Gaps and Facilities for the Compact Stellarator

This brief note provides a perspective on Gaps and Facilities for the Compact Stellarator, as requested from the fusion community by the FESAC Toroidal Alternates Panel. It is framed in terms of the gaps associated with the Theme: "Creating Predictable, High-Performance Steady-State Plasmas", developed in the recent FESAC Priorities, Gaps and Opportunities (PGO) report.

With sufficient financial support, it is likely that ITER will be able to achieve its primary goal to achieve operation at Q = 10, for 300 – 500 seconds, while producing at least 400 MW of fusion power. However it is less likely that ITER will demonstrate stable, high-gain, continuous operation. Indeed this is not within ITER's internationally accepted set of objectives. Thus the step from ITER to Demo may be an uncertain one, even with complete success in the achievement of ITER's agreed goals. In effect, it is just this issue that is articulated by FESAC PGO Theme A: "Creating Predictable, High-Performance Steady-State Plasmas."

Because it is not certain that ITER, even in combination with EAST, KSTAR and JT-60SA, will provide the data needed to have confidence in finding the way to stable, high-gain, continuous operation of a tokamak Demo, it is very important that the U.S. and world fusion program have alternative options available in the time frame when ITER is exploring high-gain, long-pulse operation. This is now anticipated in about 2026. At that time the world could sensibly be asking: What next? Stellarators offer a direct path to continuous operation that requires very little recirculating power. Furthermore, stellarators approach and exceed the beta limits predicted by linear MHD theory, as well as the density limits experienced in tokamaks, without disruptions. Because of these crucial features supporting predictable, high-performance steady-state operation it is highly desirable to acquire significant stellarator data and understanding.

Any new facility planned to make major experimental contributions to the fundamental understanding embodied in validated computational models by about 2026 should begin operation at the latest by about 2016. While it would be desirable for such a facility to be at the Performance Extension scale (*e.g.,* such as JET), data at the Proof-of-Principle scale can make very important contributions. Indeed, as evaluated by FESAC's NCSX Review Committee, NCSX, supported by a set of focused U.S. Concept Exploration facilities, would have made such major contributions, providing data on the compact quasi-axisymmetric stellarator configuration to complement the results from the quasi-isodynamic W7-X, as well as those from LHD with simpler coils and less optimized confinement. The results from NCSX would have built closely on, and shed light on, tokamak results, due to the shared symmetry and aspect ratio, making such fundamental contributions to basic toroidal science as providing data to understand why tokamaks disrupt at their linearly-calculated ideal beta limits, while stellarators do not. Results from LHD, NCSX and W7-X together would have provided clear guidance on both long-pulse stellarator operation and geometrical optimization for high confinement and high power density.

The NCSX Project has been terminated due to the remaining cost to complete NCSX and the uncertainty in that cost. With modest further studies it may be possible to develop engineering and physics concepts that lead to more cost-efficient compact stellarator designs and also to reduce the uncertainty and even the projected cost of completing NCSX construction. It should be technically achievable to phase in a Proof-of-Principle-class compact stellarator experiment at a somewhat later date than had been planned for NCSX, and still make the key contributions required in parallel with ITER's exploration of high gain, long pulse operation. Such a facility, supported by the smaller U.S. Concept Exploration experiments, would fill a major gap in the U.S. and world strategy to address FESAC PGO Theme A: "Creating Predictable, High-Performance Steady-State Plasmas," by opening the path to a compact stellarator system. Further, experiments on this device would help determine which of the constraints on stability, symmetry and construction precision need to be sustained in the future. Complemented by the world stellarator and tokamak programs, and coupled with continuing U.S. theoretical, engineering, and smaller-scale experimental work, such a facility would provide key integrated Proof-of-Principle experimental data to help the U.S. and the world choose a credible path from ITER to stable, continuous high-gain operation of Demo. Whether or not additional compact stellarator experiments would be required in advance of Demo would depend on the data that had been acquired and the depth of validated understanding that had been developed at that time.

In summary, the FESAC Toroidal Alternates Panel should consider deployment of a U.S. Proof of Principle Compact Stellarator to help address FESAC PGO Theme A. Such a device should begin operation in about 2016 in order to provide necessary results by the time of ITER's exploration of high gain, long pulse operation. It would give the U.S. and the world the option to make use of the Compact Stellarator configuration for a stable, high-gain, continuously operating Demo.

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