DEVELOPMENT OF MCNP TRAINING MODULES FOR SAFEGUARDS PRACTITIONERS

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ABSTRACT

The Monte-Carlo N-Particle® (MCNP®) software [1] developed at LANL is the most widely used neutron transport code in the world. It is an essential tool for a variety of applications including detector development and design, nuclear fuel burnup simulation, criticality safety, and nondestructive assay system optimization. For this reason, it is indispensable within the safeguards and materials control & accountability (MC&A) communities. Multiple MCNP training courses have been created and taught over the last several decades by the MCNP development team at LANL, however there are no existing courses that cover specialized topics considered fundamental to nondestructive assay (NDA) and safeguards models. To fill this gap, the MCNP team and Safeguards Science and Technology group at LANL have co-created a set of training modules customized to meet the specialized needs of the safeguards and MC&A communities. The basic modules cover concepts such as NDA system optimization, ^{3}He-specific and other capture tallies, and tools for improved theoretical understanding. An advanced module was also created to cover topics including variance reduction for active interrogation simulations, use of the LANL MCNPTools post-processor [2], PTRAC (particle tracking) and list-mode data simulations, and fuel burnup simulations. The training modules teach to the latest and most state-of-the-art MCNP features and tools released by the development team at LANL, and are intended to be taught jointly by the developers and safeguards experts. Ultimately, we hope that creation of these modules will serve to capture and convey the safeguards modeling and MCNP expertise at LANL, and that we will be able to share the modules more broadly with the MC&A and safeguards communities.

INTRODUCTION

Research and development programs for nuclear safeguards almost always utilize the MCNP software as a design, benchmarking, or research tool. The radiation transport code was developed in its initial form after the Manhattan Project, and continues to be the most widely used code of its kind in the world. For years, safeguards and materials control-specific topics in the MCNP code have been taught to students in a variety of forums including university courses, NA-22 consortia workshops, and most commonly from our observation, within R&D organizations in a one-on-one fashion. Properly using the MCNP code for safeguards simulations requires a specialized set of input parameters that tend to be passed on from generation to generation of safeguards experts via legacy input decks and internal documentation.

The Safeguards Science and Technology group at LANL collaborated with the MCNP development team to develop a set of training modules to formalize this knowledge transfer process. The modules will be taught alongside the other MCNP courses provided by the MCNP development team at LANL, but will feature instruction by LANL safeguards subject matter experts (SMEs) as well. The material and examples were curated to be highly applicable to problems typically modeled for material control and accountability including detectors, fixed sources, nuclear fuel assemblies, and more. The modules were divided into two main categories: Basic Topics and Advanced Topics for Nuclear Safeguards. This paper provides a summary of the content in the modules.

BASIC MODULES

The basic modules were created largely from content in existing MCNP training courses, however with a focus on safeguards-relevant topics and in particular, detector modeling. The modules are designed to be taught to intermediate MCNP users with a basic understanding of how to create input decks and run the code. Content includes basic and advanced geometry overview, common material definitions, fixed source definitions, and relevant tallies. For many traditional applications using the MCNP code, the subtleties of the fission model such as the distribution of number of neutrons emitted and correlation of emission with energy and direction do not impact the final answer. In safeguards measurements and detector design, these can be crucial parameters affecting the accuracy of the model and therefore the optimization of the detector. Basic geometry examples covered in the modules include simulating ^{3}He tubes in a slab of polyethylene and more advanced geometry topics include spent fuel assembly modeling with discussion of lattices, universes, and fill cards. Two examples of slides from the basic modules are provided as Figure 1. The training modules cover how to select different physics options, when to use different source types (neutrons vs. spontaneous fission events as particle type), when to run in analog mode, which tallies are most useful for detector modeling, and much more. The module is designed to be about one week in length and concludes with a capstone exercise of optimizing a model of an NDA system.

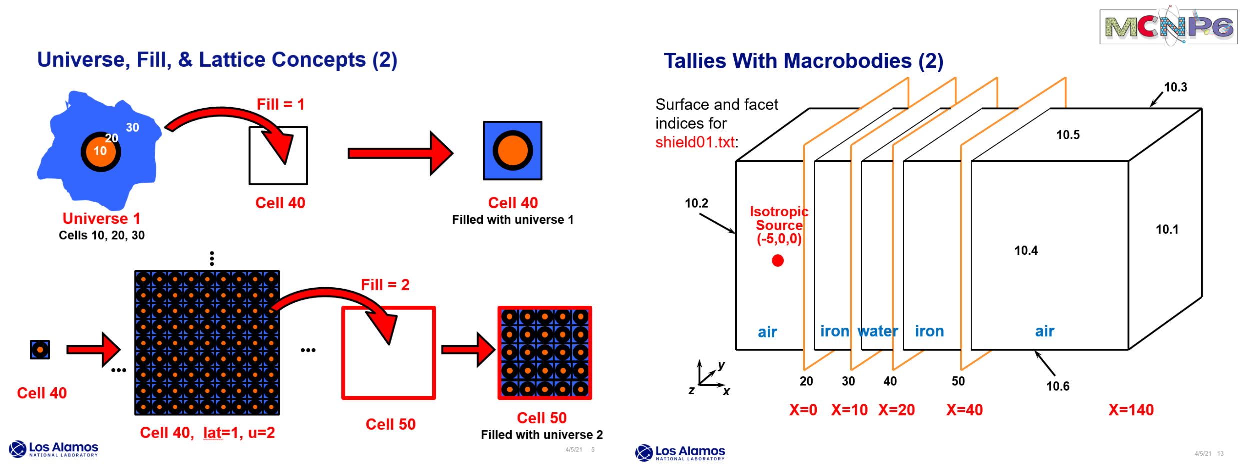

Figure 1. Two example slides from the Basic modules

ADVANCED MODULES

MCNP users in the safeguards community who have experience running the code will find the advanced modules to be particularly informative. The majority of the topics selected for the advanced modules were chosen because they are highly unique topics requiring specialized knowledge that is typically not passed down in a formalized way. This set of training modules provides both an opportunity for students to learn from MCNP developers and safeguards SMEs, and for a repository of knowledge surrounding these specialized topics for future use. Topics include spent fuel modeling, Sources4C [3], and the Intrinsic Source Calculator [4], and principles of benchmarking. Another topic selected for the set of advanced modules is use of the MCNPTools post-processor. MCNPTools is maintained by the MCNP development team, previously released with the code through RSICC, and it is expected to be available on Github at the time of the next MCNP release. This post-processing tool is highly efficient at pulling relevant information out of standard MCNP outputs and PTRAC (particle tracking) outputs, saving the safeguards and detector modelers from having to write their own post-processors.

CONCLUSIONS

The safeguards community relies on the MCNP code for a variety of crucial applications including detector design and optimization, benchmarking, and more. An official MCNP training course has not previously been offered specifically for this community. To address this gap, safeguards experts and the MCNP development team at LANL have teamed up to create a series of basic and advanced training modules covering topics that are crucial for any safeguards practitioner. We hope that creation of these modules will serve to capture and convey the safeguards modeling and MCNP expertise at LANL, and that we will be able to share the modules more broadly with the MC&A and safeguards communities.

ACKNOWLEDGEMENTS

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