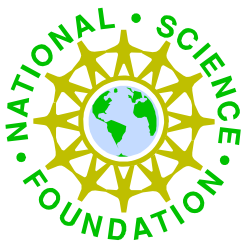
Mo-99 Presentation to NSAC

July 16, 2015

Susan J. Seestrom



Outline

- Charge and Subcommittee process
- Background – the ^{99}Mo issue
- Overview of the NNSA Material Management and Minimization ^{99}Mo program
- Findings
- Recommendations

Charge to NSAC

- What is the current status of implementing the goals of the NNSA-M MM Mo-99 Program?
- What progress has been made since the initial NSAC assessment?
- Is the strategy for continuing to implement the NNSA goals complete and feasible, within an international context?
- Are risks identified in implementing those goals being appropriately managed?
- Has the NNSA-MMM Program addressed concerns and/or recommendations articulated in the 2014 NSAC assessment of the Mo-99 Program appropriately and adequately?
- What steps should be taken to further improve NNSA program effectiveness in establishing a domestic supply of Mo-99?

Subcommittee Members

Carolyn Anderson, University of Pittsburgh
Jeff Binder, University of Illinois
Ronald Crone, Idaho National Laboratory
Jack Faught, LINDE
Mitch Ferren, Oak Ridge National Laboratory
Donald Geesaman, Argonne National Laboratory
Suzanne Lapi, Washington University Saint Louis
Meiring Nortier, Los Alamos National Laboratory
Steve Mattmuller, Kettering Medical Center
Berndt Mueller, Brookhaven National Laboratory
Ken Nash, Washington State University
Joseph Natowitz, Texas A&M University
Thomas Ruth, TRIUMF
Susan Seestrom, Chair, Los Alamos National Laboratory

Expertise of the Subcommittee

Committee Expertise		
Reactor Design and Operation	**Radioisotope Production**	**Radiopharmaceutical Chemistry**
Ron Crone Jeff Binder	Mitch Ferren Jeff Binder Suzanne Lapi Meiring Nortier Thomas J. Ruth	Carolyn Anderson Suzanne Lapi Thomas J. Ruth
Nuclear and Radio Chemistry	**Commercial Isotope Sales**	**Project Management**
Carolyn Anderson Suzanne Lapi Ken Nash Joe Natowitz Meiring Nortier Thomas J. Ruth	Jack Faught Mitch Ferren	Berndt Mueller Don Geesaman Susan Seestrom Ron Crone
Nuclear Physics	**Nuclear Engineering**	**Radiopharmacist**
Don Geesaman Berndt Mueller Joe Natowitz Susan Seestrom	Ron Crone Jeff Binder Meiring Nortier	Steve Mattmuller

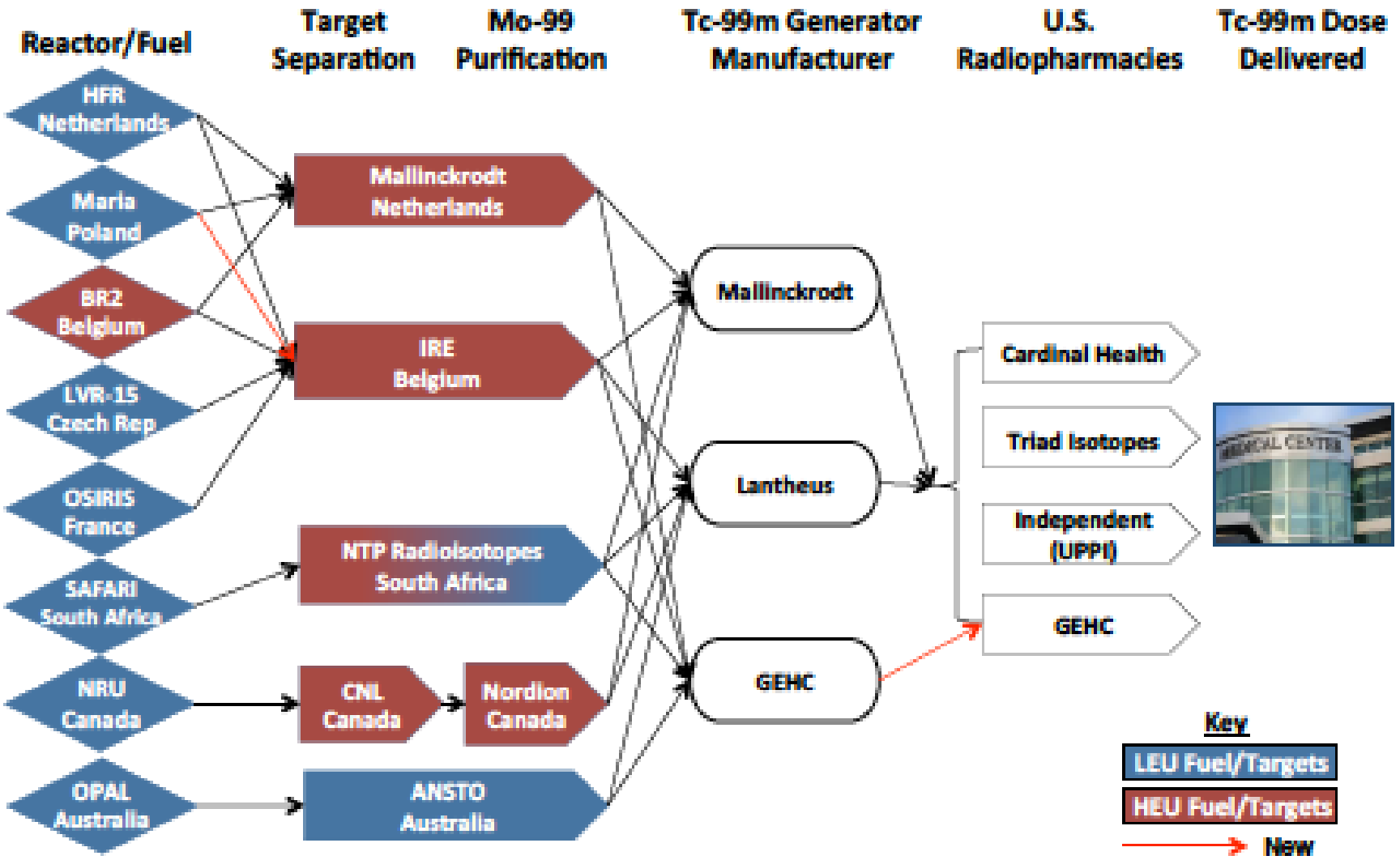
Subcommittee Process

- The Subcommittee met in the Washington area in May 7-8 2015.
- We were briefed by NNSA as well as representatives of the OECD, the NAS study group.
- We were briefed by both active cooperative agreement partners and one potential new partner.
- We devoted a session to input from the broad stakeholder community.

Background

- There is widespread use of ^{99m}Tc for nuclear medicine diagnostic imaging. ^{99m}Tc is the daughter of ^{99}Mo.
- Today,^{99}Mo is produced by fission of ^{235}U.
- There is U.S. government interest in reducing the use of Highly Enriched Uranium (HEU)
- There was concern in the medical community that this could lead to shortages or a significant increase in price.
- This issue was addressed in the 2009 National Academy study.
- Supply chain disruptions have occurred 2005-2014
- There is currently no U.S. producer of ^{99}Mo

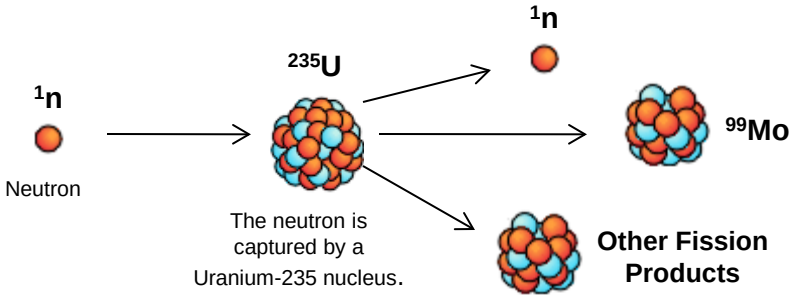
Current U.S. Mo-99 Supply Matrix



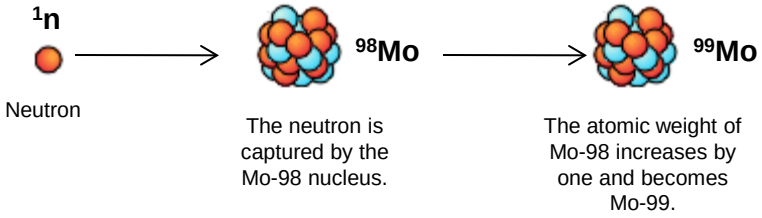
GTRI and U.S. Domestic Mo-99

Implementing a Technology-Neutral Program

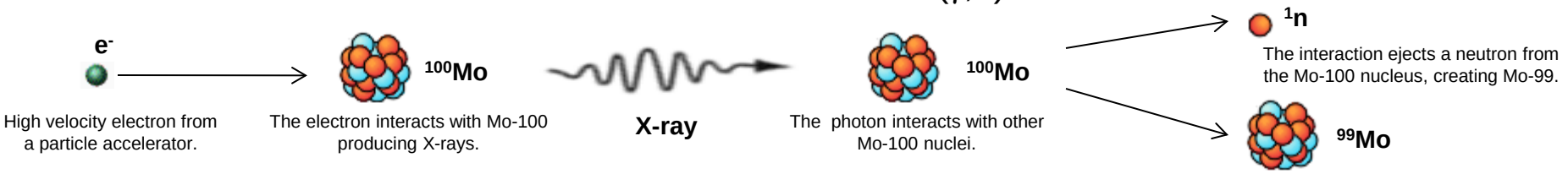
LEU Fission Based: ^{235}U (n,f)



Neutron Capture:(n,γ)



Accelerator Based: (γ,n)



GTRI and U.S. Domestic Mo-99
Cooperative Agreement Partners

Objective: To accelerate existing commercial projects to meet at least 100% of the U.S. demand of Mo-99 produced without HEU.

NorthStar Medical Radioisotopes, LLC

- NNSA has partnered with NorthStar Medical Radioisotopes to pursue accelerator and neutron capture technologies.

~~Morgridge Institute for Research~~/SHINE Medical Technologies

- NNSA has partnered with Morgridge Institute for Research to pursue accelerator with LEU fission technology in cooperation with SHINE Medical Technologies.

~~Babcock and Wilcox (B&W):~~

- NNSA has partnered with Babcock and Wilcox (B&W) to pursue LEU solution reactor technology.

~~General Electric-Hitachi (GEH~~):

- NNSA has partnered with General Electric-Hitachi to pursue neutron capture technology.

Each cooperative agreement is awarded under a 50% - 50% cost-share arrangement, consistent with the American Medical Isotopes Production Act and Section 988 of the Energy Policy Act of 2005. The cooperative agreements are currently limited to $25M each.

Changes in the international context since 2014

- OECD has assessed progress toward full cost recovery as "*slow*"
- The Canadian government has announced the possibility of providing ^{99}Mo during the period 2016-2018 should a worldwide shortage develop
  - Trigger mechanism has not been defined

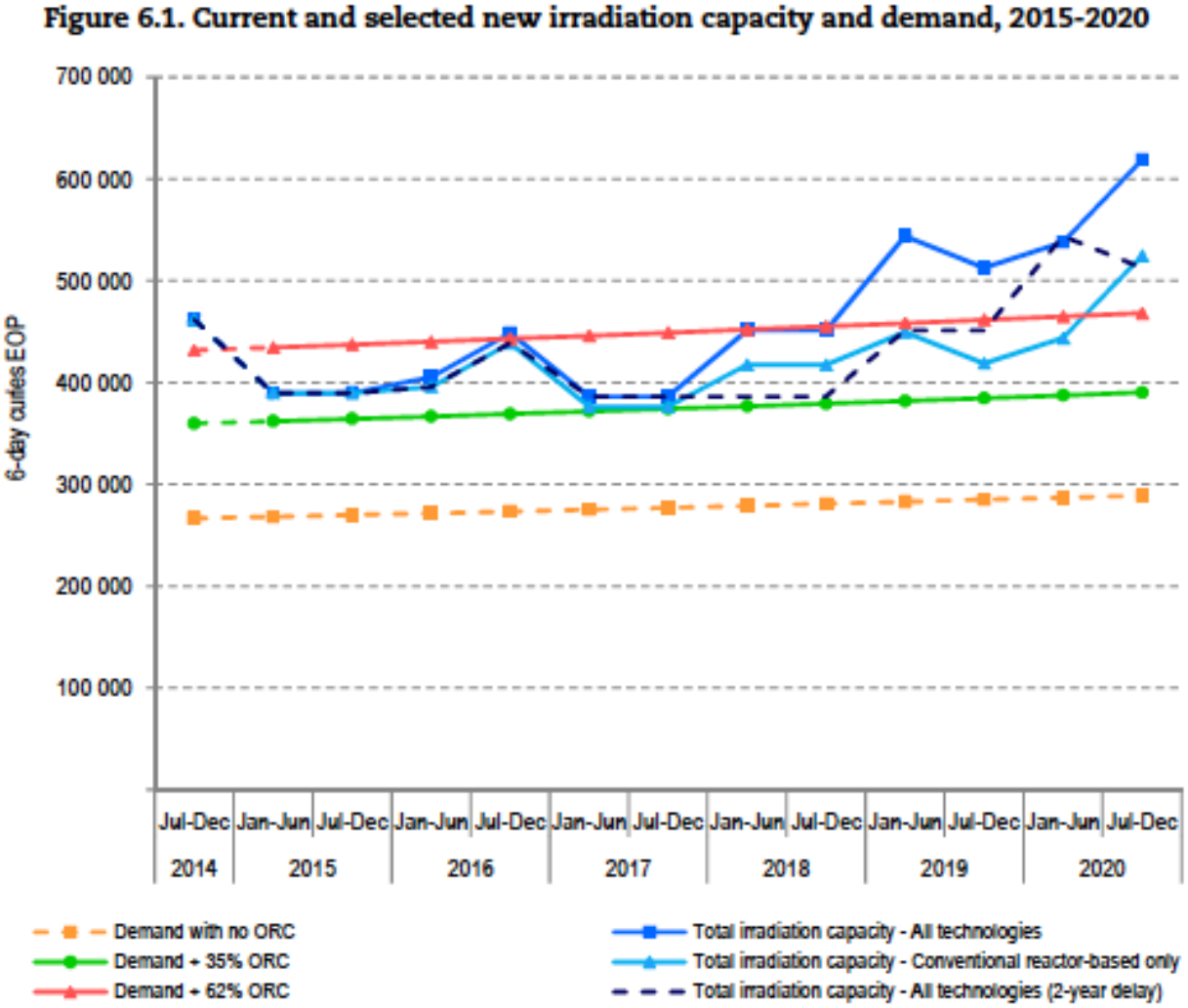
Progress in NNSA program

- NNSA has taken a leadership role in the interagency working group developing the Uranium Lease and Take Back Program (ULTB)
- The projected dates of production from the active CA projects have incurred delays ranging from 1-2 years since the 2014 review
  - However, CA partners have made some significant progress
- NNSA is evaluating a proposal from a third partner

General Conclusions

- NNSA has worked diligently and proactively over the course of the program based on the specific AMIPA requirements, especially considering the many complex factors outside their direct control
- NNSA is working with the international community to achieve full cost recovery and thus a level playing field for new U.S. producers.
- NNSA is trying to accelerate development of new domestic suppliers – funding seems to be an issue.
- Subcommittee finds that the possibility of a shortage of ^{99}Mo in the period 2016 -2018 has substantially increased since the last review in 2014

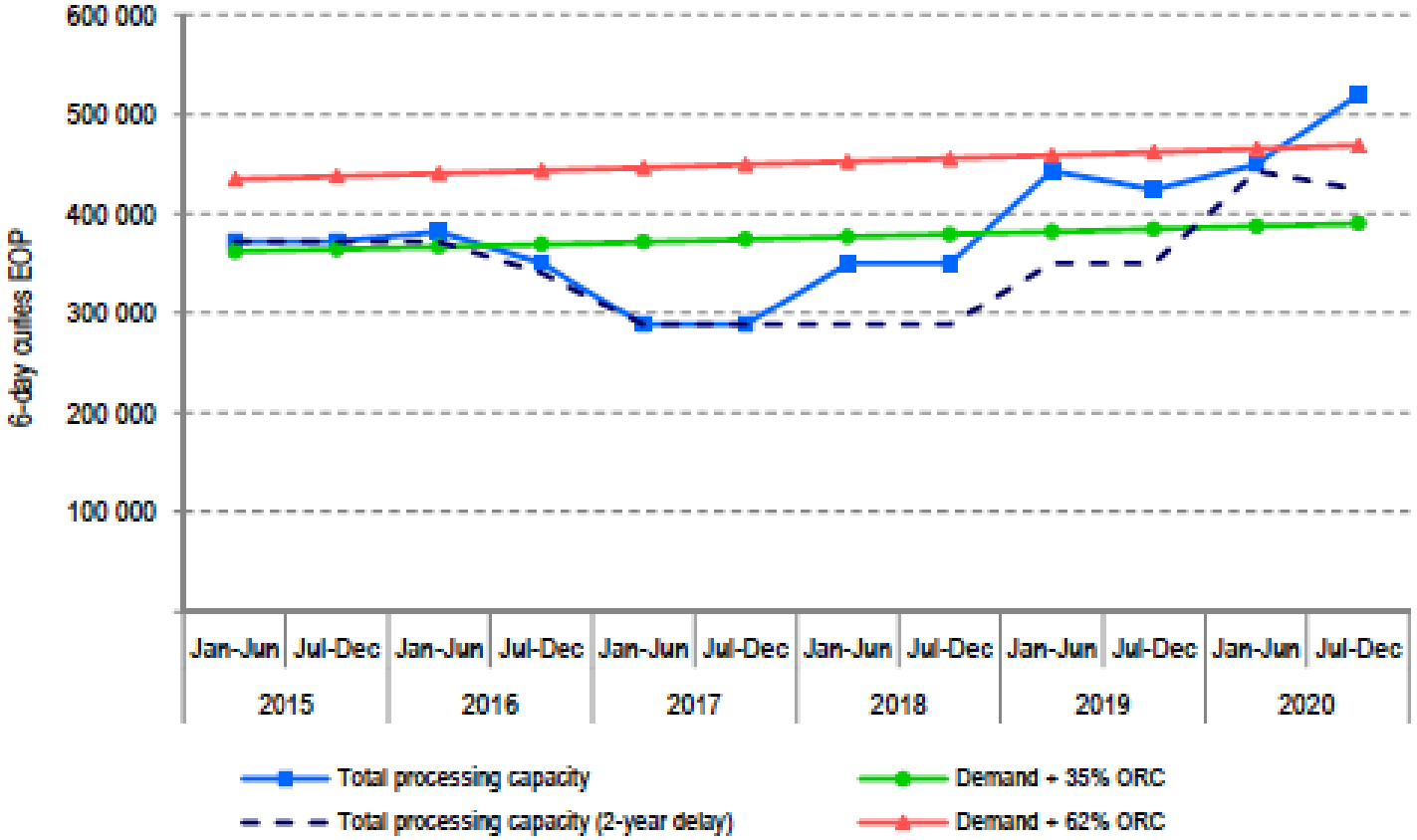
OECD* Estimates of Supply/Demand with projected new capability



*Medical Isotope Supply in the Future: Production Capacity and Demand Forecast for the 99Mo/99mTc Market, 2015-2020 (SEN-HLWG2014-2)

OECD Processing Capacity and Demand

Figure 6.2. Current and selected new processing capacity and demand, 2015-2020



*Medical Isotope Supply in the Future: Production Capacity and Demand Forecast for the 99Mo/99mTc Market, 2015-2020 (SEN-HLWG2014-2)

What is the current status of implementing the goals of the NNSA-MMM ^{99}Mo Program? What progress has been made since the initial assessment?

- None of the CA partners met the original goal to produce 3,000 6-day Curies by 2014
- Only one project anticipates producing any ^{99}Mo in 2016
- Dates of anticipated ^{99}Mo production have slipped 1-2 years since the last review
- The existing CA partners have nonetheless all made progress during the last year, with a number of important milestones

Is the strategy for continuing to implement the NNSA goals complete and feasible, within an international context?

- The NNSA strategy does not appear to have been modified to take into account delays anticipated by present CA partners or the slowness in moving toward full cost recovery by the global
- The strategy also has not been modified to account for the possibility that NRU/Nordion could serve as an emergency supplier in the October 2016 to March 2018 period
- The uncertainty in defining the ULTB program remains an issue

In the last report, the Subcommittee concluded that the strategy was reasonable but not complete, as it does not address all possible risks in the program; these recent developments reinforce this conclusion

Are the risks identified in implementation being appropriately managed ?

- In some cases the risk mitigation actions have become increasingly responsive
  - For example, NNSA has taken an active role in the development of the ULTB program and there is now a schedule in place for the issuance of draft model contracts.
- In some cases the risk management could be enhanced
  - The risk due to lack of progress in the move to full cost recovery in the international community is largely outside the control of NNSA. This impacts the ability of CA partners to gain funding in cases where significant infrastructure investment is required. It is possible that DOE could mitigate this risk if NNSA were able to increase their level of investment.
  - The risk mitigation actions still leave uncertainty with the ULTB program that appears to be discouraging private investment.

2014 Recommendations

1. NNSA should look carefully across the domestic production part of the ^{99}Mo program in view of present facts (such as progress on CA projects, economic environment for capital and projected operating costs) in order to focus resources on the most promising CA agreements.
2. Based on the slowness of progress toward implementation of full cost recovery internationally, NNSA should consider relaxing their present $25M cap on investment in any project. This change could increase the likelihood of generating a successful domestic producer of ^{99}Mo as the international market continues to move toward full cost recovery. This would address one of the major risks in the present program

Has the NNSA-MMM Program addressed concerns and/or recommendations articulated in the 2014 NSAC assessment of the ^{99}Mo Program appropriately and adequately?

- The NNSA-M^3 program has paid attention to the 2014 assessment
- Since the review NNSA has stopped national lab work related to inactive CA projects.
- NNSA stated in this review that they have carefully considered the issue of increasing the $25M limit or otherwise increasing funds available to CAs and that options are still under consideration.
- NNSA has added items to the risk register

The dates at which domestic ^{99}Mo is expected to first appear in the domestic market have been delayed by 1-2 years and progress toward full cost recovery has been slower than expected. For these reasons, the Subcommittee concludes the NNSA actions in response to the 2014 report have been less than adequate.

Recommendation 1

DOE should increase funds available to individual Cooperative Agreement projects sufficient to significantly accelerate their ability to rapidly establish domestic production. This could be accomplished, for example, by increasing the $25M cap or increasing the NNSA cost share fraction during the R&D phase of projects.

Recommendation 2

DOE must support NNSA in their continued efforts to advocate for the timely establishment of the Uranium Lease and Take Back (ULTB) Program. The publication of a draft of the ULTB model contracts is an urgent need and NNSA has taken very credible actions to move the program definition by the DOE intra-agency working group forward. However, high-level agency engagement will be essential in reducing this risk by ensuring model contracts are finalized as soon as possible.

Recommendation 3

NNSA should document a contingency plan to ensure a supply of ^{99}Mo from Canada within a few months if a significant shortage of ^{99}Mo appears imminent during the period 2016-2018. This plan should include details on working within the U.S. government and with the Canadian producers/government to address the definition of a trigger mechanism for ^{99}Mo production at NRU and ensure that valid import and export licenses for HEU are in place prior to the need for them. This contingency plan document should be available by the next NSAC review.

Recommendation 4

NNSA should develop a contingency plan to adapt the program should OECD-NEA continue to determine that the global community is not making adequate progress toward full cost recovery in order for domestic production to be economically feasible. This should be available by the next NSAC review.

Acknowledgement

- Thanks to our committee members who did a great job developing an understanding of a complex problem, starting from very different experience and knowledge
- Thanks to NNSA for their patience with our process
- Thanks to Brenda May for her support in organizing our meeting!

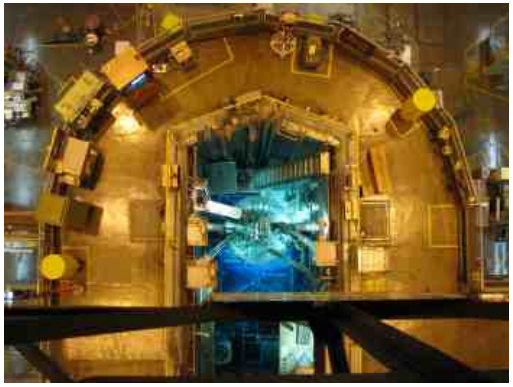
BACKUPS

Ultimately the success of the program will need to be judged based on the interpretation of the intended goal of the AMIPA. If one of the cooperative agreement partners achieves domestic production, then the NNSA will have provided assistance that accelerated domestic production. If another party who is not a cooperative agreement partner successfully enters the market and provides sufficient U.S. supply to avoid shortages, the NNSA efforts in converting irradiations internationally to LEU targets and in encouraging full cost recovery prices may be a material component of this success. If shortages in domestic supply do materialize in the 2016-2018 time frame (as seems quite possible) and no domestic production capacity exists, then the NNSA program will not have met the spirit of AMIPA.

What is Mo-99?

- Molybdenum-99 (Mo-99) is the parent product of Tc-99m, a radioisotope used in approximately 50,000 medical diagnostic tests per day in the U.S. (over 18 million per year in the U.S.)
- Primary uses include detection of heart disease, cancer, study of organ structure and function, and other applications.
- Mo-99 has a short half life (66 hours) and cannot be stockpiled
- U.S. demand is approximately 50% of the world market
  - The historic global demand is ~12,000 6-day curies per week.
  - Since the 2009-2010 shortages, global demand has been ~10,000 6-day curies per week.
- Mo-99 is produced at only 5 processing facilities worldwide, in cooperation with 8 research reactor facilities
  - Processing facilities located in Canada (HEU), The Netherlands (HEU), Belgium (HEU), South Africa (HEU and LEU), and Australia (LEU)
  - Research reactors used for irradiation located in Canada, The Netherlands, Belgium, France, Poland, Czech Republic, South Africa, and Australia

Tc-99m generator and labeling kits



SAFARI-1 Reactor (South Africa)

The American Medical Isotopes Production Act of 2012

- The Act was incorporated in the National Defense Authorization Act for Fiscal Year 2013 and enacted on January 2, 2013.

- 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 the Secretary of Energy to establish a technology-neutral program to provide assistance to commercial entities to accelerate production of Mo-99 in the United States without the use of HEU

  - Requires annual public participation and review

  - Requires development assistance for fuels, targets, and 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

GTRI's Mo-99 Objective and Strategy

Objective: Accelerate the establishment of reliable supplies of the medical isotope molybdenum-99 produced without highly enriched uranium

GTRI's strategy seeks to address weaknesses in the current Mo-99 supply chain:

- The current supply chain uses HEU to produce Mo-99
- Most Mo-99 production in today's marketplace is subsidized by foreign governments
- The current supply chain does not always have enough reserve capacity to ensure a reliable supply when one or more producers are out of operation
- The current supply chain is primarily dependent on aging facilities
- The current supply chain relies on one technology to produce Mo-99

A long-term, reliable supply of Mo-99 requires that global production of Mo-99 transition to a full-cost recovery, non-HEU-based industry

Other USG Initiatives

In addition to the American Medical Isotopes Production Act, there are other USG efforts to help achieve the objective to accelerate the establishment of reliable supplies of the medical isotope Mo-99 produced without HEU, including:

- White House Fact Sheet on Mo-99
- Participating in various domestic and international working groups
- Mo-99 stakeholder outreach
- Ensuring the implementation of OECD-NEA policy recommendations in the United States