Computational Modeling and the Experimental Plasma Research Program

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The development of a validated predictive capability is a leading challenge of the fusion energy program. The experimental plasma research (EPR) program is well positioned to make major contributions to achieving this goal through a coordinated effort that combines the data from multiple experiments to improve and validate computational models. In turn, the models greatly enhance the value of the plasma physics experiments being performed to study key physics and technology issues associated with the world-wide fusion program. The goal is to develop a validated predictive capability to mitigate risks in fusion development and promote scientific discovery.

Experimental plasma research projects explore a broad plasma parameter space while working towards improving magnetic confinement devices. Many of these experiments explore methods that contribute to the goal of reducing operational and maintenance complexity of toroidal magnetic confinement. Other experiments are designed to address key technology issues, such as the plasma-material interface. Using smaller experiments to calibrate and test the ability of computer codes to model a specific phenomenon has significant advantages. Many of the EPR experiments have as primary effects phenomena that are secondary in larger, hotter machines. This makes it easier to obtain the quantitative agreement required to develop and evaluate methods to quantify uncertainty associated with the models. At the same time, modeling assists the experimentalists in maximizing the understanding of their data, and in extrapolating to the next experiment.

As an example of how a validated model of physics needed to simulate EPR experiments can assist the mainline program, consider the effect of neutrals which can play a dominant role in smaller experiments. The models have or soon will have modules to account for the effect of neutrals interacting with the plasma, and these modules will be validated using data from EPR experiments. Once validated, this capability will contribute to the mainline modeling needs for pedestal stability and disruption, where macroscopic dynamics involve neutrals and plasma across a wide range of temperatures.

Validated modeling is a high priority goal of the fusion program. EPR experiments can help to achieve this goal through a coordinated effort to contribute to the development of uncertainty quantification methods for fusion plasma device modeling, leading to validation of models applicable to the EPR experiments. At the same time the EPR experimental groups will benefit by gaining a more thorough understanding of the underlying physics and using the improved models to assist in the design of new experiments. By employing codes that are already used to simulate the mainline experiments, this validated physics will be easily incorporated into a deeper understanding of the mainline program. Together the development of robust validated predictive models and an EPR program targeted towards overcoming technological and operational obstacles of the toroidal plasma confinement will greatly increase the possibility of large steps towards practical fusion energy in the near future.

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