

**Workshop on Federal Isotope Supply and Demand
November 15, 2018**

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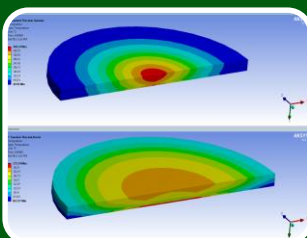
Office of Nuclear Physics, Office of Science, U.S. Department of Energy



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.

***Produce isotopes that are in short supply only – we do not compete with industry
DOE IP produces isotopes for markets not yet economically viable***



- Isotope Program in DOE has sole authority to produce isotopes for sale and distribution – labs may not embark on isotope production on their own.
- Program costs are financed by two resources: **appropriation and revenue.**
 - Appropriation supports mission readiness and R&D program
 - Revenue supports production and distribution of isotope
 - Flexibility in setting price – full cost recovery or market price; we subsidize isotopes for research
- We try to understand and anticipate isotope demand for federal missions, research and U.S. industry
 - **Increase availability of isotopes in short supply**
 - **Mitigate potential shortages**
 - **Develop new production and processing techniques of isotopes currently unavailable**
 - **Reduce U.S. dependencies on foreign supply**
- **We are prepared to make investments on your behalf – your input is important.**



Workshop is geared to federal isotope users.

- Report on IP actions to collected input from last year's federal survey.
- Report on IP progress in bringing online new isotope production capabilities that are available to federal complex.
- Report on IP progress in R&D of isotope production and processing capabilities.
- Report back to federal agencies on increased availability of isotopes of interest.
- Solicit federal input into isotope priorities for production campaigns.
- Promote cooperation and exchange of information on developing technologies and capabilities of mutual interest.
- Report back to federal agencies on progress towards mitigating U.S. dependence on foreign sources of isotopes.
- Report back to federal agencies about isotopes of concern and potential constrained supplies.
- Provide a forum for exchange of information on changing federal policies and regulations regarding isotopes.
- Collection and provision of He-4 data to BLM.

Valuable for isotope demand forecasting – 100’s of isotopes identified
 ~ 30 different agencies represented

Feedback to agencies/offices on availability

- Commercially-available isotopes – let DOE IP know if there is a problem obtaining
- Isotopes available by DOE IP – submit purchase requests
- Isotopes that could be provided by DOE IP – submit new product request
- Production not feasible – is that what they really want?
- Production may be feasible – we’ll investigate
- **Due January 14, 2019**

Federal Agency and Organization:				POC (name, phone #, email address):					Date:	
Isotope	Research or Applied	User (Agency, Nat. Lab., Univ., or others)	Intended Use	Purity and/or specifications	Physical Form	Quantity FY 2019	Quantity FY 2020	Quantity FY 2021	Quantity FY 2022	Quantity FY 2023

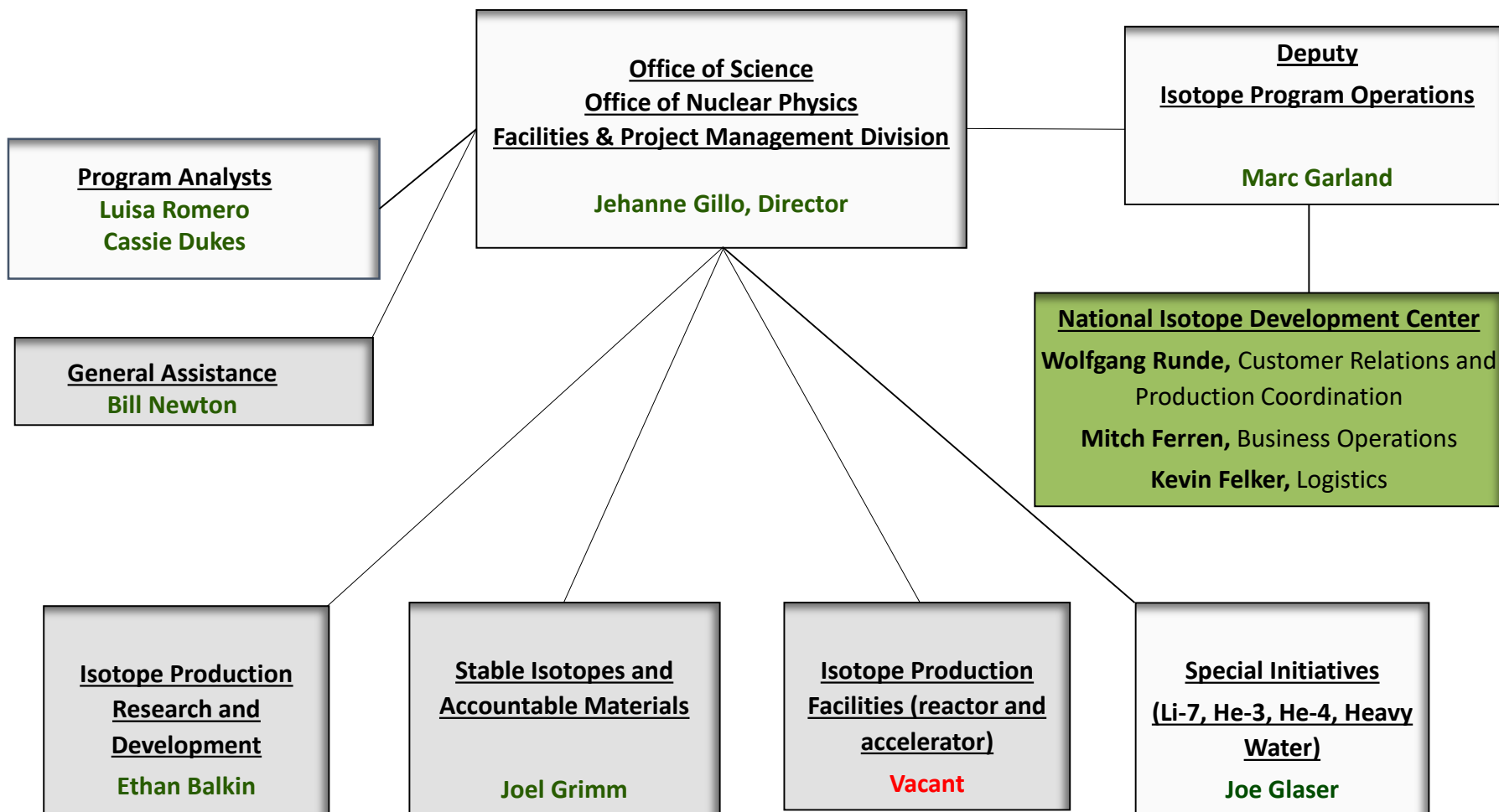
Also requests He-4 demand projections for BLM

- Inter Agency High Activity Sources Subcommittee (GARS)
- OSTP Subcommittee on Critical Materials
- Interagency He-3 Working Group – EOP National Security Staff
- DOE Iran Working Group
- DOE/NIH Working Group
- Mo-99 Stakeholders Working Group
- NRC Sealed Sources Working Group
- BLM He-4 Interagency Working Group
- Certified Reference Materials Working Group
- CRM Np-236 Sub working group
- New Brunswick Lab Interagency Working Group
- DOE Nuclear Materials Advisory Board
- Mark 18 Interagency Working Group
- IN Nuclear Materials Information Program
- Li-7 Intra-agency Working Group
- Pb-212 Users Working Group (medical)
- At-211 Users working Group (medical)
- Council on Radionuclides and Radiopharmaceuticals
- Society of New Medicine and Molecular Imaging
- Commercial stakeholder meetings twice a year
- Annual industrial survey
- Federal Workshops and survey
- Sponsorship of workshops, symposium at conferences





DOE Isotope Program Organization



Guided by recent NSAC Report released July 20, 2015

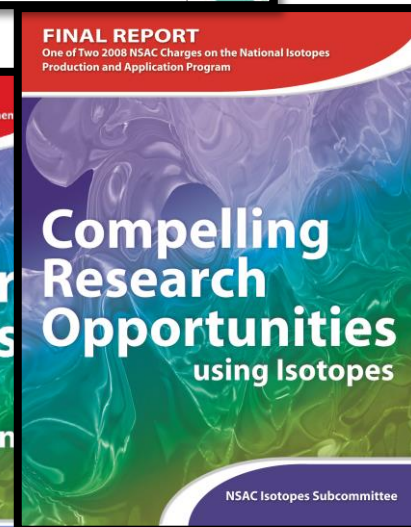
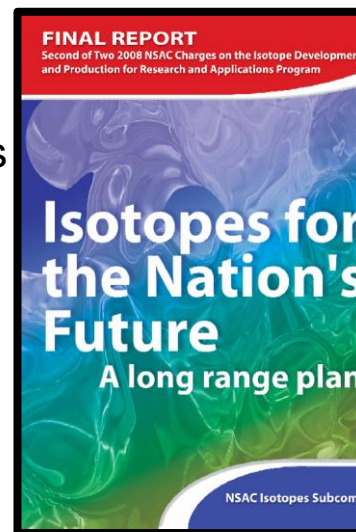
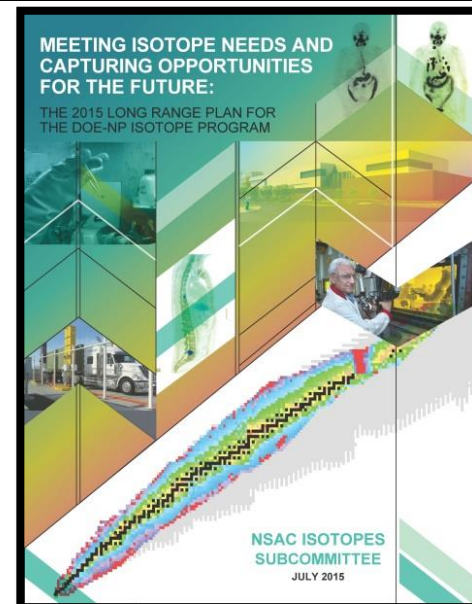
Recommendations:

- Significant increase in R&D funding
 - Continue R&D on alpha-emitters (Ac-225, At-211)
 - High specific activity theranostic isotopes
 - Electron accelerators for isotope production
 - Irradiation materials for targets

- Complete domestic stable isotope capability

- Increase in infrastructure investments and operating base
 - Isotope harvesting at FRIB
 - Separator for radioactive isotopes
 - Several programs looking at actinide EMIS
 - Potential needs for medical and research isotopes
 - BLIP intensity upgrade and second target station
 - IPF intensity, stability and energy upgrades

- Continue integration of university facilities



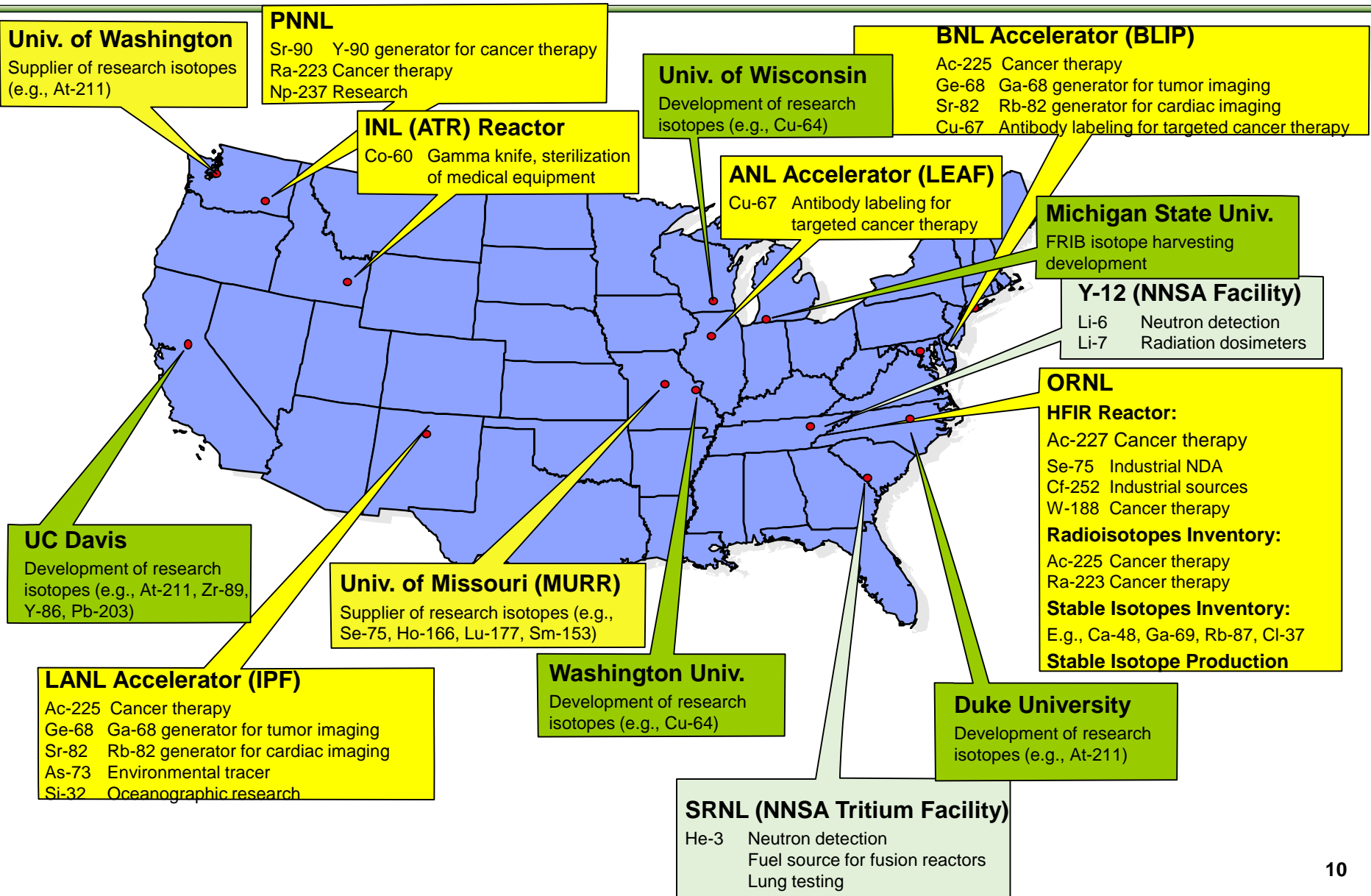


- The Department of Energy NIDC (includes the Isotope Business Office located at Oak Ridge National Laboratory) coordinates the distribution of all DOE isotope products and services available from DOE facilities.
- All contractual discussions with customers.
- Responsibilities in transportation, Q&A, public relations (website, newsletter, booth), cross-cutting technical topics, marketing strategy and assessments.
- Customers maintain technical discussions with sites.
- www.isotopes.gov

The screenshot shows the NIDC website homepage. At the top, the NIDC logo is displayed in large blue letters, followed by the text "NATIONAL ISOTOPE DEVELOPMENT CENTER". To the right of the logo is the tagline "the government source of isotopes for science, medicine, security, & applications" and the U.S. Department of Energy Office of Science logo. Below the header is a navigation bar with ten categories: Product Catalog, Quick Links, Breaking News, Business Office, About NIDC, Gatherings, Outreach Education, Production Sites, Production Research, and Contact Us. Each category has a corresponding image: a glowing tube, an atomic model, a heart with a ⁸²Sr isotope, a medical scan, a human spine, and a grid of blue spheres. Below the navigation bar is a "Welcome to the NIDC!" section. The text in this section states: "The National Isotope Development Center (NIDC) interfaces with the User Community and manages the coordination of isotope production across the facilities and business operations involved in the production, sale, and distribution of isotopes. A virtual center, the NIDC is funded by the Isotope Development and Production for Research and Applications (IDPRA) subprogram of the Office of Nuclear Physics in the U.S. Department of Energy Office of Science." Below this text are several links: "Join the NIDC Email List", "Access the Product Catalog", "Request a Quote", "Search for Products", and "Access Newsletters & Notices". At the bottom of the page, it says "You can contact the NIDC via email at isotopes@ornl.gov." and "Please read the Notice to Users of our site."

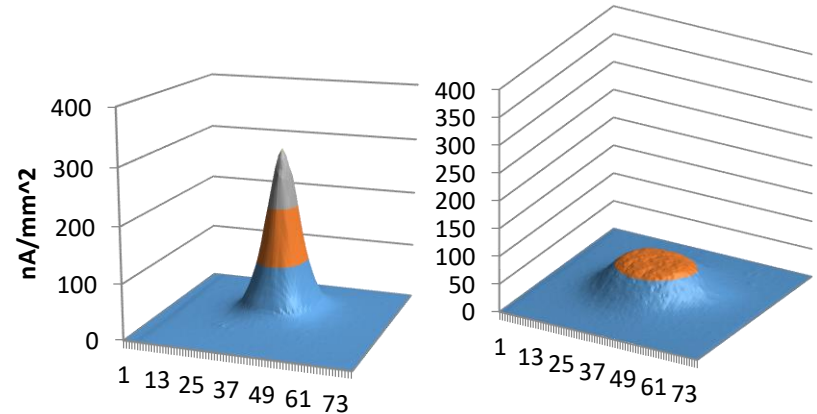


DOE Isotope Program Production and/or Development Sites -2018



Brookhaven National Laboratory Brookhaven Linac Isotope Producer (BLIP)

- The BLIP beam line directs protons up to 160 μA intensity to targets; parasitic operation with nuclear physics programs for more cost effective isotope production.
- Ac-225, Sr-82, Ge-68, Be-7, Cu-67, Y-86, Zn-65, Fe-52, Rb-83
- Currently upgrading processing infrastructure

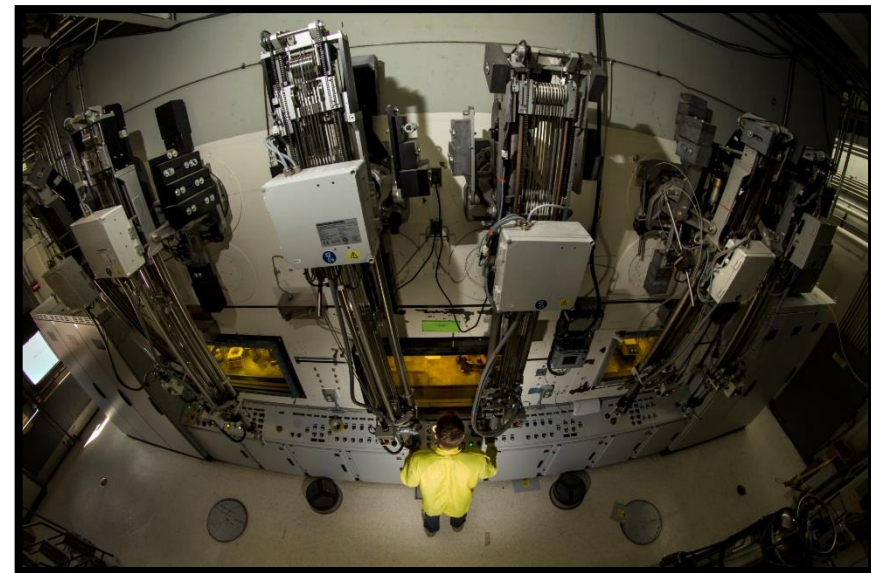


No beam raster

With beam raster

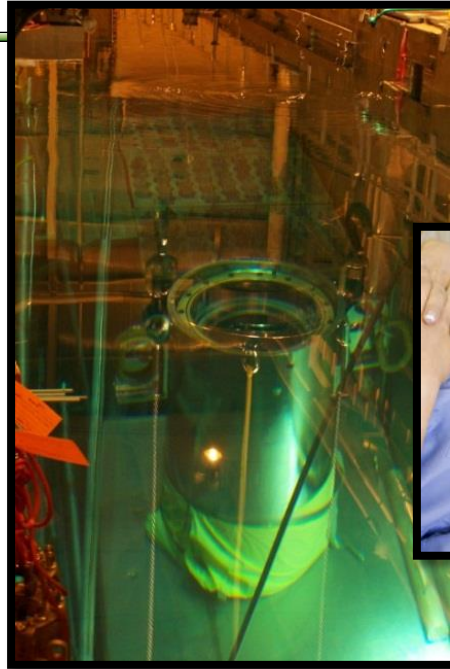
Los Alamos National Laboratory Isotope Production Facility (IPF)

- Diversion of 100 MeV proton beam to target station.
- Irradiates targets while LANSCE operates for NNSA.
- Ac-225, Sr-82, Ge-68, Na-22, As-73, Se-72, Y-88, Si-32, Cd-109
- Upgrade to IPF beam transport system upgrade completed this year to increase isotope yields and enhance R&D capabilities



Idaho National Laboratory Advanced Test Reactor (ATR)

- Office of Nuclear Energy is steward
- Co-60 target design in collaboration with ORNL
- High Specific Activity Co-60 for medical applications
- Developing Ir-192 for industrial radiography



Oak Ridge National Laboratory High Flux Isotope Reactor (HFIR)

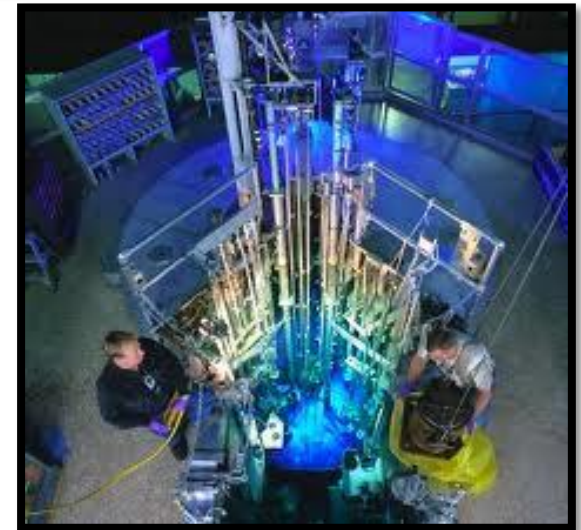
- Office of Basic Energy Science is steward
- Radiochemical Engineering Development Center (REDC)
- Ac-227, Cf-252, Se-75, Ni-63, W-188, Lu-177, Th-227, Ra-223, Pb-212/Bi-212, Th-229



- Unique capabilities and expertise
- Invest R&D and develop capabilities
- Workforce development
- Cost-effective
- Regional networks
- University of Washington; University of Missouri – MURR; University of Wisconsin; Duke University; Washington University; UC Davis; Texas A&M
- **In 2016, University of Washington became part of Isotope Program isotope production network: At-211**
- **In 2018, DOE started stewarding UW Isotope Capabilities**
- **In 2016, agreement finalized with MURR for production of Se-75 for scientific research**
 - Recently updated to include Lu-177 for research



*UW
cyclotron:
At-211*



*University of Missouri
Research Reactor*

Other Isotope Program Sites

Y-12

- Li-6
- Li-7
- Establishing emergency reserve of Li-7 for nuclear power industry



R&D for production of highly enriched Li-7 for molten salt reactors

Argonne National Laboratory

- **New for 2016**
- Low Energy Accelerator Facility (LEAF)
- Electron accelerator
- **Cu-67 production for cancer therapy**



Pacific Northwest National Laboratory

- Radiochemical Processing Laboratory
- Sr-90, Np-237, Pb-212/Bi-212, Th-227, Ra-223



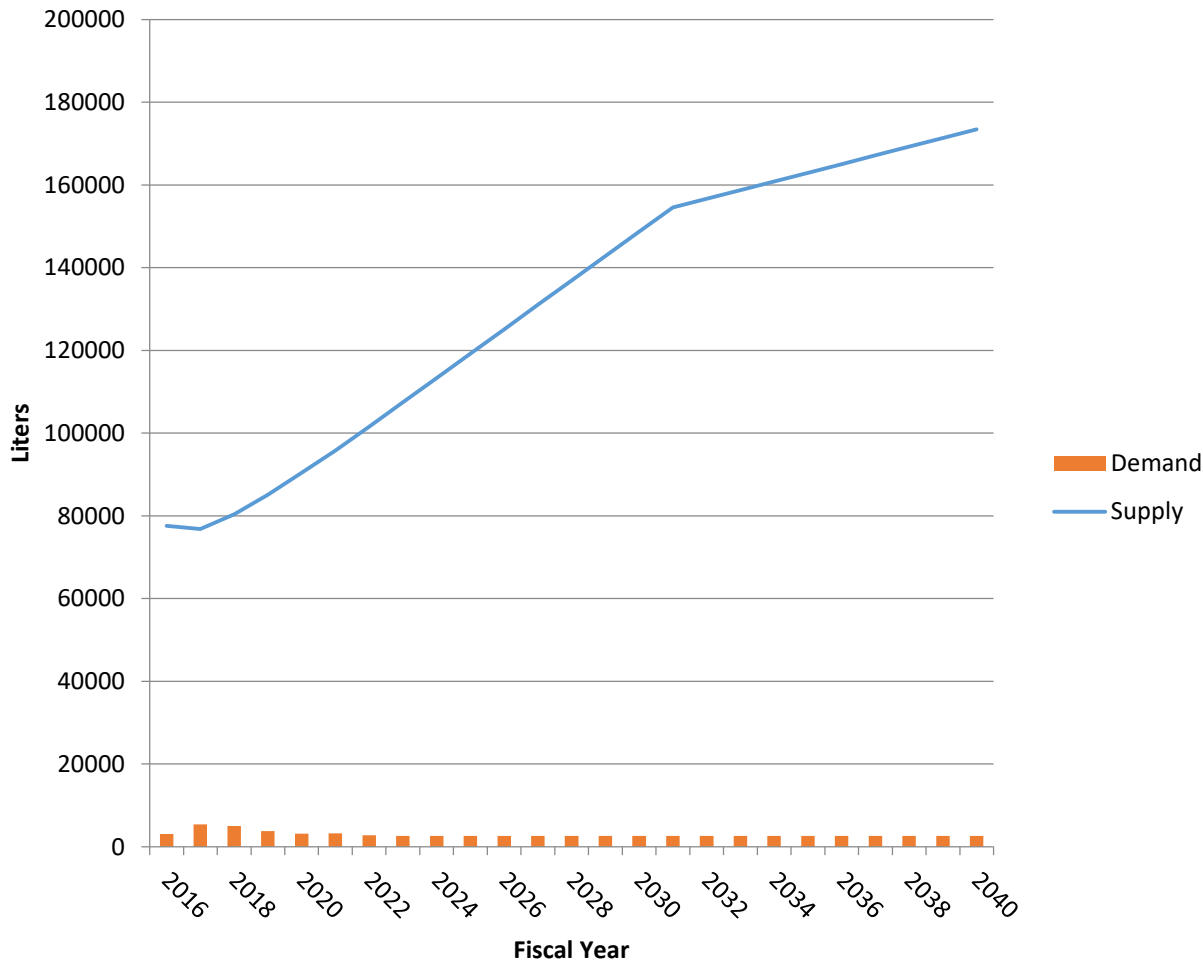
SRS

- He-3 extraction from NNSA tritium
- **Considering new sources He-3**





Federal He-3 Demand and Supply



- Current and near term demand for federal supply is positive
- We remain vigilant for possible new areas of need to ensure that balance is maintained
- We have observed increases in requests for He-3 for cryogenics for computing
- We are investigating new sources and more efficient extraction strategies to increase supply



Iranian Heavy Water

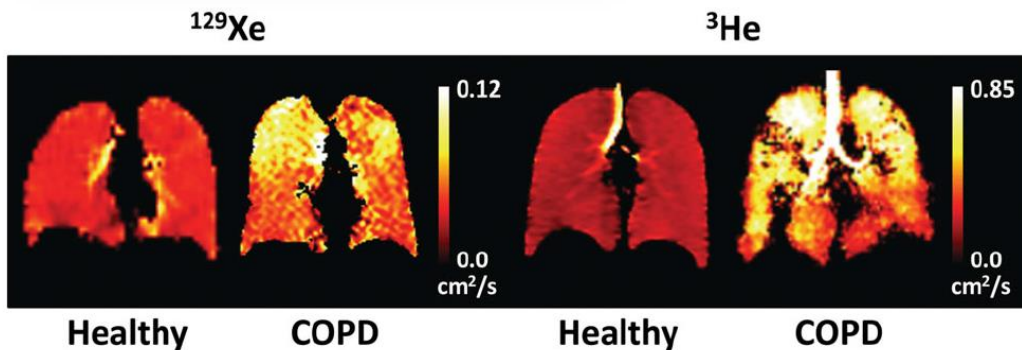
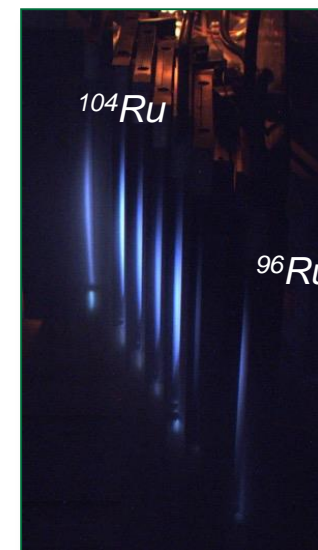
- IP negotiated with Iranian Delegation to purchase 32 Metric Tons as part of JCPOA
 - 26 MT sold to private industry and to Spallation Neutron Source in FY2017
 - MIT heavy water reactor FY2019 purchase of two MT
 - Industry sale of remainder (almost 4MT)
- IP will retain three drums (150 kg) for IAEA-related and research use
- **Supporting R&D into new production mechanism**





Re-established enriched stable isotope production in U.S. in 2017.

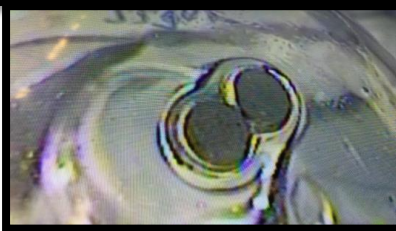
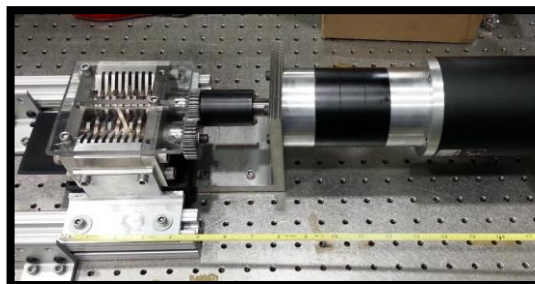
- Electromagnetic Isotope Separation (EMIS) machine and gas centrifuge technology.
- Semiconductor manufacturing, Quantum Computing, research, environmental tracers and forensics standards. Enriched targets for medical radioisotopes and medical imaging.





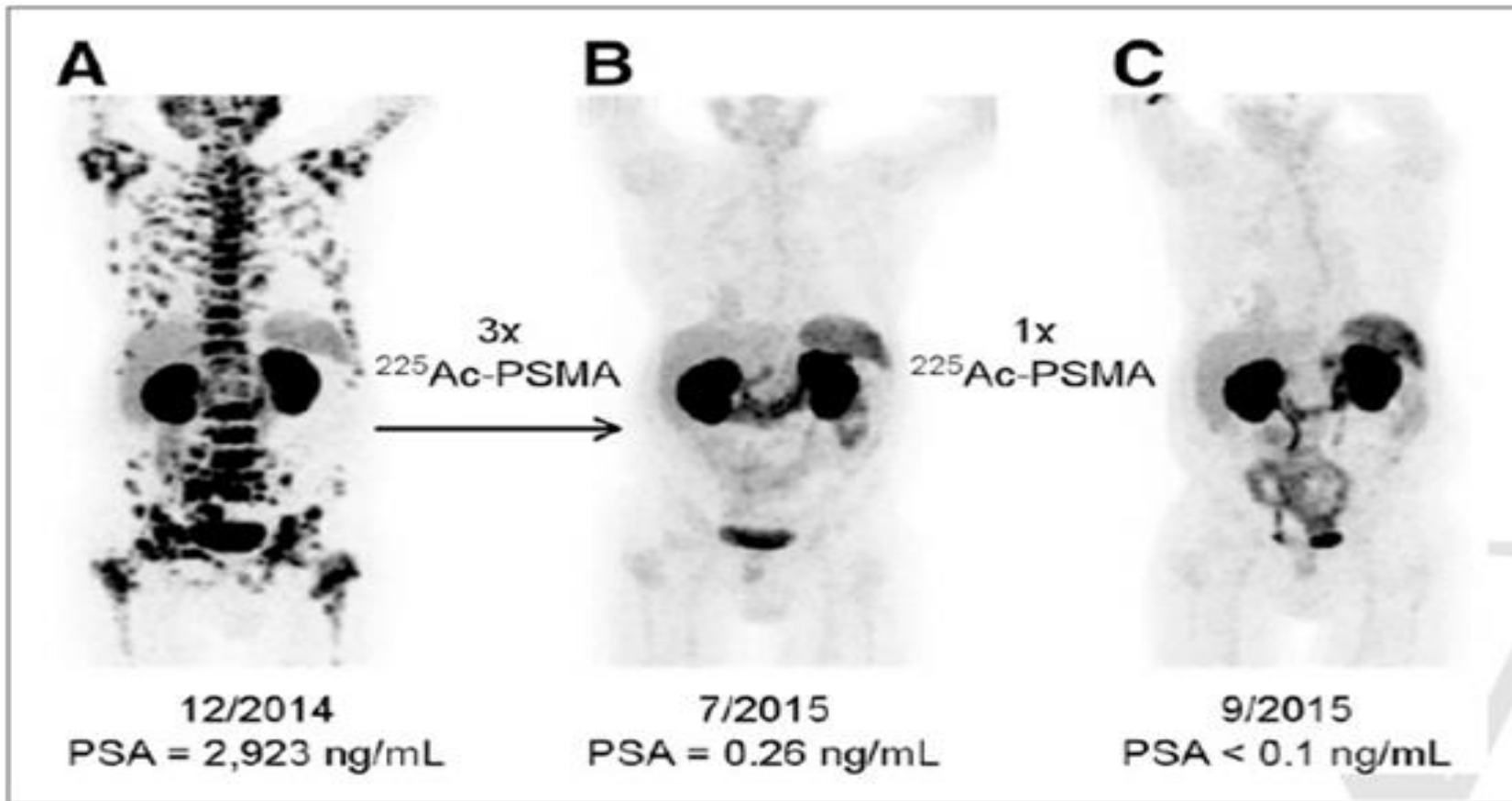
Ac-227 Production

- Bayer drug Xofigo® treats severe pain from bone metastases of prostate cancer; approved in 48 countries.
- Active ingredient *Ra-223* from limited global supplies of existing *Ac-227*.
- Recover *Ra-226* from waste medical devices secured by the DOE IP and diverted from a radioactive waste landfill. *Ra-226* targets irradiated in HFIR
- Chemically separate and purify the *Ac-227* created during irradiation – shipped to Bayer in Norway where they extract *Ra-223* which decays into *Ac-227* and ships it around the world for immediate use as a cancer therapy.
- After 2 years of R&D, scale up to full production in 2017.
- **10-year production contract signed with Bayer end of 2017**





The promise of Ac-225



J. Nucl. Med., 2016; 57 (12); 1941 DOI: 10.2967/jnumed.116.178673 C. Kratochwil

Ac-225 Routinely Available

**Basis of the Tri-Lab Effort:
Leveraging Unique Isotope
Program Facilities, Capabilities
and Expertise to Address ^{225}Ac
Supply**



*LANL Isotope Production Facility (IPF) at LANSCE;
100 MeV incident energy up to 250 μA for routine production*



*ORNL - Approximately 25 years of experience in
the isolation of ^{225}Ac from fissile ^{233}U via ^{229}Th*



*BNL Linac at the Brookhaven Linac Isotope
Producer (BLIP) 165 μA intensity to targets at
incident energies ranging from 66-202 MeV*



Am-241 for oil-gas exploration



- Re-established production capability in U.S.
- Extraction from plutonium waste stream at LANL
- Working with industrial consortium
- Mitigates U.S. dependence on Russia
- **Production began FY2018**



- Li-7
 - Used in PWR cooling water
 - Supply from Russia and China sometimes unreliable
 - Establishing emergency reserves suitable for molten salt reactors
 - Investment into R&D for new production techniques
 - Working with NE, NEI, EPRI: demonstrated feasibility of Li-7 recycling from resin beds
- He-4
 - BLM is carefully monitoring supply and demand (input on He-4 in survey important to BLM)
- Curium feedstock for actinides
 - For super heavy element discovery and heavy element chemistry
 - Pursuing extraction from Mk-18A Targets at Savannah River
 - Contain large quantities of scarce isotopes such as Pu-244, Cm-248
- Heavy Water
 - Many uses in research, medicine, commercial applications
 - Production entirely in foreign countries
 - DOE IP is considering R&D into new production techniques



- Ir-192
 - Industrial community is expressing concerns about reliable supply
 - IP designing target for production at ATR and HFIR
- Xe-129
 - Industry projects significant growth for polarized lung imaging over ~ 5 yrs
 - Phase II trials nearing completion
 - Considering production at SIPF
- Yb-176
 - Currently produced only in Russia
 - In high demand as target material for reactor production of therapeutic Lu-177
 - Validation runs at ESIPP now
- Enriched stable isotopes for physics research
 - Dark Matter and neutrinoless double beta decay
 - Project demand at the tonne scale – which could cause supply constraint in future
 - IP working with scientific community to understand demand and potential supply chains
 - SIPF could play a role



Increased Availability of Isotopes (1)

- Ac-225: Developed large-scale accelerator production capability, therapeutic medical applications research
- Ac-227: Developed reactor-based production, therapeutic medical applications research
- Am-241: Established domestic production capability
- At-211: Developing production capability at multiple sites to establish nationwide availability
- Ba-133: Reactor production. Used as gamma radiation reference source. Removed Russian dependency.
- Bk-249: Produced 22 mg target for the discovery of element 117; produced 26 mg for further super-heavy element research
- Cd-109: Developed reactor production routes, radioanalysis
- Cf-249: Heavy element chemistry research
- Cm-243: Acquired curium with a high Cm-243 content for research applications
- Cm-248: Developed recovery process for high purity Cm-248 for research applications
- Cf-251: Super-heavy element research
- Cf-252: Re-established production in FY 2009; industrial applications
- Co-60: Re-established domestic production with new target design; cancer therapy (Gamma Knife®), industrial applications
- Cu-64: Medical diagnostic imaging applications
- Cu-67: Cancer therapy research; new electron accelerator production route
- Es-254: provided for SHE nuclear science
- He-3: MRI imaging of lung function for pediatric apps; strict government controls mitigated shortage
- Heavy water: PET imaging instrumentation

Increased Availability of Isotopes (2)

<u>Li-6:</u>	Production of metal form for neutron detector isotope sales
<u>Li-7:</u>	Reserve for nuclear power industry to mitigate potential shortage
<u>Lu-177:</u>	Added new production capability at MURR
<u>Np-237:</u>	Inventory for dispensing bulk quantities and capability to fabricate reactor dosimeters
<u>Pb-212/Bi-212:</u>	Therapeutic medical applications research
<u>Ru-96:</u>	Nuclear Physics research
<u>Se-72/As-72:</u>	Developed production capability for Se-72 for As-72 generator; medical diagnostic imaging
<u>Si-32:</u>	Oceanographic and climate modeling research; replenished depleted inventory
<u>Sr-89</u>	Developed reactor production capability; palliation of bone pain associated with metastases
<u>Sr-90:</u>	Developing reserve to mitigate US dependence on foreign sources; therapeutic apps
<u>Th-227/Ra-223:</u>	Established Ac-227 cows for the provision of Th-227 and Ra-223, therapeutic medical applications research
<u>Th-232:</u>	New source available for distribution
<u>Th-238</u>	Recoverd from Ac-227 production Th-228/Ra-224 generator
<u>Ti-44:</u>	Developed accelerator production capability for medical imaging
<u>U-233:</u>	Recovered and purified mass-separated U-233 for research applications
<u>U-234:</u>	Neutron flux monitors
<u>W-188:</u>	Established routine reactor production for therapeutic medical applications
<u>Y-86:</u>	Established production capability for medical diagnostic imaging applications
<u>Zr-89:</u>	Funded development of production at universities; medical diagnostic imaging applications



- As-72/77: Exploring reactor and accelerator production for theranostic medical applications
- C-14: Ramping up to full scale production
- Cm-248: Process Mark 18 targets
- Cu-57: University production development
- Heavy water: Supporting new production techniques
- Ho-163: Demonstrated technical feasibility of production; if interest would need to scale up production
- Ir-192: Multi-lab target design team; mitigate foreign dependence
- Li-7: Developing new production capability: reactor operations, physics research
- Lu-177 HSA Large Scale processing/production capability
- Mo-98/Mo-100: Conducting validation runs
- Mn-52: PET diagnostic applications
- Nb-90: PET diagnostic applications
- Np-236/Pu-236: Ongoing R&D for accelerator-based production for security reference materials
- Pa-231: Purifying 100 mg for applications such as fuel cycle research
- Pm-147 technical feasibility established; ramping up to full scale processing capability
- Pt-191/193m/195m: Exploring accelerator production; theranostic medical applications
- Re-186: Exploring accelerator production; theranostic medical applications
- Se-72: Accelerator production for Se-72/As-72 generator
- Sc-47: Exploring accelerator production; theranostic medical applications
- Si-28: Consider EMIS and centrifuge production of Si-28 for computing and electronic applications
- Sr-89: Investigating economic feasibility of reactor production; palliation of bone pain associated with metastases
- Te-119: Accelerator production for Te-119/Sb-119 generator; technical feasibility established
- Th-229 Developing reactor production route for Ac-225
- U-230/Th-226: Medical applications; technical feasibility established
- Xe-129: Polarized lung imaging
- Yb-176: Stable production capability for production of Lu-177
- Zn-62/Cu-62: Funding production development for generators for medical diagnostic imaging applications

- DOE Isotope Program tries to ensure reliable and adequate supply of critical isotopes for federal needs and mitigate potential future shortages
- Develops production techniques for isotopes currently not available but high priority for federal missions
- Much progress in mitigating U.S. dependence on foreign sources
- Looking for opportunities for cooperation in new technologies
- Looking for input into new stable isotope production campaigns
- Surveys are very useful – thank you