NSTX

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Macroscopic Stability Theory and Computation for NSTX-U (Brainstorming and Plan)

Jong-Kyu Park
John (Jack) Berkery
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Macroscopic Stability TSG Meeting
February 14, 2012

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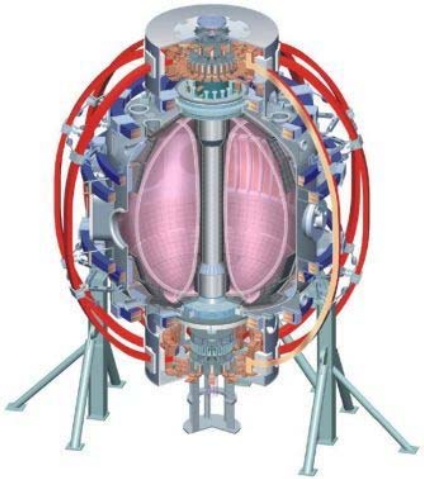

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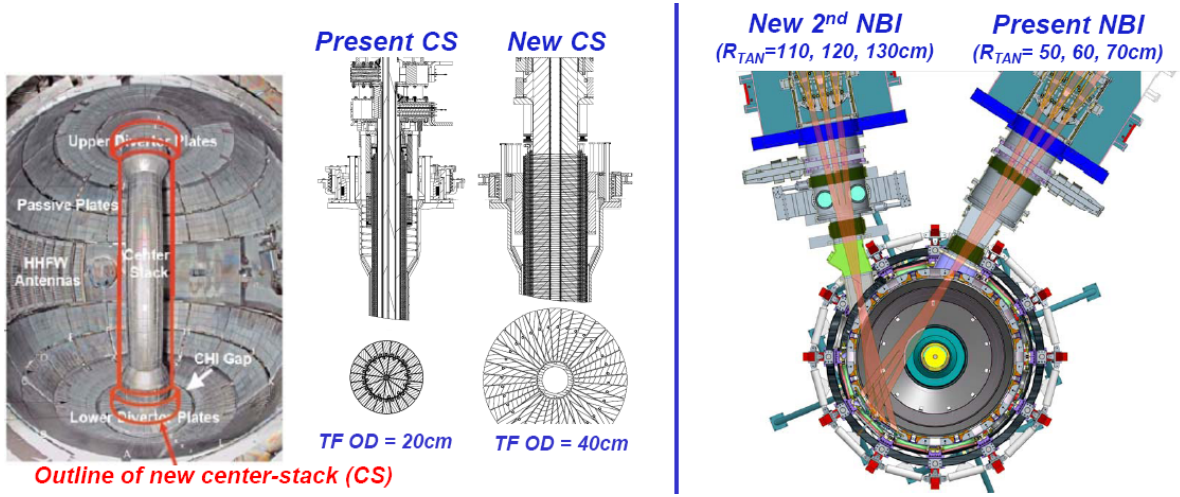
This Meeting: will discuss or identify 3-5 major topics for the next 5 year NSTX research

- To provide initial guidance for Theory/Experiment joint research topics on Macroscopic stability in preparation for next NSTX-U brainstorming meeting (March 2) and 5-year plan
  - **Identify key theory and modeling needs**
  - **Address key issues from the perspective of both experiment and theory**
- To support FY12-14 milestones during outage (good time for theory!)
- To prepare FY14-18 5 year plan for NSTX-U
  - **Higher B_T, Higher A, low ν^*, 2nd NBI (profiles, fast ions)**



MS research includes 3D field, tearing, global, RWM stability, disruption physics

Category	Main topics in NSTX-U	Needs (Potentially supporting codes)
3D physics **Tearing stability**	Error field effects, dynamics, corrections	**Precise linear or non-linear 3D equilibrium (IPEC, VMEC)** **Non-linear evolution of islands with external fields (M3D-C1)**
	Tearing mode vs. error field, q, fast ions	**Linear stability (Resistive DCON, PEST3, RPEC)** **Non-linear evolution of islands w, w/o external fields (M3D-C1)**
	NTV braking vs. everything	**Combinations (IPEC+ Theory, POCA, FORTEC3D, SPIRAL)** **Consistent methods (GPEC, M3D-C1, XGC0, XGC1)**
Global stability **RWM stability**	n=1-3 stability limit vs. q, p, shaping, Ω	**Equilibrium reconstruction (Kinetic EFITs or LRDFITs)** **Stability (DCON, PEST, GATO, ELITE? FLOW?)**
	RWM stability vs. q, p, shaping, ν^*, Ω	**Plasma model (P or P with kinetic effects in VALEN3D)** **Kinetic stability (MISK, MARS-K, M3D-C1)**
	RWM control using full 3D description	**Structure model (State space model in VALEN3D, M3D-C1)**
Disruption	Disruption (Halo current) effects	**TBD contingent upon PPPL theory support**
	Disruption detection and avoidance	**Combinations of each stability prediction**
	Disruption mitigation including MGI, runaways	**Gas penetration physics (DEGAS2)** **Non-linear evolution of plasmas and runaways (TSC, M3D)**

3D field and tearing physics

- Up to date:
  - IPEC, PEST, NTV theory can support the study of error field effects, tearing stability, and NTV braking
  - Issues: Locking threshold in low Ω? Tearing stability in ST? Consistent description of NTVs (field, dB^2,(ν, Ω, ω) mapping, neoclassical offset) ? Realistic rotation prediction for NSTX-U and ITER, including all the momentum sources?

- Existing plans for future (up to 5 years):
  - Linear fluid: GPEC to solve force balance equation with perturbed tensor pressures and islands. Perturbed tensor pressures will be solved by 3D orbit codes (POCA or FORTEC-3D) and island dynamics will also be solved numerically (RDCON or RPEC)
  - Non-linear fluid: M3D-C1 to describe non-linear fluid evolution with non-Maxwellian distribution function, including two fluid effects, gyro-viscosity, NTV
  - Non-linear full-f particle: XGC0 to describe full neoclassical effects, and XGC1 to obtain self-consistent momentum balances with 3D fields
  - For validation: 3D displacement, fast rotation profile, more 3D coils?

Global and RWM stability physics

- Up to date:
  - EFIT, LRDFIT, DCON, PEST, VALEN3D, MISK are supporting 2D equilibrium reconstructions, ideal and RWM stability
  - Issues: Kinetic EFITs consistent with TS+CHERS, fast ion contribution? 2D equilibrium and stability with rotation? Reliable ideal stability prediction? More precise and self-consistent RWM passive and active limit prediction and control?

- Existing plans for future (up to 5 years):
  - Linear fluid for RWM1: MISK including anisotropic pressures, fast ions, etc, VALEN3D with multi-modes and state space model for external structures. Better plasma model can be coupled to VALEN3D. MARS-K with self-consistent eigenfunction.
  - Non-linear fluid for RWM: M3D-C1 to describe non-linear fluid evolution with non-Maxwellian distribution function, including gyro-viscosity, NTV, resistive wall
  - Linear fluid for global stability: Equilibrium and stability with rotation (FLOW)? Separatrix issues in ideal stability in high beta (GATO)?
  - For validation: 3D displacement, precise profiles, stability limit, fast ion diagnostics?

Disruption physics

- Up to date:
  - TSC supported NSTX design studies, M3D is supporting Halo current studies
  - Issues: Fundamental physics governing disruption dynamics? Reliable disruption detection? So predictions for NSTX-U and ITER? Gas penetration physics? Gas amount to mitigate disruption in ITER?

- Discussed plans for future (up to 5 years):
  - 3D equilibrium : RPEC, VMEC, PIES + evolution dynamics? Wall structures?
  - Non-linear fluid : M3D-C1 to describe non-linear fluid evolution with non-Maxwellian distribution function, including two fluid effects and resistive wall
  - Impurities, atomics: DEGAS2 to understand gas penetration physics to plasmas and to simulate MGI disruption mitigation, TSC to predict runaway electron effects
  - For validation: More wall current diagnostics, impurity and neutron diagnostics?

List of possible topics in MS

Topics	Existing efforts	Note
Non-linear fluid modeling in 3D geometry for time-evolving dynamics of islands and neoclassical effects	M3D-C1 code with distribution function solver (Ramos theory or NTV theory), NSTX-U coils, wall structure implementation	**This will increase fundamental capabilities of MS simulation in general. Should it be more specific?**
Kinetic modeling for RWM with the full 3D geometry to improve self-consistency and controllability	MISK code including fast ions, multi-mode VALEN3D, improved plasma permeability in VALEN3D, MARS-K code can also be used for alternatives and benchmark	**This has a lot of progress already and so is highly promising**
Linear 3D equilibrium modeling including islands and neoclassical effects	IPEC code with tensor pressures and jump conditions and coupled with POCA, inner-layer solver (Rutherford equation, etc)	**This will be useful for quick estimation, benchmark with M3D-C1 and XGC0**
Gas penetration physics modeling for MGI	DEGAS2 code for massive gas injection	**This is something missing in disruption simulation efforts and can be unique in NSTX**
More robust equilibrium and stability modeling including rotation and SOL	FLOW code coupled to GEQDSK? Stability with rotation? Extend region to separatrix? MARS-F and MARS-K?	**This is typically ignored but can increase confidence and robustness in basic equilibrium and stability**