Workshop on Federal Isotope Supply and Demand
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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.

*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**.

- Commercial isotopes at full-cost recovery; research isotopes at reduced prices.
- Isotope Program operates under a **revolving fund** and is audited annually.
- Program costs are financed by two resources: **appropriation and revenue**.

![Diagram of Isotope Program Authority and Resources](image-url)
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
- Office of Science & Technology Policy
- Office of the Director of National Intelligence
Objectives

- Optimize communication on supply and demand of isotopes needed for successful achievement of federal missions.
- Surveys are very important to Isotope Program – effective manner to collect information from federal agencies. Appreciate efforts.
- Demand information enables us to guide priorities for R&D investment into new initiatives and capabilities.
- Demand information enables us to guide priorities for production of “boutique” research isotopes.
- Collection and provision of He-4 data to BLM.
- Opportunity to report back to federal agencies on progress towards developing new capabilities and provision of isotopes of interest.
- Promote cooperation on developing technologies and capabilities of mutual interest.
- Federal input into priority of production campaigns.
- Opportunity to report back to federal agencies on progress towards mitigating U.S. dependence on foreign sources of isotopes.
- Opportunity to report back to federal agencies about isotopes of concern and potential constrained supplies.
DOE Isotope Program has been re-organized

- Restructured and increased the federal organization
- Created the National Isotope Development Center
- Created R&D Program – competitive, base
- Developed priorities for research & production
- Scrubbed production costs of isotopes
- Increased portfolio of isotope production sites
  - University sites
  - Addition of other DOE/NNSA sites
- Investments in infrastructure
- Development of new capabilities
- Increased availability of research isotopes and made more affordable
- Introduced peer review into mode of operations
- Improved business operations
- Improved communication, visibility with stakeholders
- Improved marketing strategy and demand forecast
- Improved public outreach and workforce development
DOE Isotope Program Organization

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National Isotope Development Center
Wolfgang Runde, Customer Relations, Production
Mitch Ferren, Business Operations
Kevin Felker, Logistics

Special Initiatives
Joe Glaser
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
DOE Isotope Program
Production and/or R&D Sites

PNNL
- Sr-90 Y-90 generator for cancer therapy
- Ra-223 Cancer therapy
- Np-237 Research

INL (ATR)
- Co-60 Gamma knife, sterilization of medical equipment

Univ. of Washington
- Supplier of research isotopes (e.g., At-211)

BNL (BLIP)
- Ge-68 Ga-68 generator for tumor imaging
- Sr-82 Rb-82 generator for cardiac imaging
- Cu-67 Antibody labeling for targeted cancer therapy

Univ. of Missouri (MURR)
- Supplier of research isotopes (e.g., Se-75, Ho-166, Lu-177, Sm-153)

LANL (IPF)
- Ge-68 Ga-68 generator for tumor imaging
- Sr-82 Rb-82 generator for cardiac imaging
- As-73 Environmental tracer
- Si-32 Oceanographic research

Univ. of Wisconsin
- R&D in research isotopes (e.g., Cu-64)

Y-12 (NNSA Facility)
- Li-6 Neutron detection
- Li-7 Radiation dosimeters

ORNL
- HFIR:
  - Se-75 Industrial NDA
  - Cf-252 Industrial sources
  - W-188 Cancer therapy
  - Ra-223 Cancer therapy
  - Np-237 Neutron flux monitors
- Stable Isotopes Inventory:
  - E.g., Ca-48, Ga-69, Rb-87, Cl-37, Pt-195, Nd-146, Sm-149, Ru-99, Zr-96
- Stable Isotope Production
- Radioisotopes Inventory:
  - Ac-225 Cancer therapy

UC Davis
- R&D in research isotopes (e.g., At-211, Zr-89, Y-86, Pb-203)

Washington Univ.
- R&D in research isotopes (e.g., Cu-64)

Univ. of Washington
- Supplier of research isotopes (e.g., At-211)

Duke University
- R&D in research isotopes (e.g., At-211)

SRNL (NNSA Tritium Facility)
- He-3 Neutron detection
- Fuel source for fusion reactors
- Lung testing
Brookhaven National Laboratory Brookhaven Linac Isotope Producer (BLIP)
- First to use a high energy proton accelerator to produce isotopes (1972)
- BLIP utilizes the beam from the proton Linac injector for the Booster, AGS, and RHIC accelerator (nuclear physics).
- Excess pulses (~85%) are diverted to BLIP. Energy is incrementally variable from 66-202 MeV.
- The BLIP beam line directs protons up to 105μA 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

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
Idaho National Laboratory Advanced Test Reactor (ATR)
- Office of Nuclear Energy is steward
- New Hydraulic Shuttle Irradiation System (HSIS) enables production of short-lived isotopes
- Co-60 target design in collaboration with ORNL
- Ir-192 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

**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
- Investments in infrastructure
- 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

- IBO may administer university contracts to fund production and may manage customer sales
- Isotopes under consideration for additional to portfolio
Rubidium-82 used for PET myocardial perfusion imaging
- Sr-82 produced at both IPF and BLIP – at capacity
- Manufactured by GE HealthCare and Nordion
- Pursuing initiatives to increase yields
- Providing aid to industry to promote commercialization

Cf-252 for well logging
- Supplies 97% of domestic market
- Working with industrial consortium
- Long term contract in place; provision for research quantities

Re-establishing domestic Am-241 production
- Project initiated by Isotope Program in November 2011
- Extraction from plutonium waste stream
- Working with industrial consortium
- Goal is to initiate production in FY2017 at LANL
Discovery of Super Heavy Element 117

By bombarding it with $^{40}$Ca (also supplied by the U.S.)

It took 250 days to make enough Berkelium, shown here, to synthesize element 117.

Scientists Discover Heavy New Element
By JAMES GLANZ
Published: April 6, 2010
A team of Russian and American scientists has discovered a new element that has long stood as a missing link among the heaviest bits of atomic matter ever produced. The element, still nameless, appears to point the way toward a brew of still more massive elements with chemical properties no one can predict.
Fundamental R&D (2009-2010)

- Excitation function measurements
- Proof of feasibility

Scale-up Development (2011-present)

- Chemical process development
- Thorium target development
- Evaluation of accelerator produced Ac-225
  - Ac-225/Bi-213 generator performs very well
  - Direct labeling efficiency similar to Th-229 generated Ac-225
  - Toxicity/Dosimetry (Ac-227 co-produced with Ac-225)
- Facility requirements assessment
- Transportation requirements
- Quality assurance

Proton-irradiated encapsulated Th target (left); Dissolved Th target showing blue Cerenkov glow (right).
Stable Isotopes Inventory

Stable Isotope Operations at ORNL

- ORNL Inventory from Y12 Calutron enrichment 1945 - 1998
- Enriched more than 250 stable Isotopes
- No existing domestic broad-scope enrichment
- ~500 purchase orders FY 2014
- Inventory of 11 has been exhausted

- Developing new pilot capability for stable isotope enrichment at ORNL
- Electromagnetic separation coupled with centrifuge technology
- Plans to upgrade to kg production capability
- Planning first campaigns
- Looking for agency input
Increased Availability of Isotopes

- **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
- **He-3**: Strict government controls mitigated shortage
- **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
Isotopes under Development

- **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
- **At-211**: Funding production development at four institutions to establish nationwide availability
- **Am-241**: Establishing domestic production capability; product will be available starting FY 2017
- **C-14**: Exploring reactor production
- **Cd-109**: Evaluating alternate reactor production route
- **Cu-67**: Scale-up of production on electron linacs
- **Heavy water**: Consider new supplies and new production techniques
- **I-124**: Funding production development at one institution
- **Ir-192**: Multi-lab target design team; mitigate foreign dependence
- **K-40**: Exploring reactor 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
- **Se-72**: Accelerator production for Se-72/As-72 generator
- **Sc-47**: Exploring accelerator production; theranostic medical applications
- **Sr-89**: Investigating economic feasibility of reactor production
- **Sr-90**: Exploring sources of higher specific activity Sr-90 for medical and industrial applications
- **Te-119**: Accelerator production for Te-119/Sb-119 generator
- **Ti-44**: Exploring accelerator production for medical imaging
- **Zn-62/Cu-62**: Funding production development for generators for medical diagnostic imaging applications
He-3 Shortage Mitigated

- Isotope Program plays a lead role in Interagency He-3 Working Group- reports to White House National Security Staff.
- 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 auction is not anticipated in FY 2016 or in the near term.**
Commercial Isotope Supply Constraints

- Li-7 experiences occasional supply constraints, including FY15/16
  - Commercial isotope; Isotope Program not in market
  - Used as cooling reagent in nuclear power reactors – setting up emergency reserves
  - Investment into new production techniques

- He-4 – working with BLM

- High Specific Activity Co-60
  - U.S. supply challenges with target breach at Advanced Test Reactor
  - Production restarted

- Heavy water in future may become constrained
  - Canadian supply currently limited
  - Foreign exports may be constrained in future
  - Considering new production techniques and new supplies
Positive about the Isotope Program
All prior recommendations addressed

New 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
  - BLIP intensity upgrade and second target station
  - IPF intensity, stability and energy upgrades

- Continue integration of university facilities
Effectiveness of Isotope Program highly dependent upon communication with stakeholders

- Commercial stakeholder meetings twice a year
- Annual industrial survey
- Sponsorship of workshops, symposium at conferences
- Annual Federal Workshops and survey
- DOE/NIH Working Group
- Interagency He-3 Workgroup – National Security Staff
- OSTP High Activity Sources Subcommittee (GARS)
- OSTP Subcommittee on Critical Materials
- NRC Sealed Sources Working Group
- BLM He-4 Interagency Working Group
- Certified Reference Materials Working Group
- CRM Np-236 Sub working group
- DOE Nuclear Materials Advisory Board
- Li-7 Intra-agency Working Group
- Mo-99 Stakeholders Working Group
- Pb-212 Users Working Group (medical)
- As-211 Users working Group (medical)

Always looking for ways to improve communication with stakeholders
Summary

- DOE Isotope Program
  - Small federal program with limited resources
  - Significant impact to research, applications, society
  - Broad array of activities

- Recent positive report from NSAC

- Significant synergy with the Office of Nuclear Physics

- Looking for opportunities for cooperation in new technologies

- Looking for input into new stable isotope production campaigns

- Surveys are very useful – thank you