NSAC Isotope Subcommittee (NSACI) Report

L. Cardman

4/3/15

What is the DOE Isotope Program?

Isotope Development and Production for Research and Applications (IDPRA) or "The 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.

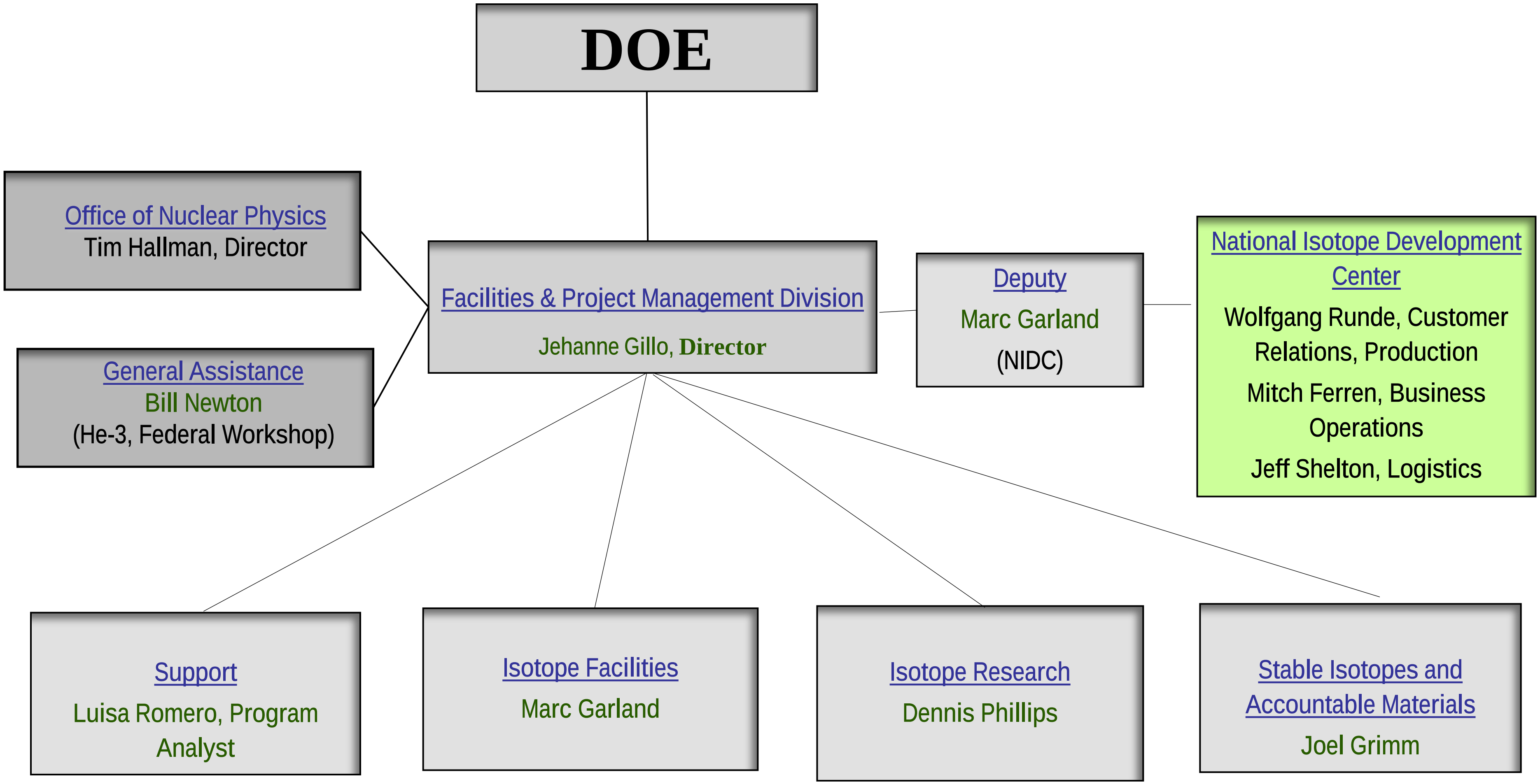
Produce isotopes that are in short supply only – we do not compete with industry

Isotope Production Facility (LANL)

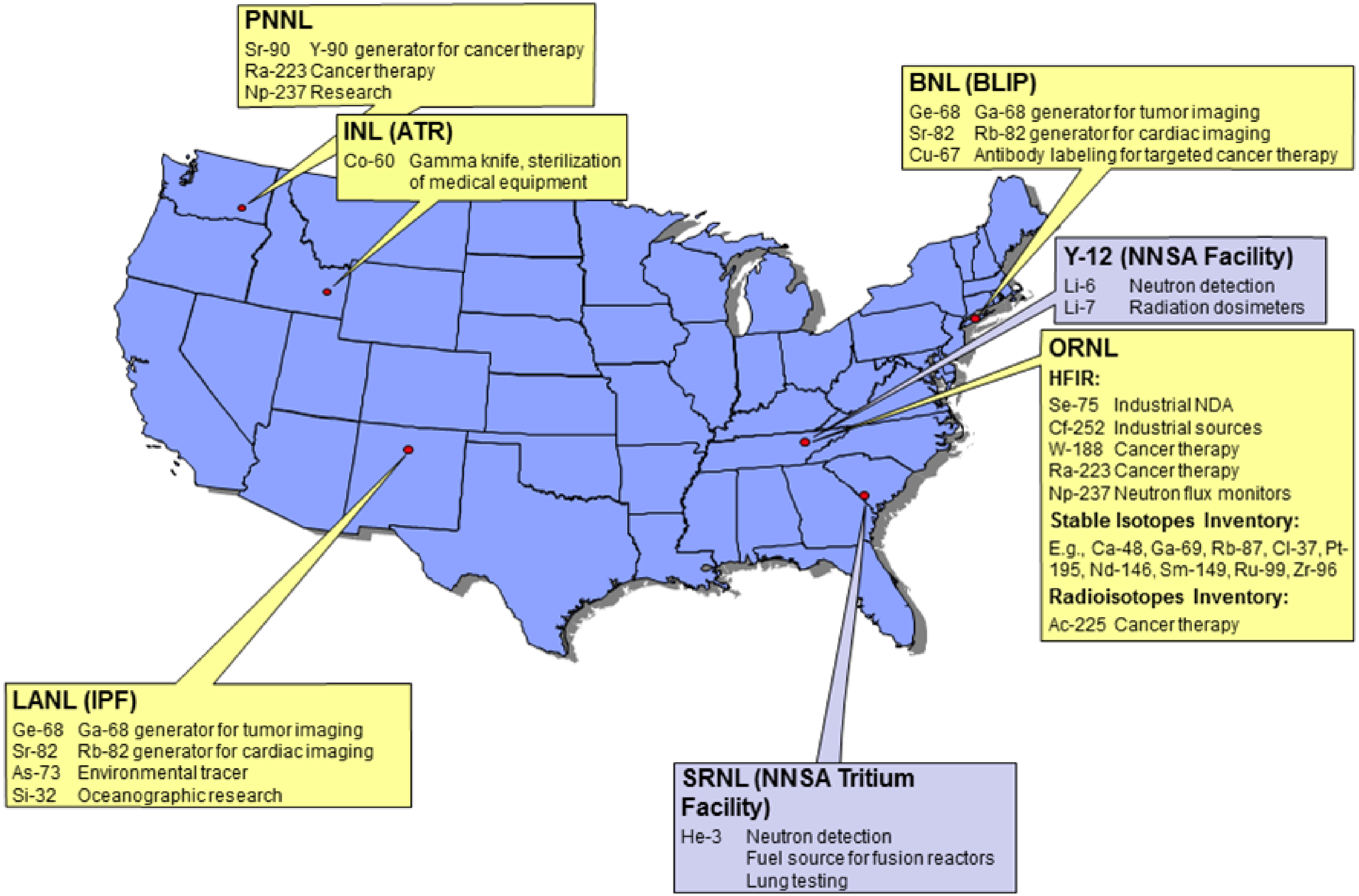
474 customer orders in FY2014
450 shipments in FY2014

Brookhaven Linac Isotope Producer

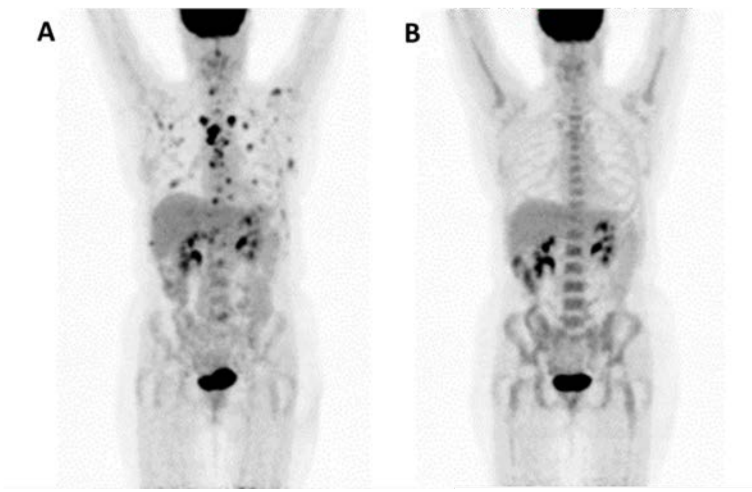
DOE Isotope Program Organization



The Network of DOE Isotope Production Sites and Examples of Isotopes Produced or Distributed from Each Site



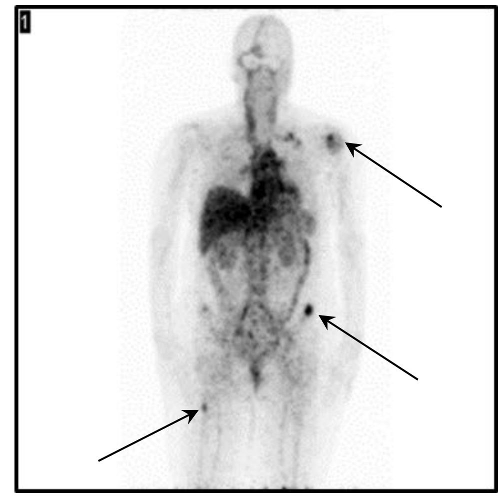
Uses of Isotopes: Biology, Medicine and Pharmaceuticals



[^{18}F]fluorodeoxyglucose scan of a woman diagnosed with T-cell lymphoma.

A. At diagnosis and
B. Following 4 months of chemotherapy

(Image courtesy of Dr. Jonathan McConathy, Washington University in St. Louis.)

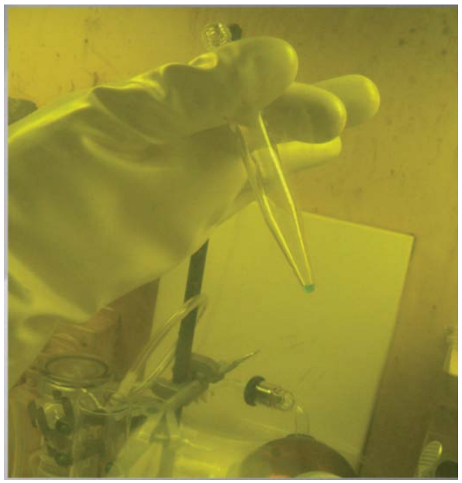


^{89}Zr Trastuzumab scan in a patient with metastatic breast cancer. There is radiopharmaceutical uptake in lesions in the shoulder, hip, and femur (arrows) indicating positive HER2 receptor expression.

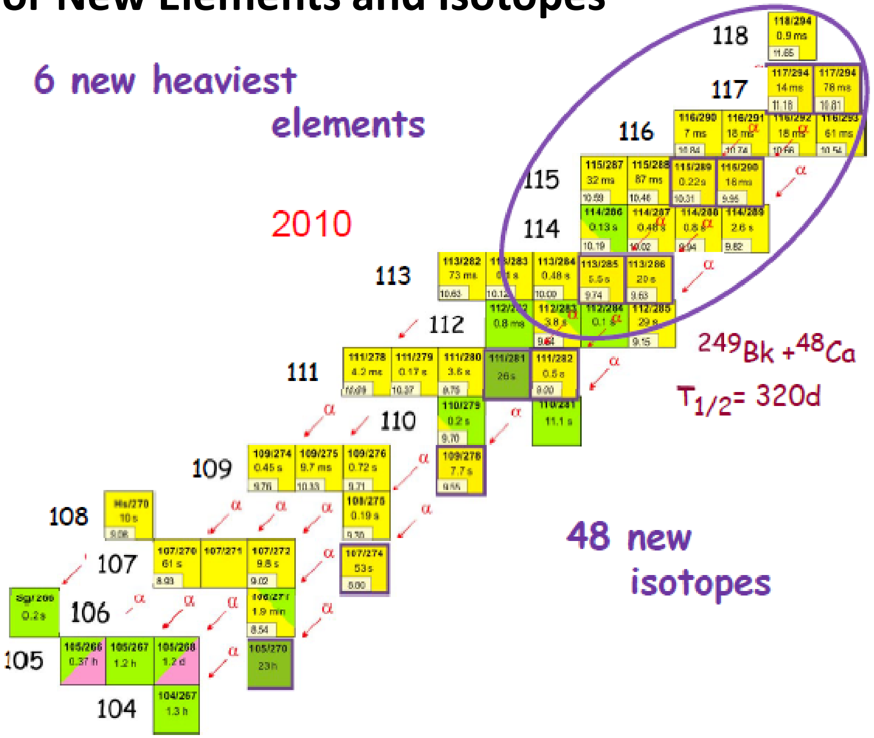
Image courtesy of Dr. Farrokh Dehdashti and Dr. Suzanne Lapi, Washington University in St. Louis

Uses of Isotopes: Physical Sciences and Engineering

Nuclear Physics Example: The Search for New Elements and Isotopes



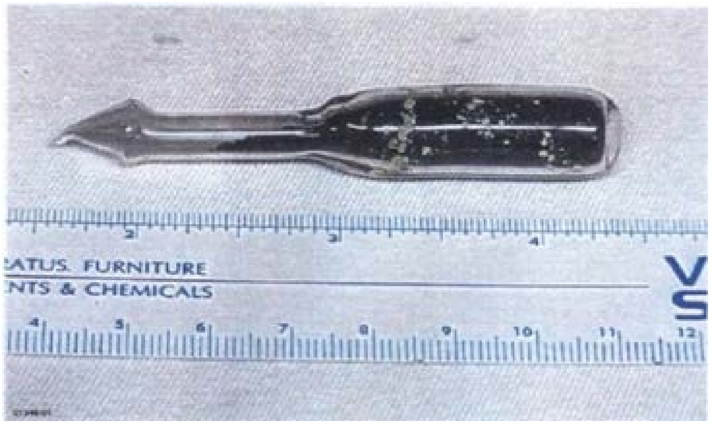
^{249}Bk from ORNL used at Dmitrovgrad to discover element 117



Yuri Oganessian. Nuclei from the Island of SHE. August 15, 2012, Int. Conf. “NS-2012”, ANL, USA

Engineering Example from the Petroleum Industry: There are over 363,460 oil and 461,388 gas wells in the US today that were evaluated, being maintained and optimized for production using these sources now and in the lifetime of the wells (Eric L. Rosemann , Association of Energy Service Companies)

Uses of Isotopes: National Security and Other Applications



Forensic analysis of a smuggled HEU sample interdicted in Bulgaria revealed that it was HEU (~73% ^{235}U) from irradiated reactor fuel reprocessed around 1993. Nuclear and forensic signatures suggested an origin in Russia or the former Soviet Union

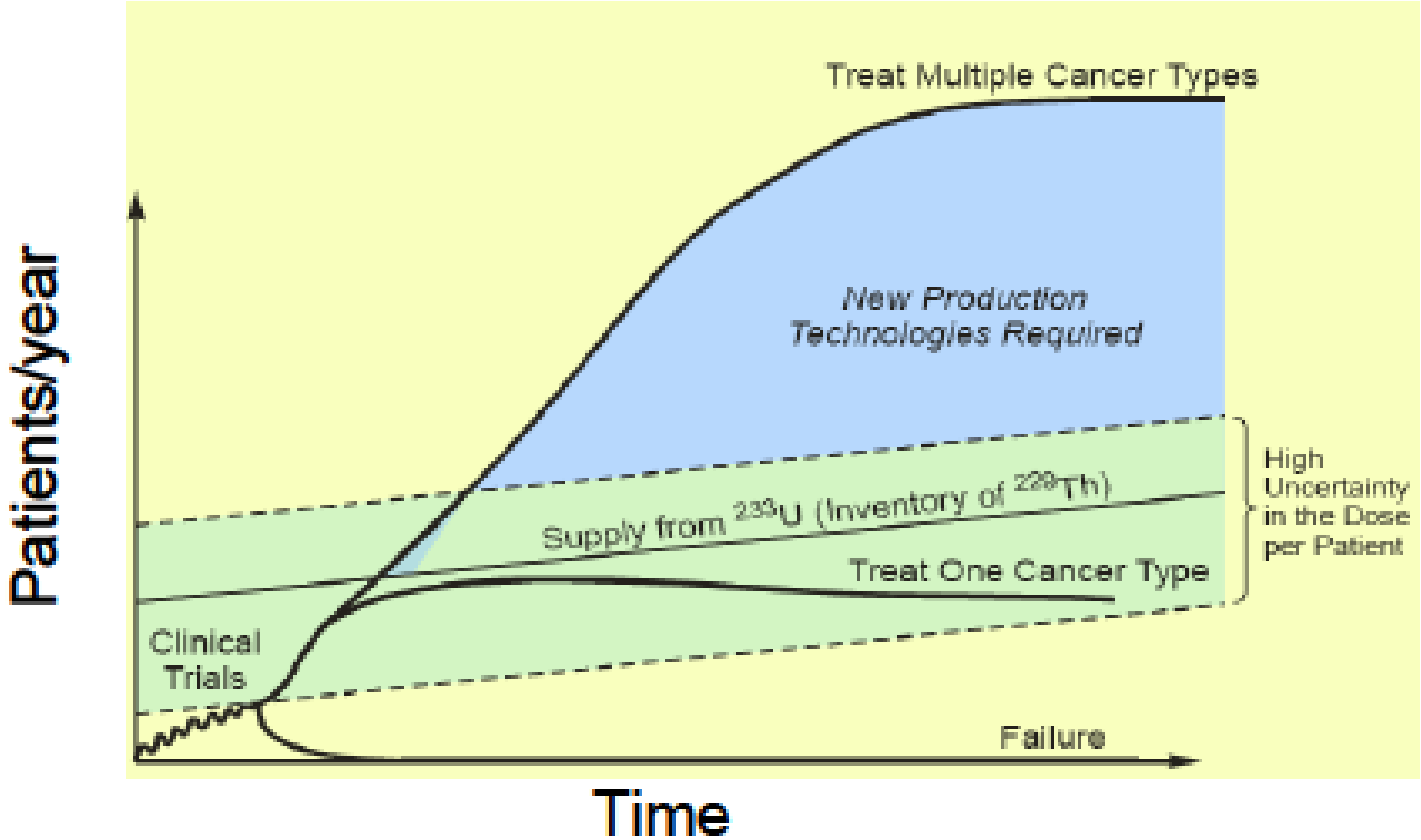
He-3 detector tubes used in Truck Portal monitors

Nuclear Physics Appropriated Funding ($k)

	FY2015	FY2016 Request	FY2016 vs FY2015
Medium Energy Nuclear Physics	150,892	158,062	+7,170
Heavy Ion Nuclear Physics	199,966	211,366	+11,400
Low Energy Nuclear Physics	75,196	79,788	+4,592
Nuclear Theory	43,096	46,220	+3,124
Isotope Program (IDPRA)	19,850	21,664	+1,814
Subtotal, Nuclear Physics	489,000	517,100	+28,100
Construction			
12 GeV CEBAF Upgrade, TJNAF	16,500	7,500	-9,000
Facility for Rare Isotope Beams	90,000	100,000	+10,000
Subtotal, Construction	106,500	107,500	+1,000
Total, Nuclear Physics	595,500	624,600	+29,100

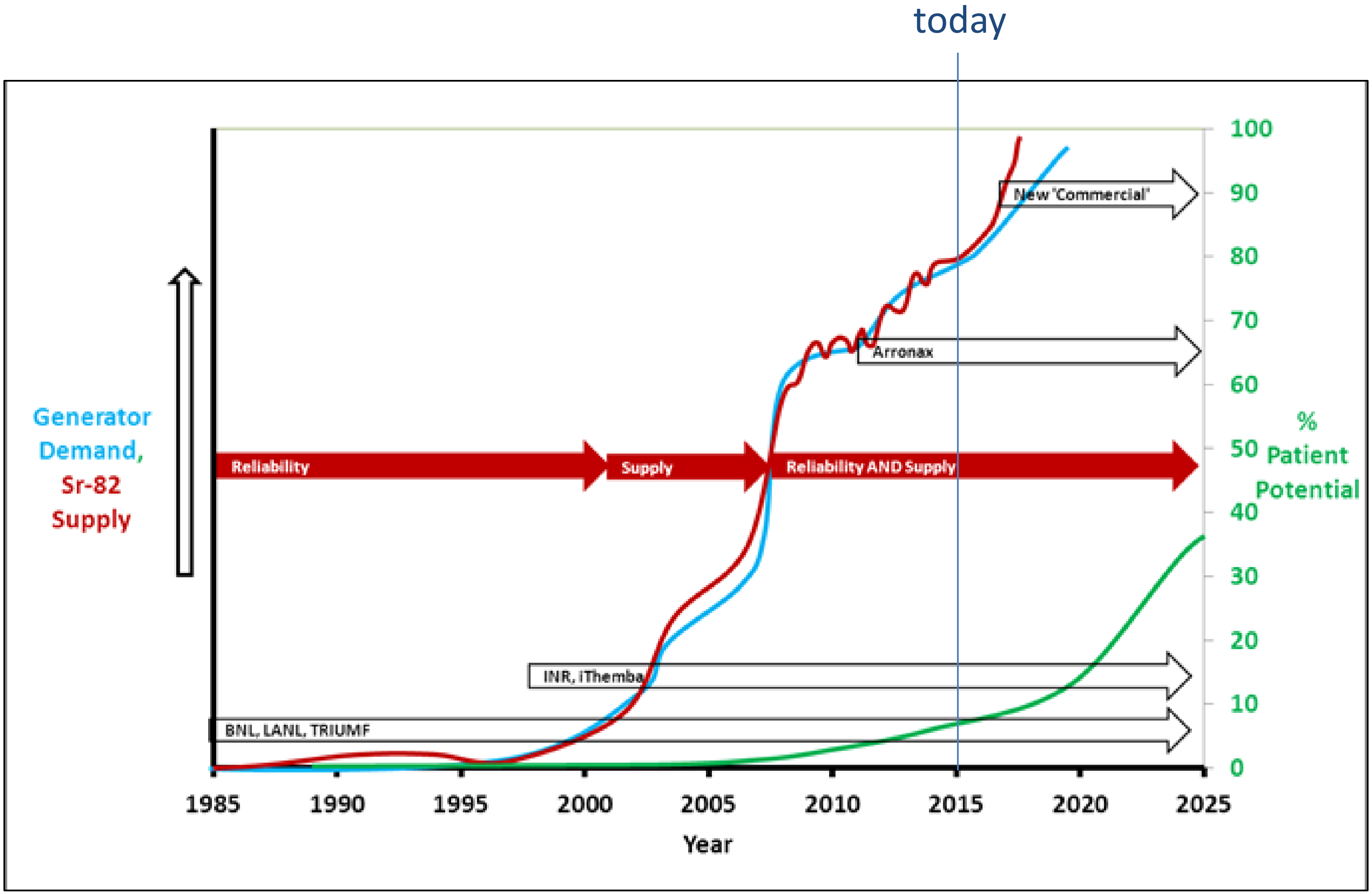
Note: the Isotope Program's total budget includes revenue (at cost recovery) from sales of isotopes as well – estimated to be $37.6 M in FY2015, *so ~2/3 of the Program's budget comes from these sales.*

Schematic illustration of the issues of supply of $^{225}Ac/^{213}Bi$ depending on the success of clinical trials



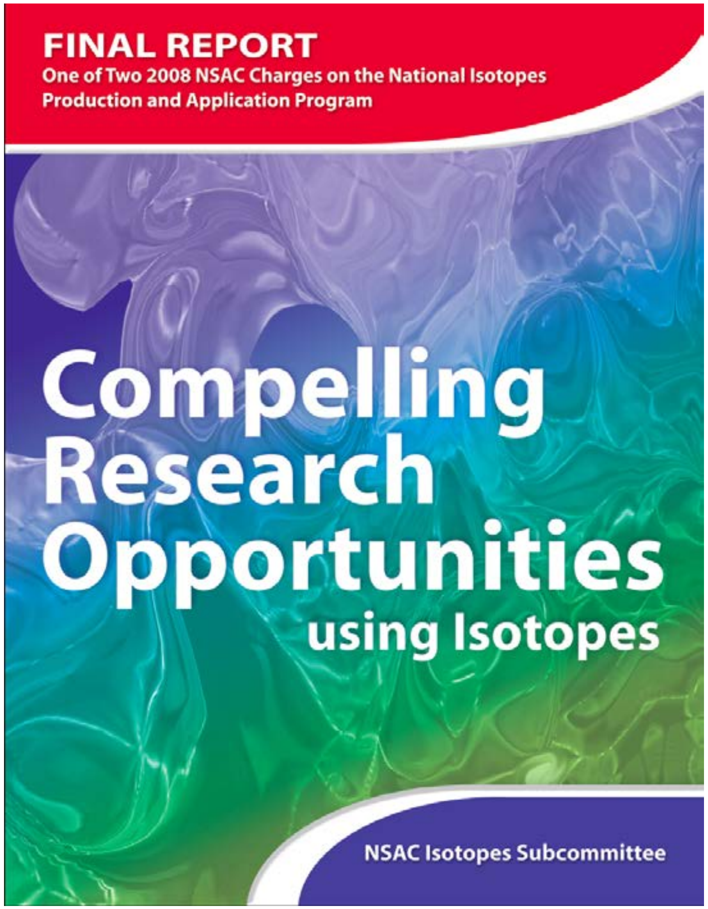
(from the 2009 NSACI Report)

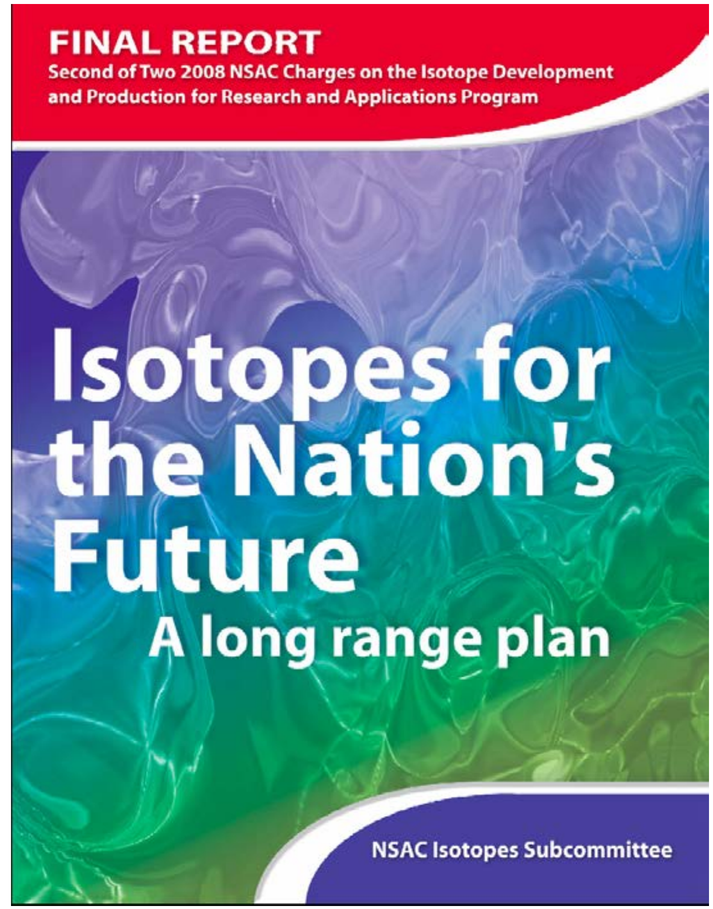
A Large Fraction (~40%) of Current Isotope Sales Revenue Comes from ^{82}Sr



(graph courtesy A. Nunn, Bracco)

The Isotope Program Moved to the Office of Nuclear Physics in 2009





Two 2009 NSACI Reports identified compelling research opportunities and recommended a Long-term Strategic Plan the provided a framework for a coordinated implementation of IDPRA.
We were basically charged to update those reports and evaluate progress since 2009

Our Charge

- Conduct a new study of the opportunities and priorities for isotope research and production…result(ing) in a **Long-Range Strategic Plan** for the Office of Science for Nuclear Physics
- **Articulate the progress** has been made since the last NSACI sub-committee published its recommendations, and the scientific and societal impacts of these accomplishments and ongoing activities
- **Identify and prioritize the most compelling opportunities** for the DOE Isotope Program to pursue over the next decade and articulate their impacts
- **Indicate the resources needed** in the timeframe 2016-25 to increase the domestic availability of isotopes appropriate to the DOE Isotope Program portfolio and deemed to be critical to the Nation.

In carrying out the charge, important aspects of the assessment include:

- existing technical capabilities and infrastructure,
- the robustness of current isotope production operations
- R&D of production techniques for research and applied isotopes
- Production of research isotopes, and
- Development of core competencies
- The plan should also consider aspects of the program that are relevant and important to stakeholder communications and the effectiveness in the provision of critical isotopes to the Nation

NSACI Subcommittee Membership

Kelly Beierschmitt	INL	Deputy Lab Director, Nuclear and Laboratory Ops
Roy Brown	Mallinckrodt	Strategic Alliances Director
Carol Burns	LANL	Former Chemistry Division Leader, Nuclear Forensics
Larry Cardman, chair	JLAB	Medium Energy Nuclear Physics
Donald Geesaman, ex officio	ANL	NSAC Chair, 2009 NSACI Chair, and Medium Energy Nuclear Physics
Suzanne Lapi	Wash. U. SL	Asst. Prof. of Radiology, Biochem., and Biomed. Eng.
Saed Mirzadeh	ORNL	Radiochemistry, Nuclear Medicine
Eugene Peterson	LANL	Isotope Production
Lee Riedinger	Tennessee	Low Energy Nuclear Physics
David Robertson	Missouri	Prof., Assoc. Director, Research & Education, MURR
Thomas Ruth	TRIUMF	Isotope Production
David Scheinberg	Memorial Sloan Kettering Cancer Center	Experimental Therapeutics Center Chair
Sally Schwarz	Wash. U., St. L	Director of Pet Radiopharmaceutical Production
Brad Sherrill	MSU	Low Energy Nuclear Physics
Mark Stoyer	LLNL	Nuclear Chemistry-Heavy Elements
Scott Wilbur	University of Washington	Radiation Oncology
Frank Yeager	Eckert and Ziegler	Sources, oil & gas, CORAR Board
~~Michael Zalutsky~~	~~Duke~~	~~Radiaton Oncology~~

How Did We Address Our Charge?

A set of three meetings: September 23, November 20-21; and January 20-21

- **The first (9/23/14) meeting included:**
  - Organization,
  - Presentations by the DOE/NP Isotopes Program on how they are organized and how they have worked to meet the recommendations of the 2009 Subcommittee Reports
- **The second (11/20-21/14) meeting included:**
  - Input from Federal Agencies and Commercial Producers
  - Initial preparations for report development
- **Third (1/20-21/15) meeting included:**
  - Input from Professional Societies representing Isotope Users and Producers
  - Presentations by the DOE isotope production facilities, and a summary presentation of the evolving university-based supplementary facilities, followed by
  - An Executive Session for the Development of the Draft of our Report

Requests for Information (and presentations at the meetings) sent to:

- 31 Government Agencies
- 15 Industrial Producers/Users of Isotopes
- 28 Professional Societies

Most responded (Details in Backup Material)

NSACI Subcommittee Meeting I, September 23, 2014

Aim: Get broad overview of the program from the perspective of the DOE/NP folk who have managed it since the transition in 2009

- **We want to understand the DOE/NP perspective on the current status, challenges, and near- and long-term goals**
- **Begin to understand how well the program has met the goals set by the 2009 NSACI report**

Agenda:

Talk	Speaker
Introduction	
Welcome	Larry Cardman
Charge from NSAC Chair	Don Geesaman
The DOE/NP Program	
Overview and Perspective	Jehanne Gillo
Isotope R&D	Dennis Phillips
Stable and Accountable Materials	Joel Grimm
Isotope Production Facilities and the National Isotope Development Center	Marc Garland
Isotope Business Office Operations	Mitch Ferren
Customer Interactions and Demand Forecast	Wolfgang Runde
User, Industry and Agency Perspective – Examples	
NIH as a major customer	Tony Sastre

NSACI Meeting II: November 20-21, 2014

Aims:

- **Get a broad overview of government agency and commercial producer needs and their interactions with the Isotope Program**
- **Begin Preparations for Report Development**

NSACI Meeting II: Day 1

Talk	Speaker
Plan for Meeting; Summary of Information Received to Date	Larry Cardman
Presentations by the Agencies on Isotope Needs and Challenges	
NIST	Lisa Karam
DHS and the National Technical Forensic Center	Richard Essex (NBL)
DOE/Office of Nuclear Energy	Richard Reister
DOE/Office of Fusion Energy	Gene Nardella
DOE/Office of Basic Energy Sciences (4 users, 1 to talk)	Lynda Soderholm(ANL)
NNSA	Joel Smith
DOE/NP	Tim Hallman
NSF	Allena Opper

NSACI Meeting II: Day 1 (cont.)

Lunch, Then Presentations by Industry	Speaker
Oil and Gas Exploration	Frank Yeager
Council of Radionuclides and Radiopharmaceuticals	Michael Guastella
Association of Energy Service Companies	Eric Rosemann
Zevacor – 70 MeV cyclotrons and commercialization of ^{82}Sr	John Zehner
Industrial Producers – Source Production & Equipment Co.	Dennis Chedraui
Braco - supplies ^{82}Sr (from multiple sources including DOE)	Adrian Nunn
Society for Nuclear Medicine (conflict with January dates)	Peter Herskovich
^{99}Mo discussion: Introduction and Background	Don Geesaman
NSAC ^{99}Mo Subcommittee Review/Findings	Tom Ruth

NSACI Meeting II: Day 2

Talk	Speaker
General Summary of plans for the day and for Meeting III (January 20-21)	Larry Cardman
Two presentations yesterday, but were delayed due to schedule conflicts	
DOE Office of Nuclear Energy – Space and Defense Power Systems	Rebecca Onuschak
DoD	Craig Wuest
Coffee Break	
Executive Session to discuss our plans for developing the report	

NSACI Subcommittee Meeting III, January 20-21, 2015

Aims:

- **Complete input from professional societies**
- **Presentations by DOE Production Facilities**
- **Presentations by Universities discussing joining the Isotopes Program**
- **Executive Session:**
  - **Develop prioritized recommendations for compelling opportunities;**
  - **Identify key points and recommendations to be included in our Long Range Strategic Plan;**
  - **Identify (and justify) resources needed; and**
  - **Evaluate the response of DOE/NP to the 2009 NSACI Recommendations**
  - **Review and finalize plans for writing our report**

NSACI Subcommittee Meeting III, January 20-21, 2015

Agenda, Tuesday AM (Professional Societies and Universities)

Talk	Speaker
Introduction to the day	Lawrence Cardman
TRTR (The National Organization of Test, Research, and Training Reactors)	Ralph Butler
ACS/DNCT (American Chemical Society / Division of Nuclear Chemistry and Technology)	Paul Mantica
SNM (The Society of Nuclear Medicine)	Erin Grady
Coffee Break	
Isotope Production at TRIUMF	Paul Schaffer or Jonathan Bagger
University Sites – status and plans (A series of brief presentations)	
University of Washington	Scott Wilbur
Washington University	Suzanne Lapi
MURR	David Robertson
University of Wisconsin	Jerry Nickles
Summary of other University sites (Duke, Texas A&M, UC Davis).	Scott Wilbur
Working Lunch (Issues and Budgets for the University Sites)	Scott Wilbur and Suzanne Lapi

NSACI Subcommittee Meeting III, January 20-21, 2015

Agenda Tuesday Afternoon (DOE Production Facilities, then Overall Budget Discussion)

Talk	Speaker
ORNL (General)	John Krueger
INL	Debbie Utterbeck
NSCL	Dave Morrissey
BNL	Leonard Mausner
LANL	Eva Birnbaum
Coffee	
SRNL	Jeff Allender
PNNL	Gertrude Patello
Discussion of Production Site budget issues Note: May switch to executive session part way through this discussion	Brad Sherrill, Lee Riedinger
Adjourn	

NSACI Subcommittee Meeting III, January 20-21, 2015

Agenda Wednesday – Executive Session

Talk	Speaker
General Summary of plans for the day , and A very brief review of the draft outline for Chapter 1 (Introduction)	L. Cardman
Review of each of the draft recommendations received to date and discussion of: • whether to include it or not, • whether to revise it or not, • where to state it first in the text, and • a first cut at prioritization). then Discussion of additional proposals for recommendations (Note we will return to the recommendation list and prioritization at the end of the day, after we have heard from each of the chapter coordinators)	L. Cardman
Chapter 2: The DOE Isotopes Program 2.A. Origins and History, and 2.B. Today (2009 to Present)	L. Riedinger, E. Peterson, L. Cardman

NSACI Subcommittee Meeting III, January 20-21, 2015

Agenda Wednesday – Executive Session

Talk	Speaker
Fully executive session with no DOE representatives in the room	
Chapter 9: Program Operations	**L. Riedinger, E. Peterson**
Chapter 10: Budget Scenarios	**B. Sherrill, L. Cardman, L. Riedinger**
Working Lunch, with discussion starting on Chapter 3 and 4 Material	
Chapters 3 (Uses of Isotopes) and 4 (Research Opportunities Using Isotopes). Do discussion for both chapters by topical subsection	
Chapters 3 and 4, Section A. Biology, Medicine and Pharmaceuticals	**S. Lapi. R. Brown, S. Mirzadeh, T. Ruth, D. Scheinberg, S. Schwartz, S. Wilbur**
Chapters 3 and 4, Section B. Physical Sciences and Engineering	**S. Mirzadeh, B. Sherrill, M. Stoyer, F. Yeager**
Chapters 3 and 4, Section C. National Security and Other Applications	**C. Burns, E. Peterson, B. Sherrill, M. Stoyer**

NSACI Subcommittee Meeting III, January 20-21, 2015

Agenda Wednesday – Executive Session

Talk	Speaker
Chapter 5. The Scope and the Scientific/Technical Challenges for the Isotope Program	B. Sherrill, T. Ruth
Chapter 6 Sources of Isotopes for the Nation	
Chapter 6, Section A: Stable Isotopes	K. Beierschmidt
Chapter 6, Section B: Accelerator Based Isotope Capabilities	E. Peterson, R. Brown, S. Mirzadeh,, B. Sherrill, T. Ruth, S. Wilbur
Chapter 6, Section C: Reactor Based Isotope Capabilities	D. Robertson, K. Beierschmidt, S. Mirzadeh
Chapter 6, Section D: Isotope Harvesting from Long-Lived Stockpiles	S. Mirzadeh
Chapter 7: Research and Development for Isotope Production	T. Ruth
Coffee Break	
Chapter 8: Trained Workforce and Education	S. Lapi, S. Mirzadeh, D. Robertson

NSACI Subcommittee Meeting III, January 20-21, 2015

Agenda Wednesday – Executive Session

Talk	Speaker
2nd of each of the draft recommendations, with final decisions on: • whether the wording is final, • where to state it first in the text, and • a final cut at prioritization 2nd review of the evaluation bullets, with final decisions on: • whether the wording is final, • whether to include it in Chapter 2 or just in Chapter 9, and • a final cut at on the ordering Review of all the sidebars to be included, including decisions on: • Where they will be placed, and • Who will be responsible for the text	L. Cardman
Reminder of the timetable for finishing the job	L. Cardman
Adjourn	

Timeline for the Report (after the Meetings)

February 7: Revised draft of recommendations, reflecting discussions, sent to all for a second round of comments

February 15: Drafts of each chapter (nominally) due to LSC by this date (most were received by this date)

February 23: First draft of entire report assembled from this material (LSC) and sent to committee for review/comment (sent with some chapters missing)

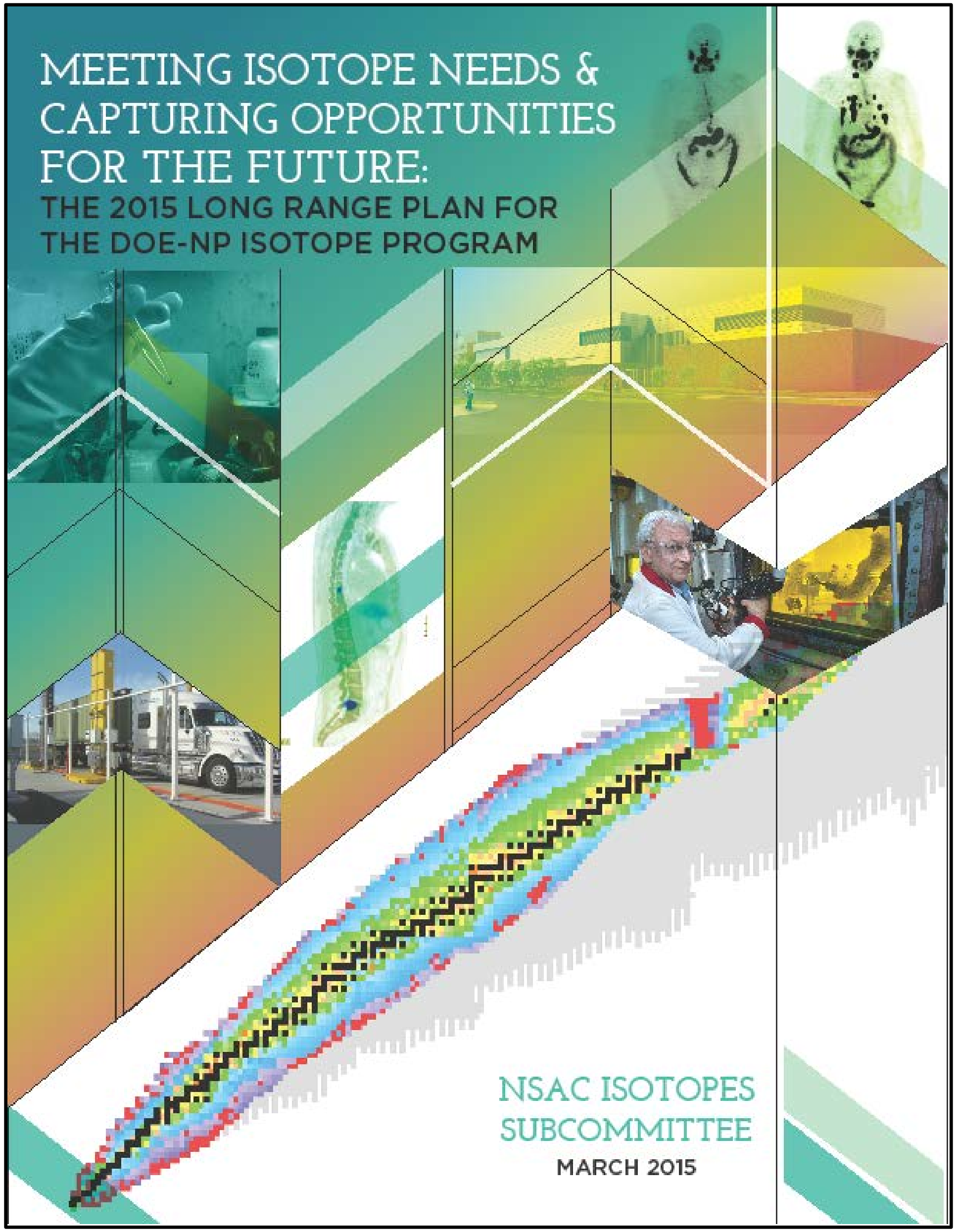
February 24 – March 10: Comments to LSC (w/ copies to full committee) for incorporation into the second draft

March 11: Second, nearly final version of report sent to committee for review/comments

March 12-19: Comments to LSC for incorporation into the draft report to be submitted to NSAC

March 20: Submitted draft report to NSAC

Our Report


MEETING ISOTOPE NEEDS & CAPTURING OPPORTUNITIES FOR THE FUTURE:
THE 2015 LONG RANGE PLAN FOR THE DOE-NP ISOTOPE PROGRAM
NSAC ISOTOPES SUBCOMMITTEE
MARCH 2015

Recommendations

1) We recommend a significant increase of funding for Research and Development

Increased R&D is essential for an optimal Isotope Program. Increased R&D is necessary to fully realize the promise of enhanced national security, improved health care, and increased industrial competitiveness the program could provide. It will also support the **expansion of the range and quantities of isotopes available** for researchers and for potential commercial application, and enhance their usefulness to the Nation. It will support the **development of more efficient techniques for their production**, reducing costs and ensuring that supplies meet demands. R&D is also a core component of the program, **enabling it to better weather fluctuations in revenues (funding) as isotopes transition to the commercial market and as foreign supplies vary**. In addition to establishing optimal base R&D funding at the production sites, the increase will facilitate annual (rather than biennial) Funding Opportunity Announcements (FOAs) to be issued, **allowing the program to identify and respond more rapidly to new ideas.** This increase will allow the program to effectively support promising new areas as they arise. Four representative areas that would benefit today from increased R&D support are:

Recommendations

1) We recommend a significant increase of funding for Research and Development (cont.)

a) ***Continue support for R&D on the production of alpha-emitting radioisotopes*** – The lack of availability of alpha-emitting radioisotopes was identified in 2009 as a major limitation in the otherwise promising investigations of their potential for cancer therapy. There has been significant progress made by the DOE Isotope Program in the development and production of some medically useful alpha-emitting isotopes in the past 5 years, but further research into new production methods, more efficient isolation methods, and automation of the isolation processes is needed to provide adequate availability of alpha-emitting radioisotopes for preclinical and clinical evaluations. A focus should continue on production of ^{225}Ac and ^{211}At. In addition, other alpha-emitting radioisotopes that may be applicable for treatment of other types of cancers, or for use in treating bacterial and viral infections are interesting. Thus, research into methods for production/isolation of alpha-emitters with shorter half-lives (e.g. ^{212}Pb/^{212}Bi, ^{213}Bi, and ^{226}Th) and longer half-lives (e.g. ^{227}Th) should also be a priority.

b) ***Support R&D into the production of high specific activity theranostic radioisotopes*** – The move towards personalized medicine can be facilitated by supporting research on the production of radioisotopes, and isotopic pairs of the same element, that have both imaging and therapeutic emissions. Such agents, termed theranostic agents, can be used to obtain valuable pharmacokinetic and disease-targeting information in real time, which can allow rapid determination of whether the therapeutic approach will be effective in a specific patient. A requirement for theranostic radioisotopes produced for medical use is that they have very low quantities of other isotopes of that element present (or “high specific activity”) after production and isolation. Personalized medicine will use highly specific targeting of diseased cells in patients to differentiate their disease and help identify treatments that will be effective. High specific activity radioisotopes are required so that the targeted receptor or cell-surface antigen on the diseased cells are bound with targeting agents containing only, or mostly, the theranostic radioisotope. If low specific activity radioisotopes are used, the disease-targeting agent containing a stable isotope (or non-useful radioisotope) can compete for the receptor or antigen, dramatically decreasing binding of the isotope that provides the diagnostic and/or therapeutic emissions. This can lead to inconclusive imaging results and ineffective therapy, resulting in an unsuccessful personalized medicine approach.

Theranostics

Baseline Post-Selumetinib

$^{131}I/^{124}I$ Theranostic Pair (Therapy and Diagnostic, α and e^+ emitters, respectively) treating metastatic thyroid cancer and imaging the treatment's progress

To be effective, theranostic radio-pharmaceuticals must have high specific activity. That is to say, the ratio of radioisotope to radiopharmaceutical molecule has to be as high as achievable without damaging the biological properties of the pharmaceutical.

R&D is needed to develop production techniques capable of providing sufficient quantities for clinical trials in a variety of possible pairs with high specific activity.

A. L. Ho, *et al*., N Engl. J. Med. 2013 Feb 14; 368(7):623-32. doi: 10.1056/NEJMoa1209288.

Recommendations

1) We recommend a significant increase of funding for Research and Development (cont.)

c) Continue support for R&D on the use of electron accelerators for isotope production – One of the major driving forces for new radioisotope production R&D is the need for increased yield and high specific activity. One of the newer approaches is the use of photons to initiate isotope production. While the concept has been around for decades, sources of photons with sufficient energy and flux to make the approach practical have only recently become available (through R&D driven by Basic Energy Sciences' need for high beam currents), so it is now possible to explore this pathway.

While the (γ,n) reaction is the mostly widely discussed, additional reactions could be examined, including (γ,p) and photofission. The (γ,p) reaction affords the possibility for producing radionuclides with high specific activity. The $^{68}Zn(\gamma,p)^{67}Cu$ reaction, where the copper isotope can be chemically separated from the target material, could be a viable route to this potential theranostic isotope (paired with ^{64}Cu). Other potential reactions of interest include; $^{232}Th(\gamma,spall)^{225}Ac$, and $^{232}Th(\gamma,spall)^{211}Rn(t_{1/2}=14.6\ h, \mathit{EC})^{211}At$. These reactions are especially promising if multiple electron machines can be made available at reasonable costs. The photofission yield distribution from 238U is almost identical to the thermal neutron fission of ^{235}U. This is a possible route to isotopes produced by fission that would remove the need for ^{235}U.

d) Support R&D on the development of irradiation materials for targets that will be exposed to extreme environments to take full advantage of the current suite of accelerator and reactor irradiation facilities – The planned upgrades in production capacity at the isotope production accelerator facilities will create demands on the materials used and will likely require the development of new materials that can withstand high temperature and radiation conditions. In a similar manner, development in ion source feedstocks for use in the proposed radioactive separation system will be required to make full use of the new capacity available with the construction of this new system outlined in recommendation 3b.

Recommendations

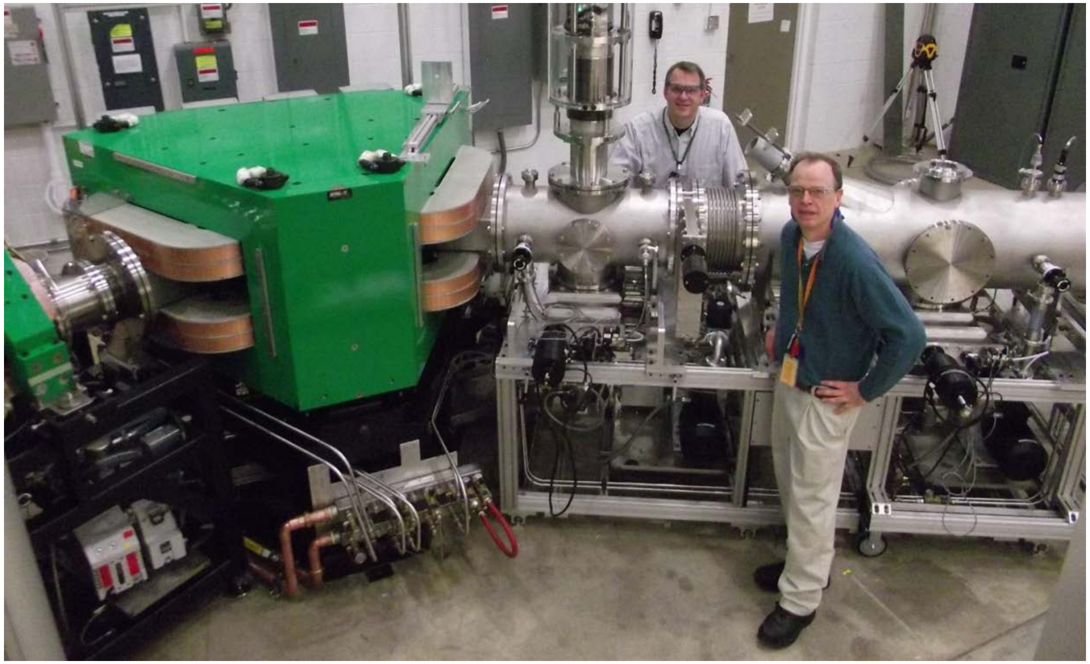
2) We recommend completion and the establishment of effective operations of the stable isotope separation capability at ORNL

The subcommittee is pleased with the progress that has been made since the 2009 NSACI recommendation toward the establishment of a stable isotope separation capability. **This ongoing effort should continue until the separation capability is fully established and available for routine use, providing a reliable U.S. source of high-purity stable isotopes, many of which are currently available only from Russia**. That will require, among other things, the allocation of a base operations budget for the separator.

In addition, to improve the current state-of-the-art for isotope separations, investments will be necessary to improve the efficiency of isotope separators through development of low temperature ion sources and improved materials chemistry. **The goal of this effort should be to increase the throughput of the existing separator to be equivalent to at least that of one calutron (100 mA ion current).**

ORNL EMIS 10 mA prototype inside the upgraded host facility

Plan:
- R&D to generate a more robust, higher current ion source for EMIS
- Existing facility modifications complete
- Augmenting with a small centrifuge cascade
- Automation to reduce cost



Basic instrument now in place, but
- It must be upgraded from 10 to 100 mA
- It will need an annual operating budget

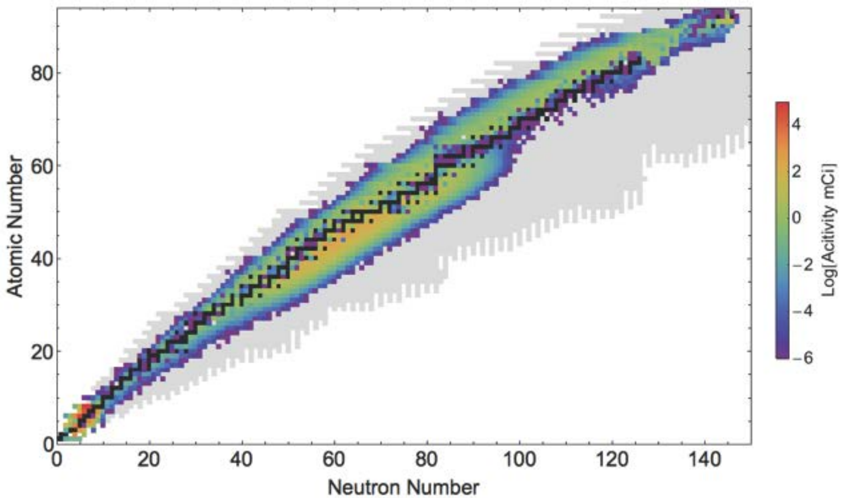
Recommendations

3) **We recommend realization of the opportunities associated with high-impact infrastructure investments. Specifically:**

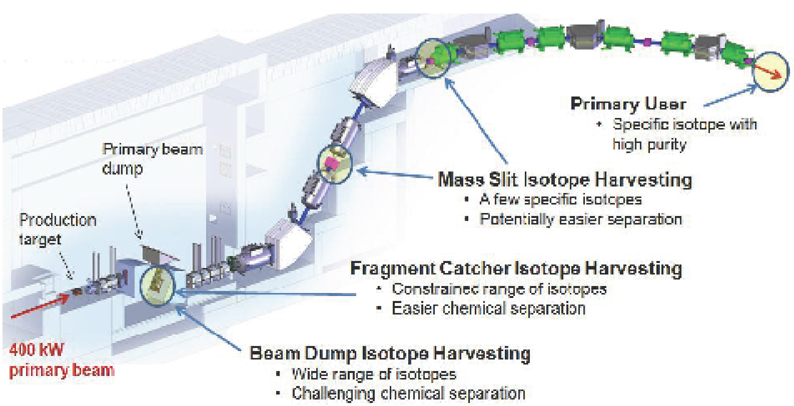
a) ***Infrastructure for isotope harvesting at FRIB* -** During routine operation for its nuclear physics mission, FRIB will produce a broad variety of isotopes that could be harvested synergistically without interference to the primary user. Research quantities of many of these isotopes, which are of interest to various applications including medicine, stockpile stewardship and astrophysics, are currently in short supply or have no source other than FRIB operation. Infrastructure to enable the development of isotope harvesting should be installed at the FRIB facility in a timely manner to capitalize on this opportunity.

b) ***Develop a strategy for the re-establishment of a separator for radioactive isotopes to support research*** – The isotope community has expressed the need for high specific activity, mass separated radioactive isotopes. A strategy for establishing a domestic capability for high purity radioactive isotopes should be developed. This capability is important to physical science programs, the medical community, and our national security. While chemical techniques can be used to separate the desired radioisotope from other elements, the selectivity to gain the isotopic purity desired by the community cannot be achieved without the development of electromagnetic separators for radioactive materials.

Isotope Harvesting at FRIB



activity produced per day by a 200kW uranium beam stopping in the water beam dump – lots of new and unusual possibilities



Radioactive Separator at ORNL

Key to higher specific activity in many cases.

Core technology similar to EMIS facility (shown) but major modifications needed to deal with highly radioactive materials

Recommendations

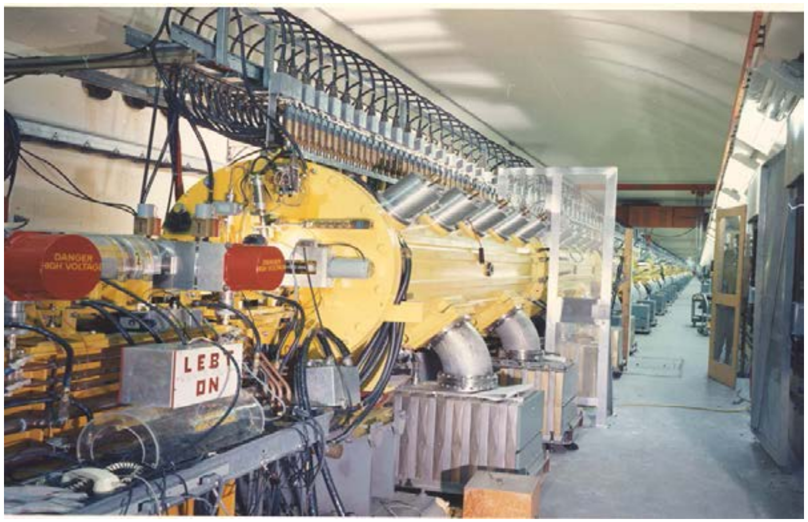
3) We recommend realization of the opportunities associated with high-impact infrastructure investments. Specifically:

c) *Increase the base infrastructure budget to sustain and expand production capacity at the Isotope Program facilities. Two near-term opportunities that merit support from this increased funding are:*

i) *BNL Intensity upgrade and implementation of a second target station* **–** Ongoing accelerator improvement projects at BLIP (installation of a beam Raster system and phase I of the Linac intensity upgrade) are expected to increase yields of ^{82}Sr. Phase I of the Linac intensity upgrade will include an assessment of the feasibility of a second doubling of the intensity of the Linac. If feasible, continued increases in intensity could further increase isotope production yields and have much merit. The Radiation Effects Facility (REF) is a spur off the BLIP beam line that could be used to provide a 2nd beam line at BLIP primarily for research irradiations. In this manner research irradiations could be performed without interfering with ongoing large scale isotope production in the existing BLIP facility, providing more flexibility.

ii) *Intensity, stability, and energy upgrades at LANL* **–** While DOE has made critical infrastructure investments at LANL over the last five years, especially in the hot cell facility (including electrical and HVAC upgrades funded as separate upgrades efforts), this facility is nearing 50 years in age, and will require additional investments to ensure continued reliable operations.

Brookhaven Linac Isotope Producer (BLIP)



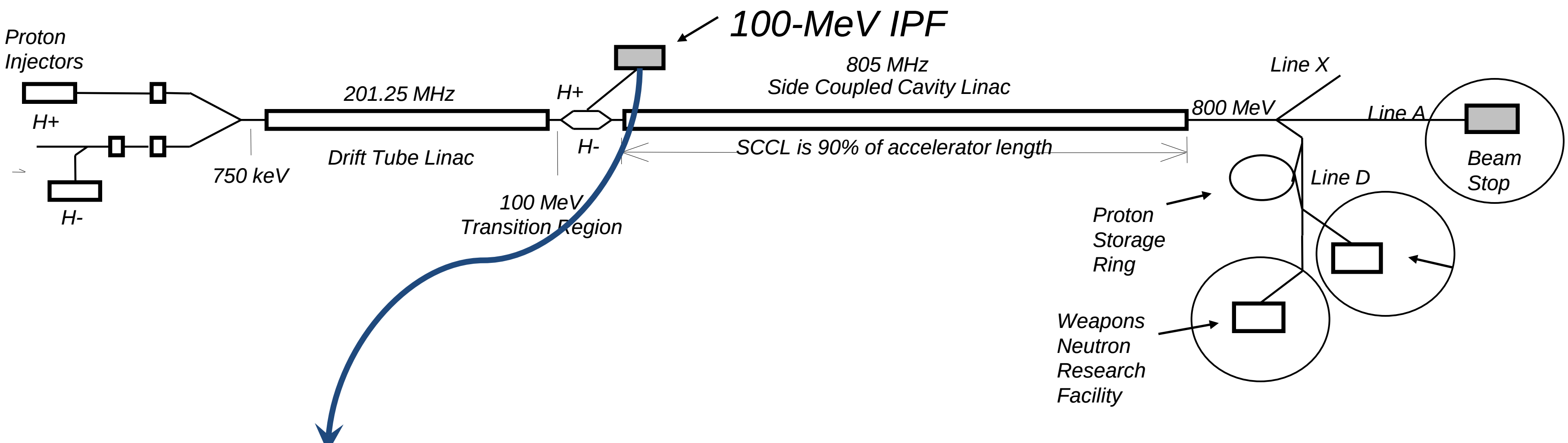
The LINAC supplies protons to the Booster for nuclear physics. Excess pulses (~88-92%) are diverted to BLIP. Energy is incrementally variable from 66-202 MeV.

Upgrades planned:

- Replace aging BLIP target drive assembly and upgrade radiation shielding
- Upgrade BLIP target leak detection system
- Relocate beta emitting Ni-63 & Fe-55 processes from hot cell to shielded glove boxes
- Add a hot cell and renovate room 66c to process Ac-225 totally segregated from Sr-82 effort
- Increase shielded storage space

Long term initiative – increase Linac intensity to 240µA and add second beam line and target station in existing defunct space

The LANL Isotope Production Facility (IPF)



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

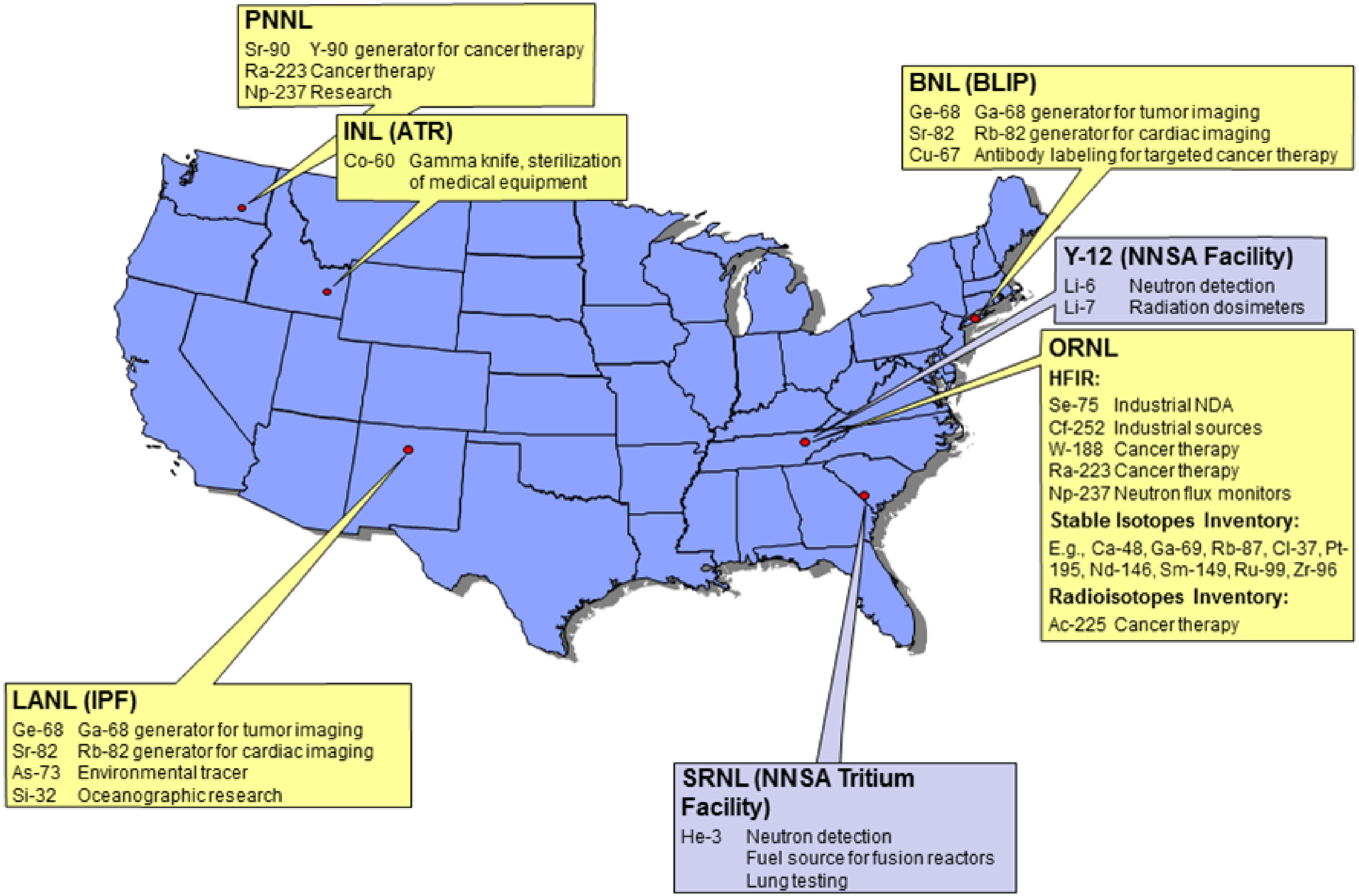
- Accelerator is powerful but > 40 years old
- High reliance on other programs to support
- total infrastructure (IPF only ~ 4% of total LANSCE budget)
- Investments such as LANSCE Risk Mitigation Project will continue to be needed
- Hot Cell Facility > 50 years old
- Significant investments from NP include HVAC, electrical, but issues remain
- Opportunity areas: improved IPF beam window and enhanced α handling capability

Recommendations

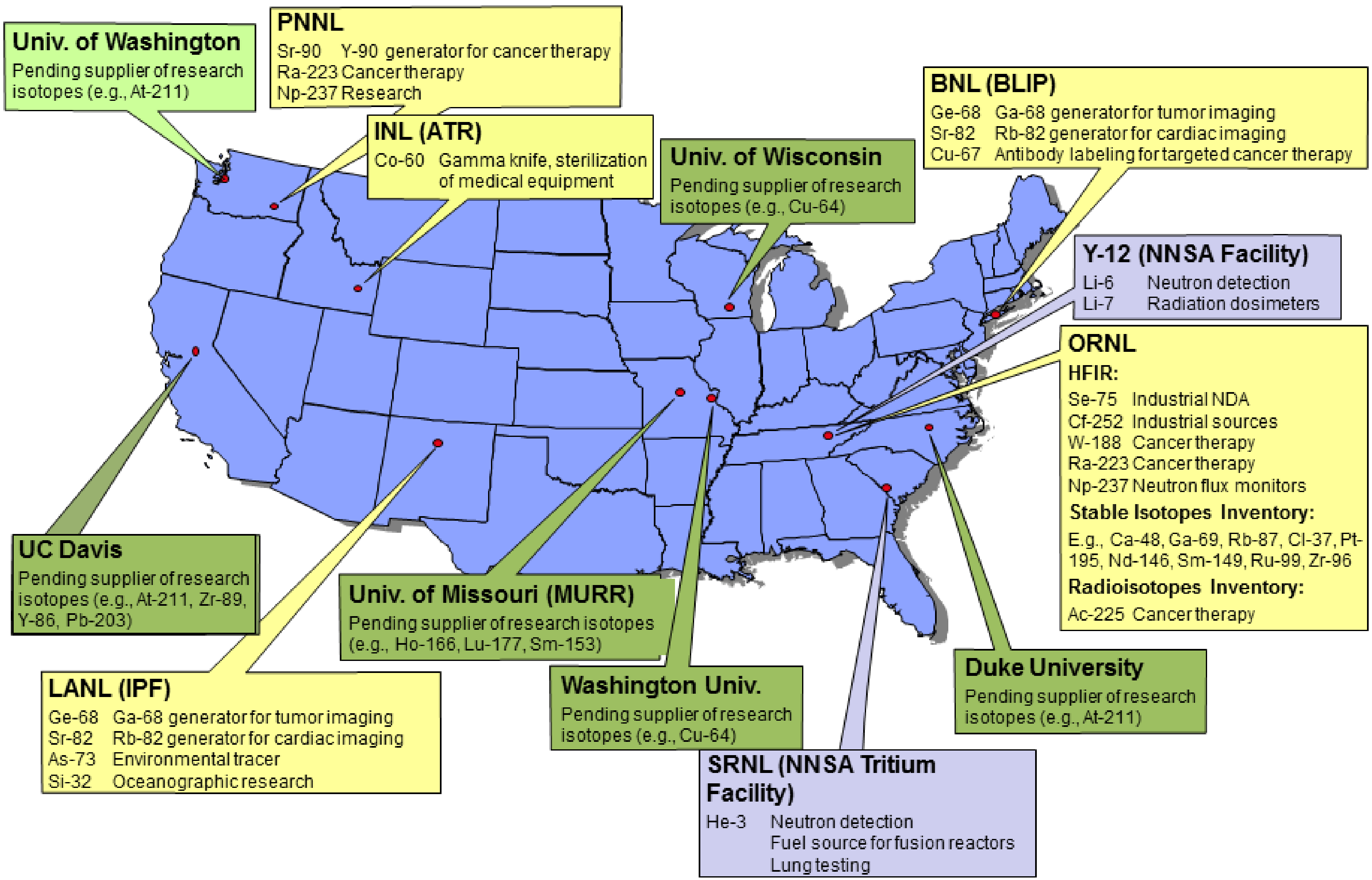
4) We recommend continuation and expansion of the effort to integrate the university facilities with the Isotope Program

The effort to form a network of university facilities that work with the DOE Isotope Program is commended and should be continued. University facilities have the ability to ***cost-effectively augment the capabilities of the national laboratories***, and to meet demands for radioisotopes and radioisotope R&D that are not possible at the national laboratories, such as regional production of short-lived radioisotopes (e.g. ^{211}At) and evaluation of some alternative methods for radioisotope production. Partnership with university sites can also provide ***complementary and/or supplemental capabilities for production of isotopes*** where demands are not currently being met. The possibilities should continue to be evaluated on a site-by-site basis, in view of the differing capabilities of the universities. Several universities already provide radioisotopes that meet national needs, either by supplying commercial sources or making radioisotopes that are not readily available from commercial suppliers. Continuing exploration of how these university radioisotope producers can work with the DOE Isotope Program and how DOE could support university infrastructure and operations without compromising the Isotope Program or the current university production and distribution network is viewed as challenging, but very important, as ***coordination of this effort with the Isotope Program would improve the availability of key isotopes.*** Other university facilities do not yet produce isotopes in significant quantity and are likely to need improvements in infrastructure and equipment. The Isotope Program should continue to consider infrastructure upgrades to university facilities to produce isotopes to meet specific national needs. It is recognized that the degree of integration and the details of the interfaces of each university facility into the DOE Isotope Program will vary by site and circumstances. ***Finally, an important additional benefit of a DOE-university site partnership is the workforce training opportunity. It is recognized that these training opportunities are currently an important part of the Isotope Program and it is strongly recommended that they be continued.***

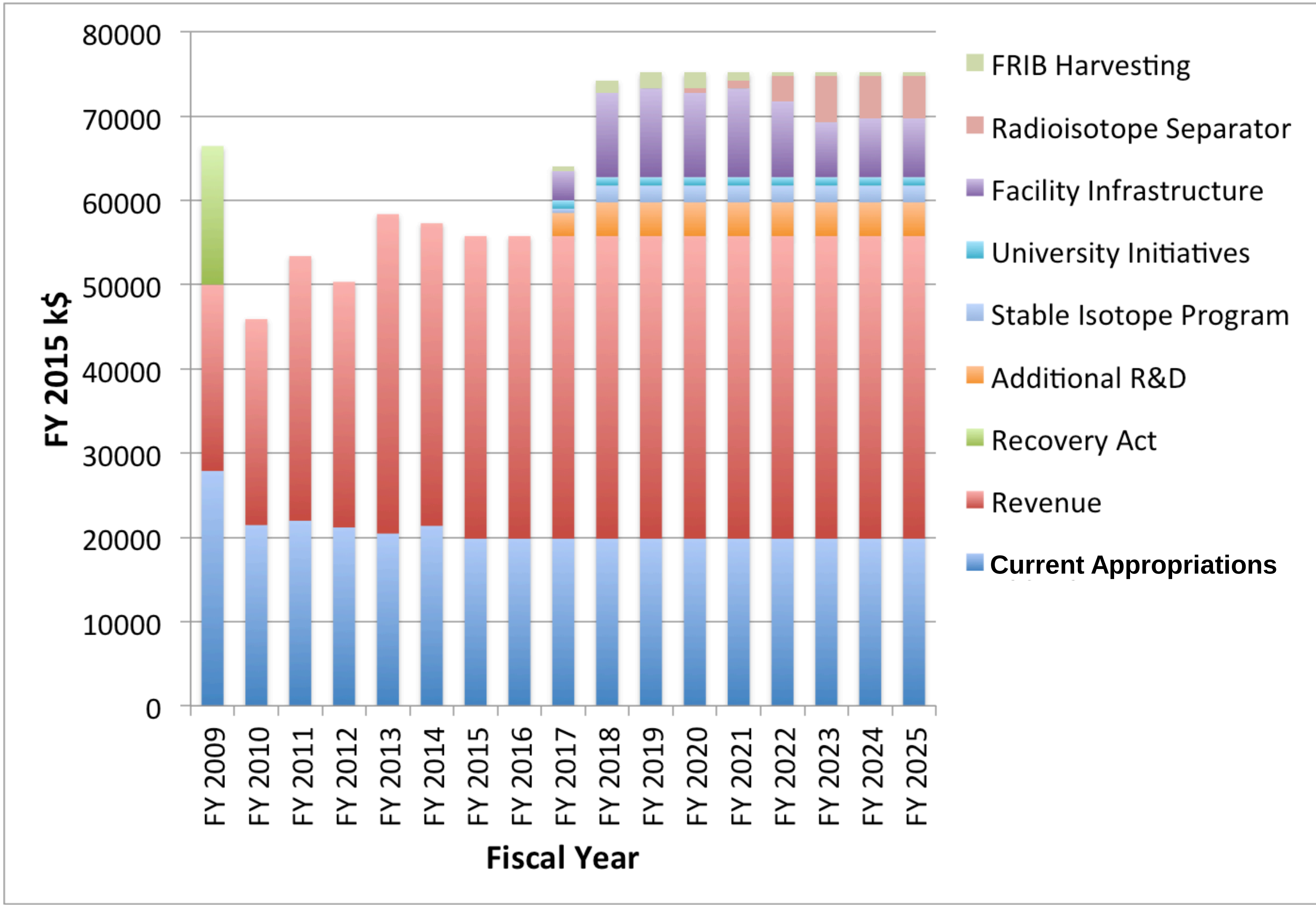
Current DOE Production Sites



DOE and University Production Sites

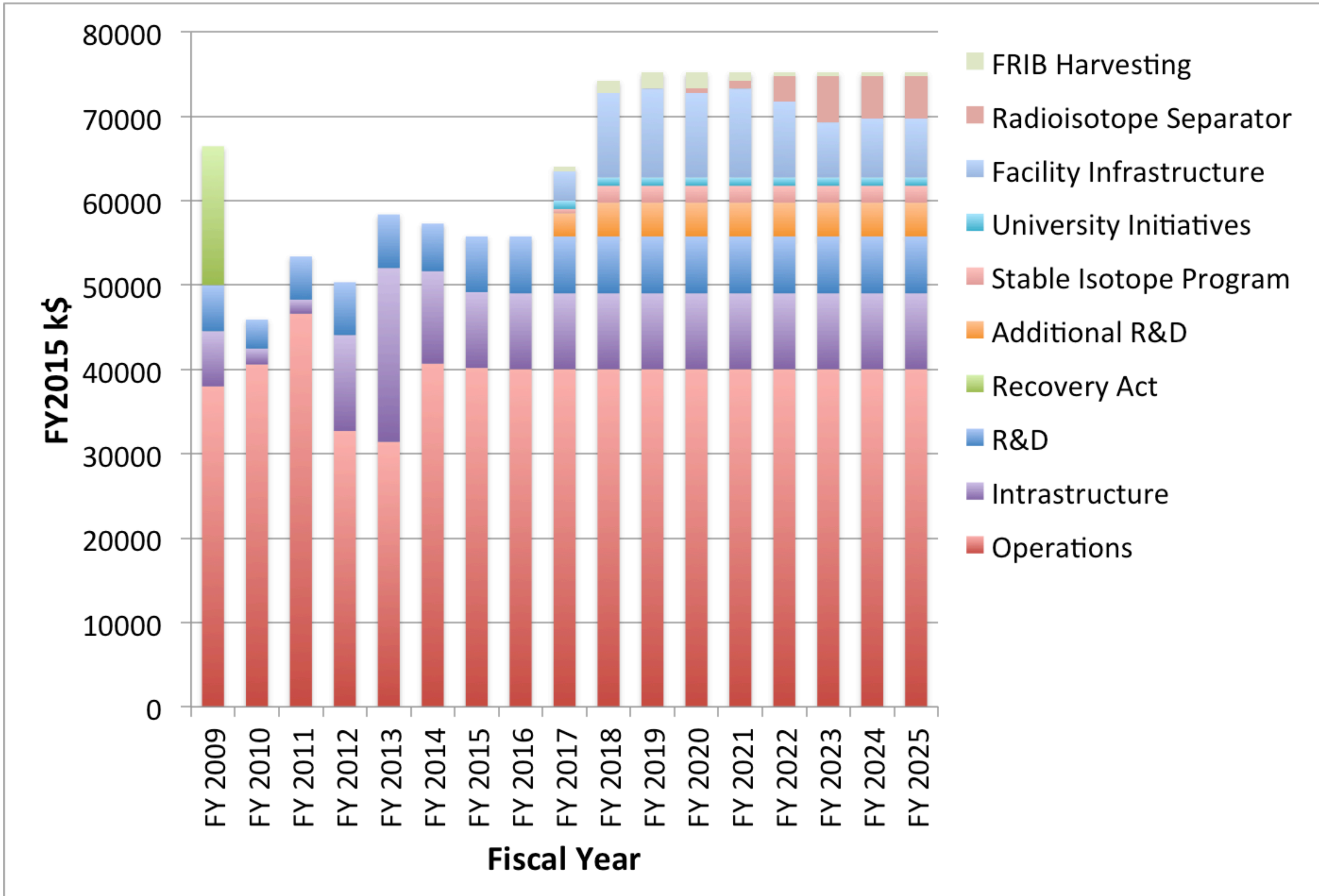


Historical and projected DOE Isotope Program funding by funding category in FY2015 k$.



The new initiatives discussed in the report are included. The total values include both base appropriations funding and funding from sales

Historical and projected DOE Isotope Program funding by category in FY2015 k$



The total values include both base appropriations funding

Incremental Annual Appropriated Funding Recommended

- **$4M to increase R&D to ~15% of the total program:** to enhance the base level of R&D at the production sites, fund critical new R&D in alpha emitter production, fund the highest rated R&D proposals, and move to an RFP each year for R&D proposals.
  (It will also add stability against revenue fluctuations)
- **$2M to operate a stable isotope production program**
- **$14M for infrastructure investments :** to realize new opportunities presented by FRIB, improvements to meet more difficult demands of alpha emitter production, funds to deal with aging infrastructure, improvements to increase production capability (as required by the charge)
- **$1M for university production facility improvements to meet demands of the program**: e.g., production of more than just single samples, special initiatives such as gaseous collection at MURR, expansion of university capabilities

Evaluation of Progress Since the 2009 NSACI Reports

The 2009 NSACI Reports made fifteen recommendations in four categories:

- **6 identified compelling research opportunities**
- **6 were on enhancing effectiveness and efficiency of program operations**
- **1 aimed at workforce development**
- **2 were on major investments in production capability**

Examples of Important Steps Forward

- Specific isotope recommendations addressed: Substantial progress on the development of new production capabilities for alpha emitters, ^{249}Bk produced in support of superheavy searches
- New management organization created within the ONP (IDPRA, and under it the NIDC), resulting in greatly enhanced coordination.
- Enhanced communication with isotope customers (e.g. annual federal workshop, annual industry survey, NIDC, interagency working groups, ….)
- Production facilities upgraded, and selective supply from six universities added. Sizable investments have been made in production facility infrastructure to refurbish aging equipment and to expand production capabilities.
- Mitigation and prioritization efforts have successfully addressed the 3He shortage
- Progress toward stable isotope mass separation (10 mA EMIS on the way toward ESIPF at ORNL)
- Workforce development is a priority (Early Career Awards, Workshops and Symposia, competitive R&D awards include postdocs, students at university and lab sites, …)
- Isotope R&D investment has increased and become more regular, with base research programs in place at BNL, ORNL, and LANL, and competitive, peer-reviewed awards to universities and national laboratories.
- The FY13 budget included $37.9M from sales, more than double the sales of five years earlier, reflecting the increase of scope of the program and effective operations.

Our Evaluation

- **Broadly: DOE/NP has done an outstanding job of reorganizing the program and setting it on a firm footing**
- **The Isotope Program now in place has realized the vision of the 2009 NSACI and is making substantial progress toward expanding that vision**
- **Key structures and processes are in place that have enhanced productivity and impact, and these should be continued and improved in the broad directions that have been established (*hence comments on operations rather than recommendations*)**

Our Comments on Operations

We note that the Isotope Program has made dramatic improvements in operations in response to the recommendations of the 2009 Long Range Plan. As discussed in Chapter 9: Program Operations, ***it is essential that the practices, procedures, and key programs put in place continue.*** Key areas where continued emphasis will be essential for continued progress are: communication; transportation; workforce development; public/private partnerships; foreign supply; and strategic planning. We summarize these areas below:

Communication: Continued excellence in communication will enable the program to nimbly respond to the diverse isotope needs of the Nation. It will be important to maintain the continuous dialogue with interested federal agencies, international suppliers, and commercial isotope customers to forecast and match realistic isotope demand and achievable production capabilities.

Transportation: The Transportation Working Group in the National Isotope Development Center (NIDC) must continue to work toward improvements in the ability to safely, efficiently, and cost-effectively transport radioactive isotopes both nationally and internationally.

Workforce Development: Investments in workforce development to educate and train the next generation of nuclear scientists focused on isotope production should continue to be a priority. Funding university programs at all levels enable a highly trained workforce and can also generate new technologies and ideas. Working together with other DOE-SC programs to expose outstanding undergraduates to nuclear science and radiochemistry has proven to be an important path for attracting young scientists and engineers to the field.

***Public/private partnerships*:** Evolving public/private partnerships are a promising and cost-effective alternate to the construction of a dedicated accelerator for isotope production recommended by the 2009 NSAC; these opportunities should continue to be pursued.

Foreign supply: The Isotope Program must continue its effort to identify critical isotopes for which the primary supply is from foreign sources and to develop mitigation strategies, as appropriate, to minimize supply constraints and disruptions.

Strategic planning: Finally, strategic planning for isotopes as they transition from R&D to commercial sales, and communication with the users of these isotopes will continue to be a priority for the Isotope Program, and to be important for the long-term viability of the program.

In Sum

- The Isotope Program is a fascinating effort that both supports basic research and bridges the gap between research and applications in many fields such as medicine, industry and national security.
- The DOE Office of Nuclear Physics has done an outstanding job of managing it since the 2009 transition, and has set in place a structure and procedures that form a firm foundation for the future. They should be encouraged to pursue the path they have laid out.
- There are many opportunities (a number of which form the basis for our recommendations) to further enhance the ability of the Isotope Program to "increase the domestic availability of isotopes appropriate to the DOE Isotope Program portfolio and deemed to be critical for the Nation."
- We can anticipate that the strengthening of the Isotope Program will be rewarded with continued progress in science, medicine, and industry, and by a further strengthening of national security.

Questions?

Note – essentially all figures in this talk have been taken from our report; the appropriate acknowledgements can be found there

Backup Material

- Outline of our Report
- 2009 NSACI Recommendations (both reports)
- List of the 7 DOE production sites and 7 University production sites contacted for input
- List of the 31 Federal Agencies contacted for input
- List of the 28 Professional Societies contacted for input
- List of the 15 Isotope Users and Producers contacted for input
- Details of the Isotope Program's response to the recommendations of the 2009 NSACI reports

Outline of Report

Executive Summary	**L. Cardman**
– Brief overview	
– Recommendations	
Chapter 1: Introduction	**L. Cardman**
– New Charge	
– Procedures (summarized)	
Chapter 2: The DOE Isotopes Program	**E. Peterson,**
– Origins and History	**L. Cardman, L. Riedinger**
– Today (2009 to present)	

Outline of Report

Chapter 3: Uses of Isotopes	
3.A: Biology, Medicine, and Pharmaceuticals	S. Lapi, R. Brown, S. Mirzadeh, T. Ruth, D. Scheinberg, S. Schwarz, S. Wilbur
3.B: Physical Sciences and Engineering	S. Mirzadeh, B. Sherrill M. Stoyer, F. Yeager
3.C: National Security and Other Applications	C. Burns, E. Peterson B. Sherrill, M. Stoyer
Chapter 4: Research Opportunities Using Isotopes	S. Lapi (overall)
4.A: Biology, Medicine, and Pharmaceuticals	Subsections A., B., C.
4.B: Physical Sciences and Engineering	as above for Chapter 3
4.C: National Security and Other Applications	subsections
Chapter 5: The Scope and the Scientific/Technical Challenges for the Isotope Program	B. Sherrill, T. Ruth

Outline of Report

Chapter 6: Sources of Isotopes for the Nation	T. Ruth
6.A. Stable Isotopes	K. Beierschmidt
6.B. Accelerator Based Isotope Capabilities	R. Brown, E. Peterson, S. Mirzadeh, B. Sherrill, T. Ruth, S. Wilbur
6.C. Reactor Based Isotope Capabilities	D. Robertson, K. Beierschmit, S. Mirzadeh
6.D. Isotope Harvesting from Long-Lived Stockpiles	S. Mirzadeh
Chapter 7: Research and Development for Isotope Production	T. Ruth
Chapter 8: Trained Workforce and Education	S. Lapi, S. Mirzadeh, D. Robertson
Chapter 9: Program Operations	E. Peterson, L. Riedinger
9.A. The Program in 2009, Its Evolution Since Then, and Its Status Today	
9.B. Evaluation of the Program and Its Evoloution since 2009	
9.C. Recommendations for Its Continued Enhancement	

Outline of Report

2009 NSAC I Recommendations: Charge I – Research Opportunities

1. Invest in new production approaches of alpha-emitters with highest priority for ^{225}Ac. Extraction of the thorium parent from ^{233}U is an interim solution that needs to be seriously considered for the short term until other production capacity can become available.

2. We recommend investment in coordination of production capabilities and supporting research to facilitate networking among existing accelerators.

3. We recommend the creation of a plan and investment in production to meet these research needs for heavy elements.

4. We recommend a focused study and R&D to address new or increased production of ^{3}He.

5. Research and Development efforts should be conducted to prepare for the reestablishment of a domestic source of mass-separated stable and radioactive research isotopes.

6. We recommend that a robust investment be made into the education and training of personnel with expertise to develop new methods in the production, purification, and distribution of stable and radio-active isotopes.

2009 NSAC I Recommendations:
Charge 2 – Long Range Plan

1.1 Maintain a continuous dialogue with all interested federal agencies and commercial isotope customers to forecast and match realistic isotope demand and achievable production capabilities.

1.2 Coordinate production capabilities and supporting research to facilitate networking among existing DOE, commercial, and academic facilities.

1.3 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

1.4 Devise processes for the isotope program to better communicate with users, researchers, customers, students, and the public and to seek advice from experts.

1.5 Encourage the use of isotopes for research through reliable availability at affordable prices.

1.6 Increase the robustness and agility of isotope transportation both nationally and internationally.

2009 NSAC I Recommendations:
Charge 2 – Long Range Plan

2. 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.

3.1 Construct and operate an electromagnetic isotope separator facility for stable and long-lived radioactive isotopes.

3.2 Construct and operate a variable-energy, high-current, multi-particle accelerator and supporting facilities that have the primary mission of isotope production.

DOE Isotope Production Sites Contacted
(All Presented at the January Meeting)

Site/Talk Topic	Speaker	Presentation	Written Material
ORNL (General), all programs there including Stable isotopes and Y-12	John Krueger	Yes	✓
INL	Debbie Utterbeck	Yes	✓
FRIB	Dave Morrissey	Yes	✓
PNNL	Gertrude Patello	Yes	✓
BNL	Leonard Mausner	Yes	✓
LANL (and Ac-225 Initiative)	Eva Birnbaum	Yes	✓
SRNL	Jeff Allender	Yes	✓

University Isotope Production Sites Contacted

Site/Talk Topic	Contact Person	Presentation	Written Input
University of Washington	Scott Wilbur	Yes (and on Ctte.)	✓
Duke University	Neil Petry	Via Scott Wilbur	✓
Washington University	Suzanne Lapi	Yes (and on Ctte.)	✓
University of Wisconsin	Jerry Nickles	Yes	✓
University of Missouri (MURR)	David Robertson	Yes (and on Ctte.)	✓
Texas A&M	Sherry Yennello	Via Scott Wilbur	✓
University of California-Davis	Barry Klein	Via Scott Wilbur	✓
And a Canadian University Facility: TRIUMF	Jonathan Bagger	Yes (and Tom Ruth on Ctte.)	talk only

Federal Agencies Contacted

Agency	Contact	Presentation	Written Material
Army Research Lab	Marc Litz	No	
Air Force Office of Scientific Research	Jeffrey Stefoneck	No	
Armed Forces Radiobiology Research Institute	Alexandra Miller and Christopher Lissner	No	
Bureau of Land Management (BLM)	John Hamak	No	✓ (brief)
Defense Logistics Agency	David Pineault	No	
Defense Threat Reduction Agency	Hank Zhu	No	✓
DoD	Craig Wuest	Yes	✓
Department of Agriculture	Kim Green	No	✓
DOE/National Nuclear Security Administration	Jeffery Joel Smith	Yes	
DOE Office of Basic Energy Sciences	Jim Rhyne	No (BES Users instead)	
DOE/BES PI	Thomas E Albrecht-Schmitt	No	✓
DOE/BES PI	Lynda Soderholm	Yes	✓
DOE/BES PI	David Shuh	No	✓
DOE/BES PI	Steven Greenbaum	No	✓

Federal Agencies Contacted

Agency	Contact	Presentation	Written Material
DOE Office of Biological and Environmental Research	Sharlene Weatherwax	No (happy with how its working)	
DOE/Office of Fossil Energy-Oil and Natural Gas	Erika Folio	No	✓
DOE Office of Fusion Energy	Gene Nardella (alternate)	Yes	✓
DOE Office of High Energy Physics	John Boger	No	✓
DOE/Office of Intelligence	Albert Davis	No	✓ (brief)
DOE Office of Nuclear Energy	Richard Reister	Yes	✓
DOE Office of Nuclear Energy, Office of Space and Defense Power Systems	Rebecca Onuschak	Yes	
DOE Office of Nuclear Physics	Tim Hallman	Yes	✓
Department of Homeland Security	David Chu	No	✓ (brief)
Department of Homeland Security - National Technical Nuclear Forensics Center	Jeff Morrison	Covered by FBI/NTFC entry below	Part of FBI/NTFC below
Department of State	Sarah Case		

Federal Agencies Contacted

Agency	Contact	Presentation	Written Material
Department of Transportation	Ken Lord	No (will attend)	no unmet needs
Federal Bureau of Investigation / DHS / National Technical Forensics Center	Richard Essex	Yes	To Come
Food and Drug Administration	Eric Duffy	No response	
National Aeronautics and Space Administration	Leonard Dudzinski or Dominic Benford???	No response	
National Institutes of Health (National Institute of Biomedical Imaging and Bioengineering to cover for all of NIH)	Tony Sastre	Yes	Talk only
National Institute of Standards and Technology	Lisa Karam / Scott Dewey	Yes	✓
National Science Foundation Directorate for Mathematical and Physical Sciences	Allena Opper	Yes	✓
Office of the Director of National Intelligence	Charlie Marineau	No.	✓
Office of Naval Research	Mike Shlesinger	Not a user	
U. S. Geologic Survey			

Professional Societies Contacted

Professional Society	Contact	Presentation	Written Material
Academy of Radiology Research	Renee Cruea, MPA, Executive Director	Input from SNMMI	No
American Association of Physicists in Medicine	Lynne Fairobent		
American Association of Cancer Research	Carlos L. Arteaga, President		
American Chemical Society - Division of Nuclear Chemistry and Technology	Mark Stoyer Paul Mantica	Yes (and on Committee)	✓
American College of Nuclear Physicians			
American College of Radiology	William T. Thorwarth, Jr., MD, Chief Executive Officer		
American Medical Association	Modena Wilson,		
American Nuclear Society	Robert C. Fine, Executive Director		

Professional Societies Contacted

Professional Society	Contact	Presentation	Written Material
American Nuclear Society - Division of Isotopes and Radiation	Steven Biegalski	No	✓
American Pharmacists Association - Academy of Pharmaceutical Research and Science (APhA-APRS)	Margaret Tomecki	Left open	✓
APS – do by division			
American Physical Society - Division of Biological Physics	Wolfgang Losert		
American Physical Society - Division of Material Physics	Laura H. Greene	No	✓
American Physical Society - Division of Nuclear Physics	Ani Aprahamian	No	✓
American Society of Clinical Oncology	Allen S. Lichter, MD, FASCO (CEO)	No	To come

Professional Societies Contacted

Professional Society	Contact	Presentation	Written Material
American Society of Hematology	Martha Liggett, Esq. Executive Director		
American Society of Nuclear Cardiology	Kathleen Flood, CEO		
American Society of Therapeutic Radiation and Oncology	Laura Thevenot, CEO		
Council on Ionizing Radiation and Standards	Roberto Uribe-Rendon	Yes	
Health Physics Society	Barbara Hamrick, President	Yes (Jan. Meeting)	✓
National Association of Nuclear Pharmacies (NANP)	Jeff Norenburg		
National Organization of Test, Research and Training Reactors	Sean O'Kelly/Ralph Butler	Yes	
Radiation Research Society	Executive Director: Veronica Haynes		
Radiation Therapy Oncology Group	Walter J. Curran, Jr., MD, Chair (executive committee)		

Professional Societies Contacted

Professional Society	Contact	Presentation	Written Material
Radiological Society of North America	Linda Bresolin, Asst. Exec. Dir. for Science and Education	No. (an advocacy group)	
Society of Nuclear Medicine	Peter Herscovitch/ Erin Grady	Yes	Yes (after 11/20)
Society of Radiopharmaceutical Sciences (SRS)	Albert Windhorst is President, Henry Van Brocklin is President Elect	No	
United Pharmacy Partners (UPPI)	John Witkowski President	No	✓

Isotope Users and Producers Contacted

User/Producer	Contact	Presentation	Written Material
Association of Energy Service Companies	Kenny Jordan (Eric Rosemann will present)	Yes	
ARRONAX, Nantes, France and a supplier of the program	Dr. Ferid Haddad , Director.		✓
Braco (supplies 82Sr from multiple sources including DOE)	Adrian Nunn	Yes	✓
Cambridge Isotopes	Peter Dodwell		✓
Eckert & Ziegler Vitalea Science (Oil and Gas Exploration)	Frank Yeager (on committee)	Yes	
EPRI (The Energy Power Research Institute)	Tina Taylor		
GE Healthcare,	Dr. Aaron Bernstein		
Jubilant Draximage	Mr. Martyn Coombs, President		
Linde	Jack Faught		
Mallinckrodt (Radiopharmaceuticals)	Roy Brown (on committee)		
Perkin Elmer	Lori Murray, Global Business Development leader, Radiotheraputics, Bio-Discovery		

Isotope Users and Producers Contacted

User/Producer	Contact	Presentation	Written Material
Radiopharmaceuticals (Council of Radionuclides and Radiopharmaceuticals)	Michael Guastella	Yes	
Source Production & Equipment Co., Inc (SPEC)	John Munro/Dennis Chedraui	Yes	
Trace Sciences	Darren Brown		✓
Zevacor – 70MeV cyclotrons and commercialization of Sr-82	John Zehner	Yes	✓

Backup:
Response to 2009 Recommendations

DOE Response to 2009 Recommendations (Compelling Opportunities)

Invest in new production approaches of alpha-emitters with highest priority for ^{225}Ac. Extraction of the thorium parent from ^{233}U is an interim solution that needs to be seriously considered for the short term until other production capacity can become available. Some examples: [Rec-1]

- **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
  - "Projectized" Ac-225 multi-lab effort – review in October 2014, January 2015
- **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

DOE Response to 2009 Recommendations (Compelling Opportunities)

We recommend investment in coordination of production capabilities and supporting research to facilitate networking among existing accelerators. [Rec-2]

- Restructured and increased the federal organization to provide more effective oversight
- Created R&D Program – competitive (*e.g.*, FOA) at universities and labs and base program at labs
- Development of university production capability and isotope production networks (such as At-211)
- Large Isotope Program Initiatives, including
  - Establish Am-241 production capability
  - Li-7 processing March 2014
  - BLIP Raster November 2013
  - He-3 equipment refurbishment
  - Cf-252 equipment refurbishment
  - Co-60 target design

DOE Response to 2009 Recommendations (Compelling Opportunities)

We recommend the creation of a plan and investment in production to meet these research needs for heavy elements. [Rec-3]

- Worked with community to develop a plan for needed isotopes for superheavy physics program; Bk-249 produced and provided leading to the discovery of heavy elements
  - New contract for long-term supply of Cf-252 for Nation
    - Cf-252 equipment refurbishment October 2012
  - Re-establishing domestic Am-241 production

DOE Response to 2009 Recommendations (Compelling Opportunities)

We recommend a focused study and R&D to address new or increased production of 3He. [Rec-4]

- Isotope Program plays the lead role in Interagency He-3 Working Group- reports to White House National Security Staff.
- DOE IP has supported initiatives at SRS to increase supply
- Have provided technical expertise to NNSA and ARPAE for consideration of He-3 production R&D
- Mitigation and prioritization efforts on behalf of the IAG have successfully addressed He-3 shortage

DOE Response to 2009 Recommendations (Compelling Opportunities)

Research and Development efforts should be conducted to prepare for the reestablishment of a domestic source of mass-separated stable and radioactive research isotopes. [Rec-5]

- R&D invested to develop capability for enriched stable isotope production
- ORNL ESIPF Pilot Plant project approved in December 2013

We recommend that a robust investment be made into the education and training of personnel with expertise to develop new methods in the production, purification, and distribution of stable and radio-active isotopes. [Rec-6]

- Have made investments in the support of students to participate in conferences and workshops
- Have supported conferences, symposia and workshops in isotope production development
- Training is considered in the selection of R&D awards
- University isotope production sites being added in 2014; will include base funding

DOE Response to 2009 Recommendations (Long Range Plan)

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-1]**

    - Restructured and increased the federal organization to more effectively interface with stakeholders
    - Created the National Isotope Development Center
    - Annual survey to industrial customers on demand
    - Annual federal workshops to assess isotope demand and promote communication regarding isotope supply and demand
    - Improved communication, visibility with stakeholders – increased number of annual stakeholder meetings
    - Increased presence and format of Isotope Booth at conferences
    - Increased federal staff participation at conferences and workshops
    - More frequent marketing assessments of individual isotopes
    - Revamped the NIDC website to make more user friendly
    - Regular publication of newslettersCreation of NIDC distribution list to advertise highlights, progress, challenges
    - Regular attendance at CORAR meetings and participate in working group on industrial relations
    - Lead for the White House NSS He-3 interagency Group on He-3
    - Member of OSTP Working Groups on Critical Materials and on Mo-99
    - Lead for DOE-NIH Working Group on medical isotopes
    - Member of NRC Task Force on Sealed Sources
    - Member of NNSA Nuclear Materials Advisory Board
    - Organize community workshops on isotopes of interest (for example O-18)
    - Organized internal federal working groups on Li-7 and on He-4 recycling

DOE Response to 2009 Recommendations (Long Range Plan)

2. **Coordinate production capabilities and supporting research to facilitate networking among existing DOE, commercial, and academic facilities. [LRP-2]**
    - Created the National Isotope Development Center
    - Created R&D Program – competitive and base funded
    - Increased portfolio of isotope production sites
        - University sites being added in 2014
        - Addition of other DOE/NNSA sites, SRS, Y-12, ATR at INL
    - Supported R&D and production investments such as to facilitate production networks of individual isotopes (such as At-211)
    - Stronger communication within program- bi-weeklies between HQ and NIDC; bi-weeklies at HQ, annual strategic planning meetings with sites, HQ and NIDC; monthlies between sites and HQ

DOE Response to 2009 Recommendations (Long Range Plan)

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-3]**
   - Created base research programs at BNL, ORNL and LANL.

DOE Response to 2009 Recommendations (Long Range Plan)

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-4]**
   - Improved communication, visibility with stakeholders
     - More frequent meetings
     - Formation of working groups (federal and with community)
     - Improve website to facilitate communication
     - Annual customer survey to obtain more information
     - Annual federal workshop and agency survey to obtain more information
     - More frequent individual market assessments
     - Created NIDC for more effective interface e with stakeholder
     - Added federal staff for more effective communication with stakeholders
   - Introduced peer review into mode of operations and assessment of proposals to solicite expert advice
     - Peer review of R&D proposals
     - Peer review of isotope projects
     - Peer review of isotope facilities

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5. **Encourage the use of isotopes for research through reliable availability at affordable prices.[LRP-5]**
   - Increased portfolio of isotope production sites – production at universities introduces cost effectiveness and increased availability
   - Scrubbed production costs of all isotopes
   - Increased availability of research isotopes (increased scope of portfolio and/or increased supply)
   - Decreased price of research isotopes
     - Unit vs batch price for research isotopes

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6. **Increase the robustness and agility of isotope transportation both nationally and internationally.[LRP-6]**
   - NIDC has staff now dedicated to transportation
   - Formed Transportation Working Group (led by NIDC) to focus on transportation challenges

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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-7]**
   - Competitive R&D FOA and Core R&D funding provides for:
     - Support of postdocs
     - Succession planning
     - Workforce development is a priority in FOA
     - Support of students at university and lab sites
   - SC Early Career Awards also includes Isotope Program
   - Isotope Program participation in workshops, conference meetings
   - Sponsorship of Workshops and Symposia
   - Organization of Workshops and Symposia
   - NNSA Sponsored Mo-99 Topical Meetings (2011, 2013, 2014)

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8. **Construct and operate an electromagnetic isotope separator facility for stable and long-lived radioactive isotopes.[LRP-8]**
   - Transition from R&D 10mA EMIS at ORNL to prototype production facility (ESIPF)

9. **Construct and operate a variable-energy, high-current, multi-particle accelerator and supporting facilities that have the primary mission of isotope production.[LRP-9]**
   - Seriously considered but did not implement
   - Industrial entities purchasing 70MeV cyclotrons
   - Cost prohibitive in times of fiscal constraint
   - More cost effective to invest in universities and establish production networks
   - Invest in capabilities that are unique to and more appropriately managed by USG