Attachment B to Calbos Declaration

National Nuclear Security Administration

Final Report for the Plutonium Pit Production Analysis of Alternatives

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DEPARTMENT OF ENERGY | NATIONAL NUCLEAR SECURITY ADMINISTRATION | DEFENSE PROGRAMS [NA-10]

APPROVAL

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

List of Acronyms

AC	analytical chemistry
AoA	Analysis of Alternatives
ARIES	Advanced Recovery and Integrated Extraction System
BAP	Aqueous Polishing Building
Be	beryllium
BMP	MOX Processing Building
BNL	Brookhaven National Laboratory
CD	Critical Decision
CDF	cumulative distribution function
CER	cost estimating relationship
CMR	Chemistry and Metallurgical Research
CMRR	Chemistry and Metallurgical Research Replacement
CPDS	construction project data sheet
D&D	decontamination and decommissioning
DBT	design basis threat
DoD	Department of Defense
EIS	environmental impact statement
EPC	engineering, procurement, and construction
FPF	Fuel Processing Facility
FPU	first production unit
ft^2	square feet
FY	fiscal year
GAO	General Accounting Office

HC	hazard category
HEPA	high efficiency particulate air
INL	Idaho National Laboratory
IPR	independent project review
KCNSC	Kansas City National Security Campus
LANL	Los Alamos National Laboratory
LCC	life cycle cost
LEP	life extension program
LLNL	Los Alamos National Laboratory
LLQR	Lessons Learned Quarterly Report
LLW	low-level waste
M&O	management and operating
MAR	material-at-risk
MBSE	model-based systems engineering
MC	materials characterization
MFFF	Mixed Oxide Fuel Fabrication Facility
MNS	Mission Needs Statement
MPF	Modern Pit Facility
NA-10	Office of Defense Programs
NA-20	Office of Defense Nuclear Nonproliferation
NEPA	National Environmental Policy Act
NRC	Nuclear Regulatory Commission
NSPM	National Security Presidential Memorandum
NQA	Nuclear Quality Assurance
NWC	Nuclear Weapons Council
O&M	operations and maintenance

OMB	Office of Management and Budget
OPC	other project cost
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
OST	Office of Secure Transportation
P&PD	Production and Planning Directive
PDF	probability distribution function
PEP	Project Execution Plan
PF-4	Plutonium Facility
PIDADS	Perimeter Intrusion Detection Assessment and Delay System
PM	program manager
ppy	pits per year
PRD	Program Requirements Document
PSO	Program Secretarial Officer
R&D	research and development
RLUOB	Radiological Laboratory Utility Office Building
ROM	rough order of magnitude
SC	security category
SDS	Safety Design Strategy
SE&I	systems engineering and integration
SME	subject matter expert
SNL	Sandia National Laboratories
TA	technical area
TEF	Tritium Extraction Facility
TPC	total project cost
TRU	transuranic

WBS	work breakdown structure
WR	War Reserve
WSB	Waste Solidification Building

EXECUTIVE SUMMARY

The National Nuclear Security Agency (NNSA) requires a sustained production capacity of no fewer than 80 pits per year (ppy) by 2030. Since 1989, when the Rocky Flats Plant was closed, the nation has had little capability to manufacture new plutonium pits that can go into the stockpile, called War Reserve (WR) pits. A limited capability of 10 WR ppy was exercised at Los Alamos National Laboratory (LANL) in the early 2000s, but no WR pits have been produced since 2012. At this time, NNSA is developing and installing capability at LANL in Plutonium Facility (PF)-4 to produce 30 ppy by 2026. The Analysis of Alternatives (AoA) for meeting pit production requirements, completed in September 2017, assessed alternatives to close this identified mission gap in the NNSA's pit production capability. The AoA is a post Critical Decision (CD)-0, pre-CD-1 activity to identify a preferred alternative for conceptual design in preparation for the Deputy Secretary of Energy to make a program decision at CD-1.

The AoA analysis resulted in the identification of two preferred alternatives, with a recommendation to conduct engineering analyses and pre-conceptual design activities on both alternatives in support of conceptual design for CD-1. The refurbishment and repurposing of the Mixed-Oxide Fuel Fabrication Facility at Savannah River Site has the most favorable cost and schedule for achieving a sustained 80 WR ppy production rate, but introduces the qualitative risk of reconfiguring a partially completed facility for a new mission in a new location. The other recommended alternative, new construction of an 80 WR ppy facility at LANL, has the lowest qualitative siting risk, but less favorable cost and schedule, and introduces risk associated with new construction of hazard category (HC)-2 facility space that includes regulatory milestones historically difficult to navigate in early design (e.g., NQA-1 and NEPA). The identification of two preferred alternatives for more detailed engineering analysis and conceptual design has precedence within the department to be addressed outside of the AoA process.

The 80 WR ppy requirement was validated prior to the start of the AoA by the Nuclear Weapons Council based on pit aging and directed military requirements. The pit production requirement is an annual "at least" production rate derived from the delivery schedule for certified, life extended nuclear weapons to the Department of Defense (DOD). Consequently, a sustained production rate of 80 ppy must be achieved with high confidence. In the context of the AoA analysis, high confidence was defined as a greater than 90% probability of achieving the required throughput (9 out of every 10 production years, the facility is expected to produce at least 80 WR pits). This constraint differs significantly from the Plutonium Sustainment Program's 30 WR ppy annual production goal. The 30 WR ppy capability is an "on average" requirement, defined as a 50% confidence in the production throughput.

The AoA Team evaluated functional and process requirements for achieving the 80 WR ppy mission requirement. These requirements informed the development of equipment and processing space estimates, which were key components of the analytical conclusions and the cost estimate ranges produced by the AoA. In order to adequately develop the equipment and space estimates, the AoA team developed a stochastic discrete event simulation of the pit production process to project pit manufacturing throughput for a given equipment set. The final equipment set was developed by adjusting equipment as needed to remove production- and logistics-based bottlenecks to ensure an 80 WR ppy throughput at high confidence. Following verification and validation of the model and the resultant equipment set by the AoA team production experts, subject matter experts estimated space needs based on analysis of analogous projects. Space needs were developed for both HC-2 and non-HC-2 functions,

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using a best value approach by moving support functions to non-HC-2 space whenever possible. Two key outcomes resulted from the equipment and space analysis:

- First, the equipment set for 80 WR ppy does not fit in the modular layout envisioned at CD-0 for the initial modular building strategy proposal.
- Second, the difference between a 50 WR ppy equipment set and an 80 WR ppy equipment set is within the range of error and, therefore, did not have an appreciable effect on the determination of the preferred alternatives. 50 ppy capability was evaluated in the context of splitting production capacity by continuing to rely on PF-4 for 30 ppy and producing 50 in another facility.

The AoA Team assessed a range of options that included both building new and refurbishing existing facilities to achieve the required annual production rate while not interfering with the mission objectives for the Plutonium Sustainment program and other required plutonium missions. The AoA Team determined that the original modular building strategy as proposed at CD-0 is not a viable option for the 80 WR ppy production requirement. Three aspects of this strategy prevent it from meeting mission requirements:

- PF-4 is only capable of an estimated 30 ppy (on average) after planned upgrades.
- Renovation of existing processing areas within PF-4 makes the 30 WR ppy sustainment capability unachievable by 2026 and presents schedule risks to other current missions not present in other options.
- An 80 WR ppy equipment set (at high confidence), requires over three times more HC-2 processing space than provided by two 5,000 square foot modules.

Although the modular building strategy envisioned at CD-0 utilizing PF-4 does not meet the functional and process requirements for an 80 WR ppy production, after a new 80 WR ppy capability is established, PF-4 can return to the research and development mission for which it was built.

A key finding of this AoA was the high schedule risk for all alternatives. There are two types of schedule risk, risk associated with the complexity of the schedule (complexity) and risk associated with the ability to execute the schedule as envisioned (executability). Complexity risk is related to the difficulty associated with design and procurement of processing equipment and the design and construction of a HC-2 facility. Complexity risk is reflected in the schedule analysis, and compounds with a phased approach to design and construction. Executability risk is related to resources, efficiency, and personnel. Executability risk is reflected in the cost estimating section. Although the complexity analysis indicated a 2030 schedule is achievable under ideal circumstances, the associated cost analysis demonstrated that executability risk would delay achievement of 80 WR ppy to 2033 at the earliest for any alternative.

Based on the AoA analyses, the Program Secretarial Officer has directed further refining each of the two preferred alternatives by executing an engineering analysis prior to conceptual design. The results of the engineering effort, coupled with the AoA analysis, will be used to inform a decision memorandum from the Program Secretarial Officer and enable pursuit of a full conceptual design package on a single preferred alternative.

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1 Introduction

1.1 Purpose

The purpose of the Plutonium Pit Production Analysis of Alternatives (AoA) is to identify and assess alternatives across the Nuclear Security Enterprise that can deliver the infrastructure to meet NNSA's pit production requirements. Specifically, NNSA requires a sustained production capacity of 80 pits per year (ppy) by 2030, which is currently not available. The AoA does this by: 1) identifying a broad set of alternatives to provide the necessary infrastructure to support the production of 80 ppy in support of enduring stockpile stewardship work, without compromising the ability to conduct all other required plutonium missions; 2) analyzing the life-cycle cost, schedule, benefits, and risks associated with each alternative; and 3) presenting the evaluation results to the Program Secretarial Officer (PSO) (designated as the Deputy Administrator for Defense Programs) to support the anticipated Critical Decision (CD)-1 selected alternative.

1.2 Scope

The planned expansion of pit production capability is classified as a major system acquisition project under DOE Order 413.3B Change 3. The results of this AoA support development of CD-1 documentation during Fiscal Year (FY) 2018. A Steering Committee/Advisory Group chaired by the Office of Defense Programs (NA-10) Deputy Administrator, who serves as the PSO for this acquisition, provided oversight for the AoA.

The Mission Need Statement (MNS) and PRD prepared in support of the CD-0 approval were updated to reflect the results of requirements validation and were approved in June 2017. These documents provide the foundation for the requirements and assumptions used and confirmed during the AoA process.

The scope of the AoA addresses the mission gap and program requirements, as outlined in the signed MNS and PRD. In particular, this analysis examines the key capabilities and capacities for NNSA plutonium missions, including:

- Ability to remanufacture 80 WR pits per year
- Ability to sustain the full suite of pit manufacturing capabilities, including pit reuse
- Required capabilities to manufacture all pit types identified in the PRD
- Capabilities for ongoing Defense Programs plutonium work identified in the PRD, including assessment and certification, surveillance, production development, environmental testing, pit development activities, and plutonium-238 production activities
- All supporting infrastructure related to plutonium operations
- Existing non-Defense Programs missions, such as plutonium-238 production for space programs and Advanced Recovery and Integrated Extraction System (ARIES) [disassembly of pits and oxidation of plutonium for Defense Nuclear Nonproliferation (NA-20) programs]

The following changes to the pit production mission are outside the scope of this AoA because they change the program requirements, rely on unproven technology, or are pre-decisional to federal funding decisions:

- Changes to the current program requirements, including the type and number of pits per year required

- Alternate methods for producing pits that would change the required equipment or facility size, such as wrought versus cast manufacturing processes
- Changes to the scope, schedule, and/or funding of other plutonium programs, including ARIES, Plutonium Sustainment Program, and plutonium-238 operations
- Funding constraints that could eliminate costlier alternatives

1.3 Project Background

Maintaining capabilities in plutonium operations is a cornerstone of NNSA's stockpile stewardship mission. As NNSA carries out this mission, the ability to maintain plutonium capabilities and increasing production capacity will be increasingly vital to sustaining the nuclear weapons stockpile. Furthermore, the nuclear security enterprise needs facilities to meet mission requirements and support current and future national security requirements related to the Nation's nuclear deterrent.

NNSA is committed to continuity in plutonium operations and is optimizing existing facilities to meet this commitment and plans to support production of up to 30 ppy at LANL. As described in the MNS, production capacity beyond 30 ppy will require additional Hazard Category (HC) 2, Security Category (SC) 1 processing area to support long-term increased capacity of plutonium operations.

Acquisition for the planned pit production mission achieved CD-0 on November 25, 2015. To ensure compliance with departmental project management best practices and policies, DOE Order 413.3B Change 3, and recent National Defense Authorization Act language, a rigorous AoA was conducted to examine viable options to meet the approved mission need. The AoA evaluated options for providing the required infrastructure to support the production of 80 ppy without compromising the ability to conduct all other required and enduring plutonium missions described in the PRD.

1.4 Major Assumptions

During initial AoA framework development, the AoA team developed the following set of major assumptions, which are consistent with the PRD:

1. Chemistry and Metallurgical Research Replacement (CMRR) and Plutonium Sustainment programs will be executed as planned, including the change to the Radiological Laboratory/Utility/Office Building (RLUOB) material-at-risk (MAR) limits. The resultant capabilities were assumed to be sufficient analytical chemistry (AC) and materials characterization (MC) capabilities to support plutonium mission activities at LANL and the capacity to manufacture approximately 30 ppy in PF-4.
2. The baseline program will be a W87-like pit. The equipment and space needs to work on or produce small quantities of all the seminal pit types, as defined in the PRD, were included.
3. Pit reuse activities can be supported by the same capabilities as pit remanufacturing.
4. Non-nuclear pit parts will be manufactured new. Production of these parts can continue at their current location [e.g., Kansas City National Security Campus (KCNSC) and LANL].
5. Future pits will continue to be cast, not wrought, and use current processes and technology.
6. Lawrence Livermore National Laboratory (LLNL) will continue to perform its current plutonium mission.

7. Pit production must be performed in the United States in government-owned facilities and by approved management and operating (M&O) partners. No commercial vendor or foreign government alternatives were considered.

2 Requirements

2.1 Mission Requirements

An enduring pit production capability is a basic requirement of the nuclear security enterprise. The capacity requirement to produce 80 ppy is based on several drivers, including pit lifetimes (as determined by plutonium aging characteristics) and the military requirements of the nuclear stockpile. The age of plutonium pits currently in the stockpile, the rate of surveillance work, and planned stockpile requirements all contribute to the production capacity requirement. The origins of this requirement are described in the classified Program Requirements Document (PRD)

2.1.1 Threshold and Objective Requirements for Plutonium Missions

The PRD contains threshold and objective requirements for Defense Programs and other plutonium mission requirements. Threshold requirements shown in **Table 2–1** represent the minimum acceptable level to meet mission needs. Objective requirements typically represent a higher level of capability or capacity than the threshold desired by the program (see **Table 2–2**). In some cases, missions have objective requirements but no threshold level. In those cases, the requirement may or may not be satisfied. The requirements for the following plutonium missions can be found in the classified PRD.

Table 2–1. Threshold requirements

Program Requirement	Requirement Description
PRD-1	Threshold: NNSA will concurrently deliver remanufactured and reused WR pits to the stockpile according to the schedule in the P&PD and in sufficient quantities to meet NWC production requirements, not to include regassed pits [derived from PRD-1, PRD-2, and PRD-4 in the classified PRD].
PRD-2	Threshold: NNSA will provide the following capabilities in sufficient quantities to meet NWC pit production requirements: receiving, packaging, storage, disassembly, metal preparation, foundry, machining, inspection, assembly, and non-destructive testing [derived from PRD-2 in the classified PRD].
PRD-3	Threshold: NNSA will provide the capability to remanufacture and reuse multiple pit types to meet NWC production requirements [derived from PRD-2 in the classified PRD].
PRD-4	Threshold: NNSA must maintain the ability to fabricate experimental devices to support subcritical experiments [derived from PRD-5 in the classified PRD].
PRD-5	Threshold: NNSA must maintain the ability to conduct surveillance, to include shelf-life surveillance, on power supplies [derived from PRD-6 and PRD-7 in the classified PRD].
PRD-6	Threshold: The NNSA must maintain the ability to perform destructive tests on pits [derived from PRD-9 in the classified PRD].

Program Requirement	Requirement Description
PRD-7	Threshold: NNSA's strategy must maintain the ability to perform production development activities concurrent with WR pit production [derived from PRD-10 in the classified PRD].
PRD-8	Threshold: In addition to meeting NWC production requirements, NNSA must maintain the ability to provide a small number of pits annually for Lawrence Livermore National Laboratory analysis [derived from PRD-11 in the classified PRD].
PRD-9	Threshold: NNSA must maintain the ability to manufacture samples to fulfill Science Campaign activities requirements [derived from PRD-12 in the classified PRD].
PRD-10	Threshold: NNSA must maintain the ability to process plutonium oxide in sufficient quantities to support the Office of Defense Nuclear Nonproliferation ARIES mission [derived from PRD-14 in the classified PRD].
PRD-11	Threshold: The NNSA must maintain the ability to fabricate fueled clads in sufficient quantities to support the DOE Office of Nuclear Energy NASA activities [derived from PRD-15 in the classified PRD].
PRD-12	Threshold: NNSA must maintain the ability to generate sufficient quantities of americium-241 to support the DOE Office of Science missions [derived from PRD-16 in the classified PRD].
PRD-13	Threshold: NNSA shall comply with all applicable laws, regulations, DOE orders, codes, standards, and contractual provisions for the prime contract with DOE/NNSA [derived from PRD-19 in the classified PRD].

Key:

ARIES = Advanced Recovery and Integrated Extraction System; NWC = Nuclear Weapons Council; P&PD = Production and Planning Directive; PRD = Program Requirements Document; WR = War Reserve

Table 2–2. Objective requirements

Objective Requirement	Requirement Description
1	Pit production [derived from PRD-1]
2	DOE-Nuclear Energy Missions [derived from PRD-10]
3	DOE Office of Science Missions (e.g., americium-241) [derived from PRD-11]
4	DOE Office of Defense Nuclear Nonproliferation ARIES Missions [derived from PRD-12]

Key: ARIES = Advanced Recovery and Integrated Extraction System; PRD = Program Requirements Document

2.2 Functional and Process Level Requirements

One of the first steps in the AoA is to determine the requirements at the functional and process-level level of detail to meet the mission requirements provided in the PRD. For this AoA the functional and process-level requirements include:

- Confirmation of the characteristics of the P&PD requirement of 80 ppy (all estimates are modelled at high confidence or at greater than 90% probability of achieving the desired production rate in any given year);
- Estimation of the specific items of processing equipment to produce 30, 50 and 80 ppy;
- Estimation of building working space to accommodate space between glovebox lines, cabinets and supplies, access areas, stairs, support equipment, and hallways.
- Definition of the support functions and building services that ensure proper operations, maintenance, and production support that must be co-located in HC-2, SC-1 space;
- Identification of supporting infrastructure needed to produce 80 ppy not necessarily co-located in HC-2, SC-1 space.
- Derivation of the required footprint of HC-2, SC-1 to support the processing equipment and support functions
- Derivation of the required footprint outside the HC-2, SC-1 space for supporting infrastructure.

The result is a comprehensive estimate of equipment and space, including functions inside and outside the main processing facility, and facilities inside and outside the security boundaries. **Table 2-3** shows the framework for the space estimates.

Table 3–3. Space estimate framework

Process equipment
Building work space
Support functions within the processing facility
Building services
Support functions within SC-1 boundaries, but outside the processing facility
Supporting infrastructure outside the SC-1 boundary

2.2.1 Equipment

The AoA Team started with a generic unclassified pit production flowsheet provided by LANL, later updated by LANL and LLNL for the W87-like pit, to develop a classified stochastic discrete event simulation[1] to represent the pit production processing steps. The model includes the equipment required to disassemble an incoming pit, purify the plutonium recovered from the pit, cast and machine the hemi-shells, assemble the parts into a finished pit, and perform required inspections to verify the final products compliance with design requirement. **Figure 2–1** shows the overall process flowsheet for each of the functional process areas.

[1] Stochastic discrete event simulation is the industry standard for modeling the capacity of manufacturing lines because it includes the effects of random events such as equipment breakdown and variable process and repair times on total throughput. In NNSA, LA-CP-05-0256, *TA-55 Pit Manufacturing Responsive Infrastructure and Capacity Study*, LANL, 2005 is one example of its use.

(b)(3) UCNI

(b)(3) UCNI

2.2.1.1 Discrete Event Simulation Model Description

The discrete event model used to determine equipment needs was developed in Innoslate,[2] a browser-based process modeling software platform available on NNSA's classified computer network. The model simulates the pit manufacturing process, with multiple parts manufactured simultaneously and multiple processes running in parallel. Each process module has logical structure similar to the example shown in **Figure 2–3**.

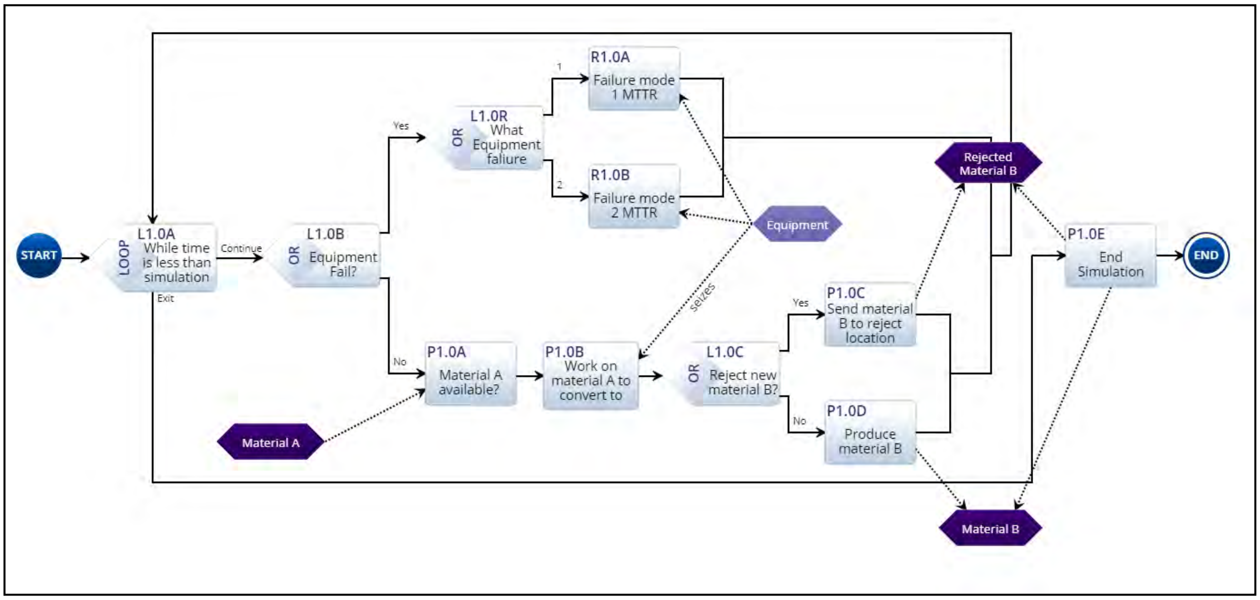

Figure 2–3. Pit production model example of process module logic

The model represents each piece of equipment and each step in the process. Input data, such as process times and equipment repair times, are represented by triangular distributions (low, high, most likely) based on LANL pit production data, input from LANL operators, and input from Rocky Flats Plant SMEs. When a part enters a process module, such as casting or machining, for example, the model draws a random number to determine if the equipment required to perform the process is in working order. If the equipment is determined to be out of order, a random number is drawn to determine which failure mode has occurred, and another random number is drawn from the appropriate equipment repair distribution for that failure mode to determine how long the equipment will be out of service. During repair time, the equipment is "seized" to prevent any other process from using it. After the appropriate wait time for the repair, the equipment is made available to process parts.

When the equipment is up and running, the model double checks to see if the part that needs to be processed is available. This step prevents the processing step from seizing the equipment before the part is ready to be processed and is necessary in cases where multiple steps use the same equipment. When the part is available, it passes into the processing activity, and a random number is drawn from the appropriate distribution to determine how long the process will take in that instance. The equipment is seized so that no other process can use it during that time.

[2] Innoslate is a model-based systems engineering (MBSE) software tool selected for its real-time simulation capability, as well as the ability to model the parallel processes involved in pit production simultaneously. The AoA team used Innoslate v3.9 to create the pit production process model. More details can be found at https://help.innoslate.com.

After the processing activity is complete, if there is an inspection at that point, the model draws a random number to determine whether the part is good or rejected. Rejected parts are sent back to the appropriate processing step if rework is possible, or they are reduced to raw material if rework is not possible. Good parts are passed on to the next processing step.

The Classified Appendix contains the process diagrams, a more complete description of the model functionality, the model data, and the classified results. In summary:

- Every manufacturing process necessary to produce a pit[3] is represented in the model based on the pit manufacturing flowsheet provided by LANL and later updated by LANL, LLNL, and Rocky Flats Plant SMEs to include specific processes required for the W87.
- Every piece of equipment has unique probabilities of failure for multiple failure modes derived from SME and current operator input, historical data from equipment use at LANL, and the pit production model developed by LANL.
- Manufactured parts can be rejected at any point in the production process where quality assurance and inspection is usually performed. Reject rates are based on historical data from the LANL production of the W88 from 2007 to 2012, as well as input from SMEs and operators.
- Planned equipment maintenance is assumed to be performed on the second shift and is, therefore, not explicitly modeled. Unplanned maintenance is assumed to occur during working and off-shift hours.

2.2.1.2 Verification and Validation of the AoA Plutonium Pit Production Process Model

The intended purpose of the model is to produce an estimate of equipment required to produce the W87-like pit at a given pit capacity (30, 50, or 80 ppy) more than 90% of the time (over 90% confidence) as input to an estimate of space needed for this function. The W87-like pit is both the program requirement and likely the most stressing type of pit, based on equipment usage. The space estimate is intended to be used in comparing costs of multiple alternatives for providing the capability. The model verification and validation effort was performed by the AoA Team and focused on ensuring that the model's representation of the problem and the model's logic and mathematical and causal relationships are reasonable for the intended purpose of the model.

The basic activities in the verification and validation process below were accomplished by the AoA Team. A brief description of these activities is provided here. See Appendix J for a more detailed explanation of the model verification and validation process and results.

- Validate Conceptual Model – confirming that the capabilities indicated in the conceptual model embody all the capabilities necessary to meet the requirements.
- Verify Design – determining that the simulation's design is faithful to the conceptual model, and contains all the elements necessary to provide all needed capabilities without adding unneeded capabilities.
- Verify Implementation – determining that the code is correct and is implemented correctly on the hardware.

[3] These include disassembly, metal preparation, foundry, machining, sub-assembly, assembly, and post-assembly.

- Validate Results – determining the extent to which the simulation addresses the requirements of the intended use.

Validation of conceptual model and verification of model design

The conceptual model for the AoA includes the pit production flowsheet provided to the AoA Team by LANL in August 2016. The Innoslate process model representation of that flowsheet developed by the Team contains the simulation design.

The conceptual model was validated and the pit production process model design was verified through a series of reviews by SMEs.

Verify Implementation

The AoA Team performed standard simulation code verification techniques, including:

- Running each module separately before integrating the modules together, tracing each pit part through the processes to ensure proper model logic.
- Making extensive use of Innoslate's animation and operational graphics capabilities to monitor the values of various performance parameters.
- Varying input parameters, fixing random variables, and manually checking the output.
- Performing extreme condition checks by evaluating model logic under extreme values of parameters, such as rapidly arriving parts, or zero inventories.
- Performing degenerate tests, such as testing whether queues continue to grow when parts arrive faster than they can be serviced, and forcing parts into multiple processes simultaneously to test the logic for equipment that is used by multiple processes or cannot be freed until the next piece of equipment is available.

Validate Results

Since there is no operational production quantity pit production capability available, and data from Rocky Flats Plant production could not be found, comparison to other models and face validity were the validation methods used by the AoA Team.

The AoA model results were compared to LANL discrete event simulation results from the early 2000s for a case with one of each type of equipment[4], and the current LANL deterministic model for the Plutonium Sustainment planned 30 ppy (average) equipment set[5]. Additionally, the AoA Team's space estimates were compared to space estimates derived from the LANL discrete event simulation and to the Modern Pit Facility estimates for 125 ppy (average).

The results of the model were reviewed for face validity by current and former pit production experts, current pit production process operators, plutonium process experts, and manufacturing experts from Y-12, as follows:

- Review of the model results for each process module by LANL, LLNL, and Rocky Flats Plant subject matter experts (SMEs) for during AoA Team site visit to LANL Feb 27-Mar 3, 2017.
- Review of the model results and the input data by LANL pit production operators and area managers during AoA Team site visit to LANL Feb 27-Mar 3, 2017.

[4] LA-CP-05-0256, *TA-55 Pit Manufacturing Responsive Infrastructure and Capacity Study*, LANL, 2005.
[5] LA-CP-12-00299, *The Plutonium Sustainment and Manufacturing Capabilities Study*, LANL, 2012.

- Review of the model during the Plutonium Advisory Team meeting held April 3-6, 2017 at HQ DOE.
- Review of the equipment set for 80 ppy by LLNL and Rocky Flats Plant SMEs during the team's site visit to SRS.

The AoA Team verified and validated the Pit Production Process model and determined that it was adequate for its intended purpose, namely estimating the amount of equipment needed to produce pits at 30 ppy, 50 ppy, and 80 ppy capacities. The process was performed according to recognized practices in the Modeling and Simulation field.

2.2.1.3 Results

The AoA team used the model to develop equipment needs for three primary cases: 30 ppy and 50 ppy (for split production cases, see Chapter 4 for a description of the alternatives) and 80 ppy, all on a single shift. As is standard practice for the use of stochastic discrete event simulations, the AoA team conducted thousands of iterations to obtain a distribution of results, with the results taken from the portion of each run deemed to be steady state. This means that the early part of the runs (the first two years of each run in this case) were thrown out to avoid deriving conclusions from perturbations in the system due to starting the modeled factory empty. In all, these simulations provided over 7,000 data points for throughput capacity to generate the results for each case.

The validated threshold requirement is 80 ppy, meaning this is the minimum level needed to meet mission requirements. The production capability needs to have the capacity to produce 80 ppy every year, so the team developed an equipment set that is predicted to produce 80 ppy more than 90 percent of the time (93 to 97 percent confidence) as input to the facility space estimates. This level will be referred to as "high confidence" throughout the remainder of this report. The space estimates LANL used to develop the equipment lists for various pit production capacities, including 30 ppy and 80 ppy were based on a deterministic model (random events such as equipment breakdowns, repair and process times, and part reject rates are represented based on average values). A deterministic model will produce the same answer every time, since no randomness is modeled. The use of average values as model input data means that the LANL model will estimate the equipment set to produce a given throughput on average. Production throughput would be expected to be below 80 ppy 50% of the years. Since the requirement is to produce a minimum of 80 pits annually, estimating using averages will systematically underestimate equipment and space needs. **Table 2–4** shows the model results for each of the three cases.

Table 2–4. Model results

	30 Pits Per Year	50 Pits Per Year	80 Pits Per Year
Confidence level %	96%	97%	93%
Lowest throughput, units	8	20	30
Average throughput, units	41	84	103
Highest throughput, units	75	143	158
Sample Size, years	7,500	7,500	7,500

Figures 2–4 through **2–6** show the probability density function (PDF) and cumulative distribution function (CDF) for all three cases. This graph can be read by identifying the desired capacity on the probability density function and then determining the point at which the CDF curve crosses. For the distribution function for the 30-ppy case below, the model estimates at least 30 ppy can be produced 95 percent of the time.

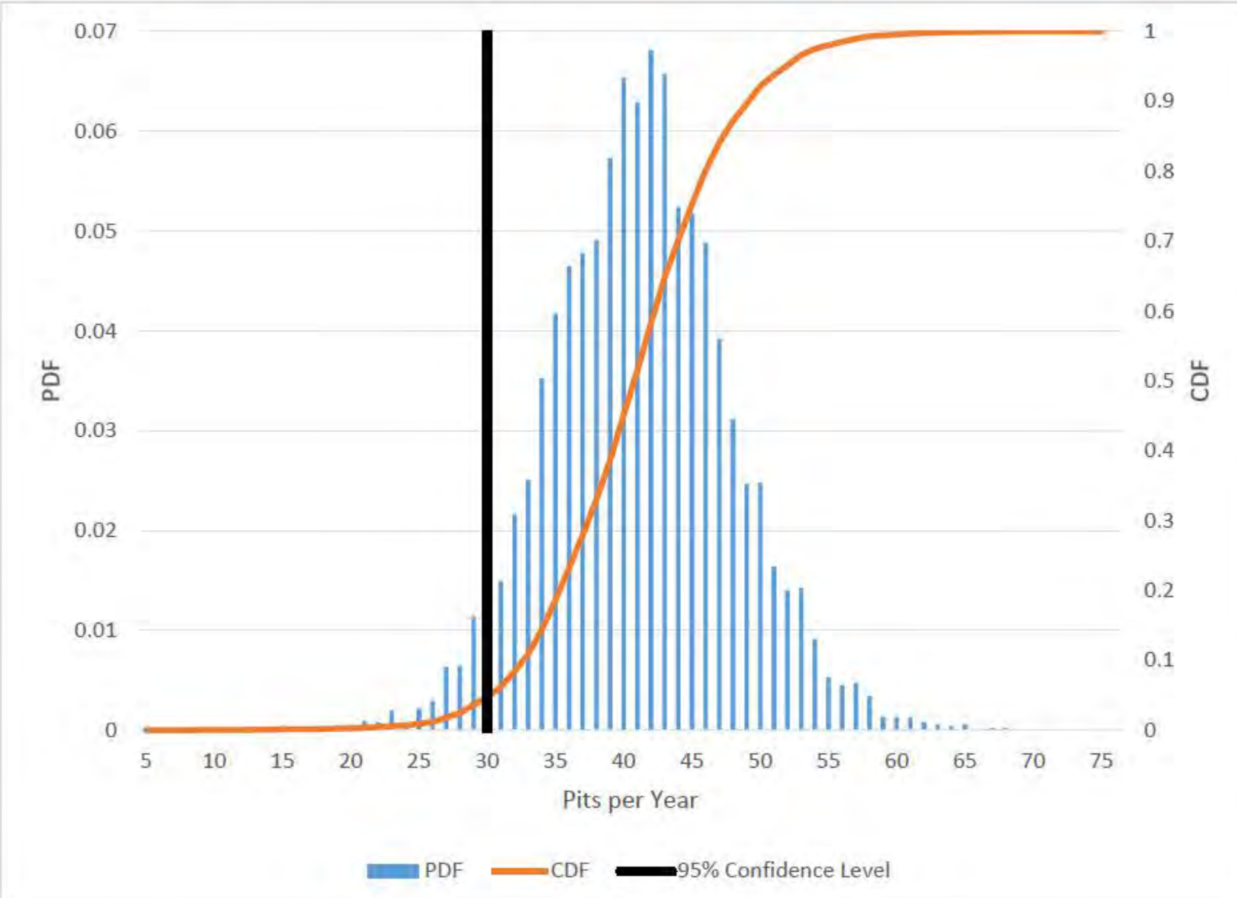

Figure 2–4. Probability density function and cumulative distribution function for 30 ppy

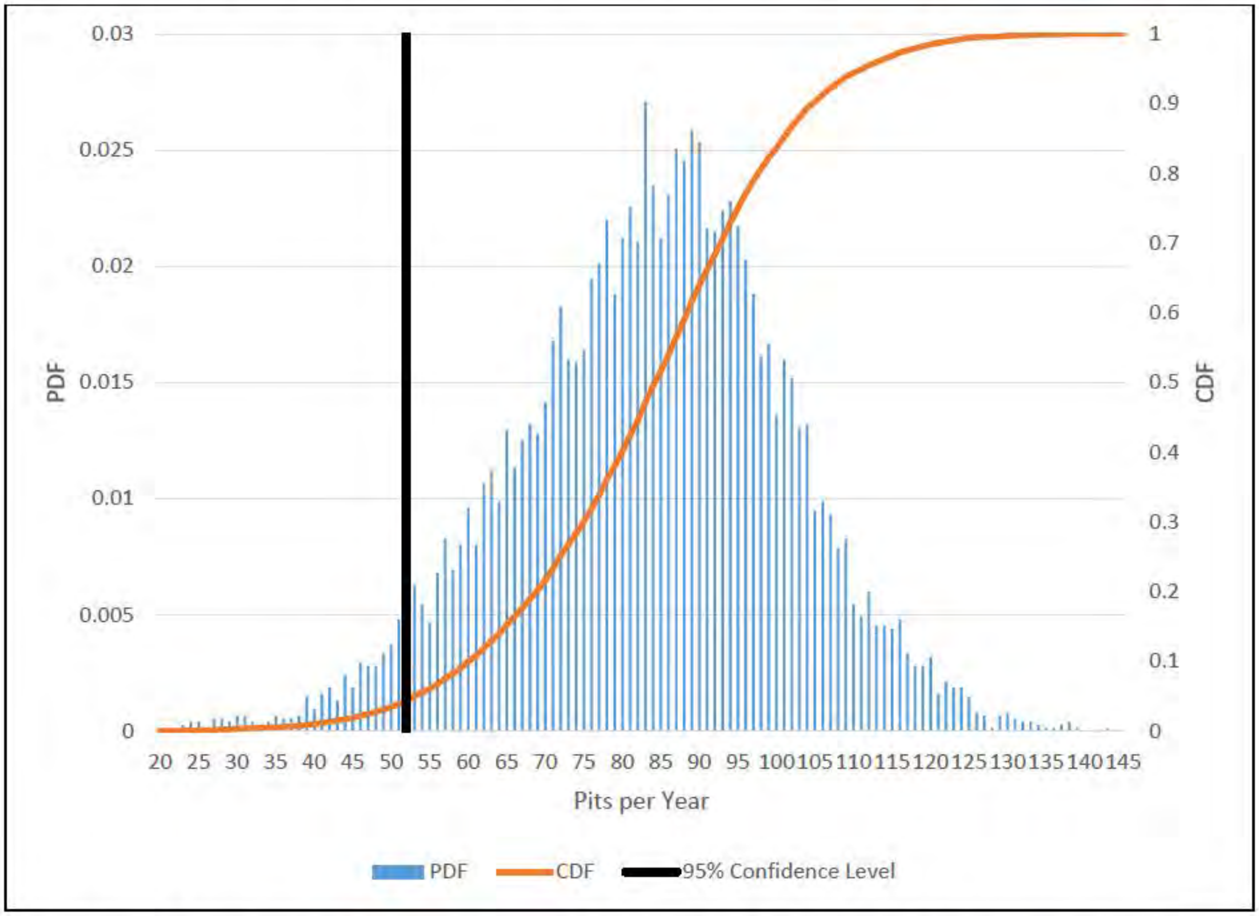

Figure 2–5. Probability density function and cumulative distribution function for 50 ppy

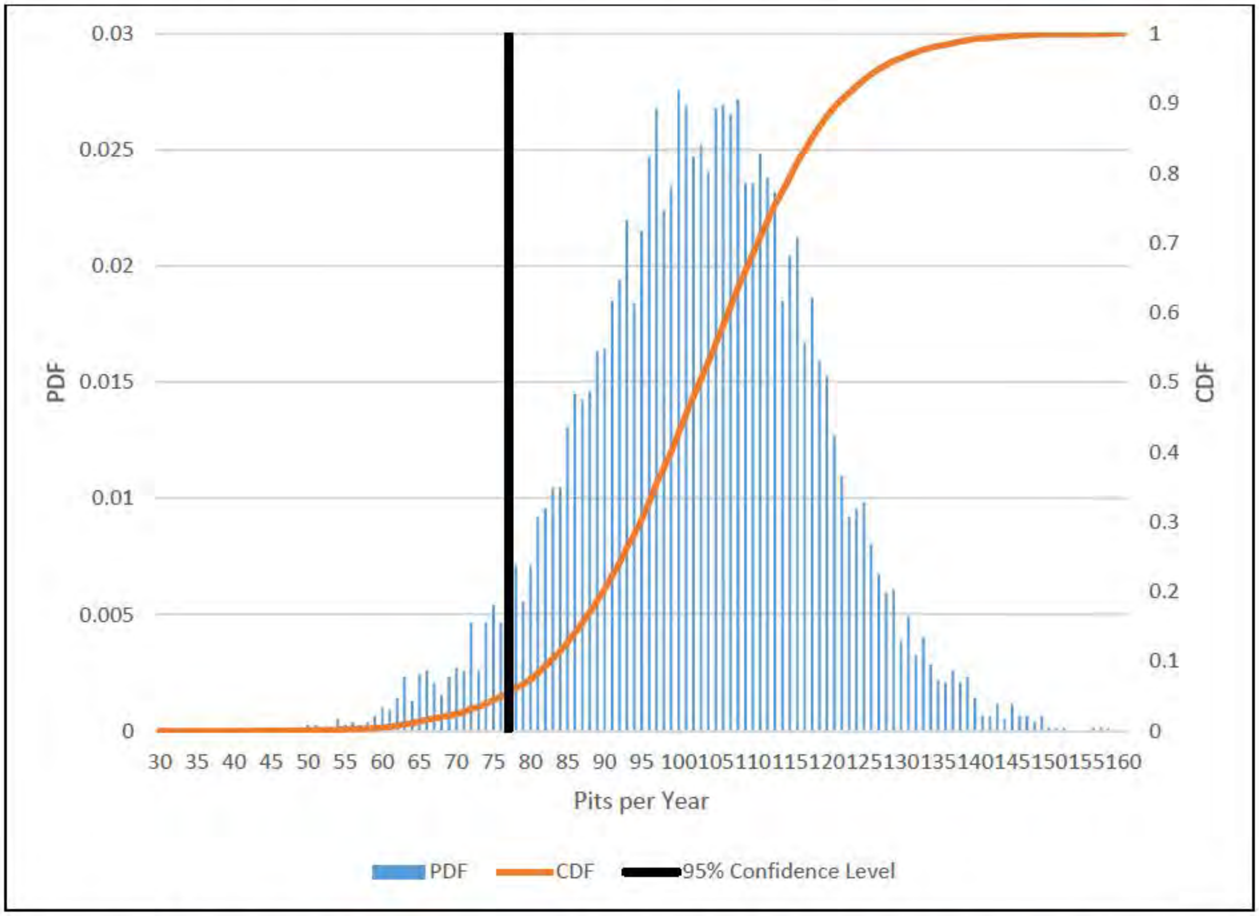

Figure 2–6. Probability density function and cumulative distribution function for 80 ppy

2.2.1.4 Equipment for Other Pit Types and Pit Re-Use Operations

The PRD includes requirements for being able to remanufacture several pit types and for delivery of re-use pits per the P&PD 2017-1. Using pit flow sheets developed for the Modern Pit Facility project, the AoA Team identified all equipment needed for the required pit types and added at least one of each, if not already included in the modeled equipment set.

Pit re-use activities were also examined. Though the exact requirements for the next planned pit re-use program have not been developed, the AoA Team consulted experts to determine likely re-use scenarios in terms of equipment usage. The pit re-use flowsheet would be expected to include most of the assembly and post-assembly processes (see Appendix I, pages 6-7). Given that the amount of equipment for those processes was determined at high confidence, there will be slack capacity in the system in most years. For example, 80 ppy at high confidence provides 103 ppy on average on one shift. The only equipment expected to be needed for pit re-use that was found to be rate limiting in the 80 ppy case was pump-down tables. Pump-down tables are small, portable devices that could easily be increased with little cost or space required.

The AoA Team determined that, for the few years that require simultaneous pit remanufacturing and pit re-use, the capacity provided by the equipment set estimated for pit remanufacturing at high confidence would likely be sufficient, especially since the AoA estimates do not include any second shift or weekend hours. If additional pump-down tables were needed, they could be installed with very little cost or space usage.

Table 2–5 shows the number of pieces of equipment and workstations that will be needed to reach and sustain 30 ppy, 50 ppy, and 80 ppy with high confidence. For a detailed equipment and workstation list by functional location, please see Appendix H.

Table 2–5. Number of pieces of equipment and workstations

30 Pits Per Year	50 Pits Per Year	80 Pits Per Year
90	111	133

2.3 Space Requirements

2.3.1 Space for Pit Manufacturing Equipment

Manufacturing space was estimated directly from the equipment set produced by the model. The size of each piece of equipment, including the size of the glovebox or hood enclosure, space for workers, and access for maintenance, was measured directly from engineering drawings of PF-4. A factor of 2, developed from drawings of processing and lab facilities that use glovebox equipment (PF-4, Mixed Oxide Fuel Fabrication Facility [MFFF], Waste Solidification Building [WSB], Tritium Extraction Facility [TEF], and RLUOB), was then applied to the equipment footprint to account for space between glovebox lines, support equipment and racks (such as power supplies and controllers co-located with the equipment/glove boxes), cabinets and supplies, access areas, stairs, support equipment, and hallways. This factor of 2 is empirically derived from the ratio of the measured square feet of the processing area to the square feet of the equipment in the only facilities similarly designed in the United States, listed above.

The team then reviewed both the quantity of each type of equipment and the space requirements with SMEs with experience in plutonium operations at PF-4, Rocky Flats, and LLNL. As a final check, the space estimates were compared to documented space plans for the Modern Pit Facility (MPF) and a LANL plan to get to 125 ppy in PF-4 plus additional construction [6].

Table 2–6 shows the space estimates for just the equipment listed in **Table 2–5** and the total including required building working space for the 50 ppy and 80 ppy cases. Additional detail can be found in Appendix H.

[6] LANL Report LA-CP-05-0256L, *TA-55 Pit Manufacturing Responsive Infrastructure and Capacity Study* (2005)

Table 2–6. Equipment and building working space footprint for 30, 50, and 80 ppy (square feet)[7]

30 Pits Per Year Equipment Only	50 Pits Per Year Equipment Only	80 Pits Per Year Equipment Only	30 Pits Per Year with Building Working Space	50 Pits Per Year with Building Working Space	80 Pits Per Year with Building Working Space
13,300	18,000	21,200	26,600	36,000	42,400

In addition to space for the main processing areas, there are support functions that must have HC-2, SC-1 space. For the support functions listed below, the space required was estimated at 68,000 square feet (ft^2) for 80 ppy (57,000 ft^2 for 50 ppy) based on interviews with LANL and LLNL personnel, and previous experience at Rocky Flats. For the 30-ppy case, these support functions were not estimated separately, but assumed to be adequate based on the 54,600 square feet currently dedicated to these activities in PF-4. Table 2-7 shows the space estimates for the three cases including the below listed support functions that must be located within the HC-2 processing facility.

- Aqueous recovery
- Actinide chemistry (processes requiring HC-2 only)
- Material management
- Hot calibration
- Waste storage and staging (RCRA and non-RCRA)
- Maintenance support
- Vault space
- Emergency equipment
- Production development
- Shipping and receiving
- Limited office space (operations manager, material control and accountability, radiation control, material handlers, final product acceptance)
- Decontamination rooms
- Job control
- Operations center
- Radiation control areas
- Material characterization (processes requiring HC-2 only)

Table 2–7. Equipment, building working space, and HC-2 support function footprint for 30, 50, and 80 ppy (square feet)

Functional Area	30 Pits Per Year	50 Pits Per Year	80 Pits Per Year
Process Equipment	13,300	18,000	21,200
Building Working Space	13,300	18,000	21,200
Support Functions within Processing Facility	54,600[8]	57,000	68,000

[7] Note that square footage numbers have been rounded throughout the report. This may cause the appearance that numbers do not quite add up.

[8] Support functions in PF-4 (currently at 54,000 square feet) were assumed to be adequate for 30 ppy. Note that in PF-4, these functions support all the missions ongoing in the facility, not just pit production.

Where possible, building services were assumed to be outside HC-2 space; however, some building services, such as process ventilation and safety class utility systems, must be located within the HC-2 area. The space required for these was estimated by measuring the areas containing building services in similar glovebox facilities (PF-4, TEF, MFFF). Based on these comparisons, the team estimated 19,600 ft^2 for 80 ppy (16,700 ft^2 for 50 ppy) for building services for the processing facility. For the 30-ppy case, there are 39,700 square feet in the PF-4 dedicated to building services. PF-4 is a legacy design, with some building services that could be located outside the HC-2 area included. Additionally, the PF-4 building services support all the current missions being performed. Therefore, this value should not be used as a comparison with the estimates for the 50 ppy and 80 ppy cases.

Table 2–8. Space requirements for 30, 50, and 80 ppy (square feet)

Functional Area	30 Pits Per Year	50 Pits Per Year	80 Pits Per Year
Process Equipment	13,300	18,000	21,200
Building Working Space	13,300	18,000	21,200
Support Functions within Processing Facility	54,600[9]	57,000	68,000
Building Services	39,700	16,700	19,600
Total HC-2 Production Facility	***137,000***[10]	***110,000***	***130,000***

Outside the main processing facility, there are several additional SC-1 facilities that should be located within the PIDADS. The team estimates that for 80 ppy, 67,500 ft^2 (46,800 ft^2 for 50 ppy) of primarily non-HC-2 space is needed for the following capabilities. For the 30-ppy case, these capabilities already exist at LANL. **Table 2-9** summarizes the space requirements inside the security area.

- Bonded stores warehouse
- Personnel support – break rooms, conference rooms, restrooms, lockers, cafeteria
- Diesel generator (HC-2)[11]
- Security control building
- Personnel support offices near production building
- Waste storage and staging (outside storage)
- Vehicle access portal
- Building services – utilities
- Backup operations center

Table 2–9. Space requirements for 30, 50, and 80 ppy (square feet) inside the security area

Functional Area	30 Pits Per Year	50 Pits Per Year	80 Pits Per Year
Process equipment	13,300	18,000	21,200
Building working space	13,300	18,000	21,200

[9] Support functions in PF-4 (currently at 54,000 square feet) were assumed to be adequate for 30 ppy. Note that in PF-4, these functions support all the missions ongoing in the facility, not just pit production.

[10] Includes other mission functions performed in PF-4 such as ARIES, plutonium-238 processing, and surveillance & certification.

[11] Generators are typically credited in the safety analysis, and are considered safety class. They must be protected in a HC-2 facility, however are typically housed in a separate facility due to the fuel tank and flammability concerns.

Support functions within processing facility	54,600	57,000	68,000
Building services	39,700	16,700	19,600
Total HC-2 Production Facility	***137,000***	***110,000***	***130,000***
Support facilities within the SC-1 boundaries	All available at LANL	46,800	67,500

Finally, supporting infrastructure for over 30 functions that can be located outside the PIDADS was also estimated. The team walked down LANL facilities and interviewed facility managers to determine required capabilities and capacity for supporting infrastructure. These critical capabilities are listed below and discussed in more detail in Appendix B:

- Low level radioactive liquid waste processing
- Transuranic solid waste processing
- Standards and calibration
- PIDADS
- Electrical power
- Fire water loop
- Security stations (response teams)
- Maintenance support facility
- Sewage treatment plant
- Transuranic liquid waste processing
- Actinide chemistry (non-HC-2)
- Cold machining and tooling
- Classified machining (beryllium, uranium, graphite, stainless steel)
- Water supply tank and valve vault
- Electrical transformers and pads
- Cooling towers or equivalent
- Grounds maintenance facility
- Water treatment plant
- Low level solid waste processing
- Material characterization (non-HC-2)
- Security Cat 1 systems
- Graphite coating
- Fire pump house (diesel and electric)
- Gas tank, liquefied gas storage tanks, and gas storage area
- Receiving warehouse
- High-efficiency particulate air (HEPA) filter test facility

The AoA team thoroughly investigated functional and process level requirements so that space needs for all required equipment and support functions, as well as infrastructure upgrades, could be included as appropriate in each alternative evaluated, as summarized in **Table 2-10**. Without careful consideration of all functional and process level requirements, cost and schedule for achieving mission needs could be underestimated.

Table 2–10. Summary of space requirements for 30, 50, and 80 ppy (square feet)

Functional Area	30 Pits Per Year	50 Pits Per Year	80 Pits Per Year
Process equipment	13,300	18,000	21,200
Building working space	13,300	18,000	21,200
Support functions within processing facility	54,600	57,000	68,000
Building services	39,700	16,700	19,600

Total HC-2 Production Facility	***137,000***	***110,000***	***130,000***
Support facilities within the SC-1 boundaries	All available at LANL	46,800	67,500
Support infrastructure outside the SC-1 boundary	All Available at LANL	95,000	122,700

3 Screening and Evaluation Criteria

3.1 Overview

After the functional and technical requirements are developed, the team developed screening and evaluation criteria. The screening criteria were used to identify and screen out alternatives that did not meet requirements to ensure remaining alternatives were able to meet threshold mission requirements as defined in the PRD.

The evaluation criteria were used to determine which alternatives provide more cost-effective solutions. The set of evaluation criteria usually includes cost, schedule, and risk. Some evaluation criteria are traceable to objective mission requirements in the PRD (additional performance above threshold desired by the program). Other evaluation criteria may include performance metrics and other benefits.

3.2 Screening Criteria

The screening criteria are listed in **Table 3–1**. Additional details on the threshold requirements can be found in the classified PRD.

Table 3–1. Screening criteria

Screening Criteria	Origin
Supports threshold pit production throughput requirements	Maps to PRD-1-4
Supports experimental device throughput requirements.	Maps to PRD-5
Supports all power supply throughput and surveillance activities	Maps to PRD-6, 7, 8
Supports all surveillance activities on pits	Maps to PRD-9
Provides production development concurrent with WR production	Maps to PRD-10
Supports annual LLNL pit analysis work	Maps to PRD-11
Supports threshold sample throughput for RDT&E	Maps to PRD-12

Key:

LLNL = Lawrence Livermore National Laboratory; PRD = Program Requirements Document; RDT&E = Research, Development, Test, and Evaluation

3.3 Evaluation Criteria

Evaluation criteria included cost, schedule, risk, and effectiveness metrics. Effectiveness metrics were derived from objective requirements as outlined in the PRD, and other characteristics identified as possibly important in distinguishing between the alternatives. The team quantitatively estimated measurable metrics and characteristics, where practical. **Table 3-2** shows the evaluation criteria that were identified and evaluated.

Table 3–2. Evaluation criteria

Evaluation Criteria	Origin
Cost • Capital (including renovation, removal of existing gloveboxes/equipment, construction of process facilities and support infrastructure, and relocating processes currently in PF-4, if applicable) • O&M (including waste disposal) • Total life cycle (including decontamination and decommissioning)	DOE O 413.3B
Schedule • Time to complete capital project (CD-4) – cold commissioning • Time to operational startup (process qualification, startup) – hot commissioning (achieve first WR pit) • Delay in achieving 30 ppy if impacted by the alternative (Plutonium Sustainment Program is outside the scope of the study, but some alternatives may disrupt the current plan) • Time to achieve 80 ppy – sustained production	DOE O 413.3B
Risk • Regulatory, legal, or policy threats • Threats from natural disasters • Threats affecting construction, qualification and development, and startup (other than natural disasters) • Threats affecting operations (other than natural disasters)	DOE O 413.3B
Effectiveness Metrics	
Supports objective requirements for: • Pit production • DOE Office of Nuclear Energy missions • DOE Office of Science (e.g., americium-241) • NA-20 ARIES missions	Derived from PRD-1, -10, -11, and -12
Capacity for pit reuse operations simultaneous with pit remanufacturing	Derived from PRD-1
Ability to accommodate surge capacity and capabilities for pit production	Derived from PRD-1
Synergy of functions: • Plutonium science • Metal preparation • Production	Derived from PRD-1, -3
Ability to accommodate future changes in mission requirements – provides flexibility	Maps to PRD-1 through -4
Useful lifetime	Maps to PRD-1 through -12

Key: ARIES = Advanced Recovery and Integrated Extraction System; CD = critical decision; DOE O = Department of Energy Order; O&M = operating and management; PF = plutonium facility; ppy = pits per year; PRD = Program Requirements Document; RDT&E = Research, Development, Test, and Evaluation; WR = War Reserve

4 Development of Alternatives

To develop an initial set of alternatives, the AoA team researched a wide range of potential locations, existing facilities, and configurations for production and support functions in order to avoid prematurely excluding any option with potential to successfully meet the mission need. Based on the AoA tasking memo dated May 2, 2016, the evaluation team considered alternatives in the following categories:

- Maintaining the status quo
- Further refurbishment, repair, or upgrade of current facilities and infrastructure
- Building one or more new facilities
- Potentially innovative or creative solutions not previously considered

The team's initial efforts to develop a robust set of alternatives included combinations of ways to split the mission, facility options, and possible sites. A diverse range of plausible preliminary alternatives for meeting the pit production mission need were developed using an iterative process that encompassed numerous alternatives and thorough research, as listed in **Table 4–1**. Almost 400 candidate alternatives were initially identified. An iterative process was used to narrow down the list to a manageable number of possibilities.

Table 4–1. Universe of alternatives

Alternative Description	Components	Site
Everything in PF-4 (80 ppy + R&D, experiments) 80 ppy in PF-4, R&D and experiments elsewhere 30 ppy plus R&D and experiments in PF-4, 50 somewhere else Only R&D, experiments, subcrits in PF-4, 80 ppy somewhere else All somewhere else	Multiple facilities with fully independent lines • All on the same site • Split over multiple sites Large facility – all in one place Smaller facilities – each contains part of the process – not a full line Refurbishment of existing facilities Combinations of new construction and refurbishment	LANL SRS Pantex NNSS LLNL Y-12/ORNL Sandia National Laboratories KCNSC Other DOE • WIPP • Hanford/PNNL • Idaho • Brookhaven Greenfield

Key: LANL = Los Alamos National Laboratory; LLNL = Lawrence Livermore National Laboratory; NNSS = Nevada National Security Site; ORNL = Oak Ridge National Laboratory; Pantex = Pantex Plant; PF-4 = Plutonium Facility; PNNL = Pacific Northwest National Laboratory; R&D = research and development; SRS = Savannah River Site; WIPP = Waste Isolation Pilot Plant, Y-12 = Y-12 National Security Campus

4.1 Siting Analysis in Support of Alternative Development

As listed in **Table 4–1**, a large selection of sites, DOE-wide, was initially identified as potentially able to host some or all of the pit production mission. In order to determine which of these sites were promising, the AoA team conducted an evaluation that included a survey of each of the sites to determine the existence of required supporting infrastructure, as well as an assessment of site-related risks. The team performed basic capability and risk research on a large selection of sites to avoid overlooking a possible optimal alternative.

A "greenfield" site (an undeveloped tract of land) was included for completeness, but it did not define a specific location. By definition, a greenfield site would not have any of the supporting infrastructure needed to support a new pit production capability, so an infrastructure investigation could not be performed. However, its lack of infrastructure was taken into account when comparing the potential sites. Without a specific location, it was not possible to assess various risk elements (e.g., nearby populations) for the greenfield site.

4.1.1 Support Infrastructure Capability Analysis

Prior to conducting a more detailed infrastructure analysis, the AoA team sought to better understand the distribution of existing capabilities relevant to pit production across the potential host sites. This effort began with the development of questionnaires to be sent to each site to determine which key capabilities the site had and which ones it lacked. The team derived these capabilities from the functional and process-level requirements developed for plutonium missions support infrastructure, as discussed in Chapter 2 and documented in Appendix B. The AoA team then contacted representatives at each site, who provided high-level assessments of each of the capabilities of interest with the knowledge that their site was being assessed as a potential pit production location. Each questionnaire was organized based on the following categories:

- **Capital items** such as waste treatment and disposal; Perimeter Intrusion Detection, Assessment, and Delay System (PIDADS)/access control; analytical chemistry
- **Operating infrastructure** such as the availability of manufacturing and quality assurance processes, qualified operators and technicians, and safeguards and accountability systems
- **Plant core infrastructure** such as the availability of SC-1 facility support and adequate power

For further details, see Appendix B.

Tables 4–2 through **4–4** list the results of the site surveys. Green boxes show where site representatives indicated the site had the capability. An evaluation of the capacity for these functions was reserved for the most promising sites, performed during AoA Team site visits, and included in the cost estimating approach to ensure equal treatment of scope across alternatives.

Table 4–2. Site survey results for capital items

Capital Items	Site Representative	Low level liquid rad waste treatment	TRU liquid waste treatment	PIDADS/Access control	Classified Be machining	Classified stainless steel machining	Classified uranium machining	Classified graphite machining	Graphite coating capability/capacity	Low level solid waste storage and shipping	TRU solid waste management	Actinide chemistry and materials characterization	Standards and calibration lab	Cold Machine and tooling shop
LANL	Bob Putnam	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
SRS	Jennifer Rice	✓	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓
Pantex	Larry Backus			✓		✓		✓		✓			✓	✓
NNSS	Joel Leeman			✓		✓		✓		✓	✓		✓	✓
LLNL	Mark Bronson	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓
Y12/ORNL	Tom Insalaco			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
WIPP[1]	Kenneth Pica/Infrast Team									✓	✓			L
Hanford/PNNL	Kenneth Picha	✓		✓						✓	✓	L[2]		
INL	Misty Benjamin	✓	✓	✓		✓	✓			✓	✓	✓	✓	✓
Brookhaven	Todd Lapointe/Infrast Team									✓		L	L	
KCNSC	Greg Enserro					✓								✓
SNL-Albuquerque	Phil Chamberlain			✓						✓		L	✓	
Greenfield														

1. EM submitted that WIPP had no capabilities in any of the identified areas. This chart reflects our knowledge of WIPP.

2. Hanford utilizes PNNL capability per Bob Putnam

✓ (green cell): site has capability

L: Site has limited capability

Key: Be = beryllium; BNL = Brookhaven National Laboratory; EM = Office of Environmental Management; LANL = Los Alamos National Laboratory; INL = Idaho National Laboratory; KCNSC = Kansas City National Security Campus; LLNL = Lawrence Livermore National Laboratory; NNSS = Nevada National Security Site; ORNL = Oak Ridge National Laboratory; Pantex = Pantex Plant; PIDADS = Perimeter Intrusion Detection Assessment and Delay System; PNNL = Pacific Northwest National Laboratory; SNL = Sandia National Laboratories; SRS = Savannah River Site; TRU = transuranic; WIPP = Waste Isolation Pilot Plant, Y-12 = Y-12 National Security Campus

Table 4–3. Site survey results for operating infrastructure

Operating Infrastructure		Prod control system	Mfg policies, procedures and training system (quality)	Materials control system	Safeguards and accountability systems	Qualified operators and technicians	NAP-24, Weapon Quality Policy, certified materials (e.g. gases, in process supplies, etc.)
	Site Representative						
LANL	Bob Putnam	√	√	√	√	√	√
SRS	Jennifer Rice	√	√	√	√	√	√
Pantex	Larry Backus	√	√	√	√	√	
NNSS	Joel Leeman		√	√	√	L	
LLNL	Mark Bronson			√	√	√	√
Y12/ORNL	Tom Insalaco	√	√	√	√	√	√
WIPP[1]	Kenneth Pica/Infrast Team	√	L			√	
Hanford/PNNL	Kenneth Picha			√	√		
INL	Misty Benjamin	√	√	√	√	√	
Brookhaven	Todd Lapointe/Infrast Team						
KCNSC	Greg Enserro	√	√	√	√	√	√
SNL-Albuquerque	Phil Chamberlain	√	√	√	√	√	√
Greenfield							
					√	site has capability	
1. EM submitted that WIPP had no capabilities in any of the identified areas.					L	Site has limited capability	

Key: BNL = Brookhaven National Laboratory; EM = Office of Environmental Management; LANL = Los Alamos National Laboratory; INL = Idaho National Laboratory; KCNSC = Kansas City National Security Campus; LLNL = Lawrence Livermore National Laboratory; NNSS = Nevada National Security Site; ORNL = Oak Ridge National Laboratory; Pantex = Pantex Plant; PNNL = Pacific Northwest National Laboratory; SNL = Sandia National Laboratories; SRS = Savannah River Site; WIPP = Waste Isolation Pilot Plant, Y-12 = Y-12 National Security Campus

Table 4–4. Site survey results for plant core infrastructure

Plant Core Infrastructure		Security Cat 1 facility support	Normal and off-normal power systems and supply	Normal utility support gas, water supply, redundant source for electrical power	Medical facilities (capable of dealing with alpha contaminated individuals)	Environmental monitoring (on-site and off-site)	Contaminated laundry (can possibly eliminate since most sites contract for these services)	Sanitary waste water facility
	Site Representative							
LANL	Bob Putnam	Y	Y	Y	Y	Y		Y
SRS	Jennifer Rice	Y	Y	Y	Y	Y		Y
Pantex	Larry Backus	Y	Y	Y	Y	Y		Y
NNSS	Joel Leeman	Y	Y	Y	Y	Y		Y
LLNL	Mark Bronson		Y	Y	Y	Y		
Y12/ORNL	Tom Insalaco	Y	Y	Y	Y	Y		Y
WIPP[1]	Kenneth Pica/Infrast Team		Y	Y	Y	Y		Y
Hanford/PNNL	Kenneth Picha	Y		Y	Y	Y	Y	Y
INL	Misty Benjamin	Y	Y	Y	Y	Y		Y
Brookhaven	Todd Lapointe/Infrast Team			Y		Y		
KCNSC	Greg Enserro		Y	Y		Y		Y
SNL-Albuquerque	Phil Chamberlain	Y(P)	Y	Y	Y	Y	Y	
Greenfield								
1. EM submitted that WIPP had no capabilities in any of the identified areas. This chart reflects our knowledge of WIPP.						Y	site has capability	
						L	Site has limited capability	

Key: BNL = Brookhaven National Laboratory; EM = Office of Environmental Management; LANL = Los Alamos National Laboratory; INL = Idaho National Laboratory; KCNSC = Kansas City National Security Campus; LLNL = Lawrence Livermore National Laboratory; NNSS = Nevada National Security Site; ORNL = Oak Ridge National Laboratory; Pantex = Pantex Plant; PNNL = Pacific Northwest National Laboratory; SNL = Sandia National Laboratories; SRS = Savannah River Site; WIPP = Waste Isolation Pilot Plant, Y-12 = Y-12 National Security Campus

At this stage, it was possible to evaluate site favorability based on reported site capabilities:

- LANL, Savannah River Site (SRS), Y-12/Oak Ridge National Laboratory (ORNL),[12] and Idaho National Laboratory (INL) provide the most comprehensive set of capabilities.
- Pantex, NNSS, LLNL, and Sandia National Laboratories (SNL) provide most capabilities but there are key capabilities that would have to be established to be equitable with the more comprehensive sites.
- Hanford, Waste Isolation Pilot Plant (WIPP), Brookhaven National Laboratory (BNL), KCNSC, SNL-Albuquerque are not well-suited based on both lack of required capabilities and the likelihood of establishing them within the operational framework of the site.

[12] Y-12 and ORNL are combined because if pit manufacturing were to be sent to Oak Ridge, capabilities at both facilities could be used.

4.1.2 Siting Risk Analysis

The team also performed a risk assessment to aid in the identification of the most promising sites for the pit production capability. The following factors were considered in evaluating the risk associated with siting the pit manufacturing capability (or parts thereof) at each of the candidate sites:

- **Site area:** Larger sites are considered lower risk due to reduced safety basis considerations for the population at or near the site boundary. For purposes of this analysis, a small site, with relatively high risk, was considered to have an area of less than 10 square miles. A large site, with a relatively low risk, was considered to have an area exceeding 100 square miles. Any site with an area in the range of 10 to 100 square miles was characterized by the term "moderate," i.e., it makes a moderate contribution to site risk.
- **Relevant site information within 5 miles:** Relevant information was collected, including population within that radius, distance to the nearest resident, nature of the countryside (e.g., farming, forested, unpopulated, industrial), and any environmental factor deemed relevant (e.g., a major river flows through or there is a lake or other sensitive environmental area). On the basis of these considerations, a judgement was made as to whether the factors within 5 miles yield a low, moderate, or high contribution to siting risk.
- **Nearby centers of population:** A few representative cities or towns were chosen and their population, distance from the site, and direction from the site were tabulated. An assessment was made as to whether these are low, moderate, or high contributors to siting risk.
- **Population within 50 miles:** The population within 50 miles was estimated in accordance with DOE Order 458.1, *Radiation Protection of the Public and the Environment.* The potential contribution to overall site risk was considered low if the 50-mile population is less than 500,000, high if it is more than 2,000,000, and moderate if it is in between.
- **Predominant wind direction:** Wind roses for each site were obtained. If the predominant wind direction blows toward nearby residents and/or major centers of population, it tends to increase the overall site risk. If it blows away from populated areas, it is regarded as a relatively low contributor to site risk.

Table 4–5 includes the results of the siting risk analysis. For more details on the siting risk analysis, see Appendix D.

Table 4–5. Summary of siting risk analysis

Site	Site Factors								Subjective Assessment of Relative Risks Arising from Siting Issues
	Area (square miles)/acres	Relevant Site Information Within 5 Miles	Nearby Cities				Population Within 50 Miles	Predominant Wind Direction (from)	
			Name	Population	Distance (miles)	Direction			
LANL	36/23,000	From PF4, the city of Los Alamos lies about 1.3 miles due N. In other directions, the area is sparsely populated.	Los Alamos, NM White Rock, NM Santa Fe, NM	12,000 5,800 68,000	1.3 (southern edge) 5 24	N SE SE	378,000	S (daytime) - i.e., toward Los Alamos; NW-SW (night)	Moderate
SRS	310/200,000	Within site (measured from F-area, site of MFFF).	Jackson, SC Augusta, GA Aiken, SC	1,700 196,000 30,000	7 20 18	NW NW N	790,000	W Not toward cities listed at left	Low
Pantex	28/18,000	Predominantly farming, sparsely populated. Only 2 people within 2 miles, ~360 within 5 miles), some unpopulated hill country to NW.	Panhandle, TX Amarillo, TX	2,500 190,000	10 10	NE SW	316,000	S-SW, away from Amarillo	Low
NNSS	1,360/870,000	No people within 5 miles of DAF.	North Las Vegas	217,000	90	SE	42,000	SW	Low
LLNL	1/640	The city of Livermore abuts the western boundary of the site. There are some tens of thousands of people within 5 miles, mostly to the west.	Livermore, CA Pleasanton, CA Dublin, CA	81,000 70,000 46,000	3 (city center) 9 14	E ESE E	7,700,000	W, WSW, SW, SSW Away from cities listed at left	High
Y-12	1.25/811 at NE corner of ORR (52/33,500)	Nearest houses ~1,500 ft. N of PIDADS; entire city of Oak Ridge within 5 miles.	Oak Ridge, TN Knoxville, TN	29,000 180,000	2 (center) 20 (center) 9 (closest approach)	N Slightly S of E SE	1,200,000	About equally from SW-SSW/NE-NNE	High
ORNL	6.9/4,400 toward center of ORR (52/33,500)	Nearest houses ~ 4 mi. E and S. Most of circle of radius 5 miles within ORR.	Oak Ridge, TN Knoxville, TN	29,000 180,000	6 (center) 22 (center) 11 (closest approach)	NE Slightly N of E ESE	1,200,000	About equally from SW-SSW/NE-NNE	Moderate

Site	Site Factors								Subjective Assessment of Relative Risks Arising from Siting Issues
	Area (square miles)/acres	Relevant Site Information Within 5 Miles	Nearby Cities				Population Within 50 Miles	Predominant Wind Direction (from)	
			Name	Population	Distance (miles)	Direction			
WIPP	16/10,000	Very sparsely populated, numerous oil and natural gas wells.	Loving, NM Carlsbad, NM No other city within 30 miles	1,400 26,000	17 24	WSW WNW	113,000	SE, passing N of Carlsbad	Low
Hanford	586/375,000	Within site (e.g., measured from Area 200E or 200W).	Richland, WA Kennewick, WA Pasco, WA	48,000 74,000 60,000	17 30 30	SE SE SE	560,000	NW, WNW, W Mostly not directly toward nearby cities	Low
INL	890/570,000	Within site (depending on where pit production facility would be sited); very sparse just outside site boundary.	Arco/Butte City, ID Blackfoot, ID Idaho Falls, ID	1,000 12,000 57,000	20 40 50	WNW SE E	179,000	SW, not toward nearby cities	Low
BNL	8/5,000	~13,000 people within 1 mile of site boundary; population within 5 miles ~67,000	Brookhaven Township, NY	~486,000	Occupies ~530 mi² around site	Surrounds site	6,200,000	Westerly	High
KCNSC	0.29/186	Nearest houses ~0.9 mi NE; ~98,000 people within 5 miles	Grandview, MO Belton City, MO Kansas City, MO	2 5 20	24,400 23,000 460,000	NNE SSE N	2,200,000	From S towards Kansas City	High
SNL	13.4/8,600 within Kirkland AFB (80/51,000)	Mostly empty except to N in Albuquerque; 25,000 people within 5 miles; nearest houses at ~3 miles.	Albuquerque, NM South Valley, NM	7 8	546,000 41,000	NNW W	910,000	From E to SE, toward Rio Grande Valley and SW Albuquerque metropolitan area.	Moderate

Key: BNL = Brookhaven National Laboratory; E = east; LANL = Los Alamos National Laboratory; INL = Idaho National Laboratory; LLNL = Lawrence Livermore National Laboratory; N = north; NNSS = Nevada National Security Site; ORNL = Oak Ridge National Laboratory; Pantex = Pantex Plant; S = south; SC = Security Category; SRS = Savannah River Site; W = west; WIPP = Waste Isolation Pilot Plant, Y-12 = Y-12 National Security Campus

Based solely on the number of red or green cells in each row Table 4-5, the AoA team roughly ranked the sites based on siting risk:

- **Lower risk:** SRS, Nevada, Hanford, INL, WIPP
- **Medium risk:** LANL, ORNL, and SNL
- **Higher risk:** LLNL, Y-12, BNL, and KCNSC

Note that Y-12 shows a higher siting risk than does ORNL because the former is at the northeast corner of the Oak Ridge Reservation (ORR), a short distance from the city of Oak Ridge, whereas the latter is in the center of ORR, about 4 miles from the nearest residents.

4.1.3 Policy Risk Assessment for Potential Sites

The AoA team also considered policy, public and legislative risks when determining the most promising sites. This, of course, is highly subjective. In assessing whether these risks are high, moderate, or low, the team considered whether there was a history of public protest or legislative resistance at or near each site. Brookhaven is an example of a site that ultimately did not make the short list because of this factor. There was significant public and legislative resistance to the proposed Shoreham nuclear reactor, located not far from Brookhaven, and the reactor was abandoned even though it was essentially complete, had many safety features, and had already cost several billion dollars. The policy risk was judged to be high or even very high for Brookhaven. Other relevant information, where pertinent, might include the presence of nearby national parks or other sensitive environmental receptors, or Native American reservations. The findings of the risk analysis are displayed in **Table 4–6.**

Table 4–6. Subjective Policy risk analysis

Site	Severity of Policy Risk	Comments/Explanation
LANL	Moderate	The city of Los Alamos is only 1.3 miles to the north of PF-4, and there has been considerable controversy in the past about changes in mission. In addition, there are many American Indian reservations within 50 miles of the site, and the Bandelier National Forest is nearby (a few years ago, a fire there almost encroached on Technical Area 55). On the other hand, many members of the local population would be expected to welcome new jobs and expenditures. On balance, the policy risk is moderate.
SRS	Moderate	There has been considerable controversy, including lawsuits, over the Mixed Fuel Fabrication Facility. However, many members of the local population would be expected to welcome new jobs and expenditures. On balance, the policy risk is moderate.
Pantex	Low	Pantex already handles pits, although it does not perform any manufacturing activities using plutonium.
NNSS	Low	Remoteness and size of site are considerable plusses. However, the low severity of policy risk could be higher if, for example, there is any residual conflict arising from the Yucca Mountain controversy.
LLNL	High	There are large numbers of people nearby. The amount of plutonium at LLNL has intentionally been reduced, and the local population is not likely to want to see that reversed.
Y-12	Moderate	The northern boundary of Y-12 adjacent to the PIDADS is very close to the city of Oak Ridge.

Site	Severity of Policy Risk	Comments/Explanation
ORNL	Moderate	Risk is likely to be lower than that for Y-12 because ORNL is in the middle of the Oak Ridge Reservation, a considerable distance from the closest houses. However, should pit manufacturing be established in Oak Ridge, both Y-12 and ORNL would likely be used. It would be difficult to disentangle the policy risk associated with the two sites.
WIPP	Low	Extremely remote site, but use of it might require either revision of the Land Withdrawal Act or passing a new act.
Hanford	High	Much previous controversy (e.g., about tanks) and great local concern about potential contamination of the Columbia River.
INL	Moderate	Extreme remoteness and a large site should mitigate public concerns. However, INL is currently operating under a consent decree with the State of Idaho dealing with radioactive waste onsite that may make it difficult to establish new activities that require bringing plutonium onsite. On balance, the policy risk is moderate.
BNL	High	In a very populated area. There is a history of hostility to nuclear power – the nearby Shoreham Nuclear Power Plant was abandoned after it had been completed because of local opposition. Likely to be an outcry over the possibility of bringing Pu to the site.
KCNSC	High	The site is dedicated to non-nuclear components. It is also very small and close to large concentrations of population.
SNL	Moderate	The amount of special nuclear material held at SNL has been considerably reduced and there would likely be concern if it were proposed to reverse that trend.

Key: BNL = Brookhaven National Laboratory; LANL = Los Alamos National Laboratory; LLNL = Lawrence Livermore National Laboratory; NNSS = Nevada National Security Site; Pantex = Pantex Plant; PF-4 = Plutonium Facility; SNL = Sandia National Laboratories; SRS = Savannah River Site; WIPP = Waste Isolation Pilot Plant

Using a method similar to that already performed for the site infrastructure and the siting risk analysis, the AoA team developed a rough ranking of the sites based on policy, public and legislative risks as listed in Table 4–6:

- **Lower risk:** Pantex, NNSS, WIPP, and INL
- **Medium risk:** LANL, SRS, Y-12/ORNL, and SNL
- **Higher risk**: LLNL, Hanford, BNL, and KCNSC

4.1.4 Siting Results for Alternatives Development

The AoA team examined the candidate sites for potential to perform plutonium manufacturing from the perspectives of capital infrastructure items, core plant infrastructure, operating infrastructure, siting risk, and policy risk. The results of these evaluations were combined using a number of different methods. Based on these results, the team concluded that the most promising sites are LANL, SRS, and INL. NNSS and Pantex fell in the second tier. For more detail on how the most promising sites were determined, see Appendix B.

The team retained all five sites for development of alternatives: LANL, SRS, INL, NNSS, and Pantex. Through the thorough evaluation of the potential of these sites for hosting plutonium capabilities, the

AoA Team identified several existing radioactive materials facilities that may be viable for housing pit production or other plutonium missions. These were used in the development of the alternatives.

- PF-4, LANL
- MFFF, SRS
- Waste Solidification Building (WSB), SRS
- K-Area Reactor, SRS
- Fuel Processing Facility (FPF), INL

4.2 Production Configuration Options

4.2.1 Separable Functions

In addition to developing a list of potential host sites for the reconstituted pit production capability, the evaluation team also identified missions currently performed in PF-4 and portions of the pit production flowsheet that could possibly be moved to other locations. These separable functions are defined in Table 4–7.

Table 4–7. Description of separable functions

Separable Function	Description and scope
Plutonium science and certification	Includes production of subcritical articles and other test articles and research and development.
Metal preparation	Includes disassembly of returned pits, purification of plutonium, disposition of any other material in the pit, recovery of plutonium residues, purification of the recovered plutonium, and processing of all waste produced. Includes flowsheet process steps up to and including electro-refining and size reduction and aqueous processing capabilities.
Production	Includes all activities on the pit production flowsheet starting at casting and ending at final assembly and inspection. "Split production" alternatives refer to creating pit production lines in two separate facilities or locations.
Advanced Recovery and Integration Extraction System (ARIES)	Includes plutonium material disposition activities to support Defense Nuclear Nonproliferation missions.
Plutonium-238 missions	Includes plutonium-238 processing activities to support weapons programs and DOE Office of Nuclear Energy missions.

4.3 Initial Alternatives for Each of the Viable Sites

The AoA team made the following assumptions during the development of the list of alternatives to be evaluated:

- At a minimum, plutonium science and certification capabilities currently at LANL and LLNL would remain there.
- CMRR project and Plutonium Sustainment Program activities are completed as planned.
- Support infrastructure will be built or upgraded as required for each alternative.

The alternatives can be categorized into four groups based on how the separable functions have been distributed. **Table 4–8** describes the alternative categories.

Table 4–8. Description of separable function categories

Alternative Category	Description and Scope
Status quo	PF-4 retains plutonium science and certification, metal preparation, and ~30 ppy production. Facility is as configured after the completion of the CMRR and Plutonium Sustainment programs.
Split production capacity	PF-4 retains plutonium science and certification, metal preparation, and 30 ppy production. Additional equipment is installed to reach 30 ppy at high confidence, if necessary. 50-ppy capability at high confidence is established in another facility. Excursions: Evaluate PF-4 capability if some functions, such as plutonium -238 and ARIES, are moved out.
Move production	PF-4 retains plutonium science and certification. Metal preparation and 80 ppy production at high confidence are established in another facility.
Split flowsheet	*Either:* PF-4 retains plutonium science and certification and metal preparation. 80-ppy capability at high confidence is established in another facility. *Or:* PF-4 retains plutonium science and certification. Metal preparation is cleared out of PF-4, and additional pit production equipment is installed in PF-4 to establish an 80 ppy capability at high confidence. Metal preparation is established in another facility

Key: *ARIES = Advanced Recovery and Integrated Extraction System; CMRR = Chemistry and Metallurgy Research Replacement; PF-4 = Plutonium Facility; ppy = pits per year*

The final list of 40 alternatives to be evaluated, shown in **Table 4–9**, was presented to the Steering Committee/Advisory Group and approved by the PSO in April 2017. Detailed descriptions of the alternatives can be found in Appendix C.

Table 4–9. Table of alternative configurations

LANL	LANL/SRS	LANL/INL	LANL/Pantex or NNSS
Status Quo at PF-4			
Split Production Capacity PF-4 As-Is (30 ppy), plus New Construction (Modules)	Split Production Capacity 30 ppy PF-4 50 ppy MFFF	Split Production Capacity 30 ppy PF-4 50 ppy FPF	Split Production Capacity 30 ppy PF-4 50 ppy New Construction
Split Production Capacity Move Pu-238, Pit production in PF-4 plus New Construction (Modules)	Split Production Capacity 30 ppy PF-4 50 ppy K-Area Reactor	Split Production Capacity 30 ppy PF-4 50 ppy New Construction	
Split Production Capacity Move Aries, Pit production in PF-4 plus New Construction (Modules)	Split Production Capacity 30 ppy PF-4 50 ppy WSB		
Split Production Capacity Move Pu-238 and Aries, Pit production in PF-4 plus New Construction (Modules)	Split Production Capacity 30 ppy PF-4 50 ppy New Construction		
Move Pit Production 80 ppy production in new construction PF-4 - existing mission w/o production	Move Pit Production 80 ppy production MFFF PF-4 - existing mission w/o production	Move Pit Production 80 ppy production FPF PF-4 - existing mission w/o production	Move Pit Production 80 ppy production New Construction PF-4 - existing mission w/o production
	Move Pit Production 80 ppy production K-Area Reactor PF-4 - existing mission w/o production	Move Pit Production 80 ppy production New Construction PF-4 - existing mission w/o production	
	Move Pit Production 80 ppy production WSB PF-4 - existing mission w/o production		
	Move Pit Production 80 ppy production New Construction PF-4 - existing mission w/o production		
LANL	LANL/SRS	LANL/INL	LANL/Pantex or NNSS
Split Flowsheet 80 ppy minus Metal Prep in new construction PF-4 retains Metal Prep	Split Flowsheet 80 ppy minus Metal Prep in MFFF PF-4 retains Metal Prep	Split Flowsheet 80 ppy minus Metal Prep in FPF PF-4 retains Metal Prep	Split Flowsheet 80 ppy minus Metal Prep in new construction PF-4 retains Metal Prep
	Split Flowsheet 80 ppy minus Metal Prep in K-Area Reactor PF-4 retains Metal Prep	Split Flowsheet 80 ppy minus Metal Prep in new construction PF-4 retains Metal Prep	
	Split Flowsheet 80 ppy minus Metal Prep in WSB PF-4 retains Metal Prep		
	Split Flowsheet 80 ppy minus Metal Prep in New Construction PF-4 retains Metal Prep		
Split Flowsheet Metal Prep in new construction 80 ppy production in PF-4	Split Flowsheet Metal Prep in MFFF 80 ppy production in PF-4	Split Flowsheet Metal Prep in FPF 80 ppy production in PF-4	Split Flowsheet Metal Prep in New Construction 80 ppy production in PF-4
	Split Flowsheet Metal Prep in K-Area Reactor 80 ppy production in PF-4	Split Flowsheet Metal Prep in New Construction 80 ppy production in PF-4	
	Split Flowsheet Metal Prep in WSB 80 ppy production in PF-4		
	Split Flowsheet Metal Prep in New Construction 80 ppy production in PF-4		

5 Initial Evaluation and Identification of Alternatives Not Retained for Full Evaluation

The AoA process includes provisions for narrowing down the number of alternatives before performing detailed evaluation of cost, schedule, and performance. Alternatives that did not meet requirements or were shown to have obvious undesirable cost, schedule, or risk and no identifiable benefit were not retained for the most detailed analyses. This phased approach allowed the AoA team to focus its efforts on the most promising alternatives while reducing the cost and schedule for the AoA. This chapter describes the initial evaluation and the rationale for eliminating some alternatives.

5.1 Initial Risk Assessment for Alternatives

The AoA risk assessment was performed in accordance with DOE G 413.3-7A, *Risk Management Guide*. The following risks were assessed for each of the alternatives. Site specific risks developed and addressed in the alternatives development activity were pulled into the alternatives risk assessment where appropriate. The results of the initial risk assessment, along with initial rough order of magnitude (ROM) cost and schedule estimates, were used in recommending that some alternatives be eliminated from further consideration.

The AoA team first developed two lists of threats. The first list is applicable to the period of construction up to the point at which the facility begins routine production of 80 ppy. These threats are listed in **Table 5–1**. For the purposes of estimating the probability that a certain threat will actually occur during this period, the team assumed that the duration of construction and startup will be approximately 10 years. The second list, included in **Table 5–2**, is applicable to the operating lifetime of the facility, assumed to be 50 years.[13]

(b)(3) UCNI

[13] Per verbal communication from the Deputy TA-55 Facility Operations Director that the PF4 facility was originally designed with the intended lifetime of 50 years. It seems reasonable to make the same assumption for an 80-ppy manufacturing facility.

(b)(3) UCNI

Table 5–2. Threats during operations

Identifier	Brief Description of Threat During Operations
O-1	Pit manufacturing adversely affects other site or facility projects, or other site or facility projects adversely affect pit production.
O-2	The facility is unable to hire, clear, train, and/or retain sufficient skilled personnel to support ongoing plutonium operations
O-3	Low level waste treatment capabilities deteriorate, become overwhelmed, or are unavailable for an extended period, impacting mission.
O-4	TRU waste treatment capabilities deteriorate, become overwhelmed, or are unavailable for an extended period, impacting mission.
O-5	WIPP shuts down for an extended period of time (months or years) so that TRU-waste storage capability reaches its limit and pit production ceases.
O-6	When WIPP comes back on line after a shutdown, additional regulatory and safety constraints mean that it accepts shipments at a rate insufficient to process waste generated by an 80-ppy program.
O-7	WIPP becomes full and is no longer able to accept solid TRU waste, and no other repository is available.
O-8	Analytical chemistry or materials characterization capabilities deteriorate, become overwhelmed, or are unavailable for an extended period, impacting mission.
O-9	Any other support infrastructure capabilities deteriorate, become overwhelmed, or are unavailable for an extended period, impacting mission.
O-10	Inability to obtain spare/replacement parts for failed equipment increases potential shutdown durations, impacting mission.
O-11	Supplier(s) of essential and unique equipment go out of business, refuse to take the job, or deliver poor quality.
O-12	Aircraft impact damages the facility.
O-13	A hazardous material release elsewhere onsite or at a nearby industrial facility or from a transportation accident affects operators and causes a facility shutdown, possibly requiring subsequent decontamination.
O-14	Transportation capacity for shipping pits and plutonium feedstock is insufficient to meet demands from all DOE sites.
O-15	A seismic event occurs during the operating lifetime.
O-16	A tornado or other high-wind event occurs during the operating lifetime.

Identifier	Brief Description of Threat During Operations
O-17	An external flood occurs during the operating lifetime.
O-18	An external fire occurs during the operating lifetime.
O-19	Any other external event occurs during the operating lifetime.

Key: ppy = pits per year; TRU = transuranic; WIPP = Waste Isolation Pilot Plant

5.1.1 Risks that Discriminate Between Alternatives

The following section provides information that the AoA team used to distinguish alternatives with high risk. Two types of risks are considered: (1) those that discriminate between alternatives and for which the risk for at least one of the alternatives is high and (2) those that are high for every alternative. The AoA team identified two threats, C-10 and O-1, which discriminated between alternatives, as shown in **Tables 5–3** and **5–4** below. A detailed description of the full risk assessment can be found in Appendix E.

Threat C-10: Construction or repair and modifications impact ongoing site or facility operations, or ongoing site or facility operations impact construction or repair and modification.

Table 5–3 shows the estimated risk levels for each alternative resulting from the potential impact of construction or repair and modifications on ongoing site or facility operations. The explanation for the assigned risk levels can be found in Appendix E.

Table 5–3. Risk levels associated with threat C-10, construction or repair and modifications impact ongoing site or facility operations

Alt Name	Capabilities in PF-4	Capabilities Outside PF-4	Alternatives			
0 – Status Quo	Plutonium science and certification + metal prep. and 30 ppy	None	LANL0			
1- Split Production	Plutonium science and certification + metal prep. and 30 ppy	Production 50 ppy at LANL	LANL1-A (new)			
		Production 50 ppy at SRS	SRS1-A (MFFF)	SRS1-B (K-Area)	SRS1-C (WSB)	SRS1-D (New)
		Production 50 ppy at INL	INL1-A (FPF)	INL1-B (new)		
	Plutonium science and certification + metal prep. and maximize production by moving out other functions	Production various at new construction at LANL	LANL1-B (ARIES and Pu-238 stay)	LANL1-C (ARIES stays, Pu-238 goes)	LANL1-D (ARIES goes, Pu-238 stays)	LANL1-E (ARIES and Pu-238 both go)
2 – Move Production and Metal Prep.	Plutonium science and certification	Metal prep. and 80 ppy at LANL	LANL 2 (new)			
		Metal prep. and 80 ppy at SRS	SRS2-A (MFFF)	SRS2-B (K-area)	SRS2-C (WSB)	SRS2-D (new)
		Metal prep. and 80 ppy at INL	INL2-A (FPF)	INL2-B (new)		
3 – Move Production	Plutonium science and certification + metal prep.	80 ppy at LANL	LANL3 (new)			
		80 ppy at SRS	SRS3-A (MFFF)	SRS3-B (K-area)	SRS3-C (WSB)	SRS3-D (new)
		80 ppy at INL	INL3-A (FPF)	INL3-B (new)		
4 – Move Metal Prep.	Plutonium science and certification and 80 ppy	Metal prep. at LANL	LANL4 (new)			
		Metal prep. at SRS	SRS4-A (MFFF)	SRS4-B (K-area)	SRS4-C (WSB)	SRS4-D (new)
		Metal prep. at INL	INL4-A (FPF)	INL4-B (new)		

High Risk	Moderate Risk	Low Risk

Threat O-1: Pit manufacturing adversely affects other site or facility projects, or other site or facility projects adversely affect pit production.

The following table shows the estimated risk levels for each alternative resulting from the potential impact of pit manufacturing on ongoing site or facility. The explanation for the assigned risk levels can be found in Appendix E.

Table 5–4. Risk levels associated with threat O-1, pit manufacturing adversely affects other site or facility projects

Alt Name	Capabilities in PF-4	Capabilities Outside PF-4	Alternatives			
0 – Status Quo	Plutonium science and certification + metal prep. and 30 ppy	None	LANL0			
1- Split Production	Plutonium science and certification + metal prep. and 30 ppy	Production 50 ppy at LANL	LANL1-A (new)			
		Production 50 ppy at SRS	SRS1-A (MFFF)	SRS1-B (K-Area)	SRS1-C (WSB)	SRS1-D (New)
		Production 50 ppy at INL	INL1-A (FPF)	INL1-B (new)		
	Plutonium science and certification + metal prep. and maximize production by moving out other functions	Production various at new construction at LANL	LANL1-B (ARIES and Pu-238 stay)	LANL1-C (ARIES stays, Pu-238 goes)	LANL1-D (ARIES goes, Pu-238 stays)	LANL1-E (ARIES and Pu-238 both go)
2 – Move Production and Metal Prep.	Plutonium science and certification	Metal prep. and 80 ppy at LANL	LANL 2 (new)			
		Metal prep. and 80 ppy at SRS	SRS2-A (MFFF)	SRS2-B (K-area)	SRS2-C (WSB)	SRS2-D (new)
		Metal prep. and 80 ppy at INL	INL2-A (FPF)	INL2-B (new)		
3 – Move Production	Plutonium science and certification + metal prep.	80 ppy at LANL	LANL3 (new)			
		80 ppy at SRS	SRS3-A (MFFF)	SRS3-B (K-area)	SRS3-C (WSB)	SRS3-D (new)
		80 ppy at INL	INL3-A (FPF)	INL3-B (new)		
4 – Move Metal Prep.	Plutonium science and certification and 80 ppy	Metal Prep. at LANL	LANL4 (new)			
		Metal Prep. at SRS	SRS4-A (MFFF)	SRS4-B (K-area)	SRS4-C (WSB)	SRS4-D (new)
		Metal Prep. at INL	INL4-A (FPF)	INL4-B (new)		

High Risk	Moderate Risk	Low Risk

5.1.2 High Risks that Apply to All the Alternatives

Risk C-4: Sufficient line item funds are not available (either in individual fiscal years or in total), resulting in a delay to completion of construction and startup.

The construction and startup period will likely extend over at least three administrations. There is a high probability that there will be changes in funding leading to critical consequences.

Risk C-8: More stringent interpretations of safety requirements during design and construction require facility structural or service system upgrades.

There is a very high probability of significant consequences or a high probability of critical consequences, based on historic changes to safety requirements. These combinations of probability and consequence are both high risk.

Risk C-9: Additional security provisions (e.g., clearances, escorts, fences, changes in the design basis threat) beyond those planned are imposed.

There is a very high probability of significant consequences or high probability of critical consequences, based on historic changes to security requirements. These combinations of probability and consequence are both high risk.

5.2 Evaluation of Status Quo Alternative

The Status Quo alternative is defined for the purposes of this AoA to be PF-4 and RLUOB as configured after the CMRR and Plutonium Sustainment programs have completed the installation of AC/MC capabilities and the reconfiguration and installation of pit production equipment to achieve up to 30 ppy. Using the pit production process discrete event simulation model developed to estimate the equipment needed to produce a given number of pits, the AoA Team estimated the pit production capability provided by the Status Quo alternative.

The model was run for 219 years using the currently programmed equipment set on one shift for the Plutonium Sustainment 30 ppy program. **Table 5.5** shows the results of the model runs. The Status Quo alternative is not sufficient to meet mission requirements.

Table 5–5. Results of model runs for Status Quo alternative

Statistic	Pits per year (ppy)
Mean	28.8
Standard Deviation	8.2
High	52
Low	7
Confidence of achieving 30 ppy	41.6%

5.3 Elimination of Alternatives

5.3.1 Screening of Alternatives

The alternatives were first checked against the screening criteria shown **Table 3-1**. Those alternatives that were shown to be not able to meet these criteria were eliminated.

5.3.1.1 Alternatives in Waste Solidification Building Were Eliminated from Further Consideration

WSB has approximately 13,000 ft^2 of processing space available. A 50-ppy production capability (for alternatives proposing to split production capacity between WSB and PF-4) is estimated to need about 110,000 ft^2 of process space. An 80-ppy capability is estimated to need about 130,000 ft^2. WSB does not have enough available space for 50- or 80-ppy production missions. Alternatives proposing to house pit production in WSB were eliminated from further consideration. However, WSB does have enough space to house metal preparation as a stand-alone capability (if existing equipment is removed to make room for the new equipment).

5.3.2 Alternatives Eliminated Based on Initial Analyses

Based on initial evaluation, the AoA team recommended the elimination of several alternatives based on the following considerations:

- Initial risk assessment
- ROM cost and schedule estimates
- Identified disadvantages such as prior contamination

5.3.2.1 Alternatives at Pantex and NNSS Were Recommended for Elimination from Further Consideration

The investigation of support infrastructure available at Pantex and NNSS showed that the following capabilities do not exist at these sites:

- Low level liquid waste processing
- TRU liquid waste processing
- TRU solid waste management
- HC-3 or rad lab analytical chemistry and materials characterization facility (HC-2 AC/MC is assumed to be installed in the processing facility in all cases)

The capital cost to provide these necessary functions is roughly estimated based on historical cost per square foot at an additional $380 million for NNSS and $650 million for Pantex. Additionally, other capabilities that were identified by the site as being available may need additional capacity. A detailed investigation of the available support infrastructure at these two sites was not conducted based on the high cost of facilities that are known to be unavailable.

Cost to perform the pit production mission at Pantex and NNSS is much higher than at the three other promising sites. The AoA Team assessed that the benefits of using these sites, such as remoteness of NNSS and proximity to the source pit material at Pantex, are not sufficient to overcome the much higher costs, and therefore recommended their elimination from further consideration.

5.3.2.2 Alternatives in K-Area Reactor Were Recommended for Elimination from Further Consideration

Alternatives involving moving some or all of pit production to K-Area Reactor at SRS were eliminated due to higher cost and risk.

- There is a very high probability that ongoing operations in K-Area Reactor will be affected by construction and that construction will be affected by ongoing operations at the significant or critical level.
- K-Area Reactor does not have credited secondary confinement, which adds to renovation costs.
- Renovating K-Area Reactor for pit production involves rad construction inside a working HC-2, SC-1 facility. This increases cost and schedule.
- There will likely be higher cost and higher risk to workers due to construction in a facility built in the early 1950s with prior contamination.

Since there are significantly higher risks and costs and no notable benefit for using K-Area Reactor over the other existing facilities identified, the AoA Team recommended these alternatives be eliminated.

5.3.2.3 Alternatives Involving Splitting the Pit Production Process by Moving Metal Preparation Out of PF-4 to Create Space for Pit Production were Recommended for Elimination from Further Consideration

Moving metal preparation out of PF-4 frees up about 13,000 ft^2 that could be repurposed for pit production. However, this option does not, by itself, provide enough space to fit the 80-ppy mission in PF-4, estimated to be an additional 36,000 ft^2. Additionally, this option comes with cost and schedule issues that make it undesirable.

The metal preparation function is necessary to support the 30-ppy capability by 2026 and, therefore, cannot be gapped. A new capability would need to be at full-rate production before space in PF-4 becomes available for repurposing. Based on LANL estimates for demolition and decontamination of gloveboxes within PF-4, the earliest that production activities could begin in the metal preparation spaces is FY 2035 under this alternative. This assumes:

- an optimistic schedule for establishing a new capability starting in FY 2018 (3 years to CD-2, 3-year construction, and 2-year startup);
- D&D of Area 400 (gloveboxes) estimated to take approximately 4 years;
- outfitting estimated to take approximately 4 years (gloveboxes); and
- startup estimated to take 2 years.

In addition to the cost of repurposing the space within PF-4, the cost to build or refurbish approximately 13,000 ft^2 for the metal preparation processing area somewhere else must be accounted for. Depending on where the metal preparation function was to be located, this option may also add transportation cost and risk for transporting purified plutonium to the pit production facility.

These alternatives were also assessed to be high risk due to a very high probability that ongoing operations in PF-4, such as the 30 ppy capability, will be affected at the significant or critical level by the D&D and construction within the facility for this alternative.