Timeline for the evolution of the modern U.S. tritium production capability (1988 to present)

Peter Lobner, 12 January 2020

This timeline addresses the U.S. efforts since 1988 to replace the tritium production capability that was lost when the last production reactors at the Savannah River Site were shut down and to modernize other parts of the tritium production cycle. From 1988 to 2005, the U.S. had no operational capability to produce more tritium for the nuclear weapons complex and the 1988 inventory of tritium was decaying with a 12.32 year half-life (at a rate of 5.5% per year).

1988 to 1992: DOE conducted the New Production Reactor (NPR) Program, but failed to select a preferred reactor technology or get Congressional support for continuation of the NPR program, which was cancelled (some say "deferred") in September 1992. The NPR program is described here:
https://www.osti.gov/servlets/purl/6320732

1992 to 1994: DOE sponsored the Accelerator Production of Tritium (APT) pre-conceptual design study. The APT program is described here:
http://accelconf.web.cern.ch/AccelConf/pac97/papers/pdf/9B003.PDF

1993: Based on the annually updated Nuclear Weapons Stockpile Plan (NWSP) and the goal of maintaining the U.S. nuclear weapons stockpile at the levels set by START II (STrategic Arms Reduction Treaty II), DOE and the Department of Defense (DoD) determined that tritium production would need to be resumed by 2011. With the higher START I limits as the target, tritium production would need to be resumed by 2005.

1994: The underground Replacement Treatment Facility in SRS H Area became operational in June 1994 to handle tritium returns for DoD. This facility unloads gases from old reservoirs, separates and purifies useful hydrogen isotopes (tritium and deuterium) using a Thermal Cycling Absorption Process (TCAP), and then mixes the gases to the correct specifications for loading into reservoirs.

1995: DOE began a program to consider dual-use facilities for tritium production.

- Based on past experience, the obvious choice was to produce tritium in a dual-use reactor.
- Other options would be considered.
- Pacific Northwest National Laboratory (PNNL) was selected to be the Design Authority for a commercial light water reactor (CLWR) irradiation demonstration.

1995: DOE issued DOE/EIS-0161 Rev. 1, "Final Programmatic Environmental Impact Statement for Tritium Supply and Recycling (Tritium Supply PEIS)."

- This programmatic EIS identified two alternatives for tritium production: a commercial light water reactor or an accelerator.
- The EIS is here: https://www.energy.gov/nepa/doeeis-0161-tritium-supply-and-recycling

12 December 1995: DOE issued 60 FR 63878, "Record of Decision (ROD): Tritium Supply and Recycling Programmatic Environmental Impact Statement."

- The ROD affirmed DOE/EIS-0161.
- The ROD is here: https://www.govinfo.gov/app/details/FR-1995-12-12/95-30238

1995 to 1997: PNNL designed and manufactured the initial Tritium Producing Burnable Absorber Rods (TPBARs) and the Lead Test Assemblies (LTAs) that would be irradiated in a commercial light water reactor to demonstrate the feasibility of safely producing tritium for DOE.

March 1997: PNNL issued report PNNL-11419 Rev 1, "Report on the Evaluation of the Tritium Producing Burnable Absorber Rod Lead Test Assembly."

- PNNL concluded that irradiation can be performed within the scope of Nuclear Regulatory Commission (NRC) regulations applicable to commercial PWRs.
- Their report is available here: https://digital.library.unt.edu/ark:/67531/metadc676921/m2/1/high_res_d/477674.pdf

May 1997: NRC issued NUREG-1607, "Safety Evaluation Report Related to the Department of Energy's Proposal for the Irradiation of Lead Test Assemblies Containing Tritium-Producing Burnable Absorber Rods in Commercial Light-Water Reactors."

- The NRC concluded that a separate, plant-specific license amendment request must be filed for irradiation of LTAs with TPBARs at the selected reactor.
- Safety issues requiring further NRC review were identified.
- This SER is here: https://www.osti.gov/servlets/purl/491562

June 1997: DOE issued a request for proposal (RFP) for a fixed-price contract to provide a commercial PWR for sale or lease for production of tritium. DOE determined that the only responsive bid was from the Tennessee Valley Authority (TVA), with two options:

- Use the existing Watts Bar Unit 1 and Sequoyah Units 1 & 2 nuclear plants, with a remaining operating life of about 25 years
- Complete and use the Bellefonte plant, with an operating life of 40 years, plus use the existing plants as needed.

DOE selected the first option.

September 1997:

- NRC issued a License Amendment allowing installation of PNNL's prototype LTAs with a total of 32 TPBARs in Watts Bar Unit 1 (WBN 1) during the fall 1997 refueling outage and irradiated for one refueling cycle (about 18 months).
- TVA installed the LTAs during the Cycle 2 refueling outage.

TVA's Watts Bar nuclear power plant.
Source: Oak Ridge Today, 13 Feb 2019

22 December 1998: Secretary of Energy Bill Richardson announced the decision to select the commercial light water reactor (CLWR) as the primary tritium supply technology, using government-owned TVA reactors for irradiation services.

- DOE determined that this approach would be cost effective and consistent with nonproliferation interests so long as the reactors burned U.S.-origin low-enriched uranium (LEU) fuel ("unobligated" LEU).

8 Feb 1999: Westinghouse Electric Company issued NDP-98-181 (Rev. 1), "Tritium Production Core (TPC) Topical Report."

- Westinghouse claimed the report demonstrated that no significant safety issues are raised by the operation of a reference Westinghouse PWR with a full complement of TPBARs.
- This Topical Report also provides a methodology and a reference for a utility to use in a plant-specific evaluation.
- This topical report is here: https://www.nrc.gov/docs/ML1607/ML16077A093.pdf

March 1999: DOE issued DOE/EIS-0288, "Final Environmental Impact Statement for the Production of Tritium in a Commercial Light Water Reactor." This EIS is available here: https://www.nrc.gov/docs/ML0324/ML032460376.pdf

March 1999: DOE issued DOE/EIS-0271, "Final Environmental Impact Statement for the Construction and Operation of a Tritium Extraction Facility at the Savannah River Site," selecting H Area at the SRS for the TEF site. This EIS is available here: https://www.energy.gov/sites/prod/files/EIS-0271-FEIS-01-1999.pdf

Spring 1999: TVA removed the LTA from WBN 1 during the Cycle 3 refueling outage. Subsequent non-destructive examination by DOE confirmed that the TPBARs had performed well.

May 1999: NRC issued NUREG-1672, "Safety Evaluation Report Related to the Department of Energy's Topical Report on the Tritium Production Core."

- The NRC concluded that the DOE generic topical report was generally acceptable and that any licensee wishing to undertake irradiation of production TPBARs must first submit an application for an operating license amendment and must address the plant-specific interface issues identified by NRC.
- The SER is here: https://ntrl.ntis.gov/NTRL/dashboard/searchResults/titleDetail/NUREG1672.xhtml

December 1999: TVA accepted the DOE contract for providing TPBAR irradiation services, with an effective start date of 1 January 2000. TVA would be paid about $1.5 billion for its costs over the agreement's 35-year term.

2000:

- Ground was broken in July for the new Tritium Extraction Facility (TEF) at SRS. TEF consists of two process buildings:
  - The Remote Handling Building (RHB) receives the TPBARs and extracts the tritium in vacuum furnaces.
  - The Tritium Processing Building provides preliminary purification of the extracted gases prior to transfer to the nearby Reservoir Loading Facility.
- NNSA contracted with WesDyne International, a subsidiary of Westinghouse, to fabricate and assemble TPBARs in Columbia, South Carolina in accordance with PNNL's design specifications. PNNL maintains a backup capability to produce TPBARs.

May 2001: Framatome ANP issued Report BAW-10237, "Implementation and Utilization of Tritium Producing Burnable Absorber Rods (TPBARS) in Sequoyah Units 1 and 2."

- This report provides a good description of the modified core and TPBARs as they would be applied for tritium production at the Sequoyah nuclear plant. Watts Bar should be similar.
- This report is Enclosure 1 to ANP letter dated 25 May 2001. Both are available here: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.388.7747&rep=rep1&type=pdf

August 2001: NNSA provided a status update, "Tritium Readiness Campaign," which is available here: https://www.nrc.gov/docs/ML0126/ML012690098.pdf

2001 to 2003: PNNL prepared the production TPBAR design to be fabricated by contractors, including WesDyne, which is responsible for some fabrication and TPBAR assembly.

20 August 2001: TVA filed an application to amend the WBN 1 operating license to permit irradiation of production TPBARs.

- The application was based on the assumption that up to 2,304 TPBARs could be loaded into the reactor and that tritium would permeate from the TPBARs into the reactor coolant at an average rate of 1.0 Curie per year per TPBAR, for a total of 2,304 Curies per year.

23 September 2002: NRC issued WBN 1 License Amendment 40 approving the irradiation of up to 2,304 TPBARs per operating cycle.

- Approval based on DOE / Westinghouse topical report "Tritium Production Core Topical Report," NPD-98-181, Revision 1 dated 8 Feb 1999.
- Amendment 40 is available here: https://www.federalregister.gov/documents/2016/07/05/2016-15867/tennessee-valley-authority-watts-bar-nuclear-plant-unit-1

18 August 2003: TVA requested approval to operate WBN 1 with a maximum of 240 TPBARs based on issues related to Reactor Coolant System (RCS) boron concentration.

8 October 2003: NRC issued License Amendment 48 for WBN 1 to operate initially with up to 240 TPBARs.

Fall 2003:

- The first load of 240 production TPBARs was installed in WBN 1 during the Cycle 6 scheduled refueling outage.
- Subsequent WBN 1 reactor operation revealed a higher than expected rate of tritium permeation from the TPBARs into the reactor coolant.

1 December 2003: NRC issued a license amendment approving the irradiation of TPBARs at the Sequoyah Nuclear Plant, Units 1 and 2.

2005: The upgraded H Area New Manufacturing (HANM) Facility, which performs tritium purification functions, became operational at SRS.

March 2005: The first load of 240 irradiated TPBARs was removed from WBN 1 during the scheduled refueling outage and 240 new TPBARs were loaded for irradiation during Cycle 7.

Summer 2005: After a cooling period, the first load of irradiated TPBARs were consolidated at Watts Bar and delivered to SRS in August for storage pending completion of the new Tritium Extraction Facility (TEF).

2005 to 2008: TPBAR design modifications intended to improve tritium permeation performance were developed by PNNL and implemented by the manufacturing contractors. The new TPBAR version was designated Mark 9.2.

January 2007: The Tritium Extraction Facility (TEF) at SRS became fully operational and started extracting tritium from TPBARs.

- From 2007 until 2017, the TEF conducted only a single extraction each year to supply tritium for the U.S. nuclear weapons complex. The TEF sat idle for nine months each year between extraction cycles.
- The tritium extracted at TEF was transferred to the HANM for further purification.

February 2007: The SRS Tritium Loading Facility received the first newly-produced tritium for loading into reservoirs for nuclear weapons.

2008: The first batch of Mark 9.2 TPBARs were loaded into WBN 1 during the Cycle 9 scheduled refueling outage in the spring of 2008. The Mark 9.2 TPBARs were used in subsequent operating cycles.

2008 to 2019: Ongoing irradiation testing programs at the Advanced Test Reactor (ATR) at the Idaho National Laboratory (INL) continued investigating TPBAR performance issues.

2010: In a report to the House of Representatives, the General Accounting Office (GAO) reviewed DOE's tritium production program:

- Despite TPBAR redesign, "no discernable improvement in TPBAR performance was made and tritium is still permeating from the TPBARs at higher-than-expected rates."
- TVA continues to irradiate TPBARs using only WBN 1.
- Report GAO-11-100 is available here: https://www.gao.gov/products/GAO-11-100

May 2013: The U.S. lost its sole supplier of "unobligated" (free from peaceful use restrictions) enrichment services when the last operating uranium enrichment plant using U.S. technology (the Paducah gaseous diffusion plant in Kentucky) ceased operation.

- LEU fuel for TVA's reactors used to produce tritium will have to come from another unobligated source, such as blended-down unobligated HEU or a future new enrichment facility.
- DOE and NNSA will be responsible for resolving this issue.

October 2015: DOE delivered the report to Congress: "Tritium and Enriched Uranium Management Plan Through 2060." The timescales affecting users of the limited U.S supply of unobligated uranium are as follows:

- Previously unobligated LEU fuel for tritium production was projected to be expended by 2027. Three short-term actions could extend the unobligated LEU fuel supply to 2038-2041.
- New sources of HEU fuel for naval reactors will be needed in about 2060.
- HEU inventories currently used to meet non-defense national priority missions may be exhausted in about 10 to 15 years.
- This DOE report to Congress is available here: http://fissilematerials.org/library/doe15b.pdf

February 2016: NNSA issued DOE/EIS-0288 Supplement 1, "Final Supplemental Environmental Impact Statement for the Production of Tritium in a Commercial Light Water Reactor (CLWR SEIS)."

- This SEIS was issued because there was new information about: (1) the amount of tritium required to support the nation's nuclear stockpile requirements, and (2) the operational performance of the TPBARs, particularly the higher-than-expected rate of tritium permeation.
- Near-term tritium requirements "could likely" be met by irradiating of 2,500 TPBARs per 18-month fuel cycle.
- A "maximum production" scenario of irradiating 5,000 TPBARs per fuel cycle would provide flexibility to respond to future changes in tritium production requirements.
- Seven alternative solutions were presented.
- The SEIS impact analysis was based on a tritium permeation rate of 10 Curies per TPBAR per year, which "is expected to bound uncertainties in relation to future operations."
- This SEIS is available here: https://www.energy.gov/sites/prod/files/2016/02/f29/EIS-00288-S1_F%20Summary%20For%20Web%202016-01-19.pdf

June 2016: In a Federal Register notice on 22 June 2016, NNSA issued a Record of Decision (ROD) that it had selected CLWR SEIS Alternative 6, which allows for the irradiation of up to 5,000 TPBARs every 18 months using TVA reactors at both the Watts Bar and Sequoyah sites.

- This ROD is available here: https://www.energy.gov/sites/prod/files/2016/06/f32/EIS-0288-S1_ROD_FR.pdf

July 2016: NRC issued WBN 1 License Amendment 107:

- WBN 1 can operate with a maximum of 1,792 TPBARs
- NRC required certain technical changed before TVA increased TPBAR loading above 704.

October 2016: Watts Bar Unit 2 (WBN 2) entered commercial service and started its operating Cycle 1 in October 2016. This reactor is a candidate for future tritium production

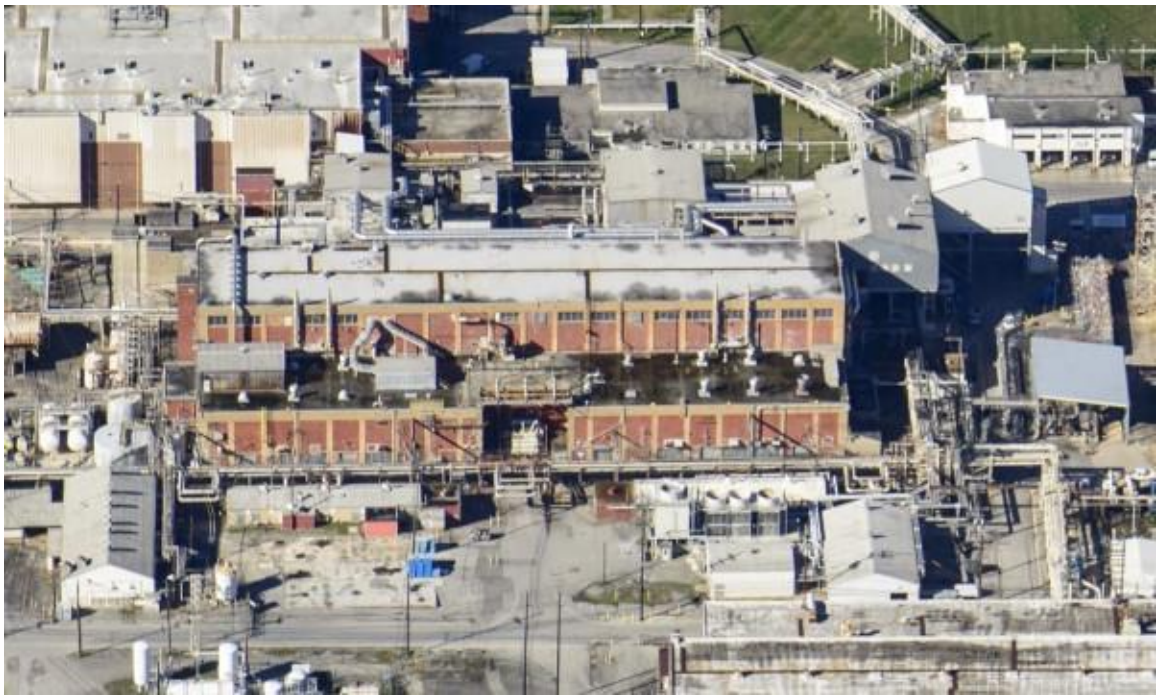
2017: For the first time, the TEF performed three extractions in a single year using the original vacuum furnace.

- Each extraction typically involves 300 TPBARs.
- Multiple extractions will be required in future years to meet NNSA's requirements for tritium production.

May 2017: INL completed a study examining the feasibility of processing zirconium-clad spent fuel through a new process called ZIRCEX.

- This process could enable reprocessing zircalloy-clad spent naval fuel stored at INL.

May 2017: Y-12 lithium activities were adversely affected by the poor physical condition of the WW II-vintage Building 9204-2 (Beta 2). This building was downgraded to handle only non-nuclear materials. Nuclear material activities were moved to the adjacent Building 9204-2E.



Y-12 Building 9204-2. Source: Oak Ridge Today, 6 April 2019

11 May 2017: The PNNL Tritium Focus Group conducted a programmatic review and issued the report, "Tritium Production Assurance."

- Summarizes actual tritium production at WBN 1 during Cycles 6 to 14 (WBN 1 tritium production started in Cycle 6)
- Defines tritium production goals WBN 1 Cycles 15 to 21 and WBN 2 Cycles 4 to 8 (WBN 2 tritium production will start in Cycle 4)
- This report is available here: https://www.energy.gov/sites/prod/files/2017/06/f34/May%2011%20-%20Stewart%20-%20Tritium%20Production%20Assurance.pdf

24 August 2017: NNSA announced the approval of plans for a new Lithium Production Facility at Y-12, replacing the current facility in Building 9204-2. See details here: https://oakridgetoday.com/2017/08/24/mission-need-approved-lithium-production-facility-y-12-cost-schedule-not-determined/

February 2018: General Accounting Office issued report GAO-18-126, "NNSA Should Clarify Long-Term Uranium Enrichment Mission Needs and Improve Technology Cost Estimates." The report identifies:

- Milestone dates for a new uranium enrichment capability.
- Two competing enrichment technologies: Centrus large advanced gas centrifuge and Oak Ridge National Laboratory small advanced gas centrifuge.
- Estimated cost for deploying a new uranium enrichment capability ($3.8 to $14 billion).
- Other options, including downblending and reprocessing spent fuel, including naval fuel.
- This GAO report is available here: https://www.gao.gov/assets/700/690143.pdf

12 May 2018: NNSA confirmed candidate siting for the new Lithium Production Facility to be built at Y-12. See details here: https://oakridgetoday.com/2018/05/28/lithium-production-facility-built-area-biology-complex-y-12/

July 2019: DOE and NNSA delivered the report to Congress: "Fiscal Year 2020 – Stockpile Stewardship and Management Plan." This Plan has a big impact on tritium production infrastructure.

- A top-level goal is to "recapitalize existing infrastructure to implement a plan to produce no less than 80 ppy (plutonium pits per year) by 2030."
    - This will drive tritium production demand, which in turn will drive demands for unobligated LEU to fuel TVA's tritium-producing reactors and enriched lithium-6 for TPBARs.
- Among the missions necessary to sustain the modern stockpile are:
    - **Increasing tritium production:** The goal is 2,800 grams per two 18-month reactor cycles of production at TVA by 2027.
    - **Restart lithium processing capabilities:** Recycle lithium components to increase the immediately usable supply and build the new Lithium Production Facility at Y-12 by 2030.
    - **Develop domestic uranium enrichment capability:** The report notes, "U.S. Government currently has no uranium enrichment capability." A source of unobligated enriched uranium is needed.
- This report to Congress is available here: https://www.energy.gov/sites/prod/files/2018/10/f57/FY2019%20SSMP.pdf

21 August 2018: Secretary of Energy Rick Perry issued a Secretarial Determination that allows NNSA to continue transfers of HEU from DOE's inventory in support of national security. This allows down-blending of unobligated U.S.-origin HEU to provide LEU to fuel TVA's tritium-producing reactors.

6 September 2018: The status of the tritium production program was assessed in Congressional Research Service report R45406, "The U.S. Nuclear Weapons Complex: Overview of Department of Energy Sites," which is available here: https://crsreports.congress.gov/search/#/?termsToSearch=R45306&orderBy=Relevance

27 September 2018: BWT Technologies, Inc. announced that its Nuclear Fuel Services (NFS) subsidiary in Erwin, TN had been awarded a $505 million contract by NNSA to downblend 20.2 metric tons of HEU to produce LEU, which would serve as a short-term source of fuel for TVA's tritium-producing reactors. The contract runs from 2019 to 2025.

11 February 2019: The NRC issued an environmental assessment (EA) finding no significant impact of operating Watts Bar Units 1 and 2 with up to 1,792 TPBARs.

- Number of spent fuel bundles increases by about four per cycle. TVA has adequate spent fuel storage on site.
- This EA is available here: https://www.govinfo.gov/content/pkg/FR-2019-02-11/pdf/2019-01859.pdf

November 2019: Savannah River's capacity for processing TPBARs and extracting tritium was increased by the addition of a second vacuum furnace at TEF.

31 December 2019: NNSA failed to meet its goal of selecting a preferred uranium enrichment technology in 2019. The contenders are:

- A privately-owned technology from Centrus Energy Corp., Bethesda, MD (AC-100 large advanced gas centrifuge).
- A technology developed at the Oak Ridge National Laboratory in Oak Ridge, TN (small advanced gas centrifuge).

2025: Current HEU downblending contract with Nuclear Fuel Services ends. NNSA needs to secure a longer-term source of U.S. origin LEU to provide fuel for TVA's tritium-producing reactors.

2025: Demonstrate the ability to produce 2,800 grams of tritium per two 18-month reactor cycles of production in TVA reactors (2018 Stockpile Stewardship goal).

2030: Y-12 New Lithium Facility operational (2018 Stockpile Stewardship goal).

mid-2030s ??: New enrichment facility operational**.**