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Verification and Validation for Magnetic Fusion: Moving Toward Predictive Capability

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Dramatic progress in the scope and power of plasma simulations over the past decade has extended our understanding of these complex phenomena. However, as codes embody imperfect models for physical reality, a necessary step towards developing a predictive capability is demonstrating agreement, without bias, between simulations and experimental results. While comparisons between computer calculations and experimental data are common, there is a compelling need to make these comparisons more systematic and more quantitative. Tests of models are divided into two phases, usually called verification and validation. Verification is an essentially mathematical demonstration that a chosen physical model, rendered as a set of equations, has been accurately solved by a computer code. Validation is a physical process which attempts to ascertain the extent to which the model used by a code correctly represents reality within some domain of applicability, to some specified level of accuracy. Verification assesses errors from spatial or temporal gridding, algorithms, numerics and convergence, as well as coding errors and bugs in compilers. In the arsenal of verification methodology are formal convergence tests, theory to code comparisons, code to code comparisons, and specialized tools like the method of manufactured solutions. The process of code validation requires an assessment of the critical elements in a physical model and a quantitative approach for testing these elements individually and in combination. Dedicated experiments are typically required along with careful analysis of errors and sensitivity. A recent development has been "synthetic" diagnostics, which allow more direct comparisons between simulations and measurements. This talk will cover principles and practices for verification and validation including lessons learned from related fields.