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PI/PD Name: Marvin L Marshak

Gender: ☒ Male ☐ Female

Ethnicity: (Choose one response) ☐ Hispanic or Latino ☐ Not Hispanic or Latino

Race: (Select one or more)
- ☐ American Indian or Alaska Native
- ☐ Asian
- ☐ Black or African American
- ☐ Native Hawaiian or Other Pacific Islander
- ☒ White

Disability Status: (Select one or more)
- ☐ Hearing Impairment
- ☐ Visual Impairment
- ☐ Mobility/Orthopedic Impairment
- ☐ Other
- ☐ None

Citizenship: (Choose one) ☒ U.S. Citizen ☐ Permanent Resident ☐ Other non-U.S. Citizen

Check here if you do not wish to provide any or all of the above information (excluding PI/PD name): ☒

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PI/PD Name: Priscilla B Cushman

Gender: ☐ Male ☒ Female

Ethnicity: (Choose one response) ☐ Hispanic or Latino ☒ Not Hispanic or Latino

Race: (Select one or more)
- ☐ American Indian or Alaska Native
- ☐ Asian
- ☐ Black or African American
- ☐ Native Hawaiian or Other Pacific Islander
- ☒ White

Disability Status: (Select one or more)
- ☐ Hearing Impairment
- ☐ Visual Impairment
- ☐ Mobility/Orthopedic Impairment
- ☐ Other
- ☐ None

Citizenship: (Choose one) ☒ U.S. Citizen ☐ Permanent Resident ☐ Other non-U.S. Citizen

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PI/PD Name: Thomas L Kieft

Gender: ☒ Male ☐ Female

Ethnicity: (Choose one response) ☐ Hispanic or Latino ☒ Not Hispanic or Latino

Race: (Select one or more)
- ☐ American Indian or Alaska Native
- ☐ Asian
- ☐ Black or African American
- ☐ Native Hawaiian or Other Pacific Islander
- ☒ White

Disability Status: (Select one or more)
- ☐ Hearing Impairment
- ☐ Visual Impairment
- ☐ Mobility/Orthopedic Impairment
- ☐ Other
- ☒ None

Citizenship: (Choose one) ☒ U.S. Citizen ☐ Permanent Resident ☐ Other non-U.S. Citizen

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PI/PD Name: Dean M Peterson

Gender: ☒ Male ☐ Female

Ethnicity: (Choose one response) ☐ Hispanic or Latino ☒ Not Hispanic or Latino

Race: (Select one or more)
- ☐ American Indian or Alaska Native
- ☐ Asian
- ☐ Black or African American
- ☐ Native Hawaiian or Other Pacific Islander
- ☒ White

Disability Status: (Select one or more)
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PI/PD Name: Earl Peterson

Gender: ☒ Male ☐ Female

Ethnicity: (Choose one response) ☐ Hispanic or Latino ☒ Not Hispanic or Latino

Race: (Select one or more)
- ☐ American Indian or Alaska Native
- ☐ Asian
- ☐ Black or African American
- ☐ Native Hawaiian or Other Pacific Islander
- ☒ White

Disability Status: (Select one or more)
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- ☐ None

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List of Suggested Reviewers or Reviewers Not To Include (optional)

SUGGESTED REVIEWERS:
Not Listed

REVIEWERS NOT TO INCLUDE:
Not Listed

COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

PROGRAM ANNOUNCEMENT/SOLICITATION NO./CLOSING DATE/if not in response to a program announcement/solicitation enter NSF 04-23

NSF 05-506 **02/28/05**

FOR NSF USE ONLY

NSF PROPOSAL NUMBER

FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) (Indicate the most specific unit known, i.e. program, division, etc.)

PHY - UNDERGROUND PHYSICS

DATE RECEIVED	NUMBER OF COPIES	DIVISION ASSIGNED	FUND CODE	DUNS# (Data Universal Numbering System)	FILE LOCATION
				555917996	

EMPLOYER IDENTIFICATION NUMBER (EIN) OR TAXPAYER IDENTIFICATION NUMBER (TIN)

416007513

SHOW PREVIOUS AWARD NO. IF THIS IS
☐ A RENEWAL
☐ AN ACCOMPLISHMENT-BASED RENEWAL

IS THIS PROPOSAL BEING SUBMITTED TO ANOTHER FEDERAL AGENCY? YES ☐ NO ☒ IF YES, LIST ACRONYM(S)

NAME OF ORGANIZATION TO WHICH AWARD SHOULD BE MADE

University of Minnesota-Twin Cities

AWARDEE ORGANIZATION CODE (IF KNOWN)

0023879000

ADDRESS OF AWARDEE ORGANIZATION, INCLUDING 9 DIGIT ZIP CODE

University of Minnesota-Twin Cities
450 McNamara Alumni Center
Minneapolis, MN. 554552070

NAME OF PERFORMING ORGANIZATION, IF DIFFERENT FROM ABOVE

PERFORMING ORGANIZATION CODE (IF KNOWN)

ADDRESS OF PERFORMING ORGANIZATION, IF DIFFERENT, INCLUDING 9 DIGIT ZIP CODE

IS AWARDEE ORGANIZATION (Check All That Apply) (See GPG II.C For Definitions)
☐ SMALL BUSINESS ☐ MINORITY BUSINESS
☐ FOR-PROFIT ORGANIZATION ☐ WOMAN-OWNED BUSINESS

☐ IF THIS IS A PRELIMINARY PROPOSAL THEN CHECK HERE

TITLE OF PROPOSED PROJECT **Site and Conceptual Design for the Soudan Deep Underground Science and Engineering Laboratory (DUSEL)**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ **500,000**	**6** months	**07/01/05**	

CHECK APPROPRIATE BOX(ES) IF THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW

☐ BEGINNING INVESTIGATOR (GPG I.A)
☐ DISCLOSURE OF LOBBYING ACTIVITIES (GPG II.C)
☐ PROPRIETARY & PRIVILEGED INFORMATION (GPG I.B, II.C.1.d)
☒ HISTORIC PLACES (GPG II.C.2.j)
☐ SMALL GRANT FOR EXPLOR. RESEARCH (SGER) (GPG II.D.1)
☐ VERTEBRATE ANIMALS (GPG II.D.5) IACUC App. Date _____
☐ HUMAN SUBJECTS (GPG II.D.6)
Exemption Subsection _____ or IRB App. Date _____
☐ INTERNATIONAL COOPERATIVE ACTIVITIES: COUNTRY/COUNTRIES INVOLVED (GPG II.C.2.g.(iv).(c))
_____
☐ HIGH RESOLUTION GRAPHICS/OTHER GRAPHICS WHERE EXACT COLOR REPRESENTATION IS REQUIRED FOR PROPER INTERPRETATION (GPG I.E.1)

PI/PD DEPARTMENT
School of Physics and Astronomy

PI/PD FAX NUMBER
612-624-4578

PI/PD POSTAL ADDRESS
School of Physics and Astronomy
116 Church St. S.E.
Minneapolis, MN 55455
United States

NAMES (TYPED)	High Degree	Yr of Degree	Telephone Number	Electronic Mail Address
PI/PD NAME **Marvin L Marshak**	**PhD**	**1970**	**612-624-1312**	**marshak@umn.edu**
CO-PI/PD **Priscilla B Cushman**	**PhD**	**1985**	**612-626-8917**	**prisca@physics.umn.edu**
CO-PI/PD **Thomas L Kieft**	**PhD**	**1983**	**505-835-5321**	**tkieft@nmt.edu**
CO-PI/PD **Dean M Peterson**	**PhD**	**2001**	**218-720-4393**	**dpeters1@nrri.umn.edu**
CO-PI/PD **Earl Peterson**	**PhD**	**1968**	**612-624-0319**	**eap@physics.umn.edu**

CERTIFICATION PAGE

Certification for Authorized Organizational Representative or Individual Applicant:

By signing and submitting this proposal, the individual applicant or the authorized official of the applicant institution is: (1) certifying that statements made herein are true and complete to the best of his/her knowledge; and (2) agreeing to accept the obligation to comply with NSF award terms and conditions if an award is made as a result of this application. Further, the applicant is hereby providing certifications regarding debarment and suspension, drug-free workplace, and lobbying activities (see below), as set forth in Grant Proposal Guide (GPG), NSF 04-23. Willful provision of false information in this application and its supporting documents or in reports required under an ensuing award is a criminal offense (U. S. Code, Title 18, Section 1001).

In addition, if the applicant institution employs more than fifty persons, the authorized official of the applicant institution is certifying that the institution has implemented a written and enforced conflict of interest policy that is consistent with the provisions of Grant Policy Manual Section 510; that to the best of his/her knowledge, all financial disclosures required by that conflict of interest policy have been made; and that all identified conflicts of interest will have been satisfactorily managed, reduced or eliminated prior to the institution's expenditure of any funds under the award, in accordance with the institution's conflict of interest policy. Conflicts which cannot be satisfactorily managed, reduced or eliminated must be disclosed to NSF.

Drug Free Work Place Certification

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative or Individual Applicant is providing the Drug Free Work Place Certification contained in Appendix C of the Grant Proposal Guide.

Debarment and Suspension Certification

(If answer "yes", please provide explanation.)

Is the organization or its principals presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from covered transactions by any Federal department or agency? Yes ☐ No ☒

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative or Individual Applicant is providing the Debarment and Suspension Certification contained in Appendix D of the Grant Proposal Guide.

Certification Regarding Lobbying

This certification is required for an award of a Federal contract, grant, or cooperative agreement exceeding $100,000 and for an award of a Federal loan or a commitment providing for the United States to insure or guarantee a loan exceeding $150,000.

Certification for Contracts, Grants, Loans and Cooperative Agreements

The undersigned certifies, to the best of his or her knowledge and belief, that:

(1) No federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.

(2) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with this Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit Standard Form-LLL, ''Disclosure of Lobbying Activities,'' in accordance with its instructions.

(3) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements and that all subrecipients shall certify and disclose accordingly.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by section 1352, Title 31, U.S. Code. Any person who fails to file the required certification shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such failure.

AUTHORIZED ORGANIZATIONAL REPRESENTATIVE	SIGNATURE	DATE
NAME		

TELEPHONE NUMBER	ELECTRONIC MAIL ADDRESS	FAX NUMBER

*SUBMISSION OF SOCIAL SECURITY NUMBERS IS VOLUNTARY AND WILL NOT AFFECT THE ORGANIZATION'S ELIGIBILITY FOR AN AWARD. HOWEVER, THEY ARE AN INTEGRAL PART OF THE INFORMATION SYSTEM AND ASSIST IN PROCESSING THE PROPOSAL. SSN SOLICITED UNDER NSF ACT OF 1950, AS AMENDED.

Project Summary

This proposal describes an ongoing initiative to design and implement a *Deep Underground Science and Engineering Laboratory (DUSEL)* at the Soudan Underground Laboratory. Soudan DUSEL is unique because: (1) Soudan is an existing laboratory with an ongoing science program, including the world's best long baseline neutrino oscillation experiment and most sensitive dark matter experiment. (2) Soudan is the only DUSEL site with a neutrino beam. The cost of a new beam to another DUSEL site is of order $200-$400 million. (3) Soudan has known diverse geological and geochemical structure, including fracture zones, potentially hydrogen-generating basalts, iron oxides, sulfide minerals, deep Canadian Shield brines, and traces of methane gas. These indicate energy sources to support diverse and active subsurface microbial communities. (4) The Soudan staff has 25 years of highly successful project management and underground science experience. (5) An initial conceptual design for a downward expansion of the Soudan Underground Laboratory to implement DUSEL was developed in 2003 and submitted to the National Science Foundation as Proposal 0335435. (6) Soudan combines the advantages of an existing infrastructure and a "green field" site. The new work proposed here updates the 2003 Conceptual Design using initial results from DUSEL Solicitation 1; gathers additional information and performs additional analyses to characterize the site; and refines previous engineering work to produce a Project Design Workbook (PDW) and an updated cost estimate and schedule, which begins the process of preparing a Technical Design Report (TDR).

Proposal Section 1 describes the existing Soudan Underground Laboratory and the 2003 Conceptual Design for the DUSEL downward expansion, including a unique decline helix to move large equipment underground and access interesting geological features and two shafts, one with a hoist for rapid personnel and small equipment access and rock hoisting. Both shafts will be used for ventilation. The Soudan Laboratory now has two large experimental halls at a depth of 710 m. The MINOS Detector is in a room that is 15 m wide by 16 m high by 82 m long. The CDMS 2 Dark Matter Search and the new Low Background Counting Facility (LBCF) are in a room 15 m wide by 15 m high by 70 m long. Soudan is the target of the NUMI Fermilab-to-Soudan neutrino beam. Geological structure, geochemical and geomicrobiological studies are recent activities at Soudan.

Section 2 discusses how Soudan's diverse geological structure, experience and infrastructure (including the NUMI beam) and the Conceptual Design impact both an initial suite of experiments and implement a vision for a 30-year science/engineering program. Soudan's heterogenous rock, including strong diorites and basalts for large caverns and the decline helix and shear, oxidizing and reducing zones for biological diversity facilitate hosting *all* of the Solicitation 1-described modules.

Section 3 describes the proposed Soudan Solicitation 2 work, some of which is already underway using funds from the University of Minnesota. The Work Breakdown Structure shows four major activities: Project Coordination, including liaison with the underground physics and geoscience communities; Site Characterization, with primary emphasis on a deep bore hole to test the geological structure model and gather engineering, geochemical and geomicrobiological data; Engineering and design, including access, underground layout, surface campus, utilities, fire and life safety, environmental and regulatory issues; and Coordination of DUSEL with the ongoing science program at Soudan, with emphasis on the Low Background Counting Facility.

Section 4 summarizes the Conceptual Design and Proposed Work by providing Soudan-specific responses to questions posed in Solicitation 05-506. Section 5 discusses "broader impacts" of both the ongoing Soudan program and Soudan DUSEL. These impacts include both a broad array of science and technology, ranging from basic research to applications, and an ongoing education and outreach program, including public tours for ~4,500 people in 2004, curriculum development by K-12 teachers and public information initiatives, using both public meetings and the media. Section 6 describes the unique capabilities of the University of Minnesota to manage both the proposed work and, eventually, Soudan DUSEL. The University's assets include 25 years of underground science management experience, sovereign immunity against lawsuits and municipal powers to acquire land by condemnation, define building and zoning codes, do inspections and issue permits. Section 7 responds to questions in Solicitation 05-506. This proposal is summarized in Section 8.

In summary, Soudan DUSEL provides a robust, cost-effective, incremental plan to achieve interesting and breakthrough underground science and technology in the United States with first science now, using existing facilities, and new science in the future for at least 30 years.

TABLE OF CONTENTS

For font size and page formatting specifications, see GPG section II.C.

*Proposers may select any numbering mechanism for the proposal. The entire proposal however, must be paginated. Complete both columns only if the proposal is numbered consecutively.

1.0 Introduction and Context

1.1 Overview: This proposal describes an ongoing initiative to design a *Deep Underground Science and Engineering Laboratory (DUSEL)* at the Soudan Underground Laboratory in Soudan, Breitung Township, St. Louis County, Minnesota (47.82° N. latitude, 92.24° W. longitude; T62N, R15W, Sections 26/27). Soudan's strengths for DUSEL include the existing scientific program and underground laboratories, the NUMI long-baseline neutrino beam, proven management and staff expertise, a well-developed public outreach and education program that has been cited as a model by the Solicitation 1 Collaboration and ongoing relationships with state and local officials, Fermilab and ~250 scientists currently participating in Soudan experiments. Soudan is also an exceptional site for DUSEL earth science, with structurally and chemically diverse rock; varied geohydrology, including deep brines; and a high metabolic potential for diverse underground life. These assets enhance Soudan's possibilities for paradigm-changing discoveries, such as leptonic CP violation, proton decay, the development of life underground and clues to searching for subsurface extraterrestrial life.

The Work Breakdown Structure (WBS) in this proposal describes 4 main tasks. A new deep borehole will test the Soudan site model by confirming at depth geological, geochemical and geomicrobiological properties observed on the surface and in the existing mine. These studies will also significantly advance Soudan geoscience research. A second major effort will update the 2003 Soudan DUSEL Conceptual Design and refine cost and schedule estimates using both existing and new geological data. The two other tasks are leadership in lab definition work and coordination with the continuing scientific program.

The Soudan DUSEL Solicitation 2 team consists of physicists, engineers and technical staff, who have collaborated for more than 20 years on two earlier expansions of the Soudan Laboratory. Geoscientists from two University of Minnesota campuses, the University's Natural Resources Research Institute and the Minnesota Geological Survey have strengthened this initial group. Additional team members are scientists and engineers from other universities and a multi-firm team of engineers and architects[1].

1.2 Soudan Underground Laboratory: Soudan DUSEL is a downward expansion of the Soudan Underground Laboratory[2], operated by the University of Minnesota since 1980. At Soudan, science is symbiotic with a State Park, which hosts ~35,000 visitors a year for historic and scientific tours. Soudan's existing laboratories are 710 m deep (2,080 meters of water equivalent—mwe) and include two fully equipped rooms, each 15 m wide by 15 to 16 m high. The Soudan 2 Lab (70 m long) houses the Cryogenic Dark Matter Search (CDMS 2), which uses ultra cold silicon and germanium to search for Weakly Interacting Massive Particles (WIMPs) by simultaneously measuring both ionization and phonon excitation. CDMS 2 recently published the world's best limits on WIMP flux [1]. It can likely collect data at its current location through ~2008, before the cosmogenic neutron background becomes significant. The removal of the Soudan 2 Kiloton Calorimeter provides space for a Low Background Counting Facility (LBCF), which reuses the proportional tube active shield. The Main Injector Neutrino Oscillation Search (MINOS) Far Detector Laboratory (82 m long) houses the 5,500 tonne MINOS Far Detector and 3

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[1] The names, institutions, areas of expertise and time commitments of the Principal and Senior Investigators are listed in the Budget and Budget Justification section of this Proposal.

[2] Institutions now participating in scientific research at the Soudan Laboratory are MINOS Collaboration: *(United States):* Argonne National Laboratory, Benedictine University, Brookhaven National Laboratory, California Institute of Technology, Fermilab, Harvard University, Illinois Institute of Technology, Indiana University, Lawrence Livermore National Laboratory, University of Minnesota—Twin Cities & Duluth, Northwestern University, University of Pittsburgh, University of South Carolina, Stanford University, University of Texas at Austin, Texas A&M University, Tufts University, Western Washington University, William and Mary, University of Wisconsin; *(United Kingdom):* Cambridge University, University College London, University of Oxford, Rutherford Appleton Laboratory, University of Sussex; *(Russia):* Institute of Theoretical and Experimental Physics (ITEP), Moscow, Institute for High Energy Physics (IHEP), Protvino, The Lebedev Institute; *(Greece):* University of Athens; *(France):* College de France; *(Brazil)* UNICAMP; CDMS 2 Collaboration: Brown University, Case Western Reserve University, Fermilab, Santa Clara University, Stanford University, University of California at Berkeley, University of California at Santa Barbara, University of Florida, University of Minnesota; *($\beta\beta$ Decay):* Pacific Northwest National Laboratory.

high-purity germanium (HPGe) detectors used by the ββ decay experiment Majorana and the dark matter searches CDMS 2 and XENON. Nine full-time support staff members currently work on Soudan experiments.

Soudan is the target of the 735 km, $125 million Fermilab Neutrinos at the Main Injector (NUMI) beamline [2], which first produced neutrinos in January 2005. A deeper understanding of lepton physics is the goal of a possible multi-decade program, using MINOS to measure 2-3 oscillations, the NOνA Off-Axis Detector [3] to study 1-3 oscillations and a Proton Driver, to upgrade the NUMI intensity. A megatonne-class detector at Soudan, optimized for proton decay and neutrino interactions, is a possible next step after NOνA. A well-matched NUMI beam and Soudan megatonne detector could observe 1-3 oscillations at both the 1st and 2nd maxima, increasing CP violation effects. A new BNL to Soudan beam (1710 km) would more than double the NUMI baseline and explore a new parameter space using the same detector. This program alone provides ~30 years of outstanding science for Soudan DUSEL.

1.3 Conceptual Design for Soudan DUSEL: The Soudan DUSEL Conceptual Design includes operation of the existing underground laboratory and expansion of its ongoing scientific program; improvement and extension of the underground access to 1,450 m and 2,500 m; and construction of a new surface campus and new underground laboratory facilities at the 1,450 m and 2,500 m levels.

1.3.1 Ongoing Science Program: The ongoing Soudan scientific program includes MINOS, CDMS 2, the LBCF and the geoscience program. The Soudan LBCF [4] will screen low background materials, prototype instrumentation and provide infrastructure to efficiently accomplish these tasks. The LBCF is a 13 m wide by 11 m high by 30 m actively shielded volume. Planned LBCF features include:

- a high-purity water shielding tank with multiple top-loading ports from a Class 10000 clean room;
- a second, flexible clean room with shielded bays for prototype detectors and screening devices;
- radon scrubbing systems for both clean rooms;
- four HPGe detectors for g screening;
- a Ne gas drift chamber and a triggerable diffusion cloud chamber for b screening;
- a high purity copper electroforming facility.

LBCF experiments scheduled in 2005 include a study of cosmogenic "soft errors" in semiconductor memories (sponsored by Medtronic), electroforming of high purity, low background copper (sponsored through Small Business Innovation Research—SBIR), a novel screening detector to measure activity of copper (SBIR) and a University of Chicago dark matter detector using a superheated bubble chamber.

In addition to the LBCF, ~500 m^2 of underground floor space at Soudan is available for proposal-driven re-use following completion of the MINOS Detector. These areas have a bridge crane, power, communications and life safety utilities. Current Soudan geoscience studies include detailed surface outcrop mapping and structural geology modeling of the Soudan DUSEL area, baseline geochemical and geomicrobiological surveys and cataloging of the underground environments in the existing mine.

1.3.2 Access: The Conceptual Design for new access for Soudan DUSEL is modeled after the Finnish Pyhäsalmi Mine. It includes a modern, circular, raise bored, concrete-lined shaft, a 1:7 decline (racetrack helix) from the surface to 2,500 m and a second raise bored shaft, solely for ventilation [5]. The new construction and the existing laboratories and shaft will be connected at the 710 m level by extending an existing tunnel. Specific design parameters will be optimized during Solicitation 2 work.

The new shafts and decline helix will be located in basalt and diorite ~1.5 km east of the current laboratory. The new shafts will provide quick access for personnel and small equipment to all laboratories, rock hoisting capacity of ~5,000 tonnes per day and a ventilation loop. Control of the hoist will be automated and self-controlled access will be available to lab and visiting staff 24/7, subject to appropriate safety protocols. The decline will provide the access to depth for large and heavy instrumentation and production equipment, an emergency egress and an unprecedented access using short drill holes from distributed instrumentation stations to ~30 km^3 of rock with varied geological and geochemical environments. The large linear extent of the decline will enable separation of conflicting activities, such as a seismic array and induced rock faulting. An initial design suggests 7 cycles to reach the 2,500 m level, with each cycle ~2,400 m in length, including both straight and curved sections and a circumscribed rectangle of ~100 acres. Use of the decline will be restricted to trained drivers and designated vehicles to minimize decline construction cost and time. The interior of the decline tunnel will resemble a mine drift more than a public-access highway tunnel.

1.3.3 Laboratories: The construction of new laboratories at Soudan DUSEL will be primarily proposal-driven. The conceptual design currently includes an aggregate 50,000 m^3 of lab space (2.3 MINOS Far Detector Laboratories) at 1,450 m and 25,000 m^3 of lab space at 2,500 m. The total projected Soudan lab volume is 112,350 m^3, (37,350 m^3 of existing space and 75,000 m^3 of new space), roughly equal to the volume of the three principal laboratories at Gran Sasso. Construction of Soudan DUSEL, including the laboratories and access tunnels but excluding a possible megatonne detector, is projected to produce ~1.7 million tonnes of excavated rock. The experience from the Soudan 2 Laboratory and the MINOS Laboratory is that the cost of excavating, rock bolting, shotcreting and installing a concrete floor represents about half of the final construction cost. An approximately equal amount is required for "outfitting" laboratories, that is, electrical systems, HVAC, networks, life safety systems, materials handling systems and minimal support structure for detectors or partitions for isolating work spaces. The conceptual design thus envisions equal funding for lab "construction" and "outfitting".

1.3.4 Surface Facilities: The Soudan DUSEL site consists of rolling boreal forest with high outcrops, ponds and marshland. It is nearby to Lake Vermilion, one of the five largest lakes within Minnesota, resort areas around the Boundary Waters Canoe Wilderness Area and a casino, golf and other recreational facilities. The Soudan DUSEL surface campus design includes a joint Interpretive Center in cooperation with Minnesota State Parks, office and laboratory facilities for science and outreach, support and utility areas, geological core storage and space for stockpiling up to 5 million tonnes of excavated rock, sufficient capacity to allow the construction of a megatonne detector. Key surface campus design criteria include efficient support for underground laboratory activities; maximal openness to the public, while maintaining the required level of security; and preservation of the natural beauty of the site, especially in areas contiguous with State Park land.

1.4 Reviews: The Soudan DUSEL Design was reviewed by the NSF in 2003. Review excerpts are [6]:

> "The proposers and the University of Minnesota have a long track record in managing an underground laboratory of significant size, with construction expenditures not greatly different from those anticipated in the expansion."
>
> "The principal part of the laboratory is a green site and will not be troubled by issues of non-optimum structures, of replacement of obsolescent equipment, etc. At the same time the existing laboratory will provide certain infrastructure advantages early in construction and will permit smaller new experiments to proceed on a fast time scale."
>
> "The proposers have done their homework well and have attempted to address nearly every issue raised about a DUSEL at such community workshops as Lead and NESS as well as the criteria specified by NFAC. To wit: depth and quality of overburden, differences among detector sizes and working materials, access, management and support facilities to name some principal ones."
>
> "This well-written proposal is one of the most exciting I have read in recent years. What I find particularly impressive is that each component of the proposed multidisciplinary laboratory is interesting in its own right. This is not a mere cobbling together of disparate parts, but a serious plan (with very strong state and national support) to build a truly multidisciplinary laboratory in the United States. I know very little about energy storage and geoscience, but I find the ideas proposed to be inspiring. Since there is no question that the proposed science is first-rate, the only significant issue is this: Is the plan credible and do the proponents have the wherewithal to execute it? The answer, I believe, is an unequivocal "yes". The authors have proposed a plan that is coherent and well thought out. Indeed, it is the most credible plan I have seen for establishing a national underground facility. Moreover, given adequate funding, I believe the proponents can make the plan work."

Table 1: Summary of Extant Information on the Soudan DUSEL Site

Current Size	Two existing rooms at a depth of 710 m; one 15x15x70 m, the other 15x16x82 m.
Suitability for Expansion	Soudan DUSEL will acquire land east of the existing shaft. Design includes a decline helix, two raise bored shafts, a connection to the existing laboratory at a depth of 710 m and multiple, proposal-driven rooms for experiments.
Geological Characterization	Because the rocks at Soudan were upturned vertically ~2.7 billion years ago, it is possible to characterize the geology at Soudan by study of glacial scoured surface outcrops. This work was completed by a geology team in Summer 2003 [7].
Availability	The existing laboratory is owned by the State of Minnesota. The expansion land is owned by U.S. Steel and is valued at ~$1,000/acre. If Soudan DUSEL is approved, the University of Minnesota will acquire the site by negotiated sale or condemnation.
Environmental Issues	The expansion area includes wetlands, which influence the layout of surface facilities. Solicitation 2 studies will acquire baseline data for environmental permitting.
Accessibility	Area is accessible through airports at Minneapolis-St. Paul, Duluth and Hibbing. 25-year experience indicates area access is adequate. MINOS regularly holds large meetings ("Week in the Woods") near Soudan. Access to laboratories is by hoists for personnel and small equipment and by decline for large equipment.
Current and Previous Use	Used for mining from 1883 to 1962, tourism since 1962 and science since 1980. Current lab is historic State Park. DUSEL expansion area is undeveloped.
Distinctive Characteristics	Existing laboratory with ongoing scientific program; 25 year record of success; existing lab facilities; proven management; experienced staff; neutrino beam; well-characterized, heterogeneous rock; minimal environmental and regulatory issues.

Table 2: Intrinsic Solicitation 1 Characteristics for Soudan Site

Rock Type	Generally metamorphic, with basalts, greenstone, iron-formation, schist, sulfide-rich zones, as well as diorites, dacite, gabbro.
Stress Environment	The horizontal stress is maximal along a north-south axis.
Thermal Gradient	The measured thermal gradient is 16 °C/km between the surface and 710 m underground.
Site Volume	The site provides access to ~30 km^3 of rock from drill stations along the decline helix. Maximal laboratory separation is ~3 km at 710 m and ~1 km at lower depths
Uniformity	The diorite and basalt selected for laboratory and decline construction are tight and homogeneous.
Fracturing	The Murray and Mine Trend Shear Zones provide large volumes of surface-to-depth fractured rock south of the planned DUSEL site. These regions are accessible by short drill holes.
Geobiology	The existing mine has biological activity ranging from microorganisms to brown bats.
Geochemistry	Soudan DUSEL has good access to potentially hydrogen generating basalts, iron oxides and sulfide minerals (redox chemistry to support microbial metabolism).
Geohydrology	The existing mine has known sources of glacial melt water near surface and Canadian Shield brines at depth with increasing salinity as depth increases.
Permeability	The permeability ranges from low in the basalts and diorites to high in the Murray and Mine Trend shear zones.
Geomechanics	The metamorphic and igneous rocks at the site provide a broad range of environments in which to conduct geomechanics research.
Seismicity	The geology at Soudan is Precambrian. The overall seismic risk is very low.

Table 3: Soudan Features With Respect to Extrinsic Solicitation 1 Characteristics

Duration	Mining at Soudan began 120 years ago. The Soudan Laboratory has operated for 25 years. The duration of Soudan as a State Park is indefinite.
Depth	Soudan has existing laboratories at 710 m. The conceptual design includes new laboratories at 1,450 m and 2,500 m and provides continuous access to rock from the surface to 2,500 m depth along the decline.
Occupancy	Soudan DUSEL is designed for high occupancies of staff and visitors. The current laboratory hosted ~4,500 visitors in 2004 and has served lunch for 180 people.
Radon	The current Soudan Lab radon level varies seasonally from 300 to 700 Bq/m^3.
Hazardous Materials	The decline helix planned for Soudan DUSEL permits large physical separation and isolated ventilation using raise bored shafts for laboratories at depth.
Temperature	The rock temperature at Soudan is 1 °C near surface and 12 °C at 710 m.
Electrical Power	Electrical power currently available at the Soudan DUSEL site is ~10 MW. The underground power capacity is currently 600 kW at 710 m.
Clean Areas	The conceptual design for Soudan DUSEL uses isolated caverns for individual detectors and experiments. This isolation permits designation of certain cavities as "clean" areas. Very high grade clean space will be constructed within these "clean" cavities.

2.0 Initial and Long-Term Science and Engineering Program at Soudan DUSEL

2.1 Program Overview: The Soudan DUSEL science and technology program includes:

a. Experiments currently in progress, which can be enhanced incrementally.

- Long-baseline and atmospheric neutrino oscillations (MINOS experiment with NUMI beam)
- Dark matter search (CDMS 2): will go deeper in the future
- Low background counting facility: now under construction; will go deeper in the future
- Materials studies and preparation (tests on "soft" memory errors, high-purity copper fabrication and assays of high purity copper and other materials begin in Winter 2005)
- Geophysical studies
- Surficial sediment studies
- Geohydrology (in existing Soudan Mine)
- Geomicrobiology (in existing mine)

b. Future experiments for which the existing depth of 710 m is adequate Some of these might require substantial construction, for example n nbar oscillations requires a new shaft, but these studies do not require additional depth. Preparations for these experiments could begin within ~1 year.

- Neutron antineutron oscillations
- Cloud physics and microgravity
- Supernova neutrinos (existing labs are sufficiently deep for a dedicated experiment)
- Geoengineering
- Mineralization (in existing mine)
- Hydroponic growth of genetically modified organisms (space exists in existing mine)
- Deep compressed air and pumped hydroelectric energy storage
- Groundwater tracing and fluid flow
- Passive Seismic Data Acquisition
- Paleohydrology / climatology
- Geogas research facility
- Geomicrobiological observatory and sequencing methodology
- Geochemistry of groundwater seeps and geomicrobiology of associated biofilms.

c. Experiments that require a 1,450 m deep site and are consistent with a longer time scale.

- Nucleon decay
- Neutrino astrophysics

d. Experiments that likely require a 2,500 m deep laboratory at some future time.

- Solar neutrinos
- Double beta decay

2.2 Soudan DUSEL Characteristics and Solicitation 1 Modules: The Soudan DUSEL conceptual design facilitates installation at Soudan of **all** 13 Solicitation 1 Modules[3].

Table 4: Soudan features that affect specific Solicitation 1 Modules and Module Characteristics.

Soudan DUSEL Features	**Description**	**Modules and Characteristics Affected**
Existing Lab and Science Program	Soudan has an attractive campus setting near lakes in a tourist/vacation-home region, existing surface and underground office and lab space, an existing neutrino beam, existing utilities and communications, experience with cleanliness and cryogens, a shaft and a Low Background Counting Facility.	A,E,L,M; 2,3,4,5,8,9,10,12, 19,20
Neutrino Beam	Soudan is the target of the NUMI long baseline neutrino beam.	C;21
Helical Decline	The decline provides access for large equipment to depth, facilitates experiments in ~30 km^3 of rock, allows isolation of incompatible experiments and facilitates raise boring of multiple shafts for experimentation and ventilation.	B,C,G,H,I,J,K;1,2 ,3,4,5,10, 11,12,1314,16,17
Hoist	Soudan will use high-speed, automated hoists for rapid access for personnel and small equipment and for efficient rock removal.	C,F,L;2,3,4,5,12,1 3,14,16,18,19
Diverse Rock and Rock Structure	Known features of the Soudan DUSEL site include geological structures ranging from tight to fractured, geochemistries ranging from oxidizing to reducing, H+ generating basalts, iron-formations and both glacial recharge and deep brine geohydrologies.	H,I,J,K;6,13,14, 16,17
Diorite and Basalt	The diorite and basalt at Soudan provide high compressive strength, homogeneous, minimally faulted rock suitable for construction of large experimental halls.	B,C,H,I,J,K,L;6,1 2,13,14,17
Vertical Ventilation	Soudan DUSEL's ready access to the land above the laboratory enables efficient raise boring of dedicated ventilation shafts for special needs detectors, such as those with large inventories of cryogens or flammables. Large quantities of fresh air are also necessary for efficient excavation for the megatonne detector with mobile diesel-powered equipment.	B,C,F,L;2,3,5,6,1 0,11,12,13,14,16, 17,18,19
Ongoing Education and Outreach	Soudan's education and outreach program in cooperation with Minnesota State Parks provides a model for involving K-12 students and the general public in fundamental science. Soudan DUSEL will encourage supervised public access to underground laboratories.	A,M;2,4,5,18
No Mining or Mining Liabilities	The last mining activity at Soudan occurred in 1962. No ore milling was done at Soudan and there are no remnant liabilities for mining. Soudan allows underground access to all staff and visitors.	A,M;2,3,4,6,7,8,9, 10,11,16,17,18,19
Existing Mine	Soudan has ~75 km of existing tunnels vertically spaced every 30 m to 60 m and numerous cavities, some open and some backfilled.	A,E,I,J,K,L;2,3,4, 5,12,17,19,20

[3] The Modules are A: Office, Laboratory, Education and Outreach; B: Large Cryogen; C: Large Cavern, D: Clean, Low Background; E: Prototype; F. Restricted Access; G: Accelerator; H: Deep Sampling and Earth Probing Observatory; I: Drift Structure Experiments; J: Very Large Block or Reservoir-Scale Experiments; K: Large Block Experiments; L: Shaft; M: Above Ground Campus. The Characteristics are 1. Accelerator; 2. Personnel Access; 3. Material Access; 4. Access Schedule; 5. Major Common Facilities; 6. Cause Rock Damage; 7. Cleanliness (Biological); 8. Cleanliness (Physics); 9. Cleanliness (General); 10. Cryogens; 11. Flammables; 12. Depth; 13. Large Caverns; 14. Large Rock Volumes; 15. Low Background; 16. Mining; 17. Quiet or pristine; 18. Secure; 19. Shafts; 20. Start Date; 21. Neutrino Beam.

3.0 Proposed Work for DUSEL Phase 2

3.1 Overview: The proposed Solicitation 2 work for Soudan DUSEL includes four major tasks: (1) project coordination; (2) site characterization; (3) engineering and design; and (4) integration of DUSEL planning with the ongoing science and technology program at Soudan. Because Soudan has 25 years experience as an operating, underground, primarily physics laboratory, the Soudan Solicitation 2 effort is focused towards geoscience, in which Soudan has a smaller existing knowledge base. Solicitation 1 work and other similar efforts will inform the Soudan Solicitation 2 studies.

3.2 Work Breakdown Structure: Table 5 lists the proposed work breakdown structure. Information about budgets is provided in the Budget and Budget Justification sections of this proposal.

Table 5: Work Breakdown Structure

Task	People Responsible
1.0 Project Coordination	M. Marshak, E. Peterson
1.1 Coordination with Solicitation 1 Physics Opportunities	E. Peterson, K. Heller, Y. Kamyshkov
1.2 Coordination with Solicitation 1 Geoscience Opportunities	D. Peterson, J. Goodge
2.0 Site Characterization	D. Peterson
2.1 Borehole	D. Peterson, S. Hauck
2.1.1 Core Logging and Analysis	D. Peterson, M. Severson
2.1.2 Borehole Geophysics	V. Chandler, T. Runkel, R. Tipping
2.1.3 Rock Mechanics Characterization	F. Tonon
2.1.4 Geohydrology	C. Alexander, M. Saar, S. Alexander, R. Tipping
2.1.5 Geomicrobiology	T. Kieft, D. Bond, T. LaPara
2.2 Structural Modeling	V. Hansen, M. Jirsa, D. Peterson
2.3 Petrology, Petrography, Geochemistry	G. Hudak, J. Goodge
2.4 Ecology Baseline	D. Pomry-Petry, K. Johnson, J. Mayasich
3.0 Engineering and Design	L. Petersen
3.1 Access	L. Petersen
3.2 Underground Layout and Design	L. Petersen
3.3 Site Layout Planning	C. Michael
3.4 Surface Facilities Layout and Design	G. Hulne, D. Holland
3.5 HVAC and Other Mechanical Systems	D. Holland
3.6 Electrical	D. Holland
3.7 Fire and Life Safety	G. Hulne
3.8 Environmental Assessment	C. Michael
3.9 Public Participation	W. Miller, M. Marshak
3.10 Risk Management	M. Marshak, L. Petersen
4.0 Integration of DUSEL Planning with Existing Opportunities	W. Miller, E. Peterson
4.1 Low Background Counting Facility (LBCF)	P. Cushman
4.2 Cryogenic Dark Matter Search (CDMS 2)	P. Cushman
4.3 Geoscience and Geoengineering	D. Peterson, F. Tonon
4.4 MINOS and NUMI Beamline	E. Peterson, K. Heller, A. Habig
4.5 Education and Outreach	P. Cushman, W. Miller, K. Heller, A. Habig

Task 1.0 Project Coordination (M. Marshak, E. Peterson):

The task of overall project coordination includes review of work completion and funding profiles, interaction with the National Science Foundation, the Solicitation 1 Collaboration, the University administration, state and local governments and the science and technology communities. Professors

Marshak and Peterson both have 25 years experience in underground science and underground lab management.

Task 1.1 Coordination with Solicitation 1 Physics Opportunities (E. Peterson, K. Heller, Y. Kamyshkov): This task requires ongoing participation and leadership in the Solicitation 1 activities, based on the extensive experience at Soudan in the construction and operation of the major deep underground U.S. science/engineering laboratory. These "S1" requirements will then be incorporated in the ongoing Soudan DUSEL conceptual design, in order to insure that Soudan continues its capability of hosting *every* proposed underground physics experiment and all proposed geoscience experiments that do not require large sedimentary rock formations.

Task 1.2 Coordination with Solicitation 1 Geoscience Opportunities (D. Peterson, J. Goodge): Geoscience coordination will include workshop attendance, discussions, weekly review of online data and journal articles and personal contacts with geoscientists. The data gathered at Soudan will be reviewed in respect to other initiatives, such as EarthScope. Because of the ability to readily integrate surface and underground observations, Soudan DUSEL has the potential to become the best-studied example of Archean lithosphere on Earth.

Task 2.0 Site Characterization (D. Peterson):

The University of Minnesota has funded pre-Solicitation 2 geological studies now in progress for completion by Summer 2005, including:

- Geophysical Site Investigation: Gravity and magnetics data will be acquired, compiled and modeled to several kilometer depths.
- Environmental Geology Site Investigation: The 3D distribution of glacial sediments at Soudan DUSEL site will be clarified by data compilation, field investigations and trenching.
- 3D Geological Software Acquisition and Training: The University has acquired the 3D visualization software gOcad with training for key members of the Soudan DUSEL team, as recommended in the EarthLab report. All Solicitation 2 data will be integrated into gOcad format in the final report.

Task 2.1 Borehole (D. Peterson, S. Hauck): The major proposed Solicitation 2 initiative is drilling a deep borehole into the center of the proposed Soudan DUSEL expansion. The funds allocated for the borehole in the proposed budget will support drilling to ~1,000 m. The State of Minnesota Iron Range Resources and Rehabilitation Agency expects to provide additional funds to deepen the borehole to ~1,600 m. The industry standard NQ hole (hole/core diameter 75.2/47.6 mm) will validate geological models, demonstrate geologic continuity from the surface to deep underground, determine the engineering properties (compressive strength, jointing, etc.) of the rock, show and monitor groundwater geochemistry and mineralogy and enable geomicrobiological characterization of formations and contacts within the DUSEL rock volume. The drill core will made available at the existing Soudan surface building.

Task 2.1.1 Core Logging and Analysis (D. Peterson, M. Severson): Industry-standard techniques will be used for core logging at the drill site, including visual and written logs of lithology, structure, alteration, mineralization and rock quality data. Core intervals collected for geomicrobiological sampling will be bagged and frozen on site.

Task 2.1.2 Borehole Geophysics (V. Chandler, T. Runkel, R. Tipping): Borehole geophysical logging will support geotechnical and geophysical studies and interpretations such as lithology, structure and groundwater temperatures and flow. A set of tools including acoustic televiewer, full wave sonic, magnetic susceptibility and e-logs will provide data for temperature, magnetic properties, natural gamma radiation, standard electric logs, fluid resistivity and visualization of fractures.

Task 2.1.3 Rock Mechanics Characterization (F. Tonon): Discontinuities will be characterized using ISRM Suggested Methods in order to obtain: orientation spacing, roughness, wall compressive strength, aperture, filling, seepage, number of discontinuity sets and RDQ. Rock mass deformability will be measured using a pressiometer and the *in situ* state of stress will be determined using the Hydraulic Test on Pre-existing Fractures (HTPF) because it provides the complete 3-D stress tensor, is independent of fluid pressure, is useful in highly stressed rock and tests significant rock volumes. Core-discing and borehole breakouts (if they occur) will be used as stress indicators. Uniaxial and triaxial core sample tests will determine deformability, strength parameters and post-peak behavior of intact rock. Cerchar drillability and abrasivity tests will be used to determine cutter and drilling bit wear and costs.

Task 2.1.4 Geohydrology (C. Alexander, M. Saar, S. Alexander, R. Tipping): Soudan groundwaters are a three-component system: (1) isotopically heavy, recent recharge, (2) glacially-pumped, Late Pleistocene recharge and (3) deep, old, Ca/Mg-Cl/SO4 brines. Initial data indicates flows of concentrated Ca rich brines at the mine's lower levels and a wide range of pH and redox conditions ranging from highly reducing to oxidizing exist within the mine, with abundant evidence of existing metal-using microbiologic communities. Groundwater sampling in the existing mine workings and in the borehole will be used to better characterize the groundwater biogeochemistry and will assist in design and managing environmental issues. Measurements of aquifer properties and groundwater flows and pressures will provide critical information for the design of underground tunnels and cavities.

Task 2.1.5 Geomicrobiology (T. Kieft, D. Bond, T. LaPara): The borehole is an opportunity for geomicrobiologists to participate in DUSEL site selection. Multiple core intervals will be selected for geomicrobiological characterization and experimentation, including geochemical, molecular and physiological studies of indigenous subsurface microbial communities and the geochemical processes that they mediate. Fluorescent, latex, carboxylated (for negative charge) 1-μm diameter microspheres (bacterial-sized particles) will be used as surrogate-bacteria drilling fluid tracer. These will then quantified in the fluid surrounding the core, in the parings and in the subcore by fluorescence microscopy. Microbial analyses will include tracer analyses, cultures, lipid analyses (to estimate biomass) and DNA-based analyses (PCR, cloning and sequencing) to identify major microbial community members and to infer their metabolic potential.

Task 2.2 Structural Modeling (V. Hansen, M. Jirsa): Structural geology is a fundamental element that links DUSEL geoengineering and geoscience initiatives. Previous geological studies [7] have outlined numerous structural zones around Soudan DUSEL. Microstructural analysis will be completed from outcrop and borehole samples to constrain models of the evolution of these rocks in terms of crustal level, large scale crustal flow, history of strain partitioning and relative displacement along discrete shear zones. Predictions resulting from outcrop, borehole and laboratory analysis will provide true, large-scale three-dimensional constraints. These data will facilitate engineering and design and will inform future geological and biological studies. Detailed geological mapping will continue through construction and models will be refined as additional data become available from excavations.

Task 2.3 Petrology, Petrography, Geochemistry (G. Hudak, J. Goodge): Detailed petrography and geochemical studies of geological units at Soudan will be integrated with studies of geological modeling, structural geology, geotechnical engineering, hydrogeology and geomicrobiology to characterize the Soudan DUSEL site. Research grade representative petrographic and geochemical samples from the deep drill hole and outcrops will be analyzed for lithological units, structural zones and anomalous alteration and/or mineralization. These studies will also evaluate the suitability and economic value of excavated rock for sale as aggregate or construction fill material.

Task 2.4 Ecology Baseline (D. Pomry-Petry, K. Johnson, J. Mayasich): The development of a Soudan DUSEL will require an Environmental Assessment process. An early start to data collection will facilitate permtting. Specific tasks include wetland delineation, a survey of threatened and endangered species and an archeological survey.

Task 3.0 Engineering and Design (L. Petersen):

The proposed work will determine the Soudan implementation of the facility and infrastructure needs identified during Solicitation 1. Specific steps are:

- Prepare a Project Design Workbook (PDW) showing the design basis and criteria (including tables of dimensions, capacities and other design parameters for each major component), the Work Breakdown Structure (WBS) and applicable building, mining and occupational safety codes. The PDW is the first, critical phase of the design process and an essential step towards a Technical Design Report (TDR) that will be used to define, control and document the entire project.
- Assess project design alternatives, for example, portal location, shaft location, tunnel sizes, shaft sizes, cavern sizes and locations and construction methods and sequencing. The geological and environmental data and analyses collected and developed by the work proposed here will underlie this assessment. The assessment criteria will include the Solicitation 1-developed Design Requirements, cost and cash flow, schedule implications and risk.

• Plan a master site layout for surface facilities and underground facilities in an updatable CAD format.
• Prepare conceptual designs of major project components, including tunnels, shafts, experimental cavern locations, major project systems (including electrical, mechanical, life safety).
• Develop a plan for site utilities.
• Develop a "roadmap" for the project environmental review.
• Encourage public participation in project development.
• Assess the conceptual design for risk and identify some possible areas for risk mitigation.
• Prepare a project cost estimate and schedule.

Task 3.1 Access (L. Petersen, S. McIntosh): The main access components are the helical decline and the raise bored access shaft. Specific access design issues include location, dimensions and grade of the helical decline; number, location and dimensions of passing and geoscience exploration cut-outs; communications and vehicle safety systems for the decline; number, length and diameter of raise bores for the access shaft; design of mechanical hoist system, including one vs. two stages of hoisting to reach 2,500 m.

Task 3.2 Underground Layout and Design (L. Petersen, S. McIntosh): This task will use the requirements developed during Solicitation 1 and the Soudan geostructural modeling to determine a layout for the laboratory caverns, underground accesses and utilities. The layout will seek to cluster compatible activities to facilitate access and minimize utility costs, while dispersing incompatible activities over the ~3 km linear extent of Soudan DUSEL at 710 m depth and ~1 km linear extent at larger depths. A significant layout consideration will be minimization of the number of air supply shafts while providing independent exhausts for laboratories with large inventories of flammables or cryogens. Other specific tasks include general design of tunnels, caverns and other underground components, identification of tunnel and cavern rock support and lining methods, developing plans for construction methods and sequencing, including evaluating drill/blast vs. tunnel boring machine (TBM) excavation. The design process will use industry-standard techniques for multicriteria optimization under uncertainty.

Task 3.3 Site Layout Planning (C. Michael): Surface site planning includes the general layout of buildings, roads, parking areas, short and long-term rock stockpiles and natural reserve areas. Criteria are maximal support of underground activities, cost and cash flow, schedule implications, preservation of the environment, security, energy conservation and maximization of opportunities for shared use, particularly with Minnesota State Parks. Known possibilities for rock disposal include on site stockpiles, as were used for the Soudan 2 and MINOS caverns; use for aggregate or fill material; and reclamation of nearby surface mine pits. The economically most advantageous use will be determined, compatible with environmental constraints. Soudan DUSEL will require a new access road, entering the site from Minnesota Highway 169.

Task 3.4 Surface Facilities Layout and Design (G. Hulne, D. Holland): This task will use the requirements developed during Solicitation 1 for support facilities at the DUSEL and the available facilities at/near Soudan DUSEL to develop a conceptual design for surface facilities. The Surface Facilities Design will be coordinated and integrated with the Site Layout Planning. Major categories of surface facilities include offices; computer facilities and networks; laboratories for biology, geology and physics; space for education and outreach, storage areas, fabrication/assembly shops; utility areas; short, medium and long term housing and food service areas.

Task 3.5 HVAC and Other Mechanical Systems (D. Holland): Specific HVAC conceptual design tasks include: (1) determine overall ventilation requirements and routings; (2) evaluate the need for special lab exhaust systems; (3) develop concepts and sizes of heating and air conditioning systems; (4) determine concepts and approximate size of cooling systems; (5) specify concepts and features of the temperature control energy management system; (6) establish domestic water system concepts including storage and pumps; (7) develop sanitary and gray water waste storage and pumping systems. Sanitary sewer and potable water are available to serve Soudan DUSEL from the Breitung Township utility district. The current wastewater treatment plant has adequate excess capacity.

Task 3.6 Electrical (D. Holland): Specific electrical systems design tasks include determining electrical service needs for labs and common spaces and defining emergency lighting and other power requirements and battery/generator systems for control and life safety systems. The design process will identify both

average and peak energy demand and explore with Minnesota Power and regional transmission utilities the possible impacts of DUSEL on the local and regional power grids.

Task 3.7 Fire and Life Safety (G. Hulne, D. Holland): The process for designing fire and life safety systems is facilitated because the University of Minnesota has legal authority for building codes and because of prior experience of University code officials in design, construction and operation of the existing Soudan facility. The Soudan Laboratory has always operated under Occupational Safety and Health Administration (OSHA) regulations. OSHA has implemented some Mine Safety and Health Administration (MSHA) requirements, but MSHA has no statutory jurisdiction because Soudan is not a working mine. Soudan DUSEL is expected to also be an OSHA environment. Specific design tasks include: establishing a list of Jurisdictional Authorities for the project; establishing a preliminary summary of applicable building codes and/or performance based safety documents (for surface facilities, tunnel/shaft access and underground laboratories); preparing a preliminary Code Review including code criteria and a code plan; developing code requirements for exit access and/or areas of refuge and smoke ventilation; developing fire detection and fire protection system based upon laboratory standards and code requirements; developing portal tunnel fire detection and protection systems based upon code requirements and fire fighting accessibility; and setting fire protection water storage and fire pump sizes based upon codes and occupancy.

Task 3.8 Environmental Assessment (C. Michael): Soudan DUSEL is subject to both Minnesota and federal environmental requirements. Minnesota Environmental Quality Board (EQB) regulations (MR 4410.4300, subpart 30) require an Environmental Assessment Worksheet (EAW) with the University of Minnesota as the Responsible Governmental Agency (RGU). The RGU prepares the EAW and decides whether an Environmental Impact Statement (EIS) is also required, a decision that may be reviewed in District Court. The National Environmental Protection Act (NEPA) applies to "major federal actions" as decided by the relevant federal agency—for DUSEL, the National Science Foundation (NSF). Soudan DUSEL will begin the environmental process early with the work proposed here and aggressively pursue State and federal environmental reviews in parallel and with as much overlap as possible.

Task 3.9 Public Participation (W. Miller, M. Marshak): Public information and community participation for Soudan DUSEL has been on-going since 2003 through the multi-jurisdictional East Range Community Readiness Committee (ERCRC) comprised of area municipalities, St. Louis County, area congressional and legislative delegations, area school districts, regional environmental groups, area economic development agencies, state agencies (DNR, Minnesota Pollution Control Agency, Department of Employment and Economic Development, Iron Range Resources), Natural Resources Research Institute, U.S. Forest Service, labor groups and area citizens. The ERCRC emphasizes open-arms, collaborative reviews of technical, environmental, economic and regulatory impacts and mitigation plans and processes, which are open to the public. Updates and project details related to Soudan DUSEL development will continue to be presented to the ERCRC and other governmental and public interest groups throughout the planning, construction and operational periods of the project.

Task 3.10 Risk Management (M. Marshak, L. Petersen): An important component of the overall Soudan DUSEL design and construction process is risk management and mitigation, starting with conceptual design. Risk management elements include identification and quantification of risk factors; steps to mitigate risk, such as extensive site characterization, qualifications based selection (QBS) of contractors, allocation of sufficient funds to support aggressive monitoring of construction by Owner's Engineers, implementation of appropriate project management software including earned value tools and active participation in construction supervision by project scientists; robustness and redundancy in design and construction solutions and monitoring measures; and strategies to deal with adverse events, such as sufficient cash contingency and, in the event of extreme adversity, a rational plan of programmatic contingencies, that is, features that could be postponed or deleted.

Task 4.0 Integration of DUSEL Planning With Existing Opportunities (W. Miller, E. Peterson):

Regardless of the eventual site of DUSEL, the Soudan Laboratory is a key asset for underground science and engineering in the United States. This task includes increasing familiarity of American underground scientists and engineers with the short and intermediate term possibilities at Soudan and facilitating current and new science activities.

Task 4.1 Low Background Counting Facility (LBCF) (P. Cushman): The LBCF is described in Section 1.3.1. This task includes leadership in the development of the LBCF and coordination of the LBCF with Solicitation 1 and other community initiatives. A questionnaire regarding low background testing and prototyping needs has already been circulated and is available on the website www.dusel.org.

Task 4.2 Cryogenic Dark Matter Search (CDMS 2) and Other Dark Matter Searches (P. Cushman): CDMS 2 was installed at Soudan 5 years ago and is now collecting and analyzing data. Prototypes for two other dark matter experiments will be tested at Soudan this year. This task includes coordination of these efforts with other DUSEL activities.

Task 4.3 Geoscience and Geoengineering (D. Peterson): Initial geoscience activities include structural observations and modeling, geohydrology and initial observations for geomicrobiology. This task includes additional work in these areas and new opportunities that will result from the deep borehole.

Task 4.4 MINOS and NUMI Beam Line (E. Peterson, K. Heller): MINOS began observing atmospheric neutrinos in 2003 and beam neutrinos in January 2005. This task includes coordination with further development of the NUMI beam line, including the NOνA Detector and the Proton Driver upgrade.

Task 4.5 Education and Outreach (P. Cushman, W. Miller, K. Heller): Soudan's education and outreach program, includes visits by ~4,500 students and others during 2004. This task includes expansion of the visitor program, improvement of curricular materials and public education about Soudan DUSEL.

4.0 Conceptual Design Summary

4.1 Match with preliminary information on technical requirements

4.1.1.Plan for initial suite of experiments: Section 2.1 includes a list of current experiments and new experiments that can be readily installed in Soudan DUSEL.

4.1.2. 30 year capability of site: Soudan DUSEL can accommodate all Solicitation 1 identified modules and has no known programmatic limitations (except extensive sedimentary rock studies). Soudan has a clear 30 year program to study 3-1 neutrino oscillations, matter effects, neutrino mass hierarchy, possible leptonic CP violation and coupled geochemical and geomicrobiological processes deep underground.

4.1.3. Plan for integrating relevant scientific and engineering communities: Soudan DUSEL is a participant in the DUSEL Solicitation 1 Collaboration. Collaboration members expect to support and work at whatever DUSEL site(s) emerge from the NSF site selection process.

4.1.4. Possibilities for international cooperation: Scientists from 6 countries work at Soudan now. More international collaboration is expected through the DUSEL Solicitation 1 Collaboration.

4.2 Comprehensive plan to address site-based issues:

1. Geological characterization: Outcrop studies have defined the geology of the Soudan site. A borehole and geological testing are proposed to better understand the deep geology.

2. Environmental assessment: Possible environmental issues are leaching from rock stockpiles, bats, historic structures and wetlands. Soudan DUSEL has 25 years experience with environmental assessment and mitigation. An Environmental Assessment Worksheet (EAW) is expected to suffice for this project.

3. Safety and health issues: Soudan Laboratory policy emphasizes life safety as an essential component of both design and operations. There is a lab safety committee with regular meetings, trainings and drills. Soudan DUSEL will continue this stress on life safety. The Soudan Lab has cooperated with Minnesota State Parks on investments in training and equipment for emergency first responder teams around Soudan.

4. Necessary permitting: The University of Minnesota has legal permitting and inspection responsibility for Soudan. It will continue these responsibilities for Soudan DUSEL.

5. Assessing level of local support: Soudan DUSEL has received letters of support [8] from the Governor of Minnesota, the President of the University of Minnesota, all 10 U.S. Senators and Representatives from Minnesota and other public officials. The Soudan Laboratory has operated for 25 years with strong public participation and support. Local meetings and media inform local residents about new programs.

6. Sharing infrastructure: The Soudan Laboratory operates cooperatively with Minnesota State Parks. Precedents and relationships for 25 years indicate good future cooperation.

7. Plan to accommodate changed conditions (including timeliness and costs of such activities): The Soudan area has been worked for both mining and science for more than 100 years, so there is a

significant experience base to minimize unforeseen conditions. Nonetheless, Task 3.10 describes plans for management and mitigation of all risk factors, including "changed conditions."

8. Developing, operating and maintaining the infrastructure: The Soudan Laboratory has 25 years experience in maintaining its infrastructure. We will review and extend existing policies.

9. Incorporating education, human resource development and outreach: See Section 5.0.

c. Management plan for planning

1. Responsibilities of the PI and co-PI's for the planning process: The PI's have always directly participated in Soudan Laboratory construction and upgrade projects. This same high level of participation will continue with Soudan DUSEL.

2. Timeline and cost for various aspects of planning: An initial Conceptual Design for Soudan DUSEL was developed and submitted to the NSF in 2003. Rock outcrop mapping and initial structural geology analysis was also completed in 2003. Additional site characterization as described in Section 3.1 will be completed by Summer 2005. All of the proposed work described in Section 3.1 will be completed in parallel over 6 months likely beginning in Fall 2005. Cost details are included in the Budget Explanation.

5.0 Broader Impacts

5.1 Science and Technology Impacts: Soudan DUSEL is explicitly broad in its scope and goals. DUSEL addresses fundamental questions in basic research, such as baryon antibaryon asymmetry in the Universe and applied questions such as "Is someone testing nuclear weapons?" DUSEL is an excellent venue to explore the relationship between basic science and applied technology. Soudan DUSEL program will use the advantages of assembling people from multiple disciplines in science and engineering in a compact and geographically remote location to facilitate connections among science and technology disciplines, which will catalyze both direct and indirect broad impacts. The bedrock geology (basalt) and deep groundwaters (brine) at Soudan are similar to those at the surface of Mars and thus the search for life on Mars can be facilitated by study of the geology and microbial communities at Soudan.

5.2 Education and Outreach: Soudan has a successful and growing education and outreach program [9]. Undergraduate and graduate students from multiple universities in several countries have improved their education and skills through research work at Soudan since 1980. The development of Soudan DUSEL will increase student participation levels, especially in geoengineering specialities such as rock mechanics. The Soudan Lab has also hosted visits by primarily K-12 and college student groups. The Laboratory has worked with electronic and print mass media to improve public understanding of content and excitement of underground science. Soudan hosts an "Open Day" each May and offers public tours during summer. K-12 teachers, working as tour guides, have developed extensive Soudan curricular materials.

Soudan DUSEL expects to significantly increase the scope and intensity of its outreach program. Northeastern Minnesota is similar to other frontier areas with few perceived opportunities and aging population. The Lab will provide a local population magnet and enrichment opportunities for both school children and adults. Soudan DUSEL will especially focus on opportunities for members of Minnesota's 12 Native American tribes, particular the nearby Bois Forte and Fond du Lac tribes.

6.0 Management

6.1 General Considerations: The paradigm that historically has worked well at the two major North American underground laboratories—Soudan and SNO—is separate management for science and for site operations. Soudan DUSEL expects to follow a similar, split-function model. Scientific leadership will come from the regional, national and international scientific and engineering communities, in a way that will be determined in consultation with the NSF. The proposed Soudan DUSEL Site Manager is the Regents of the University of Minnesota and individuals to whom the Regents delegate responsibility.

6.2 Regents of the University of Minnesota: The Regents are a constitutional corporation chartered by the 1851 Territorial Laws and endorsed by the Minnesota Constitution in 1858. The Regents have authority to govern the University, including municipal powers regarding existing or needed University property, such as condemnation, zoning, building codes and building and occupancy permits. University permitting and inspections have supervised ~$100 million of construction and capital equipment invested at the Soudan since 1980. The Regents and their employees have sovereign immunity to lawsuits [10], which

bars punitive damage claims and limits compensatory damages to amounts insured by the University's captive insurance company RUMINCO Ltd. The budget of the University of Minnesota is ~$2.5 billion per year. Soudan DUSEL thus represents a manageable increment on the University's ongoing activities.

6.3 Site and Project Management for Soudan DUSEL: The Soudan Laboratory is currently managed by three entities. The University of Minnesota is responsible for hiring the laboratory staff and managing the day-to-day operations. Fermilab performs project management oversight and its Program Advisory Committee provides assessment and recommendations for the scientific program. Minnesota State Parks manages the site access and utilities. The University Vice-President for Research chairs the Soudan Project Management Group (PMG), which includes participation by the scientific Principal Investigators, Fermilab staff and University administraotrs. The PMG coordinates major project management decisions. The Principal Investigators and the appointed Lab Manager make day-to-day operating decisions.

A similar project management is proposed for Soudan DUSEL. Since most of the Laboratory will be on University rather than State Park land, the University will assume major responsibility for site access and utilities. As indicated above, scientific leadership will come from the national and international scientific communities. The Soudan PMG will provide oversight for Soudan DUSEL project management, likely in cooperation with one or more national laboratories. The ability of the University of Minnesota to successfully perform DUSEL site management is significantly enhanced by:

- the University's 25 year experience in successful operation of the Soudan Underground Laboratory;
- the knowledge base and familiarity of the University's Construction, Facilities Management, Building Code and Environmental Health and Safety staff members with the special requirements of underground laboratories;
- the University's employment relationship with many of the Principal and Senior Investigators of this proposal, who, in total, have more than 100 years experience in underground science and engineering;
- the University's reputation and standing among the people of Minnesota and the region;
- the University's powers as a municipality and its sovereign immunity;
- the University's willingness to cooperate on Soudan DUSEL with entities such as national laboratories, which have strong scientific project management experience.

6.4 Partnering With the Scientific and Engineering Communities: The University of Minnesota has existing affiliations that could facilitate Soudan DUSEL partnerships, including Universities Research Association (URA), Association of Universities for Research in Astronomy (AURA), the Committee on Institutional Cooperation ("Big 10" plus the University of Chicago), the Midwestern Higher Education Compact (MHEC) and the Association of American Universities (AUA). The University has educational relationships with the States of Wisconsin, South Dakota and North Dakota, the Province of Manitoba and the Minnesota State College and Universities system, including Fond du Lac Tribal College (Cloquet MN) and Vermillion Community College (Ely MN).

7.0 Responses to Questions in the Program Announcement (NSF 05-0506)

7.1 What is the potential of Soudan to satisfy the needs of a world-class, cost-effective, timely and multidisciplinary candidate site for a DUSEL? What are the strengths and weaknesses? Soudan DUSEL will equal or exceed every other laboratory in terms of depth, size and ability to utilize difficult materials. Its costs are similar to those of other sites, but including cost of a neutrino beam makes Soudan the most cost effective site in North America. Soudan is timely because of its existing program and proven track record for construction and science. Soudan's time to "first science" is *zero.* The scientific program described in Section 2 includes all known aspects of underground science, except sedimentary rock studies.

7.1.1 How strong is the plan for matching the proposed site to the preliminary information on technical requirements of a DUSEL research program? This proposal for Soudan DUSEL is unique because it will test the feasibility of Soudan as the DUSEL by actually doing science. Soudan's feasibility for physics will be demonstrated by doing physics-neutrino oscillations, dark matter search and the Low Background Counting Facility. Soudan's feasibility for earth science will be demonstrated by doing earth science, including a deep borehole, structural studies, geophysical measurements, geochemical analyses and geomicrobiological studies both using the borehole and the existing mine.

7.1.2 What are the team's strengths, weaknesses and breadth for developing a credible DUSEL

conceptual design? For developing an initial research plan and a longer range science vision? The Soudan team consists of most of the few U.S. citizens with experience in designing, managing and directing a multidisciplinary underground laboratory. This team has also participated extensively in the DUSEL design discussions that have occurred in the United States over the past four years.

7.1.3 What are the possibilities for international collaboration? Soudan has a 20 year history of international collaboration, primarily with scientists from the United Kingdom. Countries with scientists now working at Soudan include the U.K., France, Greece, Russia Brazil. Soudan DUSEL expects increased future international participation through the Phase 1 Collaboration.

7.2 What are the strengths and weaknesses of the plan to identify and provide a comprehensive plan to address site-based issues? The Soudan DUSEL plan proposed here addresses the key issue of rock quality at depth with a 1,600 m borehole and moves the Technical Design Report (TDR) process ahead with a focus on the long time frame issues, including underground and surface site layout and environmental assessment and permitting.

7.2.1 To what extent does the extant information on the site, e.g., its geological and hydrological characterization and its accessibility to airports and roads, support the Soudan site? Soudan's feasibility is demonstrated by its 25 year history of doing science and by the information summarized in Tables 1-3.

7.2.2 How comprehensive is the set of issues to be addressed? The Work Breakdown Structure in Section 3.2 presents a comprehensive plan for the Soudan DUSEL Conceptual Design. This plan is informed by previous experience with major construction projects at Soudan in 1984-1986 and 1999-2001.

7.2.3 How realistic is the planned process to determine the timelines and cost estimates? The work described in Section 3 is consistent with both past experience at Soudan and standard engineering practice. The Technical Design Report (TDR) process is the standard initial procedure for managing this type and scale of project.

7.2.4 What are the unique features of Soudan relative to existing or alternative sites that would justify placing a DUSEL there? Soudan's unique features are the ongoing scientific program, the existing laboratory facilities, the NUMI neutrino beam and the proven record of the management team. The heterogeneous geological setting of Soudan meets all of the needs of the EarthLab initiative.

7.3 How strong is the plan for devising a conceptual design for developing, operating and maintaining the infrastructure? The Soudan DUSEL staff has developed, operated and maintained a lab infrastructure for 25 years. While the scale of DUSEL is larger, this experience base will well inform future operations.

7.4 What are the merits of the plans for developing a conceptual design for education, outreach and diversity activities in association with the proposed DUSEL? What are the strengths and weaknesses of the proposing team in this area? Soudan DUSEL will educate undergraduate and graduate students and extend the ongoing Soudan education and outreach program [9].

7.5 Based on the proposed plan, what is the likelihood that the DUSEL could be constructed in the time frame 2008 to 2012? Are there any specific physical, technical or management impediments to beginning construction in this time frame? Soudan DUSEL has no known issues that would impede construction in the 2008-2012 time period. To start construction in 2008, DUSEL site selection must be completed in a timely manner and sufficient funds must be available to complete design, prepare bid packages and obtain necessary permits in time before the start of construction.

8.0 Summary

The current understanding of the DUSEL Solicitation 1 requirements, the known assets of the Soudan Laboratory and the deep geology indicate that Soudan is an excellent site for DUSEL. The work proposed here will test that understanding, particularly with regard to rock properties at depth and the assumptions and analysis in the existing Conceptual Design. The results of this work significantly advance the DUSEL site selection process and help prepare the path for the United States to realize the potential of innovative research in underground science and technology.

References Cited

[1] A description of the CDMS 2 experiment and links to its publications can be found at http://cdms.berkeley.edu.

[2] Information about the NUMI beam and the MINOS experiment is available at http://www-numi.fnal.gov.

[3] The NOνA Off-Axis experiment is documented at http://www-nova.fnal.gov.

[4] The Soudan Low Background Counting Facility is described at http://www.hep.umn.edu/~prisca/soudan.

[5] Information about raise boring is available at http://www.dynatec.ca/min_raise.html, http://www.thyssenmining.com/Thyssen-RUC_JV.htm and http://www.civil.skanska.com/skanska/templates/page.asp?id=2820.

[6] The initial Soudan DUSEL Conceptual Design is documented in NSF Proposal 0335435. The entire text of both this proposal and the Referee Reports on the Proposal is available at http://www.soudan.umn.edu/DUSEL.

[7] The text and graphics of the 2003 Soudan Geological Structure Outcrop Study are available at http://www.soudan.umn.edu/DUSEL.

[8] Letters of support for Soudan DUSEL are available at http://www.soudan.umn.edu/DUSEL.

[9] The website http://www.soudan.umn.edu/DUSEL includes information about the Soudan Education and Outreach program, including grade-appropriate curricular materials for K-12 students developed with support from the National Science Foundation.

[10] More information about the corporate structure of the Regents of the University of Minnesota and the University's sovereign immunity is available at the website http://www.soudan.umn.edu/DUSEL.

Biographical Sketch: Marvin L. Marshak

a. Professional Preparation

A.B. (Physics)—Cornell University, Ithaca, NY, 1967
M.S. and Ph.D. (Physics)—University of Michigan, Ann Arbor, MI, 1969 and 1970
Postdoctoral Research Associate—University of Minnesota, Minneapolis MN, 1970-1974

b. Appointments

Institute of Technology Distinguished Professor, University of Minnesota, 2004-present
Morse-Alumni Distinguished Teaching Professor of Physics, University of Minnesota, 1996-present
Director of Residential College, University of Minnesota, 1994-1996, 1997-2004
Faculty Legislative Liaison, University of Minnesota, 1997-2003
Senior Vice-President for Academic Affairs, University of Minnesota, 1996-1997
Head, School of Physics and Astronomy, University of Minnesota, 1986-1996
Professor of Physics, University of Minnesota, 1983-1996
Director of Graduate Studies in Physics, University of Minnesota, 1983-1986
Associate Professor Physics, University of Minnesota, 1978-1983
Assistant Professor of Physics, University of Minnesota, 1974-1978

c(i). Recent and Related Publications

1. *Horizontal Muons and A Search for AGN Neutrinos in Soudan 2*. Soudan 2 Collaboration (D. DeMuth *et al.*),
Astropart. Phys. 20:533-547, 2004.
2. *Measurement of L/E Distributions of Atmospheric Neutrinos in Soudan 2 and Their Interpretation As Neutrino Oscillations.* Soudan 2 Collaboration (M. Sanchez, *et al.*) **Phys. Rev. D68:113004,2003**.
3. *Search for Neutron Anti-neutron Oscillations Using Multiprong Events in Soudan 2*. Soudan 2 Collaboration (J. Chung, *et al.*), **Phys. Rev. D66:032004,2002**
4. *Search For Nucleon Decay With Final States* $Lepton + \eta^0$, $\bar{\nu}\eta^0$, $\bar{\nu}\pi^{+,0}$ *USING SOUDAN-2,* Soudan 2 Collaboration (D. Wall *et al.*). **Phys.Rev.D62:092003,2000**
5. *Search For Nucleon Decay Into Lepton + K^0 Final States Using Soudan-2.*
By Soudan 2 Collaboration (D. Wall *et al.*). **Phys.Rev.D61:072004,2000**
6. *The Observation Of A Shadow Of The Moon In The Underground Muon Flux In The Soudan-2 Detector.*
By Soudan 2 Collaboration (J.H. Cobb *et al.*). **Phys.Rev.D61:092002,2000**
7. *The Atmospheric Neutrino Flavor Ratio From A 3.9 Fiducial Kiloton Year Exposure Of Soudan-2.* By Soudan-2 Collaboration (W.W.M. Allison *et al.*). **Phys.Lett.B449:137-144,1999**

c(ii). Other Selected Publications

1. *Nuclear Transparency in 90° c.m. Quasielastic A(p,2p) Reactions.* By J. Aclander, *et al.,* **Phys. Rev. C70:015208, 2004**
2. *The Large Momentum Transfer Reaction C-12(P,2p + N) As A New Method For Measuring Short Range N N Correlations In Nuclei.* By J. Aclander, J. Alster, D. Barton, G. Bunce, A. Carroll, N. Christensen, H. Courant, S. Durrant, S. Gushue, S. Heppelmann, E. Kosonovsky, I. Mardor, Y. Mardor, M. Marshak, Y. Makdisi, E.D. Minor, I. Navon, H. Nicholson, E. Piasetzky, T. Roser, J. Russell, M. Sargsian, C.S. Sutton, M. Tanaka, C. White, J.Y. Wu (Tel Aviv U. & Brookhaven & Minnesota U. & Penn State U. & Mount Holyoke Coll. & Massachusetts U., North Dartmouth). 1999. **Phys.Lett.B453:211-216,1999**
3. *Search For The Proton Decay Mode Proton To Neutrino K+ In Soudan-2.*
By Soudan-2 Collaboration (W.W.M. Allison *et al.*). **Phys.Lett.B427:217-224,1998**
4. *A Study Of Cosmic Ray Composition In The Knee Region Using Multiple Muon Events In The Soudan-2 Detector.* By Soudan-2 Collaboration (S.M.S. Kasahara *et al.*).**Phys.Rev.D55:5282-5294,1997**
5. *Measurement Of The Atmospheric Neutrino Flavor Composition In Soudan-2.* By W.W.M. Allison, G.J. Alner, D.S. Ayres, W.L. Barrett, C. Bode, P.M. Border, C.B. Brooks, J.H. Cobb, D.J.A. Cockerill, R.J. Cotton, H. Courant, D.M. Demuth, T.H. Fields, H.R. Gallagher, C. Garcia-Garcia, M.C. Goodman, R.N. Gray, K. Johns, T. Kafka, S.M.S. Kasahara, W. Leeson, P.J. Litchfield, N.P. Longley, M.J. Lowe, W.A. Mann, M.L. Marshak, E.N. May, R.H. Milburn, W.H. Miller, L. Mualem, A. Napier, W. Oliver, G.F. Pearce, D.H. Perkins, E.A. Peterson, D.A. Petyt, L.E. Price, D.M. Roback, K. Ruddick, D. Schmid, J.

Schneps, M.H. Schub, R.V. Seidlein, M.A. Shupe, A. Stassinakis, N. Sundaralingam, J. Thomas, J.L. Thron, V. Vasilev, G. Villaume, S.P. Wakely, D. Wall, S.J. Werkema, N. West, U.M. Wielgosz (Argonne & Minnesota U. & Oxford U. & Rutherford & Tufts U. & Western Washington U.). **Phys.Lett.B391:491-500,1997**

d. Synergistic Activities

• Founded the University of Minnesota Underground Laboratory at Soudan in 1979 and supervised the major expansion of the laboratory in 1984-1986; also collaborated in the second major expansion in 1999-2001. During the past 25 years, this Laboratory has added about ~$100 million to the economy of a very underdeveloped region of the United States.

• Established and encouraged outreach activities related to the University's Underground Laboratory at Soudan, including a public summer visitor program, open day for local residents, use of print and electronic media to explain basic research and to transmit excitement of this research to the public. Outreach activities at Soudan also include synergies between art and science in the MINOS Mural Project and connections between science and informal adult education through the University's Compleat Scholar program.

• Started unique Global Studies course Physics 5993 *Mysteries of the Universe*, which takes students to visit physics laboratories outside the U.S., in order to better understand collaboration and cooperation in international science. In May 2003 and May 2005, 30 University of Minnesota undergraduates visited the Gran Sasso Laboratory, the European Gravitational Observatory, CERN and other science sites in Italy, Switzerland and France.

• Founded and has directed for six years the University of Minnesota Residential College, a program that now includes 450 undergraduate students and integrates academic and residential activities. Mr. Marshak has taught innovative seminars for Residential College students including *The Art and Science of Color* (jointly with a Studio Arts professor), *The Deep Underground Sky* (neutrinos for the non-expert) and *America Emerges from Isolation: The History of the Manhattan Project*.

• For the past five years represented the 3,000 members of the University of Minnesota faculty in interactions with the Governor and Legislature of Minnesota. In this position, he has promoted public dialogue in Minnesota regarding the balance of access and excellence in public, land-grant, research university higher education.

• Served the University of Minnesota as its Senior Vice-President and Chief Academic Officer during the 1996-1997 conflict between the University Regents and faculty regarding policies on faculty tenure. As part of the solution to this conflict, he publicly articulated the importance of academic freedom to the University of people of Minnesota and the direct link between tenure and academic freedom. He also participated in the management of the University's reorganization of its biological sciences programs and the $225 million sale of the University Hospital to a non-profit, vertically-integrated health care organization.

• Played a significant role in raising $4 million to endow a Theoretical Physics Institute, in recruiting outstanding faculty, principally from the Soviet Union, and in organizing the Institute, which has played a major role in the recent development of elementary particle and condensed matter physics. He also raised approximately $0.5 million to endow the Abigail and John Van Vleck Lectureship in Physics, which has attracted nearly 20 Nobel-laureate lecturers.

• Often served as a Visiting Scientist in K-12 schools, principally in a program sponsored by the Science Museum of Minnesota and the Blandin Foundation.

e(i) Collaborators

Soudan 2 Collaboration (for collaborators, see www.hep.umn.edu/soudan)

MINOS Collaboration (for collaborators, see www-numi.fnal.gov or www.slac.stanford.edu/spires/experiments)

NOνA Collaboration (for collaborators, see www-off-axis.fnal.gov)

Homestake NUSEL Collaboration (for collaborators, see int.phys.washington.edu/NUSEL)

e(ii) Graduate and Post-doctoral Advisors: Alan Krisch (U. Michigan); Keith Ruddick (U. Minnesota)

e(iii) Thesis Students: 15 overall; **Post-doctoral Scholar Sponsor:** 5 overall; none in last 5 years

Priscilla Cushman Biographical Sketch

Education

Harvard University	Physics and Philosophy	AB	1976
Rutgers University	Physics	PhD	1985
Rockefeller University	HEP Research Fellow		1985-88

Professional Experience

2000-present	Director of Undergraduate Studies in Physics, University of Minnesota
2000-present	Professor of Physics, University of Minnesota
1993-2000	Associate Professor of Physics, University of Minnesota
1993	Associate Professor of Physics, Yale University
1988-1992	Assistant Professor of Physics, Yale University

Most-closely related Publications

1. D.S. Akerib et al. (CDMS Collaboration of 76 co-authors) First Results from the Cryogenic Dark Matter Search in the Soudan Underground Laboratory, Physical Review Letters 93, 211301 (2004).

2. D.S. Akerib et al.(CDMS Collaboration of 60 co-authors) New Results from the Cryogenic Dark Matter Search,, PRD**68**, 082002 (2003).

3. G.W. Bennett et al. (g-2 Collaboration) Measurement of the Negative Muon Anomalous Magnetic Moment to 0.7 ppm, hep-ex/0401008, Physical Review Letters 92, 161802 (2004).

4. G.W. Bennett et al. (g-2 Collaboration) Measurement of the Positive Muon Anomalous Magnetic Moment to 0.7 ppm. Phys.Rev.Lett.89:101804, Erratum-ibid.89:129903 (2002)

5. H. N. Brown et al (g-2 Collaboration), Precise Measurement of the Positive Muon Anomalous Magnetic Moment, Phys. Rev. Lett. 86, (2001) 2227-2231.

Other Significant Publications

1. P.B. Cushman and A.J.Heering Problems and Solutions in high-rate multi-channel Hybrid Photodiode design: The CMS Experience, Transactions in Nuclear Science (TNS-00147-2001), IEEE Trans.Nucl.Sci.49:963-970 (2002)

2. P. Cushman, A. Heering, and A. Ronzhin, Custom HPD Readout System for the CMS Hadronic Calorimeter, Nuclear Instruments and Methods A442, 289 (2000).

3. H.N. Brown et al. (g-2 Collaboration), Improved Measurement of the Positive Muon Anomalous Magnetic Moment, Physical Review D62:091101,2000, Sept 2000.

4. P. Cushman, F. Farley, K. Jungman, P. Nemethy, B.L. Roberts, W. Morse, Y. Semertzidis. A Direct Measurement of the Muon Neutrino Mass by Pion Decay in Flight in the g-2 Ring, AGS-2000 Experiments for the 21st Century, BNL Formal Report 52512, Littenberg & Sandweiss eds (1996)

5. P. Cushman, Electromagnetic and Hadronic Calorimeters, Chapter 4 of "Instrumentation for High Energy Physics", ed Fabio Sauli. Vol 9 of the series "Directions in High Energy Physics", World Scientific (1992) pp. 281-386.

Synergistic Activities

1. Site visits and reviews of Physics Departments under the auspices of the APS Committee on the Status of Women in Physics to foster a healthy environment for all members of the physics community including women and minorities.

2. Developed new physics curriculum for Liberal Arts Majors at the University which includes practical applications, encourages mathematical thinking and communicates the relevance of physics to the everyday world using energy and environmental themes: wrote textbook: Energy and the Environment: Physics Principles and Applications, P.Cushman, ISBN 0-7872-5391-X, Kendall/Hunt Publishers (1998).
3. Service to the Physics Community: NSF-DOE SAGENAP Committee (2002), SLAC Review (2001), Brookhaven User's Executive Committee (1997-1999) , Member-at-large, APS Topical Group on Fundamental Constants (1996-98).
4. Science Editor (pro bona) Carolrhoda Books (division of Lerner) - Biographies of scientists and inventors for Middle School readers: Einstein, Farnsworth, etc.
5. "Science Works!" a Minneapolis public schools systematic reform effort in K-8 science. A program supported in part by the National Science Foundation and Medtronic. Worked in the Partnership Teaching program and the Science Kit Training Sessions for Elementary Teachers.
6. Principle Investigator – QuarkNet chapter of University of Minnesota. Summer conferences for high school teachers, development of a network for HEP-related special education materials for high schools.

Collaborators (authors)
The g-2 Collaboration http://www.g-2.bnl.gov/collab.html
US-CMS HCAL Collaborators: specifically D. Green, J.Freeman, J. Elias, A. Skuja, R. Ruchti, A. Bodek, J.Reidy, N.Akchurin, Y.Onel
CDMS II Collaboration http://cdms.berkeley.edu/cdms_collab.html

Graduate Advisor: Prof. Tom Devlin, Rutgers University
Postdoc Sponsor: Prof. Rodney Cool (deceased), Rockefeller University

16 thesis grad students and 9 postdocs over 14 years

Graduate Students (last 5 yrs)
Joel Kindem (VP, DigiRad Corp.), Long Duong (University of Minnesota), Ron McNabb (University of Illinois, Champaign-Urbana), Steven Giron (College of St Catherine), Dean Miller (Robins, Kaplan, Miller & Ciresi), Ben Bousquet (College of Gustavus Adolphus) , Tao Qian, Angela Reisetter

Postdoctoral Scholars (last 5 yrs)
Charles Timmermans (University of Nijmegen, Netherlands), David Zimmerman (Lawrence Berkeley National Laboratory), Ivan Kronkvist (Software Services, Minneapolis), Arjan Heering (FNAL/CERN), Long Duong (University of Minnesota), Petr Shagin (University of Minnesota)

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New Mexico Institute of
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Socorro, New Mexico 87801
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E-mail: tkieft@nmt.edu

(a) Professional preparation

Carleton College, Biology, B.A., 1973
New Mexico Highlands University, Biology, M.S., 1978
University of New Mexico, Biology, Ph.D., 1983
University of California, Berkeley, Plant and Soil Biology, Post-doc 1983-1985

(b) Appointments

08/85 - Present	Faculty member (Professor since 1993), Biol. Dept., New Mexico Tech
12/04 -- Present	Adjunct Prof., Earth & Environ. Sci. Dept., New Mexico Tech
08/01 -- 12/01	Associate Vice-President for Academic Affairs and Dean of Students (Acting), New Mexico Tech
02/98 -- 08-01	Associate Vice-President for Research., New Mexico Tech
07/91 -- 02/98	Chairman, Biology Department, New Mexico Tech
01/97 - 12/97	Sabbatical Leave, Earth and Environmental Sciences Center, Pacific Northwest National Laboratory, Richland, WA
09/83 - 08/85	Visiting Assistant Research Microbiologist, Department of Plant and Soil Biology, University of California, Berkeley, CA
08/82 – 05/83	Asst. Prof., Biology and Environmental Science, New Mexico Highlands University

(c) Most closely related publications (40 total peer-reviewed publications, 9 book chapters)

Rutz, B. and T. L. Kieft. 2004. Phylogenetic characterization of dwarf archaea and bacteria from a semiarid soil. *Soil Biology & Biochemistry* 36:825-833.

Lehman, R. M., S. P. O'Connell, A. Banta, J. K. Fredrickson, A.-L. Reysenbach, T. L. Kieft, and F. S. Colwell. 2004. Microbiological comparison of core and groundwater samples collected from a fractured basalt aquifer with that of dialysis chambers incubated in situ. *Geomicrobiology Journal* 21:169-182.

Balkwill, D. L., T. L. Kieft, T. Tsukuda, H. M. Kostandarithes, T. C. Onstott, S. Macnaughton, J. Bownas, and J.K. Fredrickson. 2004. Identification of iron-reducing *Thermus* strains as *T. scotoductus*. *Extremophiles* 8:37-44.

Onstott, T. C., D. P. Moser, S. M. Pfiffner, J. K. Fredrickson, F.J. Brockman, T. J. Phelps, D. C. White, A. Peacock, D. Balkwill, R. Hoover, L. R. Krumholz, M. Borscik, T. L. Kieft, and R. Wilson. 2003. Indigenous and introduced microorganisms in rock samples from a deep gold mine. *Environmental Microbiology*. 5:1168-1191.

Oliver, D. S., F. J. Brockman, R. S. Bowman, and T. L. Kieft. 2003. Microbial Reduction of Hexavalent Chromium under Vadose Zone Conditions. *Journal of Environmental Quality* 32:317-324.

Five Other Publications

Fu, Z., S. Rogelj, and T. L. Kieft. Detection of *Escherichia coli* O157:H7 by immuno-magnetic separation and real-time PCR. *International Journal of Food Microbiology*. 99:47-57.

Liang, H., S. E. Cordova, T. L. Kieft, and S. Rogelj. 2003. Development of an immuno-PCR assay to detect Group A *Streptococcus*. *Journal of Immunological Methods* 279:101-10.

Kieft, T.L. 2002. Microbial Starvation Survival in Subsurface Environments. pp. 2019-2028. In: Encyclopedia of Environmental Microbiology, G. Bitton (Ed.) John Wiley, NY.

Kieft, T. L., and F. J. Brockman. Vadose zone microbiology. 2001. pp. 141-169. In: Subsurface Microbiology and Biogeochemistry. J. K. Fredrickson and M. Fletcher (Eds.), John Wiley & Sons, New York.

Kieft, T. L. 2000. Size matters: dwarf cells in soil and subsurface terrestrial environments. Ch. 3, pp. 19-46. In: Non-culturable Microorganisms in the Environment. R. R. Colwell and D. J. Grimes (Eds.), Amer. Soc. Microbiol., Washington, DC.

(d) Synergistic Activities

Mentor for NSF-funded U.S./South African Undergraduate Education and Research Workshops, 2001 and 2002, Bloemfontein, South Africa

Mentor for NSF-funded REU, Biogeochemical Educational Experiences-South Africa, Bloemfontein, South Africa 2003 and 2004. (http://geomicro.utk.edu/)

New Mexico Science Fair, mentoring of high school students and Science Fair judging, 19985 – present.

(e) Collaborators and other affiliations

i. Collaborators and coauthors, last 48 months

David L. Balkwill, Florida State University; Rob Bowman, New Mexico Tech; Fred Brockman, Pacific Northwest National Laboratory; F. S. Colwell, Idaho National Engineering Lab; Jim Fredrickson, Pacific Northwest National Laboratory; Zhu Fu, University of California, Berkeley; Lee Krumholz, University of Oklahoma; R. Michael Lehman; Huining Liang, BioSTAR, Inc.; USDA; Barbara Sherwood Lollar, University of Toronto; Sean P. O'Connell, Western Carolina University; T. C. Onstott, Princeton University; Tommy J. Phelps, Oak Ridge National Laboratory; Susan Pfiffner, University of Tennessee; A.L. Reisenbach, Portland State University; Snezna Rogelj, New Mexico Tech; Gordon Southam, University of Western Ontario

ii. Graduate and postdoctoral advisors

M.S. advisor: John W. Spencer, New Mexico Highlands Univ., retired

Ph.D. Advisor: Douglas E. Caldwell, University of Saskatchewan

Post-doctoral advisor: Mary K. Firestone, University of California, Berkeley

iii. Former Advisees (20 total graduate students, 0 postdocs)

John Ayarbe, R. Hicks, Inc., Albuquerque, NM; Robin Brown, New Mexico Environment Department; James Elliott, University of New Mexico; Bill Kovacik, Pacific Northwest National Laboratory; Sean McCuddy, Environmental consulting firm, Chicago; Misty Milleson, Lovelace Research Institute; Bridget Rutz, University of New Mexico; Rebekah Silva, University of New Mexico

Biographical Sketch: Earl A. Peterson

a. Professional Preparation
B.S. in Physics—University of Washington, Seattle, WA, 1962
M.S. and Ph.D. (Physics)—Stanford University, Stanford, CA, 1967/1968
Postdoctoral Research Associate—University of Minnesota, Minneapolis MN, 1967-1974

b. Appointments
Director, Soudan Underground Laboratory, 1997-present
Professor of Physics, University of Minnesota, 1983-present
Associate Professor Physics, University of Minnesota, 1978-1983
Assistant Professor of Physics, University of Minnesota, 1973-1978

c(i). Related Publications
1. *Search for Neutron Anti-neutron Oscillations Using Multiprong Events in Soudan 2.* Soudan 2 Collaboration (J. Chung, *et al*.), **Phys. Rev. D66:032004,2002**
2. *Search For Nucleon Decay With Final States* $Lepton + \eta_0$, $\nu\ \eta_0$, $\nu\ \pi_{+,0}$ *USING SOUDAN-2,* Soudan!2 Collaboration (D. Wall *et al*.). **Phys.Rev.D62:092003,2000**
3. *Search For Nucleon Decay Into Lepton + K* $_0$ *Final States Using Soudan-2.* By Soudan 2 Collaboration (D. Wall *et al*.). **Phys.Rev.D61:072004,2000**
4. *The Observation Of A Shadow Of The Moon In The Underground Muon Flux In The Soudan-2 Detector.* By Soudan 2 Collaboration (J.H. Cobb *et al*.). **Phys.Rev.D61:092002,2000**
5. *The Atmospheric Neutrino Flavor Ratio From A 3.9 Fiducial Kiloton Year Exposure Of Soudan-2.* By Soudan-2 Collaboration (W.W.M. Allison *et al*.). **Phys.Lett.B449:137-144,1999**

c(ii). Other Publications
1. *Atmospheric Neutrino Results from Soudan 2, Proceedings of Neutrino 2000, Osaka, Japan, 2001*.
2. *Search For The Proton Decay Mode Proton To Neutrino K+ In Soudan-2.*
By Soudan-2 Collaboration (W.W.M. Allison *et al*.). **Phys.Lett.B427:217-224,1998**
3. *The MINOS Experiment, Proceedings of PANIC02, Osaka, Japan, 2003*.
4. *A Study Of Cosmic Ray Composition In The Knee Region Using Multiple Muon Events In The Soudan-2 Detector,* By Soudan-2 Collaboration (S.M.S. Kasahara *et al*.).**Phys.Rev.D55:5282-5294,1997**
5. *Measurement Of The Atmospheric Neutrino Flavor Composition In Soudan-2.* By W.W.M. Allison, G.J. Alner, D.S. Ayres, W.L. Barrett, C. Bode, P.M. Border, C.B. Brooks, J.H. Cobb, D.J.A. Cockerill, R.J. Cotton, H. Courant, D.M. Demuth, T.H. Fields, H.R. Gallagher, C. Garcia-Garcia, M.C. Goodman, R.N. Gray, K. Johns, T. Kafka, S.M.S. Kasahara, W. Leeson, P.J. Litchfield, N.P. Longley, M.J. Lowe, W.A. Mann, M.L. Marshak, E.N. May, R.H. Milburn, W.H. Miller, L. Mualem, A. Napier, W. Oliver, G.F. Pearce, D.H. Perkins, E.A. Peterson, D.A. Petyt, L.E. Price, D.M. Roback, K. Ruddick, D. Schmid, J. Schneps, M.H. Schub, R.V. Seidlein, M.A. Shupe, A. Stassinakis, N. Sundaralingam, J. Thomas, J.L. Thron, V. Vasilev, G. Villaume, S.P. Wakely, D. Wall, S.J. Werkema, N. West, U.M. Wielgosz (Argonne & Minnesota U. & Oxford U. & Rutherford & Tufts U. & Western Washington U.).**Phys.Lett.B391:491-500,1997.**

d. Synergistic Activities
Member, NuMI/MINOS project Program Management Group, 1998-present.
Member, MINOS experiment Executive committee, 2002-present.
Often served as a speaker at public meetings, engineering groups, other public bodies interested in the MINOS experiment and neutrino physics.
Co-chair of the MINOS Outreach committee which has prepared K-12 lesson plans, pre-tour packets and other materials for school visit program.
Served as construction coordinator and financial controller for the construction and outfitting of the MINOS Far Detector Laboratory at Soudan.
Coordinated training for guides of scheduled tours of the MINOS laboratory conducted as part of the Soudan Underground Mine State Park visitor program
Hosted annual open-house days in the Soudan laboratories for local residents.

e(i) Collaborators
Soudan 2 Collaboration (for collaborators, see www.hep.umn.edu/soudan)
MINOS Collaboration (for collaborators, see www-numi.fnal.gov or www.slac.stanford.edu/spires/experiments)
Off-Axis Collaboration (for collaborators, see www-off-axis.fnal.gov)

e(ii) Graduate and Post-doctoral Advisors: *Graduate***-**Robert J. Oakes (Northwestern University); *Postdoctoral*-
Keith Ruddick (U. Minnesota)

e(iii) Thesis Students: 12 overall; last 5 years: Garrick Villaume -Seagate; **Post-doctoral Scholar Sponsor:** 4 overall; none in last 5 years

Dean M. Peterson – Biographical Sketch

a. Professional Preparation

University of Minnesota Duluth	Geology	B.S.	1987
University of Minnesota	Economic Geology	Ph.D.	2001

b. Professional Appointments

2005-present	Senior Research Associate, Center for Applied Research and Technology Development, Natural Resources Research Institute, University of Minnesota Duluth
2003-present	Assistant Professor-Adjunct, Geology, University of Minnesota Duluth
2002-2005	Research Associate, Center for Applied Research and Technology Development, Natural Resources Research Institute, University of Minnesota Duluth
2000-2002	Scientist, Center for Applied Research and Technology Development, Natural Resources Research Institute, University of Minnesota Duluth
1998-2001	Instructor, Department of Geological Sciences, University of Minnesota Duluth
1993-1998	Consulting Geologist, Mineral Exploration Industry, North America
1990-1993	Project Geologist, Newmont Exploration Limited
1987-1989	Contract Geologist, Minnesota Geological Survey and Minerals Division Minnesota Department of Natural Resources

c(i). Related Publications

Peterson, D.M and Patelke, R.L., 2004, Bedrock Geology and Lode Gold Prospect Data Map of the Mud Creek Road Area, Northern St. Louis County, Minnesota: Natural Resources Research Institute, Map Series NRRI/MAP-2004-01, scale 1:12,000. http://www.nrri.umn.edu/egg/

Hudak, G.J., Heine, J., Jirsa, M.A., and Peterson, D.M., 2004, Volcanic stratigraphy, hydrothermal alteration, and VMS potential of the Lower Ely Greenstone, Fivemile Lake to Sixmile Lake area: 50th Annual Meeting, Institute on Lake Superior Geology, Field Trip Guidebook, Volume 50, p. 1-45.

Peterson, D.M and Patelke, R.L., 2003, National Underground Science and Engineering Laboratory (NUSEL); Geological site investigation for the Soudan Mine, northeastern Minnesota: Natural Resources Research Institute, Technical Report NRRI/TR-2003/29, 97 p., 3 plates, 1 CD-rom. http://www.nrri.umn.edu/egg/

Peterson, D.M. and Severson, M.J., 2002, Chapter 4, Archean and Paleoproterozoic rocks forming the footwall of the Duluth Complex, *in* Geology and mineral potential of the Duluth Complex and related intrusions of northeastern Minnesota, Minnesota Geological Survey, Report of Investigations 58, pp. 76-93. ftp://156.98.153.1/pub2/ri58

Peterson, D. M., and Jirsa, M.A., 1999, Bedrock geologic map and mineral exploration data, western Vermilion district, St. Louis and Lake Counties, northeastern Minnesota: Minnesota Geological Survey, Miscellaneous Map M-98, scale 1:48,000. ftp://156.98.153.1/pub2/m-98/

c(ii). Other Publications

Peterson, D.M and Patelke, R.L., 2004, Economic geology of Archean gold occurrences in the Vermilion District, northeast of Soudan, Minnesota: Institute on Lake Superior Geology, 50th Annual Meeting, Field Trip Guidebook, Duluth, Minnesota, Volume 50, p. 200-226.

Hudak, G. J., Morton, R. L., Franklin, J. M., and Peterson, D. M., 2003, Morphology, Distribution, and Estimated Eruption Volumes for Intracaldera Tuffs Associated with Volcanic-hosted Massive Sulfide Deposits in the Archean Sturgeon Lake Caldera Complex, NW Ontario: American Geophysical Union Monograph 140, Subaqueous Explosive Volcanism, pp. 345-359. Purchase at https://www.agu.org/cgi-bin/agubookstore?topic=..GM

Miller, J.D., Green, J.C., Severson, M.J., Chandler, V.W., and Peterson, D.M., 2001, Geological map of the Duluth Complex and related rocks, Northeastern Minnesota; Minnesota Geological Survey, Miscellaneous Map M119, scale 1:200,000. ftp://156.98.153.1/pub2/m-119/

Jirsa, M.A., Boerboom, T.J., and Peterson, D.M., 2001 Bedrock geologic map of the Eagles Nest Quadrangle, St. Louis County, Minnesota: Minnesota Geological Survey, Miscellaneous Map M114, scale 1:24,000. ftp://156.98.153.1/pub2/m-114/

Peterson, D.M., 1997, Ore Deposit Modeling and Mineral Exploration Criteria for Footwall Copper-Platinum Group Element Mineralization in the Duluth Complex, MNDNR Report Project 317, 55 p., 46 plates, 8 data disks.

d. Synergistic Activities

President, Mesabi Range Geological Society
Co-convener of Geological Society of America North-Central Section Meeting Symposium "Deep Earth Science: Prospects for a deep underground national lab"; Minneapolis, 2005
Reviewer for *Exploration and Mining Geology Journal, Economic Geology*
Instructor, Dynamics of the Earth System, Minnesota Space Grant Consortium (summer 2005)
Instructor, TIMES Project for 8th Grade Earth Science Teachers, Minnesota Science Museum
Instructor, Elder Hostel, Duluth Minnesota
Judge, Ordean Middle School Science Fair
Coach, Destination Imagination and Odyssey of the Mind Programs, Duluth School District
Volunteer for the Northern Pine Council, Girl Scouts of America
Volunteer at the Children's Museum, Duluth Minnesota

e(i). Collaborators in last 48 months
Alexander, Calvin; University of Minnesota
Alexander, Scott; University of Minnesota
Brown, Phillip; University of Wisconsin
Chandler, Val; Minnesota Geological Survey
Drexler, Heidi; University of Wisconsin Oshkosh
Franklin, James; Franklin Geoscience
Goodge, John; University of Minnesota Duluth
Heine, John; Natural Resources Research Institute, University of Minnesota Duluth
Hudak, George; University of Wisconsin Oshkosh
Hunter, Douglas; Wallbridge Mining Company Limited
Jirsa, Mark; Minnesota Geological Survey
Larson, Phillip; University of Minnesota Duluth
Marshak, Marvin; University of Minnesota
Marma, John; Newmont Mining
Mooers, Howard; University of Minnesota Duluth
Patelke, Richard; Polymet Mining Corporation
Severson, Mark; Natural Resources Research Institute, University of Minnesota Duluth
Soever, Alar; Wallbridge Mining Company Limited
Swenson, John; University of Minnesota Duluth

e(ii). Thesis Advisor: Ronald L. Morton, University of Minnesota Duluth

e(iii). Thesis and Postgraduate Sponsorship:
Adam Hoffman, University of Minnesota Duluth
Paul Albers, University of Minnesota Duluth

SUMMARY PROPOSAL BUDGET

YEAR 1

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
University of Minnesota-Twin Cities

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Marvin L Marshak

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Marvin L Marshak - Inst. of Tech. Prof.**	1.00	0.00	0.00	$ 0	$
2. **Calvin Alexander - Professor**	0.00	0.00	0.75	6,022	
3. **Scott Alexander - Junior Scientist**	0.75	0.00	0.00	2,243	
4. **Daniel R Bond - Asst. Professor**	0.00	0.00	0.25	1,500	
5. **Val Chandler - Senior Scientist**	0.25	0.00	0.00	1,522	
6. (**20**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	13.20	0.25	1.50	53,746	
7. (**25**) TOTAL SENIOR PERSONNEL (1 - 6)	15.20	0.25	2.50	65,033	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL ASSOCIATES	0.00	0.00	0.00	0	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (**1**) GRADUATE STUDENTS				0	
4. (**0**) UNDERGRADUATE STUDENTS				0	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (**0**) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				65,033	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				21,331	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				86,364	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				16,875	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ 0					
2. TRAVEL 0					
3. SUBSISTENCE 0					
4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				5,300	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				321,642	
6. OTHER				33,015	
TOTAL OTHER DIRECT COSTS				359,957	
H. TOTAL DIRECT COSTS (A THROUGH G)				463,196	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **All Off-Campus (Rate: 26.0000, Base: 141554)**					
TOTAL INDIRECT COSTS (F&A)				36,804	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				500,000	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPG II.C.6.j.)				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ 500,000	$

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Marvin L Marshak

ORG. REP. NAME*

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET COMMENTS - Year 1

Other Senior Personnel

Name - Title	Cal	Acad	Sumr	Funds Requested
Cushman, Priscilla B - Professor	0.75	0.00	0.00	0
Goodge, John - Professor	0.00	0.00	0.75	5000
Habig, Alec - McKnight Asst. Prof.	0.20	0.00	0.00	0
Hansen, Vicki - McKnight Prof.	0.00	0.00	0.50	2623
Hauck, Steven - Program Director	0.00	0.25	0.00	1526
Heller, Kenneth J - Professor	0.45	0.00	0.00	0
Johnson, Kurt W - Research Fellow	0.75	0.00	0.00	2845
Kamyshkov, Yuri - Professor	0.20	0.00	0.00	0
Kieft, Thomas L - Professor	1.00	0.00	0.00	0
LaPara, Timothy M - Asst. Professor	0.00	0.00	0.25	1843
Mayasich, Joseph M - Research Associate	0.50	0.00	0.00	2489
Miller, William - Lab Manager	0.75	0.00	0.00	0
Peterson, Dean M - Adj. Asst. Professor	3.35	0.00	0.00	18146
Peterson, Earl - Professor	1.05	0.00	0.00	0
Pomry-Petry, D. - Research Fellow	1.00	0.00	0.00	2485
Runkel, Tony - Senior Scientist	0.50	0.00	0.00	2353
Saar, Martin - Assistant Professor	0.50	0.00	0.00	3467
Severson, Mark J - Research Fellow	1.50	0.00	0.00	7307
Tipping, Robert - Senior Scientist	0.50	0.00	0.00	2262
Tonon, Fulvio - Asst. Professor	0.20	0.00	0.00	1400

SUMMARY PROPOSAL BUDGET

Cumulative

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
University of Minnesota-Twin Cities

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Marvin L Marshak

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Marvin L Marshak - Inst. of Tech. Prof.**	1.00	0.00	0.00	$ 0	$
2. **Calvin Alexander - Professor**	0.00	0.00	0.75	6,022	
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7. (**25**) TOTAL SENIOR PERSONNEL (1 - 6)	15.20	0.25	2.50	65,033	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL ASSOCIATES	0.00	0.00	0.00	0	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (**1**) GRADUATE STUDENTS				0	
4. (**0**) UNDERGRADUATE STUDENTS				0	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (**0**) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				65,033	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				21,331	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				86,364	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				16,875	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ 0					
2. TRAVEL 0					
3. SUBSISTENCE 0					
4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				5,300	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				321,642	
6. OTHER				33,015	
TOTAL OTHER DIRECT COSTS				359,957	
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I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				36,804	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				500,000	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPG II.C.6.j.)				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ 500,000	$

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Marvin L Marshak

ORG. REP. NAME*

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

C ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

Budget Justification

Table 1. Principal and Senior Investigators

(UMD=University of Minnesota, Duluth; UMTC=University of Minnesota, Twin Cities; NRRI=Natural Resources Research Institute; MGS=Minnesota Geological Survey; UW=University of Wisconsin)

Surname	Given Name	Job Title	Company or Institution: Department
Akkerman	Justin	CADD Tech	CNA Engineers
Alexander	Calvin	Professor	UMTC: Geology/Geophysics
Alexander	Scott C.	Junior Scientist	UMTC: Geology/Geophysics
Andersen	Susan	Technical Writer	McIntosh Engineering
Bond	Daniel R.	Assistant Professor	UMTC: Biotechnology Institute
Chandler	Val	Senior Scientist	UMTC: MGS
Cramer	Matt	Senior Engineer	CNA Engineers
Cushman	Priscilla	Professor	UMTC: Physics/Astronomy
Davis	Jeffrey	Senior Civil Engineer	SEH Engineering
Digre	Brad	CADD Tech	SEH Engineering
Goodell	Tom	Senior Engineer	McIntosh Engineering
Goodge	John	Professor	UMD: Geological Sciences
Grube	Todd	Mechanical Engineer	Dunham Associates
Habig	Alec	McKnight Professor	UMD: Physics
Hansen	Vicki	McKnight Professor	UMD: Geological Sciences
Hauck	Steven A.	Program Director	NRRI
Heller	Kenneth	Morse-Alumni Prof.	UMTC: Physics/Astronomy
Holland	Dale	Principal	Dunham Associates
Hudak	George J.	Associate Professor	UW Oshkosh: Geology
Hulne	Gregory	Project Manager	Miller Dunwiddie Architects
Jirsa	Mark	Senior Scientist	UMTC: MGS
Johnson	Kurt W.	Research Fellow	UMD: NRRI
Kieft	Thomas L.	Professor/Chair	New Mexico Tech: Biology
Kost	Robert	Landscape Architect	SEH Engineering
LaPara	Timothy M.	Assistant Professor	UMTC: Civil Engineering
Leide	Heather	Architect	Miller Dunwiddie Architects
Marshak	Marvin L.	Institute of Tech. Prof.	UMTC: Physics/Astronomy
Mayasich	Joseph M.	Research Associate	UMD: NRRI
McIntosh	Scott	Principal	McIntosh Engineering
McLean	Mel	Senior Designer	McIntosh Engineering
McMullin	Donald	Senior Engineer	McIntosh Engineering
Mecum	John	Principal	Miller Dunwiddie Architects
Michael	Charles	Project Manager	SEH Engineering
Miller	William	Lab Manager	UMTC: Soudan Laboratory
Nelson	Charles	Principal	CNA Engineers
Petersen	Lee	Project Manager	CNA Engineers
Peterson	Dean M.	Assistant Professor	UMD: NRRI
Peterson	Earl A.	Professor	UMTC: Physics/Astronomy
Pomry-Petry	D.	Research Fellow	UMD: NRRI
Ruddick	Keith	Professor	UMTC: Physics/Astronomy
Runkel	Tony	Senior Scientist	UMTC: MGS
Saar	Martin O.	Assistant Professor	UMTC: Geology/Geophysics
Severson	Mark J.	Research Fellow	UMD: NRRI
Tipping	Robert	Senior Scientist	UMTC: MGS

Tonon	Fulvio	Assistant Professor	U. of Utah: Geology/Geophysics
Watson	Sandy	Senior Estimator	McIntosh Engineering

Table 2. Work Breakdown Structure and Costs (UC=University Contribution)

Task	People Responsible	Effort Months	Effort Cost	Supplies Cost	Analysis Cost	Travel Cost	Total Cost
1.0 Project Coordination	M. Marshak, E. Peterson	0.5 UC 0.5 UC					
1.1 Coordination with Solicitation 1 Physics Opportunities	E. Peterson, K. Heller, Y. Kamyshkov	0.2 UC 0.2 UC 0.2 UC					
1.2 Coordination with Solicitation 1 Geoscience Opportunities	D. Peterson, J. Goodge	0.5 0.25	$2708 $1667				$4375
2.0 Site Characterization	D. Peterson	1.0	$5417			$1000	$6417
2.1 Borehole Management	D. Peterson S. Hauck	0.1 0.25	$542 $1526				$2068
2.1.1 Core Logging and Analysis	D. Peterson M. Severson	1.5 1.5	$8125 $7307	$2000		$3000	$20432
2.1.2 Borehole Geophysics	V. Chandler T. Runkel R. Tipping	0.25 0.5 0.25	$1522 $2353 $1131			$1000	$6006
2.1.3 Rock Mechanics Characterization	F. Tonon Graduate Student[1]	0.25 UC 1.0	 $1660			$1000	$2660
2.1.4 Geohydrology	C. Alexander M. Saar S. Alexander R. Tipping	0.75 0.5 0.75 0.25	$6022 $3467 $2243 $1131	$1000	$6000	$1125	$20988
2.1.5 Geomicrobiology	T. Kieft[1] D. Bond T. LaPara	1.0 0.25 0.25	$9310 $1500 $1843	$1500	$12000	$5000	$31153
2.2 Structural Modeling	V. Hansen M. Jirsa	0.5 0.75	$2623 $7083		$1575	$1250	$12531
2.3 Petrology, Petrography, Geochemistry	G. Hudak[1] J. Goodge	0.75 0.5	$4456 $3333		$8940	$1250	$17979
2.4 Ecology Baseline	D. Pomry-Petry K. Johnson J. Mayasich	1.0 0.75 0.5	$2485 $2845 $2489	$800	$4500	$2250	$15369
3.0 Engineering and Design[2]	CNA Engineers McIntosh Engineers Miller Dunwiddie SEH Engineers Dunham Associates	3.5	$64780			$9200	$73980
3.1 Access	CNA Engineers McIntosh Engineers Miller Dunwiddie	1.1	$18801				$18801
3.2 Underground Layout and Design	CNA Engineers Miller Dunwiddie Dunham Associates	1.9	$34870				$34870

3.3 Site Layout Planning	SEH Engineers	0.3	$6086				$6086
3.4 Surface Facilities Layout and Design	Miller Dunwiddie Dunham Associates	0.2	$4065				$4065
3.5 HVAC and Other Mechanical Systems	Miller Dunwiddie Dunham Associates	0.6	$12832				$12832
3.6 Electrical	Miller Dunwiddie SEH Engineers Dunham Associates	0.6	$13434				$13434
3.7 Fire and Life Safety	CNA Engineers Miller Dunwiddie Dunham Associates	0.7	$15286				$15286
3.8 Environmental Assessment	SEH Engineers	0.4	$8114				$8114
3.9 Public Participation	W. Miller M. Marshak	0.25 UC 0.25 UC					
3.10 Risk Management	M. Marshak L. Petersen	0.25 UC 0.1	$2308				$2308
4.0 Integration of DUSEL Planning with Existing Opportunities	W. Miller E. Peterson	0.25 UC 0.25 UC					
4.1 Low Background Counting Facility (LBCF)	P. Cushman	0.25 UC					
4.2 Cryogenic Dark Matter Search (CDMS 2)	P. Cushman	0.25 UC					
4.3 Geoscience and Geoengineering	D. Peterson F. Tonon[1]	0.25 0.2	$1354 $1400				$2754
4.4 MINOS and NUMI Beamline	E. Peterson K. Heller A. Habig	0.1 UC 0.1 UC 0.1 UC					
4.5 Education and Outreach	P. Cushman W. Miller K. Heller A. Habig	0.25 UC 0.25 UC 0.25 UC 0.1 UC					

Note 1: These costs plus fringe and indirects roll up into Sub-Contracts.
Note 2: All costs shown for Engineering Companies roll up into Sub-Contracts.

Table 3: Details of the "Sub-Contract" Item (Total: $321,642)
1. Sub-Contract to Borehole Driller: $117,386 (This amount is sufficient to drill the borehole to ~1,000 m. The State of Minnesota Iron Range Resources and Rehabilitation Agency has identified the additional funds required to extend the borehole to a depth of 1,600 m.)
2. Sub-Contract to University of Utah for Professor Tonon and Graduate Student: $5490
3. Sub-Contract to New Mexico Tech for Professor Kieft: $15,550
4. Sub-Contract to University of Wisconsin for Professor Hudak: $7,440
5. Sub-Contracts to five engineering and architectural companies: $189,776

Current and Pending Support

(See GPG Section II.C.2.h for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: **Marvin Marshak**	Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **Experimental and Theoretical High Energy Physics**

Source of Support: **U.S. Department of Energy**

Total Award Amount: $ **2,173,000** Total Award Period Covered: **11/01/04 - 10/31/05**

Location of Project: **University of Minnesota**

Person-Months Per Year Committed to the Project. Cal:**0.00** Acad: **2.00** Sumr: **2.00**

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **Site and Conceptual Design for the Soudan Deep Underground Science and Engineering Laboratory**

Source of Support: **National Science Foundation**

Total Award Amount: $ **500,000** Total Award Period Covered: **07/01/05 - 12/31/05**

Location of Project: **University of Minnesota**

Person-Months Per Year Committed to the Project. Cal:**1.00** Acad: **0.00** Sumr: **0.00**

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **Soudan DUSEL Site Characterization Study**

Source of Support: **State of Minnesota**

Total Award Amount: $ **250,000** Total Award Period Covered: **07/01/05 - 06/30/06**

Location of Project: **University of Minnesota**

Person-Months Per Year Committed to the Project. Cal:**0.00** Acad: **0.00** Sumr: **0.00**

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Summ:

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Current and Pending Support

(See GPG Section II.C.2.h for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: **Thomas Kieft**	Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **Collaborative Research: South African Ultradeep Mines Long-Term Sites for Interdisciplinary Studies (LSLIS) into the Extreme Environment of the Deep Subsurface**

Source of Support: **NSF (subcontract to Princeton University)**

Total Award Amount: $ **211,086** Total Award Period Covered: **11/01/99 - 10/31/05**

Location of Project: **New Mexico Tech**

Person-Months Per Year Committed to the Project. Cal:**0.00** Acad: **0.00** Sumr: **1.00**

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **Interdisciplinary Science for the Environment: Research Experiences for Undergraduates at New Mexico Tech**

Source of Support: **NSF**

Total Award Amount: $ **261,945** Total Award Period Covered: **01/01/05 - 12/31/07**

Location of Project: **New Mexico Tech**

Person-Months Per Year Committed to the Project. Cal:**0.00** Acad: **0.00** Sumr: **0.50**

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **Biological hazard detection system for pathogen detection and surveillance, Phase I Proposal**

Source of Support: **Office of Naval Research**

Total Award Amount: $ **6,785,050** Total Award Period Covered: **04/01/00 - 09/30/05**

Location of Project: **New Mexico Tech**

Person-Months Per Year Committed to the Project. Cal:**0.00** Acad: **0.00** Sumr: **1.00**

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **Collaborative Proposal: Energetics of the Deep Biosphere: Biogenic and Abiogenic Processes**

Source of Support: **NSF**

Total Award Amount: $ **304,922** Total Award Period Covered: **10/01/05 - 09/30/08**

Location of Project: **New Mexico Tech**

Person-Months Per Year Committed to the Project. Cal:**0.00** Acad: **0.00** Sumr: **1.00**

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **Collaborative Research: Microbially Mediated C Transformation Coupled to S cycling in Deep Subsurface Fissure Waters**

Source of Support: **NSF**

Total Award Amount: $ **118,696** Total Award Period Covered: **10/01/05 - 09/30/08**

Location of Project: **New Mexico Tech**

Person-Months Per Year Committed to the Project. Cal:**0.00** Acad: **0.00** Summ: **0.50**

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Current and Pending Support

(See GPG Section II.C.2.h for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: **Thomas Kieft**	Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **Immuno-PCR Detection of Biological Food Contamination**

Source of Support: **New Mexico Waste Management Education & Research Consortium**

Total Award Amount: $ **65,076** Total Award Period Covered: **08/02/05 - 08/01/05**

Location of Project: **New Mexico Tech**

Person-Months Per Year Committed to the Project. Cal:**0.00** Acad: **0.00** Sumr: **0.00**

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **IGERT: Hydrology and Critical Inferactions Between Rock, Chemistry, and Life (Hydro-CIRCL) (Dr. Penny Boston, PI)**

Source of Support: **NSF IGERT Program**

Total Award Amount: $ **3,024,179** Total Award Period Covered: **09/01/05 - 08/31/05**

Location of Project: **New Mexico Tech**

Person-Months Per Year Committed to the Project. Cal:**0.00** Acad: **0.00** Sumr: **0.00**

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **Site and Conceptual Design for the Soudan Deep Underground Science and Engineering Laboratory (Marvin Marshak, PI) (This proposal)**

Source of Support: **NSF**

Total Award Amount: $ **500,000** Total Award Period Covered: **07/01/05 - 12/31/05**

Location of Project: **University of Minnesota**

Person-Months Per Year Committed to the Project. Cal:**0.00** Acad: **0.00** Sumr: **0.00**

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Summ:

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Current and Pending Support

(See GPG Section II.D.8 for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: **Dean Peterson**

Other agencies (including NSF) to which this proposal has been/will be submit-

Support: ☐ Current ■ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **Soudan DUSEL Site Characterization Study**

Source of Support: **State of Minnesota**

Total Award Amount: $ **250,000** Total Award Period Covered: **07/01/05 - 06/30/06**

Location of Project: **University of Minnesota**

Person-Months Per Year Committed to the Project. Cal: **3.00** Acad: Sumr:

Support: ■ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **Soudan Mine DUSEL Support Grant**

Source of Support: **University of Minnesota**

Total Award Amount: $ **75,000** Total Award Period Covered: **01/01/05 - 06/30/05**

Location of Project: **University of Minnesota**

Person-Months Per Year Committed to the Project. Cal: **1.50** Acad: Sumr:

Support: ■ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **Lode Gold and Volcanogenic Massive Sulfide Deposit Mineral Potential Analysis of the Western Vermilion District, Northeastern Minnesota**

Source of Support: **Permanent University Trust Fund, University of Minnesota**

Total Award Amount: $ **50,000** Total Award Period Covered: **09/01/04 - 08/31/07**

Location of Project: **University of Minnesota Duluth**

Person-Months Per Year Committed to the Project. Cal: **6.00** Acad: Sumr:

Support: ■ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **Detailed Geological Mapping and Drill Hole Targeting for High-grade, Copper-Platinum-Palladium-Gold Vein Systems in the Footwall Rocks of the North Range, Sudbury Igneous Complex, Ontario**

Source of Support: **Wallbridge Mining Company Limited**

Total Award Amount: $ **40,000** Total Award Period Covered: **06/10/05 - 06/09/06**

Location of Project: **Sudbury Ontario, Canada**

Person-Months Per Year Committed to the Project. Cal: **6.00** Acad: Sumr:

Support: ■ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **3D Modeling and Copper-Nickel Deposit Visualization Along the Basal Zone of the South Kawishiwi and Partridge River Intrusions, Duluth Complex, Northeastern Minnesota**

Source of Support: **Permanent University Trust Fund, University of Minnesota and the Minerals Coordinating Committee**

Total Award Amount: $ **179,000** Total Award Period Covered: **07/01/02 - 06/30/06**

Location of Project: **University of Minnesota Duluth**

Person-Months Per Year Committed to the Project. Cal: **24.00** Acad: Sumr:

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*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Facilities, Equipment and Other Resources

Underground Laboratory: The Soudan Underground Laboratory, which the University of Minnesota has operated since 1980, is the principal underground science and engineering laboratory in the United States. The Soudan Laboratory's assets for the proposed work are discussed in the Project Description.

Neutrino Beam: There are two long baseline neutrino beams operating in the world. The Fermilab-to-Soudan beam (735 km) has better potential reach for measuring neutrino oscillation parameters. This beam represents an investment of $125 million; it cannot be aimed at any other potential DUSEL site.

Natural Resources Research Institute (NRRI): NRRI facilities and equipment include:

Economic Geology Group: 3D computing capabilities (AutoCAD, gOcad and Gemcom software licenses); GPS and traditional surveying equipment; research-grade reflecting petrographic microscopes; ceramic kilns; rock cutting, polishing, and thin section laboratory; clay characterization laboratory; and underground safety equipment (headlamps, self rescuers).

Coleraine Minerals Research Laboratory: Fully equipped mineral-processing laboratory for both bench- and pilot-scale testing. Research equipment includes:

Crushing:	Jaw crushers, Gyratory crusher, Roll crushers, Hammer mill, Pulverizers.
Grinding:	Rod Mills, Ball Mills.
Classification:	Screening plant, Screw classifiers, Cyclones, Density separators, Rake classifiers
Magnetic Separation:	Drum separators, Davis Tubes, Wet and Dry High Intensity, Induced rolls.
Gravity separation:	Spirals, Table, Reichart Cone, Falcon Concentrator
Flotation:	Conventional cells, Column flotation
High Temperature:	Electric, Linear hearth, Induction and Pot-Grate furnaces
Analytical:	ICP, Automated titration, CVAFS for mercury

Ely Field Station: This laboratory, located at Vermilion Community College, is equipped for research on freshwater algae and neo- and paleolimnology. Key equipment includes water samplers, field water quality meters, a digital imaging system on a research microscope, sediment corers/extruders and freeze samplers, sediment driers, a furnace, a fume hood, a deionized water system, a centrifuge, a balance, and multiple computers set up for image processing, databasing, and ecological statistics.

Minnesota Geological Survey (MGS): Facilities and equipment owned by MGS include:

Gravity and Magnetic Equipment: LaCoste-Romberg number 320 gravity meter; Eberbach jolly balance for density determinations; Geometrics Model G-856AX portable precession magnetometer; Bison Instruments Model 3101 magnetic susceptibility meter; Schonstedt SSM-1A spinner magnetometer, for natural remanent magnetization measurements; EDA Model K-2 hand-held magnetic susceptibility meter U. S. Geological Survey Potential Field Software, version 2.2

Seismic Equipment: Bison Instruments Model 5012, 12 channel seismograph, plus accessories (cable, geophones, etc.); Bison Instruments Model 9024, 24 channel seismograph, plus accessories (cable, geophones, etc.); Bison Instruments Model EWG-1 seismic source (trailer-towed impact source); Betsy Seisgun seismic energy source (shot gun shell source); Sledgehammer seismic source with trigger; VIEWSEIS seismic interpretation software; EAVESDROPPER seismic interpretation software

Resistivity Equipment: Bison Instruments Model 2350 B Earth Resistivity system, plus accessories (cable, electrodes, etc.); Bison Instruments Model 2390 Earth Resistivity system, plus accessories (cable, electrodes, etc.); Interpex RESIX MM PLUS and SOUNDER resistivity interpretation software.

Electromagnetic Equipment: MAXMIN I-8S EM (electromagnetic) system, plus accessory cables; Interpex EMIX MM PLUS EM interpretation software

Borehole Geophysical Equipment: Century Geophysical Corporation Series VI Logging System—Natural gamma, caliper, temperature, resistivity, SP, fluid resistivity, and flowmeter logs.

Advanced Genetics Analysis Center (AGAC): Instrumentation available at the AGAC includes ABI 377 automated DNA fragment analyzers, a 3948 Perkin-Elmer 48-column oligonucleotide synthesizer, automated Hydra 96 pipetting systems, a Beckman robotic workstation, a BioRobotics Total Array System, a GSI Lumonics ScanArray 5000 and Perkin-Elmer 2400 and 9700 thermal cyclers. Supporting equipment includes high-speed microplate centrifuges, microplate vacuum centrifuges and manifolds, thermal cyclers and bench-top centrifuges to enable high-throughput sample preparation.

Special Information and Supplementary Documentation

Rationale for performance of all or part of the project off-campus or away from organizational headquarters: The proposed work will be performed at the University of Minnesota's campuses in the Twin Cities (Minneapolis and St. Paul) and Duluth and at the Soudan Underground Laboratory, located in Breitung Township, St. Louis County, Minnesota. The rationale for performing work at Soudan is this location is the site of the largest existing underground science and engineering laboratory in the United States and that expanding this laboratory is the goal of this Proposal.

Environmental impact statement for activities that have an actual or potential impact on the environment: While the actual Soudan DUSEL project may have an impact on the environment, the site studies and conceptual design activities proposed here will be managed to result in minimal environmental concerns. The borehole drill site will be positioned away from wetlands and in an area that is easily reachable from Trunk Highway 169 by 4-wheel drive vehicles with minimal impact on trees or other vegetation. Drill cores will be removed and stored. Drilling fluids and "mud" will be managed to mitigate impacts on the surroundings. Data collection activities other than drilling will be performed by teams mostly traversing on foot. Some data will be collected by aerial surveys. Conceptual design activities will mostly be performed in the offices of engineering firms and will have little or no impact on the environment.

Research in a location designated a registered historic place: The Soudan Mine was the first iron mine in Minnesota and is a Registered National Historic Site. During the previous two Soudan Laboratory construction projects (1984-1986 and 1999-2001), the University of Minnesota worked with the State Historic Preservation Office (SHPO), which is the Minnesota Historical Society, to manage and mitigate any project impacts on the historic site. The SHPO position on those projects was that the Soudan Laboratory was a historic re-use, that is, new mining in a site that is historic for mining. The required mitigations involved minimal efforts (a small wooden wall, lighting, etc.) to block the modern underground laboratory from the view of visitors participating in the historic tour program. While DUSEL is a larger project, most activity will be located ~1.5 km from the historic area. For that reason, neither the work proposed here nor the actual DUSEL project is expected to require any significant mitigation because of Soudan's historic status.