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Milestone R(19-1): Expand disruption prediction and avoidance capability for tokamaks

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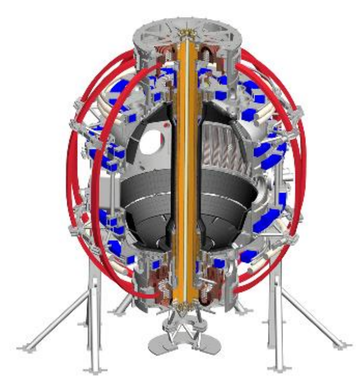

Milestone R(19-1) newly written to observe guidance consistent with delay of NSTX-U operations

- Title: "Expand disruption prediction and avoidance capability for tokamaks"
- Origin: Milestone was solicited, followed from JRT-16 effort; DOE top priority research topic
- Timing: Originally proposed for FY17-19 time frame. Logically followed other proposed milestone ideas with FY19 placement
- Evolution based on new guidance:
  - Emphasis on multi-device analysis covering national / international tokamaks, thereby de-emphasizing NSTX/-U (presently 5 tokamaks/STs)
    - E.g. This is main goal of present KSTAR international collaboration proposal; will also factor into a new proposal for the coming ST research solicitation from DOE; "real-time" component through TCV collaboration.
    - DOE guidance: tie international collaborations back to U.S. lab. This allows the milestone research to tie back to PPPL. DOE has stated that NSTX/-U database can be studied in this context going forward.
    - Multi-device emphasis is very important for reliability/extrapolability (e.g. to ITER)
  - This milestone research has always emphasized collaboration, leveraging physics tools/models, etc. Changes to text further emphasize this.

Revised text of R(19-1) "Expand disruption prediction and avoidance capability for tokamaks" follows guidance

Description: Predicting and avoiding damaging plasma disruptions in fusion-producing tokamaks is the present "grand challenge" in tokamak stability research. Meeting this significant goal requires data from a variety of tokamaks and the use of various physical models, analyses, and control methods. The present milestone will greatly expand automated disruption event characterization and forecasting (DECAF) that identifies chains of events that lead to disruptions. Once these chains are determined, methods of breaking the chains using all available forms of actuators can be defined. Through arranged collaborations, the analysis will include input from both national and international tokamaks (e.g. data from DIII-D, KSTAR, MAST-U, NSTX/NSTX-U), which is critical to produce reliable DECAF analysis applicable to ITER and future devices. Initial results using the developing DECAF code have successfully demonstrated predictive models for global MHD mode onset and automatic determination of rotating tearing mode activity, rotation bifurcation events, and mode locking precursors to disruptions. These successes will be expanded through the further development of physics modules and machine learning capabilities that address the dominant causes of disruptions across several experimental tokamak databases as stated above. Such development will produce and leverage new analysis capabilities and reduced models of results computed by stability analysis codes such as resistive and ideal DCON, M3D-C^1, and kinetic MHD analysis codes. For example, validated physics models and analysis techniques determining tearing mode stability and island growth or decay would be coupled to models of torque balance and applicable code analysis will be tested for their predictive capability of rotating MHD mode locking. A range of models and analyses evaluating density limit-induced disruptions (both low and high) will be evaluated. This varied range of modeling and analysis (including the determination of technical causes of disruptions) will be applied to the multi-machine tokamak database. The resultant statistics will objectively determine the success and false positive rates of the analysis. These results will be applied to identify how device actuators can be best used to avoid disruptions, and also to improve the prediction of disruptions in real-time to inform and aid controlled plasma shutdown algorithm development.