Assessments of the Fusion Development Path

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The US power plant studies program has initiated a 3-year integrated study, called the “Pathways Program” to investigate what the fusion program needs to do, in addition to successful operation of the ITER, in order to transform fusion into a commercial reality. The US power industry and regulatory agencies view the demonstration power plant, DEMO, as a device which is build and operated by industry, possibly with government participation, to demonstrate the commercial readiness of fusion power. As such, fusion R&D programs should generate all of the information needed by industry to move forward with the DEMO, i.e., data needed to convince power industry to invest in a fusion system, the licensing authority to license such a device, etc.

This paper summarizes the results of the first phase of the Pathways program which had aimed at two questions: 1) What are the data bases needed to field a fusion power plant? and 2) what is the impact of each R&D item on the attractiveness of the final product (i.e., quantitative metrics for prioritization of R&D)?

Many studies have been performed to identify the remaining technical challenges for fusion. To complement previous studies, we formed an Industrial Advisory Committee to help define R&D issues which are not usually considered by the scientific community (e.g., data base needed for licensing, operation, reliability, etc.). We also utilized “Technical Readiness Levels” (TRL) as a quantitative measure of maturity and R&D needs in each technical area. TRL was originally introduced by NASA and is now adopted by DoD and recommended by GAO for “Technology” Development. TRL structure, however, is readily applicable to scientific areas and provides a framework to plan and execute R&D programs as they can be utilized to assess cost, risk, and benefits of new initiatives. We also used a system-based (concurrent physics/engineering) approach to identify interconnected physics/engineering constraints and issues.

In order to define metrics for prioritization of R&D, we have developed a new approach to parametric system studies of fusion systems. Our experience indicates that “optimum” design points found by systems codes are usually driven by the constraints. In some cases, a large design window is available when some constraint is “slightly” relaxed, allowing a more “robust” and credible design. Our new approach to system analysis is based on surveying the design space. A data base of possible power-plant embodiments at the systems level is developed which, at present, contains over $10^6$ self-consistent physics/engineering points. Modern visualization and data mining techniques are used to explore the design space. This approach provides a direct measure of the impact of the R&D on the characteristics of the final product as well as a quantitative mechanism for risk/benefit analysis.