Striving Towards Higher Fidelity Radiation Transport Methods: Multiphysics Coupling, Space-Angle Adaptivity and Alternative Numerical Frameworks

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Abstract

Efforts are underway for the development of higher-fidelity radiation transport methods which potentially will enable unprecedented detailed analyses. The ultimate aim is to couple these methods to other physics in order to simulate the complex, non-linear, physical phenomena of existing and future advanced nuclear systems. These higher-fidelity methods are based on unstructured grid technology which gives them total geometrical flexibility and provides a more convenient framework for coupling radiation transport to other physics. In this talk we discuss three relevant aspects which impact directly on the successful development of such methods: namely multiphysics coupling, solution adaptivity and alternative numerical frameworks. We start by discussing multiphysics frameworks and describing experience already gained by the speaker in the context of criticality excursions in fissile solutions. We show how by coupling the classical finite element-spherical harmonics (FE-PN) method to a first-principles fluids model, the non-linear space-dependent kinetics of fissile solutions systems can be modelled to great detail. This application is very useful for criticality safety analyses and the study of beyond design-basis accident scenarios. Illustrative simulation results are presented for the CRAC, SILENE and TRACY experiments and also for the Tokaimura criticality accident, which provide useful insight into its underlying physics. We next discuss the aspect of solution self-adaptivity which can be hailed as the holy grail of numerical simulations – it potentially enables greater user transparency and accuracy combined with more efficient use of computational resources. In this context we describe recent work on space-angle adaptivity for the FE-PN method and present some preliminary results. We conclude the talk by presenting a Riemann approach to the first-order transport equation based on a higher-order finite element-finite volume framework. This framework has great affinity with computational fluid dynamics discretizations and thus offers scope for a more integrated and seamless combined multiphysics methodology.

<u>Biosketch for Cassiano R. E. de Oliveira</u>

Dr de Oliveira has been a Professor in the Nuclear and Radiological Engineering Program within the George Woodruff School of Mechanical Engineering of the Georgia Institute of Technology since 2003. Prior to that, he was a Senior Lecturer at the Department of Earth Science and Engineering of Imperial College London. There he helped to build a multidisciplinary group that is recognised internationally in diverse areas of engineering science and physics. Dr de Oliveira has specialised throughout his research career on unstructured finite element techniques, high-performance computing and advanced solution methods applied to radiation transport and radiative transfer and also to multiphase flow, electro-seismics and global ocean circulation. He has developed the general purpose radiation transport code EVENT code which has been adopted by the UK nuclear industry, and also co-developed the coupled radiation-hydrodynamics code FETCH which has been extensively used in the study of the criticality behaviour of fissile solutions, Gen IV fluidised bed nuclear reactors and criticality assessment of nuclear waste repositories.