MHD Physics Working Group (P3):

Summary of main points

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MHD stability limits are not a fundamental obstacle to the burning-plasma missions of the three proposed machines

- Base scenarios are stable to ideal MHD (except m/n=1/1 mode)
  - Ignitor operates farther from stability limits due to lower β
- The sawtooth instability is expected in all three devices, but is not expected to prevent access to the burning plasma regime
  - New physics: α-particle interactions (stabilizing effect, redistribution, . . .)
  - Major concern is that sawteeth may trigger NTMs
  - Sawtooth control techniques are crucial
- ELM instabilities are expected during H-mode operation, but are not expected to prevent access to the burning plasma regime
  - Large ELMs are a potential concern for divertor lifetime
  - Regimes of tolerable ELMs exist; FIRE & ITER have flexibility to access them
  - ELMs are not likely to occur in the Ignitor base scenario

ITER and FIRE will require active control of MHD modes

- Error field tolerances required to avoid mode locking during ohmic startup should be achievable
- ITER and FIRE will most likely require active control of neoclassical tearing modes (NTMs) to sustain their operating point
  - ECCD control for ITER is well supported by experiments
  - LHCD for FIRE is less well validated as NTM control
  - Sawtooth control (FWCD, ECCD, LHCD) could avoid NTM seeding
- Advanced tokamak cases in ITER and FIRE need wall stabilization of the n=1 kink mode. Predicted NBI-driven rotation alone may not be sufficient.
  - FIRE can approach the ideal-wall limit with feedback stabilization
  - ITER may require a combination of feedback and beam-driven rotation, due to electromagnetic shielding of feedback control coils

The three proposed burning plasma experiments offer a regime not accessible in existing devices

- Ignitor, FIRE, and ITER would all yield important new MHD physics
  - MHD stability - with p(r) from self-heating
  - reconnection, NTM seeding - with large S
  - sawtooth stability (and other modes?) - with large p_α
  - mode coupling, error field penetration - with low natural rotation
- FIRE and ITER would address additional issues in H-mode and higher β
  - NTM threshold beta, pedestal stability - with small $\rho^* = \rho_i / a$
- Advanced tokamak regimes in FIRE and ITER yield additional physics
  - MHD stability - with largely self-generated current profile
  - RWM stabilization - with low natural rotation
- *Much of the MHD stability physics learned in a burning tokamak plasma should be applicable to a broad range of confinement concepts.*