# STATE-LEVEL NUCLEAR FUEL CYCLE SIMULATIONS FOR SAFEGUARDS APPLICATIONS

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Abstract:

A high priority in international safeguards is to support more effective processing of growing amounts and streams of data while reducing analyst workflow. However, key information such as State accountancy reports and declarations are safeguards-confidential and not available to the R&D community for use in developing new data processing tools and methods. This dissertation modifies and develops tools for cradle-to-grave nuclear fuel cycle modeling to generate sophisticated and realistic synthetic State accountancy reports, enabling safeguards methodology development such as cadence of operations analysis.

## CHAPTERS

**Demonstration of Acquisition Pathway Analysis built on Cyclus infrastructure, ("APA")**

This chapter demonstrates the ability to conduct acquisition pathway analysis techniques using the Cyclus fuel cycle simulator.

**Full fuel cycle case studies for use in fuel cycle simulator development and demonstration ("Case Studies")**

Previous nuclear fuel cycle simulation literature has focused on future fuel cycle transition scenarios for individual States and regions, providing valuable technological and policy-related information. In the case of international safeguards research, however, it can be important to demonstrate software capabilities on a wide landscape of potential fuel cycles. A representative set of synthetic case studies across an intentionally diverse set of reactor designs and fuel cycle complexity will be developed.

**Enhanced facility behaviors for use in Cyclus facilities ("Behaviors")**

This chapter enhances nuclear fuel cycle facility and MBA models to incorporate more complex material movement behavior. Instead of identifying a single step in the nuclear fuel cycle and increasing agent fidelity, this work will enact a more generic set of behaviors that will be useful across the nuclear fuel cycle, each arising from a careful reflection of system behavior.

**Creating synthetic fuel cycle data in the style and with the requisite information of State's accountancy reports to the IAEA ("Code 10")**

A novel mechanism to create synthetic, but IAEA format and content compatible, State-like accounting reports that include realistic types of nuclear material inventory changes and movements for the purpose of testing and developing algorithms to detect and characterize inconsistencies and irregularities that could be associated with illicit proliferation-type activities.

**Demonstration and Summary**

Each of the above chapters contributes to an enhanced ability to model realistic movements of nuclear material throughout the fuel cycle and will be combined in a final demonstration chapter highlighting the new tools and capabilities. APA will be conducted on each of the case studies. Several of the case studies will have a disruption introduced in one facility, interrupting their regular operational pattern, or cadence of operations. After converting each simulation to Code 10-compliant data to match realistic State accounting reports, time series analysis and forecasting techniques will be used to demonstrate how the enhanced behaviors contribute further to the ability to develop new methods and for identification of errors and discrepancies in State accountancy reports.

## KEY WORDS

international safeguards · graph theory · nuclear fuel cycle simulators · advanced nuclear · agent-based models · acquisition pathway analysis · State accounting reports · Cyclus

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## KEY DATES

**Apr 2023**
ANS Student Conference

**May 2023**
Preliminary Exam

**May 2023**
INMM-ESARDA Joint Annual Meeting

**November 2023**
ANS Winter Meeting

**Fall 2023/early 2024**
Defend dissertation