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MULTI-PHYSICS IMPACT AND CRITICALITY MODELING OF SPACE REACTOR SYSTEMS

Abstract

Since 2014, LPS and its team, comprised of Sandia National Laboratories and the Center for Space Nuclear Research have performed sweeping investigations of available multi-physics models and have adapted many toward solving the integrated design problem for space nuclear systems. The initial simulation code which optimizes a nuclear rocket engine design, is called IROC for Integrated Rocket Optimization Code which forms the initial executive for the entirety of the design process. At the present time, IROC is optimized for Nuclear Thermal Propulsion, however is broadly applicable to many types of space nuclear systems. When the LPS team started the effort, IROC was comprised of two separate analysis codes under control of a Matlab routine. The two parts of the code consistent of MCNP-6X and an internally developed finite-difference thermal hydraulics code. The two codes could be manually coupled, but were not coupled at the initiation of the project. Within a Phase I SBIR effort, LPS integrated the two codes so that the neutronics analysis, which produced energy tallies, later converted to power profiles was integrated within Matlab to determine power-to-flow matching and could show hot-spots within the core. This allowed the core to be modified to enhance power flattening and produce a more uniform mixed mean outlet temperature. This enabled optimization over hundreds of parameters automatically.

In the Phase I effort, we linked the results of a simple concentric circle reactor concept via a .stl file into Sandia's massively parallel hydrocode, PRESTO. This code shows how a reactor will deform during an impact. The code is highly benchmarked and performs well for impact safety analyses. We demonstrated coupling the output of PRESTO via an LPS proprietary translator to Serpent 2, a mesh-based transport code. We performed a criticality calculation based on the high-speed impact of a UO2 penetrator into water. The results were dramatic.

Since that time, under internal RD funding, LPS has extended the results to the impact and criticality safety domain for both hard surface and water impact conditions. The first step is to produce a detailed conceptual design from the MCNP input source deck. This is converted into a file usable by Sandia's Solid Mechanics code. The design is meshed and subjected to desired impact conditions and scenarios. Results will be presented of different velocity and impact situations. Such integrated design codes will yield important results for integrating safety into the overall space nuclear system design process.