NGN PhD EARMARKED Studentship Proposal

Note that proposals will be assessed against both the quality of the scientific content and of the proposed training experience.

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<th>Proposed supervisors (lead first):</th>
<th>Professor Malcolm Joyce</th>
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<td>Industrial supervisor/partner:</td>
<td>Dr Mike Angus / NNL</td>
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**Project Title:** Combating high-intensity contamination of safeguards assay in head-end waste streams

**Host Institution(s) and Department(s)/School(s):** Lancaster University, Dep't Engineering.

**Summary of proposed project (excerpts from this may be used for publicity purposes)**

Nuclear safeguards is the technical discipline of ensuring that the quantity of nuclear material in a given process is known in order to identify if any of the nuclear material has been removed for illicit purposes at some point in the nuclear fuel cycle. A long-established technique for measuring the quantity of material is based on the measurement of the neutron emissions associated with nuclear materials, and particularly the coincident neutron emission arising from either stimulated fission (uranium) or spontaneous fission (plutonium). Historically this has been measured with\(^3\)He-filled proportional counters in fresh fuel prior to loading into a reactor.

The established \(^3\)He systems are largely fit for purpose on fresh fuel, but obsolete because the helium gas is no longer produced on a scale to satisfy demand. Furthermore, escalating concerns over international nuclear terrorism and piracy, coupled with the widespread, global increase in interest in peaceful nuclear power production, have brought about increased pressure on safeguards monitoring systems. As we look ahead, exotic nuclear fuel alternatives associated with MOX, recycle/reuse and a diversity of demand for nuclear power into what are currently non-nuclear states, has attracted renewed interest to revised safeguards monitoring schemes.

An area of key interest in this regard is the spent fuel component of an open nuclear fuel cycle, and the extreme of the reprocessing cycle in a closed fuel cycle, the latter which is often referred to as ‘head end’. Assuming an open fuel cycle is adopted for fuels used in the current renaissance suggests the dry-store of significant quantities of spent fuel. This whilst radioactive, will be vulnerable to clandestine separation and illicit diversion for many years to come. Assuming a closed cycle, then it is from head end that the waste stream is subdivided across variety routes and, whilst these are generally highly radioactive which significantly complicates the ease with which material is diverted, there are also a number which comprise a significant quantity of nuclear material, principally plutonium. This represents a potential area of interest in terms of safeguards monitoring between the accountancy done before dissolution and whatever can be achieved at head end amidst a rather intolerable radioactive environment. Whilst nuclear reprocessing is not widespread at present, political debate returns to it on a regular basis in terms of the quantity of the once-through uranium that is forecast to be available under scenarios of significant uptake of nuclear power worldwide. Further, the liquors and therefore safeguarding vulnerabilities still exist in many countries from legacy separations activities, especially where long-term geological disposal strategies have not yet been agreed.

Of particular interest in this regard is a lesser-known isotope,\(^{244}\)Cm. This isotope of curium produces an intense source of neutrons as a result of its spontaneous fission decay pathway, and in spent fuel serves as a significant source of confusion in attempts to measure the much less radioactive, even-numbered isotopic component of plutonium, usually referred to collectively as \(^{239,240}\)Pu. In this project the objective is to explore the use of fast neutron multiplicity analysis for the detection and discrimination of spontaneously-fission isotopes. If successful, this will enable heavy actinides to be discriminated from each other, and thus removing contaminant sources from spent fuel safeguards assay, as per the \(^{244}\)Cm example, leaving the way clear for the assay of plutonium and / or uranium in these streams.

Fast neutron multiplicity assay was pioneered at Lancaster, and comprises the use of organic liquid scintillation detectors to detect fast neutrons instead of \(^3\)He detectors that are constrained to thermalized neutrons. The advantage of this approach is that a much smaller coincidence window can be used to ‘trap’ those correlated neutrons associated with fissile material. This leads to a reduced number of ‘accidental’ coincidences that fall within the time window but that are not actually correlated with one another; fewer of these means much more efficient counting of ‘real’ coincidences and hence an increased sensitivity to higher orders of multiplicity i.e. 4, 5 and 6 neutrons in coincidences. At these levels of multiplicity, \(^{244}\)Cm, \(^{239,240}\)Pu and stimulated
emissions in $^{239}$Pu and $^{235}$U have different profiles and can be distinguished from each other, which we hope to prove in this work.

It is worthy of note that the curium/plutonium distinction is a significant challenge, as is commensurate with the study for a PhD. However, in the event it is not achievable this project will bring significant focus to conventional safeguards methods and is very likely to yield a significant increase in accuracy and / or saving in inspection times over methods that are currently in use. Further the equipment necessary for this project has recently been awarded as part of the digital radiometric instrumentation development under the NNUF.

**Related papers**


‘Development of a liquid scintillator-based active interrogation system for LEU fuel assemblies’, A. Lavietes, R. Plentada, N. Mascarenhas, M. Cronholm. M. Aspinall, F. Cave, M.J. Joyce, oral paper for the IEEE Advancements in Nuclear Instrumentation, Measurement Methods and Analysis (ANIMMA), Marseille (June 2013), paper #1257.


**Student Specific Training**

Two campaigns of specific training will be required, both will be compatible with the reporting requirements of the NGN project:

1. In the first instance the student will be trained at the manufacturer of the fast neutron assay systems, in order that they are fully versed in the use of the ultra-fast digitizers on which this work relies. This will take place on-site at Lancaster, at the premises of Hybrid Instruments Ltd. In Birmingham and potentially at the Neutron Metrology Facility at the National Physical Laboratory.

2. Secondly and later in the project, the student will attend the Seibersdorf laboratory at the IAEA in Vienna to take some measurements plutonium samples and to carry out the key measurements in order to infer whether the distinguishing process will be successful.