1 Introduction

This proposal is in response to the National Science Foundation Program Solicitation for a Deep Underground Science and Engineering Laboratory (DUSEL) Site and Conceptual Design (Solicitation-2: S2). The Henderson Underground Science and Engineering Project (HUSEP) Collaboration introduces a candidate site located at the Climax Molybdenum Company's Henderson Mine, near Empire, Colorado. This site presents a unique opportunity for science to benefit from the modern infrastructure of the existing commercial mining operation, which is strategically located between a commercial grade (and geologically interesting) ore body (Red Mountain) and a geologically stable formation (Harrison Mountain) of homogenous, competent granite ideal for tunneling and excavation of both large and small cavities.

In this proposal, we describe the Henderson mine, its setting and surrounding environment and the HUSEP organization; we outline the key features of the Henderson site relevant to establishment of DUSEL; we present a preliminary DUSEL layout, and our plans for developing a conceptual DUSEL design identifying both an initial suite of experiments and our 30-year vision for the facility; and we present plans for management, promotion of national and international collaborations, and education and outreach activities. The following list highlights some of the key proposed activities and goals for the S2 award period.

- Further explore science and engineering opportunities specific to Henderson DUSEL and develop a vision for experiments by (1) communicating with the potential user community, (2) holding a series of topical workshops on physics, mining & engineering, geoscience, and microbiology, and (3) holding a capstone workshop for the entire DUSEL community;
- Develop a detailed conceptual design of DUSEL that meets the requirements from the DUSEL solicitation 1 studies by (1) using existing in-house expertise at the Colorado School of Mines and the Henderson mine and (2) hiring professional consultant firms, such as CNA Engineers which has a long term association and experience with the particle physics underground facilities, and McIntosh Engineering, a firm well-known for their expertise in underground mining engineering and construction;
- Develop a detailed work plan for co-usage of the Henderson infrastructure for mining operation and DUSEL construction and experimental activities;
- Develop a strategy for a smooth transition from the period of active mining operation of the mine to the period after cessation of the mining operation in about 20 years by working closely with Henderson/Phelps-Dodge and the Colorado state government, possibly through a special state commission.
- Continue initiatives leading to securing tangible support from local government, national and international partners;
- Develop an efficient and effective DUSEL management plan supported by all involved parties;
- Develop a concrete plan for public awareness of Henderson DUSEL education and outreach and hold a series of mini-workshops for teachers and other educators.

The proposal includes a project management plan, schedule, and budget. Supplementary material accompanying this proposal contains: one-page report on the core-drilling project performed in 2004 into the region of the planned DUSEL central campus; copies of the environmental certificates and mining permits; supporting letters and documents from the Henderson Mine, the Colorado state government, and the local community; committment letters from the consulting firms; and a statement from Brookhaven National Laboratory on the suitability of DUSEL candidate sites for the proposed very long baseline neutrino oscillation experiment.

2 Henderson Mine Overview

The Henderson Mine is owned and operated by the Climax Molybdenum Company (CMC), a subsidiary of the Phelps Dodge Corporation with corporate headquarters in Phoenix, Arizona. Using an underground mining method known as panel caving, the mine currently produces 28,000 tons of raw ore per day, with estimated reserves for about twenty more years of production.

The mine site is located 50 miles west of Denver, Colorado, and lies 10,400 feet above sea level on the eastern side of the Continental Divide. It is easily reached from Denver International Airport in less than 1.5 hours by an interstate freeway, US highway, and a short distance on a paved, well maintained access road. The 2900 acre mine site is privately owned by CMC and is surrounded by the Arapaho National Forest. The site contains two mountain peaks: Red Mountain, under which the molybdenum orebody is located, and Harrison Mountain, which is believed to be barren of economically viable mineral deposits.

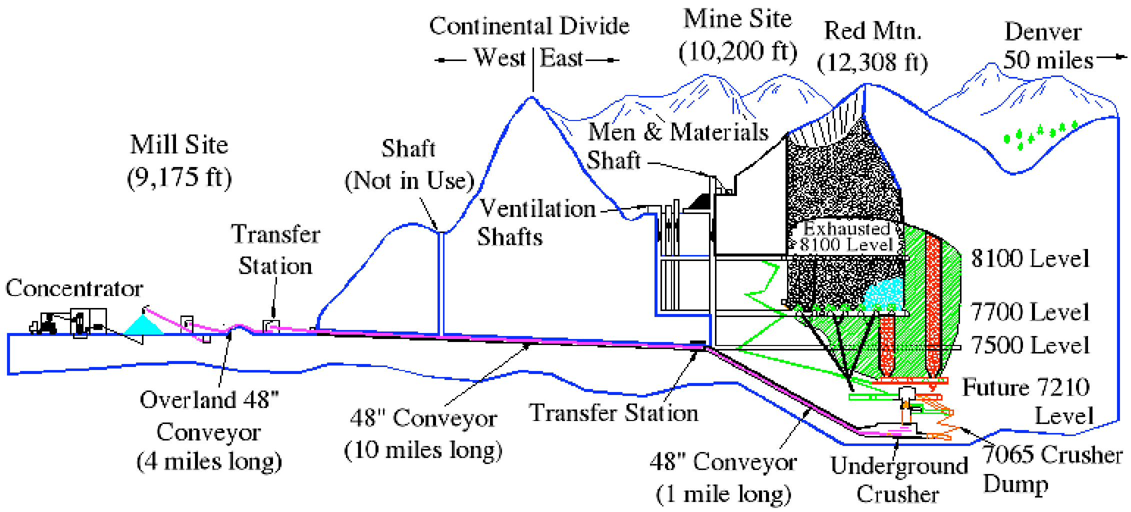

Figure 1: Idealized cross section of the Henderson Mine infrastructure.

The Henderson ore body is the second largest known molybdenum deposit in the world today. The general nature of the orebody and the surrounding host rock is that of high strength granite with compressive strengths ranging from 14,500 to 40,000 psi. The average specific gravity of this rock is about 2.5. The area under Red Mountain has been extensively explored with 606 boreholes, totaling 90 miles of core drilling. These drill holes, located both within and outside the orebody, provide detailed information about the geology as well as the geotechnical aspects of the rock mass. The Henderson orebody has been studied extensively, and numerous journal articles and reports have been published [e.g. see ref. [3]]. A wealth of additional information is available within the company.

One 2500 ft long drill hole, funded by the HUSEP member organizations and the State of Colorado, was drilled to an area 5500 ft directly below the summit of Harrison Mountain, the proposed DUSEL central campus location. The rock type was found to be competent Urad Porphory with a Rock Quality Designation in the range of 70 to 100. Based on this preliminary drilling, there is a strong likelihood that the area under Harrison Mountain is highly suitable for excavating the large openings required for DUSEL.

Henderson began operation in 1976 after a 10-year predevelopment program and a $500 million investment. The $150 million Henderson 2000 modernization program was completed in 1999. The mine was designed as a high capacity operation, and its infrastructure is engineered to support production in excess of 30,000 tons per day, making Henderson one of the ten largest underground mines in the world today.

The mine is accessed from the surface (10,200 ft) by a 28-foot diameter shaft for personnel and material to the 7500 level[1] (Fig. 1). An inter-level ramp extends from the 7500 level down to the 7065 truck level. Excellent rock mass conditions allowed a large underground excavation of the crusher station with dimensions of 61 ft wide × 48 ft high × 93 ft long in Vasquez Porphyry, and the PC1/PC2 ore transfer station in Silver Plume Granite. After crushing, the ore is transported to the mill site by a series of conveyor belts, including the 10 mile PC2 belt, which is the longest single flight conveyor in the world. Mill tailings are placed in large containment areas that will be reclaimed and re-vegetated when the mine is closed.

Because of the substantial available infrastructure, the overall costs for developing DUSEL at Henderson will be low. The infrastructure available for DUSEL includes:

- **Large Capacity Shaft:** The #2 shaft cages can transport up to 200 people at a time; the trip from the surface to the 7500 level takes about five minutes. The cage can accommodate 20-ft international shipping (ISO) containers weighing up to 30 tons. Loads of up to 50 tons can be carried if a crosshead is substituted for the cage and counterweights are used. Four other shafts are used for ventilation.
- **Drifts:** 150 miles of drifts provide access to various levels of the mine, some of which could be dedicated to DUSEL. Two Mine Safety and Health Administration (MSHA) approved emergency escape routes exist for the safe evacuation of personnel.

[1]Henderson identifies levels by their altitude above sea-level in feet.

- **Future Horizontal Access:** When mine production ends, the underground conveyors can be removed and the 10 mile long PC2 conveyor drift could be used to provide horizontal access to the underground laboratory from Grand County.
- **Rock removal system:** The mine conveyor system for rock removal was designed for a capacity of 40,000 tons per day, but the mine currently uses about 28,000 tons per day and estimates that no more than 35,000 will be needed in the future. The excess of 5,000 tons per day far exceeds the estimated 3,000 tons per day needed during DUSEL construction.
- **Mine ventilation:** The mine ventilation system has a capacity of 2,000,000 cfm provided through four shafts and three large surface fans. Of this, at least 100,000 cfm of excess capacity is available for DUSEL, significantly more than the 50,000 cfm estimated requirement.
- **Electricity:** The electrical network has a 100% redundant feed from two independent 13.8 KV power lines. Two 24 MW substations are integrated into the statewide distribution network and are located on the mine property. The mine currently uses 10 MW and reserves an additional 10 MW for backup. With the existing transformer stations, DUSEL would have 14 MW available with 14 MW for backup.
- **Mine dewatering:** The mine dewatering system has a capacity of 5000 gallons per minute (gpm). The mine is currently using about 1000 gpm. It is estimated that a maximum capacity of 500 gpm will be required to dewater the new DUSEL excavations.
- **Water treatment:** Mine water is treated at the Urad Water Treatment Plant, which has a capacity of 4000 gpm (the treated water is discharged into Clear Creek and used by various communities down stream). Historically, the mine has needed less than 2000 gpm, leaving ample excess capacity for estimated 500 gpm needed for the DUSEL excavations.
- **Concrete batch plant:** A concrete batch plant for mixing concrete and shotcrete that would be required during construction of the DUSEL is available. The batch plant has a capacity of 200 cu. yd. per day, of which the mine is currently using about 60 cu. yd. per day.
- **Office space:** Office space of 3600 ft^2 could be made available to DUSEL in the main office building.

3 HUSEP Collaboration

The HUSEP Collaboration [1] was formed to coordinate the establishment of an underground laboratory at Henderson. The PI and co-PI's of this proposal are all members of the collaboration and proposal preparation activities are carried out as an activity of the HUSEP collaboration.

At the core of the HUSEP organization is the Executive Committee, which establishes policies and makes all major decisions for collaboration matters. It is composed of one member each from The Arapaho Project Inc. [2] (S. Schultz), Univ. of Colorado (E. D. Zimmerman), Colorado School of Mines (M. Kuchta), Colorado State Univ. (R. J. Wilson) and Stony Brook Univ. (C. K. Jung), and two members from the Henderson Mine (C. deWolfe and R. Propernick). The Executive Committee communicates frequently with Henderson General Manager F. Menzer who is in close contact with CMC parent company Phelps Dodge.

The Spokesperson of the collaboration is elected by the Executive Committee to represent the collaboration nationally and internationally. Currently Jung holds this position, and he is also the PI of this proposal. The Spokesperson is assisted by a Deputy Spokesperson, who will be the Project Manager for the S2 project. This position is currently held by Wilson, who is a co-PI of this proposal.

The Executive Committee and the Spokesperson receive advice from the HUSEP International Advisory Board, which consists of renowned scientists and engineers as well as experienced managers. The current members are: A. Bettini, Univ. of Padua, Italy; W. Hustrulid, Univ. of Utah; L. Mosca, Saclay Lab, France; K. Nakamura, KEK, Japan; P. Paul, Stony Book Univ.; D. Sinclair, Carleton Univ., Canada; and S. Wojcicki, Stanford Univ. There are nine standing committees under the executive committee: Physical, Geological, and Biological Sciences; Mining and Engineering; Environmental Health and Safety; Industry Relations; Community and Regional Government Relations; Broader Impacts; and Homeland Security.

4 Science and Engineering at Henderson DUSEL

4.1 Overview

Scientific support for the DUSEL concept has been established in several national reports and proposals [4, 5, 6, 7, 8] during the last few years. A primary goal of NSF's DUSEL Solicitation 1 is to synthesize these past reports and combine them with new ideas developed during this process. In this section, we will not attempt to describe this impressive body of work; rather, we will simply identify the essential areas that drove the Henderson DUSEL preliminary conceptual design described in Sect. 5.

4.1.1 Physics

The physical requirements for DUSEL physics experiments are relatively independent of the site geology, except for an extraordinarily large cavern excavation required for a large water Cherenkov detector for nucleon decay searches and neutrino physics. Issues such as availability, accessibility, cost effectiveness, and flexibility will be important discriminating factors among candidate sites. The physical characteristics and infrastructure of Henderson are well-suited for essentially all physics modules in the draft S1 infrastructure matrix.

The primary requirement for most candidate DUSEL physics experiments is the amount of overburden, typically expressed in meters-water-equivalent (mwe), required to reduce the cosmogenic background to an acceptable rate. In this context, three basic classes of experiments are considered: (1) those, such as the EXO $0\nu\ \beta\beta$ experiment [9], and a general-purpose Low Level Counting Facility, that require a relatively modest overburden of 2000$\sim$2500 mwe; (2) a next generation nucleon decay and neutrino experiment such as UNO [10] that requires greater than 3500 mwe, and for which the engineering challenges and economic penalties grow considerably with depth; (3) finally, the class of exquisitely sensitive $0\nu\ \beta\beta$, dark matter search and solar neutrino experiments that require at least 6000 mwe and a deep low level counting facility.

One of the key physics goals for DUSEL depends strongly on the relative distance of the laboratory from two national accelerator labs, Brookhaven (BNL) and Fermilab. The measurement of the neutrino mixing angle θ_{13} and CP violation in the lepton sector has been reviewed by several national committees and rated as one of the highest priorities in particle and nuclear physics, as highlighted in the recent APS Neutrino Study Report [11]. This measurement requires a high intensity neutrino beam source directed towards a large underground detector. The distance between the detector and the neutrino beam source is generally recommended to be over 1000 km, but not much more than about 3000 km due to the reduction in the usable neutrino flux (See BNL statement, Supplemental Material and Refs. [12, 13]). Henderson is 1500 km from Fermilab and 2760 km from BNL, making it an ideal location to house a detector for such an experiment.

These key classes of experiments form the foundation for the basic structure of the laboratory; however, once the basic layout is established, other physics experiments can be added at modest additional cost.

4.1.2 Geosciences

In contrast to the physics modules, the array of geoscience studies that can be performed is, in part, intrinsically site dependent. Nevertheless, investigations focused on basic principles can be addressed at any site. Specifically, long-term access to the Henderson DUSEL provides the geosciences community with three key opportunities: (1) to characterize lithology, petrochemistry, geologic structures, hydrologic flow, and rock mechanics in three dimensions using large excavations, (2) to conduct *in situ* meso-scale experiments that bridge the gulf in both temporal and spatial scales between laboratory experiments and field tests, and (3) to monitor earth properties from long-term stations free from surface noise and weathering processes.

Most of the geoscience experiments discussed at S1 workshops are readily accommodated at Henderson. These include experiments to examine: (1) fluid flow through fractured rocks, especially hydrologic links between the surface and the deep underground; (2) the impact of stress regime on fracture development roughness, aperture, and interconnectedness; (3) coupling among thermal, mechanical, hydrological, chemical and biological processes in controlled settings at scales larger than the typical laboratory; (4) physical/chemical perturbation of characterized blocks, imaging, and eventual exhumation; (5) mineralogical and hydrochemical reactions, including biostimulation, on large spatial and temporal scales; (6) ground truth for geophysical imaging, including the ability to excavate and examine the volume imaged, and the opportunity to image known features from both the top down and the bottom up; and (7) installation of a Deep Seismic Observatory with an extensive underground 3-D array that complements EarthScope [14].

There are several unique geologic features at Henderson. For example, relatively homogeneous felsic intrusive rock can be accessed on the kilometer scale, greatly reducing chemical/mineralogical variables in experiments. These rocks, intruded at greater than 800°C, were biologically sterile at the time of emplacement 28 million years ago. Accessible sulfide-rich rocks lend themselves to a variety of biogeochemical experiments. Hydrologic studies focused on groundwater storage and flow in crystalline rocks are readily accommodated by accessing the surface above the DUSEL, tracking fluid flow through the system, and monitoring subsurface discharge into the adjacent sedimentary basin. Perhaps the most striking feature of this site is access to the roots of an extraordinarily well-studied, major ore body that can be examined by tunneling, drilling, and geophysical imaging. Magma evolution and emplacement mechanisms can be related to the kilometer-scale, three-dimensional geometry of the intrusive units. This work will build upon decades of description and scientific study by the Henderson mine staff and make use of thousands of feet of drill core, both made available by Phelps Dodge.

4.1.3 Microbiology

A deep research laboratory will provide essential support for surveys and experiments to test hypotheses (refs. [15], [16], [17]). We will determine which microbes are at the site, and how they are distributed with respect to water sources, depth beneath the surface, trace metal concentration and composition, temperature, pH, energetic resources, and growth limiting resources. Microbial communities and their metabolic capabilities will be characterized by culture-dependent (enrichments, MPNs, activity studies) and culture-independent approaches (16S rDNA, functional genes, and lipid analyses). Sequence analyses will be used to measure the variability within the community and will allow one to determine the proportion of new and unique clades and species. One intriguing possibility is that a thorough survey of microbes will yield not only previously unknown species, but species or clades that are truly ancient, which we may then compare to hypotheses about how species are delimited by depth, temperature, metal composition/concentration, moisture, and other geophysical parameters. New species of microorganisms will be examined to determine whether they provide any unique features that could be exploited for either biomedical or industrial applications.

The Henderson site has several advantages for microbial studies. Background information on surface microbial communities in nearby high elevation sites have been published ([18], [19]). The mine itself has never been flooded, and thus is optimal for studying pristine sites. Molybdenum is a trace metal necessary for metabolism, and high concentrations have probably driven microbial evolution for tolerance to, or sequestration of molybdenum or of the other minerals in high concentration. Water sources in the mine have a very wide range of pH, and this range of environments provides additional opportunities for novel physiological adaptations. Finally, water in the deepest portion of the mine is 120°F, providing a wide range of thermal environments, some quite extreme.

4.1.4 Geological Engineering

In an increasingly crowded world, underground excavations are needed to provide facilities that cannot be located above ground. Henderson Mine would provide a world class facility for a state-of-the-art experimental underground excavation laboratory. It would provide unprecedented testing facilities for tunneling technology including instrumented tunnel construction and tunnel sealing experiments, modern (including unmanned) excavation technology and equipment development. Mechanical and engineering properties of rocks under varied stress conditions during excavation of large cavities can be studied using different modeling techniques, micro-seismic research and other emerging rock mechanics technologies. Such a facility would be invaluable to institutions, contractors, and manufacturers in mining and underground construction that do not have such a facility or need a larger one.

4.2 Developing a Plan for Short-term and Long-term Experiments at Henderson DUSEL

A primary purpose of the proposed project is to develop a detailed plan for an initial suite of experiments that incorporates the results of the S1 report and to provide a multi-decade plan for a facility that can accommodate a constantly evolving set of technical requirements and budget constraints.

Though members of the HUSEP team have considerable expertise across the spectrum of DUSEL research and engineering design areas, optimization of the laboratory design and choice of experiments will require the participation of the broadest possible segment of the community. Specific tasks towards this aim are:

Task CD-1 Continued participation in DUSEL related workshops and other venues.

Task CD-2 Organization of a sequence of four focused topical workshops (physics, mining & engineering, geoscience, and microbiology) to review the requirements described in the S1 report in the context of the Henderson site; each workshop will feature an integrated broader impacts component.

Task CD-3 Organization of a capstone workshop for the entire DUSEL community to compile, refine and further develop the results of the previous workshops.

Task CD-4 Direct communication between the HUSEP team and the leadership of candidate experiments.

Task CD-5 Presentations at the major professional gatherings, such as the American Physical Society, the American Geophysical Union, American Society for Microbiology, and the Society of Mining Engineers.

Task CD-6 Consolidation of the recommendations of S1 reports from the workshops and meetings to generate a comprehensive plan for experiments at Henderson DUSEL.

5 Henderson DUSEL Preliminary Conceptual Design

Fig. 2 illustrates the preliminary Henderson DUSEL conceptual design. Main laboratory areas for physics experiments would be located under Harrison Mountain, where core drilling has shown the rock mass to be competent Urad Porphyry, well suited for large excavations. The area under Red Mountain provides a highly variable geologic environment hosting a 360 million ton molybdenum deposit, and provides excellent possibilities for a variety of geoscience experiments. Additionally, the site provides large volumes of uncontaminated rock for biogeology research. The following sections outline the development of DUSEL at Henderson in three phases that will optimize the availability, cost, and flexibility of the facility.

5.1 Phase 1: Upper Campus

The Upper Campus will be developed first and located within existing mine openings, including the currently unoccupied 8100 shop area (32,000 ft^2, $\sim$2500 mwe overburden); the 7700 underground shop area (34,000 ft^2, $\sim$2900 mwe overburden); and in the 7500 former production level ($\sim$3300 mwe overburden). After a modest clean-up and renovation effort, these areas can be made available for occupancy within one year.

An example of a physics experiment that could take almost immediate occupancy is the EXO $0\nu\ \beta\beta$ decay experiment and some low level counting experiments. Geoscience observations and experiments could begin immediately with characterization of the local geology and surface downward imaging and hydrologic studies. Investigations for the second year include drill cutouts on the 10 m scale, and various extended rock mechanics studies. Microbiologists could begin to establish controlled environment facilities and sampling from these existing chambers and potentially within the molybdenum ore body.

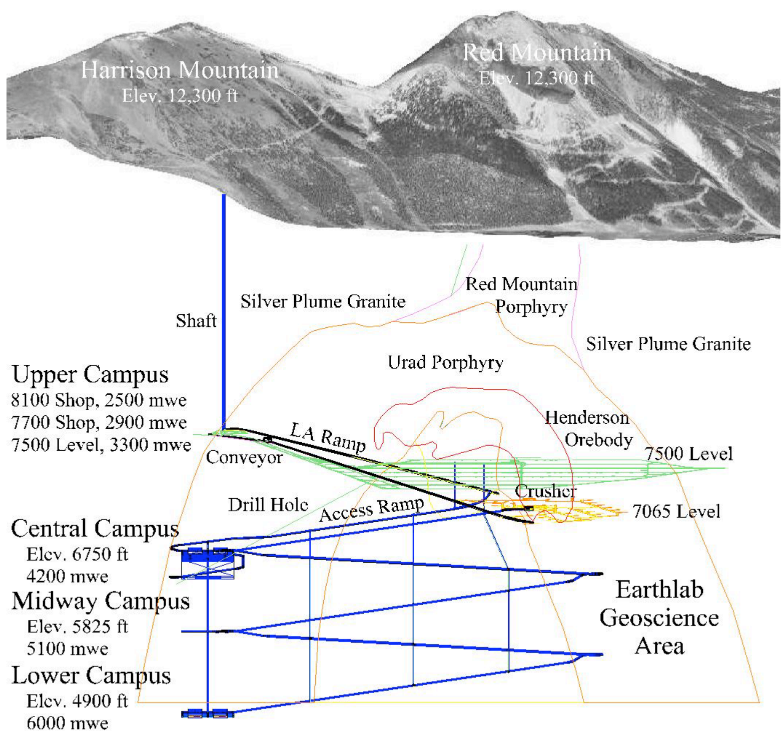

Figure 2: Vertical section through Red Mountain and Harrison Mountain showing the Henderson orebody and host rocks, some of the existing mine infrastructure, and a preliminary conceptual design for DUSEL.

5.2 Phase 2: Central Campus

Development of the Central Campus area with an overburden of 4200 mwe underneath Harrison Mountain will include access drifts and the laboratory space consisting of several large general-purpose experimental halls (20m×20m×100m), and would be the location for a single very large cavity (or a grouping of several large cavities) suitable for nucleon decay and very long baseline neutrino oscillation experiment such as UNO.

The existing 2500 ft vertical shaft will be used for access from the surface to the 7500 production level. From the shaft bottom, the existing LA Ramp would be used to transport personnel and materials to a point just above the 7065 production level. A new 3600 ft long primary access ramp would be driven from this point to the Central Campus area located 5550 ft directly below the summit of Harrison Mountain. A new 3200 ft secondary access ramp will connect the Central Campus to the 7065 level and provide a route to the crusher for rock removal and provide the secondary emergency evacuation route. Bored raises will connect the access drifts to the fresh and exhaust air systems for the mine. This phase will be completed by the end of Year 3. Excavation of the very large cavity could proceed with minimal interference to the operation of the first round of experiments at this campus. Physics experiments such as the MAJORANA double-β decay experiment [20] and WIMP searches could begin installation. Geoscientists could begin construction of test blocks and perform subsurface imaging experiments.

5.3 Phase 3: Lower Campus

The Lower Campus will be developed to provide at least 6000 mwe overburden. The current conceptual design places the campus at a depth of 7400 ft under Harrison Mountain with access through a new 21000-ft long inclined ramp, a new 2000 ft long internal bored shaft connecting the Central Campus to the Lower Campus, and laboratory space consisting of several large general-purpose experimental halls (20m×20m×50m).

The ramp will pass twice under Red Mountain and provide access to a rich and varied geologic environment. We envision two modest-sized stations in the roots of the ore body as bases for geo- and bio-science experiments. Geoscientists could perform bi-directional imaging from these bases, and perform a variety of coupled processes and perturbation experiments in these and deeper regions.

If demand arises, a small Midway Campus could be developed vertically midway between the Central and Lower campuses that would be available to experiments by Year 5 and would provide sufficient overburden for solar neutrino experiments such as HERON [21] and CLEAN [22].

The Lower Campus phase will be completed by the end of year six. Future generations of $0\nu\beta\beta$ decay, cold dark matter search and low energy solar neutrino experiments (such as MOON [23] and a next generation Super-CDMS experiment) most sensitive to cosmogenic backgrounds could be performed at this depth.

6 Development Plans and Site Specific Issues

Project tasks for planning the development, operation, and maintenance of the infrastructure required for Henderson DUSEL, and plans for addressing a series of critical site-based issues are described in this section.

6.1 Developing the Infrastructure

The concept described in Sect. 5 will form the basis for preliminary design efforts. The three-phase development concept will be linked to specific modules of experiments, and the design process will produce a robust baseline design with reliable capital and operating cost estimates. Specific tasks include:

Task DP-1 Develop the strategic vision and design criteria of laboratory development and operations. This task establishes the high-level guidelines upon which all other design work will be based.

Task DP-2 Develop project work breakdown structures for capital and operating costs.

Task DP-3 Develop a conceptual design of surface facilities required to support the science program for each of the three phases of laboratory development. Surface facilities will include office space, dormitories, cafeterias, laboratory space, staging areas for experiment assembly, facilities for core storage, academic/outreach programs, etc. Some of the surface facilities will be located at the mine site, while others may be located in Empire or other nearby communities.

Task DP-4 Develop and evaluate underground access alternatives. This would include evaluating locations and lengths of tunnels/shafts based upon accessible slope options, egress options to comply with codes, accessibility to experimental geology and evaluation of geology for cavern systems. Phasing and coordination of overlap with mining access will be a key focus of this task.

Task DP-5 Develop and evaluate underground lab layout alternatives. This would include, massing and relationship diagrams of physics and geoscience labs and estimates of required utility and support spaces serving the common facility. S1 infrastructure requirement matrices would be used as a basis for this work.

Task DP-6 The information compiled in task GS-1 will be evaluated critically to determine the range of relevant geotechnical parameters appropriate for conceptual-level analyses to determine underground excavation and support requirements.

Task DP-7 Preliminary Geomechanical Modeling. Two-dimensional and select three-dimensional numerical simulations of the most critical excavations will be performed to evaluate underground excavation and support requirements. The existing conditions of select mine openings, including overbreak characteristics, geometrical characteristics, water inflows, and ground support will be compiled and considered in developing estimates regarding design and construction requirements for development of DUSEL.

Task DP-8 Develop conceptual design of underground access, lab layouts, and ventilation raises and other project components.
Task DP-9 Develop conceptual design of primary mechanical and electrical systems for lab occupants, experiments and fire and life safety.
Task DP-10 Develop the project development cost estimates, including construction costs.
Task DP-11 Develop the construction schedule and phasing.
Task DP-12 Develop an overall construction management plan and project delivery strategy.

6.2 Geological and Geotechnical Site Characterization

Henderson management will make the relevant portions of the company's exploration database available for the planning of the DUSEL. The existing database includes an extensive suite of geomechanical information, including rock strength and deformability measurements, fracture spacing and orientation, *in situ* stress measurements, rock mass permeability and water inflow rates, and engineering rock mass classification data. Additionally, continuous core samples and initial laboratory test results from an approximately 2500 foot long exploratory boring through the site of the proposed Central Campus are available. The proposed scope of work related to site geological characterization is summarized below.

Task GS-1 Develop a geologic model. The existing geologic database for Henderson Mine will be compiled and summarized to finalize the plan for engineering, geoscience, and geobiology research at the site.
Task GS-2 Analyze the 2500 ft core and borehole from the 7500-level toward the proposed Central Campus. Geological, geochemical, and hydrogeologic analysis will constrain the age, source, and composition of existing water in fractures, provide an approximation of rock chemistry and the extent of water-rock interactions, and establish a baseline for proposed experiments.
Task GS-3 Examine the scientific characteristics of the underground environment to include local radioactivity, and microbial abundance, diversity and activity.
Task GS-4 Develop plans for a low level screening facility and assess the need for an extremely low level counting facility.
Task GS-5 Develop a detailed design-level exploration drilling program with cost estimates. This work is likely to include additional drilling and sampling, *in situ* hydrologic tests and stress measurements, laboratory testing, and geophysical studies.

6.3 Handling Construction Uncertainty

To confirm that the excavation performance criteria are satisfied, it is necessary to monitor and evaluate the actual ground conditions encountered during construction. Deviations of actual ground conditions and behavior from those assumed during design can then be evaluated, and, if necessary, design modifications to ensure excavation performance can be implemented. The specific subtasks to be performed to develop a plan for handling construction uncertainty are:

Task CU-1 Develop ground support designs. The potential adverse impacts of differing site conditions will be mitigated by developing a spectrum of ground support systems (classes) to accommodate the potential variability of subsurface conditions.
Task CU-2 Develop excavation documentation routines. Robust excavation documentation and monitoring systems will be specified. Details of these systems will be established based on analytical and numerical simulations of the construction and excavation process, and are expected to include: (1) manual and digitized recordings of ground conditions, particularly discontinuity characteristics; (2) laboratory testing of rock samples in select areas; (3) convergence arrays; (4) multi-point borehole extensometers; and (5) systems to provide advance warning of potential rock burst conditions.
Task CU-3 Design rapid feedback system. Within the limits of practicality, a "real-time" data feedback system will be specified for this project, so that important engineering decisions and modifications can be made near the face of the advancing excavations.
Task CU-4 Develop a Construction Risk Management Plan tailored to the specific Henderson DUSEL construction uncertainties. Since the type and style of design and construction contracting chosen for project implementation is the first major decision, several major contracting method (design-bid-build, design-build, etc.) will be evaluated for strengths and weaknesses in the framework of the project, including the three-party contract (CMC, owning entity and contractor). Risk management tools such as Geotechnical Data Reports, Geotechnical Design Summary Reports, and Geotechnical Baseline Reports will be used to identify

the project risks, mitigate risks to the extent practical, and assign risks via the design and construction contracts to those parties most able to control and manage the outcomes.

6.4 Health and Safety

The importance of the health and safety of the personnel who will work at Henderson DUSEL cannot be overstated. A great strength of this site is that DUSEL will benefit from the experience of the mine owners, management, and personnel who have established an enviable record. Phelps Dodge is an organization that embraces safety and environmental stewardship as core values in the work place and in the employee's personal lives. As standard policy, the company expects its suppliers, contractors, and other associations to comply with all Phelps Dodge regulations and all regulatory safety laws. A plan for a comprehensive safety program for DUSEL will be developed as follows:

Task HS-1 Develop plans for a comprehensive safety program for DUSEL and insure that appropriate systems are engineered into the overall lab layout and design. The program will include, but is not limited to, major components in the following list: incident prevention, chemical management, occupational health, emergency preparedness, ventilation and security.

Task HS-2 Identify the applicable codes and regulatory agencies that will enforce compliance for the combined mine/laboratory facility. The Henderson mine currently operates under the codes and safety requirements of the mining industry and is regulated by the MSHA. The laboratory facility will also fall under the jurisdiction of the Occupational Health and Safety Administration (OSHA) and will also be require to follow building codes related to underground structures.

Task HS-3 Perform preliminary building code review and develop fire and life safety strategies. We will meet with local and state officials to seek preliminary agreement on strategies. Preliminary code input would be used for development and concept design for all areas of the DUSEL.

6.5 Environmental Considerations

The CMC Henderson Operations, through its current environmental programs, is uniquely qualified to assess, evaluate and review the site based environmental impact of DUSEL. This section describes CMC's environmental processes and presents a plan to assess the environmental aspects of Henderson DUSEL.

Operations at the Henderson Mine are continually assessed for environmental impact and compliance. CMC and Phelps Dodge review regulatory changes on a routine basis and continually review new or revised regulations as they apply to mine and mill activities. Environmental controls are applied through regular auditing of compliance, review of chemical data, and awareness training conducted for all employees and contractors. The mine is well equipped with modern computer and institutional controls to monitor and review environmental elements of any operation. These tools would be employed to review any impact associated with the development of Henderson DUSEL.

CMC and Phelps Dodge subscribe to international, federal, state and local sustainable development and pollution prevention standards developed for the mining industry through numerous associations and trade groups. Tenants of these organizations would be incorporated into a review of the proposed project. CMC is in the final stages of implementing an Environmental Management System (EMS) based on ISO 14001 standards. Registration as an ISO certified operation at the Henderson Mine and Mill is expected to be complete by the end of the first quarter of 2005. The development of this system provides procedures by which a new program or process may be assessed with respect to significant environmental aspects and their impact on the environment. The ISO 14001 standards mandate periodic assessment of existing and new operations for both environmental aspects, and the presence and effectiveness of operational controls.

The specific tasks to be performed in the development of the conceptual design for DUSEL include:

Task EA-1 CMC will map the process to identify significant environmental aspects of the proposed operation.

Task EA-2 CMC will conduct an environmental assessment of the proposed laboratory plan for engineered risk, regulatory and compliance requirements, and operational aspects of the proposed process. Any experiment specific aspects will be reviewed on a project-by-project basis in the same manner. Potential controls and procedures will then be identified.

Task EA-3 Controls and monitoring will be established for site based environmental components that either allows for redesign to mitigate environmental risk, or secures compliance with applicable regulations. These control elements will be incorporated into the site EMS to provide for regular review and improvement.

6.6 Permitting

The Henderson Mine is a fully permitted mining operation that resides on a contiguous block of private land owned by CMC. The land base at the Henderson Mine and Mill is permitted by the State Division of Minerals and Geology for the disposition of mined materials that will be excavated to construct DUSEL. The operating permit allows for the deposition of in excess of 340 million tons of mill tailings and no additional permitting will be required for the disposal of the $\sim$1.2 million tons of waste rock estimated to be excavated for DUSEL. Mining ventilation systems are permitted by the Colorado Air Pollution Control Division, and all dewatering treatment and discharge operations are permitted by the Colorado Water Quality Control Division. There are no Federal permits required for the underground mining operations. The DUSEL facilities will be permitted as an underground building under the regulations of the International Building Code and the State of Colorado building codes. We will thoroughly investigate and plan for any permitting that may be required for the initial suite of experiments proposed as part of our conceptual design. To insure all required permitting is identified, the following tasks will be performed:

Task PM-1 The required permitting for both construction and operation will be identified, and a plan for obtaining any required permits including the timetable and associated costs will be developed.

Task PM-2 Permitting requirements for any specific experimentation will be addressed and managed on case-by-case basis, particularly in the event that Federal funds are used in experiments or activities requiring environmental analysis under the National Environmental Policy Act.

6.7 Shared Infrastructure Considerations

Simultaneous operation of the Henderson mining activities with DUSEL will have distinct advantages compared to other potential sites, however there will also be coordination challenges. These challenges will be addressed and solved through the comprehensive planning process described below.

Task SI-1 A detailed scope of development work for the DUSEL project will be developed in conjunction with CMC so that the infrastructure needs of the project are fully understood. With this information, feasibility studies will be performed for various scenarios to determine the optimum solutions to minimize disruptive interactions between mine operations and the Lab.

Task SI-2 As outlined in Sect. 8, a management model will be developed to examine the construction and operation of the Lab as it relates to mining activity. Using this management model coupled with the feasibility studies, potential issues will be identified that may result from the interaction between the mine operations and the Lab.

Task SI-3 To ensure success, a facilitated partnering process will be used involving all of the key stakeholders associated with the project. This process will result in a comprehensive plan to address communications, planning and scheduling of activities, roles and responsibilities, and conflict resolution.

Task SI-4 HUSEP, Henderson Mine and a possible Colorado State Special Commission will form a working group to develop procedures to establish legal agreements and contracts between CMC and the entity which will construct and operate DUSEL. These agreements will address issues such as safety, security, environmental requirements, cost sharing of infrastructure operating costs, areas of responsibility for management of construction, infrastructure maintenance and any other compensation to CMC. Particular emphasis will be placed on agreements that assure the continuation of Phelps Dodge's commitment to safety and the environment by all parties associated with this project.

Task SI-5 The working group will also develop a procedure to establish plans and agreements for the land required for construction of surface campus facilities required by the lab and the long-term operation of the entire facility after mining operations are completed at Henderson Mine.

Task SI-6 Develop plans for operation and maintaining the infrastructure based on the detailed three-phased development plan and conceptual design, including preliminary cost estimates. They will cover a period of co-existence with the mining operation during which cost sharing will be required for the shared infrastructure, and the period after the mine has closed for which a separate cost structure will be required.

6.8 Schedule and Cost Considerations

Using actual costs from the Henderson 2000 (H2000) modernization project with a 10% contingency, the total cost for access to the Central Campus area is estimated to be about $13 million, and access construction would require 8 months. Construction of the Central Campus Laboratory is estimated to require an additional 6 to

12 months depending on the number and size of the caverns excavated. The initial laboratory configuration would cost approximately \$5.5 million (H2000 costs with 30% contingency).

The total cost for access to the lower level is estimated to be \$48 million (H2000 costs with 25% contingency). Approximately 40 months would be required to construct the lower campus access, and an additional 6 to 12 months would be required to construct the Lower Campus Laboratory caverns.

6.9 Assessing Public Support

The citizens and local government of Clear Creek and Grand counties have pledged strong support to locating DUSEL at the Henderson Mine. Mining has been the heritage and mainstay of Clear Creek County since the Colorado gold rush, and the idea of bringing a major science facility to Henderson was first raised by two members of the Clear Creek County Planning Commission about two years ago when they were informed of a possible closure of the Henderson mine.

The communities within Clear Creek County have been thoroughly exposed to the HUSEP initiative primarily by The Arapaho Project via town hall meetings, local and state newspaper articles, planning commission hearings, mine tours and presentations at local fraternal organizations. Although Grand County to the west, which hosts the Henderson mill, will be somewhat less affected, similar outreach efforts have determined Grand County also welcomes the Henderson mine as the host for DUSEL. The County Commissioners of both Counties as well as the Mayors and City Councils of the municipalities involved have signed letters of support indicating their awareness and approval of HUSEP's initiative regarding establishment of Henderson DUSEL. HUSEP also enjoys firm backing and encouragement from the Colorado State Legislature, the Department of Local Affairs, the Department of Natural Resources, and the Governor's Office of Economic Development and International Trade. Community support has been greatly enhanced by the reputation and consistent policies of the Henderson management; for decades, both Grand and Clear Counties have enjoyed an environmentally sensitive, safety conscious and mutually responsible relationship with Henderson. Planning for developing future public support is summarized below.

Task PS-1 Continue community outreach. Public interest articles, web sites, and contact with the local FM radio station for live interviews with HUSEP members. If chosen for S-3 HUSEP plans additional outreach via advertised town halls, letters to the editor of four local papers, press releases and continued presentations to local groups by local community leaders and HUSEP scientists.

Task PS-2 Continue the on-going discussions with the local and the state government concerning their possible financial or other tangible forms of support for Henderson DUSEL.

7 National and International Cooperation

To achieve optimal productivity from DUSEL it will be necessary to develop close communication and cooperation with other national and international facilities. Here we describe three examples that we will explore further during the project period, which will serve as models for future planning.

(1) In fall 2004, BNL submitted a preliminary proposal to the US Department of Energy to construct a 1MW Super Neutrino Beam [24]. A natural host for the massive far detector (such as UNO) required to perform Very Long Baseline Neutrino Oscillation studies using this beam is DUSEL. In January 2005, based on a study of the proposed neutrino beam energy and distance to the potential DUSEL sites, BNL released a public statement of their support for Henderson as one of three suitable host sites. HUSEP is also in communication with Fermilab, which is another potential home for a super neutrino beam.

(2) With limited science funding, it is essential to avoid unnecessary duplications in large scale science projects. The existence of the approved SNOLab in Canada is an important factor in DUSEL planning. Preliminary discussion with SNOLab is underway on the possibility of cooperative program planning if Henderson DUSEL is realized. SNOLab provides experiments with immediate access to a very deep site (6000 mwe). To construct a comprehensive underground laboratory program to serve the larger science and engineering community in the most efficient way, we propose to concentrate initially on the 2500-5000 mwe overburden campuses and gradually reaching down to a very deep site, perhaps beyond the SNOLab depth. The lower DUSEL campus will be designed based on the evolution of the science so that it complements SNOLab without compromising the integrity of US-based experiment proposals.

(3) Though collaboration with SNOLab will be a linchpin of the long term physics program development at Henderson DUSEL, there are natural international collaborations with Asia, Europe and S. Africa. Many

of the proposed experiments for DUSEL are already international, especially the "Large Module" experiments. Many of the HUSEP members are involved in these experiments and we plan to explore already well established international collaboration relationships to Henderson DUSEL. On a broader scale, following the successes of the International Union for Pure and Applied Physics (IUPAP) International Committee on Future Accelerators, an equivalent group, PANAGIC (Particle And Nuclear Astrophysics and Gravitation International Committee), established by IUPAP in 1998, may be an appropriate vehicle for communication among international underground physics facilities.

Prominent scientists with extensive underground laboratory experience from Europe and Asia serve on the HUSEP International Advisory Board: Alessandro Bettini served as Director of the Gran Sasso National (Underground) Laboratory in Italy and also served as the founding Chair of PANAGIC, Luigi Mosca served as Director of the Frejus Lab in France, and Kenzo Nakamura oversaw civil construction of the Super-Kamiokande detector in the Kamioka mine in Japan.

Task CO-1 Work with BNL to develop an integrated schedule for development of the VLBNO beam and experiment. Communicate with Fermilab and keep them informed of the Henderson DUSEL development.

Task CO-2 Work with SNOLab management to develop scenarios for inter-laboratory cooperation in scheduling experiments at the two sites.

Task CO-3 Consult with a broad range of international advisors, including current and former laboratory directors, to develop a policy for participation in international organizations to promote communication, cooperation, and collaboration.

8 Management Plan for the Henderson DUSEL

The exact form and structure of the Henderson DUSEL management will require negotiations among CMC/Phelps Dodge, NSF, HUSEP and the participating universities after the DUSEL is awarded to Henderson. At the existing national laboratories we find three different management models:

- Single Professional Organization Management Model. Examples: Fermilab by Universities Research Association (URA), a consortium of major research universities, and Pacific Northwest Lab by Battelle Memorial Institute (Battelle).
- Single Academic Institution Management Model Examples: Los Alamos National Lab, Lawrence Livermore Lab and Lawrence Berkeley Lab by Univ. of California, Berkeley; Stanford Linear Accelerator Center by Stanford Univ.; and LIGO Lab by California Inst. of Technology (in partnership with Massachusetts Inst. of Technology).
- Co-management Model through Partnership Examples: BNL by Brookhaven Science Associates, LLC (consisting of Stony Brook University and Battelle, 50-50 partnership); Oak Ridge Lab by UT-Battelle, LLC (consisting of the University of Tennessee and Battelle); and National Renewable Energy Lab by Battelle, Bechtel and Midwest Research Institute.

We plan to study these and other various management models in detail and establish a management plan that will be best suited for Henderson DUSEL. We are particularly interested in the LIGO management structure which has a similar operation size and seems to have a rather efficient and effective organization.

Task DM-1 Survey and study a broad range of management schemes.

9 Broader Impact Plan

An exceptional opportunity exists at the proposed Henderson DUSEL to provide an integrated, unified program in which multidisciplinary research dovetails with education and outreach (E&O). Target audiences of students, teachers, scientists, officials, legislators, and the general public will be the focus of formal and informal E&O programs. Anticipated E&O projects will feature K-16 curriculum development, outreach programs to regional schools and communities, research experiences for undergraduate students, career development for teachers, the development of an on-site E&O facility, exchange activities for undergraduate and graduate students, and outreach to the state and nation through television and Web programs.

Our plans are guided by three distinct E&O success stories: the University of Nebraska-Lincoln's Cosmic Ray Observatory Project (CROP) [25], a highly successful, nationally recognized outreach program engaging teams of high school teachers and students in long-term cross-disciplinary research, developed by Claes and colleague Greg Snow; Pfiffner's successful international and interdisciplinary REU program in South

Africa [28], the Biogeochemical Education Experience, where undergraduates from multiple disciplines work with an interdisciplinary research team examining biogeochemical processes in the deep subsurface; and Jones' Little Shop of Physics (LSOP) [26], a nationally recognized hands-on science outreach program whose team of mostly undergraduate students present science programs to over 15,000 students and workshops on the techniques of hands-on science instruction to over 200 teachers around the world each year.

Henderson's location near popular tourist centers will maximize the impact of a Visitor's Center. Serving as the first stop of any tour of the Henderson DUSEL facilities, such a center will provide a self-contained visitor experience; its space and fixtures flexible enough to accommodate strolling individuals, families, or small groups as well as larger groups (school classes) on guided tours. An auditorium will allow lectures to larger audiences. Real-time event displays from DUSEL experiments will run continuously in the Center. A running detector setup in the Center with large visual scalers will collect data as part of the SALTA (Snowmass Area Large Time-coincidence Array) project [27] grid. Monitors in the center will also display, live, the current cosmic ray rates at each school, as well as the most recent air showers recorded.

From its inception, Henderson DUSEL has enjoyed strong community interest and involved an unprecedented cooperation with industry. Even at this conceptual stage it has brought together broad cross-disciplinary experience and close cooperation with national and international collaboration; its international collaboration of scientists and educators will be tapped to enhance scientific literacy and technology skills locally, nationally, and internationally. Maintenance of an experimental research mine will offer students and faculty a state-of-the-art facility for instruction and research in mining and geological engineering. This mine could also serve as the public's introduction to the mining industry through guided tours and a variety of informational programs.

Task EO-1 Develop an E&O component that is truly integrated with the operations and research programs of the multi-disciplinary Henderson DUSEL. We will devise new initiatives developed in consultation with the project scientists, K-12 teachers, and members of the local communities. There will be an emphasis on the local schools, but instructional materials will be distributed nationally.

Task EO-2 Organize broader impacts component of each of the four proposed Henderson DUSEL workshops, drawing K-12 and undergraduate educators and students at each of the different venues in an effort to develop genuine and effective connections with the science.

Task EO-3 In addition to invitations to workshop sessions, we propose going directly to Hispanic and Native American community leaders and request audiences at regularly scheduled Denver area special events, celebrations, and regional powwows all in an effort to assess regional needs and expectations.

Task EO-4 Develop plans to host a joint AAPT-Colorado/Wyoming and CAST (Colorado Association of Science Teachers, the Colorado section of the NSTA) meeting and organize sessions within their regular annual meetings to build interest and assess needs to be certain we develop a program appropriate for our intended audience.

10 Project Organization, Management and Team Qualifications

The Henderson DUSEL S2 project will be managed and organized through the framework of the well-established HUSEP collaboration described in Sect. 3. The project team, PI and co-PI's were chosen carefully to build a strong, well-qualified team with experience in the underground science and engineering, underground facility design and large project management. The team has local and national representatives including junior members of the community to ensure future leadership, vibrancy and continuity for this long term project. The qualifications of the project team relevant to developing the conceptual design for Henderson DUSEL and the responsibilities of the PI and co-PI's in the S2 process are described below:

C. K. Jung, PI, HUSEP Spokesperson, has made important contributions to several areas of experimental particle physics such as detector design, construction and data analysis for large experiments, and particle beam energy measurement, monitoring and tuning. He has participated in one of the most successful underground experiments, Super-Kamiokande; contributing to the seminal measurements of neutrino oscillations effect and nucleon decay partial lifetimes. He has substantial experience leading and managing large international projects as US co-spokesperson for the K2K collaboration, Chair of the Interim International Board of Representatives for the T2K collaboration, and spokesperson of the T2K US B280 Collaboration. He is also the initiator and spokesperson of the UNO experiment, and the founder of the NNN (Next generation Nucleon decay and Neutrino detectors) series workshops. Jung provides overall vision of Henderson

DUSEL and guides HUSEP committees, with input from the HUSEP International Advisory Board and the Henderson Mine/Phelps Dodge. He will oversee all S2 projects including budget and schedule. He is responsible for communicating with NSF and other federal agencies. He will recruit national and international collaborators to further strengthen the team. He will organize a capstone workshop towards the end of the S2 process, and organize and produce a final report.

R. J. Wilson, Co-PI, HUSEP Deputy-Spokesperson, has substantial experience in senior management roles for large international collaborations, such as chairman of the 75 institution BaBar collaboration council, which represents over 600 physicists and engineers. His research expertise includes: the design and construction of detectors used in particle physics; the design, fabrication and analysis of large experiments; simulation of complex processes using Monte Carlo methods. Wilson acts as the project manager for this project. He will have responsibility for tracking all project tasks including monitoring of milestones and budgets, and he will assist with the preparation and editing of the final report. Along with Zimmerman, he will organize a physics workshop and produce the physics modules summary of the report. He will manage the subcontract to CSU and assist Schultz in communicating with the local and the state governments.

M. Kuchta, Co-PI[2], is an expert in mine planning and scheduling, blasting, ground control, and other mine unit operations, and has extensive experience in project management gained from ten years industry experience at the world's second largest underground hard rock mine in Sweden. He also served on the NSF Panel that reviewed the three initial NUSEL candidate sites in 2003. Kuchta will have overall responsibility for managing the development of the engineering design of the facility. He will assist and coordinate the efforts of the engineering team consisting of the CMC engineers, CNA Consulting Engineers, and McIntosh Engineering. He and Kieffer will organize a topical Mining Engineering workshop. He will be responsible for producing mining and engineering aspect of the conceptual design for the report, and manage the subcontract to Colorado School of Mines.

E. D. Zimmerman, Co-PI[2], has worked on three major neutrino experiments: CCFR/NuTeV, BooNE, and T2K. His activities on these experiments have included experimental facility design, major hardware construction, and leadership of physics analysis groups. Zimmerman will manage the subcontract to University of Colorado and, along with Wilson, he will organize a physics workshop and produce the physics modules summary of the report.

D. Claes, Co-PI, is one of the leaders of University of Nebraska-Lincoln's Cosmic Ray Observatory Project, a highly successful, nationally recognized outreach program that engages teams of high school teachers and students in a genuine long-term cross-disciplinary research experience; CROP served as the model for the Snowmass Area Large Time-coincidence Array project, which Claes has extended to involve high school students from the region near Henderson. Along with S. Pfiffner and B. Jones, Claes will organize E&O activities, and produce the E&O report and plan for Henderson DUSEL.

J. Hannah, Co-PI, is a broad-based geoscientist with expertise in petrology and isotope geochemistry applied to tectonics and ore geology. Through extensive administrative work, she has had on-going contact with current research in geophysics and hydrology. She will coordinate the geoscience activities, build the project team, organize a geoscience workshop, and produce the report on geoscience modules.

S. Kieffer, Co-PI, has a decade of industry experience focused on the planning, analysis and detailed design of tunnels, caverns, shafts, and deep excavations. He is a registered professional engineer, certified engineering geologist and registered geologist. Kieffer will have overall technical and management responsibility for geotechnical aspects of the project, including geological site characterization, geomechanical analyses, and the development of conceptual-level excavation and ground support requirements.

J. Mitton, Co-PI, is an evolutionary molecular geneticist who has used many model systems to study evolutionary adaptation to environmental heterogeneity. He is Vice President of the Society for the Study of Evolution, Chair of the Faculty of the College of Arts and Sciences, and Chair of the Department of Ecology and Evolutionary Biology at the University of Colorado. His extensive publication includes 60 newspaper columns. Mitton will coordinate biology related activities, organize a biology workshop and produce the biology modules summary of the report.

Henderson Mine Engineering Staff, led by C. DeWolfe[2] and R. Propernick[2], bring extensive expertise in mining engineering, geologic and geotechnical engineering, mine design, operation and maintenance of mine infrastructure, construction management, environmental engineering, permitting, and health and safety.

[2]HUSEP Executive Committee Member

Henderson staff will be primarily responsible for permitting, environmental studies, developing safety plans, and will also assist in the geological and geotechnical characterization, shared infrastructure issues, and developing the plan to develop, operate, and maintain the infrastructure.

CNA Consulting Engineers [29] has extensive experience in the design of occupied underground space, including that for the Soudan 2 and MINOS experiments; VLHC feasibility study; the Noνa experiment; and the SNOLab expansion. CNA and its partners, Dunham Associates and Miller-Dunwiddie Architects, will be responsible for development of detailed laboratory designs that will include geotechnical considerations for cavity excavations, standard ventilation requirements, special ventilation requirements including clean rooms and the safe handling of cryogens, fire and life safety including access, refuge, and code enforcement, electrical, water, and sanitary systems.

McIntosh Engineering [30] is one of the largest and most experienced underground mining engineering and construction services organizations in North America. Their core business is underground hard rock mining. The company provides expertise in mining engineering, detailed design and cost estimating, and construction management. McIntosh will provide expertise in the design and costing of the internal shaft, as well as the design and cost estimates for the overall access drifts and bored raises that will comprise the ventilation system, and will also assist in the development of the facility construction management plan.

Arapaho Project Inc. [2], led by S. Schultz[2], is a non-profit science and education group that includes business people and senior former national lab employees. It is dedicated to developing the Henderson Mine as a national laboratory and acting as liaison to the regional government and stakeholders.

11 Project Deliverables, Cost, and Schedule

At the end of the six-month S2 award period, we will complete the tasks we described in this proposal, specifically the conceptual design of Henderson DUSEL, and we will produce a detailed report as NSF specifies. We will prepare additional supporting materials and post them on a HUSEP Web page.

11.1 Cost

The details of the project cost and justifications are presented separately in the budget submission section. Here we provide a broad breakdown of the project costs for various activities. The project costs shown here and in the budget do not incur overhead charges. All participating institutions have agreed not to charge indirect costs for this award showing their strong support for the proposal. CMC/Henderson Mine's substantial contributions are at no cost to the project.

- Total cost: $500,000 (100%)
- Conceptual design and engineering, including consultant fees and travel: $290,000 (58.0%)
- Four topical workshops ($10,000 each) and a Capstone workshop ($28,000): $68,000 (13.6%)
- Education and Outreach, including travel: $33,000 (6.6%)
- Science, organization and management, including travel: $109,000 (21.8%)

11.2 Schedule

During the 6 month period of S2, we will be working on most tasks simultaneously. Here we provide some key events and milestones.

- Month 1: Review status of all S2 tasks.
- Month 2: Mining Engineering Workshop at Colorado School of Mines, and Biology Workshop at University of Colorado.
- Month 3: Physics and Geology workshops at Colorado State University; midterm conceptual design report, review and feedback.
- Month 4: First Draft of the reports.
- Month 5: A capstone workshop at Stony Brook. Revised conceptual design report, review and feedback.
- Month 6: Finish final reports including final conceptual design; pre-submission review by HUSEP International Advisory Committee.