



## DOE Support for Mo-99 Production

## in the United States

**2015 MO-99 TOPICAL MEETING BOSTON** 



MATERIAL MANAGEMENT AND MINIMIZATION CONVERT, REMOVE, DISPOSE





## Material Management and Minimization

Achieving Permanent Threat Reduction by Managing and Minimizing Nuclear Materials



#### **Convert**

Convert research reactors and isotope production facilities to nonweapons-usable nuclear material both domestically and abroad

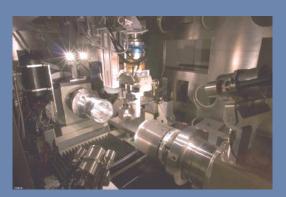
- Research Reactor Conversion
- Mo-99 Program



**Remove** 

Remove or confirm the disposition of excess weapons-useable nuclear material at civilian facilities across the globe and consolidate those materials that remain

- International Nuclear Material Removal and Consolidation
- International Nuclear Material
   Down-blending



**Dispose** 

Dispose of and manage excess weapons-useable nuclear material, from both domestic stockpiles and material returned from abroad, and implement the Plutonium Management Disposition Agreement (PMDA) with Russia

- HEU and Plutonium Disposition
- Uranium Supply for Peaceful Uses

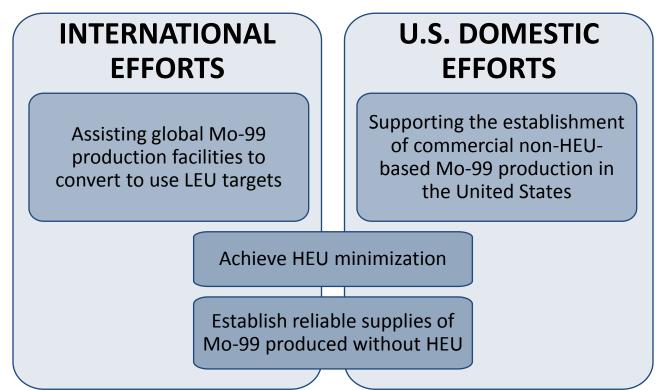




## International and Domestic Approaches

Objective: To accelerate the establishment of reliable supplies of the medical isotope molybdenum-99 (Mo-99) produced without highly enriched uranium (HEU)

- Under its HEU minimization mission, NNSA provides assistance to existing isotope production facilities to convert from HEU to LEU targets.
- NNSA's mission includes supporting the establishment of a reliable U.S. domestic supply of Mo-99 produced without the use of HEU.



U.S. DEPARTMENT OF ENERGY



## The American Medical Isotopes Production Act

- AMIPA, enacted on January 2, 2013, is intended to help establish a reliable domestic supply of Mo-99 produced without the use of HEU and includes a number of short, medium, and long-term actions:
  - Requires DOE to carry out a technology-neutral program to support projects for the production of Mo-99 in the United States without the use of HEU.
    - awarded under a 50% 50% cost-share cooperative agreement, per the Energy Policy Act; and
    - limited to \$25M in NNSA contributions per project, consistent with the OECD-NEA policy guidelines.
  - Requires annual public participation and NSAC reviews
  - Requires development assistance for fuels, targets, and manufacturing processes
  - Establishes a Uranium Lease and Take Back program
  - Requires DOE and NRC to coordinate environmental reviews where practicable
  - Provides a cutoff in exports of HEU for isotope production in 7 years, with possibility for extension in the event of a supply shortage
  - Requires a number of reports to be submitted to Congress





## **NNSA Cooperative Agreements**

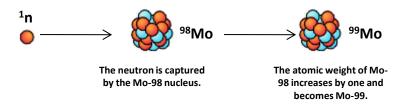


RadioGenix<sup>™</sup> – NorthStar <sup>99m</sup>Tc Generating System

**NorthStar Medical Radioisotopes** has two Cooperative Agreements for two different technical approaches to producing Mo-99. Both would use NorthStar's RadioGenix generator system.

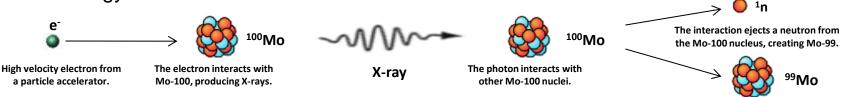
#### **Neutron Capture Technology:**

NNSA has awarded a total of \$16.1 million to NorthStar to develop its neutron capture technology.



#### **Accelerator Technology:**

NNSA has awarded a total of \$5.7 million to NorthStar to develop its accelerator-based technology.







## **NNSA Cooperative Agreements**

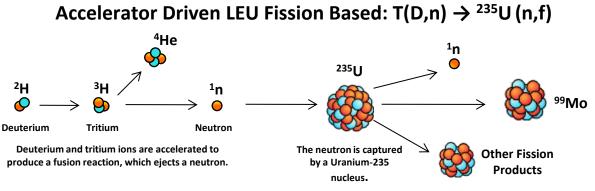
**SHINE Medical Technologies** has one cooperative agreement for its fission-based Mo-99 production technology. The Mo-99 to be produced by SHINE would be able to be used in existing generators.

#### **Accelerator with LEU Fission:**

NNSA has awarded a total of \$14 million to Morgridge Institute for Research (\$10.7M) and SHINE Medical Technologies (\$3.3M), to develop its accelerator with LEU fission technology.



SHINE Medical Technologies Accelerator-Driven LEU Subcritical Assembly for Medical Isotope Production



Neutrons and fission products are ejected; Mo-99 is six percent of the fission products produced.





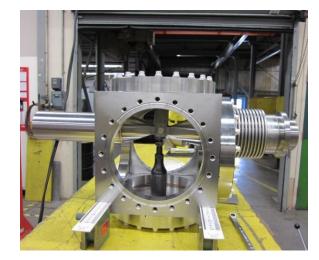
## **U.S. National Laboratories Support**

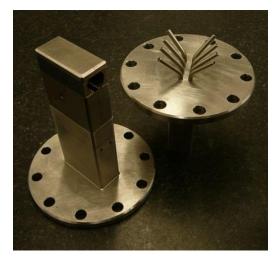
NNSA makes the expertise of the U.S. National Laboratories available to:

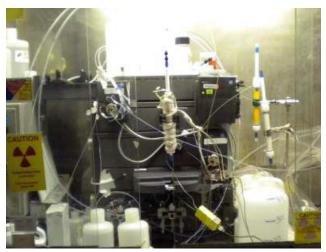
- Support technical development of each of the Mo-99 technical pathways
- Ensure the expertise at the national laboratories is available to support the acceleration of commercial projects using non-HEU technologies

All work packages funded by NNSA outside the cooperative agreement are public domain, non-proprietary, non-critical-path activities.













### **U.S. National Laboratories Support**

A         B         C         D         E         F           21.2.94.14         ANU/CSE-14/31         Superconducting Electron Line Concepts for Molybdenum-99 Production         P.N. Ostroumov, Z.A. Conway, and M.P. Kelly         Inter//www.osti.gov/scitech/servlets/purl/1165452           21         21.2.94.1.6         ANU/CSE-14/31         Scalability of the Cintichem Process Modified for Low Enriched Progress Report on Percoide Amanda J. Youker, James Jerden, Nichael Kleinsky, Kevin Quijey, Anads Jonah, Sergey Chemerisov, and Radiolytically-Induced Formation Radiolytically-Induced Formation Radiolytically Induced Formation Radiolytically Induced Formation Radiolytically Mode Radio Rovey Formulation and Analysis of Formulation an				JA			
21.2.34.14     ANL/CSE-14/31     Concepts for Molybdenum-99 Production     PN. OSTROUMOV, Z.A. CONVAY, and M.P. telly     1-Oct-2014     http://www.ostl.gov/scitech/servlets/purl/1165452       21.2.34.16     ANL/CSE-14/32     Process Modified for Low Enriched Uranium     Peter Tkac, David A. Rotsch, Kevin Orgeley, and George F. Vandegrift     1-Oct-2014     http://www.ostl.gov/scitech/servlets/purl/1165452       22     Inter/Control     Progress Report on Perxite Progress Report on Perxite Solutions: Simple Addition and Radiolytically-induced formation     Annada J. Youker, James Jerden, Michael Kalensky, Kevin Ougley, Charles Jonah, Sergery Chemerisov, and George F. Vandegrift     14-Oct-2014     http://www.ostl.gov/scitech/servlets/purl/1165455       23     Progress Report on Perxite Progress Report on Perxite Production Facility Beam Line Beord     Annada J. Youker, James Jerden, Angela Carol, Somero, Frank Patrick     14-Oct-2014     http://www.ipd.anl.gov/ables/2014/12/110941.opf http://www.ipd.anl.gov/ables/2014/12/110941.opf http://permalink.lanl.gov/ables/2014/12/110941.opf http://permalink.lanl.gov/ables/2014/12/110941.opf http://permalink.lanl.gov/ables/17:hvhatainfo.lanl. 21.2.94.1.6     ANL/CSE-14/3     Design Report     14-Oct-2014     http://permalink.lanl.gov/ables/17:hvhatainfo.lanl. 21.2.94.1.6       21.2.94.1.6     ANL/CSE-14/3     Compliant Ground Waste Form Hallow Makes String for cameras utilized in Mo-99     Modosh, Keith Albert, Naranjo, Angela Carol, Somero, Frank Patrick     14-Oct-2014     http://permalink.lanl.gov/ables/17:hvhat		A	-	-	D	E	F
21.2.94.16       ANU/CSE-14/32       Process Modified for Low Enriched Uranium       Profer Trac, David A. Rotson, Kevin Quigley, and George F. Vandegrift       1-Oct-2014       http://www.ostl.gov/scitech/servlets/purl/1165454         21.2.94.1.6       ANU/CSE-14/33       Precipitation in Urany Sufface Solutions: Simple Addition an Radiolytically-induced Formation       Amanda J. Youker, James Jerden, Michael Kalensky, Kevin Quigley, Beorge F. Vandegrift       14-Oct-2014       http://www.ostl.gov/scitech/servlets/purl/1165455         21       21.2.94.1.6       ANI/CSE-14/35       Precipitation in Urany Sufface       George F. Vandegrift       14-Oct-2014       http://www.ostl.gov/scitech/servlets/purl/1165455         21       21.2.94.1.6       ANI/CSE-14/35       Precipitation in Urany Sufface       George F. Vandegrift       14-Oct-2014       http://www.ostl.gov/scitech/servlets/purl/1165455         21       21.2.94.1.6       ANI/CSE-14/35       Precipitation in Urany Sufface       George F. Vandegrift       14-Oct       http://www.ostl.gov/scitech/servlets/purl/1165455         21       21.2.94.1.6       ANI/CSE-14/35       Precipitation in Urany Sufface       George F. Vandegrift       14-Oct       http://www.ostl.gov/scitech/servlets/purl/1105456         21       21.2.94.1.6       ANI/CSE-14/35       Precipitation and Analysis of       Woloshun, Keith Albert; Narajo,       14-Oct 2014       http://what=info:lani.         21       21.9.	21	21.2.94.1.4		Concepts for Molybdenum-99 Production		1-Oct-2014	http://www.osti.gov/scitech/servlets/purl/1165452
<ul> <li>21.2.94.1.6 ANI/CSE-14/33 Precipitation in Uranyl Sulfate Michael Kalensky, Kevin Quilgley, Charles Jonah, Sergey Chemerisov, and George F. Vandegift</li> <li>21.2.94.1.6 ANI/CSE-14/35 Precipitation in Uranyl Sulfate Radiolytically-induced formation Radiolytically-induced formation Precipitation in Uranyl Sulfate Radiolytically-induced formation Radiolytically-induced formation Report Production Facility Beam Line Design Report Production Radiity Beam Line Design Report Production Radiity Beam Line Production Radiity Beam Line Design Report Production Radiity Beam Line Radiation hardness testing for cameras utilized in Mo-99 production facility Radiation hardness testing for cameras utilized in Mo-99 production facility Mocko, Michael 21.2.94.1.4 (A-UR-14-29062 Voloshur, Keith Albert; Dale, Gregory E; Naranjo, Angela Carol and Hurtle, Performatine, Lani, gov/object/tr?what=info:lani. 21.2.94.1.4 (A-UR-14-29067 Voloshur, Keith Albert; Dale, Gregory E; Naranjo, Angela C: Chemerisov, Regery i Staranjo, Angela C: Chemerisov, Regery i Sta</li></ul>	22	21.2.94.1.6	ANL/CSE-14/32	Process Modified for Low Enriched		1-Oct-2014	http://www.osti.gov/scitech/servlets/purl/1165454
21.2.94.1.6       ANL/CSE-14/35       Formation, Destruction, and Amanda J. Youker, James Jerden, Prepiptation in Uranyl Sulfate Michael Kalensky, Kevin Quigley, Solutions: Simple Addition and Charles Joanh, Serger Chemerisov, and Radiolytically-Induced Formation George F. Vandegift       14-Oct       http://www.ipd.anl.gov/anlpubs/2014/12/110941.pdf         24       21.2.94.1.4 (LA-UR-14-2019       Report       Angela Carol; Romero, Frank Partice       14-Oct       http://permalink.lanl.gov/anlpubs/2014/12/110941.pdf         25       21.2.94.1.4 (LA-UR-14-28319       Report       Angela Carol; Romero, Frank Partice       14-Oct 2014       http://permalink.lanl.gov/anlpubs/2014/12/110941.pdf         26       21.2.94.1.4 (LA-UR-14-28325       Design Report       Bishofberger, Kip A.       24-Oct-2014       repo/lareport/LA-UR-14-28325         27       7       Tor SHINE Waste Streams       Makarashvili, and George F. Vandegift       Nov-14       http://www.osti.gov/scitech/servlets/purl/1177198         28       21.2.94.1.4 (LA-UR-14-29061       Local target shielding       Mocko, Michal       23-Nov-2014       repo/lareport/LA-UR-14-29061         29       21.2.94.1.4 (LA-UR-14-29062       Production facility       Woloshun, Keith Albert; Dale, Gregory       11/23/2014       repo/lareport/LA-UR-14-29062         20       21.2.94.1.4 (LA-UR-14-29067       Target Removal and Conveyance       Kenneth P.       Kenneth P.       Nacla, Fitc R; Romero, Frank P.;		21.2.94.1.6	ANL/CSE-14/33	Formation, Destruction, and Precipitation in Uranyl Sulfate Solutions: Simple Addition and	Michael Kalensky, Kevin Quigley, Charles Jonah, Sergey Chemerisov, and	14-Oct-2014	http://www.osti.gov/scitech/servlets/purl/1165455
25       21.2.94.1.4       LA-UR-14-28019       Report       Moloshun, Keith Albert; Naranjo, Angela Carol; Romero, Frank Patrick       http://permalink.lanl.gov/object/tr?what=info:lanl-         26       21.2.94.1.4       LA-UR-14-28019       Report       Bishofberger, Kip A.       24-Oct-2014       repo/lareport/LA-UR-34-28019         26       21.2.94.1.6       ANU/CSE-14/34       Compliant Grouted Waste Forms for SHINE Waste Streams       Makarashvili, and George F. Vandegrift       Nov-14       http://permalink.lanl.gov/object/tr?what=info:lanl-         28       21.2.94.1.6       LA-UR-14-29061       Local target shielding Mocko, Michael       23-Nov-2014       http://permalink.lanl.gov/object/tr?what=info:lanl-         29       21.2.94.1.4       LA-UR-14-29062       Icocal target shielding Mocko, Michael       23-Nov-2014       http://permalink.lanl.gov/object/tr?what=info:lanl-         29       21.2.94.1.4       LA-UR-14-29063       Nocko, Michael       11/23/2014       repo/lareport/LA-UR-14-29062         30       21.2.94.1.4       LA-UR-14-29067       Formulank.lanl.gov/object/tr?what=info:lanl-       repo/lareport/LA-UR-14-29062       http://permalink.lanl.gov/object/tr?what=info:lanl-         31       21.2.94.1.4       LA-UR-14-29068       System Design Report       Nocko, Michal       11/23/2014       repo/lareport/LA-UR-14-29062         32       21.2.94.1.4       LA-U	24	21.2.94.1.6	ANL/CSE-14/35	Formation, Destruction, and Precipitation in Uranyl Sulfate Solutions: Simple Addition and	Amanda J. Youker, James Jerden, Michael Kalensky, Kevin Quigley, Charles Jonah, Sergey Chemerisov, and	14-Oct	http://www.ipd.anl.gov/anlpubs/2014/12/110941.pdf
25       21.2.94.1.4       LA-UR-14-28019       Report       Angela Carol; Romero, Frank Patrick       14-Oct-2014       repo/lareport/LA-UR-14-28019         26       21.2.94.1.4       LA-UR-14-28325       Design Report       Bishofberger, Kip A.       24-Oct-2014       repo/lareport/LA-UR-14-28325         27       Formulation and Analysis of       Compliant Grouted Waste Forms       Milliam Ebert, Candido Pereira, Thad       Http://permalink.lanl.gov/object/tr?what=info:lanl-         28       21.2.94.1.6       ANL/CSE-14/34       Corol target shielding       Mocko, Michael       23-Nov-2014       http://permalink.lanl.gov/object/tr?what=info:lanl-         29       21.2.94.1.4       LA-UR-14-29061       Local target shielding       Mocko, Michael       23-Nov-2014       repo/lareport/LA-UR-14-29061       http://permalink.lanl.gov/object/tr?what=info:lanl-         29       21.2.94.1.4       LA-UR-14-29062       indeino facility       Mocko, Michael       11/23/2014       repo/lareport/LA-UR-14-29062         30       21.2.94.1.4       LA-UR-14-29065       System Design Report       Kenneth P.       24-Nov-2014       repo/lareport/LA-UR-14-29062         31       21.2.94.1.4       LA-UR-14-29067       Forduction of Isotope 9mTC       Kenneth P.       24-Nov-2014       repo/lareport/LA-UR-14-29067         32       21.2.94.1.4       LA-UR-14-29070 <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td>							
26       21.2.94.1.4       LA-UR-14-28325       Production Facility Beam Line Design Report       Bishofberger, Kip A.       24-Oct-2014       http://permalink.lanl.gov/object/tr?what=info:lanl- repo/lareport/LA-UR-14-28325         21.2.94.1.6       ANL/CSE-14/34       Compliant Grouted Waste Forms for SHINE Waste Streams       William Ebert, Candido Pereira, Thad Heltemes, Amanda Youker, Vakho Makarashvili, and George F. Vandegrift       Nov-14       http://permalink.lanl.gov/object/tr?what=info:lanl- repo/lareport/LA-UR-14-28061         28       21.2.94.1.4       LA-UR-14-29061       Local target shielding Radiation hardness testing for cameras utilized in Mo-99       Mocko, Michael       23-Nov-2014       repo/lareport/LA-UR-14-29061       http://permalink.lanl.gov/object/tr?what=info:lanl- repo/lareport/LA-UR-14-29062         29       21.2.94.1.4       LA-UR-14-29062       production facility       Mocko, Michael       11/23/2014       repo/lareport/LA-UR-14-29062         30       21.2.94.1.4       LA-UR-14-29065       System Design Report       Kenneth P.       24-Nov-2014       repo/lareport/LA-UR-14-29062         31       21.2.94.1.4       LA-UR-14-29067       Helium Loop Cooling Channel       Olivas, Eric Richard       24-Nov-2014       repo/lareport/LA-UR-14-29067         32       21.2.94.1.4       LA-UR-14-29070       Production of Isotope 99mTc       Olivas, Eric R; Romero, Frank P.; Naranjo, Angela C.; Chemerisov, Sregy; Naranjo, Angela C.; Chemerisov and Bailey,	25	21.2.94.1.4	LA-UR-14-28019			14-Oct-2014	
21.2.94.1.6       ANL/CSE-14/34       Formulation and Analysis of Compliant Grouted Waste Forms for SHINE Waste Streams       William Ebert, Candido Pereira, Thad Heltemes, Amanda Youker, Vakho Makarashvili, and George F. Vandegrift       Nov-14       http://www.osti.gov/scitech/servlets/purl/1177198         27       21.2.94.1.4       LA-UR-14-29061       Local target shielding Radiation hardness testing for cameras utilized in Mo-99       Mocko, Michael       23-Nov-2014       repo/lareport/LA-UR-14-29061         29       21.2.94.1.4       LA-UR-14-29062       production facility       Mocko, Michael       11/23/2014       repo/lareport/LA-UR-14-29062         30       21.2.94.1.4       LA-UR-14-29068       Target Removal and Conveyance Helium Loop Cooling Channel       Woloshun, Keith Albert; Dale, Gregory E.; Naranjo, Angela Carol and Hurtle, Kenneth P.       24-Nov-2014       http://permalink.lanl.gov/object/tr?what=info:lanl- repo/lareport/LA-UR-14-29063         30       21.2.94.1.4       LA-UR-14-29067       Hydraulic Characterization Design and Thermal-Hydraulic Performance of a He-Cooled Target for the Performance of a He-Cooled Target for the       Olivas, Eric R; Richard       24-Nov-2014       http://permalink.lanl.gov/object/tr?what=info:lanl- repo/lareport/LA-UR-14-29067         32       21.2.94.1.4       LA-UR-14-29070       For the Performance of a He-Cooled Target for the       Olivas, Eric R; Romero, Frank P.; Naranjo, Angela C.; Chemerisov, Sergey; Harvey, James       http://permalink.lanl.gov/object/tr?what=info:lanl- repo/lareport/LA-				Production Facility Beam Line			http://permalink.lanl.gov/object/tr?what=info:lanl-
21.2.94.1.6       ANL/CSE-14/34       Formulation and Analysis of Compliant Grouted Waste Forms for SHINE Waste Streams       William Ebert, Candido Pereira, Thad Heltemes, Amanda Youker, Vakho Makarashvili, and George F. Vandegrift       Nov-14       http://www.osti.gov/scitech/servlets/purl/1177198         27       21.2.94.1.4       LA-UR-14-29061       Local target shielding Radiation hardness testing for cameras utilized in Mo-99       Mocko, Michael       23-Nov-2014       repo/lareport/LA-UR-14-29061         29       21.2.94.1.4       LA-UR-14-29062       production facility       Mocko, Michael       11/23/2014       repo/lareport/LA-UR-14-29062         30       21.2.94.1.4       LA-UR-14-29068       Target Removal and Conveyance Helium Loop Cooling Channel       Woloshun, Keith Albert; Dale, Gregory E.; Naranjo, Angela Carol and Hurtle, Kenneth P.       24-Nov-2014       http://permalink.lanl.gov/object/tr?what=info:lanl- repo/lareport/LA-UR-14-29063         30       21.2.94.1.4       LA-UR-14-29067       Hydraulic Characterization Design and Thermal-Hydraulic Performance of a He-Cooled Target for the Performance of a He-Cooled Target for the       Olivas, Eric R; Richard       24-Nov-2014       http://permalink.lanl.gov/object/tr?what=info:lanl- repo/lareport/LA-UR-14-29067         32       21.2.94.1.4       LA-UR-14-29070       For the Performance of a He-Cooled Target for the       Olivas, Eric R; Romero, Frank P.; Naranjo, Angela C.; Chemerisov, Sergey; Harvey, James       http://permalink.lanl.gov/object/tr?what=info:lanl- repo/lareport/LA-	26	21.2.94.1.4	LA-UR-14-28325	Design Report	Bishofberger, Kip A.	24-Oct-2014	repo/lareport/LA-UR-14-28325
28       21.2.94.1.4       LA-UR-14-29061       Local target shielding Radiation hardness testing for cameras utilized in Mo-99       Mocko, Michael       23-Nov-2014       http://permalink.lanl.gov/object/tr?what=info:lanl- repo/lareport/LA-UR-14-29061         29       21.2.94.1.4       LA-UR-14-29062       production facility       Mocko, Michael       11/23/2014       http://permalink.lanl.gov/object/tr?what=info:lanl- repo/lareport/LA-UR-14-29062         30       21.2.94.1.4       LA-UR-14-29068       System Design Report       Woloshun, Keith Albert; Dale, Gregory E.; Naranjo, Angela Carol and Hurtle, Kenneth P.       24-Nov-2014       http://permalink.lanl.gov/object/tr?what=info:lanl- repo/lareport/LA-UR-14-29068         31       21.2.94.1.4       LA-UR-14-29067       Helium Loop Cooling Channel Helium Loop Cooling Channel Olivas, Eric Richard       Olivas, Eric Richard       24-Nov-2014       http://permalink.lanl.gov/object/tr?what=info:lanl- repo/lareport/LA-UR-14-29067         32       21.2.94.1.4       LA-UR-14-29070       Production of Isotope 99mTc       Olivas, Eric Richard       24-Nov-2014       http://permalink.lanl.gov/object/tr?what=info:lanl- repo/lareport/LA-UR-14-29067         32       21.2.94.1.6       ANL-NE-15/2       Micro-Bubble Experiments at the vg Bailey, D. Stepinski, S. Chemerisov, Sergey; Harvey, James       24-Nov-2014       http://permalink.lanl.gov/anlpubs/2015/05/113420.pdf         33       ANL-NE-15/2       Micro-Bubble Experiments at the vg       Simonv				Formulation and Analysis of Compliant Grouted Waste Forms	Heltemes, Amanda Youker, Vakho	Nov-14	http://www.osti.gov/scitech/servlets/purl/1177198
29       21.2.94.1.4       LA-UR-14-29062       cameras utilized in Mo-99       mocko, Michal       11/23/2014       repo/lareport/LA-UR-14-29062         30       21.2.94.1.4       LA-UR-14-29068       System Design Report       Kenneth P.       http://permalink.lanl.gov/object/tr?what=info:lanl- repo/lareport/LA-UR-14-29068         30       21.2.94.1.4       LA-UR-14-29067       System Design Report       Kenneth P.       http://permalink.lanl.gov/object/tr?what=info:lanl- repo/lareport/LA-UR-14-29068         31       21.2.94.1.4       LA-UR-14-29067       Helium Loop Cooling Channel Helium Loop Cooling Channel       Olivas, Eric Richard       24-Nov-2014       repo/lareport/LA-UR-14-29067         32       21.2.94.1.4       LA-UR-14-29070       Production of Isotope 99mTc       Olivas, Eric R.; Romero, Frank P.; Naranjo, Angela C.; Chemerisov, Sergey; for the       http://permalink.lanl.gov/object/tr?what=info:lanl- repo/lareport/LA-UR-14-29067         32       21.2.94.1.4       LA-UR-14-29070       Production of Isotope 99mTc       Olivas, Eric R.; Romero, Frank P.; Naranjo, Angela C.; Chemerisov, Sergey; for the       http://permalink.lanl.gov/object/tr?what=info:lanl- repo/lareport/LA-UR-14-29070         32       21.2.94.1.6       ANL-NE-15/2       Micro-Bubble Experiments at the V       Gromov, A. J. Youker, V. Makarashvili, J. Bailey, D. Stepinski, S. Chemerisov and G. F. Vandegrift       Dec-14       http://www.ipd.anl.gov/anlpubs/2015/05/113420.pdf	28	21.2.94.1.4	LA-UR-14-29061		Mocko, Michael	23-Nov-2014	
30       21.2.94.1.4       LA-UR-14-29068       System Design Report       E.; Naranjo, Angela Carol and Hurtle, Kenneth P.       http://permalink.lanl.gov/object/tr?what=info:lanl- repo/lareport/LA-UR-14-29068         31       21.2.94.1.4       LA-UR-14-29067       Hydraulic Characterization       Olivas, Eric Richard       24-Nov-2014       repo/lareport/LA-UR-14-29067         31       21.2.94.1.4       LA-UR-14-29067       Hydraulic Characterization       Olivas, Eric Richard       24-Nov-2014       repo/lareport/LA-UR-14-29067         32       21.2.94.1.4       LA-UR-14-29070       Preformance of a He-Cooled Target for the       Olivas, Eric R.; Romero, Frank P.; Naranjo, Angela C.; Chemerisov, Sergey; Harvey, James       http://permalink.lanl.gov/object/tr?what=info:lanl- tepo/lareport/LA-UR-14-29070         32       21.2.94.1.6       ANL-NE-15/2       Micro-Bubble Experiments at the V       Gromov, A. J. Youker, V. Makarashvili, J. Bailey, D. Stepinski, S. Chemerisov and G. F. Vandegrift       Dec-14       http://www.ipd.anl.gov/anlpubs/2015/05/113420.pdf	29	21.2.94.1.4	LA-UR-14-29062	cameras utilized in Mo-99	Mocko, Michal	11/23/2014	
31       21.2.94.1.4       LA-UR-14-29067       Hydraulic Characterization       Olivas, Eric Richard       24-Nov-2014       repo/lareport/LA-UR-14-29067         31       21.2.94.1.4       LA-UR-14-29007       Design and Thermal-Hydraulic Performance of a He-Cooled Target for the       Woloshun, Keith A.; Dale, Gregory E.; Olivas, Eric R.; Romero, Frank P.; Naranjo, Angela C.; Chemerisov, Sergey; Harvey, James       http://permalink.lanl.gov/object/tr?what=info:lanl- repo/lareport/LA-UR-14-29070         32       21.2.94.1.4       LA-UR-14-29070       Production of Isotope 99mTc       Harvey, James       24-Nov-2014       http://permalink.lanl.gov/object/tr?what=info:lanl- repo/lareport/LA-UR-14-29070         33       .       .       .       .       .       .       .       .         33       .       .       .       .       .       .       .       .	30	21.2.94.1.4	LA-UR-14-29068		E.; Naranjo, Angela Carol and Hurtle,	24-Nov-2014	
32       21.2.94.1.4       LA-UR-14-29070       Performance of a He-Cooled Target for the       Naranjo, Angela C.; Chemerisov, Sergey; Harvey, James       http://permalink.lanl.gov/object/tr?what=info:lanl-repo/lareport/LA-UR-14-29070         32       21.2.94.1.6       ANL-NE-15/2       Micro-Bubble Experiments at the V       Z. J. Sun, K. Wardle, K. Quigley, R. Gromov, A. J. Youker, V. Makarashvili, J. Bailey, D. Stepinski, S. Chemerisov and G. F. Vandegrift       Dec-14       http://www.ipd.anl.gov/anlpubs/2015/05/113420.pdf	31	21.2.94.1.4	LA-UR-14-29067	Hydraulic Characterization		24-Nov-2014	
21.2.94.1.6 ANL-NE-15/2 Micro-Bubble Experiments at the V 33 L. J. Sun, K. Wardle, K. Quigley, R. Gromov, A. J. Youker, V. Makarashvili, J. Bailey, D. Stepinski, S. Chemerisov and G. F. Vandegrift Dec-14 http://www.ipd.anl.gov/anlpubs/2015/05/113420.pdf				Performance of a He-Cooled Target	Olivas, Eric R.; Romero, Frank P.;		http://permalink.lanl.gov/object/tr?what=info:lanl-
21.2.94.1.6 ANL-NE-15/2 Micro-Bubble Experiments at the V Gromov, A. J. Youker, V. Makarashvili, J. 33 Bailey, D. Stepinski, S. Chemerisov and G. F. Vandegrift Dec-14 http://www.ipd.anl.gov/anlpubs/2015/05/113420.pdf	32	21.2.94.1.4	LA-UR-14-29070	Production of Isotope 99mTc	Harvey, James	24-Nov-2014	repo/lareport/LA-UR-14-29070
	33	21.2.94.1.6	ANL-NE-15/2	Micro-Bubble Experiments at the Va	Gromov, A. J. Youker, V. Makarashvili, J. Bailey, D. Stepinski, S. Chemerisov and	Dec-14	http://www.ipd.anl.gov/anlpubs/2015/05/113420.pdf





# Thanks

# for your support and attention!













