

**Workshop on Federal Isotope Supply and Demand
November 9, 2016**

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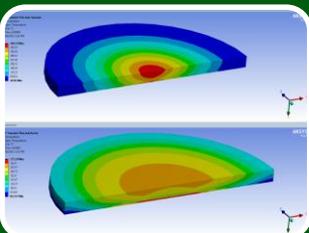
Office of Nuclear Physics, Office of Science, U.S. Department of Energy



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
Mitigation of U.S. reliance on foreign supplies of isotopes is a priority***



- Public Law 101-101 (1990), as modified by Public Law 103-316 (1995) created the Isotope Production and Distribution Program Fund (called a revolving fund) and **allow prices charged to be based on costs of production, market value, U.S. research needs and other factors.**
- 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
- 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.**



Valuable for isotope demand forecasting –
100's of isotopes identified

- Armed Research Institute
- Defense Logistics Agency
- Defense Threat Reduction Agency
- Department of Agriculture
- DOE/National Isotope Development Center
- DOE/National Nuclear Security Administration
- DOE/New Brunswick Laboratory
- DOE/Office of Fossil Energy-Oil and Natural Gas
- DOE/Office of Intelligence
- DOE/Office of Nuclear Energy
- DOE/Office of Science
- Department of Homeland Security
- Department of State
- Department of Transportation
- Federal Bureau of Investigation
- Food and Drug Administration
- National Aeronautics and Space Administration
- National Institutes of Health
- National Institute of Standards and Technology
- National Science Foundation
- National Security Staff
- Nuclear Regulatory Commission
- Office of Science & Technology Policy
- Office of the Director of National Intelligence



Homeland
Security



U.S. DEPARTMENT OF
ENERGY

Office of
Science



U.S. NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

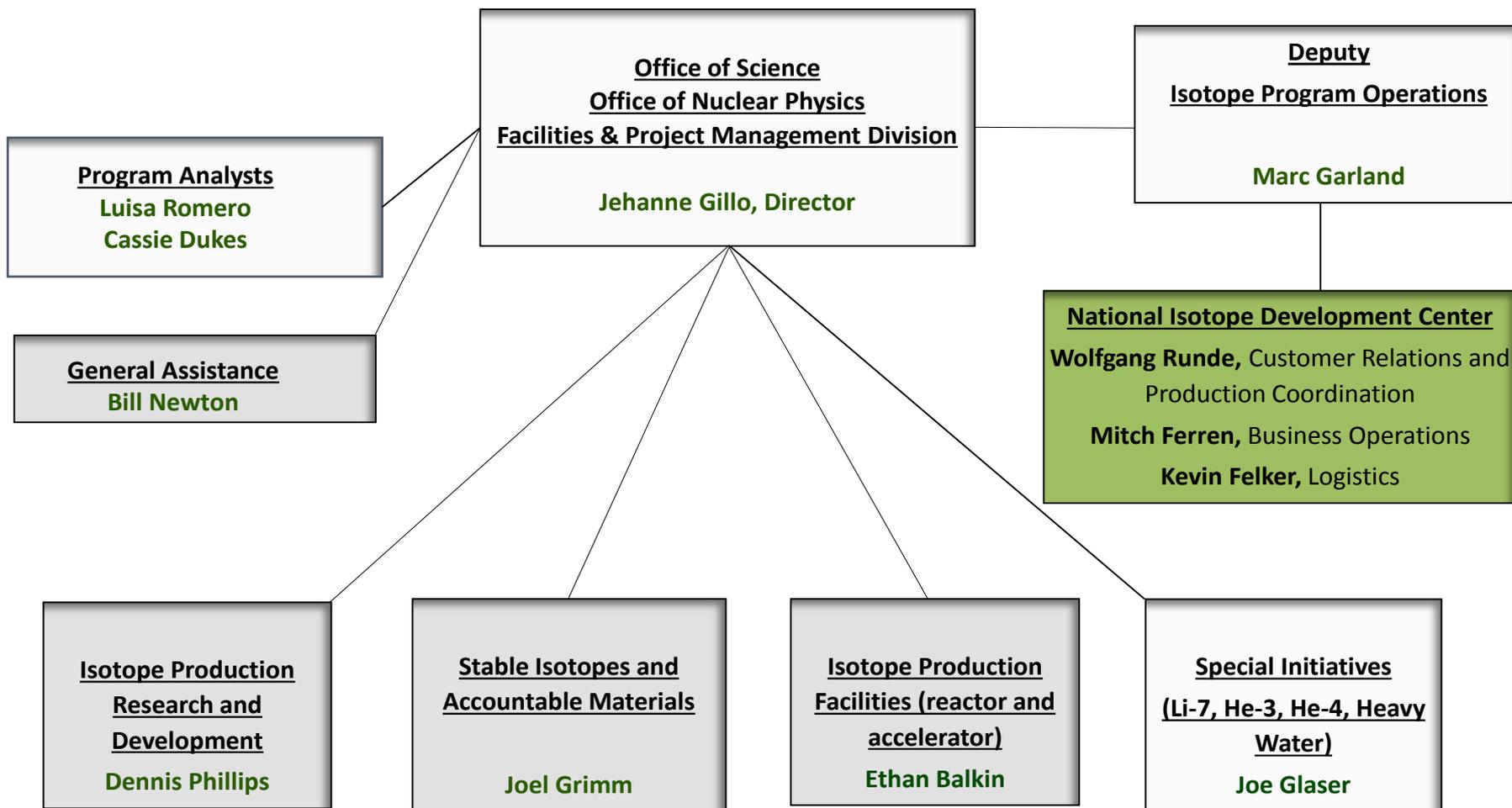


Workshop is geared to federal isotope users.

- 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.



DOE Isotope Program Organization



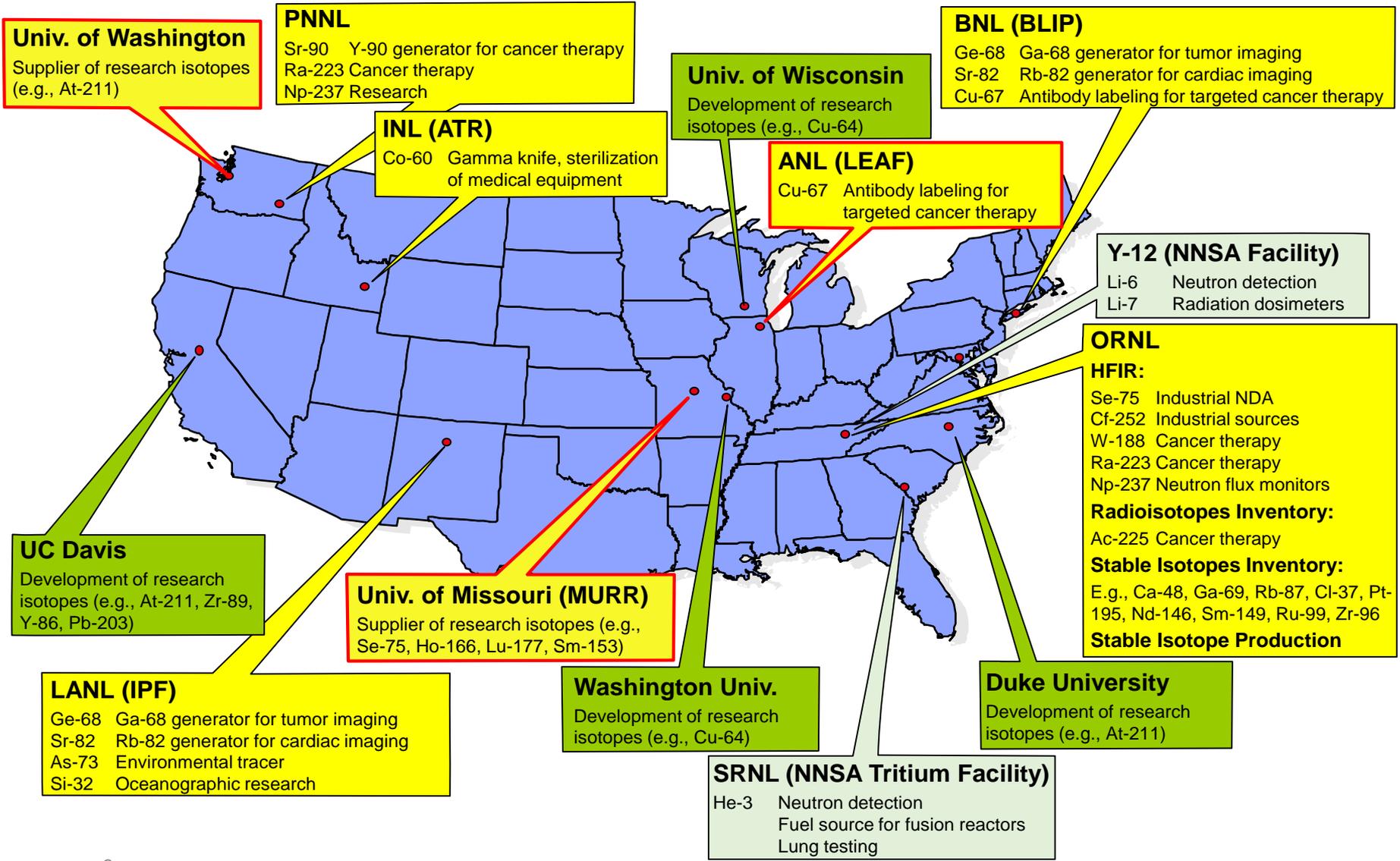


- The Department of Energy NIDC (includes the Isotope Business Office located at Oak Ridge National Laboratory) coordinates the distribution of all DOE isotope products and services available from DOE facilities.
- All contractual discussions with customers.
- Responsibilities in transportation, Q&A, 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, a tagline reads "the government source of isotopes for science, medicine, security, & applications". Below the logo is the U.S. Department of Energy Office of Science logo. A horizontal navigation bar contains ten links: Product Catalog, Quick Links, Breaking News, Business Office, About NIDC, Gatherings, Outreach Education, Production Sites, Production Research, and Contact Us. Below the navigation bar are six image thumbnails: a glowing tube, a molecular model, a heart with a ⁸²Sr isotope, a medical scan, a human spine, and a grid of blue spheres. A yellow text box below the thumbnails says "see Breaking News for details!". The main content area features a "Welcome to the NIDC !" heading, followed by a paragraph describing the center's role in coordinating isotope production and distribution. Below this, a text box encourages visitors to explore the site's content and provides links for: "Join the NIDC Email List", "Access the Product Catalog", "Request a Quote", "Search for Products", and "Access Newsletters & Notices". At the bottom, contact information for isotopes@ornl.gov and a link to the "Notice to Users" are provided.

Strong communication with stakeholders

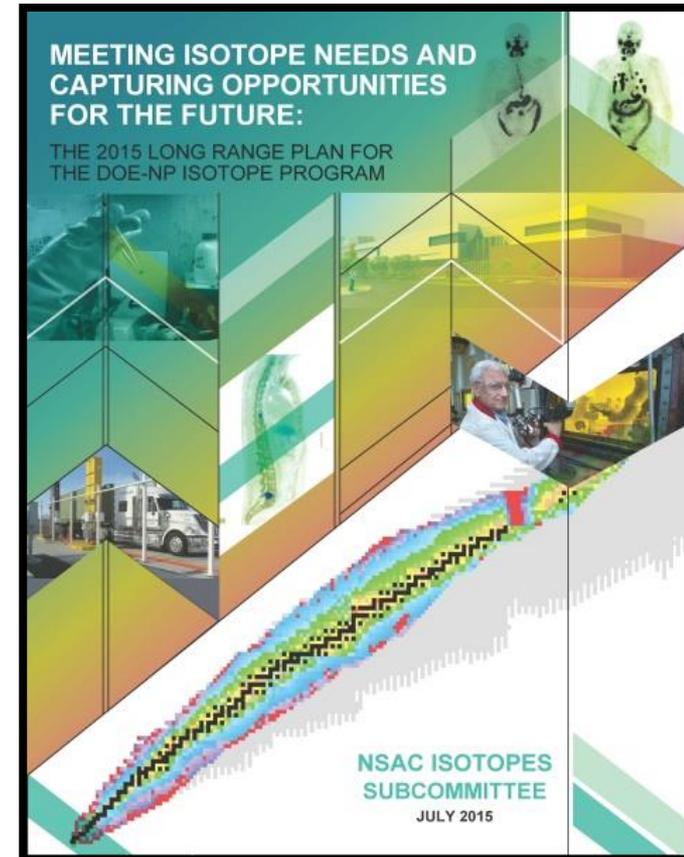
- OSTP High Activity Sources Subcommittee (GARS)
- OSTP Subcommittee on Critical Materials
- Interagency He-3 Working Group – National Security Staff
- Iran Joint Comprehensive Plan of Action
- DOE/NIH Working Group
- Mo-99 Stakeholders Working Group
- NRC Sealed Sources Working Group
- BLM He-4 Interagency 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
- U-233 Intra-agency Working Group
- Pb-212 Users Working Group (medical)
- At-211 Users working Group (medical)
- Commercial stakeholder meetings twice a year
- Annual industrial survey
- Annual Federal Workshops and survey
- Sponsorship of workshops, symposium at conferences



Guided by NSAC Report released July 20, 2015

Recommendations:

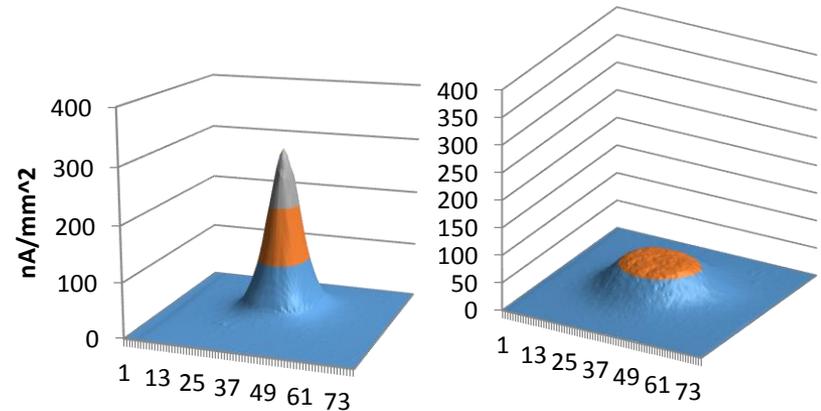
- Significant increase in R&D funding
 - Continue R&D on alpha-emitters (Ac-225, At-211)
 - High specific activity theranostic isotopes
 - Electron accelerators for isotope production
 - Irradiation materials for targets
- Complete stable isotope capability
- Increase in infrastructure investments and operating base
 - Isotope harvesting at FRIB
 - **Separator for radioactive isotopes**
 - DOE to host meetings in the new year; focus on additional mission needs
 - 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



All in progress

Brookhaven National Laboratory Brookhaven Linac Isotope Producer (BLIP)

- The BLIP beam line directs protons up to $105\mu\text{A}$ intensity to targets; parasitic operation with nuclear physics programs for more cost effective isotope production.
- Sr-82, Ge-68, Be-7, Cu-67, Y-86, Zn-65, Fe-52, Rb-83
- **New project completed this year to raster beam to increase isotope yield and decrease target fatigue**



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.
- Sr-82, Ge-68, Na-22, As-73, Se-72, Y-88, Si-32, Cd-109
- **Initiated IPF beam transport system upgrade to increase isotope yields and enhance R&D capabilities**



Reactor Facilities

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



Oak Ridge National Laboratory High Flux Isotope Reactor (HFIR)

- Office of Basic Energy Science is steward
- Radiochemical Engineering Development Center (REDC)
- Cf-252, Se-75, Ni-63, Ac-225, W-188, Lu-177, Th-227, Ra-223, Pb-212/Bi-212, Th-229



Other Isotope Program Sites

Y-12

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



Initial processing of Li-7 at Y-12 completed FY 2016. Preparing for additional cleanup to meet product specifications for future 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

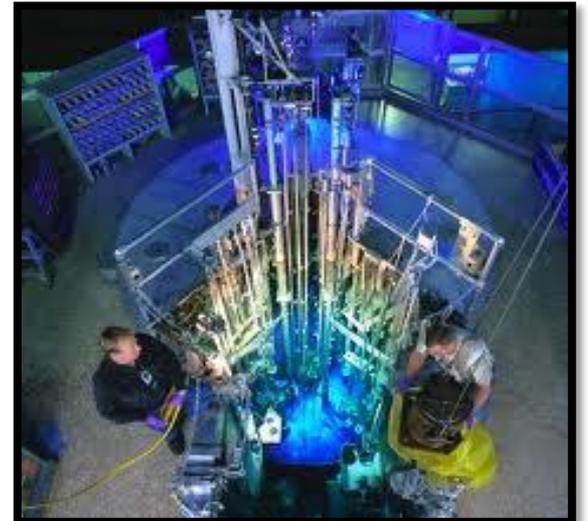


University Facilities

- 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 2016, agreement finalized with MURR for production of Se-75 for scientific research: contract about to be signed



*UW
cyclotron*



*University of Missouri
Research Reactor*



Increased Availability of Isotopes

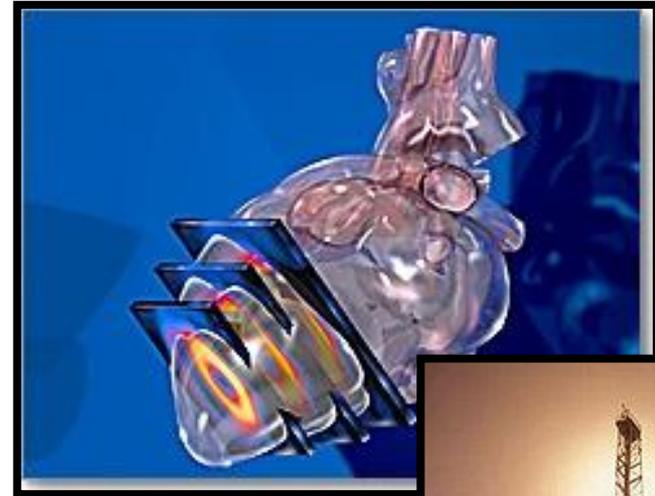
- At-211: Funding production development at four institutions to establish nationwide availability
- Ba-133: Reactor production. Used as gamma radiation reference source. Removed Russian dependency.
- Bk-249: Produced 22 mg target for the discovery of element 117; produced 26 mg for further super-heavy element research
- 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, new 6-year contract through 2018; 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
- He-3: Strict government controls mitigated shortage
- Heavy water: Acquired supply
- Li-6: Production of metal form for neutron detector isotope sales
- Li-7: Reserve for nuclear power industry to mitigate potential shortage; R&D on new production
- Np-237: Inventory for dispensing bulk quantities and capability to fabricate reactor dosimeters
- Pb-212/Bi-212: Therapeutic medical applications research
- Se-72/As-72: Developed production capability for Se-72 for As-72 generator; medical diagnostic imaging
- Si-32: Oceanographic and climate modeling research; replenished depleted inventory
- Th-227/Ra-223: Established Ac-227 cows for the provision of Th-227 and Ra-223, therapeutic medical applications research
- U-233: Recovered and purified mass-separated U-233 for research applications
- U-234: Neutron flux monitors
- W-188: Established routine reactor production for therapeutic medical applications
- Y-86: Established production capability for medical diagnostic imaging applications
- Zr-89: Funded development of production at universities; medical diagnostic imaging applications



- Ac-225: Developing large-scale accelerator production capability, therapeutic medical applications research
- Ac-227: Developing reactor-based production, therapeutic medical applications research
- As-72/77: Exploring reactor and accelerator production for theranostic medical applications
- Am-241: Establishing domestic production capability; product will be available starting FY 2017
- C-14: Exploring reactor production
- Cd-109: Evaluating cost effectiveness of alternate reactor production routes
- Heavy water: Consider new supplies and 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
- Mo-98/Mo-100: Demonstrated production capability as feedstock for Mo-99 production
- Mn-52/Nb-90: Medical 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
- Pt-191/193m/195m: Exploring accelerator production; theranostic medical applications
- Re-186: Exploring accelerator production
- Ru-96: Nuclear Physics research
- 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 quantum computing and electronic applications
- Sr-89: Investigating economic feasibility of reactor production
- Te-119: Accelerator production for Te-119/Sb-119 generator
- Ti-44: Developing accelerator production for medical imaging
- Th-232: IP acquired Th-232 and is preparing for distribution
- U-230/Th-226: Medical applications
- Xe-129: polarized lung imaging
- Zn-62/Cu-62: Funding production development for generators for medical diagnostic imaging applications

Rubidium-82 used for PET myocardial perfusion imaging

- France, Russia, South Africa, Canada, U.S.
- Increased production capability at BLIP
- Pursuing initiatives to increase yield at IPF
- Providing aid to industry to promote commercialization



Cf-252 for well logging, industrial applications

- Russia, U.S.
- Maintaining supply of 97% of domestic market
- Working with industrial consortium
- Long term contract in place; provision for research quantities



Am-241 for oil-gas exploration

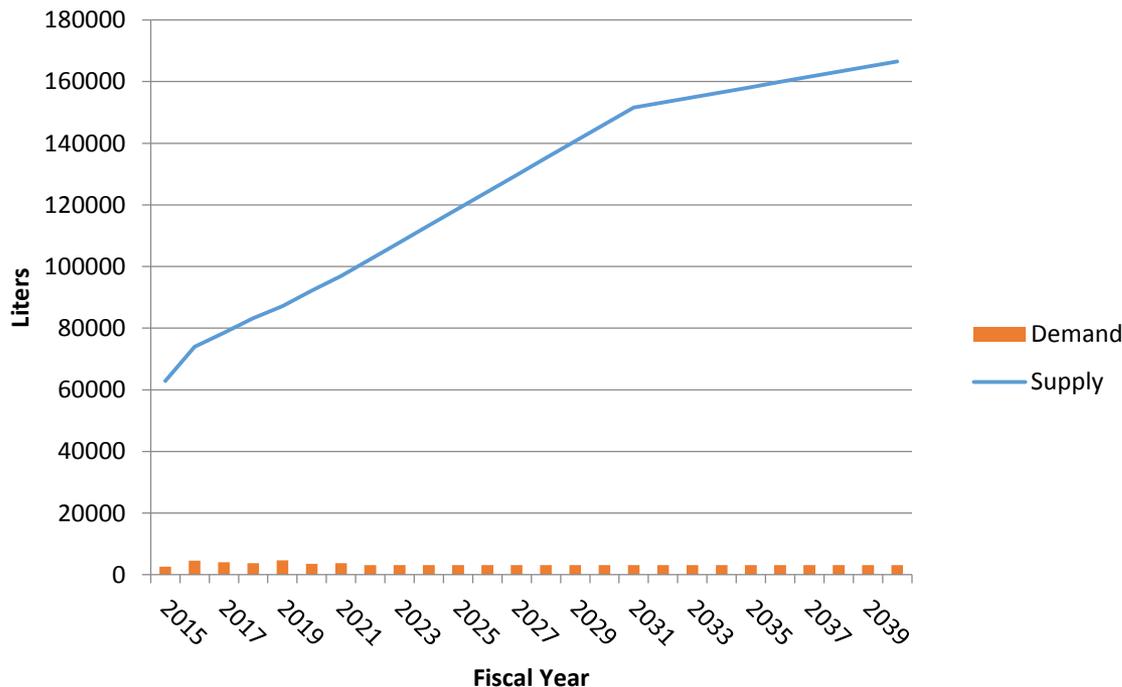
- Re-establishing production capability in U.S.
- Extraction from plutonium waste stream at LANL
- Working with industrial consortium
- Production to begin FY2017



- Enriched stable isotopes
 - Russia dominant supplier
 - Re-established general domestic production capability (ESIPP - small scale) 2016
- High specific activity Co-60 (medical and industrial)
 - Canada, Russia, U.S.
 - DOE IP continues to produce at ATR
- Cd-109 (paint analysis)
 - Russia, U.S. (accelerator-route)
 - Demonstrated two reactor production routes – determining economic feasibility
- Ir-192 (industrial radiography)
 - Russia, Canada, Belgium, Netherlands
 - DOE IP initiated target design for production at ATR and HFIR
- Sr-90 (cancer therapy)
 - Russia, U.S.
 - DOE IP now has material available
- U-234 (nuclear reactor flux monitors)
 - Russia
 - DOE IP is recovering U-234 – available FY2017

He-3 Status

- Isotope Program plays a lead role in Interagency He-3 Working Group- reports to White House National Security Staff. 12 Federal agencies.
- FY 2017 report recently approved by NSS.
- Mitigation and prioritization efforts on behalf of the IAG have successfully addressed He-3 shortage.
- The current supply is anticipated to currently meet Federal agency needs.
- He-3 available from U.S. and Russia
- He-3 auction is not planned in FY 2017 or in the near term.



2016 new policies

NIH moving away from He-3 for polarized lung imaging unless pediatric applications

On a case-by-case basis, permitting disposition of small quantities of He-3 where not economically feasible to extract or store (NNSA)

- 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 has purchased heavy water from Iran – available
 - DOE IP is considering R&D into new production techniques



- Co-60 – high specific activity – medical and industrial applications
 - NRU reactor ceasing operations in 2017
 - (2-3 year irradiation)
 - IP is qualifying additional irradiation positions in ATR
- 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
 - Can be produced at ESIPP and SIPF
- 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

- Ac-225 R&D Project passed critical Milestone in full production capability ramp-up, establishing that accelerator-based product is equivalent to Ac-225 from Th-229 generator. Ac-225 is high priority therapeutic isotope for treating metastasized cancers.
- Completed BLIP Raster Project to increase yields of Sr-82 for cardiac imaging.
- Added the LEAF electron accelerator at ANL to Isotope Production Network and announced routine availability of Cu-67 for treatment of non-Hodgkins lymphoma.
- Added the University of Washington cyclotron to Isotope Production Network for routine production of At-211.
- Re-established stable enriched production capability in the United States.
- Initiated development of enhanced production of Cf, Bk, Es, Fm availability for heavy element discovery searches and heavy element chemistry.
- Purchased heavy water from Iran and providing to U.S. industry and research institutions.



- 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
- Looking for opportunities for cooperation in new technologies
- Looking for input into new stable isotope production campaigns
- Considering a mission need for a radio-isotope separator – contact Joel Grimm
- Surveys are very useful – thank you