Agenda
1: ASC "Theory and Computation" Prep
2: NSTX-U ASC Five Year Plan Discussion

Columbia U
CompX
General Atomics
FIU
INL
Johns Hopkins U
LANL
LLNL
Lodestar
MIT
Nova Photonics
New York U
ORNL
PPPL
Princeton U
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UC Davis
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UCSD
U Colorado
U Illinois
U Maryland
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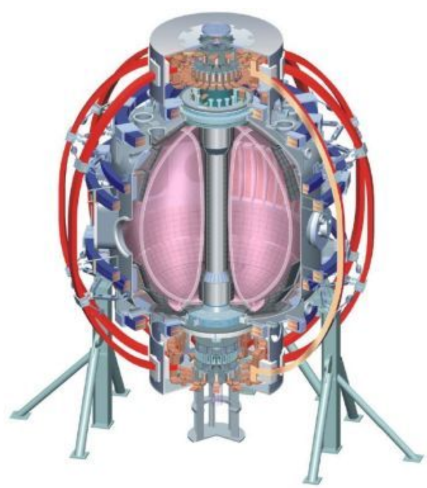
U Washington
U Wisconsin

SPG



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Goals of NSTX Advanced Scenario and Control TSG

- Study, implement, optimize axisymmetric control techniques.
  - Kinetic and magnetic profiles.
  - Boundary and divertor magnetic geometry control.
  - Vertical position control.
- Combine various tools developed in other TSGs into integrated scenarios.
  - For instance, ELM pacing XPs targeting density control were in ASC.
  - Impurity control for scenario development in FY-10.
- High non-inductive fraction under NB heating has been in ASC.
  - Typically coupled with optimization to high-κ.
  - NBCD is ASC, but details of fast ion transport & redistribution are WEP
  - However
    - RF CD and low-current 100% NI scenarios with HHFW H&CD have historically been in WEP TSG.
    - Maximization of β_N part of ASC, but more in MS.
- Discharge development for the NSTX team (sometimes).

NSTX ASC research was always cross-cutting, and will be even more so in NSTX-Upgrade

Two Overarching Theory/Modeling Needs

- 1: Need advanced control algorithms for boundary shape, divertor geometry, kinetic and magnetic profiles, and divertor heat fluxes.
  - Should include actuator dynamics & saturation.

- 2: In order to tune those control algorithms, need integrated codes with fast, benchmarked models for how sources of particles, momentum, heat and current modify the kinetic and magnetic profiles and free-boundary equilibrium.

Need #1: Models for Scenario Development

- NBCD with *AE modes
  - In the absence of low-f MHD, the neutral beam drive current is apparently classical.
  - At higher values of β_{fast}, *AE modes can lead to redistribution/modification of the fast ion distribution.
  - Theory is needed for when these modes will turn on, and what their effect on the pressure & current profile will be.
  - Need measurements of fast ion distribution (FIDA, neutrons, ssNPA, fusion product detector) and NBCD profile for comparison.
- Prediction of the thermal & momentum transport
  - The bootstrap current depends sensitively on the gradients in the thermal profiles. NBCD depends on T_e/n_e. Global stability depends on rotation.
  - Conversely, the transport, and hence thermal profiles, can be a strong function of the current and rotation profiles
  - Need a model for the thermal and momentum transport and its response to actuators.
  - Include both core & pedestal (and the joining region), including fast-ion MHD leading to transport.
- Need accurate, benchmarked models for HHFW and EBW H&CD within integrated codes such as TRANSP.

Need #2: Realtime Control

- Need a reliable algorithm for the individual and combined control of the current and rotation profiles, along with β_N.
  - The theory of that algorithm should help us to understand to what extent these quantities can be independently controlled given the coupled actuators V_{loop}, P_{inj}, J_{NBCD}, T_{NB} and T_{NTV}.
- More generally, need the ability to test the actual control algorithms in simulations with high degrees of physics fidelity, i.e. flight simulator mode.
  - Could in principle be accomplished by connecting PCS to PTRANSP, CORSICA, or TSC.
- Need the ability to predict the future equilibrium and stability properties of the plasma.
  - Faster than realtime look-ahead of the evolution of the equilibrium
    - (Very) reduced transport models.
  - Stability assessments of those future states (n=0, n=1, ELM?). Future coil currents and boundary shape.
  - Control intervention based on the predictions.

5-year Plan Prep

- Need to present these elements to the PAC, so airing them for comment now

Propose Four Interrelated Thrusts in the 5-Year Plan

- High-Performance Discharge Development
- Axisymmetric Control
- Scenario Optimization For Next-Step STs
- Off-Normal Event Detection and Handling

Thrust #1: High Performance Discharge Optimization

- 100% non-inductive scenarios (ASC).
  - Begin at ~0.7 T, I_p=600-700 kA.
  - Increase the non-inductive current level/duration as the allowed toroidal field increases.
- High current partial inductive (~2 MA) scenarios (ASC,BP).
  - Start at ~1300 kA, B_T=0.7 T.
  - Optimize startup for reduced density
    - Ramp-rate, fuelling scheme, H-mode timing.
  - Increase I_P contingent on:
    - Timing of high-current and high-field operation, TF current feed upgrade.
    - Progress on heat flux mitigation
    - Event handling and disruption avoidance.
- Couple non-inductive startup to high-performance steady state (ASC, WEP, SFSU).
  - NBCD ramp-up studies, including effect of *AE.
  - Boundary and profile control during ramp-up.
- HHFW & EBW Integration (ASC, WEP).
  - Early HHFW for current profile tailoring
  - Flat-top HHFW for electron heating in H-mode to increase the NBCD.
    - Interesting scenarios with large R_{tan} beams and HHFW?
  - Reversed shear scenarios?

Thrust 2: Axisymmetric Control Development Elements (I)

- Improved vertical position control (ASC):
  - Better vertical motion detection
  - Additional coils in the vertical control loop (biased or bi-polar PF-2, n=0 RWM?)
- MIMO Boundary Control (ASC):
  - Off-diagonal elements of the M-matrix.
  - Better inner-gap control, more generic shape controllers.
- Snowflake Divertor Control (ASC, BP):
  - Multiple X-point finding.
  - New control matrix for divertor parameters.
  - Develop better general understanding of SFD controllability.
- Profile control (ASC, MS, T&T):
  - Parameterize the effect of different NB tangency on the q-profile.
  - J, q, or ψ profile control using P_{inj}, V_{loop} (and outer gap?) as actuators.
  - Rotation profile control using P_{inj}, T_{NTV} as actuators.
  - Compatibility with each other and with β_N control (HHFW?)

Thrust 2: Axisymmetric Control Development Elements (II)

- Divertor power control (ASC, BP).
  - Radiative divertor control.
    - BP needs to provide realtime diagnostics and quantify the actuator response (gas puffing impact).
    - Need plan for new gas injectors under PCS control in upper & lower divertors.
  - Heat-flux based magnetic balance control (?).
    - BP needs to provide the realtime heat flux.
- Density control (ASC, BP).
  - Need either realtime MPTS or an interferometer
    - MPTS more generically useful, but interferometer much faster.
  - Use SGI as an actuator.
    - Other fuelling sources can be used as they are developed.

Thrust 3: Scenario Optimization For Next-Step Devices

- Optimal q-profile and rotation profiles (ASC, MS, T&T).
  - Rotation profile impacts thermal transport, RWM and tearing stability.
  - q-profile impacts thermal transport, kink/tearing stability.
  - Effects may not be complementary:
    - Elevated q_{min} might be bad for transport, good for kink/tearing.
    - Reversed shear and ITBs are good for transport, bad for stability.
  - Utilize feedback control to stay in these optimal states.
    - Or feedforward control if feedback is not so hot.
- Conditions for classical NBCD (ASC, WEP).
  - Test NBCD vs. classical predictions as a function of β_{fast}, q-profile, V_{fast}/V_A.
  - Determine the degree to which next-step devices can operate in a regime with classical NBCD.
- Validation of integrated models (ASC, WEP, T&T).
  - T&T TSG to be working on reduced models for thermal transport.
  - WEP TSG to be working fast ion transport from *AE modes.
  - Test the integrated predictions against the measured discharge evolution.
  - If reasonable, begin projection to FNSF.

Thrust 4: Off-Normal Event Detection and Response

- Disruption detection (ASC, MS).
  - Use realtime diagnostics to predict imminent disruptions.
  - Start with RWM sensors, and then add more as necessary.
    - Neutrons, MPTS, improved rtEFIT, State Space RWM info,
  - Consider realtime RFA measurements?
- PSRTC and/or PCS will be used to detect approaches to current/force/I^2t limits (ASC).
- Develop off-normal event handling infrastructure (ASC).
  - Process data from both the coil limits and disruption detection.
  - Start with I_p rampdowns based on imminent limit/disruption.
  - Develop more sophisticated responses.
    - Rampdown in the presence of a large n=1 mode may need to be different?
    - Modification of coil current requests based on approach to current limits?