Plutonium-238 and the Radioisotope Power Systems Supply Chain

Office of Nuclear Energy

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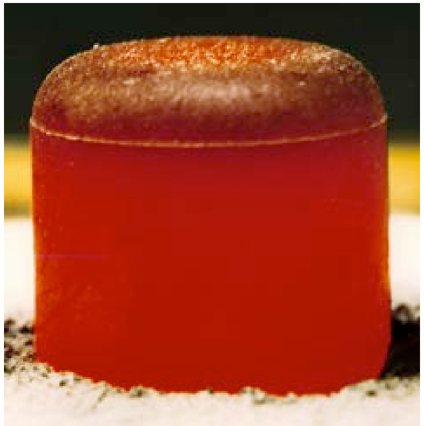
What are Radioisotope Power Systems?

- Enables and enhances missions by providing electrical power to explore remote and challenging environments where solar power is unavailable
  - Spacecraft operation
  - Instrumentation



- Converts heat from a radioisotope into electricity
  - Heat is the product of the natural isotope decay process

- Plutonium (Pu)-238 is the isotope of choice due to its long half-life and high-energy alpha particle

Pu-238 – where do we stand?

- Isotope allocation for civilian space applications is about 35 kg
  - Roughly half meets NASA specifications
- Based on the current allocation, DOE will deliver 128 fuel clads to fuel four Multi-Mission Radioisotope Thermoelectric Generators (MMRTG)
  - Sufficient to power the MARS 2020 Mission and three additional MMRTGs for a possible 2025 mission
- In Fall 2016, DOE completed the first production campaign, resulting in about 100g of plutonium oxide, utilizing refurbished capabilities at Oak Ridge National Laboratory funded by NASA
  - Second campaign planned for completion in Fall 2017

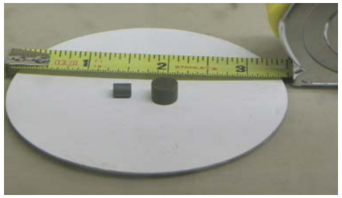
What have we learned so far?

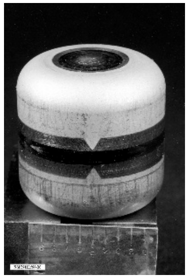
- No technical challenges to producing Pu-238, but opportunities exist to optimize irradiation activities by evaluating separation methods, target designs and reactor availability
- Producing isotopes is only the first step in the Radioisotope Power Systems (RPS) supply chain and equipment life-cycle investments are needed to improve reliability
- Approaching RPS delivery on a mission-driven cadence is not conducive to maintaining nuclear infrastructure due to start-up/shut-down costs and schedule impacts

What is DOE’s RPS Supply Chain?

Pu-238 Isotope Production
- Oak Ridge National Laboratory
- Idaho National Laboratory

Fuel Clad Manufacturing
- Oak Ridge National Laboratory
- Los Alamos National Laboratory





Fueling/Testing/Delivery
- Idaho National Laboratory

Launch Support
- Kennedy Space Center

Going Forward – what's next?

- Stronger integration between DOE and NASA to support mission requirements
  - October 2016 Memorandum of Understanding
- Identifying opportunities to reduce mission costs
  - Drive predictability and reliability into the RPS supply chain
  - Pursue innovative approaches to optimize RPS activities
- As a solution, DOE and NASA are moving to implement a constant-rate production strategy versus a mission-driven strategy for RPS activities

What is Constant Rate Production?

- Constant Rate Production will establish clear deliverables, as defined by annual average production rates for Pu-238 and fuel clads, across the DOE RPS supply chain
  - Transitioning Pu-238 isotope production from a project-based approach to a campaign model
  - Establishing annual production rates for fuel clad manufacturing to ensure an inventory is available and ready for NASA mission use
  - Accelerating research to optimize the supply chain
  - Improving integration of RPS activities across the DOE complex to inform future investment decisions

What are the benefits?

- Leverages DOE’s isotope campaign model with a proven track record to produce isotopes supporting multiple customers from the medical community to nuclear research, providing flexibility to adjust to NASA mission requirements
- Maintains an inventory of fuel clads to reduce the time to provide fueled systems for NASA missions while providing a more predictable operational pace that level-loads resources
- Results in immediate flexibility within available funding to address innovative ideas to improve the supply chain
  - New irradiation target designs
  - Equipment investments for fuel clad manufacturing
  - Utilization studies for the Advanced Test Reactor
  - Evaluation of new technology

What are the near-term goals?

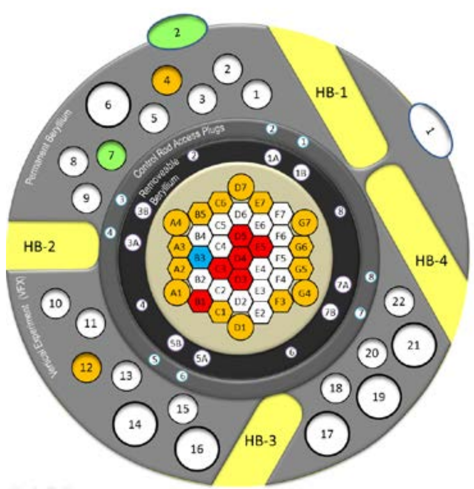
- **By fiscal year 2017**
  - Transition to constant rate production strategy and align resources
  - Initiate 2nd phase of new pure Neptunium Oxide target research
  - Complete 2nd Pu-238 production campaign
- **By fiscal year 2018**
  - Implement integrated maintenance and modernization strategy
- **By fiscal year 2019**
  - Establish 400 g/y plutonium oxide average production rate (1 reactor)
  - Complete evaluation and selection of final target design (2 reactors)
- **By fiscal year 2020**
  - Establish 10-15 fuel clads/y average production rate
  - Modify graphite impacts shell storage and monitoring

Critical to this transition to maintain commitments for Mars 2020 and a notional mission in the 2025 timeframe

End State Vision - Isotope Production

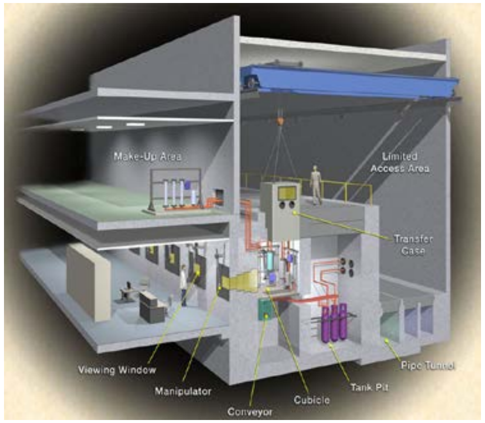
- By fiscal year 2021, add additional irradiation capability at the Advanced Test Reactor (ATR) for redundancy
- By fiscal year 2025, maintain average production rate of 1.5 kg/y with the ability to surge to 2.5-3.0 kg/y

High Flux Isotope Reactor (HFIR)

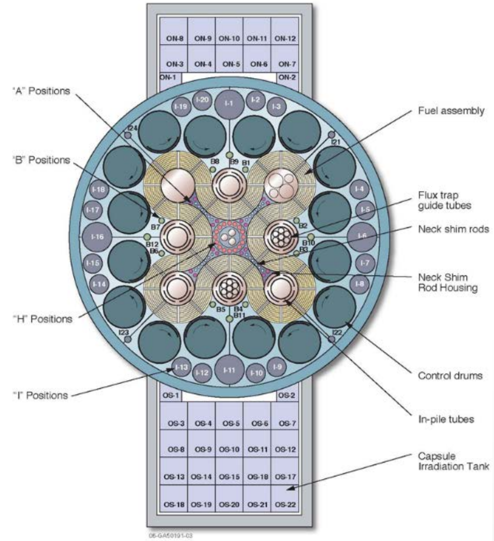


Reflector positions can be used to irradiate NpO_2 in the HFIR

ORNL Processing Capability



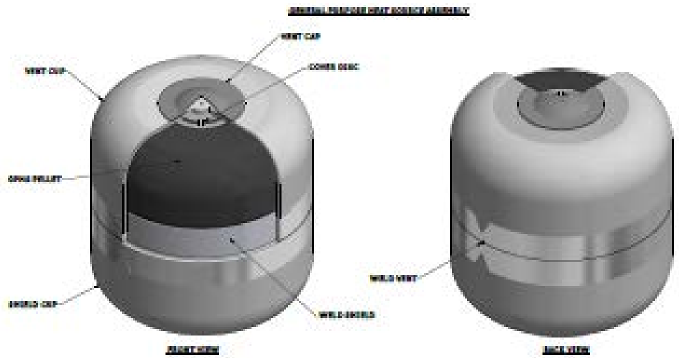
Advanced Test Reactor (ATR)



Reflector positions and flux traps can be used to irradiate NpO_2 at ATR

End State Vision – Fuel Clad Manufacturing

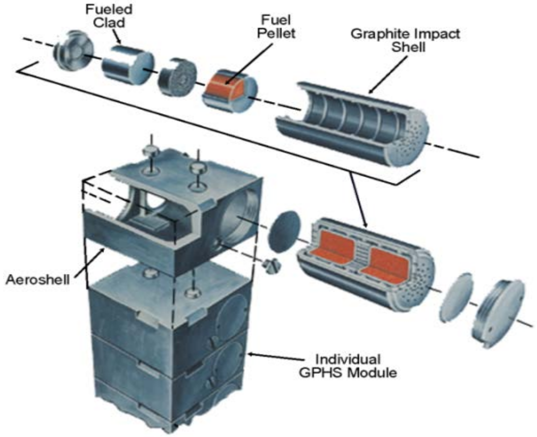
- By fiscal year 2021, constant-rate of fuel clads produced annually at Los Alamos and shipped to Idaho
- By fiscal year 2025, completed modernization campaign at Los Alamos to improve reliability of critical infrastructure and enhance worker safety

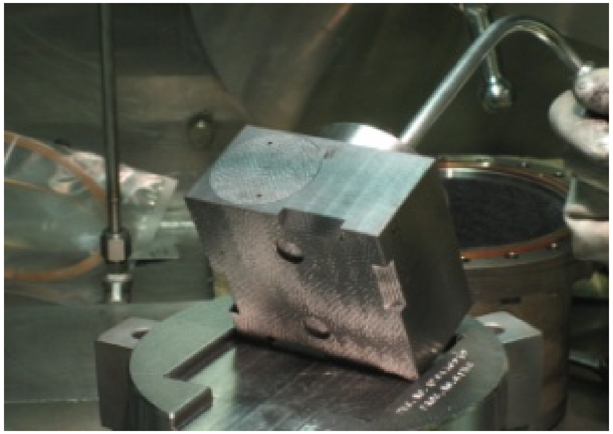


Aqueous Line

End State Vision – Fueling/Testing/Delivery

- By fiscal year 2021, modify storage at INL to reduce risk and add scheduling flexibility for fueling RPS
- By fiscal year 2025, implement process to match fuel for NASA missions based on heat output, providing more flexibility to make adjustments





General Purpose Heat Source Module

In Summary, DOE is….

- Implementing constant rate production
  - Actively aligning work and resources to meet goals
  - First campaign successfully produced new Pu-238, the first time since the 1980's Pu-238 has been produced domestically
  - Goals are to improve predictability, reliability, and flexibility for NASA mission customers
- Identifying activities to address risks
  - Completing key infrastructure investments to improve reliability
  - Accelerating new target design to inform future investments
- Pursuing opportunities for early success
  - Piloting efforts to introduce new Pu-238 into the Mars 2020 blend plan to continue RPS supply chain optimization

Questions?