NEUTRINOS

AT THE

MAIN INJECTOR

Project Execution Plan

February 1999

Project Execution Plan
Change Control Log

Revision Number	Pages Changed	Revision Date
1	13	August 2000
1	14	August 2000
1	Attachment 9.4	August 2000
2	9	September 2001
2	12-14	September 2001
3	9	October 2001
3	12-14	October 2001
3	Attachment 9.4	October 2001
3	Attachment 9.5	October 2001
4	4	March 2002
5	9	July 2004
5	12, Table 8.2	July 2004
5	13-14, Table 8.3	July 2004

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NEUTRINOS AT THE MAIN INJECTOR
PROJECT EXECUTION PLAN

TABLE OF CONTENTS

1. Introduction

1.1 Purpose and Context of This Document

This Project Execution Plan (PEP) for the Neutrinos at the Main Injector (NuMI) project describes the mission need and justification of the project, its objectives and scope, the Department of Energy (DOE) management structure, the resource plan, and the environmental, safety, and health requirements. In addition, it establishes the technical, cost, and schedule, baselines against which project execution will be measured by the DOE. It also identifies which DOE management level is authorized to approve changes to each baseline.

The project is being executed by Universities Research Association, which operates Fermi National Accelerator Laboratory (Fermilab) under contract for the DOE. The NuMI Project Management Plan (PMP), a companion document to this PEP, describes the organization and systems that the contractor will employ to manage execution of the project and report to the DOE. It also establishes the more detailed baselines against which the contractor will measure project execution.

1.2 Approval and Revision

The PEP is approved by the Director of DOE's Office of Science (SC-1) as an element of Critical Decision 2, Approval of Baseline. Revisions to the PEP that are required to incorporate baseline change actions are considered to be approved by virtue of the corresponding baseline change. Approval of revisions to the PEP that are not connected with baseline changes has been delegated to the Director of DOE's Division of High Energy Physics (DHEP). The DOE NuMI Project Manager is authorized to approve non-substantive changes to the PEP and to update the document with appropriate factual material that reflects project development (such as actual dates that project milestones are accomplished), without higher level approval.

The PMP is approved by both the DOE NuMI Project Manager and the Director of the DHEP.

2. Mission Need and Objectives

2.1 Programmatic Mission

The mission of the DHEP is to support the Director of SC in providing effective planning, funding, and management of the DOE High Energy Physics (HEP) program. In doing so, the Division is a principal focus in carrying out the Department's role as the designated Executive Agent for the United States HEP program. The mission of the HEP program is to understand the fundamental nature of matter and energy and the forces, which govern their behavior.

The mission of Fermilab is to advance the understanding of the fundamental nature of matter and energy by providing leadership and resources for qualified researchers to conduct basic research at the frontiers of HEP and related disciplines.

2.2 Project Support of Program Mission

The NuMI Project at Fermilab will provide the U.S. HEP program with a world-class facility for studying the physics of neutrino systems in general and, more specifically, addressing the fundamental question of the mass of neutrinos.

A full description of how the NuMI Project furthers the mission of Fermilab and the DOE DHEP program is set forth in Attachment 9.1. The Director of the Office of Energy Research (previous organization to the Office of Science) approved this document, which constitutes Critical Decision 1 in accordance with DOE Order 430.1, on March 17, 1997.

3. Project Description

The NuMI project will be constructed at Fermilab in Batavia, Illinois, and at the Soudan Underground Laboratory (SUL) in Soudan, Minnesota. Fermilab is a contractor-operated DOE laboratory, and SUL is owned by the State of Minnesota and operated by the University of Minnesota.

The purpose of the NuMI project is to build a facility for studying the physics of neutrinos. The proton beam of the Fermilab Main Injector will be used to produce a very intense neutrino source. The project includes the design and construction of a beam line and experimental facilities at the Fermilab site, two multi-purpose detectors for the Main Injector Neutrino Oscillation Search (MINOS) experiment (a near detector at Fermilab and a far detector at the SUL), and modifications to the SUL to accommodate the far MINOS detector.

The NuMI beam line will produce an intense beam of neutrinos to enable a new generation of experiments whose primary scientific goal is to definitively detect and study neutrino oscillations. The beam will be of sufficient intensity and energy so that experiments capable of identifying muon neutrino to tau neutrino oscillations are feasible. A beam of protons from Fermilab's Main Injector will be used to produce the neutrino beam by directing it onto a production target. The interaction of the proton beam with the target will produce mesons, which will decay into muons and neutrinos during their flight through a decay tunnel. An absorber downstream of the decay region will remove the remaining protons and mesons from the beam. The muons will be absorbed by the intervening earth shield while the neutrinos continue through it to the near experimental hall and beyond to the far detector in the SUL.

The experimental halls will contain massive detectors specially designed to detect the relatively few neutrinos that will interact in them. A near detector located on the Fermilab site will provide a measurement of the neutrino rate and energy spectrum near the point where they are produced. A far detector in the SUL will measure these same quantities 730 km from the near detector. Evidence for neutrino oscillations will be sought by comparing the neutrino interaction rates and energy spectra in the near and far detectors.

Attachment 9.2 contains an aerial view of the NuMI beam line and a map of the neutrino beam trajectory.

3.1 Scientific Objectives

The probability that a neutrino will oscillate from one type to another is given by the expression

$$P = \sin^2(2\theta)\,\sin^2(1.27\Delta m^2 L/E).$$

Here θ is the mixing angle between the two neutrino types, Δm^2 is the difference between the squares of their masses (eV^2), L is the distance traveled (km) and E is the neutrino energy (GeV). For NuMI, L is firmly established by locating the MINOS far detector at Soudan and E is constrained by the NuMI primary beam energy. The parameters $\sin^2(2\theta)$ and Δm^2 must be determined by experiment and the range of possible values for them is referred to as the parameter space for neutrino oscillations. The following sections describe the scientific objectives in exploring this parameter space.

3.1.1 Detection of Neutrino Oscillations

The primary scientific objective of the MINOS experiment is to definitively detect neutrino oscillations or, if neutrino oscillations do not occur within the region of parameter space accessible to the MINOS experiment, to place stringent new constraints upon where oscillations might occur. The specific region of parameter space to be explored and the methods of detecting neutrino oscillations are fully discussed in The MINOS Detectors Technical Design Report (October 1998).

3.1.2 Identification of Oscillation Channel(s)

There are three known types of neutrinos: ν_e, ν_μ, and ν_τ. A fourth, non-interacting type, known as the "sterile neutrino", is suggested by some theories. The NuMI neutrino beam is composed almost entirely of ν_μ. Hence the goal of the MINOS experiment is to find a clear signal for $\nu_\mu \rightarrow \nu_x$, where x represents one of the other neutrino types. The beam will be of sufficient energy to produce τ leptons, which would identify $\nu_\mu \rightarrow \nu_\tau$ oscillations. If oscillations occur, the MINOS detector will identify the non-μ neutrino flavor(s) and thus the oscillation channel(s).

3.1.3 Measurement of Neutrino Oscillation Parameters

If neutrino oscillations are detected, the MINOS experiment will measure the neutrino oscillation parameters Δm^2 and $\sin^2(2\theta)$ for each oscillation channel observed. The beamline will be optimized to search the region of parameter space that the data from recent experiments indicates is most likely to contain the actual parameters for ν_μ oscillations.

3.2 Technical Goals

The critical technical goals of the NuMI project are listed in Table 3.1. The commissioning goals are the parameter values that must be achieved for approval to start operations (Critical Decision 4). The operational goals, which are needed for the project to accomplish its scientific objectives, are expected to be reached after several years of operation.

Table 3.1
NEUTRINOS AT THE MAIN INJECTOR
Technical Goals

Parameter	Measurement	Commissioning Goal	Operational Goal
Proton intensity in target hall	Toroid beam monitor	1×10^{13}/spill	4×10^{13}/spill 3.6×10^{20}/year
Neutrino beam energy	Near detector event energy	Medium energy, 4-8 GeV	Low energy, 2-4 GeV Medium energy, 4-8 GeV High energy, 8-16 GeV
Near detector neutrino flux	Charged current event rate in 1.5 ton fiducial region	0.045 ± 0.014 events/spill	0.18 ± 0.05 events/spill
Far detector neutrino flux*	Charged current event rate	$(1.9 \pm 0.6) \times 10^{-5}$ events/kton/spill	$(7.6 \pm 2.3) \times 10^{-5}$ events/kton/spill
Muon momentum resolution+	Curvature vs. range in magnetic overlap region	20%	14%
Hadron energy resolution+	Test beam	None	$\Delta E/E = 70\%/E^{1/2} + 8\%$
Detection efficiency for charged current events+	Event length distribution	80 % with <10% neutral current contamination	90% with <4% neutral current contamination

*Assuming 50% reduction from neutrino oscillations
+Applies to both near and far detectors

3.3 Project Scope

A neutrino beamline will be constructed on the Fermilab site. Beamline components will be built for NuMI or recycled from existing beamlines at Fermilab, installed and tested prior to operation. They will produce a neutrino beam aligned with both the near and far experimental halls. The beam will be of sufficient intensity to conduct the long baseline neutrino research in the parameter space discussed in the preceding sections. The beamline design is more fully described in <u>The NuMI Facility Technical Design Report</u> (October 1998).

Civil construction for the NuMI Project at Fermilab will include the underground construction of tunnels and halls to accommodate the beamline components discussed above, an experimental hall which can accommodate the MINOS near detector, two shafts for access to the surface and a service building associated with each shaft. All underground construction will include sufficient radiation shielding to ensure compliance with applicable state and federal regulations when the NuMI beamline is operational. The civil construction is more fully described in <u>The NuMI Facility Technical Design Report</u> (October 1998).

Two detectors will be built, installed and tested for the MINOS experiment. The near detector will be installed in the experimental hall at Fermilab as a single module. Its neutrino detection capabilities will be similar to those of the far detector. The far detector will be installed as two supermodules. The detector design is more fully described in <u>The MINOS Detectors Technical Design Report</u> (October 1998).

An experimental hall will be constructed and outfitted at the Soudan Underground Laboratory. This hall will be capable of accommodating a MINOS detector comprised of either (a) three supermodules or (b) two supermodules and an emulsion detector.

4. DOE Organization and Responsibilities

The organization for the NuMI project is shown in Figure 4.1. Each of the major organizational elements is discussed below.

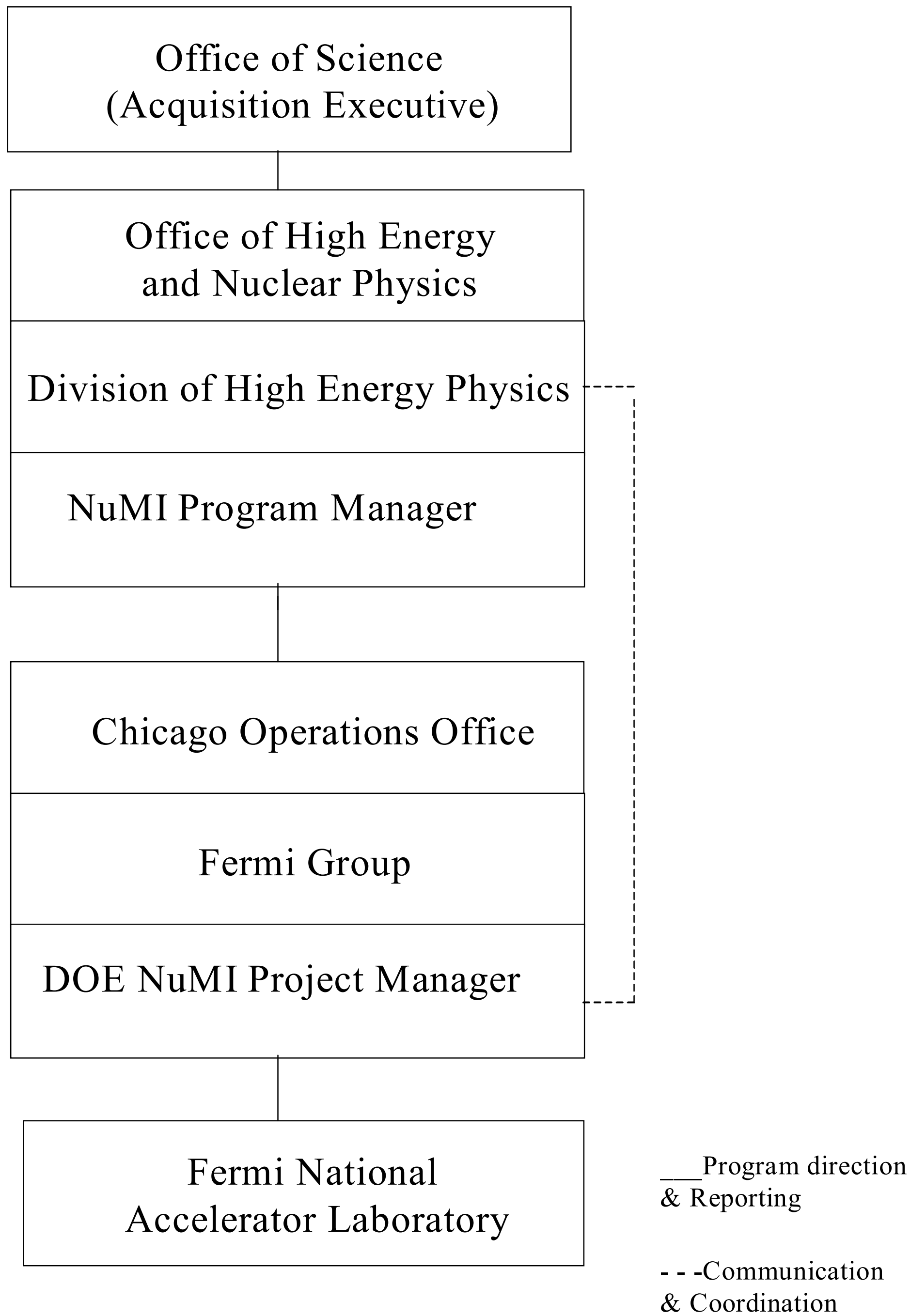
4.1 Division of High Energy Physics

Within the Office of Science, the Office of High Energy and Nuclear Physics has overall DOE responsibility for the development of high energy and nuclear physics. The Division of High Energy Physics (DHEP) is the lead organization for the NuMI project and will provide assistance, guidance and technical overview, overall program policy, planning, program development (including establishment of broad priorities) and budget preparation/defense (with support from the field organization). The prime headquarters point of contact for the project will be the NuMI Program Manager, a DHEP employee who is appointed by the Director of the DHEP.

The responsibilities of DHEP relating to the project include the following:

- generate NuMI Construction Project Data Sheet.
- in cooperation with the DOE NuMI Project Manager, generate the NuMI Project Execution Plan (PEP).
- approve substantive changes to the PEP.
- approve the initial cost, schedule, and technical baselines and subsequent Level 1 changes to the baseline.
- approve the Project Management Plan and subsequent revisions.
- approve the assignment of a DOE employee to the position of the DOE NuMI Program Manager.
- provide overall programmatic guidance and direction to the DOE NuMI Project Manager.
- carry out technical, cost, schedule and management reviews of the NuMI project in a timely and effective manner.
- ensure that funding is provided to the project on a timely basis.
- coordinate project needs with DOE headquarters.
- interact with the DOE NuMI Project Manager on a day-to-day basis.

Figure 4.1
Neutrinos at the Main Injector
Project Management Organization



4.2 Chicago Operations Office

The DOE Chicago Operations Office (CH) has the contract management responsibility for DOE's performance-based management contract with URA. The Fermi Group (FRMI) is the responsible DOE office on site at Fermilab that administers the contract and provides day-to-day DOE oversight of the laboratory. The FRMI Manager has assigned the DOE NuMI Project Manager the authority for day-to-day implementation and direction of the project. The FRMI Manager will provide the DOE NuMI Project Manager with support from FRMI staff when necessary and appropriate.

4.3 DOE Project Manager

The management responsibility, authority, and accountability for day-to-day execution of the project has been assigned to the DOE NuMI Project Manager. The DOE NuMI Project Manager is a DOE employee who is appointed by the FRMI Manager, subject to the approval of the Director of the DHEP. The DOE Project Manager receives guidance and direction from the DHEP and serves as the principal point of contact for DOE headquarters on issues specific to the project.

Specific responsibilities of the DOE NuMI Project Manager are:

- in cooperation with the DHEP, generate the Project Execution Plan.
- review and approve the Project Management Plan and subsequent revisions.
- implement procedures for baseline management and control, approve changes to Level 2 baselines, and recommend changes or corrective action to baselines above Level 2.
- maintain close contact with the activities of Fermilab to assure that the goals and schedules are met in a timely and effective manner. Review project performance monthly, and keep the DHEP informed of progress (cost, schedule, and technical accomplishments) and problems in a timely manner.
- control the project contingency funds and authorize its use within levels established in the Project Management Plan.
- coordinate with the FRMI Manager regarding approval of subcontract procurement actions performed by Fermilab.
- direct the preparation and review of the Preliminary Safety Analysis Document, Title I and II design, Safety Analysis Document, and Environmental Assessment.
- direct the periodic updating of the Project Execution Plan and the Project Management Plan.
- coordinate updates of the Construction Project Data Sheets (Schedule 44) for each budget cycle.

- participate in and provide support for the program peer reviews, reviews by oversight committees and validation of the project.

- submit quarterly reports and such other reports on the status of the project for DOE management as required in this Project Execution Plan and applicable DOE requirements.

- ensure compliance by the NuMI project with appropriate DOE requirements, e.g., ES&H and contracting regulations.

- issue construction project directives and any modifications thereto.

5. Resource Plan

The planned DOE funding for the NuMI project is shown in Table 5.1.

Table 5.1 Planned DOE Funding for the NuMI Project ($ in thousands)

	Prior Years	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	Total
Line Item Funds (TEC)	0	5,500	14,300	22,000	22,949	11,400	19,842	12,426	751	109,168
Other Project Costs	1,417	2,348	4,114	11,324	14,062	19,000	7,435	2,000	500	62,200
Total Project Costs	1,417	7,848	18,414	33,324	37,011	30,400	27,277	14,426	1,251	171,368

In addition to the DOE funding, the University of Minnesota has agreed to contribute $3.8 million towards modification of the Soudan Underground Laboratory to accommodate the far MINOS detector. An in-kind contribution of equipment for the MINOS detectors, valued at $6 million, is also expected from several institutions in the United Kingdom.

Fermilab project staffing requirements are approximately 30 full-time employees in FY 1998, increasing to approximately 150 employees in FY 2001. In addition, the MINOS collaboration includes approximately 165 people at 22 institutions. The full-time equivalent DOE manpower assigned to this project is one person at FRMI, and approximately one person in DHEP, not including support services provided as necessary by CH.

6. Project Monitoring and Reporting

The DOE Project Manager will provide quarterly reports on the NuMI project to the DHEP. Real time monitoring of the NuMI project will occur through established mechanisms among project participants. Reviews of the project status will be conducted by the DHEP approximately semi-annually. Fermilab will provide formal project monthly reports to the DOE Project Manager. The requirements of the monthly reports will be included in the PMP.

7. Environment, Safety and Health

7.1 National Environmental Policy Act (NEPA)

The effects of the NuMI project on the environment, both in Illinois and Minnesota, are assessed in the NuMI Environmental Assessment (EA). This document also describes the means through which any potential adverse effects on the environment will be avoided, minimized, or mitigated in accordance with applicable regulations. The EA has served as the basis for determining that the NuMI Project did not require an Environmental Impact Statement. A Finding of No Significant Impact (FONSI), Attachment 9.3, for the NuMI project was issued on January 16, 1998.

7.2 Preliminary Safety Analysis Document

The NuMI Preliminary Safety Assessment Document addresses the safety and health considerations in the design, construction and operation of the NuMI beamline and associated experiments. This document will form the basis for the NuMI Safety Assessment Document.

8. Project Baselines and Control Levels

The project baselines and control levels are defined in a hierarchical manner that provides change control authority at the appropriate management level. The highest level of baseline change control authority is defined as Level 0. Changes at Level 0 are approved by the Director of the DOE Office of Science. Changes below Level 0 are approved as follows: Level 1- Director of the DOE Division of High Energy Physics; Level 2 - DOE NuMI Project Manager; and Level 3- Fermilab NuMI Project Manager.

The technical, cost, and schedule baselines and the associated control levels down to Level 2 are given in Table 8.1. The project technical baseline is defined by Section 3 of this document. The cost baseline is given in Table 8.2. The baseline schedule is shown as Attachment 7.4, and controlled milestones are given in Table 8.3 and defined in Attachment 7.5.

The change control levels and procedures at Level 3 and below are addressed in the Project Management Plan.

Table 8.1

NEUTRINOS AT THE MAIN INJECTOR
Technical, Cost and Schedule Baseline Control Levels++

	Director, Office of Science (Level 0)	Director, Office of High Energy Physics (Level 1)	DOE Project Manager (Level 2)
Technical	Construction of a World-Class facility for studying the physics of neutrino systems	Scientific and technical objectives, commissioning goals, and design parameters as identified in the Project Execution Plan (Sections 3.1 and 3.2)	Project scope as identified in the Project Execution Plan (Section 3.3)
Cost	Any change to TEC or TPC (see Table 8.2)	Any change of greater than $5M at change control level 1 (see Table 8.2)	Any change of greater than $2M at change control level 2 (see Table 8.2)
Schedule	Any change to level 0 milestones (see Table 8.3)	Any change to level 1 milestones (see Table 8.3)	Any change to level 2 milestones (see Table 8.3)

++ Changes must be approved at all applicable lower levels before being forwarded to the next higher level for consideration.

Table 8.2
NEUTRINOS at the MAIN INJECTOR

Change Control Level and
Project Cost by WBS Element
($ in Millions)

CHANGE CONTROL LEVEL	WBS ELEMENT	ITEM	COST (M$)
0	1.0	TOTAL ESTIMATED COST (TEC)	109.168
2	1.1	Technical Components	28.621
2	1.2	Civil Construction	68.893
2	1.3	Project Management	3.580
2		Contingency	8.074
0		OTHER PROJECT COSTS (OPC)	62.200
1	2.0	U.S. Detector Contribution [1]	42.257
1	3.0	Project Support [2]	16.148
2		Contingency	3.796
0		TOTAL PROJECT COST (TPC)	171.368

1. Does not include United Kingdom contribution of $6.0 million, an in kind contribution, actual value conversion rate dependent; includes detector installation funds.
2. Does not include Minnesota State contribution of $3.8 million.

Table 8.3
NEUTRINOS AT THE MAIN INJECTOR
Controlled Milestones

Level 0 Milestones

Milestone No.	Description	Baseline Date	Actual Date
L-0-1	CD-1: Approve mission need	03-97	03-17-97
L-0-2	CD-2: Approve baselines	02-99	02-17-99
L-0-3	CD-4: Start operations	09-05	

Level 1 Milestones

Milestone No.	Description	Baseline Date	Actual Date
L-1-1	CD-3a: Start limited construction	02-99	02-23-99
L-1-2	CD-3b: Continue construction	04-99	05-21-99
L-1-3	Far detector prototype erected	01-00	11-10-99
L-1-4	Far detector excavation complete	10-00	12-22-00
L-1-5	Target hall excavation complete	12-02	10/04/02
L-1-6	Inner and outer conductors for first production horn assembled	04-03	02/05/03
L-1-7	First far-detector super module complete and tested	03-03	07/24/02
L-1-8	Far detector complete and tested	04-04	07/09/03
L-1-9	Start commissioning beamline	09-05	
L-1-10	Service building & outfitting bid package out	07-02	2/25/02

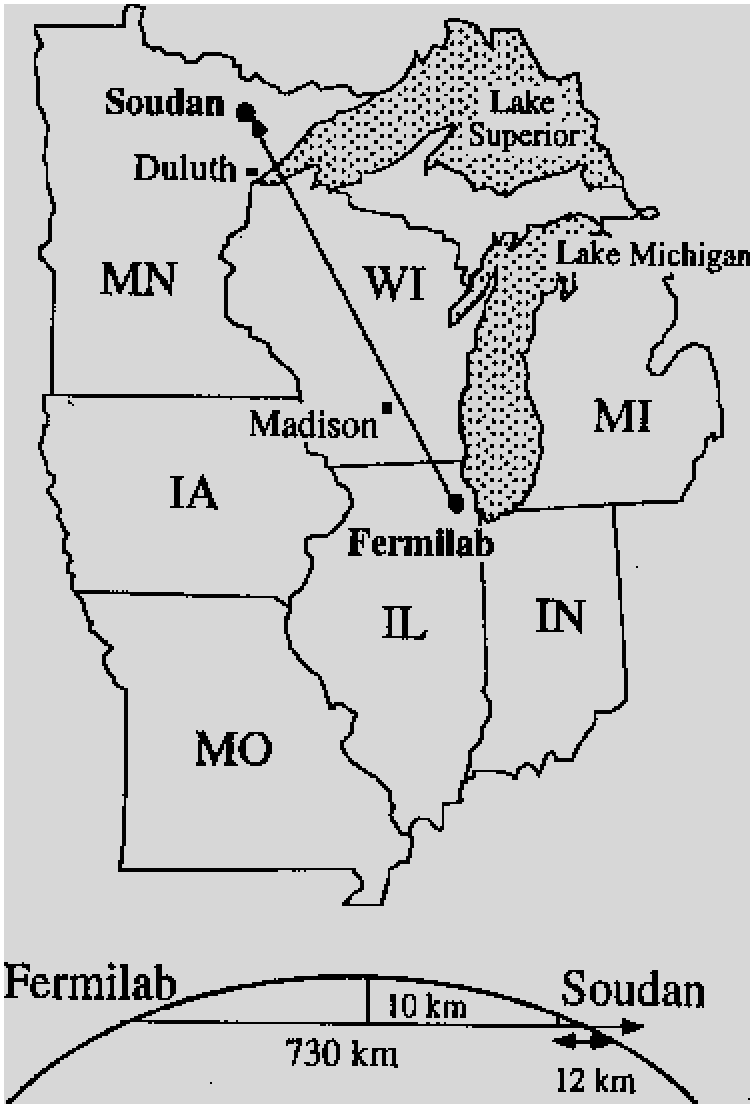
Level 2 Milestones

Milestone No.	Description	Baseline Date	Actual Date
L-2-1	MINOS steel purchase subcontract awarded	04-99	03-15-99
L-2-2	Top of Soudan #8 mineshaft located with GPS	06-99	06-16-99
L-2-3	NTP issued for Fermilab underground subcontract	03-00	03-06-00
L-2-4	High current pulse into prototype horn	03-00	07-14-00
L-2-5	Fermilab underground construction 50% complete	02-01	06-29-01
L-2-6	CalTech factory commissioned	09-00	09-01-00
L-2-7	Near detector excavation complete	12-02	08/30/02
L-2-8	Magnets for MI stub refurbished	04-01	04-30-01
L-2-9	Outfitting of far detector enclosure complete	04-01	07-19-01
L-2-10	Cosmic rays observed in far detector	09-01	09-03-01
L-2-11	Beneficial occupancy of service buildings at Fermilab	05-04	03/11/04
L-2-12	Lambertson and C-magnets assembled and tested	02-03	10/31/02
L-2-13	First horn installed	04-05	06/01/04
L-2-14	Near detector complete and tested	03-05	
L-2-15	MI stub installation complete	03-05	
L-2-16	Technology choice made for muon monitors	05-02	12/10/01
L-2-17	Complete installation of horn power supply	09-04	05/28/04
L-2-18	Target Service Building Shell Complete	09-03	06/17/03
L-2-19	75% scintillator produced	08-02	05/24/02
L-2-20	Near detector plane pre-assembly complete	10-03	12/17/02
L-2-21	Start commissioning with both Near & Far DAQ	08-04	

9. Attachments

9.1 Mission Need (CD-1)

9.2 Aerial View and Trajectory of Neutrino Beam



Trajectory of the neutrino beam between Fermilab and Soudan, Minnesota

9.3 NEPA Findings of No Significant Impact

9.4 NuMI Project Master Schedule

(Revision 3- October 2001)

9.5 Milestone Definitions

NEUTRINOS AT THE MAIN INJECTOR
Milestone Definitions

Leve l	Milestone No.	Description	Definition
0	L-0-1	CD-1: Approve mission need	Project proposal demonstrates that the project supports execution of, and project need relates to, DOE Strategic Plan goals and objectives.
0	L-0-2	CD-2: Approve baselines	Cost, schedule, and technical baselines are identified and the commissioning/operational requirements are known.
0	L-0-3	CD-4: Start operations	Project has achieved the commissioning goals shown in Table 3.1 and is ready for start of operation.
1	L-1-1	CD-3a:Start limited construction	Project is ready to start construction of the MINOS far detector cavern by the University of Minnesota.
1	L-1-2	CD-3b: Continue construction	Project is ready to start full construction of the on-site activities at Fermilab, with underground construction to receive final approval by the DOE project review in May 1999.
1	L-1-3	Far detector prototype erected	Four steel detector planes are assembled. At least one full plane of scintillator modules is constructed and mounted on the steel plane(s). Detector planes are installed on the prototype detector support in the New Muon Lab.
1	L-1-4	Far detector excavation complete	Blasting and mucking of the Soudan MINOS cavern are completed.
1	L-1-5	Target hall excavation complete	Blasting, mucking, rock bolting, grouting, and cast-in-place concrete walls, floors, and ceilings are completed for the target hall, pretarget area, and extraction addition.
1	L-1-6	Inner and outer conductors for first production horn assembled.	The inner and outer conductors for the first of two production horns are fabricated and assembled.

1	L-1-7	First far-detector supermodule complete and tested.	The first super-module, consisting of 243 detector planes, is installed and tested. The magnet coil is installed and tested.
1	L-1-8	Far detector complete and tested.	The second super-module, consisting of 243 detector planes, is installed and tested. The magnet coil is installed and tested.
1	L-1-9	Start Commissioning beamline	Start to commission technical components in NuMI beamline with protons from the Main Injector.
1	L-1-10	Service building & outfitting bid package out	The proposed package (Exhibit A, Exhibit B, and drawings for the Target and MINOS Service Buildings, the below grade outfitting, and associated Cranes) is available for potential subcontractors. All approvals for release to subcontractors obtained.
2	L-2-1	MINOS steel purchase subcontract awarded.	A subcontract for purchase of four far detector planes is issued. This subcontract contains options for purchase of steel for the final far detector in FY01 and FY02.
2	L-2-2	Top of Soudan #8 mine shaft located with GPS.	Perform the measurement the location of the top of the Soudan #8 mine shaft using Global Positioning System (GPS) in conjunction with the National Geodetic Survey Continuously Observed Reference System (CORS). Locate the top of shaft to an accuracy better than 1 meter.
2	L-2-3	NTP issued for Fermilab underground subcontract	Issue the Notice-to-Proceed to the subcontractor for the underground work at Fermilab.
2	L-2-4	High current pulse into prototype horn	Pulse the assembled inner and outer conductors of the prototype horn with a high current source to the test design current. Report on the mechanical and electrical integrity after the first pulse.
2	L-2-5	Fermilab underground construction 50% complete	Earned value of underground mining at Fermilab reaches 50% of subcontract value.
2	L-2-6	Caltech factory	Final scintillator module assembly equipment is installed in the Caltech assembly area. Required

		commissioned	utilities are installed. Assembly equipment is commissioned and Caltech assembly technicians appropriately trained. The assembly technicians produce four scintillator modules meeting the required specifications.
2	L-2-7	Near detector excavation complete	Blasting, mucking, rock bolting, grouting, and cast-in-place concrete walls, floors, and ceilings completed for the near detector cavern.
2	L-2-8	Magnets for MI stub refurbished	Finish the refurbishing of the magnets which will eventually be installed in the MI stub. This includes each magnet satisfactorily passing all electrical and mechanical tests required to certify the magnet is ready for service.
2	L-2-9	Outfitting of far detector enclosure complete	Complete the installation of electrical distribution, mechanical HVAC, and lighting in the Soudan MINOS cavern. Grant beneficial occupancy.
2	L-2-10	Cosmic rays observed in far detector	Ten planes of the far detector are assembled, tested and installed in the Soudan MINOS cavern. These planes are cabled to electronics. A cosmic ray muon event is logged by the data acquisition system.
2	L-2-11	Beneficial occupancy of service buildings at Fermilab	Beneficial occupancy of both Fermilab service buildings (Target and MINOS) is obtained.
2	L-2-12	Lambertson and C-magnets assembled and tested	Complete assembly and testing of the Lambertson and C-magnets used in the Main Injector.
2	L-2-13	First horn installed	Set the horn #1 module and horn on the alignment rail in the target station. Connect to the section of stripline in the module and connect to the water supply and return.
2	L-2-14	Near detector completed and tested	The near detector, consisting of 280 detector planes, is installed and tested. The magnet coil is installed and tested.
2	L-2-15	MI stub installation complete	Complete the installation of magnets and instrumentation in Main Injector stub area.
2	L-2-16	Technology choice	Make final choice of technology on the device

		made for muon monitors	to be used for the muon monitoring as part of neutrino beam monitoring system.
2	L-2-17	Complete installation of horn power supply	Complete the mechanical and electrical installation of the horn power supply in underground power supply room by target hall.
2	L-2-18	Target service building shell complete	The foundations, steel framing siding, and roof are complete for the Target Service Building. (Doors and Windows are not included.)
2	L-2-19	75% scintillator produced	Complete 75% of the production scintillator strips.
2	L-2-20	Near detector plane pre-assembly complete	Complete the pre-assembly of Near detector planes on the surface.
2	L-2-21	Start commissioning with both Near and Far DAQ	Start to commission Far detector DAQ system and Near detector DAQ system together.