PNNL-21218
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Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

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Richard Kouzes, David Asner, Ron Brodzinski, Jim Fast, Harry Miley

July 18, 2006 revised May 11, 2012

## Introduction

*"The International Linear Collider will give physicists a new cosmic doorway to explore energy regimes beyond the reach of today's accelerators. A proposed electron-positron collider, the ILC will complement the Large Hadron Collider, a proton-proton collider at the European Center for Nuclear Research (CERN) in Geneva, Switzerland, together unlocking some of the deepest mysteries in the universe. With LHC discoveries pointing the way, the ILC – a true precision machine – will provide the missing pieces of the puzzle.*

*Consisting of two linear accelerators that face each other, the ILC will hurl some 10 billion electrons and their anti-particles, positrons, toward each other at nearly the speed of light. Superconducting accelerator cavities operating at temperatures near absolute zero give the particles more and more energy until they smash in a blazing crossfire at the center of the machine. Stretching approximately 31 kilometres in length, the beams collide 14,000 times every second at extremely high energies – 500 billion-electron-volts (GeV). Each spectacular collision creates an array of new particles that could answer some of the most fundamental questions of all time. The current baseline design allows for an upgrade to a 50-kilometres, 1 trillion-electron-volt (TeV) machine during the second stage of the project."*[1]

The high-energy physics (HEP) community has historically relied upon evolving generations of accelerators reaching ever-increasing energies. The ILC is the follow-on accelerator to the LHC, currently operating at CERN. The LHC offers outstanding opportunities for discovery of new physics beyond the reach of today's accelerators: supersymmetry, Higgs particles, extra dimensions, etc. However, the proton-proton collisions at the LHC are not ideal for precision studies of new physics processes and particles that might be observed. Such studies are the focus of the ILC, much the way that the linear electron-positron (LEP) collider at CERN provided the precision measurements of the physics discovered at the Tevatron and SPS proton-antiproton colliders.

The ILC will require a pair of 30 km tunnels (for 1 TeV), perhaps with a 20 mrad "kink" at the interaction point. One tunnel is for the accelerator, and the parallel tunnel, which may be above or along side the accelerator tunnel, is for mechanical and electrical equipment. Surface facilities for ventilation, power, cryogenics, etc. will be required about every 5 km along the tunnel. The tunnels can follow the curvature of the Earth, rather than having to be strictly linear, which potentially simplifies the construction which otherwise would be about 100 m deep at the center.

The ILC is an international collaboration organized into three regions – the Americas, Europe, and Asia. The ILC will have a construction cost of about $15B, shared among

[1] From http://www.linearcollider.org/

the partners. Among the primary factors being considered within the Americas are proximity to existing HEP facilities, electricity costs, and geological stability.

**Hanford as an ILC Site**

The Hanford Site, owned by the DOE and seen in Figure 1, would be able to fully contain the ILC along the southwestern side of the site with easy access from public roadways (SR 240). Sufficient virgin land space is available at this location. The land could be released by the DOE to another entity, which was done when the DOE turned over the portion of the Hanford Site designated as the Arid Lands Ecology Reserve to the U.S. Fish and Wildlife Service. The Arid Lands Ecology Reserve is directly across SR 240 from the proposed Hanford ILC site. The Hanford Laser Interferometer Gravitational Wave Observatory (LIGO) is located on the Hanford Site, on land leased by DOE to NSF. The ability to segregate the ILC site from the Hanford Site enables access regardless of citizenship.

The Pacific Northwest National Laboratory (PNNL) and the adjacent Hanford Site have a ~15,000 person technical workforce, with 5000 of those at PNNL. The Environmental Molecular Sciences Laboratory, a national scientific user facility, is located at PNNL. Washington State University (WSU) has a branch campus next to PNNL, and PNNL has a strong working relationship with the University of Washington (UW) and their Department of Physics, including the Center for Experimental Nuclear Physics and Astrophysics (CENPA).

Plentiful electric power is available at Hanford due to the Bonneville Power Authority (BPA) hydropower dams and nuclear power plant within a few miles, which results in low electric rates. Fermilab pays ~7.1 cents/kWh,[2] and Fermilab spent $12-18 M/y on electricity when the Tevatron was operating. PNNL pays less than 5 cents/kWh and consumes ~85 million kWh per year. The wholesale cost of power at Hanford is ~3.3 cents/kWh. Siting the ILC on the Hanford site would save about 50% in electrical expenses alone relative to siting in Illinois. Other operating costs and labor costs should also be lower at Hanford than the proposed ILC site at Sycamore, IL, near Chicago. The Hanford area has a low cost of living, which should be especially beneficial for long-term visitors.

Access to the Hanford site for shipping of equipment is very good. There is rail access to the site as well as good highway access. There is a major DOE shipping and receiving facility on the site. There is also excellent river access for large barges at the Hanford site plus local transportation for large items. As an indication of the cargo capacity of the Columbia River, the Hanford site is the disposition site for U.S. nuclear submarine reactors that are barged to within a few miles of the site. Figure 2 shows submarine sections containing their reactors being transported and stored at Hanford.[3]

The Tri-Cities and neighboring communities have a population of ~180,000, an extraordinarily large fraction of whom are highly skilled in technical disciplines by virtue of the PNNL and engineering contractors working on the Hanford Site. Hanford is the

[2] http://www.chicagobusiness.com/cgi-bin/news.pl?id=19316
[3] http://ussskipjack.org/585images/L-hanford.jpg

largest employer in the area. Similarly, by virtue of Hanford operation over the last 60 years, nearly all facilities and equipment necessary for construction and maintenance of the ILC are already available.

Abundant housing, including hotels, motels, apartments, and homes, is available for visitors, along with expected community services, such as restaurants, theatres, and sports facilities. Local schools have excellent academic standards. The Tri-Cities airport is serviced by Delta (connections to the Salt Lake City and Minneapolis hubs), United (connections to Denver and San Francisco), and Horizon Air (connections to Seattle). The Columbia Valley is the heart of Washington's agricultural industry, especially known for fruit and wine.

The major stakeholders in the area include: Native American tribes, the U.S. Fish & Wildlife Service (land maintenance and security for DOE), the LIGO Gravitation Physics Laboratory, and DOE. Discussions with stakeholders will be necessary if this concept is to be developed further. Any final siting determination would be made with appropriate coordination of environmental laws such as the National Environmental Policy Act, the National Historic Preservation Act, Endangered Species Act, Clean Water Act, and Clean Air Act and full engagement of all stakeholders.

**Hanford Geology**

The geology of the Columbia Basin is very favorable for the ILC. The site was selected for the two-armed, 4-km-long LIGO project in large part due to the seismic stability. There is a large basalt layer near the surface offering stable, dry bedrock structure in which to work. The ILC tunnels could likely be trench construction at Hanford. The service tunnel might then be able to be at or near the surface. If this were possible, it would provide easier access to the accelerator and lower cost construction than tunneling as might be necessary elsewhere. It should still be possible to have sufficient overburden for radiation shielding purposes.

The geology of south central Washington has been studied for decades, including a recent analysis of the suprabasalt sediments of the Hanford site.[4] In this report, the stratigraphy of the Hanford site was characterized on a cross section through the site as shown in Figure 3. This roughly coincides with the location of a proposed ILC and provides an excellent basis for the characterization of an ILC foundation. See for example Reidel.[5]

[4] Lindsey, K. A. 1995, Miocene to Pliocene-Aged Suprabasalt sediments of the Hanford site, South-Central Washington, BHI-00184, Bechtel Hanford Inc., Richland, WA

[5] Reidel, S.P., N.P. Campbell, K.R. Fecht, K.A. Lindsey, 1993, Late Cenozoic Structure and Stratigraphy of South-Central Washington, available at http://www.osti.gov/bridge/servlets/purl/10193734-QVw8Cs/native/10193734.pdf

**Role of PNNL**

The Hanford Site would be an ideal location for the ILC and PNNL is enthusiastic about the science opportunities such a world-class facility would bring to our community. Should the Hanford Site be the ILC location, PNNL would have the opportunity to become a more important part of the HEP community. Even if Hanford is not selected as the ILC site, PNNL, with expertise in radiation detection, weak interaction physics and data-intensive science looks forward to contributing to the ILC.

**Figure 1**. Map showing relation of Pasco, Kennewick, and Richland to Hanford Site. Barges are unloaded near the Environmental Molecular Sciences Laboratory.

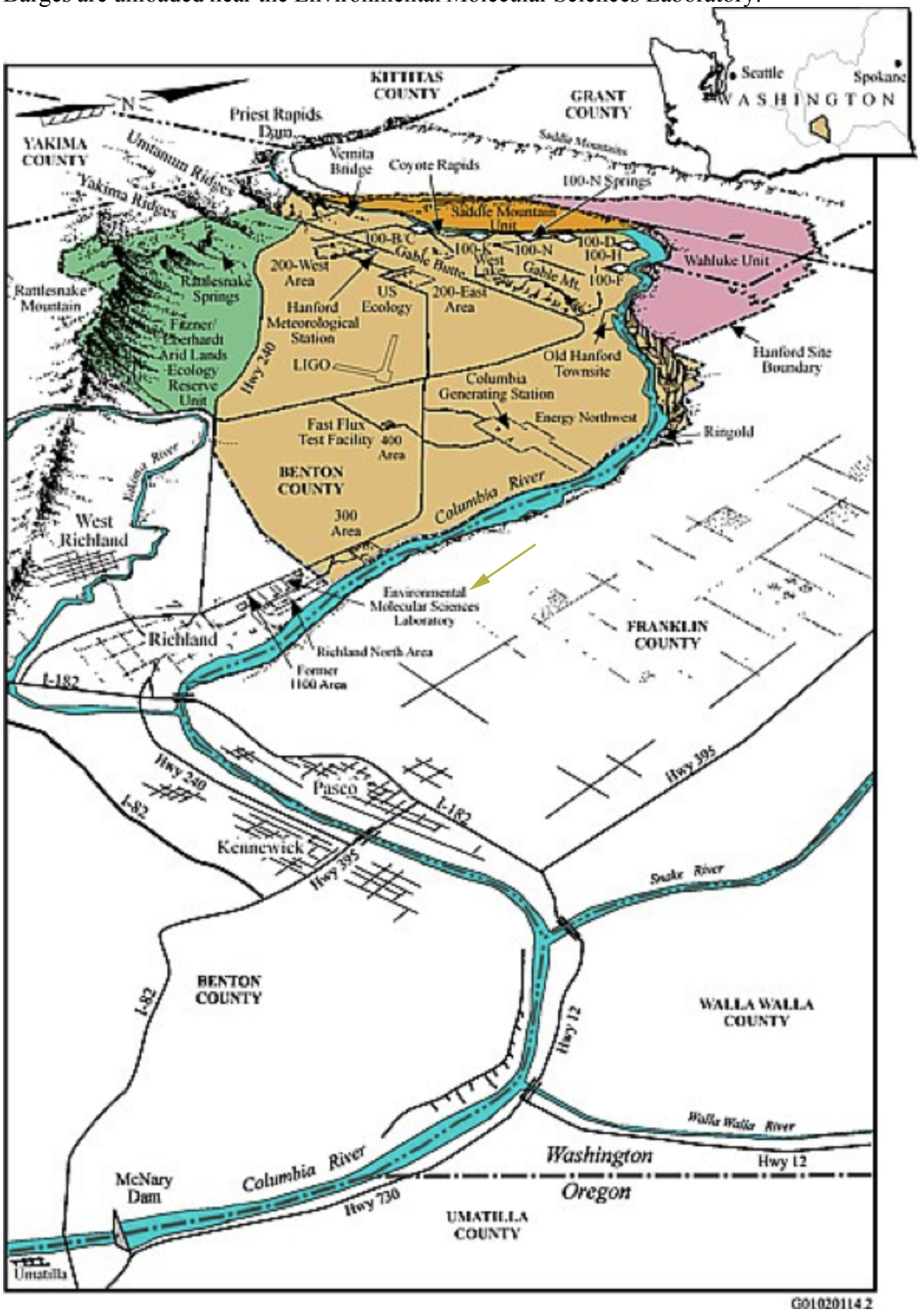

**Figure 2.** Submarine reactor transport and storage at Hanford.

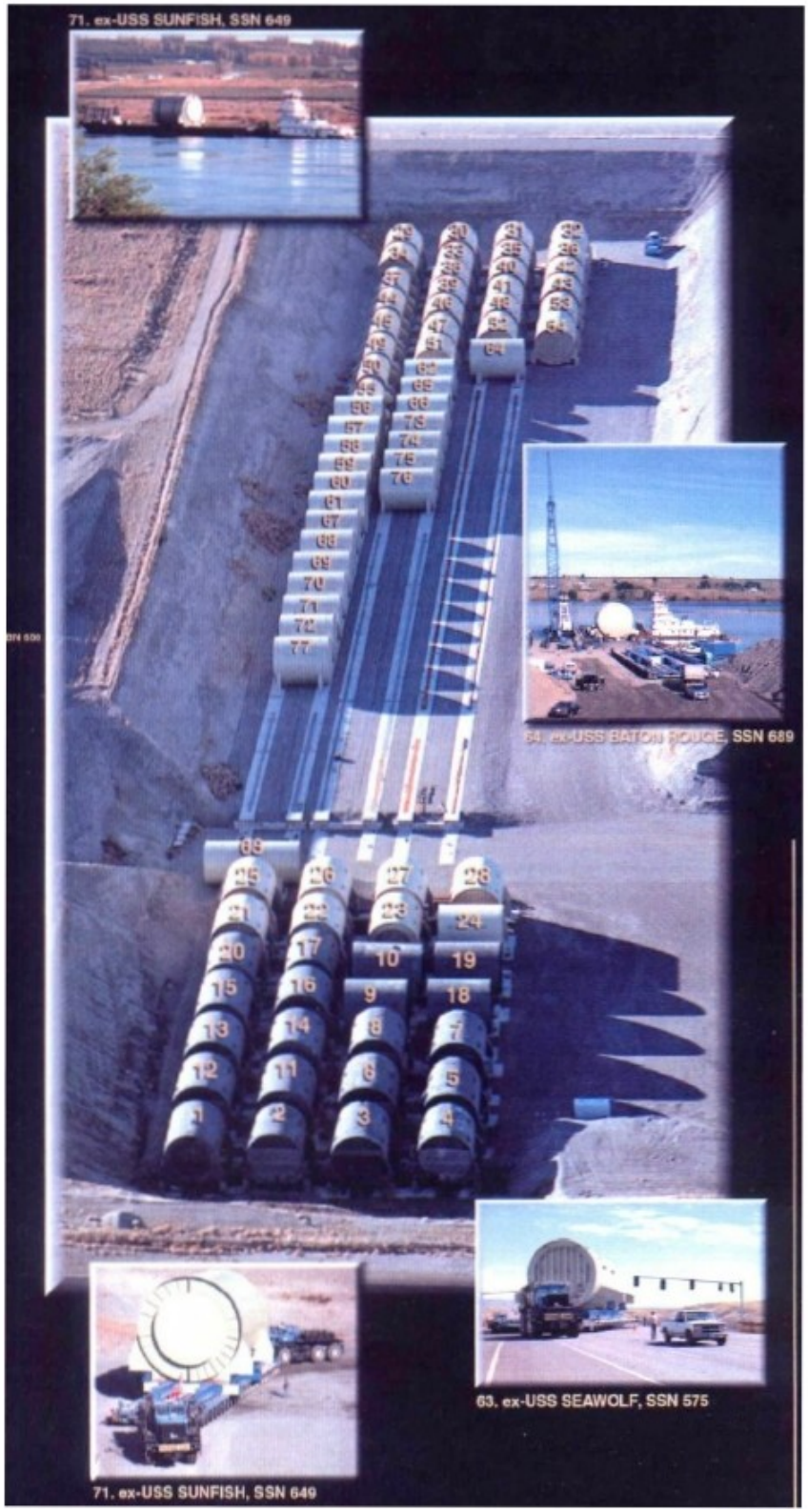

**Figure 3**. Approximate cut for referenced stratigraphy study (solid blue). Approximate location for ILC (dashed red).