

NSAC Meeting
June 30, 2014

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Director, Facilities and Project Manager Division

Director, DOE Isotope Program

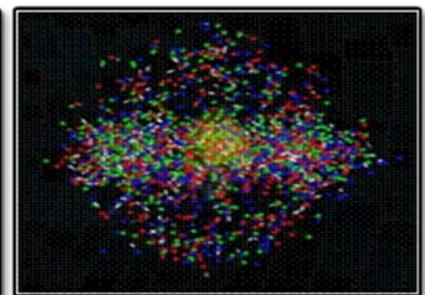
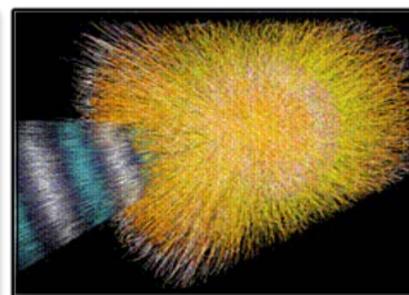
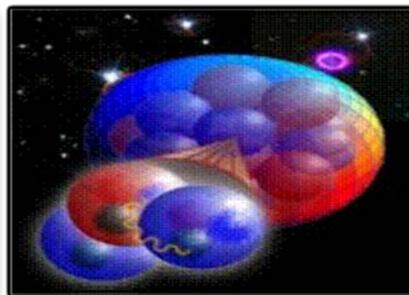
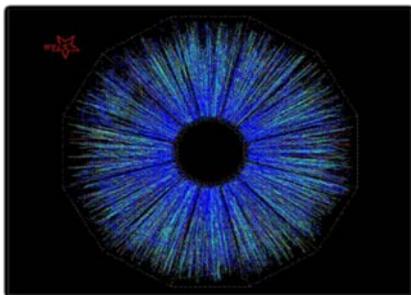
Office of Nuclear Physics, Office of Science, U.S. Department of Energy



Discovering, exploring, and understanding all forms of nuclear matter

FY 2014 Budget Highlights:

- Research at RHIC capitalizes on the 10-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.





Nuclear Physics

FY 2015 President's Request by Subprogram

Budget Structure/ Subprogram (\$ in 000s)	FY 2013 Approp (w/SBIR/STTR)	FY 2014 Enacted	FY 2015 Request	FY 2015 vs. FY 2014
Medium Energy	128,328	148,695	149,892	+1,197
Heavy Ions	193,229	199,693	198,966	-727
Low Energy*	100,190	75,704	75,269	-435
Nuclear Theory	39,057	45,142	43,096	-2,046
Isotope Program	18,483	19,404	19,850	+446
Construction	40,572	80,500	106,500	+26,000
TOTAL NP	519,859	569,138	593,573	+24,435

* FRIB included in Low Energy in FY 2013 (\$22M)

Increase in the FY 2015 budget request for NP is dominated by the construction profile of FRIB



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)*

**>225 customer orders in
FY2013
>470 shipments in FY2013

FY 14 Enacted: \$19.4M
FY 15 Request: \$19.9M**

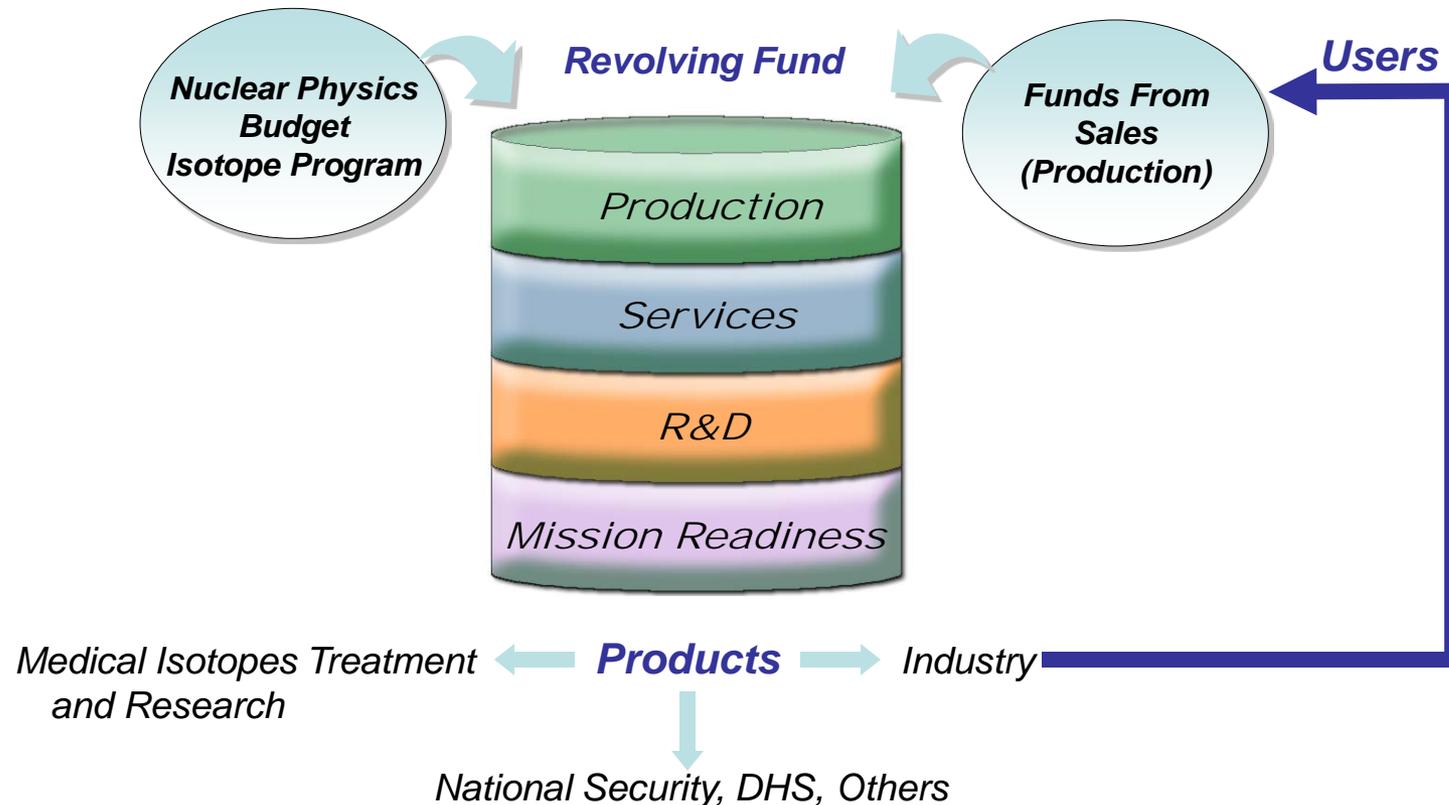


*Brookhaven Linac
Isotope Producer*



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.**

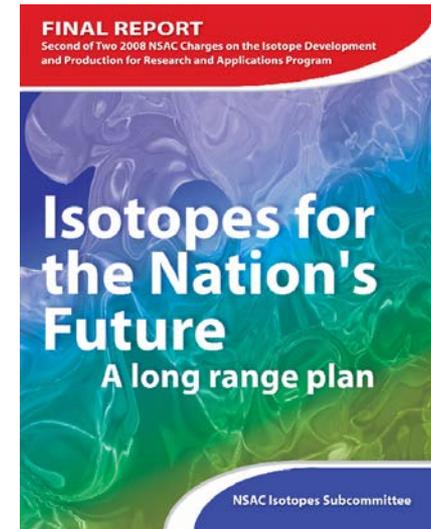


- **Prior NSACI recommendations**
 - All have been addressed

- **NSAC COV**
 - Isotope Program participated for first time January 2014
 - “NP is providing clear leadership on issues of national importance, and the process and community guidance have been improved.”

- **NSAC assessed NNSA Mo-99 approach**
 - Report completed on May 8, 2014
 - Two recommendations:
 - “...focus resources on the most promising CA agreements.”
 - “...consider relaxing their present \$25M cap on investment in any project.”

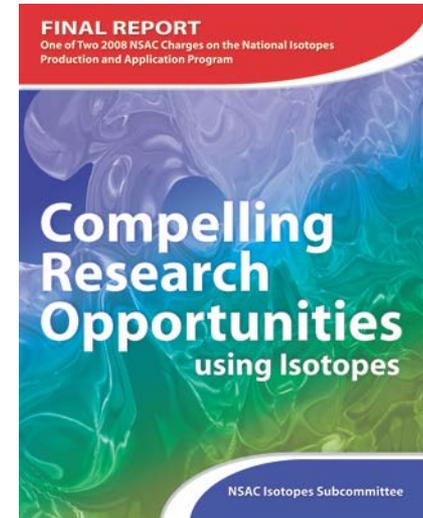
- **NSAC charged to assemble NSACI and develop new LRP**
 - Strawman committee identified
 - Report due March 25, 2015





Compelling Research Opportunities using Isotopes

- **[Res-1]** Invest in new production approaches of alpha-emitting radionuclides, e.g. Ac-225, At-211.
- **[Res-2]** Invest in coordination of production capabilities and supporting research.
- **[Res-3]** Produce isotopes of the heavy elements, e.g. Cf, Ra, TRU.
- **[Res-4]** Focused study and R&D on new or increased production of He-3.
- **[Res-5]** Re-establish domestic production and supply of stable isotopes.
- **[Res-6]** Robust investment into education and training.





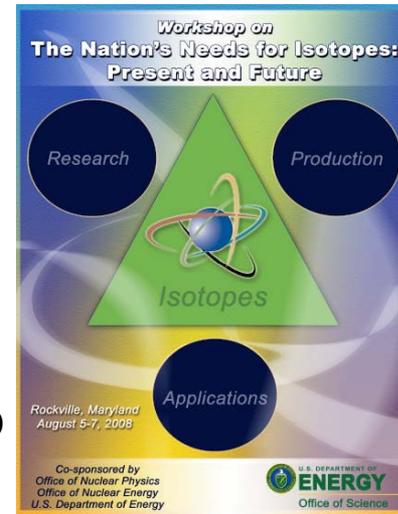
NSAC Long Range Plan Recommendations

- **[LRP-1]** Maintain a continuous dialogue with all interested federal agencies and commercial isotope customers to forecast and match realistic isotope demand and achievable production capabilities.
- **[LRP-2]** Coordinate production capabilities and supporting research to facilitate networking among existing DOE, commercial, and academic facilities.
- **[LRP-3]** Support a sustained research program in the base budget to enhance the capabilities of the isotope program in the production and supply of isotopes generated from reactors, accelerators, and separators.
- **[LRP-4]** Devise processes for the isotope program to better communicate with users, researchers, customers, students, and the public and to seek advice from experts.
- **[LRP-5]** Encourage the use of isotopes for research through reliable availability at affordable prices.
- **[LRP-6]** Increase the robustness and agility of isotope transportation both nationally and internationally.
- **[LRP-7]** Invest in workforce development in a multipronged approach, reaching out to students, post-doctoral fellows, and faculty through professional training, curriculum development, and meeting/workshop participation.
- **[LRP-8]** Construct and operate an electromagnetic isotope separator facility for stable and long-lived radioactive isotopes.
- **[LRP-9]** Construct and operate a variable-energy, high-current, multi-particle accelerator and supporting facilities that have the primary mission of isotope production.



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

- Restructured the federal organization
 - Now fully staffed [LRP-1, LRP-4]
- Created the National Isotope Development Center
 - Staff dedicated to transportation [LRP-6]
- Created R&D Program
 - Competitive R&D, base R&D [R-2, LRP-3]
- Charged NSAC to set priorities for research & to develop long-term strategic plan
- Increased portfolio of isotope production sites
 - University sites being added in 2014 [LRP-2, LRP-5]
 - Addition of other DOE/NNSA sites [LRP-2]
- Increased availability of research isotopes and made more affordable [LRP-5]
- Introduced peer review into mode of operations
- Improved communication with stakeholders [LRP-1, LRP-4]



FINAL REPORT
One of Two 2008 NSAC Charges on the National Isotopes
Production and Application Program

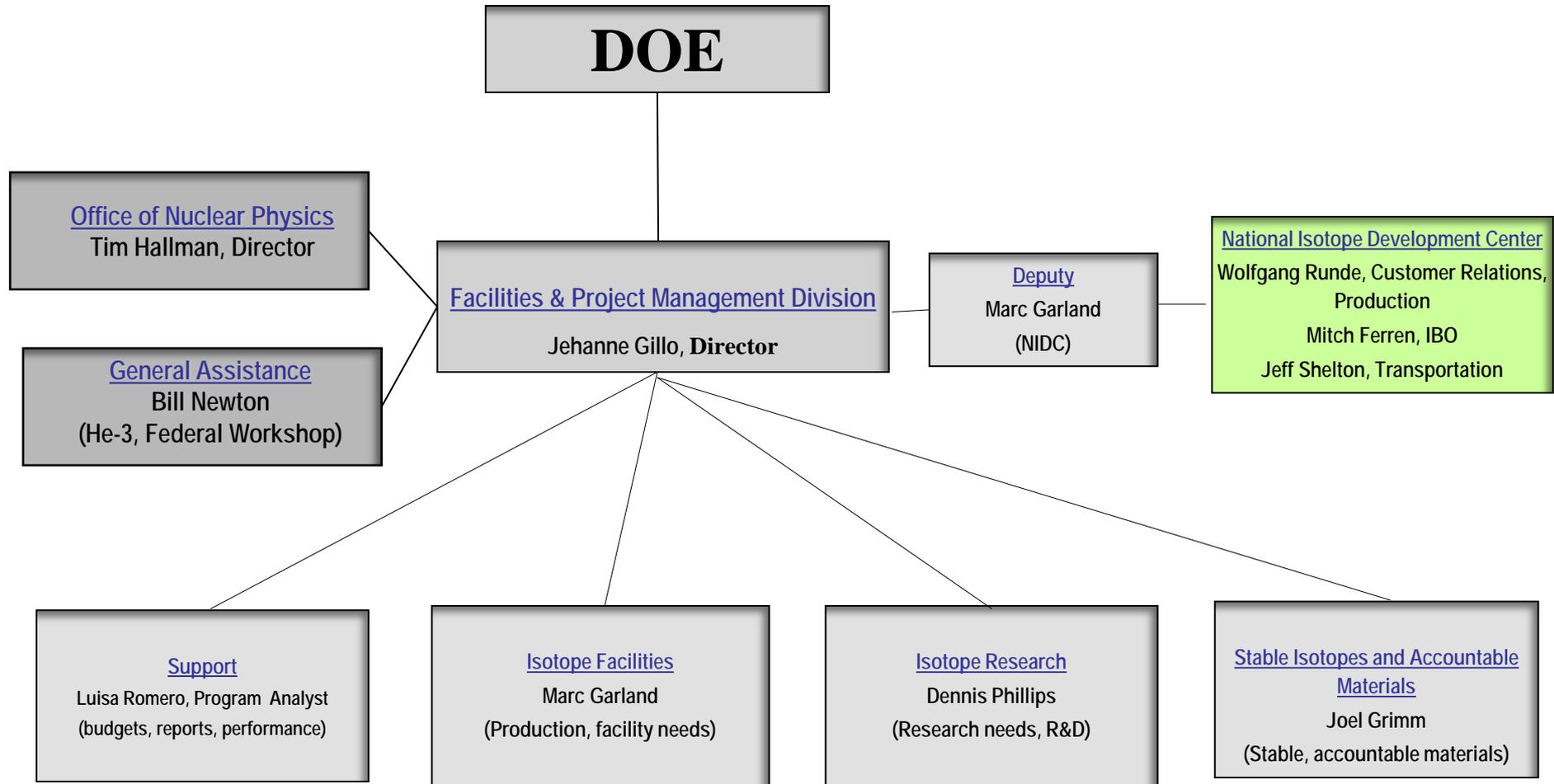
**Compelling
Research
Opportunities**
using Isotopes

NSAC Isotopes Subcommittee

FINAL REPORT
Second of Two 2008 NSAC Charges on the Isotope Development
and Production for Research and Applications Program

**Isotopes for
the Nation's
Future**
A long range plan

NSAC Isotopes Subcommittee

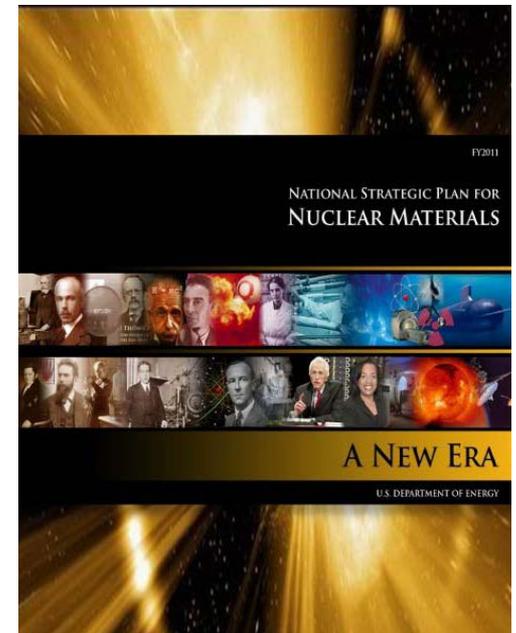




- The Department of Energy National Isotope Development Center (includes the Isotope Business Office located at Oak Ridge National Laboratory) coordinates the distribution of all DOE isotope products and services available from DOE facilities.
- All contractual discussions with customers
- **Responsibilities in transportation, Q&A, public relations (website, newsletter, booth), cross-cutting technical topics**
- Customers maintain limited technical discussions with sites
- **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
- **[LRP-1,LRP-4,LRP-6]**

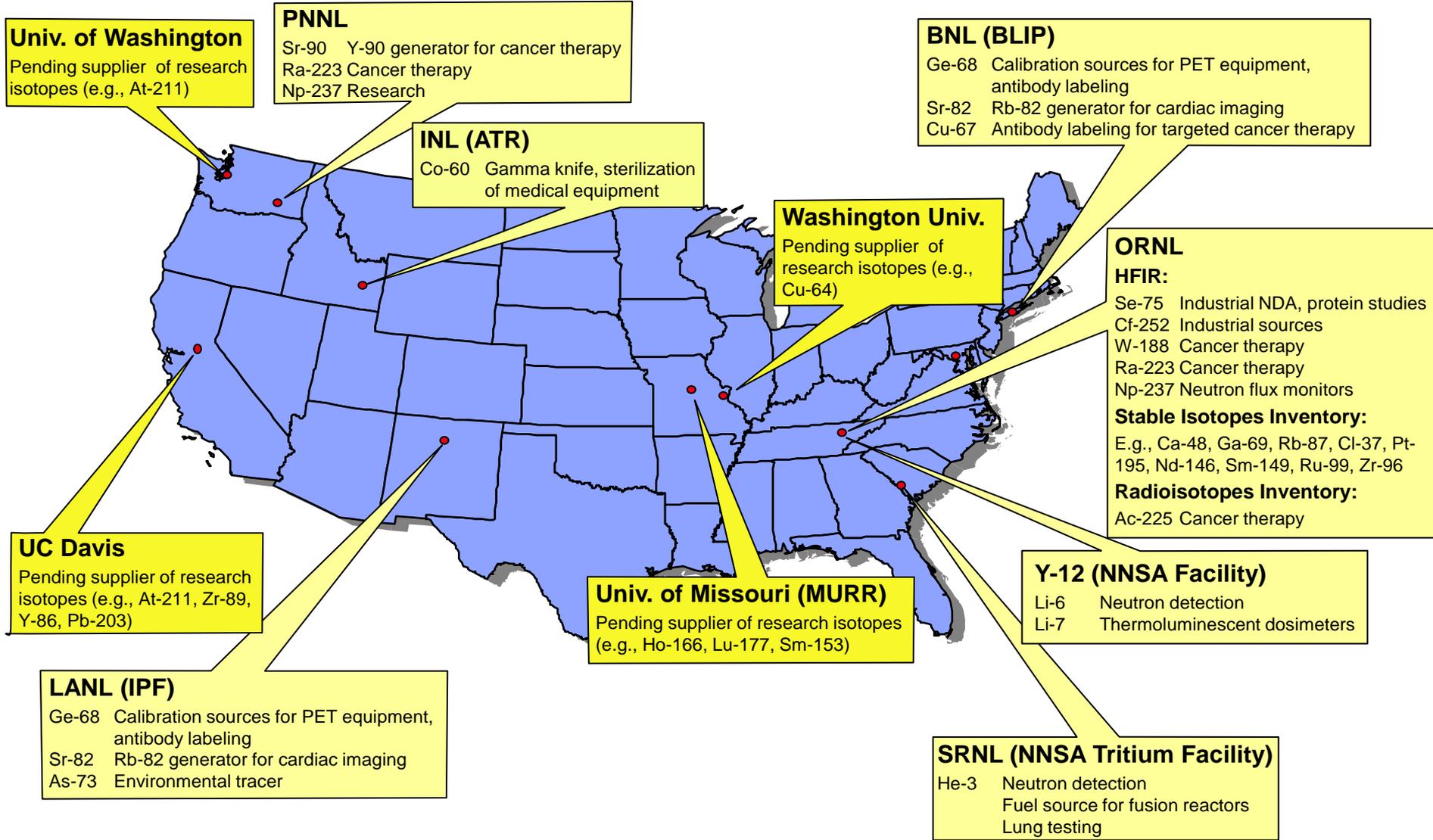


- The IP provides services to manage the distribution of isotopes that are owned by other programs
 - Most of these are legacy materials owned by other DOE programs because of stockpile stewardship
 - Communication strengthened with NNSA Office of Nuclear Materials Integration
 - IP access to materials 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
 - [LRP-1]





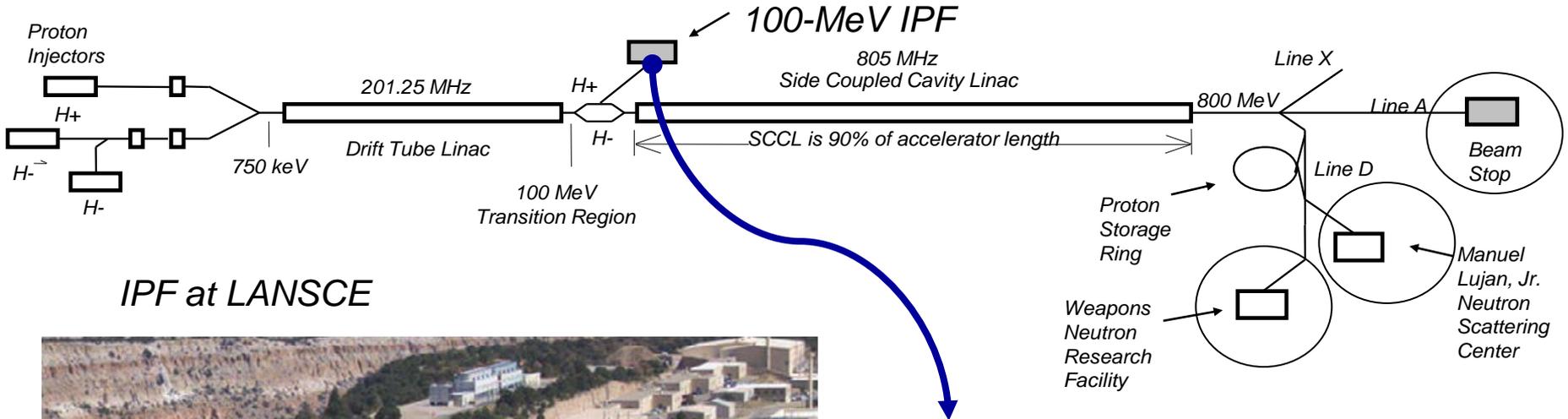
Production Sites Integrated in the DOE Isotope Program [LRP-2]



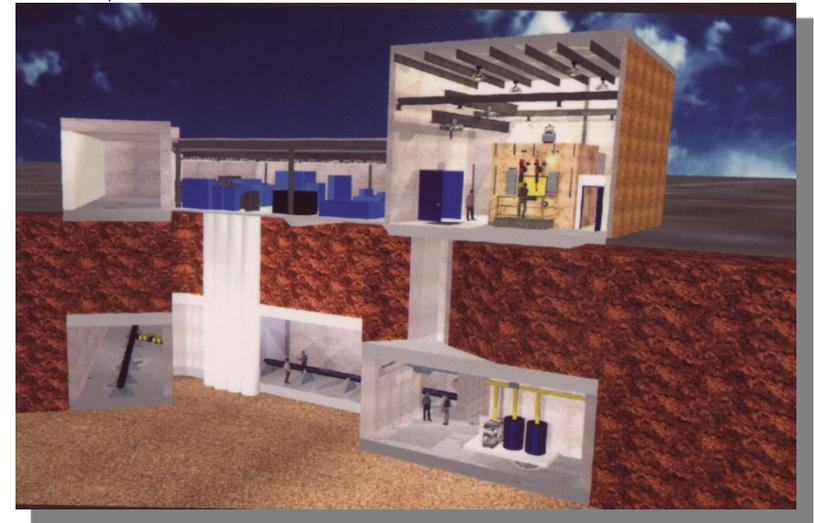
University contracts in 2014; NIH MOU under development



Isotope Production Facility (IPF)



IPF at LANSCE

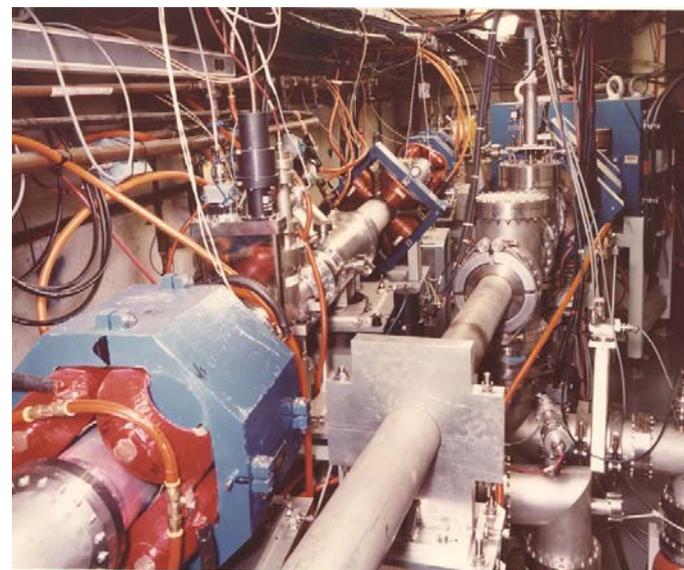


- *Diversion of 100 MeV proton beam to target station*
- *Irradiates targets while LANSCE operates for NNSA/BES*
- **[R-2]**



Brookhaven LINAC Isotope Producer (BLIP)

- 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 $105\mu\text{A}$ intensity to targets; parasitic operation with nuclear physics programs for more cost effective isotope production.
- Implementing beam rastering and/or increasing linac current to increase isotope production capabilities
- [R-2]





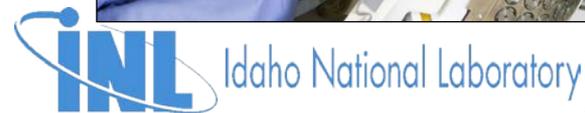
High Flux Isotope Reactor (HFIR) at ORNL:

- High neutron flux ($\leq 3 \times 10^{15}$ n/cm² s)
- Multiple hydraulic tubes, hot cell facilities
- Key Isotopes: Cf-252, W-188, Ni-63, Se-75
- Refurbish equipment
- [R-2, LRP-2]



Advanced Test Reactor (ATR) at INL:

- Moderately high neutron flux ($\leq 4 \times 10^{14}$ n/cm² s)
- Hot cell facilities
- Key Isotope: Co-60
- Investment in new Co-60 design
- [R-2, LRP-2]

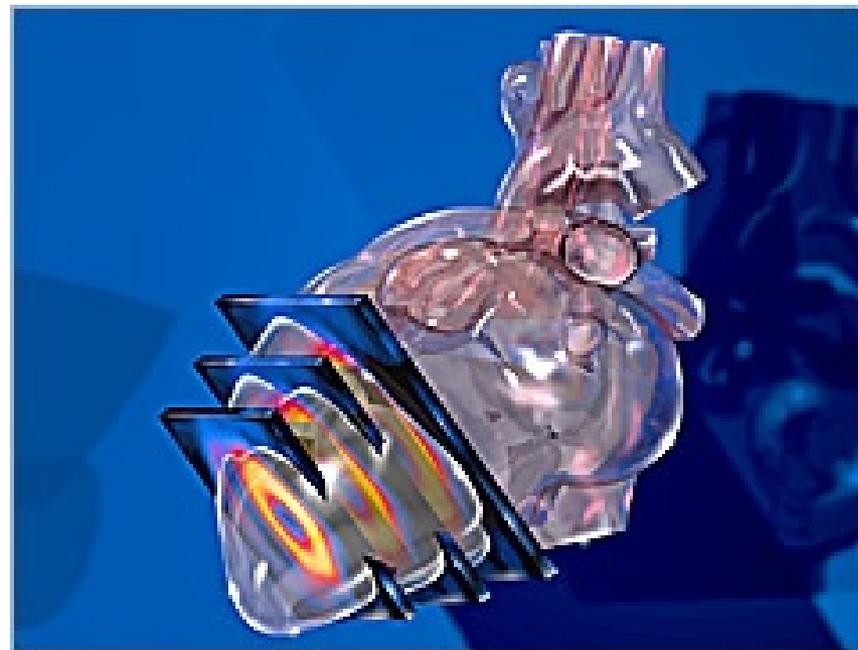




- Sr-82 ($t_{1/2} = 25.4$ d)/Rb-82 ($t_{1/2} = 1.26$ m)
- Rubidium-82 used for PET myocardial perfusion imaging
- FDA approved in 1990, Distributed by Bracco Diagnostics
- Manufactured by GE HealthCare and Nordion, International
- Sr-82 produced at both IPF and BLIP – at capacity
- Pursuing initiatives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

[R-2]

PET Image displaying multiple image cross sections



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

[R-1, R-2, LRP-2, LRP-3]

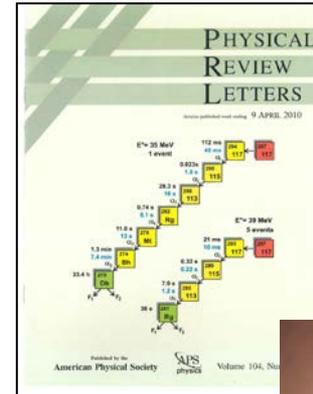
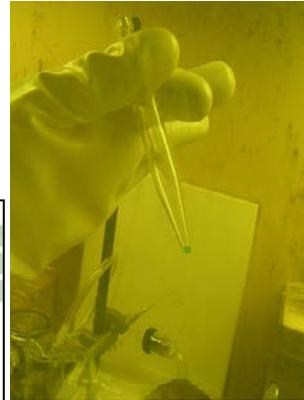




- IP is the sole provider of research isotopes for super heavy element discovery research Bk-249 produced for leading to the discovery of element 117, 119, 120
 - Super heavy international community has developed multi-year plan for isotope needs
 - IP developing plan for production of needed isotope for further super heavy element research

- New contract for long-term supply of Cf-252 for Nation
 - Supplies 97% of domestic market
 - Infrastructure improvements at HFIR on track
 - New contract in place through FY2018; provision for research quantities
 - Working with Industrial consortium

- Re-establishing domestic Am-241 production
 - Project initiated by Isotope Program in November 2011
 - 500g per year starting FY16 (200g in FY15)
 - Working with Industrial consortium



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

- 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
- Transition from R&D to prototype production facility – Start of fabrication in December 2013
- [LRP-8]





- IP facilities were in need of investment to repair aging infrastructure, modernize, increase reliability and efficiency
- Over the past 5 years, ~ \$25M investment in infrastructure, plus Am-241 and ESIPF
- BNL BLIP ~
 - BLIP raster and linac intensity upgrade, hotcells, ventilation system
- INL ~ (Co-60 and HSIS rabbit)
- LANL IPF ~
 - Hotcell windows, manipulators, hot cell train, electrical panels
 - Beam window, targetry, crane rail, single point failures
- ORNL ~
 - target design, Cf-252 equipment, remote handling system, relocation of sub-cat 3 materials

- **Funding Opportunity Announcements**
 - R&D [LRP-6, R-2]
 - New production [R-2]
 - Public Private Partnerships [LRP-9]
- **Audits**
 - Caught up on annual financial audits
 - Closed out IP-related GAO recommendations to DOE He-3 audit; closed out GAO IP Audit, Li-7 Audit
- **Isotope Program Peer Reviews of projects, facilities, FOA [R-2, R-3, R-5]**
- **Large Isotope Program Projects**
 - Establish Am-241 production capability [R-2]
 - Li-7 processing March 2014 [R-2]
 - BLIP Raster November 2013 [R-2]
 - ESIPF Pilot Plant December 2013 [R-5]
 - Cf-252 equipment refurbishment October 2012 [R-3]
 - He-3 equipment refurbishment [R-2, R-3]
 - Co-60 target design [R-2]
 - Projectizing Ac-225 – review in October 2014 [R-1]



- Website overhaul, distribution list, newsletters [LRP-1, LRP-4]
- Professional meetings, symposia, workshop, student support [LRP-7, R-6]
- Industrial Interactions [LRP-1]
 - Added second set of customer meetings in fall
 - CORAR meetings twice a year
 - CORAR Working group on isotopes
 - Cf-252 and Am-241 consortiums formed
 - Facilitating Co-60 restart
 - Increased booth presence at professional meetings
 - Annual customer survey
- Federal Activities [LRP-4]
 - Annual federal workshops
 - Member of OSTP Mo-99 Working Group, Committee on Critical Materials
 - Lead and Member of E OP NSS He-3 IAG
 - Lead Interagency Working Group on heavy water; Interagency Working Group on He-4
 - Member of NRC Task Force on Sealed Sources
 - Lead of DOE Working Group on Li-7
 - NIH/DOE Working Group

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



Valuable for isotope demand forecasting
[LRP-1]

- 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
 - First product undergoing testing – announcement imminent
-
- 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
 - Intent is to exit the market within a year
-
- 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
 - Decision to only partially exit the market; success story to commercialize
 - IP encourages customers to contact new supplier





- **Competitive FOA and Core R&D funding**
 - Creation of base R&D program at all sites
 - Support of postdocs at all of IP sites
 - Succession planning
 - Education is a priority in FOA
 - Support of students at many university and lab sites
- **ECA at Washington U (2010-2015)**
- **Isotope R&D Symposium at ACS Meeting (2010, 2013, 2015)**
- **Workshops on Isotope Harvesting at FRIB (2010, 2012, 2014)**
- ANS Symposium on Radiochemistry Workforce Development (2010, 2014)
- BER Investigators Radiochemistry and Radionuclide Imaging Workshop (2011)
- **Symposium on Targeted Alpha Therapy (2011, 2013, 2015)**
- **“Metals in Medicine” Gordon Conference (2012)**
- **Terachem Symposium on Radiometals in Medicine (2014)**
- DHS Nuclear Forensics Summer School (2012)
- International Workshop on Targetry and Target Chemistry (2012)
- **National Academy of Sciences Committee Report: Assuring a Future U.S.-Based Nuclear and Radiochemistry Expertise (2012)**
- **DNCT/ACS Summer School in Nuclear and Radiochemistry**
- NNSA Sponsored Mo-99 Topical Meetings (2011, 2013, 2014)
- Technical support to NNSA in evaluation of new Mo-99 production modalities



- **Focus of the program is on isotopes in short supply**
 - No production mechanism exists– unique expertise, capabilities
 - Provision of boutique isotopes that are economically not viable
 - Commercial isotopes – raise awareness, encourage recycling, facilitate discussions, R&D on alternatives
- **Assemble input**
 - Federal Workshop
 - Customer Survey
 - Targeted marketing assessments
 - More frequent customer meetings
 - Multiple DOE IP retreats per year
 - Annual IP Business and Planning Meeting
- **Annually update risk assessment**
- **Consideration of sole source and reliance on foreign supply**
- **Annually update internal strategic plan**
- **Goal is a proactive, current, prioritized plan**

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 6 year contract thru 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](#): Inventory for dispensing bulk quantities and capability to fabricate reactor dosimeters
- [Se-72/As-72](#): Developed production capability for Se-72 for As-72 generator; medical diagnostic
- [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 (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
- [R-2, R-3, LRP-5]



- [Ac-225](#): Developing large-scale accelerator production capability
- [Ac-227](#): Developing reactor-based production
- [At-211](#): Funding production development at four institutions to establish nationwide availability
- [Am-241](#): Establishing domestic production capability; product will be available starting FY 2015
- [C-14](#): Exploring reactor production
- [Cd-109](#): Working with industry to assess product specific activity
- [Co-57](#): Evaluating production of Co-57 for commercial source fabricators
- [Co-60](#): Re-establish domestic production
- [Cs-137 HSA](#): Pursuing reactor production feasibility for research applications
- [Cu-64](#): Funding production development at multiple institutions
- [Ho-166](#): Establishing reactor production capability
- [I-124](#): Funding production development at one institution
- [K-40](#): Exploring reactor production
- [Li-7](#): 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
- [Sr-90 HSA](#): Exploring sources to increase availability
- [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

Broaden Perspective on Challenging Isotopes [LRP-1, LRP-4]

Heavy Water- 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 and industry
- Used in **bio-chemical research, nuclear magnetic resonance and mass spectroscopy, semiconductor and optical fiber fabrication**
- **Facilitating discussions** with U.S. industry and State Department/OSTP to obtain international supply
- DOE IP program formed interagency group to consider **supply, recycling, alternatives**

He-4 – Anticipate **constrained supply in 6-7 years**

- Used in **Cryogenics and rocket propulsion systems**
- DOE IP collects demand information from federal complex and provides to OSTP and BLM
- Worked with National Laboratory Chief Scientist Council - survey to all National Labs on recycling
- **Formation of interagency working group** - alternatives, recycling technology



- Domestic nuclear power industry uses Li-7 as a chemical buffer in its pressurized water reactors
- Dependent upon international sources – there are risks to domestic supply
- DOE IP Program assembled internal working group (Isotope Program, NNSA, Office of Nuclear Energy and Office of Intelligence)
- Supporting R&D towards developing new production methods of Li-7
- Establishing reserve of Li-7
- Working with EPRI to better understand demand, inventories
- Working with industry and NE on recycling proof of principle

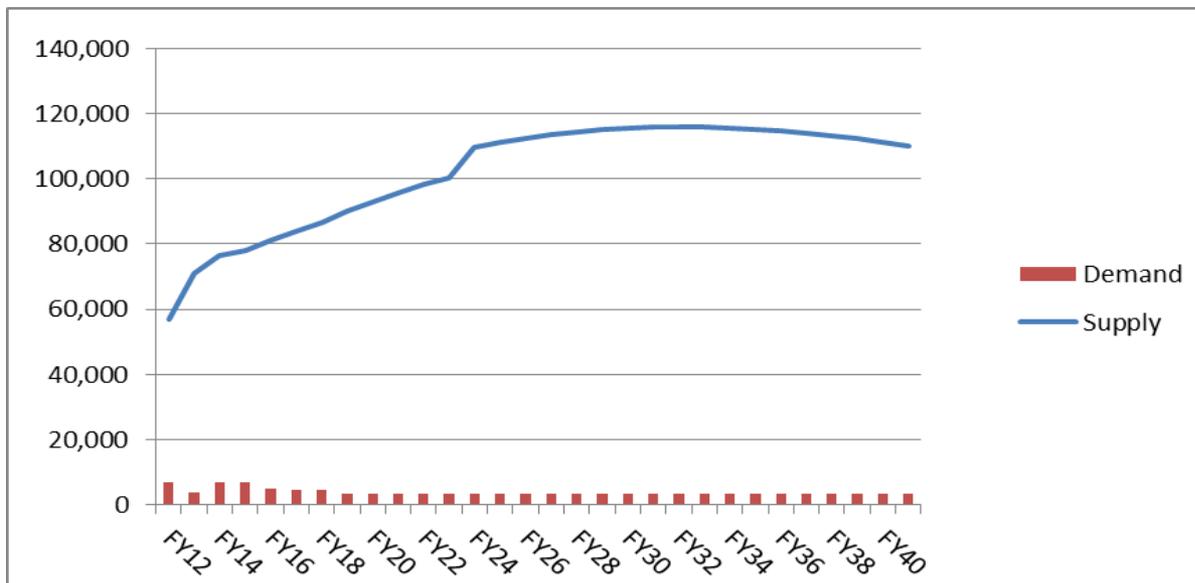


Isotope Program plays a lead role in Interagency He-3 Working Group- reports to White House National Security Staff

Mitigation and prioritization efforts on behalf of the IAG have successfully addressed He-3 shortage

The current supply is anticipated to meet Federal agency needs well beyond FY 2040

Isotope Program is having discussions with industry to facilitate establishment of domestic commercial supply to extend the lifetime of the federal reserve



[R-4]



- Isotope Program
 - Small federal program with limited resources
 - Significant impact
 - Broad array of activities
 - High visibility within Department, community, Congress

- Significant changes in all aspects of program operations

- R&D will be a priority for the program in the near future to ensure long-term viability of program

- Isotope Program remains committed to commercial isotope production

- Isotope Program remains committed to strengthening ties and communication with stakeholders

- Looking forward to new guidance from NSAC