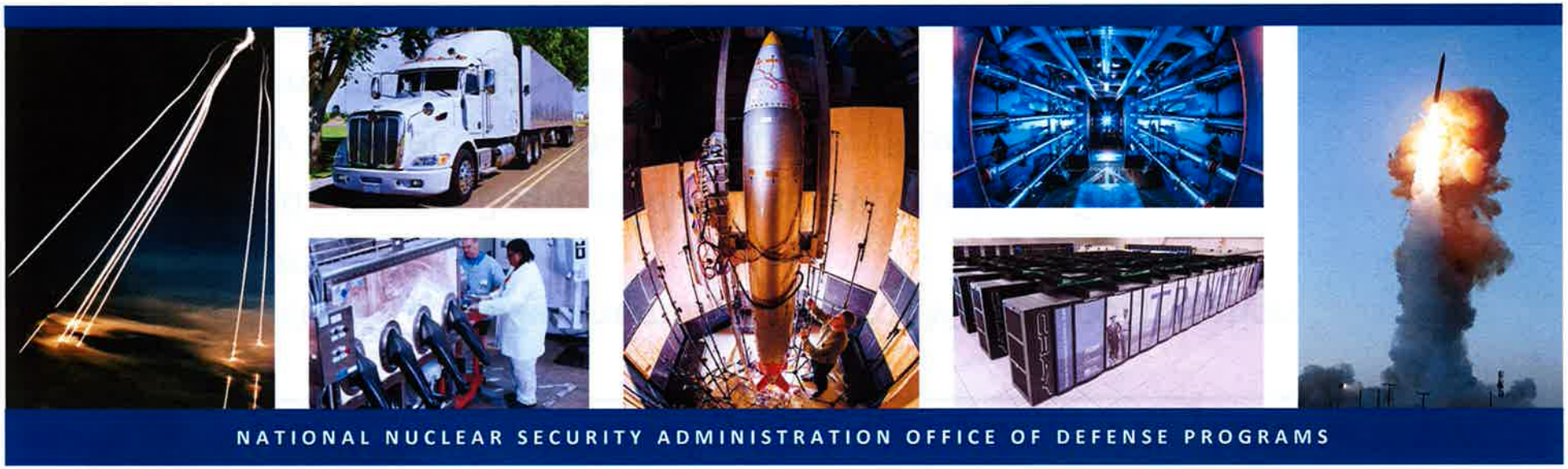
Uranium Enrichment Industry Day

November 1, 2017

National Nuclear Security Administration

DEFENSEPROGRAMS



Overview

- Introduction from Mike Thompson, ADA for Major Modernization Programs
- Enriched Uranium Requirements, History, Capability Gap
- Strategy to meet LEU Demand for Tritium Production
- Requirements for High Assay LEU
- Requirements for a Conversion Facility
- Discussion of Potential Acquisition Strategies

Enriched Uranium Requirements, History, and Capability Gap

DOE/NNSA Requirements for Enriched Uranium

EU Mission Needs	Enrichment and Obligation	Program	Need Date
Maintain nuclear weapons stockpile	Unobligated HEU	NA-10	Ongoing
Mutual Defense Agreements	Unobligated HEU	NA-10	Ongoing
Tritium production reactor fuel	Unobligated LEU	NA-10	2038-2041
Research reactors and medical isotope production	High Assay LEU*	NA-20	Est. 2035
Naval propulsion	Unobligated HEU	Naval Reactors	Est. 2065
Advanced commercial reactors	High Assay LEU	Nuclear Energy	TBD

*Requirements for High Assay LEU could be met using foreign producers and/or technology (currently none are capable of producing HA LEU)

History & Capability Gap

- No U.S.-owned uranium enrichment facilities
- Nearest term defense need for LEU to fuel Tennessee Valley Authority's (TVA) tritium production reactors
  - Long-standing US non-proliferation policy and international agreements require uranium for nuclear weapons to be free from peaceful use "encumbrances" or "obligations" (foreign or domestic)
- DOE's uranium inventory currently meets all government requirements
  - Finite resource, primarily composed of HEU
  - Committed to meeting defense requirements, except for current declarations of excess material
  - Accessing additional EU could require policy changes, significant funding and risk, and could impact defense programs

Strategy to meet LEU Demand for Tritium Production

DUE Strategy for LEU Production

- Following completion of multiple Congressionally mandated analyses, DOE/NNSA approved a strategy for re-establishing a uranium enrichment capability:

  1. **Down-blend HEU to LEU fuel to extend need date to 2038-2041 for tritium production**
  2. **Develop enrichment technology options**
  3. **Begin acquisition process to deploy an enrichment technology**

- Current strategy and schedules focused on LEU need for Tritium
- No decisions have been made regarding requirement for HA LEU

1. Down-blend HEU

Use HEU from DOE inventory to extend the fuel need date to 2038-2041

- Preserve existing unobligated EU through "obligation exchanges"
- Down-blend "less attractive" HEU materials unclaimed by other programs
  - Use obligation exchanges to preserve the LEU's unobligated status until TVA can use it
  - Down-blending to take place 2019-2025
- Provides time to construct an enrichment facility

2. Develop Technology Options

Preserve and Advance Enrichment Technologies

- Centrifuges are industry standard enrichment technology, lowest cost and lowest risk
  - AC-100 developed by Centrus Energy Corp (formerly USEC)
    - Centrifuge much larger than industry standard
    - R&D continues through FY 2018 at K-1600 facility in Oak Ridge
  - Oak Ridge National Lab designing a "small" centrifuge
    - Closer to industry standard with goal of minimizing enrichment plant costs
    - Design data for the Analysis of Alternatives by ~2019
- Intellectual Property Deployment restrictions
  - DOE owns AC-100 IP for governmental uses only
  - DOE owns Small centrifuge IP for national security or commercial uses

3. Begin Acquisition Process

Begin DOE O413.3B acquisition process to deploy an enrichment technology in time to meet national security needs

- National Security plant must provide LEU fuel to TVA by 2038 – 2041

Critical Decision (CD)	Fiscal Year (Approximate)
CD-0, Approve Mission Need	FY 2017
CD-1, Approve Alternative Selection and Cost Range	FY 2021
CD-2, Approve Performance Baseline	FY 2025
CD-3, Approve Start of Construction	FY 2027
CD-4, Approve Start of Operations	FY 2036

- CD-1 expected 2021
  - Analysis of Alternatives underway in FY 2017, will consider all alternatives including no action, non-centrifuge enrichment technologies, and non-construction options
  - Will result in a recommended technology in late 2019

National Nuclear Security Administration

DEFENSEPROGRAMS

Requirements for High Assay Low Enriched Uranium

Research Reactors & Medical Isotopes:
Future High Assay LEU Needs

Jeff Chamberlin, NNSA Office of Conversion

— PERMANENT THREAT REDUCTION —

MATERIAL MANAGEMENT AND MINIMIZATION

CONVERT, REMOVE, DISPOSE

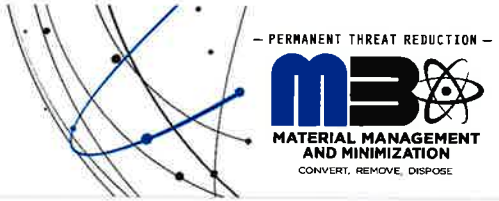
Research Reactor Fuel

- DOE/NNSA is the current supplier of high-assay LEU to research reactors in the United States and to the majority of research reactors and all major Mo-99 production facilities outside the United States.
- This provision of LEU supports and complements longstanding DOE/NNSA efforts, in support of United States nuclear security policy, to minimize the use of HEU in civilian applications by converting research reactors from HEU to high-assay LEU fuel.
- To date, DOE/NNSA has converted or verified the shutdown of 100 research reactors and radioisotope production facilities worldwide, including 20 in the United States. Many of these reactors now rely on DOE/NNSA for the provision of high-assay LEU for their fuel.
- High performance research reactors in the United States and Europe still remain to be converted
  - These reactors will require new high-density fuels currently under development – these are highly complex technical projects with significant risk and schedule uncertainty;
  - The use of high-density LEU fuel will greatly increase the demand for high-assay LEU in the future
- In 1978 the *Nuclear Nonproliferation Act* directed that the United States be a reliable supplier of nuclear materials to countries that follow nonproliferation policy— thus the U.S. supplies fuel for foreign research and test reactors.
- Since the United States has no high assay enrichment capability, excess weapons HEU is currently being down blended to the desired assay.

Mo-99 Production

- DOE/NNSA's Mo-99 program has two objectives:
  - Support major global producers in converting their Mo-99 production processes from HEU to LEU targets
  - Support the establishment of a commercial, non-HEU-based Mo-99 supply in the United States
- Provision of high-assay LEU supports the achievement of both objectives:
  - LEU for production by the major international producers (Australia, South Africa, Belgium, Netherlands)
  - LEU for prospective domestic producers via lease or sale
- Needed quantities are small, but high impact.

High Assay LEU



- DOE/NNSA Reactor Conversion Program plans to convert all domestic high performance reactor reactors to high assay LEU by 2033.
- DOE/NNSA Reactor Conversion Program also has scope and mission to convert international research reactors to LEU fuel by 2035 (not all will use U.S.-origin LEU).
- Current allocation of excess HEU for downblending to high assay (19.75%) LEU is expected to be exhausted by late 2020s.
  - This date is driven primarily by when fabrication of high-density LEU fuel cores begins.
  - If schedules for deployment of high-density LEU fuels slip, so will this date.
- Pending approval, current allocation of excess HEU for HEU fuel fabrication could be downblended, after conversion of USHPRRs, to extend supply to mid-2030s.
- Strategies are being developed to extend HEU resources to at least 2040 if necessary.

Future High Assay LEU Needs; Starting 2040

– PERMANENT THREAT REDUCTION –
MATERIAL MANAGEMENT AND MINIMIZATION
CONVERT, REMOVE, DISPOSE

Projected needs after current HEU exhausted:

- Foreign Research Reactor Commitments
  - ❑ ~2.0-2.5 MT annually
- Domestic Research Reactors
  - ❑ ~7.0-7.5 MT annually
- Mo-99 Production
  - ❑ 0.7 MT annually

➢ Total Annual Requirement: **~9.7-10.7 MT** 19.75% LEU

- These estimates are based on multiple uncertainties: e.g. - program schedules, scrap rates, who is producing Mo-99 domestically in 2040

Conversion Facility

Concept for a HA-LEU Material Purification and Metal Production Facility

- HA-LEU consumers require material in metal form
- No current capability to convert UF_6 to metal
- Government's primary interest is in a UF_6 to metal facility
  - Secondary interest in facility to receive impure oxides, U-Mo scrap, uranyl nitrate solution, or UF_6 and produce metal
- Capacity approx. 5-10 MTU/year for HA LEU only
- UF_6 to UF_4 conversion is required for new enrichment product only, not recovered materials (i.e., if a facility is built to enrich HA-LEU, a conversion facility would be needed as well)

Discussion of Potential Acquisition Strategies

Introduction to Acquisition Discussion

- Exploring the government's role in the technology
  - Government will need to evaluate technology available and make a decision to proceed with the best option(s)
- Exploring the best role for industry
- Exploring interest in a HA LEU facility
- Government is open to considering
  - Multiple facilities to meet different requirements
  - Multiple technologies to meet requirements
  - Foreign facilities/technology to meet HA LEU requirement

Introduction

- Explore a range of acquisition alternatives from

Building	to	Buying
Government funds construction, owns the IP and the building, and then contracts for operation		Industry secures funding, builds, owns the IP, and Government purchases enriched uranium product

- 3 "Buying" concepts identified to facilitate discussion
  - No decision has been made to pursue or not pursue any of them
  - Options focus on unobligated LEU requirement, but could be expanded to include HA LEU
- We welcome feedback from Industry on these concepts

Single Vendor Option

- Contract awarded to a single vendor to supply the required amount of unobligated LEU
- Government commits to purchasing LEU according to a delivery schedule starting no later than 2038 for a price and for a time period agreed to between Vendor and Government (e.g., $X/SWU for 20 years)
- Could explore contracting options for government financial support, but Vendor would be expected to solicit private equity or debt to fund the project
- Once supply to the Government begins, Vendor would be free to expand production to supply material to the commercial market (depending on the technology selected)

Multiple Vendor Option

- Contract awarded to two vendors to separately supply 50% of the required amount of unobligated and unencumbered LEU, while also providing the *capacity* to supply 75% of the needed LEU
- Government commits to purchasing 50% of the needed LEU from each vendor starting in ~2038 for a price and for a time period agreed to between Vendors and Government
  - Timing of government payments for LEU?
- Once supply to the Government begins, vendors would be free to expand production to supply material to the commercial market (depending on technology selected)
- Approach reduces risk to the government (in case one vendor fails) and creates market competition

Multi-Phase Option

- Contract awarded in two phases
  - **Phase I: Technology Development**
    - Single Vendor develops the government-selected technology until ready for deployment
    - Government funded
  - **Phase II: LEU Production**
    - One or two vendors awarded contract to construct and operate enrichment facility
    - Private financing with Government off-take agreement
- Government retains ownership of IP created during Phase I
- Once supply to the Government begins, Vendor would be free to expand production to supply material to the commercial market (depending on the technology selected)

Questions to Consider

- Do these options seem feasible for your company?
- What advantages and disadvantages do each of these options present for you?
- Of the three options presented, which one is most attractive?
- Are there other acquisition strategies or combinations of strategies that the Government should consider?
- Would you be willing to partner with another company to support this program?