**Department of Energy**
Washington, DC 20585

October 1, 1998

The Honorable John T. Conway
Chairman
Defense Nuclear Facilities Safety Board
625 Indiana Avenue, NW
Suite 700
Washington, DC 20004

Dear Mr. Chairman:

Enclosed is the Department of Energy's (DOE) document entitled, *Uranium-233 Storage Alternative Trade Study Final Report*. It represents the deliverable for Commitment 14 of the Department's Implementation Plan addressing the Defense Nuclear Facilities Safety Board's Recommendation 97-1 concerning the safe storage of Uranium-233. The purpose of this report is to evaluate other candidate facilities suitable for the long term storage of this material in comparison to Building 3019 at the Oak Ridge National Laboratory where presently a large portion of the inventory currently resides.

This trade study will be used by the Department as a technical input in making a preferred option determination of the long term storage facility for Uranium-233. Other factors will be considered by senior DOE management in making this determination, such as Departmental mission priorities and material disposition paths, and the results of this trade study will be considered in conjunction with those factors.

If you have any questions please contact me, or have your staff contact Hoyt Johnson of my staff at (202) 586-0191.

Sincerely,

David G. Huizenga
Acting Deputy Assistant Secretary for
Nuclear Material and Facility Stabilization
Office of Environmental Management

Enclosure

cc w/encl: M. Whitaker, S-3.1

**ORNL/M-6606**

## Chemical Technology Division

# URANIUM-233 STORAGE ALTERNATIVE TRADE STUDY

# FINAL REPORT

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# ACRONYMS

| | |
|---|---|
| AES | automated estimating system |
| ANL | Argonne National Laboratory |
| APSF | Actinide Packaging and Storage Facility |
| ATS | automatic transfer switch |
| BIO | Basis for Interim Operation |
| BWR | Boiling Water Reactor |
| CAM | constant air monitor |
| CAAS | Criticality Accident Alarm System |
| CEUSP | Consolidated Edison Uranium Solidification Project |
| CoC | Certificate of Compliance |
| COG | cell off-gas |
| CSE | Criticality Safety Evaluation |
| D&D | decontamination and decommissioning |
| DAS | data acquisition system |
| DNFSB | Defense Nuclear Facilities Safety Board |
| DOE | U.S. Department of Energy |
| DOE/AL | U.S. Department of Energy/Albuquerque Operations Office |
| DOT | U.S. Department of Transportation |
| DP | Defense Programs |
| EM | Environmental Management |
| EPA | U.S. Environmental Protection Agency |
| ER | Energy Researc |
| ES&H | Environmental, Safety, and Health |
| GE | General Electric |
| GBOG | glovebox off-gas |
| GWSF | Glass Waste Storage Facility |
| HEPA | high-efficiency particulate air |
| HEU | highly enriched uranium |
| HVAC | heating, ventilating, and air-conditioning |
| IAEA | International Atomic Energy Agency |
| IFSF | irradiated fuel storage facility |
| INEEL | Idaho National Engineering and Environmental Laboratory |
| INTEC | Idaho Nuclear Technology and Engineering Center |
| LMES | Lockheed Martin Energy Systems, Inc. |
| LWBR | Light Water Breeder Reactor |
| MCC | motor control center |
| MSRE | Molten Salt Reactor Experiment |
| NAC | Nuclear Assurance Corporation |
| NDA | Non-Destructive Assay |
| NDE | Non-Destructive Evaluation |
| NE | Nuclear Energy Science and Technology |
| NEPA | National Environmental Policy Act |
| NFPA | National Fire Protection Association |
| NRC | U.S. Nuclear Regulatory Commission |
| NTS | Nevada Test Site |
| ORNL | Oak Ridge National Laboratory |

## ACRONYMS (continued)

| | |
|---|---|
| OSHA | Occupational Safety and Health Act |
| OSR | Operational Safety Requirement |
| PHA | Process Hazards Analysis |
| PIDAS | perimeter intrusion detection and surveillance |
| PWR | Pressurized Water Reactor |
| RAL | Remote Analytical Laboratory |
| REDC | Radiochemical Engineering Development Center |
| SAR | Safety Analysis Report |
| S&M | Surveillance and Maintenance |
| SARP | Safety Analysis Report for Packaging |
| SRS | Savannah River Site |
| SST | safe, secure transport |
| TRU | transuranic |
| TSD | Transportation Safeguards Division |
| TSR | Technical Safety Requirement |
| TURF | Thorium-Uranium Recycle Facility |
| UFSF | Unirradiated Fuel Storage Facility |
| UPS | uninteruptable power supply |
| USQD | unreviewed safety question determination |
| VOG | vessel off-gas |

## EXECUTIVE SUMMARY

This report provides an evaluation of candidate alternative facilities for extended safe storage of separated $^{233}U$ materials in response to the Defense Nuclear Facilities Safety Board (DNFSB) Recommendation 97-1. Recommendation 97-1 was made to the Secretary of Energy identifying the need to address the safety of near-term storage as well as the development of a long-term plan for safe storage of the $^{233}U$ materials. On September 29, 1997, the Department of Energy (DOE) issued an Implementation Plan to respond to the DNFSB recommendation and committed, along with other near-term actions, to perform a study of alternatives to the continued use of Oak Ridge National Laboratory (ORNL) Building 3019 as the National Repository for $^{233}U$ materials. The majority of the nation's supply of separated $^{233}U$ is currently stored at the ORNL National Repository in Building 3019. The inventory of mixed $^{233}U$ and thorium oxide fuel stored at Idaho National Engineering and Environmental Laboratory (INEEL) is not considered part of this storage trade study. A recent DOE Highly Enriched Uranium (HEU) vulnerability assessment of the Building 3019 facility concluded that engineered system upgrades are required to safely store $^{233}U$ material for an extended period. Before additional funds are allocated for facility upgrades and capital equipment investments, DOE initiated an examination and review of alternative facilities to determine whether more attractive and cost-effective facility storage options could be implemented within the next three to five years. This report provides a comparative review, characterization, and cost estimate for upgrading and operating the existing Building 3019 facility and three alternative DOE facility storage options. A new "Greenfield" facility estimate was included for the purpose of comparing the up-front cost of existing facility modifications to a totally new construction. This Greenfield estimate is very preliminary and is intended as a cost benchmark and not as an additional option. Also, the new facility would be a budget line item and, as such would require at least 10 years for approval and implementation.

A team of technical experts in $^{233}U$ handling and processing was formed to identify, evaluate, and select the best alternative facilities. This team consisted of a multi-site group of technical experts who were collectively familiar with the DOE sites to be considered and the relevant properties and requirements for $^{233}U$ materials to be stored. After preliminary screening of alternative storage sites and facilities, four alternatives were selected for comparative evaluation. The four alternatives are: (1) Upgrading Building 3019 at ORNL; (2) Modification of Building 7930 cells at ORNL; (3) Expansion of the storage area, installation of hot cells and general facility upgrading of Building 651 at INEEL (Option 651A); and, (4) Shared storage between a moderately modified Building 651, and remote storage facilities 603 (Irradiated Fuel Storage Area) or 749 (In-ground Dry Storage Vaults) and processing at the Remote Analytical laboratory (RAL) facility (INEEL Option 651B). These four alternatives were selected after scoring highest using the following selection criteria: (1) Environment, Safety and Health Risk; (2) Safeguards and Security; (3) Operational Performance; (4) Initial Cost; (5) Life Cycle Cost; (6) Time to Implement; and, (7) Stakeholder Acceptance. Each alternative was evaluated for existing capabilities and for facility, documentation, and equipment modifications required. The initial cost and life cycle cost criteria (criteria 4 and 5, above) were relative screening judgments only, and did not enter into the costing estimates prepared later for this report.

The selected options meet the general requirements and conditions for $^{233}U$ storage. In all cases however, some modifications to these facilities must be made to prepare the facilities for the near-term and long-term storage mission. Since several facilities met the up-front storage mission selection criteria, the final facility evaluation was based primarily upon a comparison of cost for these facilities to accomplish the storage mission.

Preliminary estimates were made of the up-front costs required for the four storage options. These up-front costs consisted of: (1) <u>Initial Inspection and Repackaging Costs</u>, which are the costs to initially inspect, consolidate, and repack if necessary, the inventory prior to long term storage. This cost is the same for all facilities because these actions must be completed prior to material movement for final facility selection and storage. (2) Facility Preparative Costs, which are different for each facility since this is a cost required to upgrade, modify or construct elements which must initially be in place for a facility to accommodate the storage mission. (3) Inventory Transportation Costs, which include intra-site and inter- site inventory shipments between facilities. The other major cost category (not an up-front cost) which was used to compare these alternatives is Facility Recurring Costs. This annual recurring cost consists of items required to keep the facility functional, including facility operational costs, facility security costs, and facility maintenance costs. The following data summarizes the major cost results:

| | INEEL | INEEL | ORNL | ORNL |
|---|---|---|---|---|
| **Costs**[a] | **651A** | **651B** | **3019** | **7930** |
| Initial Inspect/Repackage | $20M | $20M | $20M | $20M |
| Facility Preparation Costs | $51M | $21M | $22M | $21M |
| Inventory Transportation Costs | $20M | $22M | $0M | $9M |
| Facility Recurring Costs (per year) | $2.4M | $2.3M | $5.9M | $2.0M |

[a] See descriptions of cost categories above.

ORNL Building 3019 is shown to have the lowest up-front cost in this preliminary study. This is expected since it currently is the repository for $^{233}$U, has most requirements for storage in place, and can accommodate the $^{233}$U long term storage with a series of modifications. However, the recurring costs and, therefore, the long-term cumulative costs for Building 3019 are quite high, due in part to the legacy of an aging, contaminated facility. Also, higher costs are due to the fact that Building 3019 was originally designed as a large radiochemical processing facility.

Option 651A at INEEL requires significant up-front modifications to meet the requirements for $^{233}$U storage and inspection.[1] Option 651B storage scenario (dividing $^{233}$U materials between Building 651 and Areas 603/749 at INEEL) has lower up-front costs compared to the Option 651A, as well as slightly lower recurring costs. Also, since INEEL is currently storing both the irradiated and the unirradiated $^{233}$U/Th fuel from the Light Water Breeder Reactor (LWBR) program, either INEEL Option 651A or Option 651B would consolidate both the separated $^{233}$U inventory, and the fabricated fuel inventory at one site.

Due partially to the fact that ORNL Building 7930 was originally designed to handle $^{233}$U materials, the facility has low Facility Recurring Costs, and it has the second lowest combined Facility Preparation and Transportation Cost. Building 7930 has other potential advantages from its current mission of $^{252}$Cf storage and processing, and from the planned future isotope missions which could result in further lowering of operational costs through additional program cost sharing.

The cost analysis from this trade study show that ORNL Building 3019 has the lowest initial up-front cost. The cumulative total recurring costs overtake its initial advantage and, within the first few years of the storage mission, ORNL Building 7930 becomes the lower total cost option and remains the lowest cost option throughout the mission. If transportation costs are removed from consideration, very little cost differences are noted between Building 7930 and INEEL Option 651B. Early deactivation and decontamination and decommissioning (D&D) for ORNL Building 3019 could reduce significant future costs to DOE, although this would require up-front deactivation and D&D money. These considerations were not included in the comparison of total mission costs; however, a top level estimate for deactivation and D&D of Building 3019 was developed in this report.

Final disposition scenarios for $^{233}U$ separated material could potentially reduce the cost of long-term storage, but these scenarios are not considered as part of the scope of this study. For example, scenarios involving the up-front disposal of the relatively impure $^{233}U$ material (materials that contain relatively large amounts of high energy gamma emitting $^{232}U$, and account for half the inventory), could significantly reduce overall storage costs. This would be due not only to a reduction in the amount of material stored, but also to a significant reduction in handling/storing expenses associated with high radiation packages.

Consideration of factors in this trade study other than cost and performance criteria, such as long-term site missions and the acceptance of interstate movement of large amounts of fissile material, lead into areas of subjective analysis that must be considered, but are not addressed in this technical report. These issues are identified in Section 5.8 and would be part of National Environmental Policy Act (NEPA) review and the DOE decision process on selection of a $^{233}U$ Storage Facility.

In summary, based on this study Building 3019 after upgrades is the lowest cost option for the first several years of the $^{233}U$ storage mission. The Building 7930 option has the lowest long-term costs of any of the options. Transportation costs are the principal cost discriminator between the Building 7930 and the INEEL 651B Option.

# 1. INTRODUCTION

This $^{233}$U Storage Alternative Trade Study, Final Report includes an overall evaluation and final assessment of near-term alternative storage facilities for the separated $^{233}$U currently stored at Oak Ridge National Laboratory (ORNL) and other sites. The storage facility evaluation is based on facility availability, mission, capabilities, performance measures, safety and cost. This report provides a comparative evaluation from a preliminary cost estimate perspective of Building 3019, the current repository, and the three selected alternative U. S. Department of Energy (DOE) facility storage options.

A broad list of prospective $^{233}$U storage facilities was screened to seven candidates by a multi-site team of $^{233}$U technical experts (The Technical Team) and reduced from seven to three candidate facilities based on specific screening criteria of: (1) Environment, Safety and Health Risk; (2) Safeguards and Security; (3) Operational Performance; (4) Initial Cost; (5) Life Cycle Cost; (6) Time to Implement (three to five year target); and, (7) Stakeholder Acceptance. Each alternative was evaluated for existing capabilities, and for facility, documentation, and equipment modifications required. A fourth candidate storage option (Option 651B) was included by Idaho National Engineering and Environmental Laboratory (INEEL), which utilized their existing, relatively inexpensive irradiated fuel storage capabilities. Option 651B consists of divided storage option (combined storage in Building 651 and storage areas 603/749). The final four facility options evaluated in this report include: (1) ORNL Building 3019, the current $^{233}$U National Repository for separated $^{233}$U; (2) ORNL Building 7930, part of the Radiochemical Engineering Development Center; (3) INEEL Option 651A (this option involves extended modifications to storage, processing and facility support functions for Building 651); and, (4) INEEL Building 651 Option B described above. Other facilities that are under design or construction were proposed and considered in the initial screening process, but they were eliminated from this trade study because their near-term availability was in question, or because major design changes would be required to accommodate $^{233}$U. However, this study does include a conceptual cost estimate for the construction of a completely new facility (i.e., Greenfield Facility, Section 2.4) solely as a basis for comparison of initial cost of a new facility, to the cost of up-front modifications required for the four alternative candidate facilities.

The storage requirements and parameters identified by the Technical Team were used to provide the basis for the cost estimates presented in this report. Cost inputs for this report were supplied by appropriate facility representatives at ORNL and INEEL. An evaluation of estimated costs to handle, repackage, inspect, process, transport, and provide long-term (50 years) storage for $^{233}$U materials is included. An overall estimate of costs associated with meeting regulatory, physical and support systems requirements (nuclear criticality, nuclear safety, radiological, industrial health, and fire protection) for the storage mission is also included as part of initial preparation and recurring costs for each facility.

Final disposition scenarios for $^{233}$U separated material could potentially reduce the cost of long-term storage, but these scenarios are not considered as part of the scope of this study. For example, scenarios involving the up-front disposal of the relatively impure $^{233}$U material (materials that contain relatively large amounts of high energy gamma emitting $^{232}$U, and account for over half the inventory), could significantly reduce overall storage costs. This would be due not only to a reduction in the amount of material stored, but also to a significant reduction in handling/storing expenses associated with high radiation packages.

A number of activities are being conducted by DOE that will influence $^{233}$U long-term storage issues. These activities include: (1) development of a packaging and storage standard[1] for $^{233}$U; (2) development of waste criteria specific to $^{233}$U[2]; (3) separation of $^{229}$Th for medical radiotherapy, and; (4) inspection of current $^{233}$U inventories. The final results of these ongoing actions may have a significant impact on reducing costs associated with the long-term $^{233}U$ storage effort. This study incorporates available information from these ongoing DOE activities where appropriate. Consolidation of the separated $^{233}U$, including the “small holdings” is assumed to take place at Building 3019 as part of Inspection/Repackage campaign as is currently planned no matter where the final $^{233}U$ storage takes place.

## 1.1 BACKGROUND

On March 3, 1997, the Defense Nuclear Facilities Safety Board (DNFSB) submitted Recommendation 97-1 to the Secretary of Energy identifying the need to address the safety of near-term storage as well as the development of a long-term plan for safe storage of the $^{233}U$ materials. On September 29, 1997, DOE issued an Implementation Plan to respond to the DNFSB recommendation and committed, along with other near-term actions, to perform a study of alternatives to the continued use of ORNL Building 3019 as the National Repository for $^{233}U$ materials. In the Implementation Plan, DOE assessments had concluded that Building 3019 would require facility and engineered systems upgrades if designated as the long-term (nominal 50+ years) repository. Before allocation of additional funds for facility upgrades and capital equipment investments, DOE initiated an examination and review of alternative facilities to determine whether more attractive and cost-effective facility safe storage options could be made available in a timely manner.

The Technical Team was formed to identify and evaluate a readily available facility for the handling and storage of the $^{233}U$ materials in the near-term. This team consisted of a multi-site group of technical experts who were collectively familiar with all of the DOE sites to be considered and the relevant properties and requirements for $^{233}U$ materials to be stored. The Technical Team initially considered the DOE nuclear sites and facilities and subsequently narrowed the facility alternatives to a list of seven facilities, and then to four by applying screening and ranking criteria described in this report. Many of the proposed facilities on the list were eliminated based on DOE site/facility mission and other attributes conflicting with this storage task. Currently the INEEL facilities under consideration are the responsibility of DOE Environmental Management (EM). The ORNL Building 3019 is a DOE Defense Programs (DP) facility, and Building 7930 is a DOE Energy Research (ER) facility.

This report provides a basis for comparison of facility attributes and costs for the alternative facilities. Major up-front and recurring costs were considered to address facility-specific characteristics, support systems availability, material transportation, and regulatory and safety requirements compliance. The alternative facility cost estimates include derived costs for updating and modifying each alternative facility to meet current regulatory standards. The assumptions relevant to anticipated facility upgrade cost estimates are listed in Section 5.

A great deal of $^{233}U$ experience from both INEEL and ORNL was utilized to develop cost estimates for this report. Building 7930 personnel also have provided engineering analyses of facility modifications required for $^{233}U$ storage.

## 1.2 REPORT PURPOSE AND OBJECTIVES

The purpose of this report is to provide a comparative review of facility characteristics, and provide a cost basis to compare the final four selected DOE facility storage options. These options were designated as viable alternatives for the national $^{233}U$ long-term storage mission. Alternative facilities were reviewed and assessed on a cost basis within a set of prescribed performance criteria and regulatory drivers. The objective of this report is to provide a comparative assessment of the four alternative facility options by applying comparable assumptions and estimating techniques.

Interviews were conducted with each alternative facility manager, facility engineer, or technical expert to gather applicable facility characterization information and cost data. An extensive listing of facility-specific documentation was requested to establish a baseline for each facility. Interview results and data gathered from the review of available facility documentation were used to estimate costs associated with the facility, equipment, documentation, and infrastructure improvements.

## 1.3 ALTERNATIVE FACILITY GUIDELINES

The DOE 97-1 Technical Team (under the direction of EM-66) was formed and assigned to provide oversight and guidance for the 97-1 Implementation Plan tasks, including this $^{233}U$ Alternative Storage Trade Study. The Team consisted of a multi-site work group with technical experts from each site to implement the study. The work group developed screening weighted criteria and ranking guidelines for proposed alternative $^{233}U$ storage sites. The initial screening of site facility options identified a number of proposed facilities at Hanford, ORNL, Y-12, Savannah River Site (SRS), Rocky Flats, INEEL, Los Alamos, Argonne National Laboratory (ANL)-West, Nevada Test Site (NTS), and even commercial sites. The Technical Team conducted the facility screening by having each site representative, or others familiar with the site, give an informal presentation of candidate facilities. Most sites were eliminated during this site discussion session. Hanford and NTS were judged by the Technical Team to have site missions that were not consistent with the long term storage of fissile materials. Los Alamos is a major plutonium site, and the $^{233}U$ does not fit into its current mission. During the initial facility selection process a modular storage facility with shielded individual casks, located inside a secured area such as Oak Ridge Y-12 Site, was considered. A combination of storage requirements, including the need for individual radiation shielding and/or remote handling for processing/repackaging needs eliminated the Y-12 option and other similar option derivatives from further consideration. Commercial sites that hold a Nuclear Regulatory Commission (NRC) license for storage of fissile materials were excluded from this study, since no known commercial sites are currently licensed to handle and store quantities of $^{233}U$.

After these discussion sessions the Technical Team selected seven candidate options: SRS-Actinide Packaging and Storage Facility (APSF); SRS-Glass Waste Storage Facility (GWSF); SRS-Transfer/Storage Facility; INEEL 651 Unirradiated Fuel Storage Facility (UFSF); a generic modular storage vault; ORNL Building 7930, part of the Radiochemical Engineering Development Center (REDC); and the current $^{233}U$ repository, ORNL Building 3019. Each proposed facility was discussed by the working group to understand facility characteristics for preliminary screening and ranking relative to each other. After the presentations, each candidate facility was compared with other prospective candidates using the following ranking criteria:

- **Environmental, Safety and Health Risk Acceptability (20% weight)**

  Ability of the facility and site infrastructure to meet DOE, Occupational Safety and Health Administration (OSHA), Environmental Protection Agency (EPA), and other regulatory requirements. Ability to provide assurance of public and worker safety and environmental protection. Status of current facility authorization basis.

- **Safeguards and Security (20% weight)**

  Availability of safeguards and security infrastructure for Category 1 fissile materials. Availability of security measures and equipment in facility or relative ease of adding such measures.

- **Operational Performance (15% weight)**

  Capability to meet operational requirements for storage, handling, inspection, receipt, shipment, and stabilization processing. Flexibility to address future mission change and recover from unusual events.

- **Initial Cost (15% weight)**

  Costs to construct or prepare the facility for use as a $^{233}$U storage facility meeting current requirements. Operational readiness expenses. Transition costs for transportation and initial loading of the storage system.

- **Life Cycle Cost (10% weight)**

  Initial, operational, and D&D costs of the $^{233}$U storage mission.

- **Timeliness (10% weight)**

  Time to implement the option. A criterion that must be met is the ability to implement within a three to five-year period.

- **Stakeholder Acceptance (10% weight)**

  Acceptability of the 50-year storage mission to local and state governments, civic organizations, public interest groups, and citizens.

The Technical Team conducted a group exercise in which each criteria was considered relative to each other, in importance to the storage mission. The results of this criteria ranking led to the assignment of a numerical value for each criteria, which was then normalized across all criteria to give the criteria weights. The candidates were rated using high, medium, low discriminators (H, M, L) to compare the candidate facilities relative to each other. The seven candidate facilities for the long-term $^{233}$U storage included: (1) the ORNL Radiochemical Development Facility, Building 3019 complex (the current $^{233}$U repository); (2) the INEEL UFSF, designated Building 651; (3) a generic modular vault facility located in a undefined secure, guarded area, such as the Idaho Nuclear Technology and Engineering Center (INTEC) site, the Oak Ridge Operations Y-12 Plant area, or other similar DOE site; (4) the ORNL transuranic materials processing facility in Building 7930; (5) the SRS-APSF; (6) the SRS GWSF; and, (7) the Transfer and Storage Facility (not yet built), also at the SRS.

During the ranking process it became apparent that two facility classes or groups were being proposed that could not be adequately compared to each other. They were the "new" facilities (the modular facility, the SRS-APSF, and the Transfer and Storage Facility), and the "existing" facilities (ORNL Building 3019, INEEL Building 651, ORNL Building 7930, and SRS-GWSF as described above). These two groups of facilities were ranked within their respective groups, and the ratings of these facility options are given below. Table 1 gives the high, medium, low (H, M, L) original ratings by the work group. The assignment of numerical values to the ratings (H=3, M=2, L=1) provides further evaluation using the previously determined weighting factors and gives the overall rating/ranking of the options applying the weighting factors to the numerical ratings. Table 1 provides the results of the candidate screening process.

**Table 1. Initial Performance Screening Results**

| Performance Measure[a] | B 3019 | B651 | Mod Facility | B7930 | APSF-SR | GWSF. | Trans/ Store |
|---|---|---|---|---|---|---|---|
| ES&H risk/Authorization[b] | H/M | H/H | H/H | M/H | H/H | M/H | H/H |
| Safeguards and security | H | H | H | M | H | L | H |
| Operational performance | H | M | H | M | H | L | H |
| Initial cost | H | M | L | M | L | L | H |
| Life cycle cost | M | M | L | H | L | H | H |
| Timeliness | H | H | L | M | M | L | L |
| Stakeholder acceptance | H | L | L | H | L | M | L |

[a] Performance Measure
H= High performance relative to other facilities.
M= Medium performance relative to other facilities.
L= Low performance relative to other facilities.
[b] This category was split into Environmental, Safety and Health (ES&H) and Facility Authorization.

The relative ranking of the existing facilities was from best to worst: ORNL Building 3019, INEEL Building 651, ORNL Building 7930, SRS-GWSF. The relative ranking of the "new facilities" was SRS Transfer/Storage Facility, Modular Facility, SRS-APSF. After a review of the rankings and facility discussions, the GWSF was eliminated from further consideration due to the low rankings in multiple areas including the safeguards and security area. Also, the GWSF had availability and operational (material treatment) shortfalls. These facilities were screened down to a final three (eventually four options) using the criteria given above that was developed by the working group.

The four final storage options were compared mainly on a cost basis for the safe storage mission. This report details this comparison which reexamine each candidate facility scenario, specific needs, and associated modifications to put these facilities in condition for long-term storage of $^{233}U$ materials. The costs associated with long-term storage of these materials at each site were then determined. Guidelines for the comparative, long-term storage estimates included the costs to remove, inspect, and restore 5% (approximately 60) of the canisters per year. Another guideline used in comparing the long-term storage costs was to estimate the cost to open, inspect, process, and repack one container per year. One container per year was selected for processing/repackaging guideline because this operation starts after all the containers have completed the initial inspection and repackaging campaign, and they should be in good condition. This estimate guideline ensures that each facility had the capability to process the $^{233}U$ resource materials for stability, and to repackage the materials as needed based on the results of continued material inspections.
This capability may also be needed to recover valuable isotopic content for medical or other purposes. The number of containers processed per year could be increased substantially for each option considered, but this

increased throughput is not considered in the cost estimate, since the actual numbers are unknown, and this estimate is applied equally to all options for comparative purposes.

## 1.4 INVENTORY DESCRIPTION OF $^{233}U$

The entire separated $^{233}U$ inventory at ORNL consists of approximately 1,000 kg of fissile uranium (both U-233 and U-235). This material is contained in approximately 1,200 containers (after consolidation) having a nominal 4-in. diameter, and varying from 4 inches to 2 ft in length (see Figure 1 for a photo of typical storage containers). The Molten Salt Reactor Experiment (MSRE) $^{233}U$ inventory and other "small holding" inventories from other sites will be part of the 1,200 packages expected after completion of the stabilization and repackaging tasks. The $^{233}U$ inventories excluded from this study consist of the Light Water Breeder Reactor (LWBR) unirradiated fuel elements which contain $^{233}UO_2$ as a mixed $UO_2$-$ThO_2$ blend that are stored at INEEL. For handling purposes, it was estimated that approximately 500 containers could be considered "high purity" material (containing less than 50 ppm $^{232}U$), which can have gamma radiation levels reading up to 2 R/hr at 1 foot distance from the package surface. The remaining material could be lumped into a "low purity" category (containing 50 ppm or more $^{232}U$), with radiation levels from several R/hr to greater than 50 R/hr at 1 foot. Table 2 shows the current $^{233}U$ storage inventory in Building 3019, and contains information on the type of material, package, and inspection plan for these containers.

The largest ORNL $^{233}U$ inventory grouping consists of the 403 containers from the Consolidated Edison Uranium Solidification Project (CEUSP). This material is classified in the "low value" category, contains about 62 weight percent uranium (mixed $^{233}U$ and $^{235}U$), and consists of an oxide monolith solidified into 24-in. long stainless steel containers (see Figure 1 for typical $^{233}U$ container configurations, the outer and inner CEUSP containers are the left two, respectively). The CEUSP material is stored in Building 3019, along with 27 containers of similarly prepared, non-CEUSP material. Other large inventory groups include 140 containers of low value, oxide powder and approximately 130 containers of high value $U_3O_8$, which has less than 10 ppm of $^{232}U$. Another large quantity of high value $^{233}U$ is contained in 68 cans as uranium oxide powder. The group containing the largest number of individual items (1,743) is the unirradiated zero power reactor fuel plates. Each plate is 2×3×0.25 in. and consists of $^{233}U_3O_8$ encapsulated in stainless steel. These plates were packaged into 130 tin-plate secondary containers and placed into storage at Building 3019 in 1985. The bulk of the $^{233}U$ metal in storage consists of large pieces, but some is in the form of metal foils. Other $^{233}U$ "small holdings" exist at other sites in various forms, including oxide, metal and uranium compounds. Building 3019 currently stores most of the separated DOE $^{233}U$ material inventory. See Table 2 for a complete listing of the $^{233}U$ inventory in Building 3019.


**Figure 1. Typical U-233 Storage Containers used in ORNL Building 3019.[3]**

## Table 2. Uranium-233 in Building 3019 Storage Tube Vaults[a]

| Reference Figure | Material Form | Package Assembly | Package Configuration | No. of Outer Packages | $^{233}$U (kg) | $^{232}$U (ppm) | Total U (kg) | Risk Category | Initial Inspection Plan |
|---|---|---|---|---|---|---|---|---|---|
| Fig. A.1 | U Metal | LANL | Unique SST | 2 | 5.89 | 40 | 6.02 | Medium | Repackage |
| Fig. A.2 | U Oxide Powder | Savannah River SRO-9 | Welded Al in Welded Al | 6 | 2.98 | 7 | 3.05 | Lower | NDE |
| Fig. A.3 | U Oxide Powder | Savannah River LZB | Welded Al in Welded Al | 6 | 2.94 | 4.5 | 2.99 | Lower | NDE |
| Fig. A.4 Fig. A.24 | U Oxide Powder | ORNL-RDF samples | Tin-plated steel over plastic bagged sample vials | 10 | 0.82 | 6-10 | 0.83 | Lower | Repackage |
| Fig. A.5 | $UF_4 \cdot LiF$ | RCP-04 | Welded Ni in Al | 2 | 1.06 | 220 | 1.16 | Medium | Stabilize |
| Fig. A.6 | $UF_4 \cdot LiF$ | RCP-04 | Screw-top Al in Al | 1 | 1.55 | 220 | 1.70 | Higher | Stabilize |
| Fig. A.7 | $UF_4 \cdot LiF$ | RCP-04 | SST in welded Al | 1 | 0.31 | 220 | 0.34 | Medium | Stabilize |
| Fig. A.8 | $U_3O_8$ Monolith | CEUSP | Tin-plated steel over welded SST | 403 | 101.14 | 140 | 1042.59 | Lower | NDE 24 packages |
| Fig. A.8 | $U_3O_8$ Monolith | RCP-06 | Tin-plated steel over welded SST | 27 | 60.27 | 20 | 65.19 | Lower | NDE |
| Fig. A.9 | U Oxide Powder | Savannah River aluminum (RCP-02) | Welded Al in welded Al | 27 | 10.72 | 38 | 11.14 | Lower | NDE |
| Fig. A.9 | U Oxide Powder | Savannah River aluminum (RCP-03) | Welded Al in welded Al | 140 | 61.57 | 220 | 67.37 | Medium | NDE 24 packages |
| Fig. A.10 | U Oxide Powder | Short oxide-product can (PZA BPL) | Tin-plated steel over plastic-bagged SST | 22 | 15.02 | 6 | 15.36 | Lower | Overpack |
| Fig. A.10 | U Oxide Powder | Short oxide-product can | Tin-plated steel over plastic-bagged SST | 68 | 54.64 | 6.5 – 10 | 58.98 | Lower | Overpack |
| Fig. A.11 | U Oxide Powder | Tall oxide-product can | Tin-plated steel over plastic-bagged SST | 71 | 33.51 | 5.6–8.3 | 34.41 | Lower | Overpack |
| Fig. A.12 | U Oxide Powder | Mound | Glass within SST within SST | 19 | 3.29 | 2 – 16 | 3.45 | Lower | NDE |
| Fig. A.13 | $U_3O_8$ Powder | ANL-ZPR (5 Packet) | Welded Ni-plated SST packets within tin-plated steel | 2 | 0.27 | 7 | 0.28 | Lower | Overpack |
| Fig. A.14 | $U_3O_8$ Powder | ANL-ZPR (12 Packet) | Welded Ni-plated SST packets within tin-plated steel | 101 | 32.94 | 7 | 33.61 | Lower | Overpack |
| Fig. A.15 | $U_3O_8$ Powder | ANL-ZPR (16 Packet) | Welded Ni-plated SST packets within tin-plated steel | 27 | 11.83 | 7 | 12.07 | Lower | Overpack |
| Fig. A.16 | U Metal | ANL-ZPR (Metal) | Welded Ni-plated SST packets within tin-plated steel | 1 | 0.56 | 5 | 0.57 | Lower | Overpack |
| Fig. A.17 | U Oxide Powder | Oxide | Tin-plated steel over plastic bagged tin-plated steel | 6 | 1.48 | 7 – 10.8 | 1.53 | Lower | Repackage |
| Fig. A.18 | U Oxide Powder | Oxide scrap | Tin-plated steel over plastic bagged tin-plated steel | 7 | 3.80 | 6 – 42 | 3.88 | Lower | Repackage |
| Fig. A.19 | U Metal | RCP-20(#2&#3) | Tin-plated steel over plastic bagged tin-plated steel | 2 | 3.99 | 5 – 42 | 4.06 | Medium | Repackage |
| Fig. A.19 | U Metal | Metal scrap | Tin-plated steel over plastic bagged tin-plated steel | 3 | 0.53 | 5 – 42 | 0.54 | Lower | Repackage |
| Fig. A.20 | Ammonium Diuranate Powder | ADU scrap | Tin-plated steel over plastic bagged tin-plated steel | 1 | 0.00 | 7 | 0.00 | Lower | Stabilize |
| Fig. A.21 | U Oxide Powder | Hanford HUA-2 | SST in welded SST | 6 | 0.35 | 8 – 38 | 0.36 | Lower | NDE |
| Fig. A.22 | U Metal | LANL AUA-84 | Welded SST in welded SST | 3 | 0.49 | 8 | 0.49 | Lower | NDE |
| Fig. A.23 | U Oxide Microspheres | ORNL-RDF misc. samples | Plastic-bagged glass in cardboard within tin-plated steel | 3 | 0.39 | 7 | 0.40 | Lower | Repackage |
| Fig. A.25 | Ammonium Diuranate Powder | ADU Product | Tin-plated steel over plastic-bagged SST | 1 | 0.09 | 7 | 0.10 | Lower | Stabilize |

## Table 2. Uranium-233 in Building 3019 Storage Tube Vaults (continued)

| Reference Figure | Material Form | Package Assembly | Package Configuration | No. of Outer Packages | $^{233}$U (kg) | $^{232}$U (ppm) | Total U (kg) | Risk Category | Initial Inspection Plan |
|---|---|---|---|---|---|---|---|---|---|
| Fig. A.26 | UO2 Powder | KZA-8 | Tin-plated steel over tin-plated steel | 1 | 0.19 | 2.5 | 0.20 | Lower | Repackage |
| Fig. A.27 | U Oxide Powder | ARF-32 | Tin-plated steel over SST | 1 | 0.07 | 7 | 0.08 | Lower | Overpack |
| Fig. A.28 | U3O8 Powder | FZA-88 | Tin-plated steel over unknown | 2 | 0.02 | 5 | 0.02 | Lower | Repackage |
| Fig. A.29 | U Foil | CZA-90 | Tin-plated steel over welded SST | 1 | 0.57 | 5 | 0.58 | Lower | Stabilize |
| Fig. A.30 | U Metal | ARF-33 Metal | Tin-plated steel over tin-plated steel | 4 | 1.43 | 7 | 1.46 | Lower | Repackage |
| Fig. A.31 | U Oxides and U Foil | CZD-G (CZ) | Tin-plated steel over glass | 1 | 0.09 | 1 | 0.09 | Lower | Stabilize |
| Fig. A.32 | U Foil | CZD-G (CX) | Tin-plated steel over plastic | 1 | 0.01 | 6 | 0.01 | Lower | Stabilize |
| Fig. A.33 | U Metal | SNM-4031 | Tin-plated steel over glass | 1 | 0.03 | 1 | 0.03 | Lower | Repackage |
| Fig. A.34 | U Metal Button & Plates | CZA-93(U-233-4) | Tin-plated steel over glass | 1 | 1.25 | 5 | 1.28 | Lower | Repackage |
| Fig. A.34 | Oxides & Metal Pieces & Foil | CZA-93(U-233-5) | Welded SST over tin-plated steel | 1 | 1.06 | 42 | 1.08 | Lower | Stabilize |
| Fig. A.35 | U Metal | AUA-84 (Jar) | Welded SST over unknown | 2 | 0.46 | 8 | 0.47 | Lower | Repackage |
| Fig. A.36 | U Metal | CZA-91 | Tin-plated steel over welded SST | 1 | 0.86 | 42 | 0.88 | Lower | Overpack |
| Fig. A.37 | U Metal | KZA-G1B | Welded SST in welded SST | 3 | 0.24 | 5 | 0.24 | Lower | NDE |
| Fig. A.38 | U Metal | SNM-9514 & LAE-03 | Tin-plated steel over unknown | 2 | 0.02 | 50 | 0.02 | Lower | Repackage |
| Fig. A.39 | U Metal | LAW-40 | Tin-plated steel over plastic | 1 | 0.52 | 4 | 0.53 | Lower | Repackage |
| Fig. A.40 | U Oxide Powder | PZA-126 | SST in welded SST | 1 | 0.28 | 1 | 0.28 | Lower | NDE |
| Fig. A.41 | U Oxide Powder | ARF-33 Oxide | SST in SST | 2 | 1.21 | 7 | 1.24 | Lower | NDE |
| Fig. A.42 | U Oxide Powder | ASA-94 (233-1,2,3-74) | Tin-plated steel over plastic | 3 | 1.43 | 7 | 1.46 | Lower | Repackage |
| Fig. A.43 | U Oxide Powder | ASA-94 (233-4-74) | Tin-plated steel over tin-plated steel | 1 | 0.24 | 7 | 0.24 | Lower | Repackage |
| Fig. A.44 | UO2 Powder | CZA-92 | Welded SST in welded SST | 1 | 2.25 | 5 | 2.29 | Lower | NDE |
| Fig. A.45 | U Oxide Powder | LZB-18 | Tin-plated steel over welded SST | 3 | 1.04 | 7 | 1.06 | Lower | Overpack |
| Fig. A.46 | U Oxide Microspheres | MM-4899 | Tin-plated steel over glass | 1 | 0.13 | 7 | 0.14 | Lower | Repackage |
| Fig. A.47 | UF4 Powder | CZD-G (CY) | Tin-plated steel over glass | 1 | 0.02 | 70 | 0.02 | Lower | Stabilize |
| Fig. A.48 | U Oxide Powder | RCP-10[b] | Tin-plated steel over unknown | 2 | 0.38 | 4 | 0.39 | Lower | Repackage |
| Fig. A.49 | U Metal | TAR-LB1[b] | Welded SST in welded SST | 1 | 0.12 | 0.45 | 0.12 | Lower | NDE |
| Fig. A.50 | U Oxide Powder | BA-35-1[b] | SST in welded SST | 1 | 0.00 | 1 | 0.00 | Lower | NDE |
| Fig. A.12 | U Oxide Powder | MURO-18[c] | Glass within SST within SST | 1 | 0.20 | 2 | 0.20 | Lower | NDE |
| | | | Totals | 1009 | 426.54 | | 1386.86 | | |

[a] As of 7/15/98 does not include material recovered from MSRE. This material will become part of 97-1 Recommendation scope after the material is stabilized.

[b] Material removed from the vaults on 5/28/98.

[c] Material removed from the vaults on 7/15/98.

## 1.5 INVENTORY STORAGE REQUIREMENTS FOR URANIUM-233[1,2]

The storage requirements for fissile materials must take into consideration containment, criticality control, safeguards, and shielding. Uranium-233 has some similar properties to Highly Enriched Uranium (HEU) and plutonium, and it has its own unique properties which are different from HEU and plutonium and require some differences in storage/handling. A convenient vault system to accommodate the above-mentioned requirements is the tube vault. The vault configuration must consider vault spacing and diameter to accommodate a maximum storage container diameter of 4 inches (taking into consideration a safety margin for criticality concerns). The quantity of separated $^{233}$U requires approximately 2,000 linear feet of tube vault capacity. Approximately half of the $^{233}$U material is considered impure or of "low value" (contains relatively high levels of $^{232}$U). The low value materials significantly complicate handling due to the $^{232}$U decay chain product $^{208}$Tl, which produces a highly penetrating 2.6 MeV gamma-ray. Uranium-233 also has some differences from HEU and plutonium in terms of criticality and safeguard requirements. As defined by the International Atomic Energy Agency, a Category I quantity of $^{233}$U in the context of physical security is 2 kg which is the same as that for plutonium. However, a Category I quantity of $^{235}$U is 5 kg. Category I quantities of weapons-usable materials are quantities sufficiently large to allow weapons construction, and mandate special accounting and security measures. Unlike HEU, there is not an agreed on definition of the isotopic percentage of $^{233}$U material necessary to constitute it weapons usable. Thus, even very low isotopic material must be placed under safeguards measures. The tube vault can be easily configured with a secure access hatch to limit unauthorized usage if necessary. A combination of efficient shielding, safeguard assurance, and configuration control for criticality, as well as physical protection and containment, make tube vaults attractive for $^{233}$U storage.

# 2. CANDIDATE $^{233}$U REPOSITORY FACILITY DESCRIPTIONS

## 2.1 BUILDING 3019 (ORNL)

Building 3019 is an ORNL facility built during the Manhattan Project and is approximately 55 years old (see Figure 2 for a photograph of Building 3019). The building has several adjacent support buildings located inside a fenced area. These include the 60-meter-tall ventilation off-gas stack (Building 3020), the two ventilation off-gas filter houses (Buildings 3108 and 3091), two diesel-powered electrical generators house (Building 3122), a mock-up test and storage building (Building 3136), a storage vault (Building 3100), and two storage tank pits. The building is on a hillside with the north side at a higher level than the south side, hence, the “ground level” facilities actually are at different elevations. The original core of Building 3019 was constructed of reinforced concrete and steel, and contains several irregular floor levels and add-ons since the original construction. The shielded hot cells in Building 3019 are built of poured, reinforced concrete. These cells are similar to miniature process canyons and were used for pilot-scale, remote process demonstrations. The outer cell walls on the north, east, and west sides are 5 ft thick, and those on the south side and the top are 4 ft thick. The interior walls separating Cells 1 through 6 have a thickness of 5 ft. Cell 1 has nominal floor dimensions of roughly 10 × 20 ft, whereas each of Cells 2–7 have floor dimensions of roughly 20 × 20 ft. Cells 6 and 7 form a double cell (20 × 40 ft cell) separated only by a partial wall. All of the cells have floor-to-ceiling heights of roughly 27 ft. Each cell has a 9 ft × 9 ft hatch in the southwestern corner of the cell roof for use as an equipment portal.

This facility currently serves as the $^{233}$U National Repository, storing most of the separated $^{233}$U material considered in this study. Section 1.4 provides a discussion of the inventory of fissile materials currently stored and soon to be consolidated in Building 3019. The facility was designed and constructed to develop and demonstrate fissile materials reprocessing flowsheets. The early mission of the facility included plutonium separation activities. The building is divided into an A and B section providing a total of approximately 55,000 sq. ft of floor space. In the late 1940's and early 1950's, the Building 3019A mission was expanded to demonstrate Purex and Thorex nuclear fuels processing. During the mid-1950's the far west wing of Building 3019 (now designated as Building 3019B) was added to service as a multi-program analytical services facility for radioactive materials. In 1962, Building 3019A began serving as the $^{233}$U National Repository. Today, Building 3019B is considered a surplus facility and is in standby operation. However, Building 3019A continues the mission of $^{233}$U materials storage, and is the candidate facility described herein.

Building 3019A contains shielded remote processing cells in which tube vaults are located for storing highly radioactive fissile isotopes. The facility also has hoods, glovebox laboratories, and other support equipment for radiochemical process development and decontamination operations. The heavily shielded tube vaults are ventilated through high-efficiency particulate air (HEPA) filters and are accessible from the Penthouse (see Figure 3 for a schematic of the Building 3019 cell layout). The radioactive materials processed and handled in the facility are normally contained in the equipment that is enclosed in the gloveboxes, or shielded enclosures. These areas are considered primary containment areas and are maintained at a negative pressure with respect to the surrounding rooms by the ventilation systems. The surrounding rooms are considered secondary containment areas and are maintained at a negative pressure with respect to outside atmosphere.

**Figure 2. Photograph of Building 3019.**

**Figure 3. Schematic of Building 3019 Cell Layout.**

Conditioned air supply is provided by four different systems which provide supply air to various rooms and areas of the building. There are two large exhaust fans on the west side of the stack, and two large fans on the east side of the stack that serve to exhaust the main building after HEPA filtration. Each side normally has one fan in operation and one on standby. Back up electrical power for these fans is provided by one of two diesel generators connected in a configuration to ensure reliable service.

The facility Glovebox Off-Gas (GBOG) system is designed to provide a relatively high-volume flow of air through the gloveboxes and shielded manipulator boxes at low differential pressure. Three electrically driven fans serve this system in a configuration where one fan operates, one is on standby, and one is off. Standby power is provided by the aforementioned diesel generators. The inlet and outlet air flowing through each glovebox is filtered through HEPA filters. Additionally, the air flowing through the GBOG header is filtered through two stages of HEPA filters.

The facility Vessel Off-Gas (VOG) system is a low-flow/high vacuum system through which off-gases from the storage tube vaults and process vessels are treated and vented. The VOG normally is routed to the 3039 stack area where it is scrubbed with caustic to remove acidic vapors before being HEPA filtered and exhausted. Back up exhaust ventilation for the VOG is provided by the east branch of the building ventilation system.

Electrical power is supplied to Building 3019 from ORNL's 2.4 kV distribution system through five substations. Major loads on the system are the Radiation Confinement Ventilation Control Board and the Motor Control Centers (MCCs). Standby power is provided by the two aforementioned diesel generators. Each MCC contains an automatic transfer switch (ATS) that senses loss of power on the connected utility supply and switches between normal and standby power as appropriate. The ATS's also send start and stop signals to the standby generators as required.

Building 3019 is connected to the ORNL fire-protection water system at the fire equipment room on the south side of the building. Control valves and volume-limiting timers are also located in the fire equipment room. Most of the building is protected by a conventional, automatic wet-type sprinkler system. Cells 3, 5, 6, and 7 are protected by a dry pipe or deluge system. The facility is served by two master fire alarm boxes and four auxiliary fire boxes. When a master fire box is actuated (either directly or indirectly by a signal from one of the auxiliary boxes), an alarm is automatically transmitted to the Fire Department, indicating the master box number, the appropriate local fire zone identification light is activated, and the building's audible alarm is sounded.

The monitoring and protection systems for Building 3019 consist of radiation, contamination confinement, ventilation, atmospheric, and temperature measurement, control instrumentation, and out-of-limits alarms. The facility has a Criticality Accident Alarm System (CAAS) that consists of neutron detectors strategically located to detect a criticality incident and the electronics necessary to process and interpret the signals received from the neutron monitors and activate the appropriate alarm or warning lights. The neutron monitors are grouped into coincidence circuits to prevent unnecessary evacuation of the building due to a single instrument failure. The probability of occurrence of a criticality incident is kept extremely low by employing the double contingency principle, using combinations of means which include geometrically favorable equipment, neutron poisons, and administrative control of mass concentrations of fissile material.

Facility security is provided by a system of hardened barriers, surveillance monitors, and on-site security response force. Special access doors and vault closures contribute to the time delay required for access needed to ensure a secure storage facility.

In 1996, a Basis for Interim Operation (BIO) document was prepared to evaluate the operation of the Building 3019 complex and provides the derivation for the Operational Safety Requirements (OSR). The BIO was developed to ensure that Building 3019 could be operated safely until approval of a full Safety Analysis Report (SAR) meeting the requirements of 10 *CFR* 830.110 and DOE Order 5480.23, and until approval of a Technical Safety Requirements (TSR) document meeting the requirements of proposed rule 10 *CFR* 830.320 and DOE Order 5480.22. The BIO with its accompanying OSR currently serve as the authorization basis for the building. The safety analysis contained in the BIO includes a Process Hazards Analysis (PHA) for operations at the facility. Building 3019 is fully operational and the authorization basis permits material handling, processing, and storage as a Category 2 nuclear facility.

Planned future upgrades to Building 3019 include continued safety documentation upgrades and a series of modifications to the heating, ventilating, and air-conditioning (HVAC), including cell off-gas (COG), VOG, and GBOG systems. These system upgrades will reduce the probability and severity of prospective damage from natural phenomena events, and other risks identified in the facility hazards analysis. Considerable $^{233}$U infrastructure is in place at Building 3019 (authorization and supporting documents, personnel training and certification, and instrument modification and calibration, etc.) which would have to be replicated for any new storage facility.

The $^{233}$U material is stored in 4- to 4.5-in. diam., 8- to 30-ft deep, storage tube vaults located in and around the central hot cell structure of the facility. Access to the storage vaults is via the upper floor or "penthouse" structure of the facility. A ten-ton overhead crane system allows the loading of packages into the bottom of a shielded cask that can be used to transfer the contents to another shielded carrier or to the repackaging or processing hot cell facilities in the adjacent cell structures. Currently, two remotely operated hot cells are being installed within the structure of Building 3019; the repackaging hot cell and the processing hot cell. The repackaging cell is not added to the long-term $^{233}$U storage costs because this cost is an up-front cost that will take place prior to, and be independent of, the selection of a final storage facility. The Non-Destructive Evaluation (NDE) equipment for digital radiography of containers and the Non-Destructive Assay (NDA) equipment for measurement and evaluation of package contents for the initial repackaging campaign, are also excluded from this estimate. The processing cell costs are included in the Building 3019 preparative cost estimates, since it will be used for storage task processing.

## 2.2 BUILDING 7930 (ORNL)

Building 7930, formerly known as the Thorium-Uranium Recycle Facility (TURF), is part of the REDC. The facility is divided into four major areas: (1) a cell complex having seven cells, six shielded and one unshielded; (2) maintenance and service areas surrounding the cell complex; (3) an operating control area; and, (4) an office area adjacent to, but isolated from, the operating areas. The three-story structure with partial basement was designed in accordance with the Southern Building Code for Group G industrial occupancy. It is constructed of structural steel, reinforced concrete, and masonry. Perimeter walls are of reinforced concrete block. Floors are reinforced concrete slabs that are either poured on compacted aggregate, or supported on structural steel. The roof is metal decking covered with built-up roofing. The building is essentially rectangular with an overall width of 124 ft, and overall length of 161 ft, and a gross floor area of 32,950 sq. ft., exclusive of hot cells. The cell complex adds approximately 3,080 sq. ft. The total enclosed volume is approximately 646,000 cu. ft. The facility contains four heavily shielded cells that were designed for remote processing of $^{233}$U/Th reactor fuels (see Figure 4, Building 7930 photograph).

The facility was constructed during 1964-1967 to develop and demonstrate the remote refabrication of $^{233}$U/Th fuel materials for recycle into power reactors. However, the program was canceled prior to the installation of any processing equipment. A portion of the building was used to prepare the $^{233}$U fuel salt

**Figure 4. Building 7930 Photograph.**

for the MSRE program, but otherwise the facility was not been used for its design purpose. The facility is part of the REDC transuranium materials processing facility, and is currently used as a small-scale radiochemical processing facility to chemically process and fabricate $^{252}Cf$ materials into neutron sources. Chemical processing activity is conducted in Cell G and includes pressurized ion exchange, pressurized extraction chromatography, resin loading-calcination, and oxalate precipitation-calcination. Special $^{252}Cf$ neutron sources are also fabricated in Cell G. Cell G is the only cell in which significant amounts of unencapsulated radioactive materials are currently handled. Cell B is used only for loading and unloading small shipping casks. Cell A and its vestibule are used only to gain entry into Cells B and C when no contamination or sources of penetrating radiation are present. Outside of the hot cells, radioactive materials are handled in the water-filled storage basin, in gloveboxes in the basement glovebox laboratory, and in the roof area over Cell G where sampling and maintenance activities are performed in a glovebox connected to Cell G. Equipment and solid waste are inserted into and removed from the cell through removable hatches and shield plugs.

Two of the highly shielded facility cells, Cells D and E, are currently empty and uncontaminated, and are being considered for several potential programs. Cell D is 41 ft long, 20 ft wide and 24 ft high. Cell E is 16 ft long, 20 ft wide and 30 ft high. The cell walls are lined with 0.25-in. thick type 304 stainless steel. Ingress and egress of equipment is through large concrete roof hatches using a 50-ton crane, or through smaller steel doors in the facility walls using an in-cell 5-ton crane. Portions of Cells D and E could be configured to support long-term $^{233}U$ storage and processing missions. Preliminary estimates indicate the storage of the $^{233}U$ material would require the addition of approximately 2,000 linear feet of storage well vault. However, the use of Cells D and E in this manner would preclude other isotope production missions.

A concept of a storage arrangement was developed for the $^{233}U$ storage in Cells D and E, and included a supporting structural evaluation.[4,5] Arrays of 48 storage tubes in Cell E, each 30 ft in length, and 30 wells in Cell D, each 24 ft in length (see cell schematics in Figures 5 and 6) were conceptually designed as part of this study. Portions of the Cell D and E roof would require modification to accommodate the storage arrays and access doors to support individual, security interlocked access/shielding closure for each storage tubular vault. The facility would require procurement and installation of equipment for $^{233}U$ processing, treatment and repackaging; however, the hot cell structure and associated support systems already exist and would only require equipment installation.

Since other isotope production and storage missions have been proposed for Cells D and E, a second concept for Building 7930 storage of $^{233}U$ containers would be the utilization of Cell F, located in the basement. The cell measures approximately 37 × 17 × 15 ft and could be configured with wells and retrieval equipment for required operations. This option is more desirable than Cell D and E for $^{233}U$ storage because it conserves Cell D and E areas for actinide processes and future programs, consolidates the uranium in one area, and the cost estimates are no higher (see Figure 5 for Cells D, E, and F location, and Figure 6 for storage tube vault schematics). The Cell F option for $^{233}U$ storage is based on increasing cell wall thickness to 4 ft, and constructing a series of 336 7-ft storage wells. These wells are constructed in 84 sets of 4 wells arranged in 2 ft × 2 ft arrays. These wells would be accessed by a low headspace crane mechanism on a x-y positioner system. The retrieved canisters would then be accessed through a Cell F secured and safeguarded ceiling entry door (Cell B floor access hatch) using a special crane assembly and bottom loading transfer cask through Cell B. A preliminary cost estimation was conducted for $^{233}U$ storage in Cell F and compared to the original estimate of using Cells D and E. Even though the Cell F storage arrangement is different than Cells D and E, the storage cost is similar. Cell F is considered here as the preferred $^{233}U$ storage option for Building 7930 with no significant, if any, cost increase over the Cell D and E storage arrangement.

**Figure 5.  Building 7930 Schematic.**

**Figure 6. Building 7930 Cell Schematic (Proposed Storage Modifications)**

Physical barriers and the ventilation system provide containment and confinement of the radioactive materials in Building 7930. Cell G constitutes the primary containment barrier for large quantities of radioactive solutions and powders. During normal operations, Cell G is maintained at a vacuum of at least 1-in. water gauge with respect to the secondary containment spaces. Cells A, B, C, D, E and F, and the building walls surrounding the cell bank constitute the secondary containment barrier, which is maintained at a vacuum of a nominal 0.3-in, water gauge with respect to the environment. All cells are ventilated by air drawn from occupied areas of the building through HEPA filters and back-flow preventers, and then through the cells on a once-through basis. The purge air leaving the cells is filtered at the point of exit by high capacity roughing filters. After leaving the cells, the air is filtered through two stages of HEPA filters and discharged to the atmosphere through a 250-ft tall stack. The COG system HEPA filters are in a shielded concrete pit located southwest of the building. The COG system is provided with a redundant (spare) exhaust fan that is switched into service automatically if the operating unit fails and is backed up by a diesel-powered generator.

Building 7930 service and utility systems include electric power, compressed air, water, steam and various cylinder gases. If normal electric power fails, a diesel generator located in Building 7931 will start automatically and supply essential buses through load sequencing. A compressed air system provides air for instruments and controls, the pneumatic transfer systems and other uses. It is backed up by the air supply system in Building 7920, with automatic switch over. The air compressors in Buildings 7920 and 7930 have separate backup power systems, and both are provided with backup cooling water.

Water systems include potable water, process water, demineralized water, cooling tower water, and fire protection water. Chilled water and hot water for building space heating and cooling are also available. Steam is supplied from the ORNL plant for building heat and for steam in Cells E, F, G, and the waste pit. Tower water is used for cooling the air compressors, and the chiller and refrigeration unit on the air supply systems.

Building 7930 employs radiation detection instruments to monitor and indicate changes in gamma radiation levels above background. Neutron monitors are also used in the facility to indicate changes from the very low neutron background in the areas served by the detectors. Continuous alpha air monitors are used to provide local indications of airborne alpha activity and alert operating personnel of potential contamination in the areas being monitored.

Upgrades would be required in the safeguards and security systems to qualify the building to store and handle Attractiveness Category I material. Safeguards arrangements utilizing time delays and remote monitoring equipment tied into on-site security and response forces would be instituted similar to the current Building 3019 implementation.[6] This security approach is utilized for the facility cost analysis and would alleviate a significant upgrade cost that would be incurred for the procurement and installation of a perimeter intrusion detection and surveillance (PIDAS) system and a dedicated facility security force.

Building 7930 maintains a fire protection system consistent with applicable standards and requirements. Fire protection and prevention, including maintenance and modification of the systems, are supervised by the ORNL Fire Department. The building is protected by an approved sprinkler system, including those cells being used for process operations.

Some Building 7930 systems would require upgrading, including criticality accident alarm systems. Relocation of the $^{233}U$ from Building 3019 to Building 7930 would require the intra-site transport as described in the transportation section (Section 3.11). Building 7930 currently has a long-term mission to prepare $^{252}Cf$ radioisotope sources and targets which was cost shared within the facility operations estimate. Also, Building 7930 has been proposed by ORNL to conduct additional missions to process/store specific transuranic (TRU) isotopes (Np/Pu-238 and Am/Cm). DOE has not made a decision about the proposed programs. Sharing of the operating costs, and some up-front cell modification costs with these additional programs could result in additional cost savings to this program. However, only the current $^{252}$Cf program operating cost is considered in this evaluation and the benefits associated with other potential programs are not included.

In 1995, a BIO document was completed for Building 7930 to evaluate operation of the facility and insure that it could be operated safely until approval of a full SAR meeting the requirements of 10 *CFR* 830.110 and DOE 5480.23 and approval of a TSR document meeting the requirements of 10 *CFR* 830.320 and DOE Order 5480.22. The BIO currently serves as a major part of the authorization basis for operating the building. DOE approved the last update of the Building 7930 OSRs in June 1998. A facility hazard classification was performed on Building 7930 in accordance with DOE-STD-1027-92. Currently the building is classified as a Category 3 facility suitable for handling inventories of low activity isotopes and sealed sources of $^{252}$Cf. The facility would require upgrades to a Category 2 facility for handling the $^{233}$U inventory.

## 2.3 BUILDING 651 UNIRRADIATED FUEL STORAGE FACILITY (INEEL BUILDING UFSF)

### 2.3.1 Option 651A - Expansion of Building 651

Building 651 is located in the INTEC. The building is a two-compartment, inner-vault, bunker-type building, measuring approximately 42 ft wide × 45 ft long and is surrounded by reinforced concrete. It is currently being used to store unirradiated $^{235}$U material. The facility originally consisted of two inner vaults. However, in 1984 the original facility was enclosed within an outer reinforced concrete shell to provide upgraded security and safeguards protection for the stored material. Access to the building is through multiple hydraulically operated double doors. As currently configured, the facility is an unoccupied storage vault. There are no personnel or materials processing systems configured in this facility.

The inner vault building is divided into two vault areas separated by a 12 inch thick reinforced concrete wall. The north vault area is 25 ft long × 19 ft wide. The south vault of the building is an L-shaped area that includes the remainder of the internal vault area. Access to the vault areas is provided through a receiving area on the west side of the facility, which measures approximately 20 ft × 42 ft, through a combination locked sliding door, followed by key-locked, hinged, double doors. The south vault is divided into six storage areas each approximately 10 ft × 12 ft. Fissile materials are stored in the vault area in specially designed racks, cabinets, boxes, or drums. The exterior walls are sloping “bunker type” on 3 sides varying in thickness from approximately 12 feet at the bottom to approximately 2 feet at the top (see Figure 7).

Nearby radiochemistry hot cell facilities exist at the INEEL Remote Analytical Laboratory (RAL). However, the hot cells would require upgrades and modifications for $^{233}$U material processing, treatment, and repackaging. Building 651 has a nuclear CAAS that is required to be functional at all times. The system employs three detection clusters with three detectors per cluster, a data acquisition system (DAS), three sirens, an uninterruptible power supply (UPS) system. Criticality Safety Evaluations (CSEs) are implemented by technical standards for the fuel handling and storage operations. Alpha constant air monitors (CAMs) are used during material handling operations, along with portable radiation instrumentation operated by health physics personnel. The facility was constructed with engineered safety features that provide security integrity and personnel protection. Ventilation is provided in the north vault by a manually operated variable speed exhaust blower in the receiving area. No ventilation is provided in the vault areas, and the facility does not have a HEPA filtered ventilation system. The facility is provided with normal,

**Figure 7. Building 651 Photograph.**

standby (diesel generator GEN-PH-601) and emergency electrical power. The criticality alarm system has its own battery-operated, 2-hr UPS system. The facility is provided with instrumentation and control systems for security, fire, radiation detection, special nuclear material accountability, and contamination control. The facility would, it is assumed, require significant upgrades to the HVAC, nuclear criticality safety system, alpha air monitoring, and other systems to meet DOE orders and other regulatory requirements for long-term storage of $^{233}$U materials.

The storage capacity of Building 651 is not adequate for the total $^{233}$U inventory. The building has 100 wells in the facility perimeter, which could hold about 300 $^{233}$U containers. Vault space has the capacity to store approximately 300 to 400 additional containers. This leaves the facility with about one-half to two-thirds the total needed storage capacity. Also, the cell access crane is insufficient for handling shielded transfer casks or overpacks. The Building 651 shipping/receiving dock is configured for a standard 13.5 ft truck bay, and the area would not support large fuel-type shipping casks that will be needed for efficient transfer of the $^{233}$U inventory (see Section 3.11).

Building 651 requires a number of upgrades or modifications to meet the requirements for $^{233}$U storage. Meeting these requirements will involve major structural modifications. Option 651 A addresses this facility modification by estimating the removal of one wall from Building 651, and the addition of a new building section which includes more storage wells, a hot cell area, and a new receiving /shipping area and associated equipment (see Figure 8 for floor plan schematic of modified Building 651 facility). This is a conceptual level estimate at this time based on estimate of required square footage, and required major items derived from the facility deficiencies (see Section 4). The major storage item cost estimates were derived from INEEL facility personnel estimates.[7,8]

Building 651 is currently operating from a BIO incorporated into the plant safety document as Rev. 2 dated April 1998. The facility is qualified to handle large quantities of fissile materials ($^{235}$U). The facility has been determined to be capable of withstanding the postulated design basis earthquake, tornado and flood. However, addition of this storage mission would require a new natural phenomenon hazards analysis to be performed.

Building 651 does not have a long-term mission. The perceived general direction at Idaho for INTEC is to downgrade the current inventory of stored materials, reduce site security requirements, and prepare the facilities for D&D.

**Figure 8. INEEL Building 651 (Floor Plan Modification for Option 651A)**

### 2.3.2 Option 651B - Shared Storage -Building 651 and Storage Areas 603 or 749

A second option originated by INEEL (Option 651B), involves splitting the $^{233}U$ inventory into the radiologically "hot," higher $^{232}U$ material, and the more pure, more easily handled, low $^{232}U$ material. The low $^{232}U$ material could be segregated, stored, and handled differently than the high $^{232}U$ material, which can have levels of radiation greater than 50 R/hr at 1 foot (see Section 1.4). The low $^{232}U$ material would be stored at the existing Building 651 with the only facility modifications being an area for an increase in storage capacity, and a new ventilation system. The nearby INEEL RAL hot cell facilities would be used for inspection and processing as needed. The "hot" $^{233}U$ material could go into the INEEL Irradiated Fuel Storage Facility (IFSF), Building 603, or the nearby in-ground dry storage Area 749. Either of these areas can handle and store materials with high associated radiation fields. Area 749 is located directly east of Building 603 and is fully fenced and secured for the handling and storage of fissile materials (see Figure 9). Building 603 has remotely operated, shielded storage capacity, and a hot cell capable of NDE inspection of the $^{233}U$ storage packages. The Building 603 facility also has an adequate receiving dock and equipment to handle the large shipping casks (see Figure 8 for a photograph of these areas and Figure 10 for Building 603 cutaway). This option is included in the cost analysis as 651 Option B, and the assumption is that 603/749 areas will have enough non-utilized capacity for the $^{233}U$ containers.

Option 651B utilizes the capability of the INEEL storage facilities that were built for irradiated fuel to handle the high $^{232}U$ materials. The option also provides consolidation of $^{233}U$ materials at one site since INEEL currently stores the LWBR $^{233}U$ fuel. However, as mentioned earlier, the $^{233}U$/Th fuel is not part of the $^{233}U$ inventory considered in this task.

**Figure 9. INEEL Storage Areas 603 & 749 Photograph.**

**Figure 10. INEEL Irradiated Fuel Storage Facility - (Building 603) Cutaway.**

## 2.4 NEW (GREENFIELD) FACILITY

The cost evaluation for a new facility was performed at a pre-conceptual level only, and these estimated costs are to be used only for comparison with the initial costs of the alternate facility options reported here. The Greenfield estimate was derived from a prior estimate generated at ORNL,[9] and was slightly modified with the addition of two new hot cells to take into consideration current cost experience and was adjusted to 1998 dollars (at 2.8%/year). Standard cost analysis procedures were used. The original contingency rate was unchanged at 25%. This alternative consists of a newly constructed storage facility placed in an as-yet unidentified location. A highly secure fissile storage area, or a similar secure location would reduce required security costs and would be the most logical location for such a new facility. This candidate facility would contain adequate storage and be fitted with appropriate facility support equipment. Estimated equipment includes remotely operated cranes, shielded storage well arrays, and remote manipulated handling and receiving equipment accessing a remote hot cell for packaging and processing type operations (see Table 3 for the estimate breakdown). The preliminary evaluation of this Greenfield option did not include an estimate of the recurring costs associated with this facility, or for transportation of the inventory to the facility, since the facility location is undetermined. See Figure 11 for a conceptual drawing of the Greenfield Facility.

**Table 3. Greenfield Facility Cost Estimate[9]**

| Description | Quantity | Unit | Unit price | Total |
|---|---|---|---|---|
| Site utilities | 90,000 | sf | | 1,000,000 |
| Operating building | 14,400 | sf | 700 | 10,000,000 |
| Hot cell area | 1200 | sf | 700 | 850,000 |
| Working hot cells and equipment[a] | 4 | ea | 1,500,000 | 6,000,000 |
| Storage wells | 400 | ea | 25,000 | 10,000,000 |
| Site work | 2000 | cy | 1000 | 2,000,000 |
| Bridge crane | 1 | ea | 2,000,000 | 2,000,000 |
| Cell and glovebox ventilation system | 1 | lot | 4,000,000 | 4,000,000 |
| Environmental and radiological monitoring | 1 | lot | 6,000,000 | 6,000,000 |
| Waste management system | 1 | lot | 2,000,000 | 2,000,000 |
| Security systems | 1 | | 1,500,000 | 1,500,000 |
| Instrumentation and test equipment | 1 | lot | 3,000,000 | 3,000,000 |
| Training | 1 | lot | 1,000,000 | 1,000,000 |
| Casks for transferring materials | 1 | lot | 1,000,000 | 1,000,000 |
| Subtotal | | | | 50,300,000 |
| Construction manager | 25% | | | 12,600,000 |
| **Subtotal** | | | | **63,000,000** |
| Design engineering | 25% | | | 15,700,000 |
| Construction engineering | 10% | | | 6,300,000 |
| Project management | 20% | | | 12,600,000 |
| **Subtotal** | | | | **34,500,000** |
| Facility documentation (SAR, etc.) | | | | 2,000,000[b] |
| **Subtotal** | | | | **99,500,000** |
| Escalation (4 years to start @ 2.8%) | 12% | | | 11,900,000 |
| **Subtotal** | | | | **111,400,000** |
| Contingency | 25% | | | 27,900,000 |
| **Grand Total** | | | | **139,300,000** |

[a] Changed from 2 hot cells in original estimate to 4 hot cells
[b] Change from $8,000,000, in original version,[10] to $2,000,000 on basis of more recent experience with Building 7930 documentation.

**Figure 11. Drawing of The Greenfield Facility.**

## 3. $^{233}$U FACILITY SYSTEMS REQUIREMENTS OVERVIEW

The $^{233}$U National Repository must meet design and engineering requirements for the Hazard Category 2 classification of DOE-STD-1027-92. The selected facility must be capable of performing mission activities related to processing, inspecting, and storing containers of $^{233}$U, and contained impurities, in oxide, ceramic monolith, and metal form. The facility will be required to meet existing regulatory requirements and appropriate DOE standard; must have or be retrofitted or upgraded with appropriate safety class, safety-related, nuclear safety and non-safety systems equipment; and, must meet appropriate code requirements for natural phenomena and hazards mitigation. Nuclear safety design requirements apply to both new and existing DOE Hazard Category 2 non-reactor nuclear facilities. Facility and new equipment design and the associated safety analysis must be conducted to the applicable requirements of the most currently released version of DOE Order 420.1. (These requirements are modified to fit work smart standards for Building 7930 and 3019 operations.)[6]

This $^{233}$U Storage Alternative Trade Study does not interpret the compliance posture of the candidate facilities to nuclear and criticality safety and other regulatory drivers. Facility-specific safety screens, safety evaluations, and unreviewed safety question determination (USQD) analyses will be required to determine if available equipment and engineered systems meet the intent and compliance requirements of regulatory drivers for the processing and storage of $^{233}$U. Site-specific evaluations, therefore, will be required to support the final facility selection process for the long-term repository. Cost estimates, however, will be based on the cost to provide the basic engineered system requirements in the four candidate facilities. These assumptions were applied to each facility cost estimate as applicable.

This section provides a discussion of the fundamental fissile material processing and storage facility engineered systems requirements to establish a baseline of expectation for use in assessing the four candidate facilities. Section 4 of this report presents the Alternate Facility Characterization Summary. The facilities were assessed using the following criteria:

- systems adequately and acceptably in place,
- systems in place marginally meeting requirements with only minor upgrades or modifications,
- systems partially in place and needing significant modifications, or
- unacceptable, obsolete, or nonexistent engineered systems/equipment, therefore, needing retrofits or the installation of new systems equipment in the facility.

Cost estimate assumption factors are associated with these four scenarios and are allocated to each candidate facility accordingly.

### 3.1 HVAC SYSTEM

The HVAC system for the selected facility must provide confinement of the $^{233}$U while preventing the spread of airborne contamination under postulated design basis accidents and other credible events. One specific hazard associated with the decay chain of $^{232}$U is the presence of $^{220}$Rn, which at normal temperatures and pressures exists as a gas and can cause problems during the storage and handling of $^{233}$U due to its mobility. Radon-220 decays with a 55.6 second half-life, therefore the presence of significant amounts of $^{220}$Rn requires retention of the off-gas to allow this isotope to decay through several half-lives (approximately 10 minutes) to ensure that it has transmuted to the filterable decay product, $^{216}$Po. A multiple air zone concept must be instituted where ventilation air moves from clean, unregulated (Zone 3 or Zone 2) areas to areas of increasing potential for airborne activity (Zone 1). Negative pressure differentials must be maintained between the zones and the atmospheric reference as controlled by the air supply and exhaust flows. The air flows and pressure differentials must be maintained when access/egress doors or other zone penetrations are opened or breached. A system of air locks should be available for these functions. If the nested $^{233}U$ material containers satisfy the primary and secondary containment requirements, the hot cell structure adequately provides the tertiary confinement requirements and the accident scenario evaluation as stated in operational documents, the HVAC system is not required to be of safety class design. The functional parameters and design requirements of the HVAC system in this scenario become one of "defense-in-depth." Supply and exhaust fans should have at least one redundant backup provided with auto-start features and isolation capabilities for maintenance. Rounded stainless steel ductwork with inspection ports should be utilized, and fire stop systems should be installed at inlets to the exhaust ductwork. Automatic dampers should be provided for controlling exhaust system pressures. Appropriate sampling and monitoring systems should be used on the exhaust stack. Ductwork should meet the National Fire Protection Association (NFPA) standards for fire and smoke dampers and firewall penetrations.

### 3.2 RADIOLOGICAL MONITORING SYSTEM

The radiological worker protection requirements for high-purity $^{233}U$ are similar to those for weapons grade plutonium. The primary health hazard of $^{233}U$ is from alpha radiation, the alpha activity is three orders of magnitude higher than that of HEU and about one order of magnitude lower than that of weapons grade plutonium. The containment and handling requirements within a Zone 1 enclosure are as demanding as those for $^{239}Pu$. The $^{232}U$ isotope concentration in $^{233}U$ materials decays to $^{208}Tl$, which emits a high-energy 2.6 MeV gamma photon. Heavy gamma shielding and remote-handling operations will be required and an integrated radiological monitoring system must be installed to protect the facility workers in the selected long-term $^{233}U$ national repository. Trained and qualified radiological control technicians will be required to conduct surveys and support personnel in the performance of material operations.

### 3.3 HEPA FILTRATION

Exhaust filter plenums are required to test HEPA filters. HEPA test sections should be available both upstream and downstream of the filters for the standard testing protocol.

### 3.4 FIRE PROTECTION

The long-term $^{233}U$ processing, repackaging, and storage facility will be required by DOE Order 420.1, Chg. 2 to have a level of fire protection sufficient to fulfill the requirements of the "Highly-Protected Risk" class of industrial systems. This includes meeting or exceeding the applicable building code and NFPA codes and standards. The applicable codes will be those in effect when the facility design commences. If significant modifications are required in the selected $^{233}U$ facility, the current edition of the NFPA code or standards will apply to the modification.

### 3.5 NUCLEAR CRITICALITY SAFETY SYSTEM

The minimum critical mass of pure $^{233}U$ is approximately 0.52 kg, which is less than that of $^{235}U$ HEU and slightly more than that of weapons grade plutonium. A nuclear criticality detector system is required if the facility in question stores more than 500 grams of $^{233}U$ and can have a credible criticality scenario. Accordingly, the long-term $^{233}U$ processing, repackaging, and storage facility will be required to have a nuclear accident criticality alarm system and program that meets the requirements of DOE Order 420.1, Chg. 2. The system will consist of a number of neutron criticality detectors (heads) located in the processing and storage areas connected to a central criticality alarm and display panel(s) in the facility control room and at other areas.

Audible alarms must be transmitted to the process and work areas and strobe beacons will be strategically located at outside egress points. The facility is to be provided with a back up power system. The Criticality Safety Program documents the process by which the facility performs criticality evaluations for operations involving $^{233}U$ movement, inspections, transportation, processing, repackaging, and storage. Since the Nuclear Criticality Safety System is a safety system, the facility SAR will provide operational requirements and OSRs or TSRs for the system.

### 3.6 ALARM AND MONITORING SYSTEM

The $^{233}U$ facility should employ monitoring, alarm, and display panel equipment for the criticality accident alarm system, fire alarm system, alpha air monitoring system, and accident/safety/disaster warning system. The alarm and monitoring systems should have display panels in the facility control room and at other locations as designated by the facility SAR.

### 3.7 SAFEGUARDS AND SECURITY SYSTEM

Safeguards and security systems are required to be in place in the selected candidate facilities since the Attractiveness Level I quantities of $^{233}U$ will be handled, processed, and stored there. Safeguards are an integrated system of physical protection, material accounting, and material control measures. This system will be designed to prevent, deter, or detect and respond to unauthorized access to nuclear material. Security refers to implementation of the Atomic Energy Act of 1954 in protecting restricted data and other classified information and materials.

Costs attributable to safeguards and security systems and operations were included in this report where available. The quantities, purity, and form of the $^{233}U$ materials to be stored will place any significant operations in the Category I classification. This classification requires significant security/safeguard involvement and requires a guard force present when quantities of the material are accessible. Based on the results of facility interviews and document reviews, it was determined that Building 3019 is able to utilize the site security force by instituting a variety of monitors, interlocks, and time delays into their storage well arrangement. It is assumed that Building 7930, due to its location, would use a similar safeguard and security approach. The current security level at the INTEC site will not need significant upgrades to meet the required level of security/safeguard protection for $^{233}U$ storage and handling.

### 3.8 AIR MONITORING SYSTEM

A stationary or portable continuous air monitoring system must be available to detect airborne alpha-emitting contamination in the process and storage areas of the $^{233}U$ facility. The system should be powered by the electrical circuitry supplied with backup power.

### 3.9 UNINTERRUPTIBLE POWER SUPPLY SYSTEM

A UPS system, either a backup generator or a battery system is required for facility loads that cannot tolerate power losses or transients on the utility grid. UPS power is provided for the fire protection system, criticality alarm system, accident/safety/disaster warning system, and other systems as required in hazards analysis documentation, the SAR and/or BIO documents.

## 3.10 PROCESSING AND THERMAL STABILIZATION SYSTEM OF $^{233}U$

The selected $^{233}U$ facility will be required to have remote hot cell systems available to dissolve, purify, and convert or thermally stabilize small batch quantities of the $^{233}U$ material from its present form to a pure oxide containing little or no water, corrosive anions, organic material, or hydrogenous impurities. The system must be designed to protect workers from gamma- and alpha-emitting uranium and isotopic contamination as the material is handled and processed. The system must be capable of thermal stabilization by calcination of the $^{233}U$ oxide at temperatures approaching 1,000 C. The system must provide filtered air or oxygen to the calcination equipment and must provide off-gas HEPA filtration to prevent the inadvertent release of radioactive particles. The system requirements for process monitoring, controls, and alarms must be met.

## 3.11 TRANSPORTATION OF $^{233}U$

Transportation of the $^{233}U$ materials, either in an intra-site (ORNL Building 3019 to ORNL Building 7930) or an inter-site (ORNL to INEEL) relocation will involve a significant number of logistical, security, nuclear safety, and radiological concerns. From a logistics viewpoint, transfer of all materials in the national repository of $^{233}U$ materials would involve a large number of shipments per month over several years. Remote handling or robotic manipulations would be required to containerize, package, and load the materials (at least the high $^{232}U$ content material) into an appropriate transportation cask. Safeguards and security personnel, procedures, and equipment will be required for each shipment. Nuclear safety and criticality safety provisions will be required for each movement. Radiological exposure could be significant for material handlers, support, operations, and transportation personnel involved in the material movement.

Costs for the preparation and handling of the $^{233}U$ materials for transportation were estimated and applied to ORNL Building 7930, and INEEL Building 651 and 603 estimates. Transportation (intra-site and inter-site) costs were allocated to each of the facilities based on distance, method, and requirements of transport (see Table 4 for a breakdown of several interstate transportation options). Shipping of this material will require detailed structural, thermal, containment, and criticality analysis, which are beyond the analysis in this report. Also, possible component testing and preparation of a Safety Analysis Report for Packaging (SARP) would be required. Alternately, an amendment to the NRC Certificate of Compliance (CoC) for the chosen cask will be required.

### Table 4. Cask Assumptions for $^{233}U$ Transport Modeling from ORNL to INEEL

| Cask | BMI-1 | GE-2000 | NAC-LWT |
|---|---|---|---|
| Gross weight (lb) | 23,600 | 33,500 | 51,200 |
| Cavity size, length x diameter (in.) | 54 x 15.5 | 54 x 26.5 | 181 x 13.4 |
| Number of 12-in long $^{233}U$ canisters carried | 16 | 52 (optimistic)<br>28 (conservative) | 60 |
| Number of 24-in long $^{233}U$ canisters carried | 8 | 26 (optimistic)<br>14 (conservative) | 28 |
| Equivalent Pb shield thickness (in.) | ~8 | ~5 | ~6.75 |
| Cask load time (days) | 3 | 3 | 4 |
| Cask unload time (days) | 3 | 3 | 4 |
| Maintenance frequency (number/yr.) | 1 | 1 | 1 |
| Maintenance downtime (days/yr.) | 20 | 20 | 20 |
| Annual lease charge (first use, after 12 mo.) ($/yr.) | 2,000 | 27,500 | 40,000 |
| Short-term daily lease fee (< 90 days of use) ($/day) | 500 | 2,000 | 3,000 |
| Mid-term daily lease fee (> 90 days but < 180 days of use) ($/day) | 500 | 1,500 | 2,500 |
| Long-term daily lease fee (> 180 days of use) ($/day) | 500 | 1,000 | 1,800 |
| Acquisition cost for new cask [a] ($) | N/A | 2,500,000[b] | [c] |
| Estimated Transportation Safeguards Division (TSD) carriage costs [d] ($/per round trip)<br>Single truck convoy<br>Two truck convoy<br>Three truck convoy | | <br><br>86,100<br>88,200<br>102,300 | |
| Estimated carriage costs for carriage in commerce with TRANSCOM Tracking [e] ($/truck-mi.) | | 7.00 | |

[a] This cost includes adding $^{233}U$ to the approved packaging contents, and obtaining the necessary CoC; 'N/A" is shown for the BMI-1 cask since additional casks of this type cannot be fabricated according to the NRC regulations.

[b] Three total casks exist: two at General Electric (GE) and one at ORNL. However, one of those at GE and the one at ORNL are heavily committed to other programs; either might be available on occasion.

[c] Five casks of this type are available and additional ones would not have to be fabricated.

[d] TSD costs include a TSD tractor for each cask trailer, all necessary security personnel and their vehicles.

[e] Based upon reported costs from Waste Isolation Pilot Plant (WIPP).

### 3.11.1 Cost Estimates For Transportation From ORNL to INEEL

The cost of transporting $^{233}U$ from ORNL to INEEL was estimated by the Lockheed Martin Energy Systems, Inc. (LMES), Transportation Technologies Group and published as an ORNL internal memo.[11] Most of this section was extracted from that memo. The primary elements for shipping are the costs for packaging the $^{233}U$ material for transport, carriage of the $^{233}U$ material, and the labor associated with the shipments.

The cost estimating model TEPTRAM was used to help determine the costs associated with shipping $^{233}U$ on campaigns which extend over many months. TEPTRAM provides the total transportation cost by summing several cost factors. These include the Packaging Acquisition Cost, which provides the cost of purchasing the shipping packages for a given campaign; the Packaging Lease Cost, which provides the cost per month to lease shipping packaging and provides an alternative to the acquisition cost; the Packaging Maintenance Cost which provides an order of magnitude cost for contracting carriers, document preparation, and record keeping which provides the cost of refurbishing the package after a predetermined number of uses; the Vehicle Lease Cost, which provides the cost of leasing the vehicle for the campaign; the Carriage Cost, which provides the "per mile" charge of the carrier; the Labor Cost, which provides the labor cost of loading, unloading, etc.; and, the Management and Administrative Cost, which provides an order of magnitude of cost for contracting carriers, document preparation, and record keeping.

### 3.11.2 Assumptions For the Transportation Cost Model

Canisters shipped to INEEL are assumed to be 4-in. diameter, 600 are assumed 12-in. long and 600 are assumed 24-in. long. Shielding will be required in order to reduce the external dose rate to within limits prescribed by U.S. Department of Transportation (DOT) regulations. Transportation packages were evaluated and spent fuel casks were selected as the most viable package type for this application. Existing spent fuel casks were examined for their availability, estimated canister capacity, weight, leasing cost and whether they are certified for transporting $^{233}U$. Three casks were evaluated to determine the transportation cost of moving the $^{233}U$ to INEEL. The chosen cask's CoC will be modified to accommodate the $^{233}U$ contents. Baskets with appropriate levels of neutron poisons will be required. Regulatory approval will be required including structural, thermal, containment, and criticality analysis, and the preparation of a SARP. Three casks were examined as possible candidates for use in shipping the $^{233}U$. See Table 4 for the assumptions relative to each of these casks.

The BMI-1 cask is an old design. Only one cask is available and is used extensively to ship research reactor fuels throughout the United States. No additional casks of this design could be fabricated without updating the SARP to current regulatory standards. As a result of its extensive use, the BMI-1 may not be available on a full time basis for shipment of $^{233}U$.

The GE-2000 is a relatively new design. Three casks are available with one being owned by DOE and is used to transport spent research reactor fuel from Oak Ridge to Savannah River. Obtaining one of these casks either by use of the DOE cask or by acquiring or leasing casks from General Electric (GE) is much more likely than gaining access to a BMI-1.

The Nuclear Assurance Corporation (NAC)-LWT cask is also a relatively new design. It is used for the transport of Pressurized Water Reactor (PWR) and Boiling Water Reactor (BWR) spent nuclear fuel and has the largest cavity of the three casks examined. It is assumed that a CoC could be appropriately amended and that one or more of these casks could be obtained by a lease agreement from NAC.

It is assumed that both shipping and receiving sites will be able to accommodate unloading and loading the casks. Additional crane capacity may be required. Design efforts will be required depending on the type of cask chosen to insure the loading process can be accomplished for both normal conditions and hypothetical accident conditions. Also, it is assumed that the use of the Transportation Safeguards Division (TSD) will be required and that approval from the U.S. Department of Energy/Albuquerque Operations Office (DOE/AL) will be obtained to allow transport without the use of safe, secure transports (SSTs). The SSTs could be utilized, but package limitations would require a larger number of shipments.

### 3.11.3 Results of Estimates for $^{233}$U Shipments from ORNL to INEEL

Two campaign scenarios were examined. As stated earlier, it is assumed that the total inventory will contain 600 12-in. long canisters and 600 24-in. long canisters. Also, it is assumed that the shipments will be conducted continuously until all of the canisters have been transported. The scenarios examined involved using the TSD transportation system and using a commercial carrier.

The following tables show the results of the calculations for using the TSD transport system. The scenarios explored are shown in Table 5.

**Table 5. $^{233}$U Shipping Campaign Scenarios Analyzed for Cost, Using TSD as the Carrier**

| Scenario | Cask used | Number of casks in convoy | Number of 12-in canisters in cask | Number of 24-in canisters in cask |
|---|---|---|---|---|
| B1 | BMI-1 | 1 | 16 | 8 |
| B2 | BMI-1 | 1 | 12 | 6 |
| G1 | GE-2000 | 1 | 52 | 26 |
| G2 | GE-2000 | 1 | 28 | 14 |
| G3 | GE-2000 | 2 | 28 | 14 |
| N1 | NAC-LWT | 1 | 35 | 14 |
| N2 | NAC-LWT | 2 | 35 | 14 |

The G3 and N2 scenarios allow for combining multiple trucking loads into a single convoy. The results of the cost calculations for the scenarios shown in Table 5, which are all for shipment using TSD as the carrier, are given in Table 6.

From the tables below it may be concluded that:

- The BMI-1 cask imposes significant cost and time penalties on shipments of $^{233}$U.

- The GE-2000 cask and the NAC-LWT cask appear to offer similar time and cost savings depending on which loading scenario is being considered. However, the GE-2000 has some less tangible advantages, in that it is loaded and unloaded vertically, may be able to be time shared with other ORNL programs, and it has the potential for accelerating the schedule, thereby reducing costs when multiple casks are used.

- The NAC-LWT casks offer a time and cost savings similar to the GE-2000, but costs increase when the schedule is accelerated due to high rental costs per container, which negate the schedule gain.

**Table 6. Estimated Costs for Different Shipping Scenarios Using TSD as the Carrier**

| Scenario | Estimated costs for 12" canisters ($ millions) | | Estimated costs for 24" canisters ($ millions) | | Estimated total costs ($ millions) | Campaign duration (months) |
|---|---|---|---|---|---|---|
| | Labor | Packaging and transportation | Labor | Packaging and transportation | Estimated total costs ($ millions) | Campaign duration (months) |
| B1 | 3.1 | 3.8 | 5.9 | 7.6 | 20.4 | 44 |
| B2 | 3.9 | 4.9 | 7.9 | 9.9 | 26.6 | 55 |
| G1 | 1.0 | 1.5 | 2.0 | 3.1 | 7.6 | 15 |
| G2 | 1.8 | 2.6 | 3.4 | 5.0 | 12.8 | 27 |
| G3 | 1.8 | 1.9 | 3.4 | 3.5 | 10.6 | 19 |
| N1 | 0.9 | 1.8 | 1.8 | 3.8 | 8.3 | 15 |
| N2 | 0.9 | 2.5 | 1.8 | 4.5 | 9.7 | 11 |

The following tables show the results of the cost calculations using a commercial carrier. The scenarios explored are shown in Table 7.

**Table 7. $^{233}$U Shipping Campaign Scenarios Analyzed for Cost Using a High Quality Commercial Carrier**

| Scenario | Cask used | Number of casks in convoy | Number of 12-in canisters in cask | Number of 24-in canisters in cask |
|---|---|---|---|---|
| B1-CC | BMI-1 | 1 | 16 | 8 |
| B2-CC | BMI-1 | 1 | 12 | 6 |
| G1-CC | GE-2000 | 1 | 52 | 26 |
| G2-CC | GE-2000 | 1 | 28 | 14 |
| N1-CC | NAC-LWT | 1 | 35 | 14 |

The results of the cost calculations for the scenarios shown in Table 7, for shipment using a high-quality commercial carrier as the carrier, are given Table 8.

**Table 8. Estimated Costs for Different Shipping Scenarios Using a High Quality Commercial Carrier**

| Scenario | Estimated costs for 12" canisters ($ millions) | | Estimated costs for 24" canisters ($ millions) | | Estimated total costs ($ millions) | Campaign duration (months) |
|---|---|---|---|---|---|---|
| | Labor | Packaging and transportation & TRANSCOM | Labor | Packaging and transportation & TRANSCOM | | |
| B1-CC | 3.1 | 2.8 | 5.9 | 5.5 | 17.3 | 44 |
| B2-CC | 4.0 | 3.6 | 7.9 | 7.1 | 22.6 | 55 |
| G1-CC | 1.0 | 1.2 | 2.0 | 2.5 | 6.7 | 15 |
| G2-CC | 1.8 | 2.0 | 3.4 | 3.9 | 11.1 | 27 |
| N1-CC | 0.9 | 1.6 | 1.8 | 3.3 | 7.6 | 15 |

### 3.11.4 Cost Estimates for ORNL Intra-Site Transportation (Building 3019 to Building 7930)

Two scenarios for transferring the inventory of $^{233}U$ from Building 3019 to Building 7930 were developed by REDC personnel[4] based on similar past transfers to Building 7930. They are a single-can carrier transfer scenario and a multi-can carrier transfer scenario.

With the single-can carrier transfer scenario, a carrier similar to the CEUSP Carrier would be used to transfer the uranium inventory one can at a time. The carrier loaded at Building 3019 would be placed onto a trailer and brought to Building 7930 where the can would be lowered into one of the new storage wells. Three carriers were assumed to be able to fit on one trailer and used to lessen the number of inter-facility transfers. This scenario would probably take the longest amount of time to complete. However, it minimizes the complexity of the operation, potentially the escort security level and the initial equipment costs. This scenario will allow for two transfers per day and involve six ORNL personnel and security.

The costs for this scenario include:

- design of carrier
- fabrication of the carriers
- engineering/criticality analysis of design
- design of a dedicated trailer and tie-downs
- fabrication of the trailer and tie-downs
- operation cost

The multi-can carrier transfer scenario estimated in this report appears to be more cost effective. Using this scenario, a new carrier will be built which can hold more than one can. Since the carrier is to be used only on-site and no extraordinary permitting requirements were assumed necessary, the carrier would be designed to meet transportation requirements but would not be licensed. With the multi-can carrier, eight canisters, and possibly more, depending on shielding requirements, can be loaded into the carrier. One or possibly two transfers per day can be made from Building 3019 to Building 7930.

The costs for this scenario include:

- design and safety analysis of an inter-facility carrier
- fabrication of the carrier
- design and safety analysis of an inside-facility carrier
- fabrication of the carrier
- design of a loading/unloading station
- fabrication of the station
- design of a dedicated trailer and tie-downs
- fabrication of the trailer and tie-downs
- operation Cost

### 3.11.5 Transportation Conclusions

The $^{233}U$ materials of interest to this study fall into categories that require significant shielding for shipment, significant criticality assessment, and have a high attractiveness level. This transportation scenario also assumes the use of DOT-certified shipping containers for inter-site transportation, and includes safeguards and security systems and personnel escorts for the shipments. TSD support systems are assumed to be required since shipments will be above the safeguards limit. The BMI-1 cask has a significant cost and time penalty. The GE-2000 cask offers a significant time and cost savings plus allowing for increased savings for an accelerated schedule, due to the possibility of using multiple casks. For purposes of the cost assessment, a lead shielded shipping cask was determined to be necessary, and the GE-2000 cask was chosen for a combination of factors[12] including ease of loading and availability (see Table 4). The inter-site shipping scenario chosen for cost estimation is scenario G3 (see Tables 5 and 6). This scenario was chosen to be compatible with the amount, type, and purity of the uranium material. A conservative container packing was assumed, but a more detailed criticality analysis is needed to verify packaging. The total $^{233}U$ transfer process is predicted to require 32 cross-country trips and a total 19-month campaign. This scenario consists of a two-truck convoy utilizing two GE-2000 casks, and employing either 28-12 in. containers, or 14-24 in. containers. This campaign would cost approximately $20M.

The intra-site transportation of the $^{233}U$ materials from Building 3019 to Building 7930 was estimated using both the multi-container transport scenario and single container described above. Costs were minimized by using prior transportation experience with in-plant transportation casks and personnel. The total cost is estimated at approximately $9M for transportation and cask handling.

### 3.12 INTERNATIONAL ATOMIC ENERGY AGENCY SAFEGUARDS SYSTEM

The requirements for International Atomic Energy Agency (IAEA) safeguards related to surplus $^{233}U$ materials have not been fully developed at this time. Although there have never been any planned activities for converting $^{233}U$ materials into a weapons usable form, from the international perspective, the material is considered to be weapons-useable material and may at some time in the future be placed under the umbrella of IAEA safeguards. Some variations of the electronic, intrusion surveillance, motion detector, and linked satellite systems would be required for all four alternative facilities, if IAEA safeguards requirements were implemented. For purposes of this report, vault accessibility is the only element that is considered, and no-cost impact is included.

# 4. CANDIDATE FACILITY CHARACTERIZATION

The “as configured” candidate facilities were rated against a series of regulations and requirements to determine how well the facility option meets the critical requirements for a $^{233}U$ storage facility. Table 9 provides the ranking results from this evaluation. The results from this evaluation clearly indicate that the best fit is Building 3019, the current repository. On the other hand, INEEL Option 651A would require numerous costly modifications to meet the storage requirements. However, Option 651B is a much better fit than Option 651A, and along with Building 7930, ranks in between Buildings 3019 and Option 651A, since both require relatively moderate modifications and upgrades. The individual building attributes are discussed in detail in the respective facilities SAR or BIO documents as required by DOE Order 5480.23.

**Table 9. Facility Characterization Summary (Before Modification)**

| Facility system, equipment, characteristic or attribute | B3019 | B7930 | B651 | B651/ 603/RAL |
|---|---|---|---|---|
| Schedule availability (meets 3–5 Year "need" ) | 1 | 2 | 3 | 2 |
| Transportation of material for storage | 1 | 2 | 4 | 4 |
| Storage space availability | 1 | 2 | 4 | 1 |
| Storage area design layout | 2 | 2 | 3 | 2 |
| Glovebox, modular cell | 2 | 1 | 3 | 1 |
| Remote handling capability, robotics, or manipulator | 1 | 2 | 4 | 1 |
| Hot cell processing potential | 2 | 1 | 4 | 2 |
| Natural phenomena design acceptability (design basis earthquake, tornado and/or flood) | 3 | 2 | 1 | 1 |
| Material inspection, repackaging availability | 1 | 2 | 4 | 3 |
| Thermal stabilization (calcination) system availability | 2 | 2 | 3 | 2 |
| Fire protection, detection & suppression system with emergency power | 1 | 2 | 1 | 1 |
| Continuous alpha air monitoring system | 1 | 1 | 2 | 2 |
| Radiation protection, detection, system with emergency power | 2 | 3 | 2 | 2 |
| Nuclear criticality alarm System with emergency power | 1 | 3 | 1 | 1 |
| Vented hot cell wells with off-gas holdup capability ($^{220}$Rn) | 1 | 2 | 3 | 3 |
| HVAC system (redundant equipment, power and monitoring) | 2 | 1 | 3 | 3 |
| HEPA filtration plenums (stages, fire suppression, testable) | 2 | 2 | 3 | 3 |
| Electrical power (normal, standby, emergency) | 1 | 1 | 1 | 1 |
| Control room within facility with instrumentation | 2 | 2 | 4 | 2 |
| Instrumentation and controls (security, fire, rad, special nuclear materials (SNM), power) | 2 | 2 | 2 | 2 |
| MC&A instrumentation, nondestructive assay (NDA) equipment, assay | 2 | 3 | 4 | 2 |
| Security and safeguards systems | 1 | 1 | 1 | 1 |
| Authorization basis (SAR, BIO, USQDs, system requirement identification document (SRID,WSS, commitments) | 1 | 3 | 3 | 3 |
| Permits, agreements, certifications (local, state, federal) | 1 | 2 | 4 | 4 |
| Stakeholder acceptance, state approval, political issues | 1 | 2 | 3 | 3 |
| Loading dock, truck bay, material handling, SST dock | 2 | 2 | 3 | 2 |
| Infrastructure (personnel, procedures, directives, instructions) | 1 | 2 | 2 | 2 |
| Training and qualification of operations personnel | 1 | 2 | 3 | 3 |
| Quality assurance program in place | 1 | 1 | 1 | 1 |
| Expertise in $^{233}$U handling, packaging, storage | 1 | 2 | 2 | 2 |
| Facility readiness assessments, operational readiness reviews | 1 | 3 | 3 | 3 |
| Occupational safety and health program in place | 1 | 1 | 2 | 1 |
| Industrial hygiene program in place | 1 | 1 | 1 | 1 |
| Qualified "Q" cleared personnel availability | 1 | 1 | 1 | 1 |

**Grading Strategy**
1. Adequate, In-place, Acceptable As Is, **or** low Cost Involved < $1 million
2. Marginally Adequate, Marginally Acceptable, **or** Minor (Modification/ Implementation) Cost $1–5 million
3. Partially Adequate, Partially Acceptable, **or** Significant Modification/Implementation Cost $5–10 million
4. Inadequate, Unacceptable, Obsolete, Nonexistent, **or** New Procurement Cost >$ 10 million

# 5. COST ANALYSIS

## 5.1 ESTIMATE BASIS

Several levels of cost estimating were used to gather data for this report. Engineering analysis was employed where possible to identify and break down sub-elements of a facility system for a more complete cost analysis. This type of analysis was possible for much of the Building 7930 modifications and Building 3019 upgrades. Much of the cost estimation for INEEL,[7,8] as well as some of the Building 3019 structural and ventilation upgrades relied on the use of best engineering judgment, utilizing the engineer or facility manager most cognizant of the system in question. Both ORNL and INEEL personnel have a great deal of $^{233}U$ experience, which was used to develop cost estimates for this report. Building 7930 personnel have also provided engineering analysis of facility modifications required for $^{233}U$ storage (see Section 2). Most of this analysis is current but portions are based on earlier work for proposed storage of $^{237}Np$ and Cm. Much of the cost data input was based on best engineering judgment supplied from appropriate facility personnel.[6,7,8,13,14] In some cases, similar cost information was prepared for other purposes, but for similar systems required for this effort. These similar system estimates were used with the appropriate engineering or monetary adjustments. One example of this is the Greenfield Facility estimate. The Greenfield Facility was originally estimated in 1991, the costs were modified slightly, adjusted for inflation to 1998 dollars, and reported, for comparison only, with the four facility options in this report. All of the basis estimates used in this report are recorded and should be traceable. All costs are based on 1998 dollars. The life cycle cumulative costs on Table 13 are based on 1998 dollars escalated at 2.8% per year for 50 years. The cost calculations in this report were done on the automated estimating system (AES) Version 6.1.

## 5.2 DOCUMENTS AND REFERENCES

This cost estimate is based on the accumulation of information and facility-specific characterization documentation related to the as-configured design, construction, and engineering systems available, in place, and operable at the four alternative facilities. References used in the compilation of cost data for this study are listed in Section 7.

## 5.3 GENERAL COST-RELATED ASSUMPTIONS

The following general cost-related assumptions were used to formulate the cost allocation strategy and develop the cost estimate included in this report:

- The total separated $^{233}U$ inventory after the consolidation, inspection/repack campaign is estimated at 1,200 packages containing about 1,000 kg of uranium isotopes and requiring approximately 2,000 linear feet of well storage space.

- Once in storage, it is estimated one container per year will be opened, sampled/processed, and repackaged (part of the Periodic Inspection task).

- The number of packages to be removed from storage and inspected per year is 5% of the inventory, or 60 containers per year (part of the Periodic Inspection task).

- The inclusion of D&D costs into the overall life cycle evaluation of these facilities was considered, however, it was decided that this would not be a discrimination between facilities (see Section 5.4).

- Initial container consolidation/inspection for $^{233}U$ will take place in Building 3019 where the containers will be inspected and repackaged, as required (they have not been inspected for a number of years), and prepared for long-term storage disposition.

- Cost escalation is assumed to be 2.8%/yr for the 50-yr life cycle facility cumulative costs.

- Maintenance costs for Buildings 3019 and 7930 were derived from actual incurred costs for these facilities. The estimates by INEEL personnel[7,8] for operations of modified Buildings 651 and 603, were split between maintenance and operational costs and allocated in ratios similar to ORNL costs.

- Transportation costs were assumed to be zero for the Building 3019 baseline option, because all $^{233}U$ material will reside in this facility in the near future for repackaging, continued storage, and disposition.

- Transportation within ORNL was estimated for Building 3019 to Building 7930 using ORNL site casks, and on-site transportation personnel.[4]

- Inter-site transportation costs from ORNL Building 3019 to INEEL assumed the use of $^{233}U$ certified shipping containers (certification to be obtained). This assumption also includes the use of transportation safeguards and security systems and personnel escorts for the shipments. (See Section 3 for various shipping options and information.)

- Interstate shipping of the $^{233}U$ material will require detailed structural, thermal, containment, and criticality analysis; possibly some component testing; preparation of and obtaining a CoC or an amendment. This regulatory process is estimated at approximately $2 M.[11]

- The $^{233}U$ repackaging program will update the Building 3019 SAR and facility authorization basis, and it is estimated that no additional SAR update would be needed for Building 3019 documentation.

- The cost basis for Building 7930 modifications used an internal ORNL rate.

- Records management is estimated at $20K/yr.

## 5.4 COST SUMMARY

The cost results are summarized in Tables 10, 11, and 12 and include the up-front facility preparation costs and the yearly recurring costs. Table 13 presents cumulative facility costs for the total 50-year storage mission and includes some of the more significant and identifiable categories encountered during this cost study. Several different approaches to reporting costs are provided in this section for the purpose of comparing the costs for each facility, for the $^{233}U$ long term storage mission. The cumulative summation of total storage costs in the first 20 years for each option is plotted in Figure 12. These costs were plotted to illustrate the point at which low initial cost facilities can be overtaken by the facilities with lower recurring costs. The initial facility preparation and transportation cost estimates are spread out over the first four years, since this is the approximate time frame needed to complete these tasks.

## Table 10. Facility Cost Summary[a]

| Initial Costs/ Facility Options[b] | B651 A | B651 B | B3019 | B7930 | New facility |
|---|---|---|---|---|---|
| **Initial Inspection and Repackaging** | $20M | $20M | **$20M** | **$20M** | **$20M** |
| **Facility Preparation and Transportation costs** | $71M | $43M | $22M | $30M | $139M+ Transportation |
| **Facility Annual Recurring Costs[c]** | $2.4M | $2.3M | $5.9M | $2.0M | Not Estimated |

[a] These costs are broken down in Tables 11 and 12.

[b] Facility Options:
Option 651A—Unirradiated Fuel Storage Facility (UFSF) INEEL facility. All necessary additions, modifications, and upgrades needed for compliance are costed to this facility. These include removal of facility wall, construction of new storage wells, addition of new facility floor space for hot cell, and other remote handling equipment. Installation of a new shipping/receiving area, new facility HVAC, and required facility sensor systems and support systems are included.
Option 651B—assumes only "high purity" $^{233}$U (low $^{232}$U ) is relocated and stored in the Building 651, and the higher $^{232}$U material is stored in the INEEL 603/749 areas. All inspect/processing is in adjacent Remote Analytical Laboratory (RAL) hot cell area. Major facility renovations are not required.
Building 3019 Option—assumes all current $^{233}$U material and small holdings remain in ORNL Building 3019. The addition of a processing hot cell box and associated equipment is included, as are ventilation system upgrades.
Building 7930 Option—assumes all the $^{233}$U will go into the existing cells of the ORNL facility, and no major facility modifications will be needed. The cell storage vaults and associated processing equipment will be constructed within the existing cells of the facility.

[c] These annual recurring costs are based on 1998 actual cost for all options. Preliminary indications are costs may increase for 1999 by 10% to 15% for Building 7930, even if this is the case it will not significantly impact these cost results or conclusions.

## Table 11. Facility Cost Summary—Recurring Costs

| Facility Recurring Costs/Yr[a] | B651 A | B651 B | B3019 | B7930 |
|---|---|---|---|---|
| **Periodic Inspection[b]** | $0.2M | $0.3M | $1.3M | $1.3M |
| **Facility Ops.** | $0.6M | $0.4M | $1.9M | $0.3M |
| **Security** | $0.7M | $1.0M | $0M | $0M |
| **Maintenance** | $0.9M | $0.6M | $2.7M | $0.4M |
| **Total Recurring Costs** | **$2.4M** | **$2.3M** | **$5.9M** | **$2.0M** |

[a] The Facility Operations and Maintenance costs are equally shared with the current Cf-252 program in Building 7930, and INEEL 651A & B facility cost are incremental costs for the U-233 storage program.

[b] The Periodic Inspection includes $1000/hr charge to ORNL facilities for security force participation.[7]

**Table 12. Initial Facility Preparation Costs**

| Initial costs[a] | B651 A | B651 B | B3019 | B7930 | Greenfield (stand alone) facility |
|---|---|---|---|---|---|
| #1 Mods (structural) | $4.1M | 0 | $5M | 0 | see Section 2.4 |
| #2 Mods (storage) | $21M | $5.3M | 0 | $11M | see Section 2.4 |
| #3 Mods (ventilation) | $5.3M | $5M | $15M | 0 | see Section 2.4 |
| #4 Mods (security) | $2.8M | $6.3M | 0 | $800K | see Section 2.4 |
| #5 Mods (criticality) | $1.3M | 0 | 0 | $1.3M | see Section 2.4 |
| #6 Mods (remote handling) | $2.1M | 0 | 0 | 0 | see Section 2.4 |
| #7 Mods (hot cell processing) | $6.3M | $500K | $2M | $3.9M | see Section 2.4 |
| #8 Mods (ship/receive) | $2.2M | 0 | 0 | 0 | see Section 2.4 |
| #9 Mods (facility document) | $3.4M | $4.6M | 0 | $2.3M | see Section 2.4 |
| #10 Transportation $^{233}U$ | $20.5M | $21.9M | 0 | $9M | TBD |
| #11 Waste disposition system | $1.6M | 0 | 0 | $1.4M | see Section 2.4 |
| **#12 Facility Preparation & Transportation Cost Total** | **$71M** | **$43M** | **$22M** | **$30M** | **$139M+** |

[a] See Section 5.7 “Cost Discussion” for cost descriptions.

**Table 13. 50-year Facility Cumulative Life Cycle Cost Summary[a]**

| Cost | B651 A | B651 B | B3019 | B7930[b] |
|---|---|---|---|---|
| #12 Initial Facility Preparation Cost Total | **$71M** | **$43M** | **$22M** | **$30M** |
| **Recurring cost (50-yr Cumulative)** | | | | |
| #13 Periodic handling Inspection | $21M | $30M | $140M | $140M |
| #14 Facility operations/Security | $137M | $148M | $194M | $32M |
| #15 Maintenance | $116M | $78M | $319M | $52M |
| #16 **Recurring cost Total** | $274M | $256M | $653M | $224M |
| #17 **Total cost** | **$345M** | **$299M** | **$675M** | **$254M** |
| #18 Contingency Total[c] | $19M | $11M | $4M | $6M |
| **#19 Total Estimated Cost** (with contingency) | **$364M** | **$310M** | **$679M** | **$260M** |
| #20 Initial Inspect/Repackage Task[d] Cost | $20M | $20M | $20M | $20M |

[a] See Section 5.7 "Cost Discussion" for cost descriptions.
[b] Building 7930 maintenance & facility Operations costs are cost shared with the current Cf-252 program.
[c] Contingency was applied only to Initial costs.
[d] See Section 5.6 "Other Costs" and Initial repackaging discussion.

Table 10 shows the yearly summary costs for the major categories of consolidation/repackaging cost, initial facility preparative costs, and yearly recurring costs. The consolidation costs are included to indicate the magnitude of the initial up-front investment that is required before the long term storage takes place. This cost will not affect the trade study, since it takes place before the long term storage mission and is equally applied to all facilities. The preparative costs are quite high for the Building 651 facility, and of course, the Greenfield Facility, since in both cases considerable structural modification and/or new construction must be performed. The recurring costs are quite low for Building 7930, based primarily on the fact that the facility was originally designed for $^{233}$U processing and has an existing $^{252}$Cf program to share 7930 facility costs.

The recurring costs are decomposed in Table 11. Large discrepancies are noted between the ORNL facilities (Buildings 7930 and 3019) and the INEEL Options (651 A and B), particularly in the area of periodic inspection. This is due, in part, to the inclusion of the security costs for INEEL as a part of overall facility operations. At ORNL, the majority of security costs are incurred only during the specific times that the services are provided. Also, the estimated number of man hours per container for periodic inspection by INEEL were significantly lower than the ORNL estimate. The bottom line recurring cost favors Building 7930 primarily due to facility capabilities and REDC cost sharing. The existing Building 7930 $^{252}$Cf program was estimated to share 50% of the building operational and maintenance costs in this estimate, but new anticipated isotope programs were not considered. These future programs could further reduce the overall $^{233}$U storage costs for Building 7930. The INEEL options are based on the spent fuel program sharing the 603/749 complex costs. In addition, the INEEL site funds general building maintenance and upkeep and these costs are not included in the incremental costs reported.

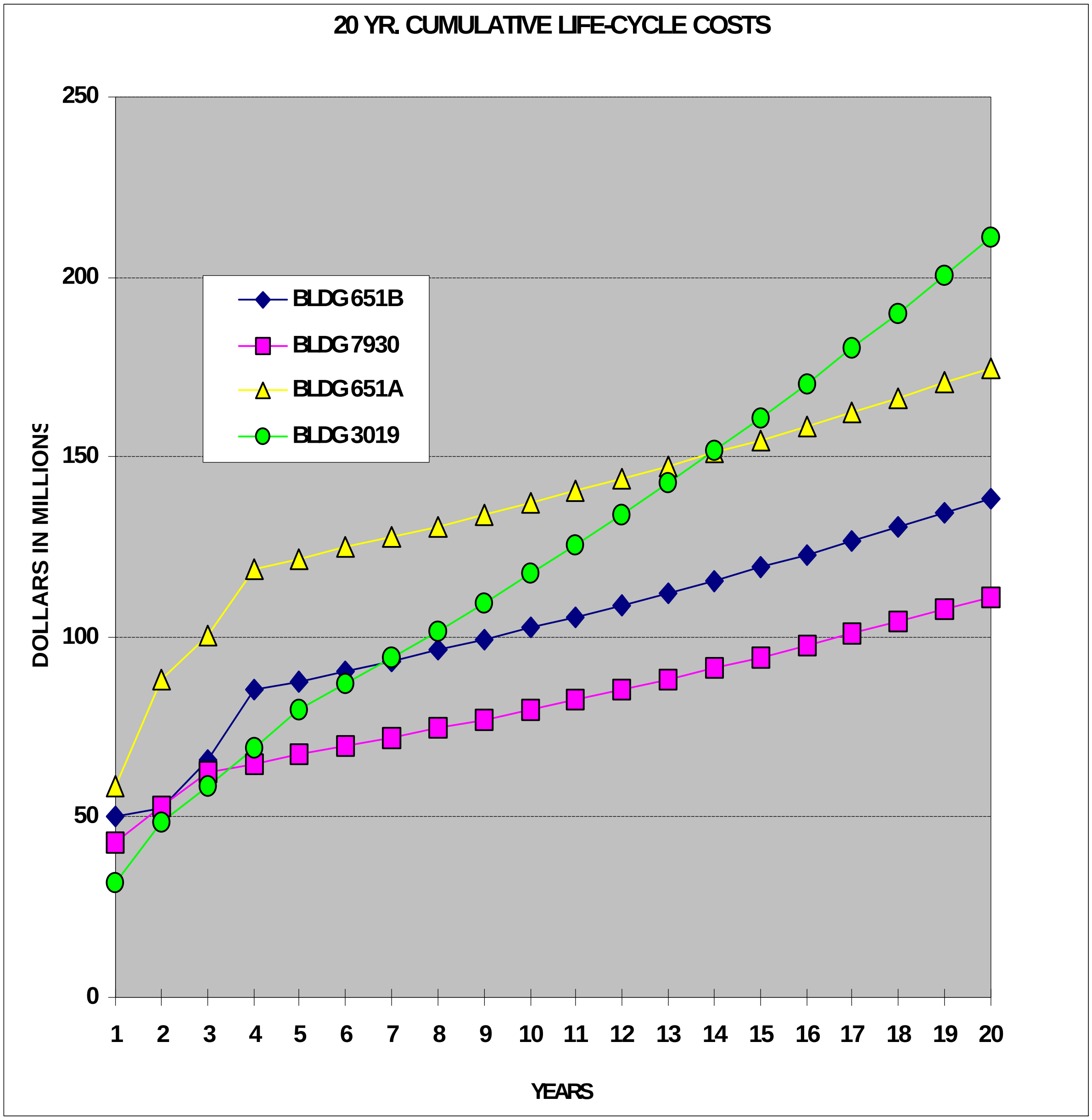


**Figure 12. Plot of Cumulative Life-Cycle Costs for the $^{233}U$ Storage Options.**

The initial preparative costs are decomposed in Table 12 and show that the current national repository, Building 3019, is the lowest in initial up-front cost to perform the $^{233}U$ long term storage mission. This is to be expected since it is currently performing this storage mission. However, this facility requires modifications and maintenance to continue the mission. Table 13 shows that the life cycle costs are not favorable to Building 3019. The plot of cumulative total costs (Figure 12) indicates that, after a few years, the lower recurring cost of Building 7930 becomes dominant. Transportation of the inventory is a significant cost element, particularly for cross-country transport from ORNL to INEEL.

### 5.5 OTHER COST CONSIDERATIONS

One item worthy of mentioning in this section is the initial repackaging costs (Table 11, line #20). The repackaging cost is the up-front cost to inspect, and repackage, as necessary, all the consolidated $^{233}U$ from the various sites for long-term storage, and is assumed to be performed at Building 3019. The current amount estimated for this task is approximately $20M, and it will not affect the comparative facility costs in this study since it will take place before the storage program is initiated and is independent of the site selected for storage. This cost is included here only for information, and completeness of near-term $^{233}U$ costs. The cost estimate for this consolidation/repackage campaign includes over $5M up-front Building 3019 facility modifications necessary for the repackage task. Also, the operations estimates are based on the following assumptions: approximately 29% of the packages will be overpacked, about 25% will need to be consolidated and repackaged, about 15% will be thoroughly inspected and repackaged, and around 1% will need stabilization and repackaging. The remaining containers will need only to be handled if some deficiency is observed in the inspection process. Included in this cost is repackaging equipment at approximately $4M in hot cell and NDE equipment, and over $1M in Building 4501 hot cell processing support.

Original cost estimates of this task were done assuming the full Building 3019 $^{233}U$ task workforce (20 people) would be needed during this task duration. However, this updated repackaging task estimate is based on assumptions that the approach can be modified, and this full workforce need only be present when the regular storage wells are accessed, and only half of this force is necessary during smaller quantity operations. The smaller quantity operations are based on the initial construction and loading of 24 small holding wells with 30 (conservative number) containers in one operation. This assumes 12 hours loading and 12 hours unloading for the full 20 people force, and then allows a smaller workforce of 10 people to access the holding wells through most of the remaining operations. This keeps the total exposed quantities during most operations below the safeguard limits, and allows an estimate of about 35% reduction in man-hours for the repackaging task. These estimates will change, possibly significantly, as the inspection/repackaging task evolves.

Facility D&D scenarios were not used as part of this cost estimation for facility comparison. The reason being that D&D cost are an inherent cost of the facility, and will be costed to DOE eventually no matter which programs are present. Also, many uncertainties and different D&D scenarios can be investigated and which ones will actually take place is more of a political/economic choice made within the background of current fiscal situation, than with technical or long term projections. A stand alone estimate for deactivation and D&D of Building 3019 was made to put into perspective the cost magnitude, which will be part of any long-term decisions.

### 5.6 BUILDING 3019 DEACTIVATION COST

Deactivation or D&D costs were not considered when comparing the storage option estimates as presented in Tables 10 through 13. However, a preliminary estimate to deactivate and D&D Building 3019 was made only for the purpose of gaining perspective the real cost involved in making a decision to relocate the $^{233}$U inventory to a new facility. Other than the storage of $^{233}$U, Building 3019 operations currently include lab-scale radiochemical processing. This is part of a medical isotope recovery and experimental $^{237}$Np test target fabrication as part of a proposed Pu-238 production demonstration. Therefore, if the $^{233}$U inventory is relocated, these tasks will have to be relocated and Building 3019 will have to be deactivated in some degree to avoid major recurring Surveillance and Maintenance (S&M) expenses. Table 14 is a summary of cost estimates to deactivate, and/or D&D the Building 3019 facility. Included in this table are cost estimates for minimal yearly operation after the inventory is removed (S&M Prior to Deactivation, $2.5M), and costs for yearly operation after deactivation operations have been completed (Post Deactivation S&M Costs, $0.75M). Deactivation operations are itemized to allow a perspective on the level of cost for various stages of deactivation that may be necessary to reduce the yearly S&M costs. The total deactivation operations were estimated at $22M. Included are the estimated D&D operations ($80M) for the Building 3019 facility based on a ratio of square footage of building footprint to 3019B, a similar facility recently deactivated and estimated by ORNL for D&D.

Included in this table also are up-front costs that will be incurred by the $^{233}$U storage task of facility preparation and repackaging/consolidation costs. These costs are included to give a more complete idea of total up-front costs involved in relocating the $^{233}$U inventory. The facility preparation example costs in this table were for Building 7930, since it was the lowest of the options, and the repackaging costs of $20M will be constant no matter which storage option is chosen. The following is a top level estimate of Building 3019 deactivation and related costs.

**Table 14. Deactivation Cost Estimate for ORNL Building 3019**

| Cost Category | Description | Cost |
|---|---|---|
| **S&M Prior to Deactivation** | **Estimate for minimal S&M in current state** | **$2.5M/Yr** |
| **Relocate Inventory/Facility Prep** | **Lowest Cost Option -- 7930** | **$30M** |
| **Repackaging Costs** | **Takes place in 3019 - same for all Facilities** | **$20M** |
| **Deactivation Costs** | **One-time up-front Deactivation costs** | |
| **Equipment Removal** | Cut, size, survey, & remove equip. from 5 Hot Cells & 8 other hot areas @ $400K/area | $5M |
| **Hot Cell Decontamination** | Five hot cell decontamination operations | $6.6M |
| **Glove Box and Hood Removal** | Costs include 18 glove box and 11 hood decontaminate, disassembly, & disposition operations | $2.4M |
| **Tank Disposition** | Disposition material, decontaminate & stabilize large tanks | $3M |
| **Solid Waste Disposal** | Costs for boxing, documenting, surveying & disposal of hot waste | $1M |
| **Seal Coat Hot Areas** | Over 90,000 sq. ft. of hot surface area to be coated with Instacoat @ $11.00 / sq. ft. | $1M |
| **Characterization & Hazard Analysis** | Pre & Post Deactivation Survey - Facility Hot Cell & Lab & Penthouse Areas, Document. For Reclassification | $1.5M |
| **Inventory Removal Costs** | Remove/decon./disposition of over 1300 tons of Pb & misc. metals (Pb-$0.55/lb decon) | $1.5M |
| **Total Deactivation Costs** | **Sum of Initial costs for deactivation** | **$22M** |
| **Post Deactivation S&M Costs** | **Extrapolated from sq. ft. adjustment (Building 3019B)** | **$0.75M/Yr** |
| **D&D Estimate** | **Based on sq. ft. ratio with Deactivated (3019B) Facility** | **$80M** |

## 5.7 COST DISCUSSION

All the costs reported in the body of this report are processed with the AES, Version 6.1, cost estimating program. As stated earlier, the costs provided in this report for the different facilities are based on many different basis of estimate, including engineering analysis where it was possible to deconstruct and analyze components. A large amount of cost information was available from prior year facility cost data, and much had to be estimated with best engineering judgment. The engineering judgment was, however, always input from a knowledgeable expert directly related to the facility being estimated.

The following discussion of each cost line in Tables 12 and 13 allows a better understanding of how these costs were derived.

### 5.7.1 Cost Details for Table 12

- Line #1. The first line in Table 12 includes the cost estimates for structural modifications, if any, required to bring each facility up to the point needed for the $^{233}$U storage mission. The structural cost entry under Building 651 was estimated for removal of a concrete blockhouse wall, addition of approximately 1,400 sq. ft area for additional storage wells, a hot cell area and support equipment and personnel. The $5M for Building 3019 is a top level estimate for the structural hardening needed to meet natural phenomena hazard analysis requirements

- Line #2. This line contains cost estimates for additional storage wells, shielding, and associated equipment. The Building 651 entry was based on an estimate from INEEL personnel.[7] This was extrapolated to include wells to store all the $^{233}$U storage needed in Option 651A, and storage for only the low $^{232}$U materials in Option 651B. The estimate for Building 7930 was based on the fabrication of over 2,000 linear feet of storage wells in the existing cell structure of the facility. These costs are based on several engineering analyses of Building 7930 cell areas.[4,5,15] See Figures 5 and 6 for schematics of Building 7930 storage locations.

- Line #3. This line addresses modifications to facility and storage area ventilation systems necessary for long-term storage. A complete new HVAC system would be needed for both Option 651A and Option 651B. The estimate was made of the Building 3019 ventilation cost based on known requirements. A major upgrade to the existing Building 3019 ventilation system would be required, and has been scheduled. These upgrades include major modifications to cell off-gas system, glovebox off-gas system, replace scrubbers, filter mounting system, ducting, electrical gear, variable speed fan system, main suction header and associated systems. Building 3019 ventilation costs were verified by the facility engineering staff, and are in the latter stages of system design.

- Line #4. This is the cost estimate for security upgrades, or additions. This includes a Building 651 moderate upgrade, believed necessary when the building is enlarged, and a more significant cost for Building 603, needed for upgrade to attractiveness Category I material storage. This cost estimate for Building 603 came from INEEL personnel. The security of the storage well access in Building 7930 would require upgrading for $^{233}$U materials handling. Since Building 7930 has access to the same off-site security force as does Building 3019, a similar system of monitoring, and timed interlocks were estimated for Building 7930.[6]

- Line #5. Building 7930 currently does not support quantities of fissile material handling, and therefore, needs a criticality accident alarm system upgrade which was estimated from similar systems in Building 3019.

- Line #6. The remote handling is in place for Building 7930 and Building 3019, the Option 651-A requires a 20-ton remotely-operated crane to handle the 33,000 lb shipping cask, and Option 651-B requires a 10-ton crane. These handling systems include bottom loading transfer cask and associated equipment.

- Line #7. This line includes the costs for hot cell and associated equipment for inspecting, processing, and re-packing (if not already available) the $^{233}U$ containers. The Building 3019 cost numbers are based on procurement and installation figures that are currently being incurred for the repackaging cell in that facility. The numbers for Building 651 are derived from these figures since it has no current hot cell capability. The Building 7930 numbers were obtained from the Building 7930 facility personnel,[4] based on manipulators, windows, and processing equipment costs for similar tasks.

- Line #8. The Shipping/Receiving dock needed upgrading for Building 651 (Option 651A) to handle the large shipping casks for efficient interstate transportation of the $^{233}U$ materials.

- Line #9. The facility SAR, BIO and/or authorization documentation will need to be reviewed and updated to varying extents. The estimated costs were obtained directly from each facility representative.[6,7,8,13]

- Line #10. The transportation costs for the $^{233}U$ materials from Building 3019 to Building 7930 (intra-site at ORNL) were obtained from Buildings 7930 and 3019 personnel. These costs were based on similar transfers at these facilities and are based on the intra-site transfer scenario[7] given in Section 3.11.4. Inter-site transportation costs from ORNL Building 3019 to INEEL Building 651/603 (Section 3.11.3) assumed the required use of DOT certified $^{233}U$ shipping containers. This transportation cost also includes the assumption of safeguards and security systems and personnel escorts for the shipments. TSD support system facilities or a special exemption, would be required for shipments above the safeguards limit. For purposes of the cost assessment, a 4- to 6-in. thick lead shielded shipping cask was determined to be necessary, and the GE-2000 cask was chosen. The shipping scenario chosen involves the shipment using scenario G3 (Transportation Section 3.11). This was chosen as the best container for capacity and shipment classification with available shipping data. Uncertainty in the criticality analysis for the transportation container required using the more conservative capacity number. The total $^{233}U$ transfer process is predicted to require 32 cross-country trips (using dual transports and casks) for a total 19-month campaign. Shipping of this material will also require detailed structural thermal, containment and criticality analysis; possibly some component testing. The preparation of a SARP; and obtaining a CoC is estimated at about 2-million dollars. The Option 651B transportation cost was estimated at an additional $1.2M (above the ORNL to INEEL costs) to individually ship the "low $^{232}U$" containers on-site to Storage Areas 651 and 749, after receipt at Building 603.

- Line #11. The cost of a waste disposition system for Building 7930 was estimated by the facility engineer, and the cost of the Building 651 waste system was estimated based on these Building 7930 cost estimates.

- Line #12. (Tables 12 &13). This line sums up the total up-front initial facility preparation costs, for the candidate facility options to become ready for the 50-year storage mission. Included on this line, for comparison only, is an estimate to build a new storage facility; which is only a slightly updated and escalated version of an estimate prepared in 1991,[13] with some modifications based on recent experience (see Greenfield Facility, Section 2.4).

### 5.7.2 Cost Details for Table 13

- Line #12. See above

- Line #13. This is the cumulative 50-year cost estimate for each facility, associated with the $^{233}U$ container periodic handling and inspection assumptions. These cost estimates are 50-year summations of the escalated, estimated cost for each facility to remove, inspect and reinsert 5% of the inventory per year, and open and sample one container per year for the full storage mission. There is a large disparity in costs between INEEL estimates and ORNL estimates for operational costs. This is due, in part, to recurring security cost at INEEL which were added to the facility operations and security costs (line 14). This is in contrast to ORNL security costs which, for the most part, are placed in the operational category since they are a pay-as-you-go cost. Also, some of the estimate discrepancies between INEEL and ORNL for periodic handling and inspection are due to INEEL estimating five people at three hours per container, while Building 3019 personnel estimate 14 people, plus a security force, at 8 hours per container (a similar estimate is also used for Building 7930). These estimates were rechecked with the submitting organizations, and differences were not completely resolved, although much of the differences are due to different facility and site operating approaches. The cumulative estimates are escalated at 2.8%/yr for the 50-year storage lifetime.

- Line #14. This line contains cumulative facility operations estimates. These costs are derived directly from the candidate facilities management input are based on 1998 actual costs, and are escalated out and summed for 50 years, as above. These numbers are cumulative inputs bases on the yearly estimates given below:

  — Option 651A. The 1998 operations estimates were supplied by INEEL.[7,8] These estimates are for incremental operations at $0.6M, and maintenance at $0.9M, and are updated and verified.
  
  — Option 651B. As with Option A above, the recurring costs estimates from INEEL[7,8] were split between maintenance ($0.6 M) and facility operations ($0.4M) These estimates closely matched Building 3019 operating/maintenance cost ratios, and reflects an updated INEEL estimate for incremental $^{233}U$ operations.
  
  — 3019 Option. $1.9M/yr[7] derived from actual 1998 operations costs.
  
  — 7930 Option. $0.3 M/yr cost efficiencies are gained by being part of the REDC complex[13] and this estimate is adjusted for cost sharing (50%) with the current $^{252}Cf$ program. These Building 7930 estimates are based on FY 1998 actual costs, as are all of the other options. Preliminary indications are 1998 recurring facility costs may be increased 10 to 15%, even if this is the case, it does not significantly impact these cost results or conclusions.

- Line #15. The recurring maintenance costs are summed for the 50-year storage mission and reported here. They are incremental costs, as reported above. The annual facility cost estimates for maintenance are derived from 1998 actual incurred costs for all options. As described above (#14), the INEEL facility maintenance costs are derived from updated incremental yearly input estimates of $0.9M-651A, and $0.6M for 651B, summed and escalated for 50 years.

- Line #16. This line presents the <u>totals of the recurring costs</u>. The costs for periodic handling and inspection, for facility operation, and for maintenance are summed for the 50-year mission, and are reported here.

- Line #17. This is the summation of initial facility preparation cost and recurring cumulative cost for each facility option.

- Line #18. The contingency applied to each option is reported here. Only the initial cost items were given a contingency cost. The preliminary contingency factors were 20% for ORNL estimates, and 25% INEEL estimates. This was a judgment made based on the feeling of a firmer basis for most ORNL inputs due to more $^{233}U$ small container experience and engineering analysis in these estimates.

- Line #19. Total Estimated Cost—this is the bottom line 50 year cost, and includes the summation of the fixed, recurring and contingency costs.

- Line #20. This cost is for the initial consolidation/repackaging program, also reported in Table 10, which will take place in Building 3019, prior to long-term storage. The cost does not affect the comparison of the long-term storage options, since it is applied equally to all facilities, and it is not included in summing up candidate facility totals in Table 13. The cost is only included for the purpose of completeness in trying to show all the $^{233}U$ storage related costs (see Section 5.5 for a discussion of this estimate).

## 5.8 DECISION ISSUES

A thorough consideration of all issues and uncertainties which potentially affect a decision associated with the long-term storage of $^{233}U$ materials is outside the scope of this report. The following issues were identified as the result of this task and are presented below for consideration.

**General Issues**

- Disposition decision impacts on $^{233}U$ storage options - Storage option changes and cost reductions could result from decisions to dispose of "low value" $^{233}U$.
- Ownership of Inventory - DOE/DP has requested transfer of $^{233}U$ inventories to DOE/EM.
- Risk of ongoing program conflicts with storage options - The $^{233}U$ program could interfere with current or future programs, such as INEEL spent fuel storage, or ORNL isotopes programs.
- NEPA review process for selecting a $^{233}U$ storage option - The NEPA review could affect the transfer of the $^{233}U$ inventory to an alternate storage location.
- Risk of mission incompatibilities - Site or organizational mission incompatibilities may affect storage options.

**Option Specific Issues**

- **Building 7930**

  - Risk of potential conflicts with proposed isotopes programs - The potential new isotope programs will have to be integrated with storage of $^{233}U$ to allow both missions to coexist.
  - Multi-program management - Need cooperation among multiple sponsors (ER, DP, NE, EM) within a single facility.
  - Consolidation and cost sharing of $^{233}U$ and transuranic inventory among sponsors - This would be a positive cost impact on all consolidated programs.
  - Intra-site transportation risks - This is low risk, but needs consideration.
  - Schedule for modifications - Multi-million dollar programs need significant lead times.
  - Pilot facility for NRC oversight - There would be potential for multiple regulatory oversite among NRC, DNFSB, DOE.

- **Building 3019**

  - Facility and inventory ownership - The possibility exists for multiple sponsors; DP, EM, MD, NE.
  - Legacy issues - The P-24 tank and 3019B disposition are two of Building 3019's legacies.
  - Facility age issues - Long term upkeep of complex building can be costly.

- **Building 651A**

  - State of Idaho acceptance - These is a risk of stakeholders not accepting new fissile material storage.
  - Site mission compatibility - Site or organizational mission, or strategic plan may have incompatibilities, such as planned removal of all nuclear materials.
  - Interstate transportation - Multiple shipments will involve many states.
  - Schedule for expansion - Significant expansion needed would require extended schedule.
  - Consolidation of $^{233}U$ - INEEL has a potential benefit of co-location of $^{233}U$/Th and separated $^{233}U$.

- **Building 651B**

  - State of Idaho acceptance - There is a risk of stakeholders not accepting new fissile material storage.
  - Site mission compatibility - Site or organizational mission, or strategic plan may have incompatibilities, such as planned removal of all nuclear materials.
  - Interstate transportation - Multiple shipments will involve many states.
  - Consolidation of $^{233}U$ - INEEL has a potential benefit due to co-location of $^{233}U$/Th and separated $^{233}U$.
  - Multi-program management - Need for cooperation among multiple sponsors for facility and multiple programs for space.

# 6. CONCLUSIONS

The $^{233}U$ Alternative Storage Facility Trade Study has systematically evaluated potential storage facilities complex wide and narrowed the candidate selection first to seven that met general storage needs, and then to four options that met specific screening criteria (see Section 1). The final evaluation of these four was based primarily on cost estimates to accomplish the storage mission. These cost estimates and conclusions are based on the cost data available at the time of this report. Changes could occur as further estimates are refined; however, trends will most likely remain the same.

The results of these cost estimates are provided in the Facility Cost Summary, Table 10**.** A comparison of the Facility Preparation Costs and the Facility Recurring Costs give a good indication of the up-front expenses and the life cycle costs that will be incurred with this $^{233}U$ storage mission. The facility preparation cost is lowest ($22M) for the existing $^{233}U$ repository Building 3019. This is logical since all the storage and support systems are in place and, although some upgrades are needed, no transportation costs are incurred. These initial advantages make Building 3019 the lowest cost option for the first few years of storage. INEEL Option 651A, on the other hand, lacks more of the basic facility requirements for $^{233}U$ storage (Table 9) and therefore has the highest facility preparation cost. Transportation is also a significant up-front preparation cost for both of the INEEL options. However the INEEL 651/603-749 (Option 651B) is clearly the lower cost INEEL option, and does not require extensive modifications to existing facilities.

The recurring cost numbers indicate a different facility ranking. Building 3019 has the highest yearly recurring cost at $5.9M/yr, and Building 7930 has the lowest recurring cost at $2M/yr, with both Options 651A ($2.4M/yr) and 651B ($2.3M/yr) also relatively low. Building 3019 cumulative operation costs become more expensive in out years due to higher yearly maintenance costs and operating costs (see Table 11). This is in part due to the age of the facility and its legacy of contamination. Also the original design of the 3019 facility was for radiochemical processing development, which requires a larger, more complex facility than is needed for storage and handling. The reasons for the lower recurring costs of the INEEL and Building 7930 estimates can probably be attributed to a smaller size, and cost sharing. Both INEEL options have included cost sharing with the current fuel storage program. In addition, the INEEL Site funds general building maintenance and upkeep and these costs are not included in the incremental costs reported. Building 7930 has cost sharing considered with the current $^{252}Cf$ program, although cost sharing with proposed new programs was not taken into consideration for this study. If transportation is not considered, both the initial facility preparation and the recurring costs, are essentially equal for Building 7930 and for 651B Options. The higher interstate transportation costs for INEEL Option 651B make Building 7930 the lowest cost option.

A plot was made of the cumulative costs per year for each facility to show the relationship of the initial costs and the recurring costs on total cumulative storage cost (Figure 11). Initially, the lowest cost option, using these preliminary estimates, is Building 3019. The cost data show that Building 3019, which has the lowest initial costs, also has the lowest cumulative yearly cost for the first two to three years of storage. However, higher recurring costs of Building 3019 make it the highest cumulative storage cost facility after several years, because of the lower recurring cost of the three other options. The combination of the lowest recurring costs, and next to lowest initial cost place Building 7930 as the overall lowest cost storage option after the first three to four years of the storage mission.

Consideration of factors in this trade study other than cost, such as long-term site missions and the acceptance of interstate movement of large amounts of fissile material, leads into areas of subjective analysis that must be considered, but are not addressed in this technical report. These issues are identified in Section 5.8 and would be part of NEPA review and the DOE decision process on selection of a $^{233}U$ Storage Facility.

## 7. REFERENCES/RESOURCES


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