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A Flexible Model for Calculating Potential Radionuclide Inventories

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Overview

- Introduction and Background
- Model Development
  - Assumptions
  - Development
  - Workflow
- Example Application

Background for the Inventory Process Model (IPM)

- The β-SOAR is a flexible performance assessment computer model designed to gain rapid insights in various geologic disposal scenarios (β-SOAR: A Flexible Tool for Analyzing Disposal of Nuclear Waste)

- The β-SOAR currently uses representative values for waste form inventories for: spent nuclear fuel (SNF), spent mixed-oxide fuel (sMOX), and high-level waste glass (HLW).
  - These inventories were derived from publically available information

- The IPM was designed to enhance the flexibility of the β-SOAR model.
  - Variability in fuel cycle characteristics were considered

Development Considerations

- The IPM provides a means to analyze the effect of variations in the fuel cycle/history on the radionuclide inventory
- The IPM considers:
  - fuel assembly types
  - initial Uranium-235 enrichment
  - Burn up
  - average reactor power level
- IPM calculations are on a per metric ton basis for consistency and mass balance

Development Considerations

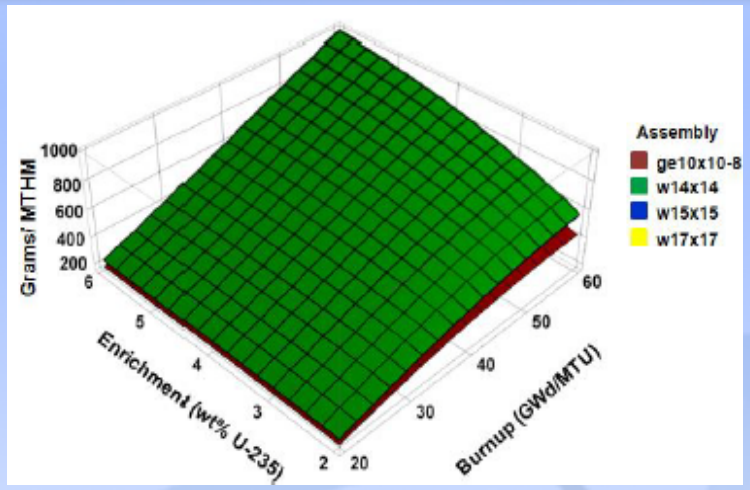
- Given the range of variables, data overload can be rapidly reached
  - Example: Detailed PWR/BWR calculations

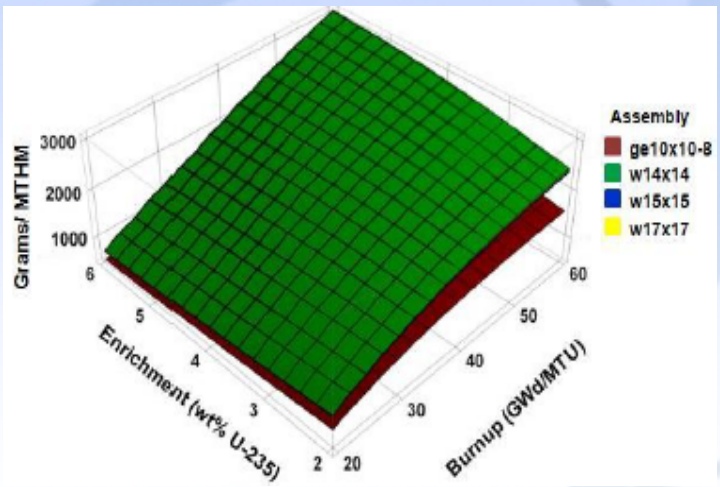
[Enrichment]	x	[Burnup]	x	[Avg Pwr]	x	[Assembly]		
9	x	9	x	2	x	4	=	648

- Calculations were performed for a subset of the potential combinations for interpolation

- Additional more detailed calculations assessed the adequacy of the interpolation

Assumptions: Instant Decay of Np-237 Precursors





- The predicted Np-237 inventory (no precursors)
- In the IPM the inventory is adjusted to account for 'instant' decay of Np-237 precursors.

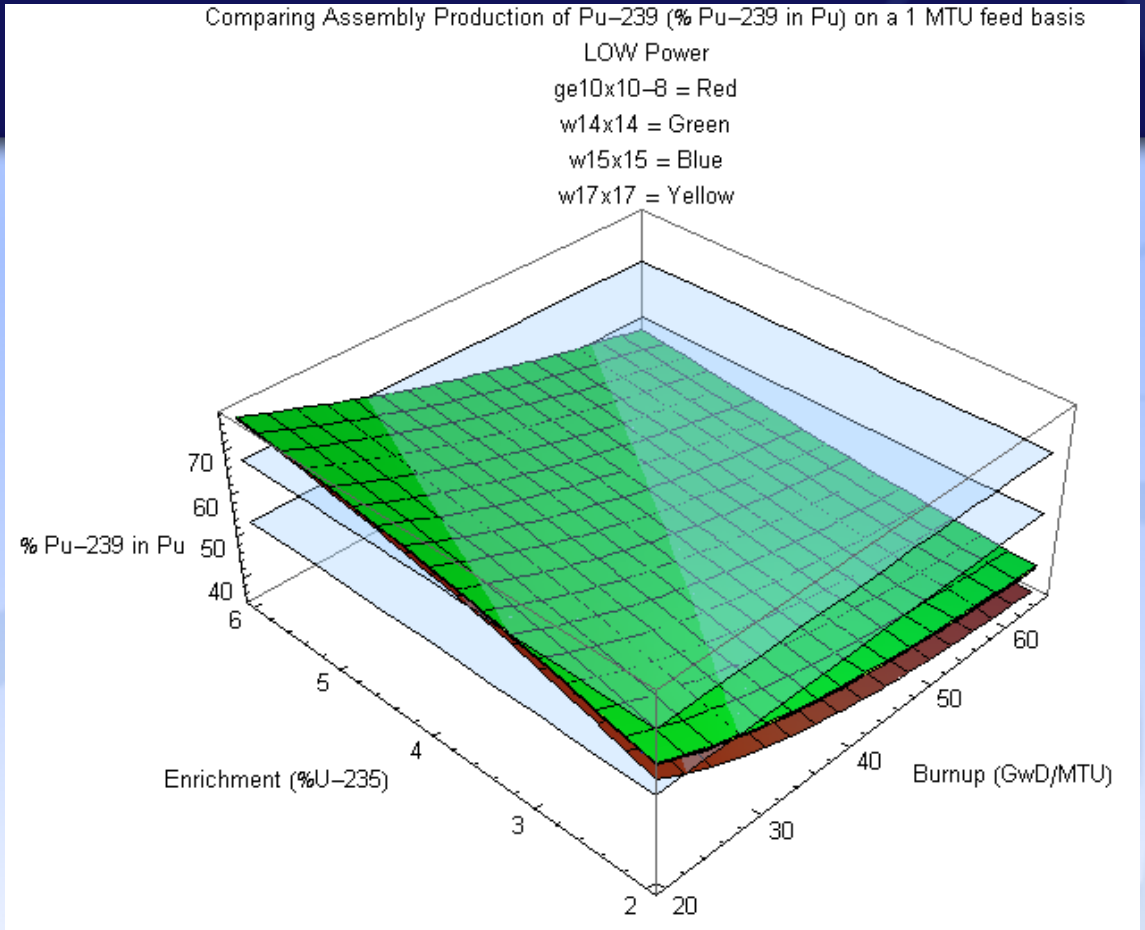
Assumptions: Nitrogen Impurities

- C-14 is mostly produced via activation of Nitrogen impurities
- C-14 is quite mobile and readily absorbed into living organisms
- Assumed 100 g/MTHM [ppm] of Nitrogen impurities

- Results: For a fixed amount of Nitrogen, the C-14 inventory:
  - Increases with increasing burnup, and
  - Decreases with increasing enrichment

Assumptions: Mixed-Oxide Characteristics

- Simplifying assumptions:
  - Only PWR MOX is modeled
  - Assembly burnup is fixed at 40 GWd/MTHM
  - A delay of 0.001 yrs is modeled between removing the spent fuel from the reactor and reprocessing
  - The delay before loading isn't modeled, so no Pu decay products are included in the fresh MOX compositions



Origen-ARP only accepts Pu-239 values between 70 and 50 % of the total Plutonium for the MOX fuel starting composition

Inventory Process Model Development

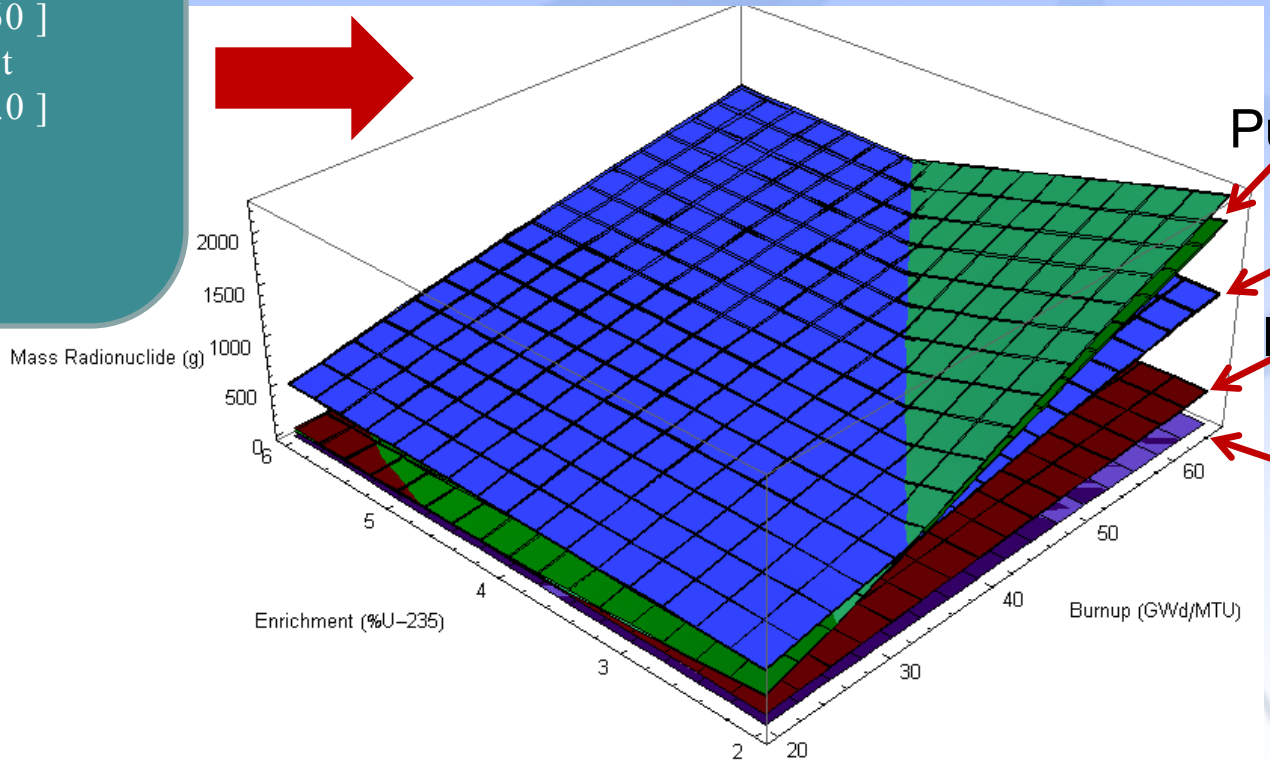
- The database for radionuclide inventories was generated from Origen-ARP runs:
  - Runs and data aggregation are fully automated using in house scripts (Python, Mathematica™)
  - The IPM is a pre-processing model, with radionuclide inventory characteristics manually input into SOAR
  - SOAR implementation allows the user to select burnup and enrichment values for the SNF inventory

Inventory Process Model Development

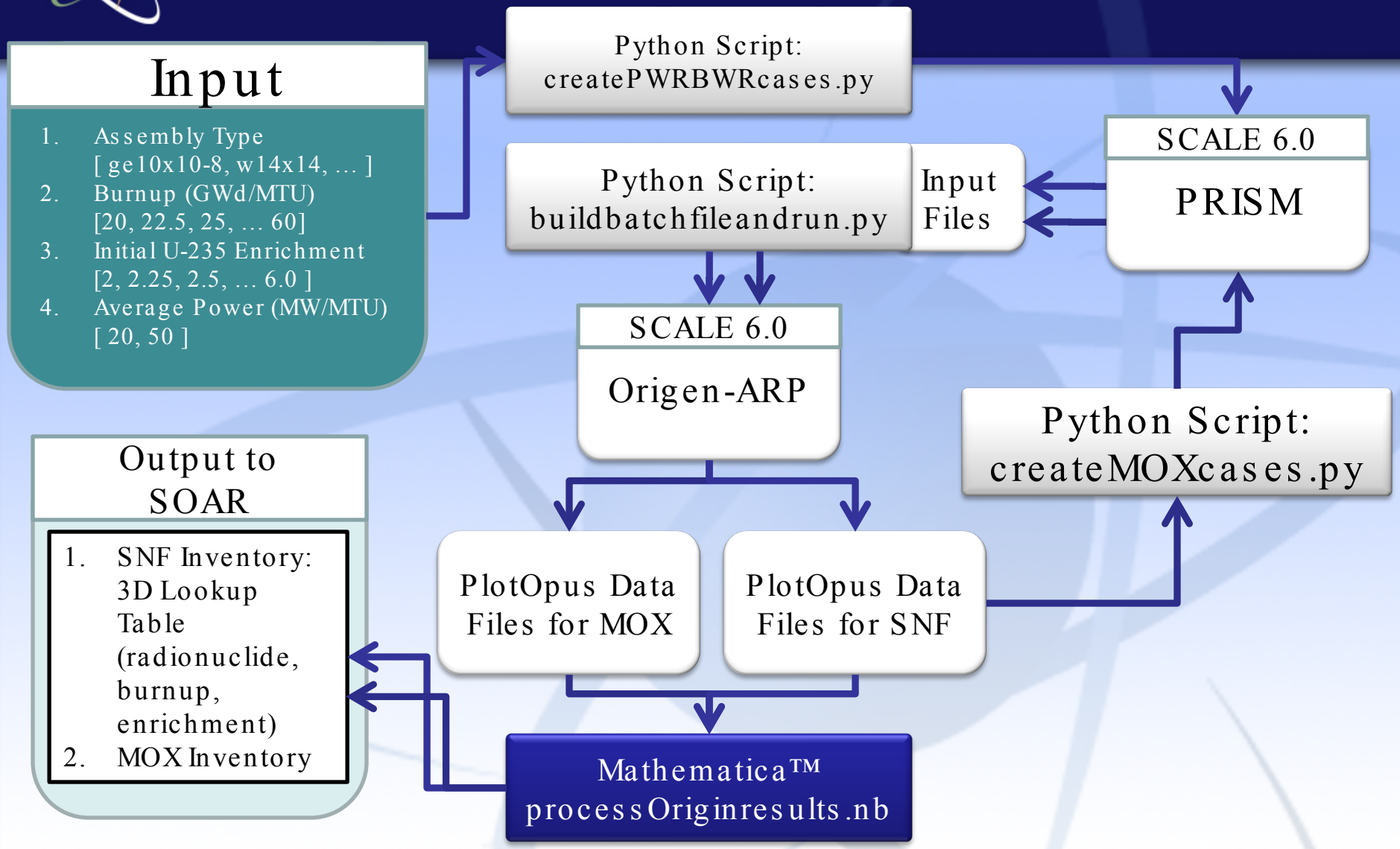
Input

1. Assembly Type
   [ge10x10-8, w14x14, …]
2. Burnup (GWd/MTU)
   [20, 22.5, 25, … 60]
3. U-235 Enrichment
   [2, 2.25, 2.5, … 6.0]
4. Average Power (MW/MTU)
   [20, 50]

Lighter Color: **ge10x10-8**
Darker Color: **w14x14**

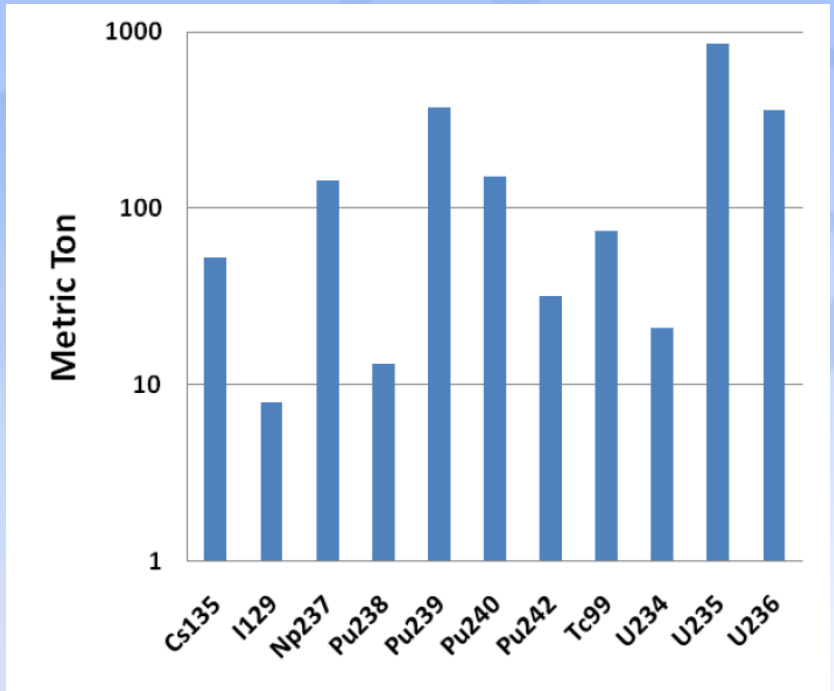


Workflow for Inventory Process Model



Calculating the 2010 Inventory

- Assumed 100 operating reactors
- With 20 MTHM/yr/reactor throughput through 2010
- Initial U-235 enrichment was 5 wt% U-235
- Burnup was assumed to be 40 GWd/MTU



IPM Inputs to SOAR

β-SOAR

Waste Form View Component

Waste form proportions tracked in the system:

Fraction of Waste Inventory that is Spent Nuclear Fuel and Spent Mixed-Oxide Fuel (the remaining fraction is assumed to be High Level Waste):	0.95
Fraction of the Spent Nuclear Fuel that is commercial SNF (the remaining fraction is assumed to be sMOX):	0.5263

	commercial SNF	sMOX	HLW Glass
Inventory Loading Factor	1	1	1
Fraction of WF Initial Inventories Available for Release:	1	1	1
Degradation Rate Multiplier	1	1	1

In Development for SOAR 1.0

Waste Form Results Home View Component

Total Number of Waste Packages 11104.9
SNF 6789 HLWg 4140
sMOX 67.7 HLWc 108

Length of Aging Prior to Disposal (years): 2010 Inventories only: 5

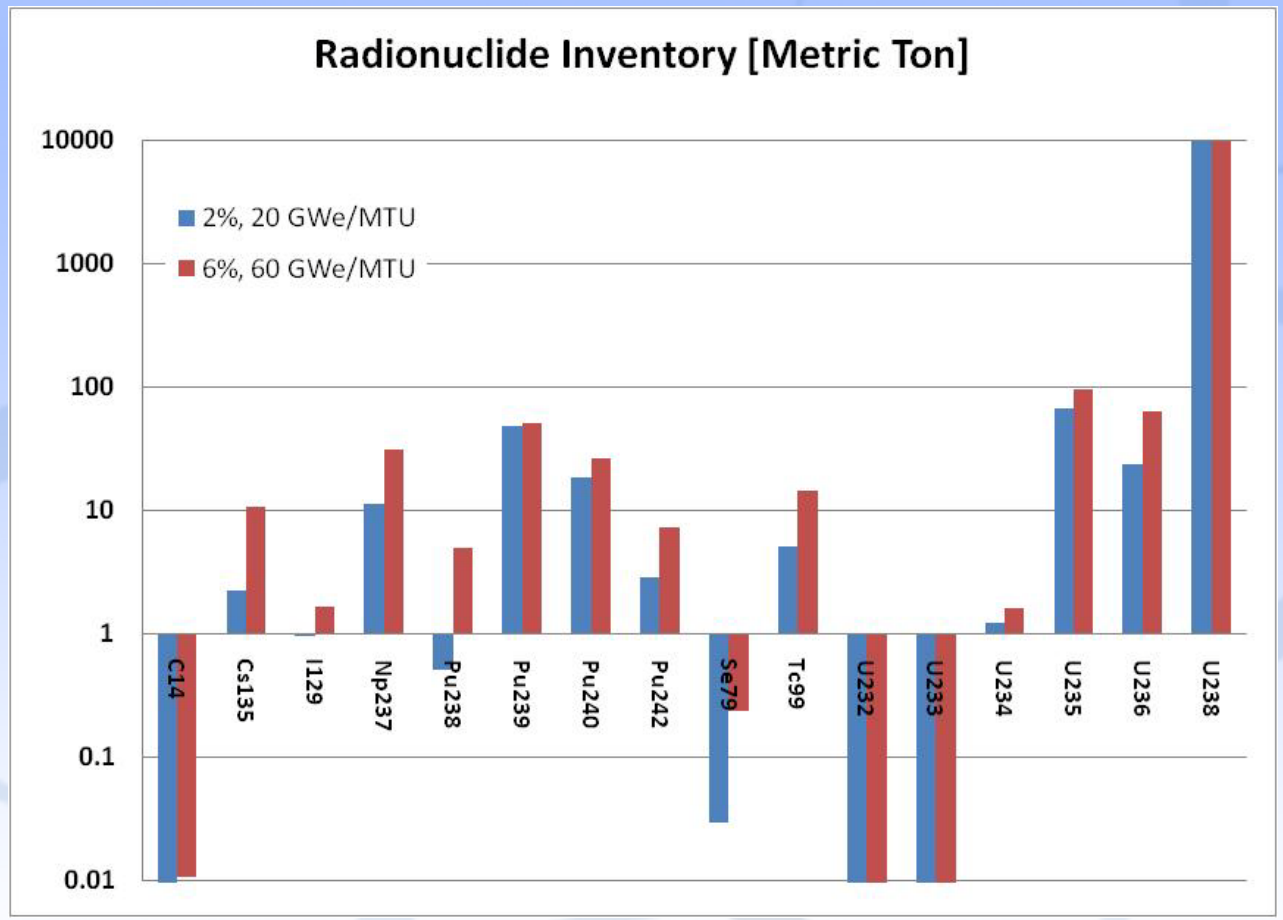
	Spent Nuclear Fuel	Spent Mixed-Oxide Fuel	High-Level Waste (glass)	High-Level Waste (ceramic)
2010 Radionuclide Inventory (Metric Tons)	67892	677	4140	108
Additional Radionuclide Inventory (Total Waste Mass in Metric Tons)	0	0	0	0
Total Disposed Mass per Waste Package (grams)	1e+007	1e+007	1e+007	1e+007
Fraction of Initial Inventory Available for Release:	1	1	1	1
Degradation Rate Multiplier	1	1	1	1
Enable Combined Oxic/Anoxic Degradation Rates	☐ Check to Enable	☐ Check to Enable	Not Applicable	Not Applicable
Initial U235 Enrichment (%)	5 ☐	Not Applicable	Not Applicable	Not Applicable
Burnup Value (GWe/MTU)	40 ☐	Not Applicable	Not Applicable	Not Applicable
Waste Form Loading Factor (%)	Not Applicable	Not Applicable	10 ☐	10 ☐

IPM Provides:
- Initial SNF Inventory
- Modifiable additional SNF inventory
- sMOX inventory

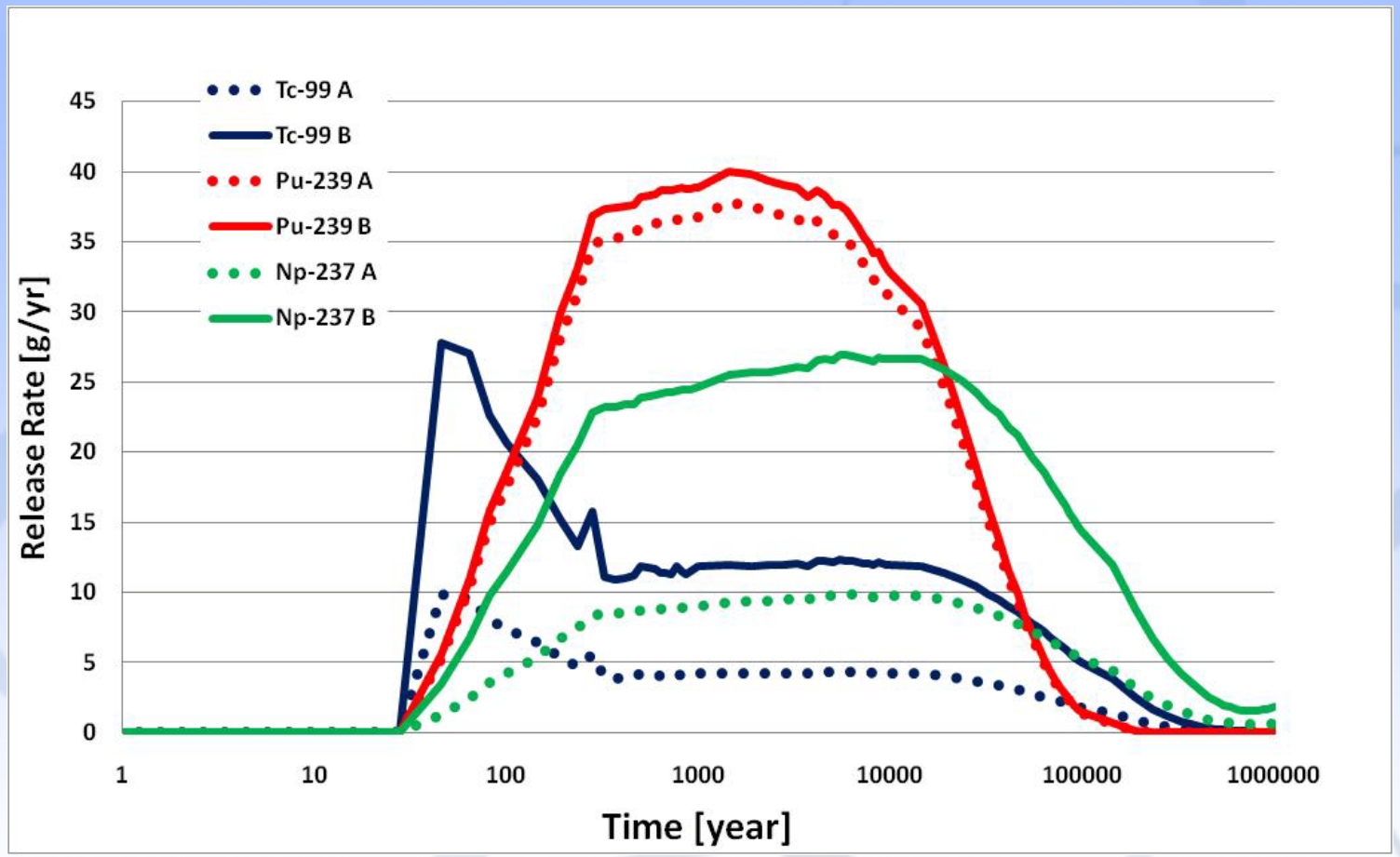
Results: Example Application

- 10,000 MTHM
- Case A (2/20):
  - 2% initial U-235 Enrichment
  - Burnup of 20 GWd/MTU
- Case B (6/60):
  - 6% initial U-235 Enrichment
  - Burnup of 60 GWd/MTU
- Early waste package failure

Results: Radionuclide Inventory



Results: Waste Form Release Rates



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Questions?