

Tokamak Model Digital Lifecycle for Neutronics Simulation Applications

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At Commonwealth Fusion Systems (CFS), we are developing the SPARC fusion device, a high-field, compact tokamak designed to achieve net energy gain to demonstrate commercial viability of fusion energy [1]. Our fusion neutronics team is meeting the fast-paced needs of designers by executing compact, highly detailed neutronics models to influence the design of the SPARC device.

Our in-device neutronics workflow relies on a detailed Computer Aided Design (CAD) model of the SPARC device to quickly analyze designs and verify SPARC meets its requirements. We have developed a process to directly integrate detailed CAD models of SPARC into our neutronics workflows to enable our team to provide accurate data that meets the designers' timelines.

The neutronics CAD model of SPARC comes directly from the SPARC Top Level Assembly (TLA). The SPARC TLA is an evolving CAD assembly made up of over a million parts within the Teamcenter and Siemens'NX software [2,3]. The fusion neutronics team works directly with system designers to defeature the system models from the SPARC TLA to prepare a new model of SPARC specifically for neutronics analysis (Neutronics TLA). Our workflows utilize unstructured mesh, which does not require the high level of defeaturing that is needed for Constructive Solid Geometry (CSG), the commonly used geometry format for radiation transport analysis. Tools within Siemens'NX are used to streamline the defeaturing process. The defeaturing process takes the over one million system parts of the SPARC TLA to about fifty system parts for the Neutronics TLA. In addition to the defeaturing process, custom NX open applications have been created specifically for the neutronics process to ease in process time, produce consistent files, and provide traceability throughout the workflow. Material assignments are tied directly to the CAD models and a custom NxOpen program was created to make the process of assigning materials easier and ensure that correct assignments are made. Tools have also been developed to rename solid bodies within NX to carry over key parameters when exporting CAD models to other software. Our neutronics workflows rely on different sector sizes of SPARC (e.g., 20-degree sector model) for analysis, and we have developed tools to create and export various sector cuts within our Neutronics TLA. Once files are reviewed and verified to mesh and function correctly within the neutronics workflow, the Neutronics TLA is put through a release process within Teamcenter for traceability purposes. Leveraging Teamcenter and Siemens'NX to build a detailed, realistic, and version-controlled model of SPARC has allowed our fusion neutronics team to keep up with the fast-paced needs of tokamak design for commercial purposes.

References:

1. J. Creely, M. J. Greenwald, S. B. Ballinger, et al., "Overview of the SPARC tokamak," Status of the SPARC Physics Basis, Focus on Fusion, Published online by Cambridge University Press, (2020).
2. Siemens Digital Industries Software. (2024). Siemens NX (Version 2406).
3. Siemens Digital Industries Software. (2024). Teamcenter (Version 2406).

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