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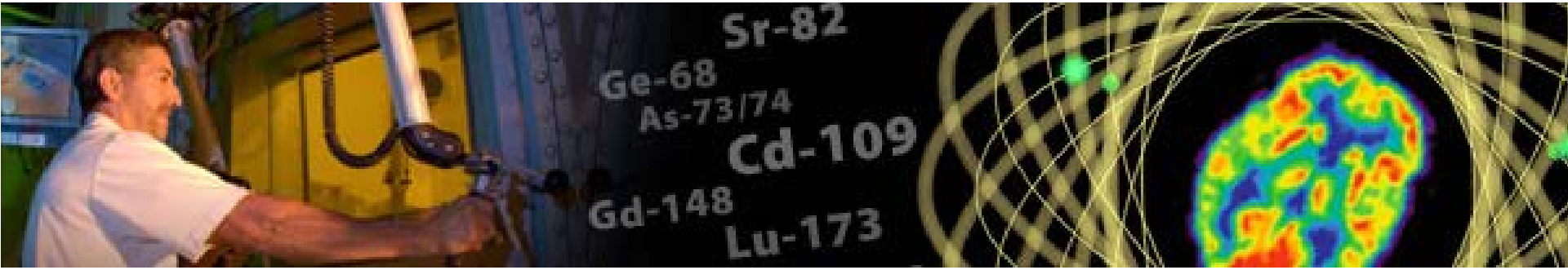
OFFICE OF SCIENCE



2013 Workshop on Federal Isotope Supply and Demand
September 19, 2013

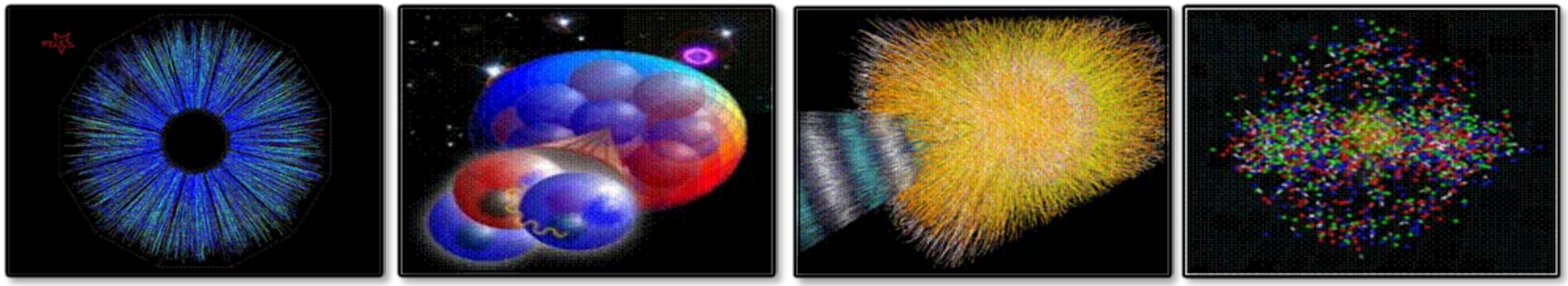
Dr. Jehanne Gillo
Director, Facilities and Project Manager Division
Director, DOE Isotope Program
Office of Nuclear Physics, Office of Science, U.S. Department of Energy

Office of Science for Nuclear Physics

Discovering, exploring, and understanding all forms of nuclear matter

FY 2014 Budget Highlights:

- *Research at RHIC capitalizes on the10-fold enhancement in luminosity to investigate the properties of a new perfect Quark-Gluon liquid.*
- *Construction continues on the 12 GeV CEBAF Upgrade to study the quark structure of nucleons and nuclei.*
- *Construction is supported for the Facility for Rare Isotope Beams to enable world leadership in research on nuclear structure and nuclear astrophysics.*
- *ATLAS beams using the new Californium Rare Isotope Breeder (CARIBU) upgrade enable the study of nuclear structure and the origin of the elements in the cosmos.*
- *Forefront research, development, and production of stable and radioactive isotopes is provided for science, medicine, industry, and national security.*



Isotope Program Mission

The mission of the DOE Isotope Program is threefold:

- Produce and/or distribute radioactive and stable isotopes that are in short supply, associated byproducts, surplus materials and related isotope services.
- Maintain the infrastructure required to produce and supply isotope products and related services.
- Conduct R&D on new and improved isotope production and processing techniques which can make available new isotopes for research and applications.

Produce isotopes that are in short supply only – we do not compete with industry

Isotope Production Facility (LANL)

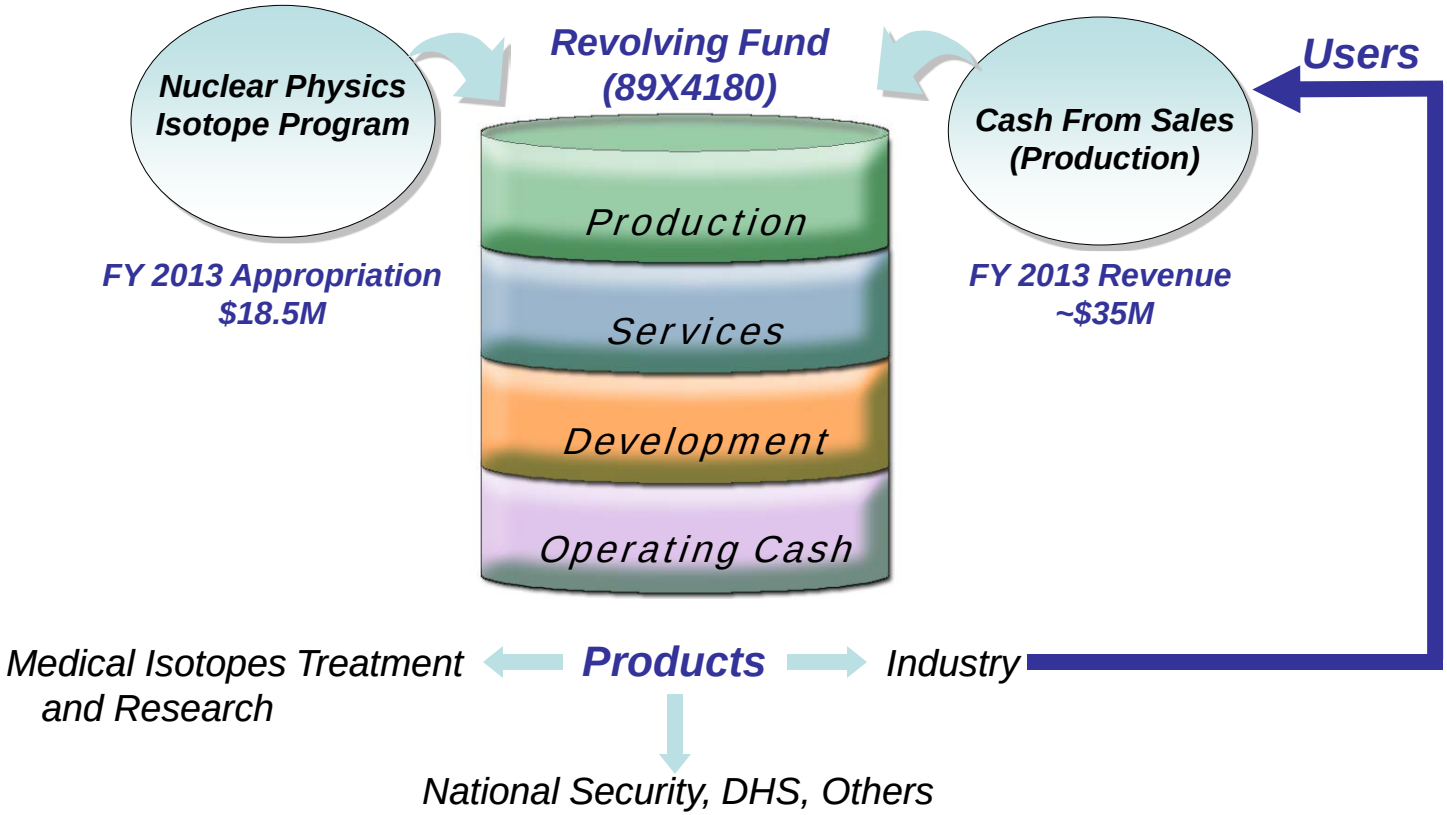
>230 customer orders in FY2012
>425 shipments in FY2012

FY 12 Appropriations: $19.1M
FY 13 Appropriation: $18.5M

Brookhaven Linac Isotope Producer

Isotope Program Resources

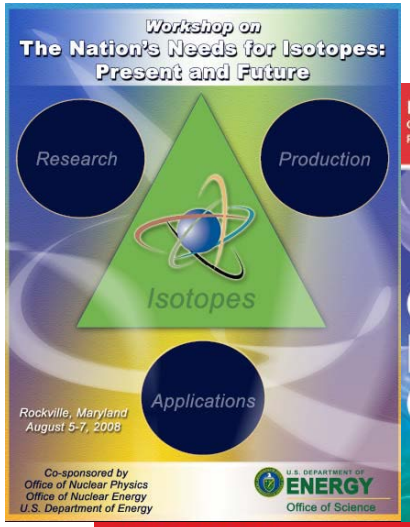
- Public Law 101-101 (1990), as modified by Public Law 103-316 (1995) created the Isotope Production and Distribution Program Fund (called a revolving fund) and allow prices charged to be based on costs of production, market value, U.S. research needs and other factors.
- Commercial isotopes at full-cost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

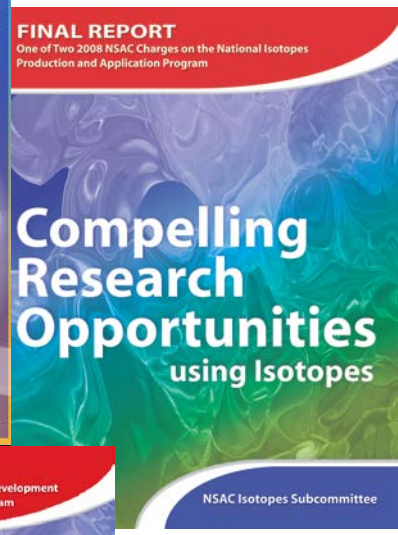


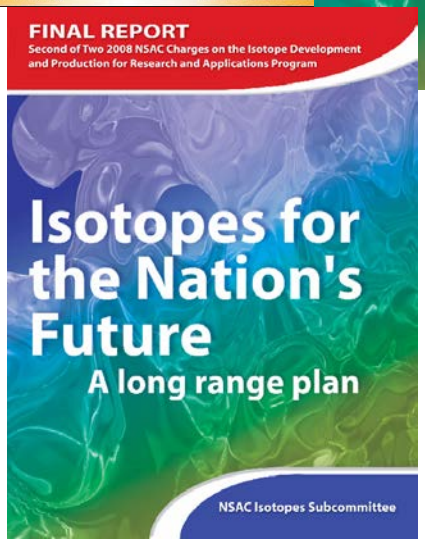
Re-organizing the Isotope Program

The changes to the program have been substantial since transferred to Office of Science in 2009

- Restructured the federal organization of the program
- Created the National Isotope Development Center to strengthen public outreach
- Created Research and Development Program for new and improved isotope production techniques
- Charged NSAC to set priorities for research opportunities and to develop a long-term strategic plan for isotope production and development
- Increased portfolio of isotope production sites
- Increased availability of research isotopes and made more affordable
- Introduced peer review into mode of operations
- Improved communication with stakeholders
  - Federal agencies, industry, research and applied







2nd Workshop on Isotope Federal Supply and Demand, *September 19, 2013*

70 attendees
23 different federal institutions
Over 200 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

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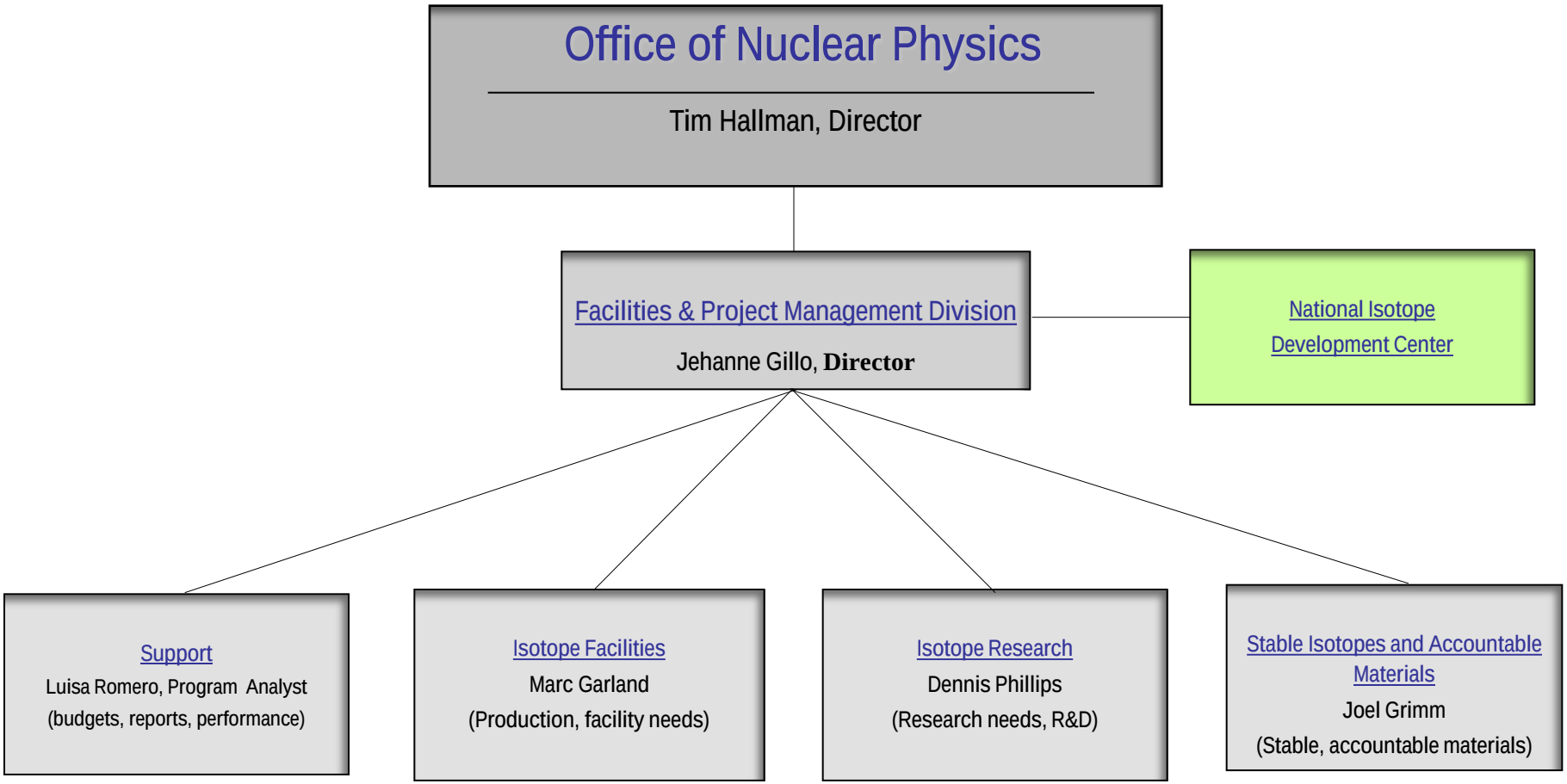
Isotope Program Organization



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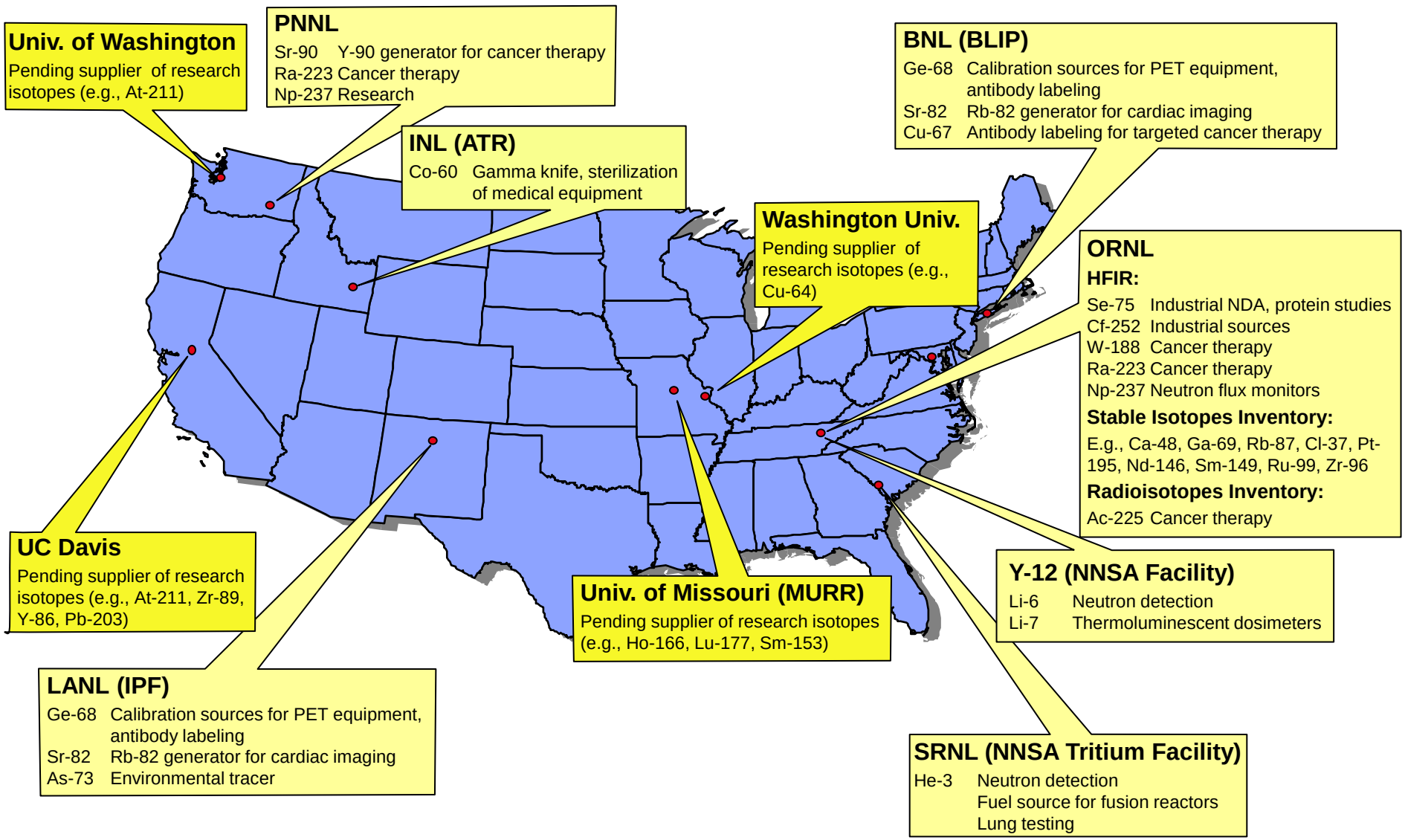
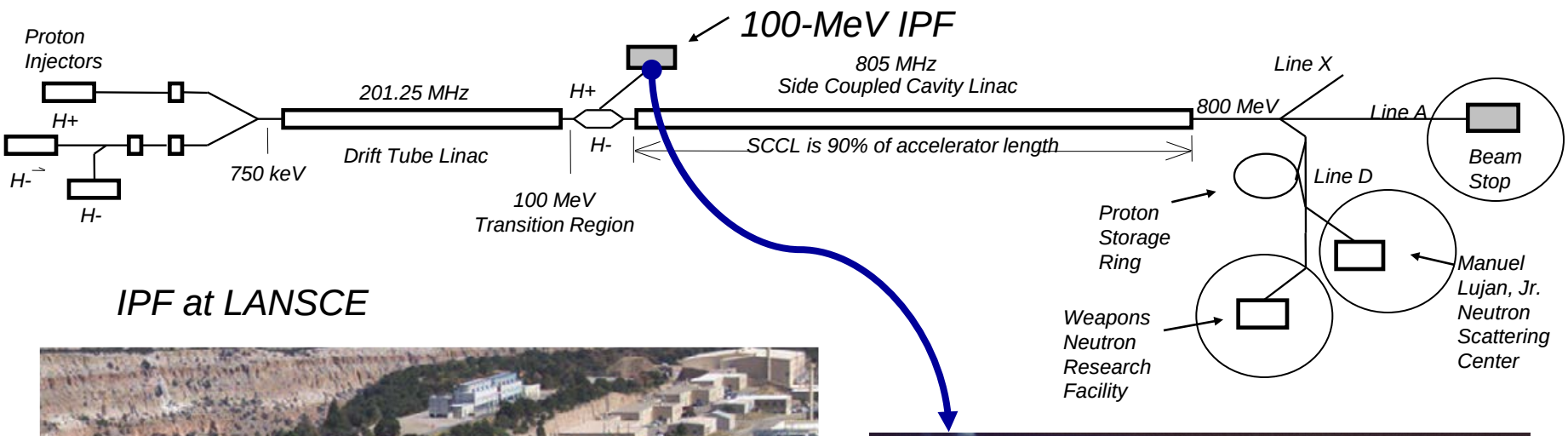
Production Sites Integrated in the DOE Isotope Program



Isotope Production Facility (IPF)

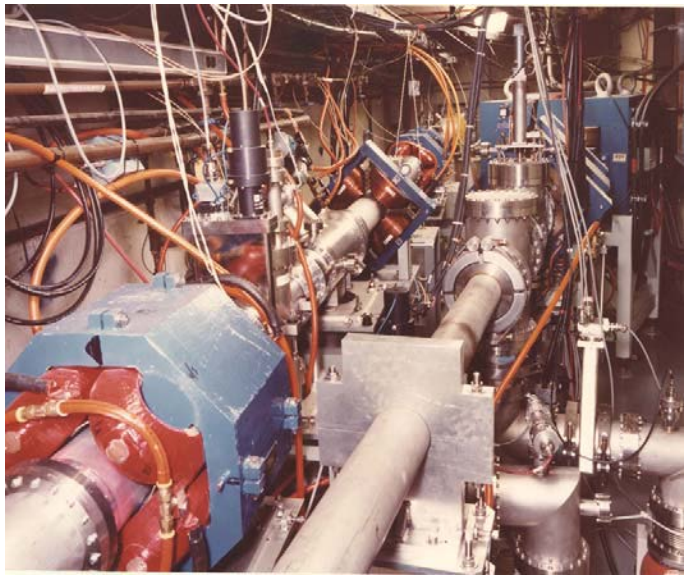


IPF at LANSCE

- *Diversion of 100 MeV proton beam to target station*
- *Irradiates targets while LANSCE operates for NNSA/BES*

Brookhaven LINAC Isotope Producer (BLIP)

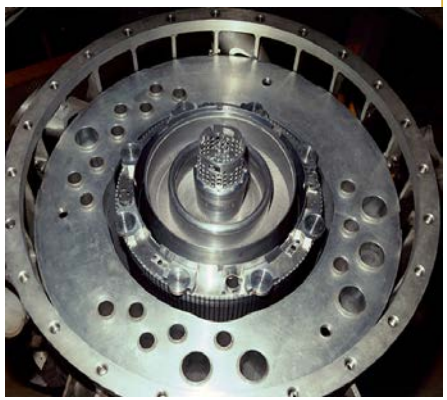
- BLIP utilizes the beam from the proton Linac injector for the Booster, AGS, and RHIC acellerator (nuclear physics)
- Excess pulses (~85%) are diverted to BLIP. Energy is incrementally variable from 66-202 MeV.
- The BLIP beam line directs protons up to 105μA intensity to targets; parasitic operation with nuclear physics programs for more cost effective isotope production.



DOE Reactor Sites: HFIR and ATR

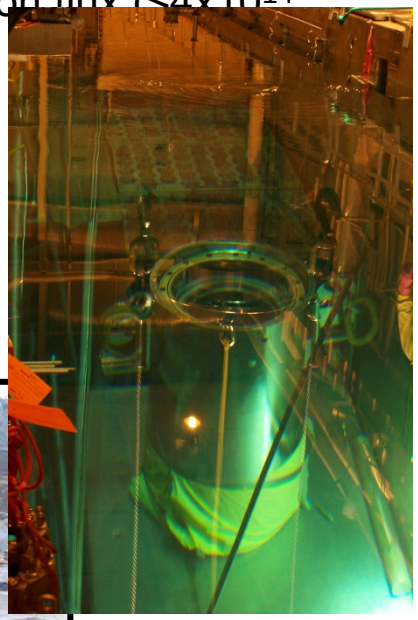
High Flux Isotope Reactor (HFIR) at ORNL:

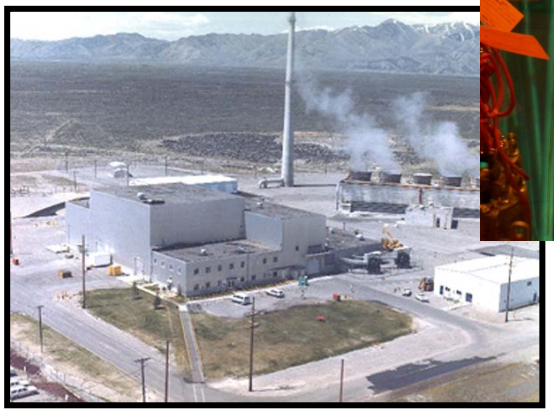
- High neutron flux (≤3x10^{15} n/cm^2 s)
- Multiple hydraulic tubes
- Several hot cell facilities
- Key Isotopes: Cf-252, W-188, Ni-63, Se-75



Advanced Test Reactor (ATR) at INL:

- Moderately high neutron flux (≤4x10^{14} n/cm^2 s)
- Hot cell facilities
- Key Isotope: Co-60





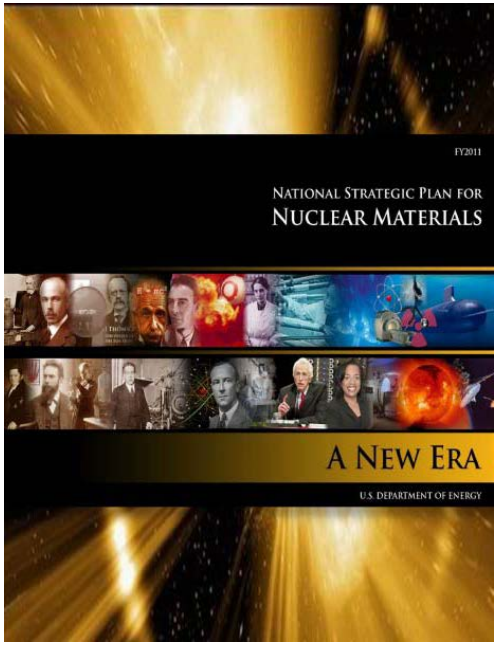
OAK RIDGE National Laboratory

INL Idaho National Laboratory

IP Distribution Services

- The IP provides services to manage the distribution of isotopes that are owned by other programs

  - Most of these are legacy materials owned by other DOE programs because of stockpile stewardship
  - Communication strengthened with NNSA Office of Nuclear Materials Integration
  - SC involved in internal Working Groups
  - IP access to materials before disposed
  - IP access to size of inventories
  - IP participated in National Strategic Plan for Nuclear Materials
  - Provides effective interface for communication and strategic planning



National Isotope Development Center

- The Department of Energy National Isotope Development Center (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.
- **www.isotopes.gov**
- Information and quotations for products and services can be obtained by contacting: National Isotope Data Center, Oak Ridge National Laboratory, Oak Ridge, TN 37831-6158, Phone: (865) 574-6984, Fax: (865) 574-6986, Email: isotopes@ornl.gov

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Increased Availability of Isotopes

- Bk-249: Produced 22 mg target that led to the discovery of element 117; produced 26 mg for further super-heavy element research
- Cf-249: Provided for actinide borate research
- Cf-252: Re-established production in FY 2009. new six-year contract for FY 2013-2018; industrial applications
- Cu-67: Production campaigns available starting Feb 13; cancer therapy
- Li-6: Production of metal form for neutron detector isotope sales
- Np-237: Established inventory for dispensing bulk quantities and capability to fabricate reactor dosimeters
- Se-72/As-72: Developed production capability for Se-72 for use in a generator to provide the positron emitter As-72; medical diagnostic
- Si-32: Produced in the 1990s for oceanographic and climate modeling research, inventory depleted, processing of targets nearing completion to make isotope available again
- Th-227/Ra-223: Established Ac-227 cows for the provision of Th-227 and Ra-223 (alpha emitters for medical applications)
- Y-86: Established production capability of the positron emitter Y-86; medical diagnostic
- Cm-243: Acquired curium with a high Cm-243 content for research applications

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Isotopes under Development

- Ac-225: Developing accelerator production capability
- At-211: Funding production development at four institutions to establish nationwide availability
- Am-241: Initiated project to produce Am-241 in association with an industrial consortium
- C-14: Investigating economic feasibility of reactor production
- Cd-109: Working with industry to assess product specific activity
- Co-57: Evaluating production of Co-57 for commercial source fabricators
- Cs-137 HSA: Pursuing reactor production feasibility for research applications
- Cu-64: Funding production development at multiple institutions
- Gd-153: Pursuing feasibility of reactor production
- Ho-166: Establishing reactor production capability
- I-124: Funding production development at one institution
- K-40: Evaluating possibility of reactor production by irradiating K rather than electromagnetically enriching K-40
- Li-7: Working to establish reserve for nuclear power industry to mitigate potential shortage
- Np-236: Pursuing feasibility of accelerator-based production for security reference materials
- Pa-231: Purifying 100 mg for applications such as fuel cycle research
- Sr-89: Investigating economic feasibility of reactor production
- U-233: Evaluating acquisition of mass separated U-233 for research applications
- U-234: Investigating alternatives for provision of U-234 for neutron flux monitors
- Zn-62/Cu-62: Funding production development for Zn-62 for use in a generator to provide the positron emitter Cu-62
- Zr-89: Funding production development at multiple institutions

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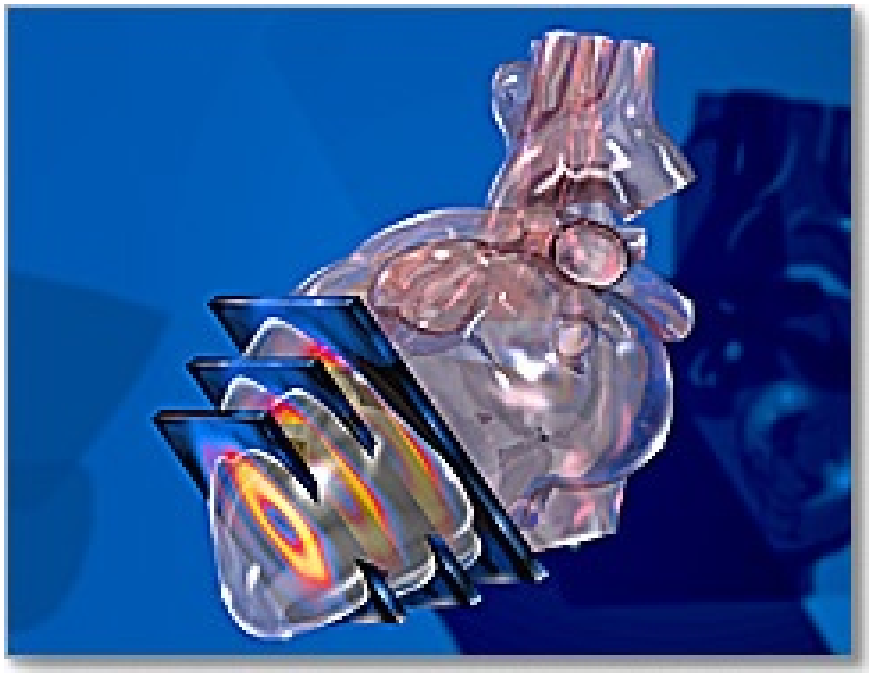
Some Recent Activities/Challenges

- Addressing increased demand for Sr-82 for medical cardiac imaging
- Mitigated shortage of some actinides for super heavy element research- discovery of elements 113-118
- Provision of long-term domestic supply of Cf-252
- Addressing lack of domestic supply of Am-241 (Joel Grimm)
- Re-establish stable isotope production capability in the U.S. (Dennis Phillips)
- Developing production capability for high priority alpha-emitters for the medical community (Dennis Phillips – Ac-225)
- Pb-212/Bi-212 Generators for medical community – addressing unreliable supply
- Commercialization of Sr-82 generator refurbishment
- Commercialization of Ge-68 production
- Re-establish robust HSA Co-60 production in the U.S.
- Update on re-establishing a domestic supply of Mo-99 for medical imaging (Parrish Staples)
- Reliability of commercial heavy water supply – long-term challenges
- Reliability of Li-7 commercial supply – nuclear power plants (Richard Reister)
- Mitigation of short and mid-term He-3 shortage, considering long-term solution
- Status of He-4 supply (Gerald Blazey)

Rubdium-82 for PET perfusion imaging

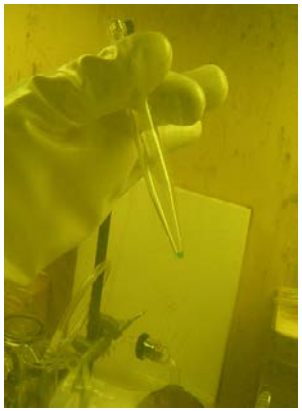
- Sr-82 ($t_{1/2}$ = 25.4 d)/Rb-82 ($t_{1/2}$ = 1.26 m)
- Rubidium-82 used for PET myocardial perfusion imaging
- FDA approved in 1990, Distributed by Bracco Diagnostics
- Manufactured by GE HealthCare and Nordion, International
- Sr-82 produced at both IPF and BLIP – at capacity
- Pursuing initiatives (target design, beam rastering) to increase yields
- Long-term: possibility for commercialization

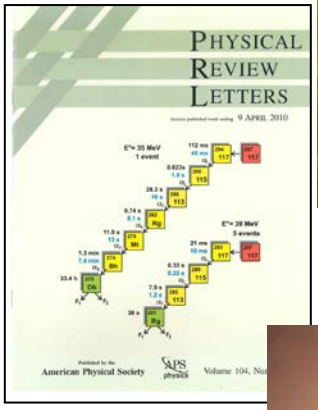


PET Image displaying multiple image cross sections

High Priority Isotopes Identified by NSAC

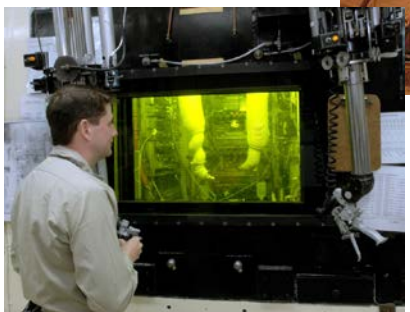
- NP is the sole provider of research isotopes for super heavy element discovery research
  - 22 mg of Bk-249 produced as by product of Cf production for collaborative experiment between U.S. and Russia leading to the discovery of element 117
  - NP supported production of ~ 25 mg of Bk-249 for follow-up search to discover element 119 and 120
  - Super heavy international community has developed multi-year plan for isotope needs – we are working to address for continued research





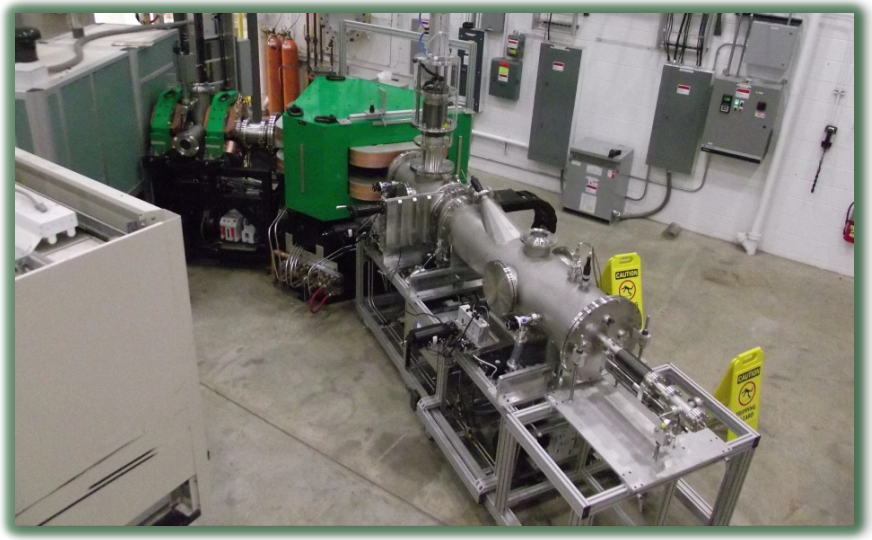
- New contract for long-term supply of Cf-252 for Nation
  - Supplies 97% of domestic market
  - Implementing significant infrastructure improvements at HFIR in the area of remote target fabrication, feedstock replenishment, Cf wire fabrication and analytical equipment
  - New contract in place through FY2018; provision for research quantities

- Re-establishing domestic Am-241 production
  - Project initiated in November 2011
  - 500g per year starting FY16
  - Exploring other sources as well, based on demand



Re-establish Production of Enriched Stable Isotopes in the United Stated

- Calutrons have not operated for over a decade.
- Isotope Program manages inventory – depleted/short for many isotopes in demand.
- Developing concepts for modern stable isotope separation technology: electromagnetic separation coupled with gas centrifuges.
- Smaller scale enrichment of specific isotopes for research
- ORNL 10 mA EMIS commissioned December 15, 2011; now developing 100mA ion source
- Successful peer review in August 2013
- Transitioning from R&D to prototype production facility – September 2013



Alpha-Emitter Production for Targeted Radiotherapy – NSAC high priority

- Actinium-225
  - Continue to process the Th-229 for Ac-225; up to about 360 mCi per year.
  - R&D has been supported to demonstrate the viability of production of Ac-225 via high energy proton-induced spallation of thorium-232 targets.
  - Developing production scale targets and processing techniques in order to implement regular and full-scale production of the isotope

- Actinium-227
  - Separated and purified Ac-227 from surplus actinium-beryllium neutron sources at ORNL and other from legacy Ac-227 at PNNL.
  - The Ac-227 can be used as a source (cow) for the decay production of very high purity Th-227 and Ra-223, important alpha-emitting isotopes for medicine.

- Astatine-211
  - Developing Nation-wide production network (2013 - ~ 2016) at four institutions

Recent Market Considerations

- Pb-212/Bi-212 generators are used for cancer therapy research
- Commercialization of generators occurred in 2002; did not succeed
- Recent decision made to re-enter market to provide reliable supply
- Availability expected in ~ 6 months

- Requested by industry to consider exiting the market on refurbishment of Sr-82 Generators
- Generators used for cardiac imaging
- Decided to remain in market due to lack of effective competition

- Requested by industry to consider exiting the market on commercial Ge-68 production
- Medical isotope used for diagnostic imaging and calibration source for PET machines
- Published notice to consider exiting market in March 2013
- Evaluation in process and decision expected in early 2014

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Re-establish Domestic Co-60 Production in U.S.

- Target failure in June 2012 at INL ATR impacted world-wide availability of high specific activity material
- HSA Co-60 used for gamma knife surgery and gamma radiography devices
- Isotope Program established multi-lab group to design robust target for use in multiple reactors to ensure more reliable supply

Long-term Supply of Commercial Heavy Water – a Concern

- Concerns over **long term reliable supply** of heavy water
- Heavy water (D_2O) is water (H_2O) whose hydrogen content has been enriched in deuterium (typically to >99.84% for U.S. commercial uses)
- A shortage of heavy water could have implications for the **missions and R&D efforts of some Federal agencies**, such as DOE (SC, NNSA, NE) or NIH
- Used in **bio-chemical research** to study chemical reactions occurring in living organisms and are heavily used as isotopic tracer in analytical and biochemical sciences
- Important applications in **nuclear magnetic resonance and mass spectroscopy** (
- Used in **semiconductor and optical fiber fabrication**
- Heavy water is a **nuclear proliferation concern** because heavy-water-moderated reactors can be fueled with natural uranium, providing the capability to produce plutonium for nuclear weapons without the need to establish uranium enrichment capabilities. Heavy water reactors can also be a source of tritium for nuclear weapons (deuterium is transformed into tritium in a nuclear reactor.
- There are **national security needs** (R&D, including the National Ignition Campaign, and nuclear weapons refurbishment), which **are satisfied** by DOE reserve
- Ontario Power Generation is **primary supplier** for U.S. commercial needs – announced that **will withdraw** from market
- Have been **facilitating discussions** with U.S. industry and State Department/OSTP to obtain international supply
- Will be **contacting** those **agencies** who identified a demand for heavy water in surveys

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Concern over Reliable Supply of Li-7

- Domestic nuclear power industry uses Li-7 as a chemical buffer in its pressurized water reactors
- Concerns raised over reliability of international supply at the first federal workshop
- Assembled internal working group (Isotope Program, NNSA, Office of Nuclear Energy and Office of Intelligence)
- There are risks
- Details in talk by Richard Reister (NE)
- Isotope Program R&D efforts discussed in presentation by Dennis Phillips
- Continuing discussions with nuclear power industry
- Will contact agencies who have identified significant demand for Li-7

He-3 Status

- He-3 extracted from tritium decay; NNSA managed facility and operations; IP coordinates sales and distribution of raw material
- Allocations of He-3 have been through an Interagency Group since 2009
  - Reports to the EOP National Security Council
  - Three Working Groups: Demand, Supply, Alternative Technologies
  - Prioritized and allocated He-3 in FY 2009; FY 2010 , FY 2011, FY 2012, FY 2013
  - Jehanne Gillo chairs the Interagency Group and Isotope Program leads the Demand Working Group
  - 14 Federal Agency Champions – demand forecast process is robust
  - Supply is currently 74,000 liters with ~ 9,700 liters added annually
  - Investments have been made into acquiring additional supply and improving extraction process
  - He-3 auction held in FY 2012 and FY 2013 for 4,000 liters to industry and international customers – complete
  - Mitigation and prioritization efforts on behalf of the IAG have successfully addressed He-3 shortage

  - The current supply is anticipated to meet Federal agency needs beyond FY 2040
  - Isotope Program is currently working with industry to facilitate establishment of domestic commercial supply to extend the lifetime of the federal reserve

Conclusions

- Optimize communication throughout federal complex on isotope supply and demand - Avoid breakdown in communication/coordination that occurred with helium-3 shortage

- One-day meeting and survey provides an opportunity for agencies to present demands important for implementing federal mission, and more importantly, significant changes in demand

- Provide sufficient time to develop isotope production R&D; mitigation plans – many years

- Provides opportunity for Isotope Program to notify agencies of important developments
  - New capabilities – isotope availability which could influence federal missions
  - Potential challenges in supply which could influence federal missions

- Thank you – surveys require effort
  - Important tool to the Program to consider potential areas of concern and consider appropriate government/isotope program role
  - Essential that they capture agency demand needed to implement mission
    - Avoid double counting
    - As opposed to agency opinion of what world-wide demand is
    - As opposed to federally sponsored community demand – which may not align with federal plans

- We want this to be useful to agencies – please – feedback welcome

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