ORNL/TM-2014/314

Recovery of Mark-18A (Mk-18A) Target Materials: Program Management Plan

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October 2014

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE US DEPARTMENT OF ENERGY

ORNL/TM-2014/314

Nuclear Security and Isotope Technology Division

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Date Published: October 2014

Prepared by
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831-6283
managed by
UT-BATTELLE, LLC
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-00OR2275

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ACKNOWLEDGMENTS

This worked was funded by the Department of Energy National Nuclear Security Administration NA-73 Office of Nuclear Materials Integration. The work was performed by a team from Oak Ridge National Laboratory (ORNL) and Savannah River National Laboratory/Savannah River Site (SRNL/SRS). The primary contributors from ORNL were Porter Bailey, Dale Caquelin, Rick Henry, Bradley Patton, and Sharon Robinson. The primary contributors from Savannah River were Jeffrey Allender, William Bates, Nicholas Bridges, Timothy Brown, David Hobbs, and Bradley Loftin.

1. INTRODUCTION

The Department of Energy (DOE) manages an inventory of materials that contains a range of long-lived radioactive isotopes that were produced from the 1960s through the 1980s by irradiating targets in production reactors at the Savannah River Site (SRS). One reactor operated in a high-flux mode to produce special heavy isotopes for defense purposes, DOE programmatic use, scientific research, and industrial and medical applications. Eighty-six Mark-18A (Mk-18A) targets were subjected to long-term high neutron fluences 44 years ago. Twenty-one targets were processed to recover ^{244}Pu, heavy curium (i.e., curium rich in $^{246\text{-}248}$Cm), and ^{252}Cf. The plutonium fraction, which was rich in ^{244}Pu, was electromagnetically enriched in the Oak Ridge National Laboratory (ORNL) calutrons to produce gram quantities of ^{244}Pu. This high-purity sample of ^{244}Pu was portioned out to scientists for basic research and for safeguards programs. The recovered tails (designated as FP-33) contain ^{244}Pu isotopic purities below 20% and are stored at ORNL. The processing of these 21 Mk-18A targets provided the supply of ^{244}Pu and heavy curium in use today. The 65 unprocessed targets are currently in a storage pool at SRS; they contain the world's supply of unseparated ^{244}Pu and heavy curium needed for heavy-actinide production and are the subject of this study.

The Mk-18A Target Material Recovery Program is being established to preserve the unique materials in the 65 Mk-18A targets for future use. This Program Management Plan (PMP) establishes a framework for the successful integrated management of the several projects required to complete the program. It defines the program scope and the organizational framework, identifies roles and responsibilities of contributors, and presents the Work Breakdown Structure (WBS), cost, and schedule. The PMP describes the management strategy for the program.

2. MISSION NEED

The Department of Energy (DOE) manages an inventory of materials that contains a range of long-lived radioactive isotopes that were produced from the 1960s through the 1980s by irradiating targets in production reactors at the Savannah River Site (SRS). As a by-product of defense materials production, the reactors produced special heavy isotopes for defense purposes, DOE programmatic use, scientific research, and industrial and medical applications (Boswell, 2000). During the late 1960s, the K Reactor was reconfigured to operate in a very high flux mode (6×10^{15} n/cm^2-s). More than 8 kilograms of ^{242}Pu, contained in 86 Mk-18A targets, was irradiated to produce large gram-scale amounts of ^{252}Cf for use in a market development program for ^{252}Cf neutron source applications. The driver fuel used 1.2 MT of ^{235}U to irradiate the targets, and the irradiation time for the targets was ten years. Twenty-one of the 86 targets were processed in 1972–1973 at ORNL to recover the ^{252}Cf as well as curium rich in the heavy isotopes ^{246}Cm and ^{248}Cm. Also, approximately 4 grams of a rare plutonium isotope, ^{244}Pu, was recovered and enriched to 98–99% isotopic purity in the Oak Ridge National Laboratory (ORNL) Actinide Calutron Facility. The processing of these 21 Mk-18A targets is today's source of the world's supply of separated ^{244}Pu and heavy curium. The 65 unprocessed targets are currently in a storage pool at SRS; they contain the world's supply of unseparated ^{244}Pu and significant amounts of heavy curium for heavy-actinide production. The reactors and support infrastructure at SRS used to produce the Mk-18A targets have now been shut down.

In 2001, DOE designated the ^{244}Pu in the targets as a National Resource material (Moniz, 2001). The 2011 DOE National Strategic Plan for Nuclear Materials (US DOE, 2011) also identified the existing inventory of $^{242/244}$Pu and $^{244/246/248}$Cm as valuable feedstock for producing new isotopes and categorized them as rare and economically irreplaceable. The Strategic Plan noted the need for DOE to make decisions regarding the preservation of these materials before the opportunity is lost. A recent audit by the Office of the Inspector General (US DOE, 2013) concerning the DOE's management of surplus nuclear materials supports this position.

The Mk-18A targets contain approximately 80% of the world's inventory of ^{244}Pu and heavy curium. Both materials are extremely rare and are economically irreplaceable. Plutonium-244 is a long-lived isotope of plutonium that is not produced in either commercial fuel or weapons-grade plutonium. It provides measurement capabilities that are highly essential in maintaining an active nuclear forensics and safeguards posture in current and future world affairs. The heavy curium is an attractive long-term feedstock for the production of ^{252}Cf and other heavy elements. The primary applications and users of ^{244}Pu and heavy curium are listed in Table 1 and are summarized below.

2.1 THE NEED FOR PLUTONIUM-244

Pure ^{244}Pu is needed at several laboratories for use as a reference material for high-precision, destructive analysis techniques such as isotope ratio mass spectrometry. These analytical techniques are needed for supporting R&D efforts and detecting clandestine activities, as well as for international safeguards efforts due to the expanded use of nuclear fuels for power production. Certified reference materials (CRMs) are an essential part of the nuclear materials control and accountability system. Together with analytical procedures, they provide assurance

Table 1. Uses of isotopes contained in the Mk-18A target materials

	Isotopes of Interest	Uses	Internal Parties of Interest	External Parties of Interest	Stakeholders	Applications
MK-18A TARGETS	**Heavy Curium – $^{246-248}$Cm**	Feedstock for ^{252}Cf Production (Provide high-yield feedstock to last through lifetime of HFIR)	DOE-Office of Science (SC) Nuclear Physics	▪ ^{252}Cf Consortium ▪ R&D Community	▪ Nuclear Reactor Operations - DOE - U.S. Navy - Commercial Nuclear Power ▪ Oil Exploration Industry ▪ Medical R&D Community ▪ DOE Laboratories ▪ Foreign Laboratories	▪ Oil Well Logging (OWL) ▪ Thickness Gauging ▪ Reactor Startup ▪ Fuel Rod Scanning ▪ Materials Neutron Analysis ▪ Education ▪ Equipment Calibration, Testing ▪ Radiation Instrument Calibration
		Feedstock for Heavy Element (^{249}Bk, ^{253}Es, & ^{254}Es) Production	DOE-SC	▪ R&D Community	▪ Universities ▪ DOE Laboratories ▪ Russian Federal Agency of Atomic Energy ▪ Super Heavy Element R&D Community	▪ Super Heavy Element R&D
	Plutonium High in ^{244}Pu	Feedstock for Producing ^{244}Pu Standards/Special R&D Projects	NA-20 DOE-Office of Intelligence & Counterintelligence (IN) DOE-Office of National Technical Nuclear Forensics (NA-45)	▪ Department of Homeland Security (DHS) Domestic Nuclear Detection Office (DNDO) ▪ Department of Defense Threat Reduction Agency (DTRA) ▪ IAEA ▪ Federal Bureau of Investigation (FBI) ▪ U.S. Intelligence Community (IC)	▪ Any Organization Conducting High Precision Plutonium Isotopic Determination ▪ IAEA ▪ Universities ▪ New Brunswick Laboratory ▪ Plutonium Processing Facilities Worldwide ▪ NNSA Office of Materials Disposition ▪ Institute for Reference Materials & Measurements (IRMM) ▪ Environmental Plutonium Transport R&D ▪ Super Heavy Element R&D Community	▪ Certified Reference Material (CRM) ▪ Spike for High Precision Plutonium Isotopic Determinations ▪ Target for Super Heavy Element R&D ▪ Low Activity Plutonium for Basic Plutonium R&D

that the measured amounts of nuclear materials are accurate, comparable, and traceable. There exists a real need to produce nuclear CRMs that meet the needs of the safeguards and nonproliferation communities for ensuring measurements that meet accuracy and precision goals.

New Brunswick Laboratory (NBL), the domestic supplier of nuclear forensic reference materials, made their ^{244}Pu CRM from the high-purity sample of ^{244}Pu obtained from the processing of the 21 Mk-18A targets in the 1970s. Ten years ago the remaining inventory of their ^{244}Pu was depleted to levels that compelled NBL to stop selling the material due to concerns of limited supply and possible hoarding. Approximately 300 1-mg ^{244}Pu units are in stock at NBL but are being held in reserve for critical needs. Many domestic labs, foreign processing facilities, and the International Atomic Energy Agency (IAEA) have nearly exhausted their supplies and have inquired about the purchase of several units. As of CY 2013, NBL is making a portion of its stock available on a case-by-case basis.

Small quantities of the FP-33 materials are available from ORNL in the form of mixed plutonium isotopes that have ^{244}Pu isotopic purities below 20%. These stocks must be enriched in the ^{244}Pu isotope before they can serve as feed for the certification protocol in the process to becoming CRM for use in forensic analyses. In the 1980s, the IAEA, the United States, and other international laboratories discussed obtaining FP-33 material from the United States to strengthen their safeguards programs. The IAEA initiated a contract with the DOE to separate ^{244}Pu from 5 grams of the FP-33 (17% ^{244}Pu) material by using Russian Institute VNIIEF calutrons to 99.99% purity.

The Russians completed an enrichment demonstration using a 0.5 g sample of FP-33. The product from that demonstration is being returned to the US to verify the purity. The contract expired before the remaining 4.5 g sample was shipped to Russia. The separated material, estimated to be less than a milligram from enrichment of 5 grams of FP-33, would have been used to create CRM which would have been provided to the IAEA to distribute to international laboratories for use in nuclear safeguards forensic activities. However, the project would not have provided enough ^{244}Pu to meet the demand for CRM.

Scientists at the DOE laboratories, National Institute of Standards and Technology (NIST), the IAEA, European Atomic Energy Community (EURATOM) and other international laboratories are concerned with the limited availability of separated ^{244}Pu and clearly see a need for recovering more ^{244}Pu and other pure isotopes to perform highly precise measurements of plutonium (Goldberg, 2001). It is recognized that there is no other isotopic material that can perform the unique function of ^{244}Pu in high-accuracy measurements of plutonium for both safeguards and environmental analyses. Because of the limited supply of high-purity ^{244}Pu needed for CRM, many scientists have begun to use ^{242}Pu for certain applications. However, ^{242}Pu is not a suitable for detecting fugitive plutonium releases in environmental samples and establishing the provenance of such releases. Therefore, the interest in low-level environmental reference materials for safeguards applications has greatly increased the need for ^{244}Pu since it improves the precision and accuracy of isotopic measurements. Other tracers can be used (such as ^{242}Pu) but will not yield the same quality results in terms of measurement sensitivity as the ^{244}Pu. The limited stock of high-purity ^{244}Pu obtained from processing of the original 21 Mk-18A targets will not meet future CRM demands for highly enriched ^{244}Pu.

The ^{244}Pu material has also been used and is needed as target materials for heavy ion bombardment for studies of transactinide elements. These isotopes are used in the production and discovery of the superheavy elements. As an example, in December 1998, a team of scientists from Lawrence Livermore National Laboratory (LLNL) and a Russian facility discovered element 114 using a heavy ion cyclotron to bombard a film of ^{244}Pu with ^{48}Ca ions for 40 days (an achievement which was recognized by *Popular Science* as one of the year's 100 greatest achievements in science and technology).

In addition, ^{244}Pu isotope has a half-life that is over 200 times longer than any other plutonium isotope, making it extremely useful in any studies that attempt to understand the fundamental thermodynamics of plutonium in either the solution or solid state. Plutonium-244 is also the prime isotope for plutonium tracing as well (e.g., marine environment). As the world continues to run nuclear power plants and recycle fuels, the ^{242}Pu fraction is going to increase, rendering that isotope unsuitable as a plutonium tracer. However, ^{244}Pu is not produced in appreciable quantities in standard power reactor fuel and will not build up in the environment, making it most valuable as a tracer for plutonium.

The Mk-18A targets are the only significant source of high-isotopic purity ^{244}Pu in the world, and the current inventory (~5 grams) of separated ^{244}Pu (obtained from processing 21 Mk-18A targets in the mid-1970s) will be depleted in the near future. It is extremely unlikely that more ^{244}Pu will ever be produced due to the very high flux required to overcome the short half-life of ^{243}Pu in a reactor. The high-flux reactors used to produce the original ^{244}Pu supply have been shut down, and the replacement cost is estimated to be in the billions of dollars. Production of ^{244}Pu in any significant quantity is not feasible given the current status of nuclear reactors within the DOE complex. Therefore, for all practical purposes, the Mark-18A targets are the only future source of ^{244}Pu (~21 grams) in the world.

2.2 THE NEED FOR HEAVY CURIUM

The heavy curium in the Mk-18A targets is an attractive feedstock for ^{252}Cf production. Californium-252 is a radioactive neutron source used in many industrial applications including oil exploration applications; process control systems in the cement, coal, and power production industries; sources to start nuclear reactors; nondestructive materials analyses; and medical research and health care applications such as cancer treatment.

The production of ^{252}Cf requires both a high-flux reactor and a unique feedstock. Since ^{252}Cf has a short half-life (2.6 years), it decays at a rate of about 25% per year, and new supplies need to be manufactured regularly to meet the various user communities' needs. In the process of producing ^{252}Cf, other heavy actinides are produced as by-products. These include ^{249}Bk, ^{254}Es, and ^{255}Fm. In 2009–2010 ^{249}Bk was recovered and used in a multinational collaborative discovery of element 117. Additional ^{249}Bk is being used to confirm the discovery of element 117 and perhaps the discovery of element 119.

The heavy curium (curium rich in the $^{246–248}Cm$ isotopes) in the Mk-18A targets is an optimal feedstock for ^{252}Cf and other heavy-element production and research. Currently, the ^{252}Cf production program is relying on an existing supply of heavy curium. Production of ^{252}Cf at the amounts needed to meet current contractual demands can be sustained until ~2030 without supplementing ORNL's current heavy-curium feedstock. If the demand for ^{252}Cf production increases beyond the contractual average and/or a significant demand is made for other heavy-element production, the useful life expectancy of the existing heavy curium supply will diminish accordingly.

The Mk-18A targets contain 680 grams of heavy curium that is optimal for ^{252}Cf production. Other, less attractive material options for supplementing the current feedstock include the existing light curium material in inventory at ORNL and the ^{242}Pu currently in inventory in the DOE complex. The present plan for sustained production of ^{252}Cf includes irradiating light curium in the ORNL inventory to replenish heavy curium lost during production, and the program life expectancy estimate of ~2030 takes this strategy into account.

3. ALTERNATIVES ANALYSIS

In 2013, the DOE Office of Nuclear Materials Integration (NA-73) tasked ORNL and Savannah River National Laboratory (SRNL) to evaluate disposition options for the Mk-18A materials. Management of these materials involves processing items for beneficial use and/or for disposition using storage and process facilities at SRNL/SRS and ORNL. The objective of the study was to identify feasible disposition options, develop preliminary cost estimates for viable options, evaluate each option versus programmatic needs, and recommend dispositioning options for the materials. The study evaluated options for recovery and/or disposition of the Mk-18A target materials as waste using the SRS H-Canyon to process the material for disposal (Robinson, 2014). Potential disposition options evaluated include

- recovery of ^{244}Pu and heavy curium for future use,
- recovery of ^{244}Pu only for future use and processing of the heavy curium for disposal at a geological repository, and
- processing the targets for disposal as waste at a geological repository without recovery of ^{244}Pu or heavy curium.

The major steps in the disposition pathways include packaging/transport of the targets to treatment/storage/disposal facilities, dissolution of the targets, and processing of the material for recovery of isotopes and/or disposal as waste. In scenarios where the isotopes are recovered for future use, the disposition endpoint is storage as oxides in sealed capsules at ORNL. The ^{244}Pu would be recovered from the Mk-18A targets, converted to an oxide, and stored in sealed capsules awaiting future enrichment. The heavy-curium/americium/lanthanide fission products would be converted to oxides and stored in sealed capsules for future heavy-actinide production.

Inclusion of processing locations led to the development of seven potential pathways for disposition of the Mk-18A targets, as summarized in Table 2. SRS facilities are considered the only viable location for processing materials for disposition as waste because the SRNL facilities do not have the waste disposal infrastructure and shipment to ORNL would require significant processing/repackaging efforts at SRS to make the materials acceptable for shipment off site. Both the SRS and ORNL sites were considered for the ^{244}Pu and heavy curium-recovery processing steps. Both H-Canyon at SRS and the Shielded Cells at SRNL were considered for the SRS processing operations. H-Canyon was considered a viable option for all five pathways, and the Shielded Cells were considered viable options for Pathways 2 and 3. The Shielded Cells Facility was not considered viable for Pathway 1 because the facility cannot support loading of targets in the off-site transport cask.

An alternatives evaluation was performed to rank the disposition options using a decision-making methodology that provides a structured framework for comparing both qualitative and quantitative selection criteria. The selection criteria for disposition pathways for the target materials include the following.

Table 2. Potential disposition pathways for Mk-18A targets in inventory at SRS

Pathway	Target Dissolution	^{244}Pu Recovery	Heavy Cm Recovery	Processing for Disposal as Waste
1—Pu/Am/Cm recovered at ORNL	ORNL	ORNL	ORNL	NA
2—Pu/Am/Cm recovered at SRS/ORNL	SRS	ORNL	ORNL	NA
2A—Pu/Am/Cm recovered at SRNL/ORNL	SRNL	ORNL	ORNL	NA
3—Pu/Am/Cm recovered at SRS	SRS	SRS	SRS	NA
3A—Pu/Am/Cm recovered at SRNL	SRNL	SRNL	SRNL	NA
4—Pu recovered at SRS	SRS	SRS	NA	SRS (Heavy Cm only)
5—No recovery	SRS	NA	NA	SRS (All)

Note: NA = not applicable.

- *Technical feasibility* – Considers likelihood of successful implementation based on processing requirements, shipping/staging requirements, regulatory approvals required, and acceptance by the DOE sites.
- *Cost and schedule* – Considers installation cost, operating cost, and impact on operating schedules at SRS/SRNL and ORNL.
- *Value of the material* – Considers uniqueness of the material for future beneficial use for heavy-isotope production and for R&D and standards.
- *Addition of capabilities* – Considers how useful the capabilities implemented for Mk-18A processing could be for other projects at SRS/SRNL.

Each of the potential disposition pathways was evaluated using the criteria described above. In 2013, Pathways 1–3 received good or average ratings, while Pathways 4 and 5 received poor ratings. The five pathways that recovered the material for future use (1, 2, 2A, 3, and 3A) were then evaluated in more detail and re-ranked in 2014. The re-ranking excluded the pathways that did not recover the material. The results are summarized in Table 3. The information used to evaluate the pathways is discussed in below.

Table 3. Evaluation results for Mk-18A disposition alternatives

Evaluation Criteria	Cost/ Schedule (M)		Uniqueness (H)		Feasibility of Implementation (M)				Adding Capabilities (L)	Overall Rating
Sub-criteria	Total Cost	Schedule	Heavy Isotope Production	R&D/Standards	Processing	Shipping/Staging	Site Acceptance	Regulatory		
Weighting Factor	H	H	H	H	H	M	H	M	M	-
Pathway 1	P	P	G	G	A	A	A	A	A	**A**
Pathway 2	A	P	G	G	A	A	A	A	G	**G-**
Pathway 2A	P	G	G	G	A	A	A	A	A	**G-**
Pathway 3	G	P	A	A	P	A	A	A	G	**P**
Pathway 3A	G	G	G	G	A	A	A	A	A	**G**

Notes: H = high; M = medium; L = low; G = good; A = average; P = poor.

Cost and Schedule

Preliminary feasibility-level order-of-magnitude cost estimates were developed for each of the disposition pathways. The cost estimates assume that DOE-EM will continue to fund the base costs for operating H-Canyon (~$150M/year) through 2023 and that only the incremental costs for processing Mark-18A targets at SRS will need to be covered by the project. The full allocated costs for processing/operating facilities at SRNL and ORNL were assumed in these cost estimates. The estimated costs for process modifications/startup and processing at each site are summarized in Table 4. All costs are in unescalated FY 2014 dollars.

The cost to recover the material varies between $64M and $96M over 10–25 years. Pathways 1, 2, and 2A require $64M–$72M over 10 years to get the materials in safe storage plus an additional $16M–$32M to purify product over the next 15 years. Pathway 3 and 3A require $64M–$75M over 10 years to purify and get the material into safe storage. By comparison the cost to disposition the material as waste is ~$17M.

A preliminary schedule was developed for each pathway based on the need to produce materials at a rate to supply feedstock for the ^{252}Cf production program. They are given in Fig. 1.

Evaluation of the schedules indicates that all pathways are viable options for accomplishing the Mark-18A recovery mission within the timeframes that H-Canyon and Defense Waste Processing Facility (DWPF) are expected to be available. Funding delays could extend the schedules past the dates that H-Canyon and DWPF are available, rendering any of these options nonviable. Schedules for Pathways 1, 2, and 3 potentially could be accelerated if some planned H-Canyon projects do not occur.

Table 4. Preliminary cost estimate for Mark-18A disposition pathways ($M in 2014 dollars)

Pathway	SRS/SRNL		ORNL				Grand Total
	Process Modification/ Startup	Repackaging/ Recovery	Process Modification/ Startup	Transport	Resizing/ Repackaging	Recovery	
1—Pu/Am/Cm recovered at ORNL	19.2	16.7	2.2	11.9	13.6	32.0	95.6
2—Pu/Am/Cm recovered at SRS/ORNL	30.3	17.0	2.2	4.0	8.6	19.3	81.3
2 A—Pu/Am/Cm recovered at SRNL/ORNL	17.2	32.2	4.0	0.2	17.9	19.3	90.8
3—Pu/Am/Cm recovered at SRS	41.6	18.2	2.2	4.0	8.6	0	74.5
3 A—Pu/Am/Cm recovered at SRNL	17.2	34.8	2.5	0.2	8.9	0	63.6

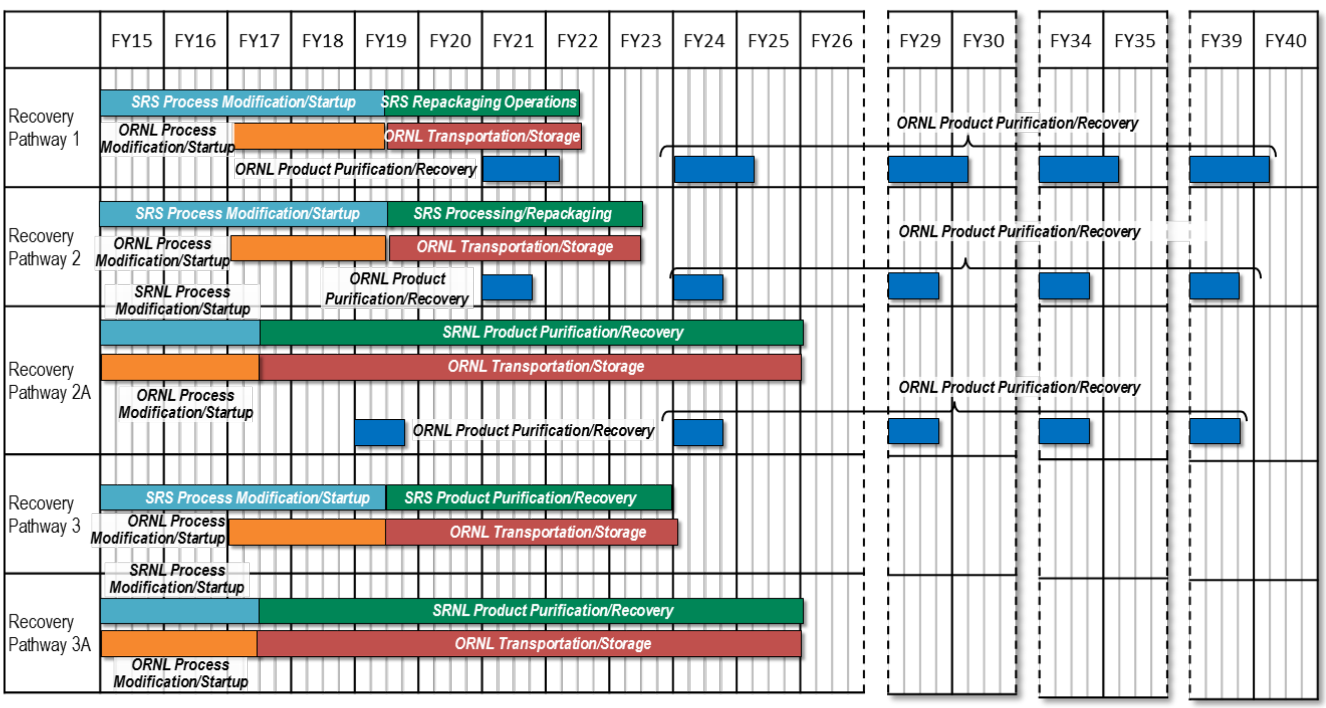

Fig. 1. Preliminary schedule for disposition of Mark-18A targets processing as quickly as possible.

Uniqueness of the Material for Future Reuse

All pathways preserve the plutonium and heavy-curium materials for future use for ^{252}Cf production and isotopes R&D/standards. The quality of the material recovered in Pathway 3 may be lower and processing losses may be higher when compared with Pathways 1, 2, 2A, and 3A.

Feasibility of Implementation

Pathways 1, 2, 2A, and 3A are considered the most technically feasible for providing the best quality material for future use. Pathway 3 has the most technical uncertainty because SRS has not processed targets to recover these materials, and new processes would have to be installed to do so. Shipping/staging, site acceptance, and regulatory issues were determined not to be discriminating evaluation criteria.

Adding Capabilities to SRS

Pathway 1 would require modifications to H-Canyon to provide an area for repackaging the Mark-18A targets before shipment to ORNL. These capabilities potentially could be useful for other future projects. Pathways 2 and 3 would require a small dissolver presently in standby to be brought online to process the Mark-18A targets for disposition. This dissolver would provide additional dissolver capacity to the two existing main-line dissolvers in H-Canyon and could be used to process various materials in addition to the Mark-18A targets. Pathways 2A and 3A upgrade the SRNL Shielded Cells to receive new casks and install R&D-scale dissolution and processing equipment in the hot cells. The upgraded cask unloading equipment could be useful for future projects in the facility.

Summary of Evaluated Alternatives and Recommended Pathway

Pathways 1, 2, 2A, 3, and 3A are all viable options for recovering the Mark-18A material for future use. Overall, Pathway 3A received a “good” rating, and Pathways 2 and 2A received “good minus” ratings. Pathways 1 and 3 received “average” and “poor” ratings, respectively. Pathways 1, 2, 2A, 3, and 3A meet the DOE National Strategic Plan for Nuclear Materials (US DOE, 2011) objective of preserving the valuable and economically irreplaceable materials for future use. Of these, Pathway 3 received a lower overall rating because it is the most technically risky pathway with the highest potential for producing low-quality product for reuse. Pathway 3A is less costly than Pathways 1, 2, and 2A. Therefore, it was rated as the preferred pathway for recovery and storage of the Mark-18A targets. Recovery and repackaging at the SRS H-Canyon received a slightly lower evaluation score and should be considered as the backup alternative if needed.. This PMP is developed for the recommended alternative, but the general PMP approach would be applicable to the other backup alternatives if needed.

4. PROGRAM DESCRIPTION

4.1 PROGRAM OBJECTIVES

This program preserves the Mk-18A targets for future use by retrieving them from wet storage in the L-Basin at SRS, processing and packaging them at SRS/SRNL, and shipping them to ORNL where they will put in dry storage at the Radiochemical Engineering Development Center (REDC) for future use. The heavy curium will be used in the production of heavy actinides (^{252}Cf, ^{249}Bk, etc.) and the plutonium stored for future enrichment. The key performance parameters are to (1) retrieve the targets from their present location in L-Basin at SRS and process them in the SRNL Shielded Cells Facility to produce heavy curium and plutonium oxides suitable for transport and storage at ORNL and (2) produce a quality of ^{244}Pu and heavy curium that will meet the feedstock requirements for end users. Evaluations by technical staff indicate that product from the program as scoped in Section 4.2 should be of adequate quality to meet feedstock requirements for heavy-actinide production and produce ^{244}Pu suitable for future enrichment.

4.2 PROGRAM SCOPE

The targets would be retrieved from their storage location in L-Basin at SRS and shipped to the SRNL Shielded Cells, where they would be dissolved and the plutonium separations step would be performed. The ^{244}Pu-rich stream and the Am/Cm/lanthanide fission products stream from the plutonium separations step each would be converted to oxides and packaged as two separate streams in containers that could be shipped to ORNL and stored in existing REDC storage wells. The packaged material would be unloaded from the off-site shipping container and transferred to an on-site shipping cask in ORNL's Irradiated Fuels Examination Laboratory (IFEL). The Mk-18A material would then be shipped to REDC, where it would be stored until needed for beneficial use.

Figure 2 provides the proposed process flow diagram, and Figure 3 summarizes the WBS for implementing the program. The process reconfiguration/documentation projects and operations projects needed to implement these activities are described in the following sections.

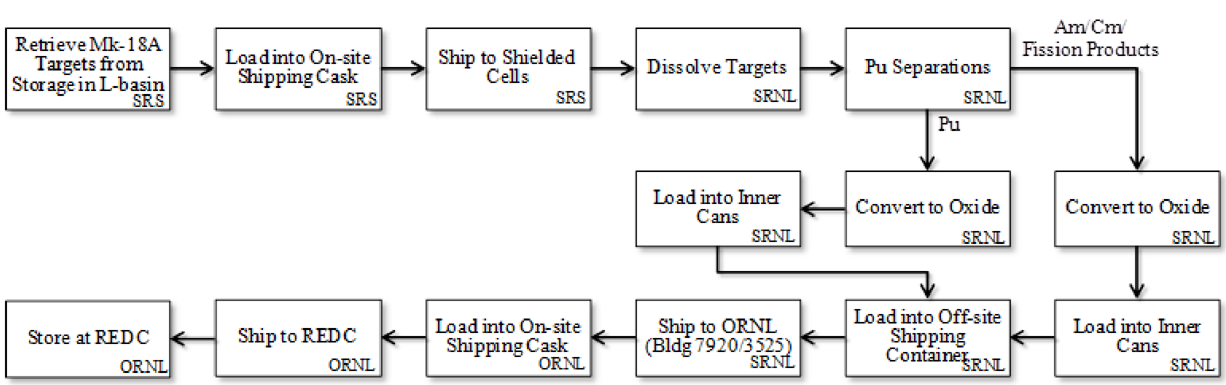

Fig. 2. Process flow diagram for Mk-18A target material recovery.

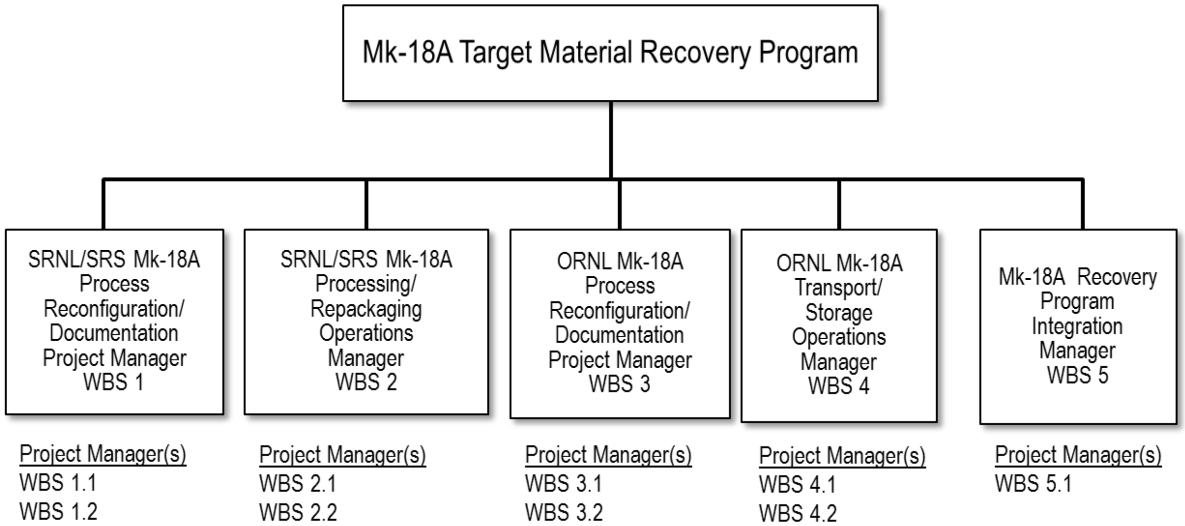

Fig. 3. Work breakdown structure for Mk-18A Target Material Recovery Program.

4.2.1 Savannah River Process Reconfiguration/Documentation (WBS Project 1)

Equipment and fixtures would be added at the Savannah River facilities to allow Mk-18A target processing, and facility operating procedures and safety documents would be updated accordingly. Equipment and fixtures would be fabricated and installed at L-Basin and the Shielded Cells facilities to retrieve the Mk-18A targets and transport them between the two facilities using modified or new on-site transport casks. Equipment and fixtures would be installed in the Shielded Cells to process and package the Mk-18A targets for off-site shipment.

4.2.2 Savannah River Processing/Repackaging Operations (WBS Project 2)

Savannah River would process and repackage the target materials for transport to ORNL. The targets would be retrieved from their storage location in L-Basin at SRS and shipped to the Shielded Cells where they would be transferred into the hot cells for processing. A 14-ft-long target would be laid horizontally across three adjacent shielded cells and would be cut into pieces for dissolution. An R&D-sized dissolver would be used to remove the aluminum cladding using caustic dissolution, and the residual material would be dissolved in nitric/hydrofluoric acid. Any undissolved material after the acid dissolution would be filtered and disposed of as solid waste. The plutonium would be loaded on an anion exchange resin for separation from the bulk fission products and the americium/curium product. The plutonium would be eluted, and the plutonium from several (~10) targets would be combined and calcined to make PuO_2 before being shipped to ORNL. The remaining liquid (americium/curium/fission product) would be evaporated and then calcined into oxide for shipment to ORNL. The targets would be processed one at a time in the Shielded Cells. It is estimated that the americium/curium oxide product from each target would be loaded into six to eight Model 9977 shipping containers or special form capsules in Type A shipping containers and transported in a single shipment to ORNL. One Type B package of plutonium would be shipped every year to ORNL; it may be transported with a shipment of the americium/curium product.

4.2.3 Oak Ridge National Laboratory Process Reconfiguration/Documentation (WBS Project 3)

ORNL facility operating procedures and safety documents would be updated to accommodate receipt, repackaging, on-site transport, and temporary storage of the Mk-18A materials. ORNL would coordinate certification and procurement of open-road transport containers. ORNL on-site storage/transport containers would be designed and procured prior to receipt of the Mk-18A materials.

4.2.4 Oak Ridge National Laboratory Transport/Storage Operations (WBS Project 4)

ORNL would coordinate the shipment and transportation of the Mk-18A materials from SRS to ORNL. The materials would be unloaded from the off-site shipping container, repackaged into REDC storage containers, and transferred to an on-site shipping cask in ORNL’s Irradiated Fuels Examination Laboratory (IFEL). The Mk-18A material would then be shipped to REDC, where it would be stored for future use. Preliminary estimates assume that 65 shipments would be made from SRS to ORNL.

4.2.5 Program Integration (WBS Project 5)

ORNL would perform integrated tracking and reporting of the projects performed at ORNL and SRNL/SRS for the Mk-18A Target Materials Recovery Project. This would include coordination of program planning and development and tracking of the integrated program schedule and deliverables for both the ORNL and SRNL/SRS projects. ORNL would provide integrated program reports to DOE.

5. MANAGEMENT ORGANIZATION

5.1 PROGRAM ORGANIZATION

The high-level program organizational structure is shown in Fig. 4.

The DOE Office of Nuclear Materials Integration Program Manager oversees the Mk-18A Target Material Recovery Program. Management of the program work is delegated through the federal Program Managers (PMs) for the respective sites where the projects are performed. Under the guidance of the federal PM, the Site (ORNL and SRNL/SRS) Project Managers would manage the planning and performance of the Mk-18A Target Material Recovery Program. The ORNL and SRS/SRNL Project Managers are responsible for execution of all activities required at the respective sites to meet technical, schedule, cost, and quality objectives. The ORNL Program Integration Manager (PIM) assists the DOE Program Manager in the integration of the projects at each site by tracking and reporting the integrated schedules and deliverables. This would include coordination of program planning, development and tracking of the integrated program schedule and deliverables, and integrated program reporting to DOE.

The program team structure is shown in Fig. 5. Work Breakdown Structure (WBS) project leads serve as principal investigators or technical leads on specific work identified on the Mk-18A Target Material Recovery Program schedule. The WBS project leads may work alone or as leaders of targeted work teams. The WBS project leads operate at Level 2 or lower in the WBS structure, as needed, to control project work, and as directed by the site Project Manager.

5.2 INTEGRATION OF THE PROGRAM TEAM

The federal and contractor managers of the Mk-18A Target Material Recovery program will participate in integrated program planning. The DOE Office of Nuclear Materials Integration Program Manager will lead these efforts and will be responsible for allocating budgets and establishing deliverables for ORNL and SRNL/SRS through the respective federal PMs. The ORNL PIM will assist the DOE program manager in the coordination of program planning and development and tracking of the integrated program schedule and deliverables for both the ORNL and SRNL/SRS projects. The PIM will provide integrated program reports to DOE. Interfacing will occur through routine conference calls, site visits, reviews, and other formal and informal communications.

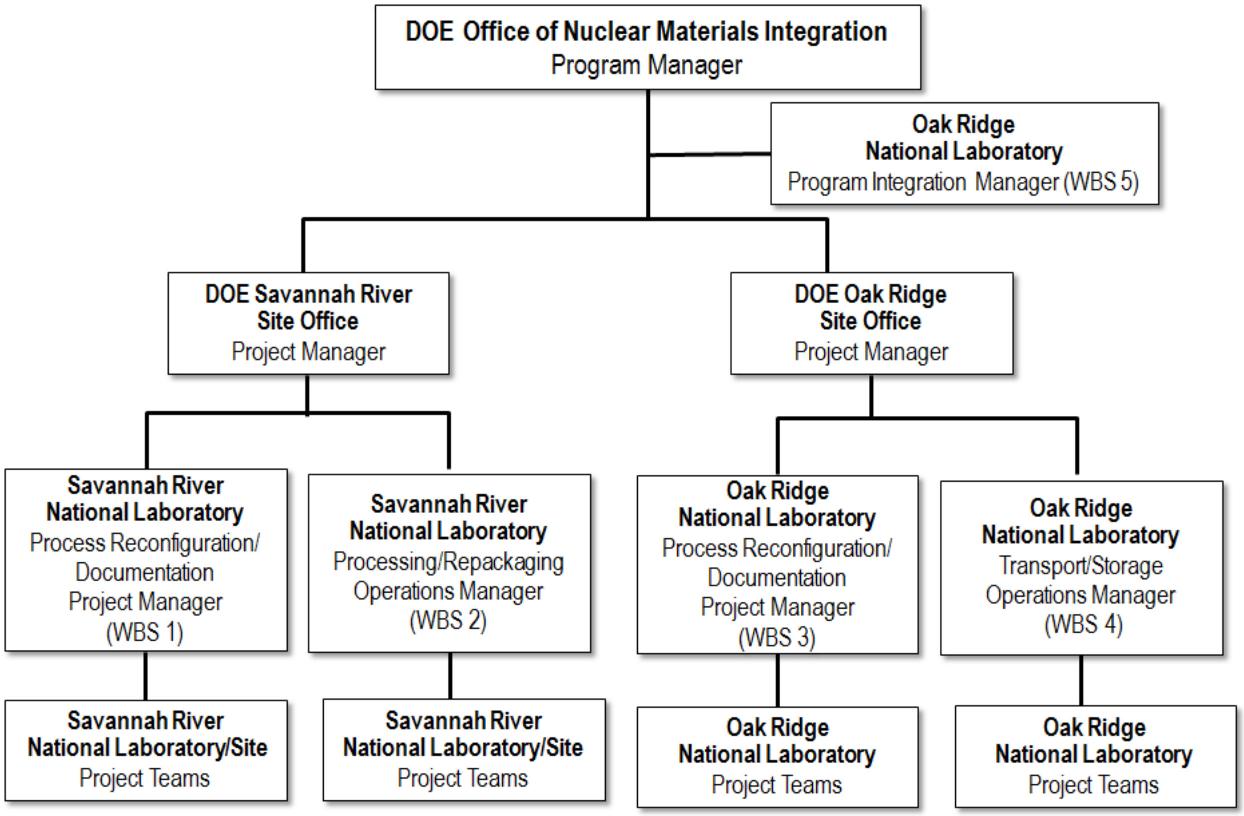

Fig. 4. High-level program organizational structure.

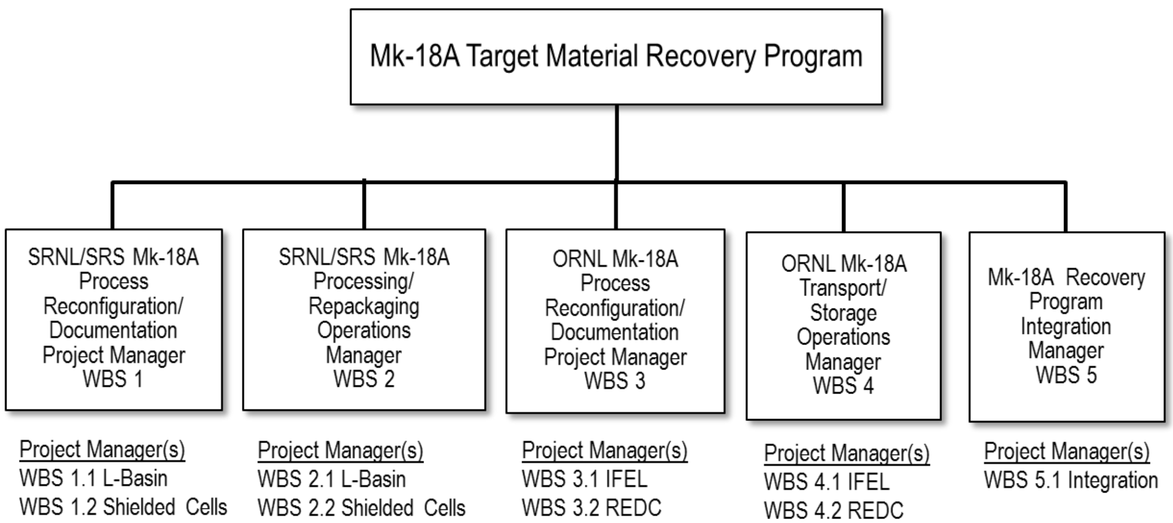

Fig. 5. Program team organization.

6. COST AND SCHEDULE

6.1 COSTS

The current estimated total program cost is approximately $84M; the cost estimate is based on the estimates for the recommended alternative in the Mk-18A evaluation report (Robinson, 2014) escalated to the estimated date of performance (FY 2017 through FY 2029). Table 5 provides a cost summary by major WBS element for the entire program. This summary is based on feasibility-level order-of-magnitude cost estimates for the projects associated with each major activity for each third-level WBS element, as shown in Appendix A. The amount of contingency at the third-level WBS elements were estimated at 0 – 44% based on the amount of experience SRNL, SRS, and ORNL have had performing similar tasks in the past. As shown in Appendix A, activities associated with (1) retrieval and on-site transport at SRS have 20% contingency since such tasks are routinely at L-Basin; (2) activities associated with transport, repackaging, and storage of materials at ORNL have 30% contingency since similar tasks are routinely performed at ORNL but repackaging of the proposed Mk-18A containers have not been done before; (3) target processing activities at SRNL have 44% contingency since Mk-18A targets have not been performed since the 1960s, and dissolution and separations of targets have not been performed in the SRNL Shielded Cells; and (4) program integration received no contingency since this function is performed routinely. At the Level 1 WBS the average contingencies ranged between 0 and 30% as shown in Table 5, with an overall average contingency of 28% for the project. This is within the DOE Cost Guide, which suggests contingency allowances of 20 to 30% at the planning stage for small projects. A risk analysis was performed for the program (Appendix B). Near-term planning activities and activities performed early in the program will focus on reducing the risks and uncertainties associated with the higher risk activities.

Table 5. Budget estimate for the Mk-18A Target Material Recovery Program[a]

Project	Estimated cost ($M)	Contingency ($M)	Contingency (%)	Total cost ($M)
1.0—SRS Process Reconfiguration/ Documentation	15	5	25	20
2.0—SRS Processing/Repackaging Operations	37	11	30	48
3.0—ORNL Process Reconfiguration/ Documentation	2	1	30	3
4.0—ORNL Transport/Storage Operations	5	2	30	7
5.0—Program Integration	6	0	0	6
Totals ($M)	**65**	**19**	**28**	**84**

[a] Dollars are escalated to estimated year of performance.

6.2 SCHEDULE AND SPENDING PROFILE

A high-level summary schedule for the program is given in Fig. 6, and Table 6 shows the program spend plan. The detailed, cost-loaded schedule for the integrated program is provided in Appendix A. It assumes the program starts in FY 2017 and will be completed in FY 2029.

The assumptions made to support the development of the processing schedules include the following.

- No capital project facility modification will be required at SRS/SRNL. Reconfiguration/documentation activities can be accomplished within 4 years. SRS/SRNL can process targets at a rate of ~nine/year.

- No capital project facility modification will be required at ORNL. Reconfiguration/documentation activities can be accomplished within 2 years. ORNL can receive target material at the SRS generation rates of ~nine/year.

- Schedules assume the project will be fully funded at the levels shown in Table 6.

- Contingency has been built into the target processing schedule at each facility at SRS/SRNL and ORNL to address other operations occurring and currently planned for these facilities.

- Storage facilities are available at both sites to accommodate any lag times between transfer of materials between facilities/sites.

6.3 WORK BREAKDOWN STRUCTURE

The program's WBS down to WBS Level 3 is shown in Table 7. A short description of each WBS program element is provided in Table 8.

6.4 MILESTONES

Key milestones for the program are given in Table 9.

Table 6. High-level program budget profile for the Mk-18A Target Material Recovery Program[a]

Project	FY17	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY29	Total
WBS 1	6.3	5.5	4.4	3.4	-	-	-	-	-	-	-	-	-	20
WBS 2	-	-	-	-	3.5	5.6	5.8	5.9	6.1	6.3	6.5	6.7	1.7	48
WBS 3	-	-	1.1	1.8	-	-	-	-	-	-	-	-	-	3
WBS 4	-	-	0.0	0.0	0.4	0.9	0.9	0.9	1.0	1.0	1.0	0.8	-	7
WBS 5	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6	-	6

[a] Dollars are escalated to estimated year of performance.

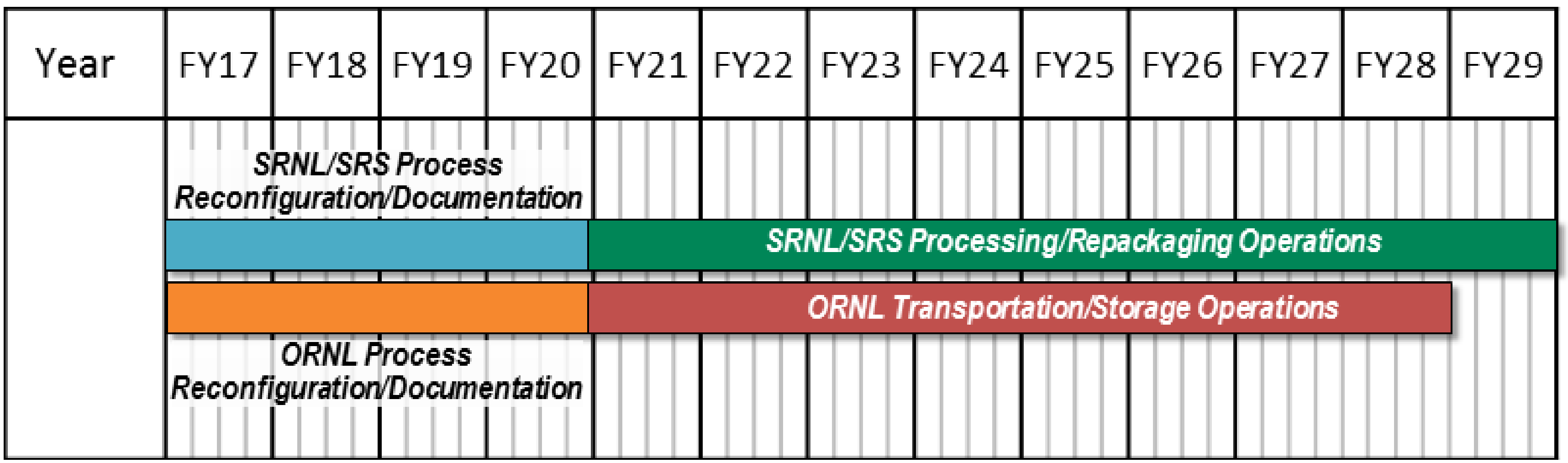

Fig. 6. Schedule for the Mk-18A Target Material Recovery Program.

Table 7. Potential work breakdown structure for the Mk-18A Target Material Recovery Program

WBS #	Description
1.	**SRNL/SRS Process Reconfiguration/Documentation Project**
1.1	*Process reconfiguration/documentation at L-Basin to retrieve/ship targets to Shielded Cells*
1.1.1	Process reconfigurations at L-Basin
1.1.2	Reconfiguration/procurement of on-site cask to transport targets from L-Basin to Shielded Cells
1.1.3	Update of safety documents and procedures, training of personnel, and preparations for processing operations at L-Basin
1.2	*Process reconfiguration/documentation at Shielded Cells to receive/process/package target material for transport to ORNL*
1.2.1	Process reconfiguration at Shielded Cells to receive/process/package target material for transport to ORNL
1.2.2	Development of processing flowsheets to remove Al cladding and convert Pu/Am/Cm/FP material to oxides
1.2.3	Update of safety documents and procedures, training of personnel, and preparations for processing operations at Shielded Cells
2.	**SRNL/SRS Processing/Repackaging Operations**
2.1	*Retrieve Mk-18A targets from L-Basin and transport to Shielded Cells*
2.2	*Receive/process/package target material at Shielded Cells for transport to ORNL*
2.2.1	Heavy curium recovery
2.2.2	Pu-244 recovery
2.2.3	Waste management
2.2.4	Project management
3.	**ORNL Process Reconfiguration/Documentation Project**
3.1	*Process reconfiguration/documentation at IFEL to retrieve material from SRS and repackage/ship targets to REDC*
3.1.1	Process reconfiguration/documentation at IFEL
3.1.2	Procure on-site storage/shipping containers for Mk-18A target materials
3.1.3	Coordinate certification of shipping containers for shipment of Mk-18A materials between sites
3.2	*Process reconfiguration/documentation at REDC to retrieve/store targets*
4.	**ORNL Transport/Storage Operations**
4.1	*Receive off-site shipments from SRS and repackage Mk-18A materials for on-site shipment at IFEL*
4.1.1	Coordinate transport of Mk-18A shipments from SRS to ORNL
4.1.2	Receive off-site shipments and repackage Mk-18A materials for on-site shipment at IFEL
4.2	*Receive on-site shipments from IFEL at REDC and transfer materials to REDC storage wells*
5.	**Program Integration**
5.1	*Track and report integrated program schedules and deliverables*

Table 8. Description of potential work breakdown structure elements

	WBS/Project Element	Purpose
1:	SRNL/SRS Process Reconfiguration/ Documentation Project	Processing equipment at L-Basin and the Shielded Cells will be modified for Mk-18A target retrieval, processing, and packaging for shipment to ORNL. Facility operating procedures and safety documents will be updated.
2:	SRNL/SRS Processing/Repacking Operations	Mk-18A targets will be retrieved from L-Basin and transferred to the Shielded Cells where they will be processed to remove the cladding, converted to plutonium and heavy curium oxides, and packaged for shipment to ORNL.
3:	ORNL Process Reconfiguration/ Documentation Project	ORNL facility operating procedures and safety documents will be updated to accommodate Mk-18A materials. ORNL will coordinate certification of the transport containers for shipment of the Mk-18A materials from SRS to ORNL.
4:	ORNL Transport/Storage Operations	ORNL will coordinate the shipment and transportation of the Mk-18A materials from SRS to ORNL. The materials will be unloaded from the off-site shipping container at the IFEL and repackaged for on-site transport to REDC where they will be stored for beneficial use.
5:	Program Integration	ORNL Program Integration Manager tracks and reports the integrated program schedules and deliverables.

Table 9. Key potential milestones

Milestone Description	Date
Complete SRS/SRNL on-site shipping analysis	9/30/2017
Complete reconfiguration/procurement of SRS on-site shipping cask	9/30/2018
Complete process reconfigurations at SRNL/SRS	9/30/2019
Complete procedure updates and training at SRNL/SRS	9/30/2020
Complete process reconfigurations, procedure updates, and training at ORNL	9/30/2020
Complete processing and transfer of material from four targets to ORNL	9/30/2021
Complete processing and transfer of material from nine targets to ORNL	9/30/2022
Complete processing and transfer of material from nine targets to ORNL	9/30/2023
Complete processing and transfer of material from nine targets to ORNL	9/30/2024
Complete processing and transfer of material from nine targets to ORNL	9/30/2025
Complete processing and transfer of material from nine targets to ORNL	9/30/2026
Complete processing and transfer of material from nine targets to ORNL	9/30/2027
Complete processing and transfer of material from seven targets to ORNL	9/30/2028
Complete program closeout report	9/30/2029

7. PROGRAM MANAGEMENT

This program reconfigures existing capabilities at SRS to potentially process and repackage Mk-18A targets and utilizes existing capabilities at ORNL to receive and store the recovered ^{244}Pu and heavy curium contained in the target materials. This capability consists primarily of procedures, processes, design information, and processing operations, not capital assets. As such, the program is not subject to the requirements of DOE Order 413.3, but it will be managed using the program management principles and best practices defined here. The projects for the Mk-18ATarget Materials Recovery Program will be performed under the program management plans established at the site where the work will be executed. Each site's program management plans are tailored application of project management and project controls appropriate for the complexity of the projects to be performed for the program as described below.

7.1 PROGRAM REPORTING

The ORNL PIM will consolidate program reports from the SRNL/SRS and ORNL sites and provide integrated program reports to the DOE Office of Nuclear Materials Integration program manager. This will consist of key program deliverables, quarterly updates, and annual progress reports.

7.2 RISK MANAGEMENT

The Mk-18A Target Materials Recovery Program will use a risk assessment to define the processes by which program risks are identified, evaluated, managed, tracked, and closed. The objective of the risk assessment is to define the strategy to manage risk throughout the duration of the program such that there is minimal impact on successful program completion within defined cost, schedule, quality, and operational performance parameters.

The Mk-18A Target Material Recovery Program will build and maintain a Risk Register. The Risk Register will identify risks, list potential risk impacts and probabilities of risk, provide risk-handling strategies for the identified risks, list applicable WBS numbers associated with each risk, and list the status of each risk. Risk, as well as opportunities, will be identified. The items in the Risk Register will be assessed using qualitative or quantitative tools that are appropriate for each risk. For example, high-impact, high-probability risks may require thorough analyses and response plans, while low-impact, low-probably risks may only require monitoring.

An initial Risk Register is provided in Appendix B. This will be considered a living document and will be revisited as the program progresses.

7.3 CONFIGURATION MANAGEMENT/PROJECT CONTROLS

7.3.1 Savannah River

The SRS performs and documents all engineering activities utilizing configuration control. The SRS Conduct of Engineering and Technical Support Manual, E7, controls these activities by providing the requirements for documentation and reporting that are essential to safe and controlled work. This configuration control is utilized for all designs, design changes, tasks, processes, and reviews performed at SRS.

7.3.2 Oak Ridge National Laboratory

All engineering work that occurs at ORNL takes place within a controlled environment. The Mk-18A Target Material Recovery Program will rely on existing administrative controls and approval steps at each work location to establish, adjust, adapt, alter, and maintain the configuration of any tool, device, instrument, system, or process that is utilized by the program.

7.4 CHANGE CONTROL

The work scope for activities supporting the Mk-18A Target Material Recovery Program will be performed within the yearly program budget provided by DOE. Decisions on the allocation of budget to each WBS program element will be determined at the discretion of the DOE NA-73 program manager with input from the ORNL and SRS site program managers.

7.5 ENVIRONMENT, SAFETY AND HEALTH (ES&H)

7.5.1 Savannah River

SRS/SRNL designs work scope that is compliant with all federal and state codes of regulations and laws. Further details are provided on how SRS/SRNL enacts these requirements for the Mk-18A Target Materials Recovery Program.

Work at SRS/SRNL will be conducted at two different facilities with on-site transportation between these facilities. The two facilities work under their own facility manuals. Both manuals are compliant with all state and federal code and laws. Before work on the Mk-18A Target Material Recovery Program will begin, each facility will complete a hazard analysis, which is SRS's method of implementing all ES&H requirements conducted on the site. L-Basin will create an automated hazard analysis (AHA), and SRNL will create an electronic hazard analysis package (eHAP) as a part of the hazard analysis.

7.5.1.1 National Environmental Policy Act

The Mk-18A targets, together with Mark-51 and special americium and curium slugs, are categorized as "Group E: High Actinide Targets" in the Savannah River Site Spent Nuclear Fuel Management Final Environmental Impact Statement (SNF FEIS) (US DOE, 2000). Although the targets are not technically "spent nuclear fuel," they are managed and collocated with spent fuel in the SRS L-Basin. Previous to the development of an environmental impact statement specific to the irradiated materials, the targets were identified as "programmatic" material in the *Final Environmental Impact Statement for the Interim Management of Nuclear Materials at Savannah River Site* (INMM FEIS) (US DOE, 1995), where analysis was made of storage, recovery, disposal, and transportation options.

The later SNF FEIS incorporated the IMNM options analysis by reference, and the ROD confirmed "DOE will continue to store small quantities of higher actinide materials until DOE determines their final disposition" and maintained the designation of the Mk-18A, Mk-51, and special americium and curium slugs as "Group E" specified for continued wet storage. Any decision to recover isotopes from the Mk-18A targets instead of continuing long-term storage is expected to require a ROD amendment. No environmental issues have been identified that would significantly affect this potential project. The IMNM analysis was based on recovery using a new capability that would have been installed in the SRS F Canyon instead of recovery in the existing SRNL facilities. The SRS funding profile assumes that a short Supplement Analysis would be prepared to analyze any substantial changes and significant new circumstances or information relevant to environmental concerns, so as to provide sufficient information for DOE to determine whether the SNF FEIS should be supplemented, whether a new Environmental Impact Statement (EIS) should be prepared, or whether no further National Environmental Policy Act (NEPA) documentation would be required.[m1]

7.5.1.2 Integrated Safety Management System

Work conducted at SRS/SRNL shall be performed in accordance of the SRS Integrated Safety Management (ISM). Within the ISM program, clear roles are defined to ensure that the safety of workers is maintained, the public and environment are not hurt due to the actives conducted within the site, and that all lesson learned are included in future similar operations while maintaining a balance between safety and production. All workers at SRS have the right and the expectation to stop work if an unsafe work condition is identified.

7.5.1.3 Safety Assessment Documentation

All SRS/SRNL work will be carried out in existing facilities that are covered by existing safety documentation and authorization. As the program will extend between multiple facilities, each facility will evaluate its individual portion of the proposed work. The process will ensure the health and safety of the workers, protection of the environment, and compliance with all relevant state and federal codes and regulations. SRNL will follow the SRS L1 manual, and L-Basin will follow the SRS 8Q manual.

The work will be carried out in Hazard Categories 1 and 2 nuclear facilities. The Unreviewed Safety Question Process for Nuclear and Facility Safety (10 CFR 830, Part B, *Safety Basis Requirements*) will be used to compare facility limits and restrictions with the planned work scope. Within SRNL, a change to the facilities safety documentation will be required to address the atypical source term of the Mk-18A targets.

7.5.2 Oak Ridge National Laboratory

ORNL is committed to conducting its business in compliance with applicable regulations and requirements and to being responsive to the changing regulatory climate and practices. The topics below describe the programs, procedures, and documents that demonstrate compliance with the Mk-18A Target Materials Recovery Program.

Before beginning work, the project team members ensure that the risks and hazards are identified and controlled (with permits, procedures, training, etc.) as specified in approved work planning documents.

If a portion of the project work must be performed through acquisition mechanisms and contract personnel must be used, then ORNL Environment, Safety, and Health (ES&H) and Acquisition staff will ensure that applicable ES&H requirements are integrated into the contracting mechanisms to flow-down requirements to subcontracted personnel.

The project team will ensure that ES&H resources are available for the different phases of the project. The ES&H organization at each work location will be responsible for providing staff (e.g., industrial safety and hygiene, training, radiological control, environmental compliance representative, fire protection, facility safety, waste management, etc.) to support project activities and to ensure those activities are conducted in accordance with ES&H policies and procedures. This support includes not only direct activities but also oversight of contract work.

The Site Program Manager is the primary point of contact for the ORNL Site Office (OSO) ES&H oversight activities and will maintain cognizance of all project activities. OSO oversight activities are designed to ensure that ORNL ES&H oversight is being performed in an effective manner and as planned by ORNL and the OSO standard operating procedure for providing such oversight. Oversight activities will include participation in facility walk-throughs and safety meetings.

7.5.2.1 National Environmental Policy Act

Projects performed at ORNL will fall under routine ongoing operations in existing facilities. No environmental issues have been identified that would significantly impact this project. The existing ORNL NEPA Categorical Exclusion 3059X (24), *Design, developing and testing processes and equipment for the preparation and/or recycle of nuclear fuels and other nuclear materials,* provides adequate NEPA coverage for this work.

7.5.2.2 Integrated Safety Management System

Work conducted at ORNL for the Mk-18A Target Material Recovery Program would be performed in accordance with the applicable ORNL ISM Program using the ES&H policies and procedures provided by the Standards-Based Management System (SBMS) or equivalent and with an understanding of the *Stop Work Authority* Subject Area. All staff shall promptly report accidents, injuries, ES&H deficiencies, emergencies, and off-normal events. Where necessary, the approved ISM Program is supplemented by project-specific plans and procedures.

7.5.2.3 Safety Assessment Documentation

All ORNL work would be carried out in existing facilities that are covered by existing safety documentation. As project work is proposed, the work will be screened using the ORNL Research Hazard Analysis and Control System, which will result in the identification of environmental, safety, and health hazards and controls and will provide an integrated analysis of operational boundaries, security risks, and quality assurance (QA) needs.

The screening process for work carried out in Hazard Category 1, 2, and 3 nuclear facilities will use the Unreviewed Safety Question Process for Nuclear and Facility Safety (10 CFR 830, Part B, *Safety Basis Requirements*) to compare facility limits and restrictions with the planned work scope. If necessary, changes will be made to either the planned work scope or the facility safety documentation (or both) in order to bring the documents in harmony while preserving the safety of the facility.

7.6 QUALITY ASSURANCE AND CONTROL

7.6.1 Savannah River

SRS's Quality Assurance Management Plan (QAMP) documents how the requirements of 10 CFR 830 Subpart A, DOE O 414.1D, DOE O 226.1B, and other requirements are implemented by the management and operating (M&O) contractor for the work scope of the SRS M&O contract. This QAMP is updated annually to reflect programmatic and organizational changes over the previous year. The updated QAMP is submitted to DOE-SR and NNSA-SRSO for review and approval. The submittal document for the QAMP provides assurance that the changes continue to satisfy quality assurance requirements.

The QAMP and the QA Program are key elements of the ISM system and the Contractor Assurance System (CAS). The QAMP is a broad management program that supports all of the five ISM core functions with a goal of providing products and/or services that meet or exceed the expectations of DOE-SR and NNSA-Savannah River Site Office (NNSA-SRSO). QA also supports two guiding principles of ISM by giving assurance that clear roles and responsibilities are established for the conduct of work and assurance that individuals have the competence commensurate with the work responsibilities they are given. Because these two principles speak to the effectiveness of the workforce, these "people" aspects are broadly and horizontally integrated into all work. QA is an integral part of the processes by which work is prioritized, facilities designed, hazards analyzed, standards and controls identified and applied, equipment procured, work performed, and performance evaluated and improved. Each section of the QAMP addresses specific areas of the QA Program's role in the ISM system.

The QAMP establishes QA requirements for conducting activities, including providing items or services that affect, or may affect, the safety of nuclear facilities in a tailored manner to ensure that ES&H risks and impacts are minimized and that safety, reliability, products, and performance are maximized by using effective management systems. The graded approach is not used in implementing the Unreviewed Safety Question (USQ) process or in implementing technical safety requirements. The QAMP also outlines contemporary principles for managing, performing, and assessing operations in an integrated and cost-effective manner. The CAS provides the road map for oversight and assurance activities for operations and business operations.

The programmatic QA requirements required by 10 CFR 830 Subpart A and DOE O 414.1D are contained in S/RID Functional Area 2 (Quality Assurance). The programmatic oversight requirements required by DOE O 226.1B are contained in S/RID Functional Area 1 (Management Systems). The S/RID functional areas identify the source requirements, provide an index of requirements that are cross-referenced to the source document, and link the requirements to the applicable implementing procedures.

7.6.2 Oak Ridge

ORNL has established a management system founded on a commitment to simultaneous excellence in science and technology, operations, and community outreach. ORNL provides the policies, systems, and tools to support the research mission through its DOE-approved QA and worker safety and health programs and its Environmental Management System.

The ORNL QA Program supports excellence in our science and technology missions through development of a quality culture that contributes to scientific and operational excellence, research integrity, and continual improvement by defining the processes to deliver quality products and services to both our internal and our external customers. The ORNL QA Program is described in its highest-level quality management document and meets requirements conveyed through DOE Order 414.1D, *Quality Assurance,* and 10 CFR 830 Subpart A, *Quality Assurance Requirements.* The QA Program describes the approach for integrating quality principles and methodologies into project planning and control processes through the implementation of the web-based Standards-Based Management System (SBMS). SBMS tracks requirements and delivers methods for complying with requirements to enable consistent success.

In addition, DOE O 414.1D drives ORNL to employ national or international consensus standards where practicable and consistent with contractual or regulatory requirements. Achieving recognition under these standards not only allows an organization to leverage the quality experiences of global businesses but also creates a common framework of fundamental quality elements that fosters understanding and collaboration with other groups that apply these standards. For this reason, ORNL implements and is registered with the international quality standard, ISO 9001:2008, as the baseline standard for its quality program. The program also sanctions the implementation of alternate standards based on client needs, expectations, and requirements. One such standard is ANSI/ASQ Z1.13, *American National Standard: Quality Guidelines for Research,* to be applied to the research and development portions of the portfolio. As projects advance, periodic task-specific work planning and reviews ensure the identification of other standards as they become applicable.

7.7 SYSTEMS ENGINEERING AND VALUE MANAGEMENT

7.7.1 Savannah River

L-Basin is designed to handle, transfer, and package spent nuclear fuel and nuclear targets. The infrastructure and appropriate procedures are in place to implement the Mk-18A Target Materials Recovery Program. SRNL will develop the processes/procedures/equipment for this program under their Reconfiguration/Documentation WBS task. SRNL will focus on product intensification values and waste management to reduce the overall cost of the program where possible.

7.7.2 Oak Ridge National Laboratory

All ORNL projects would be conducted as routine operations in existing facilities utilizing existing processing equipment. The team would apply value management techniques as appropriate in order to enhance operational flexibility and reduce costs and stay on schedule if possible.

7.8 SECURITY AND EXPORT CONTROL

7.8.1 Savannah River

7.8.1.1 Shipments

At SRS, all external transfers (shipping/receiving) of accountable nuclear material are coordinated within the site nuclear material control and accountability (MC&A) and the site transportation department/hazard material transportation (HMT). The MC&A office will verify that receiving facilities (on-site or off-site) are authorized to accept the material and will request authorization to ship from the receiving facility before releasing a shipment. Shipment of Category I and II Special Nuclear Materials (SNM) transfers are transported by Secure Transport/SafeGuards Transport (SST/SGT), and site MC&A will coordinate any requested information by the site security force and DOE Office of Secure Transportation (OST). For receipt of material into SRS, site MC&A works directly with the final destination's section coordinator to ensure the facility is capable of accepting the material before final approval for a receipt is issued to the shipper.

A shipper/receiver memorandum of understand (MOU) is commonly generated if multiple shipments are planned for a program. The MOU does not decrease or alter the requirements dictated by DOE order or the Department of Transportation as the official record of transaction is the DOE/NRC Form 741.

7.8.1.2 Transfers between Mass Balance Areas

Within SRS, defined material balance areas (MBA) are designated, and within an MBA, smaller authorized areas (building, rooms within a build) can exist. Transferring within a single MBA is coordinated internally through the MBA section coordinator in compliance with the DOE O 470.4B, Safeguards and Security Program and DOE O 474.2, Nuclear Material Control and Accountability. All internal transfers are authorized by the section coordinator before being executed and are documented through facility-controlled forms (within SRNL OSR-16-1A Form is used).

Transfers between MBA are coordinated through the site MC&A office. The site accounting system is the Savannah River Site Material Accounting System (SRSMAS), the local SRS implementation and extension of the DOE-supplied software Local Area Nuclear Material Accountability Software (LANMAS). A Material Control and Accountability Transfer (MCAT) form is generated by the site MC&A office and authorized by both the shipper and receiving MBA coordinator before the transfer of material is released. The MCAT is the official documentation required by the DOE orders, and it travels with the material during the transfer.

7.8.1.3 Access Control

At SRS/SRNL, physical access to all reportable quantities of nuclear material is limited to personnel with the need-to-know and clearance. If material exceeds the DOE Nuclear Material Category III, a minimal of an "L" security clearance is required for unescorted access. Access of all personnel is controlled at the point of entry into the room/facility. Personnel are required to have appropriate training for unescorted access. The training is specific to the facility and controlled within the facilities training program.

The proposed Mk-18A Target Material Recovery Program will utilize existing MBA. All these MBA have been evaluated against the facilities' security plans and are in compliance with DOE O 473.3, Protection Program Operation.

7.8.1.4 Export Control

At SRS, all parties are responsible for their own compliance with US export control laws and regulations. Any further agreements with other entities must contain a similar declaration of responsibility. If there is a material change to the project scope of work, or if an end-point-performance/application is identified, then a re-determination of applicable export control rules is required.

The project team must notify the Savannah River Nuclear Solutions (SRNS) Export Control Office if any foreign national(s) will be working on the project, whether inside or outside the United States. A foreign national must be a lawful Permanent Resident Alien (i.e., possesses a USCIS I-551 "Green" Card). Foreign nationals temporarily in the United States on O-1 or H-1B visas or foreign nationals located in foreign countries without visas are not eligible to participate without a specific guidance from the SRNS Export Control Office. Depending on circumstance, a license or authorization from the jurisdictional agency may be required.

Project personnel are required to be familiar with the end user and the end use of exported commodities, software, and technology. Project personnel are responsible for awareness of export control regulations issued by the Departments of Commerce, Energy, State, and Treasury, and the Nuclear Regulatory Commission, as applicable.

Documents, whether paper or electronic, containing export controlled technology or information must be marked as "Official Use Only," Exemption 3 - Statutory, in accordance with direction from the US DOE Office of Classification. An additional export control admonishment statement should be included with the Official Use Only (OUO) marking. Transmission of export controlled technology and information must be appropriate for documents marked OUO. Documents must be reviewed for export control, classification, and operations security (OPSEC) concerns prior to release beyond the project boundaries.

7.8.2 Oak Ridge National Laboratory

7.8.2.1 Shipments

All shipments of nuclear material to ORNL, and outbound shipments of nuclear material from ORNL, are authorized in advance by the ORNL Nuclear Materials Representative. Form ORNL-902, *Nuclear Material Authorization*, is required for all accountable nuclear materials entering ORNL. A DOE/NRC Form 741 serves as a record of the transaction and as a source document and is prepared by the NMC&A team to document off-site shipments and receipts when required. MBAs and site safeguards limits are checked prior to authorization and may limit the amount of material that can be received onto the ORNL Site or into the MBA.

7.8.2.2 Transfers between Mass Balance Areas

Radioactive storage and work areas are organized into MBA at ORNL. Each MBA Representative records receipts, transfers, and changes for his/her MBA inventories and transmits that information to the NMC&A team via the ORNL-2681 form, which is signed by both transferring and receiving MBA Representatives and requires prior NMC&A review of the safeguards limit for the receiving MBA. When the material is moved, the white copy of the ORNL-2681 form is forwarded to the NMC&A team by the receiving MBA (to be received by NMC&A by close of business the day following material receipt). This document serves as a record of the transaction and is utilized by the NMC&A team to enter the transfer data into the Local Area Nuclear Material Accountability Software System. This form is used for all internal receipts, shipments, transfers, and other transactions such as changes to the material weights and forms. A copy is retained by the receiving MBA to show receipt of the material, and the other copy is retained by the shipping MBA. Any movement of SNM between MBAs or control areas within MBAs must have advance NMC&A approval prior to the move.

The shipment of nuclear materials between ORNL and SRS will be performed using Shipper/Receiver Agreements, which describe the NMC&A requirements associated with such shipments.

7.8.2.3 Access Control

At ORNL, physical access to nuclear material is limited to personnel actually requiring such access. An Authorized Personnel Access List (APAL) of all personnel with access to the MBA nuclear material must be maintained by the MBA Representative and forwarded to the NMC&A department. If using/accumulating a Nuclear Material Category III (CAT III) quantity of material, a minimum of an L security clearance will be required for unescorted access to SNM, and the related MBA will need to be approved to store a CAT III quantity of material. To be authorized and approved as an NMC&A nuclear material handler and listed on the MBA APAL, employees must complete a NMC&A Nuclear Material Handler Training web module. For the REDC, this training is REDC MBA 072 and 077 Handler/Custodian.

If using an existing MBA, the security plan and supplemental procedure will need to be updated to include the new control areas and material use. If creating a new MBA, a new supplemental Procedure and Security Plan must be created and a MBA Representative and Alternate MBA Representative will need to be named and trained.

Strict rollup limits are in place for each material type for the MBA, as well as for the site. These limits cannot be exceeded. Close communication with the NMC&A team prior to any movements or processing of material is critical.

7.8.2.4 Export Control

The project team must notify the ORNL Export Control Department if any foreign national(s) will be working on the project if the foreign national does not possess a VISA status of Lawful Permanent Resident (LPR/Green Card). Otherwise, a license from the governing jurisdictional agency may be required.

Regulations require that project personnel be familiar with the end user and the end use commodities, software, and technology. There are export control restrictions covered by the Departments of Commerce, State, Treasury, and Energy, along with several other governmental jurisdictions, and project personnel are responsible for cognizance of applicable export control rules and restrictions.

When transmitting data, documents, email, faxes, etc., that contain export control technology/information, the sender must affix an export control warning on the documentation so that the recipient can be alerted to the protection requirements associated with the data transmission.

If any agreements are entered into, all parties must agree to be responsible for their own compliance with US export control laws and regulations as they relates to the work being undertaken. It should be noted that if there is a material change in the scope of work or if an end-point-performance/ application is identified, then a re-determination of applicable export control rules will be required.

Project management personnel are responsible for monitoring the performance achievements of the project and for keeping export control requirements in mind. All reports, journal papers, and other documentation that will be released to DOE or outside of the project boundaries must be screened against export control criteria before release.

8. REFERENCES

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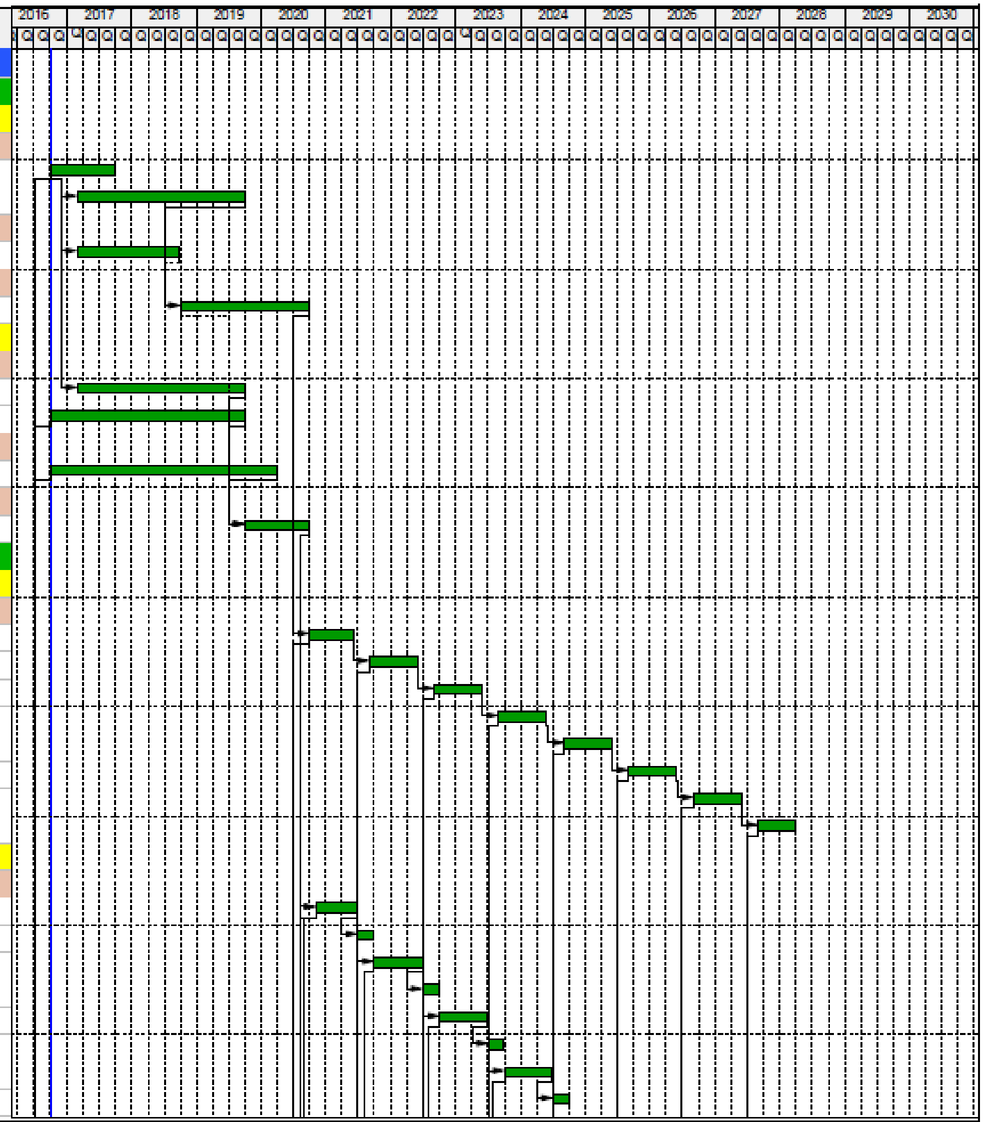
APPENDIX A. COST-LOADED SCHEDULE FOR THE MK-18A MATERIAL RECOVERY PROGRAM

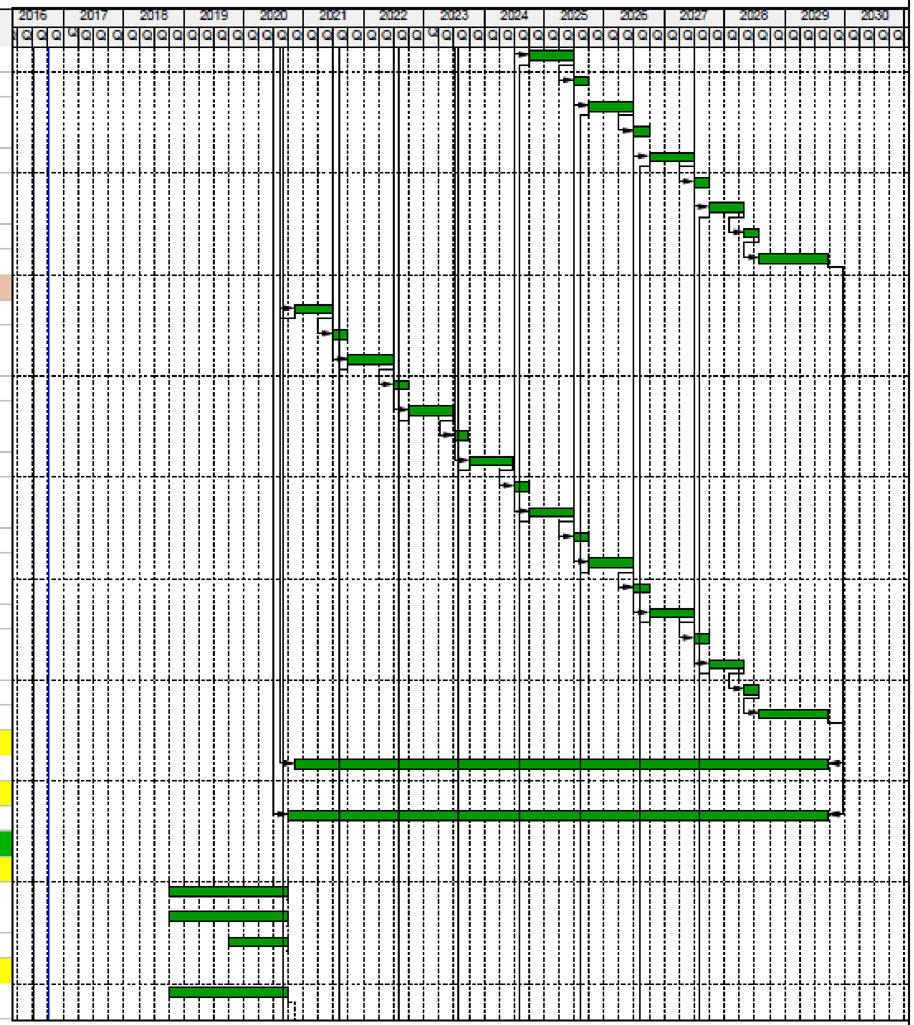
APPENDIX A. POTENTIAL COST-LOADED SCHEDULE FOR THE MK-18A TARGET MATERIAL RECOVERY PROGRAM

	Budget ($K, escalated)	**FY17**	**FY18**	**FY19**	**FY20**	**FY21**	**FY22**	**FY23**	**FY24**	**FY25**	**FY26**	**FY27**	**FY28**	**FY29**	**Total**	**Cost**	**Contingency**	**Percent Contingency**
WBS	**Task**																	
1	**SRS Process Modification/Start-up Project**																	
1.1	*SRS Process Modification/Start-up at L-Basin*																	
1.1.1	Modifications at L-Basin	918	439	730	0	0	0	0	0	0	0	0	0	0	2,087	1,739	348	20
1.1.2	Modifications/Procurement of On-Site Cask	1,967	2,026	0	0	0	0	0	0	0	0	0	0	0	3,993	3,327	665	20
1.1.3	Procedures/Training at L-Basin	0	293	603	502	0	0	0	0	0	0	0	0	0	1,397	1,164	233	20
1.2	*SRS Process Modification/Start-up at Shielded Caves*																	
1.2.1	Modifications at Shielded Caves	2,049	1,488	1,725	0	0	0	0	0	0	0	0	0	0	5,261	4,384	877	20
1.2.2	Process Flowsheet Development	1,395	1,239	1,297	616	0	0	0	0	0	0	0	0	0	4,547	3,158	1,389	44
1.2.3	Procedures/Training at Shielded Caves	0	0	0	2,232	0	0	0	0	0	0	0	0	0	2,232	1,550	682	44
2	**SRS Processing/Repackaging Operations**																	
2.1	*SRS Processing/Repackaging Operations at L-Basin*																	
2.1.1	Operations at L-Basin	0	0	0	0	130	302	311	321	330	340	351	281	0	2,367	1,973	395	20
2.2	*SRS Processing/Repackaging Operations at Shielded Caves*																	
2.2.1	Cm Recovery	0	0	0	0	610	1,414	1,457	1,500	1,545	1,592	1,639	1,313	0	11,071	9,226	1,845	20
2.2.2	Pu Recovery	0	0	0	0	501	1,161	1,223	1,259	1,297	1,336	1,376	1,109	32	9,295	7,746	1,549	20
2.2.3	Waste Management	0	0	0	0	371	700	721	742	765	788	811	1,047	240	6,185	4,295	1,890	44
2.2.4	Project Management	0	0	0	0	1,923	1,980	2,040	2,101	2,164	2,229	2,296	2,936	1,381	19,049	13,228	5,821	44
3	**ORNL Process Modification/Start-up Project**																	
3.1	*ORNL Process Modification/Start-up at IFEL*																	
3.1.1	Modificaitons/Startup at IFEL	0	0	232	239	0	0	0	0	0	0	0	0	0	471	362	109	30
3.1.2	On-site Shipping Container Procurement	0	0	49	50	0	0	0	0	0	0	0	0	0	99	76	23	30
3.1.3	Off-site Shipping Container Certification/Procurement	0	0	678	1,304	0	0	0	0	0	0	0	0	0	1,982	1,525	457	30
3.2	*ORNL Process Modification/Start-up at REDC*																	
3.2	Modifications/Startup at REDC	0	0	181	186	0	0	0	0	0	0	0	0	0	367	282	85	30
4	**ORNL Transport/Storage Operations**																	
4.1	*ORNL Transport/Storage Operations at IFEL*																	
4.1.1	Tranport from SRS to ORNL	0	0	0	0	14	33	34	35	36	37	38	30	0	255	196	59	30
4.1.2	Operaitons at IFEL	0	0	0	0	333	772	795	819	843	869	895	717	0	6,042	4,647	1,394	30
4.2	*ORNL Transport/Storage Operations at REDC*																	
4.2.1	Operations at REDC	0	0	0	0	38	88	90	93	96	99	102	81	0	687	528	158	30
5	**Project Integration**	437	450	464	478	492	507	522	538	554	570	587	605	0	6,203	6,203	0	0
	Total	**6,765**	**5,935**	**5,958**	**5,607**	**4,412**	**6,956**	**7,192**	**7,408**	**7,630**	**7,859**	**8,095**	**8,121**	**1,654**	**83,591**	**65,612**	**17,979**	**28**
	Cumulative Total	**6,765**	**12,700**	**18,658**	**24,266**	**28,678**	**35,634**	**42,826**	**50,234**	**57,864**	**65,723**	**73,817**	**81,938**	**83,591**				

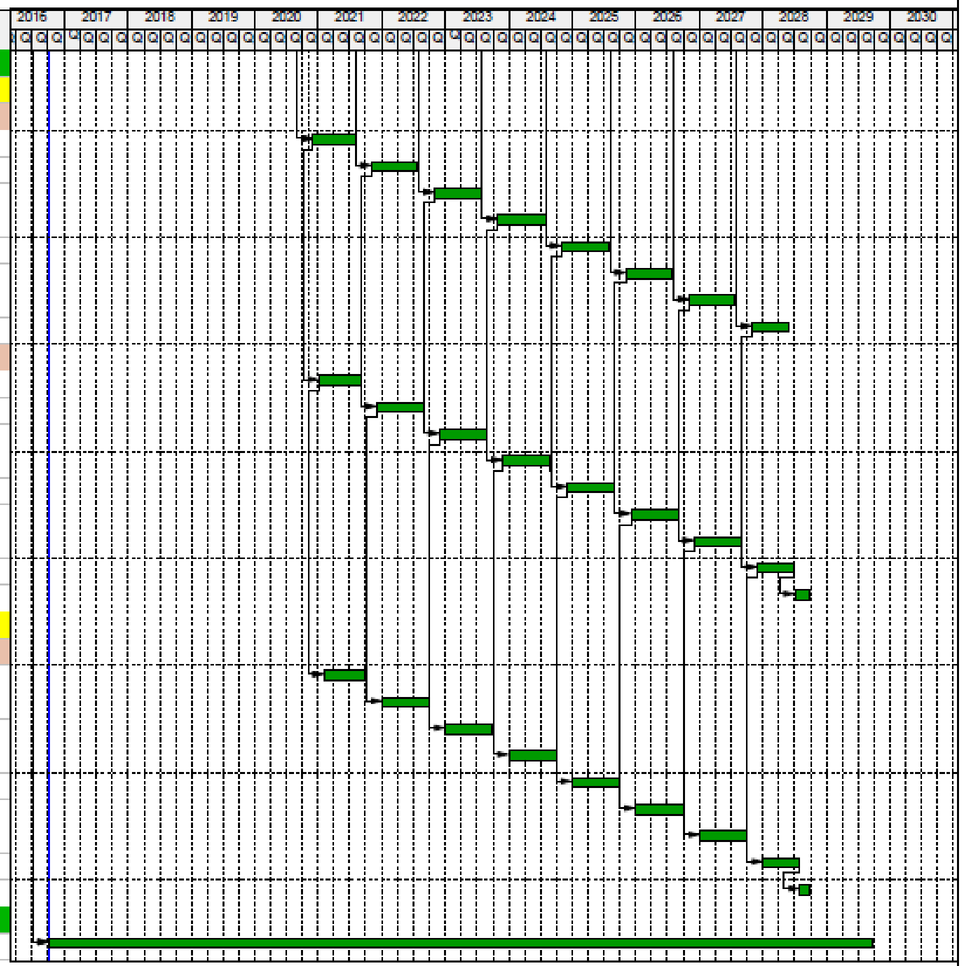
Activity Name	Start	Finish
WBS MK-18A RECOVERY	03-Oct-16	28-Sep-29
WBS.1 SRS Process Reconfiguration/Documentation	03-Oct-16	30-Sep-20
WBS.1.1 Process Reconfiguration/Documentation at L-Basin	03-Oct-16	30-Sep-20
WBS.1.1.1 Process reconfiguration at L-Basin	03-Oct-16	30-Sep-19
WBS 1.1.1.1 On-site shipping analysis	03-Oct-16	29-Sep-17
WBS 1.1.1.2 Reconfiguration to retrieve/transport targets	01-Mar-17	30-Sep-19
WBS.1.1.2 Reconfiguration/Procurement of On-Site Cask	01-Mar-17	28-Sep-18
WBS 1.1.2 Reconfiguration/Procurement of On-Site Cask	01-Mar-17	28-Sep-18
WBS.1.1.3 Procedures/Training at L-Basin	01-Oct-18	30-Sep-20
WBS 1.1.3 Procedures/Training at L-Basin	01-Oct-18	30-Sep-20
WBS.1.2 Process Reconfiguration/Documentation at Shielded Cells	03-Oct-16	30-Sep-20
WBS.1.2.1 Process recognfiguration at Shielded Cells	03-Oct-16	30-Sep-19
WBS 1.2.1.1 Reconfiguration to receive transport cask	01-Mar-17	30-Sep-19
WBS 1.2.1.2 Reconfiguration to process targets	03-Oct-16	30-Sep-19
WBS.1.2.2 Process Flowsheet Development	03-Oct-16	31-Mar-20
WBS 1.2.2 Process Flowsheet Development	03-Oct-16	31-Mar-20
WBS.1.2.3 Procedures/Training at Shielded Cells	01-Oct-19	30-Sep-20
WBS 1.2.3 Procedures/Training at Shielded Cells	01-Oct-19	30-Sep-20
WBS.2 SRS Processing/Repackaging Operations	01-Oct-20	28-Sep-29
WBS.2.1 Processing/Repackaging Operations at L-Basin	01-Oct-20	31-Mar-28
WBS.2.1.1 Processing/Repackaging Operations at Shielded Cells	01-Oct-20	31-Mar-28
WBS 2.1.1.1 Four (4) targets, processing	01-Oct-20	31-May-21
WBS 2.1.1.2 Nine (9) targets, processing	01-Sep-21	31-May-22
WBS 2.1.1.3 Nine (9) targets, processing	01-Sep-22	31-May-23
WBS 2.1.1.4 Nine (9) targets, processing	01-Sep-23	30-May-24
WBS 2.1.1.5 Nine (9) targets, processing	02-Sep-24	30-May-25
WBS 2.1.1.6 Nine (9) targets, processing	01-Sep-25	29-May-26
WBS 2.1.1.7 Nine (9) targets, processing	01-Sep-26	31-May-27
WBS 2.1.1.8 Seven (7) targets, processing	01-Sep-27	31-Mar-28
WBS.2.2 Processing/Repackaging Operations at Shielded Caves	02-Nov-20	28-Sep-29
WBS.2.2.1 Heavy Cm Recovery	02-Nov-20	28-Sep-29
WBS 2.2.1.1 Four (4) targets, processing	02-Nov-20	30-Jun-21
WBS 2.2.1.2 Four (4) targets, maintenance	01-Jul-21	30-Sep-21
WBS 2.2.1.3 Nine (9) targets, processing	01-Oct-21	30-Jun-22
WBS 2.2.1.4 Nine (9) targets, maintenance	01-Jul-22	30-Sep-22
WBS 2.2.1.5 Nine (9) targets, processing	03-Oct-22	30-Jun-23
WBS 2.2.1.6 Nine (9) targets, maintenance	03-Jul-23	29-Sep-23
WBS 2.2.1.7 Nine (9) targets, processing	02-Oct-23	28-Jun-24
WBS 2.2.1.8 Nine (9) targets, maintenance	01-Jul-24	30-Sep-24



Activity Name	Start	Finish
WBS 2.2.1.9 Nine (9) targets, processing	01-Oct-24	30-Jun-25
WBS 2.2.1.10 Nine (9) targets, maintenance	01-Jul-25	30-Sep-25
WBS 2.2.1.11 Nine (9) targets, processing	01-Oct-25	30-Jun-26
WBS 2.2.1.12 Nine (9) targets, maintenance	01-Jul-26	30-Sep-26
WBS 2.2.1.13 Nine (9) targets, processing	01-Oct-26	30-Jun-27
WBS 2.2.1.14 Nine (9) targets, maintenance	01-Jul-27	30-Sep-27
WBS 2.2.1.15 Seven (7) targets, processing	01-Oct-27	28-Apr-28
WBS 2.2.1.16 Seven (7) targets, maintenance	01-May-28	31-Jul-28
WBS 2.2.1.17 Shutdown processing operations	01-Aug-28	28-Sep-29
WBS.2.2.2 Pu Recovery	**02-Nov-20**	**28-Sep-29**
WBS 2.2.2.1 Four (4) targets, processing	02-Nov-20	30-Jun-21
WBS 2.2.2.2 Four (4) targets, maintenance	01-Jul-21	30-Sep-21
WBS 2.2.2.3 Nine (9) targets, processing	01-Oct-21	30-Jun-22
WBS 2.2.2.4 Nine (9) targets, maintenance	01-Jul-22	30-Sep-22
WBS 2.2.2.5 Nine (9) targets, processing	03-Oct-22	30-Jun-23
WBS 2.2.2.6 Nine (9) targets, maintenance	03-Jul-23	29-Sep-23
WBS 2.2.2.7 Nine (9) targets, processing	02-Oct-23	28-Jun-24
WBS 2.2.2.8 Nine (9) targets, maintenance	01-Jul-24	30-Sep-24
WBS 2.2.2.9 Nine (9) targets, processing	01-Oct-24	30-Jun-25
WBS 2.2.2.10 Nine (9) targets, maintenance	01-Jul-25	30-Sep-25
WBS 2.2.2.11 Nine (9) targets, processing	01-Oct-25	30-Jun-26
WBS 2.2.2.12 Nine (9) targets, maintenance	01-Jul-26	30-Sep-26
WBS 2.2.2.13 Nine (9) targets, processing	01-Oct-26	30-Jun-27
WBS 2.2.2.14 Nine (9) targets, maintenance	01-Jul-27	30-Sep-27
WBS 2.2.2.15 Seven (7) targets, processing	01-Oct-27	28-Apr-28
WBS 2.2.2.16 Seven (7) targets, maintenance	01-May-28	31-Jul-28
WBS 2.2.2.17 Shutdown processing operations	01-Aug-28	28-Sep-29
WBS.2.3 Waste Management	**02-Nov-20**	**28-Sep-29**
WBS 2.3.1 Waste Management	02-Nov-20	28-Sep-29
WBS.2.4 Project Management	**01-Oct-20**	**28-Sep-29**
WB 2.4.1 Project Management	01-Oct-20	28-Sep-29
WBS.3 ORNL Process Reconfiguration/Documentation	**03-Oct-18**	**30-Sep-20**
WBS.3.1 Process Reconfiguration/Documentation at IFEL	**03-Oct-18**	**30-Sep-20**
WBS 3.1.1 Process reconfiguration procedures/training at IFEL	03-Oct-18*	30-Sep-20
WBS 3.1.2 On-site shipping container procurement	03-Oct-18*	30-Sep-20
WBS 3.1.3 Off-site Shipping container certification/procurement	01-Oct-19*	30-Sep-20
WBS.3.2 Process Reconfiguration/Documentation at REDC	**03-Oct-18**	**30-Sep-20**
WBS 3.2.1 Process reconfiguration procedures/training at REDC	03-Oct-18*	30-Sep-20



Activity Name	Start	Finish
WBS.4 ORNL Transport/Storage Operations	03-Dec-20	29-Sep-28
WBS.4.1 Transport/Storage Operations at IFEL	03-Dec-20	29-Sep-28
WBS.4.1.1 Transport from SRS to ORNL	03-Dec-20	31-May-28
WBS 4.1.1.1 Four (4) shipments	03-Dec-20	03-Aug-21
WBS 4.1.1.2 Nine (9) shipments	01-Nov-21	29-Jul-22
WBS 4.1.1.3 Nine (9) shipments	01-Nov-22	31-Jul-23
WBS 4.1.1.4 Nine (9) shipments	01-Nov-23	31-Jul-24
WBS 4.1.1.5 Nine (9) shipments	01-Nov-24	31-Jul-25
WBS 4.1.1.6 Nine (9) shipments	03-Nov-25	31-Jul-26
WBS 4.1.1.7 Nine (9) shipments	02-Nov-26	30-Jul-27
WBS 4.1.1.8 Seven (7) shipments	01-Nov-27	31-May-28
WBS.4.1.2 Operations at IFEL	04-Jan-21	29-Sep-28
WBS 4.1.2.1 Four (4) shipments	04-Jan-21	01-Sep-21
WBS 4.1.2.2 Nine (9) shipments	01-Dec-21	31-Aug-22
WBS 4.1.2.3 Nine (9) shipments	01-Dec-22	31-Aug-23
WBS 4.1.2.4 Nine (9) shipments	01-Dec-23	30-Aug-24
WBS 4.1.2.5 Nine (9) shipments	02-Dec-24	29-Aug-25
WBS 4.1.2.6 Nine (9) shipments	01-Dec-25	31-Aug-26
WBS 4.1.2.7 Nine (9) shipments	01-Dec-26	31-Aug-27
WBS 4.1.2.8 Seven (7) shipments	01-Dec-27	30-Jun-28
WBS 4.1.3.9 Shutdown operations	03-Jul-28	29-Sep-28
WBS.4.2 Transport/Storage Operations at REDC	01-Feb-21	29-Sep-28
WBS.4.2.1 Operations at REDC	01-Feb-21	29-Sep-28
WBS 4.2.1.1 Four (4) shipments	01-Feb-21	01-Oct-21
WBS 4.2.1.2 Nine (9) shipments	03-Jan-22	30-Sep-22
WBS 4.2.1.3 Nine (9) shipments	02-Jan-23	29-Sep-23
WBS 4.2.1.4 Nine (9) shipments	02-Jan-24	30-Sep-24
WBS 4.2.1.5 Nine (9) shipments	02-Jan-25	30-Sep-25
WBS 4.2.1.6 Nine (9) shipments	02-Jan-26	30-Sep-26
WBS 4.2.1.7 Nine (9) shipments	04-Jan-27	30-Sep-27
WBS 4.2.1.8 Seven (7) shipments	03-Jan-28	31-Jul-28
WBS 4.2.1.9 Shutdown operations	01-Aug-28	29-Sep-28
WBS.5 Program Integration	03-Oct-16	28-Sep-29
WBS 5.1 Program Integration	03-Oct-16	28-Sep-29



APPENDIX B. RISK ASSESSMENT

APPENDIX B. RISK REGISTER

Program Activity	Risk/Opportunity Statement	Overall Risk Rating	Likelihood of Occurrence	Basis of Likelihood	Consequence Category	Basis of Consequence	Handling Strategy
L-Basin Retrieval, Packaging & Staging	Outer J-Can is failed, degraded, or damaged	1 – Low	1 – Very Unlikely	J-Cans are robust and have no history of failure	1 – Very Unlikely	Out of project scope	Target will be dispositioned per L-Basin procedures outside this program
L-Basin Retrieval, Packaging & Staging	Competing programs result in delays in shipping Mk-18A to SRNL	4 – Low	1 – Very Unlikely	Contingency time is built into L-Basin schedule to accommodate competing programs	2 – Marginal	Delays are not likely to last more than 3 months	Routine communications will be established between program & facility managers
Transport between L-Basin & SRNL	Schedule delays due to shipment logistics	3 – Low	3 – Somewhat Likely	Unforeseen impacts include weather, sicknesses, malfunctions in transfer equipment	1 – Very Unlikely	Schedule has built in contingencies. Minor delays will have little cost impact	No mitigation necessary
Transport between L-Basin & SRNL	The cask may come closer than 670 meters to the site boundary	1 – Low	1 – Very Unlikely	Transfer routes will be well documented & controlled	1 – Very Unlikely	Little impact expected on schedule or costs	Address in development of Onsite Safety Assessment (OSA)
SRNL Target Receipt & Processing	The 70-Ton cask lid redesign does not accommodate current SRNL facility parameters	36 – High	4 – Very Likely	Redesign has not been proven. Present design cannot be accommodated in facility	3 – Significant	A new cask design would be required	Procure new cask rather than redesign lid for existing cask
SRNL Target Receipt & Processing	Floor loading analysis results in the necessity for major facility modifications	36 – High	4 – Very Likely	Redesign of cask to sufficiently reduce weight has not been proven. Facility cannot handle present configuration.	3 – Significant	A new cask design would be required	Procure new cask rather than redesign lid for existing cask

Program Activity	Risk/Opportunity Statement	Overall Risk Rating	Likelihood of Occurrence	Basis of Likelihood	Consequence Category	Basis of Consequence	Handling Strategy
SRNL Target Receipt & Processing	There is a failed or degraded assembly	8 – Medium	2 – Unlikely	Failure of target assembly may happen due to handling and long-term storage	2 – Marginal	Potential loss of material	Experimental design and catch pans will be utilized within the cells to eliminate loss of material
SRNL Target Receipt & Processing	Dose rate exceeds the allowable limits	45 – High	5 – Very Likely	Dose rates are high and cannot be effectively shielded at all times outside of engineered features	3 – Significant	Personnel exposure could be greater if not mitigated	Perform MCNP modeling for baseline shielding calculations early in program; Develop ALARA plan & engineered controls to address
SRNL Target Receipt & Processing	Simultaneous opening of both sets of air lock doors (due to the size of the 70T cask trailer) while maintaining proper air flow within the nuclear facility	48 – High	3 – Somewhat Likely	Air flow cannot be maintained with both doors opened without significant adjusting of facility dampers (ventilation can only be adjusted "so much")	4 – Critical	Reduced air-flow could result in contamination release to the environment	Procure new cask that will allow airlock to be properly used rather than redesign lid for existing cask
SRNL Target Receipt & Processing	Categorization of the activity within SRNL	25 – High	1 – Very Unlikely	Approval is expected based on preliminary discussions	5 – Crisis	Alternative processing options increase costs more than 120%	Engage senior SRS/SRNL management & facility oversight personnel early in project planning
SRNL Target Receipt & Processing	Schedule is impacted by other missions competing for the shielded cells' resources	27 – High	3 – Somewhat Likely	Future missions may be realized that compete with resources	3 – Significant	Overall, other missions will have down time that will allow processing to maintain current scheduled rates and timeframes, but over a 10-year program, slippage may exceed 3 months	Contingencies are built into processing schedule. If other programs do take resources, this program will go "on hold" and costs will not be incurred, but the schedule will be pushed out.

Program Activity	Risk/Opportunity Statement	Overall Risk Rating	Likelihood of Occurrence	Basis of Likelihood	Consequence Category	Basis of Consequence	Handling Strategy
SRNL Target Receipt & Processing	Changes to current SRNL waste management practices results in the loss of access to waste treatment facilities	25 – High	1 – Very Unlikely	No changes are planned at the treatment facilities	5 – Crisis	Processing would have to be completed in another facility resulting in significant cost increases	Engage senior SRS/SRNL management & facility oversight personnel early in project planning
SRNL Target Receipt & Processing	Schedule is impacted by facility maintenance activities	16 – Medium	4 – Likely	Facility equipment frequently requires maintenance	2 – Marginal	Most maintenance can be resolved and absorbed within a minor period of performance	Preventative maintenance will be performed to reduce the likelihood. Spare items may be purchased to reduce risk
SRNL Target Receipt & Processing	Drop a target during transfer from cask to cell	9 – Medium	1 – Very Unlikely	Not expected to occur	3 – Significant	Recovery would result in significant schedule impacts	An extensive cask transfer training program will be implemented. Design of new cask would incorporate fail-safe aspects to reduce risk.
SRNL Target Receipt & Processing	Significant water drips out of the bundle during the retrieval & transfer into the shielded cells	5 – Medium	5 – Very Likely	Water is in intimate contact with the assemblies and will most likely accumulate and drip during transferring operations	1 – Insignificant	No impact expected	Disposable absorbance cloth can be positioned on the floors of the facility to catch any residual water that may drip out of the bundle.
SRNL Target Receipt & Processing	Delay due to process upsets	5 – Medium	5 – Very Likely	Process upsets are a normal part of operating the shielded cells	1 – Insignificant	Contingencies are built into processing schedule	Contingencies have been built into the processing schedule. No future mitigation needed

Program Activity	Risk/Opportunity Statement	Overall Risk Rating	Likelihood of Occurrence	Basis of Likelihood	Consequence Category	Basis of Consequence	Handling Strategy
SRNL Target Receipt & Processing	Shielded sleeve becomes contaminated and is unable to be cleared	4 – Low	1 – Very Unlikely	Proper design of the sleeve will facilitate decontamination	2 – Marginal	New sleeve must be built	Develop a new transfer cask to eliminate the need of a shielded sleeve or have a back-up sleeve
SRNL Packaging & Staging for Transport	Delay due to shipment logistics	2 – Low	2 – Unlikely	Contingencies have been built into the shipping schedule	1 – Insignificant	Impacts can be absorbed in the normal float	Identify lag storage facilities
SRNL Packaging & Staging for Transport	Dose rate may exceed the allowable limits	45 – High	5 – Very Likely	Dose rates are high and cannot be effectively shielded at all times outside of engineered features	3 – Significant	Personnel exposure could be greater if not mitigated	Perform MCNP modeling for baseline shielding calculations early in program; Develop ALARA plan & engineered controls to address
Transport between SRNL & ORNL	Approval of 9977 SARP modification is delayed	18 – Medium	2 – Unlikely	9977 SARP addendum may receive low priority	3 – Significant	delays could exceed 3 months but most likely will not exceed 6 months	SARP change and review will be scheduled well before date needed. Alternative Type A packages may be utilized for much of the content.
Transport between SRNL & ORNL	Dose limits require 2 times more shipments than estimated	18 – Medium	2 – Unlikely	Preliminary calculations indicate this is not likely to happen	3 – Significant	Purchase of additional packages may be necessary, additionally packaging and operational costs will be incurred at SRNL and ORNL	Dose analyses will be conducted in the early stages of the project. Alternative packages with additional shielding will be evaluated.

Program Activity	Risk/Opportunity Statement	Overall Risk Rating	Likelihood of Occurrence	Basis of Likelihood	Consequence Category	Basis of Consequence	Handling Strategy
ORNL IFEL Target Receipt & Repackaging	Delay in shipment due to other work at 7920	27 – High	3 – Somewhat Likely	Future missions may be realized that compete with resources	3 – Significant	Overall, other missions will have down time that will allow processing to maintain current scheduled rates and timeframes, but over a 10-year program, slippage may exceed 3 months	Identify lag storage facilities at ORNL; Investigate Type A shipment container for easier lag storage
ORNL IFEL Target Receipt & Repackaging	Delay in approval to use Loop Cask	9 – Medium	1 – Very Unlikely	Cask has been routinely reapproved for other materials	3 – Significant	Redesign of new equipment in new facilities would be required	Identify lag storage facilities at ORNL; Investigate Type A shipment container for easier lag storage; Investigate ability to unload off-siting shipment directly at REDC
ORNL IFEL Target Receipt & Repackaging	Ship directly to REDC—opportunity	20 – Medium	5 – Very Likely	If opportunity analysis proves that direct unloading is possible, the opportunity could be easily implemented	2 – Marginal	The opportunity savings is expected to be less than 5% of the total project costs (~$3.5M)	Investigate Type A shipment container for easier unloading Investigate ability to unload off-siting shipment directly at REDC

Program Activity	Risk/Opportunity Statement	Overall Risk Rating	Likelihood of Occurrence	Basis of Likelihood	Consequence Category	Basis of Consequence	Handling Strategy
ORNL REDC Receipt & Storage	No space available in storage facility	9 - Medium	1 – Very Unlikely	Major projects that could compete for space are not funded	3 - Significant	Redesign of new equipment in new facilities would be required	Identify lag storage facilities at ORNL; Investigate Type A shipment container for easier lag storage; Investigate other storage locations at REDC; Communicate with REDC program managers to keep Mk-18A on storage inventory list
Cross-cutting	Radionuclide concentrations are not accurately (within 50%) estimated	50 – Very High	2 - Unlikely	The existing data may not be complete in its estimation of the entire content profile	5 - Critical	If SRNL cannot accept the MAR, a different facility must be utilized for this project	MCNP model to predict actinide content; examine data from previously processed targets; measure a target(s) in L-Basin

Likelihood of Occurrence

Very likely [5]	Probability of occurrence in life of project judged to be greater than 90%
Likely [4]	Probability of occurrence in life of project judged to be greater than 75% but less than 90%
Somewhat likely [3]	Probability of occurrence in life of project judged to be greater than 25% but less than 75%
Unlikely [2]	Probability of occurrence in life of project judged to be greater than 10% but less than 25%
Very unlikely [1]	Probability of occurrence in life of project judged to be less than 10%

Risk/Opportunity Impact

Consequence category	Cost	Schedule	Technical
Insignificant Risk/ Opportunity [1]	Negligible change in life-cycle cost <0.01	Only activities not near the critical path are impacted. Schedule impacts can be covered with available float.	Negligible performance change; project goals can still be met.
Marginal Risk/ Opportunity [2]	Marginal impact in life-cycle cost between 1 and 5% (i.e., either increase or decrease) >0.01 but <0.05	≥1 week to 3 month change in schedule	Marginal performance change; work-arounds are available; risks might impact project goals if not mitigated.
Significant Risk/ Opportunity [3]	Cost estimates significantly exceed budget. Potential for a >5% budget or cost change (i.e., either increase or decrease) in life-cycle cost >0.05 but <0.1	3–6 month change in major milestone or completion date	Significant change in modification/project technical performance. Significant threat to facility mission, environment, or people. Requires either some equipment redesign or repair or significant environmental remediation or causes injury requiring medical treatment. Project goals may not be met (essential performance parameter not met).
Critical Risk/ Exceptional Opportunity [4]	Potential for a >10% budget or cost change (i.e., either increase or decrease) in life-cycle cost. >0.1 but <0.2	6–12 month change in major milestone or completion date.	Serious threat to facility mission, environment, or people; possibly completing only portions of mission or requiring major equipment redesign or rebuilding; extensive environmental remediation or intensive medical care for life-threatening injury.
Crisis Risk/ Outstanding Opportunity [5]	Potential for a >20% budget or cost change (i.e., either increase or decrease) life-cycle cost. >0.2	>12 month change in major milestone or completion date.	Catastrophic threat to facility (-ies), mission, environment, or people possibly causing loss of mission, long-term environmental abandonment, and/or death.

Event Risk Assessment Matrix

Likelihood of occurrence	Insignificant [1^2]	Marginal [2^2]	Significant [3^2]	Critical [4^2]	Crisis [5^2]
Very likely [5]	**Medium [5]**	**High [20]**	**High [45]**	**Very high [80]**	**Very high [125]**
Likely [4]	**Low [4]**	**Medium [16]**	**High [36]**	**Very high [54]**	**Very high [100]**
Somewhat likely [3]	**Low [3]**	**Medium [12]**	**High [27]**	**High [48]**	**Very high [75]**
Unlikely [2]	**Low [2]**	**Medium [8]**	**Medium [18]**	**High [32]**	**Very high [50]**
Very unlikely [1]	**Low [1]**	**Low [4]**	**Medium [9]**	**Medium [16]**	**High [25]**

Opportunity Assessment Matrix

Likelihood of occurrence	Insignificant [1^2]	Marginal [2^2]	Significant [3^2]	Exceptional [4^2]	Outstanding [5^2]
Very likely [5]	**Low [5]**	**Medium [20]**	**Medium [45]**	**High [80]**	**High [125]**
Likely [4]	**Very low [4]**	**Low [16]**	**Medium [36]**	**High [54]**	**High [100]**
Somewhat likely [3]	**Very low [3]**	**Low [12]**	**Medium [27]**	**Medium [48]**	**High [75]**
Unlikely [2]	**Very low [2]**	**Low [8]**	**Low [18]**	**Medium [32]**	**High [50]**
Very unlikely [1]	**Very low [1]**	**Very low [4]**	**Low [9]**	**Low [16]**	**Medium [25]**