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INTRODUCTION (HEADING A)

Nuclear engineering began as an urgent weapons development program in the early 1940s, involving work in enrichment, reactor design, shielding design, and isotope production. This work led to investigations of peaceful uses of nuclear technology, including nuclear power production and applications of radiation. Such peaceful technologies, often derived from experience gained through the weapons program, often maintained some level or attitude of secrecy. As the field continued to develop, that secrecy led to different specializations developing with different sets of terminology and methods of computation. For example, radiation safety used buildup and shielding factors while reactor designers use diffusivity and cross sections. Impressive amounts of work went into theory and application development in each sub-field over the next few decades, with much of the work left without adequate documentation or with important documentation made only within the organization. This situation has led to a loss of knowledge and experience, a lack of collaboration across nuclear sub-fields, and immense amounts of time and effort spent on redundant work.

Now, much of the documentation from nuclear's past is being digitized and made available, though typically these reports and papers are published in disparate places, often the original research organization's websites. At present, significant time and energy is spent dredging up the previous work done for a given nuclear topic, and usually one must know the name of the project or the specific entity that did the work to be able to find the work in the first place. Even long-time experts can frequently learn about past experiments or discoveries that surprise them. At present, current experts, young professionals, and students in the nuclear field do not share a common vision of the field or even a commonly understood history, resulting in a lack of focus in research and in public relations.

This paper proposes an open-access system that combines preserving and passing on the knowledge in all nuclear sub-fields with tools to make that knowledge useful, referred to as the Nuclear Knowledge and Innovation Toolkit (NuKIT). Knowledge would be captured in user-entered and expert-verified databases of reactors, applications of radiation, isotope production methods, and other pertinent nuclear information complete with technical information and tags that can be used to organize and investigate the data. Tools include community tools like forums and the ability to create collaborative projects; visualization and presentation tools; and an online programming system that allows code sharing, collaborative editing, database manipulation, and integration with all other tools. Finally, NuKIT is envisioned to include commercialization tools to allow freelance work and to compensate data entry/moderation work to help encourage participation. Eventually, integration with industry-standard tools like MCNP, SCALE, etc. is expected.

This paper will present some proposed work in the context of its use for isotopes and radiation application, as well as possible work to be done in the context of the Combined Materials Experimental Toolkit (CoMET) being developed by the Nuclear Science User Facilities (NSUF) program. It should be noted that any work done towards this system, by any group, will advance the full system. It should also be noted that similar work previously done can be integrated into NuKIT.

APPLICATIONS FOR ISOTOPES AND RADIATION

Pertinent data for isotopes and radiation in particular include isotopes and their spectra, capture cross sections for neutrons and other potential ion sources, historical applications of radiation, and source forms available for sale currently, with all data backed by references.

A few examples of how this data could prove helpful include:

1. **Isotope production calculations –** With a known source and flux, cross sections for all possible targets could be pulled and run to optimize yield from that given source. Since NuKIT also allows for code coupling, codes for isotope decay could be applied, and the results of decay could be fed back into the production calculation to determine their effects on the production. Multiple valuable isotopes, including ^{238}Pu, ^{177}Lu, ^{213}Bi, ^{225}Ac, ^{60}Co, and ^{192}Ir, have a larger market than current supply allows, making the use of these isotopes more expensive. Investigation of new production methods usually take months. Finding other targets or production methods using tools provided in NuKIT, this investigation time can be greatly reduced.

2. **Finding alternative isotopes for a given application –** Isotopes are usually selected for a given task because of the energy and intensity of the radiation provided by an isotope. Earlier, isotopes were chosen more for their chemical compatibility. NuKIT provides a means of quickly

filtering all known isotopes by half-life, radiation energy (including de-excitation gammas), atomic radius for nano-scale or materials applications, and other physical data. Matching previous applications to other isotopes with similar radiative properties would likely identify additional production paths and applications for the whole isotope family.

3. **Find nuclear solutions for non-nuclear problems** – An industry with a problem that can be solved using radiation, such as leak detection, material tracking, or an instrumentation issue, can be found from the previous application database, which will already contain useful information on isotope selection, detection methods, etc. Often, radiative instruments can be deployed for less cost and greater effectiveness than other instrumentation. NuKIT could be used to identify nuclear solutions that are superior to current methods. In fact, a section of the database could be devoted to alternative instrumentation for a given application.

4. **Visualization of decay chains and schema** – To understand the full effect an isotope might have in a given application, the full decay chain and decay schema must be considered. The decay chain will identify elements that must be compatible chemically for a given application, while each decay results in new radiation release, the effect of which must be considered for the application. Decay schemes detail all possible radiation that could be released from a given isotope, including branching paths, different energy levels or ranges of energy level, and de-excitation gammas, all of which could be useful for former or novel applications. Such full information is somewhat cumbersome to collect and analyze at present. NuKIT's programming tools would provide powerful general functions to calculate, for example, full decay chain energy release over a given period of time or total flux of a given radiation type above a certain energy level from the full decay chain over time.

5. **Practical calculations for isotope or radiation applications** – Practical questions, such as how much shielding is needed to reduce exposure to a certain level, come up when discussing applications of isotopes and radiation. NuKIT would allow for easy conversion between cross sections and mean-free-path calculations and shielding/build-up factors, allowing multiple ways to identify new or other shielding materials suitable for a given application. NuKIT can provide calculations for how long before a tracer or accidental release can no longer be detected in an environment given the amount of dilution. In short, the ability to combine past experience, a full database of physical properties, and seamlessly convert between multiple approaches to a problem provide a powerful toolkit for working with radiation.

PARTICIPATION

The members of the ANS Isotopes and Radiation division represent some of the most experienced experts, with knowledge and understanding that may not be well-known to the world at large. IRD members should be mentors, passing their broader understanding of the capabilities of nuclear technologies to students and young professionals. Many enthusiasts are very interested in nuclear technologies, but often lack the training or vocabulary to engage nuclear professionals at the same level. NuKIT provides experts with the tools to contribute to a raising generation of new nuclear professionals who will carry the torch, with enthusiasts who can breathe new life and perspective into the field and stimulate innovation, and even with the general public by producing simple visuals that explain complex topics simply.

NSUF is building a system for nuclear experimental design under the name CoMET. This tool will include tools for calculating transmutation and damage of materials in specific reactors, as well as a host of other tools to help a researcher design an experiment using known facilities and to be reasonably confident of the outcome of that experiment. Some of the tools and functionality that will eventually be in NuKIT are being built for CoMET, and some of these tools are to be tested as open-access, user-generated content. NSUF has significant experience creating similar databases and making data accessible to multiple groups of different backgrounds. For this pioneering project, professionals, enthusiasts, and students, including the readers of this paper, will be notified during the conference of where they can go to investigate and participate.

CONCLUSION

NuKIT represents an ideal—the ideal of a unified nuclear field. Sharing tools, experience, and data between all nuclear disciplines, and making it available to enthusiasts and others with fresh ideas, will breathe new life into the nuclear field. Collaborative innovation, firmly rooted in nearly a century of experience, will yield powerful new applications and nuclear technologies that will benefit those currently in the nuclear field as well as the world at large.