# MDC-21 Global mode stabilization physics and control

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| **TG priority:** High | **Start date:** 2014 | **Status:**  On-going | **Personnel exchange:**  No |
| **IO priority:**   | **End date:** N/A | **Motivation:** Physics basis of RWM stability & control |

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| **Device /****Association** | **Contact****Person** | **TGRequest** | **Activity (from JEX/JA spreadsheet)** |
| **2014** | **2015** | **2016** | **2017** |
| NSTX-U | S.A. Sabbagh | Desirable | Analysis | Analysis |   |   |
| DIII-D | J.M. Hanson | Desirable | Analysis | Analysis |   |   |
| AUG | V. Igochine  | Desirable | Analysis | Analysis |   |   |
| RFX-Mod | P. Piovesan | Desirable | Analysis | Analysis |   |   |
| JT-60U | G. Matsunaga | Analysis | Analysis | Analysis |   |   |
| EXTRAP-T2R | L. Frassinetti | Desirable | Analysis | Analysis |   |   |
| TCV | O. Sauter | Desirable | Committed | Committed |   |   |
| MAST | I. Chapman | Desirable | Upgrade | Upgrade |   |   |
| KSTAR | B.H. ParkJ.G. Bak | Desirable | Analysis | Analysis |   |   |
| EAST | Y. Sun | Desirable | Committed | Committed |   |   |
| HBT-EP | J. Levesque | Desirable | Analysis | Analysis |   |   |
| Theory | Y. Liu, F. Villone | Desirable | Analysis | Analysis |   |   |

**Purpose**

* MDC-21 focusses effort by defining specific tasks. At present, these tasks are:
1. **Comparison of kinetic RWM stabilization code calculations with experiments**
2. **Global mode feedback stabilization control results / comparison of models with experiments**
3. **Characterize low frequency noise on sensors used for RWM control**

The intended larger scope of these tasks is prediction and avoidance of disruptions due to global modes. Specific actions in these tasks include two ITER high priority needs as specified by Yuri Gribov: (i) What levels of plasma disturbances (B/B) are permissible to avoid disruption, and (ii) Assessment of low frequency noise on RWM sensors in tokamaks.

**Results for 2015**

* Kinetic RWM stability understanding has been unified by careful comparison and analysis of dedicated experiments in NSTX & DIII-D (Task 1)
* Joint analysis between NSTX and DIII-D using the MISK (Modified Ideal Stability by Kinetic Effects) code shows quantitative agreement between theory and experiment for kinetic RWM marginal stability points. These marginal stability points were found over a wide range of plasma rotation in both devices. (Task 1)
* At high V, kinetic stabilization is dominated by bounce resonances in DIII-D, and ion precession drift in NSTX; the measured stability reduction at increased qmin (DIII-D) is verified to be due to decrease in bounce resonance stabilization. (Task 1)
* Further theoretical investigations of the kinetic RWM stabilization physics model include (i) the addition of active feedback control to this model, (ii) the investigation of plasma response as predicted by the model, and (iii) application to negative triangularity plasmas. Conclusions are (i) active feedback works synergistically in theory with kinetic stabilization - this was observed independently in NSTX experiments, (ii) plasma response from the kinetic RWM model agrees with theory, and (iii) negative triangularity plasmas increase the RWM growth rate in theory. (Task 1)
* The above results, coupled to a prior extensive benchmarking effort between the MISK and MARS-K codes led the MDC-21 leaders (S.A. Sabbagh and Y. Liu) to accept the kinetic RWM stability theory as the leading theory to explain experiments. Therefore, a decision was made to de-prioritize the effort to find a baseline kinetic RWM stabilization theory in MDC-21, to test the present theory further, and to consider the ramifications of expansion of the present kinetic stabilization physics. (Task 1)
* Global mode stabilization control results have shown successful mode control in high beta tokamaks including DIII-D and NSTX. Dual-field component active RWM control using proportional gain has been used routinely in NSTX. An advanced model-based state-space controller was implemented several years ago in NSTX, and will continue to be used in NSTX-U when operation of the device begins in 2016. (Task 2)
* Ferritic material near the plasma surface in HBT-EP increases current-driven RWM mode growth rates, which increases power demands on control. (Task 2)
* The KSTAR device has operated at very high normalized beta values greater than 4, and normalized beta to li ratios of greater than 6. These values exceed the n = 1 no-wall limit by 60%. The device is in a regime in which n = 1 active mode control will be needed. Both a sufficiently high-bandwidth power supply and sensors adequate for active n = 1 mode control were installed/demonstrated in 2015 experiments. (Task 2)
* Several conclusions were made on the ITER critical need regarding maximum levels of plasma disturbances (B/B) reached before disruption from analysis of NSTX data. The maximum (Bp/B) prior to disruption increased with increasing plasma current. The maximum Bp appears to follow a de Vries-style engineering scaling - the scaling Ip1.07li1.2/a1.1q951.07 was used. The maximum (Bp/<Bp(a)>) might follow a de Vries-style scaling li1.2/q951.07 Finally, the maximum (Bp/<Bp(a)>) does not follow a scaling dependent on pressure peaking factor or li independently, nor in combination. (Task 2)
* Data was collected from 6 devices (AUG, DIII-D, JET, JT-60U, NSTX, MAST) for initial analysis of low frequency MHD noise in global mode sensors. (Task 3)

**Plans for 2016**

* NSTX/NSTX-U: Report on the initial active RWM control experiments for NSTX-U (planned to begin operation in 2016), as well as continued analysis of the existing NSTX database on active kinetic RWM control; contributions to low frequency global mode sensor noise database.
* DIII-D: Continue to quantify RWM feedback effectiveness in DIII-D and contributions to low frequency global mode sensor noise database.
* AUG: Influence of 3D structures (passive stabilizing loops, ICRH antennas, etc) on the kink mode stability boundaries at high βN. Influence of the pitch angle on kinetic profiles and plasma rotation, and analysis of kinetic stabilization in existing high βN discharges.
* JT-60U: Complement kinetic RWM analysis of JT-60U plasmas by MHD analysis code taking into account kinetic effects developed in JAEA including benchmarks with MISK and MARS-K codes.
* MAST: No operation in 2016 (device upgrade), no plans for past data analysis
* KSTAR: RWM controller design and initial implementation with new RWM sensors; continued high normalized beta results / analysis.
* HBT-EP: Continued modeling and experiments of current-driven multi-mode RWM control with ferromagnetic material near the plasma surface
* Theory (Liu): MARS-K kinetic RWM stability analysis; (Villone): CarMa code n = 1 RWM analysis/control

**Background:** The present research and plans for 2016 build on past successes from MDC-2 (now closed), and the initial two years of results produced under MDC-21.