MATERIAL DIVERSION ANALYSIS WITHIN CYCLUS

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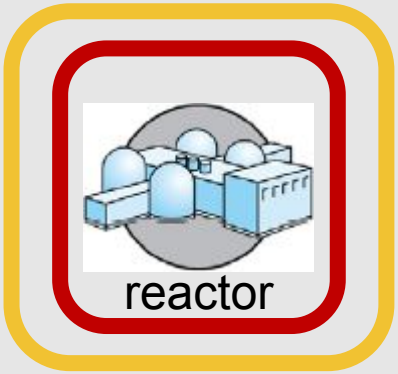
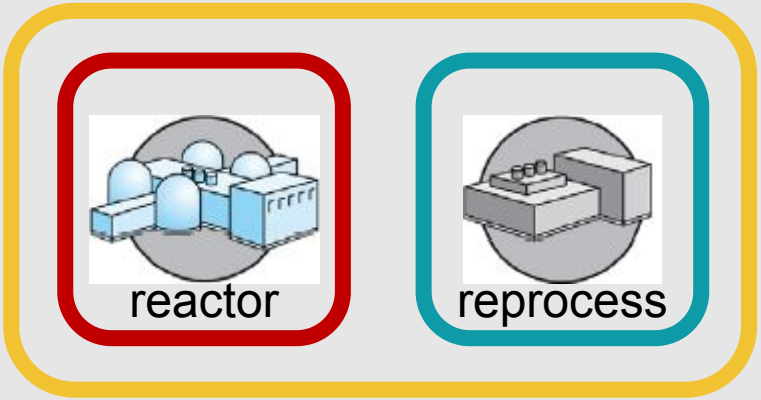
Integrated safeguards over time

- Safeguards implemented at facility level until 1991
- Additional Protocol was developed, and eventually the "State-level Concept" was born
  - States should be treated holistically when applying safeguards

State A



State B



Goal of SLC: maximize effectiveness and efficiency of safeguards

Doing this requires objective fuel cycle analysis

APA steps

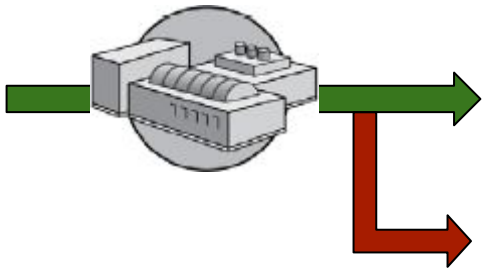
1. Fuel cycle information
2. Identify and present technically plausible acquisition paths
3. Assess technical capabilities to complete a path
4. Assessing time to complete paths

Acquisition pathway analysis (APA) is an important tool in a State-level safeguards approach

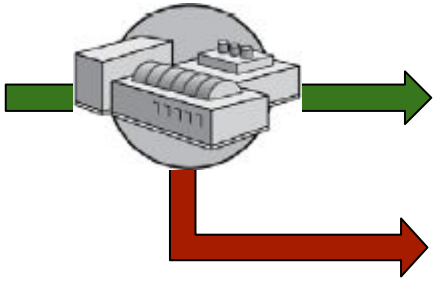
APA is “the analysis of all plausible acquisition paths or acquisition strategies for a state to acquire nuclear material usable for the manufacture of a nuclear explosive device”

Types of path steps to be captured

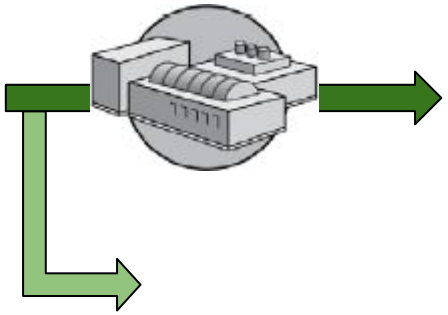
Diversion of declared material



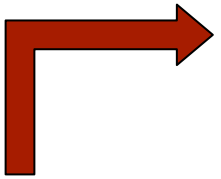
Misuse of declared facility



Produce Undeclared Material in a Clandestine Facility



Undeclared import



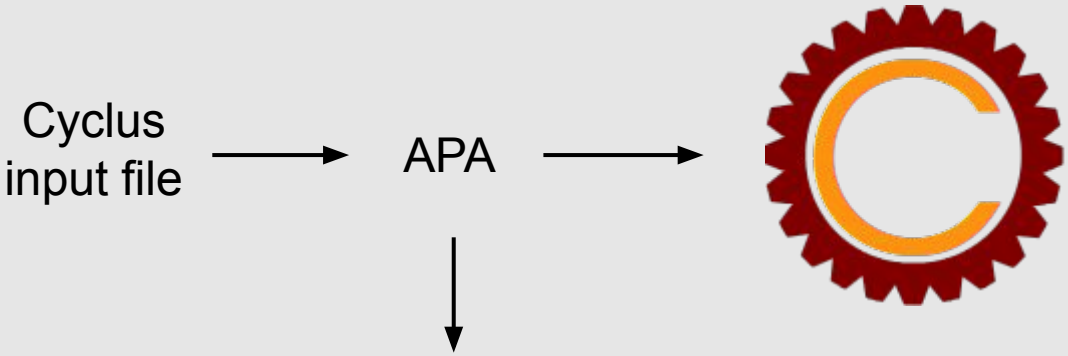
APA and fuel cycle simulation can complement each other

- APA Strength: identifying & characterizing pathways
  - Allows development of State-level safeguards approaches
- APA Weakness: little/no information about throughput & capacity of pathways
  - Could be useful to implementing tailored safeguards approaches
- The Cyclus fuel cycle simulator includes many components of pathway analysis
  - Can also provide insight on throughput and flow rates
  - Requires some enhancements/upgrades in facility fidelity

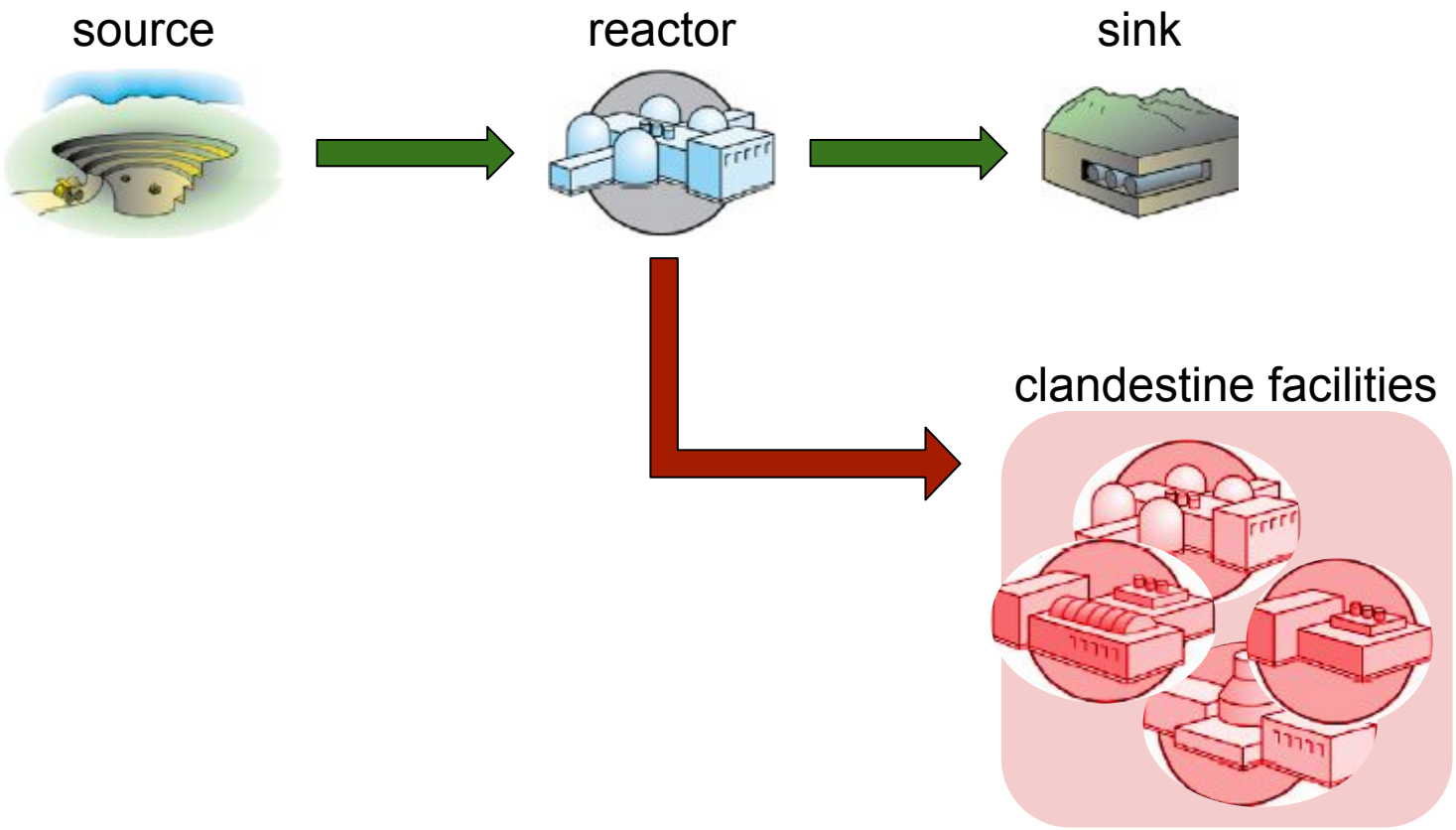
Shortcomings

- Archetypes do not include sufficient sub-facility details:
  - Internal material processes and flows
  - Material Balance Areas
  - Key Measurement Points
- Concept of safeguards not integrated into model
  - Maybe build a wrapper on top similar to PNNL?

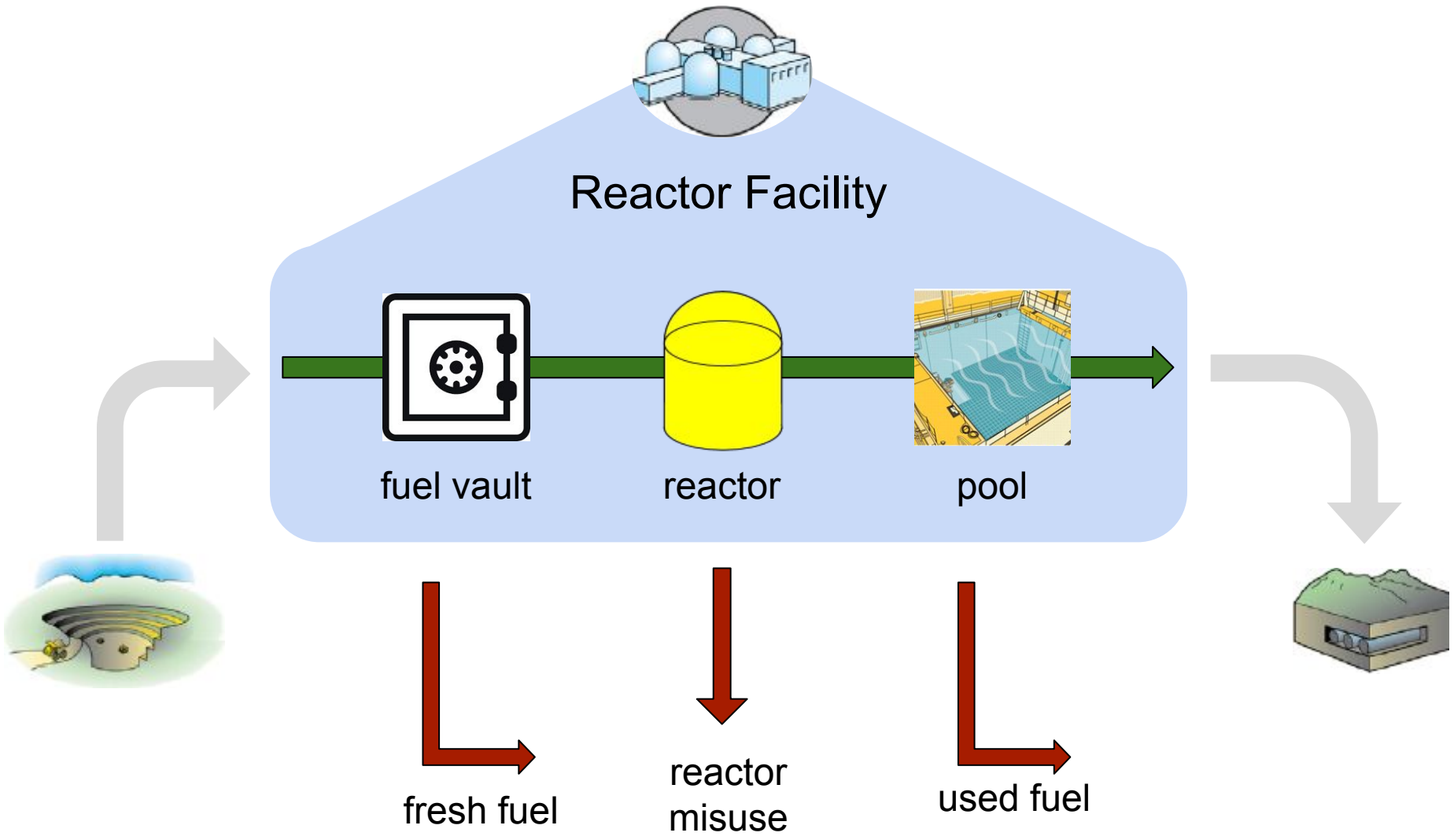
What will this look like



Current material flow in



Desired future fidelity



Brute Force Approach

- Represent each MBA or inventory KMP as a separate “facility”
  - Define commodities that ensure material only flows within real-world facilities
  - Create extra *sink* facilities that can receive fissile material from all locations
- Provides pathway analysis with very little modification to Cyclus
- Doesn’t scale well for material flow information with deployment of many real-world facilities
  - Conflict between commodity naming and intra-facility flow restrictions
  - Market-based material transfer mechanism grows

Resource Buffer Approach

- Most facility archetypes already use internal notion of *Resource Buffers*
  - Currently used to allow inventories of feed, product and waste streams
- Internal flows to/from Resource Buffers not exposed for either
  - Graph generation/pathway analysis
  - Throughput analysis
- Enhance/extend Resource Buffers to support needs of pathway and throughput analysis
  - Expose internal flows of materials to graph generation
  - Record flows in/out of Resource Buffers in output data
- May be need for process modeling at Resource Buffer level
  - Currently only implement storage

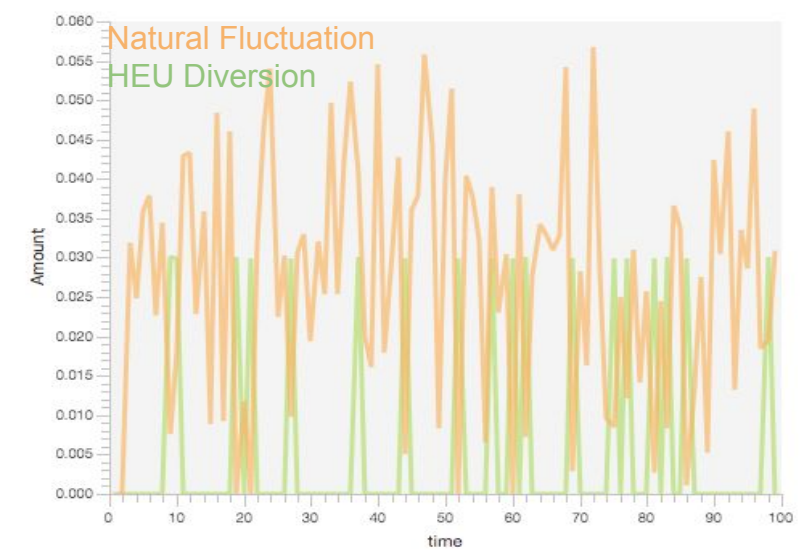
Sub-Facility Approach

- Hybrid between brute force and Resource Buffers
- Extend agent hierarchy to allow sub-facilities that operate as part of larger facility archetypes
- Improved scaling in simulations with many facilities
  - Commodity naming only needs to be unique in local scope of parent facility
  - Sub-facilities don't participate in market-based material transfer process (DRE)
  - Sub-facility archetypes can include physical process models

Gameplan

- Generate APA by connecting all possible pathways
- Develop a useful set of material balance areas to cover the fuel cycle
- Add “safeguards” to facilities across the fuel cycle
  - This concept came up yesterday in work by PNNL and collaboration-building session

Expected Fluctuation or HEU Diversion?



Acknowledgements & References

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