

Date of FINAL Report: June 30, 1999

I. Project Title: Soudan Underground Physics Laboratory Expansion

Project Manager: Marvin L. Marshak/Earl A. Peterson

Affiliation: University of Minnesota

Mailing Address: School of Physics and Astronomy
116 Church St. S.E.,
Minneapolis MN 55455

Telephone Number:

Marshak: 612-624-1312 **Email:** marshak@mailbox.mail.umn.edu

Peterson: 612-624-0319 **Email:** eap@mnhep1.hep.umn.edu

Fax: 612-624-4578

Web site address: <http://www.mnhepw.umn.edu/MINOS/>

Abstract:

The LCMR-funded portion of this project entailed preliminary engineering for the construction of a new large laboratory adjacent to the existing Soudan 2 laboratory at the lowest level of Soudan Underground Mine State Park, and the upgrades of mine facilities necessary for construction. Both goals were accomplished, and the excavation of the laboratory site is now in progress. The mine hoist system has functioned perfectly. The overall MINOS project (which includes the construction of a neutrino beam at Fermilab in Chicago, an on-site laboratory and detector, and a neutrino detector for installation at Soudan) is on-time and on-budget.

Date of FINAL Report: June 30, 1999

Date of Next Status Report:

Date of Workprogram Approval:

Project Completion Date: June 30, 1999

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LCMR Final Workprogram Report

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Total Biennial Project Budget:

\$ LCMR: \$400,000

\$ LCMR Spent \$400,000

\$ LCMR Balance \$ 0

A. Legal Citation: ML 1997, Chap. 216, Sec. 15, Subd. 5(h).

Appropriation Language: This appropriation is from the future resources fund to the University of Minnesota to assist in the construction of the Soudan Mine facilities for scientific interpretation.

B. Status of Match Requirement: Not applicable

II. Project Summary and Results: Protection, enhancement, reuse and interpretation of the Soudan Mine, a National Historic Site located in Soudan Underground Mine State Park in

northern St. Louis County. This project includes the construction of a new deep underground physics laboratory and facilities for scientific interpretation for State Park visitors. This construction project will include some renovation of mechanical and electrical systems in the Soudan Mine.

III. Progress Summary: Engineering for the excavation portion of the project was completed during the summer of 1998. A portion of the engineering for the laboratory outfitting (lights/cranes/fire systems/etc.) was also brought to a stage where cost estimation could be presented to USDOE review teams. The excavation contract was put out for bids, and a winning contractor selected. Excavation began in May, 1999.

V. Outline of Project Results:

Result 1: Design of a new physics laboratory, approximately 300 feet long, 50 feet wide and 40 feet high, located 1/2 mile underground on the 27th level of the Soudan Mine in Soudan Underground Mine State Park, Breitung Township, St. Louis County, to facilitate an international effort to investigate the question of dark matter by measuring the mass of elementary particles known as neutrinos. (See Section VI.A. below for discussion and definition of terms.)

The excavation design was completed. The contract for this design, design of the outfitting of the laboratory and work ancillary to the Soudan mine enhancements was issued in series of proceed orders to Charles Nelson and Associates of Minneapolis (CNA). This firm designed and supervised the construction of the existing laboratory in the mine. This work was also partially funded by the University of Minnesota and by Fermi National Accelerator Laboratory (FNAL).

LCMR Budget: \$200,000

Completion Date: December 31, 1998

Expenditures: \$202,355

Cavern design engineering \$202,355 to CNA Engineering

Result 2: Construction of the laboratory as described above.

LCMR Budget: \$0

Completion Date: May 1, 2001

Result 3: Public interpretation by providing facilities for approximately 10,000 visits per year by individuals and school, college and other groups. This project will permit the 40,000 people who visit the Soudan Mine each year to add a cutting-edge scientific laboratory tour to their visit to the historic Montana Stope. Additional people will be attracted to the historic area tour by the availability of the scientific laboratory tour.

LCMR Budget: \$0

Completion Date: May 1, 2001

Result 4: Protection, enhancement and reuse of the historic shaft, drifts and machinery at the Soudan Mine by restoring its capability for mining approximately 50,000 tons of Ely greenstone from the site of the new laboratory.

This work is complete at this time. It included an assessment of the hoist apparatus, done by Maurice Grieves, a professional mining consultant, non-destructive testing of the entire hoisting apparatus and replacement of the main sheave wheel bearings (done by Lakewood Engineering). Other work ancillary to this effort included moving the utilities in the existing laboratory so that the new excavation could commence and State Park supervision and auditing.

LCMR Budget: \$200,000

Completion Date: June 30, 1999

Expenditures:

Inspection and testing of hoist system:	\$17,071	(Lakehead Engineering/Twin Ports testing)
Repair of hoist system	45,610	(Lakehead Engineering)
Engineering for cage remodel	4,458	(CNA Engineering)
Cage wheels	4,800	(Precision Machine)
Cage remodel	17,492	(American Structural Metals)
Utilities relocation in entrance	6,700	(Macmillan Electric)
Trench for entrance utilities	6,158	(H.A. Oxford construction)
Blast doors in entrance	7,815	(H.A. Oxford construction)
Move sprinkler plumbing in entrance	1,788	(A.G. O'Brien Plumbing: partial)
Utilities relocation in laboratory	23,630	(Nelson Collie Electric)
Supervision and auditing	57,860	(State Park)
Cage rebuild work	2,400	(Industrial Welders)
Miscellaneous supplies	1,861	(Various)
TOTAL	\$197,645	

Result 5: Survey and enhancement of the Soudan Mine as a bat hibernaculum in conjunction with the laboratory construction.

LCMR Budget: \$0

Completion Date: December 31, 1997

Result 6: Expenditure of \$20-\$30 million over 10 years in northern St. Louis County for instrumentation construction, installation and operation.

LCMR Budget: \$0

Completion Date: June 30, 2007

V. Dissemination: The primary vehicle for dissemination will be an expected 10,000 visits per year to the underground physics laboratory by Minnesota students, teachers and the general public. Results of the physics experimentation will be disseminated through publication in scientific journals and popular and semi-popular science publications such as *Scientific American* and *Nature*. Previous activities at the Soudan Laboratory have also been reported in the general print and electronic media and this mode of communication will continue to be used for new research at Soudan.

VI. Context:

A. Significance: The eventual destiny of the universe depends on the relative balance between the rate of expansion resulting from the Big Bang which occurred 10-15 billion years ago to the gravitational attraction of the existing mass. Cogent scientific arguments suggest the existence of significant mass in the universe outside detectable stars. This hypothesized mass is known as dark matter. A likely candidate for dark matter is the elementary particle known as the neutrino, which was produced copiously in the Big Bang and is currently produced in stars such as our Sun. The purpose of the proposed laboratory is to house an experiment which will attempt to measure the mass of neutrinos and thus determine whether they are indeed candidates for dark matter.

The proposed method for measuring neutrino mass is by a search for neutrino oscillation—that is, the spontaneous transformation of individual neutrinos from one of three neutrino types to another. We will produce a beam of neutrinos using a particle accelerator at Fermi National Accelerator Laboratory, located about 50 miles west of Chicago. We will measure the relative composition among the three neutrino types of the beam at Fermilab. The neutrinos will then travel approximately 440 miles through the earth to the Soudan laboratory. (Neutrinos interact so little with matter that a tunnel is not required. The neutrinos easily pass through the rock.) At Soudan, the relative composition will again be measured by the 6,000 ton, \$40 million MINOS detector, which will be housed in the new laboratory. A change in the composition of the neutrino beam provides a measurement of the neutrino mass.

The MINOS detector will be built and operated by an international team of scientists from the University of Minnesota, twenty other universities and laboratories in the United States, and universities and laboratories in the United Kingdom and in Russia. During a 3-year installation of the detector, 50-100 scientists and technical staff members will work in the underground laboratory. The detector will likely operate for about 10 years, with an ongoing staff of 25-50 scientists and technicians working at Soudan following the installation period. The current Soudan 2 detector in an existing laboratory on the 27th level will continue to operate during this entire period.

Reports of findings at Soudan are published in scientific journals such as *Physical Review Letters* and *Physics Letters*. They have also been publicized in television science programs in the United States, the United Kingdom and Australia, in television news shows, on National Public Radio, in local, regional and national newspapers and in magazines such as *National Geographic* and *Discover*.

The overall cost of the neutrino mass experiment is about \$140 million, with approximately \$55 million to be spent on facilities installed in Minnesota and the remainder on facilities to be installed at Fermilab in Illinois. The majority of this cost will be provided by the U.S. Department of Energy, with smaller amounts expected from the British and Russian governments. The financial participation of the State of Minnesota at the requested total level of \$2.7 million including the LCMR, the IRRRB and a University of Minnesota State Special appropriation will play a crucial role in facilitating the political consensus necessary for approval

of this effort. Historical precedent suggests that positive action by the State of Minnesota will help stimulate support by the U.S., U.K. and Russian governments.

B. Time: The current expectation is that design and systems renovation will occur between July 1, 1997 and June 30, 1999, that laboratory construction will occur during the 1999-2000 time frame and that detector installation and operation will occur from 2001 to 2011.

C. Budget Context: The total project cost is \$12.2 million for design, renovation and construction of the new physics laboratory at Soudan, with \$400,000 from LCMR, \$3.75 million from the University of Minnesota and other state sources and \$8.05 million from the United States Department of Energy, via Fermilab.

	July 1995-June 1997	July 1997-June 1999	July 1999-June 2001
	Prior Expenditures on this Project	Proposed Expenditures on this Project	Anticipated future expenditures on this project
1. LCMR	\$0	\$400,000	\$0
2. Other State	\$100,000	\$400,000	\$3,250,000
3. Non State Cash		\$100,000	\$7,950,000
Total	\$100,000	\$900,000	\$10,200,000

After the laboratory is finished, significant DOE expenditures are anticipated in order to install the MINOS detector in the laboratory, to operate the laboratory for the 4-year anticipated duration of the experiment, and to decommission the detector. These total:

Installation:	\$6,700,000
Operations:	\$4,800,000
Decommission:	\$2,000,000
TOTAL:	\$13,500,000

The balance of the funding for the experiment (\$136.2M total) will be expended at Fermilab, to build the neutrino beamline and the near detector on the Fermilab site, and for the purchase and construction of the detector elements (at the various collaborating institutions).

Budget:

Engineering	\$200,000
Mechanical and Electrical Renovation	\$200,000
Total	\$400,000

VII. Cooperation: The University of Minnesota cooperates in its activities at Soudan with the Department of Natural Resources, Division of State Parks. The interpretative activities included in this workprogram will be coordinated with the DNR. A letter from Mr. Paul Wannarka, DNR Park Manager at Soudan submitted with the proposal indicates his inclusion in this project as a Cooperator on behalf of the DNR.

VIII. Location: see attached map

IX. Reporting Requirements: Periodic workprogram progress reports will be submitted not later than December 31, 1997. A final workprogram report and associated products will be submitted by June 30, 1999 or by the completion date as set in the appropriation.

X. Research projects: Not applicable

