NSTX 5 Year Plan Goals: RJButtery Response & Suggestions to JKPark, Sept 2011.

Richard, for TM and NTM stability and control

It will be very helpful if you can send me one or two bulleted lists for (1) research goal for each year (1-1,1-2,1-3,1-4,1-5), and for (2) a couple of important diagnostics for your goal.

You can include plans and goals with numerical codes for (1), and you may want to exclude some of general diagnostics, such as MSE-CIF and LIF, rtMPTS, for (2).

Overall plan for each year as follows,

* FY14: Explore new machine for each topic including FY11-12 plans
* FY15: Rotation control
* FY16: Beta control
* FY17: Rotation + Beta control, FNSF/Pilot projection
* FY18: Rotation + Beta + q control + other techniques including disruption mitigation

Preliminary views:

I think the overwhelming opportunity for FY14-18 will be that provided by the off axis beams. This will allow us to explore different q profiles – a key parameter governing MHD stability, that we need to understand better. This is particularly relevant to the whole issue of tearing mode stability and control. Further, the access to different profiles and beam distributions may expand the space in beta, and vary the distribution of fast and thermal particle pressures – enabling further explorations of RWM physics.

Rough Notes on Reading of Plan & Slides from Meeting

* It’s a little hard to work out order of plan, as don’t know probable upgrade plans
* Plans mention omega, beta and q, but omit fast particle variation (size and distribution will changes with off axis beams – an opportunity.
* Document tends to capture everything possible – should also highlight the key opportunities and differences – q and fast ion variation seem key effects.
* Disruption mitigation goal – if this includes avoidance, that whole MHD program plays into this – not a separate section.
* I would put in some hard goals – like understand what q profiles are optimal to maximize ideal and tearing stability. Also test and resolve predictive theory of RWM stability (should be possible).
* Tearing mode section a bit thin. I would also add in understanding tearing stability with advanced profiles for next step devices, and interplay with error fields and ideal plasma stability (& response) considerations.
* Major missed opportunity for focus on improved control for disruption avoidance, as well as automated disruption anticipation/recovery/response systems 🡨 this is most serious challenge leveled at tokamak by external community and we should make it a prominent focus of our program to demonstrate we can deal with them.
* Overall goals for MS are a little “Assess macroscopic stability physics in NSTX-U regimes” – not even a requirement to make much progress.
	+ I would argue for something more ambitious and specific such as “Determine requirements for stability control in future fusion devices”. (This might be directed most at ST-CTF, but there are clear benefits to ITER and other future facilities of NSTX research).
* The plans are generally put in terms of study and assess, rather than harder deliverables to make predictions for particular things, or develop control solutions and optimizations.
	+ Yes we will study lots of things. But the reader also needs to know what will be delivered and achieved – hard to predict but can be predicted somewhat.
* Important cross-fertilization between 3D field physics here and RMP-ELM understanding – error field penetration and ideal response physics inform action of 3D fields in other situations – strong collaboration with ELM thrust should be highlighted.

Ideas:

* Q profile effect on tearing stability and error field sensitivity 🡨 two aspects!
* Agree with various rotation objectives for TMs, though not clear on what your tools are here (RMP?)
* Should move towards a specific evaluation of physics at low rotation for future low torque devices like power plant, ITER (and maybe FNSF). This will impact TM, EF, RWM substantially. A specific goal on preparing low torque operation assessments might be suitable?
* Explore benefits and limits of error field correction, and how these change with beta. Extra error field coils are big plus here.

Diagnostics:

* Obviously excellent q profile is most critical
* Fast ion distributions are very important (especially for ideal stability), and give a window on burning plasma instabilities – ITER / FNSF relevant.
* Emphasis on pedestal is important for stability limits.
* Sufficient magnetics is vital (for mode resolution & plasma response).
* Diagnostics that resolve island structures are important – especially for look for small islands near the edge for things like RMP-ELM

Hardware:

* Probably more on control – can you control runaway beam position, and then look to mitigate and ramp it down (eg reverse solenoid).
* Have you got full range of disruption mitigation hardware to demonstrate path for larger ST devices – they need demonstrated solutions.

Questions:

* Plan mentions rotation control – is there any decent actuator (apart from RMP)?
* What is schedule of machine development?

RJB’s (and JKP’s) Elucidation of 5 year plan goals for TM physics

Let’s start from some high level goals:

* Must assess TM stability and EF resilience as a function of q profile and determine best stable operational points (and associated control requirements – on profile, rotation, 3D, etc.).
* Assess the stability challenges of low torque injection regimes and determine the requirements this places on additional control strategies.
* Develop viable candidate FNSF regimes that meet required stability goals.
* Develop reliable control and disruption avoidance strategies, including those based on specific instabilities (TM, RWM, etc.), and response to other events that can lead to termination.
* Develop, test and demonstrate the required control tools and techniques for avoidance of tearing mode instabilities (EFs, TM, etc.)

Yearly goals: (May be more specific with more informed hardware agenda)

2014

* Determine how q profile modification with off axis beam changes tearing mode beta limits and error field thresholds (key physics issue, relevant to ITER also).
* Measure intrinsic error field of upgraded facility and develop first order correction at low and high beta.
* *Might bring 2015 fast particle bullet forward here?*
	+ Key Diagnostics: MSE (best possible), new plasma magnetic response diagnostics, *fast ion diagnostics (if in this year)*
	+ Key hardware: New beams

2015

* Test plasma response to 3D fields at high rotation and as rotation lowered;
* Determine benefits and limits of error correction (new 3D coils if available, combine with present coils and intrinsic error). Explore variability in beta. Resolve optimal correction and role of all coil sets available.
* Commission real time control methods for rotation, current profile, as well as ensuring beta (and if possible density) are operational.
* Explore profile control methods to develop tearing (and ideal) stable operating points
* Assess whether fast particle distribution affects tearing stability using on/off axis beam experiments
* Initiate disruption precursor response to avoid / recover disruptions
	+ Key hardware: New coils; control system, real time reconstruction and associated diagnostics; fast ion diagnostics.

2016:

* Apply optimizations developed for profile and 3D fields to high beta plasmas; determine limits & re-optimizations/changes needed; test further profile effects (pressure, fast ion). (This is a major effort taking several lines from previous years to perform them in high beta plasmas).
* Commission fast wave control of tearing modes, by modification of q profile, heating or more localized current drive effects.
* Develop active (eg sensing with magnetic probing, or rotation based response) or real-time-predictive MHD boundary avoidance for disruptions.
	+ Hardware: full beam performance; fast wave reliable coupling; active sensing tools and real time code prediction (with associated real time signals and/or equilibria).

2017:

* FNSF integrated demonstration scenarios (and scoping to get there), with optimal error correction, profile control and active control tools
* Implement demonstration of optimized disruption avoidance for FNSF scenario
* Develop predictive scaling for error field limits, including Ohmic, higher beta, and interaction with (rotating) tearing mode limits.
	+ Hardware: real time control systems, all previous years requirements; integrates somewhat with scenario developments (but requires dedicated MHD scoping studies)

2018:

* Explore performance beyond individual FNSF parameters – particularly discharge duration (effects of profile evolution), higher beta, lower density (higher fast ion fraction), more advanced q profile – study tearing limits and plasma response to 3D fields.
* Develop a higher betan scenario for potential power plant
* Extend disruption avoidance systems further – goal 100% avoidance – fold in non MHD origins & event in progress sensing into response systems to maintain plasma or land to safer configurations.
* Physics push – detailed diagnosis and probing to get at underlying physics – measure structures and processes with tearing mode onset and/or 3D fields applied.
	+ Hardware: further beam improvements? Highest resolution and best range of diagnostics (magnetic response, kinetic, fast ion, q) to get at physics.