Graph representation of a fuel cycle from Cyclus input

K.A. Mummah, P. P.H. Wilson
University of Wisconsin-Madison
PI Paul P.H. Wilson, paul.wilson@wisc.edu
Consortium for Monitoring, Technology, and Verification (MTV)

Department of Engineering Physics
UNIVERSITY OF WISCONSIN–MADISON

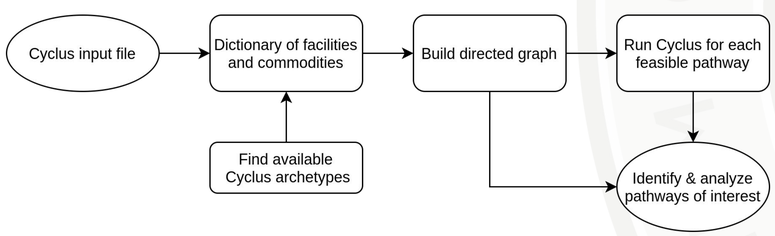
Introduction and Motivation

APA is "the analysis of all plausible acquisition paths or acquisition strategies for a state to acquire nuclear material usable for the manufacture of a nuclear explosive device"

- Goal: expand CYCLUS fuel cycle simulator to conduct APA to maximize efficient use of safeguards resources

Technical Approach

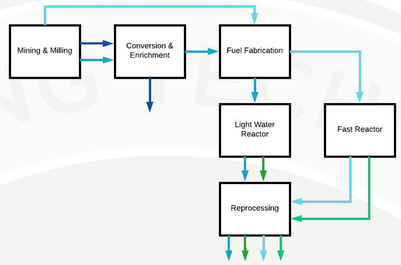
- Cyclus treats the fuel cycle as a competitive market, only connects the optimum path
- Solution: build tool Trailmap on top of Cyclus



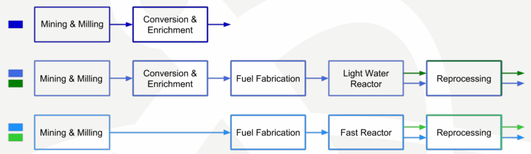
Trailmap workflow

1. Trailmap reads Cyclus input file of facilities and commodities, creates a directed graph of potential material flows
2. All pathways from a root "Source" node are enumerated.
3. Cyclus is run for each pathway
4. Output sorted for parameters of interest, e.g.
   - Shortest pathway
   - Highest throughput
   - All pathways that use reprocessing

Example visualizations



Visualizing multiple pathways on a full fuel cycle in a hypothetical scenario



Visualizing individual pathways (blue for HEU, green for Pu)

Conclusion

- Cyclus can conduct APA
  - With additional facility models, Cyclus can conduct APA at any desired fidelity
- APA automates a process that was previously conducted by experts by hand

Next Steps

- Strengthen high-fidelity facility models in Cyclus
- Build notional safeguards into Cyclus
  - Area to collaborate with PNNL? [1]

References

1. L. BURKE et al., "Math modeling and classification techniques for non-proliferation problems," in Annual Meeting Proceedings (2019).

Expected Impact

- Streamlines identification of material diversion pathways for any State or hypothetical fuel cycle

Mission Relevance

- Addresses IAEA R&D objective V.2.R1 to enhance state evaluation capabilities
- Improving global material security through quantifying State-level fuel cycle safeguardability

Attended 2017 Keepin Nonproliferation Science Summer Program at LANL with funds from CVT.

MTV Impact

- Built network from 2019 MTV fuel cycle facility modeling workkshop
  - Lead to internship offer from ORNL
- Will spend 3-6 months at Los Alamos in 2021 working on this project
- Potential future partnership with Vienna University of Technology

This research was performed under appointment to the Nuclear Nonproliferation International Safeguards Fellowship Program sponsored by the National Nuclear Security Administration's Office of International Nuclear Safeguards (NA-241). This work was also funded in-part by the Consortium for Monitoring, Technology, and Verification under Department of Energy National Nuclear Security Administration award number DE-NA0003920

National Nuclear Security Administration