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ST Role in Fusion Development, NSTX Governance, Collaborations & Program Outline

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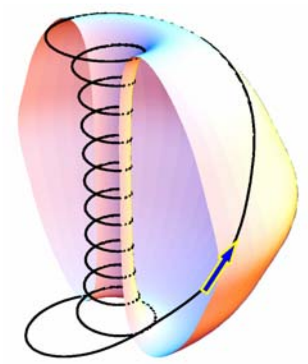
For the NSTX National Team

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

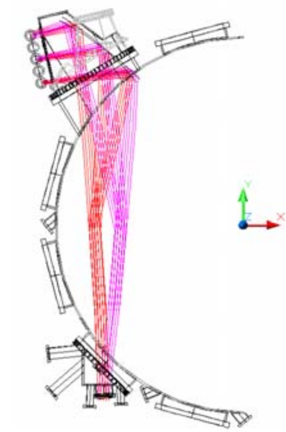
NSTX Contributes to Fusion Energy Science Along a Broad Frontier

Extended Science

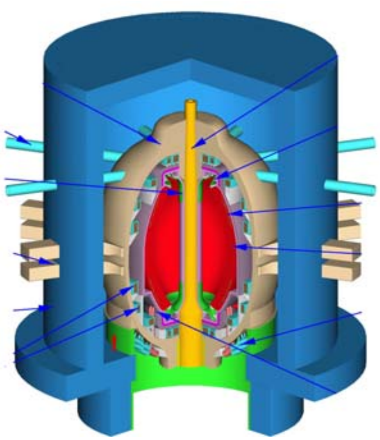


National Team

Frontier Diagnostics



Optimized Power



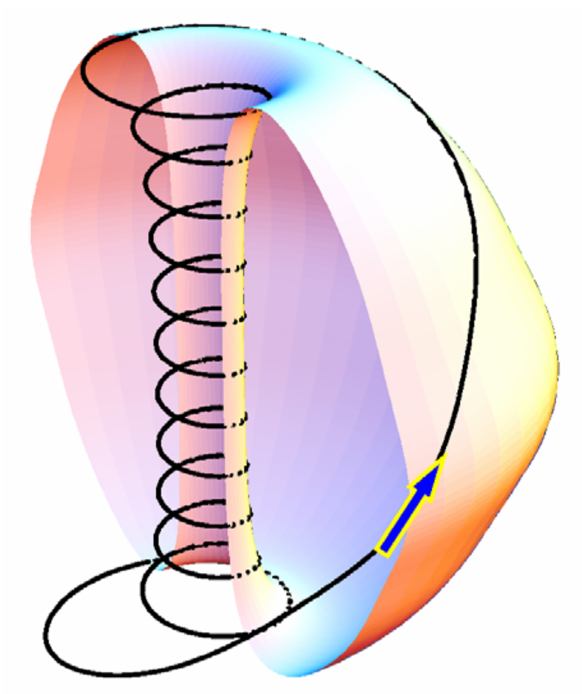
Flexible Facility

Broad Cooperation

ST – HIT-II, CDX-U, Pegasus, MAST, TST-2, etc.
ICC – Spheromak, RFP, FRC
Burning Plasma – ITPA
Astrophy. Plasmas – X-ray Spectrometer

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

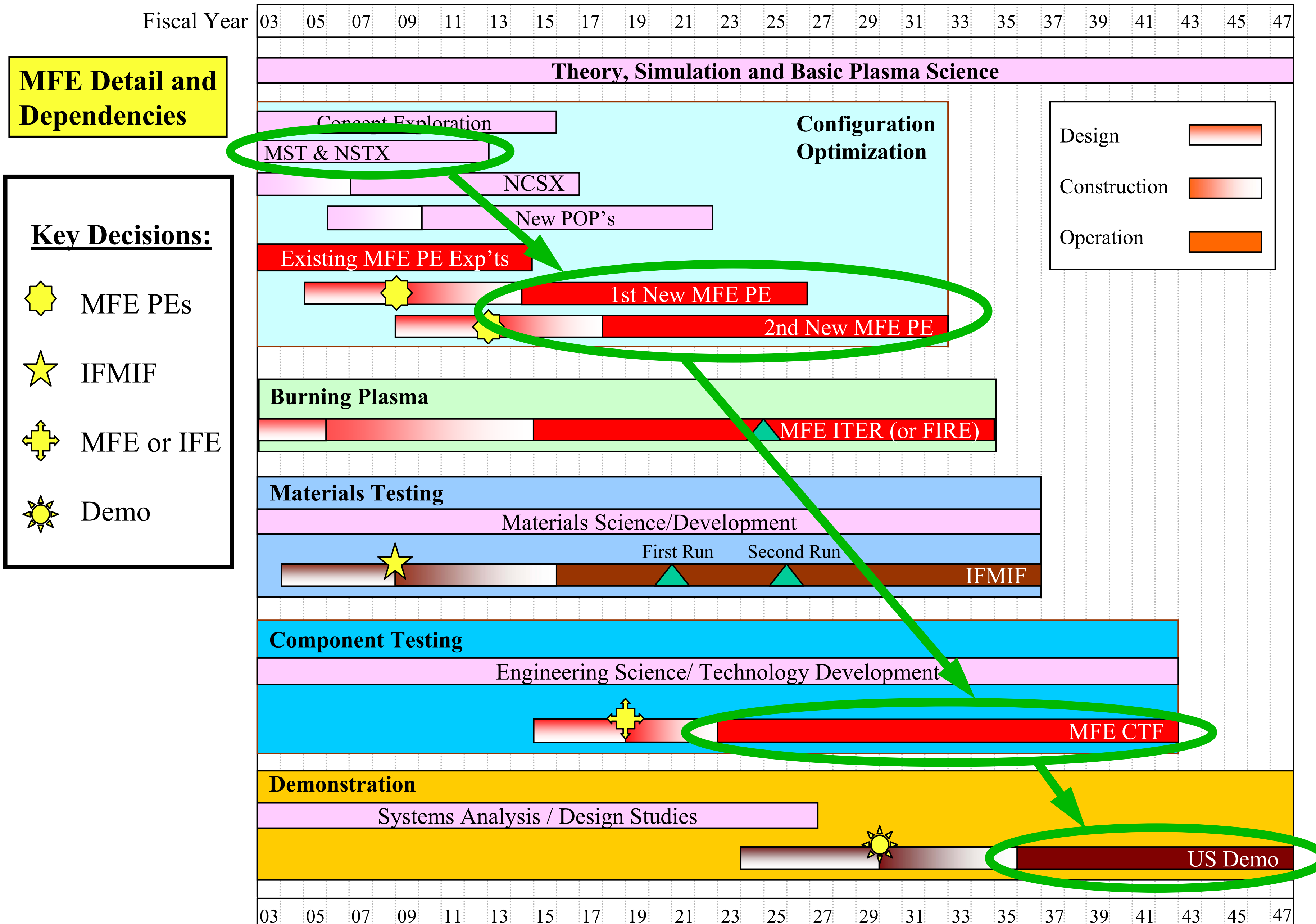
Spherical Torus provides Scientifically Interesting plasmas



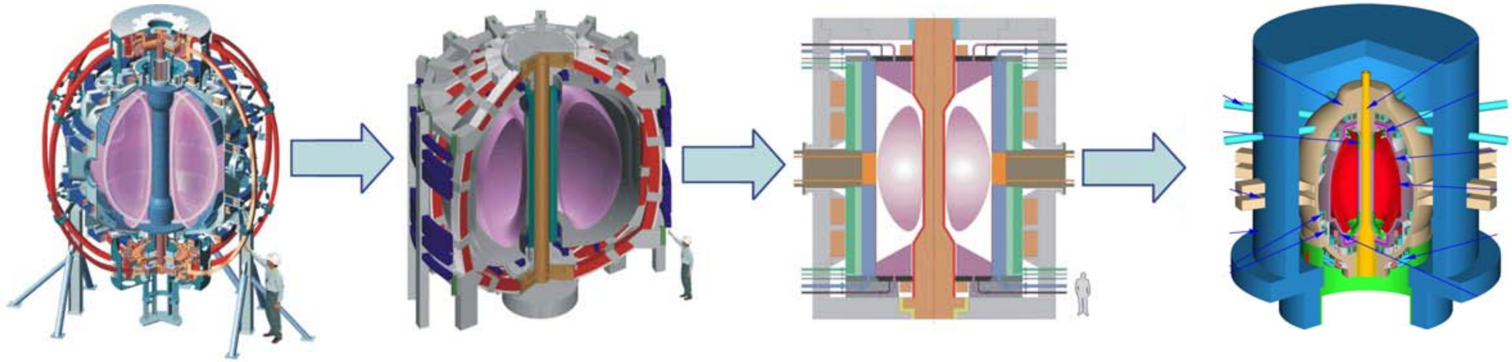
Extended Physics parameter space available for plasma science:

- High β_T (≤ 40%) & central β_0 (~100%)
- Strong plasma shaping & self fields ($A \geq 1.27$, $\kappa \leq 2.5$, $B_p/B_t \sim 1$, $q_{edge} \sim 10$)
- Small plasma size relative to gyro-radius ($a/\rho_i \sim 30$–50)
- Large mirror in core & edge B field ($f_T \rightarrow 1$)
- Large plasma flow ($M_A = V_{rotation}/V_A \leq 0.3$)
- Large flow shearing rate ($\gamma_{ExB} \leq 10^6$/s)
- Supra-Alfvénic fast ions ($V_{fast}/V_A \sim 4$–5)
- High dielectric constant ($\varepsilon = \omega_{pe}^2/\omega_{ce}^2 \sim 50$)

Spherical Torus Is Also an Integral Part of the Development Plan



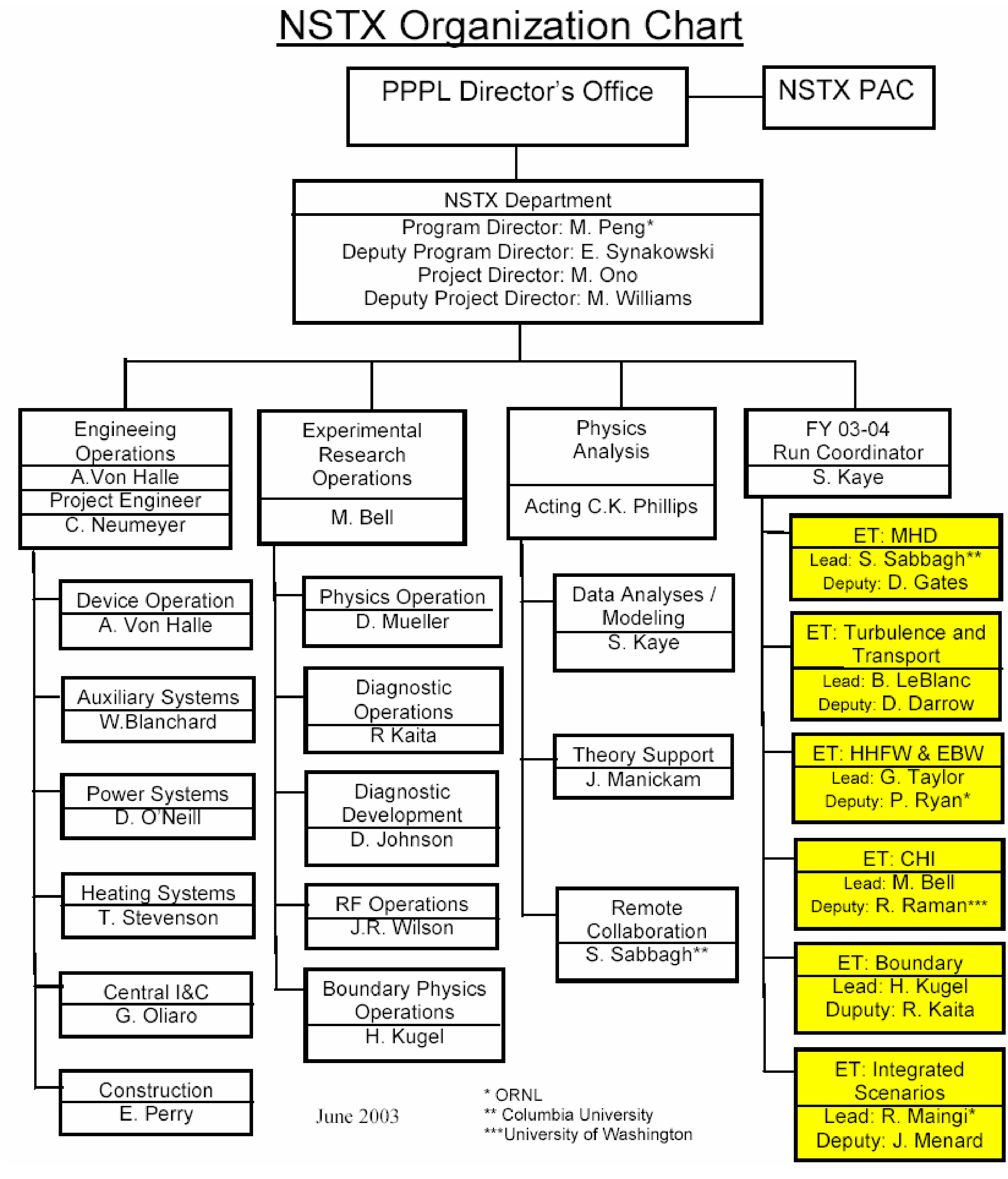
The ST Leads to Cost-Effective Steps to Fusion Energy



Device	NSTX		NSST		CTF		DEMO
Mission	Proof of Principle		Performance Extension		Energy Development, Component Testing		Practicality of Fusion Electricity
R (m)	0.85		1.5		~1.2		~3.4
a (m)	0.65		0.9		~0.8		~2.4
κ, δ	2.5, 0.8		2.7, 0.6		~3, ~0.4		~3.2, ~0.5
I_p (MA)	1.5	1	10	5	~11		~30
B_T (T)	0.6	0.3	2.6	1.1	~2.2		~1.8
Pulse (s)	1	5	5	50	Steady state		Steady state
P_{fusion} (MW)	–		50	10	~70	~280	~3000
W_L (MW/m^2)	–		–		~1	~4	~4
TF coil	Multi-turn		Multi-turn		Single-turn		Single-turn

NSTX Is Organized Towards Enabling the Experimental Task (ET) Groups' Research

- Engineering ⇒ Experimental Research Ops & Physics Analysis ⇒ Experimental Tasks
- PAC has major role, meets twice per year



NSTX National Research Team Has Been Integrated at All Levels of Research Activity

- **Run Coordinator (RC) and Deputy, and Experimental Task (ET) Leaders and Deputies are assigned each year**
- **About 1/3 leaders are from collaboration teams**

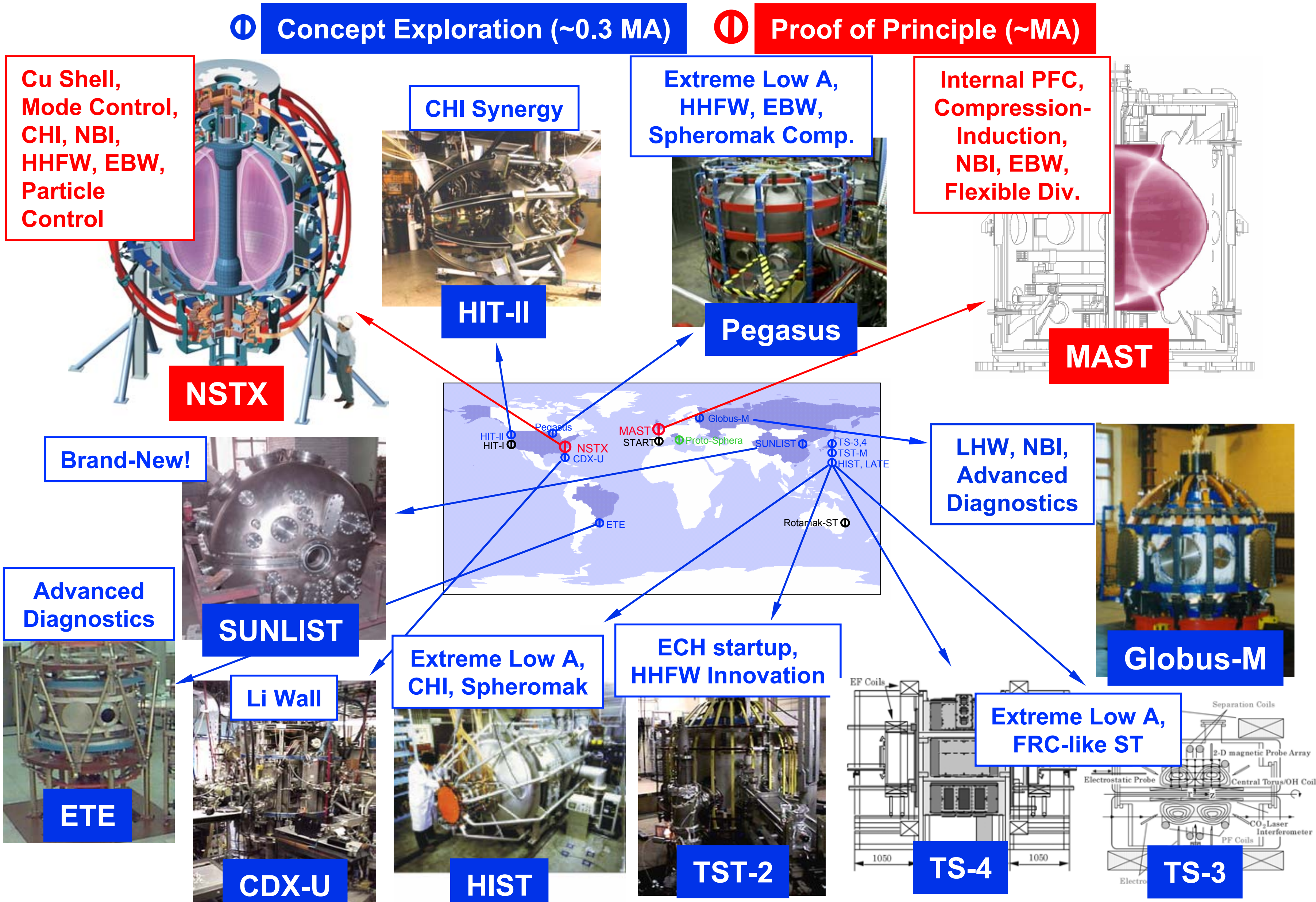
Experimental Task Groups	Leader	Deputy
FY-2000 – RC: M. Bell; Deputy: E. Synakowski		
Ohmic Plasmas	M. Bell	S. Sabbagh (Columbia U)
HHFW Heating	J. R. Wilson	D. Swain (ORNL)
CHI	R. Raman (U Washington)	D. Mueller
FY-2001 – RC: E. Synakowski; Deputy: R. Maingi (ORNL)		
MHD	S. Sabbagh (Columbia U)	J. Menard
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

Extensive Direct DOE-Funded Collaboration Forms Major Part of NSTX National Research Team

(16 Institutions, 27 Programs)

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

Worldwide Collaboration is a Hallmark of ST Research

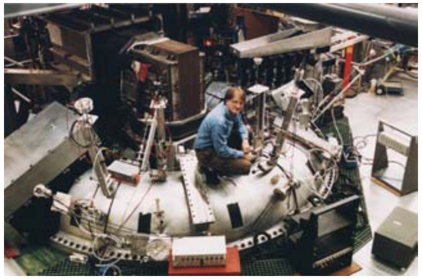


Extended ST Plasma Science Connects NSTX to the Broad Fusion & Plasma Science Portfolio

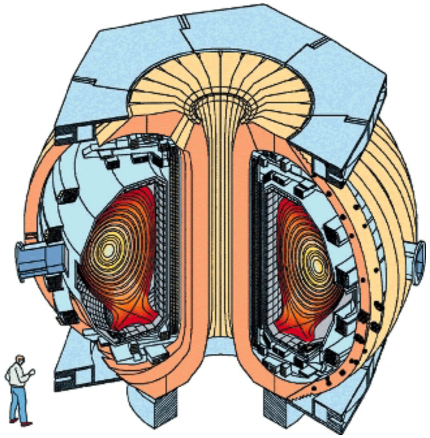
- **ICC Physics: SSPX, MST, FRC**
  - Magnetic reconnection – CHI
  - EBW H&CD – over-dense plasmas
  - Electromagnetic turbulence micro-tearing – $\beta \sim 1$ plasmas
  - TAE's – supra-Alfvénic fast ions
  - FRC-like diamagnetic plasmas
- **Burning Plasma – ITPA**
  - A and β effects: H-mode, ITB, ELM's & pedestal, SOL, RWM, and NTM
- **Tokamak Physics: DIII-D, C-Mod**
  - RWM, Fast ion MHD, pedestal, core confinement, edge turbulence, core temperatures
- **Accretion Disk Plasma Physics**
  - Electromagnetic turbulence cascade in $\beta \geq 1$ plasmas

SSPX

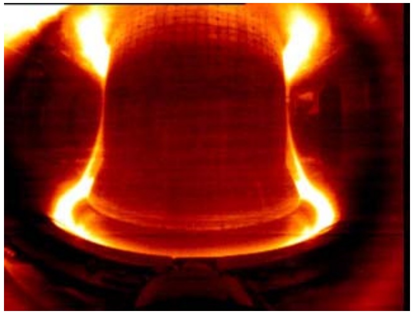
MST



DIII-D

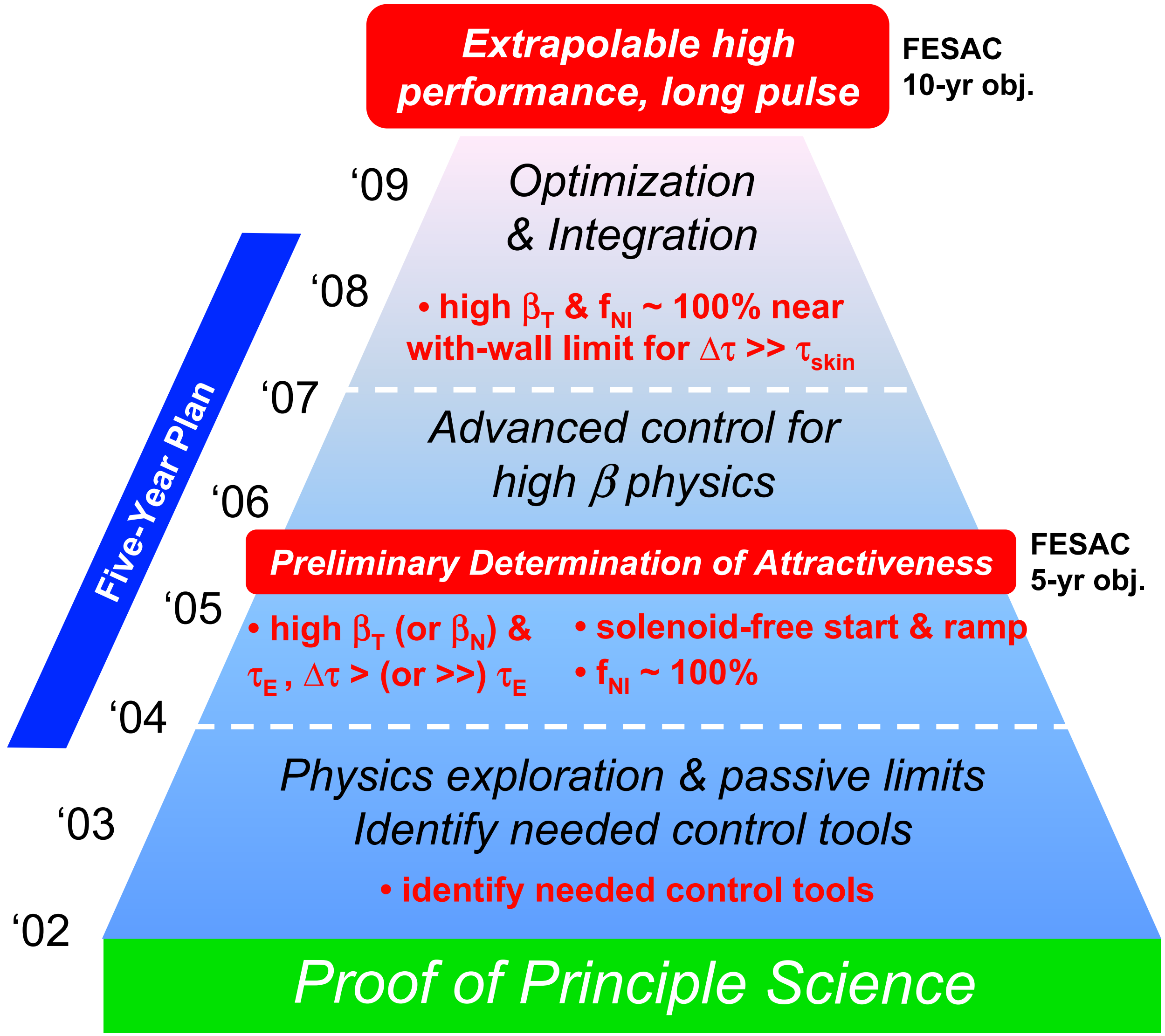


C-Mod



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

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



Exciting Diagnostic and Facility Upgrades are Proposed to Support Research

Diagnostics	Facility
MHD – EBW radiometer, fast ΔT_e – MSE/CIF, LIF polarimeter [Nova] **Transport & Turbulence** – High & low-k μ-wave scattering [UCLA, UCD] – μ-wave imaging reflectometer [UCD] – GPI – Planar LIF edge fluctuations [C-Mod, DIII-D, Nova, PSI, SBIR] **Edge & Divertor** – Divertor laser Thomson scattering **Astrophysics & Diagnostic Development** – X-ray imaging crystal spectrometer [LLNL, Chandra, C-mod, KSTAR, Adv. Diagnostics Program]	**Very High β** – Ex-vessel field and mode control coils [CU] – Modification of PF1A (k=2.6, δ=0.6) – Active mode control systems [CU] **CD, MHD, Integrated Scenarios** – EBW (1$\rightarrow$4 MW source power) [VLT, MIT, ORNL] **Startup** – EBW – CHI absorber control coils – Outboard PF-only induction **Particle & Edge Plasma Control** – Cryopumps – Lithium pellets, coating, flowing surface module [VLT-PFC, CDX-U]

NSTX Proposes a Very Exciting Five-Year Program

NSTX

- NSTX research will make very important contributions: science – energy; ST – broad portfolio
- Critical and exciting research is planned
  - MHD: mode control with β_0 ~ 1, large M_A & M_S, $\gamma_{E\times B} \sim \gamma_{MHD}$?
  - T&T: electromagnetic turbulence & μ-tearing with ability to manipulate low-k turbulences via flow shear
  - Startup & Sustainment: CHI, PF-only, HHFW, EBW (f_T ~ 1!), supra-Alfvénic ions
  - Towards non-recycling edge: Cryopumps, lithium systems
  - Exciting integrated scenarios developed to take NSTX to limit!
- Broadly based national team will carry out this exciting research