Next Step Options (NSO)

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VLT PAC Recommendations

The NSO Activity

The present NSO activity consists of pre-conceptual design of the FIRE burning plasma experiment. Over the past year, progress in the FIRE design has been rapid and impressive. Continuation of the pre-conceptual activity is needed to address a number of pivotal issues, such as the feasibility of the attractive feature of incorporating an advanced tokamak physics mission and the rough construction cost. The emphasis to be placed on the FIRE design, or other potential NSO activities, will be influenced by upcoming community activities, such as the Snowmass meeting. Thus, the committee did not attempt to reach a consensus on the priority of next steps. We suggest that NSO plans for FY 2000 be conveyed to the PAC for our feedback in the early fall.

Contributors to the FIRE Design Study

FIRE is a design study for a major Next Step Option in magnetic fusion and is carried out through the Virtual Laboratory for Technology. FIRE has benefited from the prior design and R&D activities on BPX, TPX and ITER.

Advanced Energy Systems
Argonne National Laboratory
Bechtel Technology and Consulting
General Atomics Technology
Georgia Institute of Technology
Idaho National Engineering Laboratory
Lawrence Livermore National Laboratory
Massachusetts Institute of Technology
Oak Ridge National Laboratory
Princeton Plasma Physics Laboratory
Sandia National Laboratory
Stone and Webster
The Boeing Company
University of Illinois
University of Wisconsin

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FIRE Budget Evolution

(M$)

	FY-99 Actual	FY-00 Pres	FY-00 Budget
Fusion	225	223	250
NSO	4.1	3.0	2.66

NSO/FIRE Community Involvement (FY-99)

A Proactive NSO/FIRE Outreach Program has been undertaken to solicit comments and suggestions from the community on the next step.

- Presentations have been made and comments received from:

SOFT	Sep 98	IAEA	Oct 98
APS-DPP	Nov 98	FPA	Jan 99
APEX/UCLA	Feb 99	APS Cent	Mar 99
IGNITOR	May 99	NRC	May 99
GA	May 99	LLNL	May 99
VLT-PAC	Jun 99	MIT PSFC	Jul 99
Snowmass	Jul 99	PPPL/SFG	Aug 99
U. Roch	Aug 99	NYU	Oct 99
U. Wis	Oct 99	FPA	Oct 99
SOFE	Oct 99	APS-DPP	Nov 99
U. MD	Dec 99	DOE/OFES	Nov 99

- The FIRE website has been developed to make information on FIRE and fusion science accessible and up to date. A steady stream of about 150 visitors per week since the site was initiated in early July.

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Burning Plasma Physics is Widely Accepted as the Primary Objective for a Next Step in Fusion Research

- Grunder Panel and Madison Forum endorsed Burning Plasmas as next step.
- NRC Interim Report identified "integrated physics of a self-heated plasma" as one of the critical unresolved fusion science issues.
- The Snowmass Fusion Summer Study strongly endorsed the burning plasma physics objective and that the tokamak was technically ready.
- R. Pellat, Chair of the CCE-FU has stated that "the demonstration of a sustained burning plasma is the next goal" for the European Fusion Program.
- SEAB noted that "There is general agreement that the next large machine should, at least, be one that allows the scientific exploration of burning plasmas" and if Japan and Europe do not proceed with ITER "the U. S. should pursue a less ambitious machine that will allow the exploration of the relevant science at lower cost". "In any event the preliminary planning for such as machine should proceed now so as to allow the prompt pursuit of this option."

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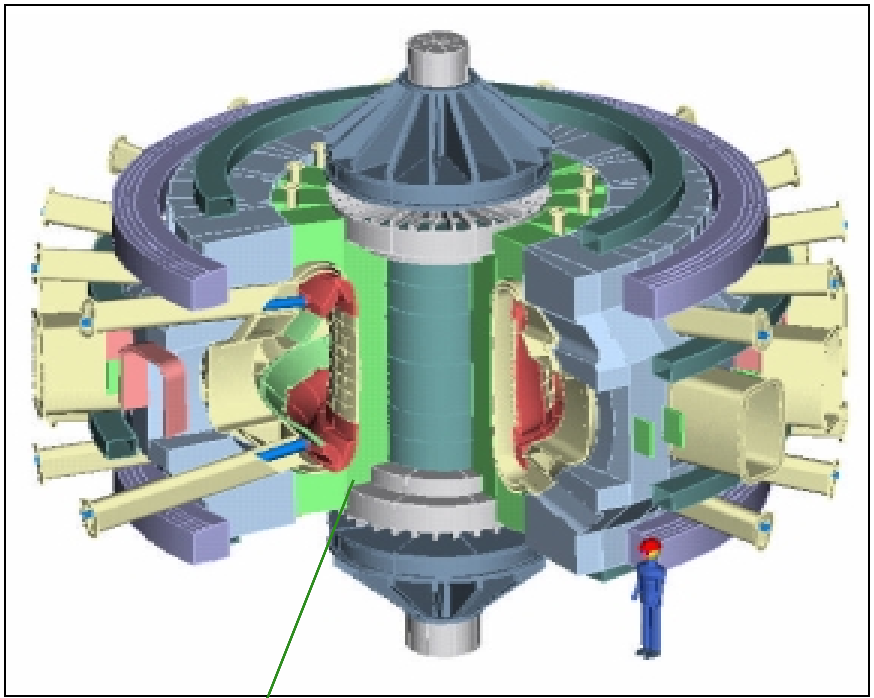
Fusion **I**gnition **R**esearch **E**xperiment
(FIRE)



LN BeCu ("HTS")

Design Goals

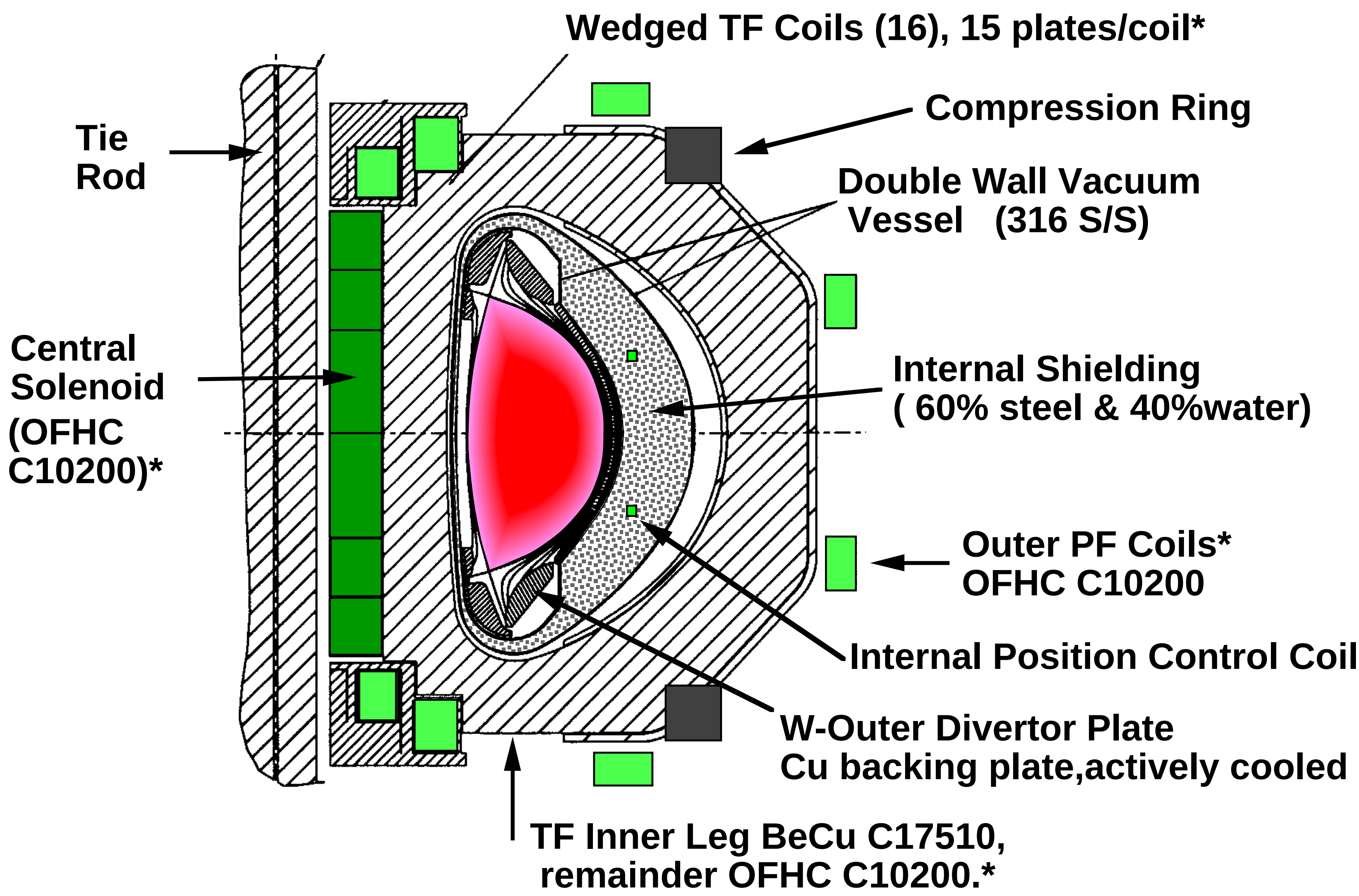
- **R = 2.0 m, a = 0.525 m**
- **B = 10 T, (12T)***
- **W_{mag}= 3.8 GJ, (5.5 GJ)***
- **I_p = 6.5 MA, (7.7 MA)***
- **P_{fusion} ~ 220 MW**
- **Q ~ 10, τ_E ~ 0.55s**
- **Burn Time $\approx$ 21s (12s)***
- **Tokamak Cost $\leq$ \$0.3B**

  Base Project Cost $\leq$ \$1B

* Higher Field Option

Attain, explore, understand and optimize alpha-dominated plasmas to provide knowledge for the design of attractive MFE systems.

FIRE Engineering Features



*Coil systems cooled to 77 °K prior to pulse, rising to 373 °K by end of pulse.

A Robust and Flexible Design for FIRE has been Achieved

- Toroidal and poloidal coil structures are independent allowing operational flexibility
  - The toroidal field coils are wedged with static compression rings to increase capability to withstand overturning moments and to ease manufacturing.

- 16 coil TF system with large bore provides
  - Large access ports (1.3m high by 0.7m wide) for maintenance and diagnostics.
  - Low TF ripple (0.3% at plasma edge) provides flexibility for lower current AT modes without large alpha losses due to ripple.

- Double-null divertor configuration for H-mode and AT modes with helium pumping that is maintainable/replaceable/upgradeable remotely

- Double wall vacuum vessel with integral shielding (ITER-like) to reduce neutron dose to TF and PF coils, and machine structure.

- Cooling to LN2 allows full field (10T) flattop for 20s or 4T (TPX-like) flattop for 250s.

The FIRE Engineering Report and 16 FIRE papers presented at the IEEE Symposium on Fusion Engineering are available on the web at http://fire.pppl.gov.

Plan for AT Modes

- Advanced Tokamak capabilities were identified by the VLT PAC and at Snowmass as important features for a burning plasma experiment.
- We have established the philosophy that the burning plasma experiment should achieve minimum performance goals without assuming Advanced Tokamak performance.
- However, we are establishing the requirements for Advanced Tokamak operation and expect to be able to accommodate these requirements.

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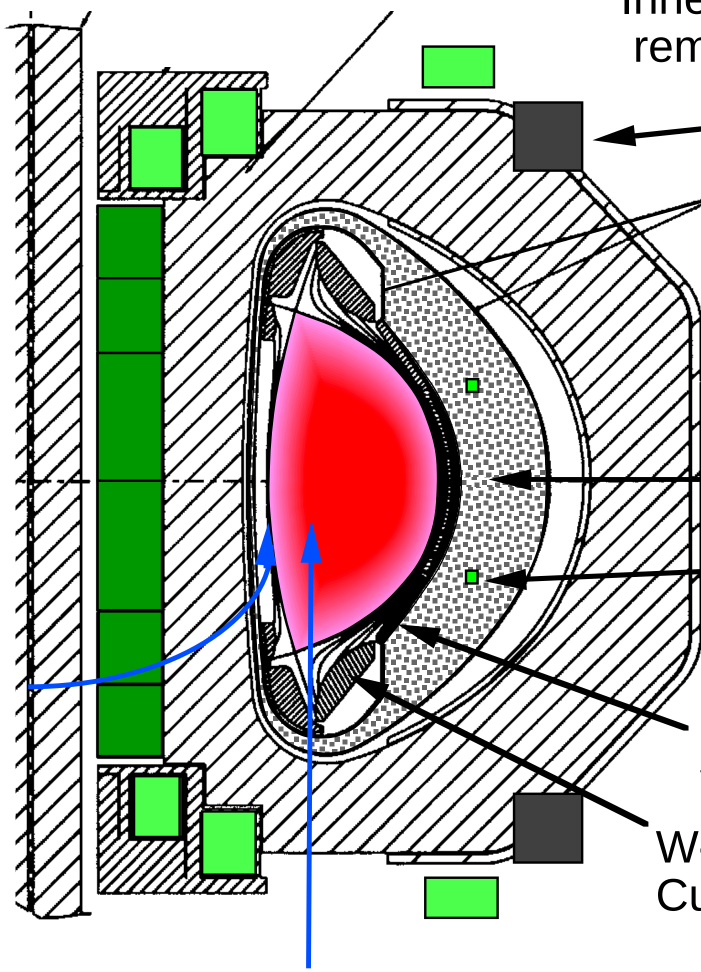
FIRE Incorporates Advanced Tokamak Innovations

AT Features

- DN divertor
- strong shaping
- very low ripple
- internal coils
- space for wall stabilizers
- inside pellet injection
- large access ports



*Coil systems cooled to 77 °K prior to pulse, rising to 373 °K by end of pulse.

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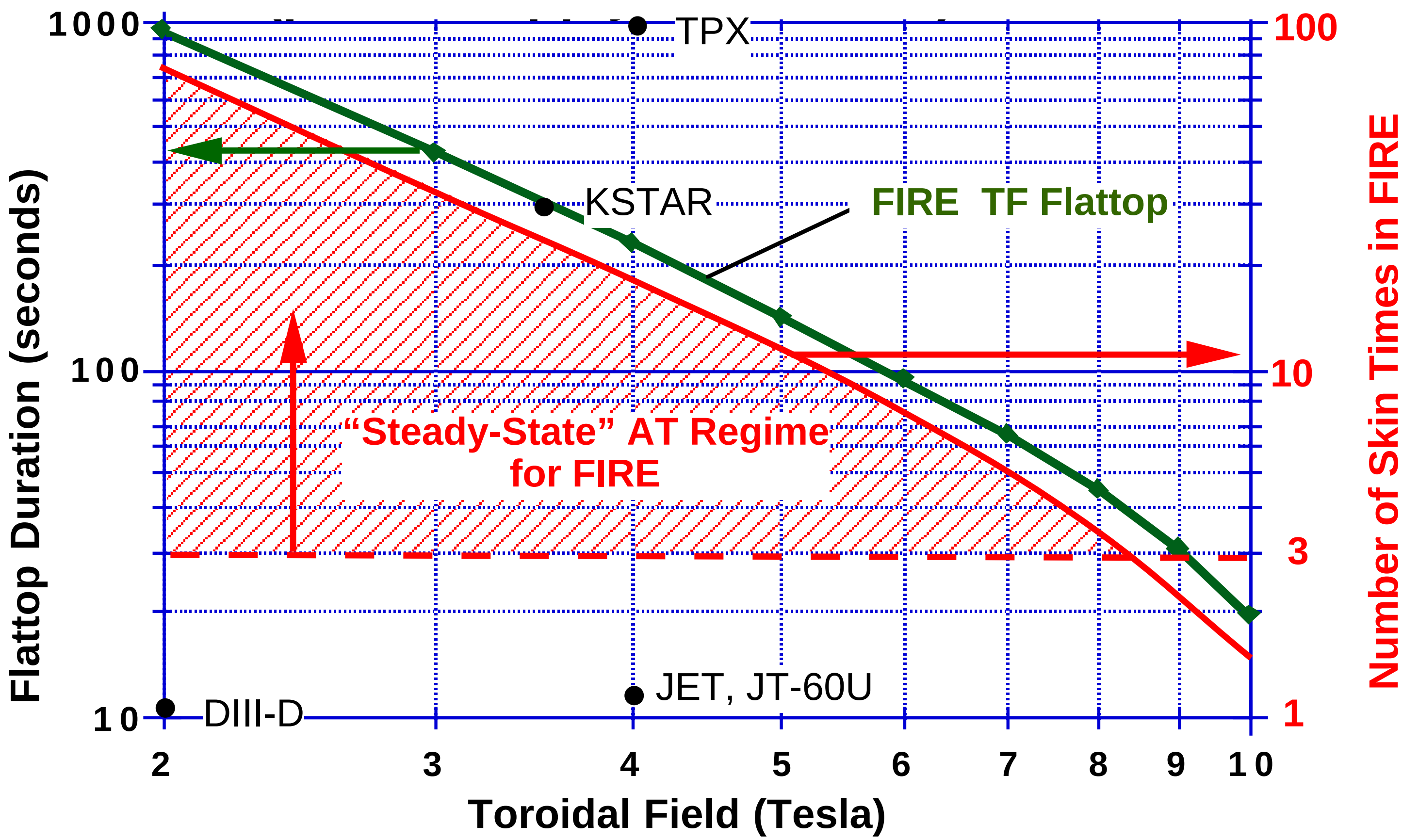
FIRE can Access "Long Pulse" Advanced Tokamak Modes at Reduced Toroidal Field.



Note: FIRE is ≈ the same size as TPX and KSTAR.
At Q = 10 parameters, typical skin time in FIRE is 13 s and is 200 s in ITER-RC .

Status of FIRE Costing Activity (12/12/99)

- Preliminary input from subsystem engineers

Tokamak	$284,500
Ancillary	$157,039
Power	$235,000
Facility	$206,035
Project Support	$180,412
Total	**$1,063,006***

*FY2000$ without contingency

- The initial estimates are being reviewed to eliminate double counting and include missing cost elements.

- The cost estimate will be available for external review by mid-July.

Siting Studies

- We are looking at a few U.S. sites for a burning plasma facility with the objective of better understanding the nature and value of site credits.

Plan

- Complete the costing exercise (with site considerations).
- Develop the burning plasma mission, requirements and design for Advanced Tokamak modes.
- Address the critical issues identified for FIRE.
- Complete a peer review of the physics and engineering design.
- Develop component manufacturing approaches to low cost.

FY 2000 Opportunities (Plans)*

Assume we proceed with a Burning Plasma design activity

- The design will be revised based on SEAB and Snowmass input
- The primary focus will be:
  - Performance Optimization (BP and AT)
  - Divertor/High Heat Flux Component Design (disruptions)
  - Pellet Injection/fueling/tritium system optimization
  - Remote Maintenance (3 D analyses, tangential ports?)
  - TF/PF joint development, coil insulator R&D,
  - High Fluence Diagnostics
  - Cost Reduction
    - Advanced manufacturing,16 vs 12 TF coils?
    - Site requirements

* presented to VLT PAC June 1999

Major Conclusions of the FIRE Design Study

- The tokamak is technically ready for the next step to explore fusion plasma physics.

- The FIRE compact high field tokamak can address the important alpha-dominated plasma issues, may of the long pulse advanced tokamak issues and begin the integration of alpha-dominated plasmas with advanced toroidal physics in a $1B class facility.