XXX-YYDDMM-ZZ-01

***TO: J. MENARD, S. KAYE, S. GERHARDT***

***FROM: THE MACROSCOPIC STABILITY TOPICAL SCIENCE GROUP***

***SUBJECT: IMPACT OF POTENTIAL POLAR REGION MODIFICATIONS ON RESEARCH AND SCENARIOS FOR THE MACROSCOPIC STABILITY TOPICAL SCIENCE GROUP***

There are significant changes to the "polar" (top/bottom inboard) regions of NSTX-U being considered, including:

* Elimination of CHI ceramic breaks
* Fish-scaled PFC tiles that would be uni-directional and would therefore constrain the helicity of the total field to its recent/historic direction
* Langmuir probes, gas feeds / divertor MGI, magnetic, and other sensors in tiles will also need to be redesigned in concert with PFCs

Flat-top duration and heating power and shape will strongly drive the PFC requirements. Here we document the physics goals of the macroscopic stability topical science group and how they may impact the decisions regarding the changes to the polar regions.

* Magnetics
  + Magnetics coverage for equilibrium reconstruction should not be adversely affected. Substantial polar region coverage is required for advanced divertor configurations such as the snowflake. The importance of magnetic sensors in the divertor region was noted in the 2nd EoC meeting summary, and enhancement of magnetic sensors in these regions was suggested.
  + Extended magnetic sensors in the divertor region were previously considered as an NSTX-U facility enhancement to extend the diagnostic capabilities for 3D modes especially at high normalized beta, and for inclusion in active mode control systems. Multi-mode computation shows that global modes can have increased amplitude in the divertor region and also have a significant change in toroidal phase in that region as well. Three conceptual locations for these extended magnetics were under the secondary passive plate lip, under the outer divertor bullnose tiles, or somewhere in between. In principle if the ceramic break for CHI is removed, another channel at even lower major radius could be considered.
  + Existing shunt tiles in Rows 3 and 4 of the outer divertor will be impacted by changes to the tiles in those rows.
  + An upgrade of the halo current sensor set was originally scheduled for the present outage. This upgrade includes a substantial increase in the number of divertor shunt tiles (IBDH and OBD) as well as the completion of mirnov arrays in the outboard divertor and on the passive plates. Capacity for these upgrades should be retained if possible.
* Low collisionality
  + Access to low collisionality is required by several MS TSG experiments, for example in stability studies.
  + Appropriate glow discharge cleaning and bakeout of carbon tiles should be retained.
  + Changes to tiles should not adversely affect outgassing such that collisionality and the ability to create long pulses are impacted.
* Massive gas injection
  + Massive gas injection requires holes in certain tiles.
  + One of the important experiments we would like to do is a comparison of private flux region injection to mid-plane injection. NSTX-U is the only machine capable of this study. Capability to inject from the PFR, may prove be quite helpful, as it will provide a radiative gas blanket over the tiles, and this may protect the divertor tiles during a VDE. Since the full high-power capability of NSTX-U will not be realized for at least one to two years, it is recommended that the holes be retained for the first two years of NSTX-U operations. This will allow time to do these important experiments, as well as for NSTX-U to study in detail the regions of the divertor plates that are subjected to high heat flux. Then before the start of the long pulse, high-power campaign, if necessary, the tiles with holes can be replaced with tiles without holes.
* Disruptions
  + Many experiments planned in the MS TSG will *purposefully* make disruptions. This ability should be retained for mitigated and unmitigated disruptions up to the maximum performance plasmas: 1T, 2MA.
  + These disruptions expose the wall tiles to increased transient thermal loads and also drive halo currents, which can exert considerable electromagnetic forces on the tiles. Expect that Memo DIS-170511-SPG-01 covers these needs.
  + These forces need to be considered for present carbon tile designs and also any future plan to implement metal tiles.
  + Conversely, experiments are planned in which disruptions are to be avoided by passive or active means. In these cases, long pulse discharges are needed to most efficiently demonstrate stability over long periods of time. Confidence in producing high beta stable plasma over long pulse will need to be conducted over at least a few current diffusion timescales and steady-state wall conditions. Such conditions will require operation at near maximum pulse lengths for NSTX-U in high performance plasmas.
  + Strikepoints move during disruptions, so they are not the same as in steady-state conditions. The impact of this on tile requirements should be studied.
  + It should be noted that studying runaway electrons is not a priority for the MS TSG and there is presently no intention to create runaway electrons in NSTX-U.
* High beta
  + Many experiments in the MS TSG aim to operate at high beta, for example RWM stability experiments. This means that the ability to operate all six neutral beam sources at one time should be retained. Additionally, in these discharges the pulse length at high beta should be long enough that magnetic braking using n=3 magnetic fields can be applied to reduce the plasma rotation over a sufficiently long time period.
* 3D Fields
  + Dynamic error fields and applied 3D magnetic fields will change the field in the divertor region which will impact the heat flux by changing the field line angles and the three dimensionality of the heat flux pattern.
  + For diagnostic purposes it is sometimes necessary to rotate applied 3D fields, and this can impact the requested pulse length. The frequency of the rotation should be low enough to minimize eddy currents and to ensure good S/N ratio of non-axisymmetric part of response. For example, a profile diagnostic with a sampling rate about 100Hz would require 0.5-1s to measure response at 12 different angles (30 degree interval) for one cycle, with time average over 5-10 points. It may also be desired to have multiple cycles, for filtering time-transient response.
* Operation on the center stack
  + Disruption avoidance and control studies, and the general desire to shut down the NSTX-U plasma in a controlled manner, will generally require movement of the diverted plasma onto the center stack first wall tiles during the shutdown evolution. This ability should be retained to allow durations of at least 0.5 s with the plasma contacting the the center stack tiles.
  + Use of L-mode plasmas for MHD studies will require the plasma to be limited on the center stack tiles. It is requested that the center stack tiles be able to handle the power flux of such limited plasmas for a duration up to 1s. Presently proposed experiments do not span the full range of available auxiliary power, but it is envisioned that such a limited L-mode plasma should be able to be accommodated with up to 3 NBI sources injected.
* BT reversal
  + In future experiments, co- vs. counter-Ip injection will be studied. Changing the direction of Ip will require reversal of BT as well to maintain the helicity of the total field helicity, which will be necessary to accommodate constraints imposed by the discussed fish-scaled tile upgrade. Therefore, the ability to reverse both Ip and BT needs to be allowed..
  + Experiments utilizing reversed Ip and BT would also lead to a new loss pattern for energetic particles, which is an overall issue for plasma facing components, not just in the polar region.

Physics priorities which may affect requested pulse lengths

* Relevant time scales: wall time, for RWM studies (relatively short), momentum time for rotation control, current diffusion time for q-profile control (for disruption prediction and avoidance studies over the longest timescales).
* Long pulses with fixed equilibria are requested for studies involving scanning 3D magnetic coil phasing and frequency.
* Long pulses at high beta are requested for studies involving the physics of magnetic braking, and plasma rotation alteration by magnetic fields to test stability limits.
* In the interest of studying the effect of current profile relaxation on stability, long shot times (a few current relaxation times) at sufficiently high beta / low collisionality to trigger global MHD or neoclassical tearing modes are desired.

Physics priorities which may affect requested plasma shapes

* For continuity with previous experimental results on tearing stability, the ability to match shaping parameters elongation up to 2.2, upper triangularity up to 0.45, and lower triangularity up to 0.7 is requested.