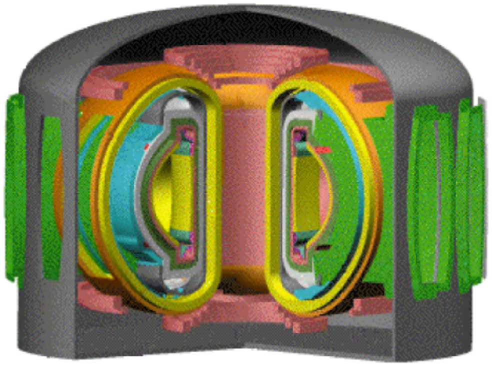
Major Domestic Facilities

FNFS



Fusion Nuclear Sciences And Technology

Plasma Confinement Sciences



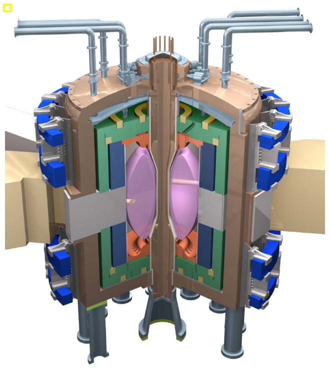
"DEMO"

Present → ITER timeframe 2020 - 2035 → Construct Decision 2025-2030

OPTIONS FOR THE FUSION NUCLEAR FACILITY

- *Program Mission:*
  Fill the gaps in ITER and existing fusion programs to support a FOAK DEMO construction

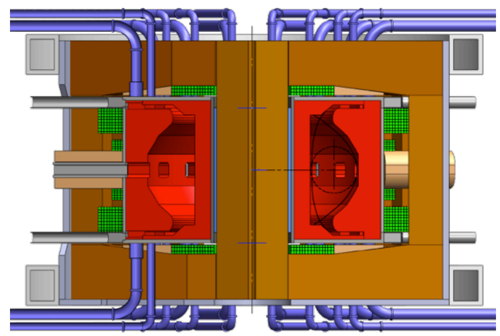
FNFS-ST



(copper)

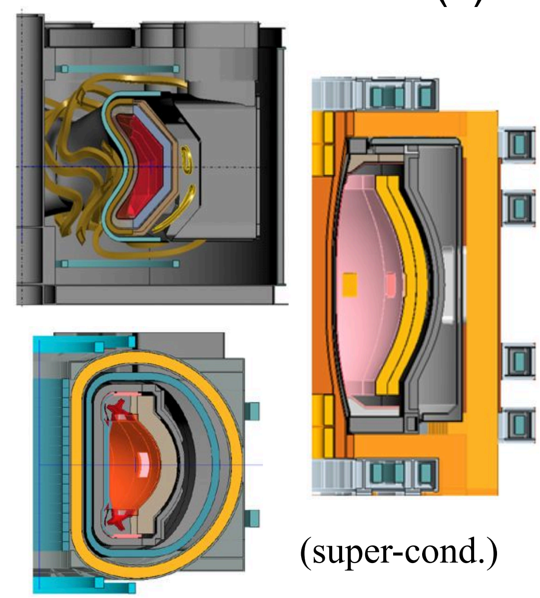
FNSF Objectives:
- 2-6 MW-yr/m^2 neutron fluence
- Test/validate materials
  (low activation, high strength,
  high temperature, radiation resistant)
- Tritium breeding; self-sufficiency
- Produce high-grade process heat

FNFS-AT



Add:
- Enable DEMO-class high-performance plasma research

FNFS-Pilot Plant(s)



(super-cond.)

Add:
- Generate net electricity
- Reactor maintenance schemes

FNF choices lie on continuum between present program and DEMO

Present | Lager step to DEMO | Larger step to FNFS | DEMO

RJF EPRI 2011

FNSF CHOICE OF OPTION: BALANCE RISK & COST

My personal view is that best approach is to select the lowest cost option that provides with some confidence the necessary nuclear environment combined with maximal flexibility for changing blanket/ PFC components:

- **The ST could be that choice but it has yet to establish the essential Steady-State current drive physics basis**
- **The AT could be that choice with the most well established physics basis.**

FNSF Choice of Option: Balance Risk & Cost

My personal view is that best approach is to select the lowest cost option that provides with some confidence the necessary nuclear environment combined with maximal flexibility for changing blanket/ PFC components:

- **The ST could be that choice but it has yet to establish the essential Steady-State current drive physics basis**
- **The AT could be that choice with the most well established physics basis.**

IN EITHER CASE, ADDING TO THE BASIC FNSP MISSION A REQUIREMENT TO GENERATE NET ELECTRIC POWER WILL REDUCE EXPERIMENTAL FLEXIBILITY AND SIGNIFICANTLY DRIVE UP COSTS – ESPECIALLY IF SUPERCONDUCTING COILS ARE EMPLOYED.

FNSP/FNSF: Opportunity for US Leadership

Yesterday Steve Koonin suggested that since we had NIF in the US for IFE burning plasma studies, but we were only 9% partners in MFE burning plasmas studies on ITER, the US was better positioned to lead in IFE. – – I disagree.

- **Physics understanding of burning plasmas on ITER is fully acquired by all partners on ITER**
- **In both IFE and MFE the burning plasma physics understanding is necessary but alone not sufficient for practical fusion power**

Developing the essential science and technology (Fusion Nuclear Science) to practically use energy from burning fusion plasma is the key intellectual property essential for US leadership in both IFE and MFE.

For MFE a US initiative on FNS with an FNSF centerpiece would provide that leadership.