A Burning Plasma Diagnostic Technology Initiative for the US Magnetic Fusion Energy Science Program

Submitted by
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A new diagnostic program would enable the US to be ready for FNSF.

White Paper Motivation

- Diagnostics and measurement systems are implicit in many of the proposals that FESAC has heard in this (and the previous) meeting.
- Many diagnostics for existing devices and even ITER are not applicable to future steady-state burning plasma devices
- A proposal that explicitly calls for adequate funding of advanced diagnostics appropriate to burning plasmas is warranted.

The US diagnostic community is eager to address burning plasma challenges.

Technical Motivation

- The US magnetic fusion energy science program requires an initiative for development of the necessary diagnostics to support burning plasma experiments beyond ITER, such as a future FNSF, CTF and eventually DEMO facilities.
- Extensive diagnostic measurements of burning plasma behavior will be essential to optimize the US investment in ITER going forward.
- Because the thermonuclear environment of steady-state burning plasmas will severely constrain the measurement capabilities and applicability of many present-day diagnostic systems, new methodologies need to be developed and integrated into plasma control and operation/safety systems.

Significant diagnostic challenges have been identified by the community.

- Many existing diagnostic systems that support current facilities and are being adapted for ITER will simply not work on burning plasma experiments beyond ITER.
  - For examples: see J. Terry talk from ReNeW (excerpts in following slides), and "Greenwald Report."
- Providing diagnostic solutions for burning plasmas is critical as there are currently both measurement gaps (e.g., alpha particles, tile erosion, dust) and measurement extensions to long-pulse, high-flux and high-fluence future burning plasma facilities that do not have viable solutions.

Assessment for Measurements in a Demo (CTF, FNSF)

assessment is different from ITER

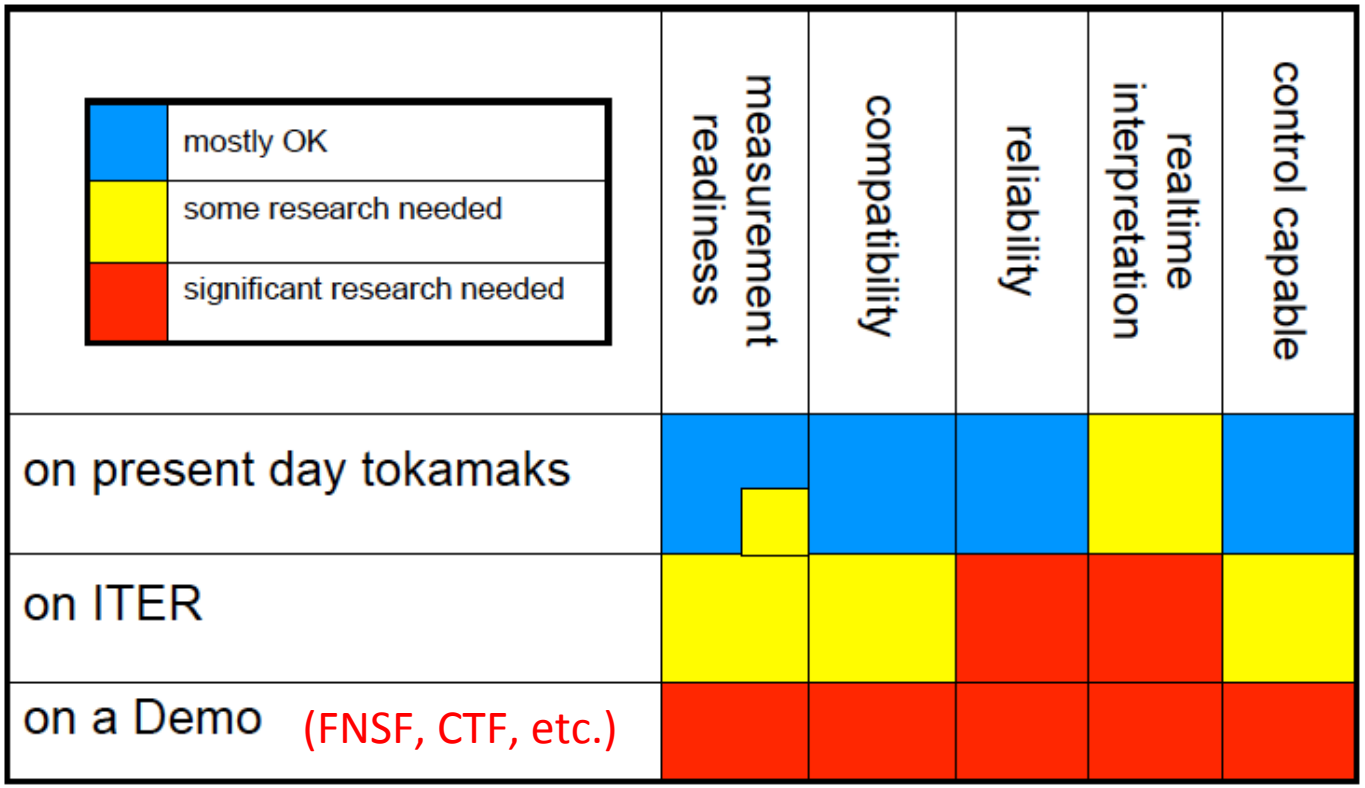
Remember that Demo diagnostics are for device protection and control!

- Relative to ITER, Demo represents major new challenges for diagnostic compatibility:
  - Some existing techniques simply will NOT transfer
  - Some existing techniques must be judged as "very risky" - e.g. optical
  - Steady-state measurement and control, real-time analysis
  - Proximity of diagnostics now major consideration
  - 3-4x higher flux, 100x fluence
  - Higher wall temperature 650° vs 240°
  - Possibility of liquid metal walls

- In examining requirements for diagnostics on Demo, one will stress:
  - High breeding ratio ⇒ min. access ⇒
  - Low streaming ⇒ min. access ⇒
  - High reliability ⇒ simplicity ⇒
  - Low cost ⇒ simplicity ⇒

} Reduced set of diagnostics

Summary of Research Gaps for Measurements



While this is challenging, it is not surprising since it reflects Greenwald assessment

ReNeW

The US magnetic fusion energy science program needs to support the development of innovative diagnostics for burning plasma experiments.

- The US ITER Project Office provides support for the construction of ~7 US-credited ITER diagnostics.
  - Some critical measurements required for the success of ITER's mission are still unmet.
- Currently, the OFES provides funding for diagnostic development supporting existing domestic experimental facilities:

  (1) Total funding has been reduced over the past 10 years, along with the number of groups (primarily universities) supported.
  - More proposals are received than can be funded.

  (2) Burning plasma diagnostics for future burning plasma experimental facilities are excluded due to insufficient funds.
- This represents a serious gap in the US program, which will negatively impact the potential for US leadership in future burning plasma experiments.

US leadership in diagnostic innovation should be maintained.

- US participation in HTPD is down (~25%) from 2012 to 2014, while Foreign participation is up (50%).
- Participation of China up (50%)
  - First invited speaker from a Chinese institution.
- US participation at international diagnostics meetings is meager (e.g. ITPA-Diagnostics, Varenna, et al.)

"ITER is a construction project, not a research project."

- Technical solutions (if identified today) would still require ~10 years as an engineering design Project to be installed on ITER.
  - Based on experience with simple (DRGA) systems and their check-in process.
- ITER (like NASA) will be running with obsolete (but qualified) technologies.
- ITER IO does not support R&D on diagnostics
  - Responsibility falls on the Domestic Agencies

Diagnostic implementation is a key aspect of workforce development.

- Development of and research in plasma diagnostics is a key area for training the next generation of fusion plasma researchers.
- Work force development is critical for the scientific exploitation of burning plasma experiments beyond ITER.
- 33% of HTPD meeting participants were students.
  - ~half of these from the US
- ~50% of invited speakers were students or postdocs.
  - ~75% of these from the US

The US DOE OFES portfolio is enhanced through better collaboration.

- A US burning plasma diagnostic initiative, as part of a strong and comprehensive overall diagnostic development program, would also strengthen the vital link among university, national laboratory, and industry groups in the US as they work together for the development of fusion energy.
- The model being used by US ITER partners universities and industry under a US national lab.

US initiative towards diagnostics for burning plasmas

1) Expansion of the present OFES diagnostic development program so as to provide support for short- and long-term development and implementation of new diagnostics and extensions of existing diagnostics (where feasible) needed for burning plasma research.

2) Integration of the capabilities of burning plasma diagnostics into existing analysis and simulation codes and, ultimately, into plasma control systems.

- Inclusion of these activities would require at least doubling the existing funding resources for OFES-sponsored diagnostic development work.