Safeguards and Spent Nuclear Fuel

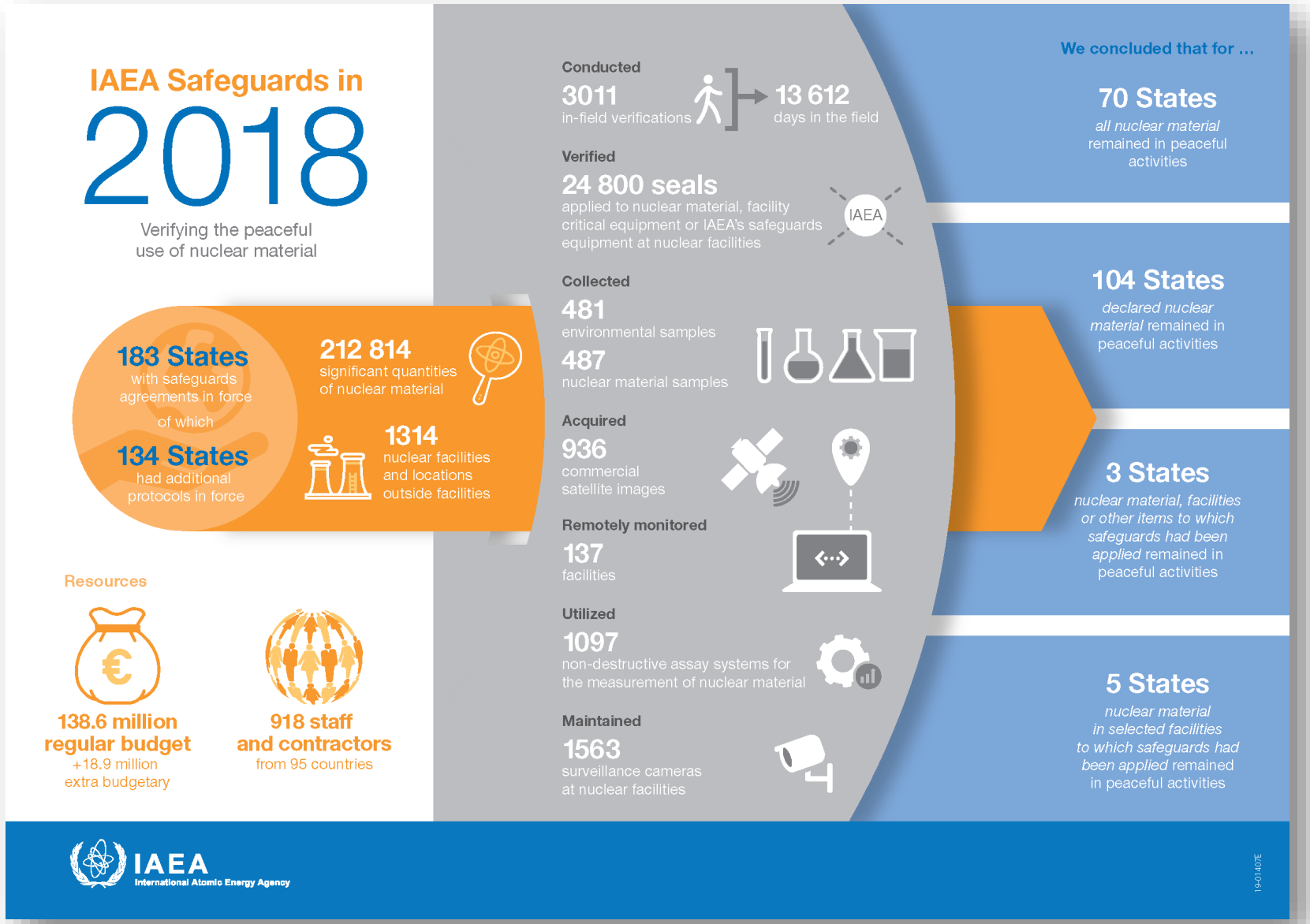
Alexis Trahan, Ph.D.
Los Alamos National Laboratory

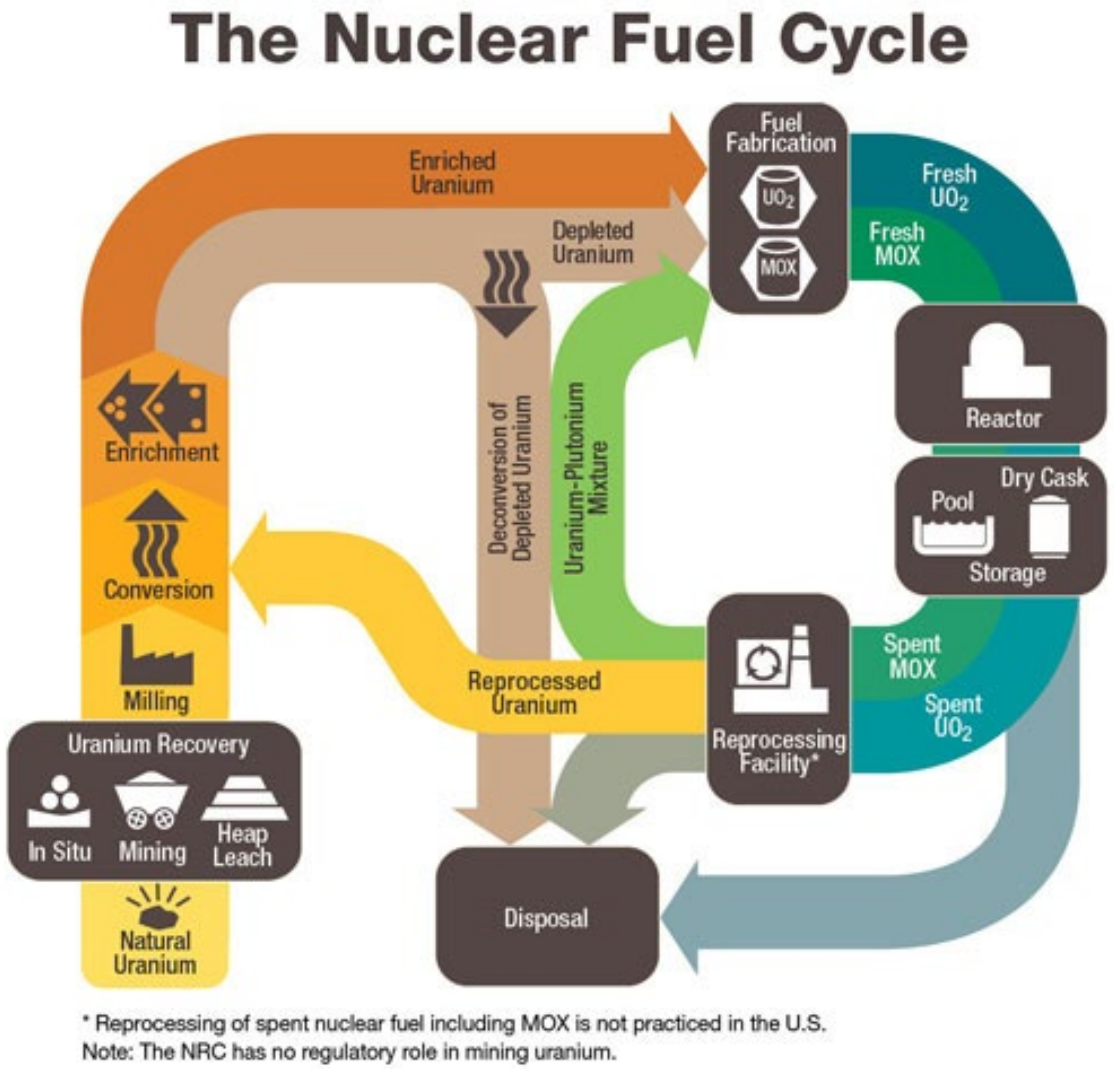
July 7, 2020

National Nuclear Security Administration

International Safeguards

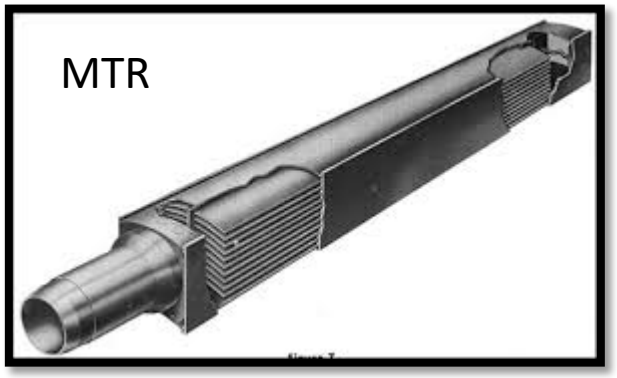
- The objective of safeguards is the timely detection of diversion of significant quantities of nuclear material from peaceful nuclear activities to the manufacture of nuclear weapons
- IAEA inspects nuclear facilities worldwide, monitors amounts of nuclear materials to ensure that it isn't going to illicit uses

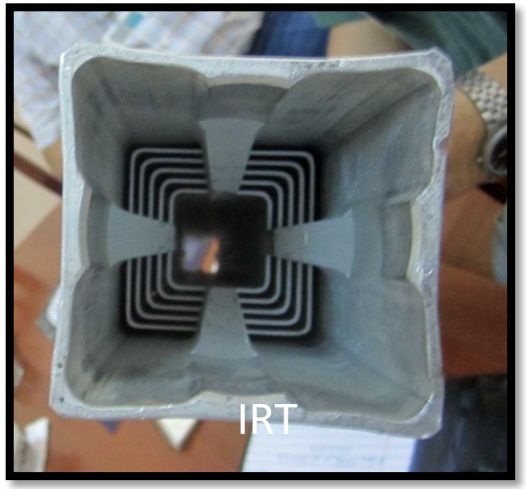


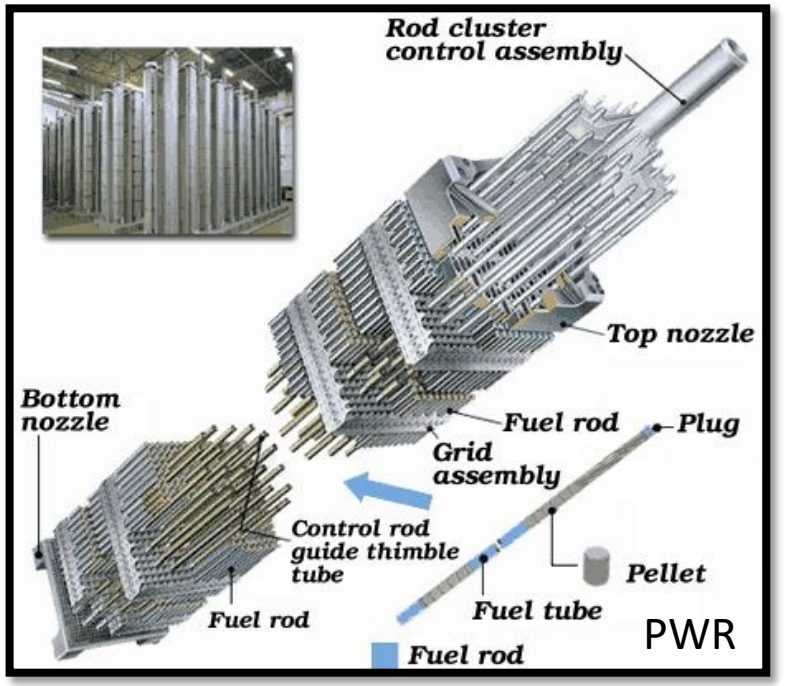

The Nuclear Fuel Cycle
Enriched Uranium
Depleted Uranium
Fuel Fabrication
UO2
MOX
Fresh UO2
Fresh MOX
Reactor
Dry Cask
Pool
Storage
Enrichment
Conversion
Milling
Deconversion of Depleted Uranium
Uranium-Plutonium Mixture
Reprocessed Uranium
Reprocessing Facility*
Spent MOX
Spent UO2
Uranium Recovery
In Situ
Mining
Heap Leach
Natural Uranium
Disposal
* Reprocessing of spent nuclear fuel including MOX is not practiced in the U.S.
Note: The NRC has no regulatory role in mining uranium.

Spent Fuel NDA: Objectives

- Verify operator declaration of residual uranium, and buildup of plutonium
  - Burnup
  - Initial enrichment
- Verify cooling time of assembly to assist with other parameters
- Verify completeness of assemblies







Spent Fuel NDA: Challenges

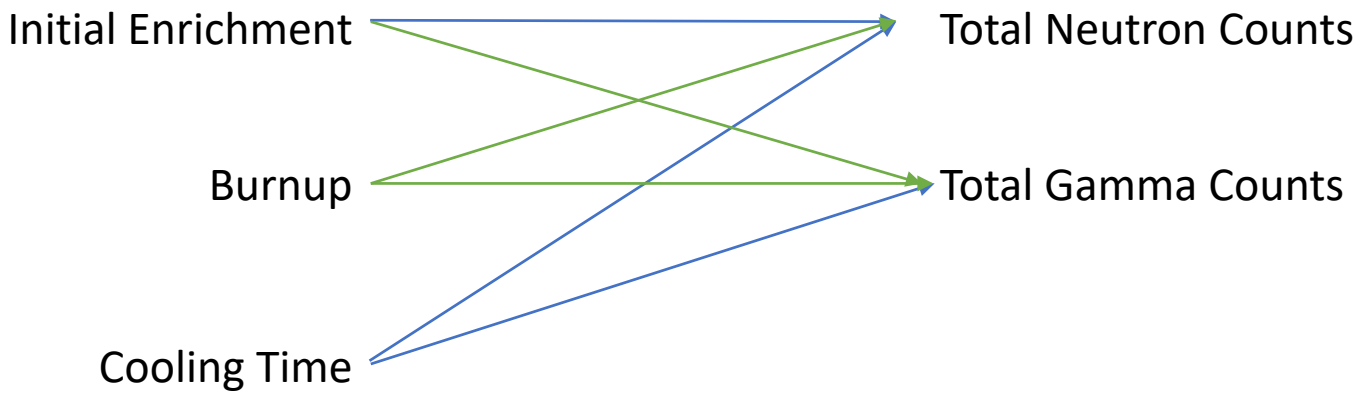
Interruptions to facility operations

Nuclear facilities have a standard way of operating and large disruptions (i.e. long measurements, drastic fuel movement) are not acceptable

Fuel inhomogeneity

Both axially and radially, neutron flux in the reactor affects burnup, resulting in inhomogeneous fuel assemblies

Competing parameters



Power Reactor vs. Research Reactor

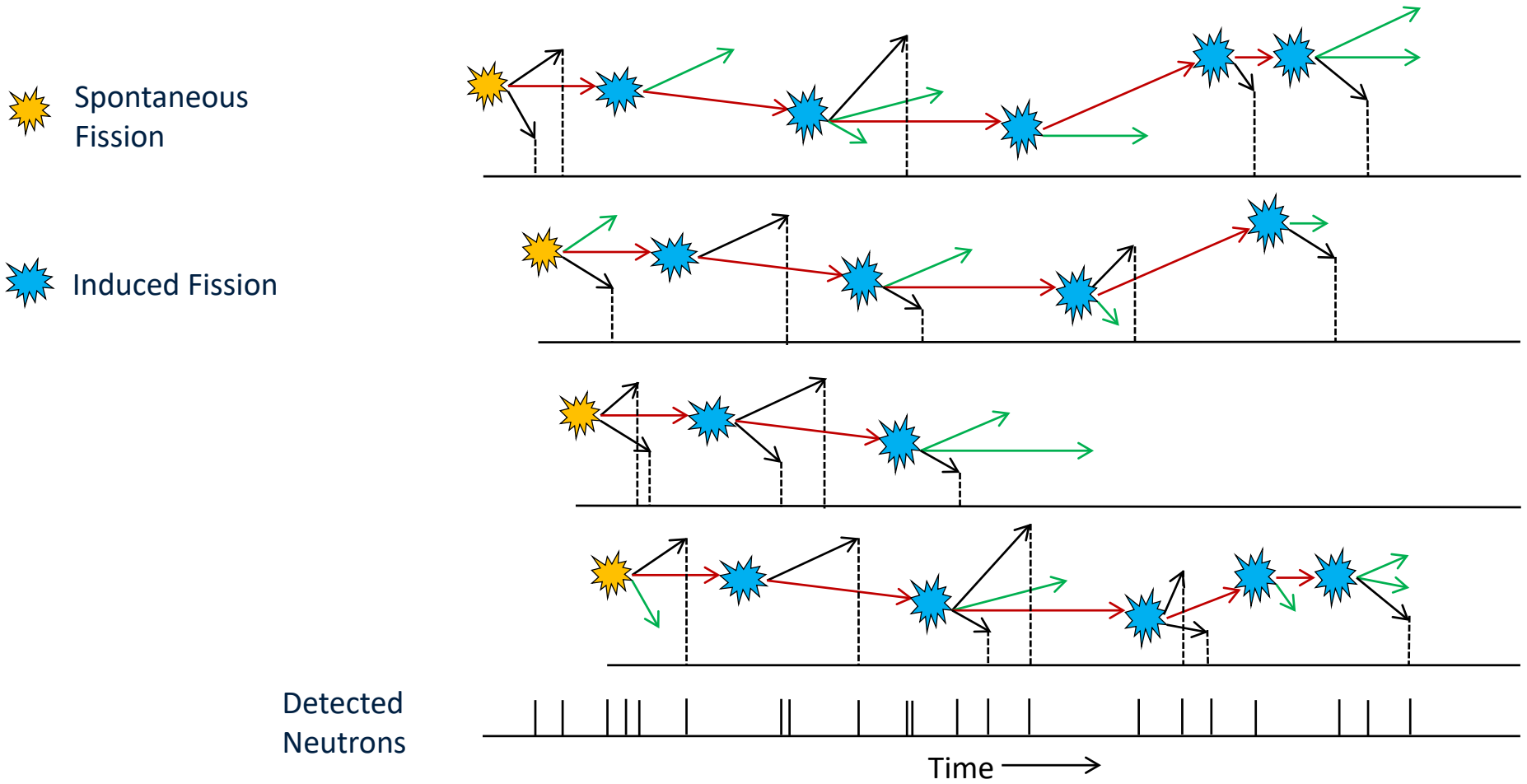
	Power	Research
Size	~4 m long, 20 cm across, 1000 lbs	~80 cm long, 8 cm across, 13 lbs
Neutrons	~1E8 1/s	~1E4 1/s
Neutron Emitters	^{242}Cm, ^{244}Cm, ^{240}Pu	^{240}Pu
Operating History	Predictable, $$$	Unpredictable, research
Easy Availability of Calibration Standards?	Nope!	Nope!

atrahan@lanl.gov

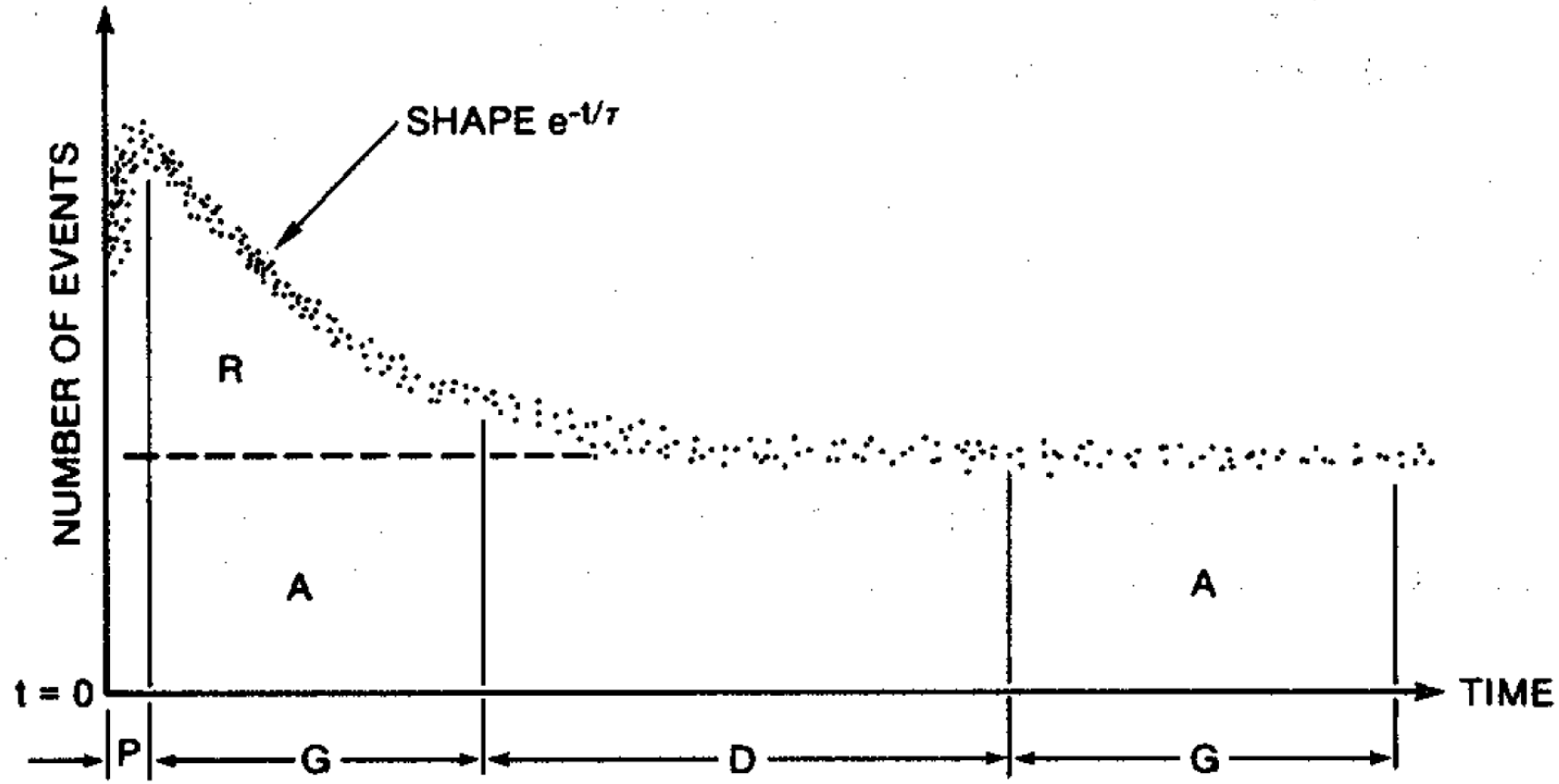
Advanced Experimental Fuel Counter

- Designed for research reactor fuel characterization
- System uses:
  - Active and passive neutron coincidence counting
  - An ion chamber for gross gamma-ray counting
- Measurement objective is to verify residual fissile mass (i.e., $^{235}U + ^{239}Pu$) using neutron coincidence counting
- Field trials have occurred as follows:
  - 2006 High Flux Australian Reactor (HIFAR), Australia,
  - 2011 Institute of Nuclear Physics (INP), Uzbekistan
  - 2014 Institute of Nuclear Physics (INP), Uzbekistan
  - 2018 Soreq Nuclear Research Center, IRR-1, Israel

Neutron Coincidence Counting

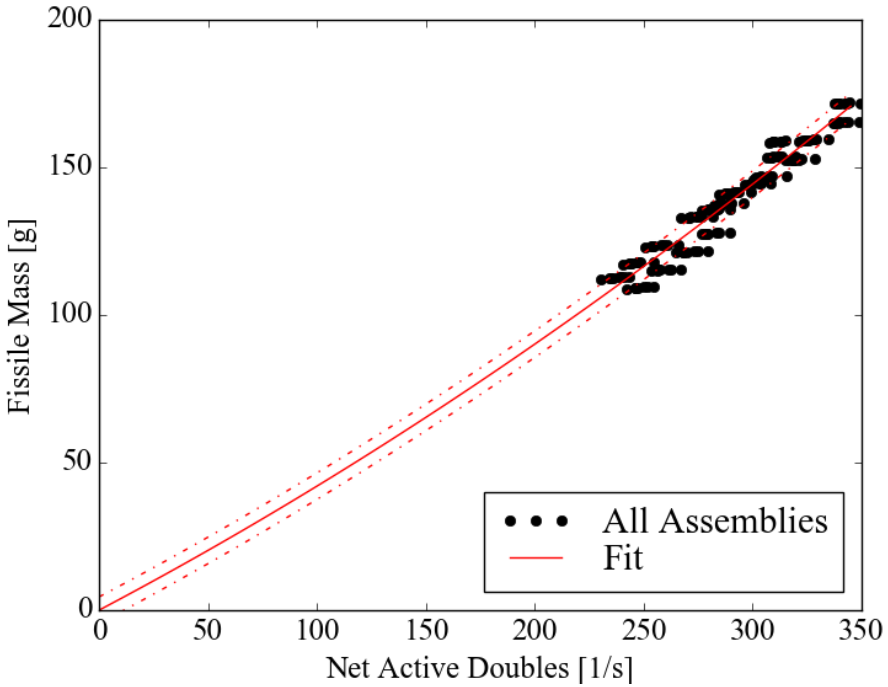


Rossi-Alpha Distribution



Advanced Experimental Fuel Counter

- Model – Predict – Measure – Compare
  - In other words, develop a simulated calibration curve
- Simulated hundreds of spent fuel assemblies representing a wide range of depletion, cooling time, and operating history parameters
- "Measure" the simulated assemblies in the top, middle, and bottom positions in the AEFC
- Create calibration curve of fissile mass vs. net active doubles rate



Acknowledgement

This work was funded in part by the Department of Energy's National Nuclear Security Administration, Office of Nonproliferation and Arms Control (NPAC), NA-24.