Isotope Program
U.S. Department of Energy

Briefing to the Nuclear and Radiation Studies Board on the U.S. Department of Energy Isotope Program

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U.S. Department of Energy

Outline:

- Introduction to the DOE Isotope Program
- Capabilities & Impact on the Dynamic Isotope Landscape
- New Investments, Products, and Workforce Development
- High-Priority Medically Relevant α-emitters

U.S. DEPARTMENT OF ENERGY

The Faces of DOE IP

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Stable Isotopes

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Isotope Program Initiatives

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Isotope Reactor Facilities

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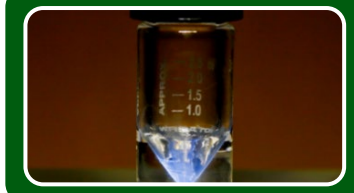
Technical Advisor

Mission

DOE Isotope Program Mission



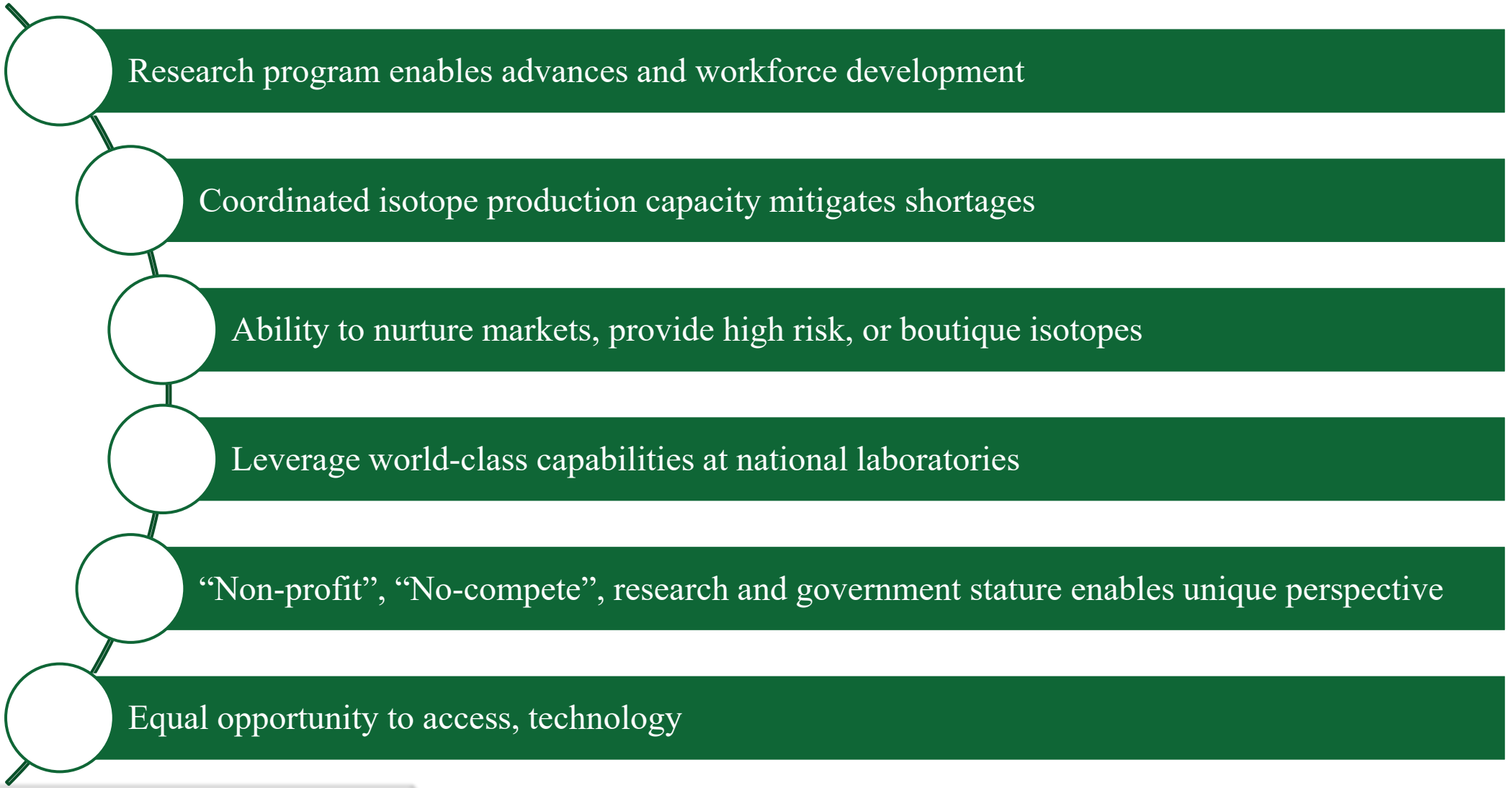
Produce and/or distribute radioactive and stable isotopes that are in short supply; includes by-products, surplus materials and related isotope services

Maintain the infrastructure required to produce and supply priority isotope products and related service

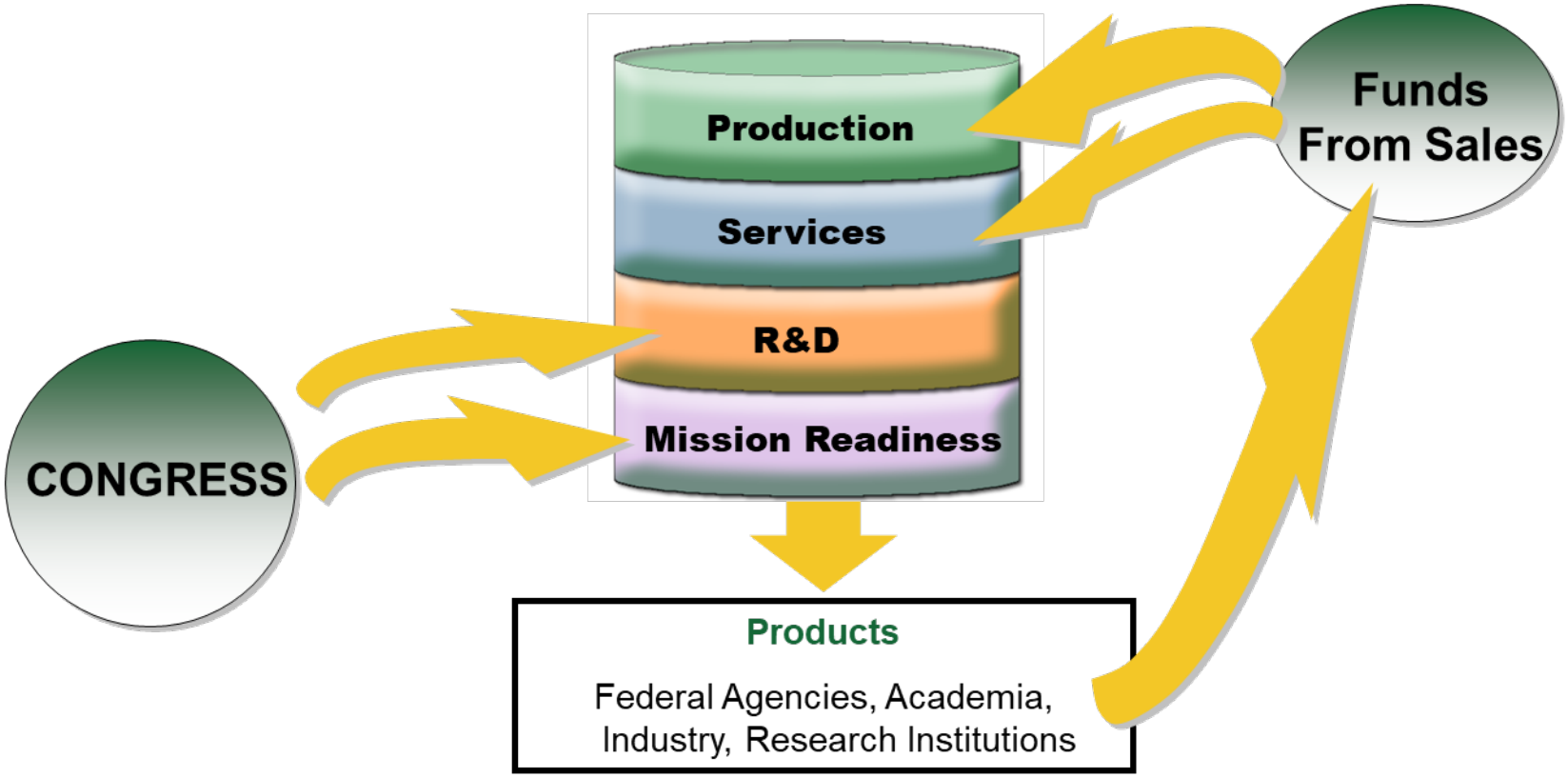
Conduct R&D on new and improved isotope production and processing techniques which can make available priority isotopes for research and application. Develop workforce.

Ensure robust domestic supply chains. Reduce U.S. dependency on foreign supply to ensure National Preparedness.

Government Role



Resources



FY 2023 Enacted Budget = $109.4 M

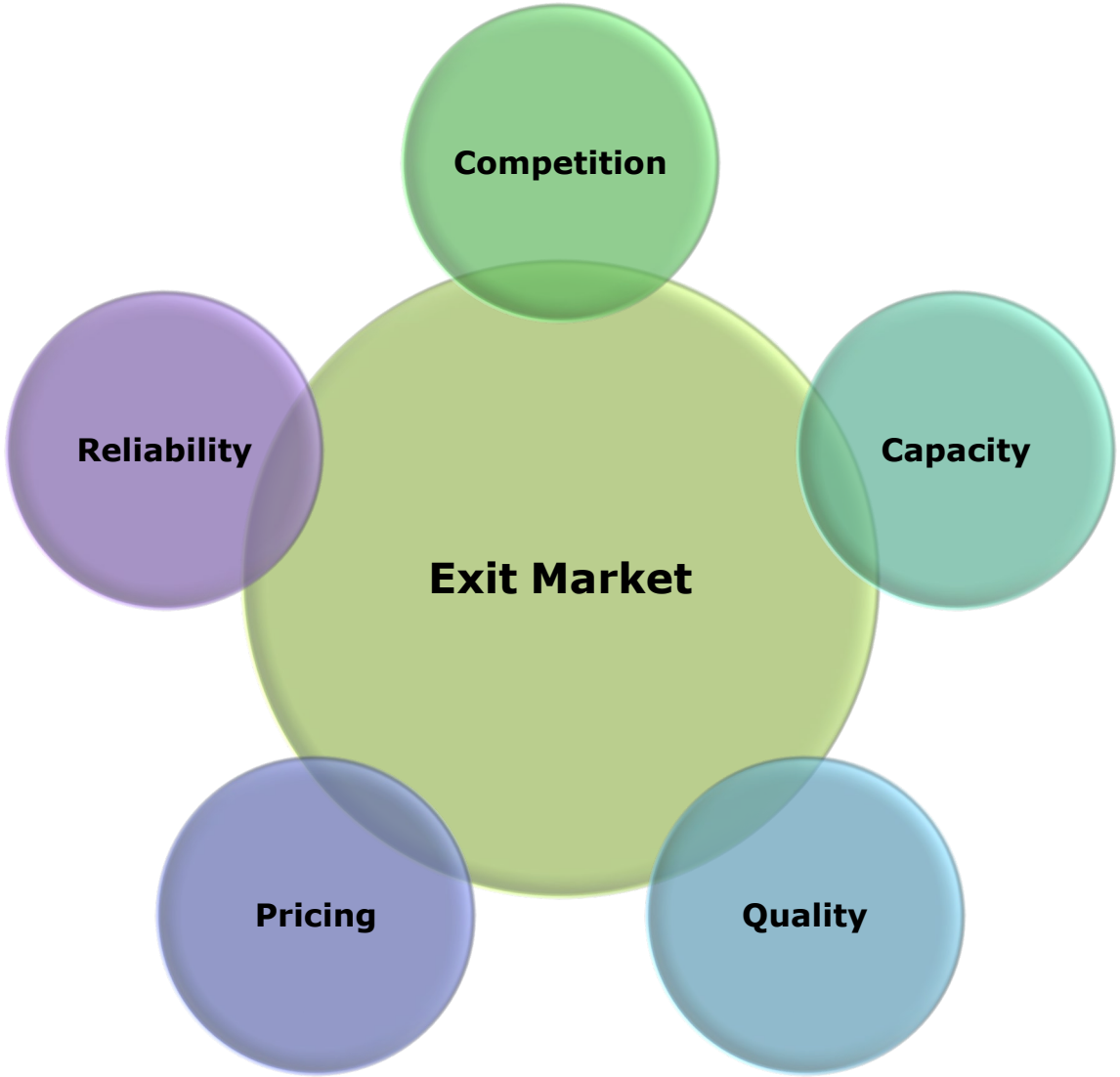
Deciding What to Produce?

Commercialization

The DOE IP does not compete with domestic private industry.

Policies and Procedures for Transfer of Commercial Radioisotope Production and Distribution to Private Industry ("Policy Notice"), 30 Fed. Reg. 3247 (March 9, 1965)

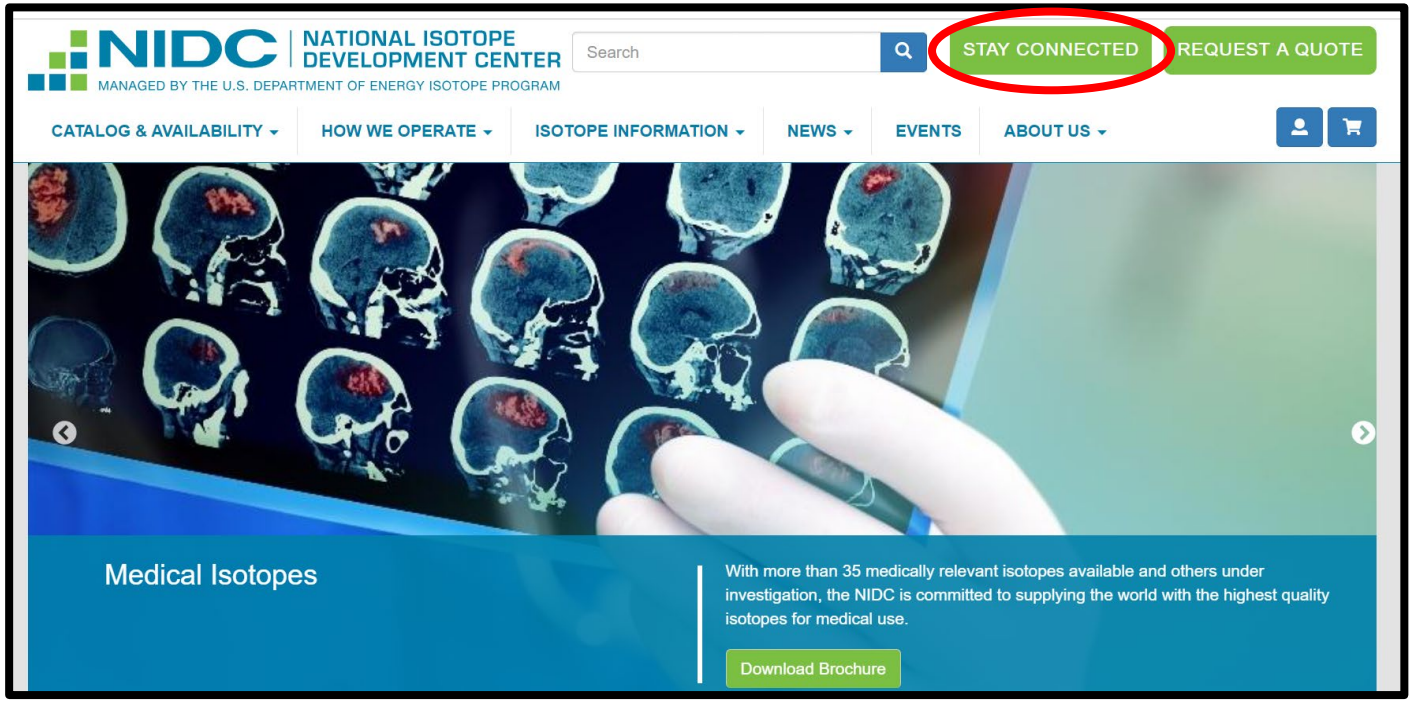
DOE IP can remain in backup capacity



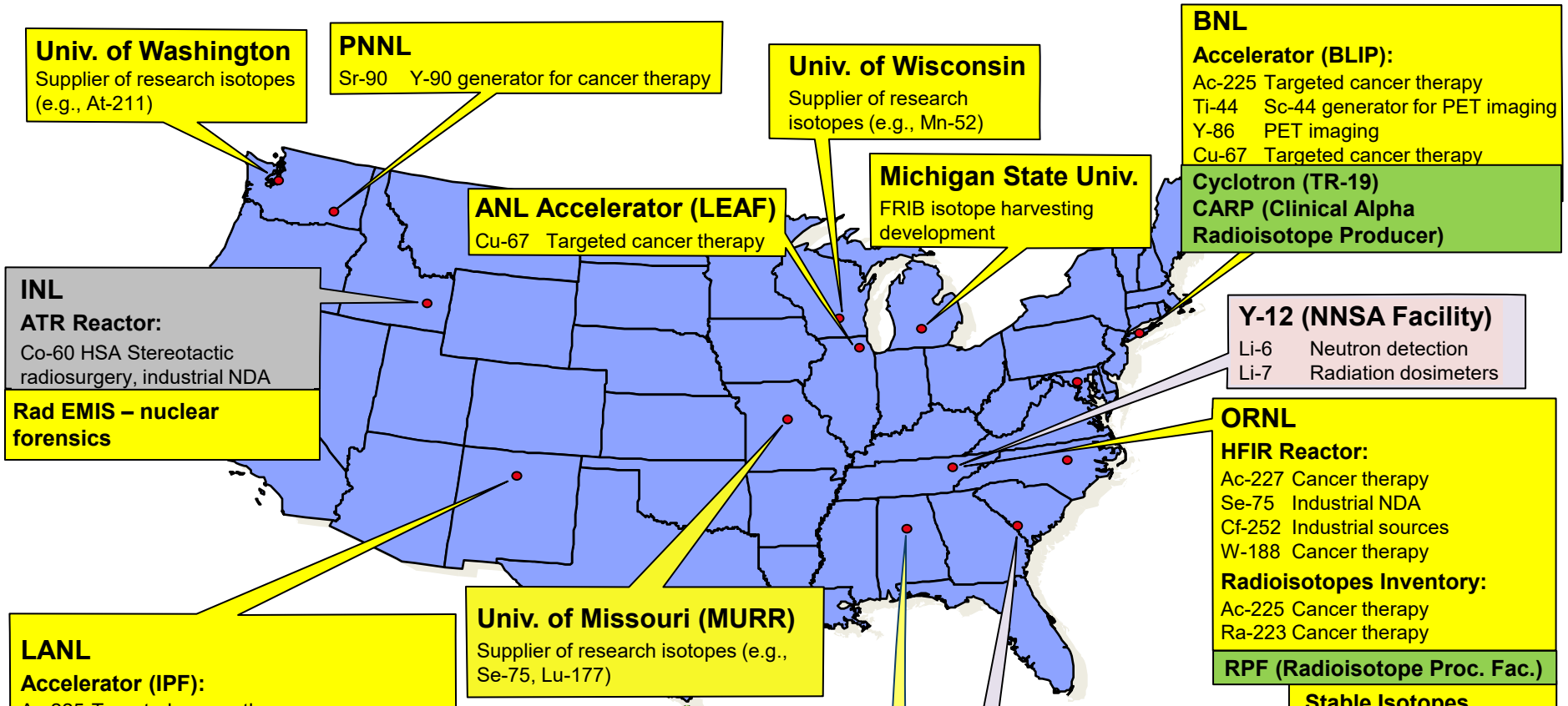
National Isotope Development Center

- The NIDC (located at Oak Ridge National Laboratory) is the business arm of DOE IP: coordinates sale and distribution of DOE isotope products and services available from DOE and UIN partner facilities.
- Contractual discussions with customers.
- Transportation, Q&A, public relations, cross-cutting technical topics, marketing strategy and assessments.
- www.isotopes.gov

Sign up here for DOE IP newsletter



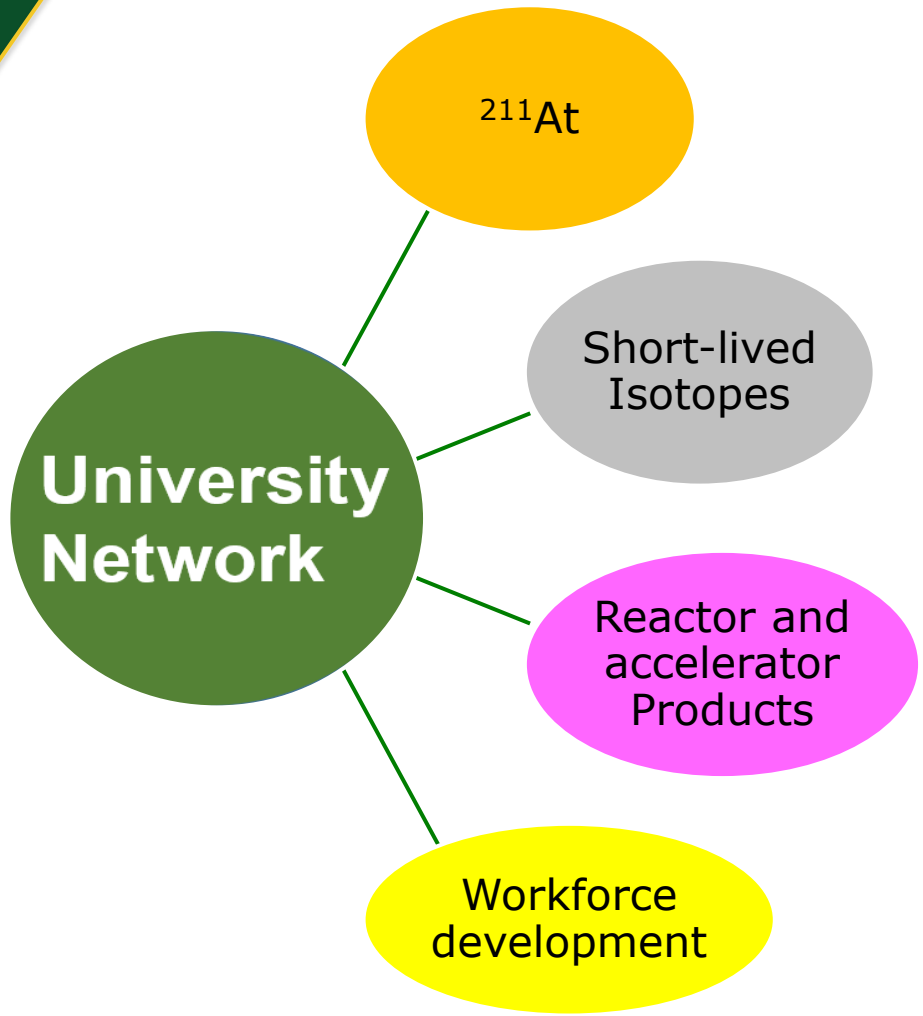
DOE IP Production Sites- 2023
Unique collection of accelerators, reactors, other capabilities



Green boxes under development

13/19 facilities added while under SC management

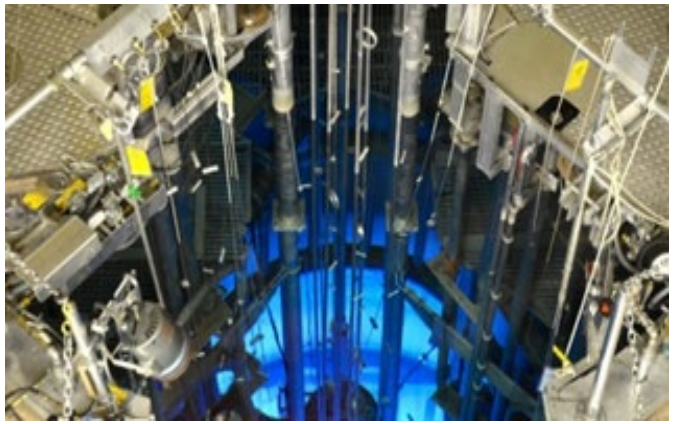
University Isotope Network

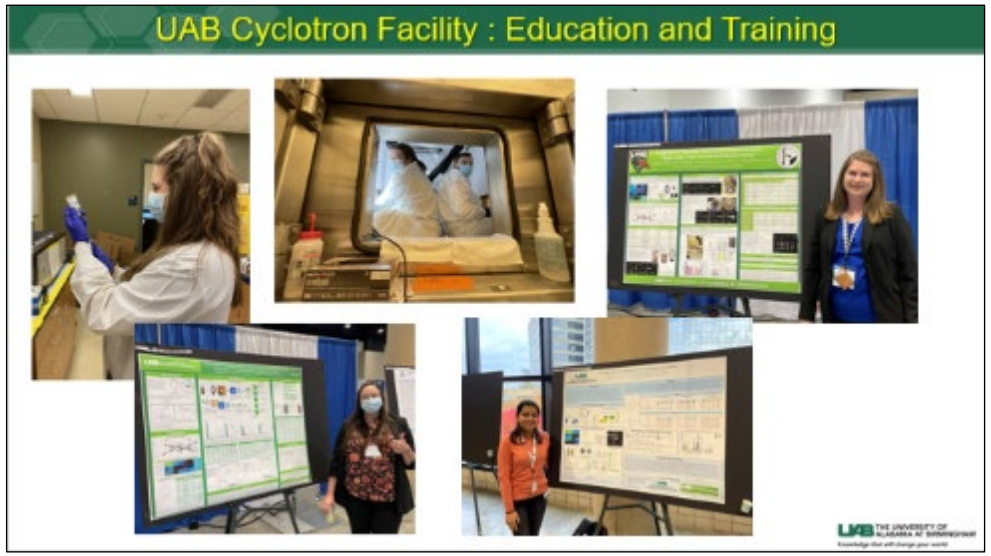


University Network continues to grow

- UW, UMO/MURR, MSU, **UAB, UWM**
- Next: TAMU

- Cost-effective
- R&D on isotope production
- Boutique isotope production
- Workforce development





Isotope Landscape

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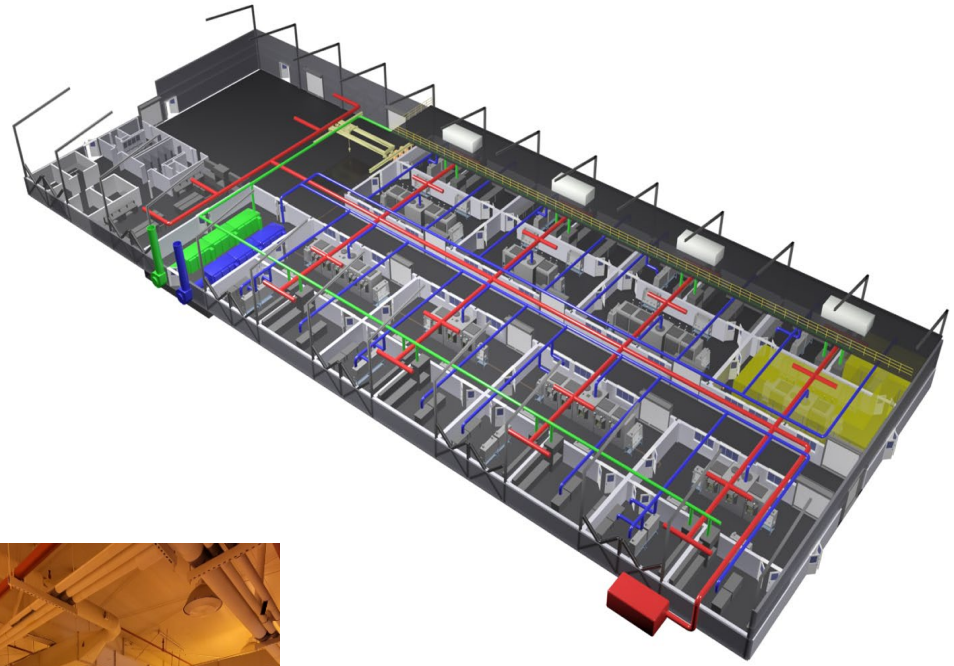
Steeply escalating demand in both radio and stable isotopes. U.S. cannot meet demand.

Independence requires additional radiochemical processing

RPF



CARP

LANL

- **Radioisotope Processing Facility (RPF)** at ORNL for reactor target processing.
  - HAZCAT 2 nuclear facility with modular hot cells, cGMP cleanroom
  - Estimated TPC ~ $310-615M
  - CD-0 April 2021
- **Clinical Alpha Radionuclide Producer (CARP) Facility** for accelerator processing at BNL
  - Haz Cat 3 facility in repurposed building. Estimated TPC ~ $60-80M
  - CD-0 December 2022
- Radiochemical Processing Enhancements at LANL: Add glove boxes and hot cells to new facility being constructed by NNSA/LANL

Stable Isotopes

Stable Isotopes are found naturally and do not decay.

Enriched stable isotopes are used in a variety of direct applications as well as to produce radioisotopes.

Samples enriched with a particular stable isotope are most desirable for applications. Enrichment technology emerged from the war-time era to enrich Uranium-235 and can be classified due to dual use technology.

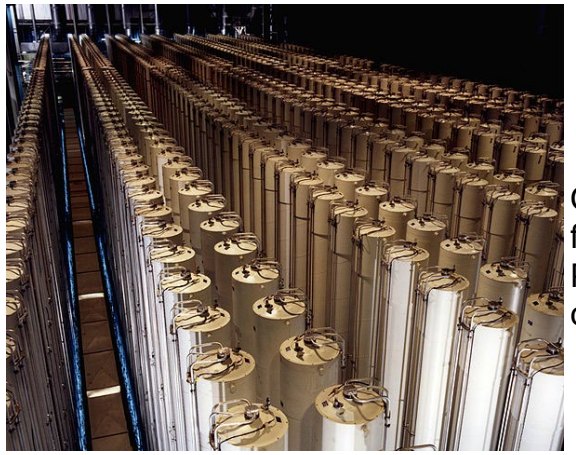
Three common methods to enrich isotopes:

Distillation: Effective if large mass difference between isotopes – often used to separate light elements.

Gas Centrifuge: Gas rotated in cylinder at high speed to separate different masses by centrifugal force. Requires a gaseous form of element or compound. Best for higher throughput, lower enrichment.

Electromagnetic Separation: Isotopes are separated by a strong magnetic field. Best for higher enrichment, lower throughput.

Manhattan project Calutrons that enriched uranium via electromagnetic separation – no longer operating



Gas centrifuges from Piketon Plant- no longer operating

Stable Isotope Production and Research Center
Strong U.S. Enrichment Capability

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Stable Isotope Production and Research Center (SIPRC)

- **Expand our nation's ability to perform multiple isotope production campaigns at large scale production; mitigate foreign dependence; promote economic resilience.**
- DOE IP vision is to nurture core competencies in a broad suite of enrichment technologies

Groundbreaking Ceremony 10/22

Variety of R&D

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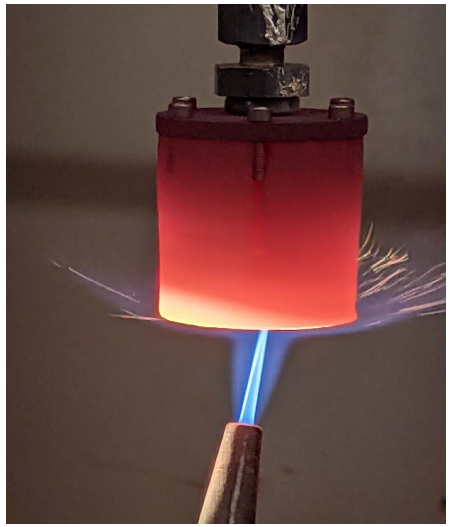
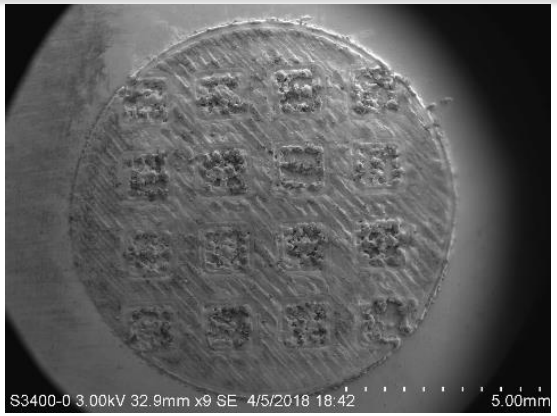
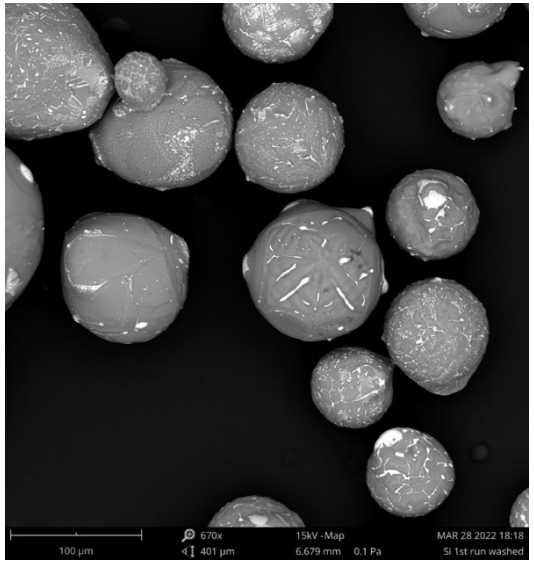
Precision dispensing: 19 Tungsten powder particles totaling 21µg

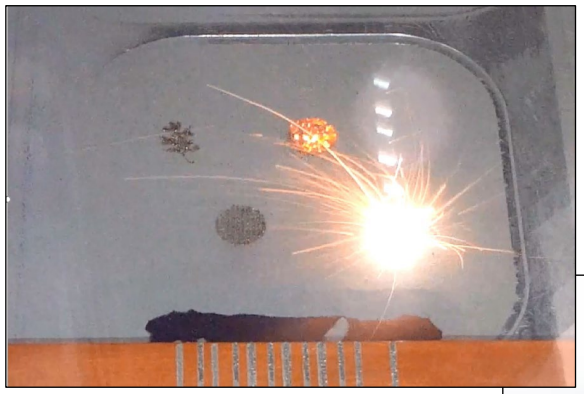


Precision feedstock for additive manufacturing of functional materials – spheroidal powders with controllable properties. Aerosol jetting is one technique developed.

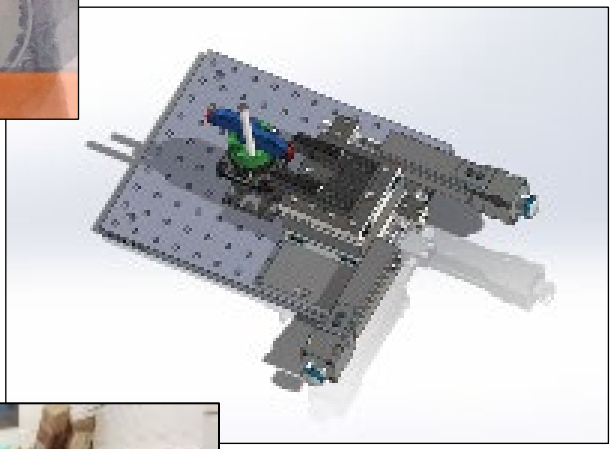




Si-28 as a spheroidal powder



Additive manufacturing of complex targets



Custom Designed and Fabricated Biofluidix Inkjet Printer for targets

Robot for extraction of irradiated targets

New Isotopes Introduced Over the Past Two-Years

Available Medical Isotopes - isotopes in red made available within the past two years				
Ac-225/Bi-213	**Br-77**	**Mn-52g**	Se-72	W-188/Re-188
Ac-227	Cd-109	**Mn-54****	Se-75	**Y-86**
Al-26	**Ce-134**	Na-22	Sn-117m (HSA)	Y-88
As-73	**Ce-139**	**Pb-203**	**Sr-85**	**Yb-176**
At-211	**Co-55**	Pm-147	Sr-89	Zn-65
Au-199	Co-60 (HSA)	Ra-223	Sr-90/Y-90	
Ba-133	Fe-52	Ra-224/Pb-212	Th-227	
Be-7	Fe-55	**Ra-226**	Th-228	
Bi-207	He-3	Rb-83	**Ti-44**	
Br-76**	Lu-177 c.a.	Rh-103m	**V-48**	

Medical Isotopes Under Development			
As-72 /Se-72	Fe-59	Pt-191,193m, & 195m	Te-119m/Sb-119
C-14	Gd-153	Re-186 & 189 (HSA)	Ti-44/Sc-44
Co-57	Ir-192	Ru-106	Xe-129
Cs-131	Mo-98 &100	Sb-119	U-230/Th226
Cs-137	Nb-90	Sc-43, 44, & 47	
Cu-67	Pd-103	Tb-155 & 161	

For the past ten years, alpha emitters have been among the highest priorities for the DOE Isotope Program.

Workforce Development

- Research, RENEW, FAIR, HIPPO
- Annual SC Early Career Research Program FOA
- Annual SC EPSCOR Program FOA
- SC Graduate Student Research (SCGSR) and SC Summer Undergraduate Laboratory Internship (SULI)
- Minority Educational Institution Student Partnership Program (MEISPP) Internships
- Support student and postdoctoral travel bursaries for conference attendance
- DOE IP co-funds the annual Nuclear and Radiochemistry Summer School with BES & NP
- Organized student seminar series during COVID to promote networking

Alpha Emitters: A High Priority

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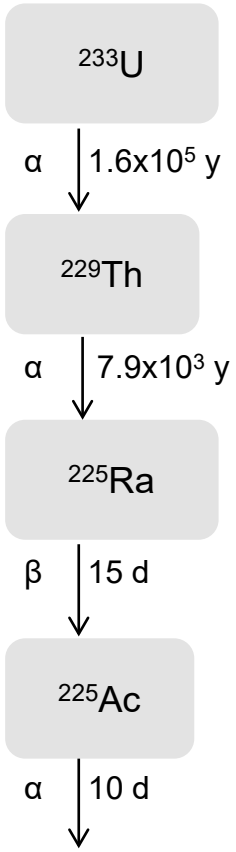
U.S. Department of Energy

Radionuclide	Half-life
^{225}Ac	10 d
^{211}At	7.2 h
^{212}Bi	60 m
^{213}Bi	46 m
^{212}Pb	10.6 h
^{223}Ra	11.43 d
^{226}Th	31 m
^{227}Th	18.7 d
^{228}Th	1.9 y

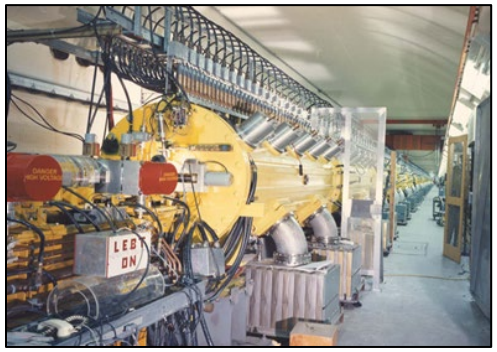
- For the past ten years, alpha emitters have been the highest priority for the DOE Isotope Program.
- The DOE Isotope Program is producing or developing production of all these isotopes.

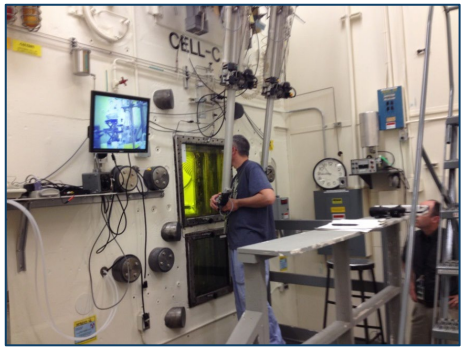
Ac-225 Cow Derived



- ORNL has been the main supplier of Ac-225 (via decay of existing Th-229 stock) since 1997
- >10 Ci (370 GBq) of ^{225}Ac shipped in >2000 packages since 1997
- Have submitted DMF and implementing cGMP
- Twelve 4-week milking campaigns are performed annually, with weekly customer shipments
- The present supply is fully subscribed and insufficient to meet the growing research and medical applications demands for Ac-225
- **Maintain standby list for small quantity/one-off requests**
- **Cancellations reallocated to others with priority given to existing domestic cow customers**

Ac-225 Accelerator Produced





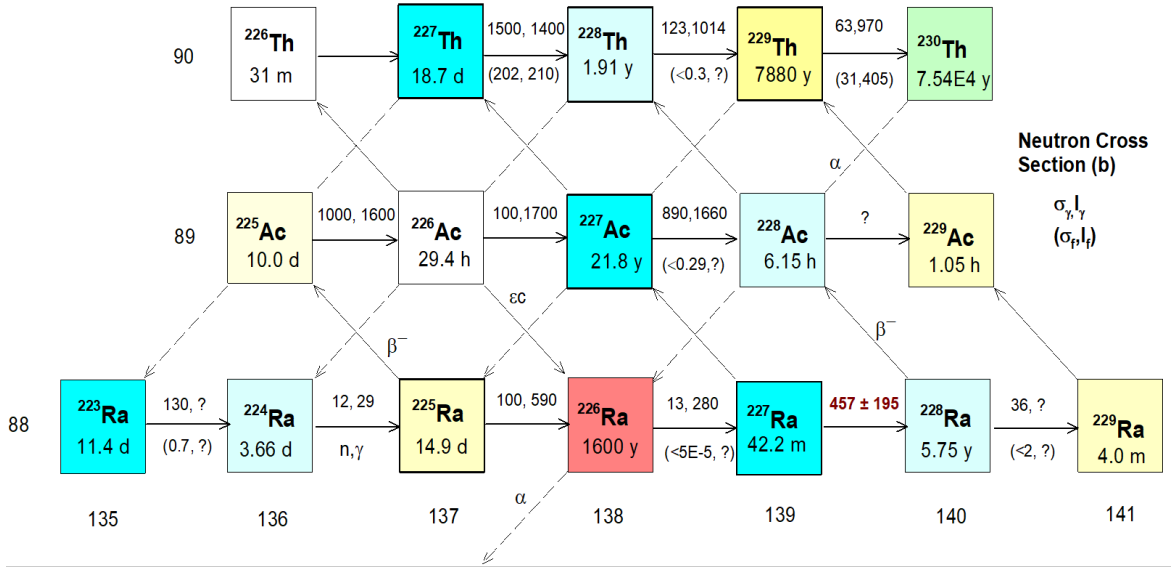
New world production record in September 2023!

Status and Update

- Effort initiated 2014
- First “batches” processed in 2018
- Consistently producing 50 mCi/batch after processing
- Up to 600 mCi present in current target design at EOB
- Amount of Ac-225 available is currently limited by:
  - Processing capabilities
  - Transit time between irradiation and processing sites
- Process is scalable by increasing target size and/or frequency of irradiations

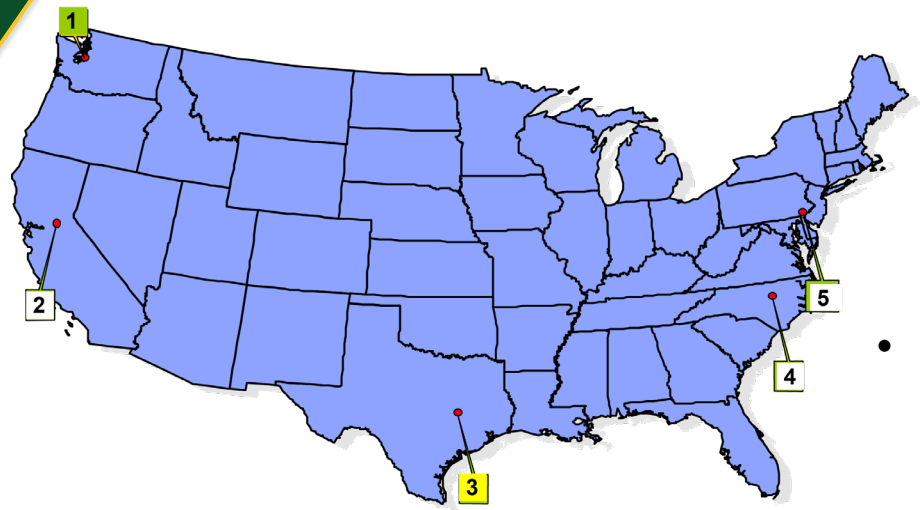
Ac-225 Alternative Production Routes

- ANL electron linac production route
  - $^{226}Ra(\gamma,n)^{225}Ra \rightarrow ^{225}Ac$
- BNL low energy cyclotron route
  - $^{226}Ra(p,2n)^{225}Ac$
- ORNL neutron production route
  - $^{226}Ra(3n,\gamma)^{229}Ra \rightarrow ^{229}Ac \rightarrow ^{229}Th$



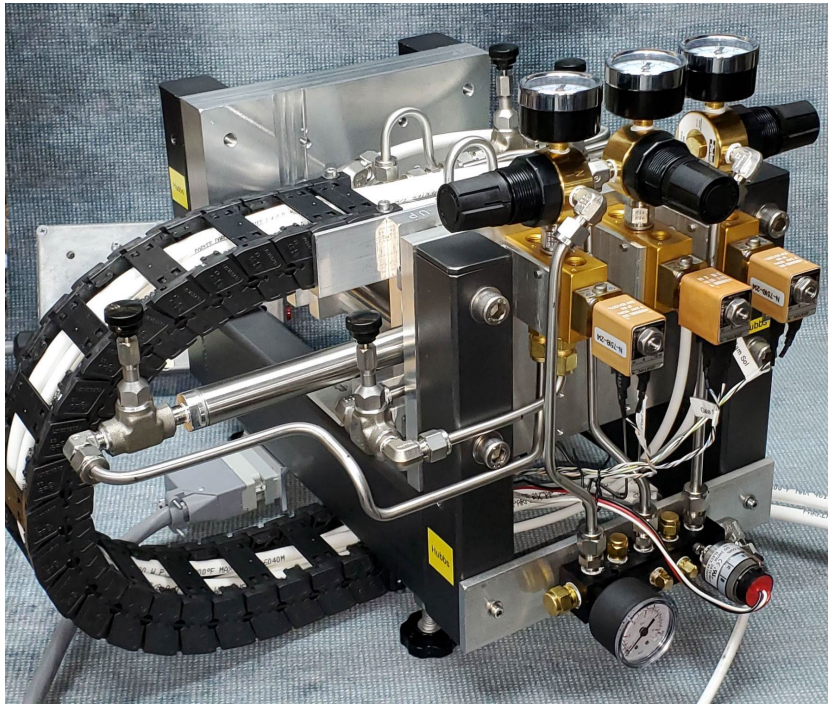
S. Hogle et al., Reactor Production of Thorium-229, Appl. Radiat. Isot. 114, 19 (2016)

At-211 Production Capabilities in the U.S.



1. University of Washington
2. University of California - Davis
3. Texas A&M University
4. Duke University
5. University of Pennsylvania

- **Limited production capabilities for At-211**
  - **None of the DOE/NNSA National Laboratories used by DOE IP are suited to produce At-211.**
- **~250 university, hospital and research facility cyclotrons in the U.S. are capable of isotope production**
  - **Only 5 with potential to produce At-211**
- **Geographic distribution constraints driven by production batch yields and short physical half-life (7.2 h)**



World Astatine Community (WAC)

The WAC aims to facilitate communication, transfer of technology and collaborative research between the regional production networks, which each country or union has established. This allows for partnering to enable a global increase in astatine-211 production capacity; and motivation of the clinical interest of astatine-211 through increased availability.

....OPEN TO ANY NEW PARTNERS

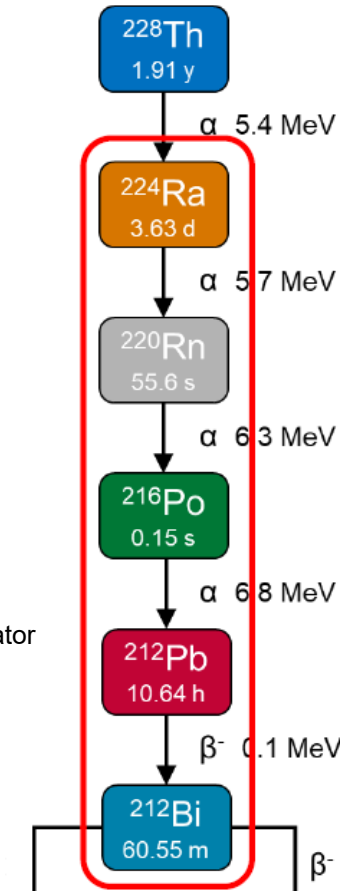
Pb-212 (Ra-224/Pb-212 Generator)

- Demand for Th-228 parent material and Ra/Pb generators is significantly increasing
- DOE IP is expanding both Th-228 and Ra/Pb generator availability in the U.S. to meet demand
- Optimizing current Th-228 and Ra/Pb generator supply from ORNL
  - Th-228
    - Dispensed ~690 mCi Th-228 in FY23
    - Plan to more than double the amount dispensed in FY24 with monthly dispensings
  - Ra/Pb Generators (up to 16 mCi generators)
    - Dispensed 10 generators in FY23
    - Monthly dispensing planned in FY24
- Added Ra/Pb generator production capabilities at PNNL
  - Monthly dispensing capabilities for up to 16 mCi generators commenced in FY24
- Work is underway at both sites to increase the generators to ~30 mCi each as an option

Th-228 cow is milked for Ra-224 at ORNL

Loading resin contacted with Ra-224 to fabricate a generator

PNNL generators in final packing step



Conclusions

- DOE IP is a small Federal Program which makes a very large impact.
- DOE IP develops and maintains world-leading radio- and enriched stable isotope production and processing capabilities.
- DOE IP is making substantial investments in workforce development.
- In response to increasing market demand DOE IP is increasing the processing capability of several DOE IP sites.
- Multiple new products have been added to the product catalog in the past 2-years.
- Alternative production approaches are being explored for alpha-emitters and other isotopes where applicable.


Thank You!