National Nuclear Security Administration

Final Report for the Plutonium Pit Production Analysis of Alternatives

October 2017

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

APPROVAL

Submitted by Michael Thompson Date: 10/4/2017
Michael Thompson
Assistant Deputy Administrator, NA-19
Major Modernization Programs
Office of Defense Programs
National Nuclear Security Administration

Approved by P. T. Calbos Date: 10/5/17
Philip T. Calbos
Acting Deputy Administrator
Office of Defense Programs

TABLE OF CONTENTS

1 Introduction 3
1.1 Purpose 3
1.2 Scope 3
1.3 Project Background 4
1.4 Major Assumptions 4
2 Requirements 5
2.1 Mission Requirements 5
2.1.1 Threshold and Objective Requirements for Plutonium Missions 5
2.2 Functional and Process Level Requirements 6
2.2.1 Equipment 7
2.2.1.1 Discrete Event Simulation Model Description 10
2.2.1.2 Verification and Validation of the AoA Plutonium Pit Production Process Model 11
2.2.1.3 Results 13
2.2.1.4 Equipment for Other Pit Types and Pit Re-Use Operations 16
2.3 Space Requirements 17
2.3.1 Space for Pit Manufacturing Equipment 17
3 Screening and Evaluation Criteria 21
3.1 Overview 21
3.2 Screening Criteria 21
3.3 Evaluation Criteria 22
4 Development of Alternatives 23
4.1 Siting Analysis in Support of Alternative Development 24
4.1.1 Support Infrastructure Capability Analysis 24
4.1.2 Siting Risk Analysis 28
4.1.3 Policy Risk Assessment for Potential Sites 31
4.1.4 Siting Results for Alternatives Development 32
4.2 Production Configuration Options 33
4.2.1 Separable Functions 33
4.3 Initial Alternatives for Each of the Viable Sites 33
5 Initial Evaluation and Identification of Alternatives Not Retained for Full Evaluation 36
5.1 Initial Risk Assessment for Alternatives 36
5.1.1 Risks that Discriminate Between Alternatives 38
5.1.2 High Risks that Apply to All the Alternatives 41
5.2 Evaluation of Status Quo Alternative 41
5.3 Elimination of Alternatives 42
5.3.1 Screening of Alternatives 42
5.3.1.1 Alternatives in Waste Solidification Building Were Eliminated from Further Consideration 42
5.3.2 Alternatives Eliminated Based on Initial Analyses 42
5.3.2.1 Alternatives at Pantex and NNSS Were Recommended for Elimination from Further Consideration 42
5.3.2.2 Alternatives in K-Area Reactor Were Recommended for Elimination from Further Consideration 43

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 43
5.3.2.4 Alternatives Involving 80 ppy Production in PF-4 Were Recommended for Elimination from Further Consideration 44
5.3.2.5 Alternatives Moving Pu-238 Missions and ARIES Out of PF-4 to Create Space for Pit Production were Recommended for Elimination from Further Consideration 44
5.3.2.6 Alternatives Involving Splitting Production Between PF-4 and Another Facility were Recommended for Elimination from Further Consideration 45
5.3.2.7 The Initial Modular Building Strategy, as Envisioned at CD-0 Does Not Meet Mission Requirements 46
5.3.3 Remaining Alternatives 47

6 Cost Estimate 50
6.1 Overview 50
6.2 Facility Costs 52
6.3 Pit Production Equipment 52
6.4 Support Equipment and Facilities 53
6.5 Systems Engineering, Integration and Program Management 53
6.6 Operations and Maintenance 53
6.7 Recapitalization 54
6.8 Waste 54
6.9 Summary: Cost Ranges for Alternatives 54

7 Schedule Estimate 57
7.1 Schedule Overview 57
7.2 General Schedule Assumptions 57
7.3 Work Breakdown Structure 58
7.4 Schedule Estimate Assumptions and Basis of Estimates 59
7.5 Schedule Estimates Methodology 60
7.6 Schedule Estimate Findings 60

8 Evaluation of Alternatives – Risk and Effectiveness 62
8.1 Overview 62
8.2 Final Risk Assessment 62
8.2.1 Identified Threats 62
8.2.2 Risk Matrix 62
8.2.3 Summary of Risks 63
8.3 Evaluation of Effectiveness Metrics and Other Considerations 65

9 Results and Conclusions 67
9.1 Space Requirements 67
9.2 Alternatives 67
9.3 Initial Evaluation and Identification of Alternatives Not Retained for Full Evaluation 69
9.4 Cost Results 69
9.5 Schedule Results 70
9.6 Risk Assessment, Effectiveness Metrics, and Other Considerations 71
9.7 Findings 75
9.7.1 The Initial Modular Building Strategy, as Envisioned at CD-0, Is Inadequate to Support the 80-ppy Mission with High Confidence 75

9.7.2 Refurbish Alternatives Have the Most Favorable Cost and Schedule Outcomes 77
9.7.3 Pit Production is Unlikely to be at Full Capacity by the 2030 Timeline, Even in the Most Optimistic Cases 77
9.8 Sensitivity Analyses....78
9.8.1 Sensitivity Analyses for Cost Estimates 78
9.8.2 Sensitivity Analyses for Schedule 78
9.8.3 Space Sensitivity Analyses and Impact on Cost 79
9.9 Conclusions....80

LIST OF FIGURES

Figure 2–1. LANL pit production overall process flowsheet 8
Figure 2–2. LANL pit production flowsheet for subassembly fabrication steps 9
Figure 2–3. Pit production model example of process module logic 10
Figure 2–4. Probability density function and cumulative distribution function for 30 ppy....14
Figure 2–5. Probability density function and cumulative distribution function for 50 ppy....15
Figure 2–6. Probability density function and cumulative distribution function for 80 ppy....16
Figure 5-1. Scaled representation of PF-4, proposed modules, and additional space needed for 80 ppy....47
Figure 6-1. Total project cost ranges through CD-4 for alternatives 55
Figure 6-2: Life-cycle cost ranges for alternatives 56
Figure 7–1. Schedule results for all alternatives....61
Figure 9–1. Life-cycle cost estimates for new construction and refurbishment alternatives 70
Figure 9–2. Schedule results for all alternatives....71
Figure 9-3. Scaled representation of PF-4, proposed modules, and additional space needed for 80 ppy....76
Figure 9–4. Cost and schedule ranges for final alternatives....77

LIST OF TABLES

Table 2–1. Threshold requirements....5
Table 2–2. Objective requirements 6
Table 3–3. Space estimate framework 7
Table 2–4. Model results 13
Table 2–5. Number of pieces of equipment and workstations 17
Table 2–6. Equipment and building working space footprint for 30, 50, and 80 ppy (square feet)....18
Table 2–7. Equipment, building working space, and HC-2 support function footprint for 30, 50, and 80 ppy (square feet)....18
Table 2–8. Space requirements for 30, 50, and 80 ppy (square feet) 19
Table 2–9. Space requirements for 30, 50, and 80 ppy (square feet) inside the security area 19
Table 2–10. Summary of space requirements for 30, 50, and 80 ppy (square feet) 20
Table 3–1. Screening criteria 21
Table 3–2. Evaluation criteria 22
Table 4–1. Universe of alternatives 23
Table 4–2. Site survey results for capital items 25
Table 4–3. Site survey results for operating infrastructure....26
Table 4–4. Site survey results for plant core infrastructure 27
Table 4–5. Summary of siting risk analysis 29
Table 4–6. Subjective Policy risk analysis 31

Table 4–7. Description of separable functions 33
Table 4–8. Description of separable function categories 34
Table 4–9. Table of alternative configurations 35
Table 5–1. Threats during construction 36
Table 5–2. Threats during operations 37
Table 5–3. Risk levels associated with threat C-10, construction or repair and modifications impact ongoing site or facility operations 39
Table 5–4. Risk levels associated with threat O-1, pit manufacturing adversely affects other site or facility projects 40
Table 5–5. Results of model runs for Status Quo alternative 41
Table 5–6. Comparison of PF-4 usage and 80-ppy space requirements 44
Table 5–7. Number of pieces of equipment for 30/50 ppy case vs 80 ppy case 46
Table 5–8. Final alternatives selection 49
Table 6–2. Gross square footage by alternative 50
Table 6–2. Work Breakdown Structure for the Plutonium Pit Production AoA cost estimate 52
Table 6–3. NNSA actual equipment projects 53
Table 7–1. Common WBS and schedule activities 58
Table 7–2. Start and completion dates for all alternatives 61
Table 8–1. Risk matrix for Plutonium Pit Production Analysis of Alternatives[a] 63
Table 8–2. Summary of results of risk assessment for short list of alternatives ordered from high to low 64
Table 8–3. Evaluation of effectiveness metrics 66
Table 9-1. Summary of space requirements for 30, 50, and 80 ppy (square feet) 67
Table 9–2. Table of alternative configurations 68
Table 9–3. Start and completion dates for all alternatives 71
Table 9–4. Summary of results of risk assessment for viable alternatives ordered from high to low 72
Table 9-5. Evaluation of effectiveness metrics 74
Table 9–6. PF-4 production space 75
Table 9–7. Production area for 80 ppy 79
Table 9–8. Space requirement estimates for 104 ppy and 125 ppy average output at PF-4 and the proposed Modern Pit Facility 80
Table 9–9. Comparative estimates for each viable alternative 82

LIST OF APPENDICES

Appendix A: Infrastructure Analysis
Appendix B: Siting Analysis
Appendix C: Detailed Description of Alternatives
Appendix D: Siting and Policy Risk
Appendix E: Qualitative Risk Assessment
Appendix F: Basis of Cost Estimate
Appendix G: Schedule Support
Appendix H: Building Space Requirements and Analysis
Appendix I: LANL Pit Production Flowsheet
Appendix J: Verification and Validation of the Pit Production Model
Classified Appendix A: Program Requirements Document (PRD)
Classified Appendix B: Pit Production Model Data
Classified Appendix C: Pit Production Model Diagrams

Classified Appendix D: Modern Pit Facility (MPF) Production Flowsheet & AoA Team Notes

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,

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.

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**.

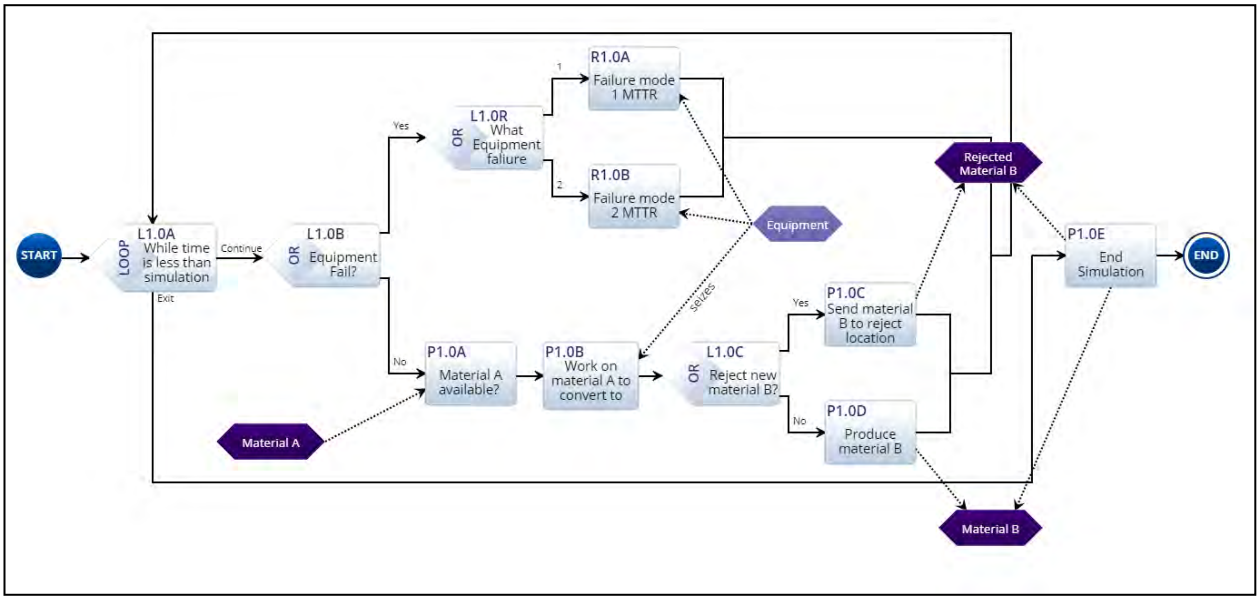


Figure 2–3. Pit production model example of process module logic

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.

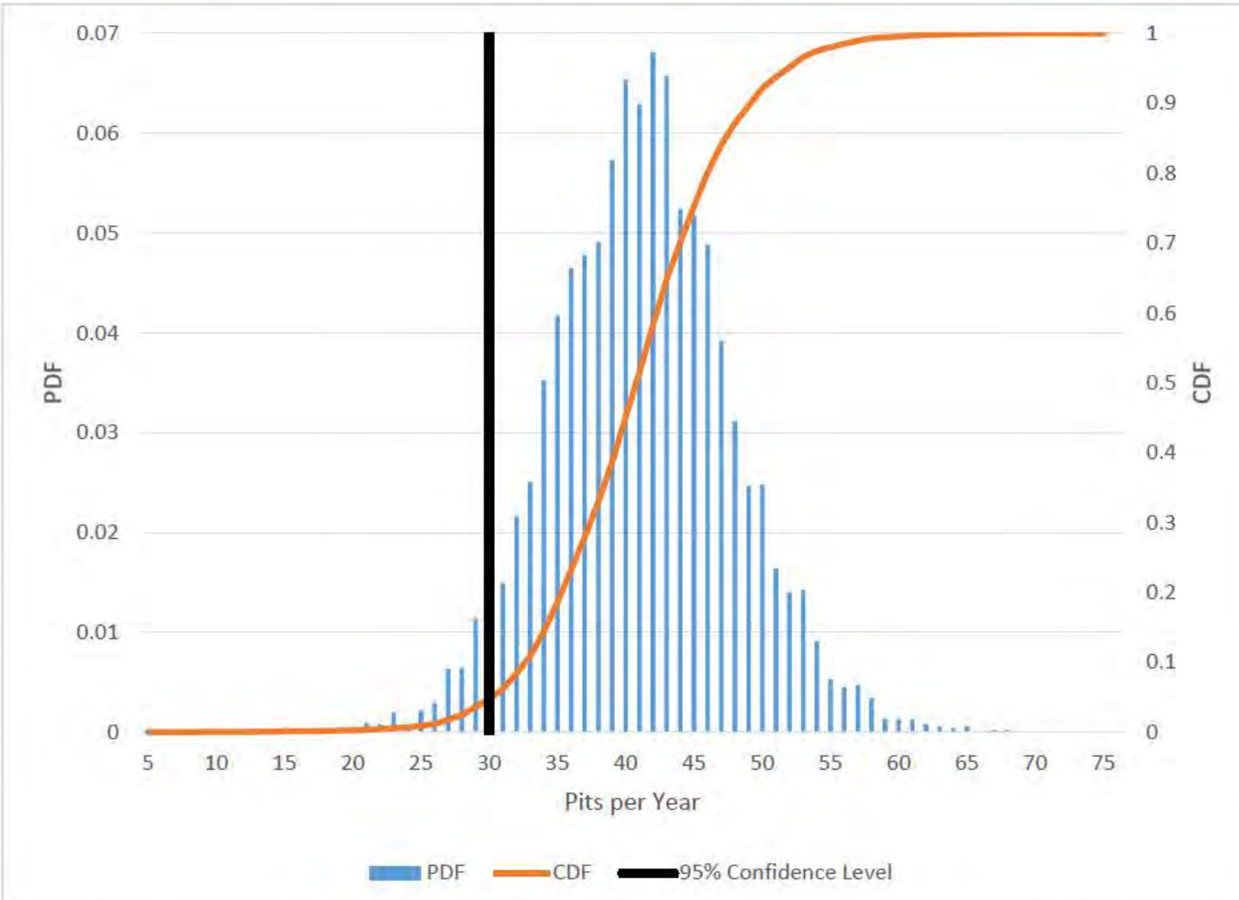


Figure 2–4. Probability density function and cumulative distribution function for 30 ppy

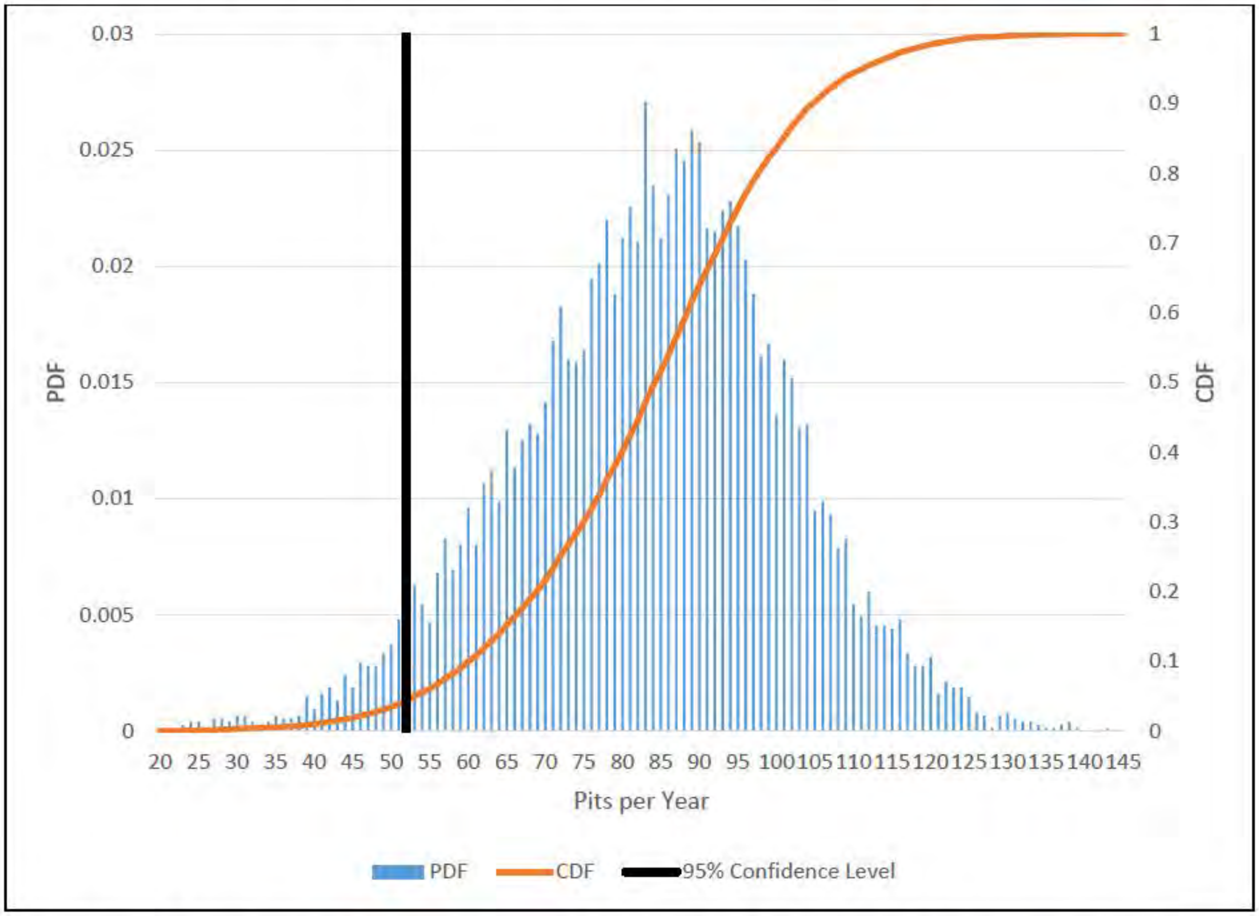


Figure 2–5. Probability density function and cumulative distribution function for 50 ppy

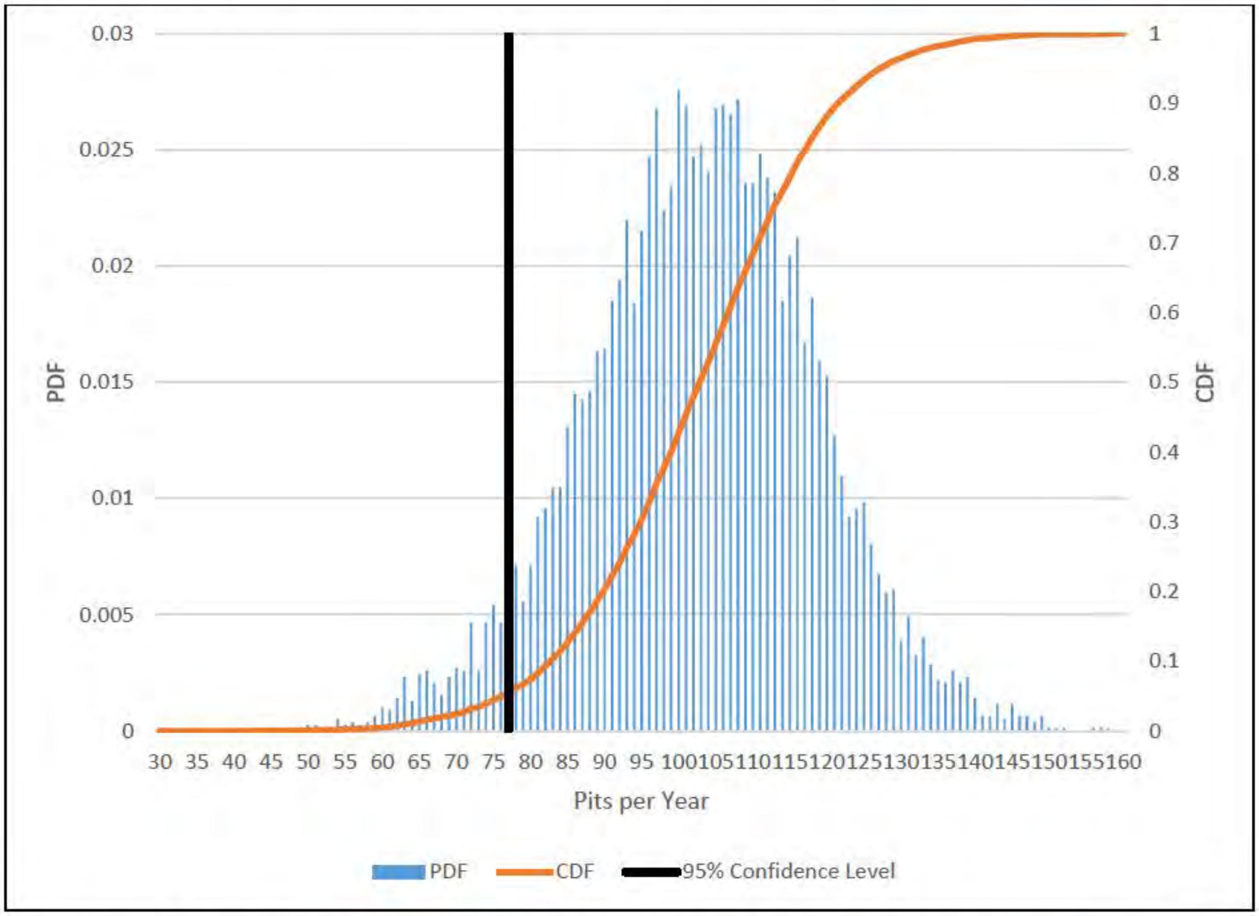


Figure 2–6. Probability density function and cumulative distribution function for 80 ppy

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)	Multiple facilities with fully independent lines • All on the same site • Split over multiple sites	LANL SRS Pantex
80 ppy in PF-4, R&D and experiments elsewhere	Large facility – all in one place	NNSS LLNL
30 ppy plus R&D and experiments in PF-4, 50 somewhere else	Smaller facilities – each contains part of the process – not a full line	Y-12/ORNL Sandia National Laboratories
Only R&D, experiments, subcrits in PF-4, 80 ppy somewhere else	Refurbishment of existing facilities	KCNSC Other DOE
All somewhere else	Combinations of new construction and refurbishment	• 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) 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	√	√	√	√	√		√
SRS	Jennifer Rice	√	√	√	√	√		√
Pantex	Larry Backus	√	√	√	√	√		√
NNSS	Joel Leeman	√	√	√	√	√		√
LLNL	Mark Bronson		√	√	√	√		
Y12/ORNL	Tom Insalaco	√	√	√	√	√		√
WIPP[1]	Kenneth Pica/Infrast Team		√	√	√	√		√
Hanford/PNNL	Kenneth Picha	√		√	√	√	√	√
INL	Misty Benjamin	√	√	√	√	√		√
Brookhaven	Todd Lapointe/Infrast Team			√		√		
KCNSC	Greg Enserro		√	√		√		√
SNL-Albuquerque	Phil Chamberlain	√(?)	√	√	√	√	√	
Greenfield								
1. EM submitted that WIPP had no capabilities in any of the identified areas. This chart reflects our knowledge of WIPP.						√	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 mi^2 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.

Based on the unfavorable schedule, high risk of disruption to ongoing missions in PF-4, no noticeable advantage in cost due to having to build or renovate space for metal preparation, these alternatives were recommended for elimination from further consideration.

5.3.2.4 Alternatives Involving 80 ppy Production in PF-4 Were Recommended for Elimination from Further Consideration

Table 5–6 lists estimated space needs for production of 80 ppy at high confidence in comparison to space usage in PF-4 after CMRR project and Plutonium Sustainment programs install AC/MC capabilities and production equipment for approximately 30 ppy, respectively.[14] Note that PF-4 is assumed to provide adequate building services, so to simplify the comparison, the space needed for building services is not included in this table.

Table 5–6. Comparison of PF-4 usage and 80-ppy space requirements

	80 pits per year	PF-4 Space Allocation (Program of Record for 30 pits per year)	Additional Space Needed for 80 pits per year	Missions in PF-4 that Could Be Relocated
Area Name	**Estimated (square feet)**			
Process equipment including building working space	42,400	19,500	**22,800**	
Support Functions within processing facility	68,000	54,600	**13,500**	
Total	**110,400**	**74,100**	**36,300**	
ARIES				5,500
Plutonium-238				9,400
	KEY: ARIES = Advanced Recovery and Integrated Extraction System			

The AoA team estimates an additional 36,000 ft^2 would be required to support the 80-ppy mission. Even if it is assumed that support functions available in PF-4 (such as the vault, shipping and receiving, production development, material management, etc.) are adequate, an additional 22,800 ft^2 in PF-4 would be necessary to support 80 ppy at high confidence.

Since PF-4 does not have adequate space for an 80 ppy mission, these alternatives were recommended for elimination from further consideration.

5.3.2.5 Alternatives Moving Pu-238 Missions and ARIES Out of PF-4 to Create Space for Pit Production were Recommended for Elimination from Further Consideration

Moving plutonium-238 production missions and ARIES out of PF-4 frees up just less than 15,000 ft^2 that could be repurposed for pit production. This is less than half of the space the AoA team estimates is needed to support the pit production mission, and these options come with cost and schedule issues that make them undesirable.

[14] See Chapter 2 for a discussion of equipment and space estimates and the difference between production at high confidence and production on average.

The plutonium-238 production mission cannot be gapped due to mission requirements described in the PRD. 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 plutonium-238 spaces is FY 2036 for 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 200 (gloveboxes and ventilation system) estimated to take at least 4 years;
- outfitting estimated to take approximately 5 years (gloveboxes and ventilation system); and
- startup estimated to take 2 years.

In addition to the cost of repurposing the space within PF-4, there is an additional cost to build or refurbish approximately 10,000 ft^2 for the plutonium-238 processing area somewhere else.

Assuming the ARIES mission is no longer needed for the current plutonium disposition program, the space occupied by ARIES could be eliminated without any mission risk. However, note that the ARIES equipment also currently supports the Material Recycle and Recovery. D&D of these spaces cannot begin until the ongoing MR&R mission in those spaces is complete, estimated to be in the 2027 timeframe.

Retrofitting the ARIES space for pit production is estimated to take roughly 10 to 12 years, including startup, based on LANL current plans for similar work in room 409 in PF-4. The earliest the ARIES space could begin to support production of pits is estimated to be no earlier than 2038. In short, moving ARIES may provide an additional 5,500 ft^2 of space that could begin producing pits in the late 2030s, but there are programmatic risks in doing so and it does not provide nearly enough space to support the 80-ppy mission.

These alternatives were also assessed to be high risk due to a very high probability that ongoing operations in PF-4 will be affected at the significant or critical level and a very high probability that ongoing operations adversely affect the ability to produce 80 ppy or vice versa at the significant or critical level. In particular, the demolition of contaminated gloveboxes and ventilation systems and installation of new gloveboxes and ventilation create unacceptably high risk to achieving of the 30-ppy capability planned in PF-4.

Based on the unfavorable schedule, disruption to plutonium-238 operations, high risk of disruption to ongoing missions in PF-4, no noticeable advantage in cost due to having to build or renovate space for the plutonium-238 mission, these alternatives were recommended for elimination from further consideration.

5.3.2.6 Alternatives Involving Splitting Production Between PF-4 and Another Facility were Recommended for Elimination from Further Consideration

Several alternatives involving splitting production between PF-4 and another facility (at various locations) were developed, i.e., 30 ppy at PF-4 and 50 ppy in another facility. These alternatives would capitalize on the capability for 30 ppy that is currently being installed in PF-4 by the Plutonium Sustainment Program, and supplement it with a new capability somewhere else.

Table 2–4 shows the total number of pieces of equipment needed for 30 ppy, 50 ppy, and 80 ppy at high confidence. If PF-4 can produce 30 ppy at high confidence, the difference between adding 50 ppy somewhere else and establishing an 80 ppy capability is 22 pieces of equipment requiring about 6,350 ft^2. The marginal cost for the additional space to get to 80 ppy is small.

The AoA Team estimates that the 30 ppy capability currently planned in PF-4 through the Plutonium Sustainment Program (the Status Quo alternative) will produce almost 30 ppy on average, similar to LANL's estimate for the capability. To provide 80 ppy at high confidence, the equipment needed to get to 30 ppy at high confidence must be added to PF-4 in the 30/50 ppy split cases.

The AoA team estimates that an additional seven pieces of equipment, requiring about 2,000 ft^2, would need to be added to PF-4 to get to 30 ppy at high confidence. **Table 5-7** shows the equipment requirements for the 30/50 ppy split case vs the 80 ppy case.

Table 5–7. Number of pieces of equipment for 30/50 ppy case vs 80 ppy case

30/50 ppy Split Case	80 ppy Case
201	**133**

The 30/50 ppy split cases require almost 70 pieces more total equipment, require additional reconfiguration of about 2,000 ft^2 of space in PF-4, and add long-term production risk and surveillance costs due to multiple production lines. The savings provided by a reduction of 6,350 ft^2 in the production facility is marginal and is offset by the above considerations. Therefore, the 30/50 split production alternatives were recommended for elimination from further consideration.

5.3.2.7 The Initial Modular Building Strategy, as Envisioned at CD-0 Does Not Meet Mission Requirements

The Initial Modular Building Strategy, as envisioned at CD-0 involved reconfiguring PF-4 and the construction of two modules with 5,250 square feet of processing space each. LANL did not provide an official proposal for how this concept would achieve the 80 ppy mission requirement without compromising other required plutonium missions. Instead, LANL had several concepts for establishing various capabilities in the modules and reconfiguring PF-4. Many of these were incorporated into the AoA alternative set, for example, splitting production capacity, and moving metal preparation operations, plutonium-238 operations or ARIES are included in the AoA alternatives. After showing that those concepts have unfavorable cost, schedule or risk profiles, and no identifiable offsetting benefit, the AoA Team double checked the modular building concept.

Using the comparison of space available in PF-4 for pit production and space needed for 80 ppy at high confidence shown in **Table 5-6**, the modular concept proposed at CD-0 would need seven total modules to create an additional 36,000 ft^2 of production space. **Figure 5-1** provides a scaled drawing of the available space in PF-4 for pit production, and the proposed modules in comparison with the additional required space.

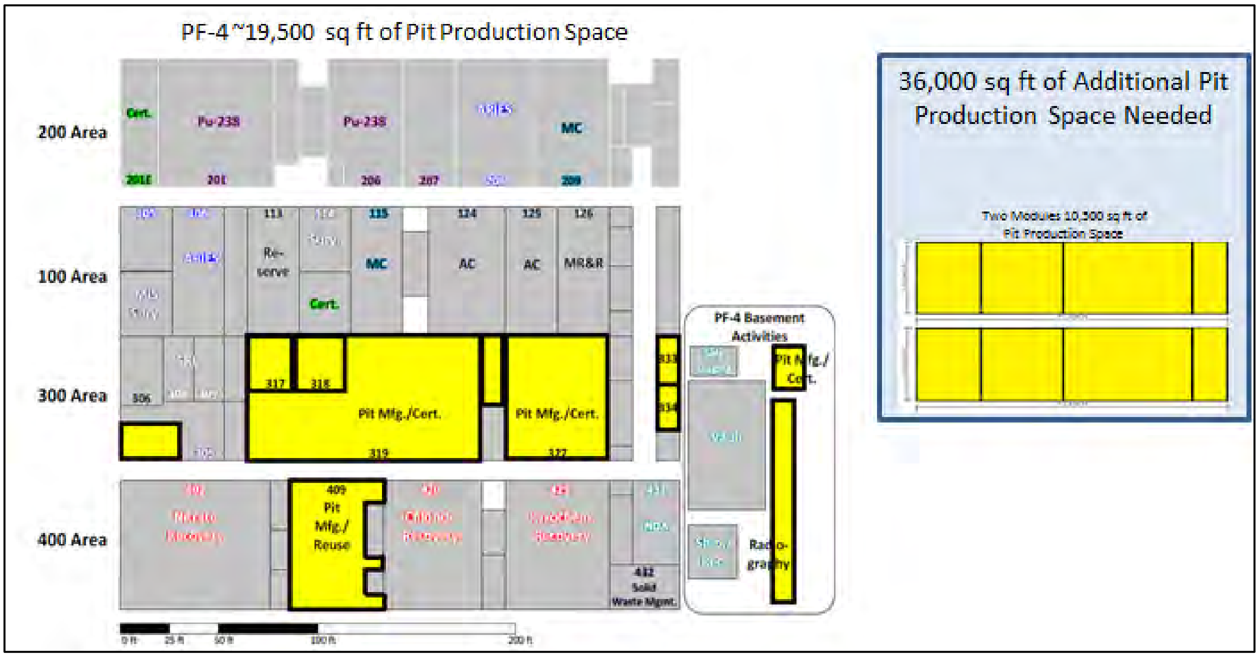


Figure 5-1. Scaled representation of PF-4, proposed modules, and additional space needed for 80 ppy

---

The Initial Modular Building Strategy, as envisioned at CD-0 (two modules, each providing 5,250 ft^2 of production space) is inadequate to support the 80 ppy mission at high confidence.

5.3.3 Remaining Alternatives

The recommendations for elimination of non-viable alternatives as described above were presented to the PSO in June 2017.

PF-4 was constructed in the mid-1970s with a planned useful lifetime of 50 years. It began operations in 1978, at which time it had ample margin to accommodate changes in safety and regulatory requirements. Over the last 35 or more years, that margin has been consumed with increasingly stringent nuclear safety requirements. By the time an 80-ppy production capability could be established in PF-4, the building would be over 50 years old. It will be problematic for PF-4 to support additional changes in nuclear safety risk tolerance, increased pit manufacturing activity, and higher capacity for plutonium missions such as pit reuse and rework. This is primarily due to the increase in MAR and resulting offsite accident dose, the age of the facility, and the available processing space capacity and condition.

Based on the preliminary AoA analyses, the PSO determined that continuing to rely on PF-4 for the Nation's enduring pit production capability presented unacceptably high mission risk for the following reasons:

- **Jeopardizes program of record:** Efforts to remove contaminated gloveboxes and install new equipment in an operating manufacturing space, beyond what is already planned under the Plutonium Sustainment program, creates unacceptably high risk to achieving 30 ppy by 2026.
- **Space and capacity constraints:** The AoA Team estimates about 110,000 ft^2 of HC-2, SC-1 processing space is necessary to produce 80 ppy with high confidence.[15] PF-4 has about 74,000 ft^2 of suitable space, 36,000 ft^2 short. Even if missions such as ARIES and plutonium-238 component manufacturing, totaling about 14,000 ft^2, were relocated, the total processing space in PF-4 would still be approximately 22,000 ft^2 short.

The recommendations for elimination of alternatives from further consideration, as described above, were approved. The following five alternatives were retained for detailed cost, schedule, risk, and effectiveness evaluation:

- New construction at LANL
- New construction at SRS
- New construction at INL
- Refurbishment of FPF at INL
- Refurbishment of MFFF at SRS

Note that under each of these final alternatives, the full 80-ppy production line plus metal preparation would occur in a single location. **Table 5–8** shows the elimination of other potential alternatives to produce this final list.

[15] Total for the HC-2, SC-1 production facility is estimated to be approximately 130,000 ft^2, including building services such as process ventilation and security class utilities.

Table 5–8. Final alternatives selection

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		

Key:
PF = Plutonium Facility; ppy = pits per year

6 Cost Estimate

6.1 Overview

The AoA's cost team examined total project cost (TPC) and life cycle cost (LCC) for each of the alternatives assessed to be the most viable: new construction at LANL, INL, or SRS and refurbishment of existing facilities at INL or SRS. This included estimates for facility construction and refurbishment, equipment procurement and installation, waste management, operations and maintenance, and other recurring expenses expected over the course of the pit production mission. These cost estimate ranges were based primarily on actual cost data from analogous projects of similar scope, as well as the AoA team's analysis of the amount of space and equipment required to achieve and sustain 80 ppy.

Table 6-1 shows the gross square footage used in the cost estimates for each of the five remaining alternatives. For each alternative, the AoA Team evaluated the capabilities at the site, and added cost to construct facility space for those capabilities unavailable, or inadequate to support the 80 ppy capability. For support facilities within the SC-1 boundaries, the team assumed all new build options would require construction of these facilities within the established SC-1 area. At LANL, depending on where the pit production facility is located, there may be some capacity available on-site for some of these functions. The MFFF complex at SRS was found to have sufficient facility space adjacent to the processing facility for these functions. For the support capabilities outside the PIDAS, such as classified beryllium and graphite machining, and graphite coating, the AoA Team notes that some of these capabilities could be provided by existing facilities at LANL. However, the AoA Team made a conservative assumption that these facilities would be co-located with the pit production capability.

Table 6–2. Gross square footage by alternative

Functional Area	LANL New	SRS MFFF	SRS New	INL FPF	INL New
Total HC-2 Production Facility	*130,000*	*130,000*	*130,000*	*130,000*	*130,000*
Support facilities within the SC-1 boundaries	67,500	-	67,500	67,500	67,500
Support facilities outside the SC-1 boundary	[redacted]				
Actinide Chemistry	-	-	-	-	-
Material Characterization	-	-	-	-	-
Admin Building 80 ppy	-	-	26,000	26,000	26,000
Classified SS Machining	-	-	-	-	-
Cold Machining & Tooling	-	-	-	-	-
Electrical Power	-	-	-	-	-
Other Utilities	-	-	-	-	-
Medical Facilities	-	-	-	-	-
Environmental Monitoring	-	-	-	-	-

Actinide Chemistry	-	-	-	-	-
Material Characterization	-	-	-	-	-
TRU liquid Waste	-	-	-	-	-
TRU Solid Waste	-	-	-	-	-
Actinide Chemistry	-	-	-	-	-
Material Characterization	-	-	-	-	-
LL Rad Liquid Waste	-	-	-	-	-
Classified Be. Machining	2,500	15,000	15,000	15,000	15,000
Graphite Coating	-	13,000	13,000	13,000	13,000
Classified Graphite Machining	6,000	13,000	13,000	13,000	13,000
Standards & Calibration	17,000	-	-	-	-
Classified Uranium Machining	-	-	-	-	-
PIDADS/PIDAS (linear feet)	1,700	3,000	2,600	2,600	2,600
Low Level Solid Waste	-	-	-	-	-
Security Cat I	-	-	-	-	-

The cost estimate ranges were developed using Government Accounting Office (GAO) and NNSA best practices for an early stage, pre-baseline construction project. Because these are early estimates with little design definition, a higher level parametric/analogous estimating approach was chosen over a "bottom-up" approach. This decision was based on the fact that bottom-up approaches are more likely to exclude key elements of scope, as well as severely underestimate both the cost and uncertainty associated with the project.

Parametric cost-estimating relationships provided the team with scaling factors to take into account technical differences (such as facility size and complexity) that are unique to the project. The parametric approach also provided uncertainty distributions around each one of the input parameters, and these distributions were then integrated into a total uncertainty distribution using a Monte Carlo simulation. The result of this integrated, data-based, cost-estimating approach was a cost-probability distribution. This cost-probability distribution was developed for each of the five alternatives that passed the initial screening and accounted for differences in scope, complexity, location, and available support facilities. This is further detailed in Appendix F.

To capture all relevant scope of the project, a work breakdown structure (WBS) was developed. This WBS ensured the complete scope required for each alternative was considered and analyzed. Data were collected from multiple sources in order to capture completed project actuals, analogous estimates, and subject matter expert observations. These data were used to estimate the costs of systems engineering, integration and program management, HC-2 facility structure, utilities, fixtures and office equipment, pit production equipment, support equipment and facilities, operations and maintenance, recapitalization, and waste processing. **Table 6–2** describes the approach and applicable data used to estimate each WBS element. A fully detailed explanation of the methodology to estimate each element is provided in Appendix F, Basis of Cost Estimate.

6.2 Facility Costs

Facility construction costs were parametrically derived based on dollars per gross building square footage. Project costs from the Construction Project Data Sheets (CPDS) from over 50 NNSA projects were collected for all of the 1993 through 2018 DOE Congressional Budget Requests. Project costs were broken out into yearly Project Engineering and Design, Other Project Costs (OPC), and Construction. Six Cost Estimating Relationships (CERs) for new construction and one refurbishment CER were developed using comparable NNSA projects based on hazard categories per DOE STD 1027-92. The facility costs were a major cost differentiator between refurbishment and new construction alternatives.

Table 6–2. Work Breakdown Structure for the Plutonium Pit Production AoA cost estimate

WBS Element	Methodology	Analogies
Facility structure, utilities, fixtures, and office equipment	Parametric based on analogous NNSA facilities	HEUMF, WSB, TEF, MFFF, MPB
Pit production equipment	Parametric based on analogous NNSA equipment procurements	CMM 1 and 2, casting upgrades, new ER, DMU 35, Pu assay, DC arc, radio chemistry, Y-12 GB-C, Y-12 Assembly GB, ARIES, RLUOB
Support equipment and facilities	Parametric based on analogous NNSA facilities	TRUWF, TRULWF, SAB, NIF, LLW, MESA, PF, HEPF, HESE, NSSB, DISL, NTSRFS, WETL
Subsystems engineering, integration and program management	Percentage based on NNSA analogous projects	PF-4 (PEI I/II), MOX, WSB, NFRR, CEF, BEC, TEF, SNMCRF
Operations and maintenance	Percentage based on PF-4 actuals	LANL (TA-55)
Recapitalization	2 to 4% of facility and equipment costs	Industry standard for recapitalization (rate is dependent on new versus refurbished facility)
Waste	Parametric based on production rate	PF-4, MPF estimates

Key:
ARIES = Advanced Recovery and Integrated Extraction System; BEC = Beryllium Capability; CEF = Component Evaluation Facility; CMM = coordinate measuring machine; DC =Direct Current; DMU = the brand name of the milling machine; ER = electro-refining; GB = glovebox; HEUMF = Highly Enriched Uranium Materials Facility; LANL = Los Alamos National Laboratory; MFFF = Mixed Oxide Fuel Fabrication Facility; MPB = …; MPF = Modern Pit Facility; MOX = mixed oxide; NFRR = Nuclear Facility Risk Reduction; NIF = National Ignition Facility; NNSA = National Nuclear Security Administration; NTSRFS = Nevada Test Site Replacement Fire Stations; Pu = plutonium; RLUOB = Radiological Laboratory Utility Office Building; SAB = Salvage and Accountability Building; SNMCRF = Special Nuclear Material Component Requalification Facility; TA = Technical Area; TEF = Tritium Extraction Facility; TRULWF = Transuranic Liquid Waste Facility; TRUWF = Transuranic Waste Facility; WETL = Weapons Evaluation Test Laboratory; WSB = Waste Solidification Building; Y-12 = Y-12 National Security Complex

6.3 Pit Production Equipment

The output from Defense Programs' Plutonium Processing discrete event model was the basis for estimating equipment procurement, design, and installation costs. As discussed above, a list of all manufacturing equipment was generated from this model for 50- and 80-ppy production rates. Once the AoA team had developed the equipment and space estimate, CERs were developed for plutonium processing equipment procurement activities based on actual costs from competed projects at LANL and Y-12 with comparable scope (shown below in **Table 6–3**). The required equipment footprint is the dependent variable in a CER of cost to square foot.

Table 6–3. NNSA actual equipment projects

Project Name	Site
Coordinate Measuring Machine #1 (CMM #1)	LANL
Glovebox (CPR P88Y2765)	Y-12
Assembly glovebox (CPR P88Y2426)	Y-12
Advanced Recovery and Integrated Extraction System (ARIES)	LANL
DC Arc Plasma Spectrometer and glovebox	LANL
DMU-35 mill and glovebox	LANL
Plutonium assay capability (design/procure/install for multiple gloveboxes) to support heat source program	LANL
Radio chemistry (design/procure/install for multiple gloveboxes) to support heat source program	LANL
Electro-refining (ER) line upgrade	LANL
Coordinate Measuring Machine #2 (CMM #2)	LANL

Key: *CMM = coordinate measuring machine CPR = brand name for the glovebox; DC = direct current; DMU = brand name for the milling machine; LANL = Los Alamos National Laboratory;*

6.4 Support Equipment and Facilities

SME team members visited prospective sites to assess additional support space and equipment needed to fulfill the 80-ppy mission. The infrastructure team provided capabilities and required list of equipment, facility footprint, and its corresponding HC. The facility construction equipment CERs discussed in Appendix F were used to calculate the additional costs associated with each capability. These values were based on historical NNSA projects and equipment procurements.

6.5 Systems Engineering, Integration and Program Management

Systems Engineering and Integration (SE&I) and Program Management (PM) were estimated as a level of effort task. It was estimated as a percentage of the base facility construction and equipment cost using comparable NNSA HC-2 actuals.

6.6 Operations and Maintenance

Production, maintenance, and operations costs only capture the cost to manage the facility, maintain the facility, and recapitalize both process and support equipment. Operations, production, and process monitoring will be a future program cost and therefore are outside the scope of this AoA. Additionally, costs will be similar for all alternatives and will not drive any acquisition decision.

The annual maintenance and utility costs where estimated as a function of the gross square footage (GSF) of the facility. Annual cost data were collected from LANL beginning in FY 2008 through FY 2012 for the current PF-4 facility. These data were then expressed as a function of GSF from year to year to derive a cost/GSF/year CER. These annual data were then used to get an average and standard deviation of costs per square foot of an active HC-2 facility. This CER was then applied to the space estimates for each alternative to give an estimate and uncertainty for the annual cost.

6.7 Recapitalization

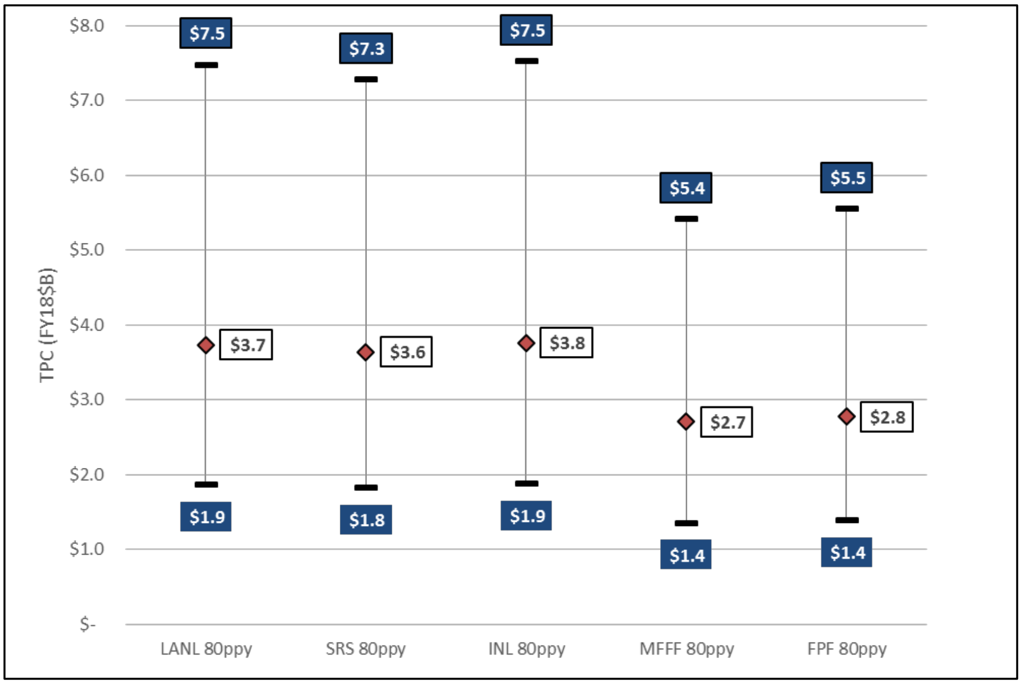
Process and support equipment recapitalization was assumed to be 2 to 4 percent of the acquisition cost annually. This cost was multiplied through the 50-year life-cycle in order to determine the total O&M life-cycle cost.

6.8 Waste

Three categories of waste were estimated: transuranic (TRU) waste, low level waste (LLW), and nonhazardous waste. The amount of waste produced at various pit production rates was previously estimated by the Modern Pit Facility (MPF) project and by LANL for the Plutonium Sustainment project (30 ppy) at PF-4. These waste processing, transportation, and disposal rates are discussed in detail in Appendix F.

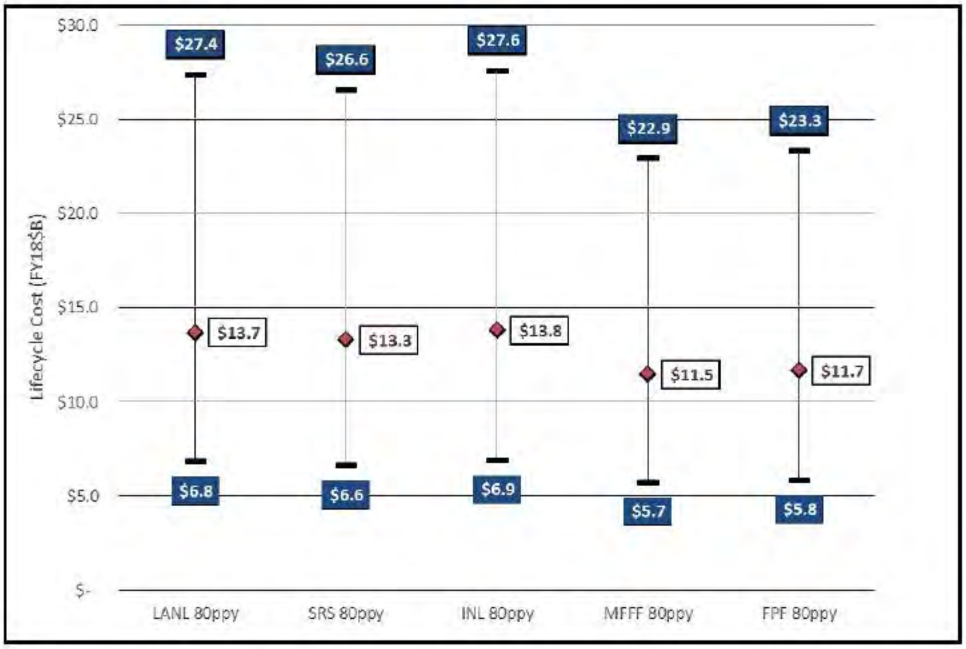
6.9 Summary: Cost Ranges for Alternatives

Figure 6–1 shows the TPC estimate ranges for each of the five final alternatives selected, and **Figure 6–2** shows the life-cycle cost estimate ranges. The number depicted by the red diamond in **Figure 6–1** represents the mean cost estimate from each alternative distribution.



Key: FPF = Fuel Processing Facility; FY = fiscal year; INL = Idaho National Laboratory; LANL = Los Alamos National Laboratory; MFFF = MOX Fuel Fabrication Facility; ppy = pits per year; SRS = Savannah River Site; TPC = total project cost.

Figure 6-1. Total project cost ranges through CD-4 for alternatives



Key: FPF = Fuel Processing Facility; FY = fiscal year; INL = Idaho National Laboratory; LANL = Los Alamos National Laboratory; MFFF = MOX Fuel Fabrication Facility; ppy = pits per year; SRS = Savannah River Site; TPC = total project cost.

Figure 6-2: Life-cycle cost ranges for alternatives

The number depicted by the red diamond in Figure 6–2 represents the mean cost estimate from each alternative distribution. This was an analysis of alternatives for a capital acquisition project, and we do not include the cost to produce a pit in the facility lifecycle cost estimate. We do, however, include the costs to operate, maintain, and recapitalize the facility and applicable equipment. NA-10 leadership decided that the actual cost of producing a pit was outside of the scope of the AoA. Additionally, the cost to produce a pit would not be a distinguishing factor when comparing various alternatives.

7 Schedule Estimate

7.1 Schedule Overview

The AoA Team performed the schedule analysis for the AoA using the GAO Schedule Assessment Guide, as applicable to a pre-conceptual design project. Because of the early stage of project definition and scope, the team employed parametric analysis, using DOE line item construction project actuals, subject-matter expertise, and past construction project precedence with a focus on aspects of a project likely to distinguish between alternatives prior to CD-1. The resultant estimates have wide uncertainty ranges, which is consistent with the current level of project definition. Actuals were compiled from several sources, including budget materials, NNSA's Office of Acquisition and Project Management (APM) project data, and the Office of NEPA Policy and Compliance's Lessons Learned Quarterly Reports (LLQRs). All the schedule estimates span from the close of the AoA process, where additional pre-CD-1 activities are still required, through ramp-up to 80 WR ppy production, to allow like-for-like comparisons among alternatives.

7.2 General Schedule Assumptions

The five alternatives evaluated by the AoA Team in detail are (1) a new production facility at SRS, (2) a new production facility at INL, (3) a new production facility at LANL, (4) the refurbishment/retrofit of MFFF at SRS, and (5) the refurbishment/retrofit of FPF at INL. The AoA Team made two primary assumptions in the development of the schedule estimates:

- Although site conditions and execution challenges will vary between the SRS, LANL, and INL alternatives, and those variations in site conditions/challenges may contribute to significant differentiating elements between the schedules for the alternatives, it is not possible at this time for the AoA team to estimate how differences between the sites will change the schedule results for a new facility.
- Similarly, based on site visits to MFFF and FPF by the evaluation team and a preliminary assessment of the technical conditions of these facilities, the team concluded that it is not possible at this time for the AoA team to predict how differing facility conditions might differentiate the project schedules for the retrofit/refurbishment of these facilities.

Therefore, the schedule development and analysis was collapsed to two scenarios/schedules: new facility and refurbished/retrofitted existing facility.

Additional major assumptions include the following:

- All alternatives assumed to require an environmental impact statement (EIS).
- Options and strategies for any combined CD-2/3 and/or advanced CD-3a will be used, where applicable.
- Funding will be provided at a point in time and rate/level that supports project development, execution, testing, startup, commissioning, process prove-in, and FPU delivery.
- The schedules developed for each option do not explicitly consider quantified consequences of each risk identified in the risk analysis but these are collectively captured in "optimistic, median, or pessimistic" cases.
- The schedules are not resource loaded, commensurate with the current, pre-conceptual design stage of the alternatives.

- AoA Decision and Start CD-1 Package will be developed by 10/2/17.

Additional assumptions and bases for the development of the two primary schedule scenarios are listed in Appendix G.

7.3 Work Breakdown Structure

The schedule sub-team developed generic schedules for each of the two remaining scenarios (new versus retrofit) to a level 5 WBS consistent with the common WBS used by the cost sub-team. WBS elements are consistent with the milestone phases and activities in the schedules. Approximately 100 unique activities were identified for each scenario, logically linked with predecessors and successors and assigned durations. The activities were linked based on:

- prescribed processes,
- DOE standards and guides,
- best management practices (BMPs) and standard operating procedures (SOPs) for DOE STD 413.3 and regulatory requirements,
- other relatable DOE project execution precedents, and
- subject matter expertise for each of the project acquisition/execution activities.

The major activities of the schedule map into the following level two elements of the common WBS:

- Systems Engineering & Integration
- Program Management
- Training
- Capital Asset
- Operations and Maintenance

Table 7- 1 shows the mapping between the schedule activities and the common WBS.

Table 7–1. Common WBS and schedule activities

WBS	Title	Schedule Activities
1.0	**Pit Production Strategy**	**New Facility/Refurb**
1.1	Systems Engineering & Integration	Title I and II Design
1.2	Program Management	Milestone Reviews and Approvals, NEPA Activities, Procedures Development
1.3	Training	Personnel Training
1.4	Development, Test, and Evaluation	
1.5	Production	

WBS	Title	Schedule Activities
1.0	Pit Production Strategy	New Facility/Refurb
1.6	Capital Assets	
1.6.1	Land	
1.6.2	Structures	
1.6.2.1	Facility	Construction
1.6.2.1.1	Facility Structures	
1.6.2.1.2	Facility Utilities	
1.6.2.1.3	Furniture, Fixtures & Office Equipment	
1.6.2.1.4	Process/Scientific/Technical Equipment	Procurement, Equipment Install, Testing, start-up and Commissioning
1.6.2.2	Support Equipment & Facilities	
1.6.2.3	Site Work	Site Prep
1.6.4	Intellectual Property	
1.7	Operations and Maintenance	
1.7.1	Operations	WR Process Qualification, Production Ramp-up
1.7.2	Maintenance	
1.7.3	Recapitalization	
1.8	Waste	
1.9	Transportation	

The AoA Team notes that activities after testing, start-up and commissioning are largely equal across all alternatives because the alternatives all reflect a common facility throughput capacity. These activities are fundamentally the same in scope across alternatives.

7.4 Schedule Estimate Assumptions and Basis of Estimates

At a fundamental level, the major differences between the two schedule scenarios (new versus retrofit) consist of the level of effort and time required for the design, procurement, installation, and construction of relevant SSCs analyzed by engineering discipline.

7.5 Schedule Estimates Methodology

The schedule analysis for this AoA leveraged several data collection efforts to inform the parametric schedule assessment for all alternatives, consistent with GAO best practices for schedule assessments and commensurate with the early stages of project definition and scope. Several project actuals (15 new build projects, 10 refurbishment projects [see Appendix G for complete list]) were used to calculate a schedule estimate basis. Actuals were used throughout the estimate, where applicable. When actuals where unavailable, the AoA team relied on subject-matter expertise to inform activity schedules and produce a range of uncertainty.

The schedules are not resource-loaded (that is, considering people, materials, procurements, etc., over time). Resource-loaded schedules will be developed after conceptual design, when more specific information about the full work scope is available. Attempts to resource-load a schedule at the current level of design maturity (pre-conceptual design) would require many assumptions without a developed basis and would likely fail to capture the range of outcomes still possible at this early stage. Such practices run counter to the GAO best practices for schedule assessments. Similar to cost estimating, a parametric analysis of schedule is most appropriate at this stage of project definition.

Executability of any budget profile cannot be determined fully until a more complete design is developed, near full scope is understood, and resources are loaded into the schedule. These, activities are most appropriate after a conceptual design. The estimates produced for this AoA focused on aspects of project schedule most likely to differentiate between alternatives, to aid in alternative selection.

The defining difference between the alternatives, in terms of schedule, was whether to build a new facility or refurbish an existing one. The mean duration of refurbishment alternatives is significantly shorter than for new construction. This means a refurbishment option that requires modification to an existing structure represents the shortest project schedule. However, the range of uncertainty in the scope of the refurbishment options is higher, so the schedule ranges for those alternatives is larger. The results show that the high end (most pessimistic) of the schedule range for the refurbish alternatives overlaps the low end (most optimistic) of the new build alternatives. To better define the scope and activity timelines associated with the preferred alternative, an engineering analysis to support conceptual design is recommended as a next step.

7.6 Schedule Estimate Findings

The team's schedule estimates are based on quantitative, parametric schedule analysis, leveraging project actuals from similar activities across the nuclear security enterprise. **Table 7-2** and **Figure 7-1** show the schedule estimate results.

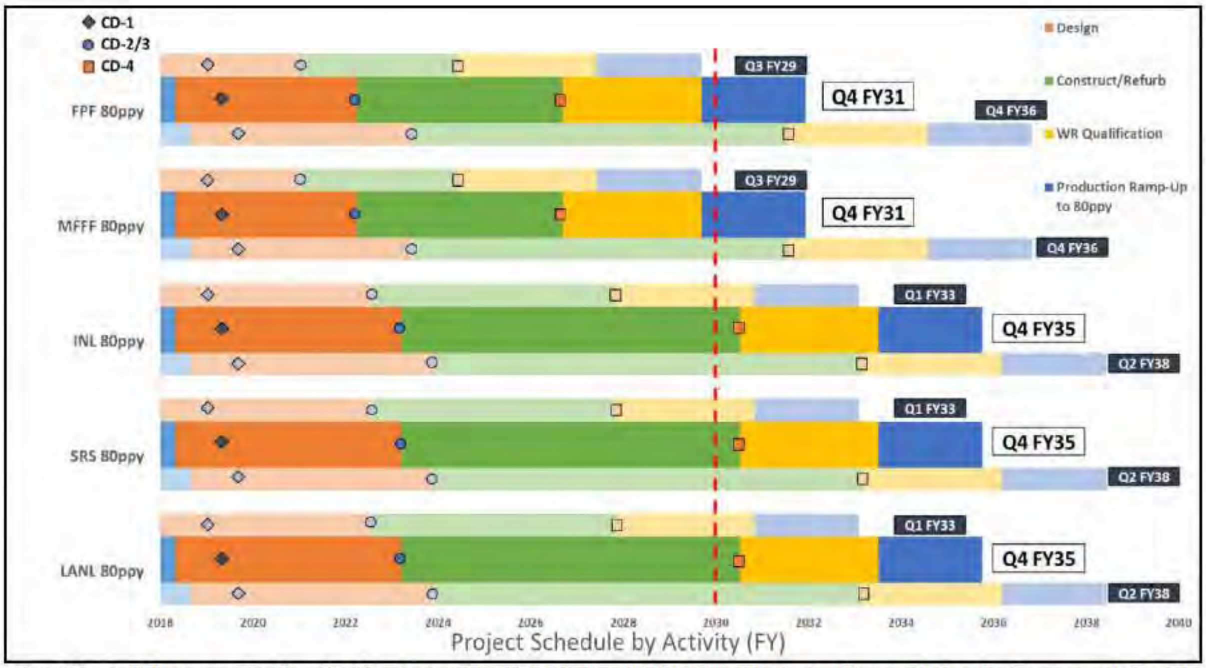
The area that drives the most schedule differentiation between alternatives is the construction phase. The pit process qualification and ramp-up to 80-ppy production are the same length for all alternatives and are significant contributors to the overall schedule. Under the current analysis, all alternatives are assumed to require a full EIS, and National Environmental Policy Act (NEPA) activities are not expected to be on the critical path for any alternative.

The schedule results show that only the refurbishment options have any chance, (albeit with some risk) of meeting the 2030 full rate production goal.

Table 7–2. Start and completion dates for all alternatives

		Start	Worst	Expected	Best
Refurbishment	MFFF – 80 ppy FPF – 80 ppy	10/2/2017	11/22/2035	5/8/2031	6/4/2029
New build	LANL – 80 ppy INL – 80 ppy SRS – 80 ppy	10/2/2017	6/30/2037	3/2/2035	10/28/2032

Key: FPF = Fuel Processing Facility; INL = Idaho National Laboratory; LANL = Los Alamos National Laboratory; MFFF = MOX Fuel Fabrication Facility; ppy = pits per year; SRS = Savannah River Site



Key: FPF = Fuel Processing Facility; FY = fiscal year; INL = Idaho National Laboratory; LANL = Los Alamos National Laboratory; MFFF = MOX Fuel Fabrication Facility; ppy = pits per year; Q = quarter; SRS = Savannah River Site; WR = War Reserve

Figure 7–1. Schedule results for all alternatives

One area of particular concern for the team was the potential effect of NEPA activities on overall project timelines. With actuals collected from LLQRs, the team created a range for the EIS timeline. Since NEPA activities typically run concurrently with design, the EIS currently would not be on the critical path for any of the alternatives considered. An EIS process would have to last over 5 years in order to cause delays to project execution, and this usually results from an unusually controversial project. This finding is further examined in Section 9.9, Sensitivity Analyses.

8 Evaluation of Alternatives – Risk and Effectiveness

8.1 Overview

In addition to the cost and schedule estimates presented in Chapters 6 and 7, the AoA team performed a detailed risk assessment, an evaluation of the effectiveness metrics identified in the Study Plan, and an assessment of additional considerations identified during the study. These detailed analyses were performed for the five remaining alternatives:

- LANL (new build)
- SRS (new build)
- SRS (refurbish MFFF)
- INL (new build)
- INL (refurbish FPF)

8.2 Final Risk Assessment

This section summarizes the risk assessment conducted by the AOA team. For more details about the risk assessment, see Appendix E.

8.2.1 Identified Threats

The AoA team identified threats in two areas. The first threat area is applicable to the period of construction up to the point when the facility begins the routine production of 80 ppy (Table 5–1). For the purposes of calculating 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 threat area pertains to the operating lifetime of the facility, assumed to be 50 years (Table 5–2).

8.2.2 Risk Matrix

The AoA team assessed the magnitude of the risk corresponding to each of the threats listed in Tables 5–1 and 5–2, making use of the risk matrix methodology described in DOE's *Risk Management Guide* (DOE, 2011). The risk matrix is reproduced in **Table 8–1**, with some minor changes. The probabilities are assigned numbers from 1 through 5, with 1 being very high and 5 being very low. The consequences are also labeled 1 through 5, with 1 being the highest consequence (crisis) and 5 being the lowest consequence (negligible).

In the text of this chapter, every time a combination of probability and consequence is identified it is noted as probability/consequence/risk for the convenience of the reader so that it is not necessary to refer back to the risk matrix. For example, a very high probability (1) and a significant consequence (3) correspond to a high risk (H); this is represented by the notation "1/3/H." Similarly, a high probability (2) and a significant consequence (3) correspond to a moderate risk (M), or 2/3/M for short. Likewise, a low probability (4) and a negligible consequence (1) correspond to a low risk (L), or 4/1/L.

Table 8–1. Risk matrix for Plutonium Pit Production Analysis of Alternatives[a]

		Consequences				
		Negligible (5)	**Marginal (4)**	**Significant (3)**	**Critical (2)**	**Crisis (1)**
Probability	Very high (1) >90%	Low (L)	Moderate (M)	High (H)	High (H)	High (H)
	High (2) 75% to 90%	Low (L)	Moderate (M)	Moderate (M)	High (H)	High (H)
	Moderate (3) 26% to74%	Low (L)	Low (L)	Moderate (M)	Moderate (M)	High (H)
	Low (4) 10% to25%	Low (L)	Low (L)	Low (L)	Moderate (M)	Moderate (M)
	Very low (5) <10%	Low (L)	Low (L)	Low (L)	Low (L)	Moderate (M)
[a] Matrix and probabilities from DOE *Risk Management Guide*, DOE G 413.3-7 (DOE, 2011).						
Numbers 1-5 against probability and consequences added for the purposes of this AoA.						
Probability of occurrence:						
Construction: calculated during the period from CD-2 to startup (assume 10 years).						
Operation: calculated during the lifetime of facility beginning at startup (assume 50 years).						

8.2.3 Summary of Risks

Table 8–2 summarizes the risk scores for each of the alternatives retained for detailed evaluation. Alternatives that rely on PF-4 to reliably deliver part or all of the required 80 ppy were not retained for detailed evaluation. However, these alternatives have been collected under one generic heading, PF-4 Alternatives, and are included in the following analysis for comparison. Note that site specific risks developed and evaluated during the alternatives development effort and documented in Appendix D were pulled into this analyses where warranted.

Table 8-2 first lists risks for which (a) the risk is high for at least one alternative and (b) the risk discriminates between alternatives. These are followed by risks that are high for all alternatives. After that, risks are listed for which (a) no risk is high, (b) at least one risk is moderate, and (c) the risk discriminates between alternatives. This allows the reader to see at a glance which high risks are true discriminators. Appendix E provides a full risk table, including risks that are moderate and/or low for all alternatives.

Table 8–2. Summary of results of risk assessment for short list of alternatives ordered from high to low

Risk Category	ID#	Brief Description of Threat	PF-4 Alts.	LANL New	SRS MFFF	SRS New	INL-FPF	INL New
High Risks that Discriminate Between Alternatives	C-10	Construction or repair and modifications impact ongoing site or facility operations, or ongoing site or facility activities impact construction or repair and modifications.	1/3/H or 1/2/H	5/5/L	5/5/L	5/5/L	5/5/L	5/5/L
	O-1	Pit manufacturing adversely affects other site or facility projects, or other site or facility projects adversely affect pit production.	1/3/H or 1/2/H	5/5/L	5/5/L	5/5/L	5/5/L	5/5/L
	C-23	If MFFF is chosen for the pit manufacturing facility, potential difficulties arise while closing out the current project with Areva.	N/A	N/A	1/3/H	N/A	N/A	N/A
High Risks that Apply Equally to All Alternatives	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.	2/2/H	2/2/H	2/2/H	2/2/H	2/2/H	2/2/H
	C-8	More stringent interpretations of safety requirements during design and construction require significant facility structural or service system upgrades.	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H
	C-9	Additional security provisions (*e.g.*, clearances, escorts, fences, changes in the design basis threat) beyond those planned are imposed.	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H
Moderate Risks that Distinguish Between Alternatives	C-11	Existing facilities require more work than planned to meet applicable codes and standards (i.e., latent conditions may unexpectedly come into play). Equivalently, unforeseen conditions in existing facilities during repair or upgrades result in more work than planned.	3/3/M	N/A	4/3/L	N/A	2/3/M	N/A
	C-24	Difficulties arise while transferring the MFFF facility licensing basis from NRC to DOE.	N/A	N/A	2/3/M	N/A	N/A	N/A
	C-5	Intra-agency and/or inter-agency disputes delay project and introduce extra costs or unwanted restrictions on the project.	5/4/L	5/4/L	3/3/M	3/3/M	3/3/M	3/3/M
	C-2	National and/or local policy/public opposition result in delays and extra costs.	3/3/M	3/3/M	2/3/M	2/3/M	2/3/M	2/3/M
	C-20	An external flood occurs during construction.	5/3/L	5/3/L	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)
	O-17	An external flood occurs during operation.	5/3/L	5/3/L	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)

8.3 Evaluation of Effectiveness Metrics and Other Considerations

In addition to cost, schedule, and risk, the AoA team independently evaluated several performance metrics and intangible benefits and disadvantages of the alternatives that should be considered in the decision. The following "effectiveness metrics" were defined in the Study Plan:

- Ability to meet objective requirements (defined to be a higher level of capacity that the program would like to have over and above the threshold "must-have" levels)
- Capacity for pit reuse operations simultaneously with pit remanufacturing
- Ability to accommodate surge requirements
- Geographical dispersion of operations
- Flexibility for future changes in mission requirements
- Lifetime of the solution

Table 8–3 shows the assessment of each alternative with respect to the defined effectiveness metrics. The qualitative assessment of these aspects of the alternatives was performed by independent SMEs with expertise in pit manufacturing at the Rocky Flats Plant, operations research, and program management (including former federal project managers for MFFF and TEF). All alternatives were found to be essentially equal for these metrics.

In addition to these, the team also addressed several other considerations discussed during the course of the study, such as impact on Office of Secure Transportation, NEPA concerns, workforce issues, waste production, and separation of production agency and research and development functions.

- **NEPA:** All alternatives will likely require an EIS. Even on the high end of the schedule estimates for an EIS, NEPA activities are not on the critical path for any of the alternatives. NEPA is not a discriminator.
- **Workforce:** Regardless of where the pit production mission is located, the chosen site will require a significant increase in staffing. Though LANL has experienced staff, and therefore has an advantage for training incoming technicians, workers are not as available at LANL as the other sites. SRS has better availability of workforce than LANL or INL, but no resident experience in pit production. Overall, workforce issues were assessed to be equivalent for LANL and SRS and a little worse for INL.
- **Transportation (Office of Secure Transportation, OST):** Regardless of where the pit production mission is located, pits used for feed material will be transported from Pantex, and finished pits will be transported back to Pantex. The only difference in OST shipments expected between alternatives would be the requirement to transport a very small number of pits to LANL for surveillance if pit production is at another site. This is not expected to be a discriminator.
- **Waste:** Regardless of where pit production is located, the process will produce approximately the same amount of waste.
- **Separation of the R&D mission from the production agency:** Though discussed by production experts as an advantage, separation of the R&D mission from the production agency could also result in loss of synergies. There are advantages and disadvantages both ways.

Based on these evaluations, the team recommends the decision be based on trade-offs between cost, schedule, and risk.

~~Unclassified Controlled Nuclear Information~~

Table 8–3. Evaluation of effectiveness metrics

Effectiveness Metric	SRS Refurbish MFFF	INL Refurbish FPF	LANL New Construction	SRS New Construction	INL New Construction
Supports Objective Reqs as stated in the Program Requirements Document					
Pit Prod, DOE-NE, DOE-OS, NA-20	Yes, Yes, Yes, Yes	Yes, Yes, Yes, Yes	Yes, Yes, Yes, Yes	Yes, Yes, Yes, Yes	Yes, Yes, Yes, Yes
Capacity for pit reuse operations simultaneously with pit remanufacturing.	Yes – **Space available for expanded capacity if necessary**	Yes – **Space available for expanded capacity if necessary**	Yes	Yes	Yes
Ability to accommodate surge	Yes – multiple shifts	Yes – multiple shifts	Yes – multiple shifts	Yes – multiple shifts	Yes – multiple shifts
Geographical dispersion of functions – separation of function from production					
Pu Science / Design Agency	Design agency and Pu Science separate from production Some additional transport of materials (surveillance)	Design agency and Pu Science separate from production Some additional transport of materials (surveillance)	No organizational separation between design agency and production	Design agency and Pu Science separate from production Some additional transport of materials (surveillance)	Design agency and Pu Science separate from production Some additional transport of materials (surveillance)
Metal Prep	No separation	No separation	No separation	No separation	No separation
Ability to accommodate changes in mission reqs – provides flexibility	Yes - PF-4 could be used, plus **ample flex space available**	Yes - PF-4 could be used, plus **moderate flex space available**	Yes - PF-4 could be used, plus **some flex space available**	Yes - PF-4 could be used, plus **some flex space available**	Yes - PF-4 could be used, plus **some flex space available**
50 Year Lifetime?	Yes	Yes	Yes	Yes	Yes
Organizational Interfaces		**More difficult – DOE-NE site**			**More difficult – DOE-NE site**
Legal Challenges – Settlement Agreements	Yes, low likelihood of interference	Yes, high likelihood of interference		Yes, low likelihood of interference	Yes, high likelihood of interference

Key: LANL = DOE NE = Department of Energy Office of Nuclear Energy; DOE-OS = Department of Energy Office of Science; INL = Idaho National Laboratory; Los Alamos National Laboratory; NA-20 = NNSA's Office of Defense Nuclear Nonproliferation; PF = Plutonium Facility; Pu = plutonium; SRS = Savannah River Site

9 Results and Conclusions

This chapter summarizes information provided in the previous chapters, discusses key results, and provides conclusions and recommendations made based on key results. This chapter also presents, the sensitivity analyses performed to investigate the robustness of the conclusions to changes in key assumptions. Finally, recommended next steps are discussed.

9.1 Space Requirements

The AoA team estimated space requirements for the pit manufacturing area based on the equipment list developed using the stochastic discrete event simulation. The space required for support functions and supporting infrastructure were also estimated based on facility tours, interviews with facility managers, and subject matter expertise. **Table 9–1** shows the total square footage needed for 30 ppy, 50 ppy and 80 ppy. Details on these analyses are provided in Chapter 2.

Table 9-1. 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[16]	57,000	68,000
Building services	39,700	16,700	19,600
Total HC-2 Production Facility	***137,000[17]***	***110,000***	***130,000***
Support facilities inside the PIDADS	All available at LANL	46,800	67,500
Support infrastructure outside the PIDADS	All Available at LANL	95,000	122,700

9.2 Alternatives

The AoA team used a thorough and iterative process to develop a robust set of alternatives for evaluation. A set of 40 alternatives was approved by the PSO as shown in **Table 9-2**. The process is discussed in Chapter 4.

[16] 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.
[17] Includes other mission functions performed in PF-4 such as ARIES, plutonium-238 processing, and surveillance & certification.

Table 9–2. 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		

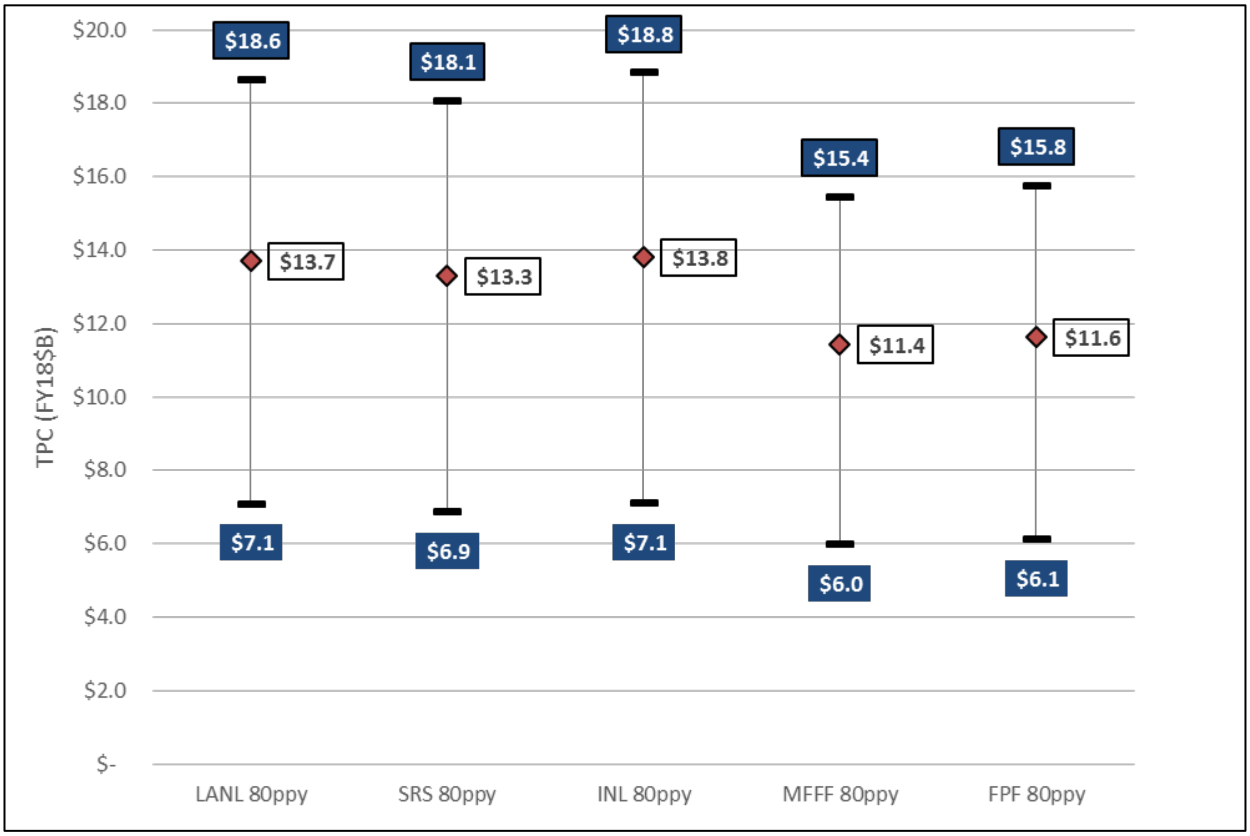
9.3 Initial Evaluation and Identification of Alternatives Not Retained for Full Evaluation

Based on screening against requirements, initial space, cost, schedule, and risk evaluations, all but five of the alternatives were eliminated from the most detailed schedule, cost, and effectiveness analyses. This is discussed in Chapter 5. The final alternatives recommended for detailed evaluation were all from the “Move Pit Production” group, involving establishing an 80-ppy capability, including metal preparation, in one of the following five places:

- LANL – new build
- SRS – new build
- INL – new build
- SRS – refurbish MFFF
- INL – refurbish FPF

9.4 Cost Results

The AoA’s cost team examined TPC and LCC for each of the alternatives assessed to be the most viable: new construction at LANL, INL or SRS and refurbishment of existing facilities at INL or SRS. This included estimates for facility construction and refurbishment, equipment procurement and installation, waste management, operations and maintenance, and other recurring expenses expected over the course of the pit production mission. These cost estimates were based primarily on actual cost data from analogous projects of similar scope, as well as the AoA team’s analysis of the amount of space and equipment required to achieve and sustain 80 ppy. **Figure 9–1** shows the life-cycle cost estimates for the five most viable alternatives. Additional details on the cost estimates are provided in Chapter 6.



Key: FPF = Fuel Processing Facility; INL = Idaho National Laboratory; MFFF = Mixed Oxide Fuel Fabrication Facility; LANL – Los Alamos National Laboratory; ppy = pits per year; SRS = Savannah River Site; TPC = total project cost; FY = fiscal year

Figure 9–1. Life-cycle cost estimates for new construction and refurbishment alternatives

9.5 Schedule Results

The team's schedule estimations are based on quantitative, parametric schedule analysis, leveraging project actuals from similar activities across the nuclear security enterprise. **Table 9-3** and **Figure 9-2** summarize the schedule estimate results.

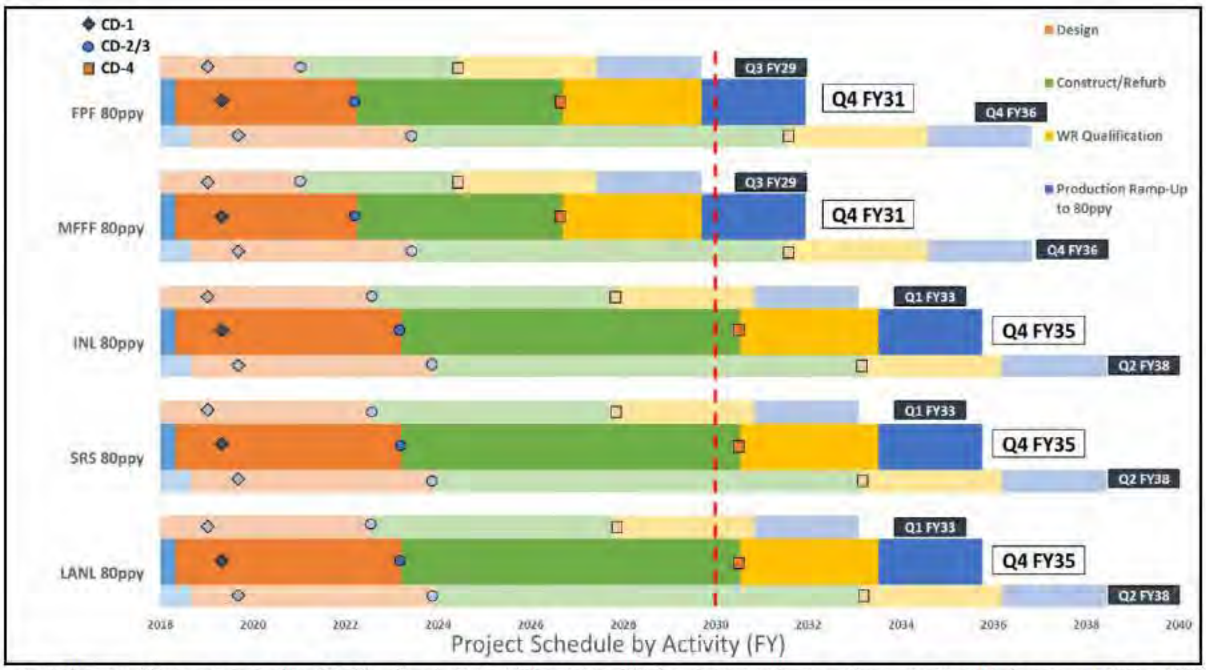
The area that drives the most schedule differentiation between alternatives is the construction phase. The pit process qualification and ramp-up to 80-ppy production are the same length for all alternatives and are significant contributors to the overall schedule. Based on current assumptions and data, all alternatives are assumed to require a full EIS, and National Environmental Policy Act (NEPA) activities are not expected to be on the critical path for any alternative.

The defining difference between the alternatives, in terms of schedule, was whether to build a new facility or refurbish an existing one. The mean duration of refurbishment alternatives is significantly shorter than for new construction. This means a refurbishment option that requires modification to an existing structure represents the shortest project schedule. However, the range of uncertainty in the scope of the refurbishment options is higher, so the schedule ranges for those alternatives is larger. The results show that the high end (most pessimistic) of the schedule range for the refurbish alternatives overlaps the low end (most optimistic) of the new build alternatives. The schedule results show that only the refurbishment options have any chance, albeit with some risk, of meeting the 2030 full rate production goal.

Table 9–3. Start and completion dates for all alternatives

		Start	Worst	Expected	Best
Refurbishment	MFFF – 80 ppy FPF – 80 ppy	10/2/2017	11/22/2035	5/8/2031	6/4/2029
New build	LANL – 80 ppy INL – 80 ppy SRS – 80 ppy	10/2/2017	6/30/2037	3/2/2035	10/28/2032

Key: FPF = Fuel Processing Facility; INL = Idaho National Laboratory; LANL = Los Alamos National Laboratory; MFFF = MOX Fuel Fabrication Facility; ppy = pits per year; SRS = Savannah River Site



Key: FPF = Fuel Processing Facility; FY = fiscal year; INL = Idaho National Laboratory; LANL = Los Alamos National Laboratory; MFFF = MOX Fuel Fabrication Facility; ppy = pits per year; Q = quarter; SRS = Savannah River Site; WR = War Reserve

Figure 9–2. Schedule results for all alternatives

9.6 Risk Assessment, Effectiveness Metrics, and Other Considerations

The risk assessment includes evaluation of threats during construction and during operations for each of the alternatives. **Table 9–4** summarizes results for the five most viable alternatives, along with an assessment of risk for alternatives that retain pit production in PF-4. These latter were eliminated primarily due to unacceptably high mission risk, so it seemed appropriate to include those results here. More detail on the risk assessment can be found in Chapter 8, and Appendix E.

Table 9–4. Summary of results of risk assessment for viable alternatives ordered from high to low

	ID#	Brief Description of Threat	PF-4 Alts.	LANL New	SRS MFFF	SRS New	INL FPF	INL New
High Risks that Discriminate Between Alternatives	C-10	Construction or repair and modifications impact ongoing site or facility operations, or ongoing site or facility activities impact construction or repair and modifications.	1/3/H or 1/2/H	5/5/L	5/5/L	5/5/L	5/5/L	5/5/L
	O-1	Pit manufacturing adversely affects other site or facility projects, or other site or facility projects adversely affect pit production.	1/3/H or 1/2/H	5/5/L	5/5/L	5/5/L	5/5/L	5/5/L
	C-23	If MFFF is chosen for the pit manufacturing facility, potential difficulties arise while closing out the current project with Areva.	N/A	N/A	1/3/H	N/A	N/A	N/A
High Risks that Apply Equally to All Alternatives	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.	2/2/H	2/2/H	1/2/H	2/2/H	2/2/H	2/2/H
	C-8	More stringent interpretations of safety requirements during design and construction require significant facility structural or service system upgrades.	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H
	C-9	Additional security provisions (e.g., clearances, escorts, fences, changes in the design basis threat) beyond those planned are imposed.	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H
Moderate Risks that Distinguish Between Alternatives	C-11	Existing facilities require more work than planned to meet applicable codes and standards (i.e., latent conditions may unexpectedly come into play). Equivalently, unforeseen conditions in existing facilities during repair or upgrades result in more work than planned.	3/3/M	N/A	4/3/L	N/A	2/3/M	N/A
	C-24	Difficulties arise while transferring the MFFF facility licensing basis from NRC to DOE.	N/A	N/A	2/3/M	N/A	N/A	N/A
	C-5	Intra-agency and/or inter-agency disputes delay project and introduce extra costs or unwanted restrictions on the project.	5/4/L	5/4/L	3/3/M	3/3/M	3/3/M	3/3/M
	C-2	National and/or local policy/public opposition result in delays and extra costs.	3/3/M	3/3/M	2/3/M	2/3/M	2/3/M	2/3/M
	C-20	An external flood occurs during construction.	5/3/L	5/3/L	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)
	O-17	An external flood occurs during operation.	5/3/L	5/3/L	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)

In addition to cost, schedule, and risk, the AoA team independently evaluated several performance and intangible benefits and disadvantages of the alternatives that should be considered in the decision. The following "effectiveness metrics" were defined in the Study Plan:

- The ability to meet objective requirements (defined to be a higher level of capacity over and above the threshold "must-have" levels)
- Capacity for pit reuse operations simultaneously with pit remanufacturing
- Ability to accommodate surge requirements
- Geographical dispersion of operations
- Flexibility for future changes in mission requirements
- Lifetime of the solution

All alternatives were found to be essentially equal for these effectiveness metrics.

In addition to these, the team also addressed several other considerations discussed during the course of the study, such as impact on Office of Secure Transportation, NEPA concerns, workforce issues, waste production, and separation of production agency and research and development functions.

- **NEPA:** All alternatives will likely require an EIS. Even on the high end of the schedule estimates for an EIS, NEPA activities are not on the critical path for any of the alternatives. NEPA is not a discriminator.
- **Workforce:** Regardless of where the pit production mission is located, the chosen site will require a significant increase in staffing. Although LANL has experienced staff and, therefore, has an advantage for training incoming technicians, workers are not as available at LANL as the other sites. SRS has better availability of workforce than LANL or INL, but no resident experience in pit production. Overall, workforce issues were assessed to be equivalent for LANL and SRS and a little worse for INL.
- **Transportation (OST):** Regardless of where the pit production mission is located, pits used for feed material will be transported from Pantex, and finished pits will be transported back to Pantex. The only difference in OST shipments expected between alternatives would be the requirement to transport a very small number of pits to LANL for surveillance if pit production is at another site. This is not expected to be a discriminator.
- **Waste:** Regardless of where pit production is located, the process will produce the same amount of waste.
- **Separation of the R&D mission from the production agency:** Though discussed by production experts as an advantage, separation of the R&D mission from the production agency could also result in loss of synergies. There are advantages and disadvantages both ways.

Table 9-5 summarizes the results of these evaluations. Based on these results, the team recommends the decision be based on trade-offs between cost, schedule, and risk.

Table 9-5. Evaluation of effectiveness metrics

Effectiveness Metric	SRS Refurbish MFFF	INL Refurbish FPF	LANL New Construction	SRS New Construction	INL New Construction
Supports Objective Reqs as stated in the Program Requirements Document					
Pit Prod, DOE-NE, DOE-OS, NA-20	Yes, Yes, Yes, Yes	Yes, Yes, Yes, Yes	Yes, Yes, Yes, Yes	Yes, Yes, Yes, Yes	Yes, Yes, Yes, Yes
Capacity for pit reuse operations simultaneously with pit remanufacturing.	Yes – **Space available for expanded capacity if necessary**	Yes – **Space available for expanded capacity if necessary**	Yes	Yes	Yes
Ability to accommodate surge	Yes – multiple shifts	Yes – multiple shifts	Yes – multiple shifts	Yes – multiple shifts	Yes – multiple shifts
Geographical dispersion of functions – separation of function from production					
Pu Science / Design Agency	Design agency and Pu Science separate from production Some additional transport of materials (surveillance)	Design agency and Pu Science separate from production Some additional transport of materials (surveillance)	No organizational separation between design agency and production	Design agency and Pu Science separate from production Some additional transport of materials (surveillance)	Design agency and Pu Science separate from production Some additional transport of materials (surveillance)
Metal Prep	No separation	No separation	No separation	No separation	No separation
Ability to accommodate changes in mission reqs – provides flexibility	Yes - PF-4 could be used, plus **ample flex space available**	Yes - PF-4 could be used, plus **moderate flex space available**	Yes - PF-4 could be used, plus **some flex space available**	Yes - PF-4 could be used, plus **some flex space available**	Yes - PF-4 could be used, plus **some flex space available**
50 Year Lifetime?	Yes	Yes	Yes	Yes	Yes
Organizational Interfaces		**More difficult – DOE-NE site**			**More difficult – DOE-NE site**
Legal Challenges – Settlement Agreements	Yes, low likelihood of interference	Yes, high likelihood of interference		Yes, low likelihood of interference	Yes, high likelihood of interference

Key: LANL = DOE NE = Department of Energy Office of Nuclear Energy; DOE-OS = Department of Energy Office of Science; INL = Idaho National Laboratory; Los Alamos National Laboratory; NA-20 = NNSA's Office of Defense Nuclear Nonproliferation; PF = Plutonium Facility; Pu = plutonium; SRS = Savannah River Site

9.7 Findings

There are several findings worth noting based on the analyses conducted during the course of the AoA.

9.7.1 The Initial Modular Building Strategy, as Envisioned at CD-0, Is Inadequate to Support the 80-ppy Mission with High Confidence

The Initial Modular Building Strategy, as envisioned at CD-0 involved reconfiguring PF-4 and the construction of two modules with 5,250 square feet of processing space each. LANL did not provide an official proposal for how this concept would achieve the 80 ppy mission requirement without compromising other required plutonium missions. Instead, LANL had several alternatives for establishing various capabilities in the modules and reconfiguring PF-4. Many of these were incorporated into the AoA alternative set, for example, splitting production capacity, and moving metal preparation operations, plutonium-238 operations or ARIES are included in the AoA alternatives. As shown in Chapter 5, those particular concepts have unfavorable cost, schedule or risk profiles, and no identifiable offsetting benefit. The following discussion describes

Table 9–6 shows estimated space needs for production of 80 ppy at high confidence in comparison to space available in PF-4 after CMRR and Plutonium Sustainment programs install AC/MC capabilities and production equipment for approximately 30 ppy.[18] Note PF-4 is assumed to provide adequate building services, so to simplify the comparison, the space needed for building services is not included in this comparison.

Table 9–6. PF-4 production space

	80 pits per year	PF-4 Space Allocation (Program of Record for 30 pits per year)	Additional Space Needed for 80 pits per year	Missions in PF-4 that Could Be Relocated
Process Area	**Estimated (square feet)**			
Process equipment including building working space	42,300	19,500	**22,800**	
Support Functions within processing facility	68,100	54,600	**13,500**	
Total	**110,400**	**74,100**	**36,300**	
ARIES				5,500
Plutonium-238				9,400
	KEY: ARIES = Advanced Recovery and Integrated Extraction System			

The AoA team estimated that an additional 36,000 ft^2 is required to support the 80-ppy mission. Even assuming that support functions such as the vault, shipping and receiving, production development, material management, etc., available in PF-4 are adequate, an additional 22,800 ft^2 over and above what is provided by PF-4 is necessary to support 80 ppy at high confidence. In addition, attempting to reconfigure PF-4 once sustainment objectives are reached presents very high risk to the 30-ppy mission.

[18] See Chapter 2 for a discussion of equipment and space estimates and the difference between production at high confidence and production on average.

Using the module design proposed at CD-0, it would take seven total modules to create an additional 36,000 ft^2 of production space. The CD-0 cost range for two modules was $1.5 to 3 billion, so a ROM cost estimate for seven modules would be $5.25 to 10.5 billion. **Figure 9-3** provides a scaled drawing of the available space in PF-4 for pit production, and the proposed modules in comparison with the additional required space.

(b)(3) UCNI

The Initial Modular Building Strategy, as envisioned at CD-0 (two modules, each providing 5,250 ft^2 of production space) is inadequate to support the 80 ppy mission at high confidence.

In June 2017, based on preliminary AoA results, the PSO determined that continuing to rely on PF-4 for the Nation's enduring pit production capability presented unacceptably high mission risk for the following reasons:

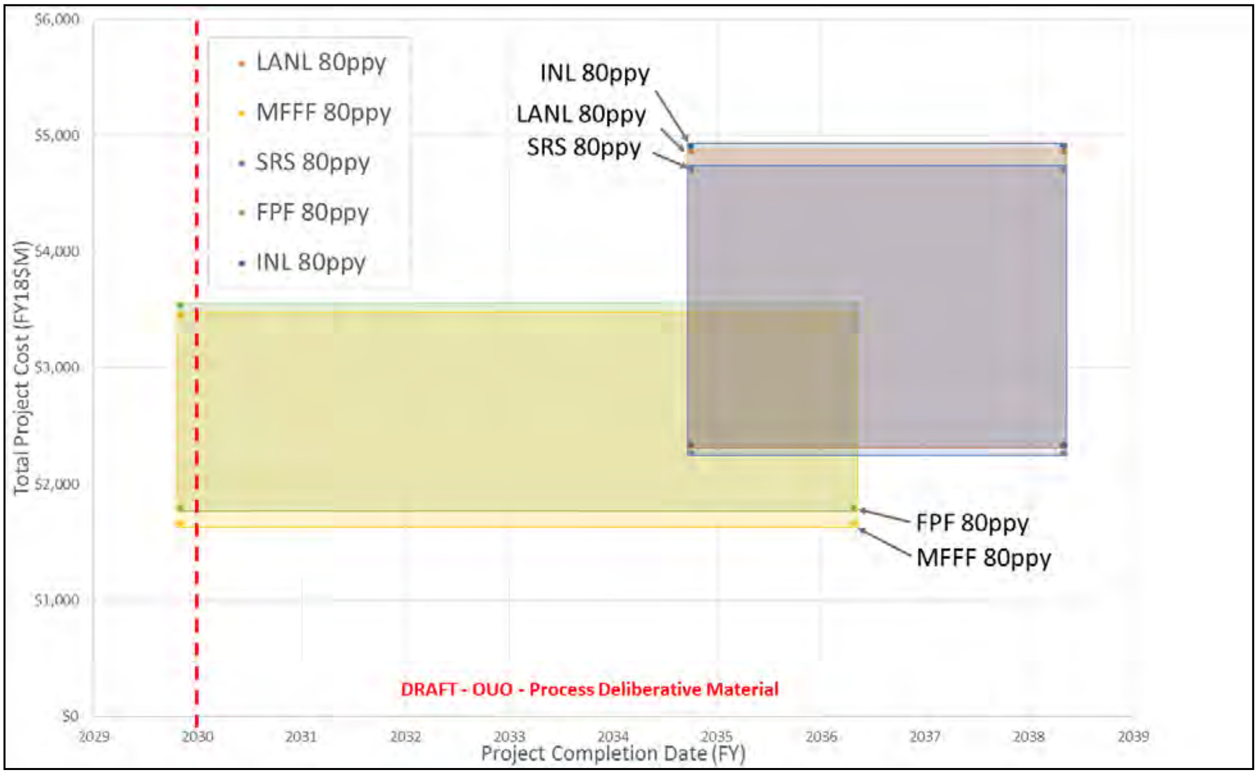
- **Jeopardizes program of record:** Efforts to remove contaminated gloveboxes and install new equipment in an operating manufacturing space, beyond what is already planned under the Plutonium Sustainment program, creates unacceptably high risk to achieving 30 ppy by 2026.
- **Space and capacity constraints:** The AoA Team estimates about 110,000 ft^2 of HC-2, SC-1 processing space is necessary to produce 80 ppy with high confidence.[19] PF-4 has about 74,000

[19] Total for the HC-2, SC-1 production facility is estimated to be approximately 130,000 ft^2, including building services such as process ventilation and security class utilities.

ft^2 of suitable space, 36,000 ft^2 short. Even if missions such as ARIES and plutonium-238 component manufacturing, totaling about 14,000 ft^2, were relocated, the total processing space in PF-4 would still be approximately 22,000 ft^2 short.

9.7.2 Refurbish Alternatives Have the Most Favorable Cost and Schedule Outcomes

The two refurbish alternatives (MFFF and FPF) are more likely to cost less and have more favorable schedules. However, given the large range of uncertainty, which is driven by a pre-conceptual design, the worst-case cost and schedule estimates for refurbishment overlap with the best-case cost and schedule estimates of the new build options, as shown in **Figure 9–4.**



Key: *FPF = Fuel Processing Facility; FY = fiscal year; INL = Idaho National Laboratory; LANL = Los Alamos National Laboratory; MFFF = Mixed Oxide Fuel Fabrication Facility; ppy = pits per year; SRS = Savannah River Site*

Figure 9–4. Cost and schedule ranges for final alternatives

9.7.3 Pit Production is Unlikely to be at Full Capacity by the 2030 Timeline, Even in the Most Optimistic Cases

A key outcome of this AoA was the emphasis on 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, design of a HC-2 facility, and the actual 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 provided a 2030 schedule 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.

9.8 Sensitivity Analyses

Results show that the refurbishment alternatives are likely to have more favorable cost and schedule outcomes than new build alternatives. Sensitivity analyses were performed to test the robustness of these results to changes in assumptions. The AoA team examined the major assumptions from Section 1.4, and other key assumptions made throughout the study to determine whether the outcome of the analysis would be invalidated if the assumption proved wrong. In all cases, except the assumption that pit production must be performed in the United States by an approved M&O contractor[20], the most likely effect on the analysis if the assumption is proven wrong would be a change in the required size of the production facility. Based on this, the AoA Team performed sensitivity analyses to determine the HC-2 facility size range expected to produce the same result.

In addition to this, the AoA Team examined uncertainty in the cost and schedule estimates. The Team determined that there may be some factors unique to the Refurbish MFFF alternative, namely that there may be a delay in obtaining the facility, which may overturn the results. The Team performed sensitivity analysis on the schedule estimates to determine how long a delay could be absorbed before the results no longer hold.

9.8.1 Sensitivity Analyses for Cost Estimates

Sensitivity analysis was conducted using Monte Carlo simulation and the parametric cost-estimating relationships that provided scaling factors to account for technical differences such as facility size and complexity. The parametric approach provided uncertainty distributions around each one of the input parameters that were then integrated into a total uncertainty using the Monte Carlo simulation. The result of this approach is a cost-probability distribution that accounts for the sensitivity of individual cost drivers. For example, the input square footage to the cost estimate was taken as a distribution of likely square footage values instead of a point estimate of square footage and integrated, with other factors, into the cost model. The Monte Carlo analysis ran 10,000 different "scenarios" in which the input parameters changed (based on actual data) and resulted in a distribution of potential outcomes. This distribution was developed for each of the five alternatives that passed the initial screening, taking into account differences in scope, complexity, location, and available support facilities. This is explained in more detail in Appendix F.

9.8.2 Sensitivity Analyses for Schedule

The AoA Team notes that a greater schedule difference between alternatives than is currently estimated could occur under certain conditions. For example, the AoA team's schedule estimate assumes that every alternative will require a full EIS but does not distinguish between the duration of an EIS at different sites. If an EIS was expected to take longer at one site than another, this could result in a greater schedule difference or a change in the result that refurbish alternatives have more favorable schedules. Unique circumstances, such as a delay in the MFFF availability date, could also cause that alternative's schedule to diverge from the current estimate.

[20] Assumption 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.

To examine how long the refurbishment schedules would have to slip before the refurbishment alternatives were equal to the new build alternatives, the team adjusted the critical path for the refurbishment schedule until the two schedules were equal. The schedule for refurbishment alternatives would have to slip by 3.8 years before being equal to the schedule for new build alternatives.

9.8.3 Space Sensitivity Analyses and Impact on Cost

As described, the AoA team estimated the space required for pit manufacturing and support functions to meet mission requirements, as summarized in **Table 9–7.**

Table 9–7. Production area for 80 ppy

HC-2, SC-1 Production Facility Area for 80 ppy	Space (square feet)
Pit production area	42,400
Support functions	68,000
Building services	19,600
Total	***130,000***

Current results show that the refurbishment alternatives have lower expected costs than new build alternatives. This is because the cost of equipment procurement and installation are expected to be about equal across the alternatives, and the renovation cost of an existing facility is expected to be lower than the cost of building a new facility, primarily due to the avoidance of the extensive civil work required to build a new facility.

In addition to the Monte Carlo analyses performed for the cost estimates, the AoA team explored how an increase or decrease in the space estimates might affect the final result. The costs of both refurbishment alternatives and new build alternatives will increase if space estimates increase and decrease if space estimates decrease. However, costs for new build alternatives change a larger amount for a given difference in square footage due to the cost of building new HC-2 footprint.

This means that the refurbishment alternatives will still cost less than the new build alternatives if the actual space requirements are larger than the AoA team estimates, as costs for new construction will grow faster than costs for refurbishment. This is true unless the space estimates are so underestimated that the actual space needed is more than is available at the existing facility. For the MFFF refurbishment alternative, there is over 400,000 ft^2 of available HC-2 space in the MOX Processing Building (BMP) and Aqueous Polishing Building (BAP). It is very unlikely that the AoA space estimate of 130,000 ft^2 of HC-2 space is underestimated by more than a factor of three. For the FPF refurbishment alternative, the total available square footage is closer to 170,000 ft^2. If the AoA space estimate is underestimated by more than 30 percent, the conclusion that refurbishing FPF is a lower cost alternative than building a new facility may no longer hold.

On the other hand, if the required space is less than the team's estimate, it is possible that the cost of the new build alternatives could approach the cost of the refurbishment alternatives. Since the space for the pit manufacturing area was estimated based on an equipment list developed using a model developed by the AoA team, this is a natural place to explore whether decreases in the estimate will affect the final result.

The model incorporated data from previous LANL experience in pit manufacturing, but the LANL experience was a limited run and possibly not representative of the performance of a steady-state manufacturing-focused plant. Some efficiencies in process time, equipment repair time, reject rates, and possibly even equipment breakdown rates are likely to be achieved with greater experience, resulting in less equipment needed to get the same throughput.

To explore the bounds of the impact of the space estimate, the AoA team attempted to determine how far off the estimate would have to be to change the result. Even if the cost to refurbish an existing facility is held constant, the space estimate must be 70,000 ft^2 smaller for the mean of the new build alternatives to reach the mean of the refurbishment alternatives. Since the cost to refurbish an existing facility will also be less if the equipment set is smaller, the actual reduction in space required to make the two cases equal will be even larger than 70,000 ft^2.

Though it is possible that the current equipment needs are overestimated, it is unlikely that the AoA estimate is over estimated by more than a factor of two as compared to actual requirements. This is borne out by two comparisons. First, the AoA team estimated 68,100 ft^2 for HC-2 support functions. PF-4 currently has 54,600 ft^2 dedicated to these functions without an 80-ppy capability. At most, the AoA estimate for these functions is overestimated by 13,500. Secondly, the comparison shown in **Table 9-8** from the Modern Pit Facility and a 125-ppy capability in PF-4 plus new construction[21] shows that the AoA space estimate for the primary pit manufacturing functions is on par with previous estimates.

Table 9–8. Space requirement estimates for 103 ppy and 125 ppy average output at PF-4 and the proposed Modern Pit Facility

	AoA 80 ppy 93 percent Confidence, Approximately 103 ppy on Average	LANL PF-4 125 ppy average	MPF 125 ppy average
Metal preparation	3,320	5,600	4,800
Foundry	8,330	9,800	8,750
Machining	11,051	16,200	10,450
Assembly	11,477	9,925	15,500
Total of identified functions	34,178	41,525	39,500
Key: AoA = Analysis of Alternatives; LANL = Los Alamos National Laboratory; MPF = Modern Pit Facility; ppy = pits per year			

In conclusion, it is very unlikely that the AoA team's space estimates are so far off as to change the result that refurbishing an existing facility is a lower cost option than building a new facility.

9.9 Conclusions

The AoA results show that refurbishing an existing facility has the most favorable cost and schedule to reach 80-ppy production rate by the 2030s.

MFFF is a new facility built to current safety and security standards and has more than sufficient space to meet mission requirements. Its host site, SRS, has most of the secondary infrastructure needed to support pit production. Additionally, there are no active missions ongoing in the building, therefore the refurbishment and installation of the pit production mission would not disrupt other work and would not have to be carried out in an active security area, which reduces cost, schedule, and risk. However, there is considerable uncertainty in the amount and nature of the refurbishment and considerable risk that policy influence or contractual issues will delay the start of the project.

While refurbishing the Fuel Processing Facility at INL offered many of the same benefits as refurbishing MFFF, FPF is an older and smaller facility, and the AoA team assessed that FPF carries greater risk of unexpected delays and cost increases due to changes to hazard, seismic, and security category standards

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

since its construction. The FPF option would also involve hosting a major NNSA mission at a non-NNSA site, and ongoing legal issues between the State of Idaho and DOE further complicate this alternative.

New construction options at INL, SRS, and LANL would likely entail longer schedules and higher costs than the refurbishment options due to the larger scope of work involved.

This assessment is the result of the AoA team's initial alternative screening, followed by an extensive investigation of each viable alternative's relevant attributes, including footprint, security features, and design and construction methods, as well as cost and schedule estimates based on past capital construction projects with similar scope and requirements for safety and security. **Table 9–9** lists the comparative estimates for each viable alternative, including identified risks and opportunities.

Evaluation of other alternatives revealed drawbacks. Specifically, the AoA team found that the initial strategy proposed at CD-0 involving reconfiguration of space in PF-4 augmented by the construction of two modules would not provide sufficient production space to support 80 ppy at high confidence. Based on the AoA team's analysis, this strategy would require up to five additional modules. Attempting to reconfigure PF-4 to accommodate additional missions or capacity also jeopardizes the ability to achieve the 30-ppy program of record.

Based on the available information, the MFFF refurbishment alternative appears to have the most favorable cost and schedule outcomes to provide the required 80-ppy capability. The AoA team acknowledges that the uncertainty inherent in modifying an existing facility to accommodate a new mission necessitates structural analysis and an evaluation of the extent of the required renovation at a more detailed level than provided by the AoA to validate the cost and schedule estimates and uncover any additional risks associated with this strategy. The team recommends conducting an engineering analysis to determine the extent of refurbishment activities to accommodate pit manufacturing.

Additionally, based on the above-mentioned risks for the refurbishment alternatives and the possibility of delays in obtaining the MFFF facility, the team recommends pursuing initial CD-1 activities, such as value engineering and initial conceptual design, for at least one other alternative. The FPF refurbishment alternative has cost and schedule profiles similar to the MFFF refurbishment alternative but higher risk of cost increases and schedule delays, as well as ongoing legal issues with the state government. Of the new build alternatives, there is little cost or schedule distinction between the three most promising sites, SRS, LANL, and INL. Therefore, the choice of building site may reasonably be made based on the decision maker's judgement of risks, benefits, and disadvantages.

Table 9–9. Comparative estimates for each viable alternative

Approach	Refurbishment		New Facility Construction		
Alternative	**SRS MFFF**	**INL FPF**	**INL**	**SRS**	**LANL**
CD-4 Cost Range (FY18$B)	1.4 – 5.4	1.4 – 5.5	1.9 – 7.5	1.8 – 7.3	1.9 – 7.5
CD-4 Schedule Range	FY24 – 31		FY27 – 33		
80 ppy Schedule Range	FY29 – 36		FY33 – 38		
Risks	Potentially contentious state government				
	No experience with pit production				
	Delays in facility availability cause schedule delays				
	Potential structural issues with refurbishment				
	Change in safety basis from NRC to DOE				Workforce availability
		Organizational Interface - Not an NNSA Site (DOE-NE site)			
Opportunities	Ample space for future flexibility				Experienced pit production techs
	Current NNSA production agency			Current NNSA production agency	
	NNSA Site Office			NNSA Site Office	

Key: CD = Critical Decision; DOE-NE = Department of Energy Office of Nuclear Energy; FPF = Fuel Processing Facility; FY = fiscal year; INL = Idaho National Laboratory; LANL = Los Alamos National Laboratory; MFFF = Mixed Oxide Fuel Fabrication Facility; NNSA = National Nuclear Security Administration; NRC = Nuclear Regulatory Commission; ppy = pits per year; SRS = Savannah River Site

PSO review of the AoA analysis resulted in the identification of two preferred alternatives, with a recommendation to conduct engineering analyses on both alternatives in support of conceptual design for CD-1. The refurbishment and repurposing of the Mixed-Oxide Fuel Fabrication Facility (MFFF) at Savannah River Site has the most favorable cost and schedule for achieving a sustained 80 WR ppy production rate, but introduces qualitative risk of re-siting the pit manufacturing capability to an existing facility. The other recommended alternative, new construction of an 80 WR ppy facility at Los Alamos National Laboratory has the lowest qualitative siting risk, but introduces risk associated with new construction of hazard category (HC)-2 facility space that will include regulatory milestones that have historically been difficult to define 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 and is a scope of work better suited outside of the AoA process.

Appendix A. Infrastructure Analysis

A.1 Introduction

The Analysis of Alternatives (AoA) Infrastructure Sub-Team (IST) has completed an assessment of the infrastructure required should the National Nuclear Security Administration (NNSA) decide to construct a facility capable of manufacturing 80 pits per year (ppy) at Los Alamos National Laboratory (LANL), the Savannah River Site (SRS), or Idaho National Laboratory (INL).

Using a combination of written input, telephone discussions, and visits to each of the sites, the IST conducted a review of the infrastructure necessary to support the manufacture of 80 ppy. The IST reviewed the following categories at each location:

Capital infrastructure and functions

- Analytical chemistry (AC)
- Material characterization (MC)
- Perimeter Intrusion, Detection, Assessment, and Delay System (PIDADS)
- Standards and calibration
- Waste treatment and management
  - Low level liquid waste treatment
  - Low level solid waste management
  - Transuranic (TRU) liquid waste treatment
  - TRU solid waste management
- Miscellaneous
  - Classified beryllium (Be) machining
  - Classified graphite machining
  - Classified stainless steel machining
  - Classified uranium machining
  - Graphite coating

Plant core infrastructure

- Security Category 1 facility support
- Normal and off-normal power systems and supply
- Gas, water, and redundant electrical systems
- Medical facilities (capable of dealing with alpha contamination)
- Environmental monitoring (on- and off-site)
- Sanitary wastewater facility

Operating infrastructure

- Production control system
- Manufacturing policies and procedures and training systems

- Material control system
- Safeguards and accountability system
- Qualified operators and technicians
- NNSA Weapon Quality Policy (NAP-24) and certified materials

A.2 Los Alamos National Laboratory

LANL has most of the necessary infrastructure in place to support an 80 ppy capacity. During its inquiry, the IST determined that additional infrastructure resources (footprint and/or equipment) beyond those currently in LANL's plans are required for AC, MC, standards and calibration, graphite fabrication, and security. Additionally, the risks identified with solid TRU waste storage and shipping warrant additional systems analysis to determine whether additional capacity is needed.

Most of these infrastructure additions are relatively low in cost (a few million dollars) in comparison to the anticipated total cost for a project of this scope. However, it is not clear that the cost to expand the PIDADS is appropriately reflected in the current estimated project costs derived from the Cost Estimate and Program Evaluation metrics. LANL asserts that the cost of the PIDADS is included in the per- square-foot cost derived from an evaluation of other relevant facilities, but these costs are not specifically identified and none of these facilities included a completed and functioning PIDADS.

Based on the recent Nuclear Materials Safeguards and Security Upgrades Project at LANL, it is estimated that it will cost over $40,000 per linear foot of PIDADS extension for the modules, assuming they are built within the footprint originally designated for the Chemistry and Metallurgy Research Replacement (CMRR) Nuclear Facility. This extension is likely to require approximately 1,800 linear feet of new PIDADS plus an allowance for tie-ins at each end. This LANL project installed approximately 5,000 linear feet of PIDADS at a cost of $245 million. Using these costs as a baseline indicates that the new PIDADS extension will cost on the order of $100 million, a significant cost that current cost estimates do not appear to cover.

Numerous other infrastructure elements necessary for a capacity to produce 80 ppy were not included in the scope of this evaluation after having been judged as highly unlikely to significantly impact this capital acquisition project. For example, the Kansas City National Security Campus (KCNSC) provides many of the non-nuclear supplies, components, and materials used in pit fabrication but was not included in this evaluation due to its capacity and ability to deal with fluctuating requirements.

This section evaluates three categories at LANL: a) capital items and functions; b) plant core infrastructure, and c) operating infrastructure. The IST compiled the information below from some or all of three sources: a) questionnaires that the IST sent beforehand; b) interviews; and c) facility tours. The members of the IST who attended the interviews and the tours at LANL during the week of September 16, 2017, were:

Name	Organization	Phone
Chris Bader	TechSource	480-650-2099
Vann Bynum	TechSource	505-603-9018
Geoff Kaiser	Leidos	301-340-9015

A.2.1 Capital Items and Functions

This section describes the information gathered on the following capital items and functions: analytical chemistry, material characterization, PIDADS, standards and calibration, waste treatment and management (low level and TRU liquid waste, low level and TRU solid waste), and miscellaneous (classified beryllium machining, classified stainless steel machining, classified graphite machining, classified uranium machining, and graphite coating).

A.2.1.1 Analytical Chemistry

Objective:

The objective of the AC unit review was to determine if sufficient capability and capacity is available to perform testing, analysis, and verification of material parameters required to produce a compliant and quality pit at a production rate of 80 ppy by the year 2030. The AC unit supports the development, qualification, and production phases of pit manufacturing by performing tests and analysis to evaluate compliance with specifications and consistency of the manufacturing processes.

Facility Description:

After completion of the CMRR project the AC unit will have laboratory facilities in the Technical Area 55 (TA-55) Plutonium Facility (PF-4) building and the Radiological Laboratory Utility Office Building (RLUOB). Most their effort will be performed in the RLUOB. The primary activity in PF-4 is preparation of samples to be tested at RLUOB and some other analytical tests. The area currently planned for AC is 17,772 ft^2 divided into 2397 ft^2 at PF-4 and 15,375 ft^2 at RLUOB.

Review Process:

Several meetings about AC were held at various locations. The participants were as follows (though not all attended every session):

Name	Organization	Phone
Chris Bader	TechSource	480-650-2099
Terry Singell	PADWP	505-665-2243
Bob Putnam	PADWP	505-500-2445
Vann Bynum	TechSource	505-603-9018
Carol Brown	NA-LA	505-667-5794
Alice Stemmons	C-AAC	505-667-9591
Ann Schake	C-AAC	505-667-0988
Leisa Davenhall	IPM	505-665-2943
Geoff Kaiser	Leidos	301-340-9015
Drew Kornreich	AET-2	505-667-2095

Discussion:

The AC and Applied Engineering Technology (AET) organizations have analyzed several different sets of requirements and assumptions. The resulting conclusion was that the AC unit will require more Hazards Category III laboratory area and additional equipment to support a capacity of 80 ppy. The fundamental differences between the calculations are based on assumptions of work rules driven by safety and security, and resultant efficiency factors. These assumptions are coupled with technical requirements related to number and types of chemical tests required for each pit build, and the workload from other NNSA programs. These analyses have indicated that additional floor space and equipment may be required.

Preliminary Risk Considerations:

1. The risk is that plans to increase the allowable material-at-risk (MAR) in RLUOB to 400 grams of plutonium-239 (gPu) fail. With the current baseline limit on MAR in RLUOB of 38.6 gPu, it will likely be impossible for the AC group to support a production rate of even 10 ppy. If this risk is realized, the consequences will be catastrophic for the 80 ppy program, so the risk is very high

even if the probability is low or very low. Not increasing RLUOB MAR, or not finding some work-around, is not an option if the 80 ppy program is to proceed at LANL.

2. Even if the allowable MAR in RLUOB is increased to 400 gPu, sample masses required in current analytical chemistry processes (radiochemistry, trace elements, mass spectroscopy, and ceric titration) would create a situation where the limit would be exceeded during steady state production at 80 ppy if programmatic work were to continue (LANL would obviously never exceed this limit. Instead LANL would take other actions, such as curtailing programmatic work, before meeting or exceeding this limit). Technology development efforts are underway to allow reduced sample size in all of radiochemistry/trace element/mass spectroscopy, and ceric titration.
3. Success in these efforts is required to be certain that the AC group can cope with 80 ppy and the Advanced Recovery and Integration Extraction System (ARIES) program needs at both average and maximum workloads. Success in either ceric titration or in the combined radiochemistry/trace element/mass spectroscopy reduced MAR developments is needed to assure sufficient capability for the average 80 ppy and ARIES analytical chemistry needs. The risk is that technology development will fail and that pit production will fall short of 80 ppy. The IST is unable to estimate the level of this risk because the probability of failure of the technology development efforts in radiochemistry/trace element/mass spectroscopy, and ceric titration is currently unknown to them.
4. Even if the allowable MAR in RLUOB is increased to 400 gPu, and sample masses required in current analytical chemistry processes (radiochemistry, trace elements, mass spectroscopy, and ceric titration) are reduced, the AC group will require a considerable increase in space and equipment to cope with the needs of the 80 ppy program. The risk is that this equipment is not made available and production falls short of 80 ppy. The IST has learned that LANL's analyses of the amount of space and equipment required have changed several times and the IST has recommended that LANL resolve their operating assumptions consistent with programmatic guidance. Until this uncertainty is resolved, it is difficult to assign a level to this risk. However, given there is ample time to allow for the purchase and installation of this equipment and to hire and train additional operators, the risk should be low to very low.

A.2.1.2 Material Characterization

Objective:

The objective of the review of the Material Characterization Unit (MCU) was to determine if there is sufficient capability and capacity to perform testing, analysis, and verification of the manufacturing process parameters to produce a compliant and quality pit. The MCU supports the manufacturing organization in the development, qualification, and production phases of the program by performing material testing and analysis that evaluates compliance with specifications and consistency of the manufacturing processes.

In addition to the Development and Qualification phase, during the production campaign W-87 pits will be randomly selected from the production line and tested by the MCU to ensure the qualified processes are stable and yielding consistent and compliant results.

Facility Description:

After completion of the CMRR project the MCU will occupy two laboratory facilities in the TA-55 area and a target fabrication facility in TA-50. The laboratories in TA-55 are currently located in separate buildings, one in PF-4 occupying 5,672 ft^2 of Laboratory area, and the other in the RLUOB occupying 1,875 ft^2

Examples of equipment contained within these laboratories include an electron microprobe, optical microscopes, a micro hardness tester, a tensile tester, a dilatometer, an auger spectroscope, gas analyzers, and other sophisticated equipment. This equipment is used to evaluate material characteristics after performing manufacturing processing such as casting, welding, and joining to ensure manufacturing parameters meet specification requirements.

Review Process:

A meeting was held in the TA55-0400-3101 conference room on September 27, 2016, at 1:00 PM. The purpose of the meeting was to review and discuss answers to previously provided questions and determine if there were any issues and concerns. The following people attended:

Name	Organization	Phone
Chris Bader	TechSource	480-650-2099
Geoff Kaiser	Leidos	301-340-9015
Dave Moore	MST-16	505-665-0645
Jeremy Mitchell	MST-16	505-665-3934
David Pugmire	MST-16	505-664-0028
Franz Freibert	MST-16	505-667-6879
Terry Singell	PADWP	505-665-2243
Bob Putnam	PADWP	505-500-2445
Vann Bynum	TechSource	505-603-9018

Discussion:

The MCU has expressed concern regarding its ability to support the schedule for non-recurring testing and analysis required to develop and qualify the manufacturing parameters for the W-87 production processes. These concerns are based on the extensive effort to develop and qualify pit production processes for the W-88 program, and compounded by the uncertainty associated with working with a different design agency, Lawrence Livermore National Laboratory (LLNL). Discussion of the issues involved identified several primary approaches to reduce the non-recurring workload, as follows:

1. Offload part of the characterization effort to another laboratory, presumably LLNL since the material is primarily plutonium and LLNL has previously insisted on characterizing the samples from their designs. Savannah River might also have this capability.
2. Apply multiple shift(s).
3. Evaluate the development and qualification schedule, perhaps to start earlier than planned.
4. Use all the above strategies simultaneously.

In addition to the noted concern regarding the development and qualification workload, the MCU has identified new equipment and laboratory space requirements to support 80 ppy. The equipment items identified are: a) electron microprobe ($1.4 million), b) micro hardness tester ($50 thousand), and c) three optical microscopes ($180 thousand). It was noted that installation of the electron microprobe will require an additional 200 ft^2 of laboratory space. Installation of the equipment in the laboratory area is expensive and according to the MCU might cost as much as the electron microscope itself.

Preliminary Risk Considerations:

1. There will be a "spike" in needed material characterization during development and qualification of the pit production process. Currently, the MCU does not know how long it will have available to cope with such a spike, nor whether it has the necessary instruments and personnel. The worst case would be that the ability to produce 80 ppy is delayed by an unspecified number of months

or years. This risk could be mitigated by allocating additional space to MCU or by using offsite (*e.g.,* LLNL) capability.

2. The MCU might have insufficient capability to perform the MC work necessary during steady state production of 80 ppy. As a result, LANL will be unable to meet its target of 80 ppy or extensive deviations, which might or might not be acceptable, and will have to be approved by the design agency. This risk is likely to be very low since LANL could identify the additional required space for MC or could use offsite (e.g., LLNL) capability.
3. In the future, there will be a need to produce some pits of a different type(s). This will require further development and qualification of the pit production process that will challenge the MCU's capabilities. It might also cause an unknown number of years delay in the ability to produce the different pit type(s). However, this is so far in the future that there will be ample time for LANL to manage the introduction of the different type of pit. This ought to be a low risk because of the long period available for planning.

A.2.1.3 Perimeter Intrusion, Detection, Assessment, and Delay System

Objective:

The objective of the review was to determine the current planning by the LANL Mission Assurance, Security and Emergency Response (MASER) team for protecting the Security Category 1 modular buildings, or possible alternatives, planned for construction for performing plutonium processing activities. An advance questionnaire was provided to the MASER team requesting information to support a meeting at LANL to review the potential security project and its requirements.

Description:

The PIDADS is a sophisticated perimeter protection system and barrier that currently surrounds the exterior of PF-4 and supporting buildings. The PIDADS provides physical security obstruction and detection systems to prevent adversaries from gaining access to nuclear materials. The PIDADS consists of three layers of protective fencing and numerous instruments and cameras to detect and identify hostile forces. The objective of the PIDADS review was to determine what will be required to provide protection to the new plutonium buildings within the designated area in TA-55.

Review Process:

A meeting was held on September 29, 2016, at LANL Building TA3-1409-105A, to discuss the impact on security systems as a result of building two Security Category 1 Plutonium Modules at TA-55, adjacent to and west of the RLUOB to accommodate a requirement to produce 80 pits per year by 2030. The following people attended:

Name	Organization	Phone
Chris Bader	TechSource	480-650-2099
David M. Telles	SAFE-DO	505-665-5913
Darryl Overbay	ADMASER	505-667-5911
Vann Bynum	TechSource	505-603-9018
Geoff Kaiser	Leidos	301-340-9015
Dennis Basile	PMI	505-660-6757
Bob Putnam	PADWP	505-500-2445
Randy Fraser	ADMASER	505-606-0291
Gart Torres	ADMASER	505-665-8983
Carol Brown	NA-LA	505-667-5794
Terry Singell	PADWP	505-665-2243

Discussion:

The TA-55 security structure underwent an extensive upgrade that was completed in 2014 at a cost of $245 million. Improvements were made to the detection systems, approximately 5,000 linear feet of triple barrier perimeter fencing were installed, upgrades were made to the personnel access facility, and a perimeter road was established to allow Protection Force vehicular access around the outside of the security fence.

To provide for the proposed two new modules, or other Security Category 1 structures, will require an additional 1800 linear feet of triple barrier fencing and security systems, plus an allowance for two new personnel access control points. The access points will be located between the limited area and the protected area (RLUOB to the underground tunnel) and between the protected area and the material access area (underground). In addition to the PIDADS extension several new equipment items will be required, including emergency doors, alarms, cameras, an elevator, and other equipment.

The interior PIDADS perimeter area will provide a 400-foot x 400-foot footprint that will require an offset from the interior protective fence. But this should yield 300 feet x 300 feet (90 thousand ft^2) of buildable space for constructing Security Category 1 and support buildings. This area can accommodate up to four 5,000 ft^2 laboratory area modules with additional support buildings, or other various modular sizes and combinations as may be determined. However, the Critical Decision 0 (CD-0) cost estimate only considered two modules. Building additional modules in that space after the PIDADS is extended will likely be prohibitively expensive.

Estimated Cost:

1. The rough order of magnitude estimated cost in 2016 dollars for providing LANL with the required PIDADS and equipment is as follows:
2. PIDADS: 1800 linear feet, plus approximately 200 feet estimated tie in to pedestrian access points = 2,000 linear feet.
3. The cost of the extra linear feet is as follows: ($245 million – 15 percent design) = $208 million ÷ 5000 feet = $41.6 thousand/foot X 2000 feet = $83.2 million + 5 percent design change + 5percent escalation = $91.8 million.
4. Equipment: Miscellaneous instrumentation, control center, alarms, cameras, elevator, and security doors = $20 million. (LANL maintains that these costs are within their existing cost estimate).
5. Total rough order of magnitude estimated cost $91.8 + 20.0 million = $111.8 million rounded up to $115.0 million.

Required Completion:

The additional PIDADS systems and operational alarms, cameras, and other items will need to be completed, checked out, and operational ready prior to the start of nuclear operations in the plutonium modules or other structures.

Other Relevant Information:

According to the MASER team, if pit manufacturing were moved to a green field site, the cost to establish the same level of security infrastructure and capability that exists at LANL would be at least $1 billion. This would appear to be a significant discriminator against such a site.

Preliminary Risk Considerations:

Two types of risks could have a significant effect on plutonium operations:

1. If the Design Basis Threat changes, this could require potentially large expenditures to reconfigure the physical security infrastructure, with unknown delays to and cost for the pit production program. This would affect other facilities and operations at LANL. Based on experience, there is a high probability that security requirements could change during development and qualification for the pit production process. The costs could vary from small to very large, so the risk level remains indeterminate but could well be high or very high.
2. There is always the possibility that the MASER team will have to shut down the LANL site for an unknown period in response to some future threat. This would lead to delays in pit production of unknown length and cost. Any other site would face the same risk, so this is not a discriminator between sites.

A.2.1.4 Standards and Calibration

Objective:

The objective of the review of the Standards and Calibration Laboratory was to determine if LANL planning has provided for a hot calibration laboratory to check contaminated instruments after the calibration interval has expired. This requirement was established by the NNSA Quality Assurance Program to verify that expired contaminated instruments are still accurate to specification and to ensure that all product tested has been accepted using instruments that are still accurate.

This issue developed during the W-88 pit campaign where the post check after the calibration interval had expired could not be verified due to lack of an area capable of performing calibration of contaminated instruments. The solution at the time required the design agency to accept the product on a Special Exception Request.

Facility Description:

The IST met in the existing Calibration Laboratory and discussed the issue and requirements for a Hot Calibration Laboratory, and also toured the facility.

The laboratory is in the west end of Building TA3-039 which was built in 1953 as a general machine shop. The Calibration Laboratory space was formerly part of the machine shop where beryllium was machined and processed. The facility has been remediated, modified, and upgraded to accommodate the Calibration Laboratory.

Several issues were noted during the review and tour. Most are created by the condition of the facility and the environmental requirements needed to support calibration of precise and sensitive instruments. Items noted include inability to meet vibration isolation, inconsistent stability and control of temperature and humidity, and the lack of clean and stable electrical power. Remediating these issues is complicated by the presence of beryllium contamination within the facility. These issues need to be addressed to ensure LANL's scientific programs and projects are provided with accurate and consistent measurements.

Review Process:

A meeting was held on September 27, 2016, at TA-03, Building 039, conference room 15Q at 10:00 AM. The purpose of the discussion was to review answers to the previously provided questions and determine if issues and concerns remain. The following people attended:

Name	Organization	Phone

Audrey Hakonson Hayes	ASM-SCL	505-667-9364
Robert Baer	ASM-SCL	505-665-4995
Chris Martinez	ASM-SCL	505-667-1292
Kenneth Nadeau	ASM-SCL	505-695-5723
Madeleine Faubert	LAFO	505-666-0113
Maribel Dominguez	AFO	505-665-9788
Geoff Kaiser	Leidos	301-340-9015
Terry Singell	PADWP	505-665-2243
Vann Bynum	TechSource	505-603-9018

Discussion:

The Calibration Laboratory currently occupies 12,100 ft^2 of non-radiological area within TA-3, Building 039. The increase in the work to accommodate the W87 build rate of 80 ppy and to support the requirement for a hot calibration area calls for an estimated 1000 ft^2 of non-radiological space and 500 ft^2 of radiological laboratory space to perform hot calibration checks. New instruments required for the workload increase as well as the Hot Calibration Laboratory expansion are estimated by the calibration team at $4.5 million. An equipment list was provided.

Preliminary Risk Considerations

1. The building that houses the Standards and Calibration Laboratory is contaminated with beryllium. The risk is that methods for controlling beryllium in the atmosphere fail and one or more workers are diagnosed with berylliosis, leading to immediate shutdown of the building and causing delays in projects that rely on the Standards and Calibration Laboratory (*e.g.,* development and qualification of the pit production process).
2. The old heating, ventilating, and air conditioning system makes it difficult to control temperature, thus reducing throughput and causing delays in projects that rely on the Standards and Calibration Laboratory (e.g., development and qualification of the pit production process).

A.2.1.5 Waste Treatment and Management

This subsection reviews treatment and management of low-level liquid waste, low-level solid waste, liquid TRU waste, and solid TRU-waste

A.2.1.5.1 Low-level Liquid Waste

Objective:

The objective of the review of the Low-Level Liquid Waste Facility that supports pit manufacturing at TA-55 was to determine if sufficient capacity exists, or is planned, to accommodate the forecast low-level radiological liquid waste generated by the production of 80 ppy by the year 2030.

Facility Description:

A new Low-Level Liquid Waste Facility is currently under construction at TA-50. The facility will consist of approximately 4,600 ft^2 of process area, 2,300 ft^2 of drum storage, wet laboratory, and control room, and 3,100 ft^2 of utilities and other support systems. In addition, six 50,000-gallon effluent storage tanks are being retained to provide backup in case of a process disruption. Of this 300,000-gallon capacity, 100,000 gallons will be used for routine operations with 200,000 gallons designated for emergency use (e.g., sprinkler activation within a facility or an event like the Cerro Grande fire). The facility is capable of processing 5 million liters per year. The project is nearing completion, expected to finalize construction in 2017 and be operational in 2018. The estimated cost is $82.7 million.

Review Process:

A meeting was held on September 26, 2016, at TA-50, Building 0001, in conference room 107 at 9:30 AM. The purpose of the meeting was to review and discuss answers to the previously provided questions and determine if there are any issues and concerns. The following people attended:

Name	Organization	Phone
Chris Bader	TechSource	480-650-2099
Hugh McGovern	RLW-OPS	505-606-0572
Geoff Kaiser	Leidos	301-340-9015
Bill Schwettmann	ADPSM-IPM	505-667-8211
Simon Balkey	AET-2	505-667-1526
Alvin Aragon	RLW-OPS	505-606-1575
Vann Bynum	TechSource	505-603-9018
Chris Del Signore	RLW-OPS	505-665-5956
Carol Brown	NNSA-LA	505-667-5794
Terry Singell	PADWP	505-665-2243

Discussion:

The current Low-level Liquid Radioactive Waste Facility is being replaced by a new process building that is almost complete, located at TA-50. The target date for construction completion is 2017 and it is planned to be operational in 2018. The new facility has capacity to adequately support on a one shift, four-day basis, a production rate of 80 ppy in 2030. The new facility is designed for a service life of 50 years, whereas the components are expected to perform for 30 years. Six 50,000-gallon low-level effluent storage tanks will be retained (with a capacity of approximately one million liters) with up to 100,000 gallons available as backup storage space if needed. The other 200,000 gallons are reserved for dealing with emergency situations such as a deluge sprinkler activation or a situation like the Cerro Grande fire.

Preliminary Risk Considerations:

1. Almost all the influent to the Low-Level Liquid Radioactive Waste Facility comes from facility equipment or facility support functions. Increasing pit production to 80 ppy would add only 1-2 percent to net influent volume (Ref. 2). Therefore, any potential risks that the facility might pose to a production rate of 80 ppy are low.
2. The IST believes that there is still a residual risk because LANL has not rigorously updated its analysis of the generation of liquid low level radioactive waste (LLW) in the past 5 years and has not estimated the quantities of liquid LLW that might be generated by the two potential modules (or of alternatives that would support an 80 ppy capacity). LANL could exceed the capacity of its liquid LLW treatment system necessitating a curtailment in pit production and other mission activities.
3. LANL presented a conservative upper bound of 4.7M liters per year of needed radioactive liquid waste-low level processing capability including a production rate of 80 ppy. The planned capacity of the new radioactive liquid waste-low level processing plant is 5 million liters per year. However, the IST believes that there are some liquid LLW flows that may not have been fully accounted for and that, in some unlikely circumstances, the capacity of the liquid LLW processing facility could be exceeded. This risk should, however, be low or very low.

A.2.1.5.2 Low-Level Solid Waste

Objective:

The objective of the review of the solid Low-Level Waste Facility supporting pit manufacturing at TA-55 was to determine if sufficient capacity exists to accommodate the management and disposition of solid LLW generated by the production of 80 ppy by the year 2030.

Facility Description:

The solid LLW storage and shipping area is located at TA-54, a few miles southeast of TA-55. The site receives low-level radiological waste from waste generators that is verified by Waste Management personnel who observe the packaging process. The Waste Operations organization then performs a non-destructive assay test to confirm the waste meets the low-level radiological requirements and performs other testing to ensure the waste does not contain improper contents. After inspection, the waste shipment is loaded and transported to either the DOE waste facility at the Nevada National Security Site (NNSS) or to other approved and authorized commercial sites for disposition and burial.

Review Process:

A meeting was held on September 26, 2016, at TA-63, Building 144, conference room 1008, at 2:00 PM. The purpose of the meeting was to discuss the Waste Operations capability and capacity to process LLW generated as a result of processing 80 ppy by 2030. The following people attended.

Name	Organization	Phone
Chris Bader	TechSource	480-650-2099
Denise Gelston	TWF Ops.	505-665-1552
Geoff Kaiser	Leidos	301-340-9015
Carol Brown	NA-LA	505-667-5794
Terry Singell	PADWP	505-665-2243
Simon Balkey	AET-2	505-667-1526
Andrew Montoya	WM –DO	505-665-1654
Vann Bynum	TechSource	505-603-9018

Discussion:

The Waste Operation Division is responsible for processing the LLW at LANL and packages and ships compliant waste to NNSS or other authorized and approved commercial companies licensed to process and store low-level radiological waste.

The Waste Operation Division has demonstrated the capacity to process and ship over 700 cubic meters of solid LLW in one month using a one shift operation. Experience has demonstrated that the volume of LLW generated from TA-55 is not particularly tied to pit production rate; but, rather the frequency of performing maintenance operations (*e.g.,* routine glove and filter replacements). The average volume of low-level solid waste generated by TA-55 is approximately 330 cubic meters per month. As previously stated Waste Operations has demonstrated a 700 cubic meter processing capability and is confident they can easily accommodate the 80 ppy requirement.

The Waste Operation Division also stated that a 15 thousand to 20 thousand ft^2 tented temporary structure could be made quickly available to provide several months of solid waste storage and added confidence in the event of shutdown of shipments due to some unforeseen upset.

In addition, the Waste Operation Division stated that no additional equipment is required other than to replace used and worn out items as they age.

Preliminary Risk Considerations:

LANL could lose its certification with NNSS and thus its ability to send drums there. The site would run out of solid LLW storage space and pit production would shut down. This is a plausible scenario because recently LANL lost its certification with NNSS for 13 months. However, it appears that this risk is easily mitigated because alternative commercial solid LLW disposal sites are available. Therefore, this risk is low.

A.2.1.5.3 Liquid Transuranic Waste

Objective:

The objective of the review of the TRU Waste Facility that supports Pit Manufacturing at TA-55 was to determine if sufficient capacity exists or is planned to accommodate the planned TRU radiological waste generated by the production of 80 ppy by the year 2030.

Facility Description:

The new TRU Liquid Waste Facility is located at TA-50. The facility consists of approximately 2,290 ft^2 of process area and 680 ft^2 of support. The facility is capable of processing 30 thousand liters per year of acid and caustic TRU waste by operating for one week each month. Operating one week per month optimizes staff use through sharing of resources with the Low-level Liquid processing plant. The effluent generation output to support 80 ppy in 2030 is forecast at 30,000 liters per year. If the waste quantities were to exceed 30,000 liters per year, then processing can be extended by running for longer periods. The project is in design and should start construction in 2018, with a completion target of 2022. The estimated cost is $80 – 90 million. The final estimated cost will be established when design is completed.

Review Process:

A meeting was held on September26, 2016, at TA-50, Building 0001, at 9:30 AM in conference room 107. The purpose of the meeting was to review and discuss answers to the previously provided questions and determine if there are any issues and concerns. The following people attended:

Name	Organization.	Phone
Chris Bader	TechSource	480-650-2099
Hugh McGovern	RLW	505-606-0572
Geoff Kaiser	Leidos	301-340-9015
Bill Schwettmann	ADPSM-IPM	505-667-8211
Simon Balkey	AET-2	505-667-1526
Alvin Aragon	RLW	505-606-1575
Vann Bynum	TechSource	505-603-9018
Chris Del Signore	RLW-OPS	505-665-5956
Carol Brown	NA-LA	505-667-5794
Terry Singell	PADWP	505-665-2243

Discussion:

The current TRU Radioactive Waste Facility is being replaced by a new facility that is nearing design completion. The target date for completion of the new facility is 2021 and it is planned to be operational in 2022. The facility has adequate capacity to support, on a one-shift, one-week-per-month basis, 30,000 liters per year, and it will support the pit production rate of 80 ppy by 2030. The new facility is designed for an equipment service life of 30 years and a facility life of 50 years.

Preliminary Risk Considerations:

It is possible to envision scenarios in which a shift in incoming feed type occurs that causes liquid TRU waste flows in excess of 29,000 liters per year from nitrate operations (the RFX, ATLAS, and plutonium-238 lines), chloride operations (EXCEL and CLEAR), and/or other sources such as chill water pumps and CMRR. However, the 29,000 liters per year is expected to be achieved with a one-shift operation for one week per month. This means that with appropriate adjustments to staffing incoming liquid TRU waste could be treated at a rate of up to 116,000 liters per year. Therefore, any risk arising from spikes in influent liquid TRU waste could easily be accommodated, so the associated risk is very low.

A.2.1.5.4 Solid Transuranic Waste

Objective:

The objective of the review of the Solid TRU Waste Facility that supports Pit Manufacturing at TA-55 was to determine if sufficient capacity exists to accommodate the management and disposition of TRU waste generated as a result of the production of 80 ppy by the year 2030.

Facility Description:

The TRU Solid Waste Facility is located at TA-63 adjacent to Pajarito Road and east of TA-55. The facility has completed construction and the assigned personnel are currently preparing for a series of operational reviews to determine readiness to start operations. The facility consists of an administrative building, five waste storage buildings, and one combined characterization and storage building. There are also two pads to accommodate trailers to perform Real Time Radiography and High Efficiency Neutron Counter characterization. A large thick sand barrier shields the facility from vehicular incursions. The facility has its own equipment storage building and a dedicated water storage tank for fire protection. The maximum storage capacity at the facility is 1,240 55-gallon drum equivalents.

Review Process:

A meeting was held on September 26, 2016, at the TA-63, Building 144, at 2:00 PM in conference room 1008. The purpose of the meeting was to review and discuss answers to the previously provided questions and determine if there are any issues and concerns. The following people attended:

Name	Organization	Phone
Chris Bader	TechSource	480-650-2099
Denise Gelston	TWF Ops.	505-665-1552
Geoff Kaiser	Leidos	301-340-9015
Carol Brown	NA-LA	505-667-5794
Terry Singell	PADWP	505-665-2243
Simon Balkey	AET-2	505-667-1526
Vann Bynum	TechSource	505-603-9018

Discussion:

The construction of a new TRU waste storage facility at TA-63 recently has been completed at a cost of $106 million. This new facility has a maximum drum storage capacity of 1,240 55-gallon drum equivalents when stacked three high, although the typical operational mode is to stack only two high. It was noted that TA-55 also has storage space for an additional 1,200 55-gallon drum equivalents for a total of 2,440 units. The TRU waste management team estimates that when TA-55 is producing at 80 ppy, generation will range between 1100 – 1500 55-gallon drum equivalents per year. At that generation rate, there is approximately 1.6 to 2.2 years of available storage.

The LANL TRU waste storage team noted that the Waste Isolation Pilot Plant (WIPP) has not been operational for over 2 years due to an incident,[1] and is concerned that more storage area may be necessary to ensure no disruptions to the pit program in the event of future shutdowns at WIPP. A member of the LANL team noted that WIPP has not demonstrated consistency in operational up time and would like to see a duplicate of LANL's new facility built at LANL to provide additional contingencies.

WIPP has a rigorous set of acceptance criteria. LANL has extremely limited capability and capacity to remediate non-WIPP compliant drums, which could further complicate the drum management situation. However, it was reported by LANL that the Pit Manufacturing Program has few problems being WIPP compliant and thus there is little increased risk from going to an 80 ppy capacity. However, other TRU generating programs (e.g., the plutonium-238 programs) do present a risk to the LANL capacity to deal with TRU solid waste, especially with respect to non-compliant drums.

Preliminary Risk Considerations:

1. WIPP experiences an event that causes it to be shut down for a sufficiently long time that TRU waste storage at LANL becomes full. Pit production shuts down for a period of months to years. At the time of writing, WIPP has just reopened after having been closed for 3 years. The event described in the risk description is highly plausible over the projected several-decade lifetime of pit production at LANL. Existing TRU waste storage capacity at LANL would be enough for 1.5 – 2 years at a production rate of 80 ppy. This risk is discussed in more detail in Appendix E. The AoA team concluded that the risk can be managed by constructing extra TRU storage capacity at marginal cost relative to the annual cost of operating the plutonium manufacturing facility, with a corresponding low risk.
2. WIPP experiences another event that causes it to be shut down. After it comes back on line, additional safety and regulatory constraints mean that it accepts and processes shipments at a much slower rate than before the event. This processing rate may be insufficient to accept TRU waste generated by 80 ppy so that after some years TRU waste storage at LANL becomes full and pit production ceases. This scenario is also realistic because, once WIPP comes back on line after its current shutdown it will be accepting and processing shipments for final disposal at a lower rate than before: similar or perhaps even more onerous restrictions are likely in the event of a future shutdown. In Appendix E the AoA team assess this risk as medium.
3. WIPP becomes full and is no longer able to accept solid TRU waste. Solid TRU capacity at LANL also becomes full and pit production shuts down. Additional TRU waste disposal capacity at WIPP or elsewhere is required to support the 80 ppy capacity. In Appendix E, the AoA team assesses this risk as low because it can be managed by construction of on-site TRU waste as needed, and it is virtually certain that, if WIPP were to become full, additional storage capacity would be built there.

A.2.1.6 Miscellaneous

This section contains information on several activities that are needed to support pit production, but which would not be expensive to implement (relative to the total cost of a pit production facility) should they not already be available at LANL. Alternatively, most of them could be readily outsourced.

[1] That observation was made at the time of the IST's visit to LANL in September 2016. The WIPP facility recently re-opened after a shut-down of over three years.

A.2.1.6.1 Classified Beryllium Machining

Objective:

The objective of the review of the Beryllium (Be) facility supporting Pit Manufacturing at TA-55 was to determine if sufficient capacity exist to provide Be components to support a pit manufacturing production rate of 80 ppy by the year 2030.

Facility Description:

The Be operation is performed at TA-3, Building 141. The entire facility is approximately 15,000 ft^2, including 3,300 ft^2 for administration, 9,800 ft^2 for production, and 1,960 ft^2 for support. The facility performs Be work for several programs throughout LANL. The facility is equipped with several conventional and computer numerical control (CNC) lathes, several conventional and CNC mills, one wire and one plunge electrical discharge machine, a coordinate measuring machine, and other equipment to support multiple projects. The production area has an essential Be dust collection safety system as well as a temperature and humidity controlled area to perform dimensional measurements. The building currently is not full and has several thousand ft^2 of unoccupied production area.

Review process:

A meeting was held on October 17, 2016, at TA-3, Building 1400, in the Director's conference room. The purpose of the meeting was to discuss and review the information provided to the IST in the provided questionnaire. The following people attended:

Name	Organization	Phone
Chris Bader	TechSource	480-650-2099
Terry Singell	PADWP	505-665-2243
Erwin Vest	PF-WFS	505-667-4904
Paul Holland	NA-LA	505-667-3168
Vann Bynum	TechSource	505-603-9018
Randy Flores	PF-WFS	505-665-3612

Discussion:

LANL stated that they can support 20 ppy as well as other NNSA programs with the current area and equipment. To achieve a production rate of 80 ppy would require an additional 1,500 ft^2 of production area and an expansion of 1,000 ft^2 of temperature and humidity controlled inspection area. Both requirements can fit into the existing facility, but would necessitate some re-arrangement and build out. The safety dust collection system would have to be expanded to support the added production area.

The LANL team also identified some additional equipment amounting to two additional CNC lathes and a new coordinate measuring machine to support inspection.

Preliminary risk Considerations:

No risks were identified other than very low.

A.2.1.6.2 Classified Stainless Steel Machining

LANL has the capability in its general machining facility within TA-39 to produce all stainless steel components but would need some additional conventional equipment. The need for classified stainless steel parts could also be met by outsourcing to a qualified supplier with an approved secure facility, or to KCNSC. Risks associated with this capability are assessed to be very low.

A.2.1.6.3 Classified Graphite Machining

Objective:

The objective of the review of the Graphite Machining facility supporting pit manufacturing at TA-55 was to determine if sufficient capacity exists to perform graphite machining operations that will support a pit manufacturing production rate of 80 ppy by the year 2030. This review considered allowances for mortality needs throughout the pit manufacturing process.

Facility Description:

The graphite machining operation is performed at TA-3, SM-66. The entire facility is approximately 200,000 ft^2, including 20,000 ft^2 for administration, 125,000 ft^2 for production, and 55,000 ft^2 for support and other. The area currently dedicated to graphite fabrication in support of pit manufacturing includes 2,500 ft^2 for administration, 2,000 ft^2 for production, and 2,500 ft^2 for support. The production area has a specialized ventilation process to capture the considerable amount of graphite dust particles that is released during the machining process. The building is approximately 56 years old, well maintained, and estimated by the current management to have approximately 40 more years of useful life with ongoing maintenance.

Review Process:

A meeting was held on October 19, 2016, at TA-3, SM-66, at the Division Leader's office. The purpose of the meeting was to discuss and review the information provided to the IST in the provided questionnaire. The IST had toured the graphite production area on September 28, 2016, and had a very good understanding of the processes required to support pit manufacturing. The following people attended:

Name	Organization	Phone
Chris Bader	TechSource	480-650-2099
Paul Dunn	MST	505-665-3180
Terry Singell	PADWP	505-665-2243
Paul Holland	NA-LA	505-667-3168
Vann Bynum	TechSource	505-603-9018
Geoff Kaiser*	Leidos	301-340-9015
Carol Brown*	NA-LA	505-667-5794

* Tour only

Discussion:

To accommodate a production rate of 80 ppy on a one-shift basis, the current production area will have to be enlarged from 2,000 ft^2 to 8,000 ft^2 including additional equipment and extended ventilation. The current administrative and support functions do not require additional area. The current production area contains eight lathes, five mills, and several electrical discharge machines. To accommodate 80 ppy will require the following new equipment items, 1) three coordinate measuring machines, 2) six lathes, and 3) two mills. Sufficient area is available within the facility to accommodate this mission.

Preliminary Risk Considerations:

No risks were identified other than those that are very low. Additional equipment and space will be needed to support 80 ppy, but this would seem to be easily achievable.

A.2.1.6.4 Classified Uranium Machining

While LANL has machined uranium in the past for the purposes of this AoA it is assumed that Y-12 will support with classified uranium machine parts.

A.2.1.6.5 Graphite Coating

Objective:

The objective of the review of the coating facility supporting pit manufacturing at TA-55 was to determine if sufficient capacity exists to perform coating operations that will support a pit manufacturing production rate of 80 ppy by the year 2030.

Facility Description:

The coating operation is performed at TA-3, SM-66. The entire facility is approximately 200,000 ft^2 and includes 20,000 ft^2 for administration, 125,000 ft^2 for production, and 55,000 ft^2 for support and other. The area currently dedicated to graphite coating for pit manufacturing includes 2,000 ft^2 for administration, 8,000 ft^2 for production, and 2,500 ft^2 for support. The production area does not require any special environmental or temperature controls. The building is approximately 56 years old, well maintained, and estimated by the current management to have approximately 40 more years of useful life with regular maintenance.

Review Process:

A meeting was held on October 19, 2016, at TA-3, SM-66, at the Division Leader's office. The purpose of the meeting was to discuss and review the information provided to the IST in the provided questionnaire. The following people attended:

Name	Organization	Phone
Chris Bader	TechSource	480-650-2099
Paul Dunn	MST	505-665-3180
Terry Singell	PADWP	505-665-2243
Paul Holland	NA-LA	505-667-3168
Vann Bynum	TechSource	505-603-9018

Discussion:

The current allocated space and equipment will be sufficient to accommodate a production rate of 80 ppy on a one-shift basis by the year 2030.

Preliminary Risk Considerations:

No risks were identified other than those that are very low.

A.2.2 Plant Core Infrastructure

Plant core and operating infrastructure elements were not part of the initial LANL review However, they have been added to improve the understanding of and to characterize other important elements of the site. Most of the information obtained for concerning plant core infrastructure (Section A.2.2) and Operating Infrastructure (Section A.2.3) resulted from initial discussions in September 2016, as well as LANL's experience obtained while supporting W88 development, qualification, and product deliveries within the past several years. Utility data were obtained and verified by LANL with the assistance of Mr. Bob Putnam.

A.2.2.1 Security Category I Facility Support

LANL has a Security Category I Facility in accordance with DOE Order 473.3, Protection Program Operations. This information was transmitted to the IST during the discussion on PIDADS on September 29, 2016. It was noted at that time that the investments in security systems at LANL have been substantial, and replacement value was estimated to be over $1.0 billion. The DOE Order is comprehensive, requiring protection of DOE assets including nuclear material and special nuclear material (SNM), buildings, Government Property, classified material, and personnel.

A.2.2.2 Normal/off normal Electrical Power

LANL operates within the Los Alamos Service Area. Power is imported to this service area by two transmission lines fed from separate substations in the Public Service Company of New Mexico system. The interconnection agreement requires a fully redundant transmission path, so the capacity is limited to the lesser of these two lines. The current import limit is 116 mega volt ampere (MVA) (peak summer day), with rapid deployment of existing on-site generation this capacity could be elevated to 131 MVA. Forecasts for LANL load growth include the projected demand to support pit production at TA-55 beginning in FY 2020 and described in the LANL Power Master Plan. The transmission-system import limit is expected to increase to 200 MVA by re-conducting both lines or installing a third transmission line in the 2022-2024 period when LANL's combined mission growth would increase demand above the current limit.

Supporting the pit production mission is not expected to require major distribution improvements.

A.2.2.3 Other Utilities

Water supply – LANL's water is supplied by the Los Alamos County groundwater collection system. Pit production water demand is included in the 2017 revision of the county's long-range water supply plan. Total available water rights for Los Alamos County/LANL is 6,741.3-acre feet per year, and maximum projected demand in the 50-year planning horizon is slightly more than 4,000-acre feet per year. Therefore, adequate water supply is available to support pit production at LANL.

Gas – Pit production facilities are expected to be heated with natural gas. TA-55 is served by a 3-inch diameter gas main operating at 88 pounds per square inch gauge. Recent modeling indicates that gas delivery capacity greatly exceeds projected current and future demand.

A.2.2.4 Medical Facility

Los Alamos Medical Center is a state-of-the art nine-bed emergency room, which opened in January 2006, and is staffed 24 hours a day by board-certified physicians from Emergency Medical Services. For the most serious emergencies, the hospital has immediate access to an air ambulance service.

In cooperation with LANL, Los Alamos Medical Center also maintains an ultra-modern decontamination facility, fully equipped to handle medical trauma patients.

A.2.2.5 Environmental Monitoring

LANL has an extensive environmental management program consisting of several elements. While working closely with LANL organizations and the State of New Mexico the LANL Environmental Organization performs:

- Monitoring of air and water discharges to ensure quality standards are met
- Clean up and remediation of legacy waste sites
- Processing and shipping of hazardous and radioactive waste to approved permanent disposal facilities
- Development of waste minimization and early detection programs with functional organizations

A.2.2.6 Sanitary Waste Facility

LANL's secondary wastewater treatment plant has a design capacity of 0.6 million gallons a day and the average daily flow is well below 0.2 million gallons a day, so adequate capacity is available to serve pit production growth. The extension of sewer service to new facilities supporting pit production may be required to connect to the existing collection system.

A.2.3 Operating Infrastructure

This section includes discussion of production control, manufacturing policy, the material control system, safeguards and accountability, qualified operators and technicians, and the weapons quality program.

A.2.3.1 Production Control

LANL developed a production control system during the early process development phase of the W88 pit manufacturing project. The system evolved from manually ordering materials and processing work orders to a sophisticated Oracle-based system capable of processing multiple programs and projects simultaneously.

A.2.3.2 Manufacturing Policy

The Pit Manufacturing organization developed a manufacturing policy manual during the process qualification program for the W88 project. The document was based on the Weapons Quality Policy QC-1, and policies established by the DOE Albuquerque Production Management Office. The LANL policy manual identifies requirements to be applied to War Reserve (WR) products and established a consistency within the Nuclear Weapons Enterprise. Based on the policy document specific procedures were developed that provided the processes to be followed by LANL organizations. These procedures are periodically updated and maintained by the Pit Manufacturing and Weapons Quality Assurance organizations to reflect changes to requirements and improvements to processes. The DOE quality assurance requirements have recently been rewritten and retitled NNSA Weapon Quality Policy (NAP-24).

A.2.3.3 Material Control System

The Material Control System is documented within the Manufacturing Policy Manual. The processes for ordering, procuring, receiving, inspecting, stocking, issuing, and tracking are identified and documented by instructional procedures.

A.2.3.4 Safeguards and Accountability

The Safeguards and Accountability system at LANL assures that special nuclear materials are accounted for at all times. These processes and instrumentation are very sophisticated and provide for the dynamics and material movement incurred during the manufacturing process. The system is managed by LANL's Threat Identification and Response Organization and provides processes and technologies to improve measurement and reduce threats.

A.2.3.5 Qualified Operators and Technicians

The Pit Manufacturing organization has an extensive training program including the qualification of operators and technicians. The training requirements are established between the first level manager and employee and cover all aspects of their assignment from security, safety, manufacturing protocols, to the unique qualifications to perform a specific manufacturing process. The requirements are reflected in the Manufacturing Policy Manual and into the specific training procedure specifying initial and refresher requirements.

A.2.3.6 Weapons Quality Program

The DOE quality requirements are specified in the DOE policy NAP-24. It requires a Quality Assurance Plan (QAP) approved by LANL and the DOE Field Office. The QAP provides a methodology for implementation of the requirements identified in NAP-24. For the weapon programs at LANL this involves specific procedures identifying the processes and responsibilities for implementation of the requirements. These procedures have been in place for several years and are updated if requirements or processes change.

A.3 Savannah River Site

The IST concluded that SRS has most of the necessary infrastructure in place to support the manufacture of 80 ppy, including strong capabilities in solid and liquid waste treatment, standards and calibration, plant core elements such as facilities to support a category I security facility, adequate electrical power, medical support, and systems such as safeguards of nuclear materials, and production and quality assurance processes to support a production mission.

While SRS can produce complex machined parts, their capability and capacity is limited and consists of a small-scale shop supporting research and development activities for the Site. While SRS could support pit production on a limited basis it is noted all the machined items can either be obtained from other DOE sites or procured from classified commercial suppliers.

The IST determined that the Savannah River National Laboratory (SRNL) has highly qualified technical staff and excellent equipment capabilities currently performing AC and MC. A primary issue is that none of the laboratory buildings in which SRNL performs AC and MC are authorized to handle more than 200 grams of plutonium at one time. It is noted that this MAR limitation also affects the capability of LANL and INL and further underscores the need for either a review and increase of this limiting requirement, or support for the production requirement by providing additional Hazard Category II space to efficiently support required laboratory work.

During the IST review, it was discovered that LLNL is planning to perform some portion of the AC and MC for the 80 ppy baseline system. This assistance will be particularly needed during the process development and certification phase of the project. To determine the potential quantitative capability and ability to support pit manufacturing DOE should consider a review of LLNL for both MC and AC.

As was the case for the LANL review, some infrastructure elements are necessary to establish capacity to produce 80 ppy that were not included in the scope of this evaluation after they were judged highly unlikely to significantly impact any of the potential alternatives. For example, KCNSC provides many of the non-nuclear supplies and process materials used in pit fabrication but was not included in this evaluation due to its capacity and ability to deal with fluctuating requirements. However, it was determined that to support the current plans for 80 ppy KCNSC might require procurement and installation of additional conventional equipment.

This section is divided into three subsections: a) capital items and functions; b) plant core infrastructure, and c) operating infrastructure. The information compiled below was assembled from some or all of three sources: a) questionnaires that the IST sent to SRS beforehand; b) on-site interviews; and c) facility tours. The members of the IST who were present at SRS during the week of April 24 and who attended the interviews and the tours were:

Name	Organization	Phone
Chris Bader	TechSource Inc.	480-650-2099
Phillip Forsberg	NA-14	202-480-4735

Geoff Kaiser	Leidos	301-340-9015

Two SRS individuals were particularly helpful in setting up interviews and tours, and providing information:

Name	Organization	Phone
Jeff Allender	SRNL/NA-23 and EM	803-208-1291
Brian Pool	SRNS	803-208-0396

A.3.1 Capital Items and Functions

This section describes the information gathered on the following capital items and functions: analytical chemistry, material characterization, PIDADS, standards and calibration, waste treatment and management (low level and TRU liquid waste, low level and TRU solid waste), and classified machining of beryllium, stainless steel, graphite, uranium, and graphite coating.

A.3.1.1 Analytical Chemistry

Objective:

The objective of the review of AC at SRS was to determine if SRS has sufficient capability and capacity to perform testing, analysis, and verification of material parameters required to produce a compliant and quality pit at a production rate of 80 ppy. AC supports the development, qualification, and production phases of pit manufacturing by performing tests and analysis to evaluate compliance with specifications and consistency of the manufacturing processes.

Facility description:

SRS has an AC laboratory housed in wings B, C, and D of Building 773-A on the SRNL campus. Portions of the building are of different ages dating from the 1960s to the 1990s. SRNL estimates that these wings contain 15,300 ft^2, divided into 9,300 ft^2 for radiological analysis, 2,700 ft^2 for non-radiological analysis, and 3,300 ft^2 for administration. SRNL provided the following description of their equipment:

1. *Conventional/ off-the-shelf equipment and techniques for radioactive samples*: a variety of radiochemistry instrumentation and preparation capabilities such as: alpha, beta, and gamma spectrometers and liquid scintillation counters; inductively coupled plasma emission spectrometry (ICP-ES) and inductively coupled plasma mass spectrometry (ICP-MS); high-performance liquid chromatography; gas chromatography–mass spectrometry; atomic absorption; ion chromatography; a carbon analyzer; a titrator; a scanning electron microscope ; x-ray diffraction and x-ray fluorescence; and a particle size analyzer. All of them are single quantity, except for the radiochemistry instrumentation.

2. *Conventional/off-the-shelf instrumentation and techniques for non-radioactive samples*: ICP-ES and ICP-MS; Fourier transform infrared spectroscopy (FT-IR); high-performance liquid chromatography; gas chromatography–mass spectrometry; a nitrogen analyzer; atomic absorption; a carbon analyzer; a titrator; scanning electron microscope; and x-ray fluorescence (all are single quantity).

3. *Customized items of equipment*: a high-flux thermal neutron generator and a californium-252 source for neutron activation analysis.

The chemistry laboratory management estimated that the facility is currently used at about 25-35 percent of maximum capacity.

In addition, SRNL provides 24/7 analytical chemistry support for SRS processing facilities (e.g., H-Canyon, HB-Line, and the tank farms); plutonium oxide characterization (for HB-Line and LANL); nuclear materials storage for International Atomic Energy Agency and other off-site customers; and nuclear reference materials. This support is provided in what is known as F/H Laboratory in Buildings 772-F and 771-F (in F-Area). 772-F is a two-story steel reinforced concrete structure with 40,000 ft^2 on the first floor and 40,000 ft^2 on the second floor for support services. About 7,000 ft^2 is dedicated to office services. 771-F is a single story commercial steel building of approximately 32,000 ft^2 with 1,000 ft^2 dedicated to office space. SRNL provided the following description of the equipment in F/H Laboratory, which is primarily radiological:

1. *Conventional/off-the-shelf equipment and techniques*: alpha and beta spectroscopy; laboratory control samples; thermal ionization; mass spectrography; ICP-MS (2) and ICP-ES (2); uranium using kinetic phosphorescence analyzers and Davies-Gray titration; ion chromatography (2); interfacial tension; cerium fluoride titration; gas chromatography with flame ionization detector; and other wet chemistry.
2. *Customized items of equipment*: controlled potential coulometry (2).
3. *Other*: four shielded cells for sample aliquotting and basic wet chemistry; and separations chemistry capability (uranium, plutonium, and Neptunium ion exchange).

Review Process:

The review was carried out as follows:

1. The IST provided an infrastructure questionnaire that was filled out by Mark. J. Barnes of SRNL for the Area A laboratories and by Curtis W. Gardner of SRNL for F/H Laboratory.
2. The entire visiting AoA team went on an SRNL tour on the afternoon of Wednesday April 26, 2017.
3. SRS provided the following relevant documents and presentations for the IST to review:
    a. 002 SRS Systems Engineering Functional Analysis, pp. 123-128: SRNL Program Infrastructure Matrix and Support Buildings 002 SRNL Info Pod
    b. LANL-MPF-G-ESR-X-00015, *Analytical Chemistry and Material Characterization Needs in the Modern Pit Facility*
    c. Alice Murray, *Overview and Actinide Science and Radiochemistry Overview*, 4/26/17
    d. Ken Cheeks, *F/H Laboratory Overview*, 4/26/17
    e. Robert Sindelar, *Material Science Capabilities*, 4/26/17

In addition to Jeff Allender and Brian Pool, SRS and SRNL people who provided most of the information summarized in this portion of the IST's report were:

	Name	Organization	Phone
1.	Mark Barnes	SRNL	803-725-2104
2.	Ken Cheeks	SRNL	803-952-3632
3.	Curt Gardner	SRNL	803-952-4636
4.	Alice Murray	SRNL	803-725-0440
5.	Robert Sindelar	SRNL	803-725-5298

Discussion:

SRNL has a large and highly accredited AC capability with potential for considerable expansion. Areas of strength, which will be invaluable in the event that NNSA establishes an 80 ppy manufacturing facility at SRS, include:

- experience in lab design and set-up
- establishing analytical chemistry programs
- obtaining and maintaining accreditation
- staffing

SRNL has established relationships with various universities and is developing a stream of qualified analysts who will be available to replace retirees and if necessary, to increase staffing levels.

There appears to be ample space for considerable expansion of effort if needed in the existing laboratories. The principal question is how much Hazard Category 2 space will be required. This will depend on the nature of the mission (e.g., whether the proposed facility is for 50 ppy or 80 ppy, or whether SRNL will also have to support the originally intended mixed oxide [MOX] mission to dispose of 34 metric tons of weapons grade plutonium that is surplus to requirements). In any event, the SRNL A-Area laboratory is currently limited to a total of 200 grams of plutonium at one time to remain within MAR limits.

During the IST's visit to LANL (see above), it was clear that, even with a proposed allowable MAR of 400 grams of plutonium in RLUOB, there might be insufficient space in RLUOB and PF-4 for adequate AC support for the proposed 80 ppy manufacturing mission and the other plutonium programs at LANL. As noted above, whether this will be a problem at SRS will depend on the ultimate plutonium programs that are established there. Various upgrades to both the A-Area laboratories and F/H Laboratory would be necessary to support pit production. In addition, F/H Laboratory is in a property protection area and security upgrades would be required. These upgrades, primarily to acquire additional Hazard Category II space, would likely be expensive.

SRNL personnel recommended that, if it is known that a plutonium manufacturing facility will be established at SRS (whether for 50, 80, or some other expected ppy), it would be best to minimize transportation and improve manufacturing process flow time by co-locating the needed actinide chemistry capabilities with or adjacent to that facility. This concept was also recommended in the Modern Pit Facility study performed in early 2000's. Thus, it may be beneficial to set aside up to 20,000 ft^2 of AC space in the proposed pit manufacturing complex.

It should also be noted that if either the Mixed Oxide Fuel Fabrication Facility (MFFF) or K-reactor facilities are utilized for pit manufacturing there would be sufficient Hazard Category 1 space available to accommodate an AC Laboratory need of approximately 20,000 ft^2.

With respect to whether additional AC equipment may be needed, this also will evolve as SRS better understands the full scope of plutonium missions that it may be requested to undertake. SRNL currently believes that existing equipment is likely adequate, but the need will evolve with assigned missions.

Preliminary Risk Considerations:

The principal risk is that if an 80 ppy manufacturing facility is established at SRS, MAR limits in the buildings housing AC equipment will be insufficient to allow SRNL to process samples at the required rate. If this were to continue indefinitely, it would become impossible to deliver 80 WR ppy to Pantex. To mitigate or remove this risk, careful planning will be necessary to ensure that the necessary amount of Hazard

Category II space is made available for AC equipment. The lead time is such that this should be possible, and the risk is assessed to be low.

The IST learned at LANL that research efforts are underway to increase the sensitivity of analytical techniques so that much smaller sample sizes are required. This would increase the number of sampling analyses that are possible at any one time while remaining within a MAR limit such as 200 grams of plutonium. This is another avenue that SRNL could explore should there be a need to further mitigate the risk already described.

Another way to further mitigate this risk would be to reduce the number of samples required per pit. Based on experience at LANL, 18-20 five-gram plutonium metal samples were analyzed for every WR pit that was produced. However, this might be reduced to 6-6.5 five-gram samples per delivered pit if the initial metal could be delivered within certain well-defined specifications. This would make a total of about 500 samples per year for an 80 ppy program. With careful scheduling and improving the quality of incoming plutonium, this strategy could potentially be managed in a building with a 200-gram MAR ceiling.

In addition to the above, the AC risk could potentially be further mitigated by calling on the AC resources at LLNL or LANL.

Considering the several potential ways of mitigating this risk, the IST's preliminary determination is that risk is low.

A.3.1.2 Material Characterization

Objective:

The objective of the review of MC was to determine if SRS has sufficient capacity and capability to perform testing, analysis, and verification of the manufacturing process parameters to produce a compliant and quality pit at a production rate of 80 ppy by the year 2030. MC supports the manufacturing organization in the development, qualification, and production phases of the program by performing material testing and analysis to evaluate the compliance with specifications and consistency of the manufacturing processes.

In addition to the development and qualification phase, during the production campaign W-87 pits will be randomly selected from the production line and tested to ensure the qualified processes are stable and yielding consistent and compliant results.

Facility Description:

SRS' material characterization capabilities are currently housed in multiple locations, including 772-F (a Hazard Category 2 facility dating from the 1950s) and 772-1F (a Hazard Category 3 facility dating from the 1980s). F/H Laboratory is a Nuclear Materials Safeguard Category IV building with the amount of plutonium metal limited to 200 grams. SRS does not currently operate their facilities for the unique requirements of supporting pit manufacturing processes. It operates multiple characterization tasks for nuclear materials missions though few are directly applicable to a production process involving bulk metal components and feed streams.

In the past, the site has operated fuel fabrication facilities and production product characterization for Defense Programs feed materials. SRS expertise supports multiple smaller-scale missions including nuclear forensics for DOE, the Department of Homeland Security, the Defense Threat Reduction Agency, and foreign collaborators. In addition, SRNL hosts the Federal Bureau of Investigation forensics laboratory.

The core capabilities of F/H Laboratory are as follows:

a. Chromatography – IC, GC (TCD/FID)
b. Classical wet chemistry
c. Electrochemistry – Coulometry
d. Radio chemistry – alpha, gamma, LSC
e. Spectrometry – ICP-ES, ICP-MS, thermal Ionization mass spectroscopy (TIMS)
f. Shielded cell sample preparation (high rad)
g. Glove box sample preparation (high alpha)

Review Process:

The review was conducted as follows:

1. The IST provided an infrastructure questionnaire that was filled out by Jeff Allender.
2. The entire visiting AoA team went on an SRNL tour on Wednesday April 26, 2017.
3. SRS provided the following relevant documents and presentations for the IST to review:

- 002 *SRS Systems Engineering Functional Analysis*, pp. 123-128: SRNL Program Infrastructure Matrix and Support Buildings 002 SRNL Info Pod (Sic)
- LANL-MPF-G-ESR-X-00015, *Analytical Chemistry and Material Characterization Needs in the Modern Pit Facility*
- Alice Murray, *Overview and Actinide Science and Radiochemistry Overview*, 4/26/17
- Ken Cheeks, *F/H Laboratory Overview*, 4/26/17
- Robert Sindelar, *Material Science Capabilities*, 4/26/17
- *F/H Laboratories Area Overview*
- T.F Severynse, *Summary Report: Plutonium Research & Development Laboratory in K-Area Complex*, 4/10

In addition to Jeff Allender and Brian Pool, the SRNL person who provided most of the information summarized in this section of the IST's report was Robert Sindelar (803-725-5298).

Discussion:

The IST assesses that SRS has limited capability to support MC needs for an 80 ppy manufacturing facility, principally because of the 200-gram plutonium MAR limit in F/H Laboratory. The necessary facilities to accomplish the MC task would have to be designed, costed, and constructed as part of the overall pit manufacturing effort, considering the potential for some of the work to be done elsewhere, such as at LLNL or perhaps LANL.

It should also be noted that if either the MFFF or K-reactor facilities are used for pit manufacturing there would be sufficient Hazard Category I space available to accommodate a Material Characterization Laboratory need of approximately 8,000 ft^2.

Preliminary Risk considerations:

1. There will be a "spike" in needed material characterization during development and qualification of the pit production process. Currently, it is not known how long will be available to cope with such a spike, nor whether SRS has the necessary instruments and personnel. The worst case would be that the ability to produce 80 ppy is delayed by an

unspecified number of months or years. This risk could be mitigated by enhancing SRS' MC capability or by using offsite (e.g., LLNL) capability. The risk is judged to be low.

2. SRS may have insufficient capability to perform the MC work necessary during steady state production of 80 ppy. As a result, SRS will be unable to meet its target of 80 ppy or extensive deviations, which may or may not be acceptable, will have to be approved by the design agency. SRNL has previously demonstrated the feasibility of a Hazard Category I laboratory within the K-Area PIDADS to support the potential movement of pit surveillance and process development affected by the LLNL de-inventory, but those functions were subsequently assigned to LANL TA-55. The risk is judged to be low.
3. In the future (*e.g.,* after 2030) there will be a need to produce some pits of a different type(s). This will require further development and qualification of the pit production process that will challenge SRS' MC capabilities, and may cause a delay of an unknown number of years in the ability to produce the different pit type(s). However, this is so far in the future that there will be ample time for SRS to manage the introduction of the different type of pit. This ought to be a low risk because of the long period available for planning.

A.3.1.3 Perimeter Intrusion, Detection, Assessment, and Delay System

Objective:

The objective of the IST's review was to determine SRS' capabilities in the areas of perimeter intrusion, detection, assessment, and delay with respect to the potential installation of an 80 ppy pit manufacturing capability.

Description:

SRS' major Security Category 1 SNM storage facility is in the former K-reactor, which is protected by a modern PIDADS that is continuously evaluated against emerging and design-basis threats.

L-Area utilizes an old reactor building for spent fuel storage. It is a Security Category II building with a plutonium MAR of two kilograms and has a functional PIDAS – note the difference between a PIDADS, which has features incorporating the ability to delay an adversary, and a PIDAS, which enables detection and assessment, but not delay.

H-Canyon and HB-Line are Security Category I buildings. They have no PIDAS, but have been operating as Hazard Category 1 facilities after rigorous vulnerability assessments. They have been evaluated for supplemental PIDADS but this has not been judged to be required for the currently assigned mission.

Finally, the tritium area has a PIDAS, but it is largely inactive.

If the MFFF is brought into operation with its originally intended purpose of converting 34 metric tons of surplus weapons grade plutonium to fuel for nuclear reactors, or if it is used for some other plutonium mission such as pit manufacturing, it will be necessary to build a PIDAS around it. SRS provided an estimate of the cost to do this: $15.8 million in FY 2016 dollars for 5,170 linear feet, which works out at $3.1 thousand per linear foot.

It is instructive to compare this with the estimated cost of a full PIDADS obtained during the IST's September 2016 visit to LANL (see above). The TA-55 security structure has recently undergone a significant and extensive upgrade that was completed in 2014 at a cost of $245 million for 5,000 linear feet of triple barrier perimeter fencing, upgrades to the personnel access facility, and a perimeter road, which works out at $49.0 thousand per linear foot. This is clearly much more expensive than SRS' proposed PIDAS around MFFF. This difference is partly due to the difference between a PIDAS and a

PIDADS. In addition, MFFF has a gabion wall and SRS may be taking credit for by planning a relatively less substantial PIDAS.

Review Process:

The review was carried out as follows:

1. The IST provided an infrastructure questionnaire that was filled out by Dick (JR) Murphy of SRNS-NNP.
2. The entire visiting AoA team went on tour of K-Area on the morning of Wednesday, April 24, 2017, and observed elements of the PIDADS protecting the K-reactor building.
3. SRS provided the following relevant documents and presentations for the IST to review:
   - 15 Security Manual 7Q (various sections apply)
   - 15 Category SNM Policy 7Q-101*,*
   - 001 *Advanced Disposition Reactor Study* (current configuration with notional expansion of capability for a single new mission within PIDADS envelope), and
   - Copy of an email titled *PIDAS cost* from Ron Curtis (CB&I Project Services Group) to Dennis W. Godbee, 4/25/2017.

Those SRS people who provided most of the information summarized in this section of the IST's report, in addition to Jeff Allender and Brian Pool, were:

Name	Organization	Phone
J.R. Murphy	SRNS/NNP	803-952-5513
Rich Koening	SRNL/NNP	803-952-5513

Discussion

The K-reactor building at SRS is a Security Category I facility that has enough space for an 80 ppy manufacturing line. Thus, it would be possible to install that capability there. Whether to do so or not would be based on considerations other than security.

Assuming the MFFF is not eventually fully devoted to its original purpose of converting 34 metric tons of weapons grade plutonium into reactor fuel, there is ample space for an 80 ppy manufacturing line. As noted above, this would require the construction of 5,700 linear feet of fencing, along with any other items necessary to implement a fully functioning PIDADS. To what extent these items would need to be paid for by the pit manufacturing mission remains to be seen.

The AoA team also discussed adapting the currently unused new Waste Solidification Building (WSB) – for example, to take the plutonium-238 mission from LANL. The building is currently a Hazard Category II structure. Such an adaptation would require implementation of a state-of-the-art PIDADS, in addition to considerable, potentially expensive internal modifications, such as removing installed equipment and reorganizing spaces.

Preliminary Risk Considerations:

Two pertinent risks could have a significant effect on plutonium operations.

1. If the design basis threat changes, this could require potentially large expenditures to reconfigure the physical security infrastructure, with unknown delays to and cost for the pit production program. This would also affect other facilities and operations at SRS. Based on experience, there is a high probability that security requirements could change as a result of newly identified threats

during development and qualification or other phases of the pit production process. The costs could vary from small to very large, so the risk level remains indeterminate, but could well be high or very high. This is not a site-specific risk.

2. There is always the possibility that SRS will have to be shut down for an unknown duration in response to some future threat. This would lead to delays in pit production of unknown length and likewise unknown cost. Any other site would face the same risk, so this is not a discriminator between sites.

A.3.1.4 Standards and Calibration

Objective:

The objective of the review of standards and calibration was to determine if SRS has the capability and capacity needed to support the production of 80 ppy. There is a need for a hot calibration laboratory to provide a post check of contaminated instruments after the calibration interval has expired, as required by the NNSA Quality Assurance Program to verify that expired contaminated instrument(s) are still accurate to specification and assure all product tested has been accepted using instruments that are still accurate.

Facility Description:

SRS' standards and calibrations activities are carried out in multiple locations, but SRS is consolidating them into a central standards and calibrations laboratory. SRS is accredited to the National Institute of Standards and Technology via NAVLAB. It is in compliance with ISO-ASME-17205. SRS has a self-described "good" dimensional lab and is accredited to echelon 1 for mass measurement. SRS is not currently equipped to perform calibration work on hot instruments.

Review Process:

The review was carried out as follows:

1. The IST provided an infrastructure questionnaire that was filled out by Ed Polz and Alexcia Delley of Savannah River Nuclear Solutions, LLC.
2. SRS provided the following relevant documents for the IST to review:
   - 13 Calibration Services BBMP Report (draft)
   - 24 Measurement Control Manual 14Q

In addition, Ed Polz (SRS: 803-725-0955) attended a brief discussion session with the IST on Tuesday April 25, 2017.

Discussion:

SRS would have to establish a hot calibration capability if an 80 ppy manufacturing facility is established there. This capability will need to be provided within the pit manufacturing facility.

An estimate of what it would cost was obtained during the IST's September 2016 visit to LANL (see above). The increase in the work to accommodate the W87 build rate of 80 ppy and to support the requirement for a hot calibration area calls for an estimated 1000 ft^2 area of non-radiological space and 500 ft^2 of radiological laboratory space to perform the hot calibration checks. New instruments required for the workload increase as well as the Hot Calibration Laboratory were estimated by the LANL calibration team to cost $4.5 million. An equipment list was provided. This should be sufficient as a rough order of magnitude estimate for establishing the needed standards and calibration capability and capacity at SRS.

Preliminary risk considerations:

No risks were identified other than low.

A.3.1.5 Waste Treatment and Management

Objective:

The objective of the review of the various waste treatment and management systems at SRS was to determine if sufficient capability and capacity exists to accommodate the treatment, management, and disposition of liquid and solid waste generated by the production of 80 ppy by the year 2030. This chapter begins with the description of waste treatment and management facilities at SRS and then discusses whether they are adequate should an 80 ppy manufacturing facility be built there.

Facility Descriptions:

Waste Solidification Building: SRS has constructed a waste solidification building intended to handle both low-level and high-level liquid waste from MFFF. The building is constructed to seismic performance category 3+ (to follow Nuclear Regulatory Commission requirements) with walls of 12-inch reinforced concrete. It is a Hazard Category II building, but is currently not Security Category I. It has no PIDAS.

WSB was constructed with the intention of accepting and treating approximately 10,100 gallons per year of highly active liquid waste from MFFF and approximately 55,500 gallons per year of low-level liquid waste made up of approximately 43,800 gallons per year from MFFF, and 11,700 gallons per year from the now-abandoned Pit Disassembly and Conversion Facility. This would be done in batches (*i.e.*, the projected rate of waste generation is not necessarily equal to the total capacity of the WSB). The WSB has been placed in a layup configuration and is managed with the intention that it will be reactivated when MFFF comes on line or after a period such as 10 years.

SRS personnel recommended that WSB be used as the liquid waste treatment facility for a pit manufacturing facility, regardless of whether that facility is in MFFF, in the K-reactor building, or in a new building. A study of potential waste generation rates from a postulated 125 ppy manufacturing facility (the Modern Pit Facility [MPF] – DOE 2005b) projected that such a facility would generate 3 m^3 per year (approximately 800 gallons per year) of high activity liquid waste. For comparison, LANL estimates that an 80 ppy manufacturing facility would generate approximately 30 m^3 (approximately 8,000 gallons) of liquid TRU waste per year (see above). The discrepancy between these two estimates remains to be explained, but either is within the capacity of WSB.

The above-referenced MPF study predicts approximately 257 m^3 per year (approximately 67,000 gallons per year) of low-level liquid waste from a 125 ppy facility. This predicted low-level liquid waste stream on its face exceeds the capacity of WSB. Pro-rating to 80 ppy is not valid because the generation of low-level liquid waste is not proportional to the number of pits manufactured[2]. However, as noted above, the WSB will be operated in a batch processing mode. SRS personnel stated that they are confident that WSB could handle the low-level liquid waste liquid generated from the manufacture of 80 ppy. However, see below for other options for waste disposal at SRS.

Liquid TRU Radioactive Waste Facility: Independent of the WSB, SRS operates a robust liquid waste management infrastructure primarily configured for the treatment of legacy wastes currently held in the tank farms. The waste, currently totaling about 36 million gallons, is stored in 44 underground carbon-

[2] Note that LANL did not provide an estimate of the low-level liquid waste generated by the manufacture of 80 ppy, but merely noted that the incremental increase would only add 1-2 percent to the amount of low-level liquid waste that is generated from all on-site sources.

steel waste tanks grouped into two "tank farms" at SRS. The liquid waste in tank storage exists in essentially two forms: sludge and salt. Liquid radioactive waste is also generated at SRS as by-products from the processing of nuclear materials for national defense, research and medical programs.

The Defense Waste Processing Facility is designed to treat the high-activity radionuclides from both forms of this waste. The sludge form, while comprising only about 10 percent of the volume in the tanks, contains about half of the radioactivity. All of it goes to Defense Waste Processing Facility, which incorporates it into glass logs for safe storage and ultimate disposal in a deep geological repository.

The salt form comprises about 90 percent of the volume and contains the balance of the radioactivity. The salt waste is treated at the Modular Caustic Side Solvent Extraction Unit and the Actinide Removal Process. The higher activity portion of the salt waste—a very small stream—is sent to the Defense Waste Processing Facility. The rest is a decontaminated salt solution sent to the Saltstone facilities. There it is mixed with a cement-like grout and poured into Saltstone Disposal Units. These above-ground units, which hold approximately three million gallons of grout each, are designed to keep the waste immobilized until long after the residual radioactivity decays away.

These two waste treatment capabilities, WSB and Defense Waste Processing Facility, are more than adequate to treat legacy wastes and the ongoing generation of liquid waste, with an intended completion date in the 2030s, subject to change because of fluctuations in funding and the potential implementation of other missions at SRS. In principle, should the use of the WSB to process liquid waste from pit manufacturing not prove to be feasible, such wastes could be sent to the liquid TRU waste processing facility – i.e., this is a potential back-up.

SRS E Area Solid Waste Management Facility: This is in the central region of SRS and manages the following waste types:

1. Sanitary waste, which is collected and transported to a sanitary landfill
2. LLW, most which is disposed of onsite in various disposal units. The disposal unit and method are dependent on curie content and waste form
3. TRU, hazardous, and mixed wastes. Commercial vendors are primarily used for hazardous waste and mixed waste treatment and disposal. TRU waste is packaged as appropriate and sent to the WIPP in New Mexico

Any low-level and TRU solid waste generated by the WSB would be sent to E-Area for disposal. Similarly, any solid low-level waste or TRU waste generated in MFFF, or in K-Area should a pit manufacturing facility be installed there, or in a new pit manufacturing building would also be sent to E-Area.

E-area currently manages and disposes of 50 m^3 of solid TRU waste per year, equivalent to approximately 250 55-gallon drums. According to studies performed for the Modern Pit Facility (DOE 2005b), a 125 ppy facility is expected to generate approximately 130 m^3 per year or 650 55-gallon drums per year. This can be regarded as an upper bound for a rate of 80 ppy. For perspective, the IST learned that LANL estimates that an 80 ppy manufacturing facility is expected to generate 1100-1500 55-gallon drums containing TRU waste per year. Whichever of these estimates is correct, E-Area would have to process TRU-waste at a considerably increased rate. SRS personnel expressed confidence that they could handle these rates. E-Area at SRS can store 2,000 – 2,500 55-gallon drums on each of five pads. This would provide many years of storage capacity and allow flexibility in coping with potential fluctuations in shipments to WIPP.

E-area also manages and disposes of 5,000 m^3 per year of solid LLW and could easily double that. According to the MPF study, a 125 ppy facility would be expected to generate approximately 1,630 m^3 per year of low-level solid waste. During its September 2016 visit to LANL, the IST was informed that experience has demonstrated that the volume of low-level waste generated from TA-55 is not particularly tied to pit production rate; but, rather the frequency of performing maintenance operations (e.g., routine glove and filter replacements). The average volume of low-level solid waste generated by TA-55 is approximately 330 m^3 per month, or approximately 4,000 m^3 per year. This higher estimate of low-level solid waste generation is within E-area's capacity.

Review Process:

The review was carried out as follows:

1. The IST provided infrastructure questionnaires about the following areas and they were filled out by various SRS personnel:
   - Low-level liquid waste treatment – SRS EM operations
   - TRU liquid waste treatment – SRS EM operations
   - TRU liquid waste treatment – NNSA WSB operations
   - Solid low-level waste storage and shipping – SRS EM operations
   - Solid TRU waste management – SRS EM operations
2. The team listened to presentations on WSB (given by Tom Cantey) and E-area (given by Don Turno).
3. The entire visiting AoA team went on a tour of WSB on the morning of Tuesday April 24 and went to E-Area on the morning of Wednesday April 25, 2017
4. SRS provided the following relevant documents:
   - Liquid Waste System Plan
   - Rad Waste Requirements 1S Manual
   - Liquid Waste Info Pod
   - Liquid Waste Fact Sheet
   - Solid Waste Management Info Pod
   - Transuranic Waste Fact Sheet

Those SRS people who provided most of the information summarized in this section of the IST's report, in addition to Jeff Allender and Brian Pool, were:

Name	Organization	Phone
Don Turno	Solid Waste Operations	803-208-8716
Jimmy Winkler	SRNS EM Programs	803-208-8182
Lee Fox	SRNS – Solid Waste	803-208-0778
Matt Haelcney	SRNS-NNP	803-952-1291

Discussion:

SRS has the capability and capacity to treat the low-level and TRU waste, both liquid and solid, that will be generated by the manufacture of 80 ppy, subject to the caveats expressed below as risks.

Preliminary Risk Considerations:

1. MFFF is eventually completed and used for its originally intended purpose of converting 34 metric tons of surplus-to-requirements weapons-grade plutonium to fuel for reactors. The low activity and high activity streams that it generates are treated in the WSB. If 80 ppy are also manufactured

at SRS, the WSB may not have enough capacity to deal with both processes. Additional liquid waste treatment capacity would have to be built, at potentially considerable expense. Because it is not known how likely it is that MFFF will eventually be used for its originally-intended purpose, it is not possible to make an estimate of the level of risk. However, as noted above, the Liquid TRU Radioactive Waste Facility has ample capacity and could potentially receive waste from pit manufacturing. Thus, this risk could potentially be mitigated to a low-level.

2. If MFFF is not used for its originally intended purpose, and instead the 34 metric tons of weapons-grade plutonium is managed through the proposed dilute and dispose effort, the amount of TRU waste to be handled by E-Area and sent to WIPP for final disposal will increase to about 100,000 55-gallon drums over the lifetime of the project. In that case, major (but unspecified) upgrades to E-Area will be needed. This will be costly and, in the opinion of the IST, it appears quite probable. This risk looks to be in the medium range, although it may not be a risk to the pit manufacturing program, since upgrades to E-Area will presumably be paid for by the dilute and dispose program, which will be by far the largest generator of TRU waste.

3. WIPP experiences an event that causes it to be shut down for a sufficiently long time that TRU waste storage at SRS becomes full. Pit production shuts down for a period of months to years. At the time of writing, WIPP has been closed for 3 years and has only recently reopened. Another such shutdown cannot be ruled out. As noted above, storage in E-Area is sufficient to accommodate TRU waste generation from pit production for many years, so this risk is probably low. However, should the dilute and dispose program ramp up to accommodate 34 metric tons of moxable plutonium, the storage capacity in E-Area could fill up relatively quickly. The likelihood of this event is quite high. However, given the already large storage capacity for TRU at SRS, and the availability of space in E-Area for construction of further storage capacity, this risk should be mitigatable to a low-level.

5. WIPP experiences another event that causes it to be shut down. After it comes back on line, additional safety and regulatory constraints mean that it accepts and processes shipments at a much slower rate than before the event. This processing rate may be insufficient to accept TRU waste generated by 80 ppy, especially if increased by enhanced TRU waste production by the dilute and dispose activity, so that after some years TRU waste storage at SRS becomes full and pit production ceases. This scenario is also realistic because, now that WIPP has come back on line after its current shutdown, it is accepting and processing shipments for final disposal at a lower rate than before. Similar or perhaps even more onerous restrictions are likely in the event of a future shutdown. This risk is medium to high.

6. WIPP becomes full and is no longer able to accept solid TRU waste. Solid TRU capacity at SRS also becomes full and pit production shuts down. Additional TRU waste disposal capacity at WIPP or elsewhere may be required to support the 80 ppy capacity and, if implemented, to support the extra TRU waste generated if 34 metric tons of plutonium is treated via dilute and dispose instead of the MOX process. The IST's initial assessment of this risk was high, but, as is discussed in Appendix E, on further consideration it was assessed to be low. This in part is because it is assumed that, in the event of WIPP becoming full, further storage capacity will be developed there.

Note that none of the WIPP-related risks described above (3-5) are unique to SRS and will likely not be discriminators between sites.

A.3.1.6 Miscellaneous

This section contains information on several activities that are needed to support pit production, but which would not be expensive to implement (relative to the total cost of a pit production facility) should they not already be available at SRS. Alternatively, most of them could be readily outsourced.

A.3.1.6.1 Classified Beryllium (Be) Machining

SRS currently has no classified Be machining capability. This information was conveyed to the IST via Jeff Allender, SRNL (803-208-1291). It is expected that, if needed, classified Be parts can be obtained through a classified procurement or from another DOE site

Preliminary Risk Considerations:

No risks were identified other than those that are very low because it seems very unlikely that SRS would not be able to obtain classified Be parts from off-site sources if needed.

A.3.1.6.2 Classified Stainless Steel Machining

Objective:

The objective of the review of SRS' classified stainless steel capability and capacity was to determine if sufficient capacity exists to accommodate the machining of stainless steel parts that will be required to support the production of 80 ppy by the year 2030.

Facility Description:

Classified stainless steel machining is carried out in SRNL's Research and Development Machine Shop, which is in Building 749-A. This building has a production area of 10,000 ft^2, of which only 600 ft^2 is designated for classified machining. Administration, support, and other areas take up about 1,300 ft^2. The facility contains eight conventional mills, six CNC mills, eight conventional lathes, and four CNC lathes, but there is only one of each of these four items of equipment in the classified area. The facility also contains a grinder, an electrical discharge machine, fabrication equipment and a welder, but none of these are in the classified area. The maximum classified machining capacity, based on four machines and four machinists working 40-hour weeks for four months is 2,560 hours.

Review Process:

The review was principally conducted by using the questionnaire, which was filled in by Monica Phillips (803-725-3622) and Tom Nance (803-725-5842). This was supplemented by a brief tour of the shop on April 26, 2017, and by conversations with Jeff Allender.

Discussion:

SRS clearly has limited capacity for classified stainless steel machining. There may be capability associated with other facilities at SRS, including the NNSA Tritium Enterprise, but these likely have limited capacity and are dedicated to specific missions. In addition, building 749-A is a research and development shop and mixing manufacturing and research capabilities may be undesirable.

Should NNSA establish a pit manufacturing capability at SRS, the required classified stainless-steel capacity should be established at that time and plans to set it up should be made at an early date. Alternatively, the site might consider outsourcing its need for classified shapes to a site such as KCNSC.

Preliminary Risk Considerations:

No risks were identified other than those that are very low, because it seems very unlikely that SRS would not be able to obtain classified stainless-steel parts from off-site sources if needed.

A.3.1.6.3 Classified Graphite Machining

Overview:

SRS currently has a limited classified graphite machining capability in the same SRNL Machining Shop. SRNL, through Monica Phillips, pointed out that classified graphite machining has been done on the same machines that are used for classified stainless steel machining, but as noted above that capability is very limited as it would share the 600-ft^2 of classified machining space. No similar capacity was identified elsewhere at SRS.

Discussion:

It would be entirely feasible for SRS to outsource graphite machining requirements to LANL or to other off-site entities. Should SRS decide to set up its own capability it would require classified space and equipment like that for stainless steel, but with enhanced ventilation and a collection system to control dust.

During its visit to LANL in September 2016 the IST determined that the area currently dedicated to graphite fabrication in support of pit manufacturing is 2,500 ft^2 to administration, 2,000 ft^2 to production, and 2,500 ft^2 to support. The production area is in a standard industrial building but, as noted above, has a specialized ventilation process to capture the considerable amount of graphite dust particles that is released during the machining process.

LANL informed the IST that, to accommodate a production rate of 80 ppy on a one shift basis, the current production area would have to be enlarged from 2,000 ft^2 to 8,000 ft^2 including additional equipment and extended ventilation. The current administrative and support functions do not require additional area. The current production area contains eight lathes, five mills, and several electrical discharge machines. To accommodate 80 ppy will require the following new equipment items: three coordinate measuring machines, six lathes, and two mills.

Thus, to install graphite machining at SRS to support 80 ppy, based on the LANL information, about 13,000 ft^2 would be required in a standard industrial building. Of that 13,000- ft^2, 8,000 ft^2 would need to be in a specially ventilated area. Equipment needed would be fourteen lathes, seven mills, several electrical discharge machines, and three co-ordinates measuring machines.

Preliminary Risk Considerations:

No risks were identified other than those that are very low. SRS should be able to build the graphite machining capability in time or to outsource the machining.

A.3.1.6.4 Classified Uranium Machining

SRS currently has no classified uranium machining capability. This information was conveyed to the IST by Jeff Allender. The IST recommends that it should either be assumed that this capability will be outsourced (*e.g.,* to Y-12) or that equipment should be built into the pit manufacturing process.

Preliminary Risk Considerations:

No risks were identified other than those that are very low.

A.3.1.6.5 Graphite Coating

Overview:

SRS currently has no graphite coating capability. This information was conveyed to the IST via Jeff Allender, SRNL (803-208-1291).

The IST considers that a conventional manufacturing structure that could accommodate an enclosed area of 3,000 ft^2 would be sufficient to handle the coating operation for an 80 ppy manufacturing facility. The area would encompass 2,000 ft^2 of manufacturing space containing two 10 feet x 20 feet paint booths and other operations for preparation and cleaning, along with a 1,000-ft^2 complex of offices, storage, restrooms, etc. This operation should be close to the mold casting machining operation. There are no shelf-life issues, so if molding and coating is not carried out at SRS, it could equally well be done at a site such as LANL.

Preliminary Risk Considerations:

No risks were identified other than those that are very low.

A.3.2 Plant Core Infrastructure

This section addresses those items of plant core infrastructure that are needed by the 80 ppy manufacturing process.

A.3.2.1 Security Category 1 Facility Support

Objective:

The objective of the review was to determine if SRS has in place a Security Category I process to support the requirements of a pit manufacturing facility. SRS has been operational since the early 1950s and has performed several vital roles in support of nuclear weapons production. Security has been a significant and very important element for the successful performance of their mission since they are required to protect all types of nuclear materials, including SNM, government property, weapon products, and personnel.

Review Process:

The Security Category I system review consisted of discussions with qualified members of SRS security team and review of documentation (i.e., DOE Order 473.3, Protection Program Operations, and SRS policies and procedures). Those participating in the discussions, which took place on April 25, 2017, were:

Name	Organization	Phone
Rich Koenig	SRNL	803-645-5608
J. R. Murphy	SRNS	803-952-5513
Jeff Allender	SRNL	803-208-1291
Brian Pool	SRNS	803-208-0396
Chris Bader	TechSource	480-782-0415
Phil Forsberg	NA-143	202-586-2108
Geoff Kaiser	Leidos	301-340-9015

The following documents were provided:

1. SRNL, Safeguards and Security Programs Manual - 7Q
2. DOE: O 473.3, Protection Programs Operations

Discussion:

- SRS is required to follow and be compliant with the DOE Order 473.3, *Protection Program Operation*s. This Order establishes requirements for the management and operation of the Protection Program Forces, Contractor Protective Forces, and the Physical Security of property and personnel under the cognizance of DOE.

- SRS has prepared a security manual with supporting implementation procedures, governing the security for the entire site. It covers all requirements within DOE Order 473.3, including physical protection of facilities, buildings, government property, and employees, and it addresses national security interests such as classified information, SNM and other elements of the nuclear weapon programs.

Based on the determination that satisfactory safeguards and security policy and facility measures are in place, the DOE will grant SRS facility approval to receive, process, use, or store classified material, nuclear materials or DOE property of significant monetary value. A Facility Data and Approval Record (FDAR) is the process used to record approvals, facility importance ratings, facility upgrades or downgrades, and changes or deletions.

The DOE Office of Safeguards, Security and Emergency Services approves the FDAR and in conjunction with the prime contractor Savannah River Nuclear Solutions Department, and the Protective Force contractor Centerra ensures that policies, programs, and systems and all operations comply with appropriate implementation of the DOE Order and specifics of the FDAR. As missions and conditions change, the FDAR is reviewed and revised if necessary.

The contractors perform periodic self-assessments to verify compliance in addition to DOE audits and assessment of the programs.

No issues were identified within the security system that would prohibit the assignment of the pit manufacturing mission to SRS.

A.3.2.2 Normal/off normal Electrical Power

Objective:

The objective of SRS Electrical Power review is to determine if sufficient power is currently available or planned to support a pit manufacturing facility capable of producing 80 ppy by the year 2030.

Review Process:

SRS Site Services organization responded to the IST questionnaire by providing existing utility capacity data versus current and planned usage. Both Jeff Allender and Brian Pool coordinated the data with the Savanah River Site Services organization

It should be noted as of the present date the size of the pit manufacturing facility has not been established and therefore the amount of power or other utility requirements have not been determined.

It has been assumed that utility usage would be half of that being considered for the MOX facility. It is understood that this assumption is conservative since the MOX facility is designed as a greater than 500 thousand ft^2 facility. Current pit facilities space estimates are considerably less than half of the MOX estimate.

Description:

SRS has robust electrical power capabilities and capacities. The system is supplied by several independent electrical power generation plants located in South Carolina and Georgia. SRS has provided transmission capacities for nine separate substations including estimated usage projections for both current and future missions.

Based on the data provided the estimated electrical power demands for a pit manufacturing facility could be adequately supported within most of the areas if needed.

Table A–1 reflects current usage and current capacities for the existing nine substations.

Table A–1. Savannah River electrical transmission capacities

Item	Savannah River Area	Demand MVA	Capacity MVA	Remarks
1	A	12.0	40.0	
2	B	4.5	16.0	
3	C	6.5	30.0	
4	F	11.0	40.0	
5	MOX	23.0	37.3	Assumption - Pit facility 50 percent of MOX approximately 12.0 MVA
6	H	26.0	40.0	
7	K	6.0	30.0	
8	L	2.5	30.0	
9	681-3G	1.5	20.0	

Key: MOX = mixed oxide; MVA = mega volt ampere

While there is sufficient power at the Site to support a pit manufacturing facility, to ensure redundancy and to provide a comfortable safety margin, power redistribution from lower demand areas to any proposed pit manufacturing area should be considered.

A.3.2.3 Other utilities

Objective:

The objective of a review of SRS' other utility areas is to determine if capacities are available or planned to support a pit manufacturing facility capable of producing 80 ppy by the year 2030.

Review Process:

SRS Site Services organization responded to the IST questionnaire by providing utility capacity data versus current and planned usage. Brian Pool (803-208-0396) coordinated the data with the Savannah River Site Services organization.

Other site utilities were reviewed to determine their ability to support the 80 ppy mission and determine if some modifications or enhancement to capacity was needed. The results of that review are as follows:

1. Chilled water – SRS has two chilled water plants with a combined design capacity of 5,800 tons with current and planned utilization at 3,450 tons. Absent changes to the current and planned missions that would require more chilled water there should be amble supply for a pit manufacturing building producing 80 ppy.
2. Domestic water – SRS has one active water treatment plant located within Area A. The capacity for domestic water treatment provided by the Area A facility is 1,500-gallons per minute versus a total combined daytime demand of 900 gallons per minute. A smaller water treatment plant is located at Area D with a 200-gallons per minute output and a 10-gallons per minute average demand. Pending change to the current planned missions there is ample capacity available to support a pit manufacturing facility.

3. Fire Protection – It is assumed that the new pit facility will have a dedicated fire protection water tank and pumping capacity of suitable size for the facility. Pumping capabilities for SRS critical buildings are supported with 2,000 – 2,500 gallons per minute pumps and tank capacities of several hundred thousand gallons. Two water tanks currently are in Area E/F where the MFFF is located with capacities greater than 500 thousand gallons. They are serviced by a 2.5-thousand gallon per minute pump that would be available if the pit manufacturing mission used the MFFF. Similarly, if K-reactor was converted to a pit manufacturing facility it has a single tank of 500 thousand gallons with a 2.5-thousand gallon per minute pump. It is assumed that the fire protection tank and pumping system would be part of the pit facility cost if built in a green field.
4. Process water – SRS process water is supported by three different process treatment plants located in Areas A, F, and H, producing at a combined peak capacity of 3,000 gallons per minute with an anticipated demand of approximately 1,125 gallons per minute. There is sufficient process water capacity to support a pit manufacturing facility.
5. River Water Capacities – SRS river water provides water for the entire site. The water is pumped from the Savannah River for use in multiple areas and multiple applications for domestic consumption, fire protection, chilled water for cooling towers, etc. The design capacity of the system is 250,000 gallons per minute but only a fraction of the capacity is being used. Most of the system is in a stand ready state but is not used or needed. Based on the foregoing there is ample capacity of river water to support a pit manufacturing facility.
6. Steam Production – SRS steam production consists of four active power plants with combined average capacity flow of approximately 290 thousand pounds per hour and an average daily flow requirement of 104 thousand pounds per hour. Pending change to the current planned missions there is currently sufficient steam capacity to support a pit manufacturing facility.

As noted above the pit manufacturing facility has not been sized so an estimate of half of the MOX facility usage was used to ensure the analysis of utilities is sufficient to support the pit initiative when applicable.

A.3.2.4 Medical Facility

An onsite medical facility with capability to treat alpha contaminated personnel has been available to SRS for many years. The facility, centrally located within Area N, has a core of trained staff capable of performing decontamination processes and methods as well as performing first aid for minor injuries. The facility is equipped and personnel trained for performing emergency service and stabilization of personnel for transport in emergency situations.

A.3.2.5 Environmental Monitoring

SRS has a comprehensive Environmental Management System in place that ensures the protection of air, water, land, biota, and other natural, archaeological, and cultural resources. The DOE Savannah River Site Policy Manual, SRSPM 250.1.1E, provides the policy guidance to the site for environmental direction. The operating contractor has prepared supporting documentation to implement the environmental program through policies, programs, procedures, and training.

The on-site contractor has established improvement goals and targets; and routinely measures performance. When issues are identified, corrective actions are identified and action is taken to improve processes and protect the environment.

A.3.2.6 Sanitary Waste Facility

SRS has a central sanitary waste water treatment facility and three satellite facilities. The central facility services the entire site and has a treatment capacity of 1.05 million gallons a day and a peak flow of 0.6 million gallons a day. The satellite treatment facilities service areas D, K, and L. Area D is being deactivated, Area K is at maximum capacity, and Area L has 10 GPD excess capacity. The pit manufacturing facility would most likely be serviced by the central system which has sufficient capacity to support that mission.

A.3.2.7 Operating Infrastructure

This section addresses the various items of operating infrastructure that are needed to operate the proposed 80 ppy manufacturing facility.

A.3.2.8 Production Control System

Production control process are applied to the weapon product currently produced at SRS. The nature of the system will most probably be modified to accommodate the product differences between the current mission and the fabrication and assembly operations of parts required to produce a plutonium pit. If SRS is selected as the pit manufacturing site there is sufficient time to make the necessary changes as required

A.3.2.9 Manufacturing policy document

Manufacturing policy documents include conduct of operations and quality requirements specified in the 1Q Quality Assurance Manual. These documents provide the basis for the operation and conduct of business, as well as how to produce quality product, in a nuclear environment.

A.3.2.10 Material Control System

Material control systems are required and specified within the 1Q Quality Assurance Manual. As established by the manual, material control requires supplier evaluations, receiving or supplier source inspections, and certificate of conformance (1Q procedure 18-7, Quality Assurance Supplier Surveillance and 1Q procedure 7-2, Control of Purchased Items and Services). In addition, the 1Q manual specifies the requirement for parts Identification during processing to ensure controls are maintained (1Q procedure 8-1, Identification and Control of Items).

A.3.2.11 Safeguards and Accountability

SRS has responsibility for storing and maintaining SNM. To manage and administer the SNM program the Site has developed an SNM policy and procedures manual consistent with DOE Order 473.3, *Protection and Program Operations*. A policy document, 14Q, *Material Control and Accountability Manual,* contains procedures to administer and control a compliant SNM program. These SNM procedures and processes are routinely assessed by the operating and management contractor as well as audited annually by the DOE.

A.3.2.12 Qualified Operators and Technicians

Requirements for qualification of personnel are addressed in NQA-1-2008/2009, Sec. 200, and NAP-24A, section 3.2, Indoctrination and Training, and specified within the Site Management and Operations Quality Assurance and Management Plan, SRNS-RP-2008-00020. The objective of the training program is to provide and ensure initial proficiency, maintain proficiency, and adapt to changes in technology, methods, or job responsibilities.

A.3.2.13 Weapons Quality Program

SRS is responsible for manufacturing and supporting the nuclear weapons production program by producing and delivering tritium products. The DOE quality policy document for weapon products is NAP-24A, Weapon Quality Policy, published in 2015. SRS has adopted this policy and published a quality manual for the site that rolls the requirements of NAP-24A and NQA-1 2008/2009 together. Each section of the manual is independently controlled and updated as the quality policies evolve. DOE has approved this process and based upon periodic reviews and assessments monitors compliance. It is noted that a revision to NAP-24 has recently been released and SRS is in process of incorporating the changes. Forecast for completion and implementation of the revision is June 2017.

A.4 Idaho National Laboratory

The IST concluded that INL has most of the necessary infrastructure in place to support the manufacture of 80 ppy. That infrastructure includes strong capabilities in solid and liquid waste management, standards and calibration, plant core elements (such as processes and facilities to support a category I secured facility), adequate electrical power, medical support, and all operating infrastructure processes and systems (such as safeguards of nuclear materials, production and quality assurance).

The IST determined that the INL has excellent equipment and facility capabilities currently performing AC and MC. The primary issue encountered is that the laboratory buildings performing AC are Hazard Category 3 and only authorized to process 200 grams of plutonium-239 at one time, which cannot support production requirements. This issue also impacts LANL and SRS and underscores the need for either a review and favorable decision to increase this limiting requirement, or support of the activity by providing additional Hazard Category 2 facilities for laboratory work dealing with nuclear materials.

As identified during prior IST reviews (*i.e.,* of LANL and SRS), the W87 DA, LLNL, is planning to perform some portion of the AC and MC work required for process development and qualification for the 80 ppy production capability. LLNL's assistance will be very helpful and can offer an alternative to INL should they need additional AC and MC capacity. LANL potentially could serve as a backup for this capability.

The IST is also concerned about the uncertainty expressed by the INL team regarding their ability to support the 80 ppy requirement for many of the infrastructure items due to the lack of information about their projected needs for INL's primary core work. While the pit manufacturing effort starts in 2026 the amount work for the basic INL core activities is unknown at this time.

While the intellectual, technical, facility, and equipment capabilities clearly exist for most items, INL is reluctant to commit to having capacity to support the pit manufacturing project based on the uncertainty of their core work requirement needs.

INL was able to evaluate and estimate the pit manufacturing laboratory and waste management requirements based on the MPF studies performed in 2004. In many areas INL concluded that the pit project could be supported by adding a second shift, off-loading non-nuclear items to other sites, or procuring from qualified suppliers.

Some infrastructure elements necessary for establishing a capacity to produce 80 ppy were not included in the scope of this evaluation after having been judged to be unlikely to impact any of the potential alternatives. KCNSC is NNSA's center of excellence for providing non-nuclear product components to supplement or support all other NNSA sites. In addition, KCNSC provides many of the supplies and materials used in pit fabrication. Most of these items are off-the-shelf controlled commodity items obtained from qualified sources but are not included in this evaluation.

During the orientation meeting several questions regarding acquisition of a skilled labor force to operate the pit manufacturing plant were discussed. INL management responded that the site is an attractive placed to work with competitive wages and benefits, and they are confident in their ability to acquire 600-1000 glovebox machinists, production operators, and other supporting personnel to support the pit mission.

As was done on the other site reviews, the IST provided questionnaires requesting specific data on the major infrastructure items. The IST then reviewed the documents to determine if capability and capacity would be available to support the mission of 80 ppy.

Unlike prior infrastructure reviews the full IST was unable to visit the INL site due to other project priorities. The process to prepare this section included an IST review of the questionnaires and communicating with INL management via teleconference as required.

This chapter is divided into three sections: a) capital items and functions; b) plant core infrastructure, and c) operating infrastructure. The information compiled below was assembled from some or all of three sources: a) questionnaires that the IST sent beforehand; b) orientation briefings: and c) telephone follow up. The work was led by Chris Bader, assisted by Ian Andrews, Geoff Kaiser, and Vann Bynum. They, as well as INL individuals who were particularly helpful in organizing and providing information for the INL infrastructure review are as follows:

Name	Organization	Phone
Ian Andrews	NNSA	202-287-5123
Chris Bader	TechSource Inc.	480-650-2099
Vann Bynum	TechSource Inc.	505-603-9018
Geoff Kaiser	Leidos	301-340-9015
Carla Dwight	Space Nuclear Power & Isotope Technologies (INL)	208-533-7651
Stephen Johnson	Space Nuclear Power & Isotope Technologies (INL)	208-533-7496
Misty Benjamin	Homeland & National Security (INL)	208-526-5940

A.4.1 Capital Items and Functions

This section describes the information gathered on the following capital items and functions: analytical chemistry, material characterization, PIDADS, standards and calibration, waste treatment and management (low level and TRU liquid waste, low level and TRU solid waste), and miscellaneous (classified beryllium machining, classified stainless steel machining, classified graphite machining, classified uranium machining, and graphite coating).

A.4.1.1 Analytical Chemistry

Objective:

The objective of the review of AC laboratories is to determine if sufficient capability and capacity is available to perform required chemical testing, analysis, and verification of chemistry parameters necessary to produce a compliant and quality pit at a production rate of 80 ppy by the year 2030. AC supports the development, qualification, and production phases of the pit manufacturing project by performing tests and analysis to determine and evaluate compliance with material specifications and verify consistency of the manufacturing processes.

Facility Description:

INL provided the following description of the facilities available for performing AC:

The Materials and Fuels Complex (MFC) Analytical Laboratory is a Hazard Category 3 nuclear facility which specializes in characterization, post-irradiation examination, and fuel fabrication.

The current mission of the AC laboratory is:

- Chemical, radiochemical and physical measurements
- Nondestructive analysis measurements
- Applied research and engineering development activities in support of advanced nuclear fuel design, waste management, environmental, and other programs conducted at the MFC
- Analysis and characterization of as-built and post-irradiated nuclear fuels and reactor components
- Analysis of hazardous, mixed, or highly radioactive waste
- Analytical chemistry support for nuclear forensics
- Radioisotope separation
- Characterization of engineered materials

Significant equipment items within the AC laboratory include:

- Six interconnected hot cells, general chemistry laboratories, gloveboxes and fume hoods
- Gas mass spectrometers
- Characterization of as-built and post—irradiated nuclear fuels and reactor components
- Segmented Barrel Gamma Scanner for non-destructive analysis
- Conventional/off-the-shelf equipment and techniques for analyzing all types of radioactive materials

Review Process:

The review process consisted of INL completing a questionnaire provided by the IST for items considered important to the success of a pit manufacturing operation. For the AC Area, this form is identified as MPA-AoA-INL-11.

INL has excellent facilities, equipment, and trained and qualified personnel to perform the AC process for the pit manufacturing mission. However, several issues need to be addressed.

The first issue is that INL's AC laboratory is operating in a Hazard Category 3 facility with a MAR limit of 200 grams of plutonium-239-equivalent (gPu) for the building. The MAR limit severely restricts the rate at which tests can be performed for product development and qualification testing and will constrain the pit manufacturing operation's ability to sustain the required production rate. This issue is also applicable to LANL and SRS. Requests to increase the MAR have been made by both sites for well over a year without a response from the appropriate nuclear safety authorities. For purposes of the AoA the IST assumes favorable passage of the MAR increase.

The second issue is that several current INL projects are expected to extend into the future and it is difficult to forecast the amount of AC support they will require. Currently these programs occupy most of the existing AC facility and capacity. It is not known how much AC capacity will be available in 2026 and beyond when the pit processes are expected to be needed.

Discussion:

Current estimated dates for starting pit manufacturing process development is 2026. It is therefore likely that the pit manufacturing workload will be operating simultaneously with other INL projects. If there is conflicting activity one possibility is to deploy a second shift. INL has reviewed the AC needs of pit manufacturing based on the modern pit facility study and concluded that, provided the INL core work does not increase from current levels, the addition of a second shift could accommodate both major work activities.

Another consideration and potential solution would be for LLNL and LANL to assist with their AC laboratory resources. This strategy could be very helpful particularly during the early process development and qualification phase.

Another possibility is to explore the placement of the AC laboratory within the Fuel Processing Facility or the green field construction if either of these is the selected option. This would eliminate the MAR issue as well as provide uninterrupted support to pit operations.

Several options appear to be available to resolve or at least assist in the resolution of the capacity issue. Pit operations are not planned to start until 2026 which should be sufficient time to come up with an acceptable solution.

Preliminary Risk Considerations:

The principal risk is that if an 80 ppy manufacturing facility is established at INL, MAR limits in the buildings housing AC equipment will be insufficient to allow INL to process samples at the required rate. If this were to continue indefinitely, it would become impossible to deliver 80 WR ppy to Pantex. To mitigate or remove this risk, careful planning will be necessary to ensure that the necessary amount of Hazard Category 2 space is made available for AC equipment. The lead time is such that this should be possible, and the risk is assessed to be low.

The IST learned at LANL that research efforts are underway to increase the sensitivity of analytical techniques so that much smaller sample sizes are required. This would increase the number of sampling analyses that are possible at any one time while remaining within a MAR limit such as 200 gPu. This is another avenue that INL could explore should there be a need to further mitigate the risk described above.

Another way in which this risk could be further mitigated could be to reduce the number of samples that are required per pit. Based on experience at LANL, 18-20 five-gram plutonium metal samples were analyzed for every WR pit that was produced. However, potentially, if the initial metal could be delivered within certain well-defined specifications, this possibly could be reduced to 6-6.5 five-gram samples per delivered pit, making a total of about 500 samples per year for an 80 ppy program. With careful scheduling and improving the quality of incoming plutonium, this strategy potentially could be managed in a building with a 200g MAR ceiling.

In addition, as mentioned above, the risk could be mitigated by calling on AC resources at LANL or LLNL.

Considering the many potential ways of mitigating this risk, the IST's preliminary determination is that it is low.

A.4.1.2 Material Characterization

Objective:

The objective of the review of MC at INL is to determine if there is sufficient capability and capacity to perform testing, analysis, and verification of the manufacturing process parameters to produce a compliant and quality pit at a rate of 80 ppy by the year 2030. MC supports manufacturing operations in the development, qualification, and production phases of the program by performing material testing and analysis to evaluate compliance with specifications and verify consistency of the manufacturing processes.

In addition to the development and qualification phase, during the production campaign W-87 pits will be randomly selected from the production line and tested to ensure the processes are stable and yielding consistent and compliant results.

Facility Description:

The Material Characterization Laboratory (MCL) is currently performed in three different facilities and consists of an 11,000-ft^2 Hazard Category 2 building, and two combined buildings containing a combined 8,000 ft^2 of Hazard Category 3 space.

Significant equipment items include:

- a JEOL 7600 scanning electron microscope that has wavelength and energy dispersive x-ray detectors, along with electron backscattering capabilities to fully characterize samples to 1nm resolution at 15kv
- PHENOM, a table-top scanning electron microscope for basic capabilities
- an electron microscopy laboratory that can handle actinides and low to moderate radiological samples (300 R beta)
- Class I radiological hoods and gloveboxes to prepare actinide bearing samples
- a JEOL 7000 scanning electron microscope, that has the most modern and versatile detectors (wave length and energy dispersive) x-ray detectors and electron backscattering diffraction detectors
- a Quantas focused ion beam instrument and a transmission electron microscope
- an electron probe microanalyzer manufactured by CAMECA
- a thermal conductivity microscope, which is planned for FY 2019

The MC laboratory has an impressive list of facilities and equipment and appears to be entirely capable of performing the tests needed to support the technical MC requirements for pit manufacturing.

Review Process:

The review process consisted of INL completing a questionnaire provided by the IST for items considered important to the success of a pit manufacturing operation. For the MC section, this form is identified as MPA-AoA-INL-12.

The MC unit can support the pit manufacturing project with process development and qualification by verifying the manufacturing parameters meet or exceed the requirements as defined by the design agency. Further, once the parameters are established the manufacturing processes are continuously monitored by sampling the product throughout the build cycle to ensure process consistency is maintained.

The facility area needed for MC has been estimated to be 7,750 ft^2, consisting of 5,875 ft^2 of Hazard Category II space and 1,875 ft^2 of Hazard Category III space. Provisions for Hazard Category II space and equipment have been included within the manufacturing process area and the Hazard Category III space could be accommodated in existing INL facilities.

If the option selected is the modification of the Fuel Processing Facility, in addition to the installation of the pit production area, there would be ample space within that facility to accommodate the entire MC and AC requirements.

Discussion:

The largest concern identified by the INL management for MC is the projected workload required for INL's core work during the time period when pit manufacturing process development would start. As currently forecast pit production type work is unlikely to start prior to 2026, and as previously stated should allow ample time to identify, plan, and execute actions to mitigate interferences.

Preliminary Risk considerations:

1. There will be a "spike" in needed material characterization during development and qualification of the pit production process. Currently, it is not known what length of time will be available to cope with such a spike, nor whether INL has the necessary instruments and personnel. The worst case would be that the ability to produce 80 ppy is delayed by an unspecified number of months or years. This risk could be mitigated by enhancing INL's MC capability or by using offsite (e.g., LLNL) capability. The risk is judged to be low.
2. INL may have insufficient capability to perform the MC work necessary during steady state production of 80 ppy. As a result, INL will be unable to meet its target of 80 ppy or extensive deviations, which may or may not be acceptable, will have to be approved by the design agency. Per the discussion above, this risk is judged to be low.
3. In the future (*e.g.,* after 2030) there will be a need to produce some pits of a different type(s). This will require further development and qualification of the pit production process that will challenge INL's MC capabilities, and may cause a delay of an unknown number of years in the ability to produce the different pit type(s). However, this is so far in the future that there will be ample time for INL to manage the introduction of the different type of pit. This ought to be a low risk because of the long period available for planning.

A.4.1.3 Perimeter Intrusion, Detection, Assessment, and Delay System

Objective:

The objective of the IST's review is to determine INL's capabilities in the areas of perimeter intrusion, detection, assessment, and delay with respect to the potential installation of an 80 ppy pit manufacturing capability by the year 2030.

Facility Description:

INL currently has an active PIDAS surrounding a MFC secured structure that is undergoing an upgrade and scheduled for completion in 2017. This MFC PIDAS installation has been operational and in place for several years.

Estimates provided by the IST indicate that for the two options being considered at INL (*i.e.,* modification of the Fuel Processing Facility, constructed in the early 90s, and a new green field constructed facility), both alternatives require support building(s) for non-nuclear activities inside the protected area. Both alternatives also require that approximately 2,600 linear feet of PIDAS or PIDADS will be required, including pedestrian and vehicular access points.

Review Process:

The review process consisted of INL completing a questionnaire provided by the IST for items considered important to the success of a pit manufacturing operation. For the PIDADS section this form is identified as MPA-AoA-INL-03.

Discussion:

Based on the experience and continuing operation of the PIDAS surrounding the MFC secured structure INL has clearly demonstrated that they are capable of operating a security perimeter protection system required to protect a pit manufacturing facility.

Preliminary Risk Considerations:

Two pertinent risks could have a significant effect on plutonium operations.

1. If the design basis threat changes, this could require potentially large expenditures to reconfigure the physical security infrastructure, with unknown delays to and cost for the pit production program. This would also affect other facilities and operations at INL. Based on experience, there is a high probability that security requirements could change during development and qualification for the pit production process. The costs could vary from small to very large, so the risk level remains indeterminate but could well be high or very high. This is not a site-specific risk.
2. There is always the possibility that INL will have to be shut down for an unknown duration in response to some future threat. This would lead to delays in pit production of unknown length and likewise unknown cost. Any other site would face the same risk, so this is not a discriminator between sites.

A.4.1.4 Standards and Calibration

Objective:

The objective of the review of the Standards and Calibration Laboratory is to determine if INL has the capability and capacity needed to support the production of 80 ppy by the year 2030.

Facility Description:

INL's Standards and Calibration Laboratory functions are performed in a facility built in 1969. This facility has undergone multiple additions and renovations and is approximately 10,500 ft^2. In addition, heating, ventilation, and air conditioning upgrades have occurred to provide the proper controlled environment as required to support an accredited calibration laboratory. INL's management has described the facility has having adequate temperature, and vibration controls.

The Standards and Calibration Laboratory is accredited to ISO/IEC 17025:2005, and ANSI/NCSL Z540-1-1994 standards in several categories of instruments including dimensional; mechanical; electromagnetics; time and frequency; and thermodynamics.

Review Process:

The review process consisted of INL completing a questionnaire provided by the IST for items considered important to the success of a pit manufacturing operation. For the Standards and Calibration section this form is identified as MPA-AoA-INL-13.

Discussion:

As reported the Standards and Calibration Laboratory has capability, experience, and is accredited in many disciplines. The calibration laboratory will be allocated 500 ft^2 of laboratory space within the pit manufacturing processing area to perform a verification, after calibration intervals have expired, that the contaminated instruments still meet the accuracy requirements. This verification provides confirmation that prior completed product was tested with accurate instruments, and is a requirement of the Weapon Quality Program NAP-24.

Based on the information provided it is concluded that the laboratory has the capability to support a pit manufacturing production program at a rate of 80 ppy. Whether the Standards and Calibration Laboratory has the capacity to support pit manufacturing is unknown. There are several possible solutions that could be applied if capacity becomes an issue. First, there are many qualified and accredited commercial calibration laboratories available to assist with the added volume of instruments; and second, another shift could be added.

Preliminary Risk Considerations:

No risks were identified other than those that are very low.

A.4.1.5 Waste Treatment and Management

Objective:

The objective of the review of the various waste treatment and management systems at INL is to determine if sufficient capability and capacity exists to accommodate the treatment, management, and disposition of liquid and solid waste generated as a result of the production of 80 ppy by the year 2030. INL used the MPF study for estimating waste generation volume, SRS-SLD-G-FRD-X-00010, dated May 5, 2004.

A.4.1.5.1 Solid Low Level Radioactive Waste

Facility Description:

INL has five solid LLW operational locations within the MFC and INTEC complexes. INL has stated that LLW is currently stored in cargo containers pending processing and shipment to authorized offsite disposal sites.

Review Process:

The review process consisted of INL completing a questionnaire provided by the IST for items considered important to the success of a pit manufacturing operation. For the Solid Low-Level Waste area, this form is identified as MPA-AoA-INL-09.

Discussion:

In 2016 approximately 80 semi-loads of solid low-level waste were shipped from INL to authorized disposal and treatment facilities. INL identified that, except for needing additional cargo containers, no additional facilities or equipment will be required to accommodate 80 ppy.

A.4.1.5.2 Solid Transuranic Radioactive Waste

Facility Description:

The solid TRU waste is processed at INL in a dedicated waste processing facility capable of processing 250 cubic meters of solid TRU waste per month. Due to programs in place this capacity is expected to be fully utilized up through year 2021.

Review Process:

The review process consisted of INL completing a questionnaire provided by the IST for items considered important to the success of a pit manufacturing operation. For the Solid TRU Waste section this form is identified as PMA-AoA-INL-10.

INL's estimated generation rate for the 80 ppy mission is approximately 28 cubic meters per month and is estimated to start waste generation in 2026 at the earliest.

Discussion:

INL stated that after year 2021 some of the existing INL workload is expected to taper off, and that adequate facility, equipment, and processing capacity should be available to support the pit manufacturing mission of 80 ppy.

A.4.1.5.3 Liquid Low-Level Radioactive Waste

Facility Description:

The INL's Liquid Low-Level Radioactive Waste Facility located within the MFC area is a 5,400-ft^2 structure capable of processing 3,000 gallons per month. The facility was constructed in 1983 and is estimated to have approximately 50 years of operating life remaining. The facility also has capability to accept tanker trucks should that be required for emergency storage.

Review Process:

The review process consisted of INL completing a questionnaire provided by the IST for items considered important to the success of a pit manufacturing operation. For the Liquid LLW treatment plant this form is identified as MPA-AoA-INL-01. INL used the MPF study to determine that the estimated waste generation rate to support an 80 ppy capability. When added to the other site requirements the capacity is exceeded requiring modification to the facility to increase output.

Discussion:

INL identified that when the facility was initially designed and built it was intended that its capacity could be doubled with relative ease. Floor space and tankage were doubled to permit expected increases in demand. Modifications are minor thru the installation of additional filter banks, shielded hot air drum evaporators, and a modified control system.

INL anticipated that the demand for liquid low waste would be increasing and provided a facility that can be easily modified to accommodate a pit manufacturing operation.

A.4.1.5.4 Liquid Transuranic Waste

Facility Description:

The INL site does not currently have a dedicated Facility to process liquid TRU waste since the site no longer generates that waste form. In the past when INL generated liquid TRU waste it was treated and stabilized in several permitted locations within the site.

Review Process

The review process consisted of INL completing a questionnaire provided by the IST for items considered important to the success of a pit manufacturing operation. For the Liquid TRU Radioactive Waste Facility this form is identified as MPA-AoA-INL-02.

Discussion:

INL's waste management organization reviewed the 2005 MPF waste study to determine the generation rate for the aqueous option adjusted for 80 ppy. INL concluded that liquid TRU waste would be generated and will require processing and solidification.

INL stated that based on the MPF study the estimated volume generated could be accommodated within existing permitted facilities. While INL projected no additional facilities, they did state that additional equipment would be needed to perform the solidification process.

Preliminary Risk Considerations:

1. WIPP experiences an event that causes it to be shut down for a sufficiently long time that TRU waste storage at INL becomes full. Pit production shuts down for a period of months to years. At the time of writing, WIPP has been closed for 3 years and has only recently reopened. Another such shutdown cannot be ruled out. This scenario could be mitigated by using and/or building extra TRU-waste storage capability at INL and so should be low.
2. WIPP experiences another event that causes it to be shut down. After it comes back on line, additional safety and regulatory constraints mean that it accepts and processes shipments at a much slower rate than before the event. This processing rate may be insufficient to accept TRU waste generated by 80 ppy, especially if increased by enhanced TRU waste production by the dilute and dispose activity, so that after some years TRU waste storage at INL becomes full and pit production ceases. This scenario is also realistic because, now that WIPP has come back on line after its current shutdown it is accepting and processing shipments for final disposal at a lower rate than before. Similar or perhaps even more onerous restrictions are likely in the event of a future shutdown. This risk is medium to high.
3. WIPP becomes full and is no longer able to accept solid TRU waste. Solid TRU capacity at INL also becomes full and pit production shuts down. Additional TRU waste disposal capacity at WIPP or elsewhere may be required to support the 80 ppy capacity and, if implemented, the extra TRU waste generated if 34 metric tons of moxable plutonium is treated via dilute and dispose. The IST's initial assessment of this risk was high, but, as is discussed in Appendix E, on further consideration it was assessed to be low. This is in part because it is assumed that, in the event of WIPP becoming full, further storage capacity will be developed there.

A.4.1.6 Miscellaneous

This section contains information on several activities that are needed to support pit production, but would not be expensive to implement (relative to the total cost of a pit production facility). If they are not already be available at INL they could readily be outsourced.

A.4.1.6.1 Classified Beryllium (Be) Machining

INL currently has no classified Be machining capability. This information was previously conveyed to the IST in January 2017. It is expected that, if needed, classified Be parts can be obtained through procurement from qualified suppliers or from LANL.

Preliminary Risk Considerations:

No risks were identified other than those that are very low.

A.4.1.6.2 Classified Stainless Steel Machining

Objective:

The objective of the review of INL's classified stainless steel capability is to determine if sufficient capacity exists to accommodate the machining of stainless steel component parts required to support the production of 80 ppy by the year 2030.

Facility Description:

Stainless steel machining is carried out in several locations throughout the INL site. It appears that there are several small machine shops distributed throughout the site supporting various projects with test articles, fixtures, and maintenance items. There does not appear to be a centralized secure location to provide the machining needs for the pit manufacturing project.

Review Process:

INL responded that collectively they have about 50 machinists and operators in the total site population.

Discussion:

Based on INL's response there are several small machine shops scattered throughout the site. While there appear to be no central shop a facility for stainless-steel machining, capability can easily be established if needed. The facility requirements would include a secured conventional manufacturing building with overhead crane, process air, CNC mills and lathes and jig bore, CNC tube bender, and a coordinate measuring machine.

Preliminary Risk Considerations:

No risks were identified other than those that are very low.

A.4.1.6.3 Classified Graphite Machining

Review Process:

INL currently has no classified graphite machining capability. This information was previously conveyed to the IST in January 2017. It is expected that, if needed, classified graphite parts can be obtained through procurement from qualified suppliers or from another DOE site.

Discussion:

Development of a graphite machining center to support pit manufacturing would require a conventional manufacturing building within a secured area. The building would require a robust ventilation and graphite dust collection system equipped with conventional CNC lathes and CNC mills as well as inspection equipment such as a coordinate measuring machine to measure multi-axis shapes.

Other alternatives to consider include procuring from a qualified supplier with a secure facility or have the Kansas City Plant provide the non-nuclear items.

Preliminary Risk Considerations:

No risks were identified other than those that are very low.

A.4.1.6.4 Classified Uranium Machining

Objective:

The objective of the review of classified uranium machining is to determine INL's capability to process and machine uranium to support a pit manufacturing operation.

Review Process:

The review process consisted of INL completing a questionnaire provided by the IST for items considered important to the success of a pit manufacturing operation. For the classified uranium machining section, this form is identified as MPA-AoA-INL-06.

Discussion

INL has extensive experience with machining uranium and uranium alloys. INL is currently performing work on a production basis at their Test Area North Special Manufacturing Capability facilities. INL's experience also includes machining enriched uranium but it is currently limited in quantity.

If uranium products are required to support the pit mission and are produced at INL, then proper facilities will be required to process the required quantities. Currently the assumption for the prospective pit mission is that uranium products will be supported by Y-12.

Preliminary Risk Considerations:

No risks were identified other than those that are very low.

A.4.1.6.5 Graphite Coating

Overview:

INL currently has no graphite coating capability. This information was conveyed to the IST in January 2017 by Misty Benjamin, INL.

Discussion:

Development of a graphite coating center to support 80 ppy would require a secure conventional manufacturing building and a conventional paint spray booth. Conventional paint spraying equipment is also required along with coating preparation and mixing areas and chemical storage.

Preliminary Risk Considerations:

No risks were identified other than those that are very low.

A.4.2 Plant Core Infrastructure

This section addresses those items of plant core infrastructure that are needed by the 80 ppy manufacturing process.

A.4.2.1 Security Category 1 Facility Support

Objective:

The objective of the review is to determine if the INL has in place a Security Category 1 process to support the requirements of a pit manufacturing facility. INL has been operational since 1949 and has performed several vital roles in support of nuclear reactor research, nuclear weapons production and the Naval reactor research programs. Security has been a significant and important element of the successful performance of their mission since INL is required to protect all types of nuclear materials, including SNM, government property, weapon products, and personnel.

Review Process:

The review process consisted of INL completing a questionnaire provided by the IST. For the Security Category 1 facility support section this form is identified as MPA-AoA-INL-15. Additionally, the analysis was assisted by briefing materials presented to the AoA orientation team by security management during the week of April 25, 2017.

Discussion:

INL is required to follow and be compliant with DOE Order 473.3, Protection Program Operations. This Order establishes requirements for the management and operation of the protection program forces and contractor protective forces, and for physical security under the cognizance of DOE.

INL has implemented policies and procedures governing the security for all requirements as specified within DOE Order 473.3. These requirements include protective forces, physical protection of facilities, buildings, Government property, and employees, as well as national security interests such as classified information, SNM and other elements of the nuclear weapon programs.

To ensure the requirements are in place and being properly executed several levels at DOE routinely perform independent assessments. These include the INL Field Office and other jurisdictions, such as the Office of Inspector General. Based on the determination that satisfactory safeguards and security policy and facility measures are in place, DOE permits the site to operate accordingly. Contractors perform periodic self-assessments to verify compliance, in addition to DOE.

No issues were identified within the security system that would prohibit the assignment of the pit manufacturing mission to INL.

A.4.2.2 Electrical Power

Objective:

The objective of the INL normal/off-normal electrical power review is to determine if sufficient power is currently available or planned to support a pit manufacturing facility capable of producing 80 ppy by the year 2030.

Review Process:

The review process consisted of INL completing a questionnaire provided by the IST for items considered important to the success of a pit manufacturing operation. For the normal/off normal electrical power section this form is identified as MPA-AoA-INL-16. In addition, the INL Site Wide Utilities organization prepared a briefing describing the overall electrical capabilities, including power generation sources and distribution system.

Discussion:

The INL Site Services organization responded to the IST questionnaire by providing data on electrical power capacity and describing upgrades currently taking place and planned for the site. The site currently has three commercial feeds providing a capacity of 63 megawatts distributed to nine major substations. Currently several upgrades to major elements of the system are underway to provide an additional 50-megawatt capacity and to extend the systems life expectancy for an additional 40-50 years.

It should be noted that currently the power or other utility requirements needed for the pit manufacturing facility have not been fully determined. INL's utilities management is confident that with the upgrades currently planned there would not be any power supply issues.

While there is sufficient power at the site to support a pit manufacturing facility, to ensure redundancy and to provide a comfortable safety margin, power redistribution from lower demand areas to any proposed pit manufacturing area should be considered.

A.4.2.3 Other Utilities

The IST did not review the other utilities at INL.

A.4.2.4 Medical Facility

INL does not have a centralized medical facility on site but does have distributed emergency first aid capabilities in major locations, such as MFC and Central. Emergency Medical Technicians are assigned throughout the site and are capable of providing medical assistance and patient stabilization along with emergency vehicles to provide transport. INL primarily relies on the local community hospital in Idaho Falls. These groups providing medical assistance are trained and qualified to address alpha contamination.

A.4.2.5 Environmental Monitoring

INL is committed to environmental protection, environmental compliance, pollution prevention, and continual improvement. To implement this policy INL has developed a comprehensive environmental management program to ensure the protection of air, water, land, biota, and other natural, archaeological, and cultural resources

INL's environmental policy is implemented throughout the site by DOE's primary contractors (Fluor and the Battelle Energy Alliance). These contractors are provided the resources and are responsible to monitor, prevent, and report environmental conditions throughout the site. In addition to the normal DOE oversight the State of Idaho provides independent monitoring of the Laboratory through their Department of Environmental Quality.

A.4.2.6 Sanitary Waste Facility

The IST did not review the sanitary waste facilities at INL.

A.4.3 Operating Infrastructure

This section addresses the various items of operating infrastructure that are needed to operate the proposed 80 ppy manufacturing facility through the year 2030.

A.4.3.1 Production Control System

Production control processes are currently being applied to weapon products manufactured at INL. The system has produced over 8,000 units but is likely to need modification to accommodate the differences in the products between the current mission and the fabrication operations and assembly processes of parts required to produce a plutonium pit. If INL is selected as the pit manufacturing site there will be sufficient time to make the necessary changes as required.

A.4.3.2 Manufacturing policy document

Manufacturing policy documents are required by the NQA-1, 2000, standard adopted by INL and include conduct of operations, quality assurance processes, specific procedures to conduct manufacturing operations (i.e., material requirements planning, procurement, and material control). These documented processes provide the basis for conducting business and producing quality products in a nuclear environment.

A.4.3.3 Material Control System

Material control systems are essential and required to ensure manufactured items meet design requirements. Control of the procurement process and procured items and services are intended to prevent unqualified suppliers and nonconforming parts and materials from entering the manufacturing process. INL has implemented ASME NQA-1-2000 as their product quality standard. The necessity for strict control of items is clearly specified in Requirements 7 and 8 of the quality standard. INL has stated that their quality record is demonstrated by a high level of customer satisfaction. INL would have to adapt their current quality system to accommodate NAP-24.

A.4.3.4 Safeguards and Accountability

INL has responsibility for processing, storing, and maintaining nuclear materials and SNM. To manage and administer the SNM program the site has developed process and procedures consistent with DOE Order 473.3, *Protection Program Operations*. INL's Safeguards & Security Nuclear Materials Control and Accountability system contains processes to administer and control a compliant SNM management program.

These SNM processes are routinely assessed by the site contractor and are routinely audited and assessed by the DOE Field Office, Headquarters, and the Office of Inspector General.

A.4.3.5 Qualified Operators and Technicians

Requirements for operational training and qualification of personnel for manufacturing product are addressed in NQA-1-2000, Requirement 2, Indoctrination and Training. Nuclear safety training for site workers is specified within the INL Standardized Nuclear Safety Basis Manual, TOC-682, Section SAR-400-12, Chapter 12. The objective of INL's training program is to provide and ensure initial proficiency, maintain proficiency and adapt to changes in technology, methods, or job responsibility. As previously mentioned, INL's management believes that a qualified workforce can readily be obtained from the local area to support a proposed pit production effort.

A.4.3.6 Weapons Quality Program

The INL is responsible for manufacturing and supporting the military with quality products and has done so for over 20 years. The quality standard adopted by INL is ASME NQA-1-2000, which is comprehensive and comparable to DOE Weapon Quality Policy, NAP-24A, published in 2015. This American Society of Mechanical Engineers standard is thorough and INL will have no difficulty adapting its systems and processes to a nuclear weapon mission.

Appendix B. Infrastructure Siting Analysis

B.1 Introduction

A number of potential sites at which the 80 pits per year (ppy) manufacturing capability, or portions thereof, might be placed were analyzed. The sites were analyzed to determine available infrastructure, siting risk, and political risk, with a view to choosing the most promising candidates for further study.

The Analysis of Alternatives (AoA) team began by considering a list of 13 Department of Energy (DOE) sites at which it might be possible to place some or all of the facilities that are needed to meet the requirement to manufacture 80 War Reserve pits per year, while also preserving all other necessary activities that are essential for the plutonium sustainment mission. Based on the evaluation as described in this chapter, the team settled on an initial short list of the three most promising candidates: Los Alamos National Laboratory (LANL), the Savannah River Site (SRS), and Idaho National Laboratory (INL). In addition, the team identified two other backup sites that potentially could be considered for the plutonium pit mission: Pantex Plant (Pantex) and the Nevada National Security Site (NNSS). In order to separate the most promising sites from the initial list, the team gathered data from site representatives to determine which of relevant capabilities each site had. The categories listed below are discussed in more detail in Section B.2.1.

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

In addition, the AoA team evaluated siting risks, such as proximity to nearby populations and predominant wind directions, and conducted a preliminary and subjective assessment of political risk. This included the presence of political tensions between DOE/National Nuclear Security Administration objectives and elected officials, in addition to local opposition groups and ongoing litigation.

The remainder of this chapter describes how data were collected and qualitative analyses were performed to finalize a short list of sites to be analyzed in detail for the pit production mission.

B.2 Support Infrastructure Capability Analysis

The AoA team evaluated a comprehensive list of DOE sites, even though some of them could probably have been eliminated by cursory review (e.g., Brookhaven National Laboratory [BNL] and the Kansas City National Security Campus [KCNSC]). This might seem excessive, but it was done to ensure a comprehensive defensible, thorough, and systematic approach to the siting analysis. The sites selected for evaluation were:

- LANL
- SRS
- Pantex
- NNSS
- Lawrence Livermore National Laboratory (LLNL)

- Y-12 National Security Site (Y-12)
- Oak Ridge National Laboratory (ORNL)
- Waste Isolation Pilot Plant (WIPP)
- Hanford Site
- INL
- BNL
- KCNSC
- Sandia National Laboratories (SNL) – Albuquerque

A greenfield site (an undeveloped or agricultural track of land) was included for completeness, but was not defined as a specific location. By definition, a greenfield site would not have any of the supporting infrastructure present to support a new pit production capability, so its infrastructure was not investigated. Likewise, with no specific location defined many risk elements (*e.g.,* nearby populations) could not be evaluated, so risk was not assessed for the greenfield site.

B.2.1 Assembly of Site Infrastructure Data

This sub-section describes the data that were collected by the Infrastructure Sub-Team (IST) to determine support infrastructure needs, namely (1) capital items and functions, (2) operating infrastructure, and (3) plant core infrastructure. This collection effort began when the AoA team visited LANL in September 2016. For a week the team held discussions with the management and operators of the significant infrastructure items and functions, with follow-up teleconferences and visits as required. Appendix A.2 includes a report of that visit.

In April 2017 the IST met again at SRS, after which the team prepared a report on SRS infrastructure (see Appendix A.3). In May, the AoA team visited INL. The report on INL infrastructure is in Appendix A.4. In addition, the sub-team sent out a questionnaire asking each site to self-report on which items of infrastructure are located there and which are not. **Table B–1** lists site representatives and sources of data for each site. These questionnaires provided the basis for the final short list of sites – LANL, SRS, and INL – as well as NNSS and Pantex.

Table B–1. Site representatives and references

Site	Site Representative	References
LANL	Bob Putnam	Appendix A-2
SRS	Jennifer Rice	Picha (2017a) and Appendix A-3
Pantex	Larry Backus	Andrews (2016a)
NNSS	Joel Leeman	Leeman (2017)
LLNL	Mark Bronson	Bronson (2017)
Y12/ORNL	Tom Insalaco	Picha (2017b) and Andrews (2016b)
WIPP[a]	Kenneth Picha/IST	Picha (2017c)
Hanford/PNNL	Kenneth Picha	Picha (2017d)
INL	Misty Benjamin	Benjamin (2017) and Appendix A-4
BNL[b]	Todd Lapointe/IST	Verbal
KCNSC	Greg Enserro	Picha (2017e)
SNL-Albuquerque	Phil Chamberlain	Andrews (2017)
Greenfield	None	None

[a] DOE Office of Environmental Management (Picha 2017e) submitted that WIPP has no capabilities in this area. However, the IST has independent knowledge that there are some relevant infrastructure capabilities.

[b] The IST did not receive a written response from BNL.

B.2.1.1 Capital Items and Functions

Capital items and functions refer to the necessary infrastructure that, if missing or inadequate to support the manufacture of 80 ppy, would require potentially significant capital expenditures. They include the following:

- Low-level liquid radioactive waste treatment
- Transuranic (TRU) liquid waste treatment
- Low-level solid waste packaging, storage, and shipping
- TRU solid waste packaging, storage, and shipping
- PIDADS/Access control
- Classified machining (beryllium, uranium, stainless steel, graphite)
- Graphite coating
- Analytical chemistry
- Materials characterization
- Standards and calibration
- Cold machine and tooling shop

Table B–2 provides the results of the data collection effort in this area.

Table B–2. Availability of capital items and functions at each candidate site

Site	Capital Items and Functions												
	Low-level liquid rad waste treatment	TRU liquid waste treatment	PIDADS/Access control	Classified beryllium 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	Analytical chemistry and materials characterization	Standards and calibration lab	Cold Machine and tooling shop
LANL	√	√	√	√	√	√	√	√	√	√	√	√	√
SRS	√	√	√		√	√	√		√	√	√	√	√
Pantex			√		√		√		√			√	√
NNSS			√		√		√		√	√		√	√
LLNL	√	√			√	√	√	√	√	√	√	√	√
Y12/ORNL			√	√	√	√	√	√	√	√[1]	√	√	√
WIPP[1]									√	√			L
Hanford/PNNL	√		√						√	√	L[2]		
INL	√	√	√		√	√			√	√	√	√	√
BNL[3]									√		L	L	
KCNSC					√								√
SNL-Albuquerque			√						√		L	√	
Greenfield													

√	Site has capability
L	Site has limited capability

1. DOE Office of Environmental Management submitted that WIPP has no capabilities in this area (Ref. 9). The chart reflects the Infrastructure Sub-team's independent knowledge of WIPP.
2. Hanford utilizes PNNL capability per Bob Putnam (LANL).
3. The Infrastructure Sub-team received no written response for BNL.

PIDADS = Perimeter Intrusion, Detection, Assessment, and Delay System; TRU = transuranic.

B.2.1.2 Operating Infrastructure

The IST determined whether each of the candidate sites has operating infrastructure (defined by the following list):

- Production control systems
- Manufacturing policies, procedures, and training system (quality)
- Materials control systems
- Safeguards and accountability systems
- Qualified operators and technicians
- NAP-24 Weapon Quality Policy
- Certified materials (e.g., gasses, in-process supplies)

As was done for capital items and functions, this information was obtained by sending a questionnaire to each site. For LANL, SRS, and INL, infrastructure information was also obtained by visiting the site. The results are shown on **Table B–3.**

Table B–3. Availability of operating infrastructure at each candidate site

	Operating Infrastructure					
Site	Production control system	Manufacturing policies, procedures and training system (quality)	Materials control system	Safeguards and accountability systems	Qualified operators and technicians	NAP-24, Weapon Quality Policy, certified materials (gases, in process supplies, etc.)
LANL	√	√	√	√	√	√
SRS	√	√	√	√	√	√
Pantex	√	√	√	√	√	
NNSS		√	√	√	L	
LLNL			√	√	√	√
Y12/ORNL	√	√	√	√	√	√
WIPP[1]	√	L			√	
Hanford/PNNL			√	√		
INL	√	√	√	√	√	
BNL						
KCNSC	√	√	√	√	√	√
SNL-Albuquerque	√	√	√	√	√	√
Greenfield						

√	Site has capability
L	Site has limited capability

1. DOE's Office of Environmental Management submitted that WIPP has no capabilities in this area. The chart reflects the Infrastructure Sub-team's independent knowledge of WIPP.

B.2.1.3 Plant Core Infrastructure

The IST determined whether each of the candidate sites has plant core infrastructure I (defined by the following list):

- Security Category I facility support
- Normal and off-normal power systems and supply, including a redundant power source
- Normal utility support – *i.e.*, gas and water
- Medical facilities capable of handling alpha-contamination
- On-site and off-site environmental monitoring
- A sanitary wastewater facility

As was the case for the capital items and functions and the operating infrastructure, this information was obtained by sending a questionnaire to each site. The results are shown on **Table B–4.**

Table B–4. Availability of plant core infrastructure at each candidate site

Site	Plant Core Infrastructure					
	Security Category 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)	Sanitary wastewater facility
LANL	√	√	√	√	√	√
SRS	√	√	√	√	√	√
Pantex	√	√	√	√	√	√
NNSS	√	√	√	√	√	√
LLNL		√	√	√	√	
Y12/ORNL	√	√	√	√	√	√
WIPP[1]		√	√	√	√	√
Hanford/PNNL	√		√	√	√	√
INL	√	√	√	√	√	√
BNL			√		√	
KCNSC		√	√		√	√
SNL-Albuquerque	√ (?)	√	√	√	√	
Greenfield						

√ Site has capability

L Site has limited capability

1. DOE Office of Environmental Management submitted that WIPP has no capabilities in this area. The chart reflects the Infrastructure Sub-team's independent knowledge of WIPP.

At this stage, it is possible to develop a simplified listing of the desirability of sites based solely on the number of green boxes along each row, summed across all three tables, as follows:

- **Favorable:** LANL, SRS, Y-12/ORNL,[1] and INL
- **Neutral:** Pantex, NNSS, LLNL, and SNL
- **Unfavorable:** Hanford, WIPP, BNL, KCNSC, SNL-Albuquerque

B.3 Siting Risk Analysis

This section describes the criteria selected to determine the siting risk (*i.e*., characteristics of the site that tend to increase the societal, individual, and/or environmental risk). Risk determinations are subjective and could in theory be changed as a result of further discussion or the availability of additional data. The description of risk criteria is followed by a description of the sources consulted to obtain data pertinent to each criterion. Finally, the results of the subjective risk analysis are presented in tabular form.

B.3.1 Factors Considered

The following factors were considered in making a subjective evaluation of the risk associated with siting the pit manufacturing capability (or parts thereof) at each of the candidate sites.

- **Area of the site:** Site size is important because if the site is small, the manufacturing facility cannot be placed far away from the site boundary. This would tend to contribute a relatively large amount to site risk should there be people living at or near the site boundary. The arbitrary criteria chosen for this analysis are that a small site, with relatively high risk, has an area of less than 10 square miles. A large site, with a relatively low risk, has an area exceeding 100 square miles. Any site with an area in the range 10-100 square miles will be characterized by the rather imprecise term "moderate," i.e., it makes a moderate contribution to site risk.
- **Relevant site information within five miles:** Miscellaneous items of information are collected under this heading, 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 it or there is a lake or other sensitive environmental area). On the basis of these considerations, a purely subjective judgement is made as to whether the factors within five miles make a low, moderate, or high contribution to siting risk.
- **Nearby centers of population:** A few representative cities or towns are chosen and their population, distance, and direction are tabulated. Again, a subjective assessment is made of whether these are potentially low, moderate, or high contributors to siting risk.
- **Population within 50 miles:** Population within 50 miles is estimated because, in environmental impact statements and other siting analyses, this population is often used as the basis for estimates of population radiation dose, either for routine operation or hypothetical accident scenarios. Again, an arbitrary range is chosen: the potential contribution to overall site risk is 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:** The wind rose(s) for each site are obtained. If the predominant wind direction is towards nearby residents and/or major centers of population this is viewed as

[1] Y-12 and ORNL are combined on the grounds that, if pit manufacturing were to be sent to Oak Ridge, capabilities at both facilities would be used.

increasing overall site risk. If it blows away from populated areas, it is regarded as a relatively low contributor to site risk.

B.3.1.1 Sources of Site Risk Data

The principal sources of data were:

- **Site fact sheets:** found on the Department of Energy's web site, energy.gov. This proved to be a particularly reliable source for site areas.
- **The Missouri Census Data Center**: http://mcdc.missouri.edu/websas/caps10c.html. This is a free source for the population in circles with user-chosen radii for any site in the country, based on 2010 census data.
- **"Suburban Stats:"** at https://suburbanstats.org/population/ provides the population of any city in the country, also based on 2010 census data.
- **NEPA documents:** Environmental impact statements, Environmental Assessments, and Annual Site Reports. These are good sources for wind roses, some maps, some population data, and where candidate buildings for the pit manufacturing capability (if any) are located.
- **Google Maps and satellite imagery:** useful for estimating as-the-crow-flies distances and assessing the nature of the surroundings (e.g., farming, forested, urban, industrialized).

Based solely on the number of red or green cells in each row of Table B–5 one can make a rough ranking of the sites:

- Favorable: SRS, Nevada, Hanford, INL, WIPP.
- Neutral/moderate: LANL, ORNL, and SNL.
- Unfavorable: LLNL, Y-12, BNL, and KCNSC.

A couple of observations are pertinent. First, 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 some four miles from the nearest residents. Second, the relative ranking of LANL is moot because, since it is the only site at which it is currently possible to manufacture a pit, it has been "grandfathered" in.

B.3.2 Results of the Siting Risk Analysis

Table B–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 PF-4, the city of Los Alamos lies about 1.3 miles due N. In other directions 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., towards Los Alamos NW-SW (night)	Moderate
SRS	310/200,000	Within site (measured from F-Area, site of Mixed Fuel Fabrication Facility)	Jackson, SC Augusta, GA Aiken, SC	1,700 196,000 30,000	7 20 18	NW NW N	790,000	W Not towards cities listed to 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 to left	High
Y-12	1.25/811 at NE corner of ORR (52/33,500)	Nearest houses ~1,500' 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 towards center of ORR (52/33,500)	Nearest houses ~ 4 miles 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
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 towards nearby cities	Low

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			
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 towards nearby cities	Low
BNL	8/5,000	~13,000 people within one mile of site boundary; population within 5 miles ~67,000.	Brookhaven Township	~486,000	Occupies ~530 mi² around site	Surrounds site	5,200,000	Westerly	High
KCNSC	0.29/186	Nearest houses ~ 0.3 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 Air Force Base (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, towards Rio Grande Valley and SW Albuquerque metropolitan area.	moderate

B.4 Political Risk Assessment

The AoA team also considered political risk. This, of course, is highly subjective. In assessing whether political risk is high, moderate, or low the team asked whether there was a history of political protest or interference at or near a site. A specific example of a site that ultimately did not make the short list is Brookhaven., There was significant public and legislative resistance to the proposed Shoreham nuclear reactor (which was 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. In that case, it is clear that the political risk is high or even very high. 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 subjective risk analysis are displayed in **Table B–6.**

Table B–6. Subjective political risk analysis

Site	Severity of Political 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 Native American reservations within 50 miles of the site, and the Bandelier National Forest is nearby (a few years ago a fire there almost encroached upon Technical Area 55). On the other hand, one would expect many members of the local population to welcome new jobs and expenditures. On balance, the political risk is moderate.
SRS	Moderate	There has been considerable controversy, including law suits, over the Mixed Fuel Fabrication Facility. However, this is also another site where one would expect many members of the local population to welcome new jobs and expenditures. On balance, the political risk is moderate.
Pantex	Low	There is little history of conflict with neighbors. Pantex already handles pits.
NNSS	Low	Remoteness and size of site are considerable plusses. However, the low severity of political risk could be revised upwards if, for example, there is any residual conflict arising from the Yucca Mountain controversy.
LLNL	High	Large numbers of people live nearby. There has been intentional reduction of the amount of plutonium at LLNL, 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.
ORNL	Moderate	Likely to be lower than 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, use would likely be made of both Y-12 and ORNL and it would be difficult to disentangle the political risk associated with what would not really be separate sites.
WIPP	Low	Extremely remote location, but would possibly require either revision of the Land Withdrawal Act or a new act to be passed.
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 that might make it difficult to establish new activities that require bringing plutonium onsite. On balance, the political 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. There is likely to be an outcry over the possibility of bringing plutonium 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.

In a way similar to that already done for the site infrastructure and the siting risk analysis, it is possible to develop a rough ranking of the sites from Table B–6.

- Favorable: Pantex, NNSS, and WIPP
- Neutral: LANL, SRS, Y-12/ORNL, INL, and SNL
- Unfavorable: LLNL, Hanford, BNL, and KCNSC

B.5 Summary and Conclusions

In this section, the results are summarized and an assessment of site suitability is made in two ways: a) from a high level, by simply a visual assessment of a composite table that summarizes infrastructure, siting risk, and political risk; and b) by adopting two simple, semi-quantitative ranking processes.

B.5.1 High Level Assessment

As noted above, each of the candidate sites was evaluated from the three perspectives of support infrastructure, siting risk, and political risk. For the siting risk and political risk, each site is assigned to the low, moderate, or high category using the results in Tables B–5 and B–6. For the support infrastructure, in order to be consistent with the risk rankings (so that the least favorable sites are ranked "high" and the most favorable are ranked "low"), the authors used an "unfavorability" ranking, derived from the conclusions at the end of Section B.2.1.3, namely:

- Favorable: LANL, SRS, Y-12/ORNL, and INL – low "unfavorability,"
- Neutral: Pantex, NNSS, LLNL, and SNL, – moderate "unfavorability," and
- Unfavorable: Hanford, WIPP, BNL, KCNSC, SNL-Albuquerque – high "unfavorability."

Table B–7 summarizes those assignments, with green for low/favorable, yellow for moderate/neutral, and red for high/unfavorable.

Table B-7. Summary of Site Risk Rankings

Site	Support Infrastructure Unfavorability Ranking	Siting Risk	Political Risk
LANL	Low	Moderate	Moderate
SRS	Low	Low	Moderate
Pantex	Moderate	Low	Low
NNSS	Moderate	Low	Low
LLNL	Moderate	High	High
Y-12[a]	Low	High	Moderate
ORNL	Low	Moderate	Moderate
WIPP	High	Low	Low
Hanford	High	Low	High
INL	Low	Low	Moderate
BNL	High	High	High
KCNSC	High	High	High
SNL	Moderate	Moderate	Moderate

Adopting subjective criteria, any sites with two or more high rankings are least preferred: LLNL, Hanford, BNL, and KCNSC. The most preferred sites are those with two or more favorable rankings and no unfavorable rankings: INL, SRS, Pantex, and NNSS. As mentioned above, LANL is grandfathered in because it is the only site at which it is currently possible to manufacture pits. Thus, the simple subjective ranking adopted in this subsection leads to the selection of five potentially satisfactory sites: INL, SRS, Pantex, NNSS, and LANL.

It is recognized that the methodology used to derive rankings from Table B–7 is extremely simplified – for example, it gives equal weight to each of support infrastructure, siting risk, and political risk. In the following section, a somewhat more sophisticated ranking method is presented.

B.5.2 Semi-Quantitative Ranking Based on Placings

The first attempt the IST made to perform a more rigorous analysis than that presented in Section 4.5.1 was to determine which of the sites ranked first, second, third, and so on, in each of three categories: total infrastructure count, economic, and risk. The overall ranking was then determined by using a simple methodology in which the rankings were simply added, and the site with the lowest score ranked first, and so on.

Total infrastructure count: Table B–8 summarizes the content of Tables B–2, B–3, and B–4. It simply counts the number of items available in the three categories: a) capital items and functions (maximum possible 13, see Table B–2); b) plant core infrastructure (maximum possible 6, see Table B–3); and operating infrastructure (maximum possible 6, see Table B–4). These three numbers are then summed for each site (maximum possible 25) and the sites are ranked in the final column of Table B–8 on the basis of that sum.

Economic criterion: This criterion focuses on a subset of six infrastructure items that are particularly costly, so that if the site already has them it has an immediate advantage. These are low-level liquid waste treatment, liquid TRU waste treatment, analytical chemistry capability, solid low-level and TRU waste handling capability, PIDADS, and a Security Category 1 site security system. The IST's initial approach was to simply count how many of these six items each site has, and to rank them accordingly. Subsequently, the sub-team decided to change this approach, because the variation in the cost of the six items is so great that the sub-team concluded that this variation should be taken into account, by adopting the simple weighting scheme described below. Note, however, that the ranking of the top five sites was not significantly changed when the weighting scheme was used.

The estimated costs of each of the high value infrastructure items were based on the data gathered during the LANL visit (Appendix A.2) and are as follows: low-level liquid waste treatment, $80 million; liquid TRU waste treatment, $90 million; analytical chemistry capability, $50 million; solid low-level and TRU waste handling capability, $100 million; PIDADS, $250 million; and a Security Category 1 site security system, $1,000 million. If a site already has some or all of these systems, points are assigned as follows:

- Low-level liquid waste 1 point
- Liquid TRU waste 1 point
- Analytical chemistry 1 point
- Solid low-level and TRU waste 1 point
- PIDADS 3 points
- Category 1 site security system 10 points

If a site does not have a specific capability, its score for that capability is zero. The scores are then summed and the rankings of the sites determined on the basis of those scores, see Table B–9 with the maximum score being 17.

Risk criterion: The siting and political risk criterion is very simple. The score assigned for a low risk is 3, for a moderate risk it is 2, and for a high risk it is 1, for both siting risk and political risk (see **Tables B–5** and **B–6**). The two scores are then summed and the sites are ranked on the basis of that sum as shown in **Table B-10**, with the sites with the lowest scores ranking highest.

Overall ranking: **Table B–11** summarizes the rankings from **Tables B–8, B–9**, and **B–10**. The overall ranking is the sum of the three individual rankings – total infrastructure count, economic, and risk. The sites rank in the following order: SRS and INL, followed by Pantex and NNSS.

Table B–8. Ranking according to the total infrastructure count

	Capital Items and Functions	Plant Core Infrastructure	Operating Infrastructure	Total Infrastructure	Rank
	Items available/items required	Items available/items required	Items available/items required	Sum	
LANL[1]	13/13	6/6	6/6	25/25	
SRS	11/13	6/6	6/6	23/25	1
Pantex	6/13	6/6	5/6	17/25	5
NNSS	7/13	6/6	3/6	16/25	6
LLNL	11/13	4/6	4/6	19/25	4
Y12/ORNL	11/13	6/6	6/6	23/25	1
WIPP	2/13	5/6	2/6	9/25	10
Hanford/PNNL	4/13	5/6	2/6	11/25	9
INL	10/13	6/6	5/6	21/25	3
Brookhaven	1/13	2/6	0/6	3/25	11
KCNSC	2/13	4/6	6/6	12/25	8
SNL-Albuquerque	3/13	5/6	6/6	14/25	7
Greenfield	0/13	0/6	0/6	0/25	12

1. LANL excluded from ranking because it is grandfathered in, as explained above.

Table B–9. Ranking according to the economic criterion

	Liquid Low-Level Waste	Liquid TRU Waste	Analytical Chemistry	Solid Transuranic and Low-Level Waste	PIDADS	Category 1 Security System	Total Score	Rank
LANL[1]	1	1	1	1	3	10	17	
SRS	1	1	1	1	3	10	17	1
Pantex					3	10	13	6
NNSS				1	3	10	14	5
LLNL	1	1	1	1			4	8
Y12/ORNL			1	1	3	10	15	3
WIPP				1			1	9
Hanford/PNNL	1			1	3	10	15	3
INL	1	1	1	1	3	10	17	1
Brookhaven							0	10
KCNSC							0	10
SNL-Albuquerque					3	10	13	6
Greenfield							0	10

1. LANL excluded from ranking because it is grandfathered in, as explained above.

Table B-10. Ranking according to siting and political risk

	Siting Risk	Score	Political Risk	Score	Total Score	Ranking
LANL[1]	Moderate	2	Moderate	2	4	
SRS	Low	3	Moderate	2	5	4
Pantex	Low	3	Low	3	6	1
NNSS	Low	3	Low	3	6	1
LLNL	High	1	High	1	2	9
Y12/ORNL	High	1	Moderate	2	3	8
WIPP	Low	3	Low	3	6	1
Hanford/PNNL	Low	3	High	1	4	6
INL	Low	3	Moderate	2	5	4
Brookhaven	High	1	High	1	2	9
KCNSC	High	1	High	1	2	9
SNL-Albuquerque	Moderate	2	Moderate	2	4	6
Greenfield	Indeterminate	na	Indeterminate	na	na	12

1. LANL excluded from ranking because it is grandfathered in, as explained above.

Table B-11. Overall ranking by sum of placings

	Total Infrastructure	Economic	Risk	Total Score	Ranking
LANL[1]					
SRS	1	1	4	6	1
Pantex	5	6	1	12	3
NNSS	6	5	1	12	3
LLNL	4	8	9	21	9
Y12/ORNL	1	3	8	12	3
WIPP	10	9	1	20	8
Hanford/PNNL	9	3	6	18	6
INL	3	1	4	8	2
Brookhaven	11	10	9	30	11
KCNSC	8	10	9	27	10
SNL-Albuquerque	7	6	6	19	7
Greenfield	12	10	12	34	12

1. LANL excluded from ranking because it is grandfathered in, as explained above.

B.5.3 Alternative Methods of Ranking

In addition to evaluating each of the sites by their ranking in each of the major categories (i.e., Total Infrastructure, Economics, and Risk), it was recognized that decision makers might value each of these major categories differently. The team performed an analysis that applied a wide range of reasonable weighting factors to each of the major categories and reassessed the rank order of the sites. These evaluations found the top ranked sites (i.e., SRS, LANL, INL, Pantex, and NNSS) consistently remained in the top rankings regardless of the distribution of weights applied to the scores. These results provide confidence that the list of top ranked sites is robust.

B.6 Conclusion

The AoA team has examined the candidate sites for the 80 ppy plutonium manufacturing facility from the perspectives of capital infrastructure items, core plant infrastructure, operating infrastructure, siting risk, and political risk. The results of this examination have been combined using a number of different subjective and semi-quantitative methods to yield the following robust result. In addition to LANL, SRS and INL are promising candidate sites, with NNSS and Pantex as backups.

Appendix C. Detailed Description of Alternatives

The Analysis of Alternatives (AoA) team determined that the three most promising candidate sites for plutonium missions are Los Alamos National Laboratory (LANL), the Savannah River Site (SRS), and Idaho National Laboratory (INL). In addition, the team identified two additional sites that potentially could be used for parts of the plutonium mission, or for new build options: Pantex (PX) and the Nevada National Security Site (NNSS).

During the siting viability assessment, the team identified several existing Hazard Category 2, Security Category 1 facilities that might be viable for housing pit production or other plutonium missions:

- LANL: Plutonium Facility (PF-4)
- SRS: Mixed Oxide Fuel Fabrication Facility (MFFF), Waste Solidification Building (WSB), and K-Area Reactor
- INL: Fuel Processing Facility (FPF)

The team also identified both missions currently performed in PF-4 and portions of the pit production flow sheet that could potentially be moved to separate locations. These separable functions, as defined below, along with the list of promising sites and the list of available existing facilities were used to develop the alternatives.

Definitions of separable functions:

- Plutonium science and certification: Includes production of sub-critical articles and other test articles, and research and development.
- Metal preparation (prep): 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 flow sheet process steps up to and including electro-refining and size reduction, and aqueous processing capabilities. These processes were deemed separable from the rest of the pit production operations. Therefore, moving some or all of it to another location is included in the alternatives.
- Production: Includes all activities on the pit production flow sheet starting at casting and ending at final assembly and inspection.
- Advanced Recovery and Integration Extraction System (ARIES): Includes plutonium material disposition activities to support the Department of Energy's (DOE) Defense Nuclear Nonproliferation missions.
- Plutonium-238: Includes plutonium-238 processing activities to support weapons programs and DOE Office of Nuclear Energy missions.

C.1 Alternatives Overview

Table C–1 shows a matrix of proposed alternatives.

Assumptions:

- At a minimum, plutonium science and certification capabilities currently at LANL and Lawrence Livermore National Laboratory would remain there.
- Chemistry and Metallurgy Research Replacement (CMRR) project and Plutonium Sustainment Program activities are completed in time for increased pit production milestones.

- Support infrastructure will be built or upgraded as required for each alternative.

Table C–1. Matrix of proposed alternatives

[redacted]		Sites				Notes
0 - Status Quo	Metal Prep Production ~30 ppy	LANL (PF-4)	[redacted]			- PF-4 as configured after completion of CMRR and Pu Sustainment. - Estimate capacity - Excursions for multiple shifts
1 - Split Production	Metal Prep Production various	LANL (PF-4)	LANL (PF-4)	LANL (PF-4) (Various Options)	[redacted]	- Use PF-4 as configured after completion of CMRR and Pu Sustainment. - Additional production capacity in another facility. - Various options for PF-4: - Maximize discarding residues - Discontinue oxidizing Uranium - Remove Special Recovery Line & gas gun - No CT at LANL - perform at Pantex - Operate on multiple shifts - Sub-options for moving Pu238 and/or Aries
	Production various	SRS (Existing)	INL (Existing)	LANL, SRS, INL, PTX, NNSS (New)	[redacted]	
2- Move Production and Metal Prep	Metal Prep Production 80 ppy	SRS (Existing)	INL (Existing)	LANL, SRS, INL, PTX, NNSS (New)	[redacted]	- PF-4 retains only Pu Science & Certification. - Full production, including metal prep somewhere else.
3 - Move Production	Metal Prep	LANL (PF-4)	LANL (PF-4)	LANL (PF-4)	[redacted]	- PF-4 retains Pu Science & Certification and Metal Prep - Additional production capacity somewhere else.
	Production 80 ppy	SRS (Existing)	INL (Existing)	LANL, SRS, INL, PTX, NNSS (New)	[redacted]	
4 - Move Metal Prep	Production 80 ppy	LANL (PF-4)	LANL (PF-4)	LANL (PF-4)	[redacted]	- Pu Science & Certification and 80 ppy production together in PF-4. - Disassembly, metal prep, and residue recovery somewhere else. - If more space needed in PF-4, determine what else needs to move out
	Metal Prep	SRS (Existing)	INL (Existing)	LANL, SRS, INL, PTX, NNSS (New)	[redacted]	

CMRR = Chemistry and Metallurgy Research Replacement; CT = computed tomography; PF-4 = Plutonium Facility; ppy = pits per year; Pu = plutonium.

C.2 Detailed Descriptions of Alternatives

Tables C–2 through C–6 provide descriptions of alternatives at the three most promising sites and the two potential sites.

Table C–2. Detailed descriptions for alternatives at LANL

Alternative	Name	Description and Notes
LANL0	**Status Quo** Excursions: - Multiple shifts	PF-4 contains plutonium science and certification, surveillance, metal prep, and ~30 ppy manufacturing capability. - Evaluate pit capacity with planned equipment - Evaluate pit capacity with planned equipment on multiple shifts (identify processes that do not benefit from additional shifts and add equipment if capacity constrained).
LANL1	**Split Production** LANL1-A – PF-4 as is after CMRR and plutonium sustainment complete – additional production space added outside of PF-4 as required LANL1-B – Maximize use of PF-4, leaving plutonium-238 and ARIES in PF-4 – additional production space added outside of PF-4 as required LANL1-C – Maximize use of PF-4, move plutonium-238, leave ARIES in PF-4 – additional production space added outside of PF-4 as required LANL1-D – Maximize use of PF-4, move ARIES, leave plutonium-238 in PF-4 – additional production space added outside of PF-4 as required LANL1-E – Maximize use of PF-4, move plutonium-238 and ARIES – additional production space added outside of PF-4 as required Excursions: - Explore which alternatives can avoid construction to reach required production capacity by using multiple shifts	PF-4 contains plutonium science and certification, surveillance, metal prep, and some capacity for pit production. Production capacity in PF-4 will be determined for each case, and additional lab space to meet production capacity requirement will be determined. Additional construction may be modular. Other construction approaches may be considered, depending on the size required. Define maximize use of PF-4 as: - Maximize discarding residues rather than recovering - Discontinuing uranium oxidation – melt instead - Removing special recovery line and gas gun - No CT at LANL (if required will be performed at PX or NTS) Sub-options include moving plutonium-238 and/or ARIES - Evaluate production capacity in PF-4 for each case, and determine how much construction necessary to meet production requirements. - Evaluate pit capacity with planned equipment on multiple shifts (identify processes that do not benefit from an additional shift and add equipment if capacity constrained).
LANL2	**Move Metal Prep and Production into New Construction**	PF-4 contains plutonium science, certification, and surveillance. 80 ppy production capability and metal prep in new construction facility at LANL.
LANL3	**Move Production into New Construction**	PF-4 contains plutonium science, certification, surveillance, and metal prep. 80 ppy production capability established in new construction facility at LANL. Note that, in this case, it is assumed the equipment installed in PF-4 for the Plutonium Sustainment Program would remain in PF-4 for use by plutonium science and certification.
LANL4	**Full Production in PF-4, Metal Prep in New Construction**	PF-4 contains plutonium science, certification, surveillance, and 80 ppy production capability. Metal prep is established in a new construction facility at LANL.

Alternative	Name	Description and Notes

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

Table C–3. Detailed descriptions for alternatives at SRS

Alternative	Name	Description and Notes
SRS1	**Split production with LANL** SRS1-A – 50 ppy in MFFF SRS1-B – 50 ppy in K-Area Reactor SRS1-C – 50 ppy in WSB SRS1-D – 50 ppy in new construction	PF-4 contains plutonium science, certification, surveillance, metal prep, and ~30 ppy pit production. 50 ppy production capability at SRS. Note that the team will evaluate the production capacity of the Plutonium Sustainment project equipment. The capacity required at SRS will be adjusted to create the total of 80 ppy.
SRS2	**Move Metal Prep and Production** SRS2-A – Metal prep and 80 ppy in MFFF SRS2-B – Metal prep and 80 ppy in K-Area Reactor SRS2-C – Metal prep and 80 ppy in WSB SRS2-D – Metal prep and 80 ppy in new construction	PF-4 contains plutonium science, certification, and surveillance. 80 ppy production capability and metal prep at SRS.
SRS3	**Move Production Only** SRS3-A –80 ppy in MFFF SRS3-B –80 ppy in K-Area Reactor SRS3-C –80 ppy in WSB SRS3-D –80 ppy in new construction	PF-4 contains plutonium science, certification, surveillance, and metal prep. 80 ppy production capability established at SRS. Note that, in this case, it is assumed that the equipment installed in PF-4 for the Plutonium Sustainment program would remain in PF-4 for use by plutonium science and certification.
SRS4	**Move Metal Prep Only** SRS4-A – Metal Prep in MFFF SRS4-B – Metal Prep in K-Area Reactor SRS4-C – Metal Prep in WSB SRS4-D – Metal Prep in new construction	PF-4 contains plutonium science, certification, surveillance, and 80 ppy production capability. Metal Prep is established at SRS.

MFFF = Mixed Oxide Fuel Fabrication Facility; PF = Plutonium Facility; ppy = pits per year; WSB = Waste Solidification Building.

Table C–4. Detailed descriptions for alternatives at INL

Alternative	Name	Description and Notes
INL1	**Split production with LANL** INL1-A – 50 ppy in Fuel Processing Facility INL1-B – 50 ppy in new construction	PF-4 contains plutonium science, certification, surveillance, metal prep, and ~30 ppy pit production 50 ppy production capability at INL. Note that the team will evaluate the production capacity of the Plutonium Sustainment project equipment. The capacity required at INL will be adjusted to create the total of 80 ppy.
INL2	**Move Metal Prep and Production** INL2-A – Metal prep and 80 ppy in Fuel Processing Facility INL2-B – Metal prep and 80 ppy in new construction	PF-4 contains plutonium science, certification, and surveillance. 80 ppy production capability and metal prep at INL.
INL3	**Move Production Only** INL3-A –80 ppy in Fuel Processing Facility INL3-B –80 ppy in new construction	PF-4 contains plutonium science, certification, surveillance, and metal prep. 80 ppy production capability established at INL. Note that, in this case, it is assumed that that the equipment installed in PF-4 for the Plutonium

		Sustainment Program would remain in PF-4 for use by plutonium science and certification.
INL4	**Move Metal Prep Only** INL4-A – Metal prep in Fuel Processing Facility INL4-B – Metal prep in new construction	PF-4 contains plutonium science, certification, surveillance, and 80 ppy production capability. Metal prep is established at INL.

PF-4 = Plutonium Facility; ppy = pits per year.

Table C–5. Detailed descriptions for alternatives at NNSS

Alternative	Name	Description and Notes
NNSS1	**Split production with LANL-** 50 ppy in new construction	PF-4 contains plutonium science and certification, surveillance, metal prep, and ~30 ppy pit production 50 ppy production capability at NNSS. Note that the team will evaluate the production capacity of the Plutonium Sustainment project equipment. The capacity required at INL will be adjusted to create the total of 80 ppy.
NNSS2	**Move Metal Prep and Production** Metal prep and 80 ppy in new construction	PF-4 contains plutonium science and certification, surveillance. 80 ppy production capability and metal prep at NNSS.
NNSS3	**Move Production Only (PF-4 retains metal prep)** 80 ppy in new construction	PF-4 contains plutonium science and certification, surveillance, and metal prep. 80 ppy production capability established at NNSS. Note that, in this case, it is assumed that the equipment installed in PF-4 for the Plutonium Sustainment Program would remain in PF-4 for use by plutonium science and certification.
NNSS4	**Move Metal Prep Only (PF-4 production)** NNSS4-A – Metal prep in DAF NNSS4-B – Metal prep in new construction	PF-4 contains plutonium science and certification, surveillance, and 80 ppy production capability. Metal prep is established at NNSS.

DAF = Device Assembly Facility; PF-4 = Plutonium Facility; ppy = pits per year.

Table C–6. Detailed descriptions for alternatives at PX

Alternative	Name	Description and Notes
PX1	**Split production with LANL-** 50 ppy in new construction	PF-4 contains plutonium science and certification, surveillance, metal prep, and ~30 ppy pit production 50 ppy production capability at PX. Note that the team will evaluate the production capacity of the Plutonium Sustainment project equipment. The capacity required at INL will be adjusted to create the total of 80 ppy.
PX2	**Move Metal Prep and Production** Metal prep and 80 ppy in new construction	PF-4 contains plutonium science and certification, surveillance. 80 ppy production capability and metal prep at PX.
PX3	**Move Production Only (PF-4 retains metal prep)** 80 ppy in new construction	PF-4 contains plutonium science and certification, surveillance, and metal prep. 80 ppy production capability established at PX. Note that, in this case, it is assumed that the equipment installed in PF-4 for the Plutonium Sustainment Program would remain in PF-4 for use by plutonium science and certification.

PF = Plutonium Facility; ppy = pits per year.

Appendix D. Siting and Policy Risk

D.1 Introduction

The purpose of this appendix is to examine a selection of potential sites at which the pit manufacturing capability, or portions thereof, might be placed, from the point of view of siting and policy risk, with a view to identifying a few promising candidates for further study.

The chosen list of sites is as follows:

- Los Alamos National Laboratory (LANL)
- Savannah River Site (SRS)
- Pantex Plant (Pantex)
- Nevada National Security Site (NNSS)
- Lawrence Livermore National Laboratory (LLNL)
- Y-12 National Security Site[1] (Y-12)
- Oak Ridge National Laboratory (ORNL)
- Waste Isolation Pilot Plant (WIPP)
- Hanford[2]
- Idaho National Laboratory (INL)
- Brookhaven National Laboratory (BNL)
- Kansas City National Security Campus (KCNSC)
- Sandia National Laboratories (SNL)
- Paducah, KY
- Portsmouth, OH

At first sight, it might appear that some of the above can be dismissed by cursory inspection. However, the team believes that by examining a large number of potential sites with a comparable degree of rigor, the eventual choice of a short list of sites for further evaluation will have enhanced credibility.

D.2 Siting Factors Considered

The following factors were considered in making a subjective evaluation of the risk associated with siting the pit manufacturing capability (or parts thereof) at each of the candidate sites.

1. *The Area of the Site*: If the site is small the manufacturing facility cannot be placed far away from the boundary. This would tend to contribute a relatively large amount to site risk. The arbitrary criteria chosen for this analysis are: a small site with an area of less than 10 square miles has relatively high risk; a large site with an area exceeding 100 square miles has a relatively low risk;

[1] Y-12 and ORNL are presented separately here although in other parts of the analysis (e.g., the team's investigation of infrastructure capabilities) they are treated as one site.
[2] In other parts of the team's analysis it is assumed that, should the pit manufacturing capability be placed at Hanford, it could draw on any infrastructure capabilities present at the nearby Pacific Northwest National Laboratory (PNNL).

and any site with an area from 10-100 square miles will be characterized by the rather imprecise term medium, i.e., it makes a medium contribution to site risk.

2. *Relevant Site Information within 5 Miles*: Miscellaneous items of information are collected under this heading, 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 the site or there is a lake or other sensitive environmental area). On the basis of these considerations, a purely subjective judgement is made as to whether the factors within 5 miles make a low, moderate, or high contribution to siting risk.
3. *Nearby Centers of Population*: A few representative cities or towns are chosen and their population, distance, and direction are tabulated. Again, a subjective assessment is made of whether these potentially are low, moderate, or high contributors to siting risk.
4. *Population within 50 Miles*: The population within 50 miles is estimated because, in environmental impact statements and other siting analyses, this is often used as the basis to estimate population radiation dose either for routine operation or for hypothetical accident scenarios. Again, an arbitrary range is chosen: the potential contribution to overall site risk is 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.
5. *Predominant Wind Direction*: A wind rose for each site is obtained (or in some cases wind roses). If the predominant wind direction is toward nearby residents and/or major centers of population this is considered to increase the overall site risk. If it blows away from populated areas, it is regarded as a low contributor to site risk.

In addition to these five factors the team also considered *policy risk*. This, of course, is highly subjective. In assessing whether policy risk is high, moderate, or low the team asked whether there was a history of policy protest or interference at or near each site. A specific example of a site that ultimately did not make the short list is BNL. In the past there was a huge outcry over the proposed Shoreham nuclear reactor, which was located not far from BNL. The reactor was abandoned even though it was essentially complete, had many safety features, and had already cost several billion dollars. In that case, it is clear that the policy risk is high or even very high. Other relevant information, where pertinent, might include the presence of nearby national parks or other sensitive environmental receptors, or Native American Indian reservations.

Once information had been collected for all six factors (area, relevant site information within 5 miles, nearby centers of population, population within 50 miles, predominant wind direction, and policy risk) the team made a subjective assessment of overall siting risk. This assessment was then combined with available infrastructure data for each site to provide a ranking of the sites, and a basis for identifying a few sites at which all or parts of the pit manufacturing facility might be placed. See Chapter 4.

D.3 Sources of Data

The principal sources of data were:

- *Site fact sheets* on Department of Energy's (DOE's) web site, energy.gov. This proved to be a particularly reliable source for site areas.
- *The Missouri Census Data Center* at http://mcdc.missouri.edu/websas/caps10c.html. This is a free source for the population in circles with user-chosen radii for any site in the country, based on 2010 census data.[3]
- *"Suburban Stats"* at https://suburbanstats.org/population/provides the population of any city in the country, also based on 2010 census data.
- *Environmental impact statements, Environmental Assessments, and annual site reports*. These are good sources for wind roses, some maps, some population data, and where candidate buildings for the pit manufacturing capability (if any) are located.
- *Google maps* are good for estimating as-the-crow-flies distances and assessing the nature of the surroundings (e.g., farming, forested, urban, industrialized).

D.4 Summary of Results

The results of the siting risk analysis are presented in **Table D–1**. Based solely on the number of red or green cells in each row of the table one can make a rough ranking of the sites:

- Favorable: SRS, NNSS, Hanford, INL, WIPP.
- Neutral/moderate: LANL, ORNL, SNL, Portsmouth, and Paducah.
- Unfavorable: LLNL, Y-12, BNL, and KCNSC.
- The results of the policy risk analysis are provided in **Table D–2**.

A couple of observations are pertinent. First, 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. Second, the relative ranking of LANL is moot. Since it is the only site at which it is currently possible to manufacture a pit, it has been "grandfathered" in.

[3] If further detail is required, the Missouri Census Data Center can break down the population figures by ethnicity, gender, and age.

Table D–1. Summary of siting risk analysis

Site	Site Factors								Subjective Assessment of Relative Risks Arising from Siting Issues
			Nearby Cities						
	Area (square miles)/acres	Relevant Site Information Within 5 Miles	Name	Population	Distance (miles)	Direction	Population within 50 Miles	Predominant Wind Direction (from)	
LANL	36/23,000	From PF4, the city of Los Alamos lies about 1.3 miles due N. In other directions: 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., towards 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 towards cities listed to 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, NV	217,000	90	SE	42,000	SW	Low
LLNL	1/640	The city of Livermore abuts the western boundary of the site. There are 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 to left	High
Y-12	1.25/811 at NE corner of ORR (52/33,500)	Nearest houses ~1,500' 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 towards center of ORR (52/33,500)	Nearest houses ~ 4 miles E and S. Most of 5-mile circle radius 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
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	560,000	NW, WNW, W Mostly not directly towards nearby cities	Low

	Site Factors								Subjective Assessment of Relative Risks Arising from Siting Issues
			Nearby Cities						
Site	Area (square miles)/acres	Relevant Site Information Within 5 Miles	Name	Population	Distance (miles)	Direction	Population within 50 Miles	Predominant Wind Direction (from)	
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 towards nearby cities	Low
BNL	8/5,000	~13,000 people within one mile of site boundary, population within 5 miles ~67,000	Brookhaven Township, MA	~426,000	Occupies ~530 mi² around site	Surrounds site	6,200,000	Westerly	High
KCNSC	0.29/186	Nearest houses ~0.9 miles 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	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 Towards Rio Grande Valley and SW Albuquerque metropolitan area	Moderate
Paducah, KY	1.2/750 within fenced area 5.6/3,550	Predominantly farming. ~7,600 people. Ohio River within 2 miles.	Metropolis, IL Paducah, KY	6,500 25,000	5 7	NE ESE	534000	SW-S Towards Metropolis	Moderate
Portsmouth, OH	1.9/1,200 within total site area 5.9/3,780	Mainly wooded, some farming. ~6,200 people	Piketon, OH Portsmouth, OH	2,200 20,000	2.5 17	NNW S	690000	SW-S Not towards cities	Moderate

Table D–2. 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 the Plutonium Facility and there has been considerable controversy in the past about changes in mission. In addition, there are many Native 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 upon Technical Area 55). On the other hand, one would expect many members of the local population to welcome new jobs and expenditures. On balance, the policy risk is moderate
SRS	Moderate	There has been considerable controversy, including law suits, over the Mixed Fuel Fabrication Facility. However, this is also a site where one would expect many members of the local population to welcome new jobs and expenditures. On balance, the policy risk is moderate.
Pantex	Low	There is little history of conflict with neighbors. Pantex already handles pits.
NNSS	Low	Remoteness and size of site are considerable plusses. However, the low severity of policy risk could be revised upwards if, for example, there is any residual conflict arising from the Yucca Mountain controversy
LLNL	High	Large numbers of people nearby. There has been intentional reduction of the amount of plutonium at LLNL – 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.
ORNL	Moderate	Likely to be lower than 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, use would likely be made of both Y-12 and ORNL and it would be difficult to disentangle the policy risk associated with what would not really be separate sites.
WIPP	Low	Extremely remote, but would possibly require either revision of the Land Withdrawal Act or a new act to be passed.
Hanford	High	Much previous controversy (e.g., about tanks) and great local concern about potential contamination of the Columbia River.
INL		Extreme remoteness and a large site should mitigate public concerns. However, INL is currently operating under a consent decree with the State of Idaho 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 plutonium to the site.
KCNSC	High	The site is by definition 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.
Paducah, KY	High	Current expectations are that the plant will be completely shut down and radioactive materials removed.
Portsmouth, OH	High	Current expectations are that the plant will be completely shut down and radioactive materials removed.
Greenfield	High	This would be site dependent, but it is hard to imagine that there would not be an outcry if a pit manufacturing facility were placed in a true greenfield.

In a way similar to that already done for both the site infrastructure and the siting risk analysis, it is possible to develop a rough ranking of the sites from Table 2–5.

- Favorable: Pantex, NNSS, WIPP, and INL.
- Neutral: LANL, SRS, Y-12/ORNL, and SNL.
- Unfavorable: LLNL, Hanford, BNL, KCNSC, Portsmouth, and Paducah.

Caveat: Site risk and policy risk alone are not the only factors that determine whether a site is suitable or not. These factors must be balanced against others, such as cost and the availability of suitable infrastructure. See Chapter 4.

D.5 Site-Specific Data

The following sections are repositories for the data that were collected on each site. Each pertinent section also provides screen shots of Google maps at various scales, wind roses, and other relevant maps or tables.

D.6 Los Alamos National Laboratory

Surrounding population:[4] From the Missouri Census Data Center,[5] based on the 2010 Census, the population within 5 miles is approximately 12,200 and the population within 50 miles is approximately 378,300. Separately, LANL has estimated that, in 2020, the population within 5 miles will be approximately 12,400, and the population within 50 miles approximately 450,000, see **Table D–3**.[6]

Nearest centers of population:[7]

- Los Alamos, NM (population approximately 12,000) approximately 1.3 miles due north of the Plutonium Facility (to nearest houses).
- White Rock, NM (population approximately 5,800) approximately 5 miles SE of Technical Area 55 (TA-55) (to nearest houses).
- Santa Fe, NM (population approximately 68,000), approximately 24 miles SE.

Nature of surroundings within 5 miles: See **Figure D–1**. Apart from Los Alamos and White Rock, essentially unpopulated, no industrial activity except for the site itself.

Size of site: 36 square miles (approximately 23,000 acres).[8]

Most likely wind direction: See **Figure D–4**. During the day, the predominant wind direction is from the south, i.e., towards Los Alamos. During the night, it is more or less evenly distributed from NW-SW, mostly not directly towards the city from TA-55.

Initial Subjective Assessment of Public External Individual and Societal Risk from pit production at LANL: Moderate, because of closeness to Los Alamos, relative smallness of the site, and predominant wind direction towards the city during the day.

Policy Risk: The risk that policyly motivated opposition could cause substantial difficulties should LANL be chosen as the site for manufacturing 80 pits per year (ppy) would appear to be low because the site already manufactures some pits and is currently working through the plutonium sustainment project that will result in a production capability of 30 ppy. One would not expect much controversy should that capability be expanded to 80 ppy. However, there are some factors that could potentially generate policy controversy, including the relative closeness of the nearest housing in Los Alamos, concerns about the nearby Bandelier National Monument, and the presence of several Native American Indian reservations within 50 miles. These factors introduce uncertainty. Thus, the policy risk for this site is assessed to be moderate.

---

[4] Measured from TA-55.
[5] http://mcdc.missouri.edu/websas/caps10c.html.
[6] DOE (U.S. Department of Energy) 2013, *Draft Supplement Analysis for the Nuclear Infrastructure Programmatic Environmental Impact Statement for Pu-238 Production for Radioisotope Power Systems*, DOE/EIS-0310-SA-02, Washington DC, September obtained from, http://www.id.doe.gov/insideNEID/PDF/Pu-238_Supplement_Analysis.pdf.
[7] Distances estimated using Google Maps (**Figures D–1** and **D–2**) and **Figure D–3**, measured from TA-55: populations mainly obtained from https://suburbanstats.org/population/.
[8] http://www.ncsl.org/research/environment-and-natural-resources/los-alamos-national-laboratory.aspx.

Table D–3. Estimated population distribution surrounding LANL in 2020
(Source DOE/EIS-0310-SA-02, Table 3-45)

Population	*5 Miles*		*10 Miles*		*20 Miles*		*50 Miles*	
	Population	*Percent of Total*	*Population*	*Percent of Total*	*Population*	*Percent of Total*	*Population*	*Percent of Total*
Nonminority	8,619	69	13,493	67	21,883	36	197,224	44
Total Hispanic [b]	2,075	17	3,613	18	31,897	52	201,687	45
American Indian or Alaska Native [a]	185	1	1,043	5	5,475	9	27,801	6
Other Minority [a]	3,615	29	5,556	28	34,206	56	222,516	50
Total Minority [a]	3,800	31	6,599	33	39,681	64	250,317	56
Total Population	12,419	100	20,092	100	61,564	100	447,541	100
Low-Income	352	3	777	4	8,712	14	54,194	12

[a] Includes Hispanic persons.
[b] Includes all Hispanic persons regardless of race.
Note: To convert miles to kilometers, multiply by 1.609. Totals may not equal the sum of subcategories due to rounding. The potentially affected area comprises the area within a 50-mile (80-kilometer) radius of the site.

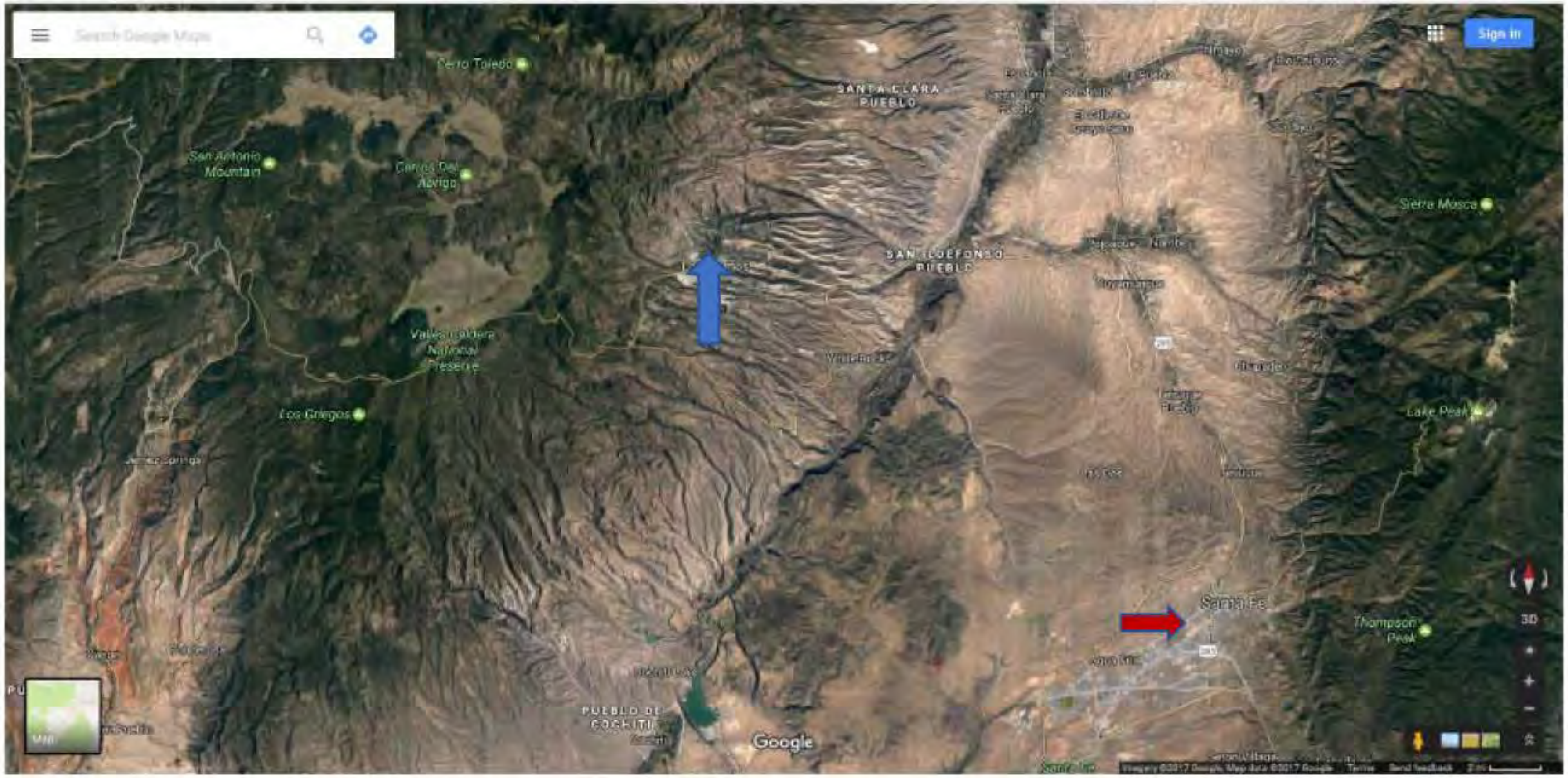


Figure D–1. Google map of Los Alamos area

Los Alamos is approximately at tip of blue arrow, Santa Fe at tip of red arrow.
Map is approximately 60 miles E-W and approximately 30 miles N-S.

Figure D–2. Larger scale Google map of LANL and Los Alamos

Map is approximately 8 miles E-W and 4 miles N-S.
TA-55 is approximately at tip of blue arrow.

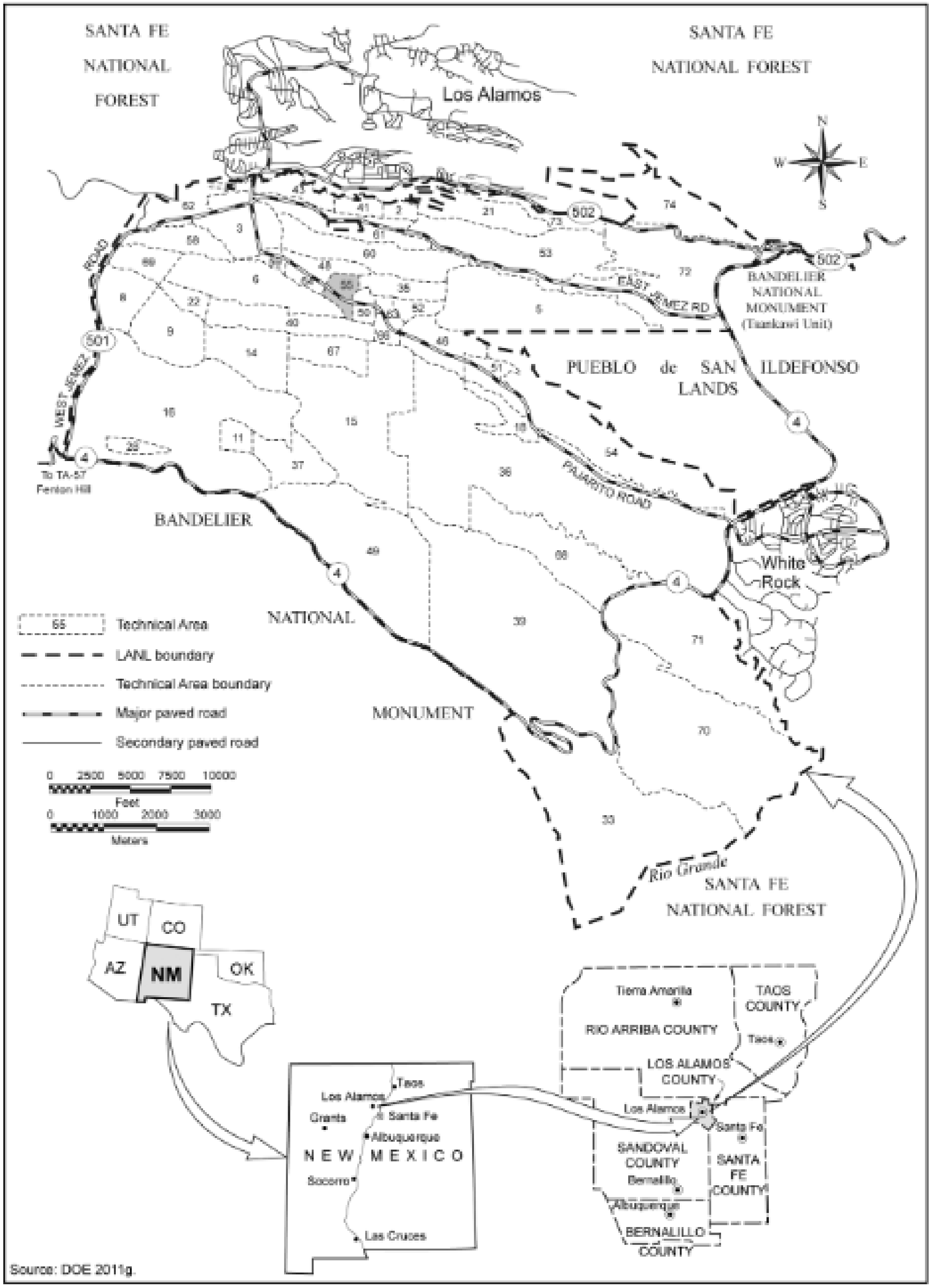


Figure D–3. Map of Los Alamos Site

(Source: *Final Surplus Plutonium Disposition Supplemental Environmental Impact Statement*, Figure 1-3[9])

[9] DOE (U.S. Department of Energy) 2015, *Final Surplus Plutonium Disposition Supplemental Environmental Impact Statement*, DOE/EIS-0283-S2, Washington DC, April, obtained from http://www.srs.gov/general/pubs/envbul/documents/EIS-0283-S2_SPD_Vol_1_EIS_Chapters.pdf.

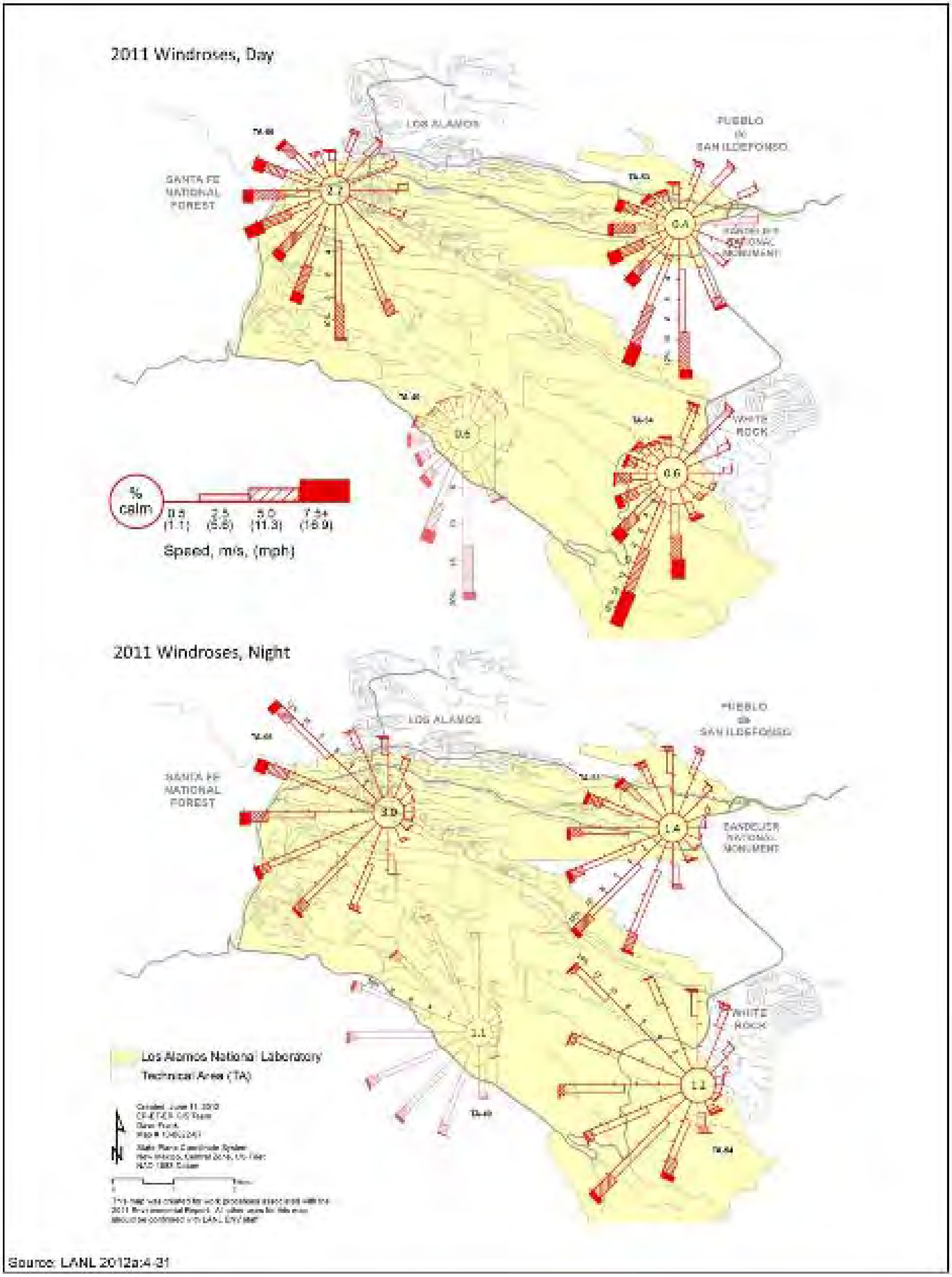


Figure D–4. Wind roses at various locations on Los Alamos Site

(Source: *Final Surplus Plutonium Disposition Supplemental Environmental Impact Statement*, Figure 3–13. Top left is closest to TA-55.)

D.7 Savannah River Site

Surrounding population: There are no members of the public within 5 miles of F-Area (which is where the Mixed Oxide Fuel Fabrication Facility [MFFF] is located) because that is entirely within the site (see **Figures D–5** and **D–6**). The total number of people within 10 miles is approximately 7,200 and the total out to 50 miles is approximately 790,000, based on the 2010 census.[10]

Centers of population:[11]

- The nearest town to F-Area is Jackson, SC (population approximately 1,700) approximately 7 miles NW.
- The biggest nearby city is Augusta, GA (population approximately 196,000) approximately 20 miles NW.
- The next largest city is Aiken, SC (population approximately 30,000), approximately 18 miles N.
- There are several other smaller cities too numerous to tabulate within 10-30 miles (see Figure D–7).

Nature of surroundings within 5 miles of F-Area (MFFF): Essentially unpopulated with no farming or industrial activity because the area is all within the site. See Figures D–5 and **D–7**.

Size of site: 310 square miles (approximately 200,000 acres).[12] F-Area (MFFF) is approximately 6 miles from the closest site boundary.

Most likely wind direction: **Figure D–8** shows four wind roses at various heights. Except for the one at the greatest height, the predominant winds are westerly, i.e., not directed towards the largest centers of population. At the greatest height, there is a somewhat greater probability of winds from the south (i.e., towards Aiken). However, for major accidents, one is generally concerned with releases near ground level so the predominant westerly winds are more significant.

Initial Subjective Assessment of Public External Individual and Societal Risk in the event that pit production is relocated to Savannah River: Low because of large distances to population centers, sparse population within 5 miles of MFFF, a very large site, and predominant wind direction not towards population centers.

Policy Risk: Factors that tend to make the policy risk low are the substantial distances to the nearest population and the fact that SRS has a long history of handling plutonium and associated wastes. In addition, many politicians have expressed concern that MFFF may be abandoned, so the prospect of the facility being put to constructive use might be attractive to the local community. However, there is an ongoing lawsuit concerning MFFF[13] that has not yet been fully resolved.[14] Therefore, the policy risk is estimated to be moderate. It is not assessed to be high because one assumes that the prospect of work for the site will lead to compromise.

---

[10] Missouri Census Data center, http://mcdc.missouri.edu/websas/caps10c.html.

[11] Distances estimated from F area (site of MOX facility) using Google Maps and Figure D–7: populations obtained from https://suburbanstats.org/population/.

[12] http://www.savannahrivernuclearsolutions.com/faq01.htm#q1.

[13] The Post and Courier, Haley Backs Plutonium Removal, Reasserts MOX Lawsuit, April 4th 2016, http://www.postandcourier.com/archives/haley-backs-plutonium-removal-reasserts-mox-lawsuit/article_6b2c712f-a16c-5210-8e91-68a30bb3e26e.html.

[14] Aiken Standard, *Judge Dismisses Part of Lawsuit over Savannah River Site MOX Plutonium Disposal*, February 17th 2017, http://www.aikenstandard.com/news/judge-dismisses-part-of-lawsuit-over-savannah-river-site-mox/article_4b5ef716-ee49-11e6-b19a-37eb5bc7d58d.html.

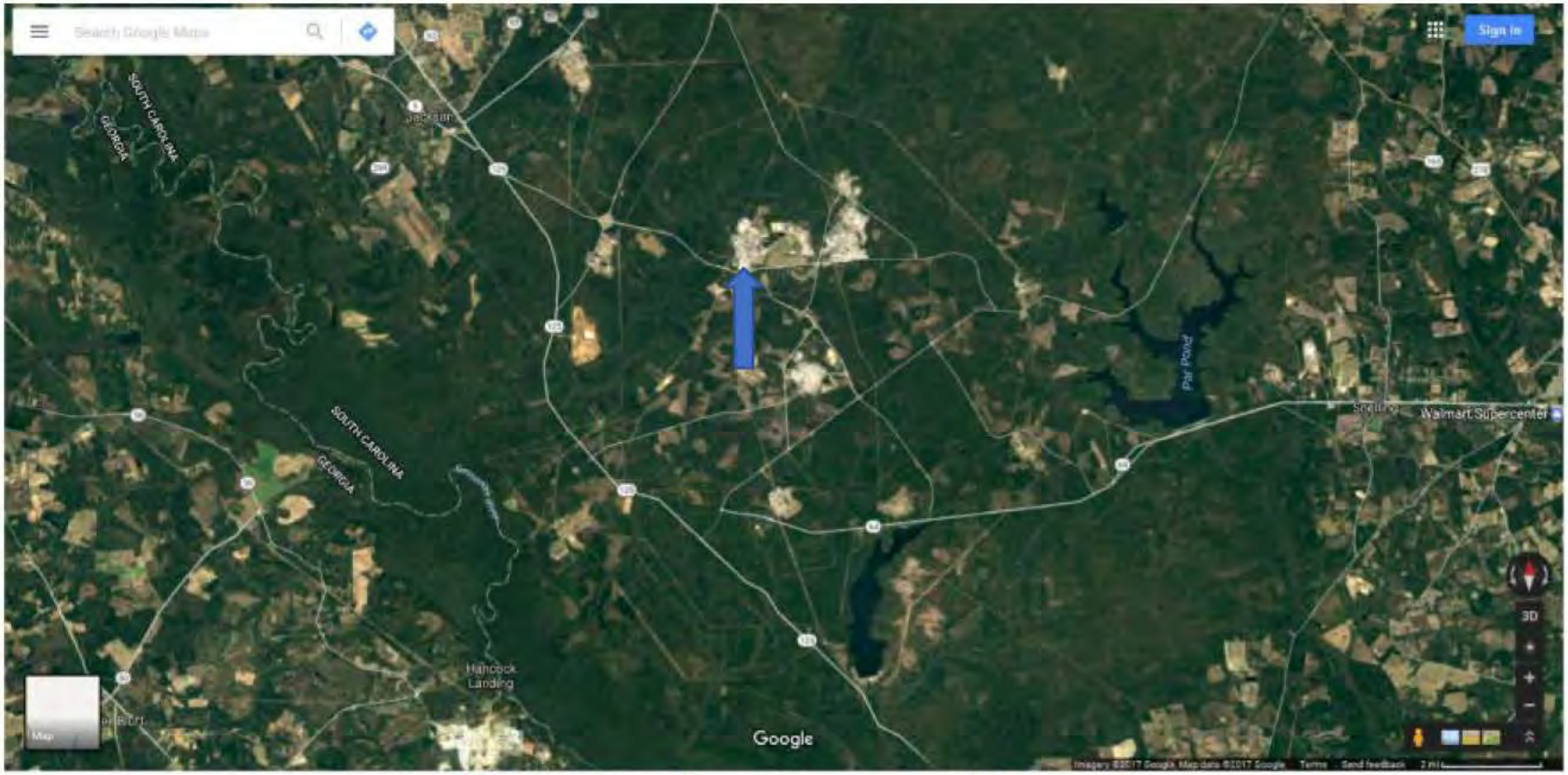


Figure D–5. Larger scale Google map of Savannah River Site

Map is approximately 30 miles E-W and 15 miles N-S. F-Area (site of MOX facility) is approximately at tip of blue arrow

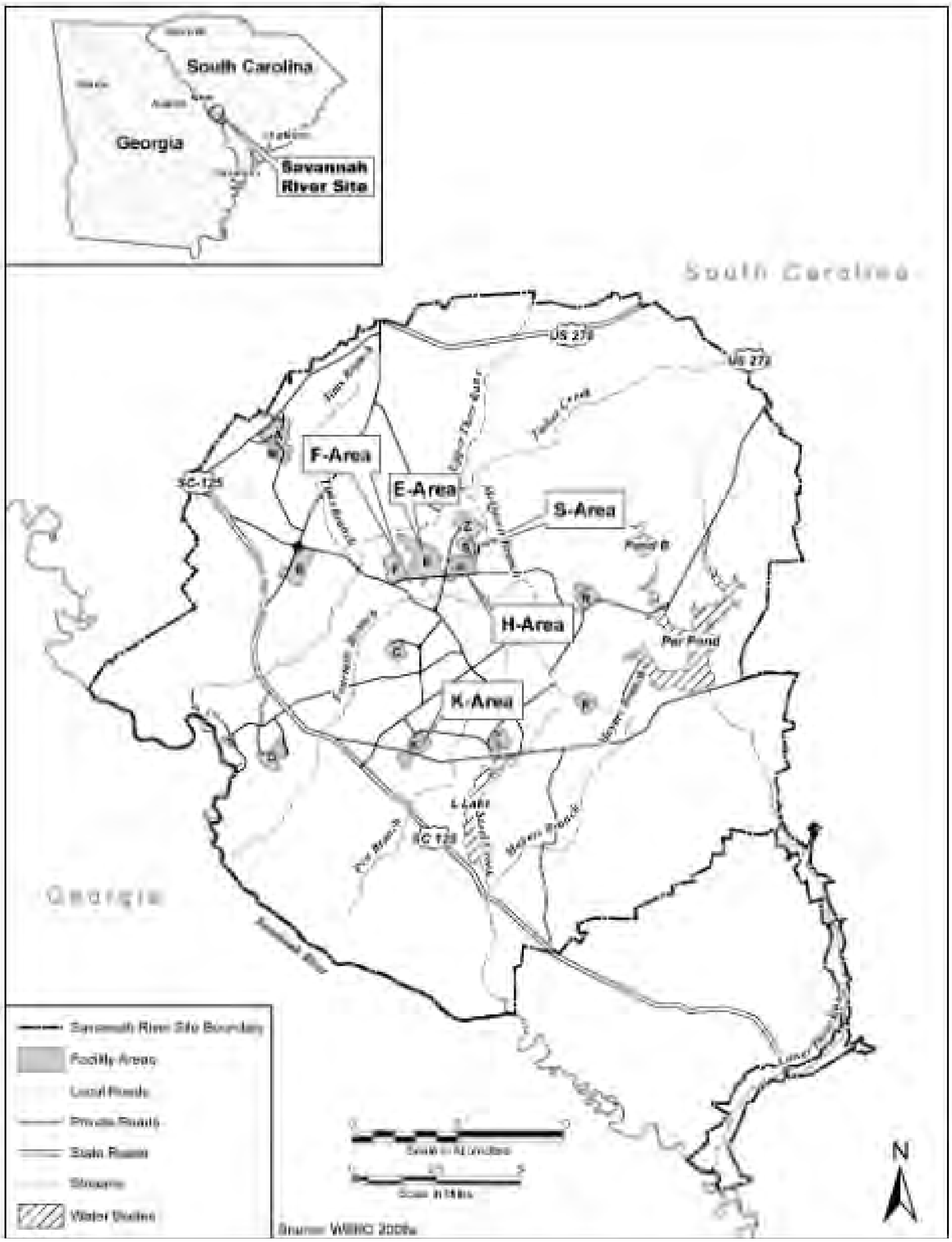


Figure D–6. Map of Savannah River Site

(Source: *Final Surplus Plutonium Disposition Supplemental Environmental Impact Statement*, Figure 1-2[15])

[15] DOE (U.S. Department of Energy) 2015, *Final Surplus Plutonium Disposition Supplemental Environmental Impact Statement*, DOE/EIS-0283-S2, Washington DC, April 2015, obtained from http://www.srs.gov/general/pubs/envbul/documents/EIS-0283-S2_SPD_Vol_1_EIS_Chapters.pdf.

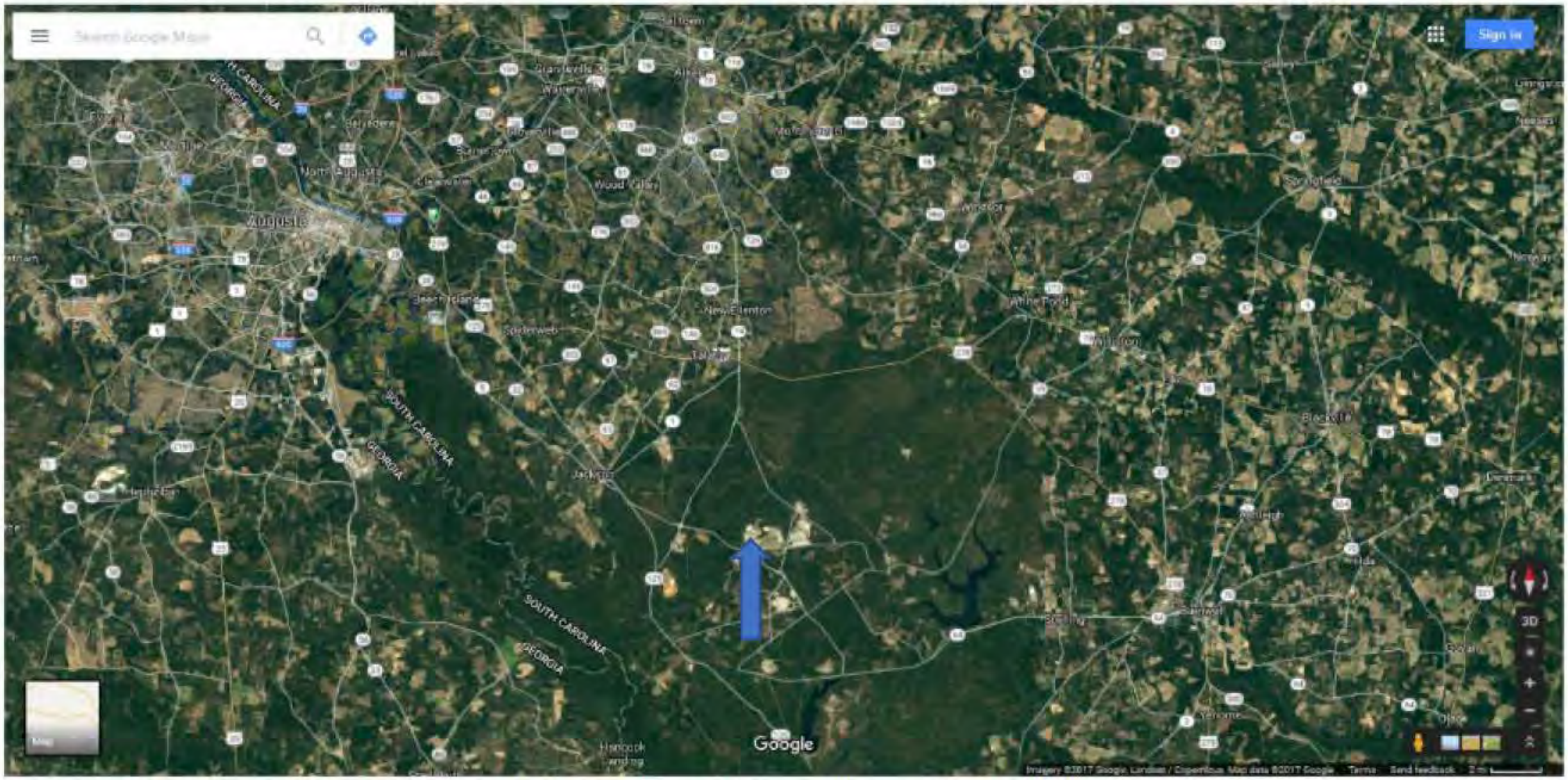


Figure D–7. Google map of Savannah River Site and vicinity

Map is approximately 60 miles E-W and 30 miles N-S. F-Area (site of MFFF facility) is approximately at tip of blue arrow.

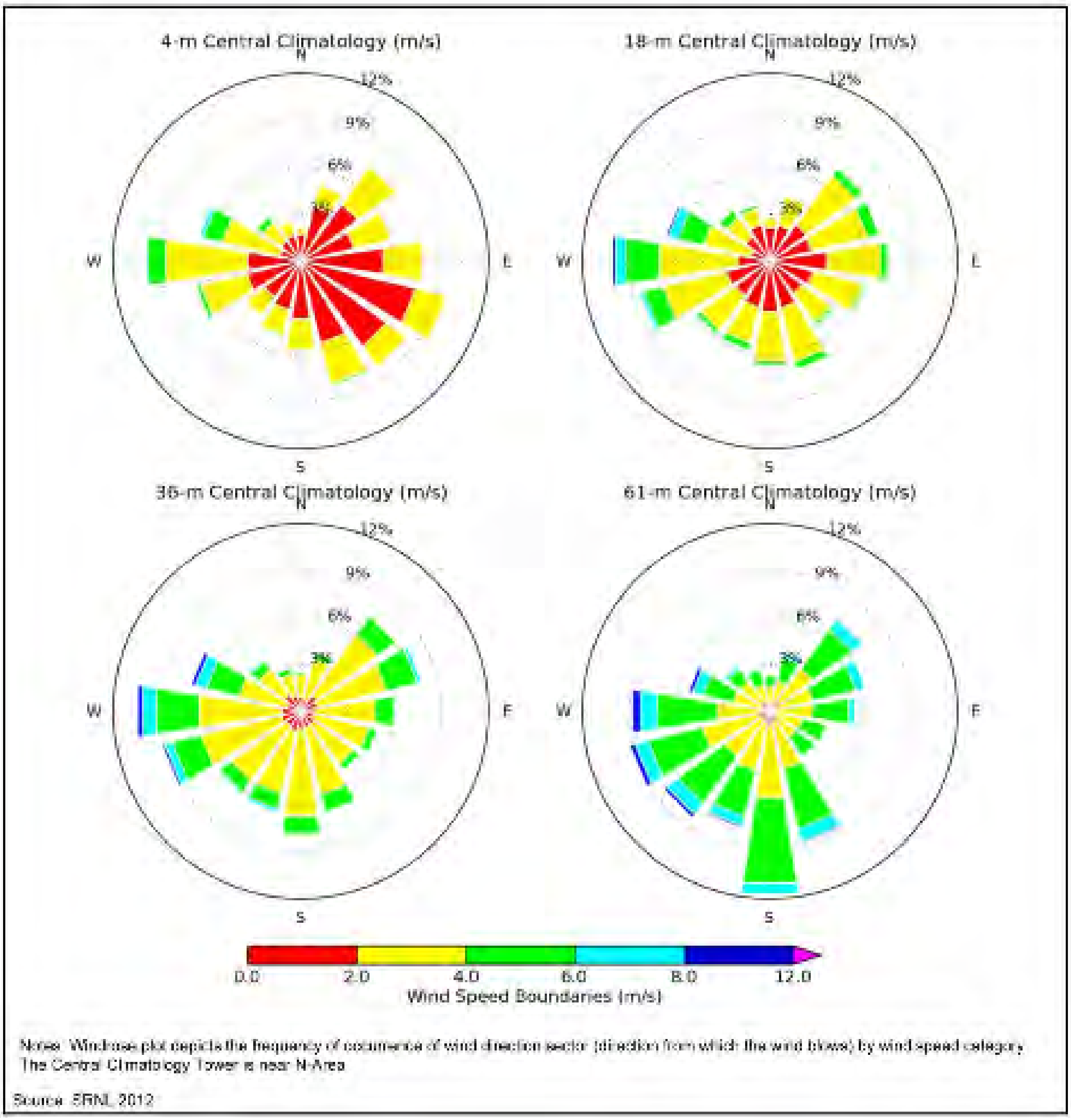


Figure D–8. Wind roses at various heights at Savannah River Site

(Source: *Final Surplus Plutonium Disposition Supplemental Environmental Impact Statement*, Figure 3-2)

D.8 Pantex

Surrounding population: Population within 5 miles is approximately 360 (only 2 within 2 miles), and within 50 miles is approximately 316,000, based on the 2010 census per Suburban Stats[16] (c.f. EIS-0225-SA-05-2013[17] also gives approximately 316,000 within 50 miles).

Nearest centers of population:[18] Estimated from Google maps. See **Figures D–9** and **D–10**.

- Panhandle, TX (population approximately 2,500), approximately 10 miles NE.
- Amarillo, TX (population approximately 190,000), approximately 10 miles SW.

Nature of surroundings within 5 miles: See **Figure D–11**. Predominantly farming, some unpopulated hill country to NW. Within this distance, only isolated houses.

Adjacent to plant: See Figures D–10, **D-12**, and **D–13**. PIDADS is near the southern boundary of the plant, Texas Tech research farm immediately to the south.

Size of site: 28 square miles (18,000 acres) with most activity concentrated in 2,000 acres.[19]

Most likely wind direction: **Figure D–14** provides the wind rose from nearby Amarillo airport. The predominant wind direction is from the south to south west and so does not blow towards Amarillo from Pantex.

Initial Subjective Assessment of Public External Individual and Societal Risk in the event that pit production is relocated to Pantex: <u>Low</u> because of moderately large distances to population centers, sparse population within 5 miles of the plant, largish site, and predominant wind direction not towards population centers.

Policy Risk: Factors that tend to make the policy risk low are the substantial distances to the nearest population and the fact that Pantex has a long history of handling pits. At the time of writing the author was not aware of any history of policy opposition to Pantex. Therefore, the policy risk at Pantex is assessed to be <u>low</u>.

---

16 http://mcdc.missouri.edu/websas/caps10c.html.

17 DOE (U.S. Department of Energy) 2012, *Final Supplement analysis for the Final Environmental Impact Statement for the Continued Operation of the Pantex Plant and Associated Storage of Nuclear Weapon Components*, DOE/EIS-0225-SA-05, Washington DC, November, obtained from https://energy.gov/sites/prod/files/EIS-0225-SA-05-2013.pdf.

18 Distance to outskirts, not town center. Population obtained from https://suburbanstats.org/population/.

19 *About Pantex*, http://www.pantex.com/about/Pages/default.aspx.

Figure D–9. Google map showing location of Pantex Site

Map is approximately 30 miles E-W and 15 miles N-S.

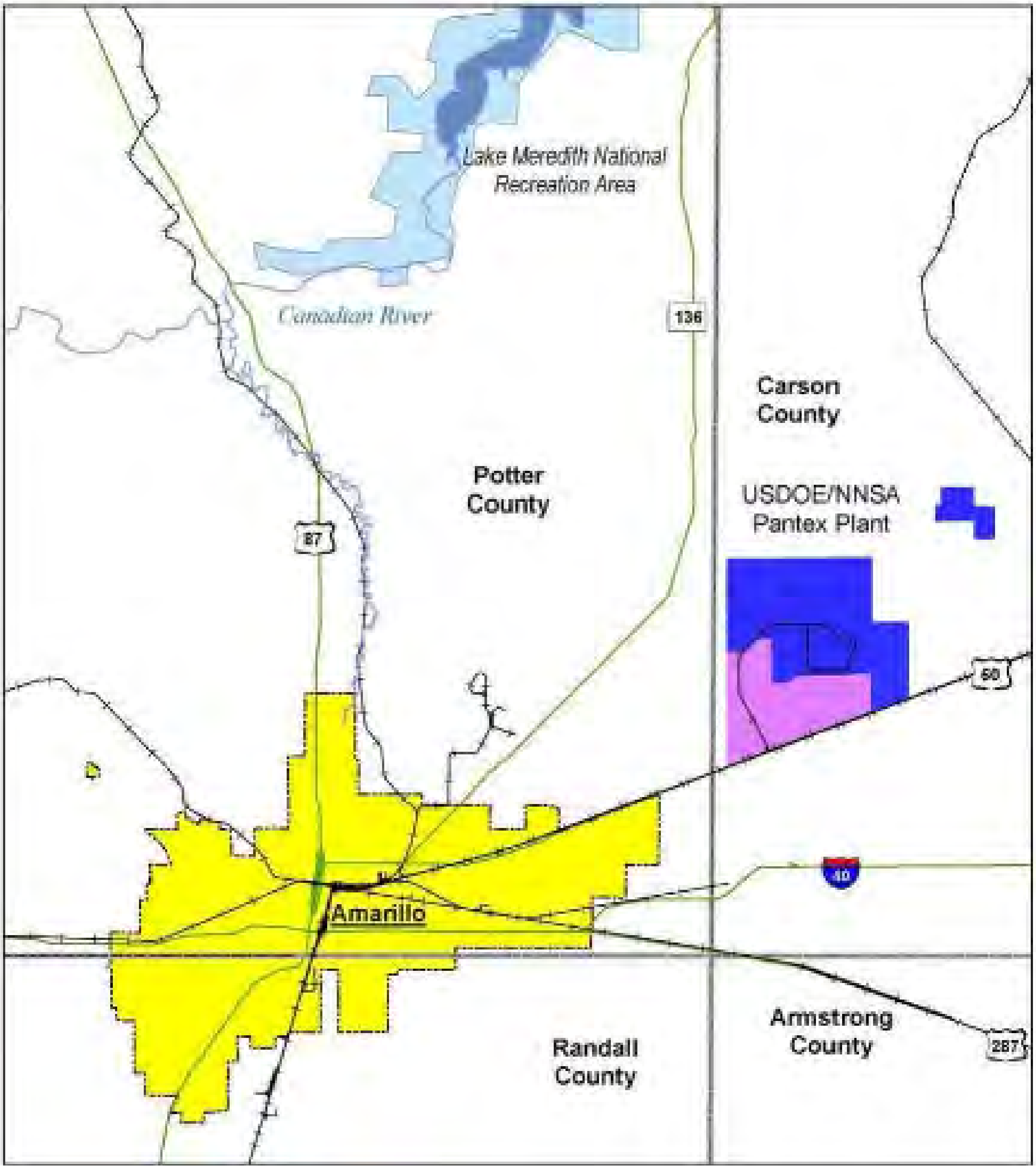


Figure D–10. Map of Pantex Site relative to Amarillo

(Source: DOE/EIS-0225-SA-05, Figure 1-2)

Figure D–11. Google map showing the vicinity of the Pantex Site at approximately 2.5 miles to 1 inch scale

The map shows the predominantly agricultural and sparsely populated nature of the countryside within 5 miles or so of Pantex.

Figure D–12. Google map of the Pantex Plant showing PIDADS

Map approximately 1.9 miles E-W and 0.95 miles N-S.

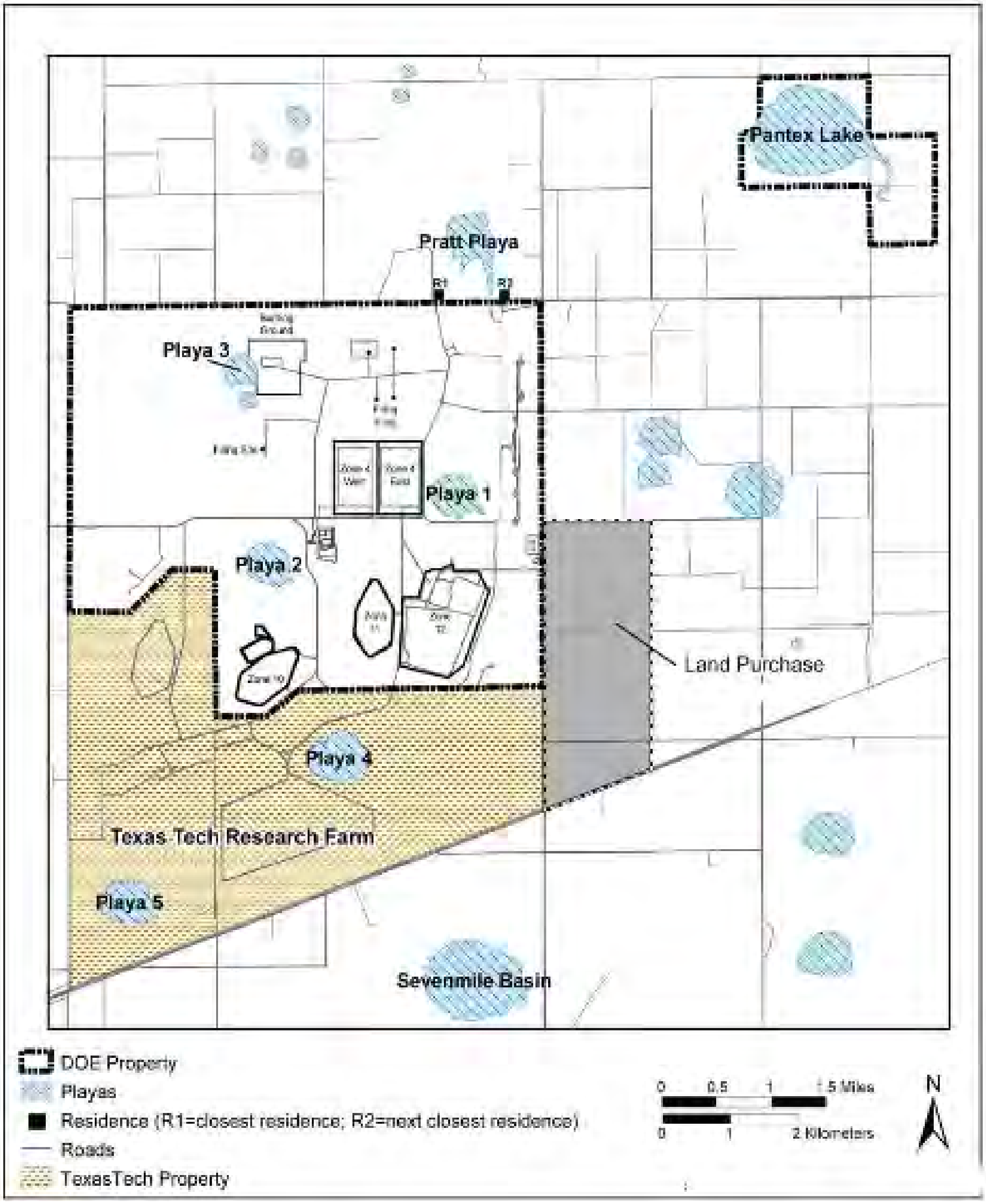


Figure D–13. Map of Pantex Site

(Source: DOE/EIS-0225-SA-05, Figure 1-2)

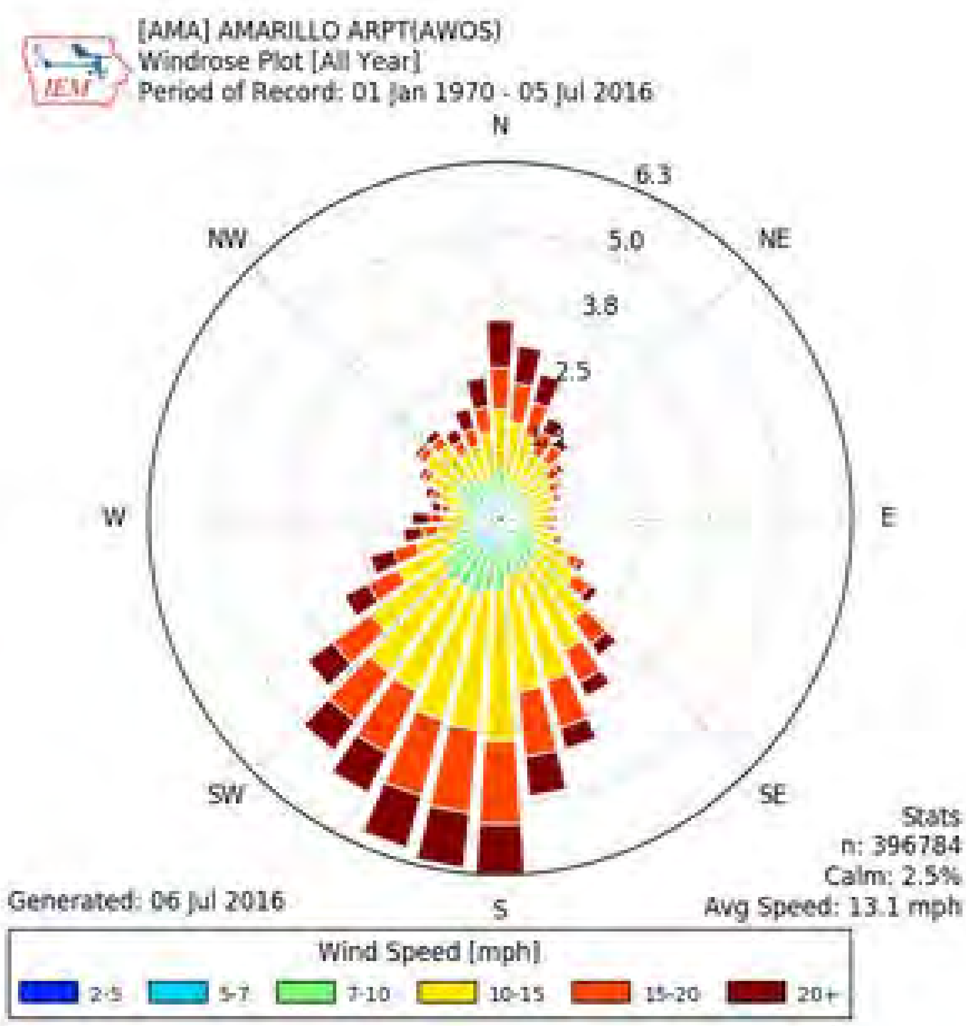


Figure D–14. Wind rose for Amarillo Airport

(Source: http://www.weather.gov/ama/amarillowindroseinformation)

Nevada National Security Site

Surrounding population:[20] Population within 10 miles is 4, and that within 50 miles is 42,000. See DOE/EIS-0246D,[21] Table G–5. The Missouri Census Data Center[22] reports 0 population within 10 miles and only approximately 14,000 within 50 miles, based on 2010 census data.

Nearest center of population:[23] North Las Vegas, NV (population approximately 217,000) approximately 90 miles SE.

Nature of surroundings within 5 miles of the Device Assembly Facility (DAF): Unpopulated. See **Figure D–15**.

Size of site: 1,360 square miles (approximately 870,000 acres).[24] See **Figure D–16**.

Most likely wind direction: **Figure D–17** shows that the predominant wind direction in the southern half of NNSS, near DAF, is from the south west, not towards any major center of population.

Initial Subjective Assessment of Public External Individual and Societal Risk in the event that pit production is relocated to NNSS: Low because of large distances to population centers, zero population within 5 miles of site, and predominant wind direction not towards population centers.

Policy Risk: There are so few people within 50 miles of this site that the policy risk is expected to be low, unless there is some residual fallout from the controversy associated with Yucca Mountain.

---

[20] Measured from the Device Assembly Facility (DAF). See Figure D–15 for the location of DAF.
[21] DOE (U.S. Department of Energy) 2011, *Draft Site-Aide Environmental Impact Statement for the Continued Operation of The Department of Energy/National Nuclear Security Administration Nevada National Security Site and Off-Site Locations in the State of Nevada (NNSS SWEIS)*, DOE/EIS-0246D, Washington DC, July, obtained from https://nnsa.energy.gov/aboutus/ouroperations/generalcounsel/nepaoverview/nepa/nnsssweis.
[22] http://mcdc.missouri.edu/websas/caps10c.html.
[23] Distances estimated from DAF using Google Maps, see Figure D–16: populations obtained from https://suburbanstats.org/population/.
[24] http://www2.nstec.com/Pages/NNSS-Mission.aspx.

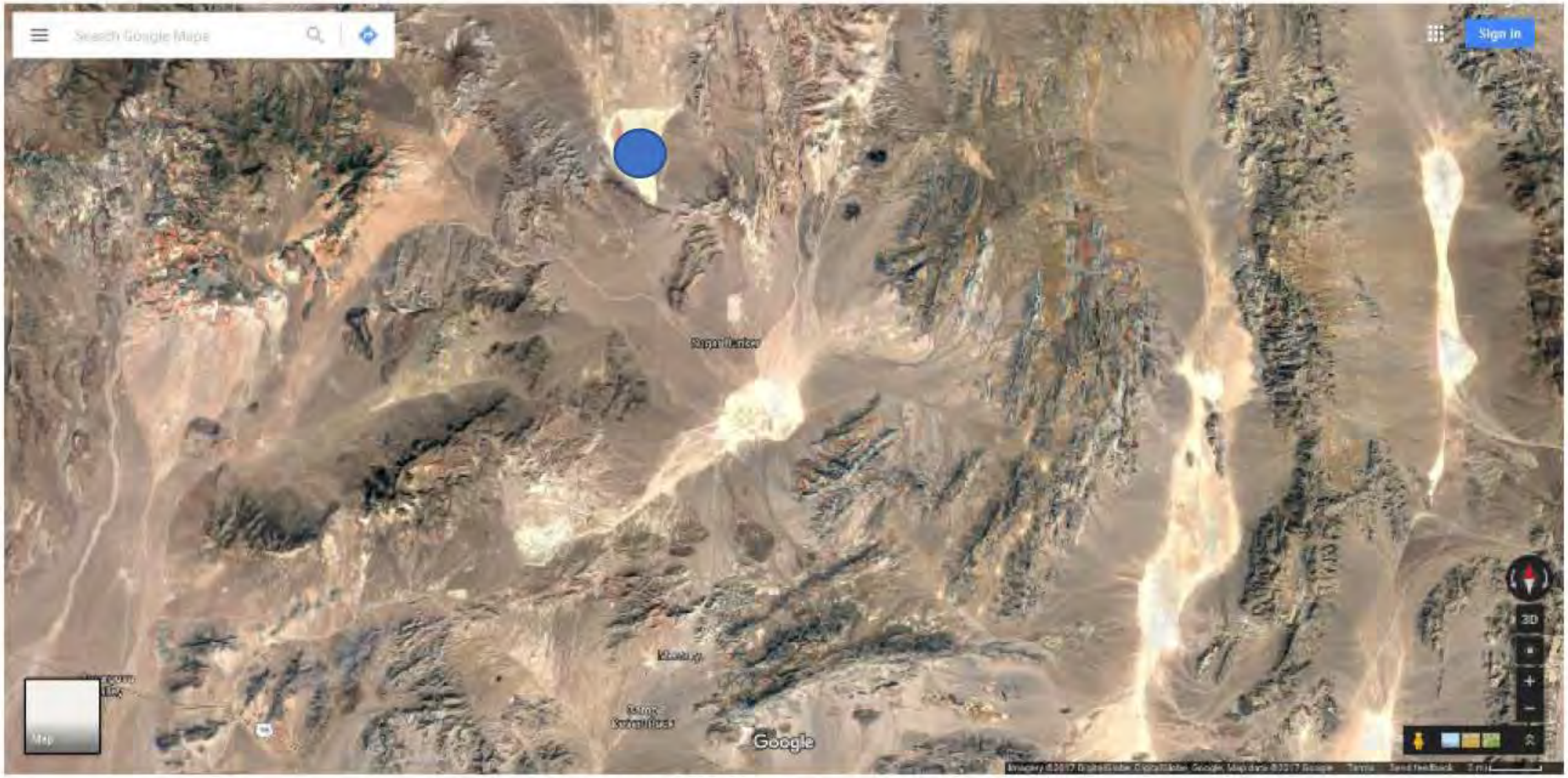


Figure D–15. Google map of NNSS area

Map is approximately 60 miles E-W and approximately 30 miles N-S.

Blue spot identifies area containing DAF.

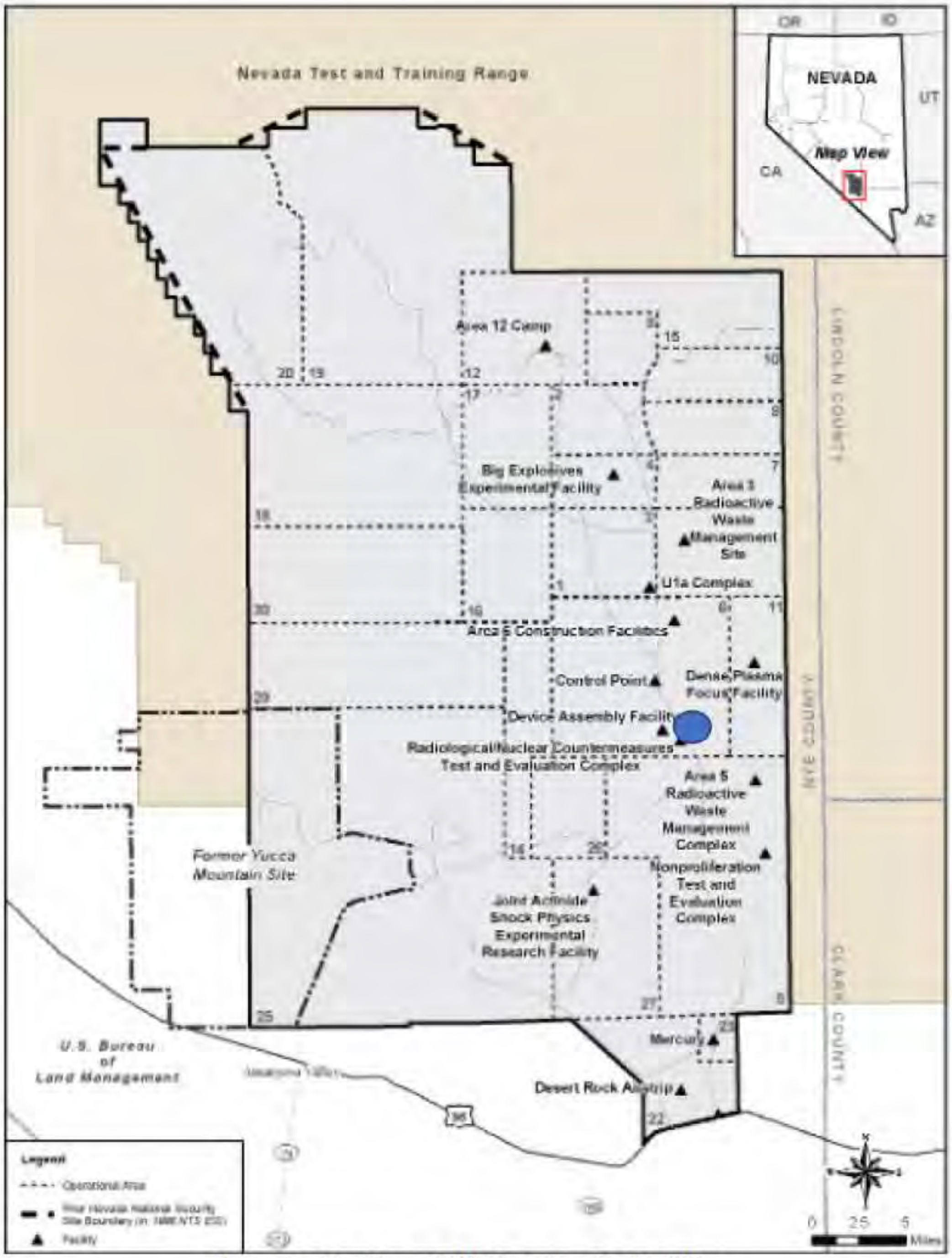


Figure D–16. Map of NNSS and major facilities

(Source: DOE/EIS-0246D Figure 2-2)

Blue circle adjacent to DAF.

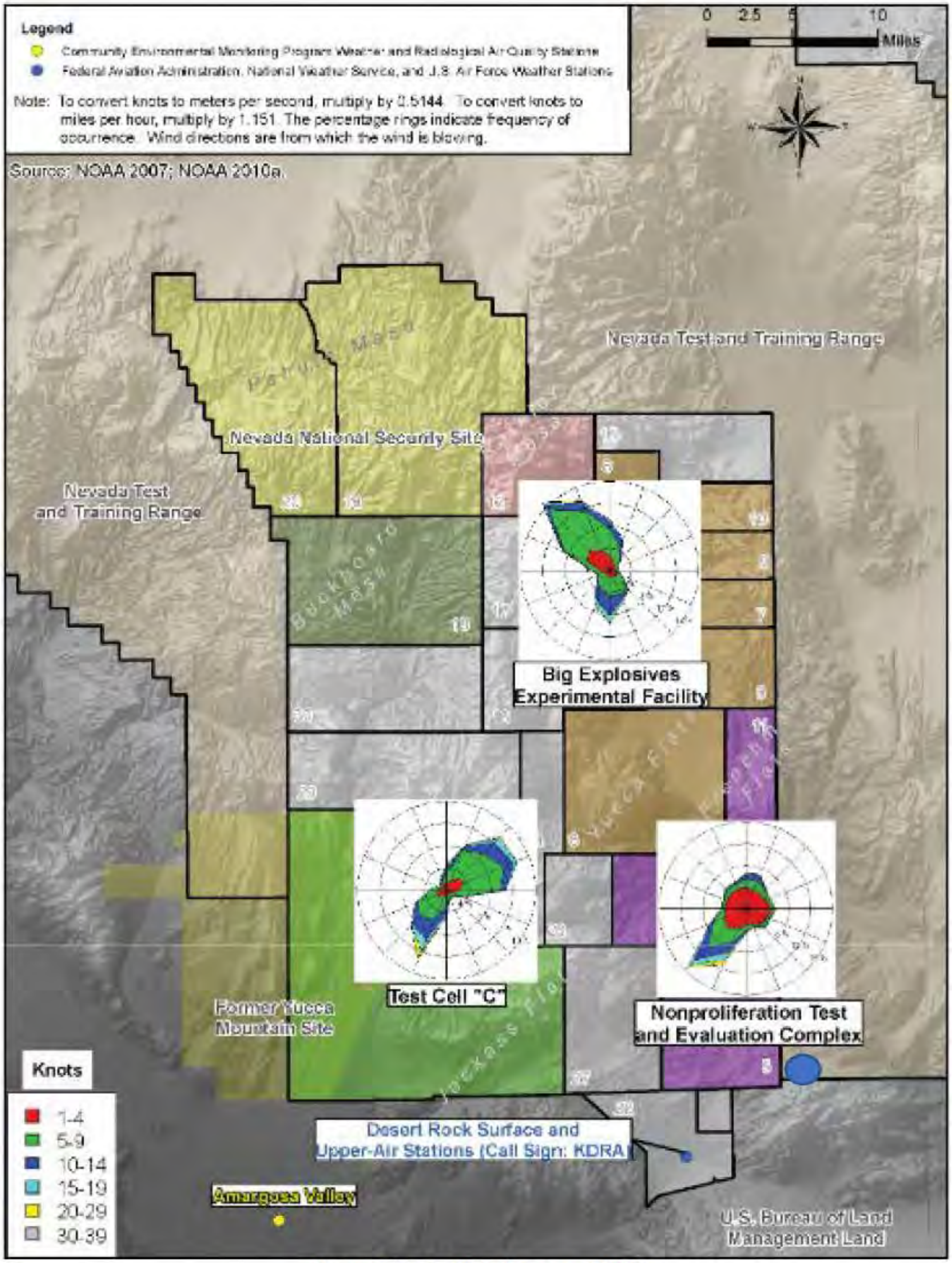


Figure D–17. Wind roses at NNSS

(Source: DOE/EIS-0246D Figure 4-18)

Bottom right wind rose is closest to DAF, which is approximately at the blue dot.

D.9 Lawrence Livermore National Laboratory

Surrounding population: Population within 5 miles is approximately 76,000 based on the 2010 census,[25] and that within 50 miles is 7,700,000. The distance from Superblock to the nearest population is approximately 0.6 miles. See **Figure D–18**.

Representative nearby centers of population:[26]

- Livermore, CA (population approximately 81,000); city center is approximately 3 miles E.
- Pleasanton, CA (population approximately 70,000) approximately 9 miles ESE.
- Dublin, CA (population approximately 46,000), approximately 14 miles E.

Nature of surroundings within 5 miles: Heavily populated to E and SE, see **Figure D–19**. Sparsely populated to the W and S.

Size of site: 1 square mile (approximately 640 acres).[27]

Most likely wind direction: **Figure D–20** shows two wind roses, one for the wet season and one for the dry season. In both seasons, the wind blows most of the time from the W, WSW, SW, and SSW, i.e., away from populated areas.

Initial Subjective Assessment of Public Individual and Societal Risk in the event that pit production is relocated to LLNL: High because of short distances to population centers and very small site, slightly mitigated by winds predominantly blowing towards relatively sparsely populated areas.

Policy Risk: High because LLNL has been reducing material-at-risk (MAR) at the site (and presumably the public would not want that to be reversed), the site is very small, and there are very large populations both close-in and within 50 miles.

[25] http://mcdc.missouri.edu/websas/caps10c.html.
[26] https://suburbanstats.org/population/.
[27] https://www.llnl.gov/about.

Figure D–18. Google map of LLNL and immediate vicinity

Map is approximately 3.8 miles E-W and 1.9 miles N-S.

Blue dot is over Superblock.

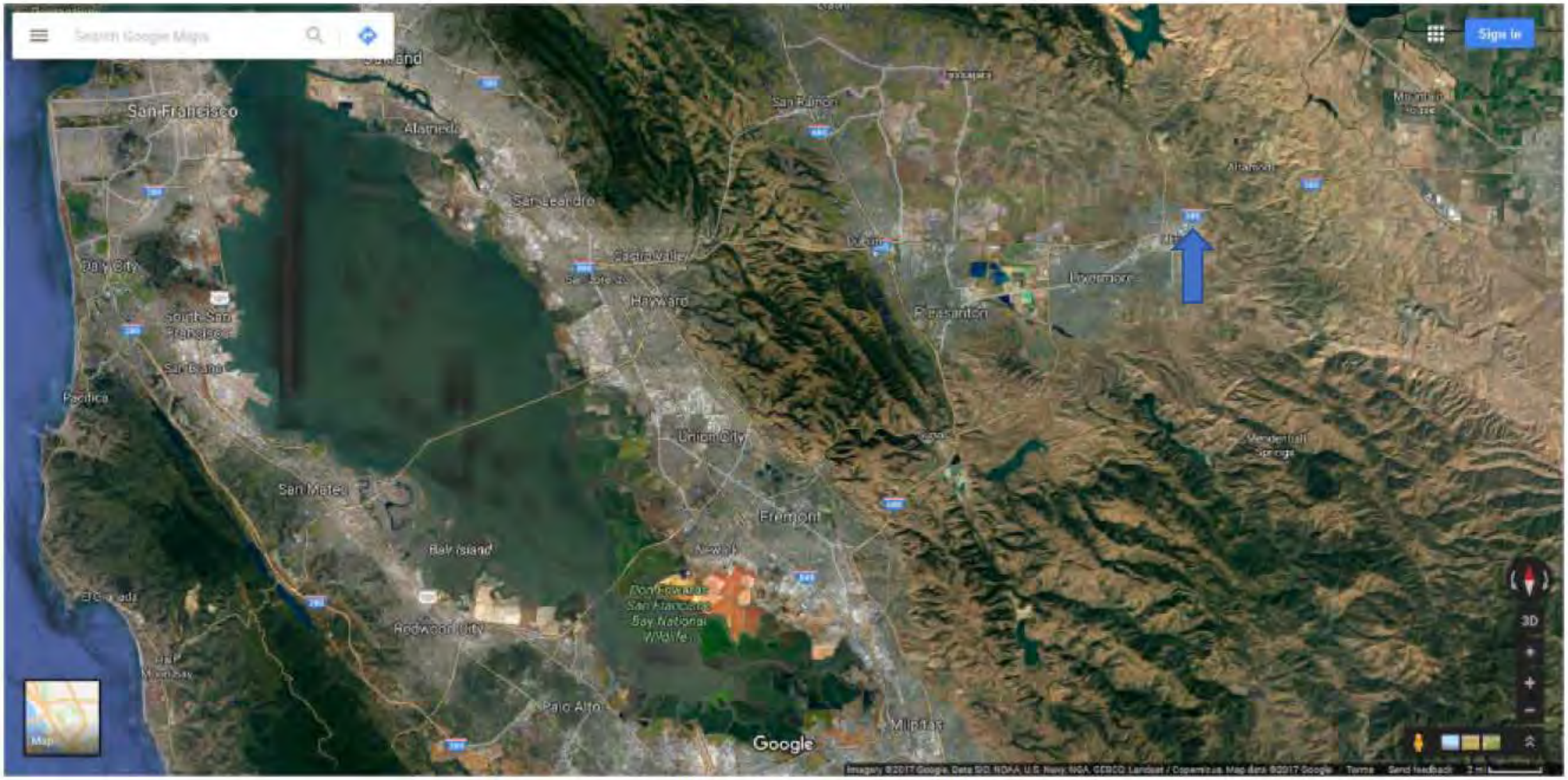


Figure D–19. Google map of San Francisco Bay area

Map is approximately 60 miles E-W and 30 miles N-S.

LLNL is approximately at tip of blue arrow.

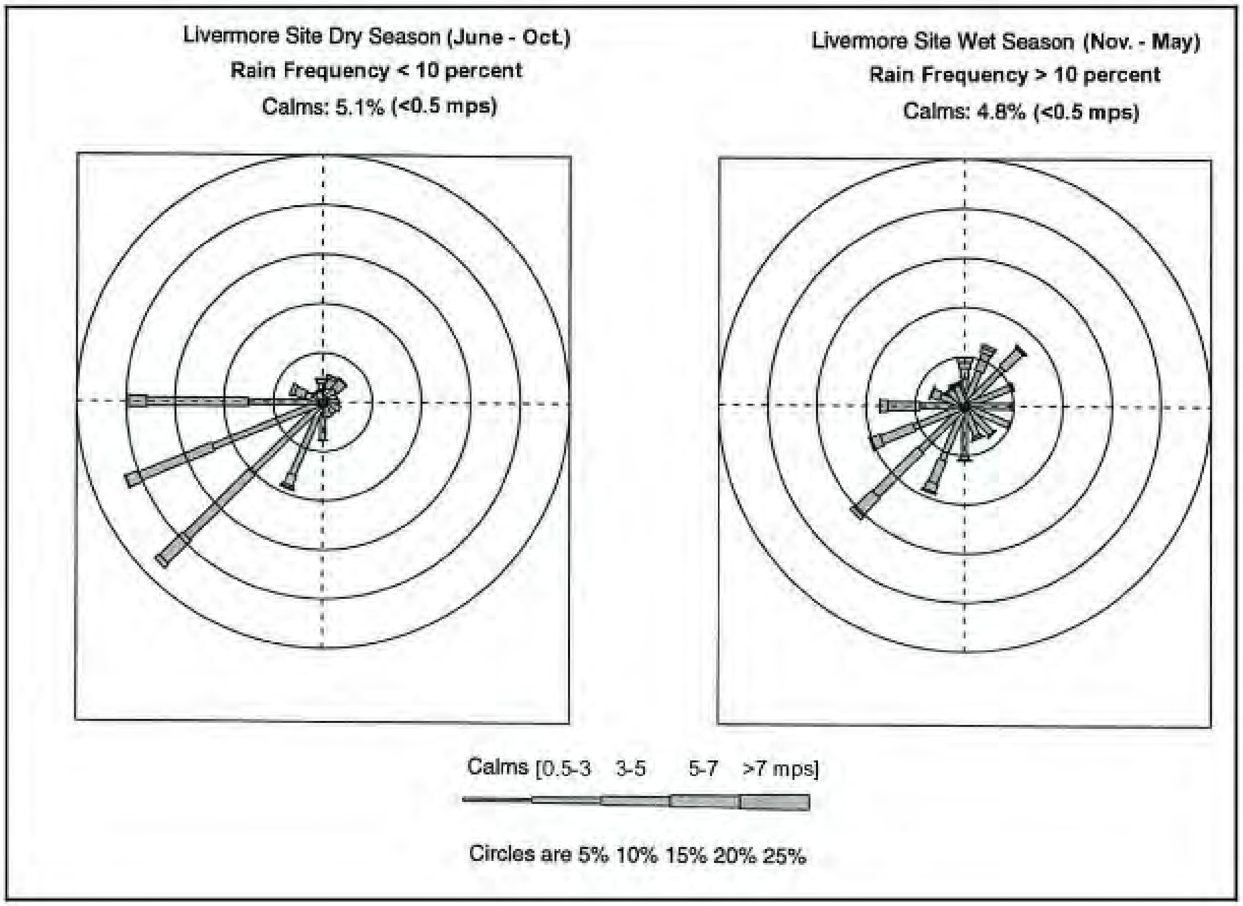


Figure D–20. Dry season and wet season wind roses for LLNL

(Source: DOE/EIS-0348 and EIS-0236-S3[28] Figure 4.7.3-1)

[28] DOE (U.S. Department of Energy) 2005, *Final Site-Wide Environmental Impact Statement: Continued Operation of Lawrence Livermore National Laboratory and Supplement Stockpile Stewardship and Management*, DOE/EIS-0348 and EIS-0236-S3, Washington DC, March, obtained from https://energy.gov/nepa/downloads/eis-0348-and-eis-0236-s3-final-site-wide-environmental-impact-statement.

D.10 Y-12 National Security Site and Oak Ridge National Laboratory

Surrounding population: Within 2 miles, 0 for ORNL and approximately 3,300 for Y-12; within 5 miles approximately 6,600 and approximately 32,700, respectively; within 50 miles both approximately 1,200,000. Populations from the University of Missouri Census data center, based on the 2010 census.[29]

Nearby Centers of Population:[30] See **Figures D–21** and **D–22**.

- Oak Ridge, TN (population approximately 29,000), centered 2 miles N of Y-12 PIDADS and approximately 6 miles NE of ORNL.
- Knoxville, TN (population approximately 180,000), centered approximately 20 miles slightly S of E from Y-12 and approximately 22 miles slightly N of E from ORNL. Nearest point of approach (roughly at I-40/162 intersection) approximately 9 miles SE of Y-12, 11 miles ESE of ORNL.
- Other centers of population within 30 miles: Oliver Springs, Clinton, Rocky Top, Lenoir City, Farragut, Kingston, and Harriman

Nature of surroundings within 5 miles:

- Y-12 – situated to S of Oak Ridge. Shortest distance between PIDADS and nearest house approximately 1,500 feet. The whole of the city of Oak Ridge is within 5 miles of Y-12. See Figure D–21.
- ORNL – most of the land within 5 miles of ORNL is inside the ORR, except to the east and south, just across the Clinch River, where residences can be found in the 4-5-mile range. See Figure D–21.

Size of site: Y-12 – 1.25 square miles (approximately 811 acres),[31] ORNL – 6.9 square miles (approximately 4,400 acres),[32] both located within ORR which has an area of 52 square miles (33,508 acres),[33] see **Figures D–23**, **D–24**, and **D–25**.

Most likely wind direction: ORR-ASER-2015 presents a large number of wind roses on the Y-12 and ORNL sites.[34] These vary somewhat depending on location and height. On average, it seems that, at lower elevations (e.g., 10 meters above ground level) winds from the NE or ENE are about as probable as winds from the SW or SSW. The wind roses from taller meteorological towers tend to show a more consistent predominant wind direction from the SW. In any event, none of the wind roses show any particular orientation towards either relatively unpopulated or relatively populated areas.

Initial Subjective Assessment of Public Individual and Societal Risk in the event that pit production is relocated to the Oak Ridge Reservation: For Y-12 high because of proximity to the city of Oak Ridge. For ORNL, somewhat lower (moderate) because the laboratory is in the middle of the Oak Ridge Reservation. The 50-mile population is over one million for both sites. This is higher than for most of the sites being analyzed in this appendix.

---

[29] http://mcdc.missouri.edu/websas/caps10c.html.
[30] Distances estimated using Google Maps, see Figures D–22 through D–25: populations obtained from https://suburbanstats.org/population/.
[31] http://www.y12.doe.gov/sites/default/files/pdf/page/ygg-14-0371r3_about_y12.pdf.
[32] https://science.energy.gov/laboratories/oak-ridge-national-laboratory/.
[33] DOE (U.S. Department of Energy), Oak Ridge Reservation Annual Site Report 2015, DOE/ORO/2509, Oak Ridge, TN, obtained from https://doeic.science.energy.gov/ASER/aser2015/index.html.
[34] http://web.ornl.gov/adm/fo/lp/orrm/page7.htm.

Policy Risk: Assessed to be moderate because Y-12 is the national center for uranium and there might be resistance to adding significant plutonium inventory.

Figure D–21. Google map showing ORNL

Map is approximately 15 miles E-W and 7.5 miles N-S.

ORNL identified by blue dot, Y-12 by red dot.

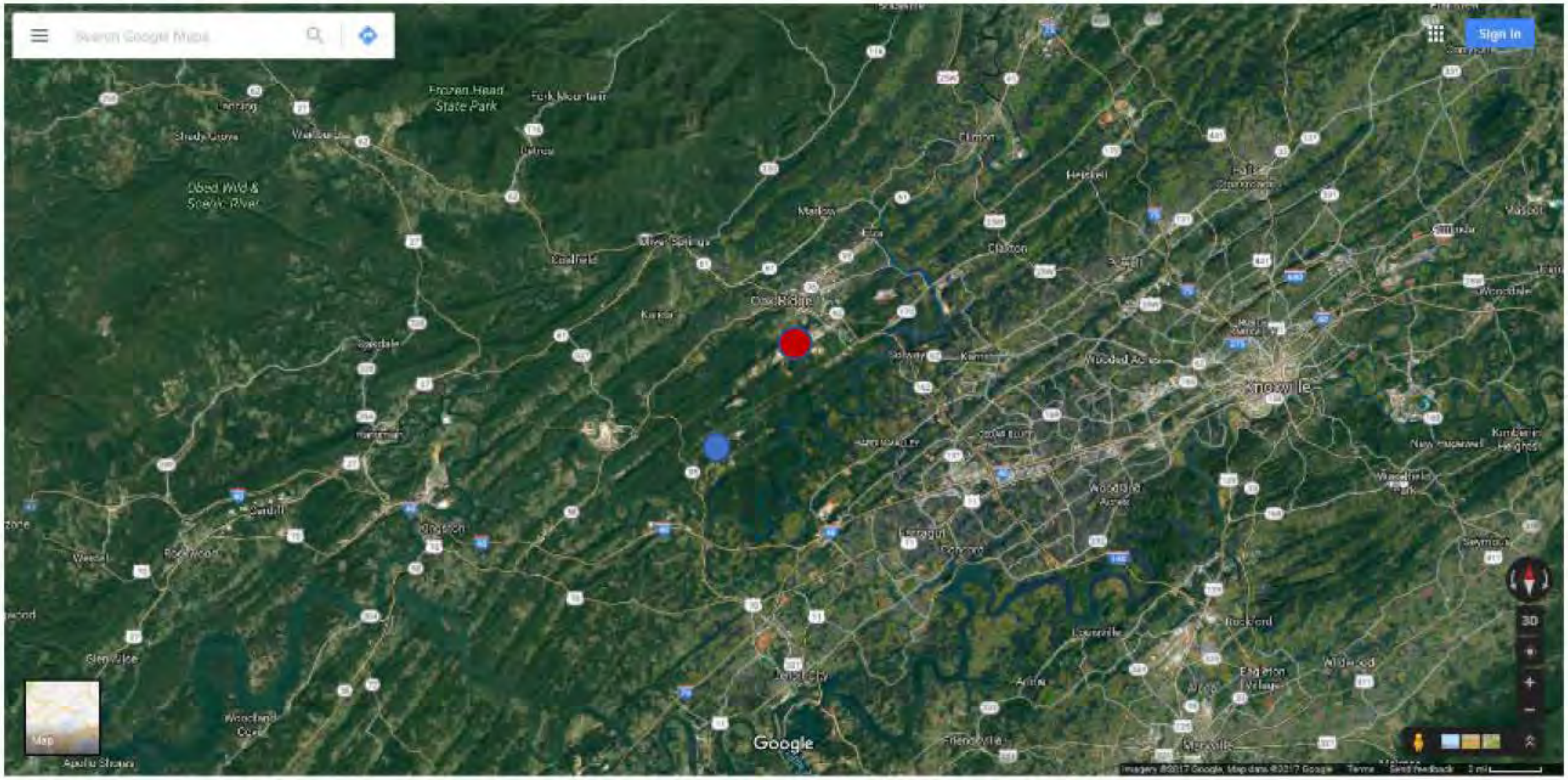


Figure D–22. Google map of area surrounding the city of Oak Ridge

Map is approximately 60 miles E-W and 30 miles N-S.

ORNL identified by blue dot, Y-12 by red dot.

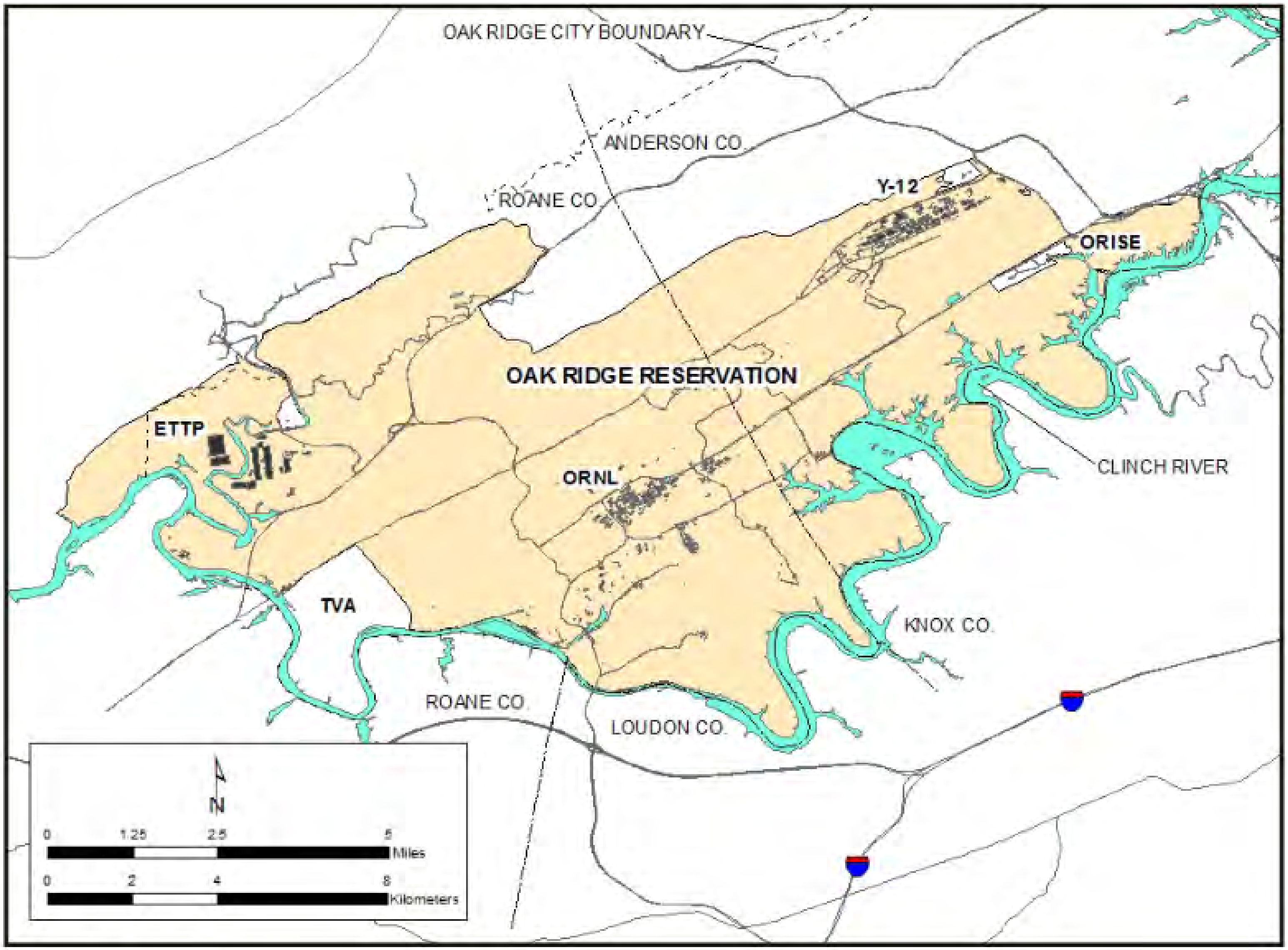


Figure D–23. Oak Ridge Reservation

(Source: ORR-ASER-2015, Figure 1-2)

Figure D–24. Close-up of SW end of Y-12 showing PIDAS

Figure D–25. Close-up of ORNL

D.11 Waste Isolation Pilot Plant

Surrounding population: Population near the site is very sparse. See **Figures D–26** and **D–27**. The nearest residences are ranches 3.5 miles SSW and 7 miles WNW.[35] The population within 5 miles is 2 and within 10 miles is 7, and that within 50 miles is approximately 113,000, based on the 2010 census.[36]

Representative nearby centers of population:[37]

- Loving, NM (population approximately 1,400) approximately 17 miles WSW.
- Carlsbad, NM (population approximately 26,000) approximately24 miles WNW.
- No other city within 30 miles, see Figure D–27 and **D–28**.

Nature of surroundings within 5 miles: Essentially unpopulated with many oil or natural gas wells. See Figures D–27 and **D–29**.

Size of site: 16 square miles (approximately 10,000 acres).[38]

Most likely wind direction: **Figure D–30** shows the WIPP wind rose at 33 meters. The most likely wind direction is from the SE, which would pass north of Carlsbad.

Initial Subjective Assessment of Public External Individual and Societal Risk in the event that pit production is relocated to WIPP: Low because of large distances to population centers, sparse population within 5 miles of site, and predominant wind direction not towards population centers.

Policy Risk: The authors have no reason to believe this would be other than low.

[35] DOE (U.S. Department of Energy) 1992, *Waste Isolation Pilot Plant Site Environmental Report for Calendar Year 1991*, DOE/WIPP 92-007, Washington DC, obtained from http://wipp.energy.gov/information_repository/cca/CCA_1996_References/Chapter%202/CREL259.PDF.
[36] http://mcdc.missouri.edu/websas/caps10c.html.
[37] Distances estimated from the center of WIPP using Google Maps, see Figure D–26: populations obtained from https://suburbanstats.org/population/.
[38] www.https://energy.gov/em/waste-isolation-pilot-plant.

Figure D–26. Google map of vicinity of WIPP Site

WIPP is approximately at tip of blue arrow.

Map is approximately 60 miles E-W and 30 miles N-S.

Figure D–27. Larger scale Google map of WIPP Site

Map is approximately 15 miles E-W and 7.5 miles N-S.

The many small rectangles are sites for oil wells, see Figure A.7-3.

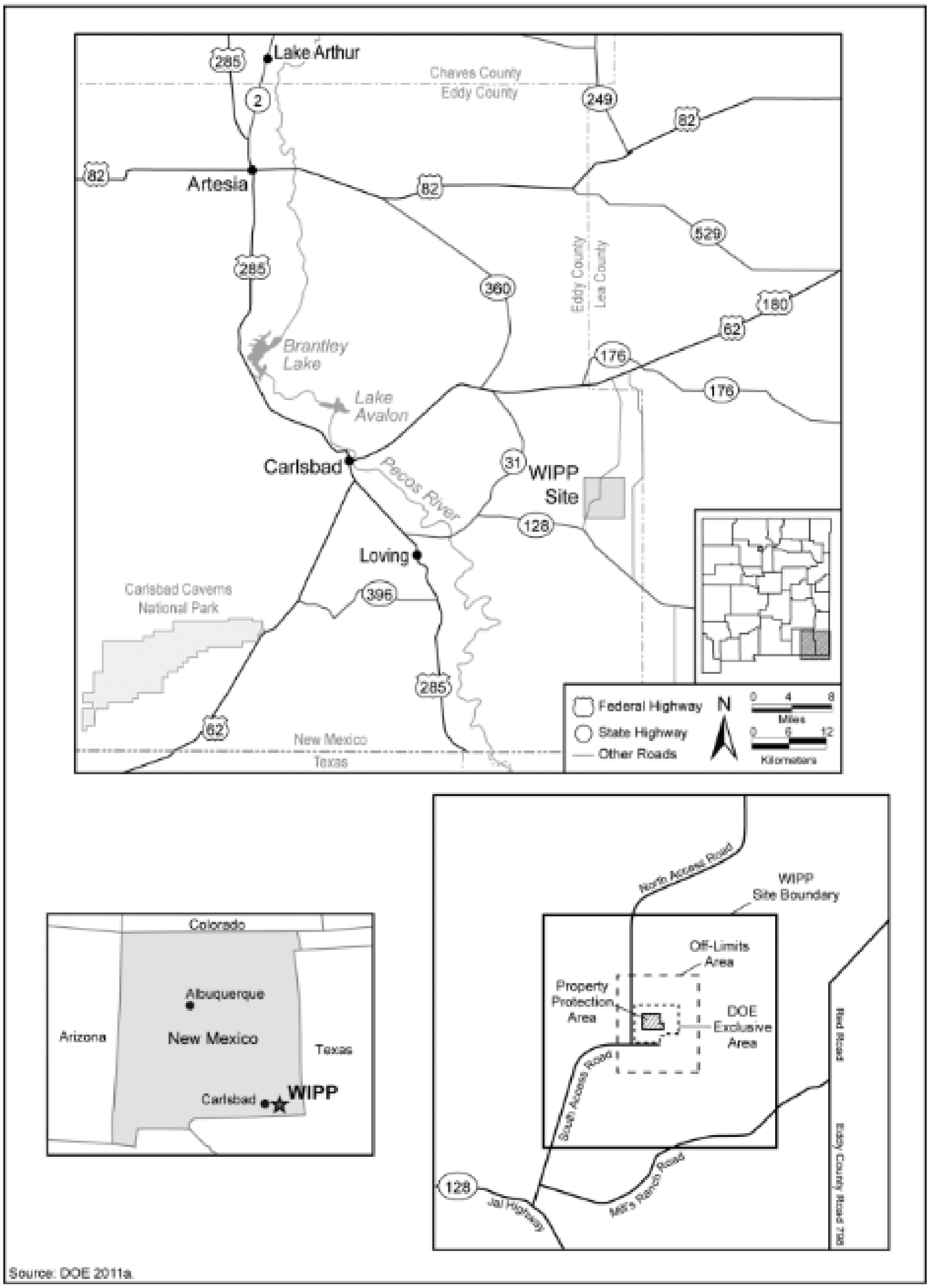


Figure D–28. Map of WIPP Site

(Source: *Final Surplus Plutonium Disposition Supplemental Environmental Impact Statement*, Figure 1-4.[39])

[39] DOE (U.S. Department of Energy) 2015 *Final Surplus Plutonium Disposition Supplemental Environmental Impact Statement*, DOE/EIS-0283-S2, Washington, DC, April, obtained from http://www.srs.gov/general/pubs/envbul/documents/EIS-0283-S2_SPD_Vol_1_EIS_Chapters.pdf.

Figure D–29. Oil well near WIPP

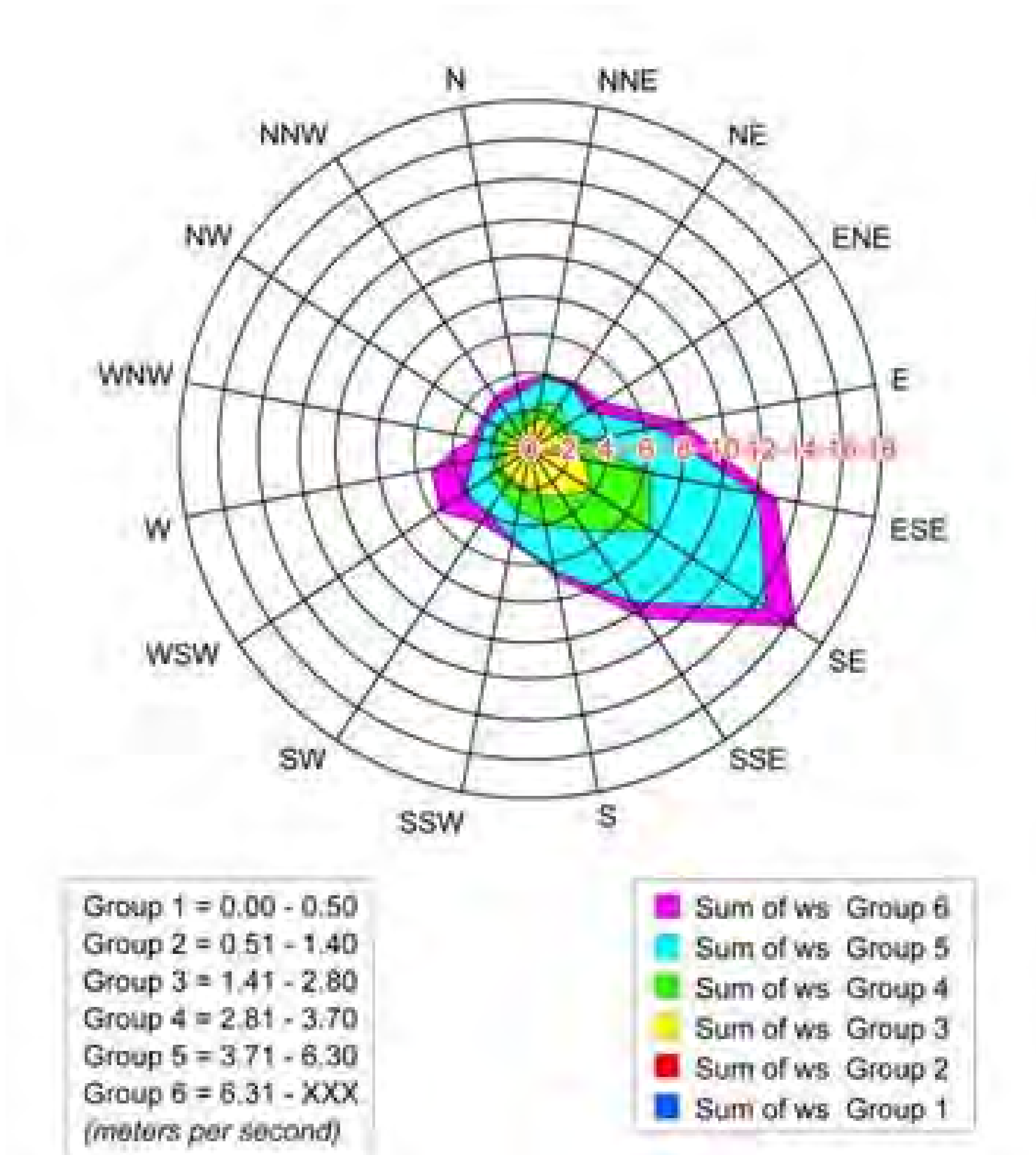


Figure D–30. 2005 wind rose for WIPP at 33 meters[40]

[40] DOE (U.S. Department of Energy) 2009, Subparts B and C Compliance Recertification, Application for the Waste Isolation Pilot Plant Content of Compliance Recertification Application(s) (40 CFR § 194.15), 2009, obtained from www.wipp.energy.gov/library/cra/2009 cra/CRA/Section 15/Section 15.htm#Figure 15-2.

D.12 Hanford

Surrounding population: Population within 10 miles is 2, and within 50 miles approximately 560,000, per the University of Missouri Census Data Center.[41]

Nearest centers of population:[42] See **Figures D–31** and **D–32**.

- Richland, WA (population approximately 48,000) approximately 17 miles SE of Area 200E.
- Kennewick, WA (population approximately 74,000) and Pasco, WA (population approximately 60,000) approximately 30 miles SE of Area 200E.

Nature of surroundings within 5 miles: See Figures D–31 and **D–33**. Essentially unoccupied except for site facilities.

Size of site: 586 square miles (approximately 375,000 acres).[43] Area 200E is approximately 10 miles from nearest site boundary.

Most likely wind direction: A detailed study of Hanford Site climatology by Pacific Northwest National Laboratory (PNNL)[44] provides tabular joint frequency distributions that show, at Areas 200E and 200W, the wind blows from W-NW 40-45 percent of the time. This is usually not towards the Tri-Cities area, although winds from the NW may just skirt the northeastern fringes of the cities.

Initial Subjective Assessment of Public External Individual and Societal Risk in the event that pit production is relocated to Hanford: Low because of large distances to population centers, sparse population within 5 miles of Area 200E, the very large site, and predominant wind directions mostly not towards population centers.

Policy Risk: Considerable controversy has centered on potential contamination of the Columbia River. This is such a high-profile issue that the policy risk should be considered at least moderate.

[41] http://mcdc.missouri.edu/websas/caps10c.html.
[42] Populations obtained from https://suburbanstats.org/population/.
[43] http://www.hanford.gov/page.cfm/FunFacts.
[44] PNNL (Pacific Northwest National Laboratory) 2005, Hanford Site Climatological Summary 2004 with Historical data, PNNL-15160, Richland, WA, May, obtained from http://www.pnl.gov/main/publications/external/technical_reports/PNNL-15160.pdf.

Figure D–31. Google map of Hanford area

Map approximately 50 miles E-W and 25 miles N-S. Plant is at top center, Tri-Cities area to South/South East.

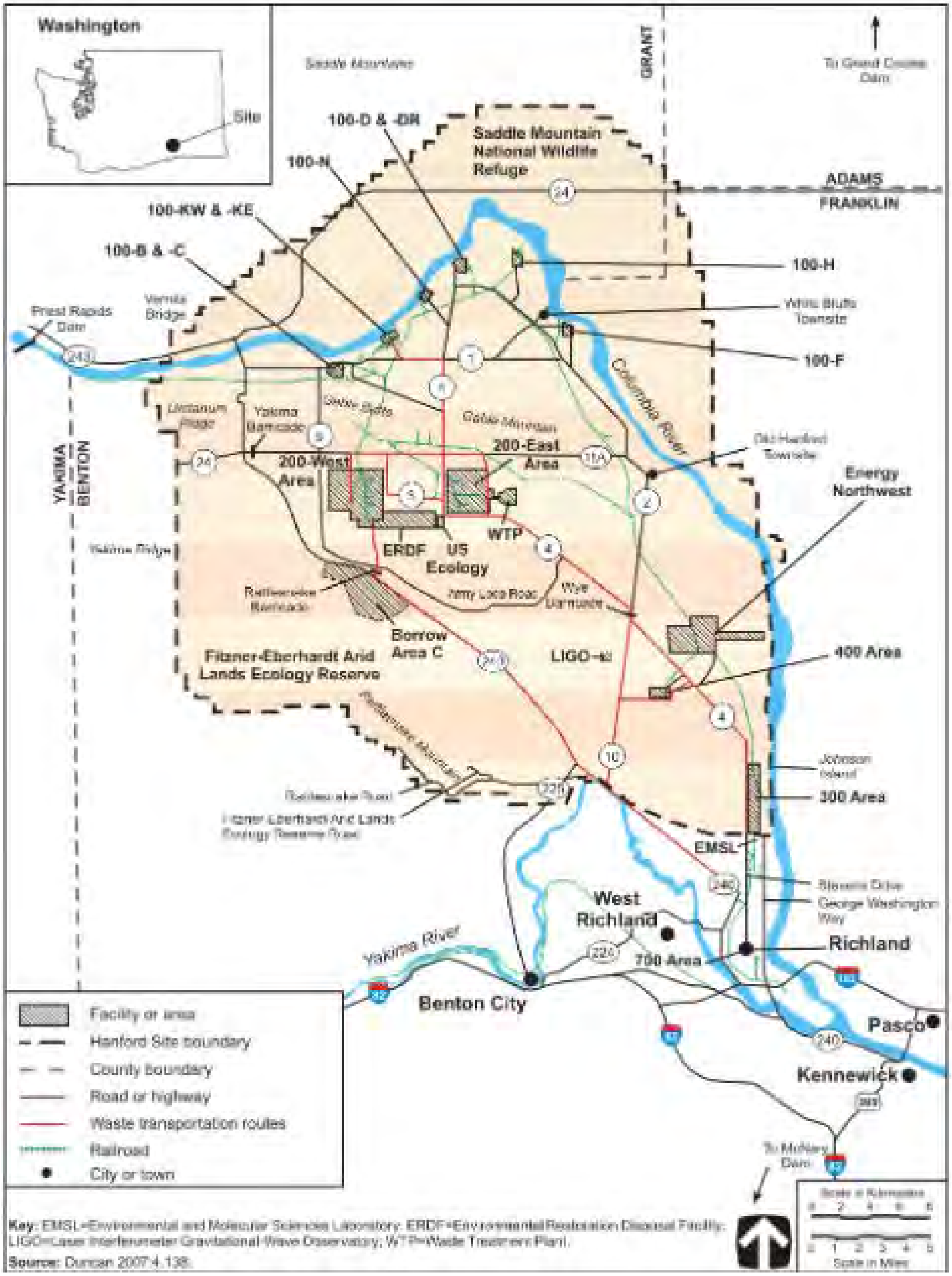


Figure D–32. Map of Hanford Site

(Source: EIS-0391, Volume 1[45])

[45]DOE (U.S. Department of Energy) 2012, *Final Environmental Impact Statement, Hanford Tank Closure and Waste Management, Hanford Site*, DOE-EIS-0391, Washington, DC, May, obtained from http://www.hanford.gov/page.cfm/FinalTCWMEIS.

Figure D–33. Google map of Hanford Plant

Map is approximately 13 miles E-W and 6.5 miles N-S.

D.13 Idaho National Laboratory

Surrounding population: Population within 5 miles of the Central Facilities Area (CFA) is zero, see **Figure D–34**. The population within 50 miles is approximately 330,000.[46] Data from the University of Missouri Census Data Center[47] confirm zero population within 5 miles, but assign only approximately 179,000 people within 50 miles.

Nearest centers of population:[48]

- Howe, ID (population approximately 220) approximately 16 miles N of CFA.
- Arco, ID/Butte City, ID (population approximately 1,000), approximately 20 miles WNW.
- Blackfoot, ID (population approximately 12,000), approximately 40 miles SE.
- Idaho Falls, ID (population approximately 57,000), approximately 50 miles E.

Nature of surroundings within 5 miles: See Figure D–34 and **Figure D–35**. Essentially unpopulated, no industrial activity except for the site itself.

Size of site: 890 square miles (approximately 570,000 acres) from https://energy.gov/em/idaho-national-laboratory. CFA is approximately 6 miles from the closest site boundary.

Most likely wind direction: Assuming the new pit production facility would be built in the general area of CFA, the predominant wind direction is from the southwest and so does not blow toward any of the population centers listed above. See **Figure D–36**.

Initial Subjective Assessment of Public External Individual and Societal Risk in the event that pit production is relocated to INL: Low because of large distances to population centers, sparse population within 5 miles of CFA, very large site, and predominant wind direction not toward population centers.

Policy Risk: Extreme remoteness and a large site should mitigate public concerns. However, INL is currently operating under a consent decree with the State of Idaho that may make it difficult to establish new activities that require bringing plutonium onsite. On balance, the policy risk is moderate.

[46] DOE (U.S. Department of Energy) 2013, *Draft Supplement Analysis for the Nuclear Infrastructure Programmatic Environmental Impact Statement for Pu-238 Production for Radioisotope Power Systems,* DOE/EIS-0310-SA-02, Washington DC, September, obtained from http://www.id.doe.gov/insideNEID/PDF/Pu-238_Supplement_Analysis.pdf.

[47] http://mcdc.missouri.edu/websas/caps10c.html.

[48] Distances estimated using Google Maps and Figure 2: populations mainly obtained from https://suburbanstats.org/population/.

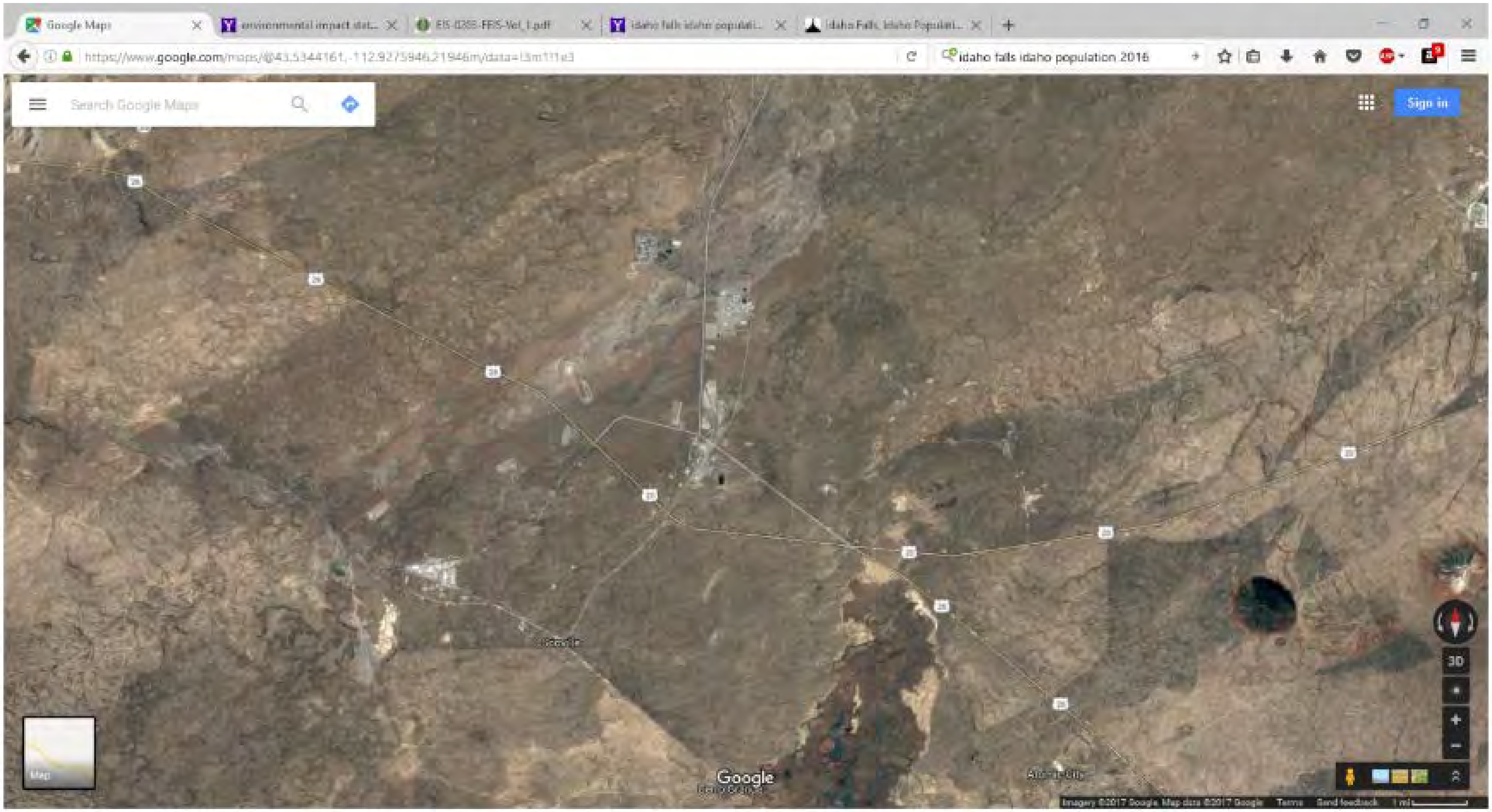


Figure D–34. Google map of INL and vicinity

INL is in center; map is approximately 25 miles E-W and 12 miles N-S.

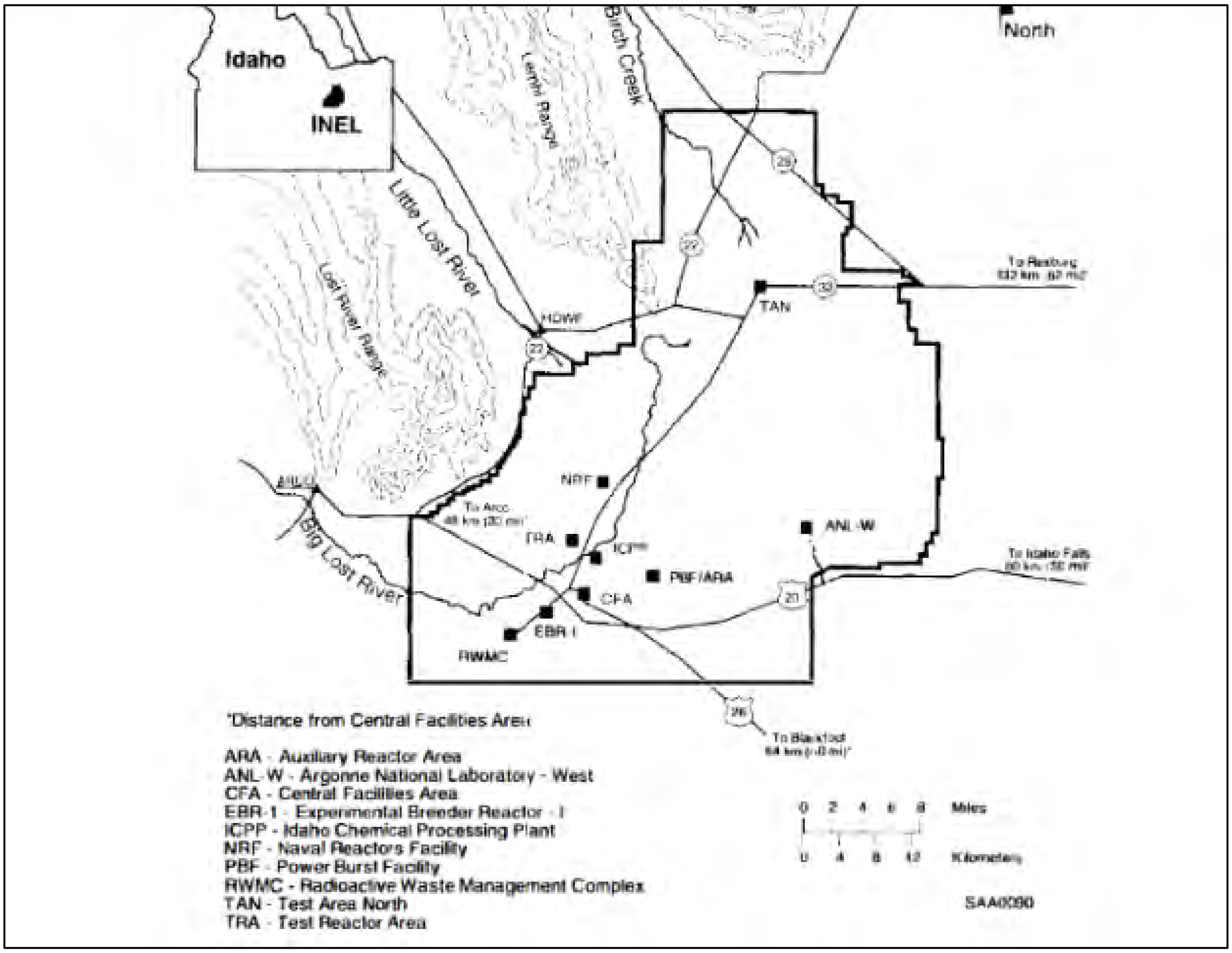


Figure D–35. Map of INL

Screenshot from FEIS,[49] Figure 4-9

[49] DOE (U.S. Department of Energy) 1996, *Department of Energy Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Restoration and Waste Management Programs Final Environmental Impact Statement,* DOE/EIS-0203-F, Washington DC, April, obtained from https://energy.gov/nepa/downloads/eis-0203-programmatic-final-environmental-impact-statement.

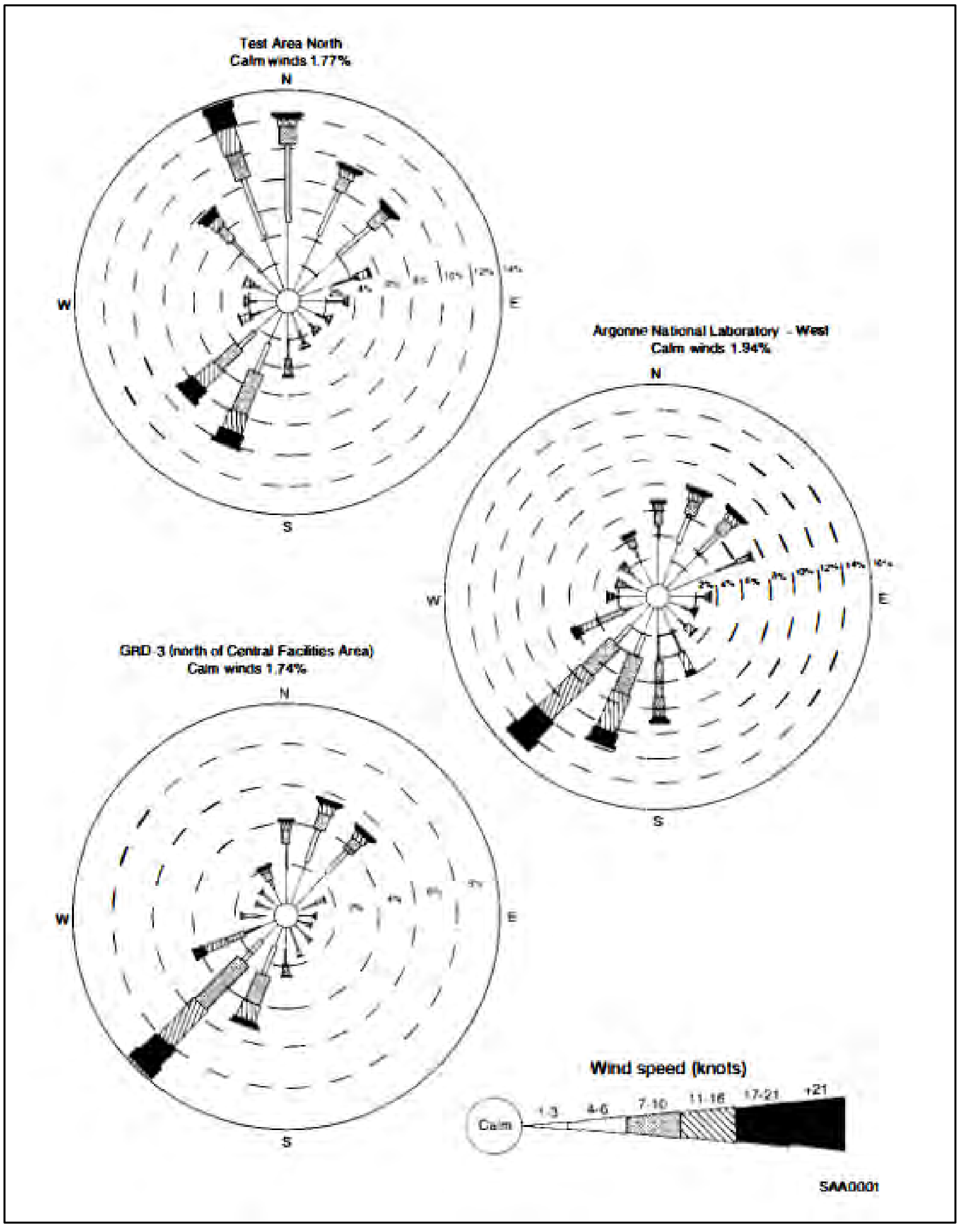


Figure D–36. Wind roses at INL

(Source: DOE/EIS-0203/F, Volume 2, Figure 4.7-1)

The wind rose at Test Area North is clearly influenced by terrain, since it is at the mouth of a valley oriented roughly NNW-SSE (see Figure D–35). For CFA and Argonne National Laboratory-West, the predominant wind direction is from the SW, which means it does not blow toward any of the population centers listed above.

D.14 Brookhaven National Laboratory

Surrounding population: Population within 1 mile of the site is 13,460 as of 2007, see **Figure D–37**.[50] That within 5 miles is 67,000 and within 50 miles is approximately 6,200,000 based on 2010 census.[51]

Nearby centers of population: Brookhaven Township, which surrounds the site, occupies an area of about 530 square miles and has a population of approximately 486,000.[52]

Nature of surroundings within 5: Numerous villages within Brookhaven Township, see **Figures D–38** and **D–39**.

Size of site: Approximately 8 square miles (approximately 5,000 acres).[53]

Most likely wind direction: Winds at BNL are predominantly from westerly directions.[54] This is away from the largest centers of population, but cannot be said to be toward lightly populated areas.

Initial Subjective Assessment of Public Individual and Societal Risk in the event that pit production is relocated to WIPP: High because of the relatively small site and its location on heavily populated Long Island.

Policy Risk: Assessed to be high – considering the controversy that surrounded the construction of the Shoreham nuclear reactor on Long Island, leading to its eventual cancellation.

---

[50] http://www.longisland.com/population.html.
[51] http://mcdc.missouri.edu/websas/caps10c.html.
[52] https://en.wikipedia.org/wiki/Brookhaven,_New_York.
[53] DOE (U.S. Department of Energy) 2009, *Environmental Assessment for BP Solar Array Project, Brookhaven National Laboratory, Upton, New York*, DOE/EA-1663, Washington DC, December, obtained from https://www.bnl.gov/community/docs/pdf/final%20final%20ea%20-%20bp%20solar%20project.pdf.
[54] BNL (Brookhaven National Laboratory) 2013, *Meteorological Services Annual Data Report for 2012*, BNL-100629-2013-IR, Upton, NY, obtained fromhttps://www.bnl.gov/envsci/pubs/pdf/2013/BNL-100629-2013-IR.pdf.

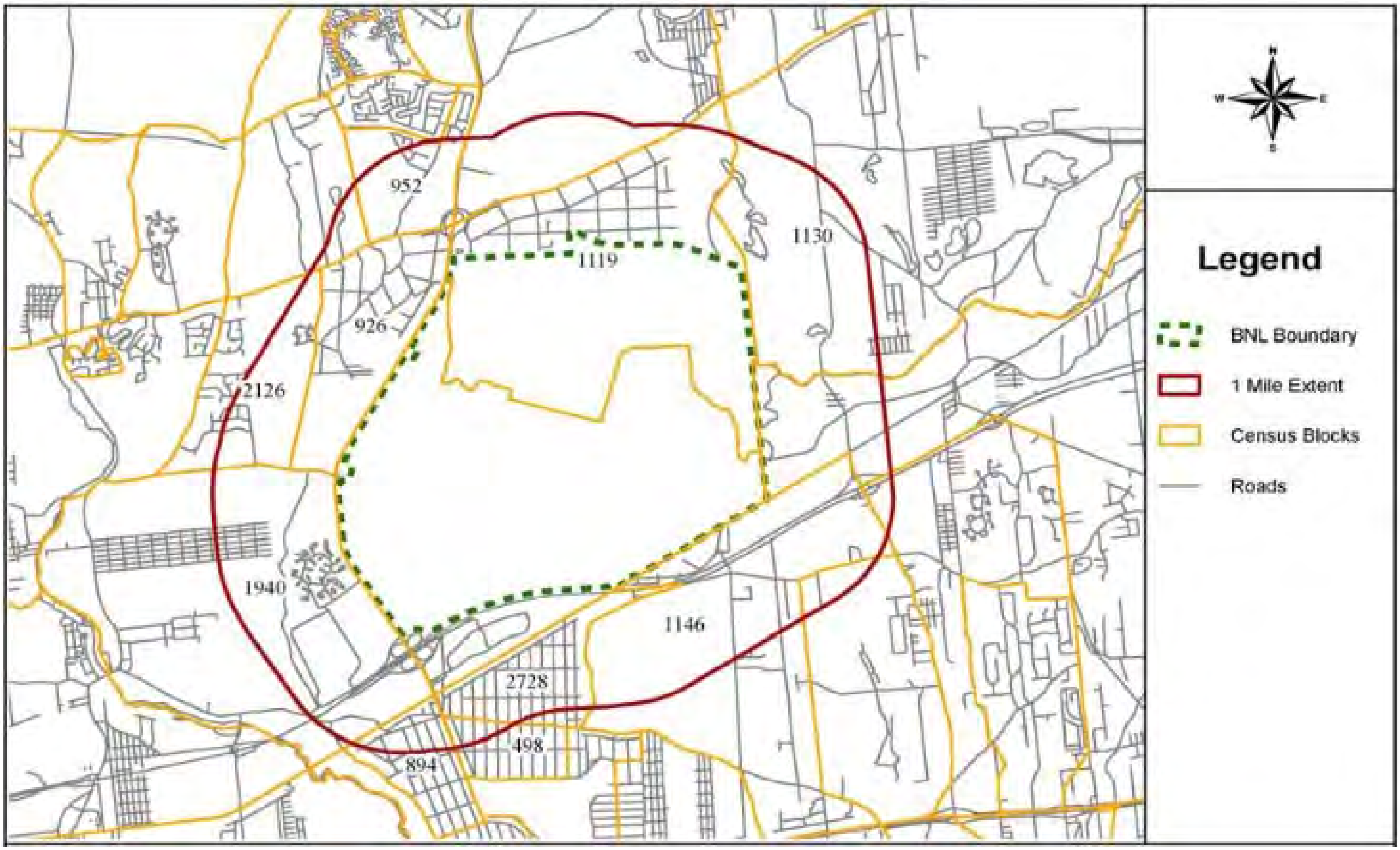


Figure D–37. Map of BNL with population within 1 mile of site boundary

(Source: DOE/EA-1663, Figure 6)

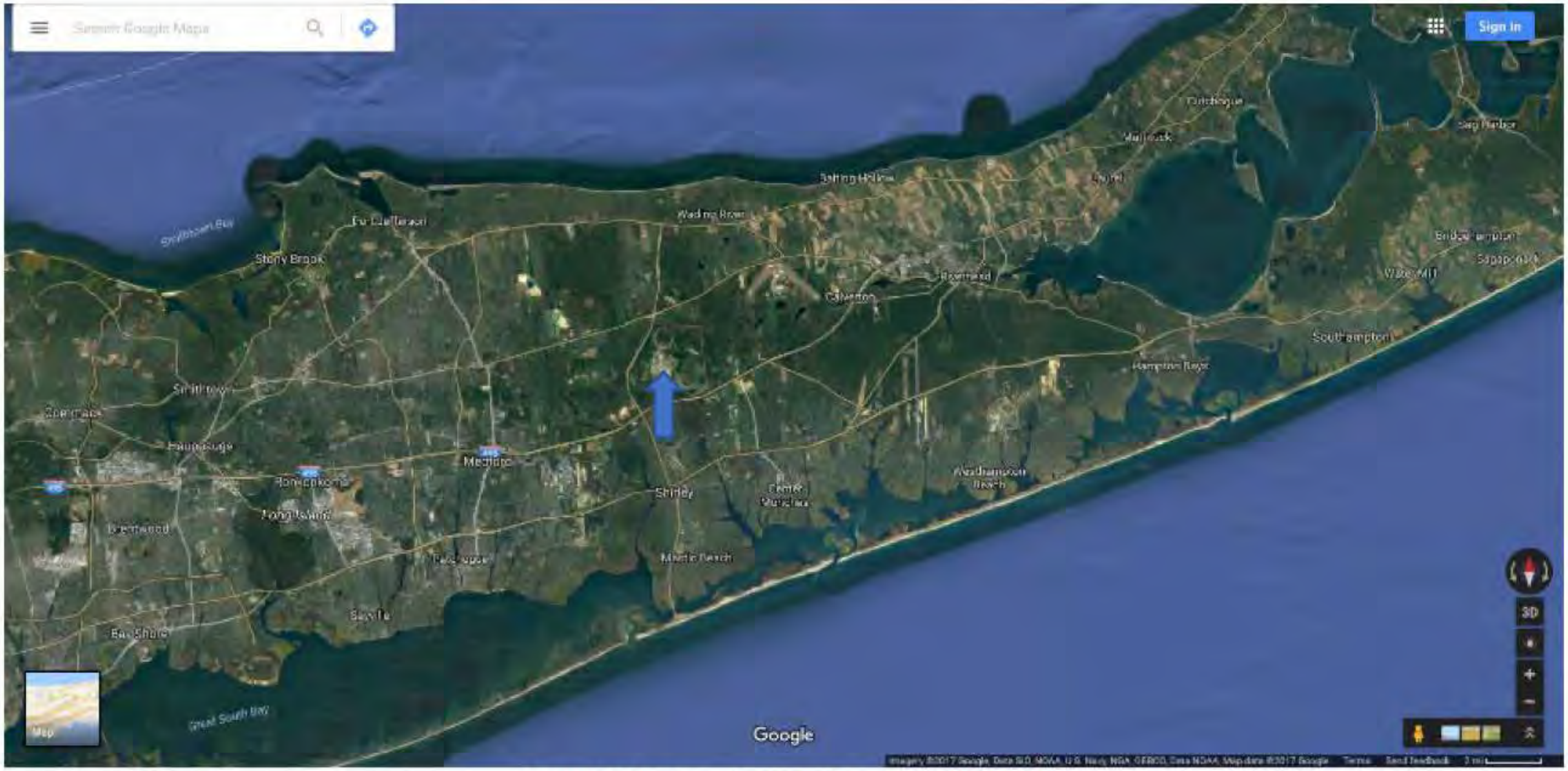


Figure D–38. Google map of part of Long Island

Map is approximately 60 miles E-W and 30 miles N-S.

BNL is approximately at tip of blue arrow.

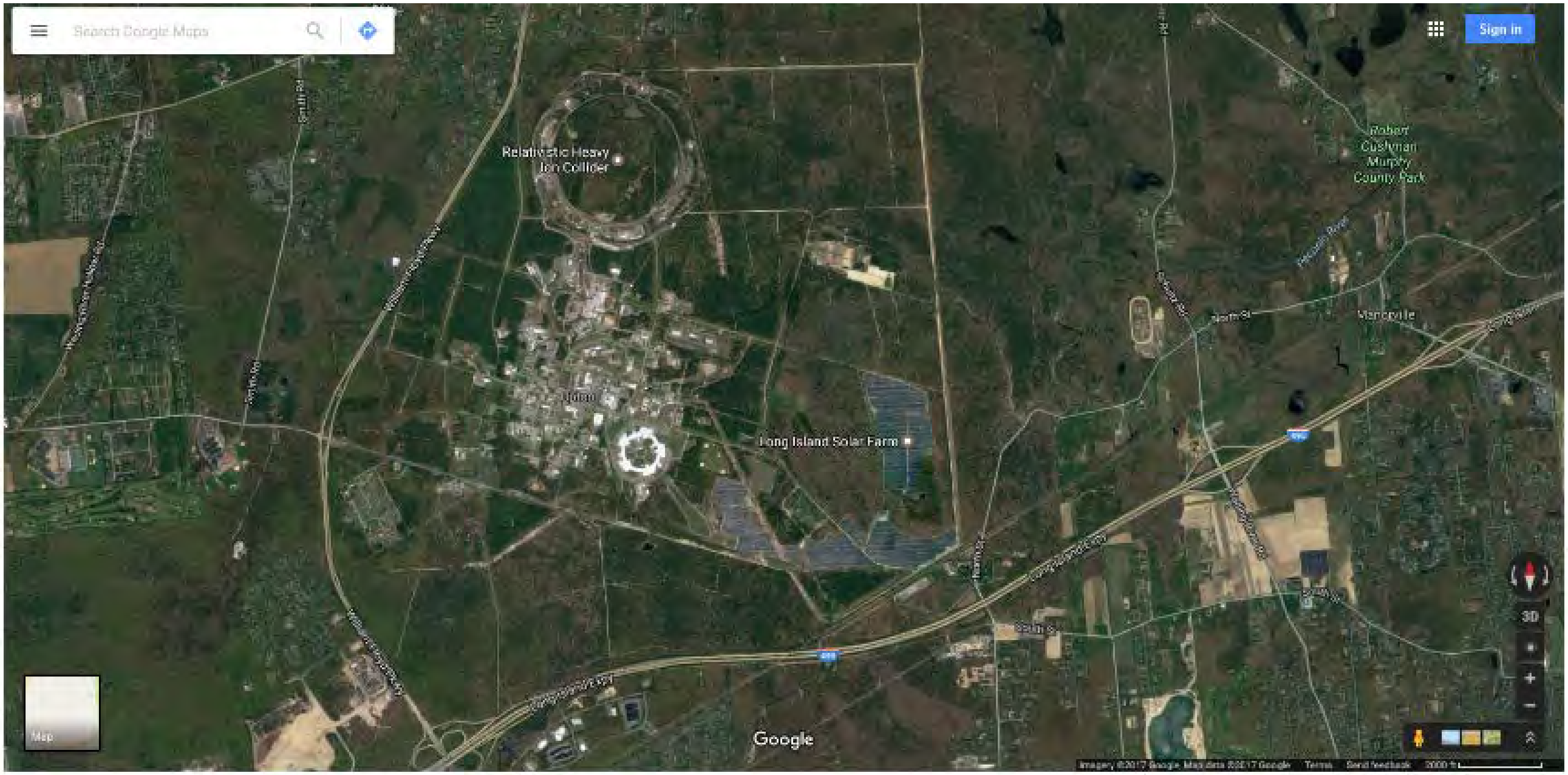


Figure D–39. Google map of BNL and immediate vicinity

Map is approximately 7 miles E-W and 3.5 miles N-S.

D.15 Kansas City Nuclear Security Campus

Surrounding population:[55] Population within 5 miles is approximately 98,000, that within 50 miles is approximately 2,200,000, based on 2010 census data. See **Figure D–40**.

Representative nearby centers of population:[56]

- Grandview, MO (population approximately 24,400) approximately 2 miles NNE (nearest houses approximately 0.9 miles).
- Belton City, MO (population approximately 23,000) approximately 5 miles SSE (nearest houses approximately 2 miles).
- Kansas City, MO (population approximately 460,000) approximately 20 miles N.

*Nature of surroundings within 5 miles of KCNSC: C*onsiderable populations to E and W, relatively unpopulated in a N-S swathe (see **Figure D–41** and **D–42**).

Size of site: 0.29 square miles (approximately 186 acres).[57]

Most likely wind direction: The 2003 monthly wind rose data for Kansas City Airport[58] show the predominant wind direction strongly from the south during March – November and about equally from the NW or SW/SSW in December – March. On average, through the whole year, the predominant wind direction is from the south and blows towards Kansas City.

Initial Subjective Assessment of Public External Individual and Societal Risk in the event that pit production is relocated to KCNSC: High because of the very small site, close-by cities, large population within 50 miles, and predominant wind direction towards Kansas City.

Policy Risk: High, because the site has not previously handled special nuclear material.

[55] http://mcdc.missouri.edu/websas/caps10c.html.
[56] Distances from KCNSC estimated using Google Maps, see Figures D–40 through D–42: populations obtained from https://suburbanstats.org/population/.
[57] http://www.ssoe.com/wp-content/uploads/GOVT-NNSA.pdf.
[58] https://www.wcc.nrcs.usda.gov/ftpref/downloads/climate/windrose/missouri/kansas_city/.

Figure D–40. Google map close-up view of KCNSC

Map is approximately 1.9 miles E-W and 0.85 miles N-S.

Figure D–41. Google map of KCNSC and nearby areas

Map is approximately 15 miles E-W and approximately 7.5 miles N-S.

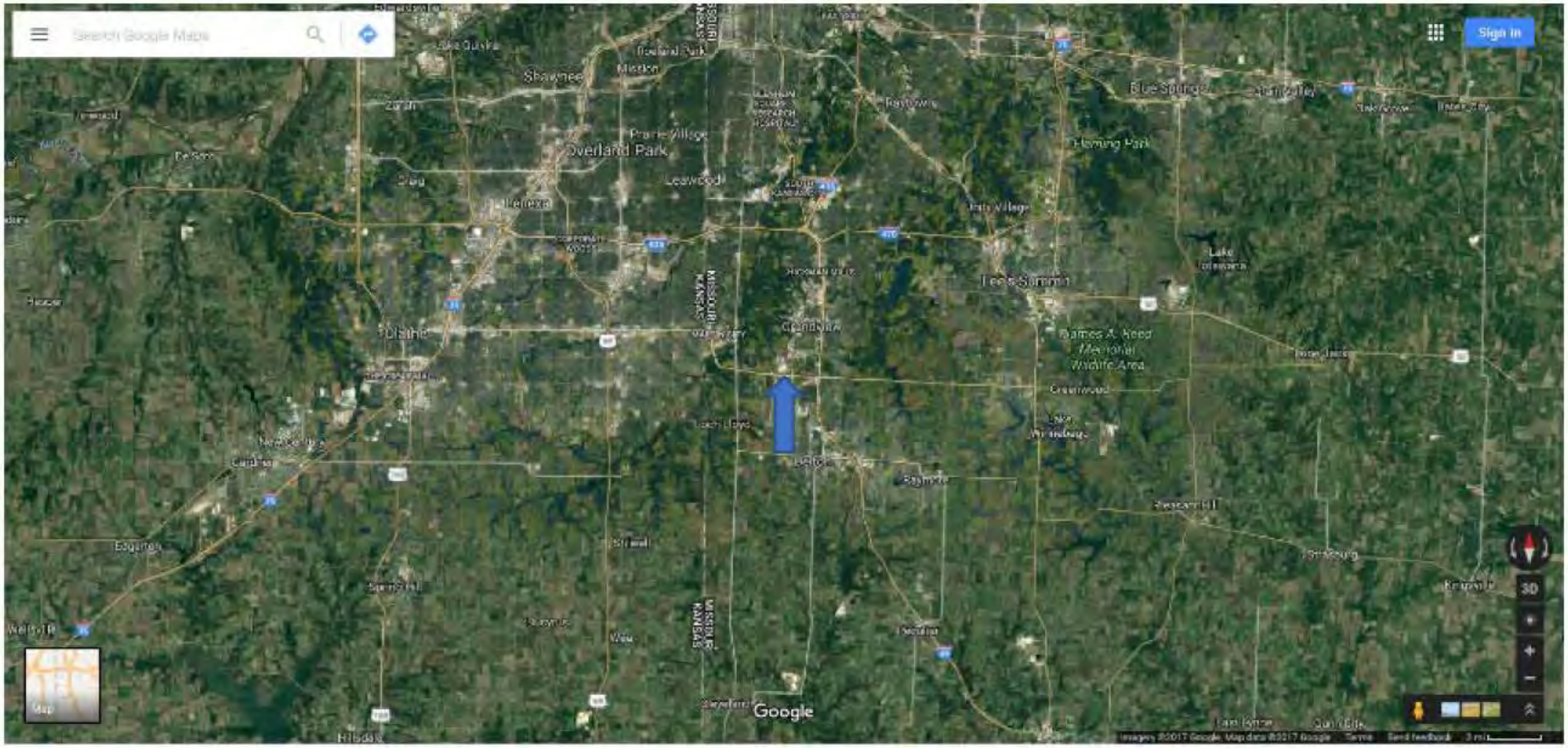


Figure D–42. Smaller scale view of KCNSC and environs

Map is approximately 60 miles E-W and approximately 30 miles N-S.

Plant is approximately at tip of blue arrow.

D.16 Sandia National Laboratories

Surrounding population distribution:[59] Population within 5 miles is approximately 25,000, and that within 50 miles is approximately 910,000, based on 2010 census data. The distances are measured from TA-V (chosen because it is relatively far from the site boundaries).

Nearby centers of population:[60]

- Albuquerque, NM (population approximately 546,000) approximately 7 miles NNW (nearest houses approximately 3 miles NNE).
- South Valley, NM (population approximately 41,000) approximately 8 miles W.

Nature of surroundings within 5 miles of SNL/TA-V: Unpopulated except to the N beyond approximately 3 miles (see **Figures D–43**, **D–44**, and **D–45**).

Size of site: 13.4 square miles (approximately 8,600 acres)[61] that is split into approximately 2,900 acres owned by DOE and 5,700 acres permitted from the United States Air Force, all within 80 square miles (approximately 51,000 acres) occupied by Kirtland Air Force Base.

Most likely wind direction: **Figure D–46** shows 3 wind roses on the SNL Site. They differ considerably due (presumably) to terrain effects. That closest to TA-V shows a preponderance of winds from the E to SE, i.e., toward the Rio Grande Valley and southwestern portions of the Albuquerque metropolitan area.

Initial Subjective Assessment of Public External Individual and Societal Risk in the event that pit production is relocated to SNL: Moderate because of the large site, somewhat offset by closeness to Albuquerque, and predominant wind directions towards south western portions of the Albuquerque metropolitan area.

Policy Risk: Reassigning pit production to SNL would require a considerable increase in the MAR permitted at that site, whereas the trend in recent years has been toward a reduction. The policy risk is assessed as moderate.

[59] http://mcdc.missouri.edu/websas/caps10c.html.
[60] Distances estimated from TA-V using Google Maps, see Figures A.12-2 and A.12-3: populations obtained from https://suburbanstats.org/population/.
[61] SNL (Sandia National Laboratories) 2015, *2014 Annual Site Environmental Report for Sandia National Laboratories,* SAND2015-6048R, Albuquerque, NM, obtained from http://www.sandia.gov/news/publications/environmental_reports/_assets/documents/2014_ASER_SNL-NM_CD_ALL.pdf.

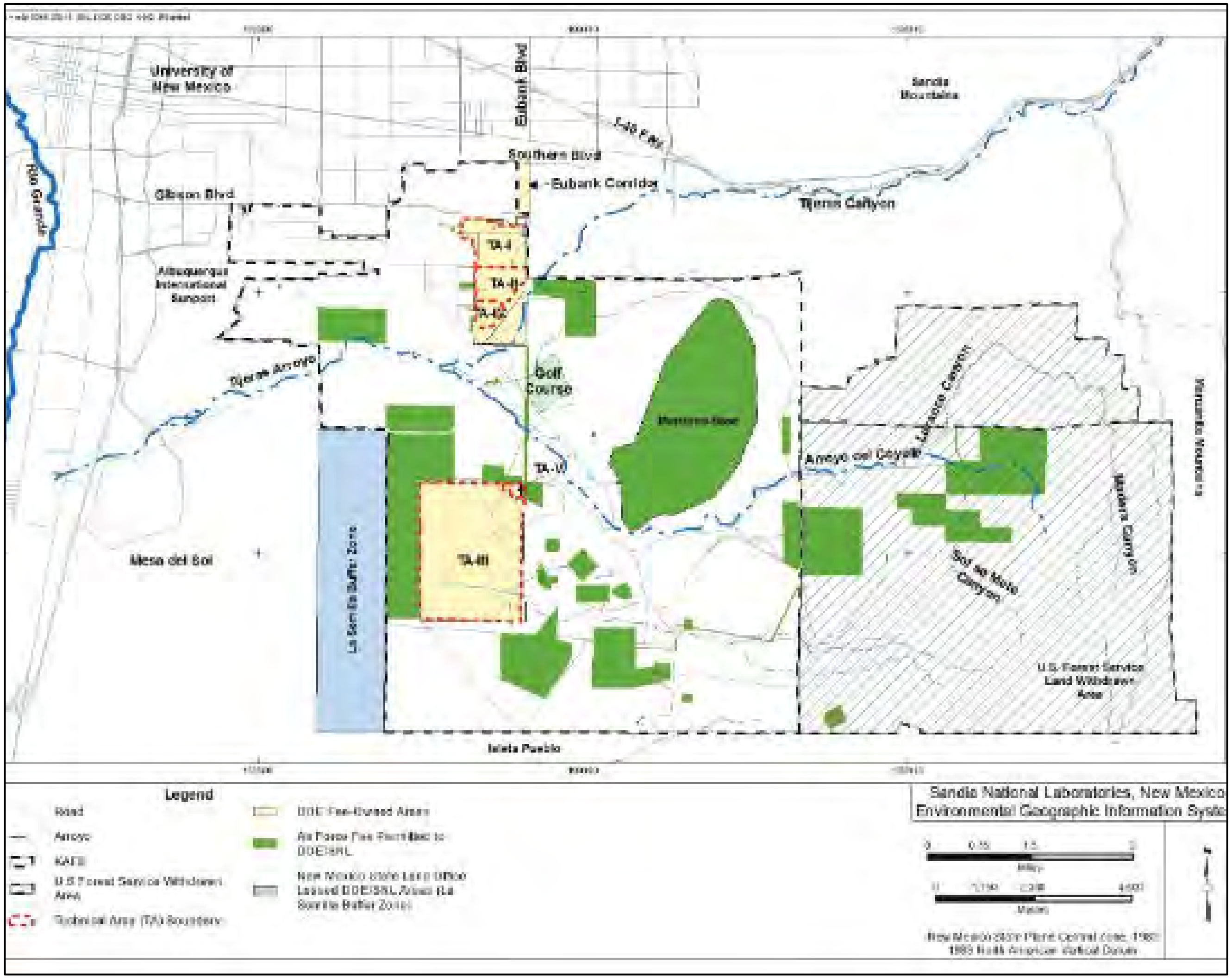


Figure D–43. Map of SNL

(Source: *2014 Annual Site Environmental Report for Sandia National Laboratories*, Figure 1-1)

Figure D–44. Google map of SNL relative to Albuquerque

Map is approximately 30 miles E-W and 15 miles N-S.

TA-V is approximately at tip of blue arrow.

Figure D–45. Smaller scale Google map of Albuquerque area

Map is approximately 60 miles E-W and 30 miles N-S.

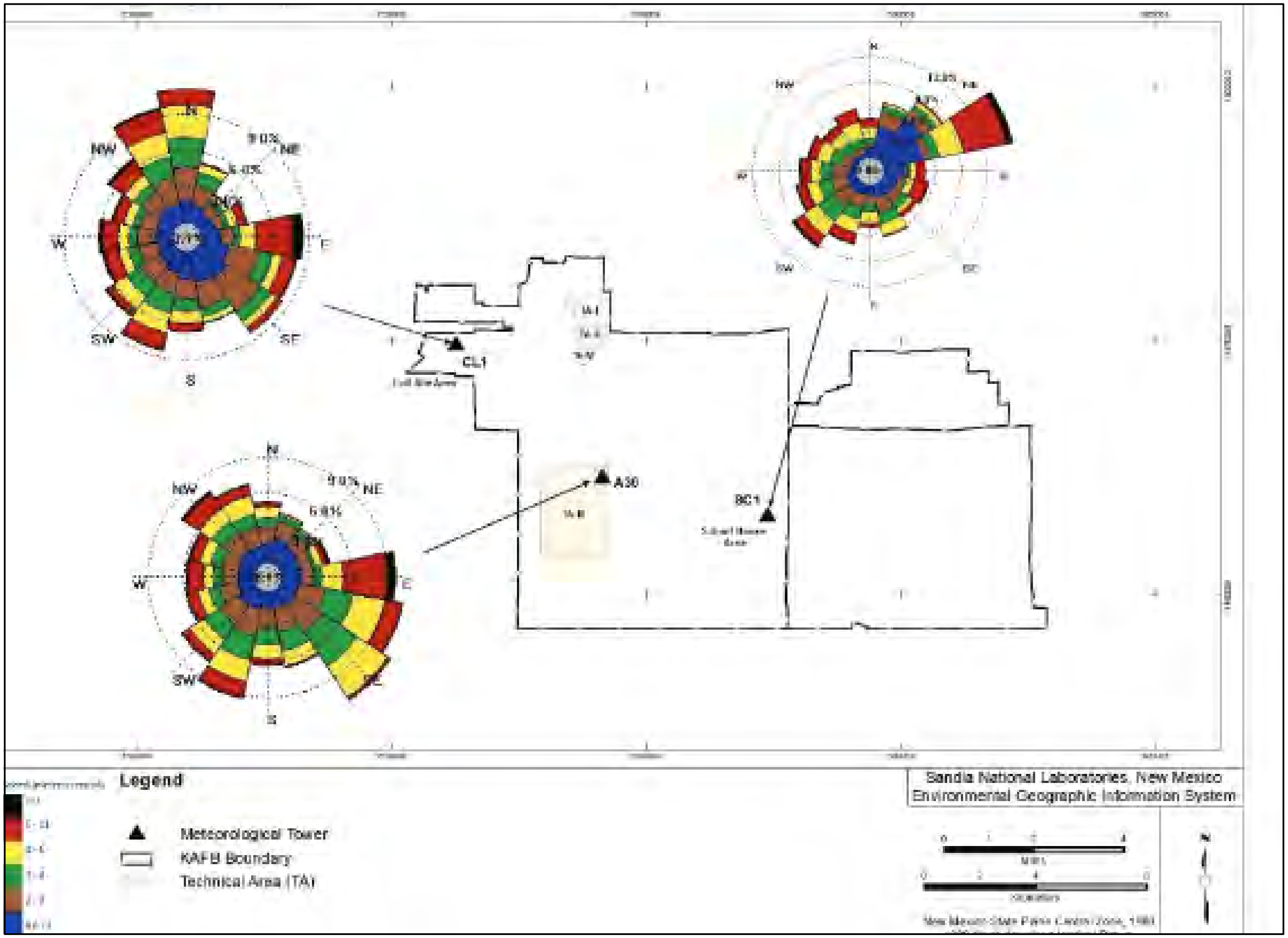


Figure D–46. Wind roses at various locations on Sandia Site

(Source: 2014 Annual Site Environmental Report for Sandia National Laboratories, Figure 5-2)

Bottom left wind rose is closest to TA-V.

D.17 Paducah, KY

Surrounding population: Population within 1 mile of the center of the site is 0, within 5 miles, 600, and within 50 miles approximately 534,000, based on the 2010 census.[62] **Figure D–47** shows a map of the site.

Nearby centers of population:[63] See **Figure D–48**.

- Metropolis, IL (population approximately 6,500) approximately 5 miles NE of center of plant.
- Paducah, KY (population approximately 25,000) approximately 7 miles ESE of center of plant.

Nature of surroundings within 5 miles: Predominantly farming, see Figure D–48. The Ohio River runs within 2 miles.

Size of site: Approximately 5.6 square miles (approximately 3,556 acres) of which approximately 1.2 square miles (750 acres) is within the fenced area.[64]

Most likely wind direction: From the SW, toward Metropolis. See **Figure D–49**.[65]

Initial Subjective Assessment of Public External Individual and Societal Risk in the event that pit production is relocated to Paducah: Moderate (not high) because relatively few people within 5 miles and there are no nearby large cities.

Policy Risk: Assessed to be high because the site is being shut down and (presumably) there would be resistance to the idea of introducing large amounts of hazardous radioactive material to the site.

[62] http://mcdc.missouri.edu/websas/caps10c.html.
[63] Populations obtained from https://suburbanstats.org/population/. Distances measured to outskirts using Google maps.
[64] https://www.energy.gov/pppo/paducah-site-description.
[65] DOE (U.S. Department of Energy) 2004, Final Environmental Impact Statement - Construction and Operation of a Depleted Uranium Hexafluoride Conversion Facility at the Paducah, Kentucky, Site, DOE/EIS-0359, Washington DC, June, obtained from https://energy.gov/sites/prod/files/EIS-0359-FEIS-FiguresTables-2004.pdf.

Figure D–47. Map of Paducah Site

(Source: https://www.energy.gov/pppo/paducah-site-description)

Scale approximately 1" = ½ miles

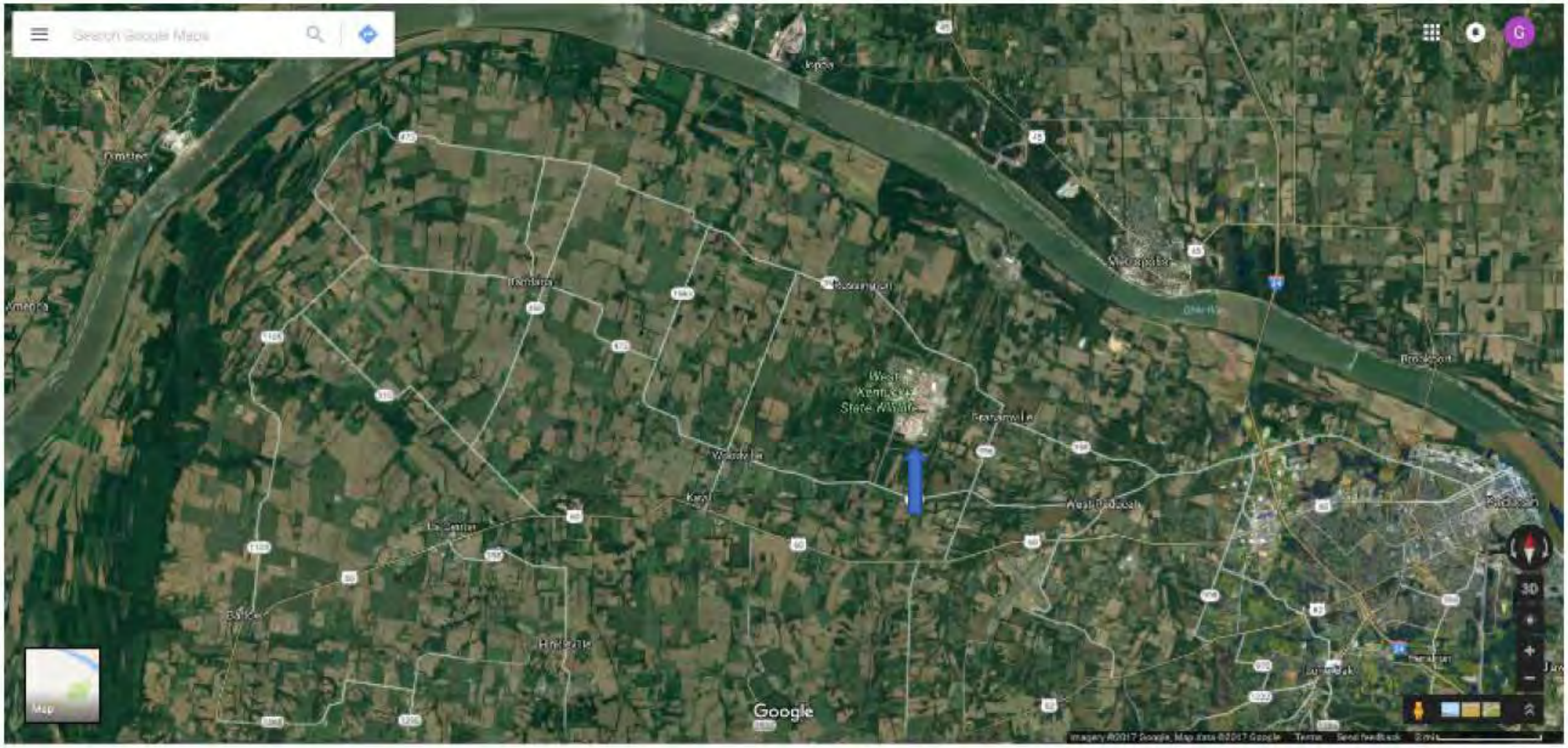


Figure D–48. Google map of Paducah Site and vicinity

Map is approximately 30 miles E-W and 15 miles N-S.

Site is approximately at tip of blue arrow.

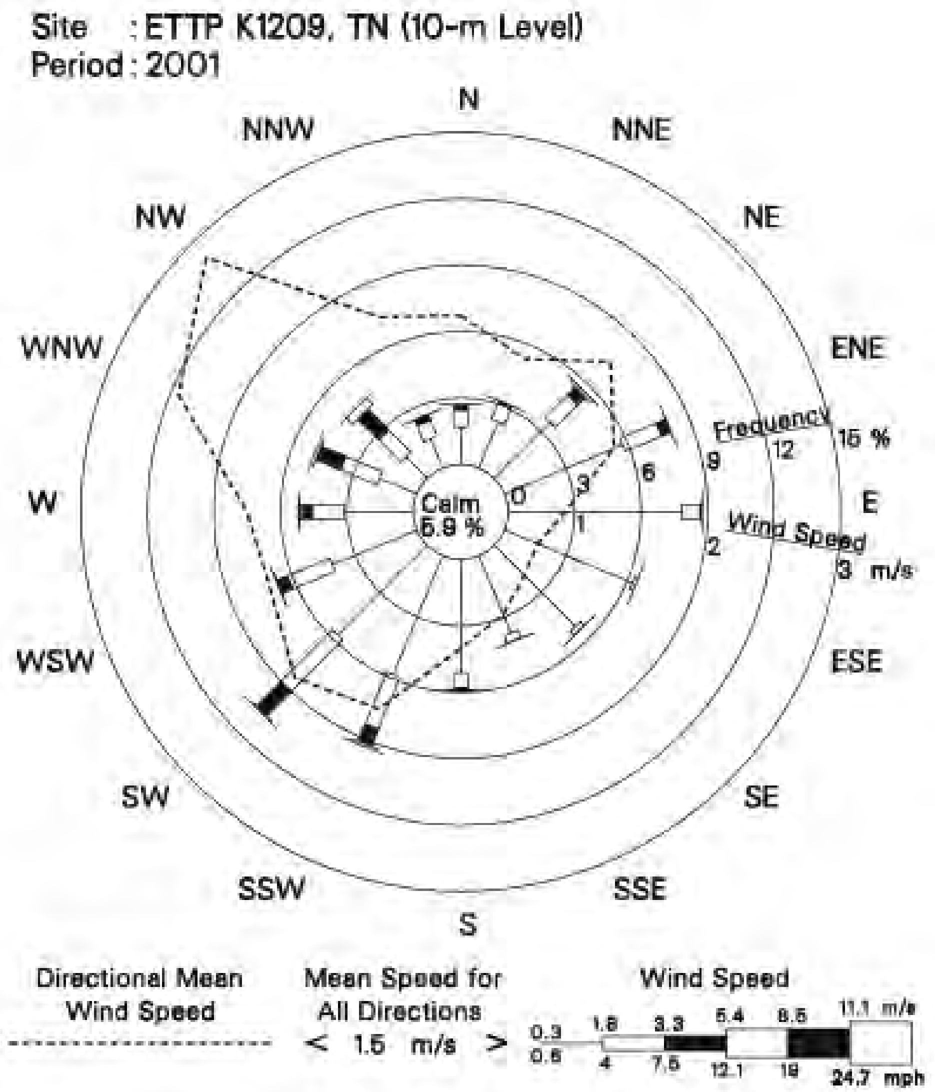


Figure D–49. Wind rose for Paducah Site

(Source: https://energy.gov/sites/prod/files/EIS-0359-FEIS-FiguresTables-2004.pdf)

D.18 Portsmouth, OH

Surrounding population: Population within 1 mile of the center of site is 91, within 5 miles approximately 6,200, and within 50 miles approximately 691,000 based on the 2010 census.[66] **Figure D–50** shows a map of site.

Nearby Centers of population:[67] See **Figure D–51**.

- Piketon, OH (population approximately 2,200) approximately 2.5 miles NNW of center of plant.
- Portsmouth, OH (population approximately 20,000) approximately 17 miles S of center of plant.

Nature of surroundings within 5 miles: Mainly wooded, some farming. See Figure D–51.

Size of site: Approximately 5.9 square miles (approximately 3,780 acres) of which approximately 1.9 square miles (1,200 acres) is occupied by the former diffusion plant.[68]

Most likely wind direction: From SW-S,[69] not toward any population center. See **Figure D–52**.

Initial Subjective Assessment of Public External Individual and Societal Risk in the event that pit production is relocated to Portsmouth: <u>Moderate</u> because relatively few people live within 5 miles and there are no nearby large cities.

Policy Risk: Assessed to be high because the site is being shut down and (presumably) there would be resistance to the idea of introducing large amounts of hazardous radioactive material to the site.

[66] http://mcdc.missouri.edu/websas/caps10c.html.
[67] Populations obtained from https://suburbanstats.org/population/. Distances measured to outskirts using Google maps.
[68] https://energy.gov/pppo/portsmouth-site.
[69] DOE (U.S. Department of Energy) 2017, *Conveyance of Real Property at The Portsmouth Gaseous Diffusion Plant in Pike County, Ohio*, DOE/EA-1856, Washington DC, January, obtained from https://energy.gov/sites/prod/files/2017/01/f34/EA-1856_Draft_EA_2017.pdf.

Figure D–50. Map of Portsmouth Site

(Source: Google Maps)

Scale approximately 1" = 2.3 miles

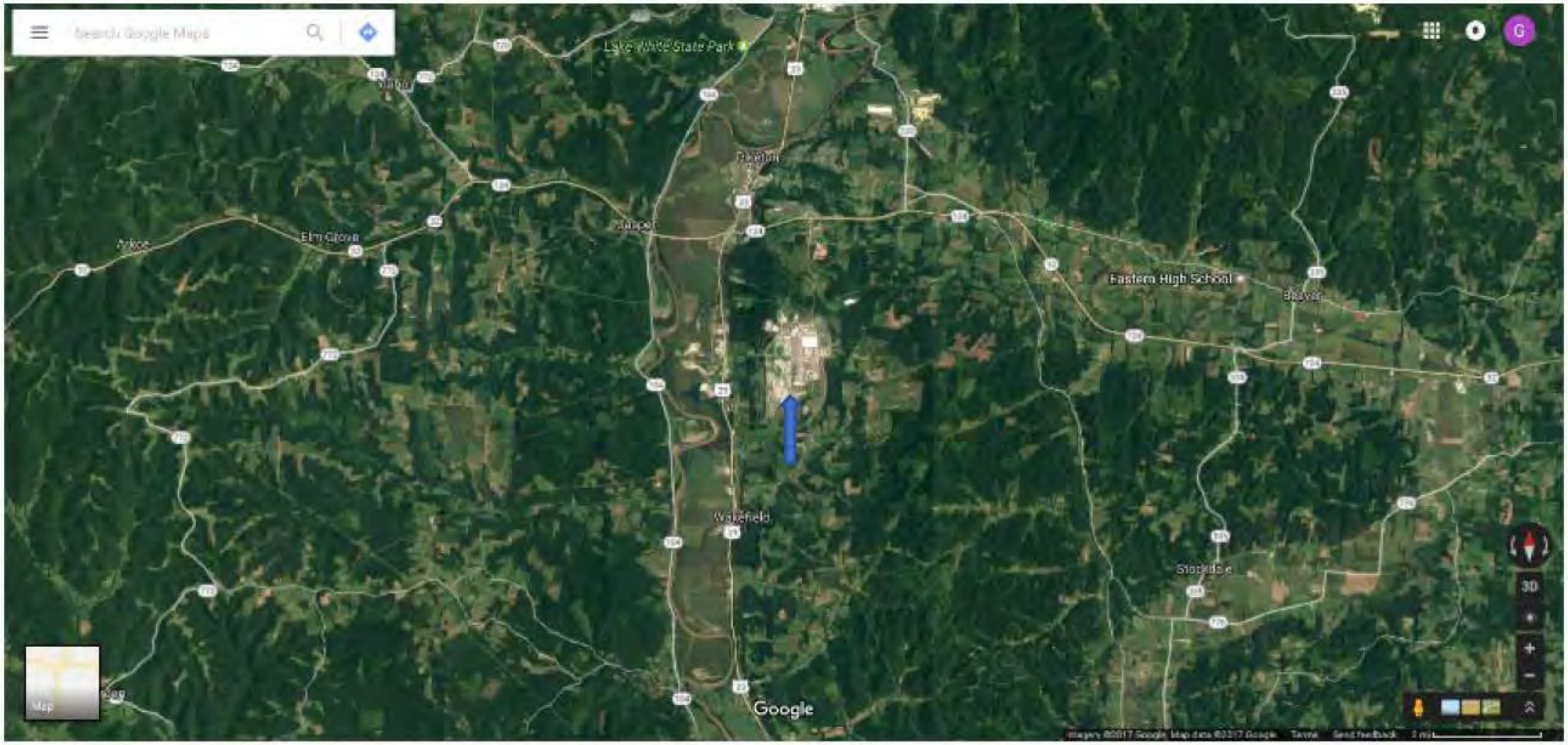


Figure D–51. Google map of Portsmouth Site and vicinity

Map is approximately 30 miles E-W and 15 miles N-S.

Site is approximately at tip of blue arrow.

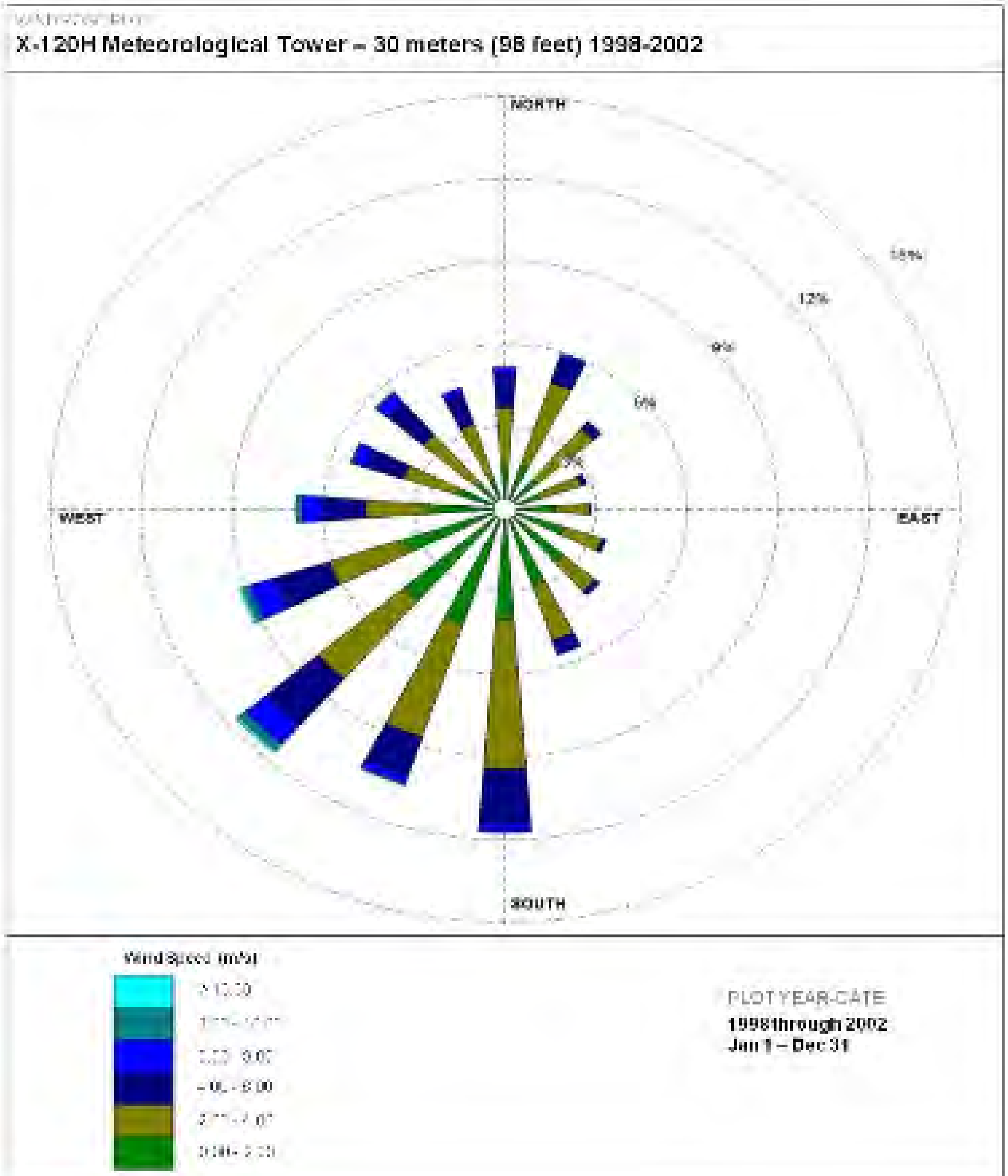


Figure D–52. Wind rose for Portsmouth Site

(Source: https://energy.gov/sites/prod/files/2017/01/f34/EA-1856_Draft_EA_2017.pdf)

Appendix E. Qualitative Risk Assessment

E.1 Overview

The Analysis of Alternatives (AoA) team performed a qualitative risk assessment of the alternatives that were identified and described in Chapter 5. This appendix is organized as follows:

- Development of a list of threats, one for the period of construction up to startup and one for the following period of routine operation (Tables E–1 and E–2)
- Introduction and discussion of the risk matrix, including the definition of probability ranges (Table E–3)
- Development of two tables of consequence guidance, one for the period of construction up to startup and one for the following period of routine operation (Tables E–4 and E–5)
- Brief summary of the initial long list of alternatives that the AoA team developed (Table E–6)
- Assignment of probability, consequence, and risk level for each pairing of threat and alternative
- Summary tables of the results of the risk assessment for alternatives at Los Alamos National Laboratory (LANL) (Table E–7), Savannah River Site (SRS) (Table E–8), and Idaho National Laboratory (INL) (Table E–9)
- Summary table of the risks for the final short list of six alternatives developed by the AoA team for presentation to senior management ("PF-4 Reuse," defined below; 80 pits per year [ppy] in new construction at LANL; 80 ppy in the Mixed Fuel Fabrication Facility [MFFF] or new construction at SRS; and 80 ppy in the Fuel Processing Facility [FPF] or new construction at LANL (Table E–10)
- Summary table for the final short list of alternatives with the risks presented in order from those that are the most discriminating between alternatives to those that are least discriminating between alternatives (Table E–11)

E.2 Lists of Threats

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 the routine production of 80 ppy. These threats are listed in Table E–1. For purposes of calculating 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, provided in Table E–2, is applicable to the operating lifetime of the facility, assumed to be 50 years.[1]

The AoA team developed the lists of threats by first consulting other AoAs, such as that for tritium(DOE 2017f) and surplus plutonium disposition (DOE 2017g). Team members brainstormed and refined these lists during a meeting in November 2016. As the potential alternatives became clearer, the list was further refined, and threats specific to the 80-ppy manufacturing capability were identified. For example, these threats included some that were specific to one alternative (e.g., K-reactor or MFFF) and others that apply

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

to all alternatives, such as the potential for disruption of the ability to ship solid transuranic (TRU) waste to the Waste Isolation Pilot Plant (WIPP).

Table E–1. Brief description of threats during construction and startup

Identifier	Brief Description of Threat
C-1	National Environmental Policy Act: environmental impact statement or additional environmental reviews cause delays and extra costs.
C-2	National and/or local political/public opposition results in delays and extra costs.
C-3	National and/or local political/public opposition results in project cancellation.
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.
C-5	Intra-agency and/or inter-agency disputes delay the project and introduce extra costs or unwanted restrictions on the project. Note that disputes arising from the transfer of the Mixed Oxide Fuel Fabrication Facility licensing basis from the Nuclear Regulatory Commission to the Department of Energy are considered separately under threat C-24.
C-6	Program requirements change (e.g., weapon types or numbers).
C-7	Functional performance requirements change (e.g., a requirement is introduced for computerized tomography).
C-8	More stringent interpretations of safety requirements and/or new safety requirements during design and construction require significant facility structural or service system upgrades.
C-9	Additional security provisions (e.g., clearances, escorts, fences, changes in the design basis threat) beyond planned are imposed.
C-10	Construction or repair and modifications impact ongoing site or facility operations or ongoing site or facility operations impact construction or repair and modifications.
C-11	Existing facilities require more work than planned to meet applicable codes and standards (e.g., latent conditions may unexpectedly come into play). Equivalently, unforeseen conditions in existing facilities during repair or upgrades result in more work than planned.
C-12	Material characterization capability is insufficient to support the schedule for the nonrecurring testing and analysis required to develop and qualify the manufacturing parameters for the W87 production process.[a]
C-13	Unexpected underground site conditions are encountered (e.g., geotechnical, buried pipelines, or buried waste).
C-14	Project design issues occur during construction, modifications, or repair work.
C-15	There are issues with process qualification and/or design agency approval.
C-16	There are issues with worker hiring, clearing, and/or training of qualified workers.
C-17	A seismic event occurs during construction, damaging site infrastructure.
C-18	A seismic event occurs during construction, causing damage to the facility.
C-19	A tornado or other high-wind event occurs during construction.
C-20	An external flood occurs during construction.
C-21	An external fire occurs during construction.
C-22	Any other external event occurs during construction.
C-23	Savannah River Site only: If the Mixed Oxide Fuel Fabrication Facility is chosen for the pit manufacturing facility, potential difficulties arise while unraveling the project with Areva.
C-24	Savannah River Site only: Difficulties arise while transferring the Mixed Oxide Fuel Fabrication Facility licensing basis from the Nuclear Regulatory Commission to the Department of Energy.

[a] This threat was included because, during the IST's visit to LANL, laboratory personnel expressed concern that that material characterization capabilities would be insufficient to handle the projected workload during development and qualification.

Table E–2. Brief description of threats during the operating lifetime

Identifier	Brief Description of Threat
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 that is 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; subsequent decontamination may be required.
O-14	Transportation capacity for shipping pits and plutonium feedstock is insufficient to meet demands from all Department of Energy 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.
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.

E.3 Risk Matrix

The AoA team assessed the magnitude of the risk corresponding to each of the threats in Tables E–1 and E–2 making use of the risk matrix methodology described in the Department of Energy's (DOE's) *Risk Management Guide* (DOE 2011). The risk matrix is reproduced in Table E–3, with some minor changes. The probabilities are assigned numbers from 1 through 5, with 1 being very high and 5 being very low. The consequences are also labeled from 1 through 5, with 1 being the highest consequence (crisis) and 5 being the lowest consequence (negligible).

In the text of this appendix, every time a combination of probability and consequence is identified it is noted as probability/consequence/risk for the convenience of the reader so that it is not necessary to refer back to the risk matrix. For example, a very high probability (1) and a significant consequence (3) correspond to a high risk (H); this is represented by the notation "1/3/H." Similarly, a high probability (2) and a significant consequence (3) correspond to a moderate risk (M), or 2/3/M for short. Likewise, a low probability (4) and a negligible consequence (1) correspond to a low risk (L), or 4/1/L.

Table E–3. Risk matrix for Plutonium Pit Production Analysis of Alternatives

		Consequences				
		Negligible (5)	Marginal (4)	Significant (3)	Critical (2)	Crisis (1)
Probability	Very high (1) >90%	Low (L)	Moderate (M)	High (H)	High (H)	High (H)
	High (2) 75% to 90%	Low (L)	Moderate (M)	Moderate (M)	High (H)	High (H)
	Moderate (3) 26% to74%	Low (L)	Low (L)	Moderate (M)	Moderate (M)	High (H)
	Low (4) 10% to25%	Low (L)	Low (L)	Low (L)	Moderate (M)	Moderate (M)
	Very low (5) <10%	Low (L)	Low (L)	Low (L)	Low (L)	Moderate (M)

Matrix and probabilities from the Department of Energy (DOE) *Risk Management Guide*, DOE G 413.3-7 (DOE 2011).

Numbers 1-5 against probability and consequences added for the purposes of this AoA.

Probability of occurrence:

Construction: calculated during the period from Critical Decision-2 to startup (assume 10 years).

Operation: calculated during the lifetime of facility beginning at startup (assume 50 years).

Note that, if the probability is very low (5), the maximum risk allowed by the risk matrix is moderate, i.e., 5/1/M. Some of the threats listed in Tables E–1 and E–2 have extremely low recurrence intervals, sometimes in the thousands or tens of thousands of years. Over the period of construction and startup or during the operating lifetime, the probability of occurrence is very low. Regarding the risks discussed below, when considering these very low probability threats, the AoA team sometimes conservatively assumed that the risk would be moderate (i.e., 5/1/M), especially when it was expected that the risk would not prove to be a discriminator between the alternatives or a factor in decision making. The conservative nature of this assignment was acknowledged by adding a (C), thus 5/1/M (C).

E.4 Guidelines for Determining Consequence Levels

The DOE *Risk Management Guide* contains only very high-level guidelines for determining the consequence level associated with each threat. The team, therefore, developed PMA AoA-specific guidelines, one for construction and startup (Table E–4) and one for operation (Table E–5).

Table E–4. Guidelines for assigning consequences – construction and startup

Consequence Magnitude	Threshold Criteria
Negligible	– Delay in achieving plutonium sustainment goal of 30 ppy by ≤ 3 months – Interference with other plutonium missions (e.g., ARIES, plutonium-238, science), causing deadlines in one or more of those programs to be missed by ≤ 3 months or annual costs to increase by not more than 0.5 percent – Delay in achieving 80-ppy startup by ≤ 3 months – Revised cost estimate at any stage up to startup of 80-ppy manufacturing capacity not more than 0.5 percent of the CD-2 estimate
Marginal	– Delay in achieving plutonium sustainment goal of 30 ppy by >3 months but ≤ 1 year – Interference with other plutonium missions (e.g., ARIES, plutonium-238, science), causing deadlines in those programs to be missed by >3 months but ≤ 1 year and/or annual costs to increase by > 0.5 percent but ≤ 2.5 percent – Delay in achieving 80-ppy startup by >3 months but ≤ 1 year – Revised cost estimate at any stage up to startup of 80-ppy manufacturing capacity 0.5 percent but ≤ 2.5 percent of the CD-2 estimate – Political sensitivity/publicity at the local level
Significant	– Delay in achieving plutonium sustainment goal by >1 year but ≤ 2 years – Interference with other plutonium missions (e.g., ARIES, plutonium-238, science), causing deadlines in those programs to be missed by >1 year but ≤ 2 years and/or annual costs to increase by > 2.5 percent but ≤ 10 percent – Delay in achieving 80-ppy startup by >1 year but ≤ 2 years – Revised cost estimate at any stage up to startup of 80-ppy manufacturing capacity 2.5 percent but ≤ 10 percent of the CD-2 estimate – Political sensitivity/publicity at the state level or requiring NNSA Headquarters intervention
Critical	– Delay in achieving plutonium sustainment goal of 30 ppy by >2 years but ≤ 4 years – Interference with other plutonium missions (e.g., ARIES, plutonium-238, science), causing deadlines in those programs to be missed by >2 years but ≤ 4 years and/or annual costs to increase by > 10 percent but ≤ 25 percent – Delay in achieving 80-ppy startup by >2 years but ≤ 4 years – Revised cost estimate at any stage up to startup of 80-ppy manufacturing capacity 10 percent but ≤ 25 percent of the CD-2 estimate – Political sensitivity/publicity at the national public level or requiring congressional intervention
Crisis	– Delay in achieving plutonium sustainment goal of 30 ppy by > 4 years – Interference with other plutonium missions (e.g., ARIES, plutonium-238, science), causing deadlines in those programs to be missed by > 4 years and/or annual costs to increase by > 25 percent – Delay in achieving 80-ppy startup by >4 years – Revised cost estimate at any stage up to startup of 80-ppy manufacturing capacity 25 percent of the CD-2 estimate – Threat to national security – Mission abandoned

Key:

ARIES = Advanced Recovery and Integrated Extraction System; CD = critical decision; NNSA = National Nuclear Security Administration; ppy = pits per year.

Table E–5. Guidelines for assigning consequences – pit manufacturing facility in operation

Consequence Magnitude	Threshold Criteria
Negligible	– Interference with other plutonium missions (e.g., ARIES, plutonium-238, science), causing deadlines in one or more of those programs to be missed by ≤ 3 months and/or annual costs to increase by not more than 0.5 percent – Underrun of the 80-ppy requirement by ≤ 2 pits in a single year – Annual operating costs of the 80-ppy program exceed estimated costs by not more than 0.5 percent
Marginal	– Interference with other plutonium missions (e.g., ARIES, plutonium-238, science), causing deadlines in those programs to be missed by > 3 months but ≤ 1 year and/or annual costs to increase by > 0.5 percent but ≤ 2.5 percent – Underrun of the 80-ppy requirement by > 2 pits but ≤ 10 pits in a single year – Annual operating costs of the 80-ppy program exceed estimated costs by > 0.5 percent but ≤ 2.5 percent – Political sensitivity/publicity at the local level or requires NA-12 Headquarters intervention – May require minor facility design change or repair, minor environmental remediation onsite, or first aid/minor medical intervention for workers
Significant	– Interference with other plutonium missions (e.g., ARIES, plutonium-238, science), causing deadlines in one or more of those programs to be missed by > 1 year but ≤ 2 years and/or annual costs to increase by > 2.5 percent but ≤ 10 percent – Underrun of the 80-ppy requirement by > 10 pits but up to 40 pits in a single year or underrun of the 80-ppy requirement by up to 10 pits for > 1 year but ≤ 4 years – Exceedance of estimated annual operating costs of the 80-ppy program by > 2.5 percent but ≤ 10 percent – Political sensitivity/publicity at the state level or requiring NNSA Headquarters intervention. – Requirement of some facility design changes or repair or significant environmental remediation onsite or causing injury requiring medical treatment onsite, minor environmental remediation offsite, or first aid/minor medical intervention for members of the public
Critical	– Interference with other plutonium missions (e.g., ARIES, plutonium-238, science), causing deadlines in one or more of those programs to be missed by > 2 years but ≤ 4 years and/or annual costs to increase by > 10 percent but ≤ 25 percent – Inability to meet the 80-ppy requirement for a whole year, or consistent underrun of the 80-ppy requirement by at least 10 pits for > 4 years – Exceedance of estimated annual operating costs of the 80-ppy program by > 10 percent but ≤ 25 percent – Political sensitivity/publicity at the national public level or that requires congressional intervention – Requiring major design efforts or facility rebuilding, extensive environmental remediation onsite, or intensive medical care for life-threatening injury onsite or significant environmental remediation offsite or causing injury to members of the public requiring medical treatment
Crisis	– Interference with other plutonium missions (e.g., ARIES, plutonium-238, science), causing deadlines in one or more of those programs to be missed by > 4 years and/or annual costs to increase by > 25 percent – Inability to meet the 80-ppy requirement for two or more years – Annual operating costs of the 80-ppy program exceed estimated costs by > 25 percent – Requiring extensive environmental remediation offsite, intensive medical care for life-threatening injuries to members of the public, or significant environmental remediation offsite or causing injury to members of the public – Threat to national security

Key
ARIES = Advanced Recovery and Integrated Extraction System; CD = critical decision; NNSA = National Nuclear Security Administration; ppy = pits per year.

E.5 Detailed Analysis of Threats and Risks

This section contains an analysis of each of the threats listed in Tables E–1 and E–2. For the convenience of the reader, the alternatives being considered are summarized below in Table E–6.

E.5.1 Threats During Construction and Startup

This section details the assignment of probability, consequence, and risk to each pairing of threats listed in Table E–2 (i.e., threats applicable during construction and startup) and alternatives listed in Table E–6.

C-1: National Environmental Policy Act (NEPA): environmental impact statement (EIS) or additional environmental reviews cause delays and extra costs.

After preliminary discussions with personnel from the Office of the General Counsel (NA-GC), it appears that every alternative at every site will conservatively require an EIS. DOE Order 451.1B (*National Environmental Policy Act Compliance Program*) establishes DOE's internal requirements and responsibilities for implementing the National Environmental Policy Act of 1969, the Council on Environmental Quality Regulations Implementing the Procedural Provisions of NEPA (40 Code of Federal Regulations Parts 1500-1508), and the DOE NEPA Implementing Procedures (10 Code of Federal Regulations Part 1021). The order states that it is the responsibility of all participants to control the cost and time for the NEPA process while maintaining its quality and that "For an environmental impact statement, the schedule, absent extraordinary circumstances, will provide for completion of a final environmental impact statement within 15 months of the issuance of the Notice of Intent." In addition, the schedule sub-team for this AoA determined that the NEPA process is not on the critical path, even if it takes 5 years. Therefore, there should be at most a low probability (4) of marginal (4) consequences, corresponding to a low risk (4/4/L) that is the same for all alternatives at all sites.

Table E–6. Summary of alternatives considered in the risk analysis

Alt Name	Capabilities in PF-4	Capabilities Outside PF-4	Alternatives[a]				
0 – Status Quo	Pu science and certification + metal preparation and 30 ppy	None	LANL 0				
1 – Split Production	Pu science and certification + metal preparation and 30 ppy	Production 50 ppy at LANL	LANL 1-A (new)				
		Production 50 ppy at SRS	SRS 1-A (MFFF)	SRS 1-B (K-Area)	SRS 1-C (WSB)	SRS 1-D (new)	
		Production 50 ppy at INL	INL 1-A (FPF)	INL 1-B (new)			
	Pu science and certification + metal preparation and maximize production by moving out other functions	Production various at new construction at LANL	LANL 1-B (ARIES and ^{238}Pu stay)	LANL 1-C (ARIES stays, ^{238}Pu goes)	LANL 1-D (ARIES goes, ^{238}Pu stays)	LANL 1-Dmax[b]	LANL 1-E (ARIES and ^{238}Pu both go)
2 – Move Production and Metal Preparation	Pu science and certification	Metal preparation and 80 ppy at LANL	LANL 2 (new)				
		Metal preparation and 80 ppy at SRS	SRS 2-A (MFFF)	SRS 2-B (K-area)	SRS 2-C (WSB)	SRS 2-D (new)	
		Metal preparation and 80 ppy at INL	INL 2-A (FPF)	INL 2-B (new)			
3 – Move Production	Pu science and certification + metal preparation	80 ppy at LANL	LANL 3 (new)				
		80 ppy at SRS	SRS 3-A (MFFF)	SRS 3-B (K-area)	SRS 3-C (WSB)	SRS 3-D (new)	
		80 ppy at INL	INL 3-A (FPF)	INL 3-B (new)			
4 – Move Metal Preparation	Pu science and certification and 80 ppy	Metal preparation at LANL	LANL 4 (new)				
		Metal preparation at SRS	SRS 4-A (MFFF)	SRS 4-B (K-area)	SRS 4-C (WSB)	SRS 4-D (new)	
		Metal preparation at INL	INL 4-A (FPF)	INL 4-B (new)			

[a] After the risk assessment was under way, some of the alternatives in Table E–6 were eliminated. For example, alternatives requiring that ^{238}Pu be removed from PF-4 are infeasible because the impact on the schedule for startup of the 80-ppy manufacturing process is too great. Alternatives in WSB were eliminated because it is too small, and K-reactor was eliminated because of the difficulty of working inside a PIDADS and because it was thought that modifications would likely encounter significant contamination. However, the AoA team decided to document the risk assessment of all the alternatives in Table E–6 for completeness.

[b] LANL 1-Dmax is LANL 1-D with excursions for multiple shifts.

Key:

ARIES = Advanced Recovery and Integrated Extraction System; FPF = Fuel Processing Facility; INL = Idaho National Laboratory; LANL = Los Alamos National Laboratory; MFFF = Mixed Fuel Fabrication Facility; PF-4 = Plutonium Facility; ppy = pits per year; Pu = plutonium; SRS = Savannah River Site; WSB = Waste Solidification Building.

C-2: National and/or local political/public opposition results in delays and extra costs.

The risk associated with this threat differs from site to site but does not distinguish between alternatives at any specific site.

LANL: There are organizations that will object to any expansion of onsite plutonium activities and/or pit manufacturing, such as the Los Alamos Study Group (www.lasg.org) and Nuclear Watch New Mexico (www.nukewatch.org). These organizations include both local and national groups. However, this opposition will be counterbalanced by support from members of the public who see LANL as a source of jobs and revenue. In addition, LANL is not subject to such severe political pressure as SRS (e.g., a lawsuit by the State of South Carolina) or INL (operating under the conditions of a consent decree and subject to a lawsuit). The AoA team considers that the political risk at LANL should be somewhat lower than at INL or SRS, for which sites it was assessed as high probability (2) with significant consequences (3), with a corresponding moderate risk (2/3/M) (see below). For LANL, the probability of significant consequences is assessed to be lower (moderate [3]), leading to a lower risk (3/3/M), which, however, is still moderate and applies to all alternatives at LANL.

SRS: In February 2016, the State of South Carolina sued over the MOX project, asserting in court documents that the federal government has failed to live up to obligations of either completing the MOX project or disposing of 1 metric ton of plutonium waste per year until the MOX building is finished. Settlement talks are under way at the time of publication; as yet, the outcome of these talks is unknown.

In general, the State of South Carolina is concerned that SRS will become a “dumping ground” for plutonium. Therefore, there will be a need to convince the State that the pit manufacturing program will not lead to the continuous accumulation of plutonium at the site. In addition, there are organizations such as Savannah River Site Watch (http://www.srswatch.org/) that will work diligently to try to prevent construction of any type of nuclear facility. On the other hand, state and local people would like to see additional jobs at SRS and, potentially, a use for MFFF. On balance, there is a high probability (2) of significant (3) consequences, with a corresponding moderate risk (2/3/M) that is the same for all alternatives at SRS.

INL: there is a consent decree, dated 10/16/95, which, among other things, places restrictions on bringing spent commercial nuclear fuel onto the site and requires transuranic waste to be removed. There is an ongoing lawsuit against DOE (Governor Andrus vs. DOE) brought by an organization known as Advocates for the West to do with alleged violations of the consent decree. Although the ultimate outcome of the case is still pending, there have already been rulings against DOE. In addition, it is reasonable to assume that Advocates for the West, with numerous member groups from across the western United States, will take a potentially adverse interest in any efforts by DOE to build further nuclear facilities at INL. This could delay the project and cause additional expense and/or lead to unwanted restrictions on the project. The probability that there will be significant consequences (3) is likely high (2). The corresponding risk is moderate (2/3/M) and applies equally to all alternatives at INL.

C-3: National and/or local political /public opposition results in project cancellation.

Because the pit manufacturing mission is critical to national security, the AoA team considers that there is a very low probability (5) that political opposition at any site would be sufficient to cause complete cancellation, i.e., crisis (1). The corresponding risk is moderate (5/1/M) for all alternatives at all sites.

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 potentially a high probability (2) that there will be changes in direction and funding leading to critical (2) consequences (e.g., the escalation in the cost of MFFF). The corresponding risk is high (2/2/H) and applies to all alternatives at all sites.

C-5: Intra-agency and/or inter-agency disputes delay the project and introduce extra costs or unwanted restrictions on the project.

LANL is a National Nuclear Security Administration (NNSA) site. There is a very low probability (5) that intra-agency or inter-agency disputes will lead to more than marginal (4) consequences. The corresponding risk is low (5/4/L) and applies equally to all alternatives at LANL.

SRS is operated by DOE's Office of Environmental Management and NNSA is the tenant, so there is potential for intra-agency friction. In addition, there may be some inter-agency friction involving (for example) the Corps of Engineers (which may become involved if wetlands are affected by any proposed construction, which does not apply to either LANL or INL). There is potentially a moderate probability (3) of significant consequences (3), with a corresponding moderate risk (3/3/M) that affects all alternatives at SRS equally.

INL is operated by DOE's Office of Nuclear Energy and has a limited track record of working with NNSA. The AoA team has limited information on the risk associated with intra-agency interactions at INL but considers that the likelihood and consequence are potentially similar to those at SRS: there is potentially a moderate probability (3) of significant consequences (3). The risk is moderate (3/3/M) and affects all alternatives at INL equally.

C-6: Program requirements change (e.g., weapon types or numbers).

This is a possibility that cannot be ruled out as administrations change and/or new external threats arise. Over the assumed 10-year construction period, the probability of this is likely high (2), but if the threat materializes, the consequences may vary over a wide range of unknown factors. It is not possible to plan by including mitigating measures in the design of the manufacturing facility. Therefore, of the four methods that the DOE *Risk Management Guide* propounds for handling risk (accept, avoid, transfer, or mitigate), acceptance is essentially the only feasible alternative. The AoA team assumes that the consequences could be significant (3). The corresponding risk is moderate (2/3/M) and applies equally to all alternatives at all sites.

C-7: Functional performance requirements change (e.g., a requirement is introduced for computerized tomography [CT]).

If functional requirements change, the facility design may have to change (*e.g.,* to accommodate CT). The cost of resultant changes to the facility could be very high—perhaps at the crisis consequence level (2). The AoA team has included this risk because, in conversations with DOE HQ and personnel at LANL, it appears that the issue of what should be included in the pit manufacturing facility is not yet settled. One assumes that it will be settled before construction begins, so that the probability that this threat will materialize is low (4). However, it is a moderate risk (4/2/M) that needs to be addressed. It applies equally to all alternatives at all sites.

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

There is a very high probability (1) of significant consequences (3) or a high probability (2) of critical consequences (2), based on the history of ratcheted safety requirements. These combinations of probability and consequence are both high risk (1/3/H or 2/2/H) and apply equally to all alternatives at all sites.

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

There is a very high probability (1) of significant consequences (3) or a high probability (2) of critical consequences (2), based on the history of ratcheted security requirements. These combinations of probability and consequence are both high risk (1/3/H or 2/2/H) and apply equally to all alternatives at all sites.

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.

LANL – High Risk: Alternatives LANL 1-B, 1-C, 1-D, and 1E and LANL 4 all require construction, repair, and/or modifications in PF-4. There is, therefore, a very high probability (1) that ongoing operations in PF-4 will be affected at the significant (3) or critical (2) level, with the same levels of probability and consequence for ongoing activities in PF-4 affecting construction and/or repair and modification. The corresponding risks are high (1/3/H or 1/2/H).

Note that, after the completion of plutonium sustainment, PF-4 will be needed to produce 30 ppy for several years until the 80 ppy capability is up and running. Following the AoA team's discussions with LANL personnel, it is clear that the construction associated with establishing the 80-ppy manufacturing capability will require equipment to be installed in the same areas as will be used for the ongoing 30-ppy manufacturing process. This will inevitably cause disruption.

LANL – Low Risk: For LANL 2 (80 ppy including metal preparation in new construction) there should be no effect on operations in PF-4 or vice versa, with a very low probability (5) of marginal consequences (5), i.e., the risk is low (5/5/L).

LANL – Moderate Risk: For alternative LANL 3, with 80 ppy outside PF-4, and only science, certification and metal preparation left in PF-4, a subjective judgement is that, with only metal preparation requiring modifications in PF-4, there may be effects on other operations in PF-4, but these would be less disruptive than when installing a full 80-ppy capability, say, a moderate probability (3) of significant (3) consequences, leading to a moderate risk (3/3/M). Likewise, there will be the same moderate risk (3/3/M) that ongoing operations in PF-4 will affect metal preparation construction.

For alternative LANL 1-A, with 50 ppy outside PF-4, and 30 ppy plus science and certification plus metal preparation in PF-4, the assumption is that the 30 ppy will be provided by the Plutonium Sustainment Program. Therefore, work on the metal preparation to provide sufficient capacity for the additional 50 ppy in another facility could potentially affect ongoing operations in PF-4. For the same reason as outlined in the paragraph immediately above, the risk is assessed to be moderate (3/3/M).

SRS – High Risk: K-reactor has ongoing activities (e.g., plutonium storage and dilute and dispose). Regarding Alternatives SRS 1-B, 2-B, 3-B, and 4-B, there is a very high probability (1) that ongoing operations in K-reactor will be affected by construction at the significant (3) level or a high probability (2) of effects at the critical (2) level, or vice versa. This corresponds to a high risk (1/3/H or 2/2/H). Alternatives that involve metal preparation in a separate facility (SRS 4-A, 4-C, and 4-D) are associated with the production of 80 ppy at LANL and require construction, repair, and/or modifications in PF-4. There is a high probability (1) that ongoing operations in PF-4 will be affected at the significant (3) or critical (2) level, or vice versa. These are high risks (1/3/H or 2/2/H).

SRS – Low Risk: Production of 80 ppy with metal preparation at SRS in MFFF, the Waste Solidification Building (WSB), or new construction (SRS 2-A, 2-C, and 2-D) should not affect ongoing site or facility operations, or vice versa, and will have a low risk (5/5/L).

SRS – Moderate Risk: for all alternatives with 80 ppy outside PF-4, with only science, certification and metal preparation left in PF-4 (SRS 3-A, 3-C, and 3-D), a subjective judgement is that, with only metal preparation requiring modifications in PF-4, there may be effects on other operations in PF-4, but these will be less disruptive than when installing a full 80-ppy capability, say a moderate probability (3) of significant (3) consequences with a corresponding moderate risk (3/3/M). Likewise, there will be a moderate risk (3/3/M) that ongoing site or facility activities will affect construction or repair and modifications.

For all alternatives with 50 ppy outside PF-4 and 30 ppy plus science and certification plus metal preparation in PF-4 (SRS 1-A, 1-C, and 1-D), the assumption is that the 30 ppy will be provided by the Plutonium Sustainment Program. Therefore, work on the metal preparation to provide sufficient capacity for the additional 50 ppy in another facility could potentially affect ongoing operations in PF-4, or vice versa. For the same reason as outlined in the paragraph immediately above, the risk is assessed to be moderate (3/3/M).

INL – High Risk: Alternatives that have metal preparation in a separate facility (INL 4-A and 4-B) are associated with 80 ppy at LANL and require construction, repair, and/or modifications in PF-4. There is a high probability (1) that ongoing operations in PF-4 will be affected at the significant (3) or critical (2) level, or vice versa. Both of these combinations of probability and consequence are high risk (1/3/H or 1/2/H).

INL – Low Risk: Production of 80 ppy with metal preparation at SRS in FPF or new construction (INL 2-A and 2-B) should not affect ongoing site or facility operations or vice versa and will have a low risk (5/5/1).

INL – Moderate Risk: For all alternatives with 80 ppy outside PF-4, with only science, certification and metal preparation left in PF-4 (INL 3-A and 3-B), a subjective judgement is that, with only metal preparation requiring modifications in PF-4, there may be effects on other operations in PF-4, or vice versa, but these will be less disruptive than when installing a full 80-ppy capability, say a moderate probability (3) of significant (3) consequences, 3/3/M.

For all alternatives with 50 ppy outside PF-4 and 30 ppy plus science and certification plus metal preparation in PF-4 (INL 1-A and 1-B), the assumption is that the 30 ppy will be provided by the Plutonium Sustainment Program. However, work on the metal preparation to provide sufficient capacity for the additional 50 ppy in another facility could potentially affect ongoing operations in PF-4, or vice versa. For the same reason as outlined in the paragraph immediately above, the risk is assessed to be moderate (3/3/M).

C-11: Existing facilities require more work than planned to meet applicable codes and standards (e.g., latent conditions may unexpectedly come into play). Equivalently, unforeseen conditions in existing facilities during repair or upgrades result in more work than planned.

LANL: Any of the alternatives that require modifications in PF-4 (all except LANL 2) may require more work than planned, with a moderate probability (3) of significant consequences (3) and a corresponding moderate risk (3/3/M). This threat is not applicable to alternative LANL 2.

SRS: For K-reactor, an old facility with potential contamination, there will be a high probability (2) that this threat will be actualized, with significant (3) consequences and a corresponding moderate risk (2/3/M). For MFFF or WSB, there will be a low probability (4) (because these facilities are new) of significant consequences (3) with a corresponding low risk (4/3/L). This threat is not applicable to new construction.

INL: Use of the Fuel Processing Facility (FPF), a building constructed in the 1990s, may require more work than expected, with a high probability (2) of significant consequences (3) and a corresponding moderate (2/3/M) risk. Note that this is higher than for MFFF (4/3/L) because MFFF is a much newer and recently designed facility and higher than PF-4 (3/3M) because PF-4, though old, has been in essentially continuous operation. This risk is not applicable to new construction.

C-12: Material characterization (MC) capability is insufficient to support the schedule for the nonrecurring testing and analysis required to develop and qualify the manufacturing parameters for the W87 production process.

LANL: This risk is included because, during a visit to LANL by the infrastructure sub-team for this AoA, LANL personnel expressed concern about a potential shortfall in MC capability based on their extensive effort during the W-88 pit production and qualification process, compounded by the uncertainty of working for a different design agency (Lawrence Livermore National Laboratory [LLNL]). In addition, the current low limit on MAR in RLUOB (38.6 grams plutonium) places severe restrictions on the rate at which samples can be processed. However, because there is ample time during the construction period to address and rectify this concern, the AoA team assesses that there is low probability (4) but that the consequences could be significant (3). However, the risk remains low (4/3/L) for all alternatives at LANL.

SRS: During a recent visit to SRS, the AoA team discovered that SRS has limited capability to support MC needs for an 80-ppy manufacturing facility. The necessary facilities to accomplish the MC task would have to be designed, costed, and constructed as part of the overall pit manufacturing effort, taking into account the potential for some of the work to be done elsewhere, such as at LLNL or perhaps LANL.

It should also be noted that if either the MFFF or K-reactor facilities are utilized for pit manufacturing there would be sufficient Hazard Category 1 space available to accommodate a Material Characterization Laboratory need of approximately 8,000 square feet. Such space could also be designed into new construction but would be infeasible in WSB. Given the decade or so of construction and startup time, the AoA team considers that there is a low probability (4) of significant consequences (3) in MFFF, K-reactor, and new construction, with a higher probability (3) of significant consequences (3) for WSB, based on the latter’s relative smallness. These risks are low (4/3/L) and moderate (3/3/M), respectively.

INL: MC capability is available in the Fuels and Applied Science Building (FASB) (a 6,000-square foot radiological facility), the Electron Microscope Laboratory (a 2,000-square foot radiological facility), and the Irradiated Materials Characterization Laboratory (an 11,000-square foot of Hazard Category 2 space) at the Materials and Fuels Complex (MFC). Per discussions at LANL, the AoA team learned that MC has 5,700 square feet of Hazard Category 2 space in PF-4 and is requesting another 200 square feet. It also has 1,900 square feet of Hazard Category 3 space in RLUOB. INL can match this space, which is sufficient to sustain production but may not be enough for activities in the nonrecurring development phase. However, there should be ample time during the construction phase to address these issues, so the team assesses a low probability (4) of significant consequences (3), i.e., the risk is low (4/3/L).

C-13: Unexpected underground site conditions are encountered (e.g., geotechnical, buried pipelines, or buried waste).

LANL: There is negligible (low) risk of this for existing facilities (5/5/L). The site is well studied, so there is a low probability (4) that significant consequences (3) will result from this cause for new construction, corresponding to a low risk (4/3/L). Note that all LANL alternatives may require new construction, currently not exactly defined for LANL 1-B, 1-C, 1-D, and 1-E, so the risk for all LANL alternatives is conservatively 4/3/L.

SRS: As at LANL, there is negligible risk of this for existing facilities (5/5/1) (K-reactor, MFFF, and WSB). The site has been well studied, so there is a low probability (4) that significant consequences (3) will result from this cause when constructing a new building, i.e., the risk is low (4/3/L).

INL: This is not expected to be a problem with FPF, for which the risk should be low (5/5/L). The site is well studied, so there should be a low probability (4) that significant consequences (3) will arise from this cause during new construction. The corresponding risk is low (4/3/L).

C-14: Project design issues occur during construction, modifications, or repair work.

This could be an issue for any alternative. There is a moderate probability (3) of significant consequences (3), corresponding to a moderate risk (3/3/M).

C-15: There are issues with process qualification and/or design agency approval.

The AoA team assesses that there is a moderate probability (3) of marginal consequences (4), i.e., the risk is low (3/4/L). This is not a discriminator between alternatives and sites. The risk may be somewhat lower at LANL than at SRS or INL because the design agency is local, but because the risk is already low, the team did not attempt to estimate how much lower that risk might be.

C-16: There are issues with worker hiring, clearing, and/or training of qualified workers.

During the construction and startup phase, the main concern would be hiring, clearing, and training enough qualified people to staff the initial development and qualification process and then to staff the startup. After considerable discussion, the AoA team concluded that this is not a high risk and assessed a moderate probability (3) of marginal consequences (4), i.e., the risk is low (3/4/L) at all sites and for all alternatives.

C-17: A seismic event occurs during construction, damaging site infrastructure.

A Modified Mercalli Intensity (MMI) level IX earthquake (which corresponds to a peak ground acceleration [PGA] of 250 to 500 gals) causes sufficient damage to the surroundings to delay construction.

LANL: The return period of such earthquakes at LANL is approximately 1,000 years (Wong et al. 2007). The probability over the assumed 10-year construction period is approximately 0.01, which is very low (5). The maximum risk associated with a very low probability (per the risk matrix) is moderate (5/1/M). This is probably conservative (designated by a (C), as in 5/1/M [C]). See above for further discussion on assuming a default conservative estimate of moderate risk for very low frequency events.

SRS: The return period of such earthquakes at SRS is approximately once every 2,000 years (Williams, Carey, and Amin 2014). The corresponding probability over the assumed 10-year construction period is less than 10 percent, i.e., very low (5). The corresponding maximum risk (per the risk matrix) is moderate (5/1/M). This is probably conservative, designated by a (C) (5/1/M [C]).

INL: The return period of such earthquakes at INL is approximately once every 4,000 years (Coleman et al. 2016). The probability over the assumed 10-year construction period is approximately 0.0025, i.e., very low (5). The maximum risk (per the risk matrix) is moderate, which is probably conservative, designated by 5/1/M (C).

C-18: A seismic event occurs, causing damage to the facility under construction.

An MMI level IX earthquake (PGA 250 to 500 gals) causes sufficient damage to the facility to require extensive reconstruction. As noted above, the probability of such an earthquake at any of the three sites over the assumed 10-year construction period is very much less than 10 percent, which is very low (5). As discussed above, the maximum risk (per the risk matrix) is moderate, which is probability conservative and is designated by 5/1/M (C) for all alternatives at all sites.

C-19: A tornado or other high-wind event occurs during construction.

The AoA team conservatively assumes that a wind speed of 100 miles per hour (mph) will be sufficient either to damage the facility under construction or to damage the surrounding infrastructure sufficiently to delay construction, in each case with significant consequences (3). Coats and Murray (1985) derive plots of the return period versus wind speed for all DOE sites (as of 1985). For straight-line 100-mph winds, those return periods are approximately 1,000 years (LANL), 1,000 years (SRS, including hurricanes), and 10,000 years (INL). These correspond to probabilities of approximately 0.01, 0.01, and 0.001, respectively, over the assumed 10-year period of construction, i.e., very low (5). The corresponding risk at all sites is low (5/3/L).

Coats and Murray also show that the return period of tornados with winds of 100 mph or more is once in 500,000 years at LANL, once in 10,000 years at SRS, and once in a million years at INL. These return periods are much longer than those for straight-line winds.

C-20: An external flood occurs.

LANL: In September 2013, Los Alamos was subject to precipitation with an estimated 1,000-year return period (Walterschied 2013). Damage in canyons was extensive, but there was little damage to facilities on the mesa. The probability that such an event will occur again during the assumed 10-year period of construction is approximately 0.01, i.e. very low (5), maybe leading to restricted access to the site for a short while but causing less than or no greater than significant damage (3). The corresponding risk is low (5/3/L).

SRS: The frequencies of flooding at A-, K-, L-, C-, F-, E-, S-, H-, Y- and Z-Areas are significantly less than 10^{-05} per year (Chen 2000), or a very low (5) probability of 0.0001 over a 10-year construction period. The projected consequences depend on the nature of the building. For example, if a building has below ground levels that could flood, the consequences could be critical (2) or crisis (1). Conservatively, the risk is moderate (5/1/M [C]) but could be significantly less if the chosen facility does not have underground levels.

INL: In PNNL Publication 20029, Skaggs et al. 2010 show that, using the most conservative assumptions for the probable maximum flood (PMF) (i.e., all culverts at the MFC and the diversion ditch located upstream of the MFC are blocked), flood levels exceeding floor elevations could potentially occur at eight locations ranging from 3.20 feet at MFC Building 774 to 0.1 foot at MFC Building 767 (EBR-II Reactor Plant Building). The flood resulting from the 10,000-year precipitation event, assuming the culverts and the diversion ditch were open (i.e., unblocked), could potentially exceed floor elevations at two locations—the MFC Building 785 (Hot Fuel Examination Facility) by 0.1 foot and MFC Building 786 (Hot Fuel Examination Facility substation) by 0.03 feet.

An analysis was also conducted for the Transient Reactor Experiment and Test (TREAT) Facility site, located in a separate drainage area approximately 4,700 feet northwest of the MFC. Results indicate that flows generated by the PMP will produce a maximum water-surface elevation at the TREAT site of only approximately 5,115 feet, approximately 7 feet below the floor elevation of the TREAT Warehouse (MFC Building 723) and over 9 feet below the floor elevation of the TREAT reactor building (MFC Building 720).

Assumption: Neither a new facility nor FPF will be affected by a flood at anything less than the 10,000-year return period. Thus, the probability in an assumed 10-year construction period is approximately 0.001, i.e., very low (5). The maximum risk (per the risk matrix) is moderate, which is probably conservative, designated by 5/1/M (C).

Note: If a flood does reach FPF, most of the building could flood because the building is largely underground. Thus, a critical level consequence (2) or even a crisis level (1) is not totally out of the question. The same would be true for a new building if it were largely underground.

C-21: An external fire occurs.

LANL: There has been a fire at Los Alamos that approached TA-55 (the Cerro Grande fire of May 2000). A forest fire could restrict access to the site but is unlikely to damage plutonium facilities. The AoA team assesses a moderate probability (3) that a fire could approach the pit manufacturing facility and/or PF-4 during the period of construction and startup, with marginal (4) delays or extra costs for pit manufacturing construction. The corresponding risk is low (3/4/L).

SRS: SRS is a heavily forested site. However, areas around K-reactor, MFFF, WSB, and any conceivable new construction are generally clear of any significant combustible vegetation. A forest fire at SRS could restrict access to construction sites for a period of days or weeks. The probability of large forest fire is conservatively moderate (3) during the assumed 10-year period of construction with marginal consequences (4) for pit manufacturing construction. The corresponding risk is low (3/4/L).

INL: The INL site has very little vegetation (see Figure D-34) fire has a very low probability (5) and at most a marginal impact on pit manufacturing facility construction (4), i.e., the risk is low (5/4/L).

C-22: Any other external event occurs.

The AoA team discussed various other external events (e.g., heavy snow, volcanic activity) and suggests a low probability (4) of marginal consequences (4) at all sites, i.e., the risk is low (4/4/L).

C-23: SRS only: if the Mixed Oxide Fuel Fabrication Facility (MFFF) is chosen for the pit manufacturing facility, potential difficulties arise while unraveling the project with Areva.

Unravelling the contract while NNSA and CB&I/Areva are in dispute will be a lengthy process. The contract cannot simply be terminated because then the design basis will be lost—a settlement must be reached in a difficult environment. This is an ongoing dispute; therefore, the probability is very high (1). This state of affairs could cause a delay of between 1 and 2 years in completion of construction and startup (significant [3]). This combination of probability/consequence (1/3) corresponds to a high risk (1/3/H).

C-24: SRS only: difficulties arise while transferring the MFFF facility licensing basis from the Nuclear Regulatory Commission (NRC) to the Department of Energy (DOE).

This has never been done before. It is doable, but there will need to be some individual or organization within NNSA that will accept that a facility that was deemed licensable by NRC also meets DOE standards and requirements. Potentially, this could require a large amount of reanalysis and safety studies. Currently, the AoA team is unable to assess the amount or duration of work that might be involved. This risk will be exacerbated if installing the pit manufacturing facility in MFFF should require structural alterations. The probability that there will be some difficulties in the transfer of the licensing basis is high (2). It is possible that this could cause a delay of between 1 and 2 years in completion of construction and startup (significant -3). This combination of probability/consequence corresponds to a moderate risk (2/3/M).

E.5.2 Threats During the Operating Lifetime

This section details the assignment of probability, consequence, and risk to each pairing of threats listed in Table E–3 (*i.e.*, threats applicable during the facility's operating lifetime) and alternatives listed in Table E–6.

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

LANL – High Risk: any alternative that requires pit manufacturing to be done in the same facility and with the same equipment as science and certification runs the risk that the requirement to produce 80 WR pits per year will clash with the needs of other programs or that the needs of other programs will affect the ability to produce 80 ppy. This observation applies to any alternative that includes the manufacture of between 30 ppy and 80 ppy in PF-4. The AoA team judges that there will be a very high probability (1) of significant (3) or critical (4) consequences for all LANL 1 alternatives and LANL 4. This corresponds to a high risk (1/3/H or 1/2/H).

LANL – Low Risk: For alternative LANL 2, there is no potential conflict between pit production and the needs of other programs, so there is a very low probability (5) of marginal consequences (5), with a corresponding low risk (5/5/L).

LANL – Moderate Risk: For alternative LANL 3, with only metal preparation in PF-4, the team judges that there is a moderate probability (3) of significant (3) consequences, with a corresponding moderate risk (3/3/M).

SRS – High Risk: As noted above for LANL, any alternative that requires pit manufacturing to be done in the same facility and with the same equipment as science and certification runs the risk that the requirement to produce 80 WR pits per year will clash with the needs of other programs, or that the needs of other programs will affect the ability to produce 80 ppy. This includes all alternatives in which a minimum of 30 ppy up to a maximum of 80 ppy are manufactured in PF-4. At SRS, this includes all SRS 1 and SRS 4 alternatives. In addition, K-reactor alternatives SRS 2-B and SRS 3-B have pit production in potential conflict with other activities such as dilute and dispose or plutonium storage. All of these alternatives are assessed to have a very high probability (1) that ongoing operations adversely affect the ability to produce 80 ppy or vice versa at the significant (3) or critical (2) level, corresponding to high levels of risk (1/3/H or 1/2/H).

SRS – Low Risk: For 80 ppy with metal preparation at SRS in MFFF, WSB, or new construction (SRS 2-A, 2-C, and 2-D), there will be no interaction with operations in PF-4, conservatively a very low probability (5) of minimal consequences (5) during operation. The corresponding risk is low (5/5/1).

SRS – Moderate Risk: For all alternatives with 80 ppy outside PF-4, with only science, certification and metal preparation left in PF-4 (SRS 3-A, 3-C, and 3-D), a subjective judgement is that, with only metal preparation remaining in PF-4, there would only be a moderate risk that metal preparation activities supporting 80 ppy manufacturing would adversely affect other programs in PF-4 or vice versa, say a probability (3) of significant (3) consequences. The corresponding risk is moderate (3/3/M).

INL – High Risk: As noted above for LANL and SRS, any alternative that requires pit manufacturing to be done in the same facility and with the same equipment as science and certification runs the risk that the requirement to produce 80 WR pits per year will clash with the needs of other programs or that the needs of other programs will affect the ability to produce 80 ppy. This includes all alternatives in which a minimum of 30 ppy up to a maximum of 80 ppy are manufactured in PF-4. This includes alternatives INL 1-A, 1-B, 4-A, and 4-B. All of these alternatives are assessed to have a very high probability (1) that ongoing operations adversely affect the ability to produce 80 ppy or vice versa at the significant (3) or critical (2) level, corresponding to high risks (1/3/H or 1/2/H).

INL – Low Risk: For 80 ppy with metal preparation at INL in FPF or new construction (INL 2-A and 2-B), there will be no interaction with operations in PF-4, conservatively a very low probability (5) of minimal consequences (5) during operation, corresponding to a low risk (5/5/L).

INL – Moderate Risk: For all alternatives with 80 ppy outside PF-4, with only science, certification and metal preparation left in PF-4 (INL 3-A and 3-B), a subjective judgement is that, with only metal preparation remaining in PF-4, there would only be a moderate risk that metal preparation activities supporting 80 ppy manufacturing would adversely affect other programs in PF-4 or vice versa, say a probability (3) of significant (3) consequences, corresponding to a moderate risk (3/3/M).

O-2: The facility is unable to hire, clear, train, and/or retain sufficient skilled personnel to support ongoing plutonium operations.

During operation, the main concern would be retaining, clearing, hiring, and training enough qualified people to staff the ongoing production process.

LANL: The AoA team is aware that there have been difficulties in hiring qualified staff at LANL but ultimately concluded that this is not a high risk and assessed a moderate probability (3) of marginal consequences (4), i.e., the risk is low (3/4/L).

SRS: The AoA team concluded that this is not a high risk and, as for LANL, assessed a moderate probability (3) of marginal consequences (4), i.e., the risk is low (3/4/L).

INL: Note that, when the AoA team visited INL, they were told that INL has very little difficulty hiring qualified staff. The team ultimately concluded that this is not a high risk and again assessed a moderate probability (3) of marginal consequences (4), i.e., the risk is low (3/4/L).

O-3: Low level waste treatment capabilities deteriorate, become overwhelmed, or are unavailable for an extended period, impacting mission.

LANL: During a visit to LANL, the infrastructure sub-team for this AoA determined that LANL has a new low level liquid waste treatment facility that has ample capacity for dealing with the waste from 80 ppy manufacturing and other sources at LANL. In addition, the sub-team determined that there is ample capacity and potential workarounds for handling and disposing of solid low level waste. There is a very low probability (5) of marginal consequences (4), i.e., the risk is low (5/4/L).

SRS: During a visit to SRS, the infrastructure sub-team determined that SRS has ample capacity for both low-level liquid and solid waste treatment and disposal. There is a very low probability (5) of marginal consequences (4), i.e., the risk is low (5/4/L).

INL has adequate capabilities and capacity to handle both liquid and solid low level waste generated by the manufacturing of 80 ppy, as established by INL's response to a questionnaire. The AoA team assessed a very low probability (5) of marginal consequences (4), i.e., the risk is low (5/4/L).

O-4: TRU waste treatment capabilities deteriorate, become overwhelmed, or are unavailable for an extended period, impacting mission.

LANL: during a visit to LANL, the infrastructure sub-team determined that LANL will shortly have a new liquid TRU waste facility that has ample capacity for dealing with liquid TRU waste from an 80-ppy manufacturing facility and other sources at LANL. In addition, LANL has the capacity to store up to 2 years' worth of TRU waste in 55-gallon drums. Absent external factors (see below), LANL will be able to manage the TRU waste packaging and disposition associated with 80 ppy manufacturing. There is a very low probability (5) of a marginal consequence (4), i.e., the risk is low (5/4/L).

SRS: During a visit to SRS, the infrastructure sub-team determined that SRS has ample capacity for dealing with liquid TRU waste from an 80-ppy manufacturing facility and other sources at SRS. In addition, SRS has the capacity to store more than 5 years' worth of solid TRU waste in 55-gallon drums. Absent external factors (see below) SRS will be able to manage the TRU waste packaging and disposition associated with 80 ppy manufacturing. There is a very low probability (5) of a marginal consequence (4), i.e., the risk is low (5/4/L).

INL: As established by INL's response to a questionnaire, the AoA team determined that INL has a facility that can process approximately 140 cubic meters (m^3) of liquid TRU waste per year. Manufacturing 80 ppy will produce liquid TRU-waste in the range 3 m^3/year (MPF) to 30 m^3/year (LANL). Either of these is well within the capacity of the INL facility.

INL is currently capable of processing 250 m^3/month of solid TRU waste. The amount of solid TRU waste generated by the manufacture of 80 ppy would be in the range of 130 m^3/year (MPF) to 220 m^3/year (LANL). The INL facility is currently fully utilized, but its current mission is scheduled to end in 2021. Assuming that the facility would then be retained for future missions, its capacity is more than adequate to handle solid TRU waste from an 80-ppy manufacturing facility. The AoA team assesses a very low probability (5) of marginal consequences (4), i.e., the risk is low (5/4/L).

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.

WIPP recently shut down for 3 years. Another shutdown of WIPP over the assumed 50-year life of the pit manufacturing program would seem to be at least moderately probable (3).

LANL: If WIPP shuts down again for 3 or more years, LANL would not have enough capacity to store all of the solid TRU waste produced over that time. This would require the construction of more storage space. Spread over a few years of operation, this would likely be a marginal consequence (4). The corresponding risk is low (3/4/L).

SRS: As noted above, SRS has ample capacity to store TRU waste for several years. There would be some costs associated with this increased storage, perhaps at the marginal level (4). This corresponds to a low risk (3/4/L).

The IST for this AoA was unable to establish **INL's** capacity to store TRU waste in the event that transportation of TRU-waste to WIPP is interrupted. However, it is anticipated that costs associated with this increased storage, if needed at all, would be marginal (4). The corresponding risk is low (3/4/L).

O-6: When WIPP comes back on line after a shutdown, additional regulatory and safety constraints mean that it accepts shipments at a rate that is insufficient to process waste generated by an 80-ppy program.

This threat is a slow-motion version of threat O-5. The chosen site (whether LANL, SRS, or INL) will generate TRU waste at a rate that is greater than the allowable rate of shipment to WIPP, so that gradually available storage capacity is filled and more will be needed. It is actually the case that, now that the recent shutdown is over, WIPP is accepting shipments at a reduced rate. In addition, there are restrictions that mean that some TRU waste is more dilute than in the past: *i.e.*, more drums are required for a given amount of TRU waste. The probability of occurrence of this scenario is very high (1) at all sites, with marginal consequences (4) related to the building over time of additional solid TRU waste storage space. The corresponding risk is moderate (1/4/M).

O-7: WIPP becomes full and is no longer able to accept solid TRU waste, and no other repository is available.

The U.S. Governmental Accountability Office (GAO) has published a report (GAO-17-390), *Proposed Dilute and Dispose Approach Highlights Need for More Work at the Waste Isolation Pilot Plant*, that states that "DOE does not have sufficient space at WIPP to dispose of all defense TRU waste. DOE's current plan is to fill the existing disposal space in WIPP by 2026, and additional space will need to be excavated to dispose of all the waste included in DOE's current TRU waste inventory report." However, one assumes that this risk will be mitigated by construction of further storage capacity at WIPP if needed. Therefore, the AoA team assesses a low probability (4) that the ability to dispose of TRU waste at WIPP will be permanently halted. There might be delays that would necessitate building further TRU waste storage capacity over time, with marginal consequences (4) at any of the sites. The corresponding risk is low (4/4/L).

O-8: *Analytical chemistry (AC) or materials characterization (MC) capabilities deteriorate, become overwhelmed, or are unavailable for an extended period, impacting mission.*

LANL: During a visit to LANL, the infrastructure sub-team for this AoA determined that there are a number of uncertainties associated with LANL's ability to provide AC support to the 80-ppy manufacturing program. Among these are limitations on MAR in CMRR and how much AC work will be required to support other programs such as ARIES. However, given that it will be a decade or so before 80 ppy manufacturing is up and running, there appears to be ample time to solve problems, build additional space, or identify workarounds. Therefore, it would seem that there is a low probability (4) of significant consequences (3). Similar considerations apply to MC. This is a low risk (4/3/L).

SRS: During a visit to SRS, the infrastructure sub-team discovered that there are a number of uncertainties associated with SRS's ability to provide AC support to the 80-ppy manufacturing program. Among these are 200-gram plutonium limitations on MAR in the buildings in which AC work is performed. However, given that it will be a decade or so before 80 ppy manufacturing is up and running, there appears to be ample time to solve problems, build additional space, or identify workarounds. Therefore, as at LANL, it would seem that there is a low probability (4) of significant consequences (3). Similar considerations apply to MC. The corresponding risk is low (4/3/L).

INL currently has the capability needed to meet the AC needs of 80 ppy manufacturing, according to answers provided in a questionnaire but would need to upgrade capacity. This capability is currently housed in Hazard Category 3 buildings, with a plan to upgrade to Hazard Category 2. Given the expected decade-long construction and startup phase, the AoA team considers that there is ample time to enhance capacity and develop workarounds, with a low probability (4) of significant consequences (3). Similar considerations apply to MC. The corresponding risk is low (4/3/L).

O-9: Any other support infrastructure capabilities deteriorate, become overwhelmed, or are unavailable for an extended period, impacting mission.

Other needed infrastructure capabilities include classified stainless-steel machining, classified graphite machining, classified beryllium machining, coating, and standards and calibration. There is a low probability (4) that these will be unavailable and lead to significant consequences (3), *i.e*., the risk is low (4/3/L) at all three sites.

O-10: Inability to obtain spare/replacement parts for failed equipment increases potential shutdown durations, impacting mission.

There is a high probability (2) that one or more items of equipment become obsolete and replacement parts are unavailable. However, workarounds are always possible, at marginal cost (4). The corresponding risk is moderate (2/4/M) and is the same for all alternatives at all three sites.

O-11: Supplier(s) of essential and unique equipment go out of business, refuse to take the job, or deliver poor quality.

Across the NNSA complex, there have been several examples of suppliers going out of business, refusing to take jobs, or delivering poor quality. There is a moderate probability (3) that this will occur during the operating lifetime of the pit manufacturing facility. There are workarounds (e.g., NNSA making equipment or materials itself) but at possibly significant cost (3), i.e., the risk is moderate (3/3/M) for all alternatives at all three sites.

O-12: Aircraft impact damages the facility.

Typical calculated aircraft crash frequencies into buildings, using standard DOE methodology, are very conservatively approximately 10^{-5}/year. This equates to a very low probability (5) of a crash over a 50-year lifetime. Per the risk matrix, the maximum risk is moderate and probably conservative (5/1/M [C]) and applies to all alternatives at all three sites. If, in the future, the need should arise to refine this conservative analysis, it will be necessary to obtain aircraft crash analyses for facilities at each of the sites.

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; subsequent decontamination may be required.

The principal concern here is that a release of hazardous material could result in contamination of the manufacturing facility such that extensive decontamination is required. This could be a consequence at a crisis level (2). However, the probability is very low (5) at any of the sites, so that the risk is also low (5/2/L).

O-14: Transportation capacity for shipping pits and plutonium feedstock is insufficient to meet demands from all DOE sites.

The 80-ppy program will require a very small number of shipments per year. The probability that transportation would not be available when needed is very low (5). The consequences could be significant (3), but the risk is low (5/3/L).

O-15: A seismic event occurs during operation

Assume that the facility is designed or upgraded to withstand an earthquake with a return period of 10,000 years, or a probability of 0.005 in a 50-year operating life. This is a very low probability (5). Therefore, per the risk matrix, the highest risk is moderate. This is probably conservative (5/1/M [C]). This conclusion applies to all alternatives at all sites.

For all sites, the probability that an earthquake occurs that is severe enough to damage infrastructure and surroundings to the extent that the facility may have to be shut down for a time is also very low (5) with a maximum moderate risk, probably conservative (5/1/M [C]); see discussion for C-17.

O-16: A tornado or other high-wind event occurs.

Assume that the facility is designed or upgraded to withstand straight-line winds with a return period of 2,500 years, hurricanes with a return period of 2,500 years (noting that no hurricanes occur at LANL or INL), and/or tornadoes with a return period of 50,000 years for a WDC-3 SSC, per DOE-STD-1020-2016 (DOE 2016). Over a 50-year operating life, the probability of winds stronger than this is < 0.075, i.e., very low (5). Per the risk matrix, the maximum risk is moderate. This is probably conservative, designated by 5/1/M (C), and applies to all alternatives at all sites.

O-17: An external flood occurs.

LANL: As discussed above, in September 2013, Los Alamos was subject to precipitation with an estimated 1,000-year return period. Damage in canyons was extensive, but there was little damage to facilities on the mesa. The probability that such an event will occur again during the assumed 50-year period of construction is 0.05, *i.e.,* very low (5), causing no greater than significant damage (3). The corresponding risk is low (5/3/L).

SRS: As discussed above, the frequencies of flooding at A-, K-, L-, C-, F-, E-, S-, H-, Y-, and Z-Areas are significantly less than 10^{-05} per year (WSRC-TR-2000-00206), or a very low (5) probability of 5×10^{-04}/year over a 50-year operating lifetime. If flooding occurs, the projected consequences could be at a crisis (5) level (e.g., if a facility is largely underground and could be completely flooded). A conservative upper bound on the risk is moderate (5/1/M [C]).

INL: Assume that new construction is designed or FPF is upgraded to the requirements of DOE-STD-1020-2016, FDC-3 SSCs subject to submersion not flooded more often than once in 10,000 years, and FDC-3 SSCs not subject to immersion not flooded more than once in 2,500 years. The probability of such severe floods during a 50-year operating lifetime is <0.075, i.e., very low. Per the risk matrix, the maximum risk is moderate. This is probably conservative, designated by 5/1/M (C).

O-18: An external fire occurs.

LANL: As discussed above, there has been a fire at Los Alamos that approached TA-55, the Cerro Grande fire of May 2000. A forest fire could restrict access to the site but is unlikely to damage facilities. The AoA team suggests a moderate probability (3) that a fire will approach the pit manufacturing facility and/or PF-4, with marginal (4) delays or extra costs for pit manufacturing operations. The corresponding risk is low (3/4/L).

SRS is a heavily forested site. However, areas around K-reactor, MFFF, WSB, and any conceivable new construction are generally clear of any significant combustible vegetation. A forest fire at SRS could restrict access to construction sites for a period of days or weeks. The probability of large forest fire over a 50-year operating lifetime is assessed to be moderate (3) with marginal consequences (4) for the pit manufacturing operation. This corresponds to a low risk (3/4/L).

INL: The INL site has very little vegetation (see Figure D-34). The probability of external fire approaching FPF or new construction is very low (5), with at most marginal impact on pit manufacturing facility construction (4). The corresponding risk is low (5/4/L).

O-19: Any other external event occurs.

The AoA team discussed various other external events (e.g., heavy snow, volcanic activity) and suggests a low probability (4) of marginal consequences (4), i.e., the risk is low (4/4/L) for all alternatives at all sites.

E.6 Summary

This section has two parts. The first is a tabular summary of the discussion in the foregoing. The second is a summary of the results for the alternatives that were finally chosen for presentation to senior management.

E.6.1 Tabular Summary

The discussion above is summarized in Tables E–7 (LANL), E–8 (SRS), and E–9 (INL).

Table E–7. Summary of results of risk assessment for LANL alternatives

ID#	Brief Description of Threat	LANL 1-A	LANL 1-B	LANL 1-C	LANL 1-D	LANL 1-Dmax	LANL 1-E	LANL 2	LANL 3	LANL 4
C-1	NEPA: EIS or additional environmental reviews cause delays and extra costs.	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L
C-2	National and/or local political/public opposition results in delays and extra costs.	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M
C-3	National and/or local political /public opposition results in project cancellation.	5/1/M	5/1/M	5/1/M	5/1/M	5/1/M	5/1/M	5/1/M	5/1/M	5/1/M
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.	2/2/H	2/2/H	2/2/H	2/2/H	2/2/H	2/2/H	2/2/H	2/2/H	2/2/H
C-5	Intra-agency and/or inter-agency disputes delay project and introduce extra costs or unwanted restrictions on the project.	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L
C-6	Program requirements change (e.g., weapon types or numbers).	2/3/M	2/3/M	2/3/M	2/3/M	2/3/M	2/3/M	2/3/M	2/3/M	2/3/M
C-7	Functional performance requirements change (e.g., requirement introduced for computerized tomography).	4/2/M	4/2/M	4/2/M	4/2/M	4/2/M	4/2/M	4/2/M	4/2/M	4/2/M
C-8	More stringent interpretations of safety requirements during design and construction require significant facility structural or service system upgrades.	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H
C-9	Additional security provisions (e.g., clearances, escorts, fences, changes in the design basis threat) beyond planned are imposed.	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H
C-10	Construction or repair and modifications impact ongoing site or facility operations, or ongoing operations impact construction and/or repairs and modifications.	3/3/M	1/3/H or 1/2/H	1/3/H or 1/2/H	1/3/H or 1/2/H	1/3/H or 1/2/H	1/3/H or 1/2/H	5/5/L	3/3/M	1/3/H or 1/2/H
C-11	Existing facilities require more work than planned to meet applicable codes and standards (e.g., latent conditions may unexpectedly come into play). Equivalently, unforeseen conditions in existing facilities during repair or upgrades result in more work than planned.	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	N/A	3/3/M	3/3/M

ID#	Brief Description of Threat	LANL 1-A	LANL 1-B	LANL 1-C	LANL 1-D	LANL 1-Dmax	LANL 1-E	LANL 2	LANL 3	LANL 4
C-12	Material characterization (MC) capability is insufficient to support the schedule for the nonrecurring testing and analysis required to develop and qualify the manufacturing parameters for the W87 production process.	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L
C-13	Unexpected underground site conditions (e.g., geotechnical, buried pipelines, or buried waste) are encountered.	4/3/L	4/3/L	4/3/L	4/3/L	4/3/l	4/3/L	4/3/L	4/3/L	4/3/L
C-14	Project design issues occur during work (construction/modifications/repairs).	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M
C-15	There are issues with process qualification and/or design agency approval.	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L
C-16	There are issues with worker training and hiring of qualified workers.	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L
C-17	A seismic event occurs during construction, damaging site infrastructure.	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)
C-18	A seismic event occurs, causing damage to facility under construction.	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)
C-19	A tornado or other high-wind event occurs during construction.	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L
C-20	An external flood occurs during construction.	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L
C-21	An external fire occurs during construction.	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L
C-22	Any other external event occurs during construction.	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L
O-1	Pit manufacturing adversely affects other site or facility projects, or other site or facility projects adversely affect pit production.	1/3/H or1/2/H	1/3/H or1/2/H	1/3/H or1/2/H	1/3/H or1/2/H	1/3/H or1/2/H	1/3/H or1/2/H	5/5/L	3/3/M	1/3/H or1/2/H
O-2	The facility is unable to hire, train, and/or retain sufficient skilled personnel to support ongoing plutonium operations.	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L
O-3	Low level waste treatment capabilities deteriorate, become overwhelmed, or are unavailable for an extended period.	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L
O-4	TRU waste treatment capabilities deteriorate, become overwhelmed, or are unavailable for an extended period, impacting mission.	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L
O-5	WIPP shuts down for an extended period of time (months or years) so that TRU waste storage capability reaches its limit.	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L

ID#	Brief Description of Threat	LANL 1-A	LANL 1-B	LANL 1-C	LANL 1-D	LANL 1-Dmax	LANL 1-E	LANL 2	LANL 3	LANL 4
O-6	When WIPP comes back on line after a shutdown, additional regulatory and safety constraints mean that it accepts shipments at a rate that is insufficient to process waste generated by an 80-ppy program.	1/4/M	1/4/M	1/4/M	1/4/M	1/4/M	1/4/M	1/4/M	1/4/M	1/4/M
O-7	WIPP becomes full and is no longer able to accept solid TRU waste, and no other repository is available.	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L
O-8	Analytical chemistry or materials characterization capabilities are insufficient to support the 80-ppy manufacturing effort.	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L
O-9	Any other support infrastructure capabilities deteriorate, become overwhelmed, or are unavailable for an extended period.	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L
O-10	Inability to obtain spare/replacement parts for failed equipment increases potential shutdown durations, impacting mission.	2/4/M	2/4/M	2/4/M	2/4/M	2/4/M	2/4/M	2/4/M	2/4/M	2/4/M
O-11	Supplier(s) of essential and unique equipment and/or materials go out of business, refuse to take the job, or deliver poor quality.	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M
O-12	Aircraft impact damages the facility.	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)
O-13	A hazardous material release elsewhere onsite or at a nearby industrial facility or from a transportation accident affects operators and causes facility shutdown; subsequent decontamination may be required.	5/2/L	5/2/L	5/2/L	5/2/L	5/2/L	5/2/L	5/2/L	5/2/L	5/2/L
O-14	Transportation capacity for shipping pits and plutonium feedstock is unavailable when needed.	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L
O-15	A seismic event occurs during operation.	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)
O-16	A tornado or other high-wind event occurs during operation.	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)
O-17	A flood occurs during operation.	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L
O-18	An external fire occurs during operation.	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L
O-19	Any other external event occurs during operation.	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L

Key:

EIS = environmental impact statement; LANL= Los Alamos National Laboratory; NEPA = National Environmental Policy Act; ppy = pits per year; TRU = transuranic; WIPP = Waste Isolation Pilot Plant.

Table E–8. Summary of results of risk assessment for SRS alternatives

ID#	Brief Description of Threat	SRS 1-A	SRS 1 B	SRS 1-C	SRS 1-D	SRS 2-A	SRS 2-B	SRS 2-C	SRS 2-D	SRS 3-A	SRS 3-B	SRS 3-C	SRS 3-D	SRS 4-A	SRS 4-B	SRS 4-C	SRS 4-D
C-1	NEPA: EIS or additional environmental reviews cause delays and extra costs.	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L
C-2	National and/or local political/public opposition results in delays and extra costs.	2/3/M	2/3/M	2/3/M	2/3/M	2/3/M	2/3/M	2/3/M	2/3/M	2/3/M	2/3/M	2/3/M	2/3/M	2/3/M	2/3/M	2/3/M	2/3/M
C-3	National and/or local political /public opposition results in project cancellation.	5/1/M	5/1/M	5/1/M	5/1/M	5/1/M	5/1/M	5/1/M	5/1/M	5/1/M	5/1/M	5/1/M	5/1/M	5/1/M	5/1/M	5/1/M	5/1/M
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.	2/2/H	2/2/H	2/2/H	2/2/H	2/2/H	2/2/H	2/2/H	2/2/H	2/2/H	2/2/H	2/2/H	2/2/H	2/2/H	2/2/H	2/2/H	2/2/H
C-5	Intra-agency and/or inter-agency disputes delay project, introduce extra costs or unwanted restrictions on the project.	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M
C-6	Program requirements change (e.g., weapon types or numbers).	2/3/M	2/3/M	2/3/M	2/3/M	2/3/M	2/3/M	2/3/M	2/3/M	2/3/M	2/3/M	2/3/M	2/3/M	2/3/M	2/3/M	2/3/M	2/3/M
C-7	Functional performance requirements change (e.g., requirement introduced for computerized tomography).	4/2/M	4/2/M	4/2/M	4/2/M	4/2/M	4/2/M	4/2/M	4/2/M	4/2/M	4/2/M	4/2/M	4/2/M	4/2/M	4/2/M	4/2/M	4/2/M
C-8	More stringent interpretations of safety requirements during design and construction require significant facility structural or service system upgrades.	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H

ID#	Brief Description of Threat	SRS 1-A	SRS 1 B	SRS 1-C	SRS 1-D	SRS 2-A	SRS 2-B	SRS 2-C	SRS 2-D	SRS 3-A	SRS 3-B	SRS 3-C	SRS 3-D	SRS 4-A	SRS 4-B	SRS 4-C	SRS 4-D
C-9	Additional security provisions (e.g., clearances, escorts, fences, changes in the design basis threat) beyond planned are imposed.	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H
C-10	Construction or repair and modifications impact ongoing site or facility operations, or ongoing site or facility activities impact construction or repair and modifications.	3/3/M	1/3/H or 2/2/H	3/3/M	3/3/M	5/5/L	1/3/H or 2/2/H	5/5/L	5/5/L	3/3/M	1/3/H or 2/2/H	3/3/M	3/3/M	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H
C-11	Existing facilities require more work than planned to meet applicable codes and standards (i.e., latent conditions may unexpectedly come into play). Equivalently, unforeseen conditions in existing facilities during repair or upgrades result in more work than planned.	4/3/L	2/3/M	4/3/L	N/A	4/3/L	2/3/M	4/3/L	N/A	4/3/L	2/3/M	4/3/L	N/A	4/3/L	2/3/M	4/3/L	N/A
C-12	Material characterization (MC) capability is insufficient to support the schedule for the nonrecurring testing and analysis required to develop and qualify the manufacturing parameters for the W87 production process.	4/3/L	4/3/L	3/3/M	4/3/L	4/3/L	4/3/L	3/3/M	4/3/L	4/3/L	4/3/L	3/3/M	4/3/L	4/3/L	4/3/L	3/3/M	4/3/L
C-13	Unexpected underground site conditions are encountered (e.g., geotechnical, buried pipelines, or buried waste).	5/5/L	5/5/L	5/5/L	4/3/L	5/5/L	5/5/L	5/5/L	4/3/L	5/5/L	5/5/L	5/5/L	4/3/L	5/5/L	5/5/L	5/5/L	4/3/L

ID#	Brief Description of Threat	SRS 1-A	SRS 1 B	SRS 1-C	SRS 1-D	SRS 2-A	SRS 2-B	SRS 2-C	SRS 2-D	SRS 3-A	SRS 3-B	SRS 3-C	SRS 3-D	SRS 4-A	SRS 4-B	SRS 4-C	SRS 4-D
C-14	Project design issues occur during work (construction/ modifications/repairs).	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M
C-15	There are issues with process qualification and/or design agency approval.	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L
C-16	There are issues with worker training and hiring of qualified workers.	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L
C-17	A seismic event occurs during construction, damaging site infrastructure.	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)
C-18	A seismic event occurs, causing damage to facility under construction.	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)
C-19	A tornado or other high-wind event occurs during construction.	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L
C-20	An external flood occurs during construction.	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)
C-21	An external fire occurs during construction.	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L
C-22	Any other external event occurs during construction.	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L
C-23	If MFFF is chosen for the pit manufacturing facility, potential difficulties arise while unraveling the project with Areva.	1/3/H	N/A	N/A	N/A	1/3/H	N/A	N/A	N/A	1/3/H	N/A	N/A	N/A	1/3/H	N/A	N/A	N/A
C-24	Difficulties arise while transferring the MFFF facility licensing basis from NRC to DOE.	2/3/M	N/A	N/A	N/A	2/3/M	N/A	N/A	N/A	2/3/M	N/A	N/A	N/A	2/3/M	N/A	N/A	N/A
O-1	Pit manufacturing adversely affects other site or facility projects, or other site or facility projects adversely affect pit production.	1/3/H or 1/2/H	1/3/H or 1/2/H	1/3/H or 1/2/H	1/3/H or 1/2/H	5/5/L	1/3/H or 1/2/H	5/5/L	5/5/L	3/3/M	1/3/H or 1/2/H	3/3/M	3/3/M	1/3/H or 1/2/H	1/3/H or 1/2/H	1/3/H or 1/2/H	1/3/H or 1/2/H

ID#	Brief Description of Threat	SRS 1-A	SRS 1 B	SRS 1-C	SRS 1-D	SRS 2-A	SRS 2-B	SRS 2-C	SRS 2-D	SRS 3-A	SRS 3-B	SRS 3-C	SRS 3-D	SRS 4-A	SRS 4-B	SRS 4-C	SRS 4-D
O-2	The facility is unable to hire, clear, train, and/or retain sufficient skilled personnel to support ongoing plutonium operations.	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L
O-3	Low level waste treatment capabilities deteriorate, become overwhelmed, or are unavailable for an extended period, impacting mission.	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L
O-4	TRU waste treatment capabilities deteriorate, become overwhelmed, or are unavailable for an extended period, impacting mission.	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L
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.	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L
O-6	When WIPP comes back on line after a shutdown, additional regulatory and safety constraints mean that it accepts shipments at a rate that is insufficient to process waste generated by an 80-ppy program.	1/4/M	1/4/M	1/4/M	1/4/M	1/4/M	1/4/M	1/4/M	1/4/M	1/4/M	1/4/M	1/4/M	1/4/M	1/4/M	1/4/M	1/4/M	1/4/M
O-7	WIPP becomes full and is no longer able to accept solid TRU waste, and no other repository is available.	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L

ID#	Brief Description of Threat	SRS 1-A	SRS 1 B	SRS 1-C	SRS 1-D	SRS 2-A	SRS 2-B	SRS 2-C	SRS 2-D	SRS 3-A	SRS 3-B	SRS 3-C	SRS 3-D	SRS 4-A	SRS 4-B	SRS 4-C	SRS 4-D
O-8	Analytical chemistry or material characterization capabilities deteriorate, become overwhelmed, or are unavailable for an extended period, impacting mission.	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L
O-9	Any other support infrastructure capabilities deteriorate, become overwhelmed, or are unavailable for an extended period, impacting mission.	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L
O-10	Inability to obtain spare/replacement parts for failed equipment increases potential shutdown durations, impacting mission.	2/4/M	2/4/M	2/4/M	2/4/M	2/4/M	2/4/M	2/4/M	2/4/M	2/4/M	2/4/M	2/4/M	2/4/M	2/4/M	2/4/M	2/4/M	2/4/M
O-11	Supplier(s) of essential and unique equipment go out of business, refuse to take the job, or deliver poor quality.	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M
O-12	Aircraft impact damages the facility.	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)
O-13	Hazardous material release elsewhere onsite or at a nearby industrial facility or from a transportation accident affects operators and causes a facility shutdown; subsequent decontamination may be required.	5/2/L	5/2/L	5/2/L	5/2/L	5/2/L	5/2/L	5/2/L	5/2/L	5/2/L	5/2/L	5/2/L	5/2/L	5/2/L	5/2/L	5/2/L	5/2/L
O-14	Transportation capacity for shipping pits and plutonium feedstock is insufficient to meet needs.	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L
O-15	A seismic event occurs during operation.	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)

ID#	Brief Description of Threat	SRS 1-A	SRS 1 B	SRS 1-C	SRS 1-D	SRS 2-A	SRS 2-B	SRS 2-C	SRS 2-D	SRS 3-A	SRS 3-B	SRS 3-C	SRS 3-D	SRS 4-A	SRS 4-B	SRS 4-C	SRS 4-D
O-16	A tornado or other high wind event occurs during operation.	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)
O-17	An external flood occurs during operation s.	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)
O-18	An external fire occurs during operation.	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L
O-19	Any other external event occurs during operation.	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L

Key:

EIS = environmental impact statement; MFFF = Mixed Fuel Fabrication Facility; NEPA = National Environmental Policy Act; NRC = Nuclear Regulatory Commission; ppy = pits per year; SRS = Savannah River Site; TRU = transuranic; WIPP = Waste Isolation Pilot Plant.

Table E–9. Summary of results of risk assessment for INL alternatives

ID#	Identifier	INL 1-A	INL 1-B	INL 2-A	INL 2-B	INL 3-A	INL 3-B	INL 4-A	INL 4-B
C-1	NEPA: EIS or additional environmental reviews cause delays and extra costs.	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L
C-2	National and/or local political/public opposition results in delays and extra costs.	2/3/M	2/3/M	2/3/M	2/3/M	2/3/M	2/3/M	2/3/M	2/3/M
C-3	National and/or local political/public opposition results in project cancellation.	5/1/M	5/1/M	5/1/M	5/1/M	5/1/M	5/1/M	5/1/M	5/1/M
C-4	Sufficient line item funds are not available, resulting in a delay to completion of construction and startup.	2/2/H	2/2/H	2/2/H	2/2/H	2/2/H	2/2/H	2/2/H	2/2/H
C-5	Intra-agency and/or inter-agency disputes delay project and introduce extra costs or unwanted restrictions on the project.	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M
C-6	Program requirements change (e.g., weapon types or numbers).	2/3/M	2/3/M	2/3/M	2/3/M	2/3/M	2/3/M	2/3/M	2/3/M
C-7	Functional performance requirements change (e.g., requirement introduced for computerized tomography).	4/2/M	4/2/M	4/2/M	4/2/M	4/2/M	4/2/M	4/2/M	4/2/M
C-8	More stringent interpretations of safety requirements during design and construction require significant facility structural or service system upgrades.	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H
C-9	Additional security provisions (e.g., clearances, escorts, fences, changes in the design basis threat) beyond planned are imposed.	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H
C-10	Construction or repair and modifications impact ongoing site or facility operations, or ongoing operations impact construction or repair and modifications.	3/3/M	3/3/M	5/5/L	5/5/L	3/3/M	3/3/M	1/3/H or 2/2/H	1/3/H or 2/2/H
C-11	Existing facilities require more work than planned to meet applicable codes and standards (e.g., latent conditions may unexpectedly come into play). Equivalently, unforeseen conditions in existing facilities during repair or upgrades result in more work than planned.	2/3/M	N/A	2/3/M	N/A	2/3/M	N/A	2/3/M	N/A
C-12	Material characterization (MC) capability is insufficient to support the schedule for the nonrecurring testing and analysis required to develop and qualify the manufacturing parameters for the W87 production process.	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L
C-13	Unexpected underground site conditions (e.g., geotechnical, buried pipelines, or buried waste) are encountered.	5/5/L	4/3/L	5/5/L	4/3/L	5/5/L	4/3/L	5/5/L	4/3/L

ID#	Identifier	INL 1-A	INL 1-B	INL 2-A	INL 2-B	INL 3-A	INL 3-B	INL 4-A	INL 4-B
C-14	Project design issues occur during work (construction/modifications/repairs).	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M
C-15	There are issues with process qualification and/or design agency approval.	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L
C-16	There are issues with hiring, clearing, and/or training qualified workers.	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L
C-17	A seismic event occurs during construction, damaging site infrastructure.	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)
C-18	A seismic event occurs, causing damage to facility under construction.	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)
C-19	A tornado or other high-wind event occurs during construction.	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L
C-20	An external flood occurs during construction.	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)
C-21	An external fire occurs during construction.	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L
C-22	Any other external event occurs during construction.	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L
O-1	Pit manufacturing adversely affects other site or facility projects, or other site or facility projects adversely affect pit production.	1/3/H or 1/2/H	1/3/H or 1/2/H	5/5/L	5/5/L	3/3/M	3/3/M	1/3/H or 1/2/H	1/3/H or 1/2/H
O-2	The facility is unable to hire, train, clear, and/or retain sufficient skilled personnel to support ongoing plutonium operations	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L
O-3	Low level waste treatment capabilities deteriorate, become overwhelmed, or are unavailable for an extended period, impacting mission.	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L
O-4	TRU waste treatment capabilities deteriorate, become overwhelmed, or are unavailable for an extended period, impacting mission.	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L
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.	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L
O-6	When WIPP comes back on line after a shutdown, additional regulatory and safety constraints mean that it accepts shipments at a rate that is insufficient to process waste generated by an 80-ppy program.	1/4/M	1/4/M	1/4/M	1/4/M	1/4/M	1/4/M	1/4/M	1/4/M
O-7	WIPP becomes full and is no longer able to accept solid TRU waste, and no other repository is available.	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L

ID#	Identifier	INL 1-A	INL 1-B	INL 2-A	INL 2-B	INL 3-A	INL 3-B	INL 4-A	INL 4-B
O-8	Analytical or materials characterization capabilities deteriorate, become overwhelmed, or are unavailable for an extended period, impacting mission.	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L
O-9	Any other support infrastructure capabilities deteriorate, become overwhelmed, or are unavailable for an extended period, impacting mission.	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L
O-10	Inability to obtain spare/replacement parts for failed equipment increases potential shutdown durations, impacting mission.	2/4/M	2/4/M	2/4/M	2/4/M	2/4/M	2/4/M	2/4/M	2/4/M
O-11	Supplier(s) of essential and unique equipment go out of business, refuse to take the job, or deliver poor quality.	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M
O-12	Aircraft impact damages facility.	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)
O-13	A hazardous material release elsewhere onsite or at a nearby industrial facility or from a transportation accident affects operators and causes facility shutdown; subsequent decontamination may be required.	5/2/L	5/2/L	5/2/L	5/2/L	5/2/L	5/2/L	5/2/L	5/2/L
O-14	Transportation capacity for shipping pits and plutonium feedstock is insufficient to meet demands from all DOE sites.	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L
O-15	A seismic event occurs during operation.	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)
O-16	A tornado or other high-wind event occurs during operation.	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)
O-17	An external flood occurs during operation.	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)
O-18	An external fire occurs during operation.	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L
O-19	Any other external event occurs.	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L

Key:
EIS = environmental impact statement; INL = Idaho National Laboratory; NEPA = National Environmental Policy Act; ppy = pits per year; TRU = transuranic; WIPP = Waste Isolation Pilot Plant.

E.6.2 Summary of Risks Associated with Short List of Alternatives

Of the alternatives listed in Table E–6, the following were eliminated:

- Alternatives in K-reactor for three reasons: (1) working inside an existing PIDADS adds considerable delay and expense; (2) it was thought likely that any construction work inside K-reactor will encounter contamination left over from its time as an operating reactor; and (3) there are other operations inside K-reactor that will interfere with construction and/or operation of the pit manufacturing facility, or vice versa (e.g., surplus plutonium disposition and plutonium storage). These alternatives are SRS 1-B, SRS 2-B, SRS 3-B, and SRS 4-B.
- Alternatives in WSB, because this building is simply too small. These alternatives are -A, SRS 3-B, SRS 3-C, and SRS 3-D.
- Alternatives with metal preparation in a separate building, because rough order of magnitude costs show that this would add excessive expense to the construction of the 80-ppy manufacturing capability. These are alternatives LANL 4, SRS 4-A and 4-D, and INL 4-A and 4-B.

The five alternatives that remain are 80 ppy with metal preparation in LANL 2 (new construction), SRS 2-A (MFFF), SRS 2-D (new construction), INL 2-A (FPF), and INL 2-B (new construction).

Alternatives that rely on PF-4 to reliably deliver part or all of the required 80 ppy are considered high risk. This is because it was felt that conflict between the other activities in PF-4 and either construction of the 80-ppy capability or its operation, or vice versa (see the discussions above of threats C-10, C-11, and O-1 in the context of LANL), would be inevitable. This eliminates LANL 1-A, 1-B, 1-C, 1-D, and 1-E; SRS 1-A and 4-A; and INL 1-A and 1-B. However, these alternatives have been collected under one generic heading, "PF-4 reuse," and are included in the following analysis for comparison.

The risk information about each of the five alternatives identified above and PF-4 reuse is summarized below in Table E–10.

Table E–11 displays the same information as Table E–10 but in a different order. At the top of the table are risks for which (a) the risk is high for at least one alternative and (b) the risk discriminates between alternatives. This is followed by risks that are high for all alternatives. After that, there are risks for which (a) no risk is high, (b) at least one risk is moderate, and (c) the risk discriminates between alternatives. The next group is of those risks that are all moderate and do not discriminate between alternatives. The final grouping is of the remaining risks, which are all low. This allows the reader to see at a glance which high risks are true discriminators.

Table E–10. Summary of results of risk assessment for short list of alternatives

ID#	Brief Description of Threat	PF-4 Reuse	LANL 2	SRS 2-A	SRS 2-D	INL 2-A	INL 2-B
C-1	NEPA: EIS or additional environmental reviews cause delays and extra costs.	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L
C-2	National and/or local political/public opposition results in delays and extra costs.	3/3/M	3/3/M	2/3/M	2/3/M	2/3/M	2/3/M
C-3	National and/or local political /public opposition results in project cancellation.	5/1/M	5/1/M	5/1/M	5/1/M	5/1/M	5/1/M
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.	2/2/H	2/2/H	2/2/H	2/2/H	2/2/H	2/2/H
C-5	Intra-agency and/or inter-agency disputes delay project and introduce extra costs or unwanted restrictions on the project.	5/4/L	5/4/L	3/3/M	3/3/M	3/3/M	3/3/M
C-6	Program requirements change (e.g., weapon types or numbers).	2/3/M	2/3/M	2/3/M	2/3/M	2/3/M	2/3/M
C-7	Functional performance requirements change (e.g., requirement introduced for computerized tomography).	4/2/M	4/2/M	4/2/M	4/2/M	4/2/M	4/2/M
C-8	More stringent interpretations of safety requirements during design and construction require significant facility structural or service system upgrades.	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H
C-9	Additional security provisions (e.g., clearances, escorts, fences, changes in the design basis threat) beyond planned are imposed.	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H
C-10	Construction or repair and modifications impact ongoing site or facility operations, or ongoing site or facility activities impact construction or repair and modifications.	1/3/H or 1/2/H	5/5/L	5/5/L	5/5/L	5/5/L	5/5/L
C-11	Existing facilities require more work than planned to meet applicable codes and standards (i.e., latent conditions may unexpectedly come into play). Equivalently, unforeseen conditions in existing facilities during repair or upgrades result in more work than planned.	3/3/M	N/A	4/3/L	N/A	2/3/M	N/A
C-12	Material characterization (MC) capability is insufficient to support the schedule for the nonrecurring testing and analysis required to develop and qualify the manufacturing parameters for the W87 production process.	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L
C-13	Unexpected underground site conditions are encountered (e.g., geotechnical, buried pipelines, or buried waste).	4/3/L	4/3/L	5/5/L	4/3/L	5/5/L	4/3/L
C-14	Project design issues occur during work (construction/modifications/repairs).	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M
C-15	There are issues with process qualification and/or design agency approval.	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L
C-16	There are issues with worker training and hiring of qualified workers.	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L
C-17	A seismic event occurs during construction, damaging site infrastructure.	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)
C-18	A seismic event occurs, causing damage to facility under construction.	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)

ID#	Brief Description of Threat	PF-4 Reuse	LANL 2	SRS 2-A	SRS 2-D	INL 2-A	INL 2-B
C-19	A tornado or other high-wind event occurs during construction.	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L
C-20	An external flood occurs during construction.	5/3/L	5/3/L	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)
C-21	An external fire occurs during construction.	3/4/L	3/4/L	3/4/L	3/4/L	5/4/L	5/4/L
C-22	Any other external event occurs during construction.	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L
C-23	If MFFF is chosen for the pit manufacturing facility, potential difficulties arise while unraveling the project with Areva.	N/A	N/A	1/3/H	N/A	N/A	N/A
C-24	Difficulties arise while transferring the MFFF facility licensing basis from NRC to DOE.	N/A	N/A	2/3/M	N/A	N/A	N/A
O-1	Pit manufacturing adversely affects other site or facility projects, or other site or facility projects adversely affect pit production.	1/3/H or 1/2/H	5/5/L	5/5/L	5/5/L	5/5/L	5/5/L
O-2	The facility is unable to hire, clear, train, and/or retain sufficient skilled personnel to support ongoing plutonium operations	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L
O-3	Low level waste treatment capabilities deteriorate, become overwhelmed, or are unavailable for an extended period, impacting mission.	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L
O-4	TRU waste treatment capabilities deteriorate, become overwhelmed, or are unavailable for an extended period, impacting mission.	5/4/L	5/4/L	5/4/L	5/4/L	4/4/L	4/4/L
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.	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L
O-6	When WIPP comes back on line after a shutdown, additional regulatory and safety constraints mean that it accepts shipments at a rate that is insufficient to process waste generated by an 80-ppy program.	1/4/M	1/4/M	1/4/M	1/4/M	1/4/M	1/4/M
O-7	WIPP becomes full and is no longer able to accept solid TRU waste, and no other repository is available.	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L
O-8	Analytical chemistry or materials characterization capabilities deteriorate, become overwhelmed, or are unavailable for an extended period, impacting mission.	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L
O-9	Any other support infrastructure capabilities deteriorate, become overwhelmed, or are unavailable for an extended period, impacting mission.	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L
O-10	Inability to obtain spare/replacement parts for failed equipment increases potential shutdown durations, impacting mission.	2/4/M	2/4/M	2/4/M	2/4/M	2/4/M	2/4/M
O-11	Supplier(s) of essential and unique equipment go out of business, refuse to take the job, or deliver poor quality.	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M
O-12	Aircraft impact damages the facility.	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)
O-13	Hazardous material release elsewhere onsite or at a nearby industrial facility or from a transportation accident affects operators and causes a facility shutdown; subsequent decontamination may be required.	5/2/L	5/2/L	5/2/L	5/2/L	5/2/L	5/2/L

ID#	Brief Description of Threat	PF-4 Reuse	LANL 2	SRS 2-A	SRS 2-D	INL 2-A	INL 2-B
O-14	Transportation capacity for shipping pits and plutonium feedstock is insufficient to meet needs.	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L
O-15	A seismic event occurs during operation.	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)
O-16	A tornado or other high-wind event occurs during operation.	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)
O-17	An external flood occurs during operation.	5/3/L	5/3/L	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)
O-18	An external fire occurs during operation.	3/4/L	3/4/L	3/4/L	3/4/L	5/4/L	5/4/L
O-19	Any other external event occurs during operation.	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L

Key:
EIS = environmental impact statement; INL = Idaho National Laboratory; LANL = Los Alamos National Laboratory; MFFF = Mixed Fuel Fabrication Facility; NEPA = National Environmental Policy Act; NRC = Nuclear Regulatory Commission; PF-4 = Plutonium Facility; ppy = pits per year; SRS = Savannah River Site; TRU = transuranic; WIPP = Waste Isolation Pilot Plant.

Table E–11. Summary of results of risk assessment for short list of alternatives ordered from high to low

	ID#	Brief Description of Threat	PF-4 Reuse	LANL 2	SRS 2-A	SRS 2-D	INL 2-A	INL 2-B
High Risks that Discriminate Between Alternatives	C-10	Construction or repair and modifications impact ongoing site or facility operations, or ongoing site or facility activities impact construction or repair and modifications.	1/3/H or 1/2/H	5/5/L	5/5/L	5/5/L	5/5/L	5/5/L
	O-1	Pit manufacturing adversely affects other site or facility projects, or other site or facility projects adversely affect pit production.	1/3/H or 1/2/H	5/5/L	5/5/L	5/5/L	5/5/L	5/5/L
	C-23	If MFFF is chosen for the pit manufacturing facility, potential difficulties arise while unraveling the project with Areva.	N/A	N/A	1/3/H	N/A	N/A	N/A
High Risks that Apply Equally to All Alternatives	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.	2/2/H	2/2/H	2/2/H	2/2/H	2/2/H	2/2/H
	C-8	More stringent interpretations of safety requirements during design and construction require significant facility structural or service system upgrades.	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H
	C-9	Additional security provisions (e.g., clearances, escorts, fences, changes in the design basis threat) beyond planned are imposed.	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H	1/3/H or 2/2/H
Moderate Risks that Distinguish Between Alternatives	C-11	Existing facilities require more work than planned to meet applicable codes and standards (i.e., latent conditions may unexpectedly come into play). Equivalently, unforeseen conditions in existing facilities during repair or upgrades result in more work than planned.	3/3/M	N/A	4/3/L	N/A	2/3/M	N/A
	C-24	Difficulties arise while transferring the MFFF facility licensing basis from NRC to DOE.	N/A	N/A	2/3/M	N/A	N/A	N/A
	C-5	Intra-agency and/or inter-agency disputes delay project and introduce extra costs or unwanted restrictions on the project.	5/4/L	5/4/L	3/3/M	3/3/M	3/3/M	3/3/M
	C-2	National and/or local political/public opposition results in delays and extra costs.	3/3/M	3/3/M	2/3/M	2/3/M	2/3/M	2/3/M
	C-20	An external flood occurs during construction.	5/3/L	5/3/L	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)
	O-17	An external flood occurs during operation.	5/3/L	5/3/L	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)

	ID#	Brief Description of Threat	PF-4 Reuse	LANL 2	SRS 2-A	SRS 2-D	INL 2-A	INL 2-B
Moderate Risks that Apply Equally to All Alternatives	C-3	National and/or local political/public opposition results in project cancellation.	5/1/M	5/1/M	5/1/M	5/1/M	5/1/M	5/1/M
	C-6	Program requirements change (e.g., weapon types or numbers).	2/3/M	2/3/M	2/3/M	2/3/M	2/3/M	2/3/M
	C-7	Functional performance requirements change (e.g., requirement introduced for computerized tomography).	4/2/M	4/2/M	4/2/M	4/2/M	4/2/M	4/2/M
	C-14	Project design issues occur during work (construction/modifications/repairs).	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M
	C-17	A seismic event occurs during construction, damaging site infrastructure.	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)
	C-18	A seismic event occurs, causing damage to facility under construction.	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)
	O-6	When WIPP comes back on line after a shutdown, additional regulatory and safety constraints mean that it accepts shipments at a rate that is insufficient to process waste generated by an 80-ppy program.	1/4/M	1/4/M	1/4/M	1/4/M	1/4/M	1/4/M
	O-10	Inability to obtain spare/replacement parts for failed equipment increases potential shutdown durations impacting mission.	2/4/M	2/4/M	2/4/M	2/4/M	2/4/M	2/4/M
	O-11	Supplier(s) of essential and unique equipment go out of business, refuse to take the job, or deliver poor quality.	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M	3/3/M
	O-12	Aircraft impact damages the facility.	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)
	O-15	A seismic event occurs during operation.	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)
	O-16	A tornado or other high-wind event occurs during operation.	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)	5/1/M (C)
Risks that Are All Low	C-1	NEPA: EIS or additional environmental reviews cause delays and extra costs.	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L
	C-12	Material characterization (MC) capability is insufficient to support the schedule for the nonrecurring testing and analysis required to develop and qualify the manufacturing parameters for the W87 production process.	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L
	C-13	Unexpected underground site conditions are encountered (e.g., geotechnical, buried pipelines, or buried waste).	4/3/L	4/3/L	5/5/L	4/3/L	5/5/L	4/3/L
	C-15	There are issues with process qualification and/or design agency approval.	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L
	C-16	There are issues with worker training and hiring of qualified workers during construction and startup.	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L
	C-19	A tornado or other high-wind event occurs during construction.	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L
	C-21	An external fire occurs during construction.	3/4/L	3/4/L	3/4/L	3/4/L	5/4/L	5/4/L
	C-22	Any other external event occurs during construction.	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L

	ID#	Brief Description of Threat	PF-4 Reuse	LANL 2	SRS 2-A	SRS 2-D	INL 2-A	INL 2-B
Risks that Are All Low (Cont.)	O-2	The facility is unable to hire, clear, train, and/or retain sufficient skilled personnel to support ongoing plutonium operations	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L
	O-3	Low level waste treatment capabilities deteriorate, become overwhelmed, or are unavailable for an extended period, impacting mission.	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L	5/4/L
	O-4	TRU waste treatment capabilities deteriorate, become overwhelmed, or are unavailable for an extended period, impacting mission.	5/4/L	5/4/L	5/4/L	5/4/L	4/4/L	4/4/L
	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.	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L	3/4/L
	O-7	WIPP becomes full and is no longer able to accept solid TRU waste, and no other repository is available.	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L
	O-8	Analytical chemistry or materials characterization capabilities deteriorate, become overwhelmed, or are unavailable for an extended period, impacting mission.	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L
	O-9	Any other support infrastructure capabilities deteriorate, become overwhelmed, or are unavailable for an extended period, impacting mission.	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L	4/3/L
	O-13	Hazardous material release elsewhere on site or at a nearby industrial facility or from a transportation accident affects operators and causes a facility shutdown; subsequent decontamination may be required.	5/2/L	5/2/L	5/2/L	5/2/L	5/2/L	5/2/L
	O-14	Transportation capacity for shipping pits and plutonium feedstock is insufficient to meet needs.	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L	5/3/L
	O-18	An external fire occurs during operation.	3/4/L	3/4/L	3/4/L	3/4/L	5/4/L	5/4/L
	O-19	Any other external event occurs during operation.	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L	4/4/L

Key:
EIS = environmental impact statement; INL = Idaho National Laboratory; LANL = Los Alamos National Laboratory; MFFF = Mixed Fuel Fabrication Facility; NEPA = National Environmental Policy Act; NRC = Nuclear Regulatory Commission; PF-4 = Plutonium Facility; ppy = pits per year; SRS = Savannah River Site; TRU = transuranic; WIPP = Waste Isolation Pilot Plant.

Appendix F. Basis of Cost Estimate

F.1 Background

The Analysis of Alternatives (AoA) cost team analyzed five alternatives in order to provide leadership with estimates and comparisons of total project cost (TPC) and life-cycle cost. These alternatives represented new construction and refurbishment options for an 80 War Reserve (WR) pits per year (ppy) production capability at three locations: Los Alamos National Laboratory (LANL), Savannah River Site (SRS), and Idaho National Laboratory (INL). The analysis was used to determine the most cost effective alternative to meet mission requirements as stated in the program requirements document (PRD) and mission needs statement (MNS).

F.1.1 Work Breakdown Structure

Since cost integration relies on a product oriented Work Breakdown Structure (WBS) that includes the use of common elements to capture all projects associated costs, the cost team developed a WBS using best practices, industry, and DOE standards. The resultant WBS, seen in **Figure F–1**, includes the total scope of a facility project, although individual alternatives may or may not have associated costs at each level.

WBS	Title
1	Pit Production Strategy
1.1	Systems Engineering & Integration
1.2	Program Management
1.3	Training
1.4	Development, Test, and Evaluation
1.5	Production
1.6	Capital Assets
1.6.1	Land
1.6.2	Structures
1.6.2.1	Facility
1.6.2.1.1	Facility Structures
1.6.2.1.2	Facility Utilities
1.6.2.1.3	Furniture, Fixtures & Office Equipment
1.6.2.1.4	Process/Scientific/Technical Equipment
1.6.2.2	Support Equipment & Facilities
1.6.2.3	Site Work
1.6.4	Intellectual Property
1.7	Operations and Maintenance
1.7.1	Operations
1.7.2	Maintenance
1.7.3	Recapitalization
1.8	Waste
1.9	Transportation

Figure F–1. Work Breakdown Structure

Individual cost estimates were developed for engineering design, systems engineering, and program management, Hazard Category 2 facility construction and refurbishment, process equipment acquisition and installation, support equipment and facilities, maintenance, recapitalization, and waste processing. These costs were integrated using the WBS to generate both a TPC and life-cycle cost estimate (LCCE) for each alternative. The TPC cost estimate includes all costs to design, construct, install, and start-up the plutonium production pit manufacturing facility. It does not include the cost to design the process or certify the pit production capability. The LCCE includes the TPC plus the annual operating, maintenance, and recapitalization cost through the design life of the facility, in this case 50 years.

F.2 Work Breakdown Structure Elements Discussion

The cost estimates were developed using Government Accountability Office and NNSA best practices for an early stage, pre-baseline construction project. As AoA's are early estimates with little design definition, a higher level parametric and analogous estimating approach was chosen over a "bottom-up" approach. This decision was based on the fact that bottom-up approaches are more likely to exclude key elements of scope, as well as severely underestimate both the cost and uncertainty associated with the project. To capture all relevant scope of the project, a WBS was developed. This WBS ensured the complete scope required for each alternative was considered and analyzed. Data were collected from multiple sources to capture completed project actuals, analogous estimates, and subject matter expert observations. These data were used to estimate the costs of: systems engineering, integration and program management, Hazard Category 2 facility structure, utilities, fixtures and office equipment, pit production equipment, support equipment and facilities, operations and maintenance, recapitalization, and waste processing costs. **Table F–1** describes the approach and applicable data used to estimate each WBS element.

Table F–1. Methodology used for each Work Breakdown Structure element

WBS Element	Methodology	Analogies
Facility Structure, Utilities, Fixtures, and Office Equipment	Parametric based on analogous NNSA facilities	HEUMF, WSB, TEF, MFFF, MPB
Pit Production Equipment	Parametric based on analogous NNSA equip. procurements	CMM 1 and 2, Casting Upgrades, New ER, DMU 35, Pu Assay, DC Arc, Radio Chemistry, Y-12 GB-C, Y-12 Assembly GB, Aries, RLUOB
Support Equipment & Facilities	Parametric based on NNSA analogous facilities	TRUWF, TRULWF, SAB, NIF, LLW, MESA, PF, HEPF, HESE, NSSB, DISL, NTSRFS, WETL
Systems Engineering, Integration And Program Management	Percentage based on NNSA analogous projects	PF-4 (PEI I/II), MOX, WSB, NFRR, CEF, BEC, TEF, SNMCRF
Operations and Maintenance	Percentage based on PF-4 actuals	LANL (TA-55)
Recapitalization	2-4% of Facility and Equipment costs	Industry Standard for Recapitalization (rate is dependent on new vs. refurb facility)
Waste	Parametric based on production rate	PF-4, MPF estimates

Parametric cost estimating relationships provided the team with scaling factors to take into account technical differences (such as facility size and complexity) that are unique to this project. The parametric approach also provided uncertainty distributions around each of the input parameters, and these distributions were then integrated into a total uncertainty distribution using a Monte Carlo simulation. The result of this integrated, data-based cost estimating approach was a cost-probability distribution. This cost-probability distribution was developed for each of the five alternatives that passed the initial screening, and accounted for differences in scope, complexity, location, and available support facilities.

F.3 Costs Estimates, Uncertainty Calculation, and Monte Carlo Analysis

Uncertainty was captured for each individual cost estimate, based on the underlying data, and then integrated using a Monte Carlo analysis. Two kinds of uncertainty were quantified and captured in the cost analysis, technical uncertainty and cost uncertainty. Technical uncertainty was captured by analyzing the technical cost drivers and their potential ranges using data, when available, or subject matter expert input. As an input for the cost estimate, the cost team requested that the space team provide both a point estimate and range around the space requirements. In addition, the cost team conducted its own analysis using blueprints of completed buildings to validate and provide ranges around the space team's gross square foot requirements. The same kind of analysis was conducted for support facilities and process equipment. The process equipment uncertainty was captured to include a range in potential equipment quantity, equipment complexity factors, and equipment footprint requirements. The uncertainty ranges in all technical cost drivers were then multiplied by the mean costs estimated by the appropriate cost estimating relationships (CERs) to develop a technical uncertainty range.

Cost uncertainty was quantified through the development of each CER based on actual cost data and then applied using a lognormal distribution with a mean of one and a standard deviation of the CER. This distribution was then multiplied by the technical uncertainty range to develop a cost-probability distribution for each individual cost estimate, which included both technical and cost uncertainty. These distributions where then correlated and summed via the WBS into a total project cost-probability distribution. The integrated cost model was then run through 10,000 iterations of a Monte Carlo analysis to develop an s-curve for each alternative.

The uncertainty analysis resulted in a cost-probability distribution that included both technical and cost uncertainty. A majority of the underlying uncertainty was based on actual data and captures uncertainty in all of the major cost drivers. In this report, the low end of the cost range is shown at 50 percent of the mean, and the high end of the cost range is 100 percent of the mean. Notional budget profiles shown later in this appendix were phased at the 85 percent confidence level as per DOE best practices for early stage, limited design definition capital acquisition projects.

Sensitivity analysis was conducted using Monte Carlo analysis and the parametric cost estimating relationships that provided scaling factors to take into account technical differences such as facility size and complexity. The parametric approach provided uncertainty distributions around each one of the input parameters that were then integrated into a total uncertainty using a Monte Carlo simulation. The result of this integrated, data-based cost estimating approach is a cost-probability distribution that accounts for the sensitivity of individual cost drivers. For example, the input square footage to the cost estimate was taken as a distribution of likely square footage values instead of a point estimate of square footage and integrated, with other factors, into the cost model. The Monte Carlo analysis ran 10,000 different "scenarios" in which the input parameters changed (based on actual data) and resulted in a distribution of potential outcomes. This distribution was developed for each of the seven alternatives that passed the initial AoA screening, taking into account differences in scope, complexity, location, and available support facilities.

F.4 Facility Construction

Facility construction costs were parametrically derived on a dollars per gross, i.e., building square foot, basis. Six CERs for new construction and one refurbishment CER were developed using comparable NNSA projects based on hazard categories (DOE Standard 1027-92). Project costs from the Construction Project Data Sheets (CPDS) from over 50 NNSA projects were collected for all of the 1993 through 2018 DOE Congressional Budget Requests. CPDS include annual costs for construction, preliminary engineering design (PED), and other program costs (OPC), which were escalated into base year FY 2018 dollars based upon 2018 Office of Management and Budget inflation tables. Scope descriptions are also provided in the CPDS, which informed the comparability of these projects to the scope of this AoA. These costs were compared to data available through the DOE Project Assessment and Reporting System II, Facilities Information Management System (FIMS), and data provided by NNSA program offices. Facility properties such as hazard category, security category, and square footage were collected from FIMS, program, and NNSA site information.

The dollars per square foot CERs included only building construction line item costs, Figure F–2. Figure F–2 does not include PED, OPC, or the cost of plutonium processing equipment procurement and installation. The detailed processing equipment discussed in Section F–5 is unique and different compared to any associated building capital equipment.

CERs were developed based on a linear relationship between cost and square footage of the building. Industry standards such as RSMeans report costs of facilities versus square feet, and earlier Department of Defense Cost Assessment and Program Analysis and Project Management Oversight and Assessment estimates all exhibit linear fits for cost per square foot.

The ratio of PED and OPC to construction was averaged over several comparable DOE projects for each hazard category and was used to determine the total project cost of the facility. The projects, along with their corresponding hazard category, costs, and gross square footage are shown in **Table F–2**. **Figure F–2** graphically shows the costs verses gross square footage of these projects and **Table F–3** shows the derived construction cost per square foot CER.

Table F–2. Historic NNSA facility costs by hazard category

Project Details		Facility Information		Costs (FY18$,M)				FY18$ / gsf	
Name	Site	Hazard Category	Gross Sq. Ft.	PED	Const.	OPC	TPC	Const.	TPC
Mixed Oxide Fuel Fabrication Facility	SRS	02 Nuclear Facility Category 2	480,000	$1,300	$3,600	$320	$5,300	$7,600	$11,000
Main Process Building	Y-12	02 Nuclear Facility Category 2	270,000	$1,200	$2,400	$370	$4,000	$8,900	$15,000
Highly Enriched Uranium Materials Facility	Y-12	02 Nuclear Facility Category 2	150,000	$130	$400	$81	$610	$2,600	$4,000
Tritium Extraction Facility	SRS	02 Nuclear Facility Category 2	63,000	$260	$300	$130	$680	$4,800	$11,000
Waste Solidification Building	SRS	02 Nuclear Facility Category 2	43,000	$51	$280	$110	$450	$6,600	$10,000
Salvage Accountability Building	Y-12	03 Nuclear Facility Category 3	140,000	$520	$1,000	$22	$1,500	$7,400	$11,000
TRU Waste Facility	LANL	03 Nuclear Facility Category 3	5,500	$22	$66	$25	$110	$12,000	$21,000
TRU Liquid Waste Facility Upgrade Project	LANL	03 Nuclear Facility Category 3	3,000	$26	$66	$13	$110	$22,000	$36,000
National Ignition Facility	LLNL	04 Radiological Facility	700,000	$510	$2,400	$1,500	$4,600	$3,400	$6,500
Low Level Liquid Waste	LANL	04 Radiological Facility	25,000	$15	$64	$15	$94	$2,600	$3,800
Microsystems and Engineering Sciences Applications	SNL	07 Beryllium Hazard Facility	290,000	$21	$560	$73	$650	$1,900	$2,200
High Explosives Science and Engineering Facility	PX	05 Chemical Hazard Facility	73,000	$15	$81	$55	$150	$1,100	$2,100
High Explosive Pressing Facility	PX	05 Chemical Hazard Facility	45,000	$10	$140	$6	$160	$3,200	$3,500
Purification Facility	Y-12	07 Beryllium Hazard Facility	10,000	$13	$38	$15	$66	$3,800	$6,600
National Security Sciences Building	LANL	12 Not Applicable	300,000	$12	$120	$30	$160	$390	$540
Distributed Information Systems Laboratory	SNL	12 Not Applicable	72,000	$4	$45	$2	$51	$630	$720
NTS Replace Fire Stations No1 and No 2	NTS	12 Not Applicable	42,000	$6	$42	$1	$49	$1,000	$1,200
Weapons Evaluation Test Laboratory	SNL	12 Not Applicable	30,000	$2	$20	$1	$23	$670	$780

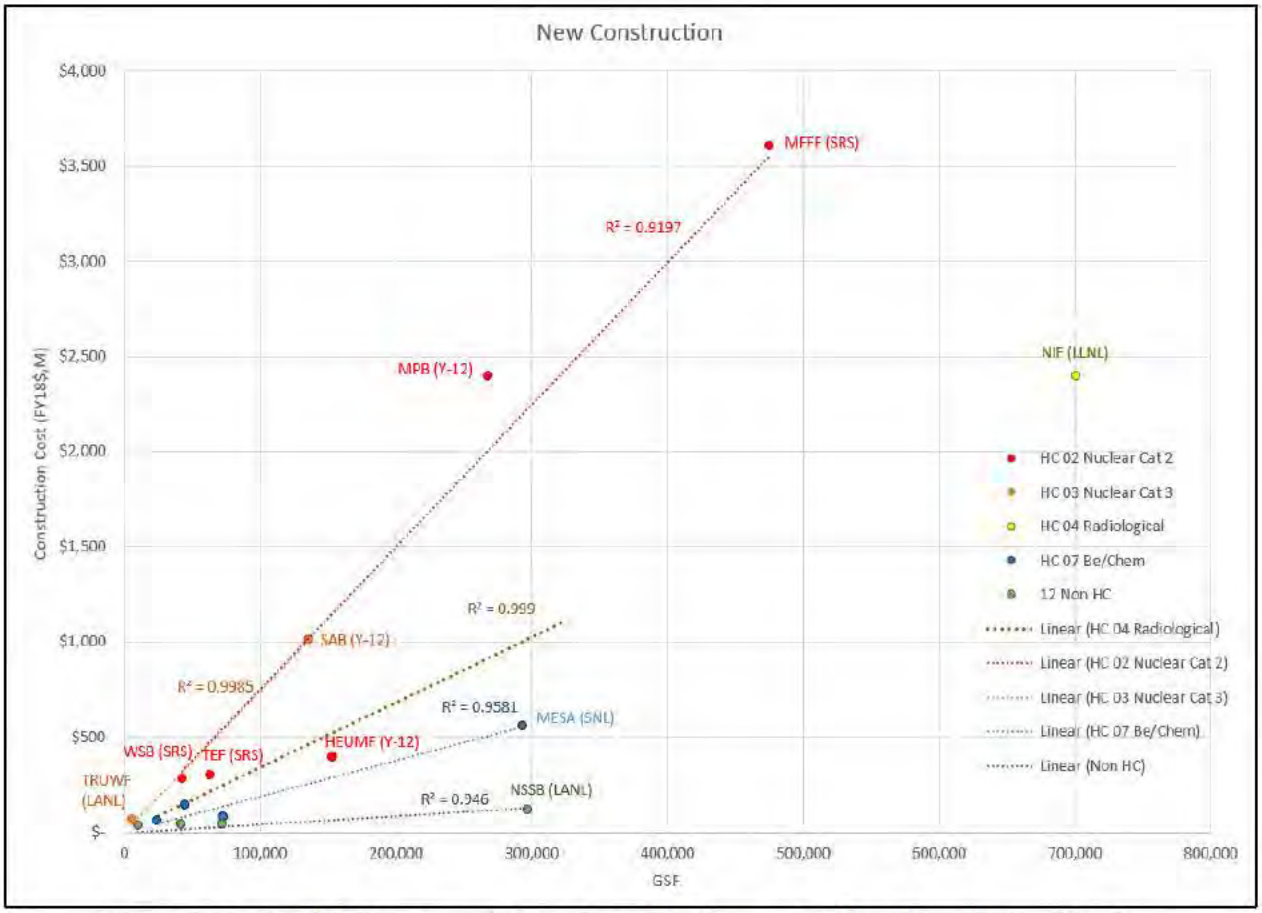


Figure F–2. Graphical representation of construction cost estimating relationships for hazard categories

Table F–3. Derived construction cost per gross square foot for NNSA programs

Hazard Category	Construction (dollars per square foot)	NNSA Historic Actuals Used
02 Nuclear Facility Category 2	7,500 ± 760	HEUMF, MOX, MPB, TEF, WSB
03 Nuclear Facility Category 3	7,400 ± 270	TRUWF, TRULWF, SAB
04 Radiological Facility	3,400 ± 30	NIF, LLW
05/07 Beryllium/Chemical Hazards Facility	1,900 ± 160	MESA, HEPF, HESE, PF
12 Nonhazardous Facility	420 ± 60	DISL, NSSB, NTSRFS, WETL

The scope of the two refurbishment alternatives does not include building construction and is for Hazard Category 2, Security Category 1 facilities. NNSA projects that had upgrades and refurbishment were Hazard Category 2 and Security Category 1 facilities, were all operational, and had radioactive contamination.

Both refurbishment options, i.e., the Fuel Fabrication Facility (FPF) at INL and the partially complete Mixed Oxide Fuel Fabrication Facility (MFFF) at SRS have no radiological contamination. The actuals used for the refurbishment CER are: Nuclear Facility Risk Reduction (NFRR) at the Y-12 National Security Complex (Y-12); Criticality Experiments Facility (CEF) at the Nevada National Security Site (NNSS); Beryllium Capability

(BeC) at Y-12; and the Chemistry and Metallurgy Research Replacement at LANL. The specific fractional footprint affected by each project was unknown, which resulted in the refurbishment CER being based upon gross square footage.

When averaged, construction costs were roughly 200 dollars per square foot. This was the low (optimistic) end of the range for refurbishment, as additional building materials and design will be minimal for a nearly completed nuclear facility. However, if walls need to be removed and reinstalled seismic and safety codes might need to be reassessed, resulting in significantly higher costs.

Lacking comparable actuals for refurbishment of existing non-contaminated Hazard Category 2, Security Category 1, the high estimate of refurbishment was set equivalent to the risk-adjusted mean for new construction. While the range is large and commensurate with a pre Critical Decision-1 scope, the AoA team recommends to have an engineering assessment on MFFF to determine the exact scope required for repurposing MFFF.

For new construction and refurbishment, PED and OPC ratios from historic NNSA projects were applied to the CERs. For Hazard Category 2 facilities, the actuals were: Plutonium Equipment Installation 1 and 2 (LANL); MFFF (SRS); Waste Solidification Building (WSB) (SRS); NFRR, Criticality Experiments Facility (NNSS); Beryllium Capability (Y-12); Tritium Extraction Facility (SRS); and Special Nuclear Material Component Requalification Facility (Pantex).

F.5 Pit Production Equipment

The AoA Team developed an equipment cost estimate that was driven by the type and amount of production-specific equipment needed to produce 80 ppy, the cost per piece of equipment, and the space needed to house it. The AoA team's subject matter experts began this process by developing an initial list of specific pieces of required equipment, the square footage each would occupy, and their respective quantities for 50 ppy and 80 ppy production levels.

The subject matter experts based their initial equipment estimates on the pit production flowsheet provided by LANL, which they supplemented with their own substantial experience in pit manufacturing, including management of production operations at the Rocky Flats Plant. The AoA Team then compared its equipment list to LANL's independent pit production equipment requirements for an 80 ppy capacity in Plutonium Facility (PF-4), and their engineering drawings for 80 ppy plutonium processing that included equipment footprints. The AoA team also validated their space estimates by measuring the equipment footprint in engineering diagrams for several current and planned facilities: LANL PF-4 current and planned configurations; LANL's Radiological Laboratory Utility Office Building (RLUOB) for RLUOB Equipment Installations-1 and -2, and Readiness Campaign-3 (planned); SRS WSB; SRS MFFF (planned); and Y-12 Uranium Processing Facility (planned). The total footprint estimate resulting from this analysis is the product of the number of each equipment type and the projected footprint requirement for that type. This total footprint is the dependent variable in cost-to-square-foot CERs that were developed to estimate the costs of pit manufacturing equipment procurement and installation.

While the footprint estimates were consistent between estimates by the AoA team and LANL, the AoA team predicted the need for higher quantities of a number of pieces of equipment to achieve 80 ppy. To provide as robust and defensible an estimate as possible, the AoA team decided that further analysis and validation was needed, particularly because equipment needs would drive facility size, and ultimately the AoA team's final recommendation.

The next phase in the AoA team's evaluation of equipment requirements was to develop a model of the pit production process. Although LANL had already provided its pit production model, this was a deterministic model that captured equipment failures and part rejections as an overall rate rather than on a case-by-case basis. Because the analysis needed a more precise method of characterizing equipment requirements, the AoA team developed a discrete event simulation model of the entire pit production process, from disassembling incoming pits and melting and casting through certification of the remanufactured WR pits. This model is known as the Plutonium Processing Basic Simulation (PPBS) and was created in the browser-based simulation software tool ***Innoslate***. PPBS is based on estimated required time ranges for more than 40 different serial and parallel processes to produce WR pits. This modeling effort allowed the AoA team to assess the effect of equipment failures and downtime on the pit production rate, as well as the effect of mitigating strategies such as adding more equipment and storage space to prevent bottlenecks and delays. More details about the structure and development of PPBS can be found in Chapter 2.

The output from Defense Programs' Office of Cost Policy and Analysis PPBS formed the basis for estimating equipment procurement and installation costs. As discussed above, multiple, independent lists of all manufacturing equipment quantities were generated and reconciled from the PPBS for 50 and 80 ppy production rates for a 95 percent confidence level. This means that the output was equal to or greater than the target rate in 95 percent of PPBS simulations with these equipment lists. In addition, analysis with PPBS revealed, and LANL scientists subsequently confirmed, that the current Plutonium Sustainment Program to produce 30 ppy by 2026 is based on an average rather than consistent yearly production objective. This means that significantly more equipment would be needed to provide 80ppy with high (95 percent) confidence.

Once the AoA team had developed a robust and defensible equipment and space estimate, CERs were developed for plutonium processing equipment procurement activities (design, fabrication, and installation) based on actual costs from completed projects at LANL and Y-12 with comparable scope. Actual costs for completed (or nearly completed) procurement and installation projects used are shown in **Table F–4** and the CER is shown in **Figure F–3**.

Table F–4. Actual equipment projects

Project Name	Site
Coordinate Measuring Machine #1 (CMM #1)	LANL
Glovebox (CPR P88Y2765)	Y-12
Assembly Glovebox (CPR P88Y2426)	Y-12
Advanced Recovery and Integrated Extraction System (ARIES)	LANL
DC Arc Plasma Spectrometer and Glovebox	LANL
DMU-35 Mill and Glovebox	LANL
Plutonium Assay Capability (design/procure/install for multiple gloveboxes) to support heat source program	LANL
Radio Chemistry (design/procure/install for multiple gloveboxes) to support heat source program	LANL
Electro-refining Line Upgrade	LANL
Coordinate Measuring Machine #2 (CMM #2)	LANL

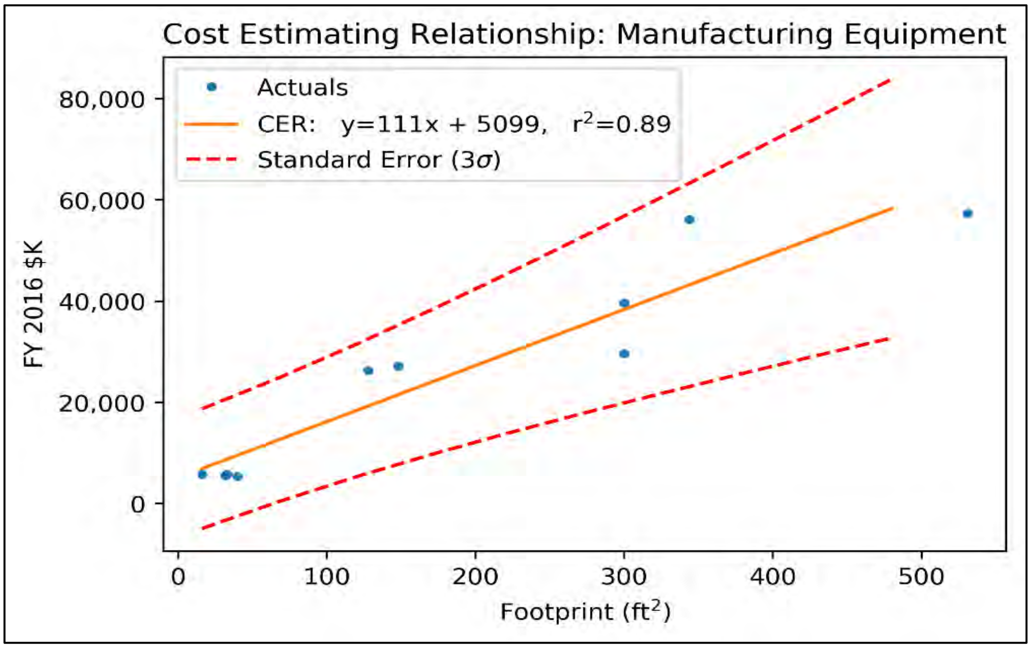


Figure F–3. Derived cost estimating relationships for manufacturing equipment

For the two Y-12 projects listed above, a normalization factor was applied to account for the differences in cost at LANL and at Y-12 due to locality. These projects are adjusted using the Geographic Cost Factors from the FIMS database and similar NNSA construction projects. A project in Los Alamos, New Mexico, is estimated to be 1.06 times more expensive than a project in Oak Ridge, Tennessee. This factor is about the same as a similar Department of Defense estimated factor of 1.07.

Uncertainty in cost and schedule was quantified using a Monte Carlo Analysis. For each equipment item, a triangular distribution was assumed for the technical uncertainty in footprint and overall complexity relative to a new glovebox procurement and installation in a contaminated nuclear facility (assumed to be 1.0 in the cost actuals used in the CER development). Cost uncertainty was captured using the standard deviation from the manufacturing equipment CER parameters. A @Risk Monte Carlo simulation resulted in a distribution that allowed identification of the cost range for manufacturing equipment at various confidence levels.

F.6 Support Facilities

The same ratio process was also used to determine the supporting facility costs for alternatives. The Infrastructure Sub-team interviewed sites and visited the most promising ones to determine the required square footage and corresponding hazard category for various processes (e.g., actinide chemistry, material characterization, radioactive waste processing). **Table F–5** shows the total cost to construct support facilities at each site.

Table F–5. Total project cost for supporting facilities needed to meet pit production requirements

Support Capability Costs Including Equipment (FY18$,M)							
HazCat	Capability	LANL	SRS (MOX)	SRS (new build)	INL	NNSS	PX
HC-4	01 LL Rad Liquid Waste	-	-	-	-	$51.74	$51.74
HC-3	02 TRU liquid Waste	-	-	-	-	$33.89	$33.89
N/A	03 PIDADS	-	-	-	-	-	-
HC-4	04 Classified Be. Machining	$20.02	$102.67	$102.67	$102.67	$102.67	$102.67
HC-12	05 Classified SS Machining	-	-	-	-	-	-
HC-7	06 Classified Ur. Machining	-	-	-	-	-	-
HC-7	07 Classified Graphite Machining	$40.45	$79.29	$79.29	$92.24	-	-
HC-4	08 Graphite Coating	-	$67.27	$67.27	$67.27	$67.27	$67.27
HC-4	09 Low Level Solid Waste	-	-	-	-	-	-
HC-3	10 TRU Solid Waste	-	-	-	-	-	$266.57
HC-2	11 Actinide Chemistry	-	-	-	-	$204.63	$204.63
HC-2	12 Material Characterization	-	-	-	-	$91.42	$91.42
HC-7	13b Stds. & Calibration	$45.49	-	-	-	-	-
HC-12	14 Cold Machining & Tooling	-	-	-	-	-	-
N/A	15 Security Cat I	-	-	-	-	-	-
HC-12	16 Electrical Power	-	-	-	-	-	-
HC-12	17 Other Utilities	-	-	-	-	-	-
HC-12	18 Medical Facilties	-	-	-	-	-	-
HC-12	19 Environmental Monitoring	-	-	-	-	-	-
HC-12	21 Admin Building (BAD)	-	-	$15.50	$15.50	$15.50	$15.50
Total (FY18$,M)		$105.97	$249.23	$264.72	$277.67	$567.11	$833.68

Adding the OPC/PED and process equipment to the Hazard Category 2 new construction and refurbishment results in the total project cost per square foot is shown in **Table F–6.**

Table F–6. Hazard Category 2 total project cost (dollars per gross square foot) including other program cost, preliminary engineering design, and construction and processing equipment

FY 2018 dollars per gross square foot	Low	Mean	High
New Construction	$16,800	$26,300	$42,500
Refurbishment	$12,300	$20,700	$37,100

F.7 Program Management and Systems Engineering and Integration

- Includes all costs to design, manage, and integrate the project
- Estimated as a percent of base construction and equipment costs
  - Used only Hazard Category 2 facility actuals
  - Data: PF-4, WSB, NFRR, CEF, Beryllium Capability Project, Tritium Extraction Facility, and Special Nuclear Material Component Requalification Facility
- Results are shown in **Table F–7**.
  - Program management and systems engineering and integration costs equal 62 percent +/- 37 percent of base construction and equipment costs
  - 62 percent applied to low, mean, and high base construction and equipment costs for each alternative to estimate costs

Table F–7. Systems engineering and integration and program management actuals

	All Data	Hazcat 2	Hazcat 3	Radiological	Chemical	Nanoparticle	Berylium	Undefined
Count	41	7	4	8	2	1	1	16
Average	49%	62%	52%	51%	31%	0%	51%	42%
Std Deviation	0.27	0.37	0.21	0.35				

F.8 Annual Maintenance, Operations, and Recapitalization Costs

For this AoA, the production, operations, process monitoring, and any other direct activity needed to produce a pit was assumed to be captured as a future program cost and not a cost of the facility life cycle, in keeping with DOE Order 413.3b. Production, maintenance, and operations costs only capture the cost to manage the facility, maintain the facility, and recapitalize both process and support equipment.

F.9 Operations and Maintenance

The life cycle of the plutonium pit production capability is 50 years after start of operations.

Operations, production, and process monitoring will be a future program cost and therefore are outside the scope of this AoA. Additionally, costs will be similar for all alternatives and will not drive any acquisition decision.

There are no additional or very small costs to maintain cold dark storage space in the MFFF or FPF.

F.10 Basis of Estimate

Annual maintenance and utility costs were estimated as a function of the gross square footage of the facility (see **Table F–8**). Annual cost data were collected from LANL for FY 2008 through FY 2012 for the current PF-4 facility. This information was then expressed as a function of gross square feet from year to year to get a dollars per gross square foot per year CER. Production and operations costs were excluded from this analysis, but all maintenance (actual and deferred) and facility management were used in the calculation. These annual data were then used to get an average and standard deviation of costs per square foot of an active Hazard Category 2 facility. This CER was then applied to the space estimates for each alternative to give an estimate and uncertainty for the annual cost. Process and support equipment recapitalization was assumed to be 2-4 percent of the acquisition cost annually. This cost was multiplied through the 50 year life cycle to determine the total operating and maintenance life-cycle cost.

Table F–8. PF-4 Annual maintenance costs from FY 2008–FY 2012

			FY12			FY11			FY10			FY09			FY08		
Facility/Project	PC	PC DESC	YTD Budgets	YTD Actual	YTD FTE's	YTD Budgets	YTD Actual	YTD FTE's	YTD Budgets	YTD Actual	YTD FTE's	YTD Budgets	YTD Actual	YTD FTE's	YTD Budgets	YTD Actual	YTD FTE's
TA-55	K55W	TA-55 Waste Processing Cost	3,005	3,494	0	2,261	4,395	0									
	KG17	MANAGEMENT & ADMINISTRATION RTBF DIRECT	6,670	6,655	23	4,693	4,714	14	3,706	3,971	14	4,691	4,366	15	5,775	5,844	14
	KG19	TA-55 WASTE MANAGEMENT															
	KG1D	TA55 REAL PROPERTY EQUIPMENT & MAIN TA55 REAL ROPERTY EQUIPMENT & MAIN	0	1	0	0	0	0	0	5	0	0	29	0	18,318	17,536	39
	KG1L	TA-55 DEV & MAINTENANCE OF TA-55 AB	5,585	5,483	9	8,015	7,611	12	7,078	6,671	13	5,413	6,900	8	5,503	6,038	8
	KG1V	TA-55 COMPUTER & FACILITY SUPPORT										0	5	0	0	6	0
	KG25	MANAGEMENT & ADMINISTRATION TARGET	13,991	13,978	0	8,825	14,857	0	14,790	15,910	0	22,922	23,525	0	18,515	16,407	0
	KG27	TA-55 ESH&Q	8,330	8,324	0	8,896	9,386	0	9,315	8,923	0	12,592	12,573	0	12,707	13,815	0
	KGR1	KGR1: TA-55 NMM													0	11	0
	KGMM	KGMM: MAINTENANCE MANAGEMENT	8,263	8,231	31	12,564	12,216	48	11,914	11,181	46	12,412	11,135	45			
	KGMP	TA-55 Facility Modifications															
	KGNN	KGNN: NON NUCLEAR FACILITIES	2,575	2,921	1	2,568	2,846	1	1,455	1,935	1	2,094	2,215	1			
	KGNU	KGNU: NUCLEAR FACILITIES	7,962	7,629	4	8,981	8,756	4	5,712	8,287	4	5,626	5,347	3			
	P45I	TA-55 CAPITAL EQUIPMENT				1,117	122	0	211	224	0	103	104	0			
	P4A1	Personal Contamination Monitor													69	69	0
TA-55 Total			56,380	56,716	68	57,519	64,662	80	56,220	57,093	77	65,854	66,259	72	60,977	59,326	62

F.11 Waste – Estimating Processing Costs

The yearly costs for processing, transportation, and disposal of waste from the production location are included in the life cycle cost estimates. Three categories of waste were estimated: transuranic (TRU) waste, low-level waste (LLW), and nonhazardous waste. The amount of waste produced at various pit production rates were previously estimated by the Modern Pit Facility project and by LANL for the Plutonium Sustainment project (30 ppy) at PF-4. These waste production rates were approximately linearly related to the pit production rate. This is illustrated in **Figure F–4.**

With the linearly estimated waste production rates, we applied a series of cost metrics (dollars per cubic foot) by waste type. These cost metrics originated from analysis completed by Argonne National Laboratory which was provided in a report found through an open-literature search. This report provided cost metrics for processing, transportation, and disposal of multiple waste types, including the three categories that were estimated for this AoA. Costs were escalated to FY 2018 dollars, and adjusted for increased regulatory requirements.

In the cost analysis, the team assumed:

- Waste Isolation Pilot Plant will be the primary waste repository throughout the lifetime of the production facility, and DOE funds operating costs for this facility
- an aqueous purification process versus pyro-chemical purification process (the later results in a smaller volumes of solid TRU/LLW waste
- ramp-up and full production rates were estimated and based on production requirements as defined in the PRD

The AoA team believes these assumptions and the level of rigor of waste cost estimates to be reasonable for a pre-Critical Decision-1 AoA. These estimates will be further refined through the critical decision process as design definition for the facility increases and waste subject matter experts are able to provide detailed input on the waste stream types and estimates of volumetric rates.

The over-all cost metrics applied for the LCCE are summarized in **Table F–9** and the volume of waste per pit is displayed in Figure F–4.

Table F–9. Waste processing costs

Waste Type	Processing ($/ft³)	Transportation ($/mile/ft³)	Disposal ($/ft³)
TRU	794	0.01451	72
LLW	363	0.00285	21

Non-Hazard	0.08	0.00600	0.105

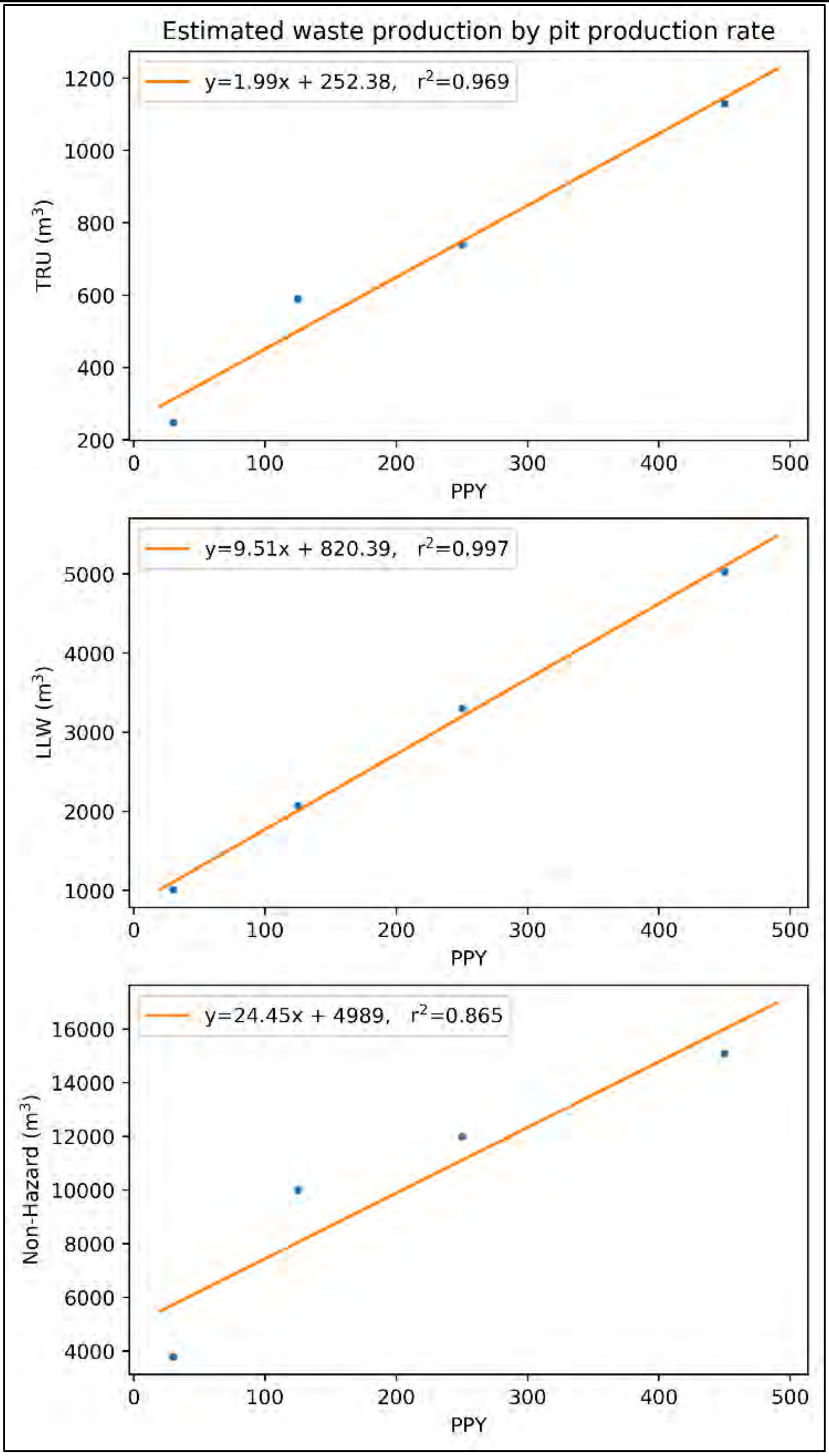


Figure F–4. Estimated waste production by pit production rate

The annual cost of a maintaining a plutonium production capability are a substantial portion of the life-cycle cost. While one may expect the annual costs to be driven by the size or capacity, there are other variables that contribute as well. These costs include operations personnel, utilities, equipment maintenance and maintenance contracts, facility management, equipment recapitalization, and process monitoring.

These costs are somewhat variable and must be managed as the facility ages and production requirements change. For instance, maintenance contracts can be lower if it is acceptable to allow longer repair times for the equipment. Furthermore, there is some variability that exists in staffing levels for a given equipment capacity. Recapitalization costs include plutonium pit production equipment (process equipment), plutonium pit production supporting process equipment (Be machining, analytical chemistry, etc.), and facility support equipment (roofing, HVAC, etc.)

For this AoA, the production, operations, process monitoring, and any other direct activity needed to produce a pit was assumed to be captured as a future program cost and not a cost to the facility life cycle as per DOE Order 413.3b. Production, maintenance, and operations costs only capture the cost to manage the facility, maintain the facility, and recapitalize both process and support equipment. **Figure F–5** shows the full LCCE range for each alternative.

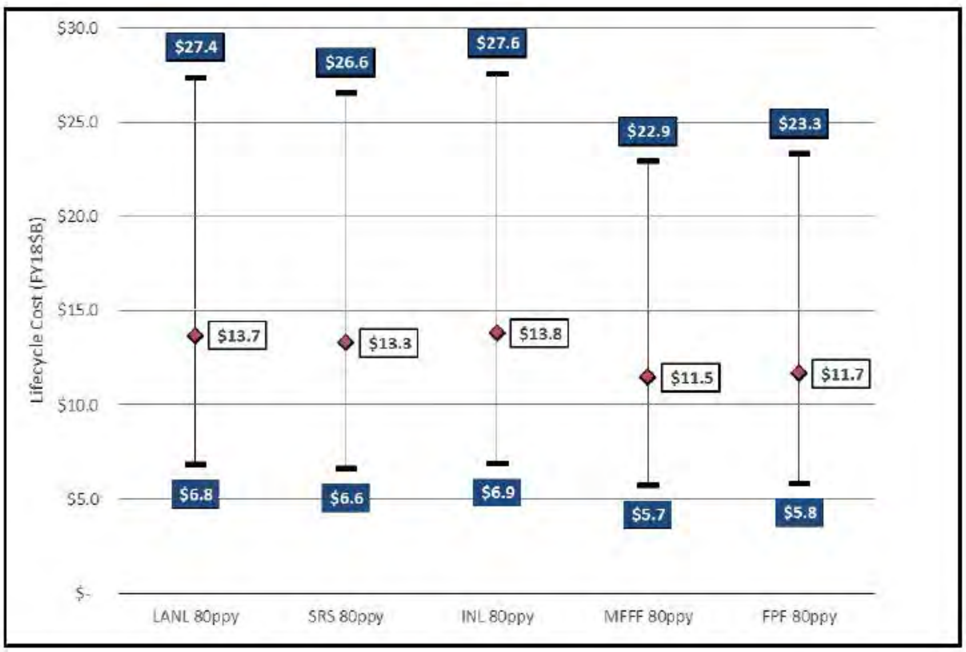
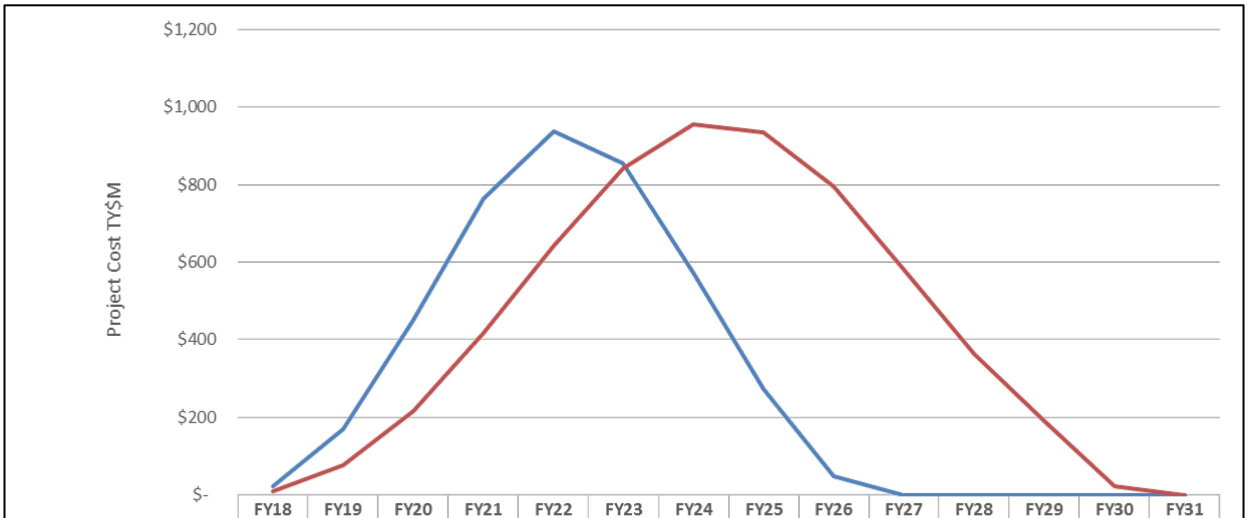


Figure F–5. Life-cycle cost estimates range by alternative

The 85 percent confidence estimate was phased using an internally developed Weibull Phasing tool. This tool generates year-to-year cost phasing using information from the National Aeronautics and Space Administration Cost Estimating Handbook, and was cross-checked with NNSA project data. The model uses a 40/60 Weibull distribution to phase costs. This phasing distribution assumes 40 percent of the cost is spent from 0 percent-50 percent of the time, and 60 percent of the cost is spent from 50 percent-100 percent of the time. This matches other studies which have found that, for constructions projects, a back-loaded cost phasing appropriately estimates real construction project data due to several factors. **Figure F–6** shows notional budget profiles for new construction and refurbishment alternatives.



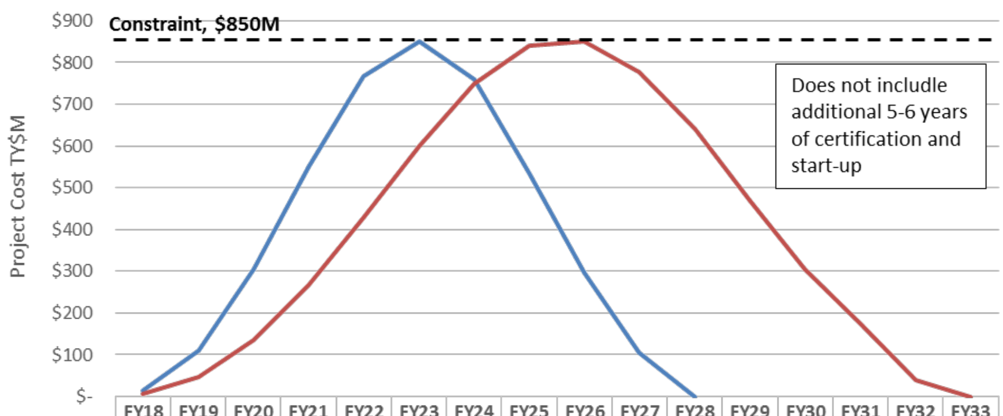
	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31
Refurbishment	$23	$170	$452	$764	$937	$854	$574	$274	$48	$-	$-	$-	$-	$-
New Construction	$10	$77	$217	$417	$644	$843	$956	$936	$796	$582	$363	$189	$21	$-

Figure F–6. Notional budget profiles for new construction and refurbishment alternatives

In addition to the above notional budget profiles, we developed constrained budget phasings based on assumptions of affordability and executability. These assumptions were:

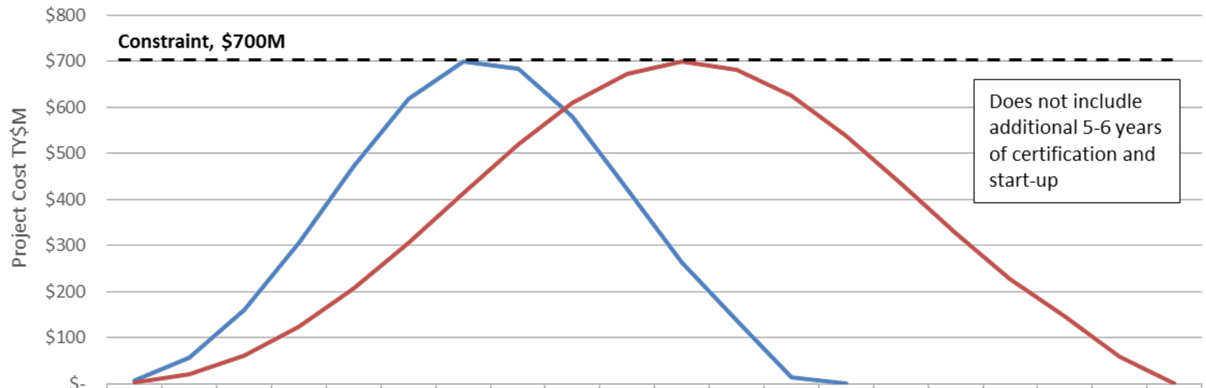
a. Affordability constraint at $700M per year based on max UPF funding of $722M (not yet demonstrated) per Bob Raines.
b. Executability constraint of $850M per year. 1800 persons per year per Bob Raines.

The budget phasing model was run to limit the maximum annual budget to $700M in the case of affordability and $850M in the case of executability. This resulted in the following profile and CD-4 dates.



	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31	FY32	FY33
Refurb	$15	$110	$304	$551	$766	$850	$759	$535	$296	$105	$-					
New	$6	$47	$135	$266	$429	$600	$750	$839	$850	$777	$640	$469	$306	$176	$40	$-

Figure 7: Constrained notional Budget Profile (Executable)



	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31	FY32	FY33	FY34	FY35	FY36	FY37
Refurb	$7	$56	$159	$306	$472	$618	$700	$684	$581	$423	$263	$137	$14	$-						
New	$3	$21	$62	$124	$207	$306	$415	$519	$610	$673	$700	$682	$626	$538	$435	$325	$227	$147	$59	$-

Figure 8: Constrained notional Budget Profile (Affordable)

The AoA cost team then conducted a present value analysis, using Government Accountability Office best practices, for the life cycle of the project. The present value analysis used Office of Management and Budget Circular A-94. Appendix C presents a value discount rate of 0.7 percent for projects over 30 years. **Figure F–9** shows cumulative present value for new construction and refurbishment alternatives.

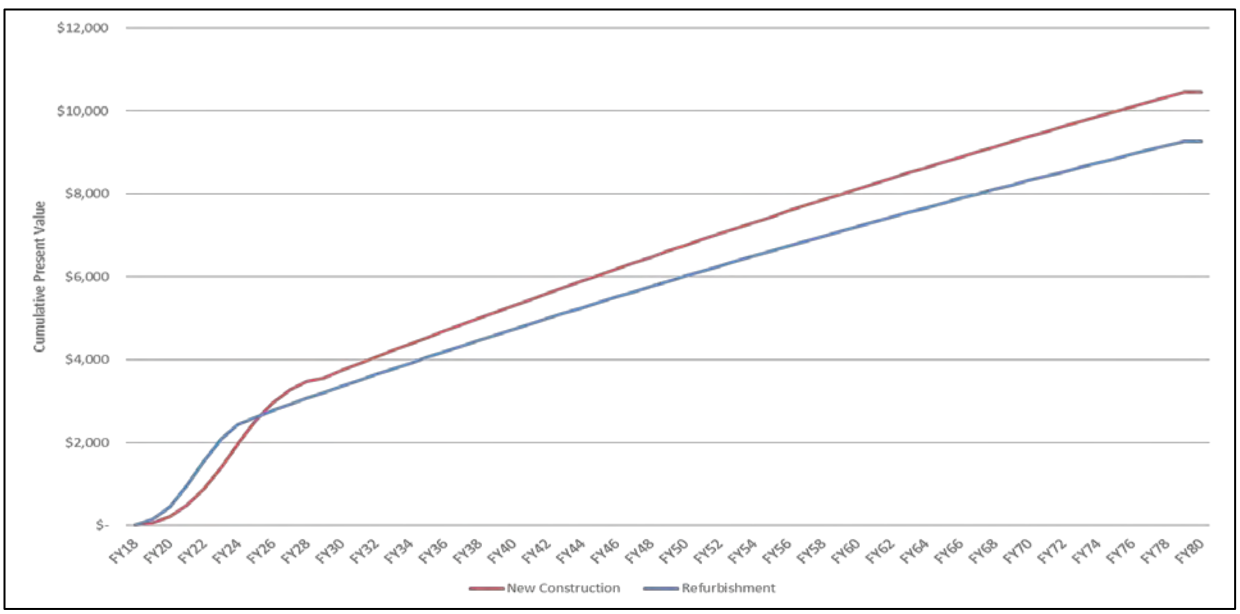


Figure F–9. Cumulative present value for new construction and refurbishment alternatives

F.12 Additional Information

Project Name	**Site**	**Scope Description (from DOE Budget)**	**Adjustments**
HEUMF	Y-12	The Highly Enriched Uranium (HEU) Materials Facility will support the consolidation of long-term highly enriched uranium materials into a state-of-the-art facility. The new facility will result in cost savings and an increased security posture and will feature storage in a hardened concrete structure for enhanced security, new Safe Secure Trailer (SST) or Safeguard Transport (SGT) shipping/receiving station, a central location near HEU processing facilities that includes a small administrative area to house the building operators. This facility will be located in a Protected Area.	The 2005 budget phased costs, but the fidelity of OPC and PED was low. Data sheets from the program was used to inform the break out of OPC and PED, with the TPC matching values recorded in the budget.
MOX	SRS	Construction activities included continuing to prefabricated pipe modules in the active gal installation of Heating, Ventilation, and Conditioning (HVAC) duct, supports and dam mechanical process system and glov installation; closure of Temporary Constru Openings; installation of electrical duct ba installation of process pipe and the associ chemical commodity equipment; and installatio electrical equipment, supports, and cable t 2017: In FY 2017, the Department prop termination of the MOX project in accordance DOE Order 413.3B. The FY 2017 Contir Resolution directed the Department to cont construction activities. In FY 2017, constru continued focusing on commodity installa Primary areas of work include the third floor o Manufacturing Process (MP) area while compl installation activities and closing work packag the first and second floors of the Aqueous Polis (AP) areas. Construction continued on insta prefabricated pipe modules in the active gal installation of HVAC duct, supports, and dam mechanical process system and glov installation; closure of Temporary Constru Openings; installation of electrical duct banks; installation of process pipe and the associ chemical commodity equipment.	Costs used the PCDS for FY99 – FY16, with FY17 and FY18 actuals coming from STARS. Since the MOX budget line includes non-HC facilities, the cost to build non-HC facilities (BAD, BEG, BRP, BRW, BSG, BSW, BTS, UGS, USF, WVA, and XFMRS) was subtracted from the construction total. The gross square footages of the HC-2 facilities (BAP, BMP, BSW, and UEF) were used for the HC-2 construction CER.

MPB	Y-12	The Main Process Building of UPF will house the casting and oxide production capabilities, nondestructive analysis and waste preparations, furnaces and repacking, and spaces needed for process support such as the shift manager's office, restrooms, and other personnel-related rooms. MPB is constructed to nuclear standards commensurate with high-hazard materials and security and includes the construction of the HEUMF connector, and the new Perimeter Intrusion Detection and Assessment System surrounding the UPF campus and support buildings.	All of UPF's $2B PED was reported within MPB. This was evenly spread to other facilities as a fraction of construction costs. Detailed schematics of MPB, SAB, and MEB allowed separation of costs and square footage by HC (only MPB is HC-2).
TEF	SRS	The CLWR TEF shall provide the capability to receive and extract gases containing tritium from CLWR Tritium Producing Burnable Absorber Rods (TPBARs), or other targets of similar design. The TEF will provide shielded remote TPBAR handling for the extraction process, clean-up systems to reduce environmental impact from normal processing and accidental releases, and delivery of extracted gases containing tritium to the Tritium Recycle Facility for further processing. The facility includes two major buildings: (1) a 15,250 (approx.) square foot Remote Handling Building (RHB) and (2) a 26,500 (approx.) square foot Tritium Processing Building (TPB). The TPB will be built above ground, while the RHB will be partially below ground. Major processes and operations systems included within the TEF will be: (1) the Receiving, Handling, and Storage System that will support all functions related to the receipt, handling, preparation, and storage of incoming TPBAR and outgoing radioactive waste materials; (2) the Tritium Extraction System that will perform initial cleanup of extracted gasses; (3) the Tritium Process Systems that will separate process gases from the irradiated TPBARs; (4) the Tritium Analysis and Accountability Systems that will support monitoring and tritium	All costs are from the PCDS within the 2006 DoE Budget. The footprint comes from FIMS for the RHB and TPB.

		accountability; (5) the Solid Waste Management System that will receive solid waste generated by TEF for management and storage prior to disposal in the E-Area vaults, which will be upgraded by TEF to accommodate that disposal; and (6) the Heating, Ventilation, and Air Conditioning System that would provide and distribute conditioned supply air to the underground RHA and the above ground tritium processing area and also discharge exhaust air to the environment via a 100-foot stack. The TEF will provide steady-state production capability to the existing SRS tritium facility of as much as 3Kg of tritium per year, if needed. Final purification of gases containing tritium shall be performed in the augmented process equipment located in the existing SRS tritium facility. The TEF shall have an operational life span of at least 40 years, minimize radiological and chemical releases to the environment; and minimize waste generation. The security requirements shall be such that TEF is designated as an exclusion area.	
WSB	SRS	Design, construction, procurement, installation, testing, demonstration, and start-up testing of structures and equipment. The major process equipment includes tanks, evaporators, and solidification equipment. The radioactive liquid waste consists of one high-activity and one low-activity stream. The high-activity stream contains significant amounts of americium removed from plutonium oxide during mixed oxide (MOX) aqueous polishing operations. The low-activity stream contains stripped uranium also removed from MOX aqueous polishing operations. The WSB operating life would be approximately 20 years; however the facility would have a design life of 30 years. After completing its mission, the WSB would be deactivated, decontaminated, and decommissioned over approximately two to four years.	We used the phased costs from the 2015 DOE Budget. Based upon engineering diagrams, we included the upper mezzanine and useable portions of the second floor for gross square footage.

Appendix G. Schedule Support

Two schedule scenarios are under consideration for this AoA: one for new construction and one for refurbishing facilities. These are initially discussed in Chapter 8, and supporting data and details are provided here for each scenario.

G.1 Data Sets

The data set for new construction consisted of actuals from the following projects:

- MOX – Mixed Oxide Fuel Fabrication Facility
- UPF-MPB – Uranium Production Facility – Main Processing Building
- WSB – Waste Solidification Building
- HEUMF – Highly Enriched Uranium Materials Facility
- TEF – Tritium Extraction Facility
- UPF-SAB – Uranium Production Facility – Salvage Accountability Building
- TRUWF – Transuranic Waste Facility
- LLW – Low Liquid Waste Facility
- NIF – National Ignition Facility
- MESA – Microsystems and Engineering Sciences Applications
- UPF-MEB – Uranium Production Facility – Mechanical and Electrical Building
- UPF-PS – Uranium Production Facility – Process Support
- NTSRFS – NTS Replace Fire Stations No. 1 and No. 2
- NSSB – National Security Sciences Building
- HEPF – High Explosives Pressing Facility
- PF – Purification Facility
- HESE – High Explosives Science and Engineering Facility

The data set for refurbishment consisted of actuals for the following projects:

- NFRR – Nuclear Facility Risk Reduction
- RLUOB+REI1 – RLUOB Equipment Installation 1
- RLUOB+REI2 – RLUOB Equipment Installation 2
- RLUOB+RC3 – RLUOB Categorization 3
- CEF – Criticality Experiments Facility
- PF-4+PEI1 – PF-4 Equipment Installation 1
- PF-4+PEI2 – PF-4 Equipment Installation 2
- SNMCRF – SNM Component Requalification Facility
- IBL – Ion Beam Laboratory
- TFM – Tritium Facility Modernization
- ETCU – Engineering Technology Complex Upgrade

Both the new building scenario and the refurbishing scenario have merits.

Table G–1 reflects the scrutiny employed by the evaluation team when considering possible advantages and disadvantages of each of the two schedule scenarios.

Table G–1. Discipline-specific schedule differentiators

			New	Retrofit/refurbish	Comment/Qualifier
Engineering Design					
	Civil		DISADV	ADV	Significant civil design advantages are possible given the facility is existing. However some advantage may be offset by the need to analyze and re-establish the design basis and Code of record (COR) for a use other than the orignal design intent in addition to the demolition/reconfiguration design requirements..
	Structural		DISADV	ADV	Significant structural design advantages are possible given the facility is existing. However some advantage may be offset by the need to analyze and re-establish the design basis and Code of record (COR) for a use other than the orignal design intent in addition to the demolition/reconfiguration design requirements.
	Mechanical				
		Engineered (Process) Equipment	ND	ND	No anticpated advantages or disadvantages.
		Building Systems	DISADV	ADV	Some advantages may exist in the potential to re-use existing building mechanical systems.
	Electrical		DISADV	ADV	Some advantages may exist in the potential to re-use existing building electrical systems.
	Instrument and Controls		ND	ND	No anticpated advantages or disadvantages
	Safeguards and Security SSCs		ADV	DISADV	Given the DBT evolutions since existing facilities were designed new construction MAY be preferential to fi
Procurement					
	Civil		N/A	N/A	
	Structural		DISADV	ADV	Bulk procurements of structural materials (rebar steel will be reduced (demo and reconfig needs) given an existing facility)
	Mechanical				
		Engineered Equipment	ND	ND	No anticpated advantages or disadvantages.
		Building Systems	DISADV	ADV	Slight advantage due to potential reuse of selected existing mechanical system.
	Electrical		DISADV	ADV	Slight advantage due to potential reuse of selected existing electrical system.
	Instrument and Controls		ND	ND	No anticpated advantages or disadvantages.
	Safeguards and Security SSCs		ND	ND	No anticpated advantages or disadvantages.
Construction					
	Civil		DISADV	ADV	Significant civil construction advantages are possible given the facility is existing. However some advantage may be offset by the need for demolition and/or reconfiguration of existing civil features to accommodate a use other than that for which the facility was originally designed.
	Structural		DISADV	ADV	Significant structural construction advantages are possible given the facility is existing. However some advantage may be offset by the need for demolition and/or reconfiguration of existing civil features to accommodate a use other than that for which the facility was originally designed.
	Mechanical				
		Engineered Equipment	ND	ND	No anticpated advantages or disadvantages.
		Building Systems	DISADV	ADV	Slight advantage due to potential reuse of selected existing mechanical systems. However that advantage may be offset by the potential need for demolition of existing systems deemed inadequate to meet current codes standards and/or process/safety requirements.
	Electrical				Slight advantage due to potential reuse of selected existing electrical systems. However that advantage may be offset by the potential need for demolition of existing systems deemed inadequate to meet current codes standards and/or process/safety requirements.
	Instrument and Controls		ND	ND	No anticpated advantages or disadvantages.
	Safeguards and Security SSCs		ADV	DISADV	Given the DBT evolutions since existing facilities were designed new construction MAY be preferential to fi
Installation					
	Civil		N/A	N/A	See Construction
	Structural		N/A	N/A	See Construction
	Mechanical				
		Engineered Equipment	N/A	N/A	See Construction
		Building Systems	N/A	N/A	See Construction
	Electrical		N/A	N/A	See Construction
	Instrument and Controls		N/A	N/A	See Construction
	Safeguards and Security SSCs		N/A	N/A	See Construction
Test, Checkout, Startup, Readiness Commissioning (CD-4)					
	Civil		ND	ND	No anticpated advantages or disadvantages.
	Structural		ND	ND	No anticpated advantages or disadvantages.
	Mechanical				
		Engineered Equipment	ND	ND	No anticpated advantages or disadvantages.
		Building Systems	ND	ND	No anticpated advantages or disadvantages.
	Electrical		ND	ND	No anticpated advantages or disadvantages.
	Instrument and Controls		ND	ND	No anticpated advantages or disadvantages.
	Safeguards and Security SSCs		ND	ND	No anticpated advantages or disadvantages.
FPU and Production Ramp up			ND	ND	No anticpated advantages or disadvantages.
DOE 413.3b Critical Decision Management			ND	ND	No anticpated advantages or disadvantages.

G.2 Assumptions

Other assumption and bases that were considered and used to develop the two schedule scenarios include:

- Schedule scenario discriminators consider (<u>but are not limited to</u>):
  - physical facility size
  - number of long-lead procurements
  - number of engineered equipment items
  - congestion of construction sites
  - location of construction sites
  - age of facility being modified
  - physical configuration and design of facility being modified
  - amount of demolition/retrofit of existing facilities
  - proximity and condition of support and operational utilities
  - the security environment in which the work (new or renovation) is being performed
  - the operational/site interfaces in which or adjacent to the area where work is being performed
- All scheduled days are work days.
- All new construction will be considered "Major Systems" and will be subject to the requirements of DOE Order 413.3b.
- Final National Environmental Policy Act (NEPA) determinations will precede any new construction.
- Demolition in preparation for new construction in existing facilities may proceed as soon as design for that work has been deemed "substantially complete."
- Critical Decision (CD)-2 and CD-3 for new nuclear facility construction and major equipment procurement will be based on a 90+ percent design completion.
- Pre-CD-1 activities will be the same for all cases.
- Aggressive CD-2 preparation and processing
  - Analysis ranges used for this activity: Optimistic = 87 days, Most Likely = 173, Pessimistic = 260
- Aggressive CD-3 preparation and processing
  - Analysis ranges used for this activity: Optimistic = 87 days, Most Likely = 173, Pessimistic = 260
- Aggressive CD-3x plus preparation and processing
  - Analysis ranges used for this activity: Optimistic = 87 days, Most Likely = 173, Pessimistic = 260
- Post-CD-3 activities will be similar for all disciplines (excluding civil and magnitude of structural work).
- Schedules developed for each of the two scenarios assume that resources required for the execution of each phase of work will be available and uninterrupted (e.g., design support, construction labor and materials, procurement and fabrication capability and capacity).

- Demolition, reuse, and retrofit scenarios do not include radiological or other chemical decontamination.
- NNSA Office of Acquisition and Project Management (NA-APM) Flat File of critical decision dates for NNSA DOE Order 413 projects used in estimation of construction, installation, and closeout times.
- NEPA time ranges taken from actuals contained in DOE Office of NEPA Policy and Compliance's Lessons Learned Quarterly Reports.
- War Reserve Process Qualification (QER) basis = Rocky Flats production mission historical and Y-12 secondary production historical.
- Assuming ±1σ range for NEPA and construction/installation/closeout.
- Low-end of refurbish range is intercept.
- U.S. Government fiscal year calendar: Quarter (Q)1 = Oct–Dec, Q2 = Jan–Mar, Q3 = Apr–Jun, Q4 = Jul–Sep.
- Working calendar year is 260 days.
- Additional specific caveats for analysis.

G.3 Schedules for Alternatives

Figures G–1 through **G–6** show possible schedules for building new and refurbishment, for optimistic, most likely, and pessimistic cases for 80 pits per year (ppy) production. **Figures G–7** through **G–12** show possible schedules for building new and refurbishment, for optimistic, most likely, and pessimistic cases for 50 ppy production.

	Name	Duration	Predecessors
1	Alternative Decision Completed	1 day	
2	CD-1	300 days	1
3	Develop CD-1 Package (413...	240 days	
4	Acquisition Strategy	240 days	1
5	Develop Project Execution Pla...	240 days	1
6	Technology Maturation Plan	240 days	1
7	Technology Readiness Assess...	240 days	1
8	Integrated Safety Manageme...	240 days	1
9	Quality Assurance Plan	240 days	1
10	Update Project Data Sheet	240 days	1
11	Identify Safety and Security ...	240 days	1
12	Authorization Basis	240 days	1
13	Initiate Code of Record	240 days	1
14	Prepare SDS	240 days	1
15	Independent Project Review	240 days	1
16	Conceptual Safety Design Re...	240 days	1
17	Concetual Safety Validation R...	0 days	1
18	CD-1 Package Reviews (ICE,+)	40 days	3
19	CD-1 Approval	20 days	18
20	NEPA Process	750 days	1
21	Engineering Design/PED (Titl...	720 days	
22	Existing Facility Retrofit	0 days	
29	New Facility Design/Enginee...	720 days	
30	Title I Design - New Facility & ...	440 days	19
31	Title I Design - Engineered Eq...	360 days	19
32	Title II Design - New Facility &...	280 days	30
33	Title II Design - Engineered Eq...	160 days	31
34	CD-2	167 days	25;28;32;33
35	Develop CD-2 Package (413.3b ...	40 days	25;28;32;33
36	CD-2 Package Reviews (ICE/EI...	87 days	35
37	NEPA Action - Complete EIS	1 day	20
38	CD-2 Approval	40 days	36;37
39	CD-3a+ - Long-Lead, Bulks, E...	167 days	25;27;31;33
40	Develop CD-3a+ Package(s) (4...	40 days	25;27;31;33
41	CD-3a+ Package Review(s) (IC...	87 days	40
42	CD-3a+ Approvals	40 days	41
43	CD-3	167 days	32;33
44	Develop CD-3 Package (413.3b ...	40 days	32;33
45	CD Package Review(s) (ICE/EIR...	87 days	44
46	NEPA Record of Decision	1 day	20
47	CD-3 Approvals	40 days	45;46
48	Procurements - Long Lead, B...	620 days	42
49	Contractor selections	120 days	42
50	Fabrication and Deliveries	500 days	49
51	Dummy Task---Remove - Do Not...	0 days	
52	Supporting Facility	5 days?	
58	Construction	1,406 days	46
59	Existing Facility	586 days	42
64	New Facility	1,240 days	47
65	Site Prep	240 days	47
66	Construction (Struct., Mech.,...	520 days	65
67	Engineered Equipment Installa...	435 days	50;66FS-130 days
68	Testing, Startup & Commissio...	240 days	67FS-65 days
69	Process Prove-In	80 days	68FS-6 months;63FS-6 ...
70	Procedures Development	40 days	68FS-6 months;63FS-6 ...
71	Operation Procedures	40 days	68FS-6 months;63FS-6 months
72	Maintenance Procedures	40 days	68FS-6 months;63FS-6 months
73	Emergency Response Procedu...	40 days	68FS-6 months;63FS-6 months
74	Off-Normal Operations Proced...	40 days	68FS-6 months;63FS-6 months
75	Personnel Training	40 days	70
76	Operations Personnel	40 days	71
77	Maintenance Personnel	40 days	72
78	Site and Facility Emergency R...	40 days	71;72;73;74
79	ORR	120 days	70;75
80	Proficiency Demonstration	80 days	70;75
81	Operations	80 days	76
82	Maintenance	80 days	77
83	Emergency Response	80 days	78
84	Documentation (Quality, Safety...	80 days	63;68
85	CD-4	60 days	84
86	Develop CD-4 Package (413.3b ...	20 days	84
87	CD-4 Package Review(s)	20 days	86
88	CD-4 Approval	20 days	87
89	WR Process Qualification	780 days	88
90	Conclude WR Process Certification	780 days	
91	Production Rampup	586 days	89
92	Start 30 ppy	260 days	89
93	Start 60 ppy	260 days	92

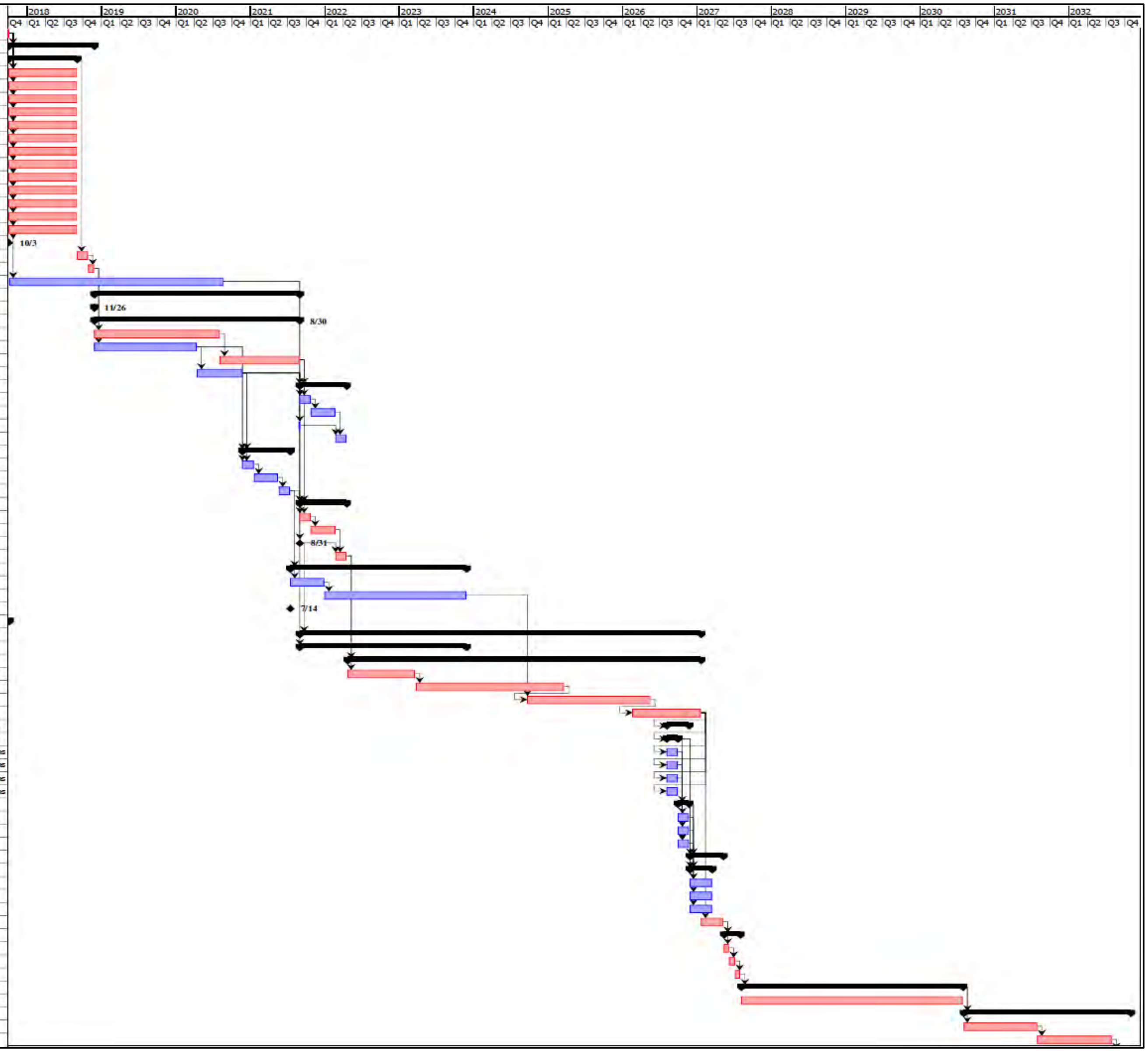


Figure G–1. Build new (optimistic) – 80 ppy

	Name	Duration	Predecessors
1	Alternative Decision Completed	1 day	
2	**CD-1**	**300 days**	**1**
3	**Develop CD-1 Package (413.3b App...**	**240 days**	
4	Acquisition Strategy	240 days	1
5	Develop Project Execution Plan (PEP)	240 days	1
6	Technology Maturation Plan	240 days	1
7	Technology Readiness Assessment	240 days	1
8	Integrated Safety Management Plan	240 days	1
9	Quality Assurance Plan	240 days	1
10	Update Project Data Sheet	240 days	1
11	Identify Safety and Security Reqs	240 days	1
12	Authorization Basis	240 days	1
13	Initiate Code of Record	240 days	1
14	Prepare SDS	240 days	1
15	Independent Project Review	240 days	1
16	Conceptual Safety Design Report	240 days	1
17	Concetual Safety Validation Report	0 days	1
18	CD-1 Package Reviews (ICE,+)	40 days	3
19	CD-1 Approval	20 days	18
20	NEPA Process	980 days	1
21	**Engineering Design/PED (Title I and T...**	**720 days**	
22	**Existing Facility Retrofit**	**0 days**	
29	**New Facility Design/Engineering**	**720 days**	
30	Title I Design - New Facility & Utilities	440 days	19
31	Title I Design - Engineered Equipment	360 days	19
32	Title II Design - New Facility & Utilities	280 days	30
33	Title II Design - Engineered Equipment	160 days	31
34	**CD-2**	**253 days**	**25;28;32;33**
35	Develop CD-2 Package (413.3b Appendi...	40 days	25;28;32;33
36	CD-2 Package Reviews (ICE/EIR/IPR/+)	173 days	35
37	NEPA Action - Complete EIS	1 day	20
38	CD-2 Approval	40 days	36;37
39	**CD-3a+ - Long-Lead, Bulks, Engineer...**	**253 days**	**25;27;31;33**
40	Develop CD-3a+ Package(s) (413.3b Ap...	40 days	25;27;31;33
41	CD-3a+ Package Review(s) (ICE/EIR/IPR)	173 days	40
42	CD-3a+ Approvals	40 days	41
43	**CD-3**	**253 days**	**32;33**
44	Develop CD-3 Package (413.3b Appendi...	40 days	32;33
45	CD Package Review(s) (ICE/EIR/IPR)	173 days	44
46	NEPA Record of Decision	1 day	20
47	CD-3 Approvals	40 days	45;46
48	**Procurements - Long Lead, Bulks, En...**	**840 days**	**42**
49	Contractor selections	120 days	42
50	Fabrication and Deliveries	720 days	49
51	Dummy Task---Remove - Do Not link or load	0 days	
52	**Supporting Facility**	**5 days?**	
58	**Construction**	**1,965 days**	**46**
59	**Existing Facility**	**840 days**	**42**
64	**New Facility**	**1,765 days**	**47**
65	Site Prep	275 days	47
66	Construction (Struct., Mech., Elec., I&...	775 days	65
67	Engineered Equipment Installation & Sy...	670 days	50;66FS-130 days
68	Testing, Startup & Commissioning	240 days	67FS-65 days
69	**Process Prove-In**	**80 days**	**68FS-6 months;63FS-6 ...**
70	**Procedures Development**	**40 days**	**68FS-6 months;63FS-6 ...**
71	Operation Procedures	40 days	68FS-6 months;63FS-6 months
72	Maintenance Procedures	40 days	68FS-6 months;63FS-6 months
73	Emergency Response Procedures	40 days	68FS-6 months;63FS-6 months
74	Off-Normal Operations Procedures	40 days	68FS-6 months;63FS-6 months
75	**Personnel Training**	**40 days**	**70**
76	Operations Personnel	40 days	71
77	Maintenance Personnel	40 days	72
78	Site and Facility Emergency Response ...	40 days	71;72;73;74
79	**ORR**	**120 days**	**70;75**
80	**Proficiency Demonstration**	**80 days**	**70;75**
81	Operations	80 days	76
82	Maintenance	80 days	77
83	Emergency Response	80 days	78
84	Documentation (Quality, Safety, IH, Engi...	80 days	63;68
85	**CD-4**	**60 days**	**84**
86	Develop CD-4 Package (413.3b Appendi...	20 days	84
87	CD-4 Package Review(s)	20 days	86
88	CD-4 Approval	20 days	87
89	**WR Process Qualification**	**780 days**	**88**
90	Conclude WR Process Certification	780 days	
91	**Production Rampup**	**586 days**	**89**
92	Start 30 ppy	260 days	89
[illegible]	Start 60 ppy	260 days	92

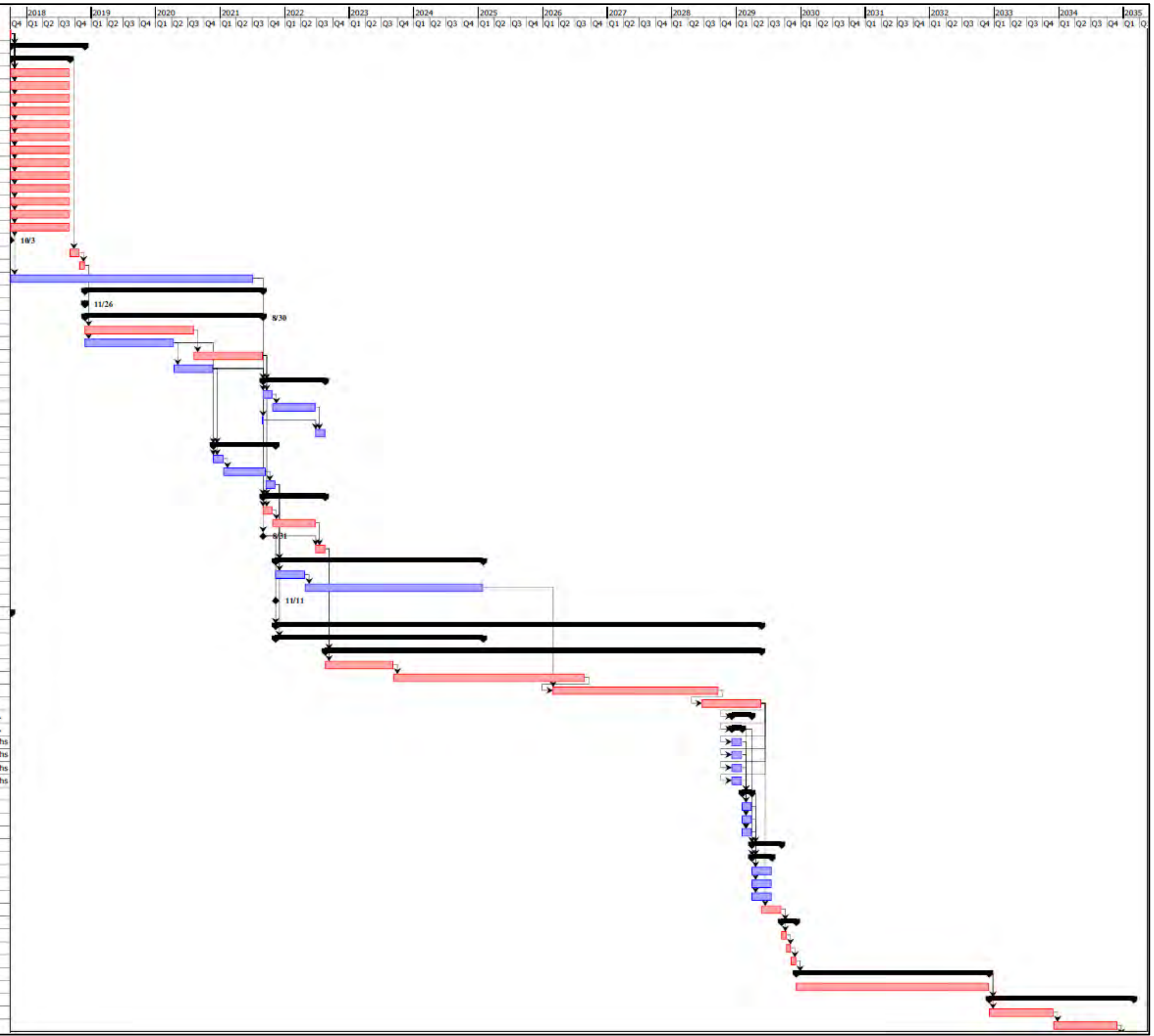


Figure G–2. Build new (most likely) – 80 ppy

	Name	Duration	Predecessors
93	Alternative Decision Completed	1 day	
2	**CD-1**	**300 days**	**1**
3	**Develop CD-1 Package (413...**	**240 days**	
4	Acquisition Strategy	240 days	1
5	Develop Project Execution Pla...	240 days	1
6	Technology Maturation Plan	240 days	1
7	Technology Readiness Assess...	240 days	1
8	Integrated Safety Manageme...	240 days	1
9	Quality Assurance Plan	240 days	1
10	Update Project Data Sheet	240 days	1
11	Identify Safety and Security ...	240 days	1
12	Authorization Basis	240 days	1
13	Initiate Code of Record	240 days	1
14	Prepare SDS	240 days	1
15	Independent Project Review	240 days	1
16	Conceptual Safety Design Re...	240 days	1
17	Concetual Safety Validation R...	0 days	1
18	CD-1 Package Reviews (ICE,+)	40 days	3
19	CD-1 Approval	20 days	18
20	NEPA Process	1,208 days	1
21	**Engineering Design/PED (Titl...**	**720 days**	
22	**Existing Facility Retrofit**	**0 days**	
29	**New Facility Design/Enginee...**	**720 days**	
30	Title I Design - New Facility & ...	440 days	19
31	Title I Design - Engineered Eq...	360 days	19
32	Title II Design - New Facility &...	280 days	30
33	Title II Design - Engineered Eq...	160 days	31
34	**CD-2**	**340 days**	**25;28;32;33**
35	Develop CD-2 Package (413.3b ...	40 days	25;28;32;33
36	CD-2 Package Reviews (ICE/EI...	260 days	35
37	NEPA Action - Complete EIS	1 day	20
38	CD-2 Approval	40 days	36;37
39	**CD-3a+ - Long-Lead, Bulks, E...**	**340 days**	**25;27;31;33**
40	Develop CD-3a+ Package(s) (4...	40 days	25;27;31;33
41	CD-3a+ Package Review(s) (IC...	260 days	40
42	CD-3a+ Approvals	40 days	41
43	**CD-3**	**340 days**	**32;33**
44	Develop CD-3 Package (413.3b ...	40 days	32;33
45	CD Package Review(s) (ICE/EIR...	260 days	44
46	NEPA Record of Decision	1 day	20
47	CD-3 Approvals	40 days	45;46
48	**Procurements - Long Lead, B...**	**840 days**	**42**
49	Contractor selections	120 days	42
50	Fabrication and Deliveries	720 days	49
51	Dummy Task—Remove - Do Not...	0 days	
52	**Supporting Facility**	**5 days?**	
58	**Construction**	**2,432 days**	**46**
59	**Existing Facility**	**787 days**	**42**
64	**New Facility**	**2,285 days**	**47**
65	Site Prep	295 days	47
66	Construction (Struct., Mech.,...	1,180 days	65
67	Engineered Equipment Installa...	765 days	50;66FS-130 days
68	Testing, Startup & Commissio...	240 days	67FS-65 days
69	**Process Prove-In**	**80 days**	**68FS-6 months;63FS-6 ...**
70	**Procedures Development**	**40 days**	**68FS-6 months;63FS-6 ...**
71	Operation Procedures	40 days	68FS-6 months;63FS-6 months
72	Maintenance Procedures	40 days	68FS-6 months;63FS-6 months
73	Emergency Response Procedu...	40 days	68FS-6 months;63FS-6 months
74	Off-Normal Operations Proced...	40 days	68FS-6 months;63FS-6 months
75	**Personnel Training**	**40 days**	**70**
76	Operations Personnel	40 days	71
77	Maintenance Personnel	40 days	72
78	Site and Facility Emergency R...	40 days	71;72;73;74
79	**ORR**	**120 days**	**70;75**
80	**Proficiency Demonstration**	**80 days**	**70;75**
81	Operations	80 days	76
82	Maintenance	80 days	77
83	Emergency Response	80 days	78
84	Documentation (Quality, Safety...	80 days	63;68
85	**CD-4**	**60 days**	**84**
86	Develop CD-4 Package (413.3b ...	20 days	84
87	CD-4 Package Review(s)	20 days	86
88	CD-4 Approval	20 days	87
89	**WR Process Qualification**	**780 days**	**88**
90	Conclude WR Process Certification	780 days	
91	**Production Rampup**	**586 days**	**89**
92	Start 30 ppy	260 days	89
93	Start 60 ppy	260 days	92

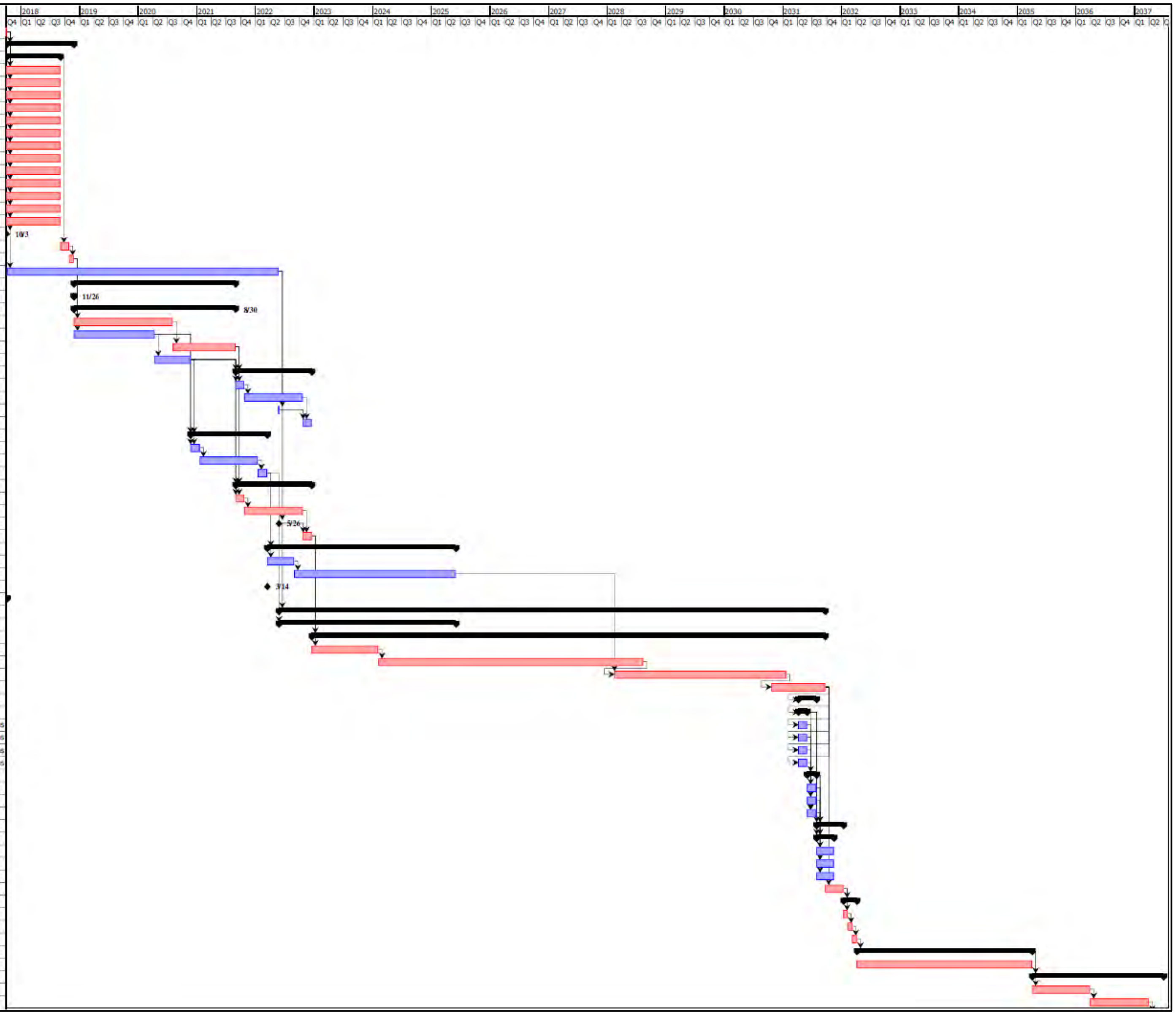


Figure G–3. Build new (pessimistic) – 80 ppy

	Name	Duration	Predecessors
1	Alternative Decision Compl...	1 day	
2	**CD-1**	**300 days**	**1**
3	**Develop CD-1 Packag...**	**240 days**	
4	Acquisition Strategy	240 days	1
5	Develop Project Execu...	240 days	1
6	Technology Maturation...	240 days	1
7	Technology Readiness ...	240 days	1
8	Integrated Safety Man...	240 days	1
9	Quality Assurance Plan	240 days	1
10	Update Project Data S...	240 days	1
11	Identify Safety and Se...	240 days	1
12	Authorization Basis	240 days	1
13	Initiate Code of Record	240 days	1
14	Prepare SDS	240 days	1
15	Independent Project R...	240 days	1
16	Conceptual Safety Des...	240 days	1
17	Concetual Safety Valid...	0 days	1
18	CD-1 Package Reviews (...	40 days	3
19	CD-1 Approval	20 days	18
20	NEPA Process	750 days	1
21	**Engineering Design/PE...**	**360 days**	
22	**Existing Facility Retro...**	**360 days**	
23	**Demolition Design/...**	**200 days**	
24	Title I Design - Existi...	120 days	19
25	Title II Design - Existi...	80 days	24
26	**Retrofit Design/Eng...**	**360 days**	
27	Title I Design - Existi...	240 days	19
28	Title II Design - Existi...	120 days	27
29	**New Facility Design/E...**	**0 days**	
34	**CD-2**	**167 days**	**25;28;32;33**
35	Develop CD-2 Package (...	40 days	25;28;32;33
36	CD-2 Package Reviews (...	87 days	35
37	NEPA Action - Complete ...	1 day	20
38	CD-2 Approval	40 days	36;37
39	**CD-3a+ - Long-Lead, B...**	**167 days**	**25;27;31;33**
40	Develop CD-3a+ Packag...	40 days	25;27;31;33
41	CD-3a+ Package Review...	87 days	40
42	CD-3a+ Approvals	40 days	41
43	**CD-3**	**167 days**	**32;33**
44	Develop CD-3 Package (...	40 days	32;33
45	CD Package Review(s) (I...	87 days	44
46	NEPA Record of Decision	0 days	20;37
47	CD-3 Approvals	40 days	45;46
48	**Procurements - Long L...**	**570 days**	**42**
49	Contractor selections	120 days	42
50	Fabrication and Deliveries	450 days	49
51	Dummy Task---Remove -...	0 days	
52	**Supporting Facility**	**5 days?**	
58	**Construction**	**788 days**	**46**
59	**Existing Facility**	**788 days**	**42**
60	Demolition / Removal	160 days	42;52
61	Facility Retrofits (Struc...	486 days	47;60
62	Engineered Equipment ...	215 days	50;61FS-130 days
63	Testing, Startup & Co...	112 days	62FS-65 days
64	**New Facility**	**480 days**	**47**
69	**Process Prove-In**	**80 days**	**68FS-6 months;63FS-6 ...**
70	**Procedures Develop...**	**40 days**	**68FS-6 months;63FS-6 ...**
71	Operation Procedures	40 days	68FS-6 months;63FS-6 months
72	Maintenance Procedures	40 days	68FS-6 months;63FS-6 months
73	Emergency Response ...	40 days	68FS-6 months;63FS-6 months
74	Off-Normal Operations...	40 days	68FS-6 months;63FS-6 months
75	**Personnel Training**	**40 days**	**70**
76	Operations Personnel	40 days	71
77	Maintenance Personnel	40 days	72
78	Site and Facility Emerg...	40 days	71;72;73;74
79	**ORR**	**120 days**	**70;75**
80	**Proficiency Demonstr...**	**80 days**	**70;75**
81	Operations	80 days	76
82	Maintenance	80 days	77
83	Emergency Response	80 days	78
84	Documentation (Quality,...	80 days	63;68
85	**CD-4**	**60 days**	**84**
86	Develop CD-4 Package (...	20 days	84
87	CD-4 Package Review(s)	20 days	86
88	CD-4 Approval	20 days	87
89	**WR Process Qualification**	**780 days**	**88**
90	Conclude WR Process C...	780 days	
91	**Production Rampup**	**586 days**	**89**
92	Start 30 ppy	260 days	89
93	Start 60 ppy	260 days	92

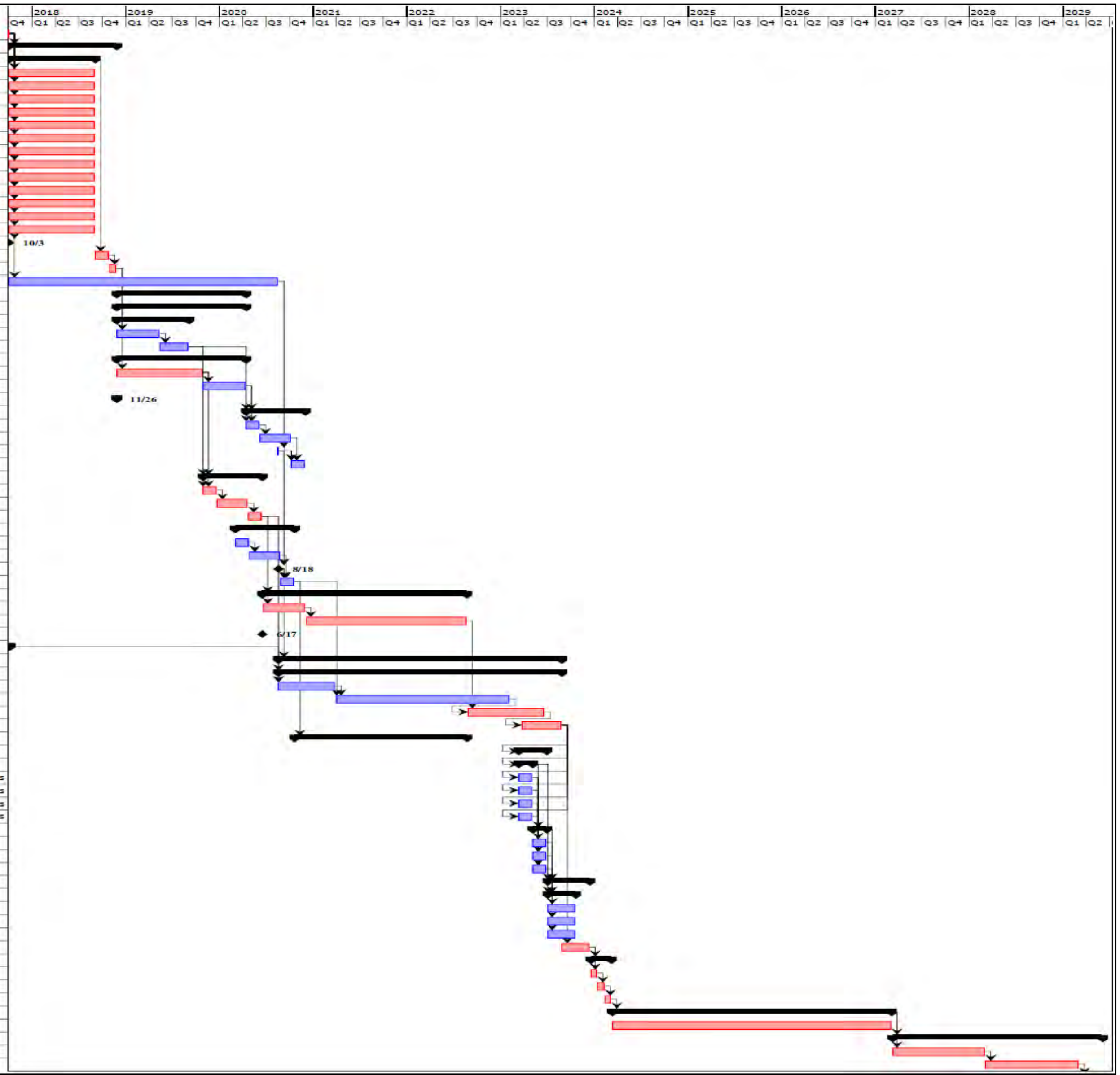


Figure G–4. Refurbishment (optimistic) – 80 ppy

	Name	Duration	Predecessors
1	Alternative Decision Completed	0 days	
2	**CD-1**	**300 days**	**1**
3	**Develop CD-1 Package (413.3b Appendix A) (t...**	**240 days**	
4	Acquisition Strategy	240 days	1
5	Develop Project Execution Plan (PEP)	240 days	1
6	Technology Maturation Plan	240 days	1
7	Technology Readiness Assessment	240 days	1
8	Integrated Safety Management Plan	240 days	1
9	Quality Assurance Plan	240 days	1
10	Update Project Data Sheet	240 days	1
11	Identify Safety and Security Reqs	240 days	1
12	Authorization Basis	240 days	1
13	Initiate Code of Record	240 days	1
14	Prepare SDS	240 days	1
15	Independent Project Review	240 days	1
16	Conceptual Safety Design Report	240 days	1
17	Concetual Safety Validation Report	0 days	1
18	CD-1 Package Reviews (ICE,+)	40 days	3
19	CD-1 Approval	20 days	18
20	NEPA Process	980 days	1
21	**Engineering Design/PED (Title I and Title II Desi...**	**360 days**	
22	**Existing Facility Retrofit**	**360 days**	
23	**Demolition Design/Engineering**	**200 days**	
24	Title I Design - Existing Facility/Systems/Utilities-D...	120 days	19
25	Title II Design - Existing Facility/Systems/Utilities-D...	80 days	24
26	**Retrofit Design/Engineering**	**360 days**	
27	Title I Design - Existing Facility/Systems/Utilities-R...	240 days	19
28	Title II Design - Existing Facility/Systems/Utilities-R...	120 days	27
29	**New Facility Design/Engineering**	**0 days**	
34	**CD-2**	**315 days?**	**25;28;32;33**
35	Develop CD-2 Package (413.3b Appendix A)	40 days	25;28;32;33
36	CD-2 Package Reviews (ICE/EIR/IPR/+)	173 days	35
37	NEPA Action - Complete EIS	1 day?	20
38	CD-2 Approval	40 days	36;37
39	**CD-3a+ - Long-Lead, Bulks, Engineered Equipme...**	**253 days**	**25;27;31;33**
40	Develop CD-3a+ Package(s) (413.3b Appendix A)	40 days	25;27;31;33
41	CD-3a+ Package Review(s) (ICE/EIR/IPR)	173 days	40
42	CD-3a+ Approvals	40 days	41
43	**CD-3**	**255 days**	**25;28;32;33**
44	Develop CD-3 Package (413.3b Appendix A)	40 days	32;33
45	CD Package Review(s) (ICE/EIR/IPR)	173 days	44
46	NEPA Record of Decision	0 days	20;37
47	CD-3 Approvals	40 days	45;46
48	**Procurements - Long Lead, Bulks, Engineered Eq...**	**748 days**	**42**
49	Contractor selections	120 days	42
50	Fabrication and Deliveries	628 days	49
51	Dummy Task---Remove - Do Not link or load	0 days	
52	**Supporting Facility**	**5 days?**	
58	**Construction**	**1,017 days**	**46**
59	**Existing Facility**	**1,017 days**	**42**
60	Demolition / Removal	160 days	42;47;52
61	Facility Retrofits (Struct., Mech., Elec., I&C., Comm...	502 days	47;60
62	Engineered Equipment Installation & Systems Hookups	400 days	50;61FS-130 days
63	Testing, Startup & Commissioning	150 days	62FS-65 days
64	**New Facility**	**514 days**	**47**
69	**Process Prove-In**	**80 days**	**68FS-6 months;63FS-6 ...**
70	**Procedures Development**	**40 days**	**68FS-6 months;63FS-6 ...**
71	Operation Procedures	40 days	68FS-6 months;63FS-6 months
72	Maintenance Procedures	40 days	68FS-6 months;63FS-6 months
73	Emergency Response Procedures	40 days	68FS-6 months;63FS-6 months
74	Off-Normal Operations Procedures	40 days	68FS-6 months;63FS-6 months
75	**Personnel Training**	**40 days**	**70**
76	Operations Personnel	40 days	71
77	Maintenance Personnel	40 days	72
78	Site and Facility Emergency Response Personnel	40 days	71;72;73;74
79	**ORR**	**120 days**	**70;75**
80	**Proficiency Demonstration**	**80 days**	**70;75**
81	Operations	80 days	76
82	Maintenance	80 days	77
83	Emergency Response	80 days	78
84	Documentation (Quality, Safety, IH, Engineering, etc.)	80 days	63;68
85	**CD-4**	**60 days**	**84**
86	Develop CD-4 Package (413.3b Appendix A)	20 days	84
87	CD-4 Package Review(s)	20 days	86
88	CD-4 Approval	20 days	87
89	**WR Process Qualification**	**780 days**	**88**
90	Conclude WR Process Certification	780 days	
91	**Production Rampup**	**586 days**	**89**
92	Start 30 ppy	260 days	89
93	Start 60 ppy	260 days	92

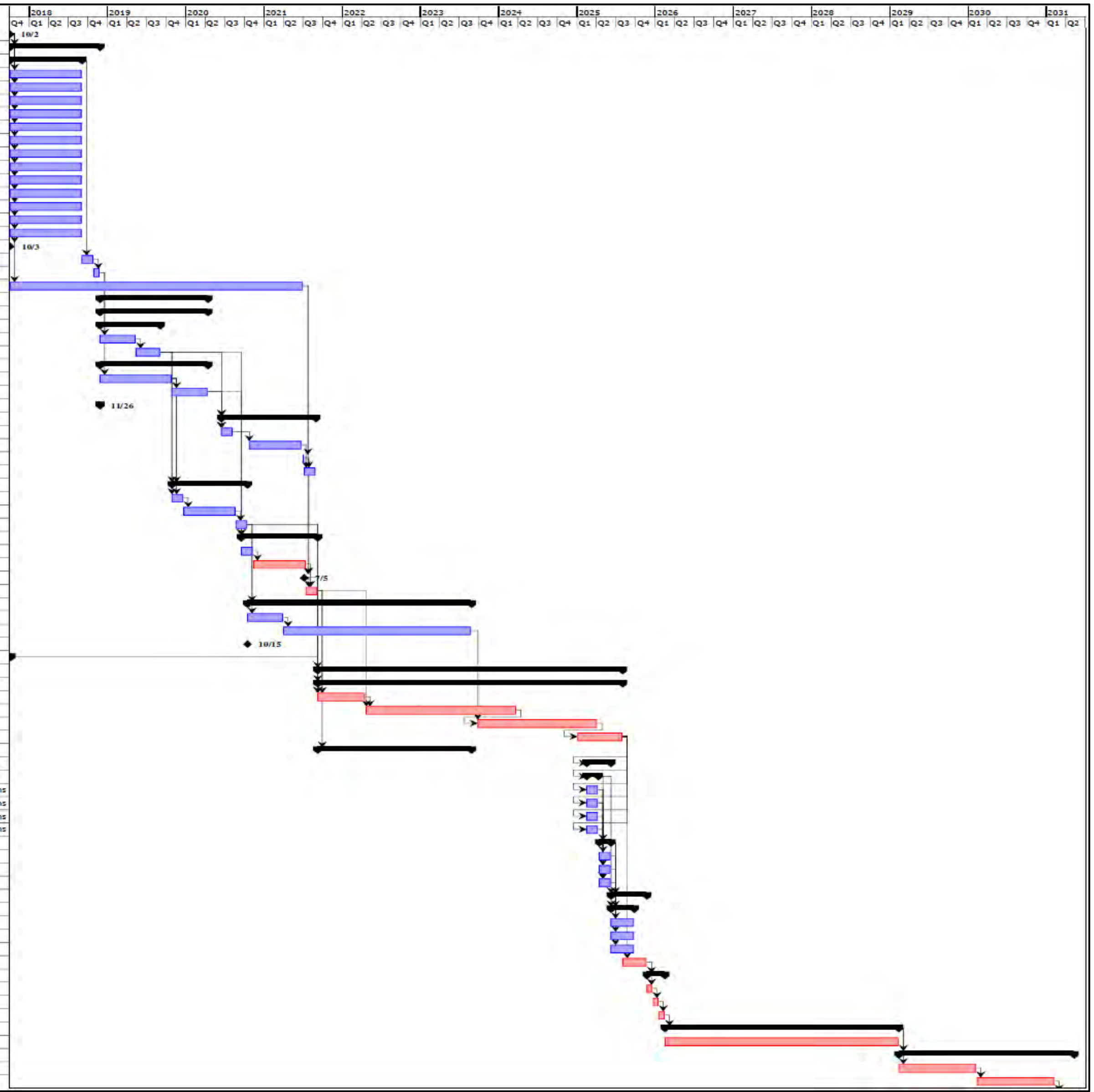


Figure G–5. Refurbishment (most likely) – 80 ppy

	Name	Duration	Predecessors
1	Alternative Decision Compl...	1 day	
2	**CD-1**	**300 days**	**1**
3	**Develop CD-1 Packag...**	**240 days**	
4	Acquisition Strategy	240 days	1
5	Develop Project Execu...	240 days	1
6	Technology Maturation...	240 days	1
7	Technology Readiness ...	240 days	1
8	Integrated Safety Man...	240 days	1
9	Quality Assurance Plan	240 days	1
10	Update Project Data S...	240 days	1
11	Identify Safety and Se...	240 days	1
12	Authorization Basis	240 days	1
13	Initiate Code of Record	240 days	1
14	Prepare SDS	240 days	1
15	Independent Project R...	240 days	1
16	Conceptual Safety Des...	240 days	1
17	Concetual Safety Valid...	0 days	1
18	CD-1 Package Reviews (...	40 days	3
19	CD-1 Approval	20 days	18
20	NEPA Process	1,208 days	1
21	**Engineering Design/PE...**	**360 days**	
22	**Existing Facility Retro...**	**360 days**	
23	**Demolition Design/...**	**200 days**	
24	Title I Design - Existi...	120 days	19
25	Title II Design - Existi...	80 days	24
26	**Retrofit Design/Eng...**	**360 days**	
27	Title I Design - Existi...	240 days	19
28	Title II Design - Existi...	120 days	27
29	**New Facility Design/E...**	**0 days**	
34	**CD-2**	**465 days?**	**25;28;32;33**
35	Develop CD-2 Package (...	40 days	25;28;32;33
36	CD-2 Package Reviews (...	260 days	35
37	NEPA Action - Complete ...	1 day?	20
38	CD-2 Approval	40 days	36;37
39	**CD-3a+ - Long-Lead, B...**	**340 days**	**25;27;31;33**
40	Develop CD-3a+ Packag...	40 days	25;27;31;33
41	CD-3a+ Package Review...	260 days	40
42	CD-3a+ Approvals	40 days	41
43	**CD-3**	**342 days**	**32;33**
44	Develop CD-3 Package (...	40 days	32;33
45	CD Package Review(s) (I...	260 days	44
46	NEPA Record of Decision	0 days	20;37
47	CD-3 Approvals	40 days	45;46
48	**Procurements - Long L...**	**840 days**	**42**
49	Contractor selections	120 days	42
50	Fabrication and Deliveries	720 days	49
51	Dummy Task---Remove -...	0 days	
52	**Supporting Facility**	**5 days?**	
58	**Construction**	**1,980 days**	**46**
59	**Existing Facility**	**1,980 days**	**42**
60	Demolition / Removal	390 days	42;47;52
61	Facility Retrofits (Struc...	985 days	47;60
62	Engineered Equipment ...	650 days	50;61FS-130 days
63	Testing, Startup & Co...	150 days	62FS-65 days
64	**New Facility**	**471 days**	**47**
69	**Process Prove-In**	**80 days**	**68FS-6 months;63FS-6 ...**
70	**Procedures Develop...**	**40 days**	**68FS-6 months;63FS-6 ...**
71	Operation Procedures	40 days	68FS-6 months;63FS-6 months
72	Maintenance Procedures	40 days	68FS-6 months;63FS-6 months
73	Emergency Response ...	40 days	68FS-6 months;63FS-6 months
74	Off-Normal Operations...	40 days	68FS-6 months;63FS-6 months
75	**Personnel Training**	**40 days**	**70**
76	Operations Personnel	40 days	71
77	Maintenance Personnel	40 days	72
78	Site and Facility Emerg...	40 days	71;72;73;74
79	**ORR**	**120 days**	**70;75**
80	**Proficiency Demonstr...**	**80 days**	**70;75**
81	Operations	80 days	76
82	Maintenance	80 days	77
83	Emergency Response	80 days	78
84	Documentation (Quality,...	80 days	63;68
85	**CD-4**	**60 days**	**84**
86	Develop CD-4 Package (...	20 days	84
87	CD-4 Package Review(s)	20 days	86
88	CD-4 Approval	20 days	87
89	**WR Process Qualification**	**780 days**	**88**
90	Conclude WR Process C...	780 days	
91	**Production Rampup**	**586 days**	**89**
92	Start 30 ppy	260 days	89
93	Start 60 ppy	260 days	92

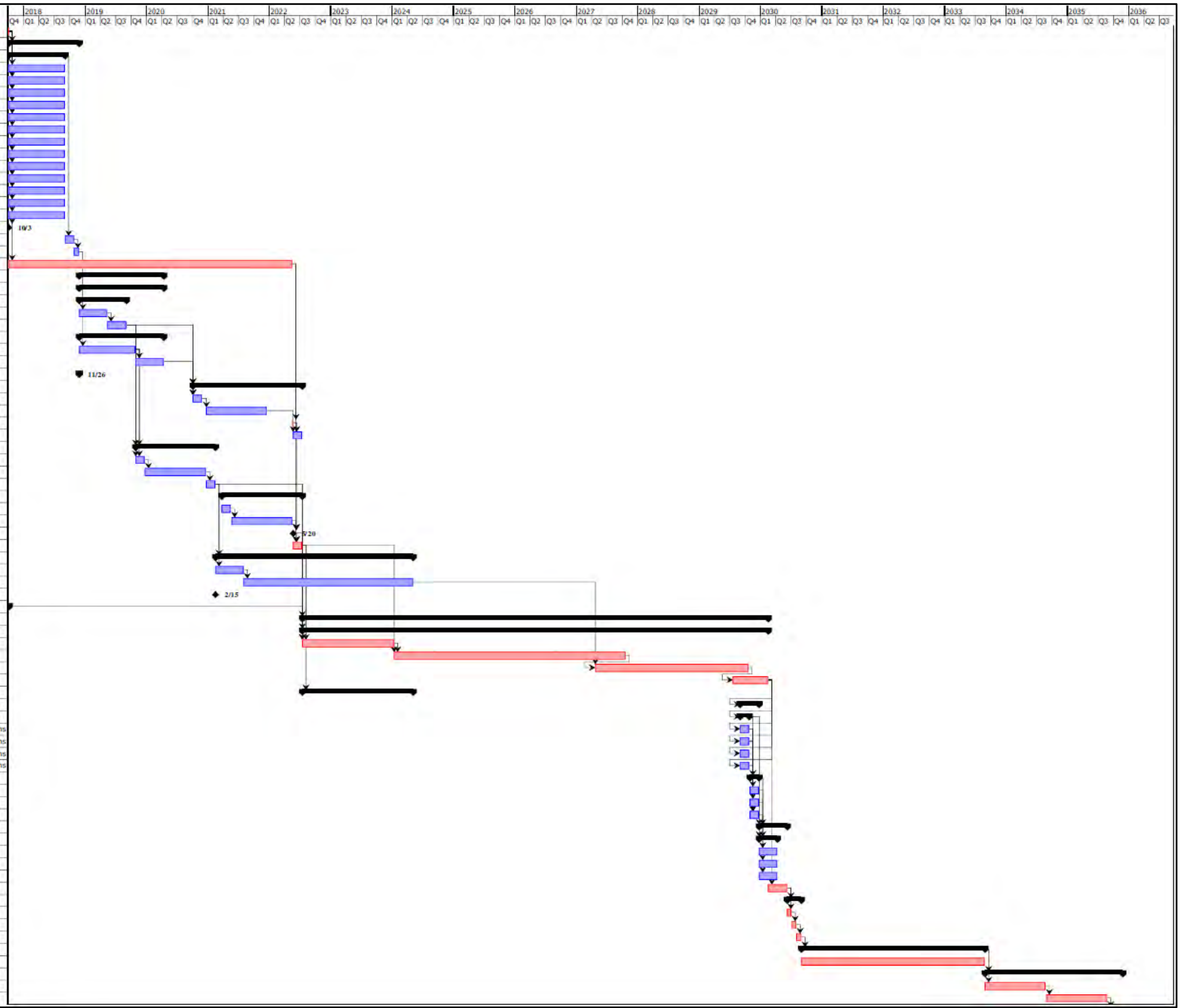


Figure G–6. Refurbishment (pessimistic) – 80 ppy

	Name	Duration	Predecessors
1	Alternative Decision Completed	1 day	
2	CD-1	300 days	1
3	Develop CD-1 Package (413...	240 days	
4	Acquisition Strategy	240 days	1
5	Develop Project Execution Pla...	240 days	1
6	Technology Maturation Plan	240 days	1
7	Technology Readiness Assess...	240 days	1
8	Integrated Safety Manageme...	240 days	1
9	Quality Assurance Plan	240 days	1
10	Update Project Data Sheet	240 days	1
11	Identify Safety and Security ...	240 days	1
12	Authorization Basis	240 days	1
13	Initiate Code of Record	240 days	1
14	Prepare SDS	240 days	1
15	Independent Project Review	240 days	1
16	Conceptual Safety Design Re...	240 days	1
17	Concetual Safety Validation R...	0 days	1
18	CD-1 Package Reviews (ICE,+)	40 days	3
19	CD-1 Approval	20 days	18
20	NEPA Process	752 days	1
21	Engineering Design/PED (Titl...	720 days	
22	Existing Facility Retrofit	0 days	
29	New Facility Design/Enginee...	720 days	
30	Title I Design - New Facility & ...	440 days	19
31	Title I Design - Engineered Eq...	360 days	19
32	Title II Design - New Facility &...	280 days	30
33	Title II Design - Engineered Eq...	160 days	31
34	CD-2	167 days	25;28;32;33
35	Develop CD-2 Package (413.3b ...	40 days	25;28;32;33
36	CD-2 Package Reviews (ICE/EI...	87 days	35
37	NEPA Action - Complete EIS	1 day	20
38	CD-2 Approval	40 days	36;37
39	CD-3a+ - Long-Lead, Bulks, E...	167 days	25;27;31;33
40	Develop CD-3a+ Package(s) (4...	40 days	25;27;31;33
41	CD-3a+ Package Review(s) (IC...	87 days	40
42	CD-3a+ Approvals	40 days	41
43	CD-3	167 days	32;33
44	Develop CD-3 Package (413.3b ...	40 days	32;33
45	CD Package Review(s) (ICE/EIR...	87 days	44
46	NEPA Record of Decision	1 day	20
47	CD-3 Approvals	40 days	45;46
48	Procurements - Long Lead, B...	520 days	42
49	Contractor selections	120 days	42
50	Fabrication and Deliveries	400 days	49
51	Dummy Task---Remove - Do Not...	0 days	
52	Supporting Facility	5 days?	
58	Construction	1,313 days	46
59	Existing Facility	486 days	42
64	New Facility	1,147 days	47
65	Site Prep	240 days	47
66	Construction (Struct., Mech.,...	405 days	65
67	Engineered Equipment Installa...	325 days	50;66FS-130 days
68	Testing, Startup & Commissio...	372 days	67FS-65 days
69	Process Prove-In	80 days	68FS-6 months;63FS-6 ...
70	Procedures Development	40 days	68FS-6 months;63FS-6 ...
71	Operation Procedures	40 days	68FS-6 months;63FS-6 months
72	Maintenance Procedures	40 days	68FS-6 months;63FS-6 months
73	Emergency Response Procedu...	40 days	68FS-6 months;63FS-6 months
74	Off-Normal Operations Proced...	40 days	68FS-6 months;63FS-6 months
75	Personnel Training	40 days	70
76	Operations Personnel	40 days	71
77	Maintenance Personnel	40 days	72
78	Site and Facility Emergency R...	40 days	71;72;73;74
79	ORR	120 days	70;75
80	Proficiency Demonstration	80 days	70;75
81	Operations	80 days	76
82	Maintenance	80 days	77
83	Emergency Response	80 days	78
84	Documentation (Quality, Safety...	80 days	63;68
85	CD-4	60 days	84
86	Develop CD-4 Package (413.3b ...	20 days	84
87	CD-4 Package Review(s)	20 days	86
88	CD-4 Approval	20 days	87
89	WR Process Qualification	780 days	88
90	Conclude WR Process Certification	780 days	
91	Production Rampup	586 days	89
92	Start 30 ppy	260 days	89
93	Start 60 ppy	260 days	92

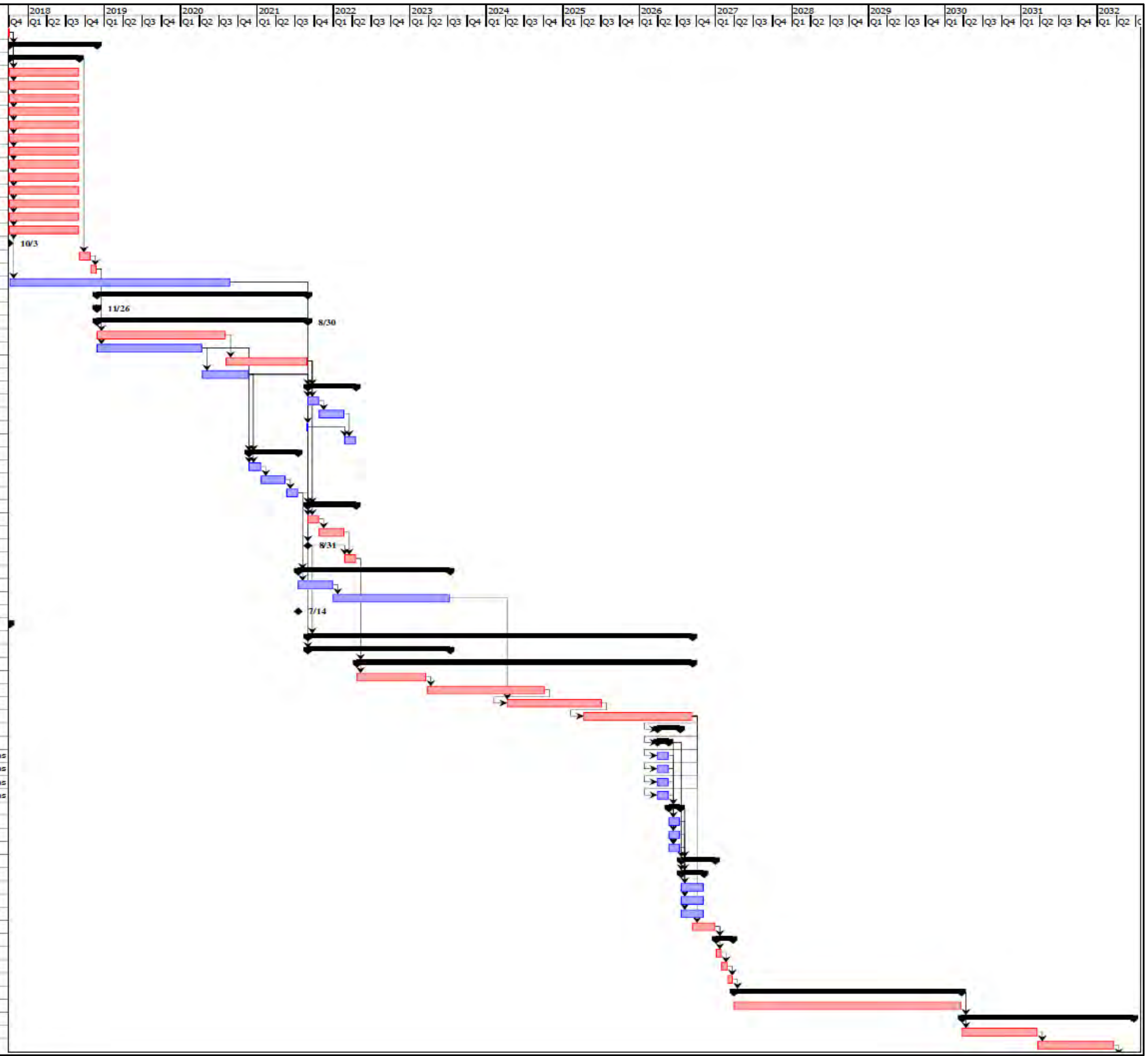


Figure G–7. Build new (optimistic) – 50 ppy

	Name	Duration	Predecessors
1	Alternative Decision Completed	1 day	
2	**CD-1**	**300 days**	**1**
3	**Develop CD-1 Package (413...**	**240 days**	
4	Acquisition Strategy	240 days	1
5	Develop Project Execution Pla...	240 days	1
6	Technology Maturation Plan	240 days	1
7	Technology Readiness Assess...	240 days	1
8	Integrated Safety Manageme...	240 days	1
9	Quality Assurance Plan	240 days	1
10	Update Project Data Sheet	240 days	1
11	Identify Safety and Security ...	240 days	1
12	Authorization Basis	240 days	1
13	Initiate Code of Record	240 days	1
14	Prepare SDS	240 days	1
15	Independent Project Review	240 days	1
16	Conceptual Safety Design Re...	240 days	1
17	Concetual Safety Validation R...	0 days	1
18	CD-1 Package Reviews (ICE,+)	40 days	3
19	CD-1 Approval	20 days	18
20	NEPA Process	980 days	1
21	**Engineering Design/PED (Titl...**	**720 days**	
22	**Existing Facility Retrofit**	**0 days**	
29	**New Facility Design/Enginee...**	**720 days**	
30	Title I Design - New Facility & ...	440 days	19
31	Title I Design - Engineered Eq...	360 days	19
32	Title II Design - New Facility &...	280 days	30
33	Title II Design - Engineered Eq...	160 days	31
34	**CD-2**	**253 days**	**25;28;32;33**
35	Develop CD-2 Package (413.3b ...	40 days	25;28;32;33
36	CD-2 Package Reviews (ICE/EI...	173 days	35
37	NEPA Action - Complete EIS	1 day	20
38	CD-2 Approval	40 days	36;37
39	**CD-3a+ - Long-Lead, Bulks, E...**	**253 days**	**25;27;31;33**
40	Develop CD-3a+ Package(s) (4...	40 days	25;27;31;33
41	CD-3a+ Package Review(s) (IC...	173 days	40
42	CD-3a+ Approvals	40 days	41
43	**CD-3**	**253 days**	**32;33**
44	Develop CD-3 Package (413.3b ...	40 days	32;33
45	CD Package Review(s) (ICE/EIR...	173 days	44
46	NEPA Record of Decision	1 day	20
47	CD-3 Approvals	40 days	45;46
48	**Procurements - Long Lead, B...**	**840 days**	**42**
49	Contractor selections	120 days	42
50	Fabrication and Deliveries	720 days	49
51	Dummy Task---Remove - Do Not...	0 days	
52	**Supporting Facility**	**5 days?**	
58	**Construction**	**1,877 days**	**46**
59	**Existing Facility**	**840 days**	**42**
64	**New Facility**	**1,677 days**	**47**
65	Site Prep	275 days	47
66	Construction (Struct., Mech.,...	837 days	65
67	Engineered Equipment Installa...	520 days	50;66FS-130 days
68	Testing, Startup & Commissio...	240 days	67FS-65 days
69	**Process Prove-In**	**80 days**	**68FS-6 months;63FS-6 ...**
70	**Procedures Development**	**40 days**	**68FS-6 months;63FS-6 ...**
71	Operation Procedures	40 days	68FS-6 months;63FS-6 months
72	Maintenance Procedures	40 days	68FS-6 months;63FS-6 months
73	Emergency Response Procedu...	40 days	68FS-6 months;63FS-6 months
74	Off-Normal Operations Proced...	40 days	68FS-6 months;63FS-6 months
75	**Personnel Training**	**40 days**	**70**
76	Operations Personnel	40 days	71
77	Maintenance Personnel	40 days	72
78	Site and Facility Emergency R...	40 days	71;72;73;74
79	**ORR**	**120 days**	**70;75**
80	**Proficiency Demonstration**	**80 days**	**70;75**
81	Operations	80 days	76
82	Maintenance	80 days	77
83	Emergency Response	80 days	78
84	Documentation (Quality, Safety...	80 days	63;68
85	**CD-4**	**60 days**	**84**
86	Develop CD-4 Package (413.3b ...	20 days	84
87	CD-4 Package Review(s)	20 days	86
88	CD-4 Approval	20 days	87
89	**WR Process Qualification**	**780 days**	**88**
90	Conclude WR Process Certification	780 days	
91	**Production Rampup**	**586 days**	**89**
92	Start 30 ppy	260 days	89
93	Start 60 ppy	260 days	92

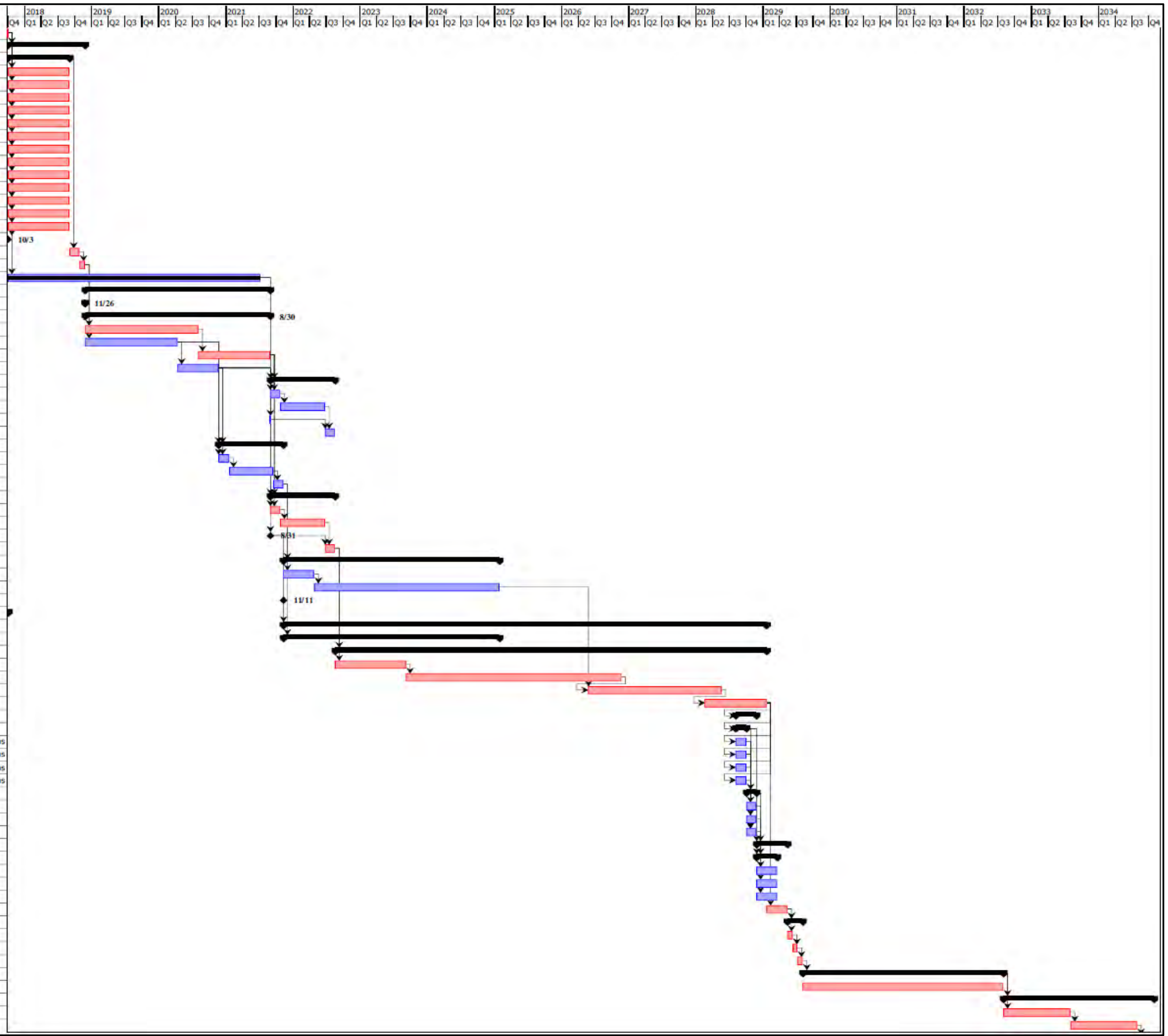


Figure G–8. Build new (most likely) – 50 ppy

	Name	Duration	Predecessors
1	Alternative Decision Completed	1 day	
2	**CD-1**	**300 days**	**1**
3	**Develop CD-1 Package (413...**	**240 days**	
4	Acquisition Strategy	240 days	1
5	Develop Project Execution Pla...	240 days	1
6	Technology Maturation Plan	240 days	1
7	Technology Readiness Assess...	240 days	1
8	Integrated Safety Manageme...	240 days	1
9	Quality Assurance Plan	240 days	1
10	Update Project Data Sheet	240 days	1
11	Identify Safety and Security ...	240 days	1
12	Authorization Basis	240 days	1
13	Initiate Code of Record	240 days	1
14	Prepare SDS	240 days	1
15	Independent Project Review	240 days	1
16	Conceptual Safety Design Re...	240 days	1
17	Concetual Safety Validation R...	0 days	1
18	CD-1 Package Reviews (ICE,+)	40 days	3
19	CD-1 Approval	20 days	18
20	NEPA Process	1,208 days	1
21	**Engineering Design/PED (Titl...**	**720 days**	
22	**Existing Facility Retrofit**	**0 days**	
29	**New Facility Design/Enginee...**	**720 days**	
30	Title I Design - New Facility & ...	440 days	19
31	Title I Design - Engineered Eq...	360 days	19
32	Title II Design - New Facility &...	280 days	30
33	Title II Design - Engineered Eq...	160 days	31
34	**CD-2**	**340 days**	**25;28;32;33**
35	Develop CD-2 Package (413.3b ...	40 days	25;28;32;33
36	CD-2 Package Reviews (ICE/EI...	260 days	35
37	NEPA Action - Complete EIS	1 day	20
38	CD-2 Approval	40 days	36;37
39	**CD-3a+ - Long-Lead, Bulks, E...**	**340 days**	**25;27;31;33**
40	Develop CD-3a+ Package(s) (4...	40 days	25;27;31;33
41	CD-3a+ Package Review(s) (IC...	260 days	40
42	CD-3a+ Approvals	40 days	41
43	**CD-3**	**340 days**	**32;33**
44	Develop CD-3 Package (413.3b ...	40 days	32;33
45	CD Package Review(s) (ICE/EIR...	260 days	44
46	NEPA Record of Decision	1 day	20
47	CD-3 Approvals	40 days	45;46
48	**Procurements - Long Lead, B...**	**840 days**	**42**
49	Contractor selections	120 days	42
50	Fabrication and Deliveries	720 days	49
51	Dummy Task---Remove - Do Not...	0 days	
52	**Supporting Facility**	**5 days?**	
58	**Construction**	**2,347 days**	**46**
59	**Existing Facility**	**787 days**	**42**
64	**New Facility**	**2,200 days**	**47**
65	Site Prep	295 days	47
66	Construction (Struct., Mech.,...	1,130 days	65
67	Engineered Equipment Installa...	730 days	50;66FS-130 days
68	Testing, Startup & Commissio...	240 days	67FS-65 days
69	**Process Prove-In**	**80 days**	**68FS-6 months;63FS-6 ...**
70	**Procedures Development**	**40 days**	**68FS-6 months;63FS-6 ...**
71	Operation Procedures	40 days	68FS-6 months;63FS-6 months
72	Maintenance Procedures	40 days	68FS-6 months;63FS-6 months
73	Emergency Response Procedu...	40 days	68FS-6 months;63FS-6 months
74	Off-Normal Operations Proced...	40 days	68FS-6 months;63FS-6 months
75	**Personnel Training**	**40 days**	**70**
76	Operations Personnel	40 days	71
77	Maintenance Personnel	40 days	72
78	Site and Facility Emergency R...	40 days	71;72;73;74
79	**ORR**	**120 days**	**70;75**
80	**Proficiency Demonstration**	**80 days**	**70;75**
81	Operations	80 days	76
82	Maintenance	80 days	77
83	Emergency Response	80 days	78
84	Documentation (Quality, Safety...	80 days	63;68
85	**CD-4**	**60 days**	**84**
86	Develop CD-4 Package (413.3b ...	20 days	84
87	CD-4 Package Review(s)	20 days	86
88	CD-4 Approval	20 days	87
89	**WR Process Qualification**	**780 days**	**88**
90	Conclude WR Process Certification	780 days	
91	**Production Rampup**	**586 days**	**89**
92	Start 30 ppy	260 days	89
93	Start 60 ppy	260 days	92

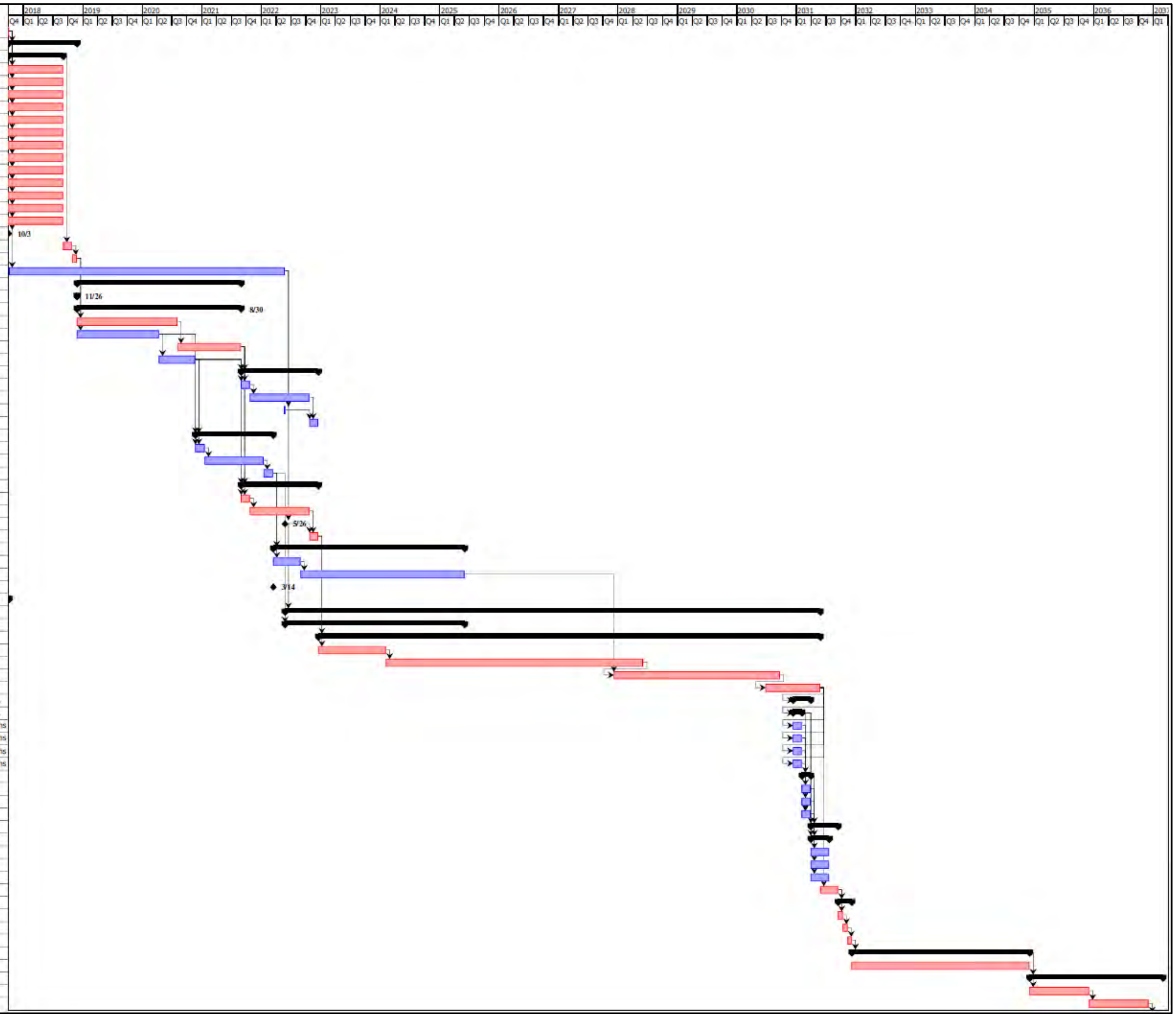


Figure G–9. Build new (pessimistic) – 50 ppy

	Name	Duration	Predecessors
1	Alternative Decision Compl...	1 day	
2	**CD-1**	**300 days**	**1**
3	**Develop CD-1 Packag...**	**240 days**	
4	Acquisition Strategy	240 days	1
5	Develop Project Execu...	240 days	1
6	Technology Maturation...	240 days	1
7	Technology Readiness ...	240 days	1
8	Integrated Safety Man...	240 days	1
9	Quality Assurance Plan	240 days	1
10	Update Project Data S...	240 days	1
11	Identify Safety and Se...	240 days	1
12	Authorization Basis	240 days	1
13	Initiate Code of Record	240 days	1
14	Prepare SDS	240 days	1
15	Independent Project R...	240 days	1
16	Conceptual Safety Des...	240 days	1
17	Concetual Safety Valid...	0 days	1
18	CD-1 Package Reviews (...	40 days	3
19	CD-1 Approval	20 days	18
20	NEPA Process	750 days	1
21	**Engineering Design/PE...**	**360 days**	
22	**Existing Facility Retro...**	**360 days**	
23	**Demolition Design/...**	**200 days**	
24	Title I Design - Existi...	120 days	19
25	Title II Design - Existi...	80 days	24
26	**Retrofit Design/Eng...**	**360 days**	
27	Title I Design - Existi...	240 days	19
28	Title II Design - Existi...	120 days	27
29	**New Facility Design/E...**	**0 days**	
34	**CD-2**	**167 days**	**25;28;32;33**
35	Develop CD-2 Package (...	40 days	25;28;32;33
36	CD-2 Package Reviews (...	87 days	35
37	NEPA Action - Complete ...	1 day	20
38	CD-2 Approval	40 days	36;37
39	**CD-3a+ - Long-Lead, B...**	**167 days**	**25;27;31;33**
40	Develop CD-3a+ Packag...	40 days	25;27;31;33
41	CD-3a+ Package Review...	87 days	40
42	CD-3a+ Approvals	40 days	41
43	**CD-3**	**167 days**	**32;33**
44	Develop CD-3 Package (...	40 days	32;33
45	CD Package Review(s) (I...	87 days	44
46	NEPA Record of Decision	0 days	20;37
47	CD-3 Approvals	40 days	45;46
48	**Procurements - Long L...**	**570 days**	**42**
49	Contractor selections	120 days	42
50	Fabrication and Deliveries	450 days	49
51	Dummy Task---Remove -...	0 days	
52	**Supporting Facility**	**5 days?**	
58	**Construction**	**788 days**	**46**
59	**Existing Facility**	**788 days**	**42**
60	Demolition / Removal	160 days	42;52
61	Facility Retrofits (Struc...	486 days	47;60
62	Engineered Equipment ...	215 days	50;61FS-130 days
63	Testing, Startup & Co...	112 days	62FS-65 days
64	**New Facility**	**480 days**	**47**
69	**Process Prove-In**	**80 days**	**68FS-6 months;63FS-6 ...**
70	**Procedures Develop...**	**40 days**	**68FS-6 months;63FS-6 ...**
71	Operation Procedures	40 days	68FS-6 months;63FS-6 months
72	Maintenance Procedures	40 days	68FS-6 months;63FS-6 months
73	Emergency Response ...	40 days	68FS-6 months;63FS-6 months
74	Off-Normal Operations,...	40 days	68FS-6 months;63FS-6 months
75	**Personnel Training**	**40 days**	**70**
76	Operations Personnel	40 days	71
77	Maintenance Personnel	40 days	72
78	Site and Facility Emerg...	40 days	71;72;73;74
79	**ORR**	**120 days**	**70;75**
80	**Proficiency Demonstr...**	**80 days**	**70;75**
81	Operations	80 days	76
82	Maintenance	80 days	77
83	Emergency Response	80 days	78
84	Documentation (Quality,...	80 days	63;68
85	**CD-4**	**60 days**	**84**
86	Develop CD-4 Package (...	20 days	84
87	CD-4 Package Review(s)	20 days	86
88	CD-4 Approval	20 days	87
89	**WR Process Qualification**	**780 days**	**88**
90	Conclude WR Process C...	780 days	
91	**Production Rampup**	**586 days**	**89**
92	Start 30 ppy	260 days	89
93	Start 60 ppy	260 days	92

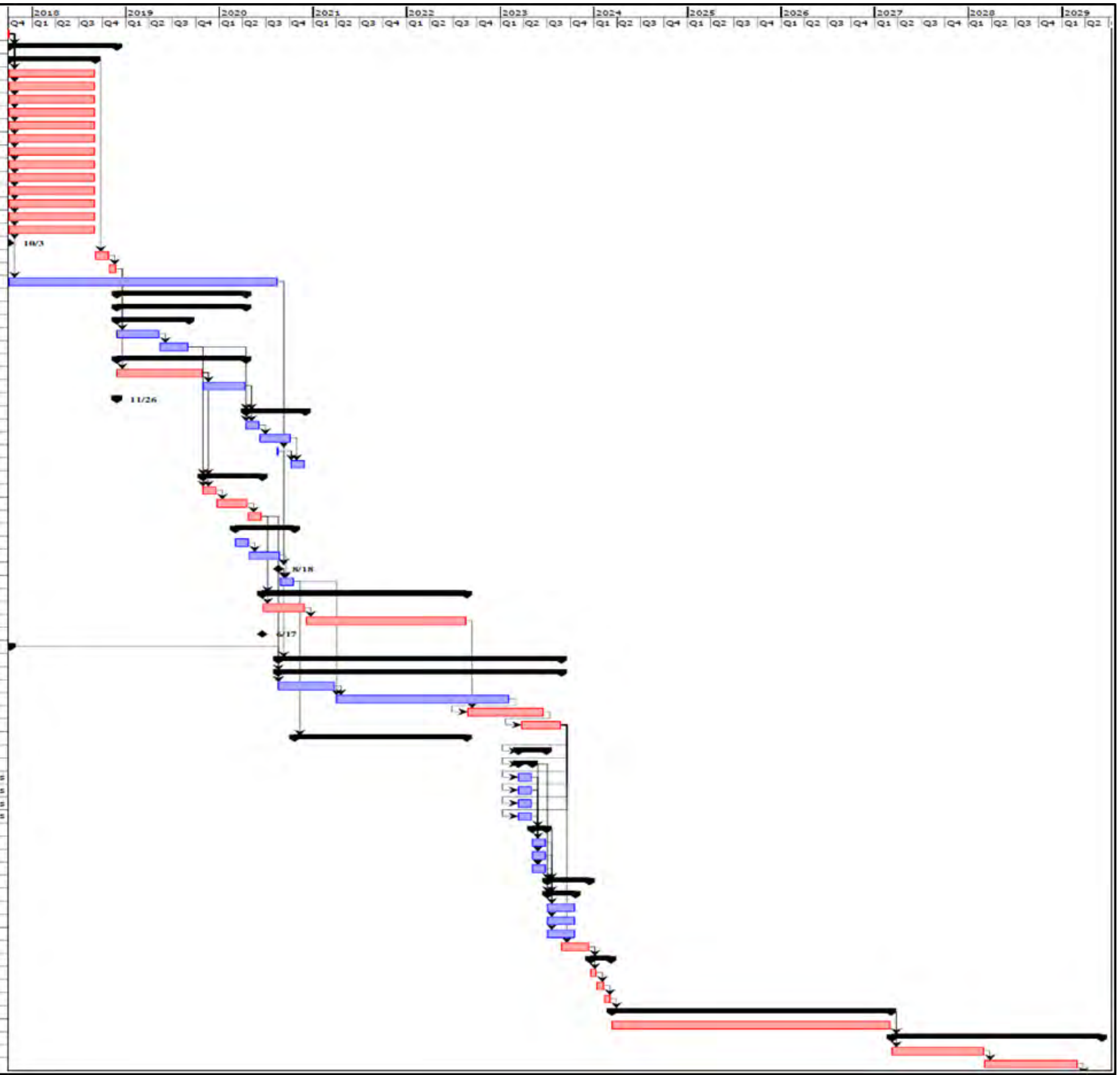


Figure G–10. Refurbishment (optimistic) – 50 ppy

	Name	Duration	Predecessors
1	Alternative Decision Compl...	1 day	
2	CD-1	300 days	1
3	Develop CD-1 Packag...	240 days	
4	Acquisition Strategy	240 days	1
5	Develop Project Execu...	240 days	1
6	Technology Maturation...	240 days	1
7	Technology Readiness ...	240 days	1
8	Integrated Safety Man...	240 days	1
9	Quality Assurance Plan	240 days	1
10	Update Project Data S...	240 days	1
11	Identify Safety and Se...	240 days	1
12	Authorization Basis	240 days	1
13	Initiate Code of Record	240 days	1
14	Prepare SDS	240 days	1
15	Independent Project R...	240 days	1
16	Conceptual Safety Des...	240 days	1
17	Concetual Safety Valid...	0 days	1
18	CD-1 Package Reviews (...	40 days	3
19	CD-1 Approval	20 days	18
20	NEPA Process	980 days	1
21	Engineering Design/PE...	360 days	
22	Existing Facility Retro...	360 days	
23	Demolition Design/...	200 days	
24	Title I Design - Existi...	120 days	19
25	Title II Design - Existi...	80 days	24
26	Retrofit Design/Eng...	360 days	
27	Title I Design - Existi...	240 days	19
28	Title II Design - Existi...	120 days	27
29	New Facility Design/E...	0 days	
34	CD-2	253 days?	25;28;32;33
35	Develop CD-2 Package (...	40 days	25;28;32;33
36	CD-2 Package Reviews (...	173 days	35
37	NEPA Action - Complete ...	1 day?	20
38	CD-2 Approval	40 days	36;37
39	CD-3a+ - Long-Lead, B...	253 days	25;27;31;33
40	Develop CD-3a+ Packag...	40 days	25;27;31;33
41	CD-3a+ Package Review...	173 days	40
42	CD-3a+ Approvals	40 days	41
43	CD-3	257 days	32;33
44	Develop CD-3 Package (...	40 days	32;33
45	CD Package Review(s) (I...	173 days	44
46	NEPA Record of Decision	0 days	20;37
47	CD-3 Approvals	40 days	45;46
48	Procurements - Long L...	748 days	42
49	Contractor selections	120 days	42
50	Fabrication and Deliveries	628 days	49
51	Dummy Task---Remove -...	0 days	
52	Supporting Facility	5 days?	
58	Construction	986 days	46
59	Existing Facility	986 days	42
60	Demolition / Removal	160 days	42;47;52
61	Facility Retrofits (Struc...	480 days	47;60
62	Engineered Equipment ...	381 days	50;61FS-130 days
63	Testing, Startup & Co...	150 days	62FS-65 days
64	New Facility	520 days	47
69	Process Prove-In	80 days	68FS-6 months;63FS-6 ...
70	Procedures Develop...	40 days	68FS-6 months;63FS-6 ...
71	Operation Procedures	40 days	68FS-6 months;63FS-6 months
72	Maintenance Procedures	40 days	68FS-6 months;63FS-6 months
73	Emergency Response ...	40 days	68FS-6 months;63FS-6 months
74	Off-Normal Operations...	40 days	68FS-6 months;63FS-6 months
75	Personnel Training	40 days	70
76	Operations Personnel	40 days	71
77	Maintenance Personnel	40 days	72
78	Site and Facility Emerg...	40 days	71;72;73;74
79	ORR	120 days	70;75
80	Proficiency Demonstr...	80 days	70;75
81	Operations	80 days	76
82	Maintenance	80 days	77
83	Emergency Response	80 days	78
84	Documentation (Quality,...	80 days	63;68
85	CD-4	60 days	84
86	Develop CD-4 Package (...	20 days	84
87	CD-4 Package Review(s)	20 days	86
88	CD-4 Approval	20 days	87
89	WR Process Qualification	780 days	88
90	Conclude WR Process C...	780 days	
91	Production Rampup	586 days	89
92	Start 30 ppy	260 days	89
93	Start 60 ppy	260 days	92

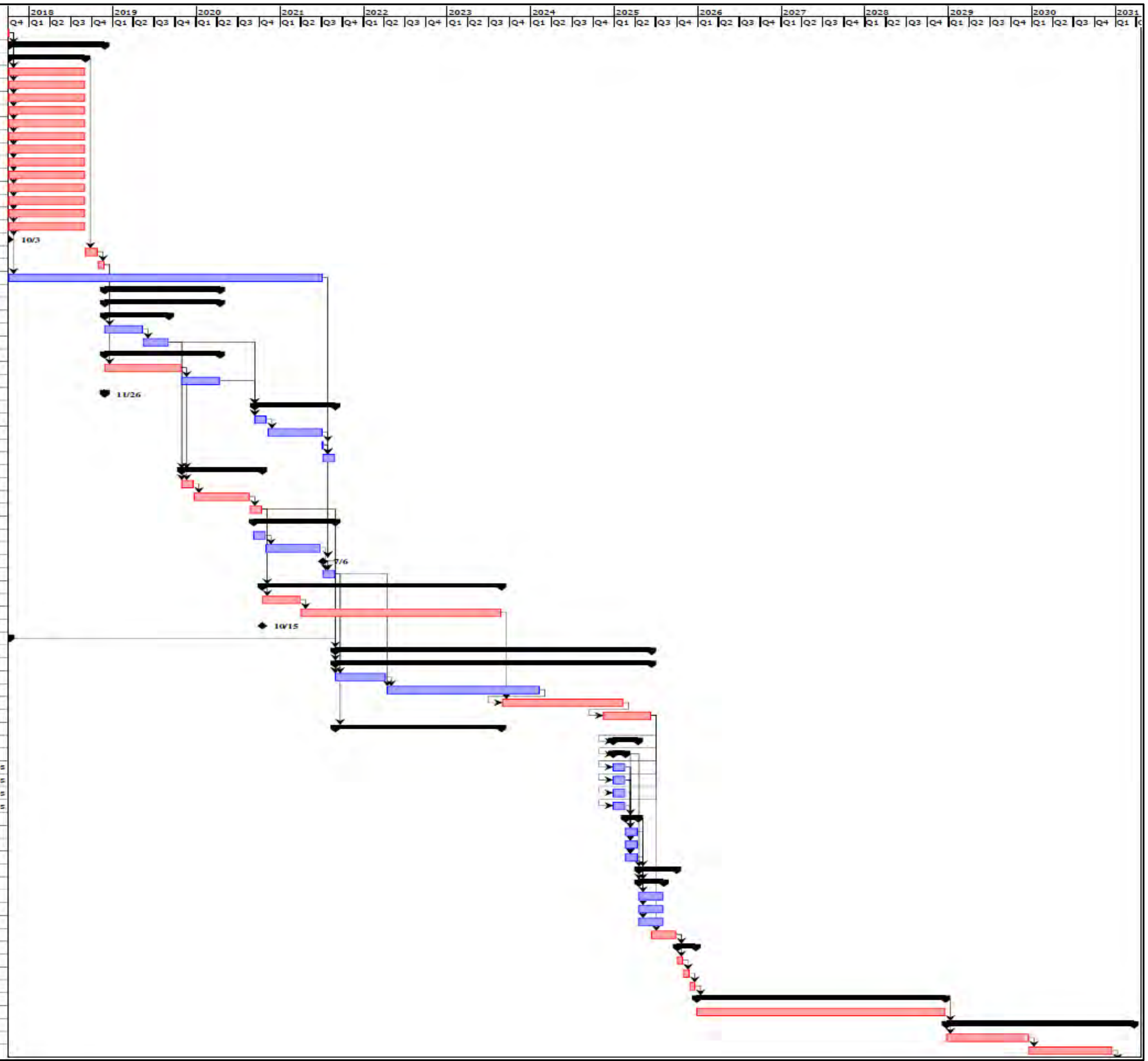


Figure G–11. Refurbishment (most likely) – 50 ppy

	Name	Duration	Predecessors
1	Start 60 ppy	1 day	
2	**CD-1**	**300 days**	**1**
3	**Develop CD-1 Packag...**	**240 days**	
4	Acquisition Strategy	239 days	1
5	Develop Project Execu...	240 days	1
6	Technology Maturation...	240 days	1
7	Technology Readiness ...	240 days	1
8	Integrated Safety Man...	240 days	1
9	Quality Assurance Plan	240 days	1
10	Update Project Data S...	240 days	1
11	Identify Safety and Se...	240 days	1
12	Authorization Basis	240 days	1
13	Initiate Code of Record	240 days	1
14	Prepare SDS	240 days	1
15	Independent Project R...	240 days	1
16	Conceptual Safety Des...	240 days	1
17	Concetual Safety Valid...	0 days	1
18	CD-1 Package Reviews (...	40 days	3
19	CD-1 Approval	20 days	18
20	NEPA Process	1,208 days	1
21	**Engineering Design/PE...**	**360 days**	
22	**Existing Facility Retro...**	**360 days**	
23	**Demolition Design/...**	**200 days**	
24	Title I Design - Existi...	120 days	19
25	Title II Design - Existi...	80 days	24
26	**Retrofit Design/Eng...**	**360 days**	
27	Title I Design - Existi...	240 days	19
28	Title II Design - Existi...	120 days	27
29	**New Facility Design/E...**	**0 days**	
30	Title I Design - New Fa...	0 days	19
31	Title I Design - Enginee...	0 days	19
32	Title II Design - New F...	0 days	30
33	Title II Design - Engine...	0 days	31
34	**CD-2**	**402 days?**	**25;28;32;33**
35	Develop CD-2 Package (...	40 days	25;28;32;33
36	CD-2 Package Reviews (...	313 days	35
37	NEPA Action - Complete ...	1 day?	20
38	CD-2 Approval	40 days	36;37
39	**CD-3a+ - Long-Lead, B...**	**340 days**	**25;27;31;33**
40	Develop CD-3a+ Packag...	40 days	25;27;31;33
41	CD-3a+ Package Review...	260 days	40
42	CD-3a+ Approvals	40 days	41
43	**CD-3**	**343 days**	**32;33**
44	Develop CD-3 Package (...	40 days	32;33
45	CD Package Review(s) (I...	260 days	44
46	NEPA Record of Decision	0 days	20;37
47	CD-3 Approvals	40 days	45;46
48	**Procurements - Long L...**	**840 days**	**42**
49	Contractor selections	120 days	42
50	Fabrication and Deliveries	720 days	49
51	Dummy Task---Remove -...	0 days	
52	**Supporting Facility**	**5 days?**	
58	**Construction**	**1,943 days**	**46**
59	**Existing Facility**	**1,943 days**	**42**
60	Demolition / Removal	545 days	42;47;52
61	Facility Retrofits (Struc...	1,150 days	47
62	Engineered Equipment ...	838 days	50;61FS-130 days
63	Testing, Startup & Co...	150 days	62FS-65 days
64	**New Facility**	**471 days**	**47**
69	**Process Prove-In**	**80 days**	**68FS-6 months;63FS-6 ...**
70	**Procedures Develop...**	**40 days**	**68FS-6 months;63FS-6 ...**
71	Operation Procedures	40 days	68FS-6 months;63FS-6 months
72	Maintenance Procedures	40 days	68FS-6 months;63FS-6 months
73	Emergency Response ...	40 days	68FS-6 months;63FS-6 months
74	Off-Normal Operations...	40 days	68FS-6 months;63FS-6 months
75	**Personnel Training**	**40 days**	**70**
76	Operations Personnel	40 days	71
77	Maintenance Personnel	40 days	72
78	Site and Facility Emerg...	40 days	71;72;73;74
79	**ORR**	**120 days**	**70;75**
80	**Proficiency Demonstr...**	**80 days**	**70;75**
81	Operations	80 days	76
82	Maintenance	80 days	77
83	Emergency Response	80 days	78
84	Documentation (Quality,...	80 days	63;68
85	**CD-4**	**60 days**	**84**
86	Develop CD-4 Package (...	20 days	84
87	CD-4 Package Review(s)	20 days	86
88	CD-4 Approval	20 days	87
89	**WR Process Qualification**	**780 days**	**88**
90	Conclude WR Process C...	780 days	
91	**Production Rampup**	**586 days**	**89**
92	Start 30 ppy	260 days	89
93	Start 60 ppy	260 days	92

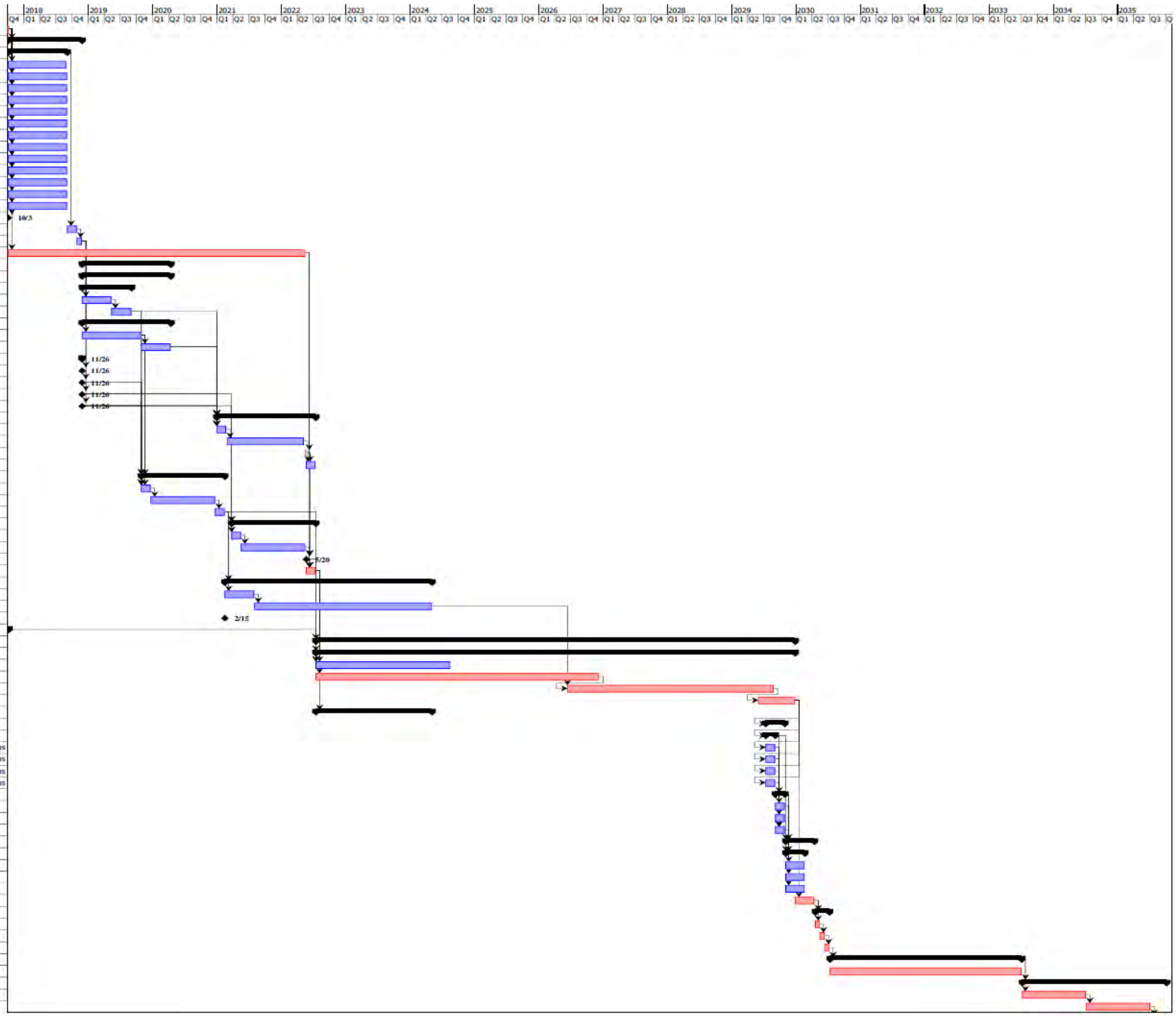


Figure G–12. Refurbishment (pessimistic) – 50 ppy

Appendix H. Building Space Requirements and Analysis

H.1 Overview

The Analysis of Alternatives (AoA) team conducted an analysis of the amount and type of space needed to support 80 pits per year (ppy) production to determine the size of a potential new production facility and to aid in identifying existing facilities that might provide viable alternatives. To better understand these space requirements, the AoA team studied the current layout of the Plutonium Facility (PF-4) as well as the proposed layout of the Modern Pit Facility, with particular emphasis on the ratio of open space to space occupied by equipment and gloveboxes and the amount of Hazard Category 2 and production space relative to other spaces.

H.2 Process Space

The AoA team combined these space requirements with the output from the pit production process model described in Chapter 2 (and in the classified appendix) to determine how much total square footage would be needed for each production activity in a 50 ppy process and an 80 ppy process. **Table H–1** provides a summary of the building footprint area estimated for the three cases, 30 ppy, 50 ppy and 80 ppy. These areas include aisles, access walkways, and space for glovebox-process equipment support service equipment.

Table H–1. Summary of building footprint estimates

Area	Building Footprint (ft^2)		
	30 ppy	50 ppy	80 ppy
1-Disassembly	1,100	1,400	1,700
2-Metal Preparation	2,880	2,880	3,320
3-Foundry	4,730	6,930	8,330
4-Machining and Inspection	4,951	7,651	9,851
5-Subassembly	2,000	3,800	4,200
6-Assembly	7,735	7,867	9,277
7-Post Assembly	3,453	5,453	5,653
Subtotal Manufacturing	**26,849**	**35,981**	**42,331**
8-Aqueous Processing	NI	7,000	7,000
9-Other Areas (identified)	NI	50,340	61,065
10-Building Services (utilities)	NI	16,686	19,631
Subtotal Hazard Category 2 space (production building)	**NI**	**110,007**	**130,027**
11-outside production building	NI	46,800	63,000

NI = Not identified for this case – assumed available in PF-4/TA-55 area

Table H–2 provides the AoA team's comparison of the required overall square footage estimates for the four primary production stages for 80 ppy, and for the Modern Pit Facility project's 125 ppy. As a check on this work, the AoA team researched historical studies to find benchmarks. **Table H–2** shows a comparison of space estimates for the primary pit production functions for this AoA, the analysis of 125 ppy in PF-4, and the Modern Pit Facility. These comparisons demonstrated consistency between the AoA team's estimates and those conducted for the Modern Pit Facility.

Table H–H2. Space requirement estimates for 80 ppy and for 125 ppy average output at PF-4 and the proposed Modern Pit Facility

	PMA AoA 80 ppy 95% confidence = ~104 ppy on average	LANL PF-4 125 ppy avg	MPF 125 ppy avg
Metal Prep	3320	5600	4800
Foundry	8330	9800	8750
Machining	11051	16200	10450
Assembly	11477	9925	15500
Total of Identified Functions	34178	41525	39500

A separate assessment of processing area space requirements was completed independent of the AoA team effort discussed above. This analysis was completed by a Defense Programs Federal staff analyst. It used facilities that were complete or had sufficient design definition to assess planned requirements for special nuclear materials processing and handling equipment in a Hazard Category 2/3 facility, as well as overall building design requirements. Facilities included in this analysis were:

- PF-4, 1st floor (Los Alamos National Laboratory [LANL])
- Mixed Oxide Fuel Fabrication Facility, 1st floor (Savannah River Site [SRS])
- Radiological Laboratory Utility Office Building (RLUOB), 1st floor (LANL)
- Waste Solidification Building, 1st floor (SRS)
- Uranium Processing Facility (Y-12 National Security Complex)

This analysis yielded an estimated equipment footprint of approximately 15,000 square feet for an 80 ppy production rate. Note that, for this analysis, the equipment footprint did not include the space for technicians to perform the process or for maintenance access. The multiplication factors derived from the above facilities are used to scale the equipment footprint to the overall building requirement footprint, where the mean multiplication factor is about 9.0, and 8.1 and 9.8 are at the 10 percent and 90 percent confidence levels, respectively (**Table H–3**). The estimated mean required footprint is about 135,000 square feet. This falls within the uncertainty range estimated by the AoA team.

Table H–3. Equipment estimates at 10%, mean, and 90% confidence levels

Equipment Estimate (Steps 1-9)	15,000 (square feet)
Gross (10%)	122,000 square feet
Gross (mean)	**135,000 square feet**
Gross (90%)	147,000 square feet

Note: These figures were not used for space analysis; instead, the uncertainty of the cost estimate was used to account for the variation in space.

Table H–4 lists the details of the equipment and the areas that the team used to develop the summary tables discussed above (Table H-1).

(b)(3) UCNI

(b)(3) UCNI

(b)(3) UCNI

(b)(3) UCNI

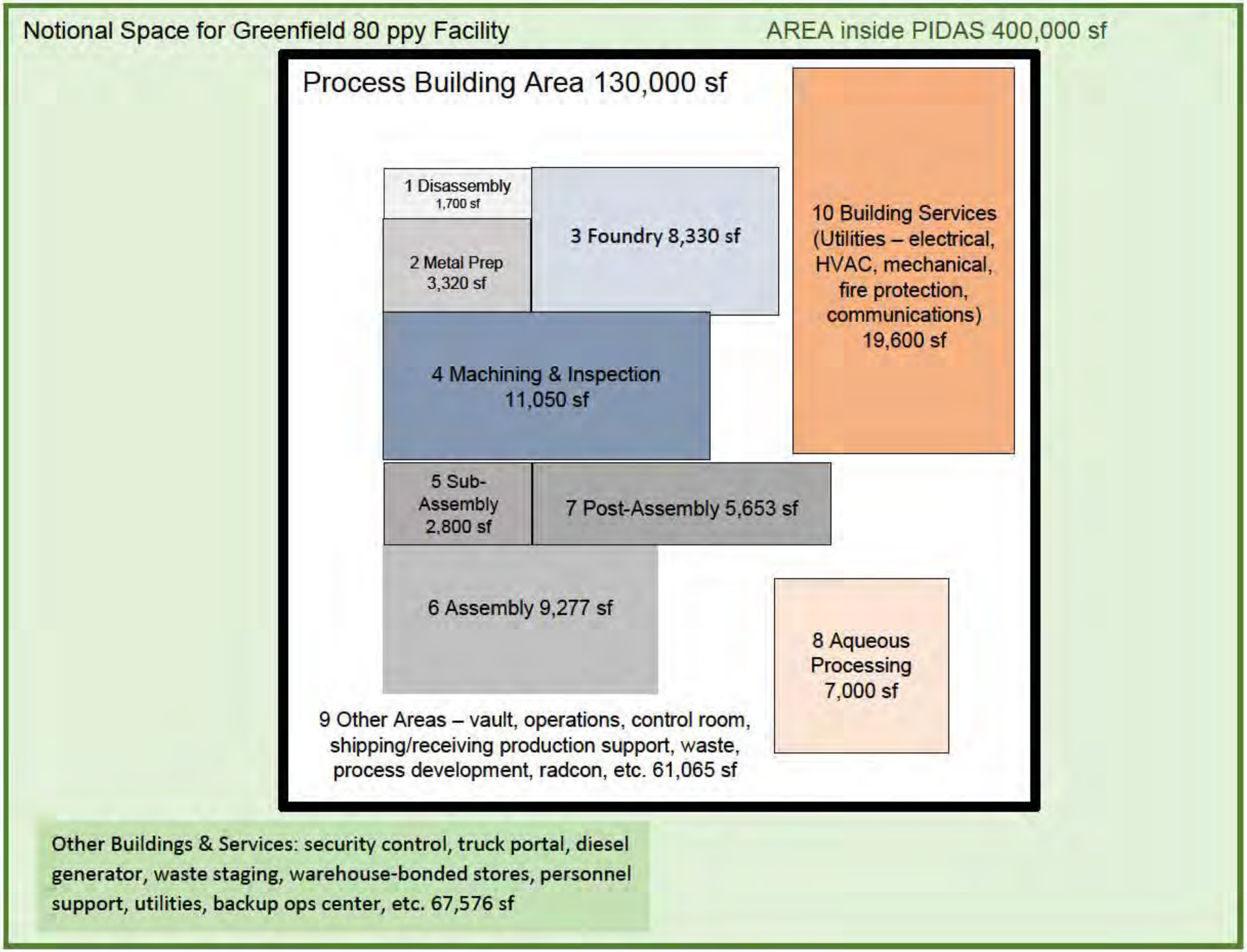
The figures in Section H.3 provide space diagrams for these 80 ppy cases:

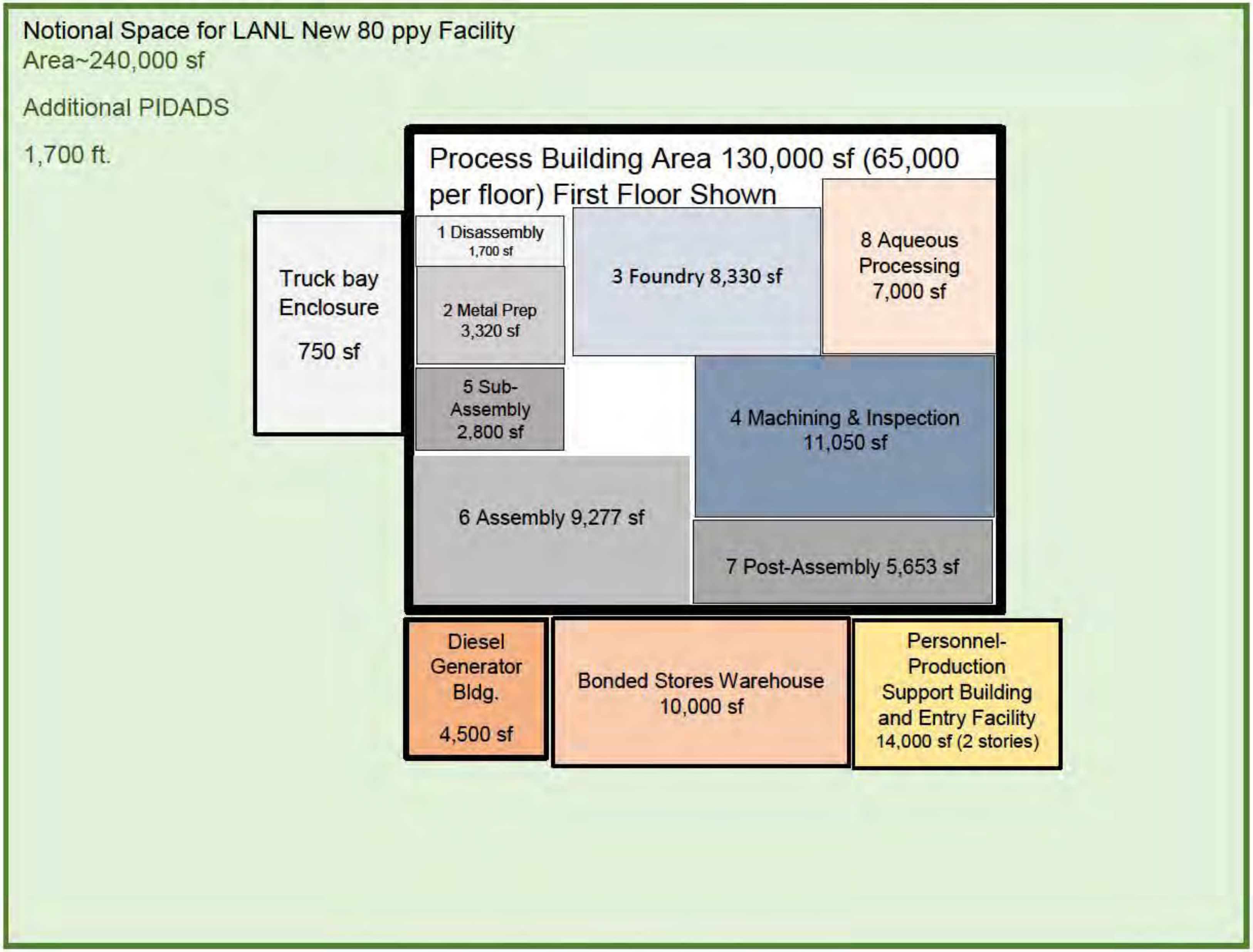
- Greenfield, which is an undeveloped tract of land (new construction)
- LANL (new construction)
- Idaho National Laboratory (INL) Fuel Processing Facility (FPF) (refurbishment)

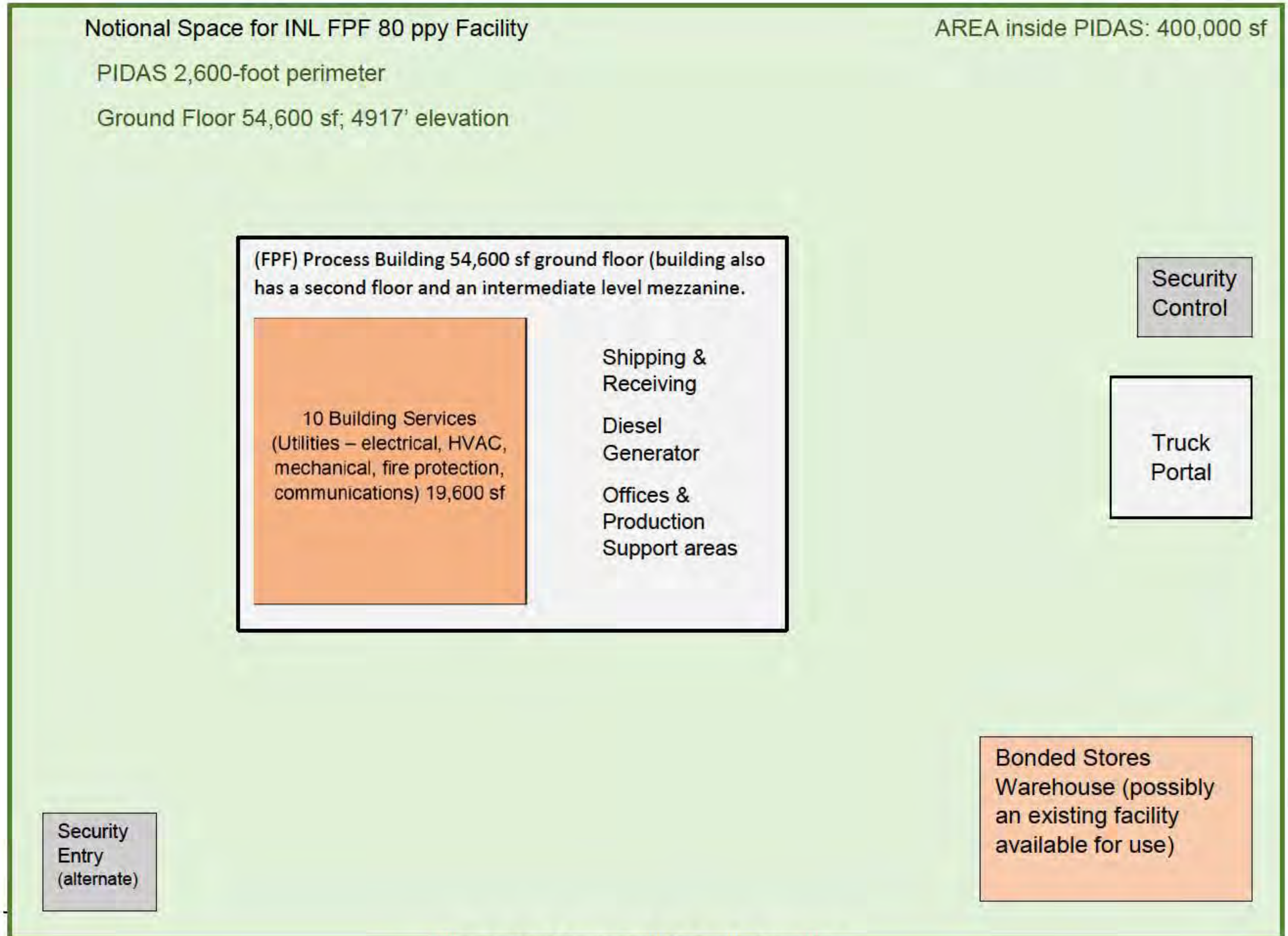
- Mixed Oxide Fuel Fabrication Facility (refurbishment)

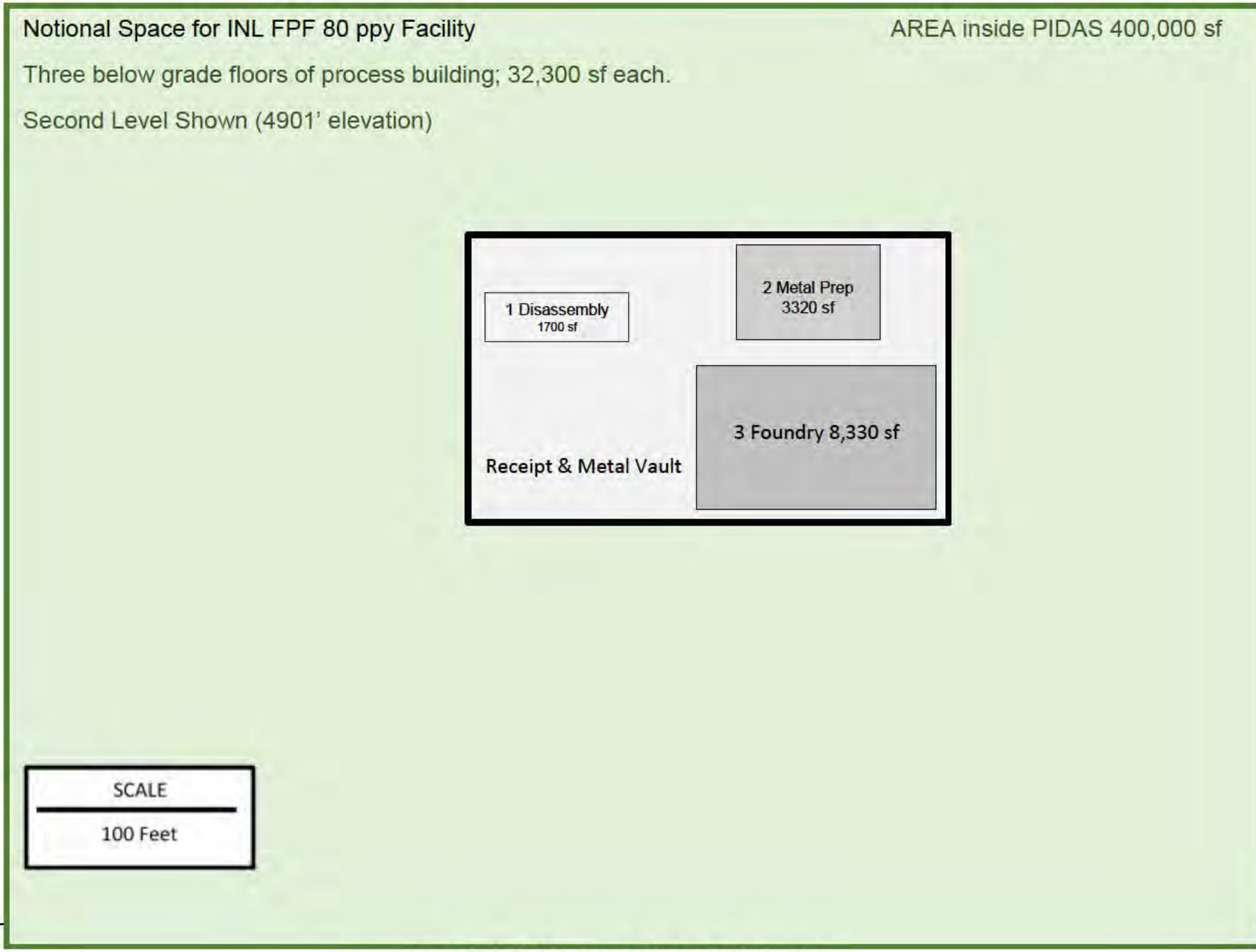
Note that these diagrams are not building layouts but show the areas required by category. For mixed oxide (MOX) and FPF the floors are shown with a notional approach to locating the areas on the various floors, as may be appropriate.

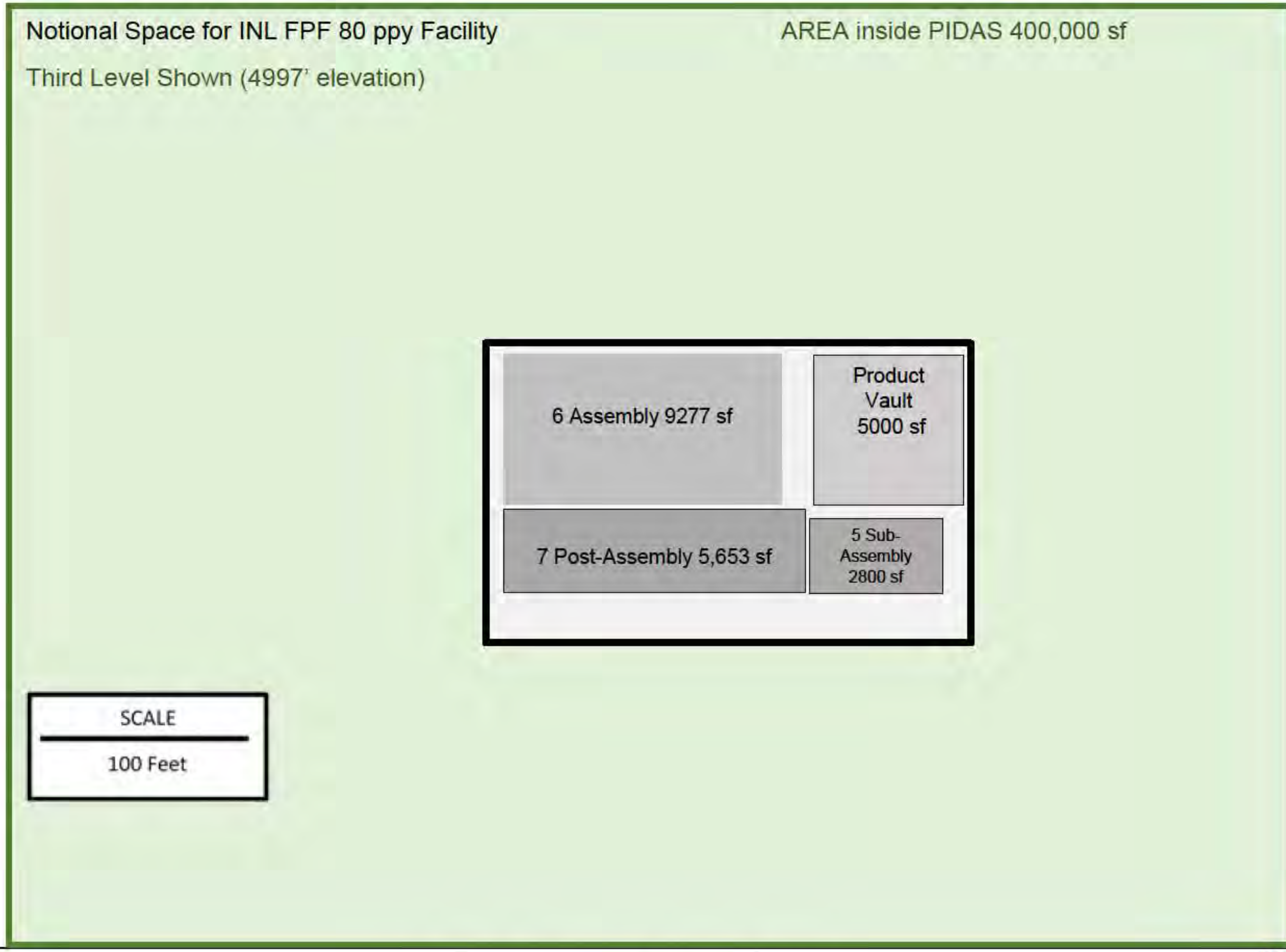
H.3 Building Space Diagrams

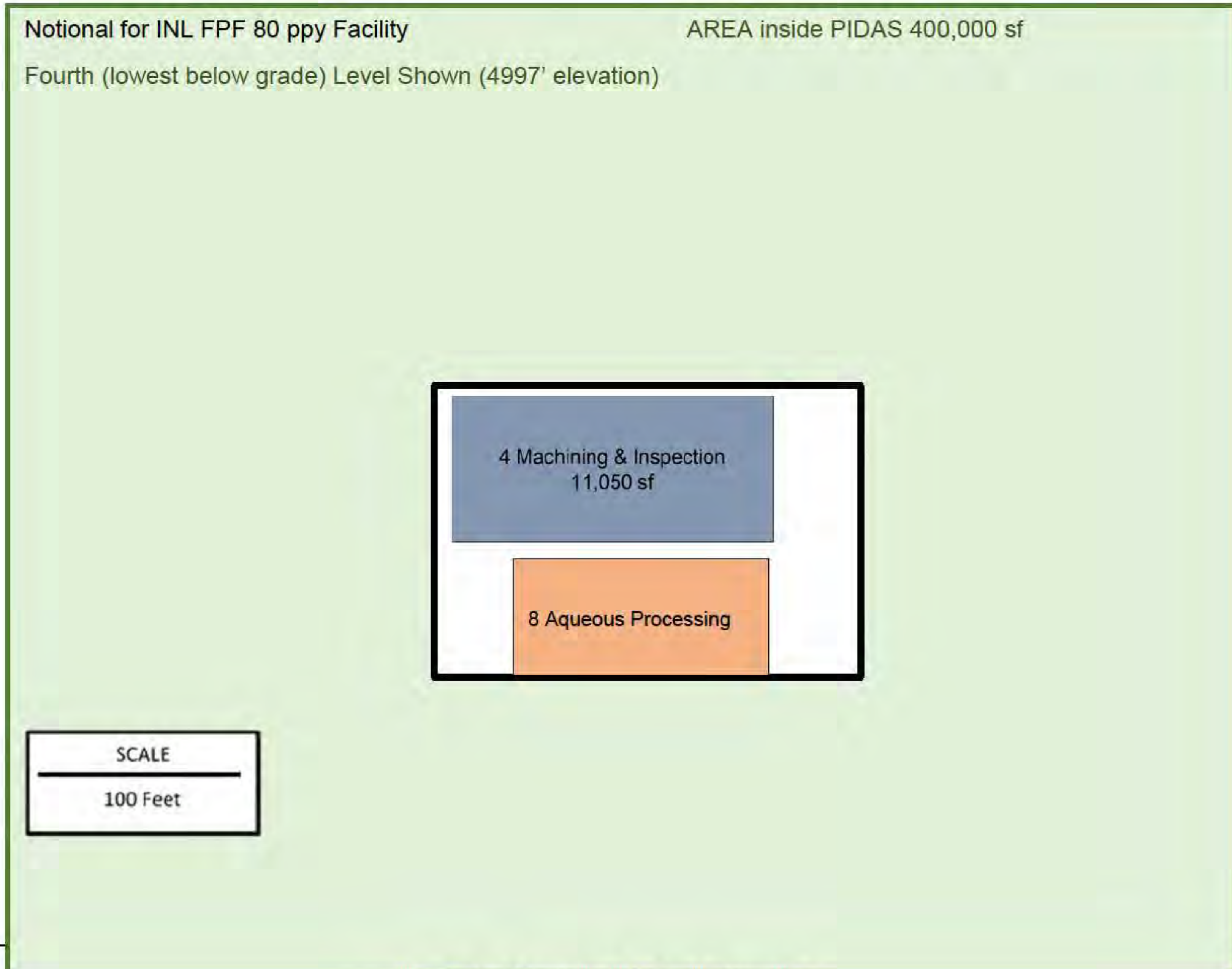

Notional Space for Greenfield 80 ppy Facility
AREA inside PIDAS 400,000 sf
Process Building Area 130,000 sf
1 Disassembly 1,700 sf
2 Metal Prep 3,320 sf
3 Foundry 8,330 sf
4 Machining & Inspection 11,050 sf
5 Sub-Assembly 2,800 sf
7 Post-Assembly 5,653 sf
6 Assembly 9,277 sf
8 Aqueous Processing 7,000 sf
10 Building Services (Utilities – electrical, HVAC, mechanical, fire protection, communications) 19,600 sf
9 Other Areas – vault, operations, control room, shipping/receiving production support, waste, process development, radcon, etc. 61,065 sf
Other Buildings & Services: security control, truck portal, diesel generator, waste staging, warehouse-bonded stores, personnel support, utilities, backup ops center, etc. 67,576 sf

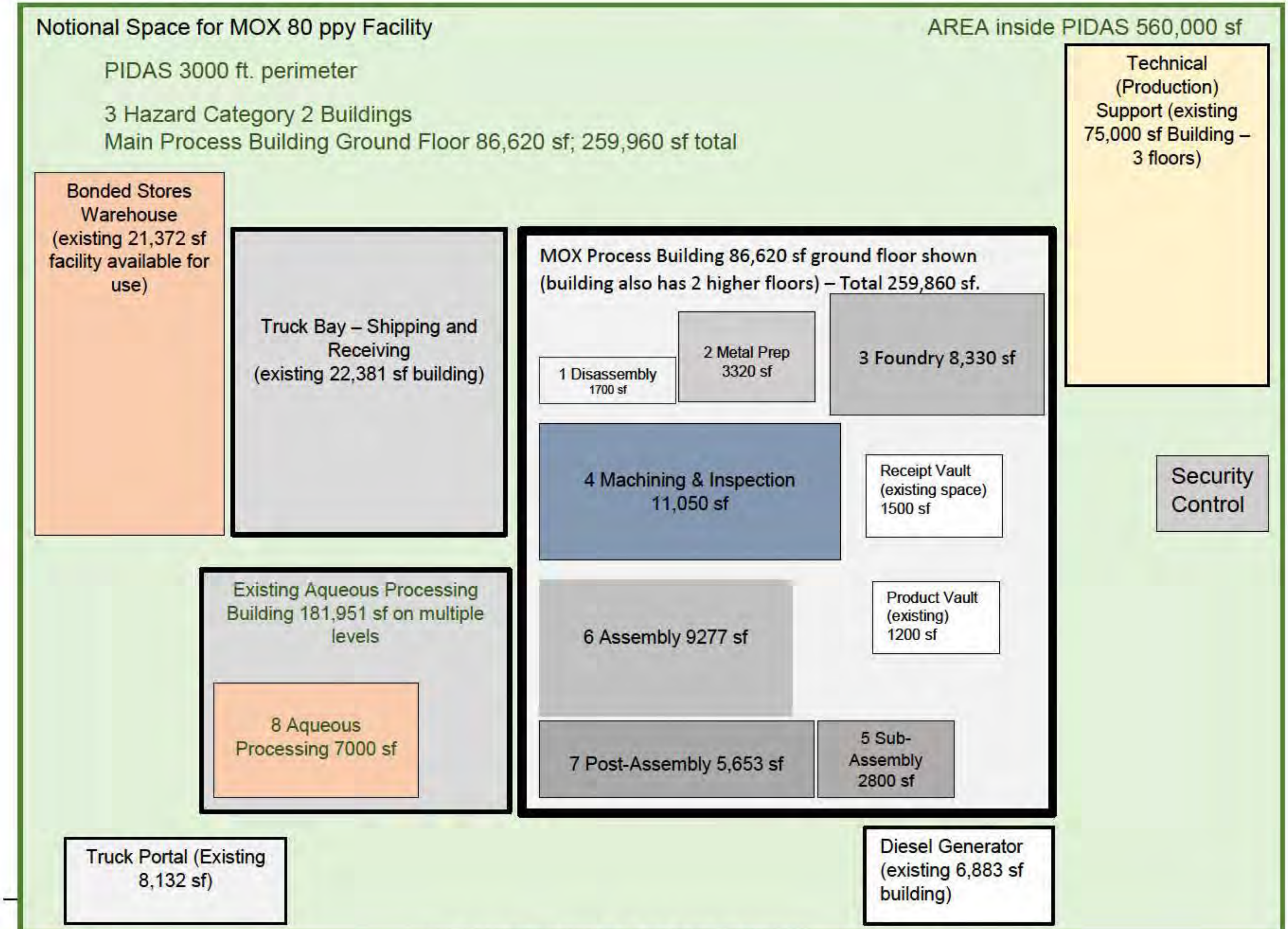

Notional Space for LANL New 80 ppy Facility
Area~240,000 sf
Additional PIDADS
1,700 ft.
Process Building Area 130,000 sf (65,000 per floor) First Floor Shown
Truck bay Enclosure
750 sf
1 Disassembly
1,700 sf
2 Metal Prep
3,320 sf
3 Foundry 8,330 sf
8 Aqueous Processing
7,000 sf
5 Sub-Assembly
2,800 sf
4 Machining & Inspection
11,050 sf
6 Assembly 9,277 sf
7 Post-Assembly 5,653 sf
Diesel Generator Bldg.
4,500 sf
Bonded Stores Warehouse
10,000 sf
Personnel-Production Support Building and Entry Facility
14,000 sf (2 stories)

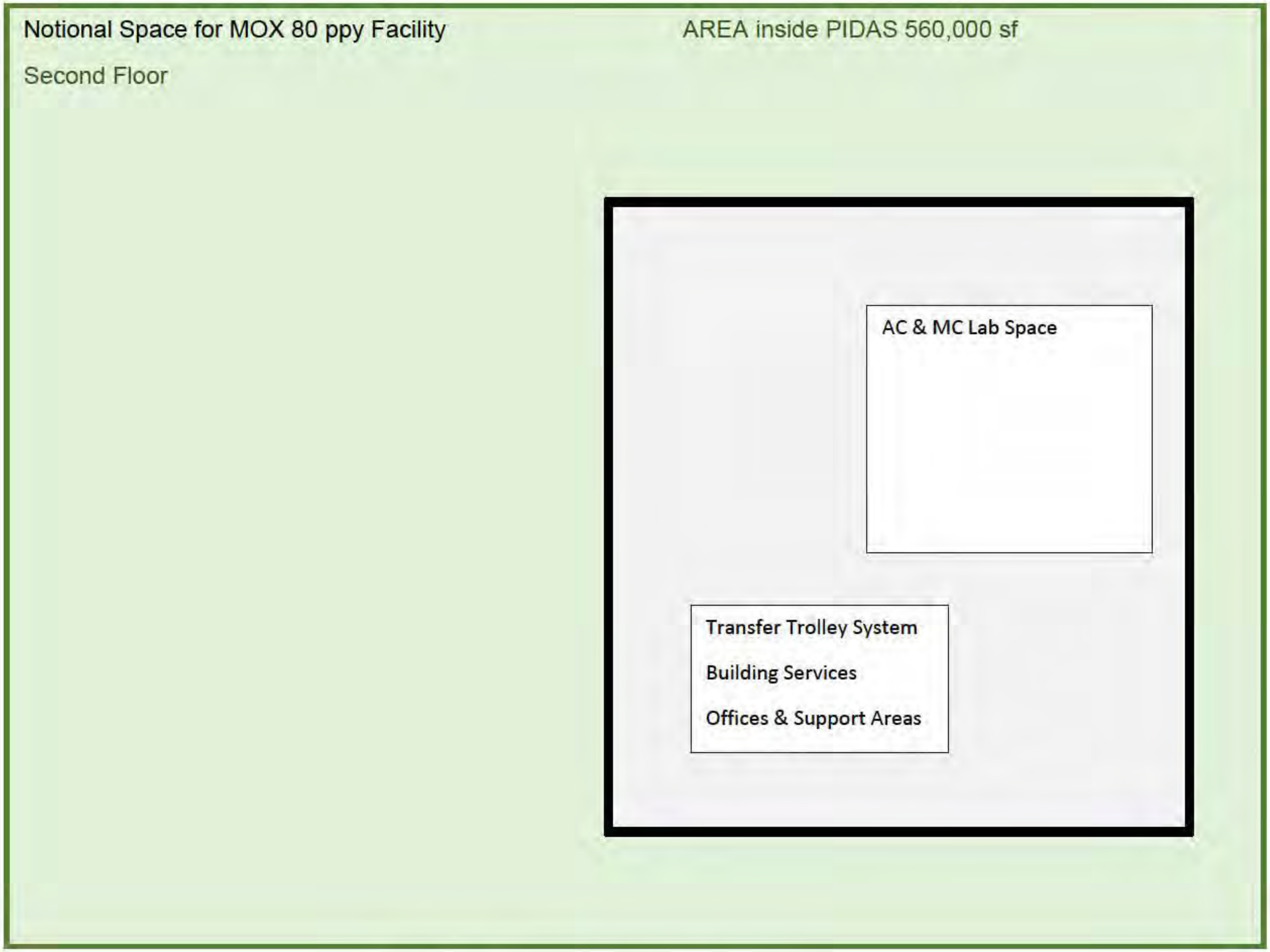

Notional Space for INL FPF 80 ppy Facility
AREA inside PIDAS: 400,000 sf
PIDAS 2,600-foot perimeter
Ground Floor 54,600 sf; 4917' elevation
(FPF) Process Building 54,600 sf ground floor (building also has a second floor and an intermediate level mezzanine.
10 Building Services (Utilities – electrical, HVAC, mechanical, fire protection, communications) 19,600 sf
Shipping & Receiving
Diesel Generator
Offices & Production Support areas
Security Control
Truck Portal
Bonded Stores Warehouse (possibly an existing facility available for use)
Security Entry (alternate)

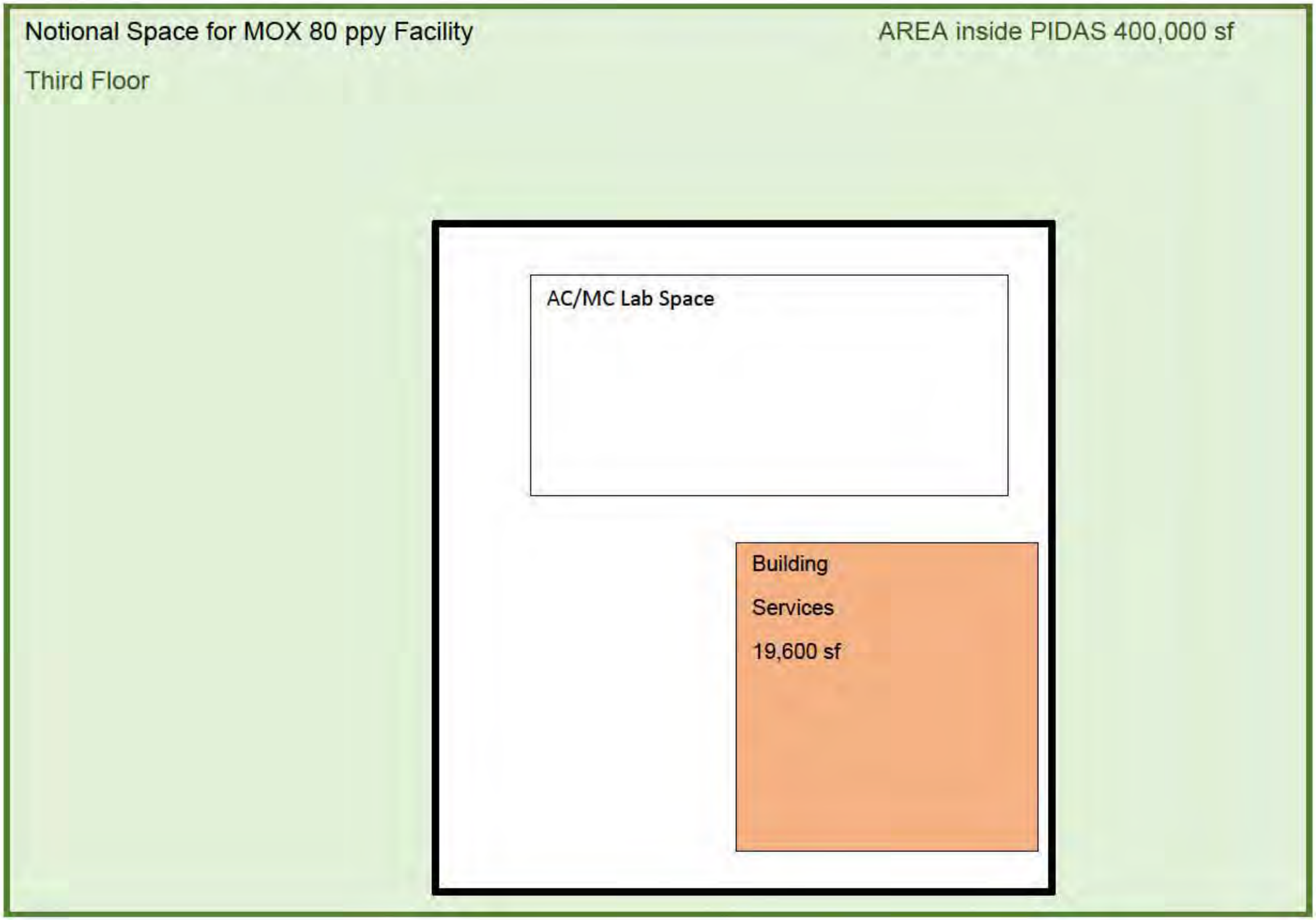

Notional Space for INL FPF 80 ppy Facility
AREA inside PIDAS 400,000 sf
Three below grade floors of process building; 32,300 sf each.
Second Level Shown (4901' elevation)
1 Disassembly
1700 sf
2 Metal Prep
3320 sf
3 Foundry 8,330 sf
Receipt & Metal Vault
SCALE
100 Feet


Notional Space for INL FPF 80 ppy Facility
AREA inside PIDAS 400,000 sf
Third Level Shown (4997' elevation)
6 Assembly 9277 sf
Product Vault 5000 sf
7 Post-Assembly 5,653 sf
5 Sub-Assembly 2800 sf
SCALE
100 Feet


Notional for INL FPF 80 ppy Facility
AREA inside PIDAS 400,000 sf
Fourth (lowest below grade) Level Shown (4997' elevation)
4 Machining & Inspection
11,050 sf
8 Aqueous Processing
SCALE
100 Feet


Notional Space for MOX 80 ppy Facility
AREA inside PIDAS 560,000 sf
PIDAS 3000 ft. perimeter
3 Hazard Category 2 Buildings
Main Process Building Ground Floor 86,620 sf; 259,960 sf total
Technical (Production) Support (existing 75,000 sf Building – 3 floors)
Bonded Stores Warehouse (existing 21,372 sf facility available for use)
Truck Bay – Shipping and Receiving (existing 22,381 sf building)
MOX Process Building 86,620 sf ground floor shown (building also has 2 higher floors) – Total 259,860 sf.
1 Disassembly 1700 sf
2 Metal Prep 3320 sf
3 Foundry 8,330 sf
4 Machining & Inspection 11,050 sf
Receipt Vault (existing space) 1500 sf
Security Control
6 Assembly 9277 sf
Product Vault (existing) 1200 sf
7 Post-Assembly 5,653 sf
5 Sub-Assembly 2800 sf
Existing Aqueous Processing Building 181,951 sf on multiple levels
8 Aqueous Processing 7000 sf
Truck Portal (Existing 8,132 sf)
Diesel Generator (existing 6,883 sf building)


Notional Space for MOX 80 ppy Facility
AREA inside PIDAS 560,000 sf
Second Floor
AC & MC Lab Space
Transfer Trolley System
Building Services
Offices & Support Areas



Key: AC = analytical chemistry; HVAC = heating, ventilating, and air conditioning; MC = materials characterization; PIDAS = Perimeter Intrusion Detection Assessment and Delay System; ppy = pits per year; prep = preparation; radcon = radiological contamination; sf = square feet.

Appendix I. LANL Pit Production Flowsheet

(b)(3) UCNI

(b)(3) UCNI

(b)(3) UCNI

(b)(3) UCNI

(b)(3) UCNI

(b)(3) UCNI

(b)(3) UCNI

Appendix J. Verification and Validation of the Pit Production Model

Pit production modeling was a key analytical tool for the Plutonium Modular Approach (PMA) Analysis of Alternatives (AoA). Starting with a generic unclassified pit production flowsheet provided by Los Alamos National Laboratory (LANL), later updated by LANL and Lawrence Livermore National Laboratory (LLNL) for the W87-like pit, the PMA AoA team developed a classified stochastic discrete event simulation[1] to represent the processing steps required to produce a W87-like pit. 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 product's compliance with design requirement.

The intended purpose of the model is to produce an estimate of equipment required to produce a given pit capacity (30, 50, or 80 pits per year [ppy]) more than 90 percent of the time (over 90 percent confidence), as input to an estimate of space needed for this function. The space estimate is intended to be used to help compare pit production capability costs for multiple alternatives. The model verification and validation (V&V) effort was performed by the AoA team. It focused on ensuring that the model represents the problem appropriately, and that its logic and mathematical and causal relationships are reasonable for their intended purpose.

J.1 Background

Several relevant terms are defined as background (Jain 2011; DoD 2009; MITRE 2017; Sargent 1999).

- *Modeling*

  Application of a standard, rigorous, structured methodology to create and validate a physical, mathematical, or otherwise logical representation of a system, entity, phenomenon, or process.
- *Simulation*

  A method for implementing a model over time.
- *Modeling and Simulation (M&S)*

  The use of models, including emulators, prototypes, simulators, and stimulators, either statically or over time, to develop data as a basis for making managerial or technical decisions. The terms "modeling" and "simulation" are often used interchangeably.
- *M&S Tools*

  Software that implements a model or simulation or an adjunct tool, i.e., software and/or hardware that is either used to provide part of a simulation environment (e.g., to manage the execution of the environment) or to transform and manage data used by or produced by a model or simulation. Adjunct tools are differentiated from simulation software in that they do not provide a virtual or constructive representation as part of a simulation environment.

[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. The Modern Pit Facility CD-0 effort – SRS-MPF-G-ESR-X-0004, *Capacity vs Facility Size Study*, SRS, 2001 is another.

- *Conceptual Model*

  The mathematical/logical/verbal representation (mimic) of the problem entity to be modeled.
- *Verification*

  The process of determining that a model implementation and its associated data accurately represent the developer's conceptual description and specifications.
- *Validation*

  The process of determining the degree to which a (simulation) model and its associated data are an accurate representation of the real world from the perspective of the intended uses of the model.

Verification answers the question "Have we built the model right?" whereas validation answers the question "Have we built the right model?" (Cook and Skinner 2005). In other words, the verification phase of V&V focuses on comparing the elements of a simulation model of the system with the description of what the requirements and capabilities of the model were to be. Verification is an iterative process aimed at determining whether the product of each step in the development of the simulation model fulfills all the requirements levied on it by the previous step and is internally complete, consistent, and correct enough to support the next phase (Lewis 1992). The validation phase of V&V focuses on comparing the observed behavior of elements of a system with the corresponding elements of a simulation model of the system, and on determining whether the differences are acceptable given the intended use of the model. If agreement is not obtained, the model is adjusted to bring it in closer agreement with the observed behavior of the actual system.

The basic activities in the V&V process (DoD 2006) are summarized as follows:

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

J.2 Validation of Conceptual Model and Verification of Design

Conceptual models may be validated to the extent possible via model walk-throughs with subject matter experts, customers and end-users (Jain 2011).

The conceptual model for the PMA 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:

- Step-by-step walk-through of both the pit flowsheet and the Innoslate process model during the AoA team site visit to LANL September 26-29, 2016[2]
- AoA team review of process model logic via online conference December 7, 2016[3]
- Step-by-step review of classified process model, including logic flow, addition of process steps unique to the W87-like pit, and all input data during LANL visit to DOE Headquarters January 24-27, 2017
- Review of the pit production flowsheet by LANL, LLNL, and Rocky Flats Plant SMEs for accuracy of process during AoA team site visit to LANL February 27 – March 3, 2017[4]

J.3 Verify Implementation

Verification techniques include traces, varying input parameters over their acceptable range and checking the output, substituting constants for random variables and manually checking the results, use of operational graphics and animation (Sargent 1999).

The AoA team used 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 and 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, and equipment that cannot be freed until the next piece of equipment is available.

J.4 Validation of Pit Production Model

A variety of methods are used to validate simulation models, ranging from comparison to other models to the use of data generated by the actual system (i.e., predictive validation). The most commonly used methods are described in **Table J–1** (Law 2008).

[2] Drew Kornreich (LANL), and Laura Driscoll, Scott Dam, Kyle Kondrat, and Ian Andrews (AoA Team) attended.
[3] Drew Kornreich and Bob Putnam (LANL), Vann Bynum and Chris Bader (Rocky Flats Plant SMEs, and members of the AoA Team), Scott Dam, Kyle Kondrat, Ian Andrews, and Geoff Kaiser (AoA Team) attended.
[4] Drew Kornreich, Bob Putnam, and Brett Kniss (LANL), Mark Bronson and Steven Stout (LLNL), Vann Bynum and Chris Bader (Rocky Flats Plant SMEs, and members of the AoA Team), Laura Driscoll, Scott Dam, Kyle Kondrat, Ian Andrews, and Geoff Kaiser (AoA Team) attended.

Table J–1. Common simulation model validation methods

Model Validation Method	Description
Comparison to other models	Various results (e.g., outputs) of the simulation model being validated are compared to results of other (valid) models. For example, (1) simple cases of a simulation model are compared to known results of analytic models, and (2) the simulation model is compared to other simulation models that have been validated.
Face validity	Asking individuals knowledgeable about the system whether the model and/or its behavior are reasonable. For example, is the logic in the conceptual model correct and are the model's input-output relationships reasonable?
Historical data validation	If historical data exist (e.g., data collected on a system specifically for building and testing a model), part of the data are used to build the model and the remaining data are used to determine (test) whether the model behaves as the system does.
Parameter variability – sensitivity analysis	Changing the values of the input and internal parameters of a model to determine the effect on the model's behavior of output. The same relations should occur in the model as in the real system. This technique can be used qualitatively—only directions of outputs—and quantitatively—both directions and (precise) magnitudes of outputs. Those parameters that are sensitive (i.e., cause significant changes in the model's behavior or output) should be made sufficiently accurate prior to using the model.
Predictive validation	Predicting (forecasting) the system's behavior, and then comparing the system's behavior and the model's forecast to determine if they are the same. The system's data may come from an operational system or be obtained by conducting experiments on the system, e.g., field tests.

With the exception of face validity and comparison to other models, all the methods detailed in Table J–1 are data-driven approaches to model validation, with predictive validation among the most commonly used methods. The use of predictive validation generally requires a significant amount of effort to acquire and analyze data to support model validation. When data-driven model validation is not possible or practical, face validity and comparison to other models are the methods of choice (Jain 2011).

In this case, there is no operational pit production capability available for the production quantities needed, and data from Rocky Flats Plant production could not be found. Therefore, comparison to other models and face validity were the only validation methods available.

J.4.1 Comparison to Other Models

J.4.1.1 "One-of-Each" Equipment Scenario

In the early 2000s, LANL had developed a discrete event simulation in ExtendSim for pit manufacturing, but the model has not been kept up to date, and has not been used since 2005 (LANL 2005). The AoA team compared results reported from the LANL ExtendSim model to results obtained with the AoA Pit Production Process Model developed by the team for a run with one piece of each type of equipment. **Table J–2** shows the results from the two discrete event models.

Table J–2. Los Alamos National Laboratory model versus Analysis of Alternatives model results

Model	$\overline{ppy}$ (average)	σ
LANL	16.9	5.87
AoA	14.48	4.61

LANL = Los Alamos National Laboratory; ppy = pits per year

The results are within one standard deviation of each other. Differences are likely due to differences in data. LANL provided the data for both models, but the data used in the LANL ExtendSim model was not available for inspection by the AoA team.

J.4.1.2 Plutonium Sustainment Program 30 Pits Per Year Plan

The AoA Pit Production Process Model was run with the set of equipment planned for the 30 ppy capability to be installed under the Plutonium Sustainment Program. Note that for these runs, input from discussion with SME's from LANL, LLNL, and Rocky Flats, and modifications for the W87-like pit had been included in the model, making it slightly different from the LANL deterministic model used to develop the 30 ppy equipment set. To make the comparison, all equipment not represented in the LANL model were set such that they were not a limiting factor for the process flow.

The LANL deterministic model projects a $30\ \overline{ppy}$ for the Plutonium Sustainment Program equipment set. The AoA model produced 28.76 $\overline{ppy}$ with a σ of 8.23. The results of the AoA model are within less than one quarter of one standard deviation, showing very good agreement.

J.4.1.3 Comparison to Modern Pit Facility and Los Alamos National Laboratory 125 Pits Per Year Space Estimates

The intended purpose of the model is to estimate the equipment for use in square footage estimates for the production facility. The following comparison from the Modern Pit Facility and a 125-ppy capability in PF-4 plus new construction (LANL 2005) shows that the AoA space estimate for some of the primary pit manufacturing functions is on par with previous estimates.

Table J–3. Space requirement estimates for 104 pits per year and 125 pits per year average output at the Plutonium Facility and the proposed Modern Pit Facility

	AoA 80 ppy 95 percent Confidence, Approximately 104 ppy on Average	LANL PF-4 125 ppy average	MPF 125 ppy average
Metal preparation	3,320	5,600	4,800
Foundry	8,330	9,800	8,750
Machining	11,051	16,200	10,450
Assembly	11,477	9,925	15,500
Total of identified functions	34,178	41,525	39,500

Key:
AoA = Analysis of Alternatives; LANL = Los Alamos National Laboratory; MPF = Modern Pit Facility; ppy = pits per year.

J.4.2 Face Validity

The AoA model performance was validated through a series of reviews by SMEs:

- Review of the model results for each process module by LANL, LLNL, and Rocky Flats Plant SMEs during AoA team site visit to LANL February 27-March 3, 2017.[5]
- Review of the model results and the input data by LANL pit production operators and area managers during AoA team site visit to LANL February 27-March 3, 2017.

[5] Drew Kornreich, Bob Putnam, and Brett Kniss (LANL), Mark Bronson and Steven Stout (LLNL), Vann Bynum and Chris Bader (Rocky Flats Plant SMEs, and members of the AoA Team), Laura Driscoll, Scott Dam, Kyle Kondrat, Ian Andrews, and Geoff Kaiser (AoA team) attended.

- Review of the model during the Plutonium Advisory Team meeting held April 3-6, 2017, at DOE Headquarters.[6]
- Review of the equipment set for 80 ppy by LLNL and Rocky Flats Plant SMEs during the team's site visit to Savannah River Site (SRS).[7]

J.5 Conclusion

The PMA 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.

[6] Tim Driscoll (NNSA), Drew Kornreich and Brett Kniss (LANL), Mark Bronson (LLNL), John Gertsen (Y-12), Sachiko McAlhany (NA-20, SRS), Vann Bynum (Rocky Flats Plant and AoA Team member), and Laura Driscoll and Kyle Kondrat (AoA Team) attended.
[7] Steven Stout and Jim McNeese (LLNL), Chris Bader and Vann Bynum (Rocky Flats Plant and AoA team members), Laura Driscoll, Scott Dam, Kyle Kondrat (AoA team) attended.

J.6 References

Cook, D. A., and J. M. Skinner, 2005, "How to Perform Credible Verification, Validation, and Accreditation for Modeling and Simulation," *CrossTalk: The Journal of Defense Software Engineering*, May.

DoD (Department of Defense), 2006, *VV&A Recommended Practice Guide (RPG)*.

DoD (Department of Defense), 2009, *DoD Modeling and Simulation (M&S) Verification, Validation, and Accreditation (VV&A)*, DoD Instruction 5000.61, December 9.

Jain, M., 2011, *Best Practices for Modeling, Simulation and Analysis (MS&A) for Homeland Security Applications*, March.

LANL (Los Alamos National Laboratory), 2005, *TA-55 Pit Manufacturing Responsive Infrastructure and Capacity Study*, LA-CP-05-0256, Los Alamos, New Mexico.

Law, A. M., 2008, *How to Build Valid and Credible Simulation Models*, paper presented at the 2008 Winter Simulation Conference.

Lewis, R. O., 1992, *Independent Verification and Validation*, Wiley & Sons.

MITRE (MITRE Corporation), 2017, Systems Engineering Guide (accessed at https://www.mitre.org/publications/systems-engineering-guide/se-lifecycle-building-blocks/other-se-lifecycle-building-blocks-articles/verification-and-validation-of-simulation-models), September 20.

Sargent, 1999, *Verification and Validation of Simulation Models*, Proceedings of the 1999 Winter Simulation Conference.