



Report on the Isotope Workshop

“The Nation’s Needs for Isotopes: Present and Future”

August 5-7, 2008

John D’Auria
Detaillee in Office of Nuclear Physics

Outline:

Goal/Purpose of Workshop - JSG

The Workshop – Details

Work sessions - (Was work really done?)

- Stable and Enriched Isotopes**
- Radioisotopes for Research and Development**
- Radioisotopes for Applications**

Preliminary summaries - What did we learn?

**sponsored by Department of Energy
Office of Science for Nuclear Physics and Office of Nuclear Energy**

Layout of the Workshop

- Workshop would be useful to learn first-hand about the needs of the Nation for isotopes
- Establish/strengthen communication with stakeholders in isotope production (research, federal, industrial)
- Assemble **for the first time** broad representation of stakeholders (users and producers of isotopes) to discuss current and projected isotope needs
- Scheduled a 3 day workshop consisting of a plenary and break-out work sessions
- Plenary Session to give broad introduction into how isotopes are used by various disciplines
- Three Working Groups (Second and Third days) **[By Invitation Only]:**
 - Stable and Enriched (both research and applied)
 - Radioisotopes for Research and Development
 - Radioisotopes for Applications
 - All included broad federal, research, academic and industrial representation
 - Size of Working Groups kept purposefully “**small**”
- Poster Session
 - Additional details and background for Working Groups
- Circulated a background information form on isotopes to all invitees of work sessions prior to workshop

Goals of the Workshop

- **Workshop Questions:**
 - **Who uses isotopes and why?**
 - **Who produces them and where?**
 - **What is the status of the supply and what is missing?**
 - **What are the needs today and in the future?**
 - **What are the options for increasing availability and associated technical hurdles?**
- **The deliverable** will be a report which articulates the Nation's needs for isotopes across the various disciplines, the challenges in meeting those needs and options for improving the capabilities for meeting the demands.
 - First step towards development of comprehensive and prioritized strategic plan
 - NSAC can use this input (and others) to develop a long range plan

Not part of Workshop

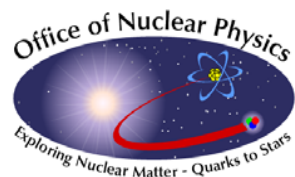
What the Workshop did **NOT** include:

- Setting priorities
- Making business deals
- Discussions on future pricing policy
- Discussions of propriety information
- Observers only, in the Working Groups – invited and active participants only

Serious expressions of frustration – need to put aside to be productive

Lots of individual agendas – left them at home

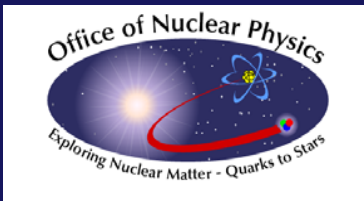
Several major isotope issues in supplies of certain isotopes; did not let dominate discussions – items acknowledged, articulated and then group moved on



Institutions



- **Federal**
 - National Institute of Health
 - Department of Homeland Security
 - Department of Agriculture
 - Nuclear Regulatory Commission
 - DOE Nuclear Energy
 - DOE Basic Energy Sciences
 - DOE Nuclear Physics
 - DOE Biological and Environmental Research
 - DOE Chicago
 - DOE CFO
 - Office of Scientific and Technological Policy
 - National Nuclear Security Administration
 - National Institute of Science and Technology
 - National Institute of Child Health and Human Development
 - Department of State
 - Federal Bureau of Investigation
 - Environmental Protection Agency
 - National Science Foundation
 - Office of Naval Research
 - Armed Forces Radiobiology Research Institute
 - The National Academies
- **National Laboratories**
 - Argonne National Laboratory
 - Brookhaven National Laboratory
 - Lawrence Berkeley National Laboratory
 - Los Alamos National Laboratory
 - Oak Ridge National Laboratory
 - Pacific Northwest National Laboratory
 - Idaho National Laboratory
 - Lawrence Livermore National Laboratory
- **Others/International**
 - International Atomic Energy Agency (IAEA)
 - MDS Nordion
 - TRIUMF (Canada)
- **Universities**
 - Michigan State University
 - University of Washington
 - University of Missouri
 - Texas A&M University
 - Duke University
 - Washington University
 - University of California/Davis
 - Georgetown University Hospital
 - University of Buffalo
 - University of British Columbia
 - California Institute of Technology
 - University of Tennessee
 - Research Triangle Institute
 - North Carolina State University
 - University of Connecticut
 - University of San Francisco
 - Memorial-Sloan Kettering
 - American College of Radiology
- **Industrial**
 - Nidnano
 - GE Energy Reuter Stokes
 - Spectra Gases
 - Trace Life Sciences, Inc.
 - Association of Energy Services
 - SABIA, Inc.
 - Council of Radionuclides and Radiopharmaceuticals
 - General Atomics
 - Techsource, Inc.
 - Halliburton
 - Advance Medical Isotope
 - JUPITER Corp.
 - Raytheon
 - NorthStar Medical Radioisotopes
 - TRIGA Reactor Systems/General Atomics
- **National Academies**



Workshop Plenary Session

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- Welcome and Opening Remarks – **Dr. Raymond Orbach**, Under Secretary for Science, Department of Energy
- Objectives of Workshop – **Dr. Jehanne Simon-Gillo**, Acting Associate Director, Office of Science for Nuclear Physics, Department of Energy
- Perspective at OSTP for Isotopes - **Dr. Jean Allen Cottam**, Ass. Director, Physical Sciences and Engineering, OSTP
- Nuclear Physics & Strategic Planning of the Isotope Program – **Prof. Robert Tribble**, Dept. of Physics, Texas A&M and Chair of NSAC
- Importance and Role of Isotopes in Basic Research – **Prof. Lee Riedinger**, Dept. of Physics, University of Tennessee
- Importance and Role of Isotopes to the NIH Mission – **Dr. Roderic Pettigrew**, Director, NIBIB, National Institute of Health
- Importance and Role of Isotopes to the Medical Community - **Prof. Michael Welch**, Dept. of Radiology, Wash. Univ. School of Medicine
- Importance and Role of Isotopes to the Department of Homeland Security Mission and National Security – **Dr. Charles Gallaway**, Deputy Director, Domestic Nuclear Detection Office, Department of Homeland Security
- Importance and Role of Isotopes to the Agricultural Research and Applications – **Mr. John Jensen**, Dir. Radiation Safety Div. Dept. Agric.
- Importance and Role of Isotopes to current and planned Nuclear Reactors – **Mr. Ira Goldman**, Project Manager, IAEA
- Importance and Role of Isotopes to the Radiopharmaceutical Industry – **Mr. Roy Brown**, *Council on Radionuclides and Radiopharmaceuticals*
- Importance and Role of Isotopes to the Oil Industry, **Mr. Eric Rosemann** - Director of Safety for Gray Wireline, Chairman of the Ass. of Energy Service Companies Radiation, Safety and Security Comm
- Recent and Ongoing National Academy Studies Relevant to Isotope Production – **Dr. Kevin Crowley**, Dir, Nucland Radiation Studies Board, The National Academies
- The Mission of the Nuclear Regulatory Commission and its Role Pertinent to Radioactive Isotopes – **Dr. Donna-Beth Howe**, NRC
- Status of International Isotope Production – **Dr. Tom Ruth**, Senior Research Scientist and Director of the UBC/TRIUMF PET Program
- Isotope Program in the USA – **Mr. John Pantaleo**, Program Director, Isotope Program Office of Nuclear Energy, Department of Energy

Attendance ~170



Workshop Poster Session



Workshop Attendees

Subjects/Titles

Worksession 1

Stable and Enriched Isotopes

John Greene	ANL Physics Division Accelerator Target Laboratory
Richard Kouzes	Separated Isotope Requirements for Double-Beta Decay
Andreas Stolz	Rare Isotope Research at the National Superconducting Cyclotron
Clifford Unkefer	Stable Isotope Enhanced Metabolomics
Robert Vocke	Isotopic Reference materials for the 21st Century
Alfred Yergey	Nutritional Uses of Stable Isotopes: An example of Iron Absorption
Scott Aaron	Enriched Stable Isotopes and Technical Services at ORNL
Ercan Alp	Mossbauer Spectroscopy: Stable and Radioactive Isotopes

Worksession 2

Radioisotopes for Research and Development

Robert Atcher	Optimizing a pre-labeling approach to synthesize a water-soluble conjugate for therapy with the Ac-225 decay chain
Glenn Young	Overview of HRIBF
Michael Hughes	Use of arsenic-73 in research supports US EPA's regulatory decisions on inorganic arsenic in drinking water.
Calvin Howell	Capabilities of High Intensity Gamma-ray Source at TUNL Isotope Requirements for Research at TUNL
Randy Hobbs	High Flux Isotope Reactor (HFIR) Radioisotope Production Facilities and Capabilities
Russ Knapp	Medical Radioisotope Research at ORNL
Claude Lyneis	Isotope use and production at LBNL's 88-Inch Cyclotron
Alexandra Miller	Using a Multiple Isotope Approach to Understand Uranium Cellular
Leonard Mausner	BNL Radioisotope Research and Production Program
Heino Nitsche	Isotope Needs for Physics and Chemistry of the Heaviest Elements
Richard Pardo	CARIBU-Radioactive Beams for Research Using ^{252}Cf
J. David Robertson	Isotope Production at the University of Missouri Research Reactor
James Symons	88-Inch Cyclotron
Mark Stoyer	Isotopes for Nuclear Science at LLNL
Robert Tribble	Present and Future Capabilities of the TAMU Cyclotron Institute
Robert Schenter	"Producing Maximum Specific Activity Molybdenum-99 with 14MeV neutrons on a Technetium-99 Target".
Vigil Toby	Am-241 Production at Los Alamos National Laboratory
Michael Welch	Non Standard Pet Radioisotopes

Worksession 3

Radioisotopes for Applications

Cathy Cutler	Radiopharmaceutical Research at the University of Missouri
Jennifer Jackson	Geophysical and Planetary Applications of Enriched Stable and
Manuel Lagunas-Solar	Radioisotope Research facilities at UC Davis
Meiring Nortier	Isotope Science and Production at Los Alamos
John Snyder	Potential For Accelerator Generated Tc-99m and FPEX display



Background Information



- Isotopes Workshop Background Information
- As an invited participant of the Workshop, you are representing a particular community or area of expertise. Please respond to these questions in that context.
- This information will be made available to the Working Group participants to provide relevant background for the Work sessions. Provide responses on extra pages as needed and please submit by e-mail (preferably Word format) to John D'Auria (John.D'Auria@science.doe.gov) by **July 28**.
- **[Isotopes = radioactive and/or stable]**
- **A.** Which isotopes do you (company, agency, university, community) currently use in your activities or distribute (repackage) to end-users?
- **B.** Describe generally what these isotopes are used for, i.e. the science or application.
- **C.** Which isotope(s) do you anticipate may have significant future increase in demand. Identify the isotope (s), its priority, possible chemical form and for what purpose it would be used.
- **D.** Are there other isotopes that you might use but are currently unavailable or not available in sufficient quantities? If so, please identify this isotope, from whom have you tried to obtain it and for what purpose would it be used.
- **E.** Do you have any specific issues with respect to the purity, availability, reliability of supply, etc. of isotopes at present?
- Please provide the information below with your responses.
- Name _____ Organization _____
- _____
- Web page _____ Phone _____ e-mail address _____
- _____
- Additional Comments: _____

Results

- Received 29 replies prior to workshop
- Circulated to Work session Chairs
- Responses summarized and will be included in final report



Stable and Enriched Isotopes



- Co-Chairs: Lee Riedinger, UTenn and Jack Faught, Spectra Gases

#	Name	Position	Institution
1	John Greene	Target Development Engineer	Argonne Nat Lab
2	Andreas Stolz	Assistant Prof.& Dept. Head of Operations	Michigan State Univ
3	Scott Aaron	Isotope Development Group Leader, NSTD	Oak Ridge Nat Lab
4	Richard Kouzes	Laboratory Fellow	Pacific NW Nat Lab
5	Craig Reynolds	National Cancer Institute	NIH
6	Robert Vocke	Research Chemist	NIST
7	Alfred Yergey	Section Chief	NIH
8	Ercan Alp	Senior Scientist	Argonne Nat Lab
9	Molly Kretsch	National Program Leader, Human Nutrition	USDA
10	Gary Hatch	Chief, Pulmonary Toxicology Branch	EPA
11	Brad Keister	Program Director	NSF
12	Darren Brown	President	Trace Sciences
13	Alfred Wong	Professor	UCLA
14	Thomas Anderson	Product Line Leader	GE Reuter-Stokes
15	Bill Casey	Professor of Chemistry	UC Davis
16	Abdul Dasti	Division of Stockpile Tech and Special Materials	NNSA
17	Victor Gavron	Second Line of Defense Program	LANL
18	Jehanne Simon-Gillo	Acting AD, Office of Nuclear Physics	DOE
19	Clifford Unkefer	Director, National Stable Isotope Resource	Los Alamos Nat Lab



Who uses stable isotopes and Why?

Tremendous diversity of uses with an incomplete list below

- Materials Science, biology, chemistry, earth sciences
- Human nutrition, obesity, disease prevention, and medical imaging - NIH and USDA -
- Food and agriculture - USDA
- Pharmaceutical and FDA (e.g. ^{18}O as a target to make ^{18}F for PET studies)
- Double beta decay - fundamental properties of neutrino
 - 1000 kg of ^{76}Ge , ^{82}Se , ^{100}Mo , ^{116}Cd , ^{130}Te , ^{136}Xe , ^{150}Nd
- NIST – standards and spike materials
- Homeland security, neutron scattering research, safeguards (IAEA), oil drilling, low-T physics, medical, DOE NA25
 - Li, ^3He - 75K liters/yr
- Environmental and toxicology; cosmogenic and earth sciences
- Atmosphere and hydrosphere
- Detector technology
- Nuclear energy
- DOE and NSF nuclear physics research
 - Isotopes for accelerator beams - ^{48}Ca , ^{50}Ti ,
 - Isotopes for targets - highest enrichment of many cases
- SNS cooling of moderator, medical community, fiber optics, semi-conductors, neutron scattering (deuterated compounds)



Brief summary/comments/concerns

- Most demands are being met by either domestic or foreign suppliers.
- **No new active domestic production** since the U.S. EM (Calutrons) enrichment facility at ORNL was put into standby (1998).
- In the domestic inventory all isotopes are available for next 20 years depending upon spike demands with the exception of those listed on table.
- For double beta decay experiments, there is no stockpile or production facility for the large (~1000 kg) quantities of the required isotopes (e.g. ⁷⁶Ge) [only Russia]
- The demand for ³He (for neutron detectors, etc) exceeds supply and will continue to rise.
- Certain isotopes not available anywhere such as ⁹⁶Ru
- Increasing demand for special enriched isotopes (⁴⁸Ca) to produce neutron rich beams.
- There is concern about cost of isotopes, purity, and availability when only one supplier.



Stable and Enriched Isotopes

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What is the status of the supply and what is missing?

Table of Stable Isotope Stockpile	ORNL/ Scott Aarons
Isotope	Years Remaining Inventory
GADOLINIUM 154, SECOND PASS	2.5
GALLIUM 69	3.7
NICKEL 62	3.9
OSMIUM 187	5.2
LUTETIUM-176	5.5
RUTHENIUM 99	6.3
OSMIUM 186	7.5
BARIUM 136	7.6
NEODYMIUM 150	7.9
MERCURY 204	10.2
CADMIUM 106	10.7
MERCURY 202	11.5
PALLADIUM 106	12.6
SILVER 109	14.3
ZIRCONIUM 94	18.5
BARIUM 137	19.0
SAMARIUM 149	19.6
GADOLINIUM 157	0.2
PLATINUM 195	12.0
GADOLINIUM 157 SECOND PASS	0.0
LEAD 204, SECOND PASS	0.0
LEAD 207, SECOND PASS	0.0
RUTHENIUM 96	0.0
SAMARIUM 150, SECOND PASS	0.0
TANTALUM 181	0.0
VANADIUM 51	0.0
TUNGSTEN 180, SECOND PASS	0.0



Radioisotopes for Research & Development

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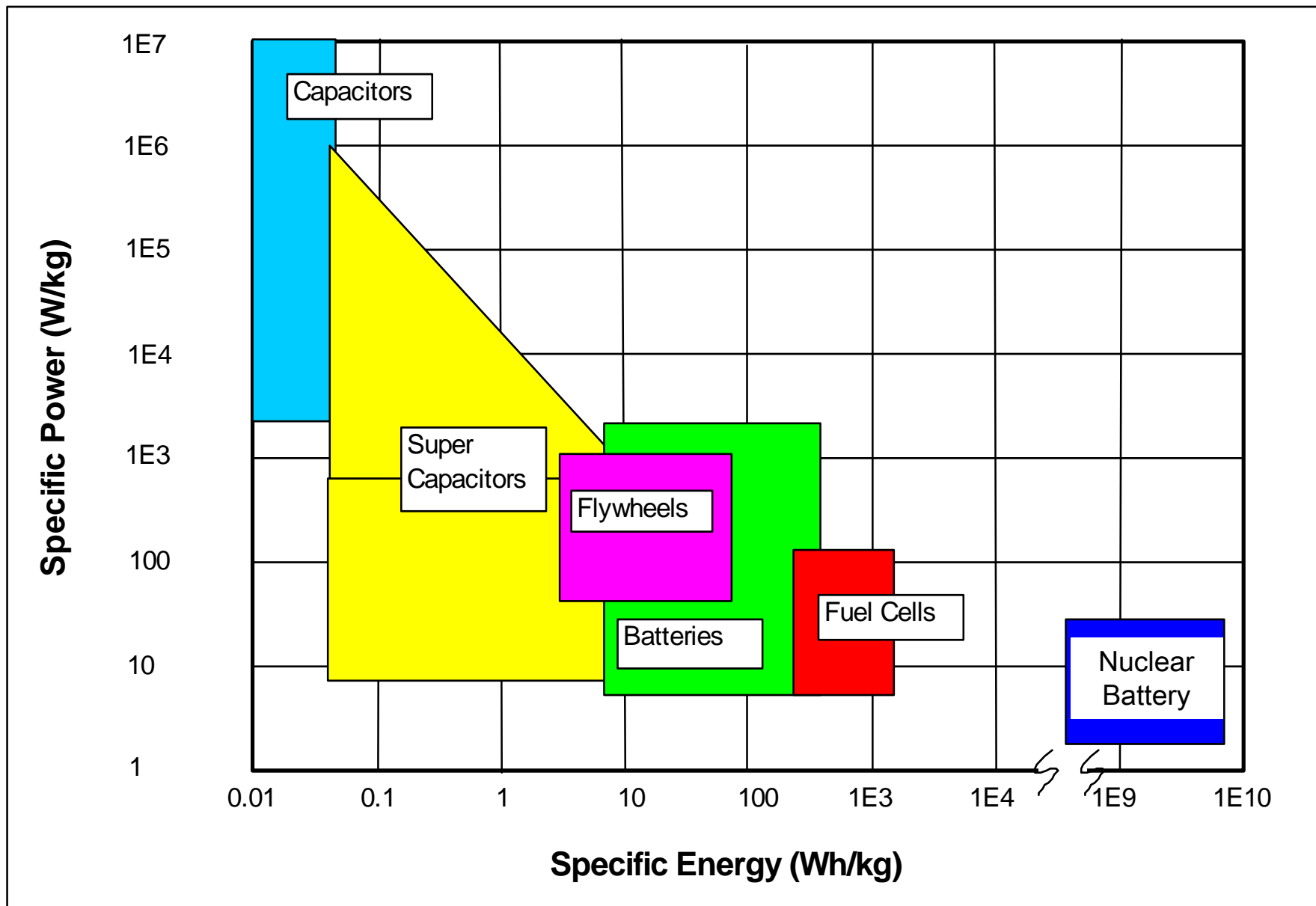
NAME	ORG
Darrell R. Fisher	PNNL
Martin Brechbiel	NCI/NIH
Leonard Mausner	BNL
J. David Robertson	MURR
Nick Baldasaro	RTI
Heino Nitsche	LBNL/UCB
Jill Chitra	MDS Nordeni
Brian Zimmerman	NIST
Alexandra C. Miller	AFRRI/USUHS
Lynn Kaczmarek	Universtiy of Buffalo
John Snyder	INL
Jim Harvey	Northstar Med. Rad.
Jason Lewis	MSKCC
Ram Ramabhadran	USEPA
Calvin Howell	TUNL/Duke University
John D'Auria	DOE NP
Mark Stoyer	LLNL
Lester Morss	DOE-BES
Steve Laflin	INIS
Roger Moroney	Siemens M/PETNET
Russ Knapp	ORNL
Randy Hobbs	ORNL
Meiring Nortier	LANL
Bill Courtney	Trace Life Sciences

Co-Chairs: Robert Atcher, LANL and Bob Tribble, TAMU

34 invited participants

Bill Courtney	Trace Life Sciences
Richard Pardo	ANL/ATLAS
Claude Lyneis	LBNL/88-Inch Cyclotron
Michael Hughes	US EPA
Michael Welch	Washington University
Prem Srivastava	DOE/SC/OBER
Henry VanBrocklin	UCSF
Glenn R. Young	ORNL

- **Who uses (stable and) radioisotopes for R&D and Why?**
 - Wide diversity of users and again not all given below
 - Medical community for both diagnostic and therapeutic research (**many isotopes**)
 - some key concerns: alpha emitters (^{225}Ac , ^{211}At)
: beta emitters (^{67}Cu , ^{77}Br , ^{177}Lu among others)
 - Environmental, e.g. ^{73}As , ^{32}Si , ^{26}Al , ^{109}Cd
 - National security
 - Use of stable to produce heavy ion stable and radioactive beams/ Nucl. Phys.
 - Heavy element (actinide chemistry) and SHE research
 - Development of nuclear batteries (^{147}Pm , ^{210}Po , ^{33}P)/ Security applications
 - Calibration sources in various applications
 - Nuclear physics , CARIBU (^{252}Cf)



Potential Isotopes for Radioisotope Micropower Source Applications

Radioisotope	E_{avg} (keV)	Half-life (years)	Maximum BOL activity (TBq/cm ³)	Maximum BOL source power (mW/cm ³)	Particle range in source (μm)	"Realistic" BOL P_{out} ($\mu\text{W}/\text{cm}^2$)
¹⁴⁷ Pm	61.8	2.6	247	2448	9.6	141.1
²¹⁰ Po	5304	0.38	1566	1.3E6	1	1.4E4

+ 6 other isotopes

β source

- 100% isotope enrichment
- $\eta_{\text{conv}}=10\%$, $\eta_{\text{source}}=30\%$
- source thickness=2 x beta range

α source

- 100% isotope enrichment
- $\eta_{\text{conv}}=10\%$, $\eta_{\text{source}}=90\%$
- source thickness=1 μm

Issues: purity of source and ultimately, supply, if successful development.

Brief summary/comments/concerns

- **Most demands are being met by either domestic or foreign suppliers.**
- **Availability of isotopes often time dependent and dictates research plans.**
- **Medical needs for R&D can vary significantly which makes it hard to plan**
- **Concern about supply of actinides and especially ^{252}Cf .**
- **Production concerns**
 - Facilities not fully utilized nor matched to production needs of community
 - Shortage of trained personnel for processing
 - Need for qualified shipping containers
 - Cost, purity and availability of research isotopes especially when only one supplier.

Radioisotopes for Applications



NAME	ORG
Parrish Staples - Co-Chair	NNSA
Jeff Norenberg - Co-Chair	Univ. of Mexico
Roy Brown	CORAR
Jim Wilson	Eckert+Ziegler - Isotope Products
Tony Veca	General Atomics - TRIGA
Gene Peterson	LANL
Steve Goldberg	DOE-NBL
Zane Bell	ORNL
Jerry Klein	ORNL
Alan Remen	SABIA Industry
Bernard W. Wehring	NC State University
Cathy Cutler	MURR
Dan Fenstermacher	DOS
Frances Marshall	INL
Eric L. Rosmann	AESC
Hugh W. Evans	QSA-global
Richard Rebs	Georgetown University
Michael Zalutsky	Duke University
Wolfgang Runde	DOE Isotope Program
Michael Shlesinger	Office of Naval Research
Ira Goldman	IAEA
James Symons	LBNL
Jennifer M. Jackson	Caltech
David J. Schlyer	BNL
John T. Jensen	USDA
John Pantaleo	DOE
Tracey Lane	Tnace Life Sciences
Ron Crone	ORNL-HFIR
Elly Melamed	NNSA/DOE
Manuel Lagunas	SOLAR
Thomas Ruth	TRIUMF
Mike Peaarson	LANL
David W. Martin	DHS/OIP/Nuclear SSA
Ken Inn	MIST
Tom DeForest	PNNL/NNSA
Jason Shergur	LANL/DHS
James Tatum	NIH/NCI
Susan Seestrom	LANL

Co-Chairs: Jeff Norenberg, Univ. New Mexico and Parrish Staples, NNSA
39 invited participants

Who uses Radioisotopes for Applications and Why?

- **National Security**
 - Defense programs (^{252}Cf)
 - Stockpile stewardship
 - Homeland Security
- **Industrial Applications**
 - Petroleum (^{252}Cf)
 - Tracers
 - Radiography
 - Nuclear Power
- **Research**
- **Agriculture**
- **Medical** (many isotopes)
 - Diagnostic ($^{99}\text{Mo}/^{99}\text{Tc}$)
(~15M procedures/year)
 - Therapeutic
- **Occupational Health**
- **Environmental**
- **Reference Materials**

Radioisotopes for Applications



Isotopes for National Security and Medical Uses

Full table: 34 +medical isotopes

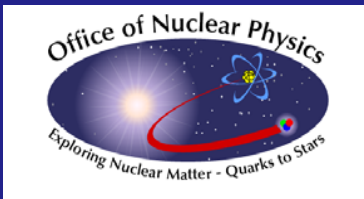
Nuclides	Use	Producer	Status of Supply	Missing	Current/ Future Demand	Impact	Special Considerations	Options for increased availability
Cf-252	Process control, analysis, well logging,, Safety, NationalSecurity Medical	ORNL & RIAR (Russia)	1	Processing facilities.	1	1	ORNL – has capacity – Zero funding – current material in the reactor needs funding for the 9 month process exercise, 4 year cycles	Reinstate irradiation and processing
Mo/Tc-99	Medical Diagnoses	NRU, Canada Petten, Netherlands Safari, South Africa BR-2, Belgium	1	High purity required	1	1	HEU versus LEU Status of Maple Reactors unclear	MURR have proposed LEU production
Th-228	Calibration standard	DOE	1	No current efforts for separation	1	1	ANSI standard for certifying radiation detection instruments.	Requires U232 and situation not clear

Legend: Supply/Demand

- 1. Demand > Supply
- 2. Demand = Supply
- 3. Demand < Supply

Impact: economic/multiple industries/multiple populations

- 1. Massive
- 2. Moderate
- 3. Minimal



Radioisotopes for Applications

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Brief summary/comments/concerns/issues

- Need better coordination/efficient use of existing production resources
(coordination of public and private facilities/new facilities may be needed)
- Implicit vulnerabilities with dependence on foreign supply (e.g. ^{99}Mo)
 - Transportation
 - Political
 - Security (LEU vs HEU)
- Single/no supplier (e.g. ^{252}Cf); and also need multiple sourcing/suppliers

- Alpha emitters availability diminishing
 - Need supply for medical research (^{225}Ac & ^{211}At from ^{229}Th)
 - Extraction of ^{229}Th from ^{233}U feasible but becoming impossible

- Cradle-to-grave husbandry needed

- Utilize public/private/partnerships (Industry not consulted on ^{252}Cf , e.g.)

- Identify/socialize **strategic importance** of key isotopes,
e.g. ^3He , ^{99}Mo , ^{137}Cs , ^{241}Am , ^{252}Cf

- Need more/better Training and Education programs for related programs



- Preliminary
 - Workshop was a success, namely good communication between academic, medical, industrial, commercial, federal and national laboratory personnel.
 - Lines of communication between separate groups now opening.
 - Strong suggestion that it should be repeated annually.
 - DOE NP learned a good deal of the needs of the Nations for isotopes.
 - There are a number of key issues that need addressing.
 - Final report is in preparation....Completion date? **Oct. 1, 2008**
 - **(Personal observations)**

Same old, same old ... to be avoided
Costs of research isotopes
Lack of multiple suppliers or absence of suppliers
Apparent decreasing support in government



- THE END