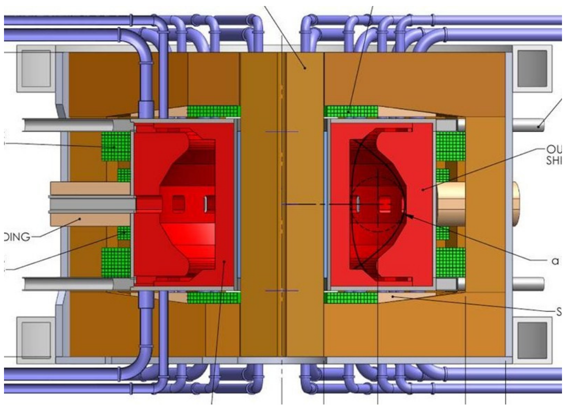
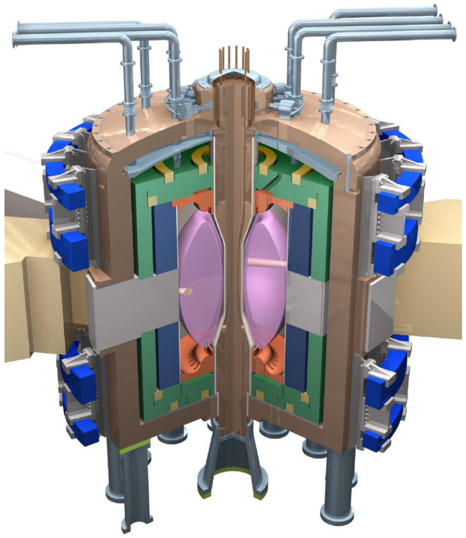
Fusion Nuclear Science Facility: Its Mission, Characteristics, Programmatic Needs, etc.



Normal Plasma Aspect Ratio Example:
Fusion Development Facility (FDF)

Martin Peng, ORNL

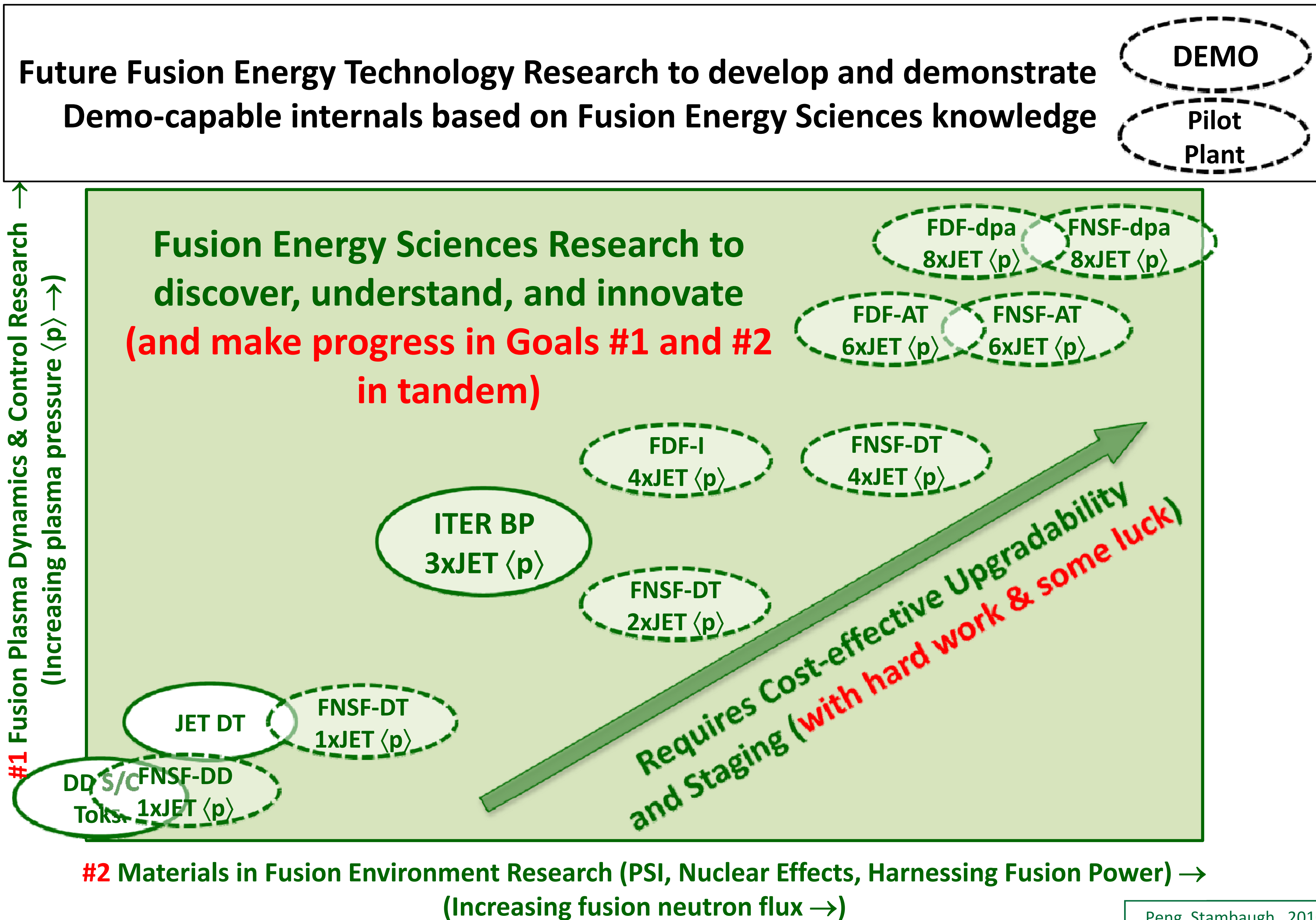
Ron Stambaugh, GA



Low Plasma Aspect Ratio Example:
Fusion Nuclear Science Facility (FNSF)

Update from VLT discussion 20100420,
Presented for discussion at ARIES PMI Town Meeting
UCSD
May 20-21, 2010
(Updated in red based on feedback on May 22, 2010
for distribution)

Fusion Nuclear Science Facility (FNSF) provides the environment needed to support the “Materials in Fusion Environment” research to develop basis for Pilot Plant and Demo, benefitting from research in “Plasma Dynamics & Control”



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In the space of FES Goals #1 (“Plasma Dynamics and Control” science) and #2 (“Materials in Fusion Environment” science), FNSF as a “Science Users’ Facility” enables effective management of performance-cost-risk

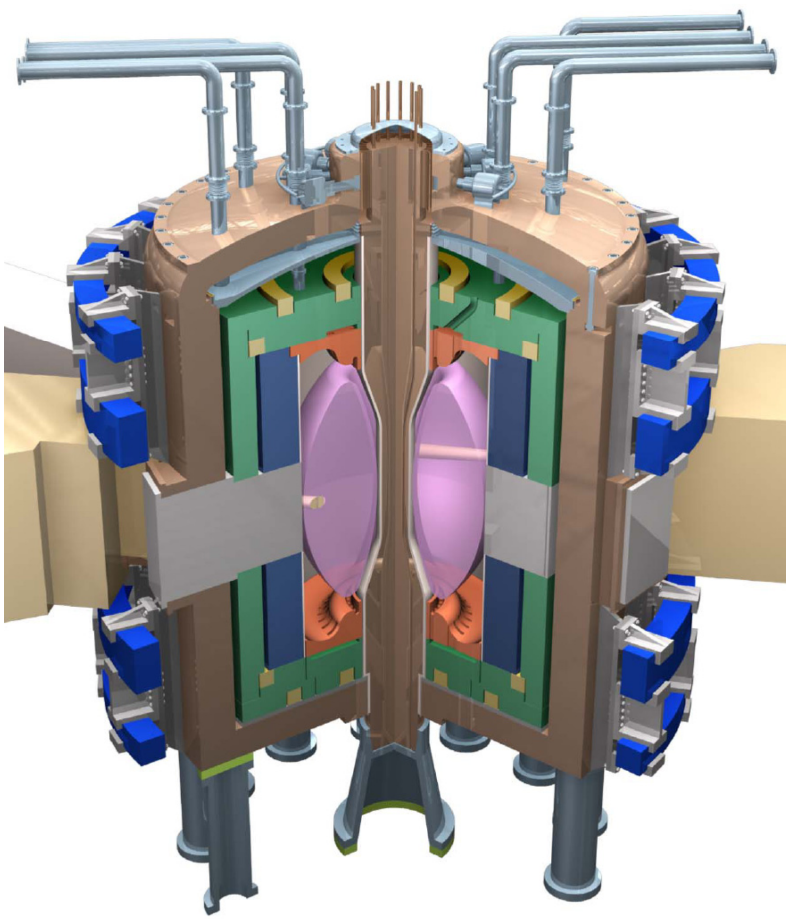
- FNSF mission: to provide the fusion environment to address FES Goal #2:
  - Start with conservative toroidal plasma performance (JET DD and DT level, low Q)
  - And conservative materials, engineering and technology performance (TBD)
  - Achieve progress in Goals #1 and Goal #2 in tandem – both or none.
- Prerequisite R&D: to ensure the initial provision of this environment, such as,
  - How much conservatism to avoid plasma-induced disruptions?
  - What should be the best divertor approach to enable the start of research ops?
  - Remote handling and “Fusion Materials Hot-Cell Laboratories” capabilities?
  - Expert stakeholders to develop the internal modules to enable start of Goal #2 research on FNSF, using conservative capabilities in Goal #1 research.
- Cost-effective upgradability: from H, D, DT, to DT-AT, aiming to deliver 30-60dpa
  - Fully modular internals + extensive remote handling: for fast replacement
  - Remote-handling enabled new “fusion materials hot-cell laboratories”
  - Standardized interface for all internal modules, enabling competitive designs
  - Multiple backup modules in waiting, to ensure high utilization
- Fusion Nuclear Science Program (FNSP) and FNSF:
  - Expert stakeholders use FNSF to carry out research
  - FNSF enabled to support FNSP research fully in cost-effective stages
- Combined we will discover, understand, and innovate the needed FES basis for Demo

With hard work and some luck, can only promise critical new knowledge in “Materials in Fusion Environment” using “Plasma Dynamics & Control” for Demo.

Low-A Example: Conservative parameters are available for R_0 = 1.3m, A = 1.7 plasmas to enable this FNSF mission

Disruption-minimized plasma: $\beta_N \leq 0.75\beta_{N\text{-no-wall}}$; HH $\leq$ 1.25; $q_{cyl} \geq$ 2xlimit; $J_{avgTF} \leq$ 4 kA/cm^2

Low-A FNSF



Plasma ⟨Pressure⟩-Fuel	JET-DD	JET-DT	2xJET	4xJET
⟨Pressure⟩ = $B_T^2\beta_T$ (T^2%)	32	32	85	140
Tests enabled	PFC	FNS	FNS	FNS
W_L (MW/m^2)	0.005	0.25	1.0	2.0
Current, I_p (MA)	4.2	4.2	6.7	8.4
Field, B_T (T)	2.7	2.7	2.9	3.6
Safety factor, q_{cyl}	6.0	6.0	4.1	4.1
Toroidal beta, β_T (%)	4.4	4.4	10.1	10.8
Normal beta, β_N	2.1	2.1	3.3	3.5
Avg density, n_e (10^{20}/m^3)	0.54	0.54	1.1	1.5
Avg ion T_i (keV)	7.7	7.6	10.2	11.8
Avg electron T_e (keV)	4.2	4.3	5.7	7.2
BS current fraction	0.45	0.47	0.50	0.53
NBI H&CD power (MW)	26	22	44	61
Fusion power (MW)	0.2	19	76	152
NBI energy to core (kV)	120	120	235	330

Normal-A Examples also exist.

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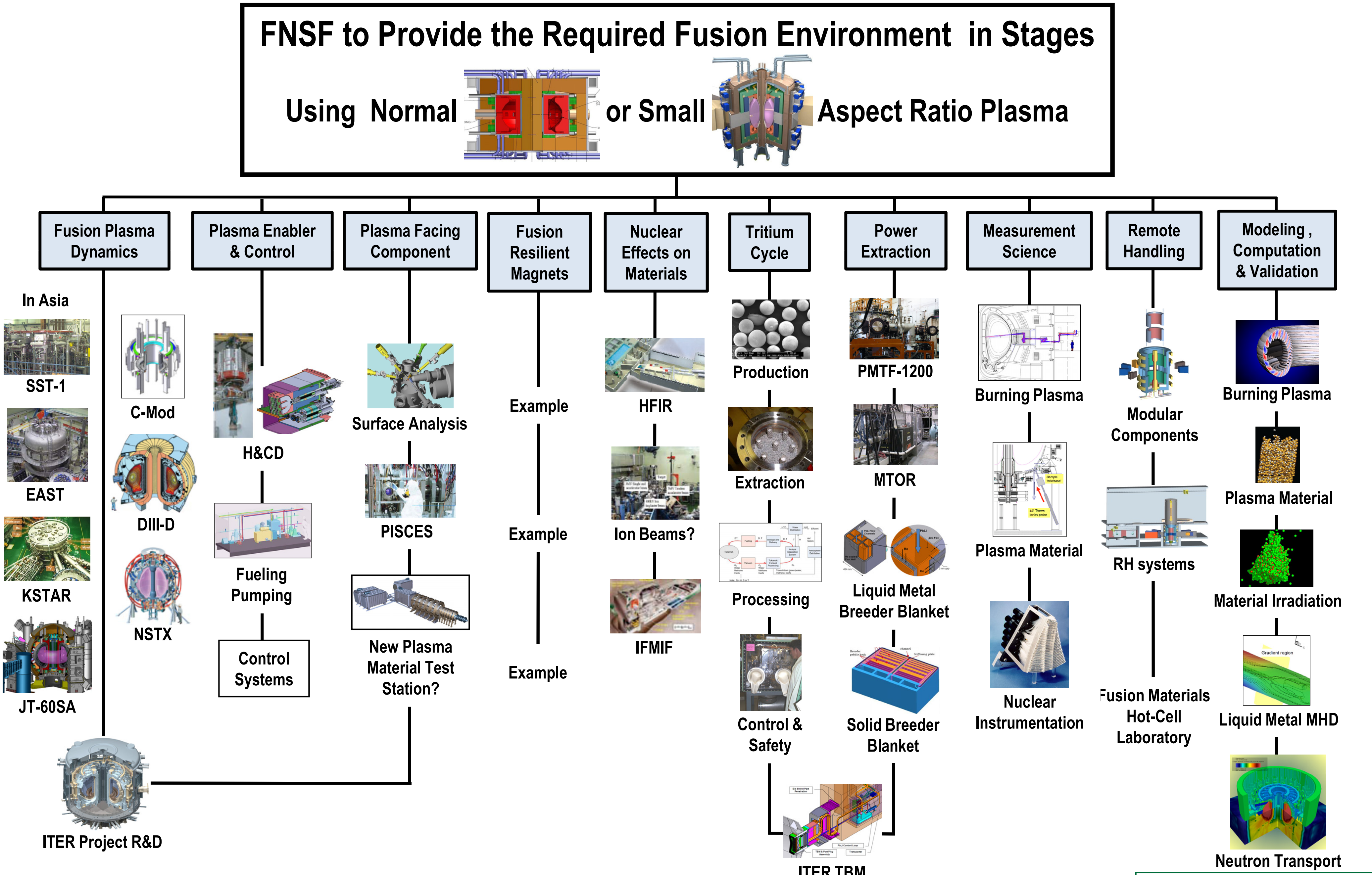
Available and Likely Needed New Capabilities of the Fusion Nuclear Science Program (FNSP) Components



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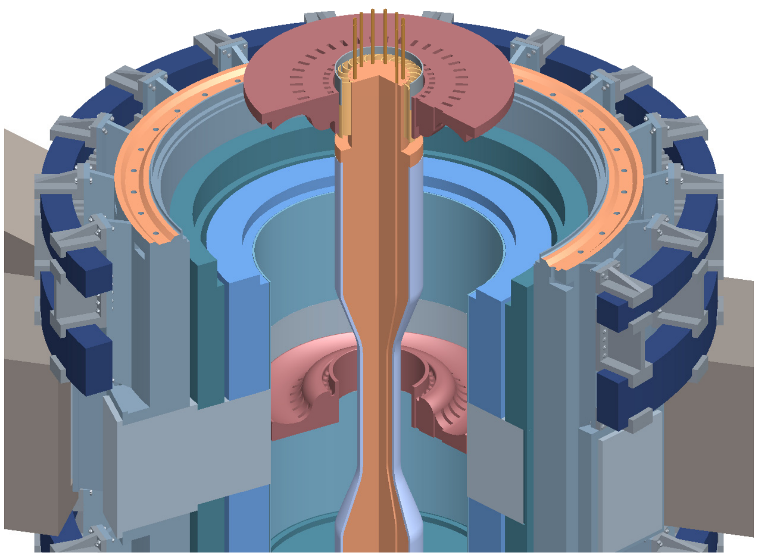
Plasma Surface Interaction research can begin at JET-level H, D, then DT operation (W_L = 0.25 MW/m^2)

Plasma facing surfaces: modular divertors, outboard blanket, inboard W-He shield



Goal: To investigate the synergistic effects of plasma surface interactions to discover, understand, and innovate for improved solutions, involving:

- High levels of ion, α, neutron, deuterium, tritium, and heat fluxes
- Sputtering, erosion, redeposition, migration
- Near-surface T/He implantation (diffusion source)
- Temperature gradients and thermal stresses
- Bulk radiation damages – defects, dislocations, voids, tritium trapping
- Radiation induced changes/degradations in thermo-mechanical properties
- Multiple materials, joints/interfaces, coolants, corrosion, contamination

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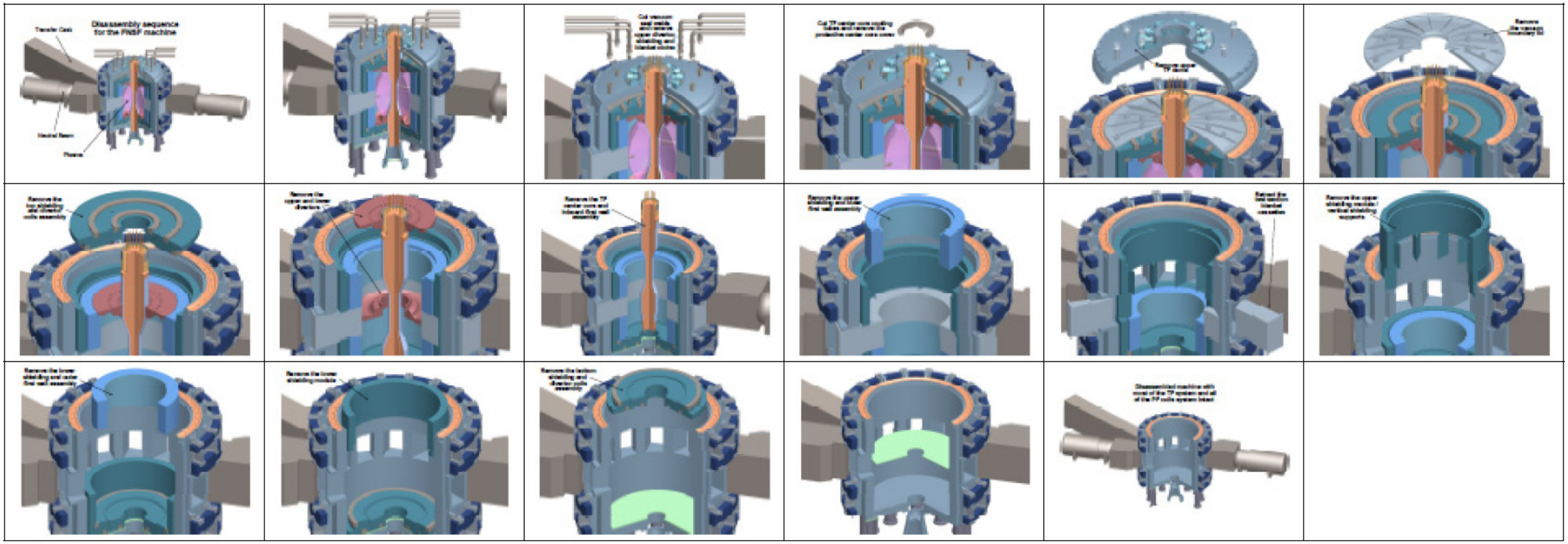
Configuration for Full Modularization of the FNSF Internals to allow extensive Remote Handling will be analyzed as part of the tradeoff of performance-cost-risk



All internal or activated components of FNSP are accounted.

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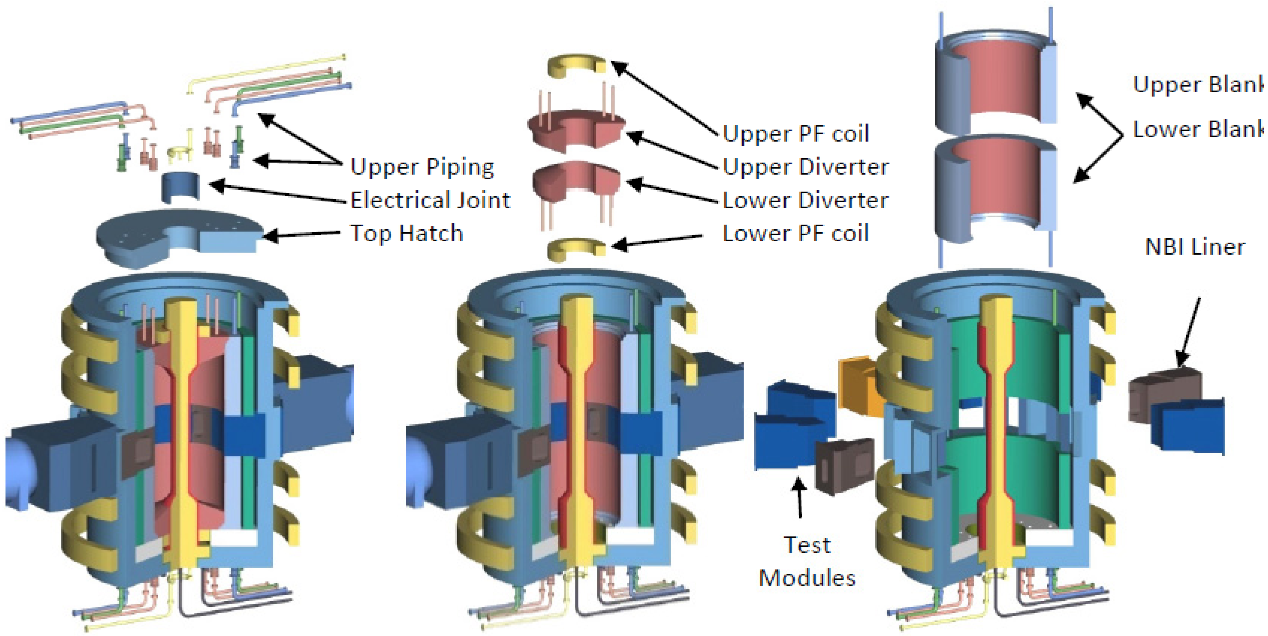
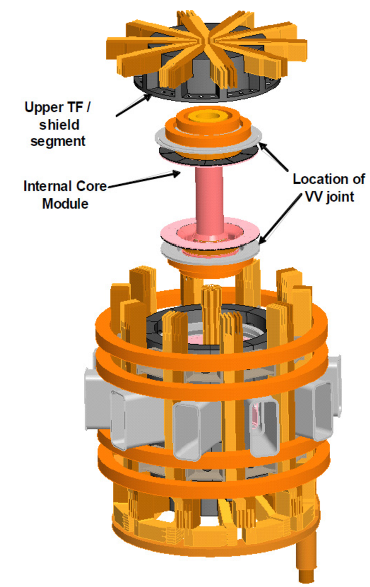
We are particularly pleased to see the 2010 NHTX to adopted the 2008 FNSF "Maintainability via Modularity" concept

2008 FNSF, ORNL (FEC08, SOFE08)



2010 NHTX, PPPL (ARIES mtg)



- Provided PPPL upon request in 3/2010 the animation movies for the 2008 FNSF "High Maintainability via Modularity" [Peng et al, FEC 2008; SOFE 2008 papers].
- Will repost animation movies due to interests during ARIES PMI mtg.
- Recommend that expert core competencies are shared among participating institutions, to ensure common approaches to concept evaluations and scientific and technical clarity of results.

Issues recommended for further discussion & development – outreach to obtain feedback on missions, characteristic, prerequisites for the FNSP-FNSF

- Focus on FNSP-FNSF for now; pleased to discuss the direction of our work with many potential expert stakeholders, who we hope to be part of FNSP-FNSF assessments.
- Discuss and refine draft mission of FNSP-FNSF with fusion, nuclear science & technology communities: to provide needed fusion environment with capabilities to address FES Goal #2 and develop experimental data base for all fusion reactor internals and, in parallel with ITER, to provide the basis for Demo.
- Discuss and refine FNSP mission components for FES Goals #1 & #2 that enable and utilize the FNSF
- Move on to develop "programmatic needs", to assess reasonable risks in FNSF design, construction and operation, such as in:
  - Nuclear and nonnuclear materials science
  - Optimal geometry informed by improved understanding of operating environment and risk tolerance
- Discuss drafts and results with community for feedback before finalizing input to DOE.
- Tentative: Aug/2010 – UCLA; Oct/2010 – GA; Dec/2010 – ORNL