INDEPENDENT COST ESTIMATE OF THE DEPARTMENT OF ENERGY OFFICE OF SCIENCE LONG BASELINE NEUTRINO FACILITY/DEEP UNDERGROUND NEUTRINO EXPERIMENT (LBNF/DUNE) PROJECT CRITICAL DECISION 3A FERMI NATIONAL ACCELERATOR LABORATORY

U.S. DEPARTMENT OF ENERGY
OFFICE OF PROJECT MANAGEMENT
OVERSIGHT AND ASSESSMENTS

FEBRUARY 2016

Independent Cost Estimate of Department of Energy Office of Science Long Baseline Neutrino Facility/Deep Underground Neutrino Experiment (LBNF/DUNE) Project

FEBRUARY 2016

Executive Summary

The Department of Energy's (DOE) Office of Project Management Oversight and Assessments (PM) prepared an Independent Cost Estimate (ICE) of the CD-3A scope request for the Long Baseline Neutrino Facility/Deep Underground Neutrino Experiment (LBNF/DUNE) project. This ICE provides Project Management Executive (PME), senior leaders within the DOE, and Congress with an unbiased, independent assessment of the project's costs and schedule to complete.

In 2009, the Long Baseline Neutrino Experiment (LBNE) was envisioned as a joint DOE - National Science Foundation (NSF) project. The NSF would provide the Deep Underground Science and Engineering Laboratory (DUSEL) in the Homestake Mine in Lead, South Dakota, as a site for the DOE-provided LBNE remote detector. The NSF however, terminated the DUSEL project in December 2010 and DOE pursued a smaller scale, domestically funded LBNE project that received Critical Decision-1 (CD-1) approval in December 2012.

In 2014, the new national strategic plan for U.S. particle physics—developed by the Particle Physics Project Prioritization Panel (P5) and approved by the High Energy Physics Advisory Panel (HEPAP)—recommended "a change in approach" for the LBNE project. The project reformed as an internationally coordinated and funded program as a single project with two subprojects: (1) Long Baseline Neutrino Facility (LBNF), a DOE project with an international contribution, and (2) the international Deep Underground Neutrino Experiment (DUNE) project, managed by the DUNE collaboration and primarily supported by multiple international partners, with a contribution by DOE. The new LBNF/DUNE project includes installation of large liquid argon (LAr) detectors deep underground at the Sanford Underground Research Facility (SURF) in Lead, SD.

The new LBNF/DUNE project received CD-1 (revised) approval in November 2015. It is now seeking CD-3A approval in order to start excavation and building/site infrastructure construction activities at the SURF site. The CD-3A scope covers the initial construction work necessary to support installation of cryostats and cryogenic systems to be ready for installation of two DUNE LAr detectors.

This includes new and refurbished surface facilities, underground excavation of caverns and drifts, and installation of the utilities in the shaft, including half of the gas piping. The Project Team's cost estimate to complete the CD-3A work scope is $302 million, consisting of $219 million in base costs and $83 million contingency (27% of total CD-3A cost). The project schedule shows completion of CD-3A work scope by May 1, 2022.

The ICE for the CD-3A work is $270 million, including escalation and contingency. The base cost (escalated) is estimated at $207 million, and the contingency is $63 million (23% of total CD-3A cost). The contingency was derived using Monte Carlo simulation and output was evaluated at the 90% confidence level, which is consistent with the methodology used by the Project Team. Results are summarized in Table i-1: Project Cost Estimate vs ICE. The ICE is about 11% less than the Project Team estimate.

Table i-1: Project Cost Estimate vs ICE

Description	Project Estimate, $M	ICE, $M
Base Costs	219	207
Contingency	83	63
Total CD-3A Request	**302**	**270**

The ICE also examined the Project Team's schedule to complete the CD-3A work scope. This reasonableness review concluded that it is likely the work can be completed within the time allotted, and that the proposed schedule is reasonable. The schedule appears to be well-constructed, though some areas for improvement were found, such as high float, lag values, and pending detailed planning.

The ICE Team concluded the following:

- The proposed cost and schedule for the LBNF/DUNE CD-3A project scope is reasonable, well-documented, and supports CD-3A approval.
- The 11% variance between the Project estimate and ICE drops to 3% when escalation and contingency differences are excluded, which is excellent agreement.
- Differences in base costs between both estimates were reconciled. Differences in escalation and contingency were not reconciled, however the escalation and contingency figures used in both estimates are reasonable and defensible.
- The Project estimate conforms to the GAO Best Practices for Cost Estimating.

Figure i-1: Yates Shaft Headframe – Homestake Mine

Contents

SECTION 1 INTRODUCTION 1-1

1.1 PURPOSE AND OBJECTIVE 1-1
1.2 PROJECT BACKGROUND AND STATUS 1-1

SECTION 2 BASELINE 2-1

2.1 PERFORMANCE BASELINE (SCOPE, COST AND SCHEDULE) 2-1
2.2 GROUND RULES AND ASSUMPTIONS 2-4

SECTION 3 REVIEW APPROACH AND ANALYSIS 3-1

3.1 COST ESTIMATING METHODOLOGY 3-1
3.2 SCHEDULE ANALYSIS AND RESULTS 3-2
3.3 SENSITIVITY ANALYSIS 3-5
3.4 COST RISK AND UNCERTAINTY ANALYSIS 3-9

SECTION 4 RESULTS AND FINDINGS 4-1

4.1 SUMMARY OF RECONCILIATION 4-1
4.2 SUMMARY OF VARIANCE ANALYSIS 4-2
4.3 OVERVIEW OF RESULTS AND FINDINGS 4-3

APPENDIX A REFERENCES A-1

APPENDIX B LIST OF ACRONYMS B-1

APPENDIX C BIOS OF ICE TEAM MEMBERS C-1

APPENDIX D TYPES OF INDEPENDENT COST ESTIMATES D-1

APPENDIX E BASIS OF ESTIMATE E-1

APPENDIX F DETAILED SCHEDULE ANALYSIS F-1

APPENDIX G ICE RISK REGISTER G-1

APPENDIX H RISK ANALYSIS DETAILS H-1

APPENDIX I GAO 12-STEP BEST PRACTICES FOR COST ESTIMATING I-1

FIGURES

Figure i-1: Yates Shaft Headframe – Homestake Mine iii
Figure 1-1: Hoist Room – Yates Shaft 1-3
Figure 1-2: Preparing for Underground Tour 1-3
Figure 2-1: Manlift at top of Yates Shaft 2-6
Figure 2-2: Underground drifts and railway at 4850 Level 2-6

Figure 3-1: Primavera XER File List 3-3
Figure 3-2: Sensitivity Analysis – Escalation 3-6
Figure 3-3: Sensitivity Analysis – Construction Mgr/General Contractor 3-7
Figure 3-4: Sensitivity Analysis – Productivity 3-8
Figure 3-5: Estimate Uncertainty – Monte Carlo Results 3-10
Figure 3-6: T&P Risk Contingency – Monte Carlo Results 3-10
Figure 4-1: Ross Shaft Headframe 4-5
Figure H-1: Estimate Uncertainty – Frequency View H-1
Figure H-2: Estimate Uncertainty – Cumulative Frequency View H-2
Figure H-3: Estimate Uncertainty – Split View H-2
Figure H-4: T&P Contingency – Frequency View H-3
Figure H-5: T&P Contingency – Cumulative Frequency View H-4
Figure H-6: T&P Contingency – Split View H-4

TABLES

Table i-1: Project Cost Estimate vs ICE ii
Table 2-1: ICE Type by WBS Activity 2-3
Table 3-1: Project Cost Estimate vs ICE 3-2
Table 3-2: Sensitivity Analysis – Escalation 3-6
Table 3-3: Sensitivity Analysis – Construction Mgr/General Contractor 3-7
Table 3-4: Sensitivity Analysis – Productivity 3-8
Table 3-5: Independent Risk Analysis Results 3-9
Table 4-1: Variance Comparison 4-3
Table 4-2: Project Cost Estimate vs. ICE 4-4
Table E-1: Annual Escalation Rate Forecast for LBNF/DUNE CD-3A Costs E-7
Table I-1: GAO 12-Step Process for Cost Estimating I-1

Section 1
Introduction

1.1 PURPOSE AND OBJECTIVE

The Office of Project Management Oversight and Assessments (PM) performs Independent Cost Estimates (ICEs) to provide Project Management Executives (PMEs), senior leaders within the DOE, and Congress with an unbiased, independent assessment of a project's costs and schedule to complete (GAO Step #1[1]).

In addition, Public Law 2055, enacted December 23, 2011, specifically requires that an ICE be prepared prior to Critical Decision (CD)-2 and CD-3 for a project with a Total Project Cost (TPC) over $100 million. PM performs ICEs as required by law.

DOE PM prepared an ICE of the CD-3A scope request for the Long Baseline Neutrino Facility/Deep Underground Neutrino Experiment (LBNF/DUNE) project, which included a site visit to the Sanford Underground Research Facility (SURF) in Lead, SD the week of December 1, 2015. Team members interviewed Project Team personnel, toured the site and underground mine where the remote detectors will be located, and gathered additional documentation, as necessary. The draft ICE report was initially provided to the Project Team for factual accuracy review and followed up by reconciliation between the ICE and the Project Team estimate (GAO Step #6).

The PM ICE Team consisted of five members, who reviewed project documentation prior to and during the site visit, interviewed Project Team participants, and prepared the ICE. Appendix C shows the specific team member assignments and provides team member bios (GAO Step #2).

1.2 PROJECT BACKGROUND AND STATUS

In 2009, the Long Baseline Neutrino Experiment (LBNE) was envisioned as a joint U.S. Department of Energy (DOE)–National Science Foundation (NSF) project. The NSF would provide the Deep Underground Science and Engineering Laboratory (DUSEL) in the Homestake Mine in Lead, SD, as a site for the LBNE remote detector. In January 2010, DOE approved CD-0, but the National Science

[1] As applicable, specific sections throughout the report will be mapped to their corresponding step in the GAO 12 Steps of High-Quality Cost Estimating. See Appendix I for more details.

Board terminated the DUSEL project in December 2010 because it believed this facility was too large an undertaking for the NSF.

In March 2012, the Director of the DOE Office of Science asked the Director of Fermilab to lead the development of an affordable and phased approach to LBNE based on alternate configurations that would enable important science at reduced scope and cost. The selected alternative included a reduced mass detector, not sited underground, and eliminated the smaller detector at Fermilab for monitoring the neutrino beam near its source.

The LBNE project was formed primarily as a domestically-funded effort, having a minimal CD-1 configuration of a 10-kiloton far detector on the surface, about 1,300 km from the near site. LBNE was tailored to allow for enhancement of scientific capabilities and additional scope (such as a near neutrino detector and a far detector underground with additional mass), should opportunities attract the support of other domestic and international agencies. This reconfiguration was the basis for DOE approval of CD-1 in December 2012 with a DOE cost range of $805 million to $1.11 billion.

In May 2014, the new national strategic plan for U.S. particle physics—developed by the Particle Physics Project Prioritization Panel (P5) and approved by the High Energy Physics Advisory Panel (HEPAP)—recommended “a change in approach” for the LBNE project. The project reformed as an internationally coordinated and funded program, under the auspices of a new international collaboration.

The LBNF and DUNE became a single project with two subprojects: (1) Long Baseline Neutrino Facility (LBNF), a DOE project with an international contribution, and (2) the international Deep Underground Neutrino Experiment (DUNE) project, managed by the DUNE collaboration and primarily supported by multiple international partners, with a contribution by DOE. The DUNE collaboration brings together a global neutrino community to pursue an accelerator-based, long-baseline neutrino experiment, as well as neutrino astrophysics and nucleon decay, with a large liquid argon (LAr) detector deep underground at the Sanford Underground Research Facility (SURF) and a high-resolution near detector at Fermi National Accelerator Laboratory (FNAL).

The new LBNF/DUNE project received approval for a revised CD-1 with a cost range of $1,260 million to $1,860 million in November 2015. It is now seeking CD-3A approval in order to start excavation and building/site infrastructure construction activities at the SURF site.

The information provided here complies with GAO Step #3.

Figure 1-1: Hoist Room – Yates Shaft

Figure 1-2: Preparing for Underground Tour

Section 2
Baseline

2.1 PERFORMANCE BASELINE (SCOPE, COST AND SCHEDULE)

Scope of Work. The CD-3A scope covers the initial construction work necessary to support installation of cryostats and cryogenic systems to be ready for the installation of two DUNE LAr detectors. The specific work scope includes:

Underground Excavation (4850 feet below surface level)

- Initial work to prepare the area around the Ross shaft to support excavation.
- Excavation of two detector chambers to support two 10kt fiducial cryostats.
- Excavation of a Central Utility Cavern to house cryogenics systems supporting the detector operation and conventional facilities infrastructure (electrical power equipment, air-handling units).
- Excavation of new drifts and ramps for access, egress, and cavern excavation and enlargement of existing drifts from the Ross Shaft to near the LBNF site for construction and operations.

4850L Underground Infrastructure

- Utilities on the 4850L (i.e. 4,850 feet beneath the surface) and outfitting of chambers 1 & 2 and the Central Utility Cavern including industrial water for process and fire suppression, air handling and cooling systems, fire detection and alarm, normal and standby power systems, water sump drainage and discharge system, cyber infrastructure for data communications and experiment and facility control and security monitoring, cellular phone access underground, and monorail cranes.

Shaft Infrastructure

- Installation in the Ross Shaft of utilities to support the facility, including: electrical power, water for fire suppression and process cooling, fiber optic lines.
- Installation in the Yates Shaft of redundant fiber optic lines.

- Partial installation (50%) of the argon and nitrogen gas piping.

Surface Building & Infrastructure

- Installation of a waste rock handling system to crush and convey excavated rock from the Ross Shaft for transport and placement off-site.
- Installation from existing substation of electrical power feed to the top of the Ross Shaft and to new surface facilities.
- Construction of a new Cryogenics Compressor Building to house cryogenic systems equipment to allow installation of cryogenic system components.

Total CD-3A Scope Cost. The Project Team's cost estimate to complete the CD-3A work scope is $302 million, consisting of $219 million in base costs and $83 million contingency.

Escalation. The estimate includes escalation at an annual rate of 3.4%. LBNF uses escalation rates based on historical and predictive models from industry and other sources. In April 2013 the Project Team developed a methodology regarding the escalation rate to be used for the Far Site and Near Site conventional facilities scope. This approach was based on an independent report prepared by Jacobs Engineering (January 2012) that incorporated information from Engineering News Record, Turner Building Cost Index, Rider Levett Bucknall National Building Cost Index, and Jacobs' own internal escalation tracking tools. The Project Team reviewed other escalation models that provided a prediction of future rates including those from Gilbane, the University of Chicago, and DOE Office of Science. Based on the Jacobs report, it was decided to use an annual escalation rate of 3.4% as the middle of the predictive models in the analysis.

Schedule. The project schedule shows completion of CD-3A work scope by May 1, 2022.

Independent Cost Estimate. The ICE was conducted in accordance with PM's *Independent Cost Review (ICR) and Independent Cost Estimate (ICE) Standard Operating Procedures (SOP),* September 2013. The ICE is also consistent with guidance provided in DOE Guide 413.3-21, *Cost Estimating Guide*. The ICE is conducted using the same ground rules and assumptions as the Project Team, and incorporates practices that produce a high quality cost estimate, in accordance with the criteria included in the GAO 12-Steps of a High-Quality Cost Estimating Process found in *GAO Cost Estimating and Assessment Guide*, GAO-09-3SP, March 2009.

The ICE consists of a combination of Types II, III, IV, and V independent cost estimates, as described in Appendix D of this report.

The following list of Work Breakdown Structure (WBS) elements defines the CD-3A scope. The type of ICE performed for each element are shown below:

Table 2-1: ICE Type by WBS Activity

WBS	Description	Cost ($M)*	ICE Type
131.01.02.02.04.01	**FSCF Construction Management**	**23**	**IV- Sampling V- Bottom-up**
131.01.02.02.04.02	**Buildings & Site Infrastructure (BSI)**	**48**	**II- Reasonableness III- Parametric IV- Sampling**
131.01.02.02.04.02.01A	BSI- General Conditions	8	
131.01.02.02.04.02.01B/1C	BSI- Initial Work	10	
131.01.02.02.04.02.02	BSI- Phase 1 (Chamber 1, Central Utilities Cavern utilities, Surface Bldg & utilities)	22	
131.01.02.02.04.02.03	BSI- Phase 2 (Chamber 2 utilities & infrastructure)	1	
131.01.02.02.04.02.04	BSI- Shaft Utilities (1/2 gas piping)	7	
131.01.02.02.04.03	**Cavern & Drift Excavation (EXC)**	**119**	**II- Reasonableness III- Parametric IV- Sampling V- Bottom-up**
131.01.02.02.04.03.01A	EXC- General Conditions	42	
131.01.02.02.04.03.01B/1C	EXC- Initial Work	21	
131.01.02.02.04.03.02	EXC- Phase 1 (Drifts, Chamber 1, CUC)	47	
131.01.02.02.04.03.03	EXC- Phase 2 (Chamber 2)	9	

* Project Team's Estimate (un-escalated)

The ICE was structured similarly to the WBS developed by the Project Team and major assumptions used by the Project Team are adopted, as appropriate. Any concerns with the WBS or assumptions were reconciled during the onsite review meetings. Escalation is included, based on the midpoint of construction.

The ICE also includes a reasonableness review of the proposed project schedule for CD-3A work scope. The team assessed the logic, critical path, and durations of the proposed activities, but did not develop a completely new schedule.

The ICE Team performed an independent risk analysis of the cost uncertainty as well as the technical & programmatic (T&P) risks in order to generate an independent contingency for CD-3A work scope. This was facilitated by review-

ing/modifying the risk registers prepared by the Project Team, assessing the reasonableness of the risks, and analyzing the probabilities and cost/schedule impacts for each risk. The ICE Team then used Monte Carlo probabilistic simulation techniques to develop T&P risk contingency and cost uncertainty.

An independent, Monte Carlo-based risk analysis was not performed for the schedule contingency. Since CD-3A work will be absorbed in the LBNF/DUNE CD-2/3 baseline, a more detailed schedule uncertainty analysis would not provide useful information and was omitted from the independent schedule development. Rather, the risk schedule impacts derived by the Project Team were reviewed for reasonableness and validity, and a very simplistic approximation of schedule float was performed by the ICE Team (see Section 3.4).

The preceding discussion complies with GAO Step #4.

2.2 GROUND RULES AND ASSUMPTIONS

The ICE was developed to the highest level possible/practical given the state of the design, information available to the ICE Team and time/resource considerations. The type of estimate is determined based on two factors:

1. Cost drivers on the project
2. Available definition of work on the drawings and specifications

Since the excavation elements of the project comprise over half the construction costs, the greatest time and effort was placed on the 40-plus excavations as defined on the Project Team drawings. Additionally, the Construction Management and General Contracting (CM/GC) costs were considered significant cost drivers and therefore considered for deterministic estimating techniques (Type IV/V).

The excavations and CM/GC costs were developed as a Type IV/V estimate and are broken down into labor, material, equipment, and subcontract costs.

The remainder of the project cost estimates are either Type III (Parametric estimates) or Type II (reasonableness). For the Type II costs, we accepted the Project Team costs in the tabulation of the ICE estimate. Items included as Type II include:

- Ross and Yates Headframe rehabilitation
- Rock Crusher Rehabilitation
- Cryogenic Piping Costs
- Electrical Substation Costs
- Cyber Infrastructure backbone
- Control Room in the Ross Dry building
- Waste Rock Handling - Underground

- Waste Rock Handling - Surface

Items specifically excluded from the ICE, as this scope of work is outside of the CD-3A request, include the following:

- Ross Dry Rehabilitation
- Equipment in the New Cryogenic Building
- Cryogenic Equipment in the Central Utility Cavern
- Ross Shaft rehabilitation
- All equipment associated with the DUNE experiment

The ICE is based on FY2015 dollars. It includes escalation determined at the centroid of cost expenditures. This rate is 2.4% compounded annually. This rate is derived from several sources including OMB and DOE Office of Science (see Appendix E and Table E-1). DOE no longer publishes escalation projections and the last one available is from 2011. This Budget Call guidance showed that the escalation rates in out years for the years in question for the LBNF/DUNE construction would be 1.9% for Administrative/Warehouse, 2.0% for Remediation or D&D, 2.1% for Scientific Projects, and 4% for nuclear projects. The LBNF/DUNE site preparation efforts are somewhere in between these categories. As such, we referred to OMB Circular A-94 which also indicated rates in the 1.9% range, as well as input we received from recent ICRs on other projects. The combination of data sources led to our selection of 2.4%

Escalation was applied at the centroid of the CD-3A work scope. We established the 50% point for project expenditures to be in 2019. The ICE team did not generate an independent schedule, so the expenditure rate and timing is based on SME opinion and experience. Use of a compounded escalation rate at the centroid of the project expenditures is a common approach to determining the escalation costs to be added to a point estimate for a design and construction project. In addition, the spend rate in the Project Team documentation resembles a symmetrical Bell curve over the CD-3A life; therefore, any differences between a centroid approach versus applying the escalation to each year's expenditures are minimal. Assuming the centroid to be approximately 2019, the compounded escalation rate to be applied in the point estimate is 12.59%.

Additional assumptions used in the development of the estimate are contained in the Basis of Estimate (BOE) in Appendix E.

The preceding discussion complies with GAO Step #5 and #7.

Figure 2-1: Manlift at top of Yates Shaft

Figure 2-2: Underground drifts and railway at 4850 Level

Section 3
Review Approach and Analysis

3.1 COST ESTIMATING METHODOLOGY

The LBNF project is in preliminary design for many of the facilities and near final design on the major sections of the project. The excavation is the major cost element of the project and is very detailed with plans, sections, detailed takeoffs for rock removal, surface areas for shotcrete and floor area for concrete floors. The buildings and other site improvements are at a level of detail to allow a Type III estimate, including takeoffs of square footages and estimates of lighting and mechanical loads.

The data available was sufficient to develop the ICE and the specialty elements (substation, electrical equipment, and mining equipment) were backed up by vendor quotes which were made available to the ICE team.

Deterministic methodology was used for the major portion of the construction work, providing detailed takeoffs of quantities and credible unit cost rates. The excavation was broken into labor, material, equipment, and subcontract costs. Labor rates were developed independently using regional area base salaries and building up the fully loaded cost rates with credible factors for fringes, taxes, overheads, general and administrative.

The Project Team WBS was used as the structure for building the estimate with the following three major WBS elements:

- Construction Manager/General Contractor
- Buildings and Site infrastructure
- Excavation for Drifts and Caverns

The Construction Manager/General Contractor (CM/GC) and excavation costs were developed using Type IV/V deterministic methodologies. The Buildings and Site Infrastructure (BSI) elements of the WBS were developed primarily using parametric estimating (Type III). Reasonableness reviews (Type II) were used in cases of specialized work or equipment.

Roll up factors were used where necessary and included General Contractor insurances, bonds, and profit. Excise taxes were included at 2% of the project costs, consistent with the approach used by the Project Team.

No costs were included for Fermi Lab personnel, DOE personnel or Other Direct Costs (ODCs).

Historical data on excavation productivity was discussed with the Project Team and was included in the independently developed productivities for drilling, explosives placement/detonation, rock mucking, rock crushing, and lifting rock from the underground.

Commercial rates were used for trucking costs, equipment operational costs, and general construction of building and systems. There were no special factors applied as is often done on restricted DOE facilities and nuclear sites.

The ICE for the CD-3A work is $270 million, including escalation and contingency. The base cost (escalated) is estimated at $207 million, and the contingency is $63 million. The contingency was derived using Monte Carlo techniques evaluated at the 90% confidence level, which is consistent with the methodology used by the Project Team. Results are summarized in Table i: Project Cost Estimate vs ICE. The ICE is about 11% less than the Project Team estimate.

Table 3-1: Project Cost Estimate vs ICE

Description	Project Estimate, $M	ICE, $M
Base Costs	219	207
Contingency	83	63
Total CD-3A Request	**302**	**270**

The preceding discussion complies with GAO Step #7.

3.2 SCHEDULE ANALYSIS AND RESULTS

The ICE Team reviewed the Primavera XER file (LBNF-DUNE_10Schedules_20151202.xer) provided by the Project Team to evaluate whether or not it supports the proposed baseline. The integrated project schedule includes 10 separate Primavera projects, with five related to the Far Site (highlighted below).

Project ID	Project Name
LBNF-DUNE	LBNF-DUNE
131.01.01-4	Project Office - LBNF
131.01.02.01-4	Far Site Facilities Management
131.01.02.02-4	Far Site Conventional Facilities (FSCF)
131.01.02.03-4	Cryogenics Infrastructure
131.01.03.01-4	Near Site Facilities Management
131.01.03.02-4	Near Site Conventional Facilities (NSCF)
131.01.03.03-4	Beamline
131.02.01-4	Project Office - DUNE
131.02.02-6	Far Detector
131.02.03-4	Near Detector

Figure 3-1: Primavera XER File List

A review of the CD-3A schedule was performed by the ICE Team to ensure the reasonableness and validity of the schedule. This review evaluated the schedule based on principles and guidelines found in the GAO Schedule Assessment Guide, NDIA PASEG, and the DOE EVMSIH. The Project Team noted that the current schedule will be substantially more detailed once a Construction Manager (CM) is brought onboard. The ICE Team believes this will impact durations, total float values, and lags currently observed in the schedule. The analysis findings, based on GAO's four characteristics of a reliable schedule, are described below.

Comprehensive. The complete CD-3A scope has been captured within the activities making up the schedule, along with resource assignments and durations. There is a traceable connection between the scope and cost described in the BOE documents, ARUP estimates, DOE cost book, and the activities in Primavera. Traces were completed between these artifacts. Alignment and discrepancy explanations (scope changes) were satisfactorily documented in the 'Arup P6 Cost-Book FSCF Construction Estimate Reconciliation' document.

Durations identifying the time required to complete each activity have been established, with longer durations indicating the schedule still needs to be detailed out into smaller pieces of work (see Appendix F). For example, an activity that is 100 days in duration should be broken out into multiple activities with more definable scope. However, high durations were not unexpected given the pending detailed planning.

Some activity names, such as "4850-34.1 - Heading 1", should be better defined so that users easily understand the content. Activity names are most effective when they begin with a present-tense action verb and describe the scope in such a manner that clearly defines the intent.

Well-Constructed. The schedule is a logic-driven, critical path schedule with work starting on January 3, 2017 and continuing through the completion of CD-3A scope on May 1, 2022. Activities prior to CD-3A scope reflect procurement

actions. All discrete tasks are logically tied, having at least one predecessor and one successor, with the schedule logic producing a critical path that presents a true picture of the project plan (see Appendix F for details). In accordance with scheduling guidelines, the Integrated Master Schedule (IMS) logic has been structured with predominantly Finish-to-Start (FS) relationships, with the predecessor activity needing to finish before its successor can start.

Negative float was not observed in the schedule, indicating that the work can be completed within the allotted time. In addition, there are no hard constraints applied to CD-3A activities, allowing logic and durations to establish forecast dates.

The schedule appears to be largely well-constructed, though some shortcomings are expected to be improved once the schedule is detailed out, including high float and lag values. These schedule changes could potentially change the logic network and critical path.

Activities finishing significantly earlier than required, based on their successor paths (high total float) seem to be due to a lack of hard constraints applied to end milestones and a lack of schedule detail at this point. Alternatively, based on discussions with the Project Team, some instances of high total float accurately reflect a long period of time between the finish of an activity and its need date within the successor path. See Appendix F for details.

Lags illustrate a delay between predecessor and successor activities. Since lag durations are not represented as activities, these can hide detail in the schedule, potentially affecting the logic and critical path. Thus, during detail planning and where appropriate, it is recommended that the durations represented by lags on CD-3A activities be converted into new activities, splitting existing activities into logical break points that will better model how the work is accomplished. See Appendix F for details.

Half the gas piping, reflected in the Late Shaft Fit Out activities, is expected to be pulled forward and completed as part of CD-3A scope during pre-excavation, completing in the first quarter FY2021. The remaining half will be completed after all excavation is complete and will be part of CD-3c. The project schedule currently does not reflect this plan, but the Project Team plans to pull the related activity dates earlier. At this time, the CD-3A end date is shown as May 1, 2022 in the project schedule. If the gas piping is completed early, the CD-3A work will complete in 1st Quarter FY2021.

Credible. The schedule includes all detailed work that supports the completion of the second detector, which is linked accordingly so any slippage is apparent. In addition, the critical path seems to be complete and accurate. Overall, the schedule is planned in a rational, logical sequence that accounts for interdependencies.

The risk analysis approach and methodology used to determine schedule contingency for the CD-3A scope were reviewed for reasonableness. A summary sched-

ule derived from the full project schedule was used to model probabilistic risk events, with ranges of impacts, using Monte Carlo techniques. Separate risk analyses were completed for the full project scope and the Far Site Conventional Facilities (FSCF) scope, since the latter directly relates to CD-3A. The schedule contingency for CD-3A was calculated at the 90% confidence level, based on the completion of all the excavation (four caverns) and included the 26 risks that impact FSCF.

The risks with the greatest potential schedule impact include the following:

- PM-013, Changes to the funding profile
- CFFS-4850L-1000, Cryogenics or FD changes impact layout/design of Far Site facilities
- CFFS-4850L-010, Specialized construction labor is unavailable

Controlled. At this time, the CD-3A schedule has not yet been baselined or statused since the work for CD-3A begins on January 3, 2017. Based on the procedures outlined in the "Procedure 12.PM-006 Monthly Status Reporting" documentation that was provided by the Project Team, it is expected that the schedule will be updated regularly by trained schedulers, using actual progress and logic to forecast dates and compared to a baseline schedule to determine variances from the plan. Narratives for monthly status reports will be provided. In addition, changes to the baseline will adhere to the change control procedures outlined in the "Procedure 12 PM-007 Change Control" documentation.

Although the schedule will be planned in more detail once a Construction Manager (CM) is brought onboard, based on the schedule analysis, procedural documentation and discussions with the Project Team, the ICE Team believes the schedule is reasonable and it is likely the work can be completed within the time allotted.

3.3 SENSITIVITY ANALYSIS

As stated in Section 3.1, the ICE for the CD-3A work is $270 million, including escalation and contingency. The base cost (escalated) is estimated at $207 million, and the contingency is $63 million. The ICE Team performed the following sensitivities around the base costs of the ICE:

1. Escalation rate variation.
2. Time Dependent Costs (CM/GC) costs.
3. Excavation productivities.

The base escalation rate used by the ICE team is 2.4% compounded annually. We performed a sensitivity analysis starting at 1% up through 5%. The resultant escalation costs are shown in Table 3-2.

Table 3-2: Sensitivity Analysis – Escalation

Annual Rate	% at Midpoint	Escalation	TPC	+/- From Base 2.4%
1.00%	5.10%	$9,384,855	$193,401,615	-$13,782,855
1.50%	7.73%	$14,224,496	$198,241,256	-$8,943,214
2.00%	10.41%	$19,156,145	$203,172,905	-$4,011,565
2.40%	***12.59%***	***$23,167,710***	***$207,184,470***	***$0***
2.75%	14.53%	$26,737,635	$210,754,395	$3,569,925
3.00%	15.93%	$29,313,870	$213,330,630	$6,146,160
3.50%	18.77%	$34,539,946	$218,536,706	$11,372,236
4.00%	21.67%	$40,042,047	$224,058,807	$16,874,337
4.50%	24.62%	$45,304,926	$229,321,687	$22,137,216
5.00%	27.63%	$50,842,831	$234,860,591	$27,675,121

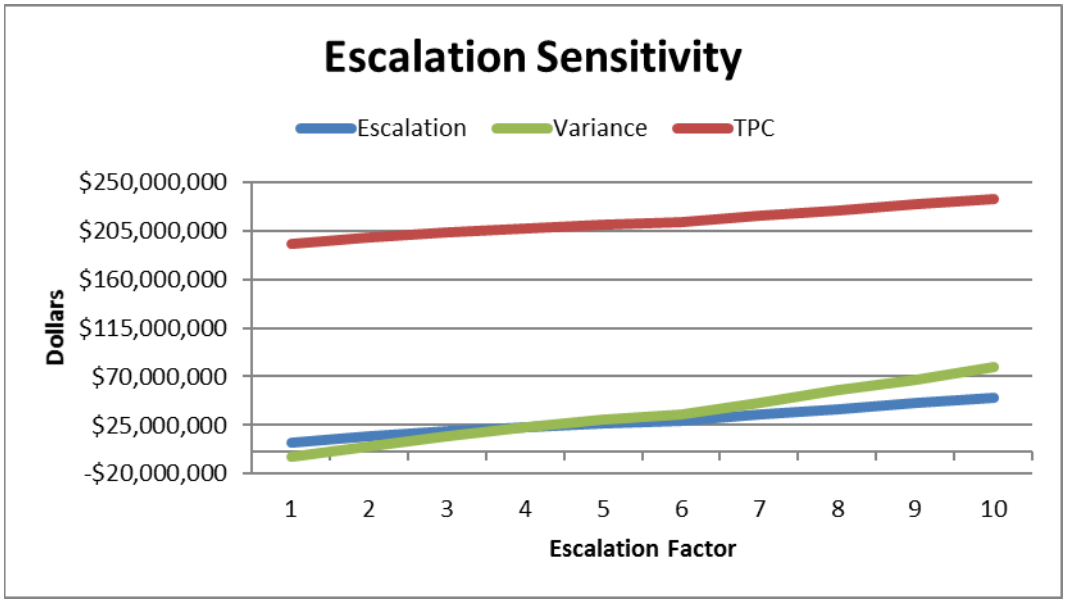


Figure 3-2: Sensitivity Analysis – Escalation

The duration of the project was assessed from 2.5 years to 5 years. The ICE is based on 3.75 years for the CM and 2.5 years for the GC (same contractor). The results are shown in Table 3-3.

Table 3-3: Sensitivity Analysis – CM/GC

Years	Total CM Cost	TPC	+/- from base 3.75 Years
2.50	$13,653,318	$200,815,963	-$6,368,507
3.00	$15,912,459	$203,363,366	-$3,821,104
3.25	$17,042,029	$204,637,067	-$2,547,403
3.50	$18,171,599	$205,910,769	-$1,273,701
3.75	***$19,301,170***	***$207,184,470***	***$0***
4.00	$20,430,740	$208,458,172	$1,273,702
4.25	$21,560,311	$209,731,873	$2,547,403
4.50	$22,689,881	$211,005,575	$3,821,105
4.75	$23,819,452	$212,279,277	$5,094,807
5.00	$24,949,022	$213,532,978	$6,348,508

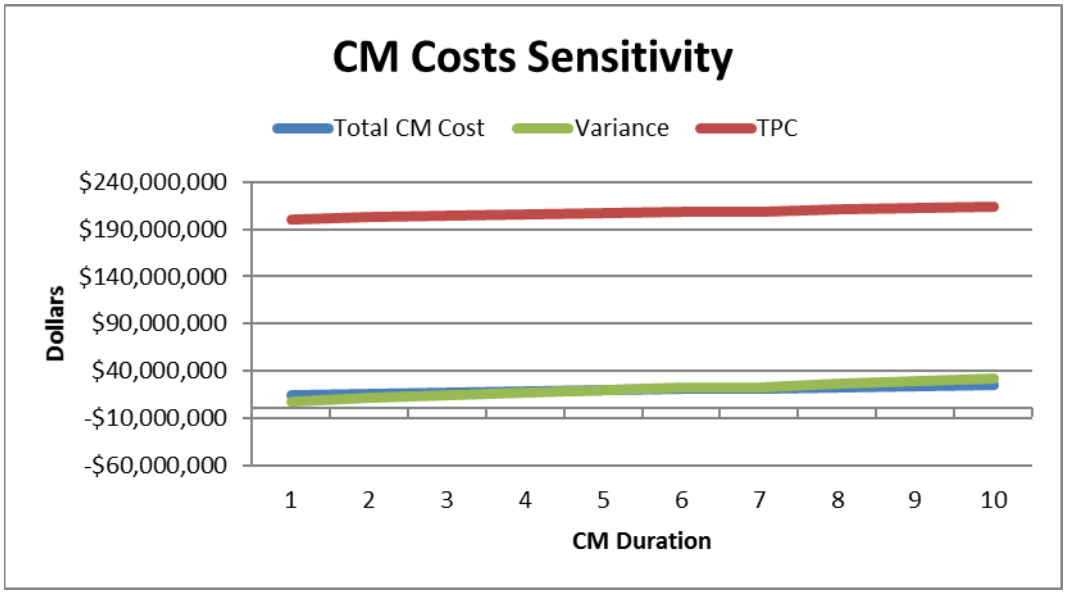


Figure 3-3: Sensitivity Analysis – CM/GC

The productivity for excavation of materials from the rock face to the skip hoist was examined. The labor hours per CY to drill, blast, scale, muck, transport and lift were varied from 50% to 275% of baseline. The results are shown in Table 3-4, based on adjusting only labor hour productivity.

Table 3-4: Sensitivity Analysis – Productivity

% of Nominal	Total Excavation $	TPC	+/- from base Productivity
50.00%	$81,818,115	$188,630,910	-$24,902,068
75.00%	$92,885,736	$201,091,944	-$12,441,034
100.00%	***$103,953,357***	***$213,532,978***	***$0***
125.00%	$115,020,977	$226,014,012	$12,481,034
150.00%	$126,088,598	$238,475,046	$24,942,068
175.00%	$137,156,219	$250,936,080	$37,403,102
200.00%	$148,223,839	$263,297,114	$49,764,136
225.00%	$159,291,460	$275,858,148	$62,325,170
250.00%	$170,359,080	$288,319,182	$74,786,204
275.00%	$181,426,701	$300,780,217	$87,247,239

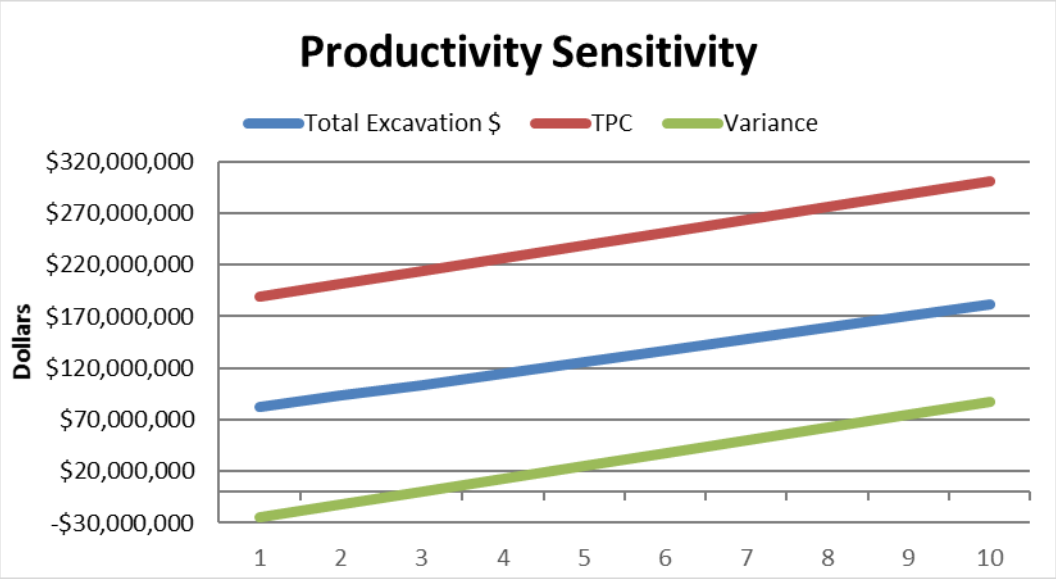


Figure 3-4: Sensitivity Analysis – Productivity

Inspection shows the estimate is most sensitive to labor productivity. A 50% difference in excavation productivity results in a 12% swing in base costs. A similar 50% swing in escalation changes the base costs by about 5%. Finally, altering the project duration from a low of 2.5 years to a high of 5 years results in a 3% variance around the base cost.

The preceding sensitivity analysis complies with GAO step #8.

3.4 COST RISK AND UNCERTAINTY ANALYSIS

The risk register for the ICE is shown in Appendix G. This is patterned after the Project Team's risk register, but one new risk was added and three were deleted. Deletion rationale is based on the following: 1) alterations to scope are normally handled through the Baseline Change Control process resulting in a new Performance Baseline for the project, 2) there is no way to quantify scope changes for risk impacts until the change is known, and 3) this risk deals with damaged cryostat equipment due to a rock fall, but this work is not part of the CD-3A scope.

Deletions:

- 1- Missing scope
- 2- Scope increases due to changing codes or regulations
- 3- Rock falls damage cryogenic equipment

Additions:

- Ross shaft rehab is delayed

We also adjusted the cost and/or schedule impacts for some risks based on our independent assessment, and altered the probabilities of a few risks.

Results from the independent risk analysis are shown in Table 3-5. The Technical and Programmatic (T&P) risk contingency, as well as the cost uncertainty, are determined using Monte Carlo probabilistic simulation techniques, evaluated at the 90% confidence level.

Table 3-5: Independent Risk Analysis Results

Description	Contingency, $M
Cost uncertainty	15.4
Technical & programmatic risks	36.5
Schedule contingency	10.8
Total	**62.7**

The estimate uncertainty is developed by taking the estimate details, establishing a low estimate, a most likely estimate, and a high estimate for each major WBS element. The data is then run through a Monte Carlo simulation (see attached results) using 50,000 trials and a 90% confidence level. The difference between the point estimate and the 90% certainty upper bound is identified as the estimate uncertainty, which is $15.4 million. Figure 3-5 shows the results of the cost uncertainty simulation analysis.

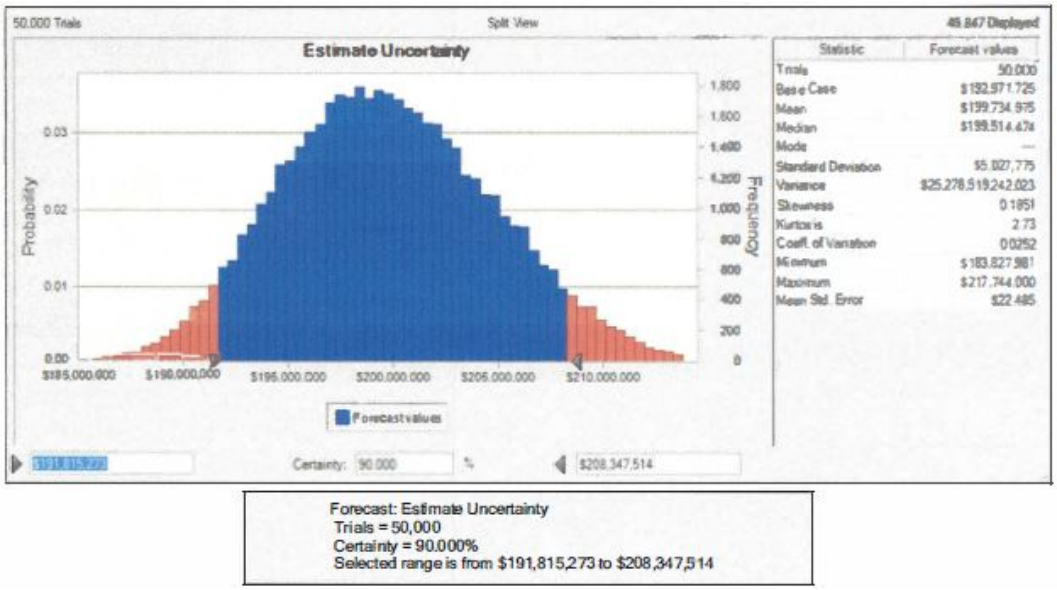


Figure 3-5: Estimate Uncertainty – Monte Carlo Results

The T&P contingency is based upon the risk register shown in Appendix G. The identified risks, along with their probability of occurrence and impacts, are then run through a Monte Carlo simulation using 50,000 trials, and the risk contingency is determined at a 90% confidence level. This T&P risk-based contingency is identified as $36.5 million. Figure 3-6 shows the results of the T&P contingency simulation analysis.

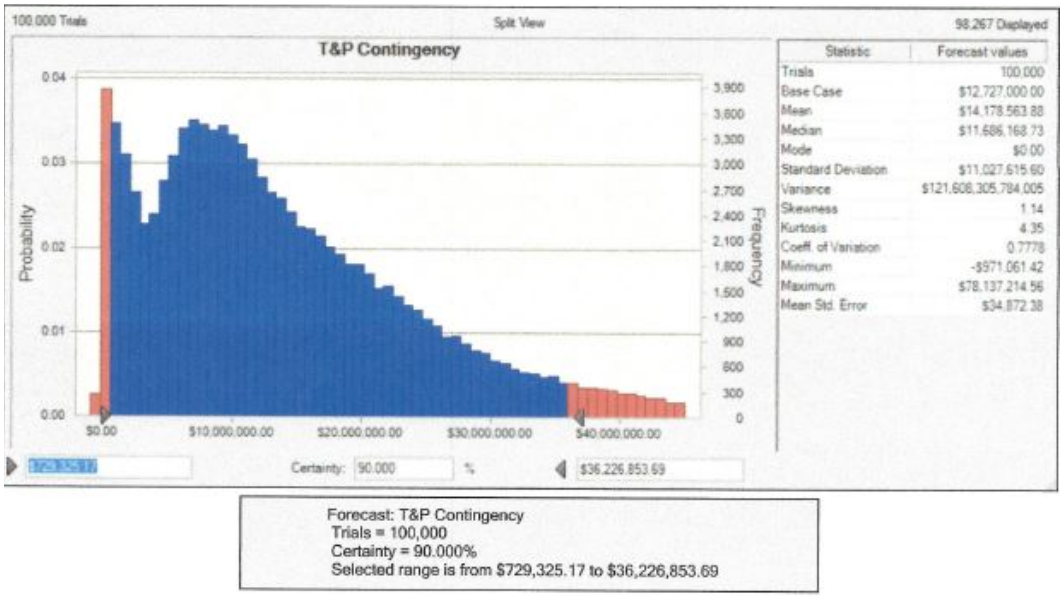


Figure 3-6: T&P Risk Contingency – Monte Carlo Results

The schedule contingency is derived using the 14.4 months of schedule float determined by the Project Team, and multiplying that by the ICE Team's hotel load of $750K per month. This results in schedule contingency of $10.8 million. The hotel load is independently calculated from the CM and GC staff required to remain onsite during schedule delays, as well as the temporary facilities, equipment and utilities. The ICE Team did not simulate schedule contingency using probabilistic techniques, but instead performed a very rudimentary check on the Project Team's schedule float. This was done by averaging the best, most likely, and worst case schedule impacts (months) for each risk event, multiplying the average by the expected probability, and summing the resultant value for all risks. This yielded 15.3 months of float, which is very close to the Project Team's 14.4 months.

As a percentage of base costs, the $62.7 million ($63M rounded) total contingency determined by the ICE represents 34.6% of the base costs. This compares with 38% for the Project Team estimate.

The preceding discussion complies with GAO Step #9.

Section 4
Results and Findings

4.1 SUMMARY OF RECONCILIATION

Following completion of the first draft of the ICE, reconciliation telecons were held with the Project Team on February 3 and 5, 2016. The purpose was to address variances between the two estimates. The total variance was $58 million (19%) between the Project Team estimate ($302 million) and the ICE ($244 million). Based on the initial ICE, fairly significant variances (>15%) were observed for the major cost elements of Construction Management, Buildings and Site Infrastructure, and Excavation. These were both positive and negative variances. In addition, large variances were observed for escalation and contingency.

For the base estimate, discussions between the two teams revealed that 1) certain general conditions costs were binned differently, 2) different assumptions about the contracting approach were made by the Project Team and the ICE Team, and 3) there was a significant variance in waste rock handling costs between the two estimates.

Concerning the first issue, the ICE placed all costs for contractor overhead, profit, bonds, and insurance within the CM category, whereas the Project Team distributed these among the CM, BSI, and Excavation sub-elements. The ICE subsequently re-distributed the general condition costs to mirror the way the Project Team did it. This change did not affect the costs, only where the costs are collected.

Concerning the second issue, the ICE assumed that the CM/GC contractor would self-perform all trade subcontracts for the project, whereas the Project Team assumed the CM/GC would be managing multiple separate subcontracts, which creates some overlap in project management and project engineering personnel. The ICE added more management personnel to its GC staff in order to be consistent with the Project Team's approach. However, there may be an opportunity to decrease costs if the CM/GC self-performs some or all of the subcontract work.

On the final issue, the waste rock handling modifications represent specialty work not easily estimated. In fact, the Project Team used a specialty contractor to estimate the waste rock handling costs. The ICE agreed to accept the Project Team's estimate for this work, which increased the ICE by $8.3 million in direct costs alone.

Differences in escalation and contingency were not reconciled. The bases of both estimates are reasonable, but there tends to be much more subjectivity in calculating escalation and contingency costs than in estimating base costs. Therefore, it was determined to show the unreconciled figures from both teams.

During reconciliation, we also verified that the excavation scope of work was consistent between the Project Team and ICE. Results showed the estimates of mined rock agreed within 0.2%.

The information provided here complies with GAO Steps #7 and #12.

4.2 SUMMARY OF VARIANCE ANALYSIS

Base Costs. Fairly significant variances are evident between the Project Team cost estimate and ICE at WBS level 6. However, these variances are largely attributed to how each estimate bucketed specific work activities within each WBS element. For example, the ICE included rock handling-surface costs in the BSI work, whereas the Project Team included these costs in Excavation.

More importantly, the total base costs show only 3% variance, which is agreement.

Escalation. The escalation variance is directly proportional to the escalation rates assumed by the two estimating teams (3.4% per year vs. 2.4% per year). The variance tightened up following reconciliation due to moving excise taxes into the base costs, adding more GC staff, and increasing the cost for waste rock handling modifications. The teams agreed that both rates were reasonable, and each team would maintain their respective rates.

Contingency. The 24% contingency variance is attributed to the different approaches utilized between the Project Team and ICE Team. The ICE based its contingency on the combined costs of cost uncertainty, T&P risk, and schedule contingency.

Part of the variance is due to differences in schedule contingency (burn rate) between the two estimates. Although the ICE Team used the same schedule float as the Project Team, it independently determined a higher hotel load based on required personnel and facilities. This results in a variance of $3 million between the two estimates.

Further, the ICE Team deleted three scope-related risks from the Project's risk register (see App G), and also adjusted some of the probabilities and impacts of remaining risks based on our independent analysis.

Summary. Table 4-1 compares the variances in the major estimate areas both before and after reconciliation.

Table 4-1: Variance Comparison

WBS	Description	% Variance before Reconciliation	% Variance after Reconciliation
131.01.02.02.04.01	FSCF Construction Management	+46	(16)
131.01.02.02.04.02	Buildings & Site Infrastructure (BSI)	(19)	+27
131.01.02.02.04.03	Cavern & Drift Excavation (EXC)	(26)	(13)
	Subtotal	(17)	(3)
	Escalation	(30)	(20)
	Contingency	(24)	(24)
	Total	**(19)**	**(11)**

The information provided here complies with GAO Step #7.

4.3 Overview of Results and Findings

DOE's Office of Project Management Oversight and Assessments (PM) prepared an Independent Cost Estimate (ICE) of the CD-3A scope request for the Long Baseline Neutrino Facility/Deep Underground Neutrino Experiment (LBNF/DUNE) project. The Project Team's cost estimate to complete the CD-3A work scope is $302 million, consisting of $219 million in base costs and $83 million contingency. The project schedule shows completion of CD-3A work scope by May 1, 2022.

The ICE Team reviewed all CD-3A project documentation, met with members of the Project staff, toured the construction site, and conducted reconciliation meetings with the Project Team. We found good support documentation for the CD-3A work scope, which was complemented with excellent cooperation and responsiveness from the Project.

The ICE was conducted in accordance with PM's *Independent Cost Review (ICR) and Independent Cost Estimate (ICE) Standard Operating Procedures (SOP),* and used the same ground rules and assumptions as the Project Team. The ICE consists of a combination of Types II, III, IV, and V independent cost estimates. The ICE also performed a completely independent risk analysis using Monte Carlo simulation techniques.

Table 4-2 provides a comparison of costs between the project estimate and the ICE following reconciliation. Variance percentages are also indicated.

Table 4-2: Project Cost Estimate vs. ICE

WBS	Description	Project Cost, $M	ICE, $M	Variance, %
131.01.02.02.04.01	**FSCF Construction Management**	**23**	**19.3**	(16)
131.01.02.02.04.02	**Buildings & Site Infrastructure (BSI)**	**48**	**60.8**	+27
131.01.02.02.04.03	**Cavern & Drift Excavation (EXC)**	**119**	**103.9**	(13)
	Subtotal	**190**	**184**	(3)
	Escalation	29	23	(20)
	Subtotal	**219**	**207**	(5)
	Contingency	83	63	(24)
	Total CD-3A Request	**302**	**270**	**(11)**

The ICE Team concluded the following:

- The proposed cost and schedule for the LBNF/DUNE CD-3A project scope are reasonable, well-documented, and supports CD-3A approval.
- The 11% variance between the Project estimate and ICE drops to 3% when escalation and contingency differences are excluded, which is excellent agreement.
- Differences in base costs between both estimates were reconciled. Differences in escalation and contingency were not reconciled, however the escalation and contingency figures used in both estimates are reasonable and defensible.
- The Project estimate conforms to the GAO Best Practices for Cost Estimating.

The information provided here complies with GAO Step #7.

Figure 4-1: Ross Shaft Headframe

Appendix A
References

1. DOE Order 413.3B, *Program and Project Management for the Acquisition of Capital Assets*, November 29, 2010
2. Department of Energy (DOE) Office of Engineering and Construction Management, *Cost Review and Estimate (ICR, ICE) Standard Operating Procedure*, Rev.1, September 2013
3. DOE Guide 413.3-9, *Project Review Guide for Capital Asset Projects*
4. U.S. General Accountability Office, *GAO Cost Estimating and Assessment Guide*, GAO-09-3SP, March 2009.
5. DOE Guide 413.3-21, *Cost Estimating Guide*, May 9, 2011
6. U.S. Department of Energy, *Preliminary Project Execution Plan for the Long Baseline Neutrino Facility/Deep Underground Neutrino Experiment (LBNF/DUNE) Project*, December 2015.
7. *Long Baseline Neutrino Facility/Deep Underground Neutrino Experiment (LBNF/DUNE) Project Management Plan*, October 16, 2015.
8. *LBNF/DUNE Procurement Plan*, October 2015.
9. U.S. Department of Energy, *Acquisition Strategy for the Long Baseline Neutrino Facility/Deep Underground Neutrino Experiment (LBNF/DUNE) Project*, October 2015.
10. *LBNF/DUNE Project Assumptions*, October 12, 2015.
11. Fermilab Office of Project Support Services, *Fermilab Risk Management Procedure for Projects*, May 20, 2015.
12. Far Site Conventional Facilities Risk Register, November 14, 2015.
13. *LBNF/DUNE Contingency Analysis and Plan*, November 2015.
14. Fermilab, *Long Baseline Neutrino Facility/Deep Underground Neutrino Experiment (LBNF/DUNE) Risk Management Workshop*, April 14-15, 2015.
15. Various Risk Assessment Forms
16. Far Site Conventional Facilities Work Breakdown Structure
17. Far Site Conventional Facilities Critical Path Schedule, November 18, 2015
18. Far Site Conventional Facilities Milestone Dictionary and Chart, November 13, 2015
19. Far Site Conventional Facilities Detailed Schedule, October 12, 2015
20. Far Site Conventional Facilities Milestone Schedule, October 12, 2015
21. Far Site Conventional Facilities CD-3A Schedule, November 12, 2015
22. *Long Baseline Neutrino Facility/Deep Underground Neutrino Experiment (LBNF/DUNE) Conceptual Design Report*, June 23, 2015.
23. ARUP USA, Inc., *South Dakota Science and Technology Authority – Sanford Underground Research Facility - A/E Services for Excavation Design and Site Investigation in Support of the LBNF Far Site Conventional Facilities - Excavation and Site Investigations 100% Preliminary Design Report*, August 14, 2015.
24. Long Baseline Neutrino Facility – Far Site Conventional Facilities – Excavation Design Drawings
25. Long Baseline Neutrino Facility – Far Site Conventional Facilities – Final Design Plan,

October 21, 2015

26. ARUP USA, Inc., *South Dakota Science and Technology Authority –Services for Infrastructure Design in Support of the LBNF Far Site Conventional Facilities Technical Authority – Buildings, Site and Infrastructure 100% Preliminary Design Report*, August 26, 2015.
27. Long Baseline Neutrino Facility – Far Site Conventional Facilities – Buildings, Site and Infrastructure Design Drawings
28. ARUP USA, Inc., *South Dakota Science and Technology Authority – A/E Services for Excavation Design in Support of the LBNF Far Site Conventional Facilities Time Dependent Movement Assessment Report*, February 2, 2015.
29. ARUP USA, Inc., *South Dakota Science and Technology Authority –A/E Services for Infrastructure Design in Support of the LBNF Far Site Conventional Facilities Technical – Buildings, Site and Infrastructure 100% PD Cost/Schedule Report*, September 21, 2015
30. ARUP USA, Inc., *SDSTA/SURF – Long Baseline Neutrino Facility Far Site Detector Conventional Facilities – Excavation 100% Preliminary Design Cost/Schedule Report*, September 22, 2015.
31. Helander, Adam, *Estimate Development for CD-3A, Initial Far Site Construction*, Briefing, November 30, 2015.
32. Lundin, T., *LBNE Conventional Facilities (CF) Approach to Cost Escalation*, April 25, 2013.

Appendix B
List of Acronyms

AD	FNAL Accelerator Division
A-E	Architect-Engineer
ANSI	American National Standards Institute, Inc.
ARR	Accelerator Readiness Review
AS	Acquisition Strategy
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
BOE	Basis of Estimate
BCP	Baseline Change Proposal
BCY	Bank Cubic Yard
BNL	Brookhaven National Laboratory
BSI	Buildings & Site Infrastructure
CAM	Control Account Manager
CD	Critical Decision
CDR	Conceptual Design Report
CERN	European Laboratory for Particle Physics
CH	Chicago Office
CM	Construction Manager
COR	Contracting Officer's Representative
D&D	Decontamination & Decommissioning
DOE	Department of Energy
DUNE	Deep Underground Neutrino Experiment
DUSEL	Deep Underground Science and Engineering Laboratory
EA	Environmental Assessment
EFIG	Experiment-Facility Interface Group
EVMS	Earned Value Management System
ES&H	Environment, Safety and Health
FESS	FNAL Facilities Engineering Services Section

FNAL	Fermi National Accelerator Laboratory
FPD	Federal Project Director
FRA	Fermi Research Alliance, LLC
FSCF	Far Site Conventional Facility
FY	Fiscal Year
GC	General Contractor
ICE	Independent Cost Estimate
ISMS	Integrated Safety Management System
IPT	Integrated Project Team
HEP	High Energy Physics
HEPAP	High Energy Physics Advisory Panel
KPP	Key Performance Parameters
LAr	Liquid Argon
LBNC	Long Baseline Neutrino Committee
LBNE	Long Baseline Neutrino Experiment
LBNF	Long Baseline Neutrino Facility
LI	Funding Type – Line Item
LLP	Long Lead Procurement
M&O	Management & Operating
MOU	Memorandum of Understanding
NEPA	National Environmental Policy Act
NSF	National Science Foundation
NUMI	Neutrinos at the Main Injector
ODC	Other Direct Costs
OPC	Other Project Costs
OPSS	FNAL Office of Project Support Services
OSHA	Occupational Safety and Health Administration
P5	Particle Physics Project Prioritization Panel
PARS	Project Assessment and Reporting System
PD	Project Director
PEP	Project Execution Plan
PM	Office of Project Management Oversight and Assess-

	ments
PME	Project Management Executive
PMP	Project Management Plan
PPD	FNAL Particle Physics Division
QA	Quality Assurance
QC	Quality Control
R&D	Research & Development
RLS	Resource-loaded schedule
SC	Office of Science
SDSTA	South Dakota Science & Technology Authority
SOW	Statement of Work
SURF	Sanford Underground Research Facility
TEC	Total Estimated Cost
TPC	Total Project Cost
WBS	Work Breakdown Structure

Appendix C
Bios of ICE Team Members

Team Member	Cost	Schedule	Risk Mgt
Pete Bako, DOE Team Lead	**A**	**A**	**A**
Doug Gray, Contractor Lead	**A**		**L**
Dave Jansen, Contractor	**L**		
Joy Sichveland, Contractor		**L**	**A**

L-Lead, A-Assist

PETER I. BAKO, PMP, CCP, DOE

Peter I. Bako has over 20 years of experience in program and project management and is responsible for successful completion of a wide variety of both construction and operations & maintenance projects. Having served over 20 years as a U.S. Air Force Civil Engineering Officer, he planned, programmed, designed, and managed numerous facility and infrastructure projects throughout the United States, Honduras, Germany, England, Iraq, Kuwait, and Saudi Arabia. Mr. Bako has been with the Department of Energy for just over one year in his current position in the Office of Project Management Oversight and Assessments (PM) and recently began supporting the Office of Science capital asset program. Mr. Bako has a BS degree in Mechanical Engineering from the University of Connecticut and is a certified Project Management Professional and Certified Cost Professional.

DOUGLAS A. GRAY, BS, PE

Douglas A. Gray has 40 years of experience in program and project management, engineering supervision, and independent consulting. Work experience includes the chemical, mining, energy, nuclear, and environmental industries. Mr. Gray's focus over the past 20 years has been in support of the DOE performing independent cost estimates (ICEs), independent cost reviews (ICRs), and external independent reviews (EIRs) of major DOE projects and programs ranging in cost from $5 million to $60 billion. These reviews include independent assessment of baseline life-cycle costs, construction and operations cost estimates, D&D costs, work breakdown structures, risk assessments, and contingency analyses. Mr. Gray performed cost reviews for several DOE capital line-item projects such as the

Remote-Handled Low Level Waste Project at Idaho, and the Saltstone Disposal Unit #6 at the Savannah River Site. Independent cost estimates completed by Mr. Gray include the Highly Enriched Uranium Material Facility (HEUMF) Project at the Y-12 National Security Complex, and the Muon-to-Electron Conversion Experiment Project at FermiLab. Mr. Gray was responsible for the cost review and risk assessment portions of the external independent reviews conducted for the DOE Environmental Management baseline programs at Brookhaven National Laboratory, Lawrence Livermore National Laboratory, Pantex, Nevada Test Site, Lawrence Berkeley National Laboratory, Los Alamos National Laboratory, Hanford Reservation, Waste Isolation Pilot Plant, Idaho National Laboratory, Oak Ridge, and the Portsmouth/Paducah sites. He also co-authored the new Level 2 and Level 3 risk management courses for DOE, as well as the new cost-estimating course. Mr. Gray has a BS degree in chemical engineering, and is a licensed Professional Engineer.

W. DAVID JANSEN, CCP, PMP, LGC

W. David Jansen is a professional manager with over 40 years' experience in engineering, construction, estimating, scheduling, and project management. He has managed hundreds of projects start to finish, including conceptual design development, design programs, independent reviews, independent cost estimates, and project schedules. Mr. Jansen has worked on numerous projects that required implementation of DOE-O 413.3B related to completion of the various Critical Decision Points (CD-0 through CD-4). As a certified cost professional, Dave has been lead estimator for numerous large-scale DOE projects including in the last year, the National Interim Storage Facility for commercial spent nuclear fuel and the Permanent Ventilation System (including drifts and shaft) for the WIPP TRU waste repository. In addition to his many assignments on DOE projects, Mr. Jansen has worked extensively with major industry leaders including Intel, Honeywell, Motorola, Southwest Airlines, Bechtel, Parsons, Shaw, CB&I, Orbital Science, and numerous city, county, state and federal agencies. He has spent much of his career managing high-tech, design–build projects. As a key manager in the commercial construction industry, along with his strong experience in the DOE complex, Dave has been intimately involved with developing construction contracting strategies, preparing budgetary/planning assessments, conducting life cycle cost analyses, performing bid/proposal analysis and performing monthly performance assessments on multiple projects. Mr. Jansen is a Certified Cost Professional (CCP) through AACE-International, Professional Project Manager (PMP) through Project Management Institute, and is also a Licensed General Contractor, having held licenses in several states. Mr. Jansen holds a Master's Degree in Mechanical Engineering from Drexel University and has a strong civil engineering background.

JOY SICHVELAND, BA, MS

Joy Sichveland is a project management consultant specializing in scheduling and earned value management, with over ten years of experience. She is proficient in advanced scheduling techniques using Microsoft Project and Primavera. She has developed, maintained, analyzed and reported on large, complex DoD, DOE and NSF programs, including engineering, construction and information technology schedules. She has hands-on experience in all aspects of EVMS implementation, evaluation, validation, and surveillance and is proficient in EVM policy and guidance, including the EVM Implementation Guide (EVMIG), ANSI/EIA-748-B and the Planning & Scheduling Excellence Guide (PASEG). She has been selected as an EVMS subject matter expert and a key team member for EVM implementation for multiple DoD contracts. She has also served on program reviews for DCMA, DoD and DOE. As a scheduling and EVMS specialist, Ms. Sichveland has trained and coached Control Account Managers (CAMs) in all facets of project management, such as establishing baselines, preparing for major reviews, understanding CPRs and interpreting schedule data analysis. She has also authored various training guides for SRAs, IRAs and IMS assessments for Air Force SAF/AQXC, DCMA and NAVAIR. She has helped develop policy and guidelines through her work to establish requirements for Air Force risk management policy, process, training, advocacy, and enabling. In addition, she has been a team member in the EVMIG update effort to reflect current policy documents and contributing author to the PASEG that follows the Generally Accepted Scheduling Principles (GASP). Ms. Sichveland holds a BA degree in Psychology from Emory University in Atlanta, Georgia and a MS degree in Mental Health Counseling from Western Washington University in Bellingham, Washington.

Appendix D
Types of Independent Cost Estimates

Following is a general description of the various types of independent cost estimates.

Type II (Reasonableness Review). For this review, the ICE Team reviews all available project documentation; receives briefings from and holds discussions with the Project Team; completes sufficient analysis to assess the reasonableness of the project assumptions that support the cost and schedule estimates; ascertains the validity of those assumptions; assesses the rationale for the estimating methodology used; and checks the completeness of the estimate, including appropriate allowances for risks and uncertainties. The Team addresses the following review areas and associated lines of inquiry.

- For selected WBS elements (see Section 2.1), review the detailed basis for the cost estimate and schedule duration.
- Identify and assess key cost estimate assumptions and evaluate the reasonableness of these assumptions, as related to the quality of the cost estimates for each WBS element selected for detailed review.
- Examine the cost estimates for completeness without omission or duplication.
- Ensure the cost estimate reflects the selected methods, processes and schedule for its implementation.
- Review allocated resources to determine appropriateness of the costs.
- Review estimates of level-of effort work to determine if discrete work is inappropriately classified as level-of-effort work.
- Review and assess the estimating methods used (historical data, parametric estimating, vendor quotes, etc.).
- Review the reasonableness of project management and project support costs compared to the overall project costs.

Type III (Parametric Estimating Approach). This approach, in addition to incorporating all of the activities needed for a Reasonableness Review, utilizes parametric techniques, factors, etc., to analyze project costs and schedules, and is usually accomplished at a summary WBS level. A parametric estimate comprises cost estimating relationships and other cost estimating functions that provide logical and repeatable relationships between independent variables, such as design parameters or physical characteristics and cost, the dependent variable. Capacity factor and equipment factor are simple examples of parametric estimates; howev-

er, sophisticated parametric models typically involve several independent variables or cost drivers. Parametric estimating is reliant on the collection and analysis of previous project cost data in order to develop the cost estimating relationships. A key in the use of parametric techniques is the occurrence of valid statistical relationship, or CER, between historical costs and program, physical, and performance characteristics established and how logical is the relationship between key cost drivers.

Type IV (Sampling Approach). This review also begins with the activities needed for a Reasonableness Review, but in addition requires the ICE team to identify the key cost drivers. A "cost driver" is a major estimate element whose sensitivity significantly impacts TPC. Detailed, independent estimates will be developed for these cost drivers. Such estimates will include vendor quotes for major equipment, and detailed estimates of other materials, labor, and subcontracts. The approach for developing detailed ICE estimate of the cost drivers is similar to what is described below for Type V estimates. Cost elements which are not cost drivers are evaluated by a combination of methods that entails a detailed evaluation of specific cost elements. This detailed review might include quantity checks against the design/approach, price comparison to historic or published data for specific elements, etc.

Type V (Bottom-up Estimating Approach). This is the most detailed and extensive ICE effort. It begins with the activities needed for a Reasonableness Review. In addition, this approach requires a detailed bottom-up independent cost estimate, a schedule assessment, and an independent cost/schedule risk analysis. This requires quantity take-offs/development, vendor quotations, productivity analysis, use of historical information, and any other means available to do a thorough and complete estimate of at least 75 percent of the project's cost. Cost estimates shall be developed utilizing current pricing and best available data relative to the local area and work on the site. Davis-Bacon wage rates or local prevailing wage rates shall be used for construction Subcontractor activities. Installation unit rates shall be adjusted for site construction impacts, if necessary. Equipment and construction equipment and required material cost shall be included. Subcontractor overhead including FUI (Federal Unemployment Insurance), SUI (State Unemployment Insurance), miscellaneous taxes, profit, bond, and general requirements shall be detailed in the cost estimate. Estimated construction labor hours shall also be determined in order to estimate the duration for general requirements.

It may not be possible to do a completely independent estimate on some portions of the project estimate, and for those portions – which should not exceed 25 percent of the total estimate – the project estimate may be used if it has passed the test of reasonableness.

Appendix E
Basis of Estimate

LBNF–DUNE CD-3A Conventional Facilities

The LBNF-DUNE project is initiating site work at the Far Site in Lead, South Dakota to house the neutrino detection experiment portion of the DUNE project. As part of the review process to determine project readiness to proceed, DOE is conducting an Independent Cost Estimate (ICE) for the conventional facilities in South Dakota.

The scope of this estimate includes four major categories/areas.

1. Construction Management
2. Pre-Excavation
3. Excavation of the Large Detector Caverns
4. Buildings & Site Infrastructure (BSI) at the surface and below grade

The basis of estimate is developed in accordance with the project team WBS structure which will provide a clear roadmap should reconciliation be required between the Project Team estimate and the ICE.

The scope of the conventional facilities is extensive, and the ICE effort is developed at various levels of detail commensurate with the work involved and the risk to the project.

Type II estimates (Reasonableness Assessment) are used on some of the WBS elements that are not cost drivers and represent limited risk to the success of the project. Type III (Parametric) estimates are used where the design is reasonably advanced and quantity takeoffs can be performed. Examples of this type of estimate include building costs, utility costs, and common construction systems (no unique or experimental systems). The most detailed estimates are Type IV/V (Deterministic) and have been used for the excavation work and BSI systems below grade as well as the Construction Management costs.

Work Breakdown Structure (WBS)

The initial WBS was provided by the LBNF Project Team and was used to structure the ICE data. The original WBS is shown as follows:

131.01.02.02.04 FSCF Construction
- 131.01.02.02.04.01 FSCF Construction Management
- 131.01.02.02.04.02 Buildings & Site Infrastructure (BSI)
  - 131.01.02.02.04.02.00 Milestones and Procurements

131.01.02.02.04.02.1A General Conditions
131.01.02.02.04.02.1B Phase A
131.01.02.02.04.02.1C Phase B
131.01.02.02.04.02.02 Phase 1 BSI
131.01.02.02.04.02.02.1 BSI – Surface
131.01.02.02.04.02.02.2 BSI - 4850L
131.01.02.02.04.02.02.3 BSI - 4905L
131.01.02.02.04.02.02.4 BSI – Shaft
131.01.02.02.04.02.03 Phase 2 BSI
131.01.02.02.04.02.03.2 BSI - 4850L
131.01.02.02.04.02.04 Phase 3 BSI
131.01.02.02.04.02.04.3 BSI - Ross Shaft
131.01.02.02.04.03 Cavern & Drift Excavation (EXC)
131.01.02.02.04.03.00 Milestones and Procurements
131.01.02.02.04.03.1A General Conditions
131.01.02.02.04.03.1B Phase A
131.01.02.02.04.03.1C Phase B
131.01.02.02.04.03.02 Phase 1 Excavation
131.01.02.02.04.03.02.01 Ventilation and Blast Containment
131.01.02.02.04.03.02.05 Underground: Excavations
131.01.02.02.04.03.02.06 Underground: Additional Items
131.01.02.02.04.03.03 Phase 2 Excavation
131.01.02.02.04.03.03.01 Ventilation and Blast Containment
131.01.02.02.04.03.03.02 Underground: Excavations
131.01.02.02.04.03.03.03 Underground: Additional Items
131.01.02.02.04.03.04 Phase 3 Excavation (EXCLUDED–FUTURE)
131.01.02.02.04.03.04.01 Ventilation and Blast Containment
131.01.02.02.04.03.04.02 Underground Excavations
131.01.02.02.04.03.04.03 Underground: Additional Items
131.01.02.02.04.03.04.04 Additional
131.01.02.02.04.03.05 Phase 4 Excavation EXCLUDED – FUTURE)
131.01.02.02.04.03.05.02 Underground: Excavations
131.01.02.02.04.03.05.03 Underground: Additional Items

The WBS was restructured by the Project Team after the start of the ICE work, but does not affect the data or results developed by the ICE team.

WBS 131.01.02.02.04.01 FSCF Construction Management

The LBNF/DUNE Project Team expects to retain the services of a Construction Manager/General Contractor (CM/GC) to manage the entire scope of construction services as well as self-perform a number of the construction activities. As such, the estimate developed for CM/GC services was broken into two levels. The Construction Management Services are contained in this WBS.

The project anticipates completion in 1st quarter 2021, marking the completion of construction services. While the Project Team intends to bring on a CM/GC in mid-2016, the bulk of services will be delivered during the actual construction, which begins in 2018. Consequently, the duration for the CM services is assumed to be 3.75 years. Included in these CM services are the following functions:

- Project Management
- Construction Management
- ES&H
- QA/QC
- Project Controls
- Estimating
- Scheduling
- Subcontract Administration
- A/E support
- SDSTA support staff
- Temp Facilities
- Temp Utilities
- Temp Services
- Security
- General Services

This scope of services does not include direct supervision of the work or the management of direct hire craft. These items are contained in a WBS element associated with the execution of the work.

WBS 131.01.02.02.04.02 Buildings & Site Infrastructure (BSI)

The Building and Site Infrastructure is a myriad of improvements to the facility at the surface, within the Ross shaft, and at the 4850L of the laboratory.

The following items are included at the surface:

1. Expansion of the electrical substation
2. Construction of a new Cryogenics building
3. Refurbishment of the Ross and Yates head-frame structures

4. Rehabilitation of the rock crushing equipment
5. Construction of a rock handling system to transport crushed rock to the truck loading station
6. Cryogenic piping at the surface
7. Cybernetic backbone and distribution at the surface.

Where information is common conventional construction, the ICE Team prepared a Type III estimate. This would include the buildings and miscellaneous surface systems. Where the work is specialty work, the ICE team prepared a Type II reasonableness assessment and accepted the Project Team's estimate of the cost of the work. These items included: Substation, Rock Crusher rehabilitation, Shaft head frame rehabilitation and cryogenic piping and cybernetic backbone. The project team data is supported by numerous supplier and subcontractor quotations and is deemed by the ICE Team to be reasonable for purposes of recommending approval of the CD-3A costs.

At the 4850L area of the laboratory, the following items are included:

1. Fire protection throughout
2. General lighting
3. Electrical distribution
4. Communications distribution
5. Structural support for all distributed services
6. Electrical substation and switchgear
7. Central Utilities Cavern (CUC) fit-up (exclusive of cryogenic equipment)
8. Backup generator and fuel tank
9. Cryogenic piping to the CUC but not from the CUC into the detector caverns
10. Nitrogen vent piping to the surface
11. Laboratory offices
12. Concrete mixing station
13. Concrete receiving Station
14. Specific equipment required for construction of the drifts and caverns
15. Ventilation bulkheads and blast pressure protection

Where the Project Team has specific quotes from suppliers and vendors, those costs were reviewed for reasonableness (Type II). This included the cryogenic piping, communications distribution, electrical equipment, and specialty equipment. The ICE Team accepted these costs as reasonable and included those costs in the ICE TPC.

The ICE Team developed Type III estimates of all other services throughout the drifts and caverns. These costs included fire protection distribution, structural

supports, laboratory offices, and generator/fuel tank, concrete stations, and miscellaneous.

131.01.02.02.04.02.04.3 BSI - Ross Shaft

The Ross shaft is being rehabilitated under a separate contract and is not part of the LBNF CD 3A scope of work. The shaft will, however, be the path for execution of all of the work in the underground and will be the conduit for much of the piping, electrical and communications required for the future DUNE experiment.

The following items are included in the Ross Shaft BSI:

1. Relocation of the existing de-watering lines to eliminate conflict with cryogenic piping to the 4850L.
2. Installation of a new fire line from the 4100 level reservoir to provide fire protection at the 4850L throughout the laboratory
3. New Cryogenic piping (Argon and Nitrogen) to support the LAr detectors and their experiments.
4. New cybernetic backbone

The ICE Team prepared a Type II estimate for these scope items and accepted the costs as prepared by the Project Team and deemed them to be reasonable.

Per discussions with the Project Manager, only half of the cryogenic piping will be included in this CD-3A portion of the total project. The remainder will be part of a subsequent release.

131.01.02.02.04.03 Cavern & Drift Excavation (EXC)

The Cavern and drift excavation is the most complicated and costly portion of the CD-3A scope of work. The ICE Team performed deterministic estimates for this portion of the project and prepared a Type IV/V estimate for all drift and cavern excavation. While the excavation is segregated into discrete phases, we have prepared a single BOE for the entire excavation process. Included in this WBS element are:

131.01.02.02.04.03.00 Milestones and Procurements
131.01.02.02.04.03.1A General Conditions
131.01.02.02.04.03.1B Phase A
131.01.02.02.04.03.1C Phase B
131.01.02.02.04.03.02 Phase 1 Excavation
- 131.01.02.02.04.03.02.01 Ventilation and Blast Containment
- 131.01.02.02.04.03.02.05 Underground: Excavations
- 131.01.02.02.04.03.02.06 Underground: Additional Items

131.01.02.02.04.03.03 Phase 2 Excavation
- 131.01.02.02.04.03.03.01 Ventilation and Blast Containment
- 131.01.02.02.04.03.03.02 Underground: Excavations
- 131.01.02.02.04.03.03.03 Underground: Additional Items

131.01.02.02.04.03.04 Phase 3 Excavation (EXCLUDED–FUTURE)
- 131.01.02.02.04.03.04.01 Ventilation and Blast Containment
- 131.01.02.02.04.03.04.02 Underground Excavations
- 131.01.02.02.04.03.04.03 Underground: Additional Items
- 131.01.02.02.04.03.04.04 Additional

131.01.02.02.04.03.05 Phase 4 Excavation EXCLUDED – FUTURE)
- 131.01.02.02.04.03.05.02 Underground: Excavations
- 131.01.02.02.04.03.05.03 Underground: Additional Items

The drifts, rooms or caverns contained in each phase are fully detailed in the design drawings. The neat line dimensions are defined and the volumes of rock to be excavated are calculated.

A significant factor in the cost of the excavation is the over-break included in the volumes of rock to be removed. The over-break is assumed to be one foot in all directions beyond the neat line dimensions. This is to ensure that the neat line is not violated and that all equipment will have sufficient space to be moved and that estimates of the volume of rock to be disposed are adequate.

In developing the ICE data, we used a deterministic technique wherein the required cost elements were built up from productivity factors, primarily based on Costs/BCY. For labor we used MH/BCY. For materials we used a $$/BCY for items such as drill bids, explosives, machinery maintenance materials, etc. For equipment we used $$/CY for some equipment operations and $$/Hour for unit operational equipment such has haul trucks, dozers, and the like.

An average labor rate was developed and applied to all hours of work within the mine. This blended rate was comprised of first shift and second shift, with a shift differential of $2.00 per hour. Additionally, each shift is 11 hours and is comprised of eight regular time hours and three overtime hours. The overtime premiums were built into the blended average rate for work in the underground. Additionally, it was anticipated that much of the work force will be travelers and will be reimbursed for travel and per-diem; a premium of $10 per hour was added

for the TM&E expenses. We made no attempt to differentiate between first and second shift hours and addressed all labor hours using the blended rate.

Man-hours, material costs and equipment costs were developed for each identified separate excavation and costs were developed for each of the following tasks:

1. Drilling
2. Explosive placement and detonation
3. Rock mucking
4. Rock crushing and movement to the Ross shaft skips
5. Raising the rock up the Ross shaft
6. Loading and hauling to the disposal site
7. Ground controls (drilled/epoxy rods, wire mesh and end plates)
8. Floor concrete – unreinforced except in the caverns
9. Shotcrete over all surfaces.

To provide a direct comparison to the project team estimate, all rock was assumed to be hauled by truck to the Gilt Edge Mine, a six-mile one way haul. The Project Team is considering alternative disposal methods, but these were not evaluated in the ICE.

Quantities:

All BCY quantities were taken from the engineers' drawings. A swell factor of 1.5 was applied to a BCY to achieve loose CY quantities. Tonnage was estimated using a factor of 1.5 tons per loose CY of rock.

Escalation Factor:

The project costs will be expended over the several-year duration for the project. The point estimate in the ICE includes a single number, which escalates the entire cost of the project to the centroid of cost expenditures. This rate was 2.4% compounded annually (see Table E-1 for basis). We established the 50% point for project expenditures to be in 2019. The compounded escalation rate at that point is 12.59% and this rate was included in the ICE point estimate.

Table E-1: Annual Escalation Rate Forecast for LBNF/DUNE CD-3A Costs

Candidate Annual Escalation Rates[1]	Source
3.00%	DOE ICR of Pantex Admin Support Complex, March 2015
2.80%	IHS Global Insight, Nonresidential Construction Cost Index, Mean Forecast 2016-2024

Candidate Annual Escalation Rates[1]	Source
2.40%	*Engineering News-Record*, July 2015 Building Cost Index
2.30%	DOE Guidance to the Strategic Petroleum Reserve, July 2015
2.10%	*Engineering News-Record*, July 2015 Construction Cost Index
2.10%	The Budget and Economic Outlook, Fiscal Years 2013-2023, Congressional Budget Office
2.09%	Energy Information Administration http://www.eia.gov/forecasts/steo/report/us_eco.cfm
2.40%	Mean of candidate rates
2.30%	Median of candidate rates

[1] Office of Management and Budget Circular A-94, Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs, p. 8, paragraph b., Recommended Inflation Assumption. When a general inflation assumption is needed, the rate of increase in the Gross Domestic Product deflator from the Administration's economic assumptions for the period of the analysis is recommended. For projects or programs that extend beyond the six-year budget horizon, the inflation assumption can be extended by using the inflation rate for the sixth year of the budget forecast. The Administration's economic forecast is updated twice annually, at the time the budget is published in January or February and at the time of the Mid-Session Review of the Budget in July. Alternative inflation estimates, based on credible private sector forecasts, may be used for sensitivity analysis.

Haul Size:

A haul size of 10 loose CY or 15 tons per load for truck was used to calculate the number of trips. The haul capacity of the Ross skips was taken as that provided by the Project Team at 3,000 tons per day maximum.

Exclusions:

The following items are excluded from the ICE determination:

1. Equipment within the new Cryogenics building that support the experiment (except cooling towers which were included in the ICE)
2. Half of the cryogenic piping to the 4850L down the Ross shaft
3. Equipment to support the experiment in the Central Utilities Cavern
4. Backup generator and day tank
5. Any of the equipment or materials associated with the Experiment itself.
6. Ross shaft rehabilitation
7. Ross dry rehabilitation (except the control room where finishes are included but control equipment is not)
8. Mezzanine structures in the caverns
9. Conveyance to the open cut, which is an alternative being considered by the Project Team

Appendix F
Detailed Schedule Analysis

Lag values are expected to be converted into activities to represent durations. There are also large lag values not included in the CD-3A scope but are within the logic network for these activities.

Lag values for CD-3A scope:

Predecessor Id	CD-3a Schedule Scope	Predecessor	Pred Type	Successor Id	CD-3a Schedule Scope	Successor	Succ Type	Lag	Type
1.DRF.HVPi	Yes	Ph1 Drifts - HVAC Piping	Normal	1.DRF.HVIn	Yes	Ph1 Drifts - HVAC Insulation	Normal	2	StartToStart
1.CUC.HVDis	Yes	Ph1 Central Utility Cavern - H	Normal	1.CUC.HVPi	Yes	Ph1 Central Utility Cavern - H	Normal	12	StartToStart
SURF10060	x	FSCF - OPS - Ross Crusher Ro	Normal	EXC-S-PhBMS	Yes	T6 MS - Start Phase B	Milestone	28	FinishToStart
1.DRF.HVPi	Yes	Ph1 Drifts - HVAC Piping	Normal	1.DRF.Sht	Yes	Ph1 Drifts - Sheet Metal	Normal	12	StartToStart
131122.0403.MB02MS4	Yes	T4 MS - FSCF - Beneficial Occu	Milestone	131122.0403.MB02MS2	x	T2 MS - FSCF - Beneficial Occu	Milestone	182	FinishToStart
SURF10140	Yes	FSCF - OPS - Ross Headframe	Normal	SURF10110	x	FSCF - OPS - Ross Cage Replac	Normal	6	FinishToFinish
1.DRF.HVPi	Yes	Ph1 Drifts - HVAC Piping	Normal	1.DRF.HVIn	Yes	Ph1 Drifts - HVAC Insulation	Normal	2	FinishToFinish
1.CUC.Sht	Yes	Ph1 Central Utility Cavern - S	Normal	1.CUC.HVIn	Yes	Ph1 Central Utility Cavern - H	Normal	12	StartToStart
131122.0403.MS2B	Yes	T4 MS - FSCF - EXC - Phase 2 F	Milestone	131122.0403.MB03MS	Yes	T4 MS - FSCF - Beneficial Occu	Milestone	60	FinishToFinish
131122.0403.MB02MS4	Yes	T4 MS - FSCF - Beneficial Occu	Milestone	131122.0403.MB02MS3	x	T3 MS - FSCF - Beneficial Occu	Milestone	92	FinishToStart
1.CUC.HVPi	Yes	Ph1 Central Utility Cavern - H	Normal	1.CUC.Sht	Yes	Ph1 Central Utility Cavern - S	Normal	12	StartToStart
131122.0402.MB01MS4	Yes	T4 MS - FSCF - Beneficial Occu	Milestone	131122.0402.MB01MS3	x	T3 MS - FSCF - Beneficial Occu	Milestone	92	FinishToStart
WDS1220MS	Yes	T6 MS - Start Waste Disposal	Milestone	GRZ1120	Yes	4850L Grizzly and Rock Breake	Normal	100	FinishToStart
SURF10090	x	FSCF - OPS - Ross Skip Replac	Normal	EXC-S-Ph1MS	Yes	T6 MS - Start Phase 1 Excavati	Milestone	6	FinishToStart
1.DRF.Sht	Yes	Ph1 Drifts - Sheet Metal	Normal	1.DRF.InWa	Yes	Ph1 Drifts - Industrial Water	Normal	12	StartToStart
131122.0403.MS1B	Yes	T4 MS - FSCF - EXC - Phase 1 F	Milestone	131122.0403.MB02MS4	Yes	T4 MS - FSCF - Beneficial Occu	Milestone	126	FinishToFinish
WDS1220MS	Yes	T6 MS - Start Waste Disposal	Milestone	GRZ1135	Yes	Procurement of LHD dump ar	Normal	99	FinishToStart
SURF10140	Yes	FSCF - OPS - Ross Headframe	Normal	SURF10090	x	FSCF - OPS - Ross Skip Replac	Normal	6	FinishToFinish
131122.0403.M00005MS	Yes	T5 MS - FSCF - EXC - Pre-EXC 1	Milestone	VenRehab01	Yes	Rehab To #31 via #4 Winze W	Normal	28	StartToStart
1.DRF.MEPSp	Yes	Ph1 Drifts - MEP Supports	Normal	1.DRF.HVPi	Yes	Ph1 Drifts - HVAC Piping	Normal	12	FinishToFinish
131122.0402.MB01MS4	Yes	T4 MS - FSCF - Beneficial Occu	Milestone	131122.0402.MB01MS2	x	T2 MS - FSCF - Beneficial Occu	Milestone	182	FinishToStart
4850-35.12 - INV	Yes	4850-35.12 - Concrete Invert S	Normal	Rail02	Yes	Concrete Invert Slabs Driver I	Normal	15	FinishToFinish
131122.0403.M00005MS	Yes	T5 MS - FSCF - EXC - Pre-EXC 1	Milestone	REL1030	Yes	Relocate Electrical Equipmen	Normal	28	StartToStart
1.DRF.MEPSp	Yes	Ph1 Drifts - MEP Supports	Normal	1.DRF.ElcDi	Yes	Ph1 Drifts - Normal Electrical	Normal	12	FinishToFinish
1.DRF.InWa	Yes	Ph1 Drifts - Industrial Water	Normal	1.DRF.Sprk	Yes	Ph1 Drifts - Sprinkler Fire Pro	Normal	12	StartToStart

High durations are expected to be reduced once additional activities are added to represent smaller pieces of work.

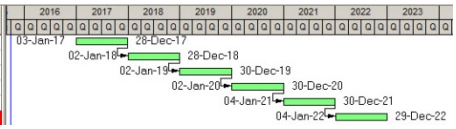
CD-3A activities with high durations:

WBS Path	Activity ID	Activity Name	Original Duration	Start	Finish
04.01.02	131122.0401.D00010	FSCF - Construction Administration Support (2017)	250	03-Jan-17	28-Dec-17
04.02.02.03.1	TRC1020	Install New Equipment	88	17-Jan-17	15-Jun-17
04.02.02.01.2.1	VenRehab01	Rehab To #31 via #4 Winze Wye	280	31-Jan-17	04-May-18
04.02.02.05.1.43	4850-43	4850-43 - ROSS SHAFT BROW	60	21-May-17	20-Jul-17
04.02.02.01.2.2	VenRehab04	3500 L Rehab for New Raise	100	23-May-17	14-Nov-17
04.02.02.07.2	RHB1140	Empty waste pass to intersection with #6 Winze waste pass. Install grou	70	11-Aug-17	20-Oct-17
04.02.02.06.3	WDS1200	Procurement	90	01-Sep-17	16-Jan-18
04.02.03.02.3	REL1260	Electrical into permanent 4850 L Shaft Sub Station	84	06-Oct-17	29-Dec-17
04.02.02.02.1	SURF10140	FSCF - OPS - Ross Headframe Reinforcement	85	10-Oct-17	13-Feb-18
04.01.02	131122.0401.D00070	FSCF - Construction Administration Support (2018)	251	02-Jan-18	28-Dec-18
04.02.03.03.7	WDS1260	Electrical WRHS	134	02-May-18	09-Nov-18
04.02.03.03.6	WDS1250	Surface WRHS	134	02-May-18	09-Nov-18
04.02.02.06.5	GRZ1135	Procurement of LHD dump and rock breaker components	44	13-Jul-18	14-Sep-18
04.02.02.02.1	SURF10200	FSCF - OPS - Yates Headframe Reinforcement	85	06-Aug-18	07-Dec-18
04.03.02.05.03.50.01	5000-01	5000-01 - ROSS SHAFT ACCESS RAMP	57	31-Dec-18	26-Feb-19
04.01.02	131122.0401.D00080	FSCF - Construction Administration Support (2019)	251	02-Jan-19	30-Dec-19
04.03.02.05.06.1	4850-36.1	4850-36.1 - Heading 1	50	28-Apr-19	17-Jun-19
04.03.02.05.02.41	4850-41 R	4850-41 - Raise	148	10-Jun-19	04-Nov-19
04.01.02	131122.0401.D00090	FSCF - Construction Administration Support (2020)	252	02-Jan-20	30-Dec-20
04.04.02.2.6.1.01.A	1.DRF.MEPSp	Ph1 Drifts - MEP Supports	44	03-Jan-20	09-Mar-20
04.04.02.2.4.3.02.03	1.CUC.ElcDi	Ph1 Central Utility Cavern - Normal Electrical Distribution System	66	17-Jan-20	22-Apr-20
04.04.02.2.2.5.02.03	1.CUC.Sht	Ph1 Central Utility Cavern - Sheet Metal	45	03-Apr-20	08-Jun-20
04.04.02.1.2.2.04.01	1112240103-E	Interfacing/Integrating w/ non-HVAC systems	90	14-Apr-20	20-Aug-20
04.04.02.2.4.8.02.03	1.CUC.PowT&C	Ph1 Central Utility Cavern - Testing & Commissioning	50	11-May-20	22-Jul-20
04.04.03.2.3.13.02.03	2.Ch2.T&C	Ph2 Chamber 2 - Testing & Commissioning	50	23-Jul-20	02-Oct-20
04.04.02.2.3.13.02.03	1.CUC.T&C	Ph1 Central Utility Cavern - Testing & Commissioning	50	12-Aug-20	23-Oct-20
04.04.02.1.5.4.3.4.6	1.Cry.T&C	Ph1 Cryo Building Complex - Testing & Commissioning	50	31-Aug-20	12-Nov-20
04.04.04.3.2	RS-1040	Ph4 Cyrogen structural steel support sets collar - set 295	55	23-Apr-21	17-Jun-21
04.04.04.3.2	RS-1050	Ph4 Cryogen pipe install/New Pump Discharge Install (7 Pipes) - Set 8	133	17-Jun-21	28-Oct-21

Total float values greater than two months are attributed to multiple reasons. It is expected that some high float values will be reduced once more detailed activities representing different phases of work required/expected throughout different times of the project are added to the schedule.

Other activities with high total float values seem to be LOE in nature but are identified as Task Dependent in the schedule.

Activity ID	Activity Name	Total Float	Start	Finish	Activity Type	Successors
131122.0401.D00010	FSCF - Construction Administration Support (2017)	1911	03-Jan-17	28-Dec-17	Task Dependent	131122.0401.D00070
131122.0401.D00070	FSCF - Construction Administration Support (2018)	1911	02-Jan-18	28-Dec-18	Task Dependent	131122.0401.D00080
131122.0401.D00080	FSCF - Construction Administration Support (2019)	1911	02-Jan-19	30-Dec-19	Task Dependent	131122.0401.D00090
131122.0401.D00090	FSCF - Construction Administration Support (2020)	1911	02-Jan-20	30-Dec-20	Task Dependent	131122.0401.D00100
131122.0401.D00100	FSCF - Construction Administration Support (2021)	1911	04-Jan-21	30-Dec-21	Task Dependent	131122.0401.D00110
131122.0401.D00110	FSCF - Construction Administration Support (2022)	1911	04-Jan-22	29-Dec-22	Task Dependent	



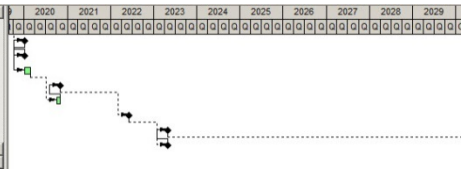
Examples of Task Dependent activities that seem to be LOE in nature:

Successor paths for CD-3A activities go to other areas of the schedule which have not been fully built out or logically tied. For example, T0 MS - CD-4 Approval (DOE Completion) does not have a successor or constraint applied, causing high total float values for CD-3A activities that are within the logic path to this milestone.

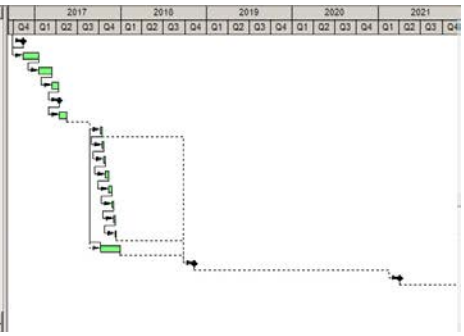
T4 MS - FSCF - Completion & Closeout is on the successor path for some of these CD-3A activities and may be a better fit to apply a constraint to, rather than T0 MS - CD-4 Approval (DOE Completion) which represents the overall completion of the LBNF/DUNE project and is logically tied to all ten schedules.

Examples of logic networks with high total float that go to T0 MS - CD-4 Approval (DOE Completion). These logic networks also go through T4 MS - FSCF - Completion & Closeout.

Activity ID	Activity Name	Total Float	Start	Finish	CD-3a Scope	Successors	Primary Constraint
131122.0402.MS1A	T4 MS - FSCF - BSI - Phase 1 Start	40	03-Jan-20		YES	131122.0402.BSI1, 1	
131122.0402.M00010M	T4 MS - FSCF - BSI - Construction Phase 1 NTP	59	03-Jan-20		YES	131122.0402.MS1C,	
4850-45 - Fit	Yates Shaft Fiber Fit Out	442	03-Jan-20	24-Feb-20	YES	131122.0402.PL02	
131122.0402.MS2B	T4 MS - FSCF - BSI - Phase 2 Finish	287		03-Nov-20	YES	131122.0402.BSI2, 1	
131122.0402.PL02	FSCF - BSI - Underground Phase 2 Punchlist	287	06-Oct-20	03-Nov-20	YES	131122.0402.MS2B	
BSI-CompletedMS	T6 MS - Complete BSI	1565		06-Jun-22		131122.0402.M0003	
131122.00.CD-4MS	T4 MS - FSCF - Completion & Closeout	1238		01-May-23		13111.8750MS0, 13	
131122.0402.M00030M	T6 MS - FSCF - BSI - Construction Contract Closeou	851		01-May-23		131122.00.CD-4MS	
13111.8750MS0	T0 MS - CD-4 Approval (DOE Completion)	0		11-Aug-30			



Activity ID	Activity Name	Total Float	Start	Finish	CD-3a Scope	Successors	Primary Constraint
131122.0403.P00230M	T5 MS - FSCF - Advance Procurement Pre-EXC Co	181	10-Nov-16		YES	131122.0403.P0023	As Late As F
131122.0403.P00230	PROC. - FSCF - Pre2 - Advance CM/GC Bid / Evalu	181	10-Nov-16	17-Jan-17	YES	131122.0403.P0024	
131122.0403.P00240	PROC. - FSCF - Pre2 - Advance DOE Construction (	181	18-Jan-17	14-Mar-17	YES	131122.0403.P0025	
131122.0403.P00250	PROC. - FSCF - Pre2 - Advance CM/GC Finalize Co	181	15-Mar-17	12-Apr-17	YES	131122.0403.M0001	
131122.0403.M00010M	T5 MS - FSCF - EXC - Pre-EXC 2 NTP	266	13-Apr-17		YES	EXCMOB, 131122.0	
EXCMOB	Mobilization for Pre-EXC Package 2	181	13-Apr-17	15-May-17	YES	EXI1260, RS-1220, /	
REL1265	Transfer Power Feed: Yates to Ross Fed	331	06-Oct-17	12-Oct-17	YES	REL1270, EXC-104	
REL1270	Relocate 12.5 KV CASPAR Temp to Perm	331	12-Oct-17	20-Oct-17	YES	REL1275	
REL1275	Remove Temp Yates Feed from Trolley	331	20-Oct-17	28-Oct-17	YES	REL1278	
REL1278	Hookup Fire/Wtr Ross to 17Ledge	331	28-Oct-17	11-Nov-17	YES	REL1279	
REL1279	Remove 6" Fire/Wtr through Trolley	331	11-Nov-17	25-Nov-17	YES	REL1285	
REL1285	Install Blast Wall in Trolley Drift	331	25-Nov-17	02-Dec-17	YES	REL1288	
REL1288	#6 Winze Blast Wall Access Drift	331	02-Dec-17	09-Dec-17	YES	REL1290	
REL1290	Outfit Exc Equip Ass Room	331	09-Dec-17	13-Dec-17	YES	EXC-F-PhBMS	
REL1260	Electrical into permanent 4850 L Shaft Sub Station	315	06-Oct-17	29-Dec-17	YES	REL1265, EXC-F-Ph	
EXC-F-PhBMS	T6 MS - Complete Phase B Excavation	0		09-Nov-18	YES	EXC-CompletedMS	
EXC-CompletedMS	T6 MS - Complete All Excavation	1995		02-Apr-21		131122.0403.M0003	
131122.0403.M00030M	T6 MS - FSCF - EXC - Construction Contract Closeo	1121		04-Apr-22		131122.00.CD-4MS,	
131122.00.CD-4MS	T4 MS - FSCF - Completion & Closeout	1238		01-May-23		13111.8750MS0, 13	
13111.8750MS0	T0 MS - CD-4 Approval (DOE Completion)	0		11-Aug-30			

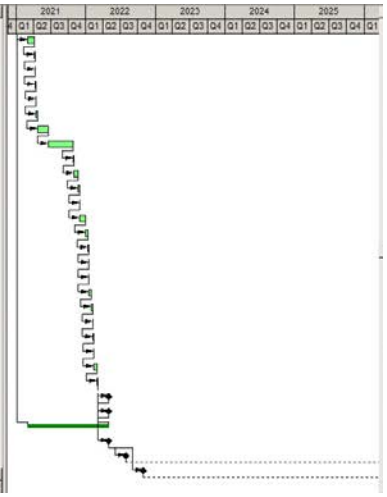


Other logic networks that include CD-3A activities are tied to T0 MS - CD-4 Approval (DOE Completion) through other activities/milestones (not T4 MS - FSCF - Completion & Closeout, as mentioned above).

Example of a logic network with high total float that goes to T0 MS - CD-4 Approval (DOE Completion):

Note that this network does not include T4 MS - FSCF - Completion & Closeout.

Activity ID	Activity Name	Total Float	Start	Finish	CD-3a Scope	Successors
RS-1261	Ph4 Brattice removal for the skip compartments	282	03-Mar-21	06-Apr-21	PART	RS-1000
RS-1000	Ph4 New structural pipe supports sets 4 to 12	282	06-Apr-21	08-Apr-21	PART	RS-1010
RS-1010	Ph4 4" water line (2) re-route between sets 7 & 8	282	08-Apr-21	09-Apr-21	PART	RS-1020
RS-1020	Ph4 6" compressed air re-route above set 12	282	09-Apr-21	13-Apr-21	PART	RS-1030
RS-1030	Ph4 6" deluge line reroute @ 12" below the collar	282	13-Apr-21	14-Apr-21	PART	RS-1035
RS-1035	Ph4 Excavation at Tramway ,1700L,2450L,3350L,3650L, 4100L & 4850L for pipe exit & entry	282	14-Apr-21	23-Apr-21	PART	RS-1040
RS-1040	Ph4 Cyrogen structural steel support sets collar - set 295	282	23-Apr-21	17-Jun-21	PART	RS-1050
RS-1050	Ph4 Cryogen pipe install/New Pump Discharge Install (7 Pipes) - Set 83-296	282	17-Jun-21	28-Oct-21	PART	RS-1055
RS-1055	Ph4 New 12" discharge set 297 to 308	282	28-Oct-21	29-Oct-21	PART	RS-1060
RS-1060	Ph4 Install new thrust blocks (1250L, 2450L, and 3650L)	282	29-Oct-21	19-Nov-21	PART	RS-1070
RS-1070	Ph4 New 12" Pump discharge column install (set 12-82) 1250L to Tramway	282	19-Nov-21	28-Nov-21	PART	RS-1075
RS-1075	Ph4 10" Decant line re-route	282	28-Nov-21	28-Nov-21	PART	RS-1090
RS-1090	Ph4 12" Old pump discharge removal and cryogen pipe install set 28-82	282	28-Nov-21	28-Dec-21	PART	RS-1100
RS-1100	Ph4 12" Old pump discharge, 10" Decant removal and cryogen pipe install set 12-27	282	28-Dec-21	12-Jan-22	PART	RS-1110
RS-1110	Ph4 Tie-in 12" pump discharge (3650L)	282	12-Jan-22	14-Jan-22	PART	RS-1120
RS-1120	Ph4 Tie-in 12" pump discharge (2450L)	282	14-Jan-22	16-Jan-22	PART	RS-1130
RS-1130	Ph4 Tie-in 12" pump discharge (1250L)	282	16-Jan-22	18-Jan-22	PART	RS-1140
RS-1140	Ph4 12" Old pump discharge removal sets 227-305 - 3650L-5000L & installation of skip com	282	18-Jan-22	28-Jan-22	PART	RS-1145
RS-1145	Ph4 Tie-in 12" pump discharge (1250L)	282	28-Jan-22	05-Feb-22	PART	RS-1160
RS-1160	Ph4 Cryogen pipe install 3650L	282	05-Feb-22	07-Feb-22	PART	RS-1170
RS-1170	Ph4 Cryogen pipe install 2450L	282	07-Feb-22	10-Feb-22	PART	RS-1180
RS-1180	Ph4 Cryogen pipe install 1250L	282	10-Feb-22	13-Feb-22	PART	RS-1190
RS-1190	Ph4 12" Old pump discharge removal 300L-3650L Sets 28-226	282	13-Feb-22	02-Mar-22	PART	RS-1200
RS-1200	Ph4 Install cryogen piping from set 12 to collar (6 pipes per set)	282	02-Mar-22	06-Mar-22	PART	RS-1210, E
BSI - Phase4.1MS	T6 MS - Ph4Complete Ross Shaft Fit Out	282		01-May-22		BSI - Phas
BSI - Phase4.2MS	T6 MS - Ph4Complete Cryogenic Piping System	282		01-May-22		BSIDEMOI
RS-Pipe	Ph4 LBNF Piping Services Cost	282	03-Mar-21	01-May-22	PART	RS-1261, F
131122.0402.MB002MS	T4 MS - FSCF - Beneficial Occupancy - Cryo Piping - Bldg to Governor's Corner	281		01-May-22		131122.04(
131122.0402.MB002MS	T3 MS - FSCF - Beneficial Occupancy - Cryo Piping - Bldg to Governor's Corner	2932		01-Aug-22		13111.875(
131122.0402.MB002MS	T2 MS - FSCF - Beneficial Occupancy - Cryo Piping - Bldg to Governor's Corner	2842		30-Oct-22		13111.875(
13111.8750MS0	T0 MS - CD-4 Approval (DOE Completion)	0		11-Aug-30		



All CD-3A activities with high total float values:

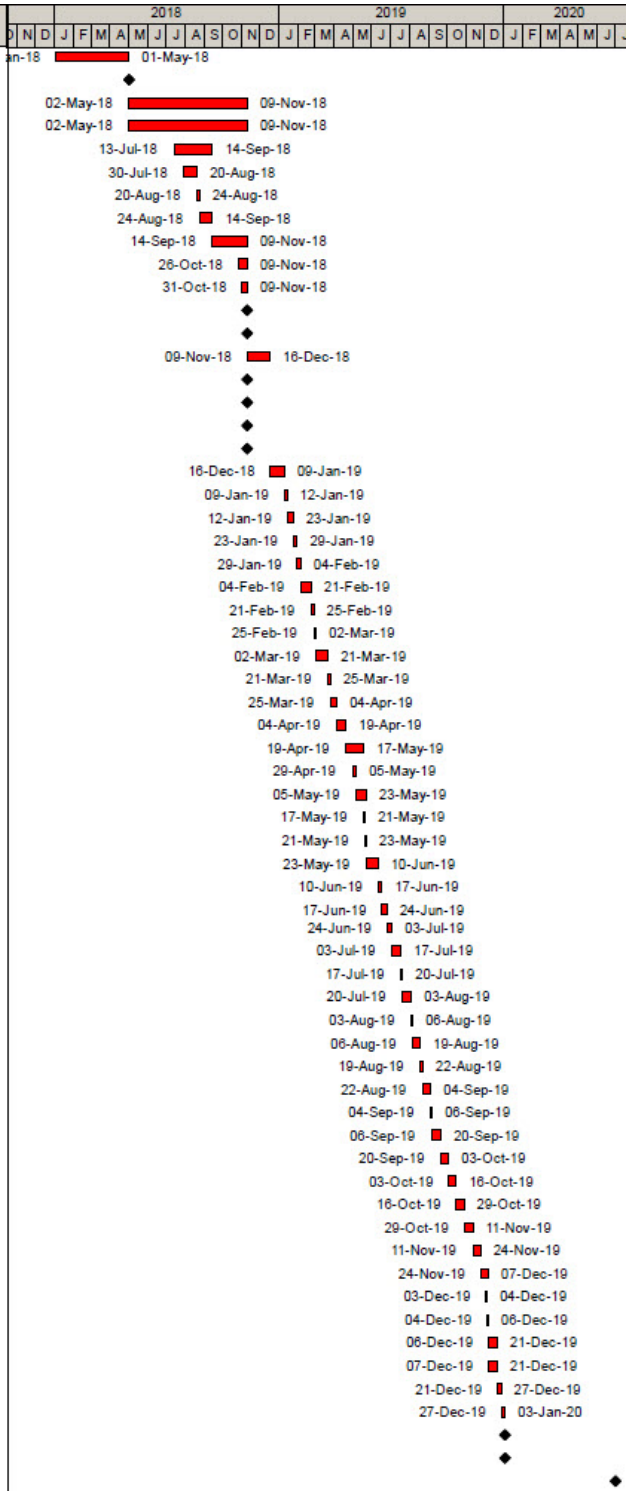
Activity ID	Activity Name	Total Float	Start	Finish	Activity Type
131122.0403.P00200	PROC. - FSCF - Pre1 - Advance CM/GC Bid / Evalu	49	02-Aug-16	29-Sep-16	Task Dependent
131122.0403.P00200MS	T5 MS - FSCF - Advance Procurement Pre-EXC Cor	49	02-Aug-16		Start Milestone
131122.0403.P00210	PROC. - FSCF - Pre1 - Advance DOE Construction (	49	30-Sep-16	28-Nov-16	Task Dependent
131122.0403.P00230	PROC. - FSCF - Pre2 - Advance CM/GC Bid / Evalu	181	10-Nov-16	17-Jan-17	Task Dependent
131122.0403.P00230MS	T5 MS - FSCF - Advance Procurement Pre-EXC Cor	181	10-Nov-16		Start Milestone
131122.0403.P00220	PROC. - FSCF - Pre1 - Advance CM/GC Finalize Co	49	29-Nov-16	29-Dec-16	Task Dependent
131122.0401.D00010	FSCF - Construction Administration Support (2017)	1911	03-Jan-17	28-Dec-17	Task Dependent
TRC1010	Raze Existing Equipment	221	03-Jan-17	12-Jan-17	Task Dependent
131122.0403.M00005MS	T5 MS - FSCF - EXC - Pre-EXC 1 NTP	70	03-Jan-17		Start Milestone
TRC1020	Install New Equipment	327	17-Jan-17	15-Jun-17	Task Dependent
131122.0403.P00240	PROC. - FSCF - Pre2 - Advance DOE Construction (	181	18-Jan-17	14-Mar-17	Task Dependent
REL1030	Relocate Electrical Equipment in 4850 L Ross Shaft	153	31-Jan-17	23-Mar-17	Task Dependent
131122.0403.P00250	PROC. - FSCF - Pre2 - Advance CM/GC Finalize Co	181	15-Mar-17	12-Apr-17	Task Dependent
REL1040	Relocate 12.5 KV feeder from Yates shaft to feed ter	153	28-Mar-17	06-Apr-17	Task Dependent
REL1050	Relocate 12.5 KV feeder for CASPAR/#6 Winze De	153	11-Apr-17	14-Apr-17	Task Dependent
EXI1260	Water Tanks	293	13-Apr-17	13-May-17	Task Dependent
131122.0403.M00010MS	T5 MS - FSCF - EXC - Pre-EXC 2 NTP	266	13-Apr-17		Start Milestone
BSI - SPhAMS	T6 MS Start Phase A	281		13-Apr-17	Finish Milestone
EXCMOB	Mobilization for Pre-EXC Package 2	181	13-Apr-17	15-May-17	Task Dependent
BROW1100	Install Ventilation door at #6 Winze Access	153	17-Apr-17	28-Apr-17	Task Dependent
RHB1230	Empty waste pass above 4850 L. Dispose of muck i	153	19-Apr-17	27-Apr-17	Task Dependent
RHB1240	Install foam in waste pass above 4850 L	153	27-Apr-17	28-Apr-17	Task Dependent
RHB1250	Pour Concrete Plug in the Waste Pass just above th	153	28-Apr-17	28-Apr-17	Task Dependent
RHB1260	Fill waste pass from 4850 L to 4700 L with cellular co	153	28-Apr-17	28-Apr-17	Task Dependent
RS–1101	Strip Ross Shaft of existing sets below set 293 thru tc	153	01-May-17	03-May-17	Task Dependent
RS–1000MS	T6 MS - Complete Ross Shaft Refurbishment to Set	153	01-May-17		Start Milestone
RS–1102	Bolt and screen existing excavation are that is to rer	153	04-May-17	09-May-17	Task Dependent
EXI1270	Distrubution	269	07-May-17	06-Jun-17	Task Dependent
BROW1070	Construct shaft Bulkhead at 4850 L in preparation for	262	09-May-17	10-May-17	Task Dependent
BROW1080	Construct Blast wall in 17 Ledge Access Dr., west of	262	10-May-17	17-May-17	Task Dependent
TRC1030	Reconnect Cabling	327	15-May-17	15-Jun-17	Task Dependent
BROW1090	Remove 4850L Waste Dump Barrier wall	262	17-May-17	21-May-17	Task Dependent
4850-43	4850-43 - ROSS SHAFT BROW	262	21-May-17	20-Jul-17	Task Dependent
VenRehab04	3500 L Rehab for New Raise	328	23-May-17	14-Nov-17	Task Dependent
WDS1220MS	T6 MS - Start Waste Disposal System	269	06-Jun-17		Start Milestone
WDS1030	Cleanup and secure work site	184	06-Jun-17	07-Jun-17	Task Dependent
WDS1170	Engineering inspections, work plan & initial survey	184	08-Jun-17	20-Jul-17	Task Dependent
131122.0403.P00020	FSCF - EXC - CM/GC Bid / Evaluate / Recommend	237	06-Jul-17	01-Sep-17	Task Dependent
131122.0403.P00020MS	T5 MS - FSCF - Advance Procurement EXC Constru	237	06-Jul-17		Start Milestone
4850-03	4850-03 - WASTE ACCESS DRIFT 1	262	20-Jul-17	24-Jul-17	Task Dependent
RossFit1	Underground: Post Shaft at 4850L	281	20-Jul-17	24-Jul-17	Task Dependent
WDS1190	Detail Engineering of new skip loader to current star	184	21-Jul-17	31-Aug-17	Task Dependent
4850-04	4850-04 - WASTE ACCESS DRIFT 2	262	24-Jul-17	25-Jul-17	Task Dependent
4850-31	4850-31 - #6 WINZE WASTE DRIFT	262	24-Jul-17	28-Jul-17	Task Dependent
RossFit2	HVAC	281	25-Jul-17	27-Jul-17	Task Dependent
131122.0402.P00010	FSCF - BSI - CM/GC Bid / Evaluate / Recommend (	546	27-Jul-17	25-Sep-17	Task Dependent
131122.0402.P00010MS	T5 MS - FSCF - Advance Procurement BSI Construc	546	27-Jul-17		Start Milestone
4850-30	4850-30 - HIGH VOLTAGE ELECTRIC ROOM	262	28-Jul-17	02-Aug-17	Task Dependent
4850-46	4850-46 - CDR ROOM	262	02-Aug-17	03-Aug-17	Task Dependent
4850-44	4850-44 - LV/MV ELECTRICAL ROOM	262	03-Aug-17	05-Aug-17	Task Dependent
PHA - INV	Concrete Invert Slabs Driver Ph1	262	05-Aug-17	11-Aug-17	Task Dependent
RHB1140	Empty waste pass to intersection with #6 Winze was	281	11-Aug-17	20-Oct-17	Task Dependent
RS–1100	Complete Ross Shaft Refurbishment to Set 306	262	11-Aug-17	06-Oct-17	Task Dependent
WDS1200	Procurement	184	01-Sep-17	16-Jan-18	Task Dependent
131122.0403.P00030	FSCF - EXC - DOE Construction Contract Approval	237	05-Sep-17	30-Oct-17	Task Dependent
131122.0402.P00020	FSCF - BSI - DOE Construction Contract Approval	546	26-Sep-17	20-Nov-17	Task Dependent
RS-1220	Normal Electrical Distribution	262	06-Oct-17	09-Nov-17	Task Dependent
REL1260	Electrical into permanent 4850 L Shaft Sub Station	315	06-Oct-17	29-Dec-17	Task Dependent
REL1265	Transfer Power Feed: Yates to Ross Fed	331	06-Oct-17	12-Oct-17	Task Dependent
A-SLI-1010	4580L Receiving Excavation	214	10-Oct-17	06-Nov-17	Task Dependent
A-SLI-1000	4550L Batch Plant Prep	212	10-Oct-17	26-Oct-17	Task Dependent
SURF10140	FSCF - OPS - Ross Headframe Reinforcement	182	10-Oct-17	13-Feb-18	Task Dependent
REL1270	Reloacte 12.5 KV CASPAR Temp to Perm	331	12-Oct-17	20-Oct-17	Task Dependent
RHB1150	Install balloon above #6 Winze Waste Pass Access	281	20-Oct-17	24-Oct-17	Task Dependent
REL1275	Remove Temp Yates Feed from Trolley	331	20-Oct-17	28-Oct-17	Task Dependent
ABN1230	Install 6' Foam above Balloon	281	24-Oct-17	27-Oct-17	Task Dependent
A-SLI-1020	4550L Stockpile Prep	212	26-Oct-17	28-Nov-17	Task Dependent
ABN1240	Remove balloon from #6 Winze Trouser leg	281	27-Oct-17	28-Oct-17	Task Dependent
ABN1250	Pour concrete Plug Above Foam	281	28-Oct-17	01-Nov-17	Task Dependent
REL1278	Hookup Fire/Wtr Ross to 17Ledge	331	28-Oct-17	11-Nov-17	Task Dependent
131122.0403.P00040	FSCF - EXC - CM/GC Finalize Construction Contract	237	31-Oct-17	30-Nov-17	Task Dependent
ABN1260	Remove Bulkhead	281	01-Nov-17	03-Nov-17	Task Dependent
RHB1160	Draw muck out of #6 Winze waste pass & install gro	281	03-Nov-17	24-Nov-17	Task Dependent
A-SLI-1030	Drill Borehole (4550L to 4850L)	214	07-Nov-17	14-Nov-17	Task Dependent
RS-1240	Telephone & Data Systems	262	09-Nov-17	06-Dec-17	Task Dependent
REL1279	Remove 6" Fire/Watr through Trolley	331	11-Nov-17	25-Nov-17	Task Dependent
A-SLI-1040	4550L Batch Plant Install	214	15-Nov-17	21-Nov-17	Task Dependent
A-SLI-1050	4850L Receiving Station Installation	217	15-Nov-17	16-Nov-17	Task Dependent
VenRehab94	Install Ventilation Controls	328	15-Nov-17	11-Jan-18	Task Dependent
131122.0402.P00030	FSCF - BSI - CM/GC Finalize Construction Contract	546	21-Nov-17	21-Dec-17	Task Dependent
RHB1170	Install a bulkhead above the intersection in the Ros:	281	24-Nov-17	26-Nov-17	Task Dependent
REL1285	Install Blast Wall in Trolley Drift	331	25-Nov-17	02-Dec-17	Task Dependent
RHB1180	Complete removal of muck and ground support inst	281	26-Nov-17	17-Dec-17	Task Dependent
A-SLI-9999MS	T6 Complete Slick Line	306		28-Nov-17	Finish Milestone
131122.0403.P00060MS	T4 MS - FSCF - EXC - Award Construction Contract	343		30-Nov-17	Finish Milestone
REL1288	#6 Winze Blast Wall Access Drift	331	02-Dec-17	09-Dec-17	Task Dependent
RS-1250	Brattice installation for skip compartments	262	06-Dec-17	09-Jan-18	Task Dependent
REL1290	Outfit Exc Equip Ass Room	331	09-Dec-17	13-Dec-17	Task Dependent
RHB1190	Pour a concrete plug above the bulkhead	281	17-Dec-17	18-Dec-17	Task Dependent
RHB1200	Remove bulkhead below the concrete plug	281	18-Dec-17	19-Dec-17	Task Dependent
RHB1210	Fill the Ross Waste dump with Waste rock up the 12	281	19-Dec-17	20-Dec-17	Task Dependent
RHB1220	Pour concrete floor over the Ross Waste Dump	281	20-Dec-17	21-Dec-17	Task Dependent
131122.0402.P00040MS	T4 MS - FSCF - BSI - Award Construction Contract	801		21-Dec-17	Finish Milestone
131122.0401.D00070	FSCF - Construction Administration Support (2018)	1911	02-Jan-18	28-Dec-18	Task Dependent
RS-1230MS	T6 MS - Ross Shaft Pipe Services Compartment Co	262	09-Jan-18		Start Milestone
WDS1110	Remove existing skip loader	262	09-Jan-18	16-Jan-18	Task Dependent
EXC-S-PhBMS	T6 MS - Start Phase B	264	09-Jan-18		Start Milestone
4850-01	4850-01 - ROSS SHAFT DRIFT 1	264	09-Jan-18	02-Feb-18	Task Dependent
BSI - FPhAMS	T6 MS Complete Phase A	264		09-Jan-18	Finish Milestone
Inst2213010101	Install temp electrical infrastructure	216	10-Jan-18	10-Jan-18	Task Dependent
VenRehab104	Replace 1/10 length of Rail	328	12-Jan-18	18-Jan-18	Task Dependent
WDS1210	5000L Brow Pocket and Skip Loader Installation anc	262	16-Jan-18	20-Feb-18	Task Dependent
VenRehab114	Muck Sand	328	19-Jan-18	22-Jan-18	Task Dependent
VenRehab124	Ground Fall Removal	328	23-Jan-18	23-Jan-18	Task Dependent
4850-06	4850-06 - MAINTANANCE SHOP ACCESS DRIFT-I	264	02-Feb-18	04-Feb-18	Task Dependent
4850-32	4850-32 - MAINTANENCE SHOP	264	04-Feb-18	11-Feb-18	Task Dependent
4850-07	4850-07 - MAINTANANCE SHOP ACCESS DRIFT-S	264	11-Feb-18	13-Feb-18	Task Dependent
4850-98	4850-98 - Powder Room	264	13-Feb-18	16-Feb-18	Task Dependent
4850-99	4850-99 - Cap Room	264	16-Feb-18	18-Feb-18	Task Dependent
SURF10200	FSCF - OPS - Yates Headframe Reinforcement	266	06-Aug-18	07-Dec-18	Task Dependent
131122.0401.D00080	FSCF - Construction Administration Support (2019)	1911	02-Jan-19	30-Dec-19	Task Dependent
4850-33.16	Drop Raise	88	21-Mar-19	31-Mar-19	Task Dependent
4850-35.16	Drop Raise	61	21-Mar-19	08-Apr-19	Task Dependent
4850-41 R	4850-41 - Raise	60	10-Jun-19	04-Nov-19	Task Dependent
4850-35.2	4850-35.2 - Heading 2	282	27-Nov-19	12-Dec-19	Task Dependent
4850-35.3	4850-35.3 - Heading 3	282	12-Dec-19	26-Dec-19	Task Dependent
4850-35.4	4850-35.4 - Heading 4	282	26-Dec-19	09-Jan-20	Task Dependent
131122.0401.D00090	FSCF - Construction Administration Support (2020)	1911	02-Jan-20	30-Dec-20	Task Dependent
131122.0402.MS1C	T4 MS - FSCF - Surface - Phase 1 Start	494	03-Jan-20		Start Milestone
1.Civ.Mob	Ph1 Site / Civil - Mobilization	490	03-Jan-20	18-Feb-20	Task Dependent
1.DRF.ElSub	Ph1 Drifts - Electrical Substation	182	03-Jan-20	24-Jan-20	Task Dependent
1.DRF.MEPSp	Ph1 Drifts - MEP Supports	141	03-Jan-20	09-Mar-20	Task Dependent
4850-45 - Fit	Yates Shaft Fiber Fit Out	442	03-Jan-20	24-Feb-20	Task Dependent
131122.0402.M00010MS	T4 MS - FSCF - BSI - Construction Phase 1 NTP	59	03-Jan-20		Start Milestone
131122.0403.MS2A	T4 MS - FSCF - EXC - Phase 2 Start	197	03-Jan-20		Start Milestone
BLUK02.01	Temporary Blast Bulkheads (4850-01, 4850-22, 485(	283	03-Jan-20	08-Jan-20	Task Dependent
1.1&2.HVPi	Ph1 Chamber 1/2 Mid - HVAC Piping	228	08-Jan-20	09-Jan-20	Task Dependent
1.1&2.Lig	Ph1 Chamber 1/2 Mid - Lighting	228	09-Jan-20	10-Jan-20	Task Dependent
4850-35.5	4850-35.5 - Heading 5	282	09-Jan-20	23-Jan-20	Task Dependent
1.1&2.RpPow	Ph1 Chamber 1/2 Mid - Receptacle Power	228	10-Jan-20	13-Jan-20	Task Dependent
1.1&2.Fire	Ph1 Chamber 1/2 Mid - Fire Detection & Alarm Syst	229	13-Jan-20	14-Jan-20	Task Dependent
1.Ch1.Air	Ph1 Chamber 1 - Air Handling Equipment	194	13-Jan-20	14-Jan-20	Task Dependent
1.Ch1.ElSub	Ph1 Chamber 1 - Electrical Substation	104	13-Jan-20	17-Jan-20	Task Dependent
1.Ch1.HVPi	Ph1 Chamber 1 - HVAC Piping	194	14-Jan-20	22-Jan-20	Task Dependent
1.1&2.Tel	Ph1 Chamber 1/2 Mid - Telephone & Data Systems	232	14-Jan-20	15-Jan-20	Task Dependent
1.CUC.ElcDi	Ph1 Central Utility Cavern - Normal Electrical Distrib	104	17-Jan-20	22-Apr-20	Task Dependent
1.Ch1.Sht	Ph1 Chamber 1 - Sheet Metal	194	22-Jan-20	07-Feb-20	Task Dependent
4850-35.6	4850-35.6 - Heading 6	282	23-Jan-20	06-Feb-20	Task Dependent
1.DRF.StPow	Ph1 Drifts - Standby/Emergency Power Substation	182	24-Jan-20	27-Jan-20	Task Dependent
4850-35.7	4850-35.7 - Heading 7	282	06-Feb-20	20-Feb-20	Task Dependent
1.Ch1.HVIn	Ph1 Chamber 1 - HVAC Insulation	194	07-Feb-20	13-Feb-20	Task Dependent
1.Ch1.RpPow	Ph1 Chamber 1 - Receptacle Power	206	13-Feb-20	14-Feb-20	Task Dependent
1.Ch1.SmPu	Ph1 Chamber 1 - Sump Pump System	194	13-Feb-20	21-Feb-20	Task Dependent
1.Civ.Eart	Ph1 Site / Civil - Grading & Site Drainage	490	18-Feb-20	21-Feb-20	Task Dependent
4850-35.8	4850-35.8 - Heading 8	282	20-Feb-20	05-Mar-20	Task Dependent
1.Civ.Rds	Ph1 Site / Civil - Roads & Access	490	21-Feb-20	24-Feb-20	Task Dependent
1.Ch1.Sprk	Ph1 Chamber 1 - Sprinkler Fire Protection System	194	21-Feb-20	04-Mar-20	Task Dependent
1.Civ.Wat	Ph1 Site / Civil - Water Infrastructure	490	24-Feb-20	05-Mar-20	Task Dependent
1.DRF.HVPi	Ph1 Drifts - HVAC Piping	141	26-Feb-20	16-Mar-20	Task Dependent
1.Ch1.Lig	Ph1 Chamber 1 - Lighting	194	04-Mar-20	05-Mar-20	Task Dependent
1.CUC.ElSub	Ph1 Central Utility Cavern - Electrical Substation	122	04-Mar-20	15-Apr-20	Task Dependent
1.MAN.Arch	Ph1 Maintenance shop - Misc. Architectural Item	117	04-Mar-20	09-Mar-20	Task Dependent
4850-35.9	4850-35.9 - Heading 9	282	05-Mar-20	18-Mar-20	Task Dependent
1.Civ.Cyb	Ph1 Site / Civil - Data Path from Ross Hoist to Ross	490	05-Mar-20	26-Mar-20	Task Dependent
1.Ch1.Fire	Ph1 Chamber 1 - Fire Detection & Alarm System	194	05-Mar-20	11-Mar-20	Task Dependent
1.DRF.ElcDi	Ph1 Drifts - Normal Electrical Distribution System	154	06-Mar-20	16-Mar-20	Task Dependent
1.DRF.HVIn	Ph1 Drifts - HVAC Insulation	193	09-Mar-20	17-Mar-20	Task Dependent
1.MAN.ElSub	Ph1 Maintenance shop - Electrical Substation	194	09-Mar-20	11-Mar-20	Task Dependent

Activity ID	Activity Name	Total Float	Start	Finish	Activity Type
1.DRF.Mez	Ph1 Drifts - Mezzanine Platform (Ch1)	195	09-Mar-20	11-Mar-20	Task Dependent
1.GEN.Arch	Ph1 Generator Room - Misc. Architectural Item	117	09-Mar-20	16-Mar-20	Task Dependent
1.DRF.Air	Ph1 Drifts - Air Handling Equipment	195	11-Mar-20	13-Mar-20	Task Dependent
1.MAN.Lig	Ph1 Maintenance shop - Lighting	194	11-Mar-20	12-Mar-20	Task Dependent
1.Ch1.Tel	Ph1 Chamber 1 - Telephone & Data Systems	194	11-Mar-20	16-Mar-20	Task Dependent
1.MAN.RpPow	Ph1 Maintenance shop - Receptacle Power	194	12-Mar-20	13-Mar-20	Task Dependent
1.MAN.Tel	Ph1 Maintenance shop - Telephone & Data System	194	13-Mar-20	16-Mar-20	Task Dependent
1.GEN.Air	Ph1 Generator Room - Air Handling Equipment	172	16-Mar-20	17-Mar-20	Task Dependent
1.DRF.HVDis	Ph1 Drifts - HVAC Distribution Equipment	141	16-Mar-20	17-Mar-20	Task Dependent
1.DRF.RpPow	Ph1 Drifts - Receptacle Power	154	16-Mar-20	17-Mar-20	Task Dependent
1.SRP.Arch	Ph1 Spray chamber - Misc. Architectural Item	117	16-Mar-20	23-Apr-20	Task Dependent
1.DRF.CryPi	Ph1 Drifts - Cryogenic Piping System	152	16-Mar-20	13-May-20	Task Dependent
1.DRF.Fire	Ph1 Drifts - Fire Detection & Alarm System	154	17-Mar-20	06-Apr-20	Task Dependent
1.GEN.HVEq	Ph1 Generator Room - HVAC Equipment	172	17-Mar-20	20-Mar-20	Task Dependent
1.DRF.Sht	Ph1 Drifts - Sheet Metal	141	17-Mar-20	01-Apr-20	Task Dependent
1.DRF.Lig	Ph1 Drifts - Lighting	187	17-Mar-20	23-Mar-20	Task Dependent
4850-35.10	4850-35.10 - Heading 10	282	18-Mar-20	01-Apr-20	Task Dependent
1.GEN.HVDis	Ph1 Generator Room - HVAC Distribution Equipmer	172	20-Mar-20	23-Mar-20	Task Dependent
1.GEN.HVPi	Ph1 Generator Room - HVAC Piping	172	23-Mar-20	24-Mar-20	Task Dependent
1.GEN.Sht	Ph1 Generator Room - Sheet Metal	172	24-Mar-20	25-Mar-20	Task Dependent
1.DRF.InWa	Ph1 Drifts - Industrial Water	141	24-Mar-20	27-Apr-20	Task Dependent
1.GEN.RpPow	Ph1 Generator Room - Receptacle Power	184	25-Mar-20	26-Mar-20	Task Dependent
1.Civ.Storm	Ph1 Site / Civil - Storm Water Pollution Prevention P	490	26-Mar-20	27-Mar-20	Task Dependent
1.GEN.Lig	Ph1 Generator Room - Lighting	184	26-Mar-20	27-Mar-20	Task Dependent
1.Civ.Remo	Ph1 Site / Civil - Misc Site Demo	490	27-Mar-20	30-Mar-20	Task Dependent
1.GEN.Fire	Ph1 Generator room - Fire Detection & Alarm Syster	184	27-Mar-20	30-Mar-20	Task Dependent
1.Stem.S	Ph1 Steam Tunnel - Concrete, conduit, 15kV Verlocl	627	30-Mar-20	28-Apr-20	Task Dependent
1.RHd.Pit.Prep	Ph1 Ross Headframe - Site Preparation	641	30-Mar-20	01-Apr-20	Task Dependent
1.RHd.Pip.Prep	Ph1 Ross Headframe - Site Preparation	634	30-Mar-20	06-Apr-20	Task Dependent
1.RHd.Cyb	Ph1 Ross Hoist Building - Cyber Infrastructure	630	30-Mar-20	23-Apr-20	Task Dependent
1.CryPi.Pit.Prep	Ph1 Cryo Piping/Conduit Trench Pit - Site Preparatic	643	30-Mar-20	02-Apr-20	Task Dependent
1.CryPi.Tr.Prep	Ph1 Cryo Piping/Conduit Trench Pit - Site Preparatic	627	30-Mar-20	17-Apr-20	Task Dependent
1.Cry.Sub.Foun	Ph1 Cryo Building Complex - Foundation	490	30-Mar-20	20-Apr-20	Task Dependent
1.DRF.Sprk	Ph1 Drifts - Sprinkler Fire Protection System (2x Crev	141	31-Mar-20	29-May-20	Task Dependent
1.RHd.Pit.Mech	Ph1 Ross Headframe - Site Mechanical Utilities	641	01-Apr-20	02-Apr-20	Task Dependent
4850-35.11	4850-35.11 - Heading 11	282	01-Apr-20	15-Apr-20	Task Dependent
1.RHd.Pit.Elec	Ph1 Ross Headframe - Site Electrical Utilities	641	02-Apr-20	03-Apr-20	Task Dependent
1.CryPi.Pit.Mech	Ph1 Cryo Piping/Conduit Trench Pit - Site Mechanic	643	02-Apr-20	03-Apr-20	Task Dependent
1112240201-E	Air Handling Equipment	547	03-Apr-20	07-Apr-20	Task Dependent
1.CryPi.Pit.Elec	Ph1 Cryo Piping/Conduit Trench Pit - Site Electrical	643	03-Apr-20	06-Apr-20	Task Dependent
1.CUC.EmEl	Ph1 Central Utility Cavern - Emergency Electrical Di	104	03-Apr-20	22-Apr-20	Task Dependent
1.RHd.Pip.Mech	Ph1 Ross Headframe - Site Mechanical Utilities	634	06-Apr-20	10-Apr-20	Task Dependent
1.DRF.Tel	Ph1 Drifts - Telephone & Data Systems	154	06-Apr-20	11-May-20	Task Dependent
1112240309-D	Sprinkler Fire Protection System	547	07-Apr-20	08-Apr-20	Task Dependent
1112240406-E	Receptacle Power	547	08-Apr-20	09-Apr-20	Task Dependent
1112240405-E	Lighting	547	09-Apr-20	10-Apr-20	Task Dependent
1112240501-E	Fire Detection & Alarm System	547	10-Apr-20	13-Apr-20	Task Dependent
1.RHd.Pip.Elec	Ph1 Ross Headframe - Site Electrical Utilities	634	10-Apr-20	14-Apr-20	Task Dependent
1.CUC.HVIn	Ph1 Central Utility Cavern - HVAC Insulation	62	10-Apr-20	05-May-20	Task Dependent
1112240104-D	Telephone & Data Systems	547	13-Apr-20	14-Apr-20	Task Dependent
1112240103-E	Interfacing/Integrating w/ non-HVAC systems	547	14-Apr-20	20-Aug-20	Task Dependent
1.RHd.Ser.Tel	Ph1 Ross Headframe - Telephone & Data Systems	634	14-Apr-20	17-Apr-20	Task Dependent
4850-35.12	4850-35.12 - Heading 12	282	15-Apr-20	29-Apr-20	Task Dependent
1.CryPi.Tr.Mech	Ph1 Cryo Piping/Conduit Trench Pit - Site Mechanic	627	17-Apr-20	24-Apr-20	Task Dependent
1.Cry.Shell.Sup	Ph1 Cryo Building Complex - Superstructure	490	20-Apr-20	21-Apr-20	Task Dependent
1.Cry.Shell.Ext	Ph1 Cryo Building Complex - Exterior Enclosure	490	21-Apr-20	22-Apr-20	Task Dependent
1.Cry.Shell.Roof	Ph1 Cryo Building Complex - Roofing	490	22-Apr-20	23-Apr-20	Task Dependent
1.CUC.StPow	Ph1 Central Utility Cavern - Standby/Emergency Po	104	22-Apr-20	11-May-20	Task Dependent
1.CUC.Mech	Ph1 Central Utility Cavern - Mechanical Equipment (	113	22-Apr-20	23-Apr-20	Task Dependent
1.Cry.HVEq	Ph1 Cryo Building Complex - HVAC Equipment	490	23-Apr-20	24-Apr-20	Task Dependent
1.SRP.HVDis	Ph1 Spray chamber - HVAC Distribution Equipment	117	23-Apr-20	05-May-20	Task Dependent
1.CUC.Lig	Ph1 Central Utility Cavern - Lighting	113	23-Apr-20	27-Apr-20	Task Dependent
1.HIG.Arch	Ph1 HIGH VOLTAGE ELECTRICAL ROOM - Misc. A	159	23-Apr-20	28-Apr-20	Task Dependent
1.Cry.HVDis	Ph1 Cryo Building Complex - HVAC Distribution Equ	490	24-Apr-20	12-May-20	Task Dependent
1.MUK.SmPu	Ph1 Mucking Ramps - Sump Pump System	162	27-Apr-20	28-Apr-20	Task Dependent
1.CUC.RpPow	Ph1 Central Utility Cavern - Receptacle Power	113	27-Apr-20	28-Apr-20	Task Dependent
1.MUK.InWa	Ph1 Mucking Ramps - Industrial Water	162	28-Apr-20	29-Apr-20	Task Dependent
1.HIG.ElcDi	Ph1 HIGH VOLTAGE ELECTRICAL ROOM - Emerg	159	28-Apr-20	29-Apr-20	Task Dependent
1.COM.Arch	Ph1 COMMUNICATION ROOM - Misc. Architectural	159	28-Apr-20	29-Apr-20	Task Dependent
1.COM.Fire	Ph1 COMMUNICATION ROOM - Fire Detection & Al	160	29-Apr-20	30-Apr-20	Task Dependent
1.HIG.Fire	Ph1 HIGH VOLTAGE ELECTRICAL ROOM - Fire De	159	29-Apr-20	30-Apr-20	Task Dependent
1.COM.ElSub	Ph1 COMMUNICATION ROOM - Electrical Substatic	159	29-Apr-20	01-May-20	Task Dependent
4850-35.13	4850-35.13 - Heading 13	282	29-Apr-20	13-May-20	Task Dependent
1.LV.Fire	Ph1 Low VOLTAGE ELECTRICAL ROOM - Fire Det	160	30-Apr-20	01-May-20	Task Dependent
1.HIG.Sprk	Ph1 HIGH VOLTAGE ELECTRICAL ROOM - Sprinkl	159	30-Apr-20	04-May-20	Task Dependent
1.COM.Sprk	Ph1 COMMUNICATION ROOM - Sprinkler Fire Prot	159	01-May-20	04-May-20	Task Dependent
1.SRP.HVPi	Ph1 Spray chamber - HVAC Piping	117	05-May-20	10-Jun-20	Task Dependent
1.CUC.PowT&C	Ph1 Central Utility Cavern - Testing & Commissionin	104	11-May-20	22-Jul-20	Task Dependent
1.CUC.CryPi	Ph1 Central Utility Cavern - Cryogenic Piping Syster	140	11-May-20	01-Jun-20	Task Dependent
1.CUC.Int	Ph1 Central Utility Cavern - Interfacing / Integrating w	141	11-May-20	29-May-20	Task Dependent
1.Cry.HVPi	Ph1 Cryo Building Complex - HVAC Piping	490	12-May-20	01-Jun-20	Task Dependent
4850-35.12 - INV	4850-35.12 - Concrete Invert Slab	284	13-May-20	20-May-20	Task Dependent
Rail02	Concrete Invert Slabs Driver Ph2	284	17-May-20	26-May-20	Task Dependent
4850-35.13 - INV	4850-35.13 - Concrete Invert Slab	284	20-May-20	26-May-20	Task Dependent
131122.0402.MS2A	T4 MS - FSCF - BSI - Phase 2 Start	285	27-May-20		Start Milestone
2.DRF.SmPu	Ph2 Drifts - Sump Pump System	370	27-May-20	28-May-20	Task Dependent
2.Ch2.Strt	Ph2 Chamber 2 - Misc. Architectural Item	284	27-May-20	29-May-20	Task Dependent
131122.0403.MS2B	T4 MS - FSCF - EXC - Phase 2 Finish	250		27-May-20	Finish Milestone
2.DRF.Lig	Ph2 Drifts - Normal Electrical Distribution System	370	28-May-20	29-May-20	Task Dependent
2.Ch2.HVIn	Ph2 Chamber 2 - HVAC Insulation	284	29-May-20	03-Jun-20	Task Dependent
2.Ch2.Fire	Ph2 Drifts - Fire Detection & Alarm System	370	29-May-20	04-Jun-20	Task Dependent
1.Cry.HVTs	Ph1 Cryo Building Complex - HVAC Testing & Balar	490	01-Jun-20	05-Jun-20	Task Dependent
2.Ch2.Sht	Ph2 Chamber 2 - Sheet Metal	284	03-Jun-20	18-Jun-20	Task Dependent
1.Cry.HVSh	Ph1 Cryo Building Complex - Sheet Metal	490	05-Jun-20	10-Jun-20	Task Dependent
1.Cry.HVIn	Ph1 Cryo Building Complex - HVAC Insulation	490	10-Jun-20	11-Jun-20	Task Dependent
1.SRP.HVIn	Ph1 Spray chamber - HVAC Insulation	117	10-Jun-20	11-Jun-20	Task Dependent
1.Cry.Vib	Ph1 Cryo Building Complex - Isolation Vibrators	490	11-Jun-20	12-Jun-20	Task Dependent
1.Ph.T&C	Ph1 Phase1 - HVAC Testing & Balancing	117	11-Jun-20	22-Jun-20	Task Dependent
1.Cry.Sprk	Ph1 Cryo Building Complex - Sprinkler Fire Protectic	490	12-Jun-20	16-Jun-20	Task Dependent
1.Cry.CryPi	Ph1 Cryo Building Complex - Cryogenic Piping Syst	490	16-Jun-20	19-Jun-20	Task Dependent
2.Ph.HVT&B	Ph2 Chamber 2 - HVAC Testing & Balancing	284	18-Jun-20	22-Jun-20	Task Dependent
1.Cry.Plm	Ph1 Cryo Building Complex - Plumbing Allowances	490	19-Jun-20	22-Jun-20	Task Dependent
2.Ph.Vib	Ph2 Chamber 2 - Isolation Vibrators	284	22-Jun-20	23-Jun-20	Task Dependent
1.Cry.Elc	Ph1 Cryo Building Complex - Standby/Emergency F	490	22-Jun-20	16-Jul-20	Task Dependent
1.Ph.Vib	Ph1 Phase1 - Isolation Vibrators	117	22-Jun-20	23-Jun-20	Task Dependent
2.Ch2.ElSub	Ph2 Chamber 2 - Electrical Substation	284	23-Jun-20	30-Jun-20	Task Dependent
1.SRP.InWa	Ph1 Spray chamber - Industrial Water	117	23-Jun-20	25-Jun-20	Task Dependent
1.SRP.ElSub	Ph1 Spray chamber - Electrical Substation	117	25-Jun-20	29-Jun-20	Task Dependent
1.SRP.Lig	Ph1 Spray chamber - Lighting	117	29-Jun-20	30-Jun-20	Task Dependent
2.Ch2.Lig	Ph2 Chamber 2 - Normal Electrical Distribution Syst	284	30-Jun-20	01-Jul-20	Task Dependent
1.SRP.RpPow	Ph1 Spray chamber - Receptacle Power	117	30-Jun-20	01-Jul-20	Task Dependent
2.Ph.NoEl	Ph2 Phase2 - Normal Electrical Distribution System	338	01-Jul-20	20-Jul-20	Task Dependent
2.Ch2.SmPu	Ph2 Chamber 2 - Sump Pump System	284	01-Jul-20	09-Jul-20	Task Dependent
1.SRP.Fire	Ph1 Spray chamber - Fire Detection & Alarm Syster	117	01-Jul-20	02-Jul-20	Task Dependent
2.Ch2.Sprk	Ph2 Chamber 2 - Sprinkler Fire Protection System	284	09-Jul-20	21-Jul-20	Task Dependent
1.Cry.Nel	Ph1 Cryo Building Complex - Normal Electrical Distr	490	16-Jul-20	06-Aug-20	Task Dependent
2.Ph.StElc	Ph2 Phase2 - Standby/Emergency Power Substatic	338	20-Jul-20	21-Jul-20	Task Dependent
2.Ch2.Tel	Ph2 Chamber 2 - Telephone & Data Systems	284	21-Jul-20	24-Jul-20	Task Dependent
2.Ch2.T&C	Ph2 Chamber 2 - Testing & Commissioning	284	24-Jul-20	05-Oct-20	Task Dependent
1.Cry.Lig	Ph1 Cryo Building Complex - Lighting	490	06-Aug-20	07-Aug-20	Task Dependent
1.Cry.Rep	Ph1 Cryo Building Complex - Receptacle Power	490	07-Aug-20	10-Aug-20	Task Dependent
1.Cry.Sub	Ph1 Cryo Building Complex - Standby/Emergency F	490	10-Aug-20	21-Aug-20	Task Dependent
131122.0403.MB03MS	T4 MS - FSCF - Beneficial Occupancy - Cavern 2	364		19-Aug-20	Finish Milestone
1.Cry.Fire	Ph1 Cryo Building Complex - Fire Detection & Alarm	490	21-Aug-20	25-Aug-20	Task Dependent
1.Cry.Tel	Ph1 Cryo Building Complex - Telephone & Data Sys	490	25-Aug-20	31-Aug-20	Task Dependent
1.Cry.T&C	Ph1 Cryo Building Complex - Testing & Commissior	490	31-Aug-20	12-Nov-20	Task Dependent
2.MAN.Tel	Ph2 Maintenance shop - Telephone & Data System	284	05-Oct-20	06-Oct-20	Task Dependent
131122.0402.PL02	FSCF - BSI - Underground Phase 2 Punchlist	287	06-Oct-20	03-Nov-20	Task Dependent
131122.0402.MS2B	T4 MS - FSCF - BSI - Phase 2 Finish	287		03-Nov-20	Finish Milestone
131122.0402.PL01B	FSCF - Surface Facilities Punchlist	491	12-Nov-20	14-Dec-20	Task Dependent
131122.0402.MS1D	T4 MS - FSCF - Surface - Phase 1 Finish	491		14-Dec-20	Finish Milestone
131122.0402.MB01MS4	T4 MS - FSCF - Beneficial Occupancy - Surface Fac	715		14-Dec-20	Finish Milestone
RS-1261	Ph4 Brattice removal for the skip compartments	282	03-Mar-21	06-Apr-21	Task Dependent
RS-1000	Ph4 New structural pipe supports sets 4 to 12	282	06-Apr-21	08-Apr-21	Task Dependent
RS-1010	Ph4 4" water line (2) re-route between sets 7 & 8	282	08-Apr-21	09-Apr-21	Task Dependent
RS-1020	Ph4 6" compressed air re-route above set 12	282	09-Apr-21	13-Apr-21	Task Dependent
RS-1030	Ph4 6" deluge line reroute @ 12' below the collar	282	13-Apr-21	14-Apr-21	Task Dependent
RS-1035	Ph4 Excavation at Tramway ,1700L,2450L,3350L,365	282	14-Apr-21	23-Apr-21	Task Dependent
RS-1040	Ph4 Cyrogen structural steel support sets collar - se	282	23-Apr-21	17-Jun-21	Task Dependent
RS-1050	Ph4 Cryogen pipe install/New Pump Discharge Inst	282	17-Jun-21	28-Oct-21	Task Dependent
RS-1055	Ph4 New 12" discharge set 297 to 308	282	28-Oct-21	29-Oct-21	Task Dependent
RS-1060	Ph4 Install new thrust blocks (1250L, 2450L, and 365(	282	29-Oct-21	19-Nov-21	Task Dependent
RS-1070	Ph4 New 12" Pump discharge column install (set 12-	282	19-Nov-21	28-Nov-21	Task Dependent
RS-1075	Ph4 10" Decant line re-route	282	28-Nov-21	28-Nov-21	Task Dependent
RS-1090	Ph4 12" Old pump discharge removal and cryogen	282	28-Nov-21	28-Dec-21	Task Dependent
RS-1100	Ph4 12" Old pump discharge, 10" Decant removal a	282	28-Dec-21	12-Jan-22	Task Dependent
RS-1110	Ph4 Tie-in 12" pump discharge (3650L)	282	12-Jan-22	14-Jan-22	Task Dependent
RS-1120	Ph4 Tie-in 12" pump discharge (2450L)	282	14-Jan-22	16-Jan-22	Task Dependent
RS-1130	Ph4 Tie-in 12" pump discharge (1250L)	282	16-Jan-22	18-Jan-22	Task Dependent
RS-1140	Ph4 12" Old pump discharge removal sets 227-305 -	282	18-Jan-22	28-Jan-22	Task Dependent
RS-1145	Ph4 Tie-in 12" pump discharge (1250L)	282	28-Jan-22	05-Feb-22	Task Dependent
RS-1160	Ph4 Cryogen pipe install 3650L	282	05-Feb-22	07-Feb-22	Task Dependent
RS-1170	Ph4 Cryogen pipe install 2450L	282	07-Feb-22	10-Feb-22	Task Dependent
RS-1180	Ph4 Cryogen pipe install 1250L	282	10-Feb-22	13-Feb-22	Task Dependent
RS-1190	Ph4 12" Old pump discharge removal 300L-3650L S	282	13-Feb-22	02-Mar-22	Task Dependent
RS-1200	Ph4 Install cryogen piping from set 12 to collar (6 pip	282	02-Mar-22	06-Mar-22	Task Dependent
RS-1210	Ph4 Remove current 6" air line and install 6" Fire wa	282	06-Mar-22	28-Mar-22	Task Dependent
RS-1262	Ph4 Brattice removal for the skip compartments	282	28-Mar-22	01-May-22	Task Dependent

The critical path for CD-3A starts with A1000, FSCF-EXC-WRH at Surface Design, which is driven by funding availability that is scheduled to be available January 1, 2018. The critical path for CD-3A ends with 131122.0403.MB02MS4, T4 MS - FSCF - Beneficial Occupancy - Cavern 1 & Central Utility Cavern. The Far Site CD-3A scope is not on the critical path of the overall project. The program critical path reflects the longest path for the Near Site. A constraint of December 26, 2025 was added to 13122.01.02.87MS4 in order to calculate the Far Site critical path. This reflects the completion of the second detector to align with the KPPs at the Far Site.

CD-3A Critical Path:

Activity ID	Activity Name	Total Float	Start	Finish
A1000	FSCF - EXC - WRH at Surface Design	0	an-18	01-May-18
13111.10530MS	T4 MS - Secure All Easement Required for Waste Rock Han	0		
WDS1260	Electrical WRHS	0	02-May-18	09-Nov-18
WDS1250	Surface WRHS	0	02-May-18	09-Nov-18
GRZ1135	Procurement of LHD dump and rock breaker components	0	13-Jul-18	14-Sep-18
EXT1170	Existing Track Dump and Chain Controls	0	30-Jul-18	20-Aug-18
GRZ1110	Install foundations for #6 Winze Waste Dump Grizzly	0	20-Aug-18	24-Aug-18
GRZ1130	Remove Waste and Ground Support Down Waste Dump (B:	0	24-Aug-18	14-Sep-18
GRZ1120	4850L Grizzly and Rock Breaker Station Installation and corr	0	14-Sep-18	09-Nov-18
MechAssm	Machine Assembly	0	26-Oct-18	09-Nov-18
ELECON	Temporary Power	0	31-Oct-18	09-Nov-18
13111.10670MS	T4 MS - Validate Rock Crusher is guarded and access is co	0		
EXC-S-Ph1MS	T6 MS - Start Phase 1 Excavation	0		
4850-02	4850-02 - ROSS SHAFT DRIFT 2	0	09-Nov-18	16-Dec-18
WDS1070MS	T6 MS - Complete Waste Disposal System	0		
EXC-1040MS	T6 MS - Start 2nd Crew Excavation	0		
131122.0403.M000	T4 MS - FSCF - EXC - Construction Phase 1 NTP	0		
EXC-F-PhBMS	T6 MS - Complete Phase B Excavation	0		
4850-09	4850-09 - WEST ACCESS DRIFT	0	16-Dec-18	09-Jan-19
4850-47	4850-47 - CONCRETE SUPPLY ROOM	0	09-Jan-19	12-Jan-19
4850-08	4850-08 - TROLLEY DRIFT	0	12-Jan-19	23-Jan-19
4850-10	4850-10 - CHAMBER 1 ACCESS DRIFT	0	23-Jan-19	29-Jan-19
4850-11	4850-11 - CHAMBER 1 ENTRANCE	0	29-Jan-19	04-Feb-19
4850-33.1	4850-33.1 - Heading 1	0	04-Feb-19	21-Feb-19
4850-34.1	4850-34.1 - Heading 1	0	21-Feb-19	25-Feb-19
4850-15	4850-15 - CENTER ACCESS DRIFT 1	0	25-Feb-19	02-Mar-19
4850-35.1	4850-35.1 - Heading 1	0	02-Mar-19	21-Mar-19
4850-21	4850-21 - CHAMBER 2 ACCESS DRIFT	0	21-Mar-19	25-Mar-19
4850-18.1	4850-18.1 - EAST ACCESS DRIFT 1	0	25-Mar-19	04-Apr-19
4850-18.2	4850-18.2 - EAST ACCESS DRIFT 1	0	04-Apr-19	19-Apr-19
4850-23	4850-23 MAINTENANCE SHOP ACCESS DRIFT- SOUTH	0	19-Apr-19	17-May-19
3500-01	3500-01 - VENTILATION SHAFT ROOM	0	29-Apr-19	05-May-19
4850-41 P	4850-41 - Pilot Bore	0	05-May-19	23-May-19
4850-42	4850-42 - GENERATOR ROOM	0	17-May-19	21-May-19
4850-24	4850-24 - SPRAY CHAMBER ACCESS DRIF	0	21-May-19	23-May-19
4850-40	4850-40 - SPRAY CHAMBER	0	23-May-19	10-Jun-19
4850-19	4850-19 - EAST ACCESS DRIFT 2	0	10-Jun-19	17-Jun-19
4850-16	4850-16 - CENTER ACCESS DRIFT 2	0	17-Jun-19	24-Jun-19
4850-17	4850-17 - CENTER ACCESS DRIFT 3	0	24-Jun-19	03-Jul-19
4850-33.2	4850-33.2 - Heading 2	0	03-Jul-19	17-Jul-19
4850-34.2	4850-34.2 - Heading 2	0	17-Jul-19	20-Jul-19
4850-33.3	4850-33.3 - Heading 3	0	20-Jul-19	03-Aug-19
4850-34.3	4850-34.3 - Heading 3	0	03-Aug-19	06-Aug-19
4850-33.4	4850-33.4 - Heading 4	0	06-Aug-19	19-Aug-19
4850-34.4	4850-34.4 - Heading 4	0	19-Aug-19	22-Aug-19
4850-33.5	4850-33.5 - Heading 5	0	22-Aug-19	04-Sep-19
4850-34.5	4850-34.5 - Heading 5	0	04-Sep-19	06-Sep-19
4850-33.6	4850-33.6 - Heading 6	0	06-Sep-19	20-Sep-19
4850-33.7	4850-33.7 - Heading 7	0	20-Sep-19	03-Oct-19
4850-33.8	4850-33.8 - Heading 8	0	03-Oct-19	16-Oct-19
4850-33.9	4850-33.9 - Heading 9	0	16-Oct-19	29-Oct-19
4850-33.10	4850-33.10 - Heading 10	0	29-Oct-19	11-Nov-19
4850-33.11	4850-33.11 - Heading 11	0	11-Nov-19	24-Nov-19
4850-33.12	4850-33.12 - Heading 12	0	24-Nov-19	07-Dec-19
4850-34.4 - INV	4850-34.4 - Concrete Invert Slab (1st)	0	03-Dec-19	04-Dec-19
4850-34.5 - INV	4850-34.5 - Concrete Invert Slab (2nd)	0	04-Dec-19	06-Dec-19
BULK01.02	Ph1 Mid-Chamber Bulkhead	0	06-Dec-19	21-Dec-19
4850-33.13	4850-33.13 - Heading 13	0	07-Dec-19	21-Dec-19
4850-33.12 - INV	4850-33.12 - Concrete Invert Slab (1st)	0	21-Dec-19	27-Dec-19
4850-33.13 - INV	4850-33.13 - Concrete Invert Slab (2nd)	0	27-Dec-19	03-Jan-20
131122.0403.MS1B	T4 MS - FSCF - EXC - Phase 1 Finish	0		
EXC-F-Ph1MS	T6 MS - Complete Phase 1 Excavation	0		
131122.0403.MB02	T4 MS - FSCF - Beneficial Occupancy - Cavern 1 & Central	0		



There is potential for the critical path to change once fixes are put in place to reduce high float values since this could change the logic network. In addition, there are three lag values associated with the last activity on the CD-3A critical path, 131122.0403.MB02MS4, T4 MS - FSCF - Beneficial Occupancy - Cavern 1 & Central Utility Cavern. Since these durations are not represented as activities, these can hide detail in the schedule, potentially affecting the critical path.

Lag values associated with T4 MS - FSCF - Beneficial Occupancy - Cavern 1 & Central Utility Cavern:

Predecessor Id	Predecessor	Pred Type	Successor Id	Successor	Succ Type	Lag	Type
131122.0403.MB02MS4	T4 MS - FSCF - Beneficial Occupancy - Cavern 1 & Central Utility Cavern	Milestone	131122.0403.MB02MS2	T2 MS - FSCF - Beneficial Occupancy - Cavern 1 & Central Utility Cavern	Milestone	182	FinishToStart
131122.0403.MB02MS4	T4 MS - FSCF - Beneficial Occupancy - Cavern 1 & Central Utility Cavern	Milestone	131122.0403.MB02MS3	T3 MS - FSCF - Beneficial Occupancy - Cavern 1 & Central Utility Cavern	Milestone	92	FinishToStart
131122.0403.MS1B	T4 MS - FSCF - EXC - Phase 1 Finish	Milestone	131122.0403.MB02MS4	T4 MS - FSCF - Beneficial Occupancy - Cavern 1 & Central Utility Cavern	Milestone	126	FinishToFinish

Appendix G
ICE Risk Register

Risk ID	Risk Event	Probability, %	Cost Impact, $M			Schedule Impact, Months			Basis of Impact	Model Results	
			Best	Most Likely	Worst	Best	Most Likely	Worst		Cost	Schedule
1	Escalation rate greater than expected.	50	0	5	25	0	0	0	Most likely based on 3% escalation; 25% higher than base.		0.0
2	Specialized construction labor not available.	50	0	6	12	0	2	6	Risk is mitigated by assuming all labor is brought in from outside the region. Labor rates include per diem. Labor should not be a problem due to 11-hour days and 7 days/week, which is attractive to workers. Most likely impact assumes 10% higher cost; worst case assumes 20% higher cost.		1.3
3	Cryogenics or detector changes affects design/layout of FS facilities	50	0	1	2.5	0	2	6	Accept project assumptions on impacts.		1.3
4	Funding delays	75	0	0	0	0	4	12	Accepted project team assessment of schedule impact.		4.0
5	Adverse conditions in far site underground excavation	15	0	20	40	0	3	6	Accept project assumptions on impacts.		0.5
6	Shaft ventilation path is blocked	10	0	5	10	0	6	24	Reduced cost impacts. $50M seems excessive for worst case. Increased probability to 10%.		1.0
7	Blasting at far site	15	0	3	7	0	1	5.5	Accept project assumptions on impacts.		0.3

Risk ID	Risk Event	Probability, %	Cost Impact, $M			Schedule Impact, Months			Basis of Impact	Model Results	
			Best	Most Likely	Worst	Best	Most Likely	Worst		Cost	Schedule
	causes damage or distress										
8	Missing scope	25	N/A			N/A			ICE does not consider this a risk.		0.0
9	Multiple contractor interface problems cause de-lays/claims	10	0	1	7.5	0	1	6	Accept project assumptions on impacts.		0.2
10	Additional costs for waste rock disposal at Gilt Edge	40	0.25	0.5	1	0	0	0	Agreement with DENR establishes maximum exposure at $500K for design and $500K for construction.		0.0
11	Lower costs for waste rock disposal (O)	80	-1	-0.5	0	0	0	0	FNAL did comparative analysis showing a potential $1M cost decrease by using open cut.		0.0
12	Litigation to resolve contract disputes - REAs	25	0	3	6	0	0	0	Requests for equitable adjustment need to be considered, es-pecially for any fixed price work. Worst case of 10% of labor costs is not unreasonable.		0.0
13	Scope in-creases due to changing codes or regulations	5	N/A			N/A			ICE does not agree that this should be a risk. There is no way to approximate what the costs might be due to changing regs or codes.		0.0
14	Rock falls damage equipment	1	N/A			N/A			ICE does not consider this a risk. It pertains to a damaged cryostat, which is outside the CD-3A work scope.		0.0
15	Waste rock disposal deadline at	15	0	0.5	1	0	0	0	Accept project assumptions on impacts.		0.0

Risk ID	Risk Event	Probability, %	Cost Impact, $M			Schedule Impact, Months			Basis of Impact	Model Results	
			Best	Most Likely	Worst	Best	Most Likely	Worst		Cost	Schedule
	Gilt Edge canot be met										
16	As-built conditions are differ-ent than drawings	50	0	0.5	1	0	1	2	Accept project assumptions on impacts.		0.5
17	Construc-tion activi-ties impact community	20	0	0.5	3	0	0	0	Cost impacts based on SME opinion. Worst case fixes to community concerns could be in the $M.		0.0
18	Delays obtaining regulatory approvals	25	0.1	0.25	0.5	0	3	12	Increased schedule impact.		1.3
19	Dam-age/delays caused by theft or vandalism	25	0	0.1	1	0	3	6	Project impacts largely accepted. Increased probability to 25%.		0.8
20	Water in-undation under-ground	1	0	0.2	1	0	1	6	Cost and schedule impacts increased over project team esti-mate.		0.0
21	Spontane-ous com-bustion of timber at far site	5	0	0.25	2	0	2	6	Cost impacts based on design/construct new safety or other systems to correct problems. Fixes could be $2M.		0.1
22	Union work stop-page	30	0	0	0.25	0	0.5	2	Worst case cost impact of $250K to satisfy union.		0.3
23	ESH inci-dent shuts down pro-ject	10	0	1	3	0	3	12	ESH incident could delay the project by a year. There would be some cost impact.		0.5

Risk ID	Risk Event	Probability, %	Cost Impact, $M			Schedule Impact, Months			Basis of Impact	Model Results	
			Best	Most Likely	Worst	Best	Most Likely	Worst		Cost	Schedule
24	Protests from CM/GC bidders cause delay	25	0	0	0	0	3	6	Only schedule delay. Could affect critical path.		0.8
25	Ross shaft rehab is delayed (new risk)	50	0	0.75	3	0	3	12	Escalation impacts only - $250K/mo		2.5
									Total	0.0	15.3

Appendix H
Risk Analysis Details

Included in this Appendix are the probability distribution histograms generated from the Monte Carlo analysis of cost uncertainty and T&P risks.

Cost Uncertainty Charts

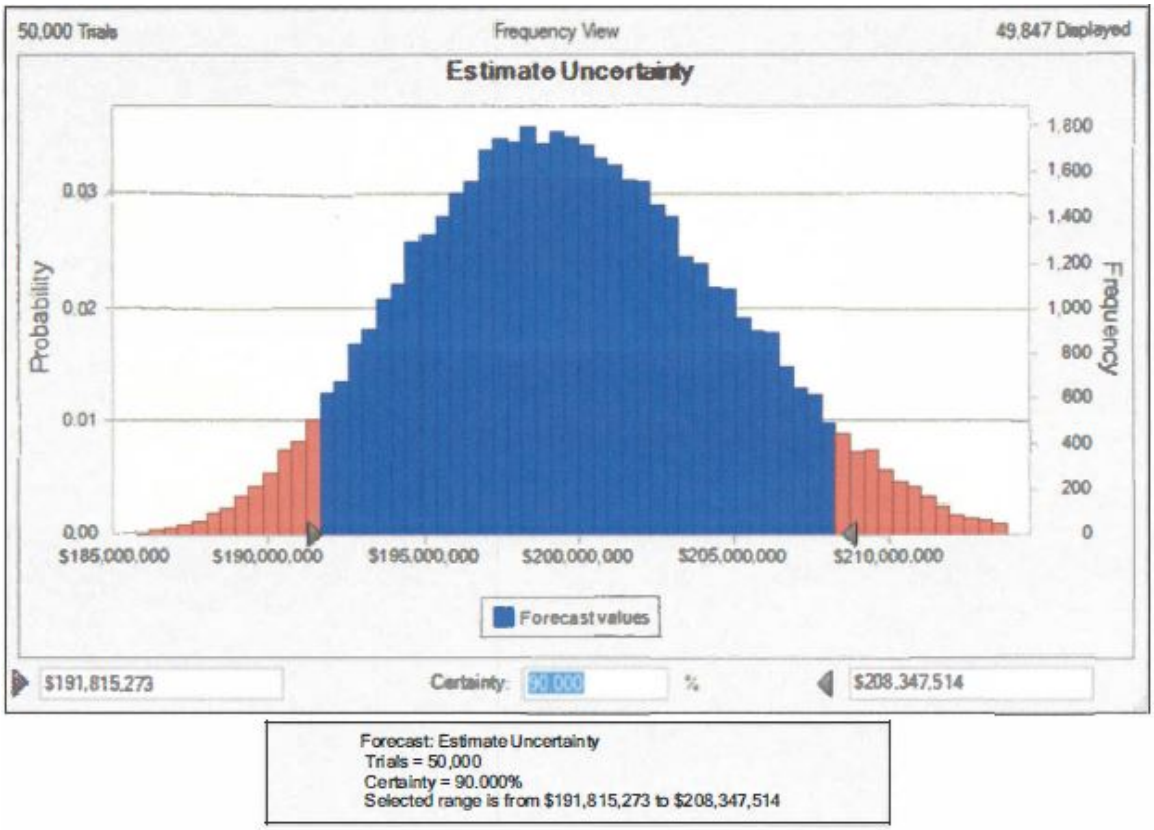


Figure H-1: Estimate Uncertainty – Frequency View

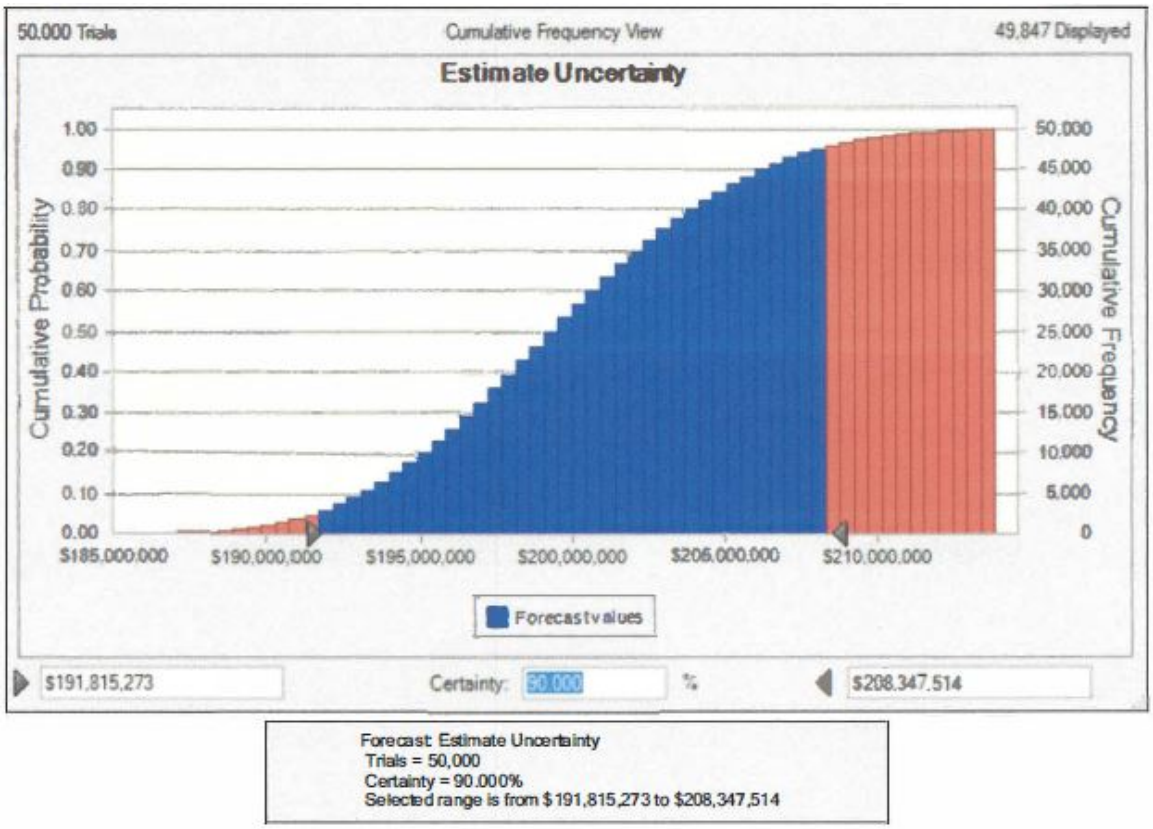


Figure H-2: Estimate Uncertainty – Cumulative Frequency View

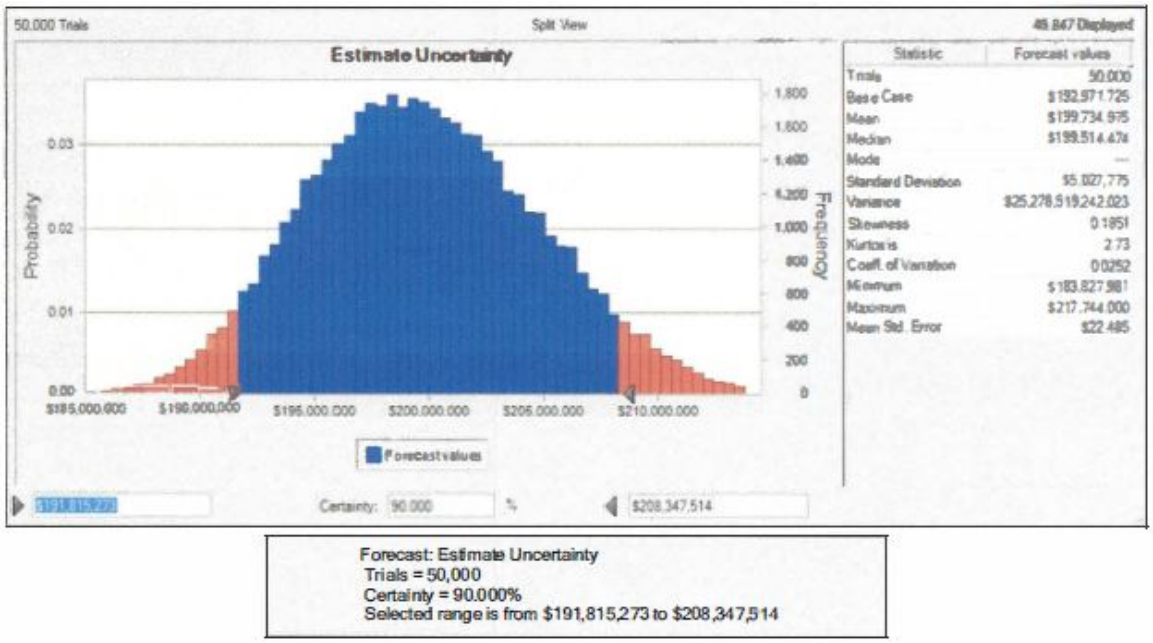


Figure H-3: Estimate Uncertainty – Split View

T&P Contingency

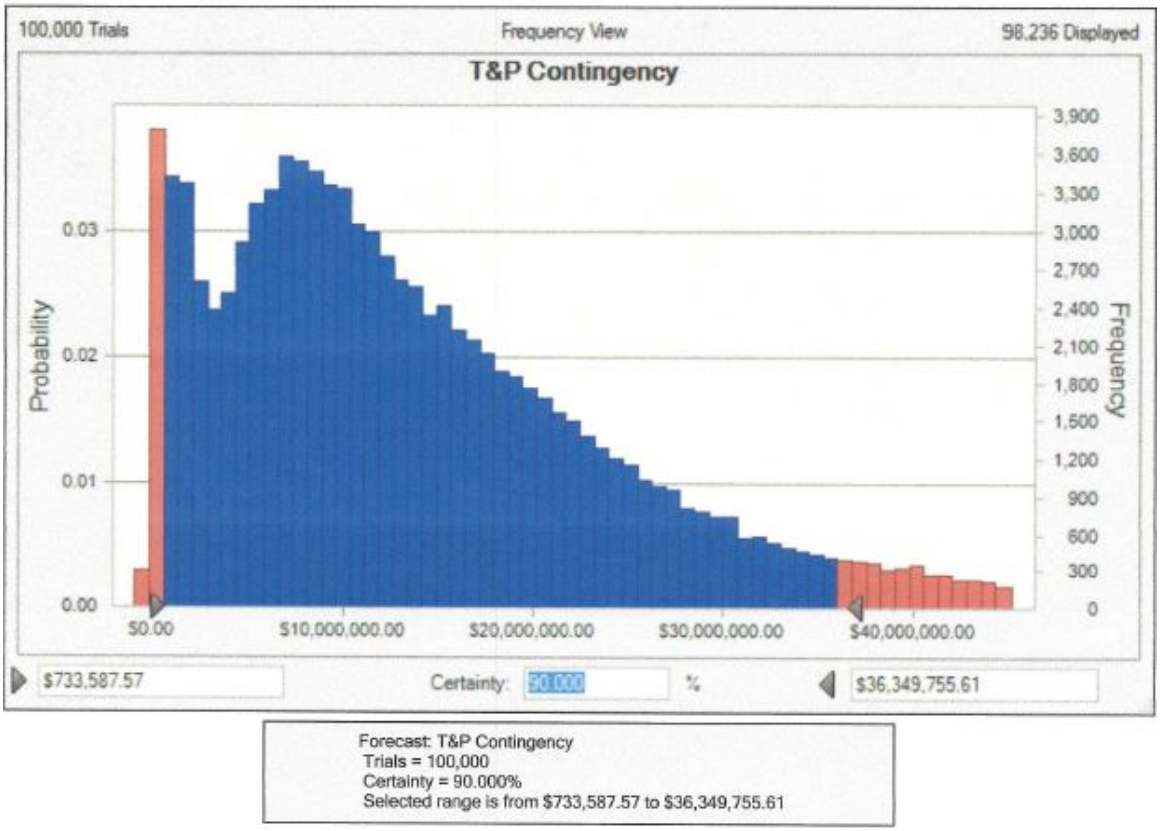


Figure H-4: T&P Contingency – Frequency View

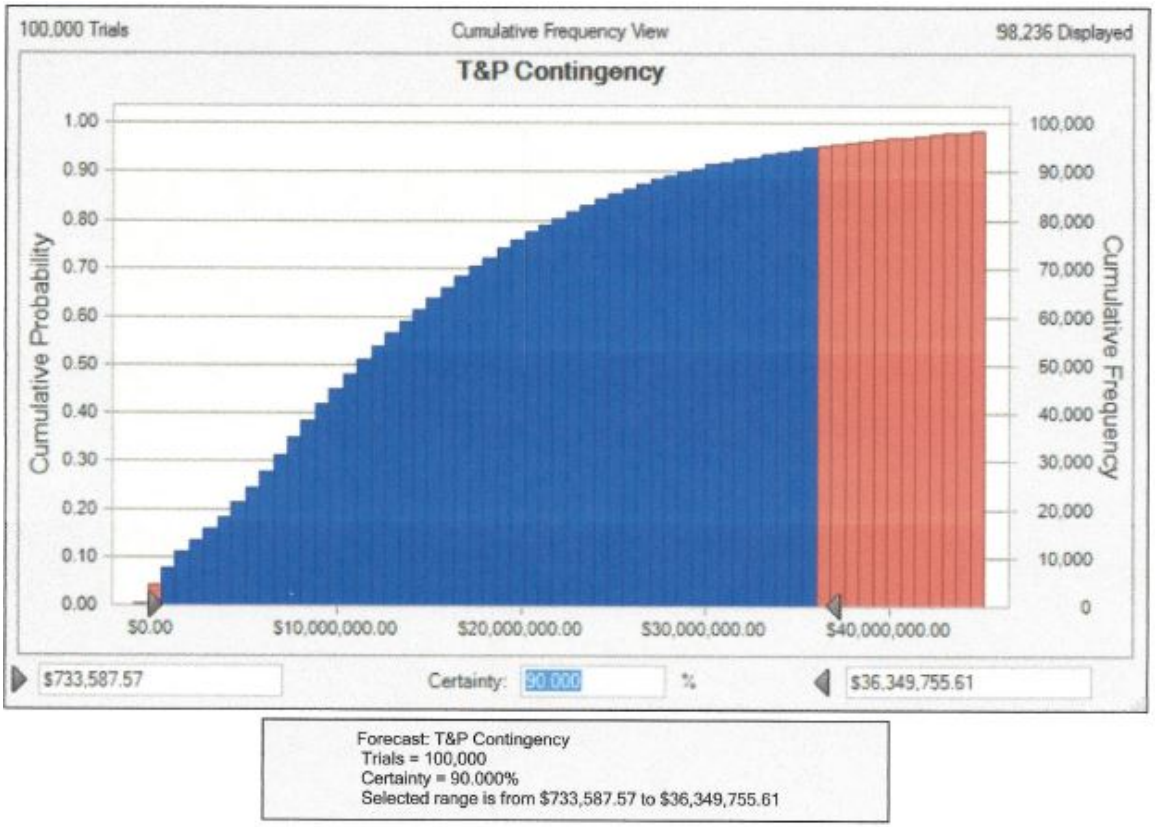


Figure H-5: T&P Contingency – Cumulative Frequency View

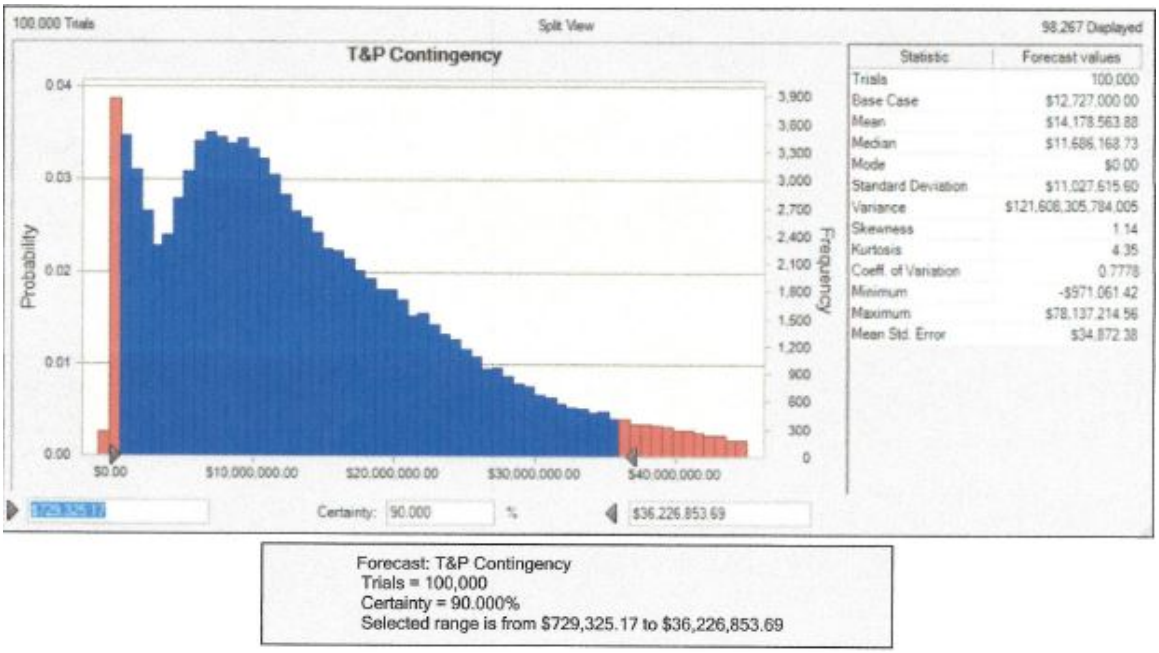


Figure H-6: T&P Contingency – Split View

Appendix I
GAO 12-Step Best Practices for Cost Estimating

In executing its federal government oversight responsibility, GAO has identified best practices for cost estimating and scheduling that can be used across the federal government to "develop, manage, and evaluate capital program cost estimates [and schedules]". The intent of these best practices is to improve federal government and agency "stewardship" of public funds consistent with fiscal accountability. DOE recognizes these practices as a minimum acceptable standard for performance.

In this Appendix, the ICE team identifies specific report sections that discuss the topical areas shown in the GAO's 12-step best practices for cost estimating. The purpose is two-fold: (1) to provide a "map" for easy reference and (2) to ensure and demonstrate compliance with the GAO best practices.

Table I-1: GAO 12-Step Process for Cost Estimating

Step	Description	Associated Tasks	Report Section
1	**Define estimates purpose**	*1. Determine estimate's purpose, required level of detail, and overall scope.*	Section 1.1
		2. Determine who will receive the estimate.	
2	**Develop estimating plan**	*1. Determine the cost estimating team and develop its master schedule.*	Section 1.1, Appendix C, and Appendix D
		2. Determine who will do the independent cost estimate; outline the cost estimating approach.	
		3. Develop the estimate timeline.	
3	**Define program characteristics**	*1. Identify the program's purpose and its system and performance characteristics and all system configurations.*	Section 1.2
		2. Any technology implications.	
		3. Program acquisition schedule and acquisition	

Step	Description	Associated Tasks	Report Section
		strategy.	
		4. Its relationship to other existing systems, including predecessor or similar legacy systems.	
		5. Support (manpower, training, etc.) and security needs and risk items.	
		6. System quantities for development, test, and production.	
		7. Deployment and maintenance plans.	
4	**Determine estimating structure**	*1. Define a work breakdown structure (WBS) and describe each element in a WBS dictionary (a major automated information system may have only a cost element structure).*	Section 2.1
		2. Choose the best estimating method for each WBS element; Identify potential cross-checks for likely cost and schedule drivers.	
		3. Develop a cost estimating checklist	
5	**Identify ground rules and assumptions**	*1. Clearly define what the estimate includes and excludes.*	Section 2.2
		2. Identify global and program-specific assumptions, such as the estimate's base year, including time-phasing and life cycle.	
		3. Identify program schedule information by phase and program acquisition strategy.	
		4. Identify any schedule or budget constraints, inflation assumptions, and travel costs.	
		5. Specify equipment the government is to furnish as well as the use of existing facilities or new modification or development.	

Step	Description	Associated Tasks	Report Section
		6. Identify prime contractor and major subcontractors.	
		7. Determine technology refresh cycles, technology assumptions, and new technology to be developed.	
		8. Define commonality with legacy systems and assumed heritage savings.	
		9. Describe effects of new ways of doing business.	
6	**Obtain data**	*1. Create a data collection plan with emphasis on collecting current and relevant technical, programmatic, cost, and risk data.*	Section 1.1, Appendix A, and Appendix E
		2. Investigate possible data sources.	
		3. Collect data and normalize them for cost accounting, inflation, learning, and quantity adjustments.	
		4. Analyze the data for cost drivers, trends, and outliers and compare results against rules of thumb and standard factors derived from historical data.	
		5. Interview data sources and document all pertinent information, including an assessment of data reliability and uncertainty.	
		6. Store data for future estimates.	
7	**Develop point estimate and compare it to an independent cost estimate**	*1. Develop the cost model, estimating each WBS element, using the best methodology from the data collected, and including all estimating assumptions.*	Sections 2.2, 3.1, 4.1, and 4.2
		2. Express costs in constant year dollars.	

Step	Description	Associated Tasks	Report Section
		3. Time-phase the results by spreading costs in the years they are expected to occur, based on the program schedule.	
		4. Sum the WBS elements to develop the overall point estimate.	
		5. Validate the estimate by looking for errors like double counting and omitted costs.	
		6. Compare estimate against the independent cost estimate and examine where and why there are differences.	
		7. Perform cross-checks on cost drivers to see if results are similar.	
		8. Update the model as more data become available or as changes occur and compare results against previous estimates.	
8	**Conduct sensitivity analysis**	*1. Test the sensitivity of cost elements to changes in estimating input values and key assumptions.*	Section 3.3
		2. Identify effects on the overall estimate of changing the program schedule or quantities.	
		3. Determine which assumptions are key cost drivers and which cost elements are affected most by changes.	
9	**Conduct risk and uncertainty analysis**	*1. Determine and discuss with technical experts the level of cost, schedule, and technical risk associated with each WBS element.*	Section 3.4, Appendix G, and Appendix H
		2. Analyze each risk for its severity and probability.	
		3. Develop minimum, most likely, and maximum ranges for each risk element.	
		4. Determine type of risk distributions and reason for their use.	

Step	Description	Associated Tasks	Report Section
		5. Ensure that risks are not correlated.	
		6. Use an acceptable statistical analysis method (e.g., Monte Carlo simulation) to develop a confidence interval around the point estimate.	
		7. Identify the confidence level of the point estimate.	
		8. Identify the amount of contingency funding and add this to the point estimate to determine the risk-adjusted cost estimate.	
		9. Recommend that the project or program office develop a risk management plan to track and mitigate risks.	
10	**Document the Estimate**	*1. Document all steps used to develop the estimate so that a cost analyst unfamiliar with the program can recreate it quickly and produce the same result.*	Section 4.3
		2. Document the purpose of the estimate, the team that prepared it, and who approved the estimate and on what date.	
		3. Describe the program, its schedule, and the technical baseline used to create the estimate	
		4. Present the program's time-phased life-cycle cost.	
		5. Discuss all ground rules and assumptions	
		6. Include auditable and traceable data sources for each cost element and document for all data sources how the data were normalized.	
		7. Describe in detail the estimating methodology and rationale used to derive each WBS element's cost (prefer more detail over less).	

Step	Description	Associated Tasks	Report Section
		8. Describe the results of the risk, uncertainty, and sensitivity analyses and whether any contingency funds were identified.	
		9. Document how the estimate compares to the funding profile.	
		10. Track how this estimate compares to any previous estimates.	
11	**Present estimate to management for approval**	*1. Develop a briefing that presents the documented life-cycle cost estimate.*	To be done.
		2. Include an explanation of the technical and programmatic baseline and any uncertainties.	
		3. Compare the estimate to an independent cost estimate (ICE) and explain any differences.	
		4. Compare the estimate (life-cycle cost estimate (LCCE)) or independent cost estimate to the budget with enough detail to easily defend it by showing how it is accurate, complete, and high in quality.	
		5. Focus in a logical manner on the largest cost elements and cost drivers.	
		6. Make the content clear and complete so that those who are unfamiliar with it can easily comprehend the competence that underlies the estimate results.	
		7. Make backup slides available for more probing questions.	
		8. Act on and document feedback from management.	
		9. Request acceptance of the estimate.	

Step	Description	Associated Tasks	Report Section
12	**Update the estimate to reflect actual costs and changes**	*1. Update the estimate to reflect changes in technical or program assumptions or keep it current as the program passes through new phases or milestones.*	Section 4.1
		2. Replace estimates with EVM EAC and independent estimate at completion (EAC) from the integrated EVM system.	
		3. Report progress on meeting cost and schedule estimates.	
		4. Perform a post mortem and document lessons learned for elements whose actual costs or schedules differ from the estimate.	
		5. Document all changes to the program and how they affect the cost estimate.	