

**CONCEPTUAL DESIGN:
THE DEEP UNDERGROUND SCIENCE AND ENGINEERING LABORATORY-CASCADES
A HORIZONTAL-ACCESS FACILITY
(Released February 28, 2005)**

1. OVERVIEW

This proposal responds to the NSF call for conceptual designs for the Deep Underground Science and Engineering Laboratory (DUSEL). DUSEL-Cascades is a proposal to develop a horizontal access facility in the Mt. Stuart batholith, a 20 km by 30 km granite mass on the eastern slopes of the Cascades, famous for its record-setting tunnels. Key features of the proposal include:

- The DUSEL site provides excellent depth with a modest tunnel length of 4.9 km: the peak cover will be 7400-7700 ft (6550-6800 mwe, or meters of water equivalent), depending on the laboratory orientation.
- Site properties include: 1) a tunnel path that can be fully cored; 2) a location in an area of low to moderate seismicity, well separated (~ 76 km) from the nearest identified active crustal fault; 3) a tunnel alignment that appears to be free of intersections with the older host rock; and 4) an outstanding data base on rock properties and tunnel aging due to seven previous tunnel excavations in the batholith, including the 12.5-km, 1000-m-deep Great Cascade Tunnel [1]. The parallel Pioneer Tunnel is largely unlined, providing access to over eight kilometers of deep rock.
- The portal site is on United States Forest Service (“USFS”) land, designated as suitable for such development. There are no mining, environmental contamination, or legacy issues and no requirements for indemnifying previous owners. The permitting process through Chelan County and state and federal agencies is clearly established. Initial steps in this process are already underway.
- Outstanding accessibility: the low-elevation portal is about two hours by car from an international airport (SeaTac) and port (Seattle), via Interstate 90 or Highway 2, the two major highways through the Cascade Mountains. There are five flights daily from SeaTac to the regional airport at Wenatchee, 23 miles from the site. The portal site is connected to a class-II access highway by an existing 1-km USFS road. The climate is mild and dry, and excellent visitor accommodations are available.
- The construction plan, prepared with the help of leading geotechnical and engineering firms, emphasizes outstanding access, quietness, and safety, including dual-tunnel access, tracked transportation, all-electric operations, and a recirculating ventilation system that maximizes cleanliness while minimizing mechanical requirements and environmental impacts. The short tunnel path reduces the time to first science: the TBM (tunnel boring machine) construction period is estimated to be 475 days.
- The University of Washington (UW) proposes to acquire land and build the DUSEL surface facilities (Science Campus and Visitor Center), according to the requirements of the NSF and the DUSEL operator. For illustrative purposes, the proposal discusses one visually spectacular candidate Campus site, on the banks of the Wenatchee River.
- DUSEL-Cascades construction costs should be significantly below those of other undeveloped sites, and very similar to mine sites that aim to provide similar functionality. Cascades has significant cost advantages in laboratory operations and experiment operations/construction due to the horizontal access and extremely low power costs in Chelan County, \$0.016/kw-hr. This reduces projected operating costs, relative to some other candidate sites, by as much as \$300M over a nominal 40-year laboratory lifetime (\$7.5M annually).
- Proximity to and partnership with Pacific Northwest National Laboratory: PNNL is one of the nation’s lead laboratories in biogeochemistry, subsurface science, and low-level-counting applications to national security.
- An outstanding environment for public outreach and educational partnerships at all levels (K-12, undergraduate, and graduate): Leavenworth is a major tourist center, hosting 1.1M visitors each year. The proximity to Puget Sound will allow the outreach program to serve a large, ethnically diverse population. A program to encourage involvement of undergraduate and EPSCoR institutions in DUSEL science is proposed.
- Careful preservation of values important to local citizens: The engineering plan includes sustainable (LEED certifiable) buildings, noise abatement, dark sky initiatives, clean transport, and buried power and data lines.
- An outstanding large-detector option: a long-baseline neutrino/proton decay detector could be a centerpiece of the future U.S. underground science program. One important advantage of DUSEL-Cascades is a second, already developed horizontal access site, immediately off the Great Cascade Tunnel, connected to the DUSEL Science Campus by both rail and highway, with good depth (3200 mwe) and outstanding rock

quality, haulage facilities, power, water, and “broader impact” potential. This would allow the Science Campus to serve both DUSEL and a future large detector effort, while avoiding the access/cleanliness compromises that would be required were such a long-term construction project undertaken within an operating DUSEL.

2. POTENTIAL OF THE CASCADES SITE TO MEET TECHNICAL REQUIREMENTS

2.1 References Cited

This conceptual design proposal is intended to be self-contained. The cited references involve several non-journal reports produced during 18 months of project development including two UW preprints. These documents have been widely distributed electronically and in hard copy, but may not be readily available to all members of the public. Those needing copies can find the cited materials in the DUSEL-Cascades pre-proposal, which is available on the web site <http://www.int.washington.edu/DUSEL/Cascades>. The “science book” (Ref. [7]) is available on the LANL preprint archive (nucl-th/0308018/). A series of documents on TBM performance (including Ref. [9]) can be found at http://www.mines.edu/academic/mining/research/emi/10_publications.html. Ref. [12] is available only in draft form, but will be made public as soon as the draft is finalized.

2.2 Project Components

The project described here, DUSEL-Cascades, includes three components:

- A deep underground horizontal-access site consisting of a portal, two parallel 4.9 km tunnels, a 0.9 km “ring tunnel” encircling the laboratory area, and laboratory rooms located on USFS land in Chelan County, WA.
- A Science Campus located outside the forest, on a nearby site that is available, properly zoned, and served by utilities.
- A Visitor Center focused on public outreach, K-12 teacher and student development, and undergraduate and graduate education.

In addition, we discuss a second horizontal-access site of intermediate depth, convenient to the Science Campus and already developed, ideally suited for a future neutrino superbeam/nucleon decay detector, should the U.S. elect to pursue such a project in the next decade.

2.3 Proposal Background: The Identification of the DUSEL Underground Site

For the past 4.5 years our group has worked with other physicists, earth scientists, engineers, and educators to formulate science arguments and identify sites for a deep, multipurpose U.S. underground laboratory. Because of changing conditions in the Homestake Mine, we decided in July 2003 to do a broad search for potential horizontal-access DUSEL sites. The motivation came from the reports of the Bahcall Committee and the May 2003 NSF DUSEL Site Panel, which noted several reasons such sites are attractive:

- Easier access, simplifying construction and lowering the costs of experiments;
- The potential for significant cost savings in operations and maintenance; and
- The opportunity to design DUSEL to meet the highest standards of cleanliness and safety, unconstrained by past engineering decisions or legacy/liability issues, and free of interference from mining activities.

The world’s major multipurpose underground laboratories of the past 20 years, Gran Sasso, Baksan, and Kamioka, as well as many smaller laboratories – for example, Frejus, Mont Blanc, and Canfranc – provide horizontal access. Horizontal access is particularly important for experiments with challenging requirements, as large modules can be carefully packed and transported directly to the clean lab, with minimal effort, handling, and cost. This type of facility is lacking in North America: WIPP, Soudan, and SNOLab are vertical-access (hoist) facilities.

Our preference for an undeveloped site grew out of first-hand experiences building detectors in active mines. Experiments generally must adapt to the use restrictions of the mine owner: the control of materials (cryogenics, flammables, etc.), experiment duration (usually the contract specifies a fixed term), and access remains with the mining company. For example, access to SNO has been disrupted by mining accidents, strikes, and month-long periods of hoist maintenance. Blasting and other mining activities are a potential source of interference, and equipment generally has to be cleaned if transported on hoists and through drifts that are also used in mining. The viability of the site may depend on difficult-to-predict conditions, such as market fluctuations, ownership changes,

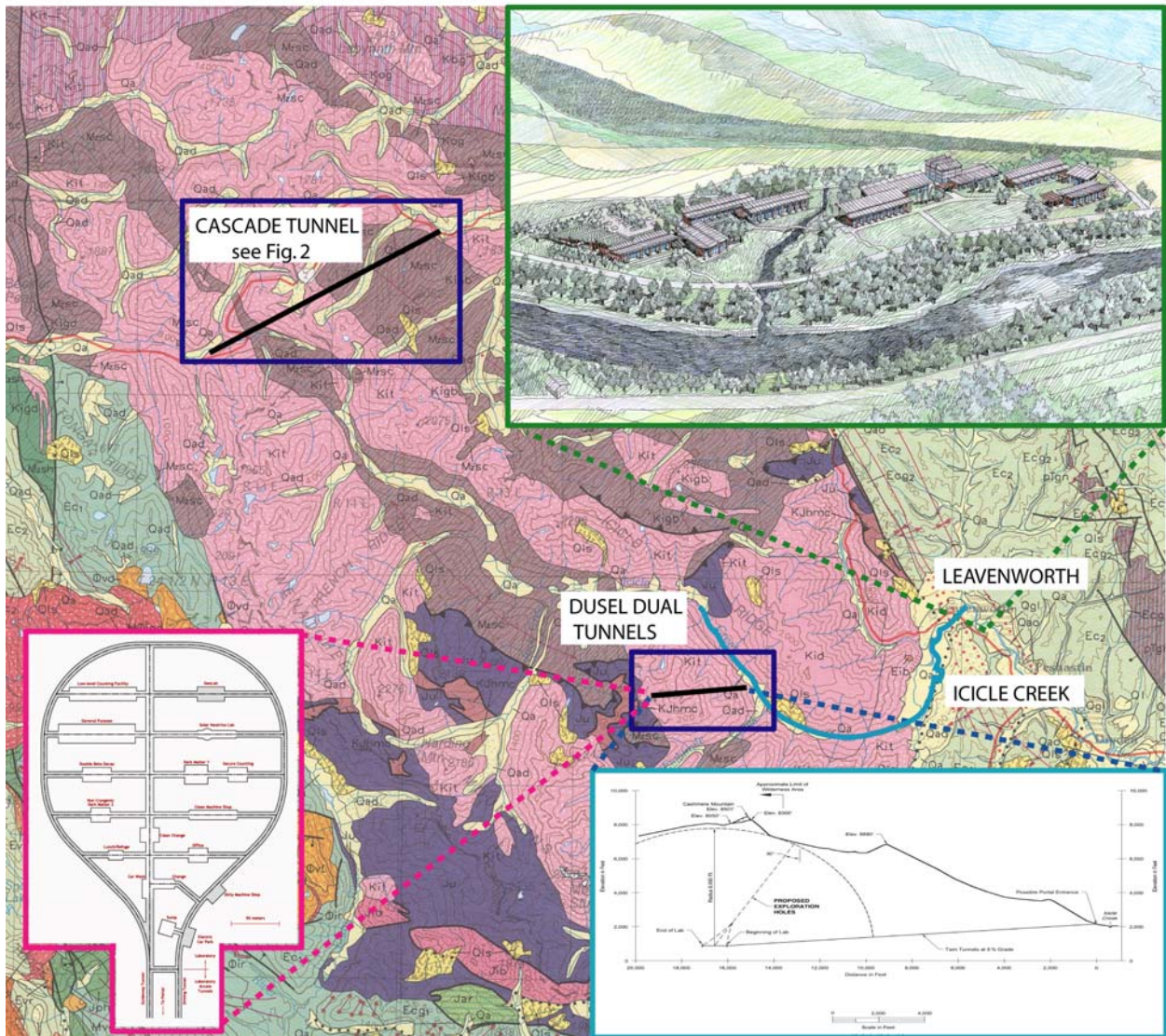
and the rate of ore-body depletion. If scientists become the sole tenants in a mine, new issues may arise. The cost of cutting down the “footprint” of the facility – ventilation, cooling, hoists, conveyors – to manageable size can be high, and may still not yield an efficient laboratory. Legacy issues can complicate ownership transfer.

For these reasons our search [2] focused on undeveloped horizontal access sites. It extended over most of the western U.S. and included criteria designed, in part, to address concerns the 2003 NSF Site Panel expressed about another horizontal-access candidate site. Twelve potentially interesting sites were identified. Two independent geotechnical evaluations rated one of these sites as outstanding, Cashmere Mountain.

2.4 Physical Attributes of the DUSEL Underground Site

Location. The proposed portal for the underground laboratory is in a steep mountain valley (Icicle Valley), about nine miles from the town of Leavenworth (pop 2500), near which the Science Campus and Visitor Center will be located (Fig. 1). All facilities would be in Chelan County, WA. Maps and photos in [3] show proposed portal, Campus, and Center sites, and the locations of regional research centers and of SeaTac and Wenatchee airports.

Figure 1: The locations of the DUSEL-Cascades tunnels, a candidate Science Campus site, and Cascade/Pioneer Tunnels are shown. Inlays show the proposed tunnel alignment, laboratory layout, and Science Campus design.



Accessibility and property designation. By road, Leavenworth is 110 miles from Seattle, a metropolitan area of 3.3 million with major international port and airport facilities, and about 145 miles from PNNL. SeaTac International Airport is the major hub in the Northwest, with frequent direct connections to Europe, Asia, and all major U.S. cities. There are two nearly equivalent routes from Seattle/SeaTac to Leavenworth, by Interstate 5 and State Highway 2 or by Interstate 90 and State Highway 97. Driving time is about two hours. (Alternatively, Alaska Airlines flies from SeaTac to the Wenatchee airport, 23 miles from Leavenworth, five times daily.) All roads are well maintained throughout winter. The nine-mile route from the proposed Science Campus near Leavenworth (1180 ft) to the portals (2100 ft) is via Icicle Creek Road, a Class II highway. The drive up Icicle Valley is gentle, with an average gradient of 2%. The Burlington Northern & Santa Fe (BNSF) railway, the major intermodal connecting the Seattle and Tacoma ports with Chicago, and Highway 2 provide door-to-door connections between the Science Campus and the second (large detector) site discussed in Sec. 6.

The portal can be reached by crossing a USFS bridge (built for logging towers and rated at 40 tons) directly off Icicle Creek Road and following a USFS road for about 800 m. Thus only road upgrading, rather than new road construction, is required. The portal area and the surface above the proposed tunnels are located within the Wenatchee National Forest. Our proposed activities – construction and coring – can be done from lands with an appropriate designation. The portal area is designated multiple-use (“matrix”).

Climate. The eastern side of the Cascade Mountains is dry: Leavenworth has 300 sunny days each year and an average precipitation of 27 inches. Leavenworth’s warmest months are July and August, with average highs/lows of 87°/50°. The coldest months are December and January, 33°/19°.

Regional technical infrastructure. There are eight research institutions within 250 miles of Leavenworth, several with long-established interests in underground science: the UW; PNNL; TRIUMF and the University of British Columbia; Simon Fraser; the University of Victoria; Washington State; and the University of Idaho. Oregon State, the University of Oregon, and the University of Montana are about 350 miles from Leavenworth.

Seattle is a major center for high-tech industry, including aerospace, software, biotechnology, and telecommunications. It is one of two west-coast hubs of UltraScience Net and its Pacific Wave international links. The region is home to many major construction and geotechnical firms, including a leading TBM manufacturer.

Cultural and physical environment, suitability for visitors. There are approximately 30 hotels and 20 B&Bs in the immediate vicinity, several of these along Icicle Creek Road. The Sleeping Lady Retreat, a 70-acre reserve on Icicle Creek popular for conferences of up to 180, is five miles from the portal. Icicle Creek Road is the trailhead for some of the most spectacular backcountry hiking in Washington, including the Snow Lakes entrance to the Enchantments. Leavenworth hosts several winter festivals based on its adopted Bavarian theme, as well as classical and jazz festivals throughout the summer. A major downhill skiing area, Stevens Pass, is about 40 miles from Leavenworth. There are many cross-country ski trails off Icicle Creek Road and commercial Nordic areas nearby.

2.5 Geotechnical Characteristics.

Regional geologic setting. Cashmere Mountain is one of the major peaks in the Mount Stuart batholith, a 600 km² granite pluton on the eastern slopes of the Cascades that rises abruptly from the Columbia plateau (800 ft) to almost 9500 ft. The batholith surrounding Cashmere Mountain is dominated by medium-grained hypidiomorphic granular hornblende-biotite tonalite and, to the east, granodiorite. Isotopic ages for the batholith range from 85-93 Myr.

Geotechnical assessments of Cashmere Mt. pointed out several important features:

- Icicle Valley, a deep cut into the center of the batholith that leads to the foot of Cashmere Mt, is of very recent glacial origin. This has several important consequences. First, the steep relief is not associated with an active fault. Second, based on the information available from our surface field studies (and pending coring studies), the proposed tunnel alignment appears to be fully contained in the batholith, with no known intersections with the older host rock. (Such intersections typically involve weaker rock and shear zones that may be conduits for water.) Third, because the entire tunnel is located in relatively unevolved tonalite characteristic of the deep batholith, the U and Th content is low. Measurements on samples from the portal area yielded averages of 0.77 and 0.53 ppm, respectively.

- Because of past tunneling in the batholith, we have direct access to deep rock and detailed histories on tunnel construction and on 100 years of tunnel aging. This includes three major transportation tunnels and four water tunnels. The excavations of most value are the 12.5 km Cascade Tunnel, which reaches depths in excess of 1000 m; the largely unlined and unsupported parallel Pioneer utility tunnel, which allows us to inspect 8 km of deep rock; and the Snow Lakes water tunnel, which was excavated on the ridge that includes Cashmere Mt.
- The records from these excavations are very encouraging. For example, while the Cascade and Pioneer tunnels were excavated in areas of the batholith far less favorable than Cashmere Mt., significant water flows were short lived. Current flow from the 20 km of tunnels is about 600 gpm. In the Snow Lakes excavation a water tunnel was excavated directly under, and within seven feet of the bottom, of a lake.
- As discussed in Sec. 6, the Cascade and Pioneer tunnels provide access to a second site of intermediate depth that would be suitable for a future long-baseline neutrino detector. This site is ideal from the perspectives of ease of the civil construction and quality of the existing geotechnical database.

Geotechnical Report. The geotechnical site report [1] was prepared by Shannon and Wilson, Inc. This study included literature searches, significant surface fieldwork, and inspections of nearby excavations. The report includes an extensive section on inspections of the Pioneer Tunnel. The following is a summary of the conclusions:

- An expected average deep-rock uniaxial compressive strength in excess of 15 kpsi, based on extrapolations of surface weathered-rock measurements, and measurements of 15 kpsi for granodiorite samples taken from the Pioneer Tunnel. (These were tunnel wall samples that have been exposed for 70 years.) In the RMR system an unconfined compressive strength of 15 kpsi is considered to be at the border between medium- and high-strength rock. In other rating systems it corresponds to the borderline between strong and very strong. The expectation of our geotechnical firm is that the initial coring study will find deep rock strengths that are higher (~ 25 kpsi) than those obtained from the weathered rock extrapolations.
- A Barton Q-system rating was done for 53 samples of moderately to slightly weathered rock taken from surface outcroppings. The Qs ranged from fair to very good, averaging 19.3 (good). One expects the quality of unweathered rock (rock taken at depths of 20 meters or greater) to be higher.
- An average RMR, or Bieniawski Geomechanics Classification, of 55.1, for weathered surface rock in the fair classification. The RMR is a sum of individual ratings for uniaxial compressive strength, rock quality designation, spacing of discontinuities, groundwater conditions, and orientation of discontinuities. The RMR for unweathered rock is expected to be higher.
- An estimate of ambient rock temperature at the proposed DUSEL laboratory site of 40-49° C, based in part at thermal gradient records from the Cascade Tunnel excavation.
- Typical surface-fracture spacing of 1 to 10 ft, and fracture lengths of 10 to 100 ft.
- An expectation of favorable hydrology due to the low porosity of the rock, though uncertainties exist which should be addressed by coring and by packer tests in areas of observed fractures/joints or groundwater flow.

The conclusion is that the rock that will be encountered at depth in Cashmere Mountain should be medium to high strength, ideally suited for TBM excavation. The rock should require only modest support, while remaining below the hardness (~ 30-35 kpsi) where excessive wear of the rock disk would decrease productivity and increase costs. These conclusions will be tested in future coring studies.

Seismic suitability. The site is located in older, relatively stable accreted terrane on the eastern side of the Cascade Range. The historical record of earthquakes above magnitude 3.5 shows none within 30 km of Cashmere Mountain, and very few in the region. The major regional discontinuities, the Leavenworth (13 km from the site) and Entiat faults, ceased being active in the middle of the Eocene Period. The nearest known, potentially active crustal fault is the Devil's Mountain fault, 76 km northwest of the DUSEL-Cascades site. The facility can be readily designed to meet earthquake accelerations indicated by standard hazard indices. (The USGS Seismic Mapping Hazard Index gives 14% of g as the peak acceleration anticipated with a 10% probability in the next 50 years.)

Depth. The construction plan discussed in the next section employs an 8% negative gradient tunnel to maximize overburden and minimize tunneling. The laboratory has a peak overburden of 6550 mwe, assuming a nominal density of 2.9 for in-place granite. The minimum distance/overburden to the surface is 6800 ft/6010 mwe. Both measures exceed corresponding Gran Sasso depths by 3000 mwe. Horizontal access allows experiments to be sited at any shallower depth (e.g., to exploit a nonvanishing muon flux for detector calibration).

2.6 Environmental Issues

As an undeveloped site, there are no pre-existing environmental contamination or legacy issues. Ref. [4] discusses project environmental impacts during construction and operations. Our collaboration has a very strong engineering component with extensive experience in environmental issues. Three key issues are discussed below:

Haulage and crushed rock disposal: DUSEL's crushed rock production will be about 10% of the current production of the area's largest quarries. The principal impact is the trucking, which will increase traffic on lower and upper Icicle Creek Road by 4% and 16%, respectively, over the 2.6 years of construction. Potential mitigation steps include scheduled and caravanned trucking, use of modern trucks and low-sulfur fuel, covered loads, wheel washes, and implementing a shuttle system to relieve traffic generally on Icicle Creek Road during and after construction. The key goals are to minimize impacts to local residents, preserve the undeveloped character of the valley, and avoid undue interference with area tourism during construction.

The most effective mitigation is limiting mileage. We have discussed with the USFS and with the County possibilities for donating the rock for planned maintenance projects in the vicinity of the portal and for restoration of a County gravel pit on Icicle Creek Road, six miles from the portal. These projects could consume about 70% of the rock. Alternatively, there are several pits off Highway 2 with capacities of about one million yards, nearly twice our production. Both commercial and government groups have approached us to express interest in the rock.

Roads and power: Approximately five miles of the hauling will be done on the USFS portion of Icicle Creek Road, a paved road not engineered for heavy trucking. This road is currently high on the USFS's Northwest repair list. The State proposes to undertake an upgrade of this road, in conjunction with burying underground distribution lines and fiber connections to the laboratory. Environmental issues include protecting the nearby creek during construction and avoiding undue delays for residents of the upper Icicle Valley. Potential environmental benefits include removing existing overhead lines in the Icicle and buffer zones to better manage road runoff. The UW is working with the Access Fund to guard against any damage to roadside climbing rocks, etc., during the upgrade: there is no need to widen the road.

Water: The key environmental issue is disposing of any excess tunnel water (and keeping all experiments isolated from ground water). Department of Ecology, UW, and PNNL engineers have experience with soil injection and other methods of returning water to ground. Several meetings with Ecology officials have already occurred.

2.7 Permitting: SEPA, NEPA, and Public Outreach

As a large federally funded science project, DUSEL will be subject to NEPA.

Two site models are being pursued in DUSEL, the use of active or abandoned mines belonging to a private owner, or the use of public federal or state lands. While there are very few examples to follow in the first case (commercial properties), federal and state public lands have frequently hosted major public science projects, including ones requiring long-term access and substantial construction:

- Public science and education are recognized in law as appropriate uses of federal and state lands. The use-permit process is designed to be fair to the applicant while protecting public lands.
- Because procedures are established, we have been able to complete a detailed roadmap for permitting DUSEL-Cascades [5]. Agencies with key responsibilities are the USFS, the NSF, the State, and Chelan County. The applicant initiates the process by submitting a USFS special use permit application.
- While the permitting process requires patience (the USFS advice for DUSEL-Cascades is three years) and funds (typically in excess of \$1M), the record of success is very good. For example, of the 27 UW off-campus research facilities, three (Apache Point Observatories, the Northwest Seismic Network, and Wind River) operate under USFS use permits; one (Glacier Bay) under a National Park Service use permit; and three others under state park (Alaska, Washington) or tribal government permits. (See <http://www.washington.edu/research/facilities>.) Efforts like Apache Point are comparable to DUSEL in complexity. The UW also has permitted, operated, and closed an underground laboratory on USFS lands in the Mt. Stuart batholith (laser demolition and seismic facilities within the Old Cascade Tunnel).

DUSEL-Cascades public outreach. The UW has supported the early public outreach important to a successful permitting process. Over the last 18 months the DUSEL-Cascades proponents have taken part in approximately 75 meetings with the public, including citizens groups, public media, regulatory agencies, and local, state, and national environmental and recreational groups. A UW Regent and an experienced environmental/public policy consultant have also assisted in interactions with major environmental organizations.

Our public outreach includes a web site (including Frequently Asked Questions), email distribution list, press releases, and a newsletter. A detailed 300-page pre-proposal was issued to allow the State's Department of Community, Trade, and Economic Development (CTED) and the Port of Chelan, the State's economic development agency for Chelan and Douglas Counties, to fund and conduct a four-month public study of DUSEL-Cascades. The Port's elected commissioners responded to the resulting Citizens Advisory Committee's report by endorsing DUSEL while urging continued attention to environmental protection. The Port is likely to be the agency through which state support is provided to DUSEL-Cascades. Other agencies with regulatory responsibilities will engage in similar public processes before reaching decisions on permits.

As in many public projects, adverse impacts of DUSEL-Cascades are very localized, while its benefits are countywide, regional, and national. The UW initiated the public outreach at the local level, as it is important to the eventual success of projects to work with the local community to address concerns and identify beneficial partnership opportunities. While an opposition group has formed, 90% of this opposition appears to be focused on a single issue, the impact of rock haulage on residents along Icicle Creek Road. A core group of about 30 project opponents, primarily residents along the haul route, maintains a web site and writes letters to and appears before public agencies to express their opposition. The UW's approach is continued public education and, later in the process, exploration of potential mitigation to address legitimate concerns of these residents.

The USFS, the County, and potentially the city of Leavenworth (depending on the location of the Science Campus and Visitor Center) will have regulatory roles. County and city support is strong: in addition to the Port's resolution, local, state, and regional governments and organizations have expressed support for the current proposal and a desire to work with the UW on further study, analysis, and public involvement. Major environmental groups value DUSEL's research and educational goals, and have adopted neutral positions pending further discussions of impacts and mitigation. Regular meetings are being held with these groups.

3. DUSEL SCIENCE, ENGINEERING/APPLICATIONS, AND EDUCATION/OUTREACH

DUSEL science, engineering, education, and outreach have been the subjects of a series of community and agency-sponsored meetings, two National Research Council studies, and the current S-1 process. Pending the report of the S-1 group, our group has updated its previously published "Science Book" [6] and drafted an executive summary. The Science Book summarizes several years of working-group input on DUSEL space, cleanliness, and infrastructure requirements (mechanical, electrical, safety). It provides the basis for our conceptual design.

Physics. Both the Science Book and S-1 discussions through Feb. 6 are consistent with the following project plan:

- Three smaller, individualized rooms for "deep and clean" physics (e.g., double beta decay, dark matter) that would allow tenant experimental groups significant freedom to optimize their setups.
- One high-bay general-purpose large cavern in the style of Gran Sasso that could house multiple experiments or one large experiment, serve as a staging area, or be used in R&D efforts.
- Capability within the initial plan to excavate a special-purpose cavity, such as would likely be required for a low-energy solar neutrino experiment.
- The placement of these rooms within a space that could be maintained at Class 1000-3000, with provision for achieving higher levels of cleanliness beyond the room doorway; an efficient method of transporting large experimental modules to the laboratory and washing them at the clean barrier.
- The ability to expand the laboratory and to excavate new specialized cavities, without jeopardizing the clean status or operations of ongoing experiments.
- A sophisticated ventilation system that will meet high standards for both cleanliness and safety, including emergency modes adequate for experiments using large volumes of cryogenics or flammables, for example.

- An isolated room for a low-energy nuclear-astrophysics accelerator.
- Underground facilities (lunchroom, clean and exterior machine shops, some office space) adequate to eliminate unnecessary travel to the surface; state-of-the-art fiber communications to the surface; a sophisticated surface campus providing mechanical, electronics, chemistry, and other support services.
- Provision for future “large-detector” science (e.g., long-baseline neutrino studies, nucleon decay) (see Sec. 6).

Earth science and geomicrobiology: DUSEL-Cascades permanent infrastructure includes an underground geosciences laboratory, one or more drilling stations, provisions for permanently instrumenting the project’s deep core holes, and isolation boxes for geomicrobiology. Aspects of the overall S-1 program suited to our site include:

- *Geomicrobiology:* Evaluation of the “geo-gas” hypothesis in a nonmarine environment (diffuse source); H₂ generated from ophiolite weathering as a microbial energy source (local source – surface geology indicates a serpentinite body may be reachable by coring from the lab area); relatedness of surface and near-surface microbial communities and deep communities; *in situ* biostimulation in fractured rock; limits of life at depth; the effects of recent rapid cooling and geochemical weathering on microbial migration (recent glacial activity responsible for the Icicle Valley cut into and exposed the mesophile zone).
- *Mountain hydrogeology and ecology:* Groundwater flux between shallow and deep flow systems; global climate change implied by groundwater geochemistry and isotopics; geophysics of fracture flow systems; glacial retreat and soil microbiology.
- *Rock mechanics of fractured systems:* Transient processes during tunneling; testing numerical predictions for fractured media; imaging of fractured rock systems.
- *Coupled processes in fractured crystalline rocks:* Thermal/mechanical/hydrological/microbiological coupled processes; long-term geomicrobiological and abiotic mineral dissolution and precipitation, including processes governing ore formation.
- *Geology and tectonics:* Emplacement mechanisms for plutons; evaluation of the hypothesis that large plutons have floors; direct analysis of paleomagnetic uncertainties and cooling effects; possible collaborations with the Northwest Seismic Network.

The second site discussed in Sec. 6 provides access to both batholithic and older metamorphic host rock, thus extending earth science possibilities. Alternatively, if a distant DUSEL satellite site were to be supported by NSF earth science, a sedimentary site like Kimballton would be complementary to DUSEL-Cascades.

Engineering/applications: The DUSEL-Cascades plan has a strong engineering component focused on project construction. It includes TBM performance in hard rock; modeling and design of large cavities; tunnel safety systems; underground tracked transportation; visualization tools for science and public outreach; high speed communications; sustainable design strategies for surface and subsurface construction; and environmental engineering issues ranging from road repair near riparian zones to soil injection and other water-return strategies.

Among applications *low-level counting* (LLC) deserves special note because of the proximity of PNNL. PNNL, generally regarded at the lead laboratory in this field, is willing to design and operate a national facility for both open and secure LLC within DUSEL-Cascades [7]. The advantages include efficiencies in coordinating open and closed LLC (e.g., common utilities) and the presence of an experienced partner to handle the issue of a secure room in an otherwise open facility.

Education/Outreach: The Visitor Center, the keystone for DUSEL-Cascades outreach and education, is of great importance to the local community and to the region. The UW, Wenatchee Valley College, and other regional institutions are anxious to partner with the Visitor Center in bringing additional educational opportunities to an underserved region of the state. Examples of goals set in the Science Book include:

- Siting the Visitor Center so that it contributes to and benefits from the large ecotourism base in Leavenworth and the existing science-oriented facilities, such as the Audubon Center (<http://wa.audubon.org/new/audubon/default.cfm?pageID=13>) and National Fish Hatchery.
- Coupling K-12 student group visits to long-term efforts in distance education (making use of the site’s 10Gb potential) and teacher professional development. There is a large, ethnically diverse K-12 population within daytrip distance to Leavenworth. Native Americans have important cultural ties to the Icicle Valley that we would emphasize in the Visitor Center.

- Building around DUSEL a regional effort in undergraduate research, focused on primarily undergraduate institutions, in addition to a national program styled on summer REU programs. We are approaching a Northwest foundation with a request for initial funding of these programs.
- Development efforts to establish a program like Berkeley’s Miller Fellowships, to promote interdisciplinary interactions among DUSEL’s postdocs and visiting faculty. The Fellows program would be connected to the Visitor Center, as Fellow participation in public outreach/education will be a cornerstone of the program.
- Designing leading-edge facilities into the Center to accommodate educational partnerships and continuing education, thereby facilitating partnerships with university extension programs and local institutions.

4. PROJECT PLAN AND FUTURE ENGINEERING-PROPOSAL ACTIVITIES

This section summarizes the conceptual design and costing of DUSEL-Cascades [8]:

- The Facilities Development Plan: bringing utilities to the portal; tunnel and ring boring; laboratory room excavation; the mechanical and electrical outfitting of underground spaces; and Science Campus construction.
- The Facilities Operation Plan: the facilities and site operations plan.
- The Outreach/Education Plan: Visitor Center construction and operations.

Key issues are summarized below.

4.1 Underground Facilities Development Plan

Subsurface Access: Two parallel tunnels, approximately 6 m in diameter and 4.9 km in length, connected at their ends by a ring tunnel (0.9 km in length) encircling the laboratory site, provide subsurface access. The tunnel grade is -8%. The design is by Charles Nelson Associates. The tunnels are joined by crosscuts and air/fire doors every 500m. One (“guideway”) tunnel is equipped with rubber-tired tracked transport that can bring large equipment (20-ft cargo containers, I-beams and other oversized items) directly from the portal loading area into the laboratory, through a carwash similar to that at SNO. Tracking enhances safety while minimizing the required tunnel diameter. The second “driving” tunnel is the main access: electric cars will be used to transport personnel and light equipment. The laboratory room configuration of Fig. 1 corresponds to the rooms discussed in Section 3. The design allows “dirty-side” access to all rooms and future expansion/specialized room excavation outside of cleanroom barriers. Tunnels are finished with concrete floors, overhead ventilation ducts, and a below-floor pumping/drainage system.

Tunnel boring, rock removal, and schedule: In the past decade important improvements in hard-rock TBM performance have come from heavier cutter disks and improved bearings [9]. The DUSEL-Cascades design allows the tunneling to be done in a single pass. Important figures-of-merit for comparing projects (and the reality of schedules/costing) are the total length of tunnels/drifts required to gain 7400 ft of depth and provide dual horizontal access to lab rooms (10.7 km), the assumed advance rate (30m/day assuming 40% efficiency per shift), and the estimated cost (\$10.3K/m, sealed and including floors). The costs take into account the -8% grade: there are good benchmarks for TBM use on grades up to -20%. (A Frontier-Kemper consultant prepared the TBM and drill-and-shoot (laboratory room) cost estimates. The latter agreed with independent engineering estimates to better than 10%.) The TBM work period is estimated at 475 days and the civil construction period (from portal room/starting chamber through laboratory room excavation) is estimated as 2.6 years. That is, access to depth is obtained quickly because the tunnels are short. Rock would be transported to the portal room by conveyor and loaded onto trucks. Approximately 44 truckloads would be transported daily, as discussed earlier.

Utilities, ventilation and cooling, process engineering, communications, monitoring: DUSEL-Cascades average power needs at full operations are estimated to be 3.3 MW; this is substantially lower than most sites due to the efficiency of the design, the tunnel length, and low mechanical requirements. Power needs were estimated by Dunham Engineering based on a specific plan for ventilation, cooling, access lighting, and experimental needs. Power needs during the TBM phase of construction are estimated to be 4.0 MW. The Chelan Public Utilities District plan for DUSEL [10] provides (in its initial phase) 5 MW of average power and 10 MW of peak power. We view the bringing of utilities to the portal as a state responsibility and have initiated discussions with CTED: currently power ends four miles from the portal.

The ventilation system is crucial to safety and cleanliness. The all-electric design (no internal combustion engines below ground) reduces ventilation requirement and enhances safety. The tunnel (“dirty”) ventilation system delivers

a normal flow of 38,000 cfm, but is capable of 150,000 cfm in emergency mode. The emergency system allows for the exhaustion of any tunnel section through tunnel ceiling ducts, thereby keeping all other sections of both tunnels habitable. Laboratory rooms have a separate ducted system, based on recirculation with 20% replacement. This reduces fresh air requirements while increasing cleanliness (through repeated filtration). The laboratory is divided into a Class 100,000 “white space” and Class 1000-3000 clean space. There is a high-volume emergency (not recirculated) mode for laboratory areas that guarantees eight exchanges per hour in the largest cavity. Finally, there is a third “special processes” ventilation system for toilets, flammable liquid storage, machining areas, etc.

Other systems – chilled water (four 400-ton air-cooled chillers), central and unit controls, security and fire alarms, fire suppression systems (including pumps and storage tanks), water (domestic, industrial, and gray), sanitary waste, and data and communications – were designed to meet all applicable 2004 codes. We have also studied possible guide systems; radon mitigation; production, distribution, and purity control for experimental “utilities” such as liquid nitrogen and ultrapure water; mechanical processes like Cu electroforming; intercavern communications and controls; and shared facilities for open and secure LLC.

4.2 Surface Facilities: Science Campus and Visitor Center

Our study of Gran Sasso and other facilities led to the following assessment of Science Campus requirements:

- Surface lab/shop services must include a machine shop (complementing two underground machining areas); electronics shop; a plating, glass, and high-vacuum-technology shop; stores and receiving; chemistry facilities; surface support for the low-background facility; cryogenics support; and a computing and data acquisition support facility. The estimated requirement is 28,800 gsf.
- A minimum of 25,000 gsf is required for assembly (including clean space), receiving, and staging.
- Office space is provided for 30 permanent scientists and postdocs (160 asf/FTE), 100 visiting scientists (80 asf/FTE), and 60 administrative and support staff (130 asf/FTE), for a total of 38,000 gsf.
- Common spaces (auditorium, meeting rooms, library, cafeteria) require approximately 22,400 gsf.

The total (113,000 gsf) is similar to Gran Sasso, but provides more assembly space and less administrative space.

The Visitor Center plan was based on evaluations of several comparable centers serving between 130,000 and 650,000 visitors/year. While wide variations in uses were found, the design adopted for this conceptual proposal is most similar to the Lawrence Hall of Science, which serves 250,000 visitor/year, with a strong K-12 component. The main floor of the facility will focus on exhibits (including an auditorium and store) that tie DUSEL science to the geologic and cultural history of the area, including the importance of the Icicle and Wenatchee Rivers as Native American fisheries. A second floor would consist primarily of flexible classroom space to accommodate the Center’s educational missions (including possible university partnerships) and staff office space.

We have identified outstanding candidate sites for these buildings. One visually spectacular site for the Science Campus is a 40-acre parcel on the banks of the Wenatchee River, convenient to Leavenworth hotels, and about ten miles from the portal. The Port of Chelan owns the property. The quality and location of the Visitor Center is important to many Leavenworth citizens, who see the facility as a component of Leavenworth’s ecotourism. These citizens have asked the UW to consider designs emphasizing sustainability. Conceptual drawings by Mithun Architects illustrate how the Port site might be adapted to sustainable design, including natural ventilation, water reuse, natural vegetation, etc. (See Fig. 1: the drawing includes a possible 50,000 gsf far-future addition.)

The UW proposes to acquire the land and build/maintain the Science Campus and Visitor Center for the NSF and DUSEL operator, as is done for many other off-campus science facilities. The costs of these facilities have been estimated from costs of comparable laboratory and office space recently constructed on the UW Seattle campus. The UW Capital Projects office is preparing more detailed plans. As with all UW campus buildings, buildings would conform to the latest ADA standards.

4.3 Personnel Needs

DUSEL-Cascades personnel needs have been studied. The totals for most categories are effectively independent of site, assuming comparable levels of service: these include scientific support staff; engineering staff for assembly and transport of detectors; laboratory administration; onsite staff for the laboratory operator; and Visitor Center staff. The total number of required FTEs, derived by analyzing actual Gran Sasso, KamLAND, and SNO staffing, is 86.

However, the staff required to operate and maintain an underground facility are exceedingly site dependent: we find 21 FTEs are sufficient for a well-designed horizontal-access site providing 24/7 access.

4.4 Cost Summary

There are three site-dependent components to costs: construction costs, operations costs, and costs for experiments. Our group has costed construction for a former mine with existing deep access (<http://xxx.lanl.gov/pdf/nucl-ex/030815/>) and for the present site, using in many places identical spread sheets, adjusted to reflect local wage indices. Our conclusion is that development costs for an undeveloped site of the quality of Cascades are comparable to those for adapting an existing site, while greater functionality can be achieved with the undeveloped site.

Our site-development costs for DUSEL-Cascades employed contingencies of 50% for property issues (environmental, permitting, easements, mitigation) and surface utilities; 40% for TBM work and nonpersonnel operating costs; and 25% for laboratory room excavation, underground systems, and surface construction. The resulting proposed, potential funding agency responsibilities are:

- Underground construction, insurance/mitigation, and operations for the first five years (site operations and maintenance, all scientific and administrative operations, on-campus indirect cost (IC) rate): \$258M
- LLC instrumentation, operations, and IC: \$23M (possibility of PNNL/DOE partnership)
- Education and outreach five-year operations and IC: \$4.6M
- Laboratory management costs and IC: \$8.9M

DUSEL-Cascades will have very low facility operations and maintenance costs because of the horizontal access, efficient ventilation, and low power rates (\$0.016/kW-h). The total for personnel, electricity and other utilities, and supplies is \$4.0M/y. Power costs provide a 40-year advantage of up to \$300M over some competing sites.

Perhaps the most important advantage is the lower cost of experiments in horizontal-access facilities. For example, most SNO experimentalists attribute the four-year delay in that experiment to the ship-in-the-bottle problem of hoist footprints limited to 3.6m × 1.1m × 1.75m; hoist use restrictions that often imposed two-day delays on repairs requiring surface facilities; and complications due to the daily traversal of the mine to reach SNO. The savings possible with a drive-in, clean facility over 40 years are equivalent to many, many person-years of scientific effort.

4.5 Site Issues to be Addressed in the Engineering-Proposal Phase

The UW has been the primary source of support for the development of this proposal, as well as for an earlier proposal for a former mine. It intends to continue to support administrative, scientific, engineering, and legal teams for DUSEL-Cascades (see Sec. 5) while partnering with the NSF on future studies:

- The Shannon and Wilson geotechnical study describes a program of additional site investigations and evaluations, the completion of which will take about three years, depending on outcomes. The most immediate task is the further characterization of the candidate portal sites. This includes further fieldwork and surface probes, such as seismic refraction studies, to evaluate soil and weathered rock depths, coupled with reconnaissance to evaluate rockfall/ice hazards and staging-area constraints due to terrain or proximity of the riparian region. The outcome will be a ranking of the candidate portal sites.
- Two coring efforts will be undertaken. Horizontal drilling at the portal can probe 15% of the proposed tunnel alignment (2000-2500 ft) with good core recovery. The existing deep access at Pioneer Tunnel provides an opportunity to complete *in situ* stress-field measurements under Cowboy Mountain (see Sec. 6), important to assessing large-detector potential and likely instructive for the batholith as a whole.
- Initiating critical-path permitting. Portal coring is most likely categorically excluded under NEPA in accordance with USFS Handbook 1909.15 Sec. 31.2.g, which governs coring for geophysical data. However a ruling will not be made until a permit is requested. The UW has retained a consultant to begin work on water for coring and other needs, including the availability of water rights for lease or purchase.
- We intend to host collaboration meetings focused on engineering, earth science, and education/outreach issues critical to project construction. The first two groups will be involved in coring program decisions. The collaboration's engineering group will support the project managers by providing civil construction, ventilation, underground transport, networking, and environmental expertise. As the education/outreach program is critical to public support of DUSEL-Cascades, we would like to further engage the local

community, building on recent discussions between the UW's Partnerships and Learning Technologies Office and local institutions, such as Wenatchee Valley. UW Development will also play a role.

- The UW will continue with surface facilities planning and coordination with CTED, as this is a proposed state responsibility that will be the basis of a request to state government in the next biennium.
- As described previously, the UW has formed a strong public relations team for DUSEL-Cascades. The next step of this effort, jointly supported by the UW and the Port of Chelan, is the completion of an economic profile for the project, focused on local impacts. A consulting firm has been hired.

5. ORGANIZATION, MANAGEMENT, SNOLAB AND OTHER INTERNATIONAL ISSUES

We have adopted the following organization for the engineering-proposal phase:

- *Cascades Science Collaboration*: This is a group of about 130 collaborators from 39 institutions [11]. The collaboration is open. The group's interim executive committee (or "science council") will help us reach others in the community, organize collaboration activities, and critique proposal components.
- *DUSEL-Cascades Office*: This office was created by the Provost to provide the DUSEL-Cascades project with technical and administrative support, through existing UW offices and outside consultants.
- *DUSEL-Cascades Engineering-Proposal Group*: This group consists of key individuals from the Collaboration and Office groups, the project managers, engineering firms under contract to the project, and two outside advisory committees (on tunneling/excavation and on international laboratories). The PI will work with this group to produce an engineering proposal.

DUSEL-Cascades Science Council

Physics and Astrophysics: Coordinator John Wilkerson (UW)

Low-Energy Neutrinos: S. Freedman, J. Klein, P. Vogel

Accelerator Neutrinos: B. Louis, J. Peoples, M. Shaevitz

Dark Matter, Supernovae: D. Akerib, E. Aprile, K. Scholberg

Nucleon Decay: B. Marciano, J. Siegrist, J. Wilkes

Nuclear Astrophysics: A. Champagne, U. Griefe, M. Wiescher

Low-level Counting: P. Cushman, H. Miley, T. Shutt

Earth Science and Geomicrobiology: Coordinator Phil Long (PNNL)

Geology/Geophysics: S. Hubbard, B. Miller, H. Wang

Geomicrobiology: J. Fredrickson, T. Kieft, T. C. Onstott

Hydrogeology: B. McPherson, F. Spane, J. Wang

Geochemistry/Geobiochemistry: R. Bodnar, R. Colwell, G. Wasserburg

Engineering and Environment: Coordinator Bob Holtz (UW)

Rock Mechanics: E. Cording, D. Elsworth, C. Fairhurst, C. Laughton

Vis/Mech/Transp/Envir: T. DeFanti/J. Leigh, A. Emery, S. Rutherford, Anne Steinemann

Education/Outreach: Coordinator Paula Heron (UW)

K-12/Teacher Prof. Enhancement/Outreach: L. Fortson, S. Pfiffner, L. McDermott

Undergraduate/EPSCoR Institutions: W. Buck, R. Dawes, R. Machleid

UW DUSEL-Cascades Project Office: Coordinator Marilyn Cox (UW Director, Capital Planning)

Spokesperson: L. Huntsman *UW Support*: C. Hogan (V. Provost) *Development*: M. Dietz (Assist. V.P.)

Legal: T. C. Richmond (Asst. Attorney General), R. Brown (Brown, Reavis, and Manning)

Environment, Community Outreach: K. Cottingham *Capital Project Delivery*: R. Chapman (UW Capital Projects)

Architects: L. Copeland, B. LaPatra (Mithun Inc) *Economic Profile*: Reed Hansen/Chase Economics

Networking: R. Johnson (UW V.P., Computing) *Water Permitting*: John Segerson, SEMCON, Inc.

PNNL Partnerships: L. Peters (Director, PNNL), J. W. Rogers (Chief Scientist, PNNL and INL)

Educational Partnerships: L. Fox (UW V. Provost, Ed. Partnerships), C. Goodheart (Exec. Dir., Ed. Partnerships)

Intergovern. Coordination: B. Perry (UW Assoc. V.P., Fed. Relations), R. Hodgins (Director, State Relations)

DUSEL-Cascades Engineering-Proposal Group: Coordinator Wick Haxton (UW)

Project Management: B. Hartline, J. Marx

All Coordinators for Science, Project Office Leads, and the WA Dept Community, Trade, Economic Development Engineering Consultants: (currently Shannon and Wilson; CNA; Parsons Brinckerhoff; Dunham Engineering)

Adv. Committee, Labs: S. Bettini, V. Gavrin, A. McDonald, Y. Suzuki

Adv. Committee, Tunneling: T. Doe, P. Gilbert, H. Parker, R. Robbins

General DUSEL management issues are discussed in [11], where a model recommended to us by URA is described. We anticipate that an experienced management group, selected by the NSF in a competitive process, would hold the cooperative agreement and that the State's need to fulfill its health, safety, and user permit responsibilities would be addressed through a MOU with the manager. The S-1 process is expected to address this issue. The current DUSEL-Cascades Office would evolve into the entity that fulfills State oversight obligations.

IUPAP's recent creation of PANAGIC illustrates the growing recognition of the importance of international coordination in large-scale underground science. To help us in this area, we have recruited a strong advisory committee on international facilities (Bettini, Gavrin, McDonald, Suzuki). One charge to the group will be advice on the relationship between DUSEL and SNOLab, the two future deep labs in North America. The Cascades site presents special opportunities for SNOLab cooperation. The SNOLab and Cascades sites are on opposite ends of the continent, and offer different types of access: US experiments with modest access requirements might prefer to work at SNOLab because of proximity. Similarly, four of the eight major research institutions nearest Leavenworth are Canadian, including TRIUMF, Canada's lead subatomic physics lab. TRIUMF's underground interests (the nuclear astrophysics accelerator, long-baseline neutrino physics now focused on Japan) align well with programs planned for DUSEL. Thus we anticipate significant Canadian participation in DUSEL-Cascades. We can envision a formal relationship between DUSEL-Cascades and SNOLab where the decisions on siting of new experiments would be done cooperatively, in order to make the best use of all deep North American underground space.

6. OPTION FOR A LONG-BASELINE/NUCLEON DECAY LARGE DETECTOR

The construction of a large underground detector for superbeam long-baseline neutrino studies and nucleon decay is a key future goal for US underground science. This project is distinct from DUSEL because of its size (perhaps \$650M) and timing (construction starting sometime after DUSEL is operational). It will be funded separately from DUSEL and likely by a different agency. But many in the community hope that funding for such a detector will follow the establishment of DUSEL, and that DUSEL will play a lead role in its construction. Thus the capacity to participate in and support a future large detector is an important DUSEL site issue:

- The detector site has to be an appropriate distance from the superbeam source: a distance of ~ (2500-2800) km may be optimal for envisioned proton drivers, while the range 1000-5000 km is acceptable.
- Cavities of dimension 60m × 60m × 180m have been proposed. S-1 discussions to date suggest that the preconstruction engineering program to establish the feasibility of such a cavity – including detailed coring studies of the rock mass, laboratory testing of the rock, modeling the rock, and further tests to validate the model – and to design the required specialized excavation protocol might take two years. This favors sites with existing access, so that preconstruction feasibility and engineering studies can be completed at low cost.
- The site should be convenient for major underground construction and rock haulage or disposal.
- The detector should be placed at moderate depth. The NRC Neutrino Facilities committee recommended at least 2000 mwe for proton decay; 3000 mwe has been given as a depth adequate for solar neutrinos (e.g., day/night studies). HEPAP gave 4000 mwe as its goal. As stress fields generally increase with depth, physics goals and geotechnical support costs should be considered together in determining the optimal depth. Hyper-Kamiokande's modest depth (1400-1900 mwe) is due in part to geotechnical considerations.
- The stability of site ownership/operations is crucial due to the expected 40-year project lifetime.
- HEPAP envisioned ten years of excavation/detector construction. If the detector is co-located with DUSEL "deep and clean" science, this raises issues of reduced access, quietness, and cleanliness for DUSEL users.

Ref. [12] describes a plan by which DUSEL-Cascades, working in partnership with the State of Washington and the

BNSF Railway, could develop a detector site under a second peak in the batholith, Cowboy Mt. (elev. 5853 ft). The plan addresses all of the issues discussed above:

Location: Cowboy Mt. is 16 miles north and west of the Cashmere Mountain DUSEL site. (See Fig. 1.) The peak is immediately above the BNSF Cascade and Pioneer tunnels, 2.3 miles from their west portals, on USFS land. Access is horizontal at a 1.56% positive gradient. Highway 2 and the railway connect the tunnel portals directly to the proposed DUSEL Science Campus (near Leavenworth). The rail and highway (west portal) distances are 35 and 42 miles, respectively. Thus the DUSEL Science Campus could conveniently support this second site. The neutrino baseline to FermiLab (2630 km) is ideal and to BNL (3830 km) well within the acceptable range.

Geology: There is an outstanding database. The site corresponds to tunnel station 279 on the Pioneer Tunnel map [1,12], an area of batholith granodiorite, separated by about 0.9 km from the nearest significant feature, a quartz dike to the west that marks a boundary with a finger of the older host rock (schist). In the immediate vicinity there is one mapped shear zone, about 75m to the east. The rock is dewatered. Uniaxial compressibilities of 15 kpsi were obtained for granodiorite samples from weathered Pioneer Tunnel walls, and 25 kpsi is expected for the deep granodiorite. The joints are tight, slightly altered, and slightly rough, with typical continuities of 5-10+ ft and spacings of 0.5-2.0 ft. The RQDs were 85%. The rock temperature for new openings under Cowboy Mt. is 21°C.

Overburden: Our plan would place the base of the large detector at a depth of 1120 m or 3240 mwe.

Existing infrastructure: Highway 2 is a major power and communications corridor, connecting Columbia River dams with Seattle. Abundant power and fiber communications are available at the portal. Rail/highway access has been described. Drainage from 21 km of tunnels, measured at the west portal, is 600 gpm. The water is of good quality and is potentially useful for filling a detector.

Site stability: The site should be available indefinitely. The project would require a use permit from the USFS and a cooperative agreement with BNSF. The USFS land designation is appropriate.

Ventilation: While an experiment like UNO might be given an exemption, the code requirement for emergency venting is six exchanges/hr. Using $\sim 300,000 \text{ m}^3$ as the air space, this requires a system capable of about 1M cfm. Our location could provide 0.55 M cfm initially, with the possibility of an additional 0.55 M cfm within 10-20 minutes of an emergency.

Project phases, timing: In Phase I drilling would be done from the Pioneer Tunnel into the rock mass north of the Cascade Tunnel, the proposed detector site. This would entail a series of short (600-700 ft) borings at angles ranging down to 30% from horizontal. Laboratory core tests and rock-mass modeling would be done to evaluate the suitability of the site, the support requirements, and a preferred excavation strategy, as discussed above.

Were a decision made to proceed with the large detector, Phase II would begin with the enlargement of the Pioneer Tunnel, using smooth-wall blasting techniques, to enhance its ventilation capacity and to allow large vehicles (trucks and train cars) to enter. No new access drifts would need to be bored. The only new construction for the purposes of access or ventilation would be a 660-ft concrete-lined raise-bore exhaust shaft costing $\sim \$1.2\text{M}$, at the eastern end of the Pioneer Tunnel. (Effectively this reopens the Mill Creek shaft, which was used in the original construction.) The Pioneer Tunnel floor would be a drivable, railed surface (such as that used in the Whittier Tunnel). This would convert the Pioneer Tunnel into a siding on the BNSF main line, connected to the mainline outside the west portal (see Fig. 2). During excavation crushed rock would be loaded onto railcars underground and marketed in Seattle; subsequent detector construction could be supported by both rail and truck. The value of the crush rock produced in the UNO-scale excavation ($\$6.50/\text{ton}$) could exceed the cost of all access improvements. The horizontal rail and truck access would be an enormous asset throughout construction. The large-detector laboratory would be built off the Pioneer access/ventilation drift.

The development would sequester scientific activities and BNSF operations apart from three functions, ventilation, drainage, and refuge. A series of cross cuts connecting the enlarged Pioneer Tunnel to the Cascades Tunnel would provide refuge for each. BNSF would benefit from improved safety, drainage, and ventilation (see below).

Broader impacts and potential cost sharing: The tunnel and ventilation aspects of this project also address one of the Northwest’s pressing transportation problems. The Stevens Pass route is the main freight intermodal between the Seattle/Tacoma ports and the east because the clearance is sufficient for double-stack trains. As the current one-zone Cascade ventilation system imposes a minimum separation between eastbound trains of about 64 minutes, the tunnel is a bottleneck that will lead to route saturation by about 2012. Several solutions have been explored previously, but proved either ineffective or very expensive. The Puget Sound ports, which rank third nationally behind the New York and Los Angeles port areas in total cargo handled, are concerned about the rail limitations.

The steps described above for providing ventilation, enhanced access, and an exhaust shaft are exactly the steps needed to convert the existing one-zone Cascade Tunnel ventilation system into a two-zone system, such as that deployed in Canada’s MacDonald Tunnel. The only additional construction is an airdoor at the tunnel’s midpoint. The BNSF ventilation requirement of 550,000 cfm matches well our desires for a tunnel cross section adequate from truck and rail-car access. Such a two-zone system would reduce the minimum separation between eastbound trains by nearly a factor of two, to 34 minutes, significantly relieving congestion on this route. This would be a major upgrade for BNSF at very low cost. There is an additional upgrade possible, to a three-zone system that would reduce the separation time to 24 minutes. This requires a second 1000-ft shaft and fan system, which are not costly. We anticipate that this “broader impact” could lead to opportunities for cost sharing with BNSF and with CTED and other State agencies.

The site also has outstanding potential to provide an underground experience for the general public. One interesting possibility is a “science train” – modeled on Leavenworth’s current Christmas trains – that would link Seattle, the Cascade Tunnel site, and the Visitor Center in Leavenworth.

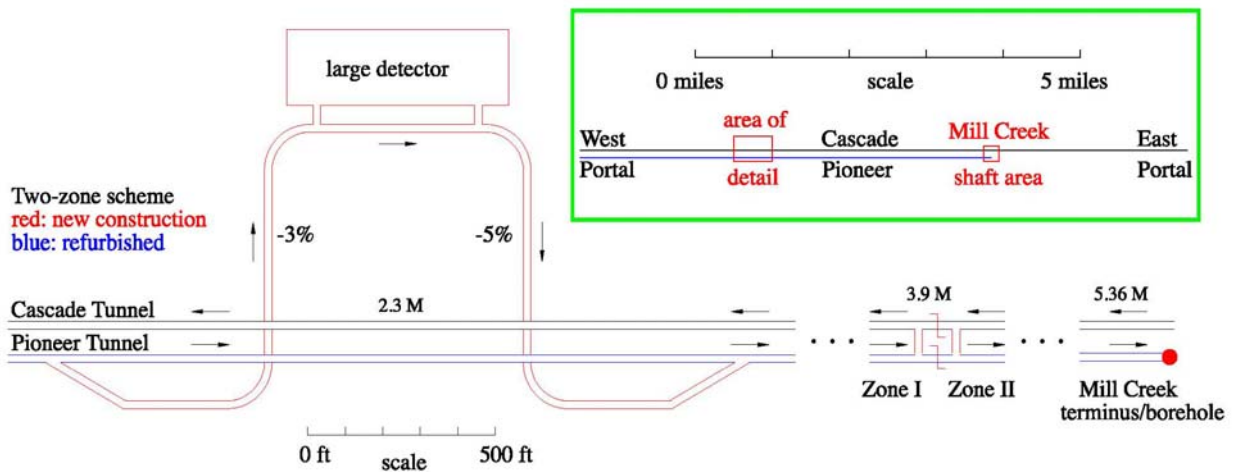


Figure 2: The large detector/BNSF two-zone configuration.

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