PERFORMANCE BASELINE FOR THE FERMILAB NOνA PROJECT

EXTERNAL INDEPENDENT REVIEW

REPORT DE820T1

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Performance Baseline for the Fermilab NOνA Project:
External Independent Review

DE820T1/DECEMBER 2007

Executive Summary

The Department of Energy Office of Engineering and Construction Management wants to

- validate the proposed performance baseline for the NuMI Off-Axis ν_e Appearance (NOνA) Experiment project, and
- recommend ways to improve project planning and execution.

OECM asked LMI to independently review the project and submit its findings, observations, and recommendations.

The NOνA project will produce near and far detectors that can perform the state of the art study of neutrino oscillations. The project consists of four main elements:

1. An upgrade of the Fermilab accelerator complex from 400 kilowatts (kW) to a complex capable of 700 kW of beam power
2. A 222-ton Near Detector
3. A Far Detector Experiment Hall built on a site near the U.S.-Canadian Border in Ash River, MN
4. A 15,000 ton (15 kiloton) NOνA Far Detector.

Table ES-1 summarizes the proposed baseline costs for this project.

Table ES-1. Proposed Baseline Costs ($)

Description	Costs to date FY06-07	Costs to go FY08-13	Total
Performance measurement baseline	3,998	195,201	199,199,000
Management reserve	—	696	696,000
Contingency	—	60,105	60,105,000
Performance baseline (TPC)	3,998[a]	256,002	260,000,000

[a] Does not include costs between CD-0 and CD-1.

Project completion is proposed for September 2013.

A preliminary draft CAP shell including the draft recommendations was provided to the project team in advance of the draft report to allow the project team to initiate a corrective action plan. The preliminary draft EIR Corrective Action Plan (CAP) shell documented 23 recommendations resulting from four major findings, nine findings, and 10 observations. Our overall conclusion, following the on-site portion of the EIR, was that the project could be successfully executed and the proposed baseline validated once the major findings were resolved and approved resolutions to the findings were in progress.

Recommendations in the preliminary draft CAP represented a snapshot of the EIR at the time of the out brief with the understanding that they might be augmented with additional recommendations in the report. During completion of the review and the writing of the report, no additional findings were identified however; some original draft findings and observations were elevated to major findings and findings respectively. The CAP shell includes a total of five Major Findings, 12 Findings, and 6 Observations with recommendations. Our overall conclusion, following completion of the EIR and writing of this report, remains that the project can be successfully executed and the proposed baseline validated once the major findings are resolved and approved resolutions to the findings are in progress.

The major findings require the following actions:

- Increasing the DOE contingency by $696,000 to absorb the cost misidentified as management reserve
- Consolidating key NOνA project technical, cost, schedule, and programmatic assumptions into a single document
- Identifying and reflecting all NOνA project costs in the Total Project Cost consistent with DOE definition

- Reviewing the practices of not charging Fermilab physicist direct labor to the NOνA project
- Executing the MOU between Fermilab and the University of Minnesota.

We note that there is an irregularity with the assignment of a Federal Project Director (FPD) for this project. The designated FPD, Mr. Pepin Carolan, is certified at Level 2. The project requires an FPD certified at Level 3. Mr Carolan is pursuing Level 3 certification.

The results of the Office of Science (SC) Independent Project Review (IPR) conducted prior to the EIR were requested by the EIR team but were withheld by SC management. Through site interviews we were informed that the IPR recommended increased flexibility in scope and in cost but no specific information was provided. The Project Team indicated that they, along with SC management, would be addressing the IPR recommendations in a manner consistent with the major EIR findings and recommendations.

DOE M 413.3-1 acknowledges that scientific systems such as accelerators do not follow linear processes where all sub systems reach the same maturity at the same time and that there is increased risk when concurrency of sub system design is required. These scientific systems projects often include facilities as one component and the scientific instrument as another. The NOνA project generally follows this structure with a conventional facilities component and the accelerator systems and experimental facilities acting like a large Major Item of Equipment (MIE) component to be installed in the newly constructed facilities. Preliminary design of the conventional facilities for NOνA is essentially complete with the review process still in progress. Following completion and documentation of the conventional facilities preliminary design review it is likely that the conventional facilities construction could be baselined as a separate component with the baseline for the accelerator and experimental facilities established at later dates when their respective designs are more mature. This phased baseline approach would require some additional planning effort on the part of the project team to repackage the project but may provide a more expedient way forward for these types of projects where the design requirement progresses sequentially across sub systems.

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Chapter 1
Introduction

1.1 PROGRAM REVIEW

At the direction of the Department of Energy (DOE) Office of Engineering and Construction Management (OECM), LMI conducted an external independent review (EIR) of the NOνA Project at Fermi National Accelerator Laboratory. The purpose of the EIR was to support OECM's validation of the performance baseline, Critical Decision (CD)-2. LMI conducted the review using the guidelines and procedures in DOE Order 413.3A[1] and DOE Manual (M) 413.3-1.[2]

After reviewing documentation received from the project team, we conducted an on-site review November 26–30, 2007. This EIR report details the scope of our review, documents our findings and observations, and provides 23 recommendations for improving project management. The recommendations stem from 5 major findings, 12 findings, and 6 of the observations. Our overall conclusion is that the project can be successfully executed and the performance baseline validated once the project team resolves the 5 major findings and has an acceptable plan in progress to resolve the other findings. Appendix A contains recommendations corresponding to the major findings, findings, and selected observations in a corrective action plan (CAP) shell.

1.2 PROJECT DESCRIPTION

The NOνA Project will produce near and far detectors that can perform the state-of-the-art study of neutrino oscillations. The project consists of four main elements:

1. An upgrade of the Fermilab accelerator complex from 400 kilowatts (kW) to a complex capable of 700 kW of beam power

2. A 222-ton Near Detector

3. A Far Detector Experiment Hall built on a site near the U.S.-Canadian Border in Ash River, MN

4. A 15,000 ton (15 kiloton) NOνA Far Detector.

[1] U.S. Department of Energy, Office of Management, Budget and Evaluation, *Program and Project Management for the Acquisition of Capital Assets*, DOE O 413.3A, July 28, 2006.

[2] U.S. Department of Energy, Office of Management, Budget and Evaluation, *Project Management for the Acquisition of Capital Assets*, DOE M 413-3-1, March 2003.

1.3 PROPOSED PERFORMANCE BASELINE

Table 1-1 shows the proposed $260 million performance baseline for the NOνA Project.

Table 1-1. Proposed Performance Baseline ($000)

Description	FY06–07	FY08	FY09	FY10	FY11	FY12	FY13	Total
PED	—	—	—	—	—	—	—	—
Construction	17	7,560	29,542	48,542	55,234	37,747	875	179,517
TEC	17	7,560	29,542	48,542	55,234	37,747	875	179,517
OPC (R&D and Ops)	3,981	14,240	4,902	458	1,363	—	—	24,943
OPC (CA only)	—	12,105	32,862	9,876	—	—	—	54,844
OPCs (expense funded)	3,981	26,345	37,764	10,334	1,363	—	—	79,787
TPC	3,998	33,905	67,306	58,876	56,597	37,747	875	260,000
PMB	3,998	27,528	52,982	45,036	40,519	28,508	626	199,199
MR	—	—	—	—	—	—	—	696
Fee	—	—	—	—	—	—	—	—
Noncontract/ DOE direct costs	—	—	—	—	—	—	—	—
Contingency	0	6,378	14,323	13,840	16,078	9,239	249	60,105
Performance baseline (TPC)	3,998	33,905	67,306	58,876	56,597	37,747	875	260,000

Table 1-2 shows the proposed performance baseline schedule Level 1 milestone schedule.

Table 1-2. Project Performance Baseline Schedule

Milestone	Date
CD-0 (Approve Mission Need)	Nov 22, 2005 (A)
CD-1 (Approve Alternative Selection and Cost Range)	May 11, 2007 (A)
CD-2 (Approve Performance Baseline)	Feb 2008
CD-3a (Long Lead Procurement/Site Work)	Feb 2008
CD-3b (Approve start of Construction)	Oct 2008
CD-4 (Project Closeout)	Sep 2013

Note: A=actual.

1.4 REPORT ORGANIZATION

The remainder of this report is organized as follows:

- Chapter 2 presents our findings, observations, and recommendations, which correspond to 17 key EIR areas of the NOνA "Final Review Plan" dated November 26, 2007, included in this limited review in the following sections:
  - 2.1 Work Breakdown Structure
  - 2.2 Project Costs and Resource-Loaded Schedule
  - 2.3 Project Schedule/Critical Path
  - 2.4 Risk Management
  - 2.5 Funding Profile
  - 2.6 Key Project Cost, Schedule, Technical, and Programmatic Assumptions
  - 2.7 System Functions and Requirements
  - 2.8 Basis of Design
  - 2.9 Preliminary Design, Design Review, and Comment Disposition
  - 2.10 Value Management/Engineering
  - 2.11 Start-Up Test Plan
  - 2.12 Acquisition Strategy
  - 2.13 Hazards Analysis
  - 2.14 Sustainability
  - 2.15 Project Execution Plan
  - 2.16 Integrated Project Team
  - 2.17 Project Execution
- The appendixes provide supporting information, including a CAP shell, review team background, persons interviewed, documents reviewed, and abbreviations.

Chapter 2
Findings

The EIR team focused on the key review elements (listed at the end of Chapter 1) identified in DOE M 413.3-1 and the *EIR Review Plan for the NOvA Project*, November 26, 2007. In the following sections, we present background information, explain the scope of our review, and document our major findings, findings, observations, and recommendations for each element.

Our findings and observations are limited to specific concerns and issues associated with the key review elements:

- A *major finding* is any finding that has a significant scope, cost, or schedule impact and, in our professional judgment, needs to be satisfactorily addressed before we recommend validating the baseline. Major findings also include findings that significantly impact safety or the ability of the project team to successfully execute the baseline.

- A *finding* is any deficiency that can impact the estimated project cost or schedule. In general, findings include deficiencies in the hazard analysis, design, risk assessment, scope definition, system requirements, or start-up. Findings also include concerns for safety or the ability of the project team to successfully execute the baseline.

- An *observation* is a comment that is not related to potential scope, cost, or schedule impacts.

If a finding states that a deficiency exists, we recommend a way to resolve it. We intend our recommendations to help the project team address programmatic, operating, and statutory requirements; identify accurate cost, schedule, and technical scope baselines; and manage and control successful execution of the project.

For this review, we provided an early release draft of the CAP shell to the project team in advance of the draft report. To facilitate organizing and understanding of this early-release draft CAP, we identified review elements by letter on the basis of the review plan, and we then sequentially numbered the recommendations within each lettered element. When we drafted this EIR report, we reordered the early-release draft CAP recommendations within each section for readability, but retained the original letter/number designation to remain consistent with the early-release draft CAP. In this EIR report, we added some recommendations that were not in the early-release draft CAP. These new recommendations were numbered using the next available number within each lettered section. The CAP shell associated with this report contains all the recommendations.

The letter designations for the review elements are as follows:

A. WBS

B. Project Costs and Resource-Loaded Schedule

C. Project Schedule and Critical Path

D. Risk Management

E. Funding Profile

F. Key Project Cost, Schedule, Technical, and Programmatic Assumptions

G. System Functions and Requirements

H. Basis of Design

I. Preliminary Design, Design Review, and Comment Disposition

J. Value Management/Engineering

K. Start-Up Test Plan

L. Acquisition Strategy

M. Hazards Analysis

N. Sustainability

O. Project Execution Plan

P. Integrated Project Team

Q. Project Execution.

2.1 WORK BREAKDOWN STRUCTURE

2.1.1 Key Review Element Background

A work breakdown structure (WBS) is a product-oriented grouping of project elements that organizes and defines the total scope of a project. Each descending level represents an increasingly detailed definition of a project component. This structure integrates and relates all project work (technical, schedule, and cost) and is used throughout a project's life cycle to identify and track specific work scope elements. The system architecture should be tailored to the size and complexity of the project and should allow the project to be successfully completed and flow from the mission operational requirements.

The WBS dictionary is a listing of individual WBS elements that describes the work scope content of each element, deliverables, basis of estimate (BOE), assumptions, milestones, and resource requirements. WBS dictionaries may also show logic ties with other WBSs. DOE M 413.3-1 calls for preparing an organized WBS and WBS dictionary that

- define the total work scope;
- incorporate and represent a reasonable breakdown of all project work;
- include discrete WBS work packages or elements that describe specific items of hardware, service, or data; and
- contain sufficient levels to adequately manage the project.

The WBS should provide a comprehensive basis for projecting financial requirements and be compatible with the cost estimate and resource-loaded schedule (RLS). The WBS should provide the means to allocate resources and schedule and control the project at the product level. It should be structured around activity-based products and make only limited use of level-of-effort (LOE) activities.

2.1.2 Element Scope of Review

The EIR team assessed the WBS and WBS dictionary to ensure the WBS incorporates all project work. We assessed whether the RLS is consistent with the WBS for the project work scope and evaluated whether the WBS is product-oriented and represents a reasonable breakdown of the project work scope.

2.1.3 Findings/Observations/Recommendations

2.1.3.1 WBS Structure

Table 2-1 shows a Level 2 breakdown of the proposed WBS.

Table 2-1. Work Breakdown Structure—R&D

WBS	Description
R&D	
1.0	Accelerator and NuMI Upgrades
1.1	Site and building
1.2	Liquid scintillator
1.3	Wavelength shifting fiber
1.4	PVC extrusions
1.5	PVC modules
1.6	Electronics production
1.7	Data acquisition systems
1.8	Near and far detector assembly
1.9	Project management
Construction	
2.0	Accelerator and NuMI Upgrades
2.1	Site and building
2.2	Liquid scintillator
2.3	Wavelength shifting fiber
2.4	PVC extrusions
2.5	PVC modules
2.6	Electronics production
2.7	Data acquisition systems
2.8	Near detector assembly
2.9	Far detector assembly
2.10	Project management

2.1.3.2 CONTINUITY WITH PROJECT SCOPE OF WORK

Observation: The WBS represents a reasonable breakdown of the project work scope, incorporates all the major work activities, and is product-oriented.

Finding: The project is the result of combining two projects: (1) the accelerator modifications, and (2) the NuMI experiment. There appears to be a gap in the scope of the combined project between the physical completion of the accelerator modifications and the use of the modified beamline by the experiment. The commissioning of the accelerator modifications, including the Accelerator Readiness Review (ARR), is not included in the combined project.

> **Recommendation K1:** Clearly document the justification for excluding the commissioning of the modified beamline and the ARR from the project.

2.1.3.3 CONSISTENCY WITH RLS

Observation: The WBS aligns with the RLS, and its hierarchy is well-presented on the project schedule.

2.1.3.4 WBS DICTIONARY

Finding: A well-defined WBS dictionary is not apparent. The Technical Design Report contains only summary work scope descriptions by WBS.

> **Recommendation A1:** Revise the WBS dictionary to contain more information about each WBS activity, such as comprehensive scope description, deliverables, milestones, basis of estimate, assumptions, and resource requirements.

2.2 PROJECT COSTS AND RESOURCE-LOADED SCHEDULE

2.2.1 Key Review Element Background

Three elements are necessary for an acceptable RLS activity—a reasonable duration, an accurate cost, and an accurate loading profile over the duration. In addition, each element must be considered in the context of the level of completion of the project documents.

2.2.2 Element Scope of Review

For selected WBS elements (typically, those constituting significant cost or risk), we summarized the detailed basis for the cost estimate and schedule duration. We also assessed the method of estimation and strengths or weaknesses of the cost and schedule estimates for each WBS element reviewed. Table 2-2 shows the 12 target WBS elements included in our detailed cost and schedule evaluation.

Table 2-2. Target WBS Elements for Detailed Review

WBS	Description	BAC (FY07 $M)	Schedule
1.0.1.2	Recycler Kicker Systems	4.5	01 Dec 06–22 Sep 10
1.0.3.3	NuMI Target Hall Infrastructure	1.1	01 May 07–10 Nov 10
2.0.1.1.1	Beam Lines	4.5	12 Dec 07–05 Jul 11
2.1.2	Far Detector Building	32.4	30 Oct 07–30 Apr 10
2.2.1	Mineral Oil	12.3	01 Oct 08–28 Sep 12
2.3.2.1	WLS Fiber—Vendor Production and Delivery	8.9	12 Feb 09–30 Mar 12
2.4.3.2	Far Detector	21.1	04 Nov 09–26 Jun 12
2.5.3.3	Module Assembly	3.0	21 Apr 10–24 Aug 12

Table 2-2. Target WBS Elements for Detailed Review

WBS	Description	BAC (FY07 $M)	Schedule
2.6.1.2	APD Arrays	5.6	22 Jan 09–24 Feb 11
2.81	Near Detector Site Prep	3.2	08 Feb 08–20 Jan 12
2.9.4	Block Assembly & Installation	6.8	08 Jan 10–01 Feb 13
2.10	Project Management	4.1	N/A

These target elements were selected on the basis of their size, complexity, risk, and how well they represented the overall work associated with the NOνA Project.

2.2.3 Findings/Observations/Recommendations

This section presents our evaluation of the twelve target WBSs that constitute our baseline review of the NOνA Project. This section presents our findings and observations for each target area, including the scope and evaluations of the bases of cost and schedule.

Observation: Extremely detailed and well-conceived plans support most cost and schedule estimates.

- Costs are generally based on previous site experience, recent vendor quotations, time and motion studies, etc.
- Far Detector Building costs are supported by reasonably close independent estimates from 3 contractors.
- The basis of estimate (cost and schedule) is generally well-documented at low levels of the WBS.

Observation: The RLS appears reasonable and complete.

- The RLS includes all work anticipated for the project and is more than adequate for successful project execution.
- Schedule durations are adequate and based on available funding, vendor production capacities, or past experience.
- Some cost and schedule estimates appear conservative, even before the addition of contingency allowances.

Observation: An overall Basis of Estimate (BOE) summary document that fully describes all key assumptions has not been prepared. This can hinder effective management of the baseline, including identifying causes of changes and

variances. We discuss this issue further in Section 2.6, where we include a major finding and recommendation.

2.2.3.1 WBS 1.0.1.2—RECYCLER KICKER SYSTEMS

2.2.3.1.1 Scope of Work

This summary task covers engineering, design, and prototyping for the five new kicker systems: RR Injection, Injection Gap Clearing, RR Extraction to MI, MI Injection, and RR Abort.

2.2.3.1.2 Basis of Cost

Table 2-3 shows the items that constitute the $4.5 million Recycler Kicker Systems cost estimate and our evaluation.

Table 2-3. Recycler Kicker Systems Cost Estimate and Evaluation

WBS subelement	Estimated cost ($000)	Basis of cost estimate	Assessment	Finding or observation
RR Injection & Gap Clearing Prototype Magnet	1,126	Detailed estimates, based on experience with the same or very similar components or activities at Fermilab, were prepared by those responsible for execution of the tasks and are well-documented in BOEs	Estimates are well-supported and appear reasonable	See below
RR Injection & Gap Clearing Prototype Pulser	1,113	Same as above	Estimates are well-supported and appear reasonable	See below
RR Injection & Gap Clearing Prototype Bumper Power Supply	136	Same as above	Estimates are well-supported and appear reasonable	See below
RR Ext/MI Inj Kicker Magnets	1,301	Same as above	Estimates are well-supported and appear reasonable	See below
RR Ext/MI Inj Kicker Power Supply System	815	Same as above	Estimates are well-supported and appear reasonable	See below
Recycler Kicker Systems Reviews	25	Same as above	Estimates are well-supported and appear reasonable	See below
Total	4,516			

Observation: Although much of this work is presently underway, we could not ascertain the extent to which actual performance is tracking the cost and schedule estimates because the project control system is not yet fully functional.

Observation: This WBS element is organized as part of the non-MIE portion of the NOνA Project; thus, this work is OPC funded. Although this approach is apparently in response to guidance provided by the FPD, we noted that there are costs included within this WBS for preliminary design that are typically funded with PED funds. The NOνA Project is not using PED funds.

2.2.3.1.3 Basis of Schedule

Table 2-4 shows the Recycler Kicker Systems schedule activities and our evaluation.

Table 2-4. Recycler Kicker Systems Schedule Estimate and Evaluation

WBS subelement	Estimated duration (days)	Basis of duration estimate	Assessment	Finding or observation
RR Injection & Gap Clearing Prototype Magnet	609	Detailed schedules, based on experience with the same or very similar components or activities at Fermilab, were prepared by those responsible for execution of the tasks and are well-documented in BOEs	Schedules are well-supported and appear reasonable	None
RR Injection & Gap Clearing Prototype Pulser	594	Same as above	Schedules are well-supported and appear reasonable	None
RR Injection & Gap Clearing Prototype Bumper Power Supply	404	Same as above	Schedules are well-supported and appear reasonable	None
RR Ext/MI Inj Kicker Magnets	932	Same as above	Schedules are well-supported and appear reasonable	None
RR Ext/MI Inj Kicker Power Supply System	438	Same as above	Schedules are well-supported and appear reasonable	None
Recycler Kicker Systems Reviews	585	Same as above	Schedules are well-supported and appear reasonable	None

2.2.3.2 WBS 1.0.3.3—NuMI Target Hall Infrastructure

2.2.3.2.1 Scope of Work

This WBS element comprises the planning, engineering, and design/drafting needed to develop a comprehensive new layout plan for moving horn 2 to the medium energy position and includes the design of new equipment needed. It also includes the following:

- Removal and staging of R-blocks and blue blocks associated with the horn 2 move
- Engineering, design and drafting for the stripline extension, target chase cooling upgrades, and stripline block forced air cooling
- Engineering needed for analyzing radiant heat effects of chase blocks on chase components and design of additional chase temperature monitoring equipment
- Reviews for this design work.

2.2.3.2.2 Basis of Cost

Table 2-5 shows the items that constitute the $1.1 million NuMI Target Hall Infrastructure cost estimate and our evaluation.

Table 2-5. NuMI Target Hall Infrastructure Cost Estimate and Evaluation

WBS subelement	Estimated cost ($000)	Basis of cost estimate	Assessment	Finding or observation
Target Hall Operations Space Planning	234	Detailed estimates, based on experience with similar activities at Fermilab, were prepared by those responsible for execution of the tasks and are well-documented in BOEs	Estimates are well-supported and appear reasonable	None
Horn 2 Relocation to Medium Energy	456	Same as above	Estimates are well-supported and appear reasonable	None
Target Chase	363	Same as above	Estimates are well-supported and appear reasonable	None
NuMI Target Hall Infrastructure Reviews	54	Same as above	Estimates are well-supported and appear reasonable	None
Total	1,107			

2.2.3.2.3 Basis of Schedule

Table 2-6 shows the NuMI Target Hall Infrastructure schedule activities and our evaluation.

Table 2-6. NuMI Target Hall Infrastructure Schedule Estimate and Evaluation

WBS subelement	Estimated duration (days)	Basis of duration estimate	Assessment	Finding or observation
Target Hall Operations Space Planning	450	Detailed schedules are based on experience with similar activities at Fermilab, were prepared by those responsible for execution of the tasks and are well-documented in BOEs	Schedules are well-supported and appear reasonable	None
Horn 2 Relocation to Medium Energy	784	Same as above	Schedules are well-supported and appear reasonable	None
Target Chase	736	Same as above	Schedules are well-supported and appear reasonable	None
NuMI Target Hall Infra-structure Reviews	299	Same as above	Schedules are well-supported and appear reasonable	None

2.2.3.3 WBS 2.0.1.1.1—BEAM LINES

2.2.3.3.1 Scope of Work

The scope of work is to convert the Recycler Ring from an anti-proton storage ring to a proton pre-injector. It includes

- refurbishment of existing magnets;
- procurement and fabrication of new magnets;
- installation of injection and extraction lines;
- procurement, fabrication, and installation of a new 53 MHz RF system; and
- procurement, fabrication, and installation of instrumentation upgrades.

2.2.3.3.2 Basis of Cost

Table 2-7 shows some of the major items that comprise the $4.5 million Beam Lines estimate, and our evaluation.

Table 2-7. Beam Lines Cost Estimate and Evaluation

WBS subelement	Estimated cost ($000)	Basis of cost estimate	Assessment	Finding or observation
Vertical Dipole Magnet Power Supplies	503	Previous purchases. Site has built many power supplies. Fabrication based on in-house experience. Material pricing available based on vendor information and past purchase orders	Reasonable	None
Installation	1,792	Past experience. Backup files contain good information on installation activities such as rigging requirements for equipment, shielding durations, vacuum system installation based on number of welds, etc.	Reasonable	None
Areas not reviewed	2,203	Not reviewed	Accepted as is	None
Total	4,498			

2.2.3.3.3 Basis of Schedule

Table 2-8 contains the Beam Lines duration estimates from the project schedule and our evaluation.

Table 2-8. Beam Lines Schedule Estimate and Evaluation

WBS subelement	Estimated duration (days)	Basis of duration estimate	Assessment	Finding or observation
Vertical Dipole Magnet Power Supplies	364	Based on labor availability. Duration is not on critical path. Fabrication is performed as people are available	Duration is sufficient	None
Installation	669	Experience; professional judgment	Duration is sufficient	None

2.2.3.4 WBS 2.1.2—Far Detector Building

2.2.3.4.1 Scope of Work

The scope of work includes the design, construction, and outfitting of the Far Detector Building in Ash River, Minnesota.

2.2.3.4.2 Basis of Cost

Table 2-9 shows the $25.14 million Far Detector Building cost estimate and our evaluation. We focused our review on WBS 2.1.2.3—Build Phase, which includes the concrete work and the building construction.

Table 2-9. Far Detector Building Cost Estimate and Evaluation

WBS subelement	Estimated cost ($000)	Basis of cost estimate	Assessment	Finding or observation
Build Phase	25,141	3 independent cost estimates from general contractor, design/build, and construction management firms. Title I drawing package was available for all 3 contractors to use as a reference. The 3 estimates were reasonably close (±10 percent). Fermilab made some adjustments to normalize the estimates, and also performed additional value engineering to arrive at the baseline estimate	Reasonable. Good Title I drawings. All 3 firms are reputable and experienced in this type of work. Estimates are close enough to one another to provide credibility. Spot check of concrete pricing used by each contractor shows reasonable agreement (concrete is a major component of the building). The building construction is relatively simple and straightforward, and is not particularly challenging from a construction standpoint	None
Total	25,141			

2.2.3.4.3 Basis of Schedule

Table 2-10 contains the Far Detector Building duration estimate and our evaluation.

Table 2-10. Far Detector Building Schedule Estimate and Evaluation

WBS subelement	Estimated duration (days)	Basis of duration estimate	Assessment	Finding or observation
Build Phase	382	Average duration based on resource loaded schedules provided by 3 independent contractors, during preparation of independent cost estimates	Duration is adequate	Observation

2.2.3.5 WBS 2.2.1—MINERAL OIL

2.2.3.5.1 Scope of Work

The scope of work includes the vendor selection, procurement, transport, and quality assurance of the mineral oil required for the liquid scintillator.

2.2.3.5.2 Basis of Cost

Table 2-11 shows the major items that comprise the $12.3 million for Mineral Oil cost estimate and our evaluation.

Table 2-11. Mineral Oil Cost Estimate and Evaluation

WBS subelement	Estimated cost ($000)	Basis of cost estimate	Assessment	Finding or observation
Mineral oil production and delivery	12,122	3.08 million gallons at $3.36/gallon, based on vendor quotation. Delivery, storage, and other miscellaneous charges also documented in vendor quote	Reasonable	None
Areas not reviewed	210	Not reviewed	Accepted as is	None
Total	12,332			

2.2.3.5.3 Basis of Schedule

Table 2-12 shows the Mineral Oil project schedule and our evaluation.

Table 2-12. Mineral Oil Schedule Activities and Evaluation

WBS subelement	Estimated duration (days)	Basis of cost estimate	Assessment	Finding or observation
Mineral oil production and delivery	630	Schedule duration is funding-driven, not production-based. This activity is not on the critical path	Reasonable based on available funding	None

2.2.3.6 WBS 2.3.2.1—WLS FIBER—VENDOR PRODUCTION AND DELIVERY

2.2.3.6.1 Scope of Work

The scope of work includes the procurement and delivery of the wavelength shifting fiber (WLS).

2.2.3.6.2 Basis of Cost

Table 2-13 lists the major components of the $8.9 million WLS Fiber—Production and Delivery cost estimate and our evaluation.

Table 2-13. WLS Fiber—Production and Delivery Cost Estimate and Evaluation

WBS subelement	Estimated cost ($000)	Basis of cost estimate	Assessment	Finding or observation
WLS fiber vendor production and delivery	8,855	13,000 kilometers at $0.675/meter, based on vendor quote. This vendor has previously supplied WLS fiber to Fermilab	Reasonable	None
Total	8,855			

2.2.3.6.3 Basis of Schedule

Table 2-14 summarizes the WLS Fiber—Production and Delivery schedule activities and our evaluation.

Table 2-14. WLS Fiber—Production and Delivery Schedule Activities and Evaluation

WBS subelement	Estimated duration (days)	Basis of duration estimate	Assessment	Finding or observation
WLS fiber vendor production and delivery	788	Previous procurements. Production capacity is about 4500 kilometers/year, which will require about 3 years to meet the NOVA requirement of 13,000 kilometers	Reasonable	None

2.2.3.7 WBS 2.4.3.2—FAR DETECTOR

2.2.3.7.1 Scope of Work

The scope of work includes procurement of the PVC resin, production of the PVC extrusions, shipping, and quality control.

2.2.3.7.2 Basis of Cost

Table 2-15 shows representative examples of the blocks that comprise the $21.1 million Far Detector cost estimate and our evaluation.

Table 2-15. Far Detector Cost Estimate and Evaluation

WBS subelement	Estimated cost ($000)	Basis of cost estimate	Assessment	Finding or observation
Horizontal Extrusions				
Obtain PVC resin—Block 1H (typical of 33 blocks)	154	$0.98/pound based on actual purchases (purchase order provided). Quantities based on block configuration (Type A or Type B), which is defined in BOE	Reasonable	None
Produce PVC extrusions–Block 1H (typical of 33 extrusions)	136	$0.92/pound based on vendor quote. Quantities based on block configuration (Type A or Type B), which is defined in BOE	Reasonable	None
Shipping Block 1H (typical)	5	Not reviewed	Accepted as is	None
Quality control Block 1H (typical)	4	Not reviewed	Accepted as is	None
Total horizontal extrusion (typical of 33 blocks)	298			
Vertical Extrusions				
Obtain PVC resin—Block 1V (typical of 33 blocks)	230	$0.98/pound based on actual purchases (purchase order provided). Quantities based on block configuration (Type A or Type B), which is defined in BOE	Reasonable	None
Produce PVC extrusions–Block 1V (typical of 33 extrusions)	204	$0.92/pound based on vendor quote. Quantities based on block configuration (Type A or Type B), which is defined in BOE	Reasonable	None
Shipping Block 1V (typical)	5	Not reviewed	Accepted as is	None
Quality control Block 1V (typical)	5	Not reviewed	Accepted as is	None
Total vertical extrusion (typical of 33 blocks)	445	—	—	—
Total	21,055			

Note: Variations in quantities among 33 blocks result in slight differences in costs/block. Above costs for horizontal and vertical extrusions are examples only, and cannot be multiplied by 33 to get $21.1 million total cost.

2.2.3.7.3 Basis of Schedule

Table 2-16 shows the principal Far Detector schedule activities and our evaluation.

Table 2-16. Far Detector Schedule Activities and Evaluation

WBS subelement	Estimated duration (days)	Basis of duration estimate	Assessment	Finding or observation
Horizontal Extrusions				
Obtain PVC resin—Block 1H (typical of 33 blocks)	20	Historically, it takes about 3 weeks to obtain the resin after the Purchase Order (PO) is issued. Duration is not production-limited because the vendor can produce as much as 1 million pounds per day if needed	Reasonable	None
Produce PVC extrusions—Block 1H (typical of 33 extrusions)	7	Historical experience. Extruder capacity is in excess of 100,000 pounds per week, which is sufficient to meet expected demands	Reasonable	None
Shipping Block 1H (typical)	14	Historical experience	Reasonable	None
Quality control Block 1H (typical)	7	Historical experience	Reasonable	None
Vertical Extrusions				
Obtain PVC resin—Block 1V (typical of 33 blocks)	20	Historically, it takes about 3 weeks to obtain the resin after the PO is issued. Duration is not production-limited because the vendor can produce as much as 1 million pounds per day if needed	Reasonable	None
Produce PVC extrusions—Block 1V (typical of 33 extrusions)	9	Historical experience. Extruder capacity is in excess of 100,000 pounds per week, which is sufficient to meet expected demands	Reasonable	None
Shipping Block 1V (typical)	14	Historical experience	Reasonable	None
Quality control Block 1V (typical)	8	Historical experience	Reasonable	None

2.2.3.8 WBS 2.5.3.3—MODULE ASSEMBLY

2.2.3.8.1 Scope of Work

This WBS element covers the assembly of both the near and far detectors.

2.2.3.8.2 Basis of Cost

Table 2-17 shows the $3 million Module Assembly cost estimate and our evaluation.

Table 2-17. Module Assembly Cost Estimate and Evaluation

WBS subelement	Estimated cost ($000)	Basis of cost estimate	Assessment	Finding or observation
Far Detector	2,890	Very detailed estimates for materials & supplies as well as the factory labor and oversight needed for assembly operations of the Far Detector. Approximately 75–80 percent of the assembly activities have been estimated based on the results of time & motion studies.	The plans are very detailed and well-considered. The estimates are well-documented and supported and appear reasonable.	None
Near Detector	78	Minor cost, not reviewed	N/A	N/A
Total	2,968			

2.2.3.8.3 Basis of Schedule

Table 2-18 shows Module Assembly schedule activities and our evaluation.

Table 2-18. Module Assembly Schedule Estimate and Evaluation

WBS subelement	Estimated duration (days)	Basis of duration estimate	Assessment	Finding or observation
Far Detector	592	Very detailed schedules, by module for the Far Detector. Approximately 75–80 percent of the assembly activities have been estimated based on the results of time & motion studies. Overall logistics, including component delivery, shipping schedules/durations, and shipment of assembled modules to the Far Detector site, have been evaluated and appropriately planned	The plans are very detailed and well-considered. The schedules are well-documented and supported and appear reasonable	None
Near Detector	22	Minor element, not reviewed	N/A	N/A

2.2.3.9 WBS 2.6.1.2—APD ARRAYS

2.2.3.9.1 Scope of Work

This WBS element encompasses the procurement (manufacturing and delivery) of the Avalanche Photo Diodes (APD) arrays from Hamamatsu.

2.2.3.9.2 Basis of Cost

Table 2-19 shows the APD Arrays $5.6 million cost estimate and our evaluation.

Table 2-19. APD Arrays Cost Estimate and Evaluation

WBS subelement	Estimated cost ($000)	Basis of cost estimate	Assessment	Finding or Observation
Prepare purchase order	—	No cost here—covered by other LOE accounts	N/A	N/A
APDs PO issued	—	No cost here—covered by other LOE accounts	N/A	N/A
APD Array Manufac-turing	5,607	Based on estimated number of APDs to be needed, using unit cost obtained from vendor quoted range derived from efforts to produce prototype arrays already delivered, with high end of range used for estimate	Estimate appears reasonable and is well-supported	None
Evaluate APDs used in IPND	—	No costs estimated because this work is to be completed by scientists who will not be charging the project	N/A	N/A
Total	5,607			

2.2.3.9.3 Basis of Schedule

Table 2-20 shows APD Arrays schedule activities and our evaluation.

Table 2-20. APD Arrays Schedule Estimate and Evaluation

WBS subelement	Estimated duration (days)	Basis of duration estimate	Assessment	Finding or observation
Prepare purchase order	80	Based on typical dura-tions for work completed on Fermilab projects in the past	Reasonable	None
APDs PO issued	—	Milestone—no duration	N/A	N/A
APD Array Manufactur-ing	330	Based on past experi-ence with vendor, antici-pated purchase quantities, and planned shipments to match available funding	Reasonable	None
Evaluate APDs used in IPND	180	Allowance duration	Reasonable	None

2.2.3.10 WBS 2.8.1—NEAR DETECTOR SITE PREP

2.2.3.10.1 Scope of Work

This WBS element provides for site preparation of the region to contain the Near Detector. The site preparation consists of the repositioning of considerable MINOS cabling and infrastructure, and the construction of a new cavern at the appropriate off-axis angle, once the repositioning is compete.

2.2.3.10.2 Basis of Cost

Table 2-21 shows Near Detector Site Prep $3.2 million cost estimate and our evaluation.

Table 2-21. Near Detector Site Prep Cost Estimate and Evaluation

WBS subelement	Estimated cost ($000)	Basis of cost estimate	Assessment	Finding or observation
Cave Excavation Design and Engineering	73	Based on experience with past tunnel projects successfully executed by Fermilab.	Reasonable	None
Tunnel and Cave Infrastructure Design and Engineering	49	Based on experience with prior tunnel modifications completed at Fermilab.	Reasonable	None
Tunnel Infrastructure Contract	355	Based on detailed estimate using cost and productivity rates experienced on prior Fermilab work and appropriately used/adjusted costs from RSMeans	Reasonable	None
Excavation Contract	2,760	Parametrically developed estimate using historical data and engineering judgment estimates—average of two estimates derived using different approaches	General approach is reasonable, given the absence of detailed design and cost basis. Factors applied factors to the base estimates may result in an overly conservative estimate	Finding–see below.
Connect and certify FIRUS	7	Not reviewed	N/A	N/A
Total	3,244			

Finding: The cost estimate for the tunnel excavation for siting the Near Detector is based on only conceptual design information. The general approach used for the cost estimate—obtaining two different estimates using different techniques and historical bases—is appropriate. However, the mean base value derived from this approach, was then "built-up" by applying a series of factors, which may already be reflected in the base estimates derived from historical costs (Chicago

adjustment per RSMeans, tunnel difficulty factor, construction overhead and profit, and A/E firm oversight). Since these adders may not be necessary, the estimate may have been inflated unnecessarily. Next a 100 percent contingency was applied to these inflated costs. The project team recognizes the need to develop a better design and cost estimate for this work and is in the process of accelerating the design effort to FY09, even though project logistics (MINOS shutdown is required) will not permit this work to be completed until 2010–2011. Because we believe this change will reduce overall project costs and free up available contingency allowances, we have not classified this finding as a "Major Finding."

Recommendation B1: Ensure plans are in place to complete a preliminary design and the associated cost estimate for the Near Detector site preparation, including the required tunnel excavation, in FY09. Complete a BCP at that time and include more detailed and supportable cost and schedule details in the revised project cost and schedule baseline.

2.2.3.10.3 Basis of Schedule

Table 2-22 shows Near Detector Site Prep schedule activities and our evaluation.

Table 2-22. Near Detector Site Prep Schedule Estimate and Evaluation

WBS subelement	Estimated duration (days)	Basis of duration estimate	Assessment	Finding or observation
Cave Excavation Design and Engineering	315	Durations based on experience at Fermilab and logic ties to timing of tunnel contract needs	Reasonable	None
Tunnel and Cave Infrastructure Design and Engineering	180	Durations based on experience at Fermilab and logic ties to timing of planned MINOS outage when work can be completed	Reasonable	None
Tunnel Infrastructure Contract	435	Durations based on experience at Fermilab and logic ties to timing of planned MINOS outage when work can be completed	Reasonable	None
Excavation Contract	190	Durations supported by cost estimate assumptions and constraints, especially planned MINOS outage	Reasonable, but not adequately supported	See Finding under "Cost" (above)
Connect and certify FIRUS	5	Not reviewed	N/A	N/A

Table 2-22. Near Detector Site Prep Schedule Estimate and Evaluation

WBS subelement	Estimated duration (days)	Basis of duration estimate	Assessment	Finding or observation
Specify safety and training requirements for this region	20	Not reviewed	N/A	N/A
Beneficial occupancy of near detector cavern	—	Milestone—no duration	N/A	N/A
Survey location for detector	3	Not reviewed	N/A	N/A

2.2.3.11 WBS 2.9.4—Block Assembly and Installation

2.2.3.11.1 Scope of Work

This WBS element includes the labor and block components needed for block assembly and installation of the Far Detector Assembly. This includes

- the infrastructure needed for assembly, installation and commissioning of the machines needed to assemble the detector;
- the assembly of the adhesive dispenser and block pivoter;
- fabrication and shipment of the block pallets, adhesive, expansion tanks and grout;
- the labor needed to assemble the blocks; filling each block with scintillator;
- installation of readout electronics and associated support systems; and
- detector turn-on and checkout.

2.2.3.11.2 Basis of Cost

Table 2-23 shows the Block Assembly & Installation $6.8 million cost estimate and our evaluation.

Table 2-23. Block Assembly & Installation Cost Estimate and Evaluation

WBS subelement	Estimated cost ($000)	Basis of cost estimate	Assessment	Finding or observation
Assembly Infrastructure Setup	393	Costs based on detailed estimates using vendor quotes and catalog pricing for M&S and labor estimates based on experience and engineering judgment	Cost estimates appear reasonable and well-supported	None
Block Assembly Components	2,747	Same as above	Cost estimates appear reasonable and well-supported	None
Block Assembly and Alignment	2,481	Same as above	Cost estimates appear reasonable and well-supported. Time and motion studies not yet completed, but assumptions appear reasonable; plans to confirm estimates using T&M studies are in place	None
Detector Block Filling	345	Same as above	Cost estimates appear reasonable and well-supported	None
Detector Block Outfitting	417	Same as above	Cost estimates appear reasonable and well-supported	None
Detector Turn-on and Checkout	2	Same as above	Cost estimates appear reasonable and well-supported	None
Assembly Crew Management—Minnesota	396	LOE estimates needed for oversight and coordination efforts, beginning when the building outfitting is completed through completion of detector assembly	Cost estimates appear reasonable and well-supported	None
Total	6,781			

2.2.3.11.3 Basis of Schedule

Table 2-24 shows Block Assembly & Installation schedule activities and our evaluation.

Table 2-24. Block Assembly and Installation Schedule Estimate and Evaluation

WBS subelement	Estimated duration (days)	Basis of duration estimate	Assessment	Finding or observation
Assembly Infrastructure Setup	771	Detailed schedule of procurement, shipping, and installation activities	Reasonable	None
Block Assembly Components	558	Detailed schedule of fabrication and shipping of components	Reasonable	None
Block Assembly and Alignment	548	Schedule activity for each block that is based on estimated duration used to derive cost estimate. Schedule tied to delivery and other logistical plans for project	Reasonable	None
Detector Block Filling	591	Schedule activity for filling each block based on engineering judgment as to duration	Reasonable	None
Detector Block Outfitting	450	Schedule activity for each block that is based on estimated duration used to derive cost estimate	Reasonable	None
Detector Turn-on and Checkout	52	Schedule activity based on engineering judgment	Reasonable	None
Assembly Crew Management—Minnesota	708	LOE duration over planned schedule	Reasonable	None

2.2.3.12 WBS 2.10—PROJECT MANAGEMENT

2.2.3.12.1 Scope of Work

This Level 2 summary element comprises reviews, reports, site visits, local supervision, holding technical board meetings, standards preparation, tracking, and analysis, schedule preparation, tracking, and analysis, and change control. It also includes procurement of relevant software and computers, the cost of managing the project office, and the salaries of non-scientists working in the project office.

2.2.3.12.2 Basis of Cost

The Project Management $4.1 million cost estimate covers labor, travel, office equipment, materials and supplies for the NOνA Project Office. Approximately $3.6 million is for labor derived from LOE staffing of the project office. Costs are identified by Fiscal Year with a ramp-down near the end of the currently planned project life.

Observation: The estimated Project Management cost for the NOνA Project represents approximately 3.6 percent of the other estimated project costs during the construction phase of the project (WBS 2)—lower than is typically seen on comparable DOE projects. When the lower levels of management that are allocated to the various second level WBS elements (the Cost Account Managers and

other non-project office supervision) are considered, Project Management increases to approximately 8.9 percent. Although this percentage is still lower than most DOE projects, we consider it reasonable given the nature and requirements of the NOνA Project.

2.2.3.12.3 Basis of Schedule

The Project Management WBS element comprises a series of annual LOE activities. The duration is consistent with the overall project schedule.

2.3 PROJECT SCHEDULE AND CRITICAL PATH

2.3.1 Key Review Element Background

A critical path schedule highlights the most important work activities, the delay of one or more of which will delay the project unless corrective action is taken. It is an important tool for project management.

2.3.2 Element Scope of Review

We reviewed the critical path as defined and evaluated its reasonableness, determined whether the critical path is reasonably defined and whether schedule durations are reasonable, identified the duration between the critical path completion date and project completion date (CD-4), and assessed the reasonableness of identified schedule contingency.

2.3.3 Findings/Observations/Recommendations

Observation: The critical and near-critical paths are well-defined and understood by the project team. Logic in the schedule appears correct and should allow the project team to understand the impact of any project execution issues.

Observation: The Open Plan schedule is resource-loaded but not escalated. The complete resource load requires the Cobra output.

Observation: Milestones are well-defined to Level 5 in the milestone dictionary.

Finding: The schedule does not include the processes to reach CD-2 and EVMS certification. These processes are critical to successful project execution and must be visible to enable progress tracking.

> **Recommendation C1:** Expand the schedule to include the CD and EVMS certification processes.

Observation: There are 8 months of schedule contingency between the completion of work and the scheduled date for CD-4.

2.4 RISK MANAGEMENT

2.4.1 Key Review Element Background

DOE Order 413.3A requires, "Project technical, cost, and schedule risks must be identified, quantified, and mitigated (as appropriate). Risk mitigation strategies must be developed and implemented." Risk management must be analytical, forward-looking, structured, informative, and continuous. Risk assessments should be performed early and should identify critical technical, performance, schedule, and cost risks. Risk mitigation plans should not use contingency as the only mitigation strategy. The entire project team performs effective risk management throughout the project life cycle. All stakeholders should participate in the assessment process so that an acceptable balance between cost, schedule, performance, and risk is maintained. Risk mitigation actions should be tracked using project action tracking process.

2.4.2 Element Scope of Review

We did the following to evaluate project risk management:

- Assessed the adequacy of the risk management plan and of the method(s) used to identify risks, including evaluation of assumptions, and whether a reasonably complete list of potential risks was developed for analysis.
- Assessed the adequacy of the qualitative analysis and rating (high, medium, or low) of current risks (including site specific factors such as availability of contractors) for probability of occurrence and consequence of occurrence.
- Evaluated the extent and adequacy of quantitative risk analysis.
- Evaluated whether the risk registry, watch list, and risk assessment sheets appear to be complete, accurate, and appropriate.
- Evaluated the adequacy of the management control process for risk status and updating.
- Confirmed that risks associated with use of any new technology have been accounted for appropriately in the risk assessment.
- Assessed the range of cost and schedule management reserve.
- Assessed whether the basis of contingency is reasonable for this type of project.

- Assessed whether all appropriate risk handling actions, including accepted risks, and residual risks have been incorporated into the performance baseline, including cost and schedule contingency.

- Assessed whether the DOE cost and schedule contingency are adequate to cover the likely overall performance.

2.4.3 Findings/Observations/Recommendations

Observation: Risk management methodology and approach are addressed in the document *NOνA Risk Management Plan Version 1.9,* NOνA-doc-185, September 18, 2007. The risk management process resembles the 6-step process described in DOE M 413.3-1.

Observation: Risks are ranked according to probability and consequence, and a risk matrix is used. Risks are classified as high, moderate, or low. This is an appropriate technique for the NOνA Project.

Observation: The risk list is comprehensive, yet somewhat redundant because of the way the risks are segregated according to the WBS (with risks identified for each WBS Level 2 element). This approach results in the same risk frequently being repeated since it may apply to more than one WBS element. Some consolidation and re-organizing of the risks could simplify the risk management and tracking process.

> **Recommendation D1:** Consider re-organizing the risk list so that the same risk is not repeated.

Observation: The high-rated risks are documented and tracked using a Risk Accounting Form, which describes the risk, its cost impact and probability of occurrence, WBS elements affected by the risk, and mitigation strategy. We believe this approach and the form used satisfies the needs of the NOνA Project.

Observation: Contingency is largely estimated through the application of established contingency rules. These rules consider both cost estimating uncertainty and technical/programmatic risks on a lower-level WBS basis. However, on the basis of our sampling of the target WBS elements, we believe the contingency rules have sometimes been applied too rigidly. We observed instances where there was little uncertainty or risk associated with a particular element; however, because only conceptual design information might have been available, or the item had not been previously purchased, a high contingency allowance was applied. Since the underlying estimate was oftentimes already conservatively estimated, these added high contingency allowances are not necessary or appropriate.

Observation: Additional contingency is included through Monte Carlo analysis of risks associated with key project cost drivers (e.g., crude oil pricing, currency exchange rate fluctuations). The rationale and approach used to conduct these analyses appeared complete and reasonable.

Observation: The total project contingency allowance included in the proposed performance baseline for the NOνA project is $60.1 million—approximately 30 percent of the estimated costs before contingency. This overall contingency allowance appears adequate. The allowance has been determined based on good risk identification, conservative contingency rules, and Monte Carlo analysis of key risks.

Major Finding: The NOνA project baseline includes an allowance of $696,000, which has been labeled Management Reserve (MR). This MR is not consistent with DOE definitions or based on an analysis of contractor risks. Rather, this is simply a "rounding" number that represents the difference between the Total Project Cost and the cost estimate after the calculated contingency has been added.

> **Recommendation D2:** Increase the contingency to $60.8 million by incorporating the costs defined as management reserve into the project contingency.

Observation: The 8-month schedule contingency was not separately determined by risk analysis; instead, it is the difference between the established date for CD-4 and the end date of project activities as determined by the RLS. Although this duration contingency has not been derived from a quantitative analysis that fully considers uncertainty and risk, we consider the 8-month schedule contingency reasonable for the NOνA Project.

Finding: A separate DOE Risk Management Plan has not been prepared. Key DOE risks (high-rated risks) are identified in the overall risk register. DOE risks not captured in the risk register are generally considered by NOνA project personnel to be low-rated risks having minimal impact on contingency.

> **Recommendation D3:** Evaluate whether all significant DOE risks are captured in the current risk register and incorporate additional risks as appropriate. Consider such programmatic risks as stakeholder issues and University of Minnesota capabilities and performance.

Observation: A contingency spend plan has been derived through the application of contingency allowances at the lower level of the WBS and accordingly assigned to activities appearing on the project schedule. This approach should successfully relate contingency needs over time with anticipated project uncertainties and risks.

Observation: The NOνA Project has identified points in time when contingency usage and requirements are to be re-evaluated. Generally, these points have been correlated with the timing of procurement activities for major elements of the Far Detector. Since those procurements will include options for additional quantities, the idea is to identify in a timely manner whether there might be adequate unused and unneeded contingency funds that could be applied to procure additional components with the end objective of being able to build a larger detector. We consider this approach and foresighted planning an exemplary practice.

2.5 FUNDING PROFILE

2.5.1 Key Review Element Background

Every DOE project is constrained by the fiscal year funding authorized by Congress. The federal funding profile represents the "checkbook" for the project and requires that each project manage its resources and annual expenditures to stay within the authorized funding each FY. The limitations of the available funding also directly affect the project schedule; less funding year to year equates to a longer project schedule and, typically, higher project costs.

The project cost profile (the expected schedule of monetary expenditure over the project life) needs to be assessed with respect to the federal funding profile authorized. When the funding profile exceeds the cost profile, excess funds may be carried over to the next fiscal year. If the cost profile exceeds available funding, a deficit occurs and the project may need to reduce the scope or reprioritize the work to stay within funding constraints. The latter situation usually leads to delay in the project.

2.5.2 Element Scope of Review

We reviewed the basis for the project funding profile, comparing the annual funding with the cost requirements reflected in the RLS. We assessed whether the costs and funding are reasonably linked and identified any significant disconnects between the funding profile and project cost and schedule requirements.

2.5.3 Findings/Observations/Recommendations

Table 2-25 shows a comparison of the proposed funding profile with the anticipated TPC cost profile for the NOνA Project.

Table 2-25. TPC Funding and Cost Profiles ($000)

Fiscal year	Funding profile	Cost profile	Cumulative variance
Prior years	10,300	3,998	6,302
2008	36,000	33,906	8,396
2009	70,000	67,305	11,091
2010	69,000	58,876	21,215
2011	46,000	56,597	10,618
2012	28,000	37,747	871
2013	700	875	696
Total	260,000	259,304	696

Finding: The cumulative variance never goes negative during the project life; in fact, the large positive variance through FY11 creates opportunities for schedule acceleration, reduced costs, and/or enhanced project scope (i.e., greater mass in the detectors).

Recommendation E1: Evaluate opportunities for a compressed project schedule given the large positive carryover evident from the NOνA Project funding profile.

Observation: The NOνA Project's funding profile that was provided to us showed a separate $696,000 line item identified as "management reserve." This amount represents the difference between the baseline cost estimate and the project's $260 million TPC—a "rounding" component in the project's funding chart in order to match the cost profile with the funding profile. Instead of showing this residual as management reserve, we identify it as a positive variance at the end of the project. As we stated in Section 2.4, we recommend including this residual $696,000 in the project contingency rather than identify it as management reserve.

2.6 KEY PROJECT COST, SCHEDULE, TECHNICAL, AND PROGRAMMATIC ASSUMPTIONS

2.6.1 Key Review Element Background

The project cost and schedule assumptions form the foundation for development of the cost and schedule estimates, and ultimately the RLS. The assumptions need to be documented, applied to the project, and consistently applied to the cost and schedule estimates. The assumptions should cover all project phases.

2.6.2 Element Scope of Review

The EIR team identified and assessed key project cost and schedule assumptions, including the basis for assumptions, and evaluated the reasonableness of assumptions related to the quality of the cost and schedule estimates.

2.6.3 Findings/Observations/Recommendations

Table 2-26 lists some of the cost, schedule, technical, and programmatic assumptions for the NOνA Project, the basis for each assumption, and our assessment of the reasonableness of the assumption.

Table 2-26. NOνA Project Cost, Schedule, Technical, and Programmatic Assumptions

Assumption	Basis of assumption	Assessment	Finding or observation
The project contains few risks from a technical perspective.	Similar work has been performed at Fermilab. Construction is conventional. Vendors are available and have supplied similar components in the past	Reasonable	None
Suppliers are available to meet expected quantities of materials, and according to the project schedule.	Vendors/suppliers have been used in the past for similar procurements	In some cases there is only one supplier of materials, which introduces a certain amount of project risk. Limited risk is addressed in risks 113, 193, and 146	None
Adequate construction labor force.	Peak manpower is only expected to be about 35 people. Adjacent communities of Hibbing, Virginia, and International Falls have adequate labor available	Reasonable	None
University of Minnesota is capable of managing construction of the far detector.	University has performed similar activities in the past, and is familiar with contractors in the state. Fermilab has worked with Univ. Of Minnesota in the past	Reasonable	None
Fermilab scientists and engineers are available when needed to support the project.	Personnel are utilized as available, but most are not committed full-time to the project	Reasonable, although this is a risk. Also, key people may leave Fermilab. Staff availability is addressed in risks 26, 39, 92, and 95	None

Table 2-26. NOνA Project Cost, Schedule, Technical, and Programmatic Assumptions

Assumption	Basis of assumption	Assessment	Finding or observation
The project will construct as much detector mass as possible, but has established a baseline of at least 15 kilotons for the far detector.	Baseline cost estimates and schedule support construction of at least 15 kilotons for the proposed $260 million. If money is available, as determined at key points in the project, additional mass will be built	Reasonable. The project has established four break points in the schedule whereby a decision will be made whether to use contingency to build more mass	None
Escalation is based on local markets and economies.	Escalation studies by independent contracting firms show escalation indices ranging between 4.9–5.4 percent	Reasonable	None
Additional key cost assumptions	—	Not documented	Need to include in key assumptions document
Key schedule assumptions	—	Not documented	Need to include in key assumptions document
Total project cost starts at CD-1	HQ direction	Adequate documentation not provided. TPC starts at CD-0 per DOE O 413.3A	All project costs are not included.
Total project cost does not include commissioning of the modified beam line.	Modified beam line may take an additional 2 years to commission after project is substantially complete	CD-4 typically includes final commissioning and startup, per DOE O 413.3A	All project costs are not included.
Total project cost does not include costs for all personnel (e.g. Scientists) working on the project	Standard practice at Fermilab. Scientists work on many different projects	True costs of the project are not being documented, nor priced in the baseline estimate	All project costs are not included.

Observation: The assumptions in Table 2-26 are extracted either from briefing documentation provided by, or discussions conducted with, NOνA project personnel, and are not all-inclusive. Many of the assumptions are undocumented, but rather alluded to and discussed during briefings and interviews. This informality could cause consistency problems, confusion, and delays for the project, especially if key individuals leave prior to completion. The NOνA project risk register would be a good reference point for a comprehensive assumptions document.

Major Finding: The key project technical, cost, schedule, and programmatic assumptions are not contained within a consolidated project assumptions document.

Recommendation F1: Consolidate the key project technical, cost, schedule, and programmatic assumptions into a single document.

Major Finding: The total project cost (TPC) is inconsistent with the DOE definition. Inconsistencies are as follows:

- TPC does not start until CD-1; it should start with CD-0.
- Not all costs are captured because some Fermilab physicists perform direct labor on the project but do not charge to the NOνA project.
- Commissioning of the modified beam line is not included.

Recommendation F2: Identify and reflect all NOνA project costs in the TPC consistent with the DOE definition.

Major Finding: Fermilab physicists perform direct labor on the NOνA project but are not charged to the project. Fermilab labor will charge to normal operating accounts when they are working on installing and adjusting the NOνA experiment equipment during installation.

Recommendation F3: Review and clearly document the practice of not charging Fermilab physicist direct labor to the NOνA project.

2.7 System Functions and Requirements

2.7.1 Key Review Element Background

Requirements for a project usually start with a mission need statement and site or program planning documents. Program functional requirements identify specific features or capabilities that the project or process must meet, including acceptance criteria. Projects must also meet applicable DOE and other federal, state, and local laws, rules, and regulations, including safety and environmental protection regulations. Detailed design requirements or criteria should be prepared by the project team to guide the project design. The project may require external approvals by regulatory, licensing, or permitting agencies. These requirements should be reflected in the design features of the project.

2.7.2 Element Scope of Review

We assessed whether "design to" functions are complete and have a sound technical basis, including safety and external regulatory requirements; assessed whether system requirements are derived from and are consistent with mission need; and assessed whether the CD-4 activities are clearly defined in the requirements documents and whether these activities are quantified and measurable or can otherwise be reasonably determined as complete.

2.7.3 Findings/Observations/Recommendations

Observation: The project requirements are documented by an array of requirements documents that appear to cover the full project scope. The requirements identified are generally quantitative with specific measurable requirements. The Design requirements are compiled into a detailed Technical Design Report (TDR).

Observation: the design is based on the documented requirements. The design requirements support and are consistent with the mission need.

Observation: Quantitative performance requirements of the design are well-documented in the TDR but are not included in the project execution plan (PEP). See our Finding and Recommendation in section 2.17.

2.8 BASIS OF DESIGN

2.8.1 Key Review Element Background

DOE O 413.3A and DOE M 413.3-1 provide requirements and guidance for establishing the technical baseline necessary for CD-2. The preliminary design package should be adequate to describe the scope of the project consistent with the system functions and requirements.

2.8.2 Element Scope of Review

We evaluated the adequacy of preliminary design, including the adequacy of drawings and specifications, and assessed whether they were consistent with system functions and requirements.

2.8.3 Findings/Observations/Recommendations

Observation: The accelerator design is based heavily on the existing machine and uses “standard” accelerator components. There is no new technology required for the accelerator modifications.

Observation: The infrastructure design (facilities, roads, etc.) is based on the experiment requirements and operational considerations. Design criteria are well documented in the TDR document.

Observation: The basis for the design of the experiment components is documented in the TDR and appears fully integrated across all project components.

Observation: Design drawings appear to be consistent with design requirements.

2.9 PRELIMINARY DESIGN, DESIGN REVIEW, AND COMMENT DISPOSITION

2.9.1 Key Review Element Background

DOE O 413.3A and DOE M 413.3-1 provide requirements and guidance for establishing the technical baseline necessary for CD-2. The preliminary design package should have been subject to a design review and had corrective actions identified and any additional work incorporated into the baseline design documents. Specifically, DOE O 413.3A Table 2 "Critical Decision Requirements" states: "Conduct a Design Review of the preliminary design. Design Reviews are performed to determine if a product (drawings, analyses, or specifications) is correct and will perform its intended functions and meet requirements."

2.9.2 Element Scope of Review

We reviewed the disciplines and experience of the project design review team and assessed whether it has the appropriate experience and technical disciplines. We reviewed and assessed the results of recent design reviews, including the disposition of comments, and assessed whether any additional work identified in the design reviews has been incorporated into the design and reflected in the cost and schedule.

2.9.3 Findings/Observations/Recommendations

Observation: The project team has conducted numerous preliminary design reviews with various subject matter expert teams. Review comments are being tracked. The project team indicated that the latest round of reviews did not recommend any substantive design changes.

Observation: The design appears to have reached, and in some areas surpassed, a level of maturity consistent with a preliminary design. The project team indicates the following design status for various project components:

- Accelerator Upgrade—60–80 percent complete
- Far Detector—25–30 percent complete
- Far Detector Facility–30–40 percent complete
- Far Detector Site Work—Greater than 90 percent complete.

The accelerator design is based largely on existing equipment, which accounts for its high level of design completion. Accelerator design to close the gap between the existing equipment and the final design is approximately 10 percent complete.

The project team's assessment of design completion is consistent with the documentation provided.

Finding: The project team does not update the status of design review recommendations until immediately prior to the next design review. This practice may have merit in terms of providing the follow-on review the most recent status of comments. However, this approach does not provide sufficient documentation as to what is actually in the baseline.

> **Recommendation I1:** Update the status of all design review comments to reflect their status at CD-2 to support the design baseline.

Observation: The project team has additional design reviews scheduled to occur as the design matures.

2.10 VALUE MANAGEMENT/ENGINEERING

2.10.1 Key Review Element Background

In accordance with guidance of DOE M 413.3-1, Chapter 5,

> The value management methodology, (also known as value analysis, value engineering, value planning, etc.) is a consideration in all capital asset acquisition process phases. Further, the Department uses a two-tiered approach, as defined in the Federal Acquisition Regulation to implement a viable cost-effective value management program. The two approaches are the "mandatory program" and the "incentive" (also known as voluntary) program. The first approach, the mandatory value management program, is used for all facility construction. This is an organized effort commonly referred to as the Value Methodology Standard. The Value Methodology Standard is the systematic application of recognized techniques which identify the functions of the product or service, establish the worth of those functions, and provide the necessary functions to meet the required performance at the lowest overall life-cycle cost.

The second approach is the value management incentive program, which consists of including cost-saving incentive clauses ("shared savings" clauses) in contracts awarded on facility construction projects. This approach should be used in all contracts awarded on facility construction projects after CD-2 where certain conditions exist:

- The Department or its agents have dictated the specifications, design, process, etc., that the contractor is to follow.
- The contractor's cost reduction effort is not covered under award fee (or any other incentive).

- The contracting officer has confidence in the cost estimate for the work at issue (that it is close to normal Federal Acquisition Regulation pricing).
- The contracting officer has great confidence in the contractor's accounting system and/or can separately track costs of value management efforts based upon the contractor's assertions and confirmation from the cognizant DOE chief financial officer.
- The proposal, if accepted, requires a change to the contract and results in overall savings for DOE after implementation.

2.10.2 Element Scope of Review

In accordance with DOE requirements and guidance, the extent of our review for DOE Value Management compliance was to

- ensure that a formal value engineering (VE) study had been performed (or specifically excluded and so documented in the PEP),
- resolve whether a trained, qualified VE leader directed any formal VE study,
- determine that a formal VE study had been conducted during the early phases of the project to yield the greatest cost reductions
- ascertain whether recommendations from a formal VE study have actually been incorporated into the design concept,
- decide whether project conditions are appropriate for implementing cost savings incentive clauses in contracts awarded post CD-2, and
- determine whether the project proposes to use cost savings incentive clauses in contracts awarded post CD-2 at this time.

2.10.3 Findings/Observations/Recommendations

Observation: The project team applied Value Management and VE principles in project-wide reviews conducted during the summer of 2007. The reviews, which are well-documented, identified several candidates for optimization. The project team achieved approximately $13 million in savings through optimization and the current baseline reflects these savings. Although the studies were not formal VE studies, led by a Certified Value Specialist, they generally followed the VE process.

Observation: Numerous other (some 25) cost-driven design changes were made prior to the 2007 project-wide review, and are well-documented in the project records. The project team plans to continue seeking cost savings through additional

design optimizations; further studies are planned. The Project Management Plan (PMP) describes the Value Management process as applied to the project.

Observation: Performance incentives ("shared savings" clauses) are not planned for subcontracts; however, appropriate conditions may develop for implementing cost savings incentive clauses in contracts awarded post CD-2.

> **Recommendation J1:** Consider the use of cost savings incentive clauses in contracts awarded post CD-2.

2.11 START-UP TEST PLAN

2.11.1 Key Review Element Background

DOE O 413.3A and DOE M 413.3-1 provide requirements and guidance for start-up testing to ensure the production facility meets acceptance criteria. To establish the technical, cost, and schedule performance baseline (CD-2), provisions for start-up testing should be provided with sufficient basis to evaluate the baseline. Key tests should be determined to ensure the facility and systems meet operational and safety requirements. Any permanent plant equipment necessary for testing or validation should be included in the plant design.

2.11.2 Element Scope of Review

We evaluated whether the *Start-Up Test Plan* identifies the acceptance and operational system tests required to demonstrate that the system meets design operational specifications and safety requirements. We also assessed whether it describes the tests well enough to estimate the associated cost and schedule durations.

2.11.3 Findings/Observations/Recommendations

Observation: The project team has developed a start-up test plan which includes how the start up of the various components is linked to CD-4 deliverables.

Finding: The project schedule does not include start-up test plan activities.

> **Recommendation K2:** Expand the schedule to include detailed start-up test plan activities.

2.12 ACQUISITION STRATEGY

2.12.1 Key Review Element Background

DOE O 413.3A and DOE M 413.3-1 address the timing and requirements for developing an AS that sets forth management's approach to ensuring the project

contract satisfies the mission need. The AS broadly describes the business and technical management approach designed to achieve project objectives within resource restraints. It is a federal document approved by the acquisition executive. The acquisition plan, developed by the contractor, describes the contractual means by which the project's AS will be executed.

2.12.2 Element Scope of Review

We determined whether the way the project is being executed is consistent with the AS. We evaluated any changes from CD-1 and assessed whether the current AS still represents best value to the government. We assessed whether the contractor's acquisition plan comprehensively defines major procurements.

2.12.3 Findings/Observations/Recommendations

Observation: The NOνA Acquisition Strategy (AS) for CD-1 was approved by the DOE Acquisition Executive in April 2007. With a few minor exceptions, this document remains consistent with current execution planning for the project. For example:

- The Far Detector is described as 18 kilotons in size instead of the present 15-kiloton configuration.
- The use of a blending contractor to mix the scintillator medium is not described. Although this is a relatively small contract, it is a very important one.

Because the AS still materially describes the planned acquisition path forward, these minor discrepancies need not be addressed with changes.

Observation: Fermilab plans to act as the prime contractor for the accelerator modifications and detector fabrication. The University of Minnesota is to provide the Far Detector site and enclosure through a Cooperative Agreement.

Observation: There is a "Contractor Acquisition Plan," which defines the major procurements, or "cost drivers" for the project. This October 15, 2007 document was approved by the NOνA Project Manager, and concurred with by the FPD and DOE Fermi Site Office Contracting Manager. The major procurements, work description, cost estimate, funding constraints, contract types, bid evaluation methodology, and procurement milestones for each major procurement are described. The major procurements comprise the following:

- Scintillator constituents
- Mineral oil
- Pseudocumene

- Wave shifting powders
- Wavelength shifting fiber
- PVC extrusions
- Avalanche photo diodes
- Near Detector cavern excavation.

Observation: The Fermilab has small business participation goals delineated in the "Small Business, Veteran-owned Small Business, Service-disabled Veteran-Owned Small Business, HUBZone Small Business, Small Disadvantaged Business, and Women-owned Small Business Model Subcontracting Plan Outline." For the first 9 months of 2008, Fermilab plans to award a total of $80 million laboratory-wide. Of this total, $32 million (40 percent) is planned for small business, and $48 million (60 percent) for large business.

Observation: Fermilab generally achieves its small business participation goals. For 2006, the results were exemplary: the laboratory planned for Small, Small Disadvantaged, Woman Owned, HUBZone, and Service Disabled Veteran Owned Businesses 41.3 percent, 6.33 percent, 5.76 percent, 2.22 percent, and 1.25 percent participation respectively, and achieved 46 percent, 8.8 percent, 6.4 percent, 2.8 percent, and less than 1 percent, respectively.

2.13 HAZARDS ANALYSIS

2.13.1 Key Review Element Background

For facilities that are below the Hazard Category 3 threshold as defined in 10 CFR 830, Subpart B, a preliminary hazard analysis report is prepared for DOE approval (field level) at CD-1. At CD-2, a hazard analysis report is prepared for DOE approval (field level) by updating the preliminary report on the basis of new hazards and design information. DOE O 420.2B, *Safety of Accelerator Facilities*, has been established to define accelerator-specific safety requirements. Attachment 2 to the order establishes the contractor's responsibility to flow down accelerator safety requirements to subcontractors at any tier.

2.13.2 Element Scope of Review

We evaluated the quality of the hazard assessment (HA) and assessed whether all scope, schedule, and costs necessary for safety are appropriately incorporated into the baseline. We also assessed the HA process and the qualifications of the HA team.

2.13.3 Findings/Observations/Recommendations

Observation: This project presents minimal impact to the environment. In accordance with the State of Minnesota (MN) environmental review process, an Environmental Assessment Worksheet (EAW) was completed to determine if further MN environmental review will be required for the NOνA activities. The Minnesota Pollution Control Board has concluded that the liquid scintillator to be used by NOνA is not a hazardous substance; therefore, no problem with this major detector component is anticipated. Overall, based on the EAW and its review, MN has determined that neither further review nor an environmental impact statement is required.

A separate Environmental Assessment (EA) document, dated October 16, 2007, is in "predecisional draft" form. It assesses the potential impact of the activities associated with the NOνA project on safety, health, and the environment. The NOνA EA appraises activities at Fermilab, Ash River, MN, and at universities engaged in project work. This document goes together with the MN EAW to satisfy both Federal and State requirements. Because of the minimal effect on the environment, it is anticipated that the EA will lead to a DOE determination that the proposed federal action to construct and operate the NOνA experiment does not significantly affect the quality of the human environment within the meaning of the National Environmental Policy Act (NEPA). Therefore, it is likely an Environmental Impact Statement (EIS) will be found unnecessary, and DOE will issue a finding of no significant impact (FONSI) in response to the EA.

Observation: The HA team is well-qualified and very knowledgeable of hazards and related safety issues.

Observation: Because the present NOνA project was originally two separate projects, two HAs have been written; one for the "Accelerator and NuMI Upgrades" and one for the "NuMI Off-Axis ν_e Appearance Experiment" (detector and supporting component work). These documents are generally consistent with the expectations of DOE O 413.3A and DOE O 440.1B, *Worker Protection Program for DOE (including the National Nuclear Security Administration) Federal Employees*, dated May 17, 2007.

Observation: The accelerator modification work falls under a DOE-approved Fermilab ES&H Manual 2010 (equivalent to DOE O 420.2B, *Safety of Accelerator Facilities).* The Fermilab ES&H Manual 2010, *Planning and Review of Accelerator Facilities and their Operations,* which is incorporated into the DOE contract with Fermilab, is cited as the governing requirement. The DOE Order is not referenced in the Accelerator and NuMI Upgrades HA.

Recommendation M1: Suggest updating the HA for Accelerator and NuMI Upgrades to document that all requirements of DOE O 420.2B are being met by virtue of following the DOE-approved equivalent, Fermilab ES&H Manual 2010, *Planning and Review of Accelerator Facilities and their Operations*. Clearly state that the accelerator work will comply with its requirements.

Finding: NuMI Off-Axis ν_e Appearance Experiment HA cites the operations associated with scintillator mixing on Fermilab property as the principle hazard. However, the present plan is to contract for the mixing at an off-site, "toll blending" facility. Accordingly, this hazard will not materialize under the present path forward scenario.

Recommendation M2: Update the Hazards Analysis for NuMI Off-Axis ν_e Appearance Experiment to ensure that all references to scintillator mixing as a hazard are removed from the document.

Observation: A comprehensive (incorporates all facilities of the NOνA Project) Preliminary Safety Assessment Document (PSAD) has been written, on the basis of the two NOνA Hazard Analysis documents. The goal of the PSAD is to demonstrate that there is reasonable assurance that construction, installation, operations, and decommissioning can be conducted in a manner that will limit risks to the health and safety of employees and the public and will adequately protect the environment. Prior to sustained operations, a Safety Assessment Document (SAD) will be written and approved by the Project office. Updates to the existing Accelerator Division (AD) SAD and the NuMI/MINOS SAD will be prepared and approved prior to commissioning the accelerator and NuMI Beamline.

2.14 SUSTAINABILITY

2.14.1 Key Review Element Background

Executive Order 13423 "Strengthening Federal Environmental, Energy, and Transportation Management" and the supporting implementing instructions define the policy of the United States that Federal agencies conduct their environmental, transportation, and energy-related activities under the law in support of their respective missions in an environmentally, economically and fiscally sound, integrated, continuously improving, efficient, and sustainable manner. In implementing this policy, each agency must

- improve energy efficiency and reduce greenhouse gas emissions;
- ensure that at least half of the statutorily required renewable energy consumed by the agency in a fiscal year comes from new renewable sources;
- implement renewable energy generation projects on agency property for agency use;

- reduce water consumption intensity;
- require in acquisitions the use of sustainable, energy-efficient, water-efficient, and recycled-content products;
- ensure reductions in quantity of toxic and hazardous chemicals and materials acquired or used;
- reduce the vehicle fleet's total consumption of petroleum products by 2 percent annually, relative to a FY05 baseline;
- acquire at least 95 percent of electronic products that meet Electronic Product Environmental Assessment Tool (EPEAT) designation; and
- ensure that new construction and major renovation of agency buildings comply with the Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings set forth in the Federal Leadership in High Performance and Sustainable Buildings Memorandum of Understanding (2006).

We recognize that the executive order applies to "new construction and major renovations of agency *buildings*" and not necessarily to construction of a new neutrino detector or Fermilab accelerator complex upgrade from 400 kilowatts (kW) to a complex capable of 700 kW of beam power. Nonetheless, the design process for any conventional facilities associated with the project should use sustainable building design principles and involve maintenance and operations personnel during reviews.

2.14.2 Element Scope of Review

We assessed whether the project has identified sustainable building design features in accordance with the Energy Policy Act of 2005, Executive Order 13423, and DOE O 450.1 and that these features have been properly accounted for within the performance baseline. Energy and water conservation, minimization of waste, and use of recycled and recyclable materials were the major areas of focus in our review. Procurement documents were evaluated to determine whether they incorporate waste disposal and recycle requirements. We also assessed whether the project is eligible and intends to apply for Leadership in Energy and Environmental Design (LEED) certification.

2.14.3 Findings/Observations/Recommendations

Observation: Fermilab incorporates sustainable design principals into the design and construction of its projects. This direction is taken from the Fermilab Director's Policy 3. While Fermilab projects are generally not intended to become certified buildings, project processes and each project element are evaluated during the design phase to reduce their impact on natural resources without sacrificing

program objectives. Project designs are intended to incorporate maintainability, aesthetics, environmental evenhandedness and program requirements to deliver a well-balanced endeavor. Several Fermilab initiatives are in progress or planned to meet goals of Executive Order 13423.

Observation: Most facility energy usage at Fermilab is process-related. The accelerators and experimental facilities are large consumers of energy, and their designs offer little opportunity to apply sustainable design concepts. However, the Far Detector building at Ash River, MN, is a conventional facility. A LEED checklist prepared for this facility indicates a potential for LEED "gold" certification for the structure. The Cooperative Agreement (CA) with the University of Minnesota for the work at the Ash River site, however, does not provide any requirements for LEED certification or conformance to Executive Order 13423 on the part of the university.

> **Recommendation N1:** Encourage the University of Minnesota to either seek LEED certification for the Far Detector building, or at a minimum, to apply LEED concepts to the design of the facility.

2.15 PROJECT EXECUTION PLAN

2.15.1 Key Review Element Background

DOE O 413.3A and DOE M 413.3-1 require a PEP to be developed for each project that accurately reflects how the project is to be accomplished and defines resource requirements, technical considerations, risk management, and roles and responsibilities. Also, the PEP should define a traceable, documented change control process through which project changes are identified, controlled, and managed. As a condition of CD-2 approval, an approved, formal, final PEP embodying these requirements should be in place.

2.15.2 Element Scope of Review

Our review assessed whether the PEP reflects and supports the way the project is being managed, is consistent with the other project documents, and establishes a plan for successful execution of the project. Specifically, and in accordance with DOE requirements and guidance, the extent of our review of the PEP for this project was to determine whether the PEP

- is complete and current and reflects and supports the way the project is being managed, and
- establishes a plan for successful execution of the project.

We also assessed whether Key Performance Parameters needed for CD-4 approval are identified in the PEP, as well as project acceptance criteria.

2.15.3 Findings/Observations/Recommendations

Observation: We were able to reach firm conclusions on the PEP issues after reviewing documentation provided by the project team before our site visit and through discussions with project team members. The PEP generally reflects current plans and addresses all topics in DOE M 413-3.1. However, we noted a couple deficiencies:

- The project life-cycle cost is not well defined. A proper life-cycle cost estimate considers the estimated cost of design, construction, start-up, operations, and D&D—all brought to a single, present worth number.
- CD-4 acceptance criteria (deliverables) and Key Performance Parameters (KPPs) are not sufficiently described—see our "Project Execution" discussion in section 2.17.3 for a more detailed description of the shortcomings.

Recommendation O1: Include a proper life-cycle cost analysis in the PEP; include acceptance criteria and KPPs as required in section 2.17.3 of this report.

Observation: The PEP is complemented by a Fermilab NOνA Project Management Plan. Taken together, the PEP and PMP clearly define the project structure and goals.

2.16 INTEGRATED PROJECT TEAM

2.16.1 Key Review Element Background

According to DOE O 413.3A, a CD-1 requirement is to

> Establish and charter an Integrated Project Team. An Integrated Project Team, led by the Federal Project Director, is a multidisciplinary team, which includes safety expertise. The Charter includes membership, roles and responsibilities, decision making authority and operating guidance. The Charter may be included in the Project Execution Plan.

An IPT is an essential element of the acquisition process and should be employed during all phases of a project's life cycle. The IPT is a team of professionals representing diverse disciplines with the specific knowledge, skills, and abilities necessary to support the successful execution of a project. Project directors, project managers, contracting officers, safety and quality assurance personnel, legal specialists, and technicians typically constitute IPT membership. Members of an IPT can be DOE federal staff or contractor employees. Membership, which can be full or part time, should change as the project progresses through various stages. The FPD charters and leads the IPT.

2.16.2 Element Scope of Review

We reviewed the Federal IPT charter and staffing plans to determine whether the project management staffing level is appropriate and whether appropriate disciplines are included on the IPT. We assessed the means and appropriateness of communication within the IPT, and determined the means by which the IPT may be modified or expanded to match the needs of the evolving project. We examined whether any deficiencies exist in the IPT that could hinder successful execution of the project.

2.16.3 Findings/Observations/Recommendations

Observation: The IPT charter is included as an attachment to the PEP, and adequately describes the roles and responsibilities of the core and support members. However, the IPT charter is not signed as a separate document, but is approved as part of the PEP package. We have found this generally to be the practice of the Office of Science projects recently reviewed. This custom does not provide the appropriate management focus on the IPT make-up, and does not offer a "buy-in" signature page (similar to that found in a memorandum of agreement) for the core members to indicate their understanding and acceptance of IPT duties. The OECM publication *Integrated Project Teams*, Rev. E, June 2003, provides an extensive primer on expectations for an IPT and an IPT charter. That document defines the steps for initiating an IPT as follows:

- Organize the IPT as soon as possible following charter sign-off
- Ensure IPT agreement and understanding of charter
- Ensure IPT members are trained.

The intent of OECM is clearly for the charter to be a "stand alone document," created at the time of the mission need statement and approved at that time. Ensuring "IPT agreement and understanding of the charter" is best demonstrated through a signature page for all the core participants.

> **Recommendation P1:** Consider making the IPT charter a stand alone document with a page of "acceptance" signatures for the appointed core members in order to better comply with OECM expectations.

Observation: The IPT appears adequate with respect to depth and qualification of personnel. Fermilab personnel are included in the core IPT. Support is also obtained, as needed, from the Fermi Site Office, the DOE Office of Science Chicago Integrated Support Center (CH), and the institutions participating in the project. The IPT meets weekly; minutes/action items are produced and used to focus project activity.

Finding: A Level 3 FPD is required for the NOνA Project, in accordance with Chapter IV of DOE O 361.1, which requires "Certification Level 3: TPC between $100M and $400M." The NOνA FPD, who serves as the IPT Leader, is certified at Level 2 (acceptable for projects between $20M and $100M). In addition, the Deputy FPD is also certified at Level 2.

Recommendation P2: Develop a plan or strategy for either meeting the requirements of DOE O361.1A to provide a Level 3 certified FPD for this project, or to obtain a waiver from this requirement. Submit the plan as part of CD-2 documentation for approval by the Acquisition Executive.

2.17 PROJECT EXECUTION

2.17.1 Key Review Element Background

The evaluation of project execution entails determining the factors that bear upon whether the contractor can execute the required work to the proposed performance baseline. This includes assessing recent performance; sampling a select set of the management systems—including the adequacy of methodology used to acquire source data for EVMS measures and integration; assessing adequacy of the DOE cost and schedule contingency; assessing appropriateness of the project's KPPs that define successful completion of the project; and assessing a level of confidence that transition to hot operations will result in no significant plant performance or safety issues.

2.17.2 Element Scope of Review

The EIR team assessed the following

- Likelihood that the contractor can execute the required work to the proposed baseline, taking into consideration Contractor's past performance
- The contractor's ability to execute to the performance measurement baseline by sampling a select set of the management systems (i.e., EVMS implementation and Cost Account Managers' performance)
- Adequacy of the methodology used to acquire source data for EVMS measures and integration of EVMS with project schedule and project management, and the relationship between project status and project schedule
- Adequacy of the project's KPPs that define successful completion of the project.

2.17.3 Findings/Observations/Recommendations

Finding: The KPPs and CD-4 "deliverables" are not adequately defined and are co-mingled in the PEP section 3.2 ("Technical Goals and Capabilities") thereby jeopardizing clear communication of project success criteria. Specifically,

- KPPs presently found in the PEP are vague and lack measurable characteristics. A KPP is a vital attribute of the project that expresses performance in terms of accuracy, capacity, throughput, quantity, processing rate, purity, or that otherwise numerically defines how well a system, facility, or the project as a whole will perform.

- A comprehensive table of specific CD-4 deliverables has not been defined in the PEP.

Recommendation Q1: Develop both a list of appropriate Key Performance Parameters and a list of CD-4 deliverables for the project. Clearly delineate the lists and include them in the PEP.

Major Finding: The Fermilab/University of Minnesota MOU for implementation of the University of Minnesota/DOE CA has not been executed.

Recommendation Q2: Make execution of the Fermilab/University of Minnesota MOU for implementation of the University of Minnesota/DOE Cooperative Agreement (CA) a high priority. The CA should be executed prior to CD-2.

Finding: Currently the project team does not report earned value in its monthly reporting cycle; in fact, it is unable to report earned value progress at this time. EVMS reporting is a prerequisite for CD-2 approval, as defined in DOE O 413.3A. We found that, although EVMS tools are in place, cost and schedule data transfers and manipulation cannot be done without errors occurring in the results. The project team felt that the project controls systems merely need some "tweaking" to overcome the difficulties. While this may be true, it must be done and demonstrated prior to CD-2.

Recommendation Q3: Ensure that the project controls system is completely "debugged" and capable of producing accurate EVMS reports prior to CD-2. If this cannot be done, obtain a written waiver from OECM that specifically allows a delay in EVMS reporting until the current errors can be corrected.

Observation: Fermilab scientists and some other personnel, and outside scientists who perform NOνA work do not charge their time to the project. As a result, earned value calculations cannot be made for such work. Thus, a portion of the project will never have accurate Estimates at Completion (EAC), or forecasts, calculated and reported to senior management. This approach is a long-standing practice of Fermilab, and of SC facilities in general.

Appendix A
Corrective Action Plan

Table A-1 presents the current corrective action plan shell based on the recommendations presented in the EIR report for the NOνA Project. A preliminary draft of this CAP shell was released in advance of the DRAFT Report at the request of OECM. Items in this version that were not in the preliminary draft are identified with **BOLD** type.

Items are identified by letter corresponding to EIR elements and then numbered sequentially within the element. In the report these recommendations appear in logical sequence based on the subject area. In the CAP shell they appear in order of their appearance in the report.

Items noted with ** are the result of Major Findings. A single * indicates items related to Findings. All other items are the result of observations.

Recommendations in this CAP shell are not provided as a checklist for CD-2. Many of the recommendations require the Project Team to assess impacts across the entire project which may then require additional actions to keep the scope, cost, and schedule baseline fully coordinated.

CAP Shell Sections

A. WBS

B. Project Costs and Resource-Loaded Schedule

C. Project Schedule and Critical Path

D. Risk Management

E. Funding Profile

F. Key Project Cost, Schedule, Technical, and Programmatic Assumptions

G. System Functions and Requirements

H. Basis of Design

I. Preliminary Design, Design Review, and Comment Disposition

J. Value Management/Engineering

K. Start-Up Test Plan

L. Acquisition Strategy

M. Hazards Analysis

N. Sustainability

O. Project Execution Plan

P. Integrated Project Team

Q. Project Execution.

Table A-1. CD-2 Corrective Action Plan for the NOνA Project

ID no.	Sec ref	Page ref	Recommendation	Required action (discussion)	Action office	Start/compliance	Current status	Site use	OECM perspective
K1*	2.1.3.2	2-4	Clearly document the justification for excluding the commissioning of the modified beamline and the ARR from the project.						
A1*	2.1.3.4	2-5	Revise the WBS dictionary to contain more information about each WBS activity, such as comprehensive scope description, deliverables, milestones, basis of estimate, assumptions, and resource requirements.						
B1*	2.2.3.10.2	2-20	Ensure plans are in place to complete a preliminary design and the associated cost estimate for the Near Detector site preparation, including the required tunnel excavation, in FY09. Complete a BCP at that time and include more detailed and supportable cost and schedule details in the revised project cost and schedule baseline.						
C1	2.3.3	2-24	Expand the schedule to include the CD and EVMS certification process.						
D1	2.4.3	2-26	Consider re-organizing the risk list so that the same risk is not repeated.						

Table A-1. CD-2 Corrective Action Plan for the NOνA Project

ID no.	Sec ref	Page ref	Recommendation	Required action (discussion)	Action office	Start/compliance	Current status	Site use	OECM perspective
D2**	2.4.3	2-27	Increase the contingency to $60.8 million by incorporating the costs defined as management reserve into the project contingency.						
D3*	2.4.3	2-27	Evaluate whether all significant DOE risks are captured in the current risk register and incorporate additional risks as appropriate. Consider such programmatic risks as stakeholder issues and University of Minnesota capabilities and performance.						
E1*	2.5.3	2-29	Evaluate opportunities for a compressed project schedule given the large positive carryover evident from the NOνA Project funding profile.						
F1**	2.6.3	2-31	Consolidate the key project technical, cost, schedule, and programmatic assumptions into a single document.						
F2**	2.6.3	2-32	Identify and reflect all NOνA project costs in the TPC consistent with the DOE definition.						
F3**	2.6.3	2-32	Review and clearly document the practice of not charging Fermilab physicist direct labor to the NOνA project.						

Table A-1. CD-2 Corrective Action Plan for the NOνA Project

ID no.	Sec ref	Page ref	Recommendation	Required action (discussion)	Action office	Start/compliance	Current status	Site use	OECM perspective
I1*	2.9.3	2-35	Update the status of all design review comments to reflect their status at CD-2 to support the design baseline.						
J1	2.10.3	2-37	Consider the use of cost savings incentive clauses in contracts awarded post CD-2.						
K2*	2.11.3	2-37	Expand the schedule to include detailed start-up test plan activities.						
M1	2.13.3	2-41	Suggest updating the HA for Accelerator and NuMI Upgrades to document that all requirements of DOE O 420.2B are being met by virtue of following the DOE-approved equivalent, Fermilab ES&H Manual 2010, *Planning and Review of Accelerator Facilities and their Operations* . Clearly state that the accelerator work will comply with its requirements.						
M2*	2.13.3	2-41	Update the Hazards Analysis for NuMI Off-Axis ν_e Appearance Experiment to ensure that all references to scintillator mixing as a hazard are removed from the document.						

Table A-1. CD-2 Corrective Action Plan for the NOνA Project

ID no.	Sec ref	Page ref	Recommendation	Required action (discussion)	Action office	Start/compliance	Current status	Site use	OECM perspective
N1	2.14.3	2-43	Encourage the University of Minnesota to either seek LEED certification for the Far Detector building, or at a minimum, to apply LEED concepts to the design of the facility.						
O1	2.15.3	2-44	Include a proper life-cycle cost analysis in the PEP; include acceptance criteria and KPPs as required in section 2.17.3 of this report.						
P1	2.16.3	2-45	Consider making the IPT charter a stand alone document with a page of “acceptance” signatures for the appointed core members in order to better comply with OECM expectations.						
P2*	2.16.3	2-46	Develop a plan or strategy for either meeting the requirements of DOE O361.1A to provide a Level 3 certified FPD for this project, or to obtain a waiver from this requirement. Submit the plan as part of CD-2 documentation for approval by the Acquisition Executive.						
Q1*	2.17.3	2-47	Develop both a list of appropriate Key Performance Parameters and a list of CD-4 deliverables for the project. Clearly delineate the lists and include them in the PEP.						

Table A-1. CD-2 Corrective Action Plan for the NOνA Project

ID no.	Sec ref	Page ref	Recommendation	Required action (discussion)	Action office	Start/compliance	Current status	Site use	OECM perspective
Q2**	2.17.3	2-47	Make execution of the Fermilab/University of Minnesota MOU for implementation of the University of Minnesota/DOE Cooperative Agreement (CA) a high priority. The CA should be executed prior to CD-2.						
Q3*	2.17.3	2-47	Ensure that the project controls system is completely "debugged" and capable of producing accurate EVMS reports prior to CD-2. If this cannot be done, obtain a written waiver from OECM that specifically allows a delay in EVMS reporting until the current errors can be corrected.						

Appendix B
Review Team Background

This appendix gives the background of the EIR review team for the NOvA Project.

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Education

B.S., Civil Engineering, The University of Michigan
M.S., Civil Engineering, The University of Michigan

Experience Summary

Mr. Flannery has more than 36 years of experience in all phases of management and control of projects as an employee of owner, A-E, and consulting firms. He possesses extensive experience in cost engineering involving estimation, control, and analysis of capital expenditures for varied industrial applications. He is experienced in conceptual and detailed estimating, cost monitoring, trending, value engineering, performance measurement and cost control; bid analysis and contract development; cost management system development and evaluation; planning and scheduling; and procedures development.

Mr. Flannery has 16 years' experience in directing up to 70 professional and support personnel. He has extensive experience performing independent cost estimates and validations of projects for the U.S. Department of Energy's Environmental Restoration, Waste Management, and Civilian Radioactive Waste Management programs.

He has provided successful management and execution of cost engineering projects including independent cost estimate and schedule reviews, system and procedure evaluation and development, estimate and schedule development, and economic and financial feasibility analyses. His experience also includes extensive work in environmental restoration, hazardous waste management facilities and operations, utility (power plant) engineering and construction, oil field facilities design and construction, petroleum refinery construction, and U.S. Department of Energy reviews of high technology projects and programs.

Certification/Professional Affiliations

Certified Cost Engineer No. 01473, Certificate expires March 1, 2007
Member, Project Management Institute (PMI)

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Education

B.S., Chemical Engineering, Iowa State University, 1975

Experience Summary

Mr. Gray has 30 years of experience in engineering and design, project and program management, and consulting. He was past program manager for an independent cost estimating contract with DOE FM-20. Mr. Gray's focus over the past 15 years has been in support of the U.S. Department of Energy, and in particular, performing independent cost estimates, independent cost reviews, and external independent reviews of over 50 major DOE projects and programs ranging in cost from $5 million to about $25 billion. These reviews include independent assessment of baseline life-cycle costs, construction/operations cost estimates, D&D costs, work breakdown structures, risk assessments, and contingency analyses.

Mr. Gray has been responsible for the cost review and risk assessment portions of many of the external independent reviews related to ongoing DOE projects. These include review of the Environmental Management programs for such sites as Brookhaven National Laboratory, Lawrence Livermore National Laboratory, Pantex, Nevada Test Site, Lawrence Berkeley National Laboratory, and Los Alamos National Laboratory. Mr. Gray also has assessed the costs and risks/contingency for such DOE capital construction projects as the Tritium Extraction Facility, the Depleted Uranium Hexafluoride Conversion Project, the Highly Enriched Uranium Materials Facility, the Weapons Evaluation Test Laboratory, and the Microsystems and Engineering Sciences Applications project. As a result of these reviews, numerous recommendations have been implemented by DOE to improve project/program management, project cost estimates, and overall project performance.

Certification/Professional Affiliations

Professional Engineer, Colorado, No. 25722
Professional Engineer, Ohio, No. E-55299
American Institute of Chemical Engineers
Society of Mining Engineers
Colorado Hazardous Waste Management Society

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Education

M.B.A., Finance, St. Josephs University, Philadelphia, PA
B.A., Business Economics, Albright College, Reading, PA

Experience Summary

Consultant with over 30 years of experience in all facets of cost engineering, cost management, risk management, and project management and control related to construction, operation and decommissioning of complex capital projects. Extensive experience with the assessment and evaluation of projects of all types at all points of the project life cycle, as well as project management and control capabilities, practices, processes, tools and systems. Experience gained during 18 years of employment by Gilbert/Commonwealth, a large architect engineer, two years with Pathfinder, Inc., a project management consulting firm, 5 years as the managing partner of a cost management consulting practice, and over 8 years working as an independent consultant. Consulted for owner organizations in both the public and private sectors, either directly or through arrangements with various consulting and contractor organizations.

DOE/NNSA experience spans the past 20 years. Regularly perform independent reviews of cost estimates, schedules, risk management and project management processes and capabilities for the NNSA and various DOE Program Offices. Managed a variety of Independent Cost Estimating (ICE) tasks for Gilbert/Commonwealth, including the first independent cost estimate of DOE's EM Program, an effort that produced almost 1,600 independent estimates and covered all DOE clean-up sites. Supported various other DOE IPRs and EIRs, including serving as the lead technical support contractor for the USACE "Project EM." Experience also includes ICEs and consulting support to RW, NE, and SC, as well as various DOE projects and field offices, including the Yucca Mountain Project and the Accelerator Production of Tritium Project. Supported the development/revision of DOE project management and cost estimating guidance and tools, including application of the Construction Industry Institute's Project Definition Rating Index to DOE projects.

Certification/Professional Affiliations

Certified Cost Consultant, No. 1009, originally certified February 27, 1975
Project Management Professional, PMI

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Education

B.S., Civil Engineering, Penn State University
M.S., Civil Engineering, Penn State University

Experience Summary

Mr. Reams is an LMI research fellow with more than 30 years of engineering experience in construction management, program management, project planning, facilities management, contract administration/management, and engineering data management. In his 20 years as a commissioned officer in the U.S. Navy Civil Engineer Corps, he served in various assignments, including operational construction forces, installation staffs, research positions, and senior-level operational staffs. His project experience includes management of multiple construction projects at major military installations, historical sites, and secure facilities at critical operational locations.

Working on the staff of U.S. Central Command during Desert Storm and later for the Chairman of the Joint Chiefs of Staff, Mr. Reams developed the policy and procedures that define engineer operations for major contingencies, integrating the engineer capabilities of the various services' uniformed and civilian engineer teams. While on the staff of the Chief of Naval Operations, he assembled the multi-year funding requirements for the Navy's shore infrastructure program, including new construction, maintenance, and operational requirements and balanced requirements against available appropriations. During an assignment to the Defense Nuclear Agency, Mr. Reams developed and managed a multi-year theoretical shock physics program including instrumented simulations.

Before coming to LMI, Mr. Reams was the Chief Operating Officer for a construction consulting company providing project reviews and analysis for financial institutions and government agencies.

Certification/Professional Affiliations

Registered Professional Engineer, Pennsylvania

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Education

Graduate of Industrial College of the Armed Forces; Air Command and Staff College, and Squadron Officers School
M.B.A., Wright State University
M.S., Electrical Engineering, University of Pittsburgh
B.S., Engineering Science, U.S. Air Force Academy

Experience Summary

Mr. Westerbeck is the LMI Program Manager for the DOE program. He has over 44 years of experience in the public sector as an engineer, program and project manager, and consultant, including 32 years in facilities engineering and environmental management at both the federal installation and headquarters levels. He has served as a construction project planner, programmer, designer, and construction manager for major construction, alteration, and repair projects at U.S. Air Force bases in the United States, Okinawa, and Vietnam. He also served as the deputy manager of a USAF office coordinating the efforts of the other military services and the Office of the Secretary of Defense to improve the productivity of the U.S. industrial base and its preparedness for increased wartime production and reduced U.S. dependency on foreign critical/strategic materials.

In 1987, Mr. Westerbeck was selected to establish an environmental restoration and compliance program at Wright-Patterson Air Force Base; that program quickly became a model for other federal operating bases facing federal and state regulation under RCRA and CERCLA. As a DOE site manager in the field and at DOE Headquarters, he gained extensive experience in the management and technical aspects of environmental restoration, the management and disposition of hazardous and radioactive waste materials, and decontamination and decommissioning of excess facilities and equipment.

At LMI, he has managed studies and analyses for numerous federal agencies, including more than 85 External Independent Reviews, Independent Cost Reviews, and Business Case Analyses of DOE and NNSA line item projects. Mr. Westerbeck is a retired member of the Senior Executive Service and a retired Colonel from the U.S. Air Force. His decorations and awards include the Legion of Merit, the Bronze Star, the Meritorious Service Medal, and the Distinguished Career Service Award. He holds active DoD TS and DOE Q clearances.

Certification/Professional Affiliations

The Military Officers Association
The Reserve Officer Association

Appendix C
Personnel Interviewed

During the course of this review, we interviewed the following:

- Mike Andrews
- Chris Ader
- David Ayers
- Greg Block
- Mark Bollinger
- Dixon Bogert
- Dan Broemmelsiek
- Carl Bromberg
- Pepin Carolan
- Robert Cibic
- John Cooper
- Paul Derwent
- Steve Dixon
- Ken Domann
- Harry Ferguson III
- Bil Freeman
- TJ Gardner
- Nancy L. Grossman
- Ken Heller
- Dean Hoffer
- Steve Holmes
- Chris Jensen
- O Kiemschies
- Peter Lucas
- Patrik Lukens
- Elaine McCluskey
- Chuck McNabney
- William Miller
- Hugh Montgomery
- Marvin Morshak
- Leon Mualem
- Stuart Mufson
- Suzanne Pasek
- Anna Pla-Dalmau
- Dave Pushka
- Ron Ray
- Bob Reilly
- Roger Rusak
- Keith W. Schuh
- Alex Smith
- Richard Talaga
- Salman Tariq
- Linda Valerio
- Steve Webster
- Alan Wehmahn

Appendix D
Documents Reviewed

[1] Technical Design Report, October 8, 2007

[2] Detailed project component design parameter documents, various dates

[3] ANU Design Parameters, undated

[4] Building Size Calculations, Jul 19, 2007

[5] Extrusion Dimensions, 4/10/07

[6] Integration Prototype Near Detector Parameters, May-07

[7] Near Detector Parameters, Sep 07

[8] NOνA Far Detector Parameters, Oct 8, 2007

[9] Project Execution Plan, Oct 12, 2007

[10] Acquisition Strategy, March 21, 2007

[11] Project Management Plan, NOνA-doc-129, Oct 12, 2007

[12] Acquisition Plan for the NOνA Cost Drivers, Version 1.9, October 15, 2007, NOνA-doc-1321

[13] Quality Assurance Program for the NOνA Project, V1.0, NOνA-doc-1353, Fermilab, May 2, 2007

[14] NOνA Risk Management plan Version 1.9 September 18, 2007 NOνA-doc-185

[15] Risk Summary Tables, undated

[16] Integrated Safety Management (ISM) Program for the NOνA Project, undated

[17] Security Vulnerability Assessment Report for the NOνA Project Fermilab August 21, 2006 NOνA-doc-1442

[18] Contingency Analysis Rules for NOνA October 9, 2007 NoνA-doc-616

[19] DRAFT NOνA Configuration Management Program and Change Management Plan Version 1.8 November 19, 2007 NOνA-doc-131

[20] NOνA Configuration Management Items Listing, 15 Oct 2007

[21] Requirements for NOνA Systems and Components, various dates

[22] Monthly reports, May 06 through September 07

[23] Sustainability Guidance NOνA Project, FESS/Engineering Project No. 15-1-3, October 17, 2007

[24] Design Review Documentation, 7/18/05 through 8/22/07

[25] Value Management /Engineering Documents, various dates

[26] NOνA's Implementation of Fermilab's Earned Value Management System Version 0 October 19, 2007

[27] MOU with U Minnesota (Duluth), 11 Oct 07

[28] MOU with Indiana U part 1, 14 Oct 07

[29] MOU between the NOνA Project and the Fermilab Directorate, 16 Nov 07

[30] MOU between the NOνA Project and the Fermilab Directorate, 16 Nov 07

[31] DRAFT MOU between U Minnesota & Fermilab on the Cooperative Agreement, 11 Oct 2007

[32] MOU with Argonne National Lab, 11 Oct 2007

[33] DRAFT Environmental Assessment, Pre-decisional Draft, Oct 16, 2007

[34] NOνA Updated NuMI Off-Axis νe Appearance Experiment Hazard Analysis Document November 11, 2005 Updated October 17, 2007

[35] NOνA Accelerator & NuMI Upgrades Preliminary Hazard Analysis Document, February 7, 2007

[36] The NOνA Project, Preliminary Safety Assessment Document, October 18, 2007

[37] Start-Up Test Plan for the NOνA Project, NOνA-Doc-2646, October 31, 2007

[38] Earned Value Management System Description, Latest revision 28 Jul 2006

[39] NOνA Organization Chart, 10/21/07

[40] Various “OPEN Plan” Schedule reports, various dates

[41] Basis of Estimate Documentation, various dates

[42] Conceptual Design Report Proton Plan 2 November 9, 2006 (Updated: 1/31/07)

[43] NuMI Off-Axis νe Appearance Experiment Conceptual Design Report March 31, 2006

[44] Cooperative Agreement between the Department of Energy and the University of Minnesota, 9/27/07

[45] Far Detector Title I Drawings, 17 Aug 07

[46] Site Prep Package Drawings, 4/18/07

[47] Technical Specifications, 4/10/07

[48] WBS Interface Responsibility Matrix, 3 Oct 07

Plus various working documents, spreadsheets, and briefings provided by the project team.

Appendix E
Abbreviations

APD	avalanche photo diodes
AS	Acquisition Strategy
BOE	basis of estimate
CA	cooperative agreement
CAP	corrective action plan
CD	critical decision
DOE	Department of Energy
EAC	estimate at completion
EAW	environmental assessment worksheet
EIR	external independent review
EIS	environmental impact statement
EPEAT	electronic product environment assessment tool
EVMS	earned value management system
FONSI	Finding of No Significant Impact
FPD	federal project director
FY	fiscal year
HA	hazards assessment
ICE	Independent Cost Estimate
IPR	Independent Project Review
IPT	integrated project team
KPP	key performance parameters
LEED	Leadership in Energy and Environmental Design
LOE	level-of-effort
M	manual
MIE	major item of equipment
MINOS	Main Injector Neutrino Oscillation Search
MR	management reserve
NEPA	National Environmental Policy Act

NOνA	NuMI Off-Axis ν_e Appearance
O	order
OECM	Office of Engineering and Construction Management
OPC	other project cost
PEP	project execution plan
PMB	performance measurement baseline
PMP	Project Management Plan
PSAD	Preliminary Safety Assessment Document
PVC	Polyvinyl Chloride
R&D	research and development
RF	radio frequency
RLS	resource-loaded schedule
RMP	risk management plan
SC	Office of Science
SAD	safety assessment document
SME	subject matter expert
SRD	system requirements documents
T&M	time-and-materials
TDR	Technical Design Report
TEC	total estimated cost
TPC	total project cost
VE	value engineering
WBS	work breakdown structure
WLS	Wavelength shifting fiber