U.S. DEPARTMENT OF ENERGY

OFFICE OF SCIENCE

Workshop on Federal Isotope Supply and Demand
November 9, 2015

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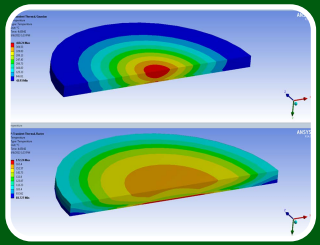
DOE Isotope Program Mission

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

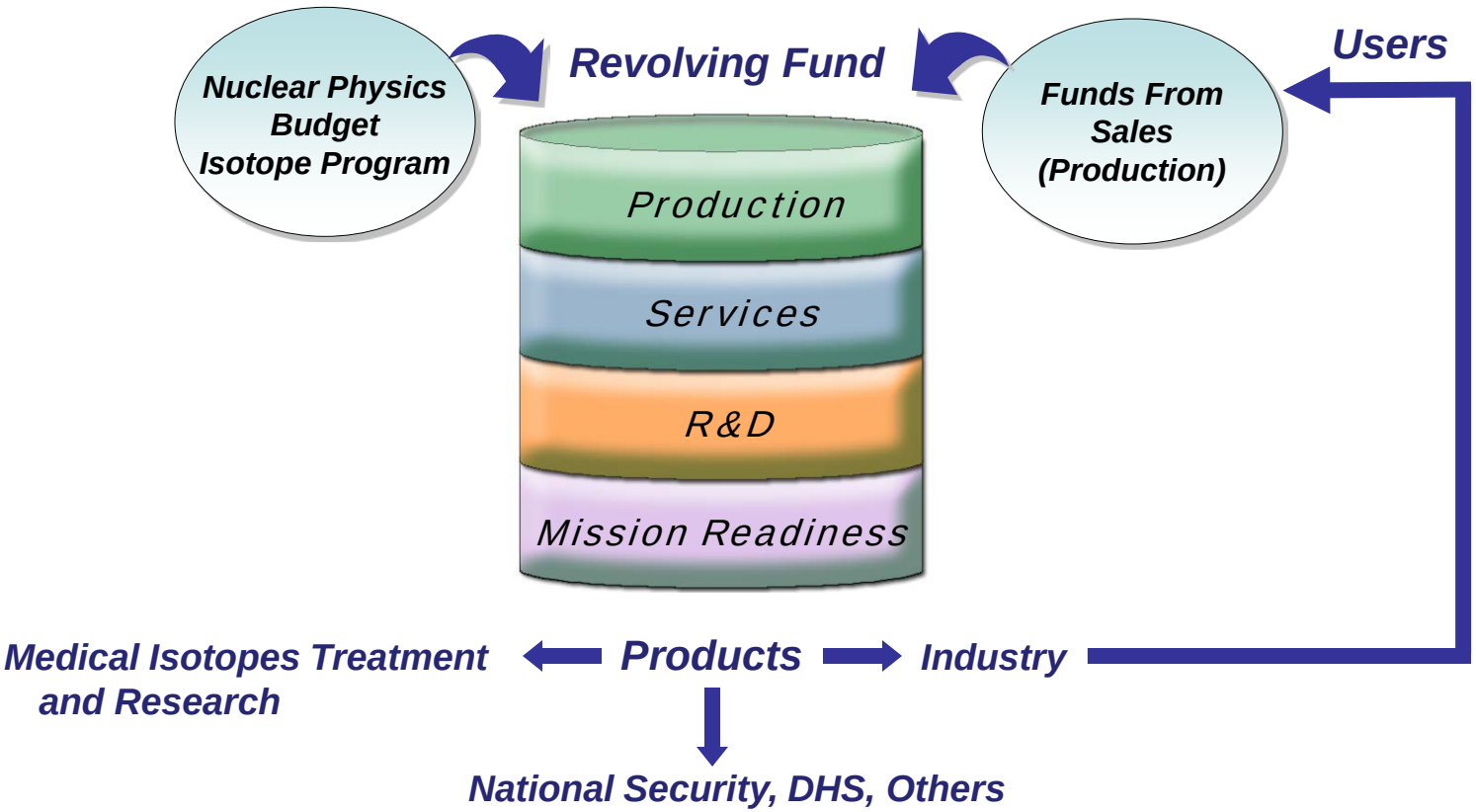


Conduct R&D on new and improved isotope production and processing techniques which can make available priority isotopes for research and application. Develop workforce.

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

Isotope Program Authority and 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**.



4th Workshop on Isotope Federal Supply and Demand, *November 9, 2015*

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.

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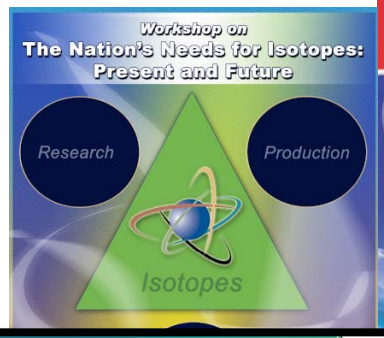
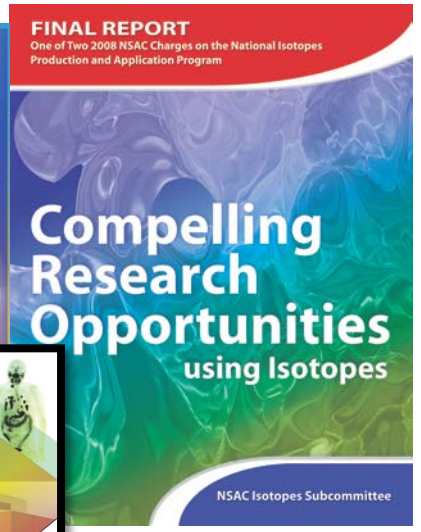
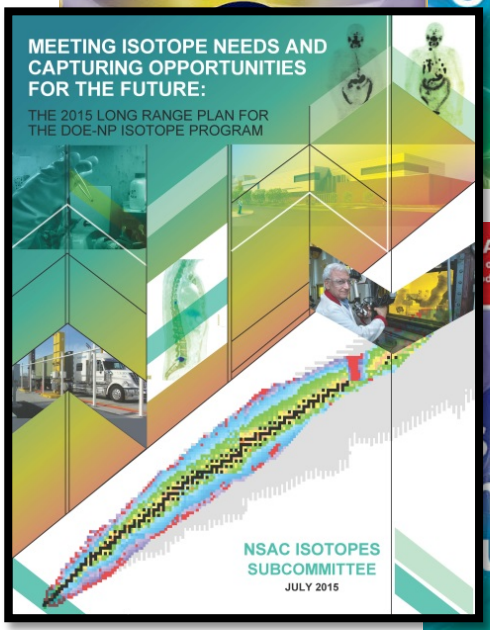
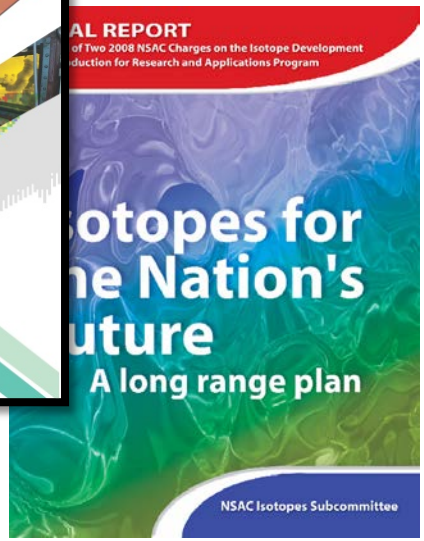
DOE Isotope Program has been re-organized

- 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









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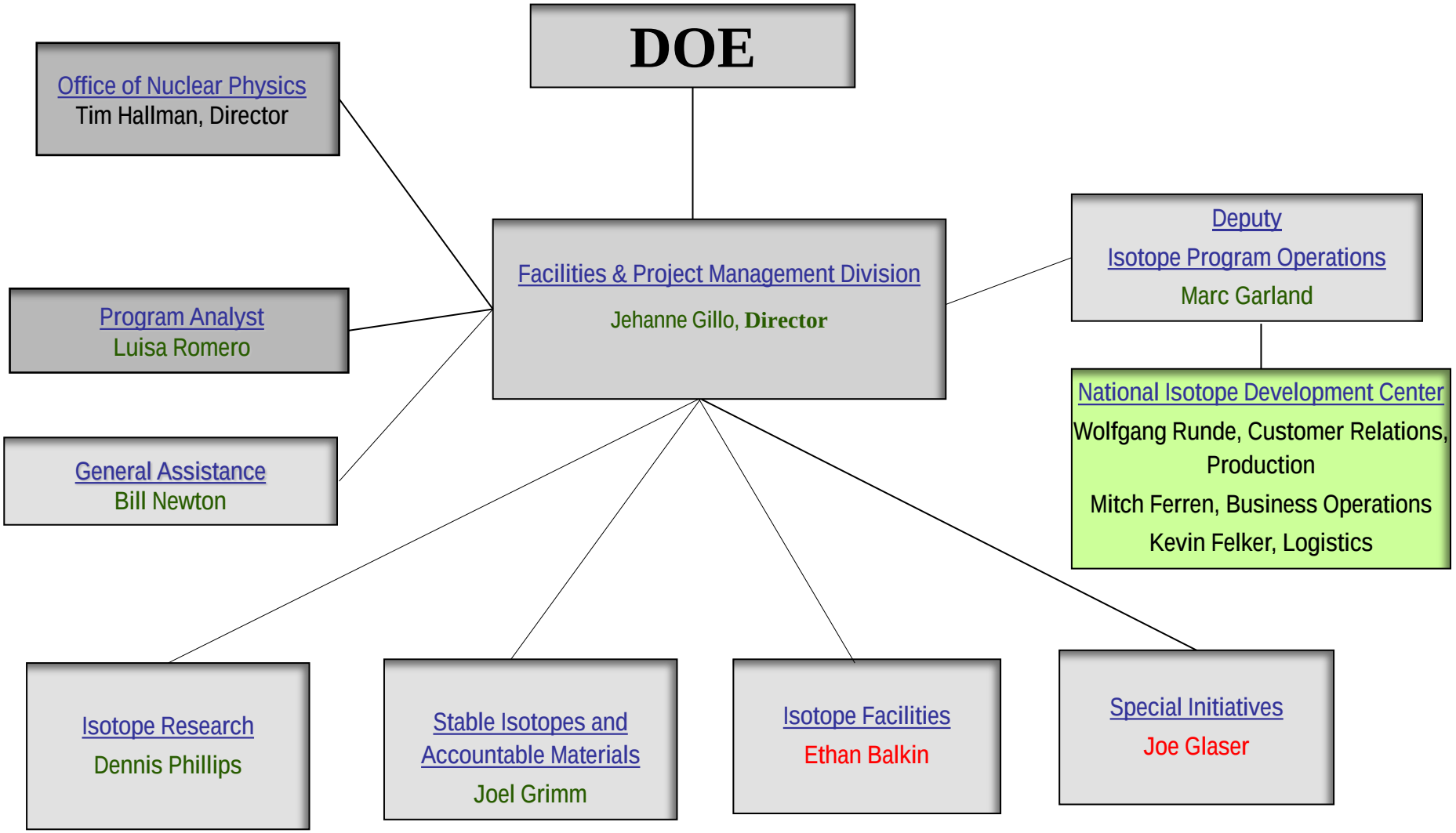
DOE Isotope Program Organization



National Isotope Development Center

- 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**

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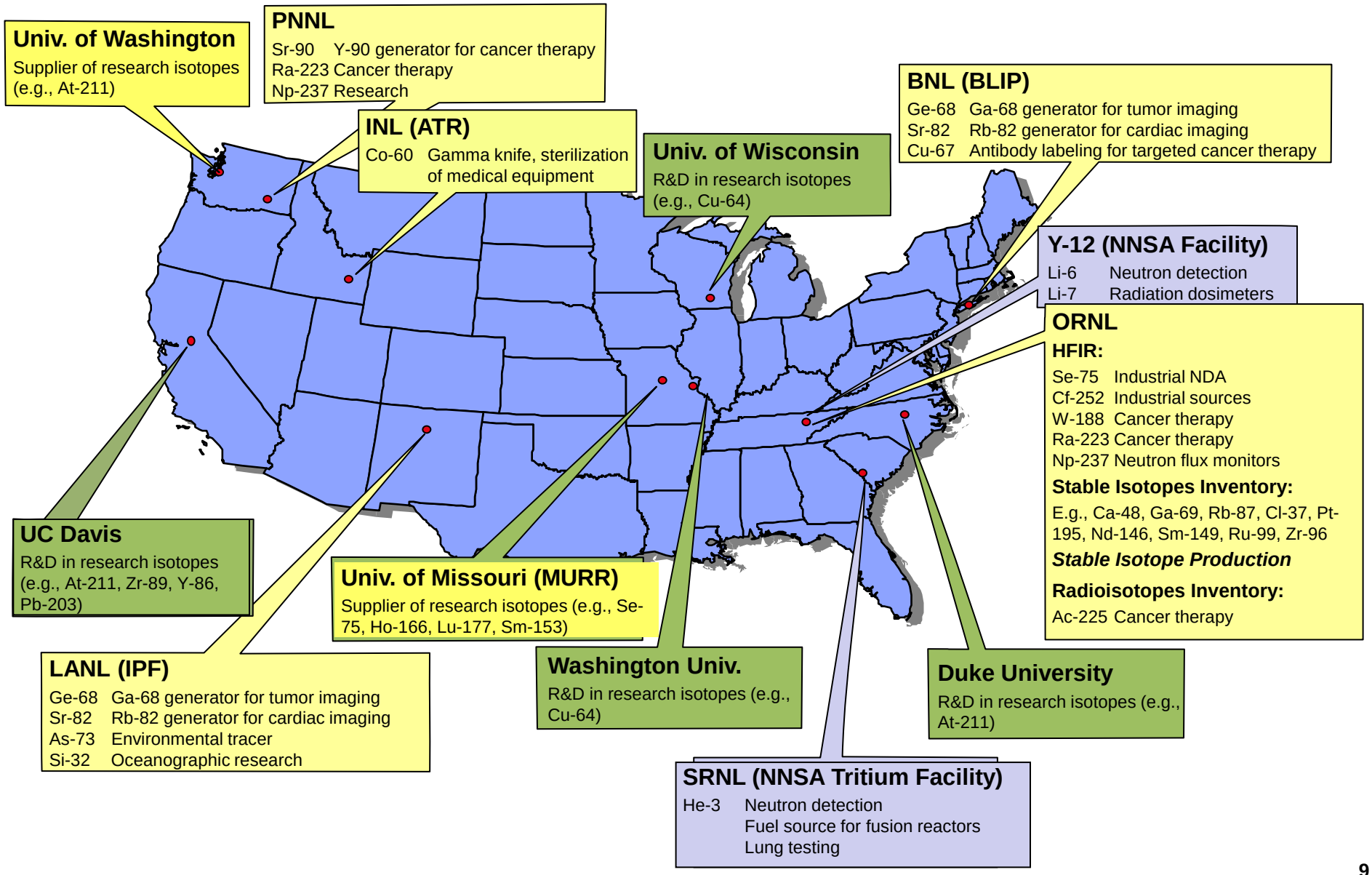
DOE Isotope Program Production and/or R&D Sites



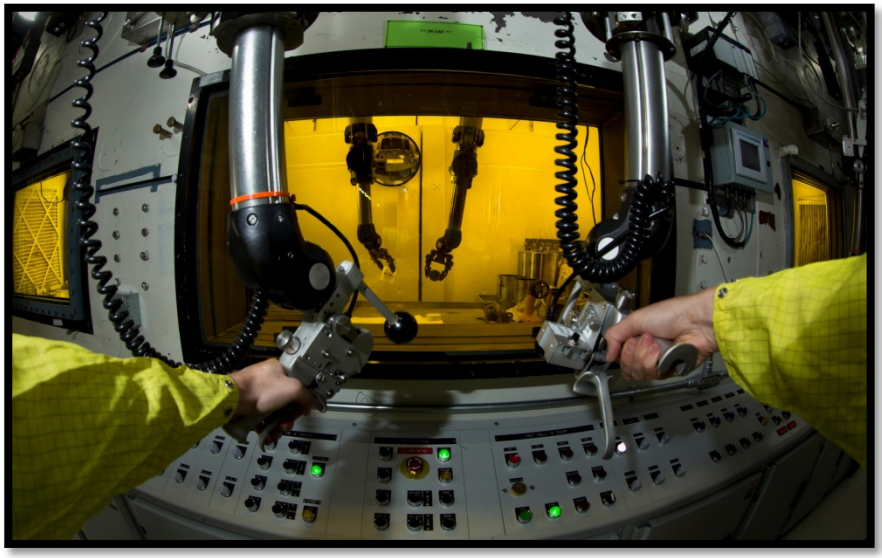
Accelerator Facilities

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



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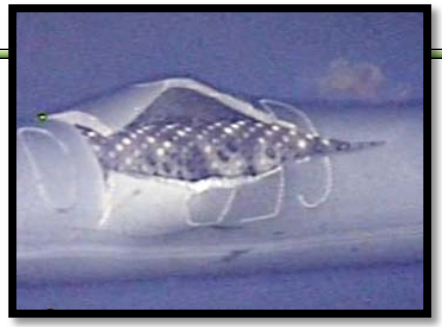
Reactor Facilities

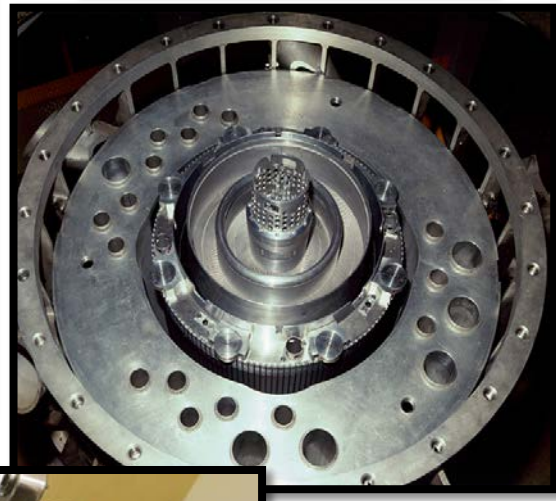
Idaho National Laboratory Advanced Test Reactor (ATR)

- 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

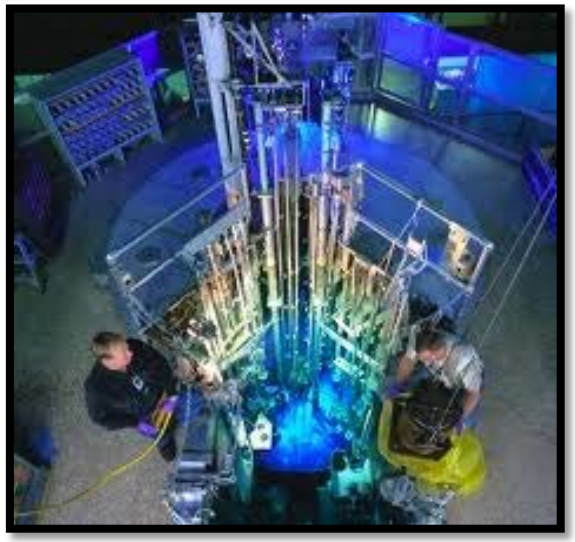
- He-3 extraction from NNSA tritium
- Investments in infrastructure

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

UW cyclotron

- IBO may administer university contracts to fund production and may manage customer sales
- Isotopes under consideration for additional to portfolio



University of Missouri Research Reactor

Examples of Industrial Isotopes

Rubidium-82 used for PET myocardial perfusion imaging

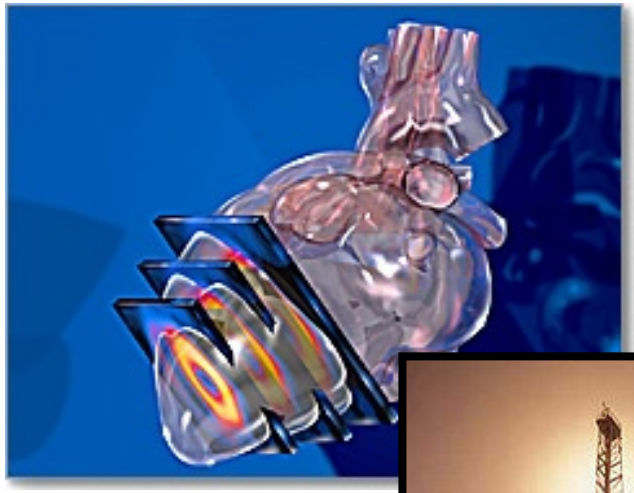
- Sr-82 produced at both IPF and BLIP – at capacity
- Manufactured by GE HealthCare and Nordion
- Pursuing initiatives to increase yields
- Providing aid to industry to promote commercialization

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



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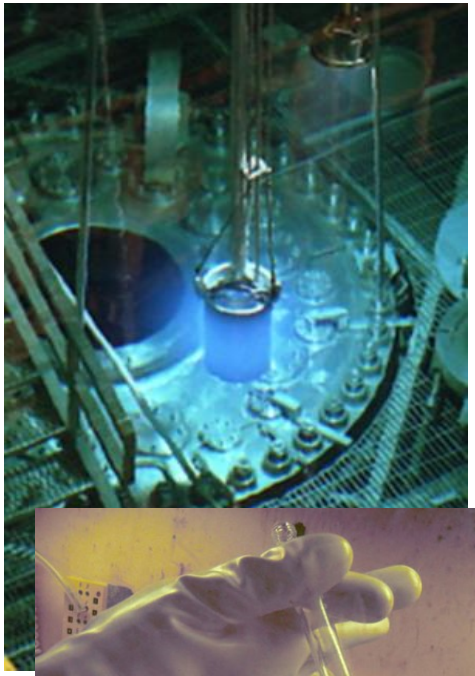
Discovery of Super Heavy Element 117

High Flux Isotope Reactor at ORNL



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

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

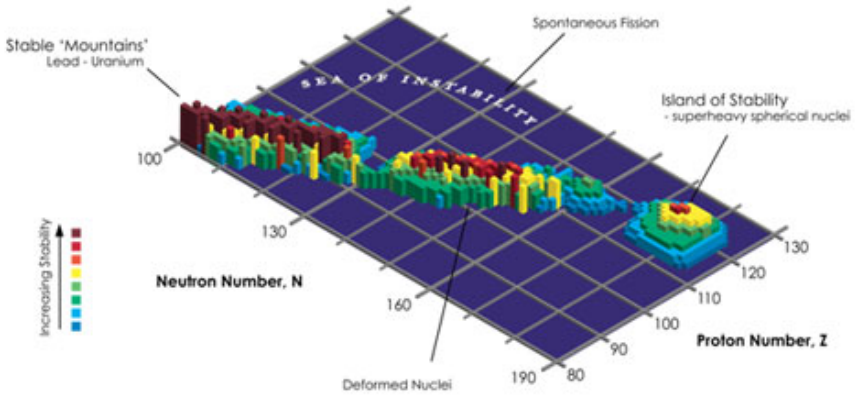
The New York Times

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.



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Actinium-225 Production Development

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

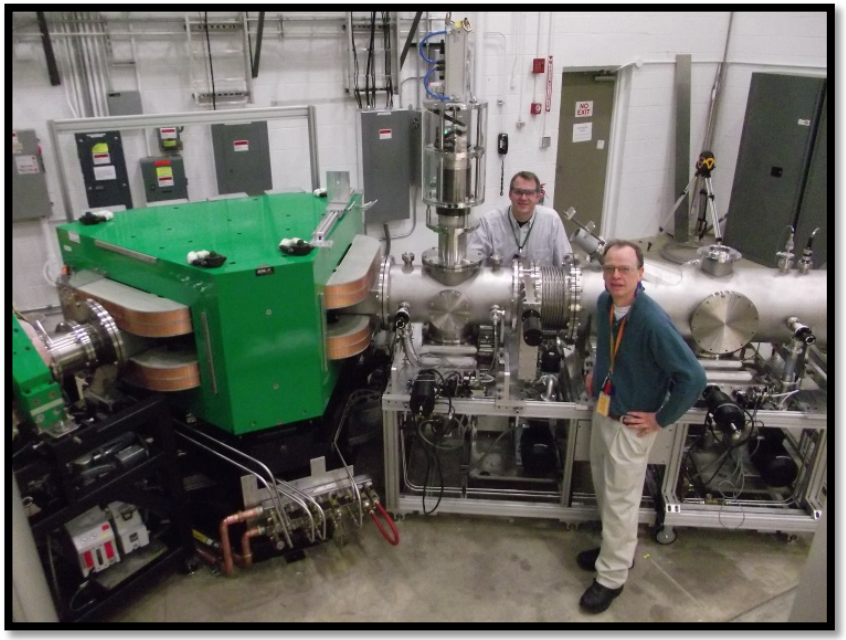
Proton-irradiated encapsulated Th target (left); Dissolved Th target showing blue Cerenkov glow (right).

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



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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

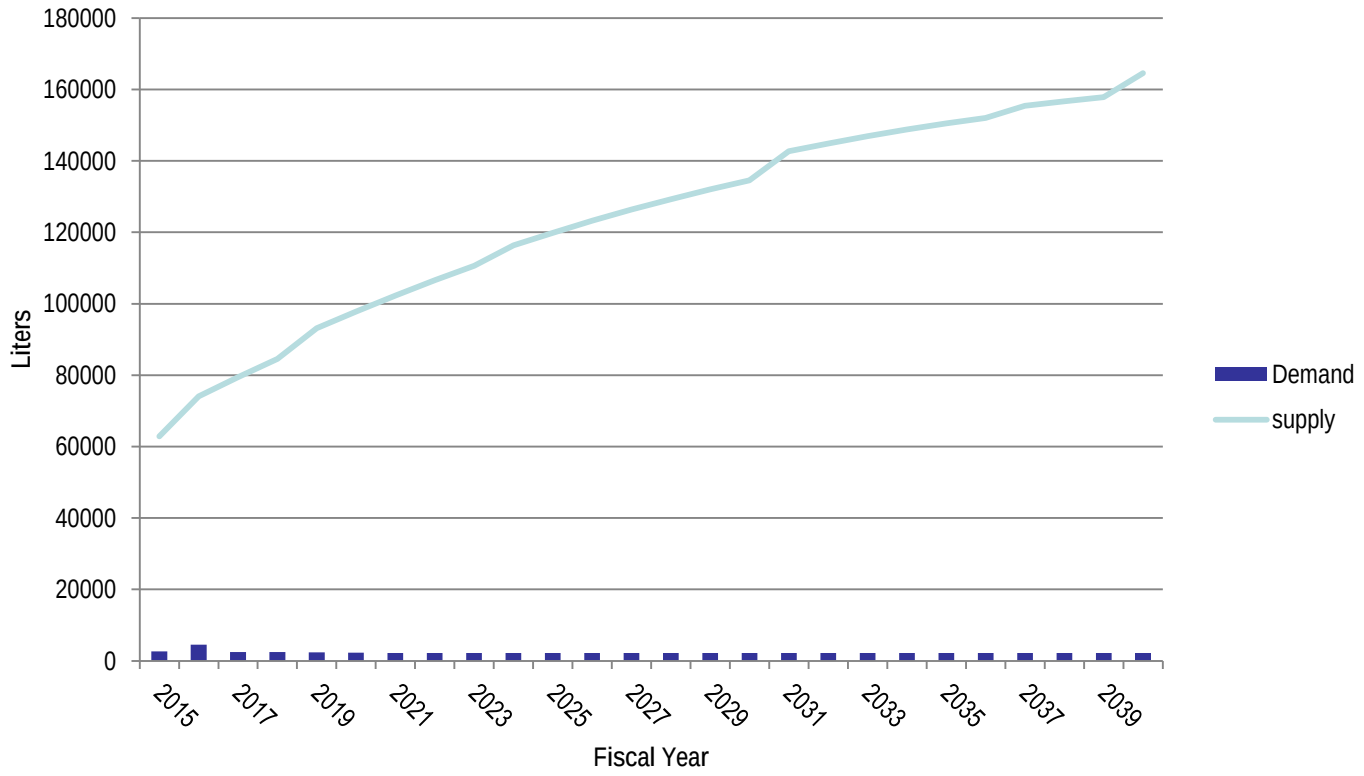
Isotopes under Development

- 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

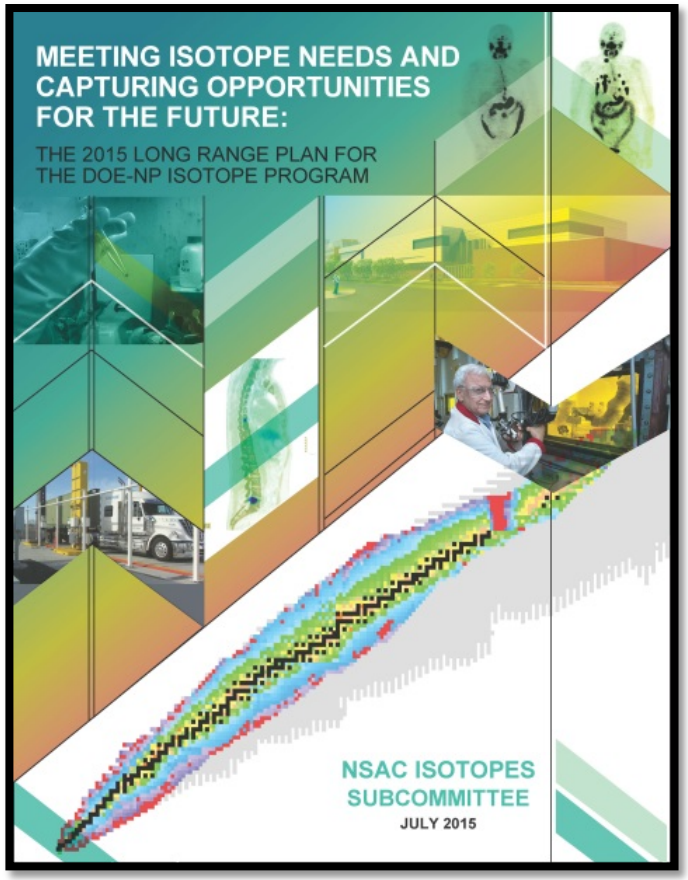
- Li-7 experiences occasional supply constraints, including FY15/16
  - Commercial isotope; Isotope Program not in market
  - Used as cooling reagent in nuclear power reactors – setting up emergency reserves
  - Investment into new production techniques
- He-4 – working with BLM
- High Specific Activity 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

New NSAC Report

New Report released July 20, 2015
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



Communication

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