The Commission's Use of the Consortium for Advanced Simulation of Light Water Reactors Tools in its Licensing Process and Safety Reviews

This report is being provided by the U.S. Nuclear Regulatory Commission (NRC) in response to the direction in the Joint Explanatory Statement that accompanied the Consolidated Appropriations Act, 2018 (Public Law 115–141). The report details the NRC's potential uses of the Consortium for Advanced Simulation of Light Water Reactors (CASL) tools in its licensing process and safety reviews.

Background

The U.S. Department of Energy (DOE) initially established CASL as a stand-alone program with limited government involvement, with the strategic goal of developing and applying contemporary science-based modeling and simulation practices for design, operational, and safety challenges for light water reactors (LWRs). The program aims to advance nuclear technology by deploying new capabilities for predicting the performance of commercial nuclear power plants and supporting progress toward key nuclear industry goals of higher power ratings, greater fuel burnup, and next generation designs.

There has been a separate effort to merge the modeling and simulation developments of the CASL program with a DOE Nuclear Energy Advanced Modeling and Simulation (NEAMS) program that is directed toward LWR and non-LWR concepts and problems that are not addressed by CASL. The coordinated effort between the two programs is expected to produce computational tools capable of analyzing two areas of high interest for the NRC: Accident Tolerant Fuel (ATF) in LWRs and advanced non-LWRs. Therefore, this report acknowledges the relationship between CASL and NEAMS and reports the potential uses of advanced modeling and simulation generally.

NRC's Collaboration Efforts with the U.S. Department of Energy

Modeling and simulation are critical supporting components of the NRC's licensing and oversight responsibilities. For example, the NRC may perform independent confirmatory calculations for first-of-a-kind designs or operations, or when the safety margins are small. NRC sponsors work at multiple DOE national laboratories and with specialized nuclear contractors to develop confirmatory analysis tools to meet the needs of the NRC.

Over the past several years, the NRC has been working with DOE to determine how best to leverage the CASL and NEAMS programs. With respect to CASL, there are several areas where CASL has been used to improve the NRC's confirmatory tools for safety and licensing reviews. The majority of the collaboration between NRC and CASL has been in the area of neutronics and nuclear data. For example, the Shift CASL code, which calculates radiation transport, is being integrated into the NRC-funded SCALE code to improve the NRC's capability in reference depletion calculations, criticality safety, and shielding analysis. The integration is expected to be completed by January 2019 and will improve calculations of neutron fluences, which are used to estimate the neutron embrittlement of the reactor pressure vessel, a critical part of the NRC's evaluation of proposed plant lifetime extensions.

Another successful joint NRC-DOE endeavor was the update of the NRC's ORIGEN code under the CASL program. This effort updated nuclear data libraries that provide essential information

needed for calculations of neutron interactions with reactor materials. This update resulted in an approximately 90 percent reduction in computer runtime for the depletion (i.e., nuclear fuel utilization in the reactor) component in ORIGEN calculations. As a result, confirmatory calculations for licensing can be performed faster.

Finally, the SCALE-CASL effort was able to collaboratively develop the CASL Denovo 3D discrete ordinates transport code for the NRC's use in many licensing reviews, including those to evaluate the adequacy of shielding in proposed spent fuel cask designs and to calculate nuclide inventories of fuel rods for subsequent accident safety analysis. This software application improved runtime performance and reduced code maintenance costs for the NRC.

The NRC is reviewing its existing regulatory infrastructure and identifying needs for additional analysis capabilities and for developing unique critical skillsets within its staff. In February 2018, the NRC and DOE established a Memorandum of Understanding (MOU) to collaborate on nuclear safety research on ATF that will make appropriate data available for regulatory decision-making (Attachment 1). As part of this agreement, a CASL pilot test stand will be initiated to make the NRC's TRACE thermal-hydraulic code interoperable with DOE's fuel performance code (BISON) through the DOE-developed numerical framework (MOOSE). Testing of these coupled codes will be accomplished using both NRC and DOE codes, as well as examining potential uses of these codes for future licensing and safety reviews.

NRC Future Plans and Priorities

One important potential application of DOE's developments in advanced modeling and simulation for the NRC is in the area of code architecture. DOE's codes developed under both NEAMS and CASL aim to achieve state-of-the-art code architecture; DOE employs computer science experts in this effort. The NRC staff is making progress on modernizing the architecture of its codes and would benefit from DOE expertise. There are opportunities to leverage the DOE efforts to further enhance and modernize NRC codes or replace certain functionalities. The NRC staff is working with developers of CASL and NEAMS tools to identify and pursue these opportunities.

Another potential application of DOE's investment in advanced modeling and simulation for the NRC is in the evaluation of non-LWRs. One of the primary objectives of NRC's strategy for non-LWRs is the development of codes suitable for confirmatory analysis of gas-cooled reactors, sodium fast reactors, and molten salt reactors. Codes used by the agency to date for confirmatory analysis have been designed and assessed for LWRs, and are not immediately extendable to these non-LWR designs. Initial efforts with DOE have been directed at understanding requirements for modeling and simulation for these new designs and in identifying codes that can meet these requirements. While development and modification of NRC codes are potential means to obtain codes suitable for non-LWRs, codes developed outside of the NRC, including DOE codes, are also under consideration. In particular, codes developed under CASL and NEAMS possess some unique advanced modeling capabilities that could be adopted for NRC use if they prove to be a cost-efficient means of achieving the required functionality.

Summary

The NRC staff has historically collaborated with DOE and national laboratory staff, to better explore the plans, capabilities, applications, and limits of DOE codes. These efforts have helped identify specific opportunities to leverage elements of DOE's CASL and NEAMS modeling and simulation tools to improve the NRC's nuclear safety analysis capabilities. As documented in a February 2018 NRC-DOE MOU, the NRC staff expects to continue to follow DOE's development efforts in the area of advanced modeling and simulation and looks forward to opportunities to leverage these capabilities.