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NSTX Program Overview, Collaborations, Governance

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Oak Ridge National Laboratory

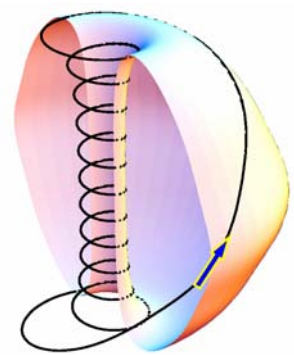
For the NSTX National Team

DOE Review of
NSTX Five-Year Research Program Proposal
June 30 – July 2, 2003

Columbia U
Comp-X
General Atomics
INEL
Johns Hopkins U
LANL
LLNL
Lodestar
MIT
Nova Photonics
NYU
ORNL
PPPL
PSI
SNL
UC Davis
UC Irvine
UCLA
UCSD
U Maryland
U New Mexico
U Rochester
U Washington
U Wisconsin
Culham Sci Ctr
Hiroshima U
HIST
Kyushu Tokai U
Niigata U
Tsukuba U
U Tokyo
Ioffe Inst
TRINITI
KBSI
KAIST
ENEA, Frascati
CEA, Cadarache
IPP, Jülich
IPP, Garching
U Quebec

NSTX Proposes to Extend Plasma Science Basis for Optimized Fusion Energy Development

Extended Science

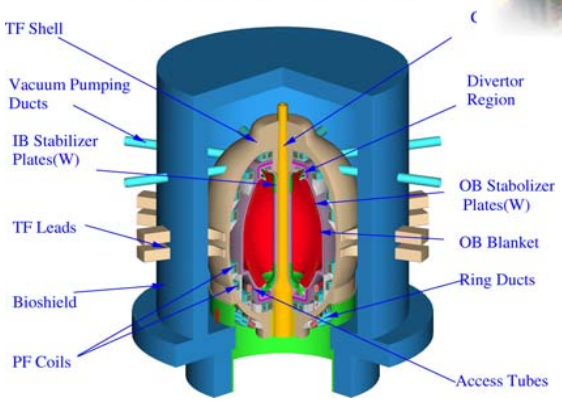


National Team

Frontier Diagnostics

(figure to be added)

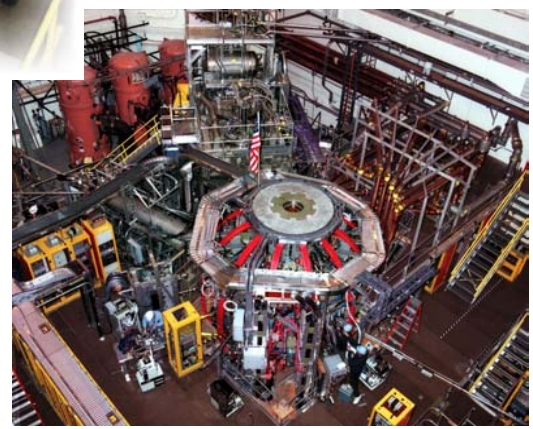
Optimized Power



Broad Cooperation

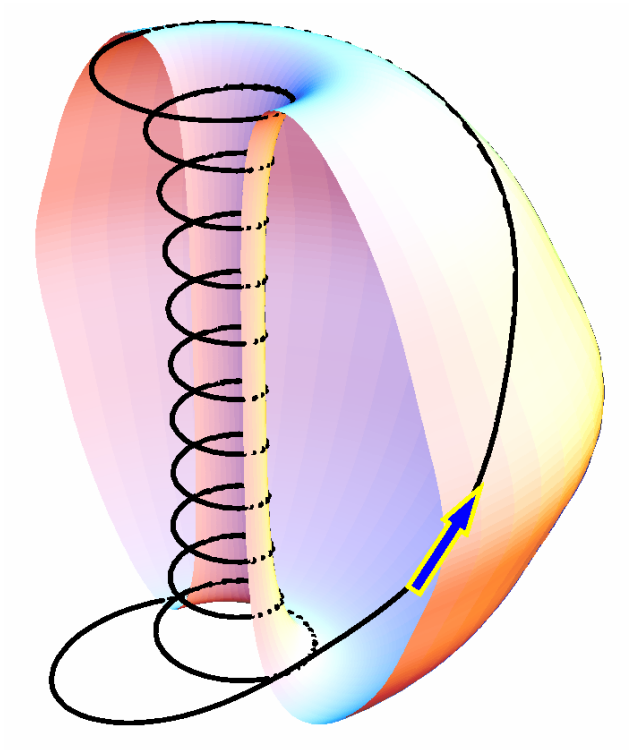
ST: MAST, TST-2, etc.
ICC: Spheromak, RFP, FRC
Burning Plasma: ITPA
Other: IEA on ST, etc.

Flexible Facility



Spherical Torus Offers High β Plasmas with Strong Toroidicity & High Safety Factor (q_{edge} ~ 10)

Spherical Torus provides interesting plasmas

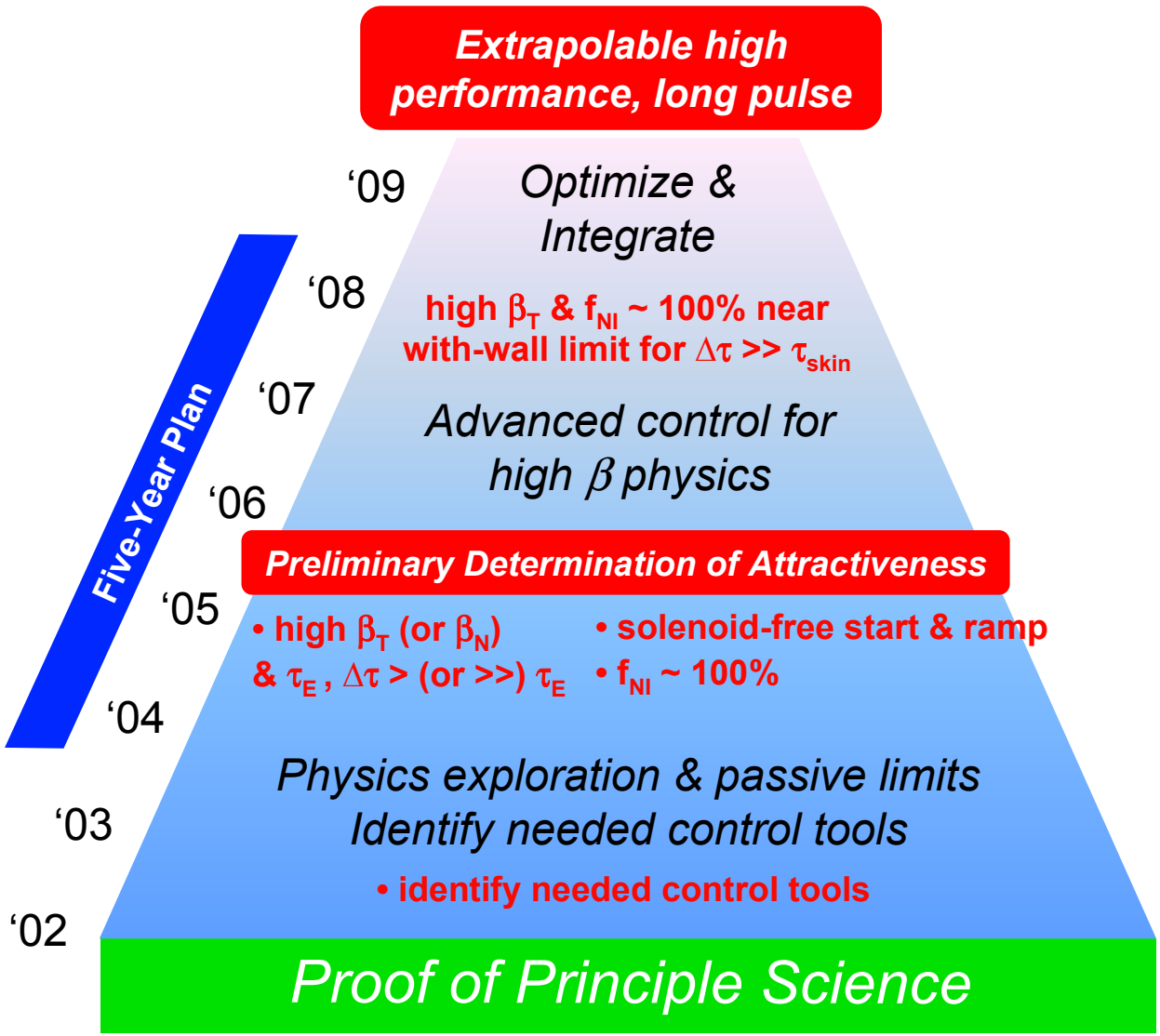


Extended parameter space identified for NSTX plasma science:

- High β_T ($\leq$ 40%) & central β_0 (~100%)
- Stronger plasma shaping & self fields ($A \geq 1.27$, $\kappa \leq 2.5$, B_p/B_t ~1, q_{edge} ~10)
- Reduced internal inductance (ℓ_i) & magnetic stored energy ($\propto \ell_i R I_p^2$)
- Large plasma flow ($V_{rotation}/V_A$ ~0.3)
- Larger flow shearing rate ($\gamma_{ExB} \leq 10^6$/s)
- Supra-Alfvénic fast ions (V_{fast}/V_A ~4–5)
- High dielectric constant (ε ~ 50)
- Large B-mirror in edge magnetic field

Proposed 5-Year Research Aims to Demonstrate Long Pulse, High Performance Plasma Operations

- **5-year goals**
  - Determine attractiveness
  - Establish basis for extrapolable high performance & long pulse
  - Database for next PE step (NSST), & in turn for CTF
- **Supporting**
  - Implement key measurements
  - Advance control tools & facility upgrades
  - Carry out supporting analyses



Key Diagnostic Upgrades are Planned to Support Proposed Research

MHD

- Soft x-ray arrays [JHU]
- Ultra-fast tangential x-ray camera [PSI]
- Electron Bernstein wave radiometer
- MSE/CIF polarimeter [NOVA]
- MSE/LIF polarimeter [NOVA]

Transport and Turbulence

- Toroidal CHERS
- Poloidal CHERS
- Thomson scattering upgrades
- Edge fluctuation imaging [NOVA, PSI]
- Microwave backscattering [UCLA]
- Tangential microwave scattering
- Imaging reflectometry [UC Davis]

Fast Particles

- Scintillator fast lost ion probe
- Neutron collimator

Edge and Divertor

- Fast scanning edge probe [UCSD]
- Deposition monitor
- Edge Doppler spectroscopy
- Divertor Thomson scattering

Proposed Facility Upgrades Build Steadily on Solid Research to Enable a Vibrant Program

Upgrade	Research Areas of Interest							Development/Installation					
	MHD	Transport	HHFW	EBW	CHI	Boundary	Integration	FY03	FY04	FY05	FY06	FY07	FY08
Auxiliary Systems													
Absorber field null control					√								
NB power modulation	√	√					√						
PF power supply upgrade	√		√				√						
HHFW antenna end-feed			√										
EBW system, 1MW	√	√		√									
EBW system, 3MW	√	√		√			√						
MHD/Error Field Control													
RWM sensors & detection	√						√						
Active mode-control	√						√						
PF1A coil modification	√					√	√						
Passive stabilizer relocation	√						√						
Fueling, Power and Particle Control													
Li/B pellet injector		√				√	√						
Supersonic gas injector		√				√	√						
Lithium wall coating	√	√	√	√	√	√	√						
Divertor cryo-pump		√	√	√	√	√	√						
D pellet injector (LFS)		√				√	√						
D pellet injector (HFS)		√				√	√						
CT injector		√				√	√						
Divertor long-pulse upgrade						√	√						
Liquid Li surface module	√	√	√	√		√	√						

Extensive Important DOE-Funded Collaboration Characterizes NSTX National Research Team

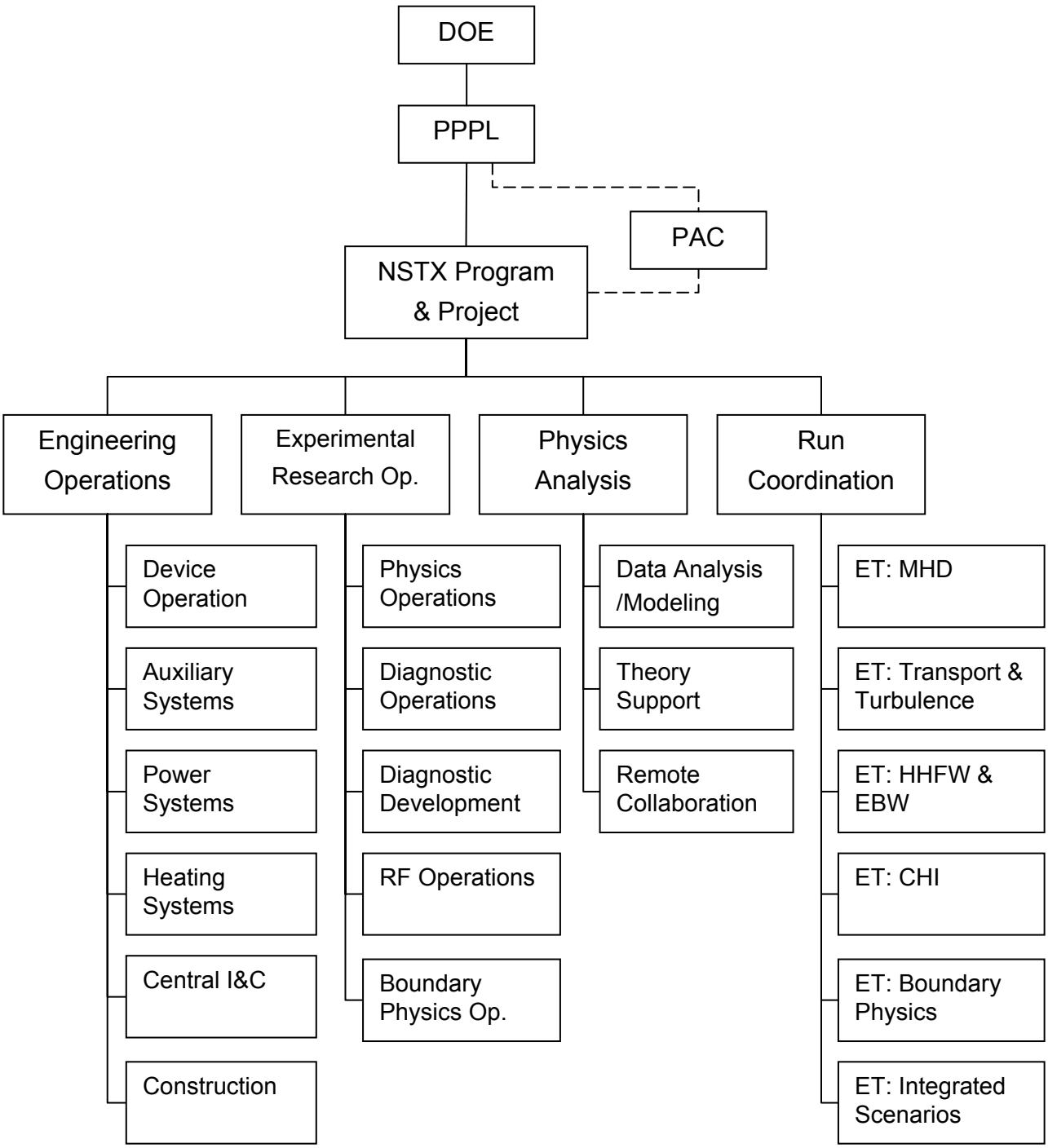
Institution	Home-Site Lead	Topical Programmatic Role	Collab. Lead	Onsite Contact
Columbia U	J. Navratil	MHD studies	S. Sabbagh	J. Menard
Comp-X	R. Harvey	RF heating and current drive	R. Harvey	C. Phillips
General Atomics	J. Ferron	CHI equilibrium reconstruction	M. Schaffer	S. Kaye
		RF physics	R. Pinsker	R. Wilson
		Plasma control	J. Ferron	D. Gates
JHU	M. Finkenthal	Ultra-soft X-ray diagnostics	D. Stutman	R. Kaita
LANL	G. Wurden	Fast visible & infrared imaging	R. Maqueda	S. Zweben
	A. Glasser	CHI plasma MHD	X. Tang	R. Raman (UW)
LLNL	G. Porter	Edge, scrape-off layer modeling	G. Porter	R. Maingi (ORNL)
		Boundary stability & turbulence	X. Xu	D. Stotler
Lodestar	D. D'Ippolito	Boundary stability & turbulence	J. Myra	D. Stotler
MIT	M. Porkolab	EBW Modeling	A. Bers, A. Ram	G. Taylor
		HHFW modeling	P. Bonoli	C. Phillips
Nova Photonics	F. Levinton	MSE diagnostics	F. Levinton	D. Johnson
ORNL	D. Rasmussen	RF launcher & experiments	D. Swain	R. Wilson
		ECH/EBW initiation & ramp-up	T. Bigelow	G. Taylor
		Fueling & transport modification	L. Baylor	H. Kugel
	P. Mioduszewski	Edge, H-mode experiments	R. Maingi	V. Soukhanovskii
	D. Batchelor	Transport and RF modeling	W. Houlberg	S. Kaye
UC Davis	N. Luhmann	FIRe-TIP and scattering	K.C. Lee	H. Park
UC Irvine	B. Heidbrink	Fast ion-plasma interactions	B. Heidbrink	D. Darrow
UCLA	T. Peebles	Reflectometry	S. Kubota	T. Munsat
UCSD	F. Najmabadi	HHFW modeling	T. K. Mau	C. Phillips
	J. Boedo	Fast probe	J. Boedo	H. Kugel
	S. Krasheninnikov	Edge intermittent transport	A. Pigarov	R. Maingi (ORNL)
U Washington	T. Jarboe	Coaxial helicity injection	R. Raman	D. Mueller
U Wisconsin	J. Callen	Neoclassical transport modeling	K.C. Shaing	R. Bell

NSTX National Research Team Has Been Integrated at All Level of Research Activities

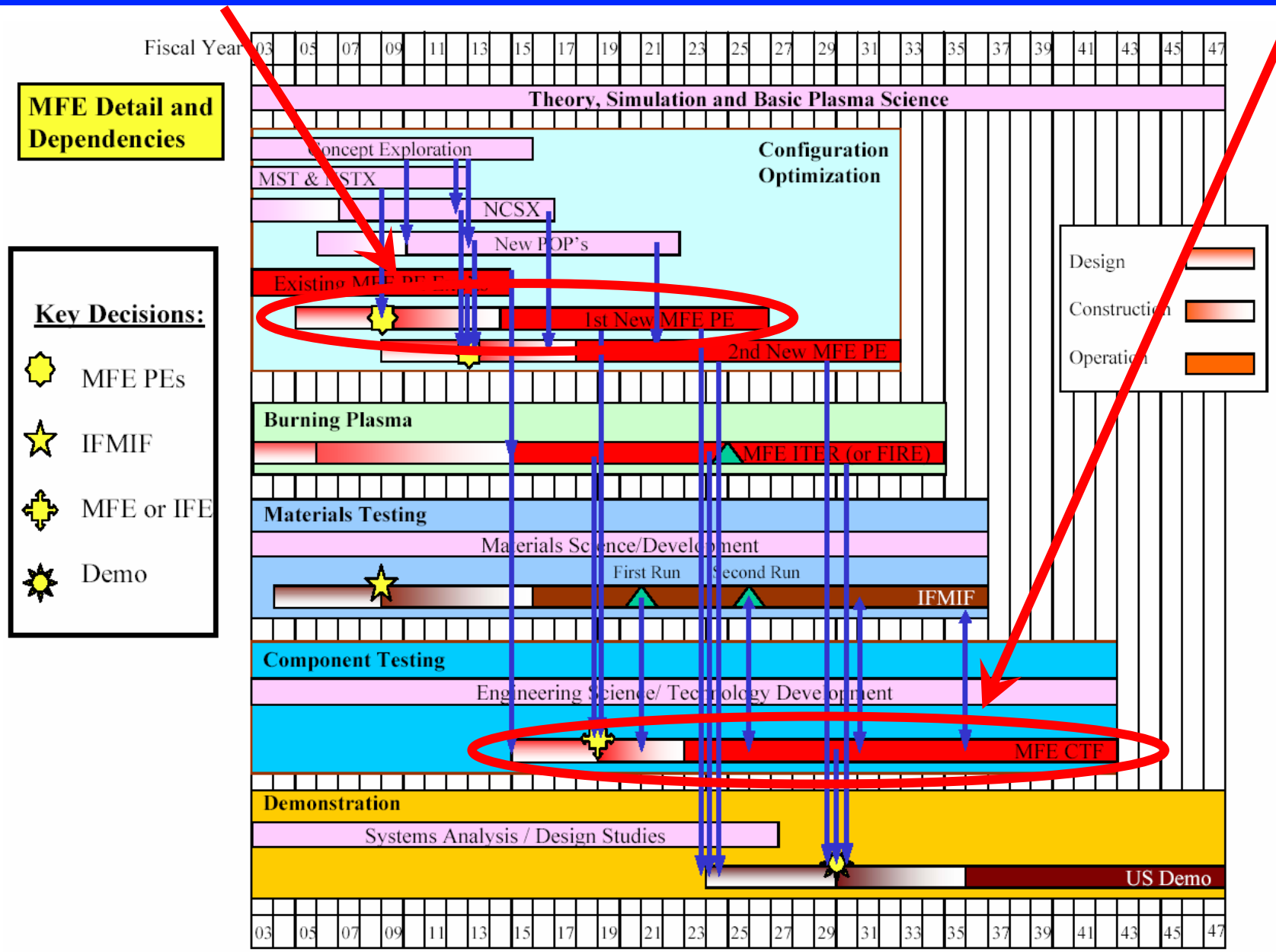
Experimental Task Groups	Leader	Deputy
FY-2000 – RC: M. Bell; Deputy: E. Synakowski		
Ohmic Plasmas	M. Bell	S. Sabbagh (Columbia U)
HHFW Heating	J. R. Wilson	D. Swain (ORNL)
CHI	R. Raman (U Washington)	D. Mueller
FY-2001 – RC: E. Synakowski; Deputy: R. Maingi (ORNL)		
MHD	S. Sabbagh (Columbia U)	J. Menard
Transport & Turbulence	S. Kaye	B. LeBlanc
HHFW	J. R. Wilson	D. Swain (ORNL)
CHI	R. Raman (U Washington)	D. Gates
Boundary Physics	R. Maingi (ORNL)	C. Skinner
FY-2002 – RC: R. Maingi (ORNL); Deputy: S. Kaye		
MHD	J. Menard	E. Fredrickson
Transport & Turbulence	D. Darrow	D. Stutman (JHU)
RF Heating & Current Drive	J. R. Wilson	D. Swain (ORNL)
Non-Inductive Startup	R. Raman (U Washington)	D. Mueller
Boundary Physics	H. Kugel	C. Bush (ORNL)
Integrated Scenarios Development	D. Gates	S. Sabbagh (Columbia U)
FY-2003 – RC: S. Kaye		
MHD	S. Sabbagh (Columbia U)	D. Gates
Transport & Turbulence	B. LeBlanc	D. Darrow
HHFW & EBW	G. Taylor	P. Ryan (ORNL)
CHI	M. Bell	R. Raman (U Washington)
Boundary Physics	H. Kugel	R. Kaita
Integrated Scenarios Development	R. Maingi (ORNL)	J. Menard

NSTX Is Organized Towards Enabling the ET Groups' Research

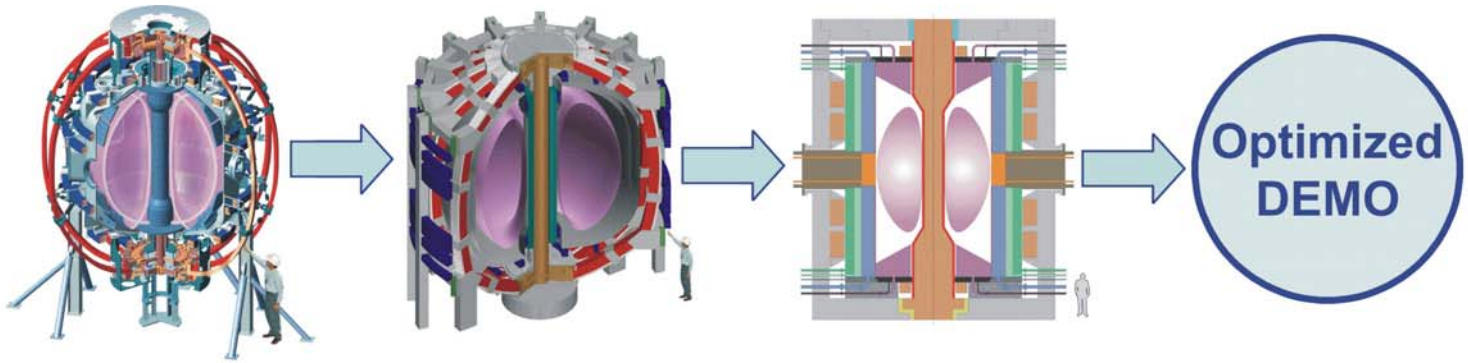
- **Engineering ⇒ Experimental Research Ops & Physics Analysis ⇒ Experimental Tasks**
- **PAC has major roles**
- **PPPL management provides great guidance**



Spherical Torus Is A Strong Candidate for MFE Performance Extension (PE) Experiment and Component Test Facility (CTF)



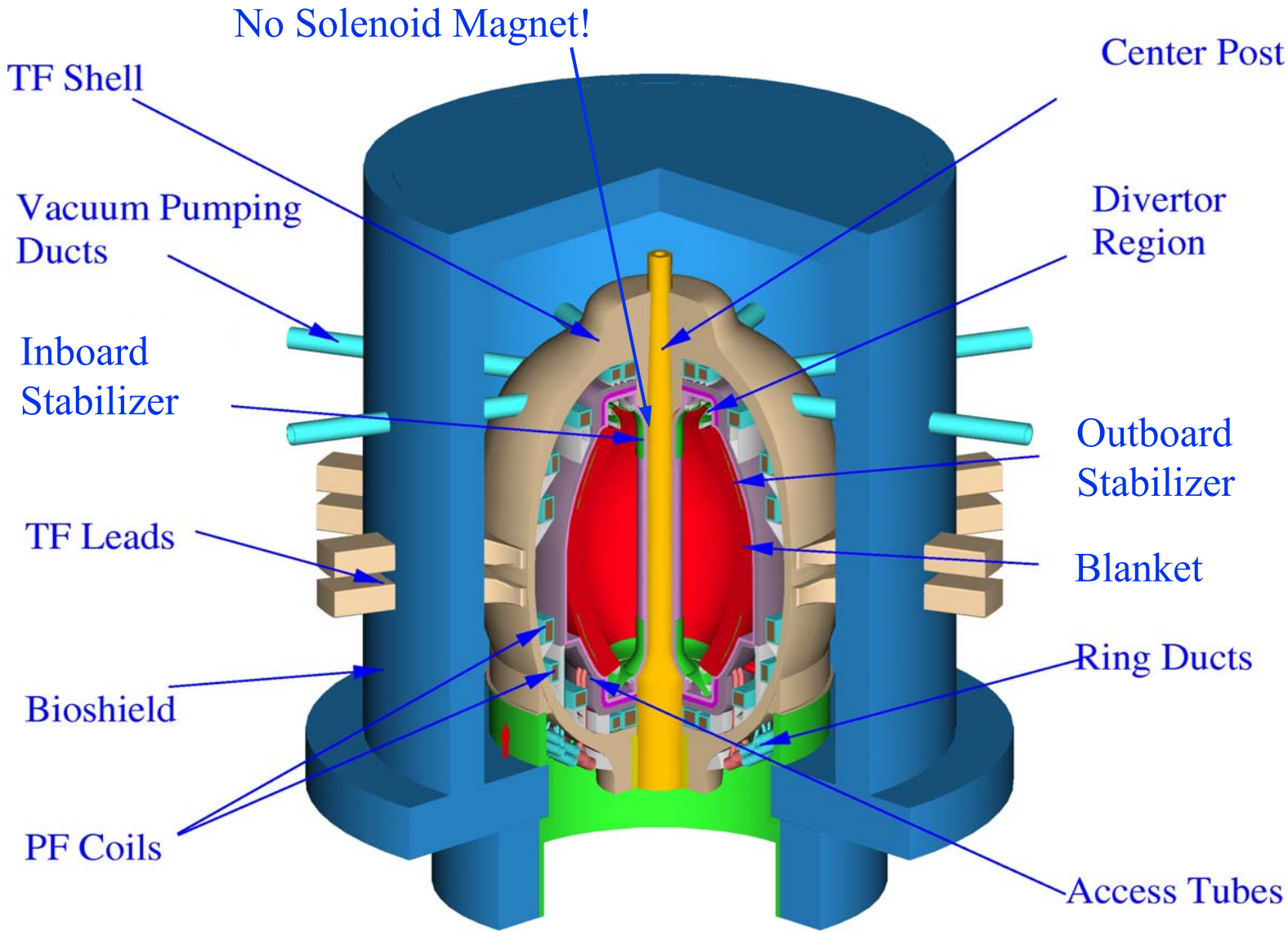
The Benefits of Projected ST Properties Include Potentially Cost-Effective Next Step Devices



Device	NSTX	NSST	CTF	DEMO
Mission	Proof of Principle	Performance Extension	Energy Development, Component Test	Economy of Fusion Electricity
R (m)	0.85	1.5	1.2	~2.5
a (m)	0.65	0.9	0.8	~1.8
κ, δ	2, 0.8	2.7, 0.6	3, 0.4	~3.4, 0.5
I_p (MA)	1.5	5 – 10	12	~20
B_T (T)	0.3 – 0.6	1.1 – 2.6	2.4	~2
P_{fusion} (MW)	–	10 – 50	$\geq$ 70	~2000
t-pulse (s)	1 – 5	50 – 5	Steady state	Steady state
TF coil	Multi-turn	Multi-turn, LN_2	Single-turn	Single-turn

ST DEMO & Power Plants Can Have Simplified Modular Designs Using a Demountable Center Post

ARIES-ST



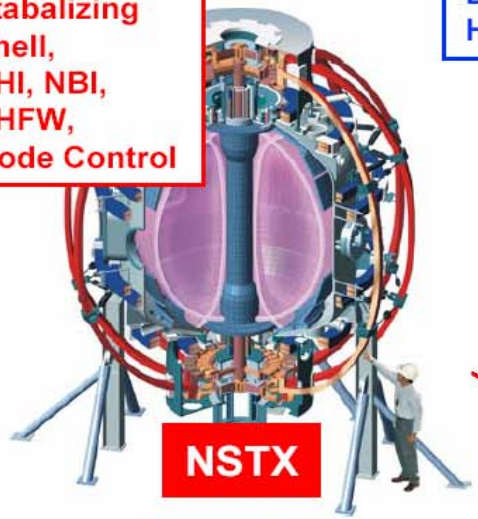
Worldwide Collaboration is Key to NSTX Research

NSTX

Concept Exploration (~0.3 MA)

Proof of Principle (~MA)

Stabalizing Shell, CHI, NBI, HHFW, Mode Control



NSTX

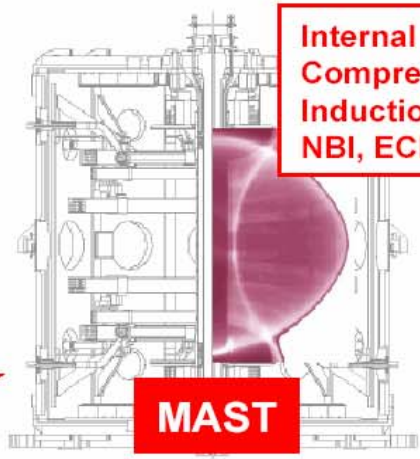
Extreme Low A, HHFW, EBW

Pegasus

CHI Synergy

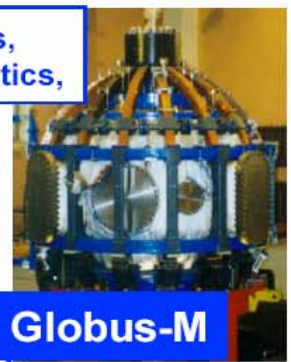
HIT-II

Internal PFC, Compression-Induction, NBI, ECH/EBW



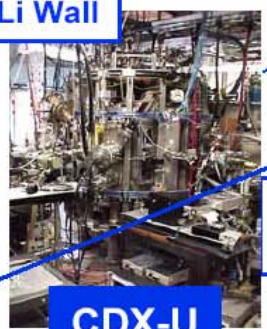
MAST

LHW Physics, Adv Diagnostics,



Globus-M

Li Wall



CDX-U

Advanced Diagnostics

ETE

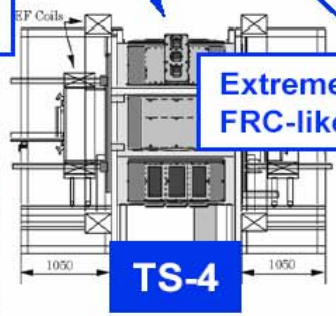
Extreme Low A CHI, Spheromak

HIST

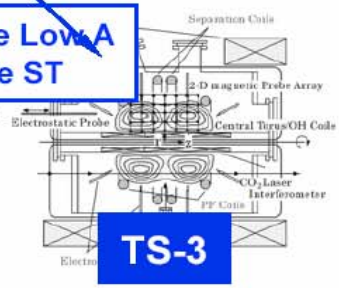
ECH startup HHFW Innovation

TST-2

Extreme Low A FRC-like ST



TS-4



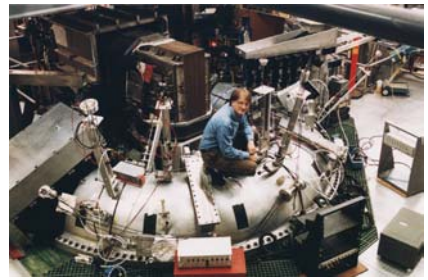
TS-3

NSTX Team Plans to Broaden Experimental Collaborations Further

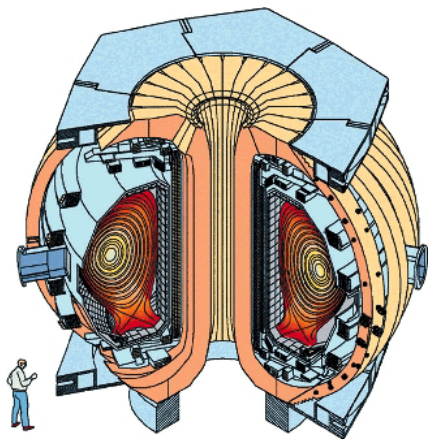
- **MAST, U.K.**
  - NBI H-mode, transport, τ_E
  - EBW H&CD (1 MW, 60 GHz)
  - Divertor heat flux studies
  - NTM, ELM characterization
- **MST, SSPX**
  - Helicity injection startup, sustainment
  - Electromagnetic turbulence
  - EBW
- **Began participation in ITPA**
  - A and β effects: H-mode, ITB, ELM's & pedestal, SOL, RWM, and NTM
- **DIII-D & C-Mod collaboration**
  - RWM, Fast ion MHD, pedestal, core confinement, edge turbulence, core temperatures

SSPX
(add picture)

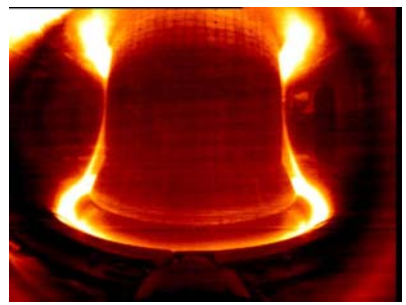
MST



DIII-D



C-Mod



NSTX Proposes to Extend Plasma Science Basis for Optimized Fusion Energy Development

- Extend toroidal fusion plasma science base
- Enable attractive fusion energy development
- Installs key diagnostics to support planned research
- Upgrade facility to enable a vibrant program
- Expand broadly based national research collaboration
- Encourage growing ST research worldwide
- Enhance research cooperation in ST, ICC, and burning plasma contributions