

Deep Underground Science and Engineering Laboratory: DUSEL-Cascades

Background

The Deep Underground Science and Engineering Laboratory is a proposal to the National Science Foundation to create a deep-underground laboratory for basic research in physics, astrophysics, earth sciences, geomicrobiology, and engineering. This effort began in September 2000 with a recommendation by the Long Range Planning Group of the Nuclear Science Advisory Committee, which advises the National Science Foundation and the Department of Energy on basic research needs. Russia, Italy and Japan already have such laboratories.

The purpose of going very deep underground is to escape cosmic rays and other contaminants that interfere with our most sensitive detectors. To be clean enough, a laboratory must be built under a mile or more of rock.

Underground research is at the cutting edge of science. One group of experiments seeks to solve the mystery of dark matter and energy. We know that the matter we can see—the planets, stars, and all of the galaxies they form—accounts for only four percent of the matter and energy of the universe. The rest is invisible to us, although its gravity shapes and controls the motion of our universe. Dark matter experiments are designed to identify this new form of matter.

Other experiments involve massive underground observatories to detect neutrinos. Neutrinos are particles produced by our sun as well as in extraordinary stellar explosions called supernovae. The ghostly neutrinos pass through matter almost undetected. They come to us directly from the centers of stars, carrying information about the mechanisms of stellar energy generation. Their properties also are central to fundamental theories about nature. Very recent discoveries in solar neutrino physics have shown that our “standard model” of particle physics is wrong—and hint of new physics that may explain how matter was created in the Big Bang.

Another type of underground research, geomicrobiology, seeks to determine the limits of life. Microbiologists have discovered that new forms of microbial life have evolved deep underground, at high temperatures and under great pressure, deriving energy from chemical reactions in the rock. Some scientists believe such deep microbes provide our best model for astrobiology—the study of life forms that may exist elsewhere in the solar system. Because Earth and Mars have exchanged matter, life could have migrated between the two, in the form of hardy microbes.

Other earth science experiments focus on cracks and fissures in the rock, minerals and their formation, transport of surface water to and from the deep subsurface, and associated biological activity.

Such basic science work often has practical applications. The pharmaceutical industry is interested in geomicrobiology because properties of new microbes could lead to new drugs. Massive detectors modeled after those from neutrino physics are being developed to create rapid images of large cargo containers—a crucial post-9/11 issue for the ports of

Seattle, Tacoma, and Portland. Hydrological studies are essential to understanding how long-term climate change may be affecting the quality and purity of subsurface water supplies.

Developments since September 2000

The University of Washington, acting on behalf of a national collaboration of leading scientists and their research institutions, submitted the original DUSEL proposal to the National Science Foundation in June 2001. Seven committees, including two from the National Academy of Sciences, have strongly endorsed the importance and urgency of a deep underground laboratory.

The primary site identified in the original University of Washington proposal was the historic Homestake Gold Mine in South Dakota

In June 2003 the mine's new owner, Barrick Gold Corporation, turned off the pumps that kept water out of the lower reaches of the mine. University of Washington scientists who had led the underground laboratory effort began a search for an alternate site. In February 2004 the National Science Foundation returned the Homestake proposal and announced a new process for evaluating DUSEL and identifying the best site.

The site search for and the identification of the DUSEL-Cascades Site

The new University of Washington site search focused on horizontal-access sites, laboratories placed at the end of a tunnel excavated under a mountain. Such sites are generally more functional and significantly less expensive to operate. The major multipurpose international underground laboratories are all of this type.

The University of Washington conducted a study in summer 2003 to identify sites similar to those developed in Russia and Italy: steep, tall mountains with high-quality rock through which tunnels could be built to depth. The group searched likely areas, including California, Nevada, Washington, Arizona, New Mexico, and Colorado. Search criteria included the potential to achieve the required depth, tunnel paths no longer than five miles, and land suitable for such a project. Scientific developments are generally permitted only in private, National Forest, or National Recreational Areas. Twelve sites were identified for further study.

Geotechnical criteria important to any potential site include competent rock, favorable hydrology, and the absence of major faults. Consulting geologists and geotechnical groups used these and other criteria to evaluate the sites, and agreed that Cashmere Mountain was the outstanding candidate. The attributes of this site include great depth (7400 ft); uniform, highly competent rock; a long and successful history of tunneling in the same rock mass; and excellent accessibility. The utility tunnel for one previous excavation, the 8-mile New Cascade Tunnel, is largely unlined, allowing geologists an extraordinary opportunity to assess the geology and hydrology. Other Cashmere Mountain advantages include low-cost power and good visitor accommodations in the nearby town of Leavenworth.

Proposed construction

The 5-year construction cost of the project is approximately \$300 million. There are three major components:

- **The underground laboratory:** This would consist of a portal (tunnel entrances) at the base of Cashmere Mountain, two 3-mile parallel tunnels deep under the mountain, and a series of rooms for experiments at the tunnel ends. Underground construction would be completed in about 32 months.
- **The surface campus:** This, the main center of activity, would be sited in or near Leavenworth. Here, scientists, technicians, postdoctoral researchers, and students would monitor experiments, build detectors, and analyze data. The estimated space is 110,000 gross square feet, including the underground basement area. The site would resemble a portion of a university.
- **The Visitor Experience Center:** This would be an education-and-outreach center of about 48,000 square feet. The staff would host K-12 students and teachers interested in science, as well as conducting public outreach programs on science and sponsoring research in science education, while partnering with other community and educational groups. Sites are being identified that could accommodate, together or separately, the surface campus and the Visitor Experience Center.

Types of materials used underground

The materials used underground are generally not hazardous. Almost any material that would be used in such a laboratory is common in urban university physics departments. As they would for a physics department, U.S. national science agencies impose the strictest standards on materials handling. All liquids in the laboratory must have complete primary and secondary containment. Detector materials include solids like sodium iodide and germanium (from which detector crystals are made), liquid scintillator (a hydrocarbon), and cryogenic liquids such as helium, nitrogen, neon, and xenon. Cryogenic liquids, on warming, form gases which, while not dangerous chemically, displace oxygen and thus could cause asphyxiation. The laboratory's ventilation system must therefore be capable of venting these gases. The underground lab will have environmental and safety oversight committees on which state officials and the public will be represented.

Project impacts and mitigation measures

The laboratory's basic science program is part of humanity's ongoing effort to understand the nature of the universe in which we live. Its discoveries will be a lasting legacy of our generation. Applications of those discoveries could improve microelectronics and medicine, and extend our capacity to monitor our environment. The laboratory's outreach and education programs would help introduce the next generation to science, fostering technological literacy and equipping citizens to make informed decisions about the stewardship of the world around us.

The laboratory also will have some negative impacts, particularly during the three-year underground construction period. Because our group wants the laboratory to be accepted as a net positive for the community, we will take great care to identify and minimize adverse impacts on the greater Leavenworth area. Potential impacts and mitigation measures include:

- **Underground laboratory construction:** The proposed entrance to the tunnels is north of the bridge near Bridge Creek campground: a gravel/dirt road parallels (and is screened by trees from) Icicle Creek Road on the south side, running upstream. The proposed portal site is off this road, about 500 yards from the bridge, in U.S. Forest Service lands, outside the riparian areas. We would need to improve this road. The bridge was built for logging and is sturdy, rated at 40 tons.

The physical impact of the finished portal would be very modest: it would resemble a standard tunnel opening in a rock wall. The tunnels would go deep into bedrock, 7400 feet below the peak of Cashmere Mountain. There would be no disturbance of the surface above.

Scientists needing access to the underground observatories will be transported by electric shuttle from the surface campus to the underground laboratory. Internal combustion engines will not be allowed in the facility. Most experiments will run remotely, by fiber connections to the surface campus. While the use of private automobiles to reach the portal will be discouraged, there will be deliveries, emergencies, and other occasions where individuals will drive to the portal. The laboratory will provide several parking spots just inside the portal entrance, to minimize any noise or surface visual impact from such vehicles.

Prior to the start of construction, it is likely that one or more core samples will be taken to characterize the geology. This process is similar to drilling a well, though the core diameter is significantly smaller. The surface entry for core sampling would be on National Forest lands outside the wilderness. Once coring is completed, there will be no visible impact.

The most intrusive construction impact will be the trucks hauling crushed rock. During the 2.6 years of tunnel and laboratory construction, an average of 44 trucks per day will be needed for rock removal. Potential impacts include traffic, noise, diesel fumes, and dust.

Every effort will be made to mitigate truck impacts. Measures we are considering include:

- Carefully covering loads
- Driving at low speeds through areas with houses
- Scheduling the traffic so that quiet periods are preserved (including grouping trucks in threes and fours)
- Periodic cleaning of the road and any private property that is affected
- Restoring and improving the road before and after construction
- Requiring trucks to be retrofitted and to use low-sulfur fuels to minimize emissions.

While accurate traffic data for Icicle Creek Road is not currently available, local officials estimate that approximately 400,000 vehicles (cars, RVs) use the road each year, with about 25% of this traffic proceeding beyond the Snow Lakes trailhead (and thus onto the Forest Service portion of the road). Laboratory construction would temporarily increase this load by about 4%.

- **Power:** Because of the underground laboratory's cooling, ventilation, and communications needs, a 12kV distribution line and high-speed cable must be installed. We intend to bury these lines, as better reliability and aesthetics is worth the extra cost. The Chelan PUD has suggested bringing the power down Icicle Creek Road, from the Leavenworth transmission station. While the burying of the cable is an adverse impact, the potential for property owners to bring their lines underground at very little additional expense is a potential positive impact. Currently, the overhead lines near Icicle Island detract from views of the valley.
- **Water:** We are investigating potential sources of construction water. The needs are quite modest. Some water will be recovered from the tunnel during construction. That water might be used for construction purposes before it is monitored, treated, and returned to the underground.

We are also investigating potential sources of water for the operation of the underground laboratory. The daily water needs are small, approximately 1000-2000 gallons.

It is possible that DUSEL will contain a water-based Cerenkov detector. Currently the largest such detector contains 50,000 tons of water. Typically such detectors run for several years before being drained and refilled for maintenance. Possible water sources for the detector are being explored.

- **Wildlife:** Areas sensitive because of wildlife would not be suitable for our portals or construction. Coring would be done at optimal times, e.g., well after nesting has been completed.

Potential positive impacts

In addition to the important basic and applied science, education, and outreach performed by the laboratory, the community may benefit in other ways:

- **Rock disposal:** Part of the crushed rock would be used in the construction of the tunnel roadbed. But the bulk of this material would have to be moved off site, as noted above. It is possible that the USFS will claim part of the rock for its maintenance purposes. Other beneficial uses of the rock from the construction of the tunnels and underground rooms are being explored.
- **Laboratory buildings and civic planning:** Several sites have been suggested for the surface campus and Visitor Center. The Visitor Center should be positioned to support the already established visitor industry in Leavenworth. The surface campus requires sufficient space and reasonably convenient access to Icicle Creek Road, but several sites appear to satisfy these requirements. Because of the laboratory's engineering mission, we very much want these buildings to be energy efficient, environmentally sound, and architecturally attractive. The University of Washington will work with community planners to make the proposed campus a source of civic pride.

- **Visitor Center/Other campus connections to the community:** The proposed theme for the Visitor Center will link the site's unusual geology to the region's cultural history and to the physics and earth-science research of the lab. The proximity to the National Fish Hatchery and to the Audubon Center is a strong positive: both have (or are planning) active outreach efforts. We believe community coordination in outreach is important. During the academic year, school groups will make up most of the Center's visitors; in the summer, the users will be more diverse. The Center will play an important role in DUSEL summer research programs for undergraduates and for K-12 teachers.
- **Research of special regional relevance:** While the principal science activities are physics, earth science, and geomicrobiology, the laboratory will host other activities of interest to the local community and regional institutions (including the UW, PNNL, Washington State University, Wenatchee Valley College, and the Forest Service). For example, the surface campus has been suggested as a base for field studies in ecology. There are active programs in the Schools of Forestry and Aquatics/Fisheries on issues relevant to the Icicle Valley, such as forest fire recovery and stream restoration. Laboratory infrastructure—support staff, computing, chemistry and microbiology labs—would make the campus an attractive base for graduate and undergraduate students and other researchers wanting to do field work.

Economic and social benefits: Approximately 80 permanent staff and a total of about 100 visiting scientists, postdoctoral researchers, and students would occupy the surface campus. The Visitor Experience Center will have a permanent staff of 20-25. Most of the permanent jobs associated with the laboratory are white collar or technical: administrators, chemists, machinists, laboratory technicians, draftspeople, educators, and the like. The positions will include good benefits and job security. Approximately two-thirds of laboratory employment, both in construction and operations, would come from the local area.

The laboratory may attract other high-tech ventures to Chelan County. The research interests the microelectronics and pharmaceutical industries. Companies wanting to locate nearby will include those supplying instrumentation and those anxious to apply laboratory detector developments.

The NSF estimates the annual activity at the Laboratory to be about \$50 million. The lab's duration is indefinite, but likely to be no less than 40 years.

The University of Washington submitted its proposal for the Cascades sites on February 28, 2005. The collaboration includes 130 scientists from 39 institutions, including several overseas. A principal partner is Pacific Northwest National Laboratory in Richland.

The planning process envisioned for the next several years is one of partnership with Leavenworth and the County, so that the laboratory can be integrated into a larger vision for the community. The NSF is supportive of projects that take into account community and environmental benefits.

See <http://int.phys.washington.edu/NUSEL/cascades.html> for more information.