Chapter 3

Conventional Facilities

3.1 Introduction

The Next Linear Collider (NLC) will be a twenty-mile-long (32 kilometer) linear electron accelerator very much like the two-mile (3.2 kilometer) accelerator at SLAC. The accelerator will be located underground in a tunnel that would be suitable for housing a single-track subway. At most, the surface presence will consist of periodic access points to equipment buildings spaced several football fields apart. In one alternative these would be covered with earth and grass. In another alternative they would be replaced by additional underground housings aligned with the accelerator much like a two-track subway. In this approach there would be very little surface presence except at the central campus.

The NLC design includes potential sites in both California and Illinois, where the solutions chosen have been based on local geology and locally appropriate construction techniques. The California 135 site on the eastern slope of the California coastal mountain range is a rural, near-surface cut-and-cover solution with remote injectors, a distributed three-laboratory campus, adjacent power and water, and uniform geology . The Illinois North-South site is a suburban deep-tunnel solution with a central injector complex that takes maximum advantage of the uniform rock strata and the existing Fermilab site infrastructure. Additional sites being considered are an East-West cut-and-cover site in Illinois as well as bored tunnel sites in California which take advantage of the hilly terrain to provide horizontal access to a tunnel in competent rock.

The basic requirements of the configuration will be to include accelerator housings long enough to provide adequately for 1-TeV center-of-mass beams in the future even though the main linac housings would initially contain components to reach just 500 GeV. The total of enclosed beam line will be 36.5 km. By comparison, the existing LEP tunnel at CERN is 27 km in length. Two experimental interaction halls are planned. One hall will be a high-energy hall and the other hall will be for lower-energy collisions. The two halls will be offset from each other by about 440 meters longitudinally and 20 meters transversely. The high-energy hall will be in a direct line with the main linacs which are not collinear, but are tilted at a very small 20-milliradian angle with respect to each other. Two alternates are planned for the configuration of the injector complexes. One will place the positron and electron injectors at opposite ends of the machine. The other will place all injectors near the center of the machine.

Electric power consumption will be less than 200 megawatts of metered demand, about equivalent to that used by a city of 200,000 people. Water consumption will be roughly 7 acre feet each day of operation or about what is used by a city of 28,000 people. Emissions of radiation from the accelerator will be contained underground within the tunnel housing, and exposures from the accelerator to human populations off-site will be much less than natural backgrounds. Similar accelerators are presently operated safely at laboratories in heavily populated areas at SLAC (California), Fermilab (Illinois), Hamburg (Germany), and Geneva (Switzerland).

The sections that follow describe preconceptual development and options for configurations, sites, injectors, main linacs, detectors and campuses.

3.2 Sites

3.2.1 Site Criteria

The NLC beam housings must be structurally stable, thermally stable, and be subjected to an absolute minimum of local noise and vibration [1]. To reduce rf microwave losses, the beam housing must be adjacent to a klystron gallery housing which is continuously accessible by personnel for maintenance. The klystron housing must be separated from the beam housing by at least 2.4 meters (8 feet) of concrete or rock shielding. The beam housing must be shielded from the general surface environment by at least 7.3 meters (24 feet) of earth and/or rock. Where the beam and klystron housings are in adjacent parallel bored tunnels, the required housing separation is greater than 2.4 meters (8 feet) to maintain adjacent tunnel structural stability. Slow drift of the beam housing floor may not exceed a maximum of ±1.5 mm (± 0.059 inches) during a nine-month run period, after which realignment smoothing can be done to return the remotely controlled movers on the beam-line components to the center of their working range. The allowed amount of motion is roughly twice that observed in the SLAC linac tunnel after construction and more than that observed at LEP. The diffusive motion of the floor may not exceed about 3 microns over 100 meters (328 feet) after a day. The motion measured at SLAC and in other tunnels built in competent rock is much less than this limit, so the stability should be achievable. To restrict the motion of components mounted on the girders, the temperature of the tunnel must be stabilized to a fraction of a degree, similar to what is typical for the SLAC linac.

The beam housing must be either deep underground or near the surface in a very quiet rural location to avoid local sources of noise and vibration. NLC utility-induced vibration in the beam housing floor directly below the beam-line magnet pedestals is limited to 3 nanometers at frequencies above 3 Hz. Various specific frequency amplitude peaks (for example 60 Hz) are evaluated on a total power spectrum basis. The beam housing cooling water system is limited to a low flow rate velocity to minimize mechanical vibration. Critical technical components inside the beam housing are cooled with low conductivity water supplied at 32°C, ± 0.17°C at 17°C rise (90°F, ± 0.3°F, at 30°F rise). The air temperature in the beam housing is close to 95°F during normal beam operation. Except for drainage sump motors, no utility motors are permitted inside the beam housings or in the adjacent klystron gallery and housings. Remote utility motor controllers are to be variable frequency drives and phase locked to the 120 hertz beam repetition rate. Low conductivity cooling water for the klystron and modulator rf systems is to be 90°F supply, ± 5°F, at 65°F rise. Sections that follow describe preconceptual development and options for configurations, sites, injectors, main linacs, detectors and campuses.

3.2.2 Illinois North-South

The Illinois North-South site for the NLC is centered on the 2,750 hectare (6,800 acre) Fermilab site and takes advantage of the favorable geology of the area. The alignment chosen seeks to minimize adverse impact to the surrounding community by aligning the off-site portions of the NLC complex within developed utility corridors and surrounding light industrial areas. Parallel tunnel construction, similar to transportation tunnels, allows greater distances between necessary points of egress, thus reducing off-site construction at grade.

The North-South orientation, shown in a section view in Fig. 3.1, provides consistently flat geological features with rock conditions proven to be favorable. The Chicago Deep Tunnel, the local Aurora Area Mine and the current MINOS project at Fermilab have provided extensive experience with the geologic strata of Northern Illinois. Further investigation and understanding of local ground motion is underway.

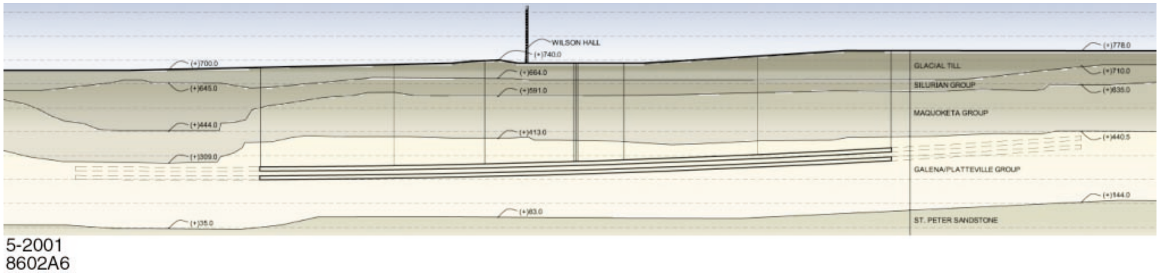

Figure 3.1: North-South Geologic Section View (galena / platteville in yellow)

3.2.3 California 135

The California sites for the NLC that have been investigated to date have been aligned to be parallel and close to both the west coast North-South electric power transmission corridor and the adjacent California aqueduct system that stores and distributes water along the Great Central Valley. Native California sandstone comes to the surface in long straight formations providing a stable competent rock base for the NLC.

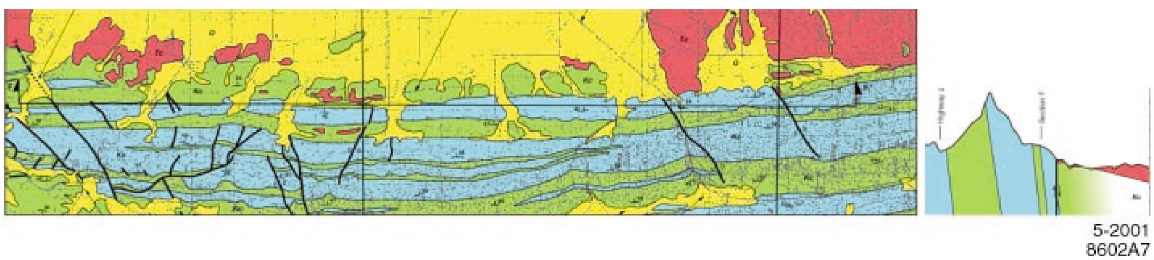

Figure 3.2: Site 135 Geologic Plan View (40 x 10 km) and Cross-section View (sandstone in blue)

The 135 site plan and cross section view is shown in Fig. 3.2. The rock formations are typical of the region and other sites are available with similar attributes. To obtain the best structural stability, the beam housing must be in a location where the bedrock is either at or very near the surface. A near-surface site must also be in a rural environment away from man-made cultural noise and vibration sources. These conditions exist along the eastern slope of the California coastal mountain range. There, the critical assets: geology, power, water, and quiet available land, are all in close proximity. There are possible sites which are straight and parallel and extend for several tens of kilometers to provide an attractive location for the NLC.

3.2.4 Site Development Work

A collaborative effort between the Facilities Engineering Services Section at Fermilab and the NLC Conventional Facilities group at SLAC is developing potential sites in both California and Illinois [2]. To expand and augment the R&D work, the NLC has employed a variety of consultants to evaluate and develop portions of the project. Technical areas investigated so far include geology, geotechnical engineering, tunnel construction costs, life safety, land use, mechanical cooling, electric power distribution, and electric power resource development. Firms contributing to these studies include: Anderson & Associates, Fluor Daniels, P. Frame & Associates, Gauge Babcock, Harza Engineers, Jacobs Associates, Knight Advanced Technology, and Patrick Engineering.

3.3 Injectors

The different solutions chosen for the Illinois and California sites also lead to a different optimization of the layout of the injector complexes. For the California site, the injectors are located at the far ends of the site at the low-energy ends of the main linacs. This minimizes the length of tunnel and transfer lines required between the injectors and the linacs. For the more densely populated Illinois site, the injectors are centrally located on the existing Fermilab campus.

3.3.1 Central Injectors

The North-South machine alignment at Fermilab is envisioned to have centralized injection complexes at or near the surface, with low-energy transport lines taking the beams to the remote ends of the machines. These complexes will be located on the existing Fermilab site, thus avoiding the need for land acquisition for the injectors at the far ends of the main linacs and allowing ease of access because of their central location. The central injector schematic is shown in Fig. 3.3. The electron and positron injectors are positioned in a central location adjacent to the interaction regions. A transfer line connects the injectors to their respective compression bends and main linacs. The centralized injection complexes will be configured to house several beam lines in common housings and will be located at or near grade level. Utilities to support the centralized injector complexes will come from the existing Fermilab central utility complex. The near-grade locations of the injection complexes are presumed to provide effective noise and vibration isolation between the injector complex and the final focus and experimental detector halls.

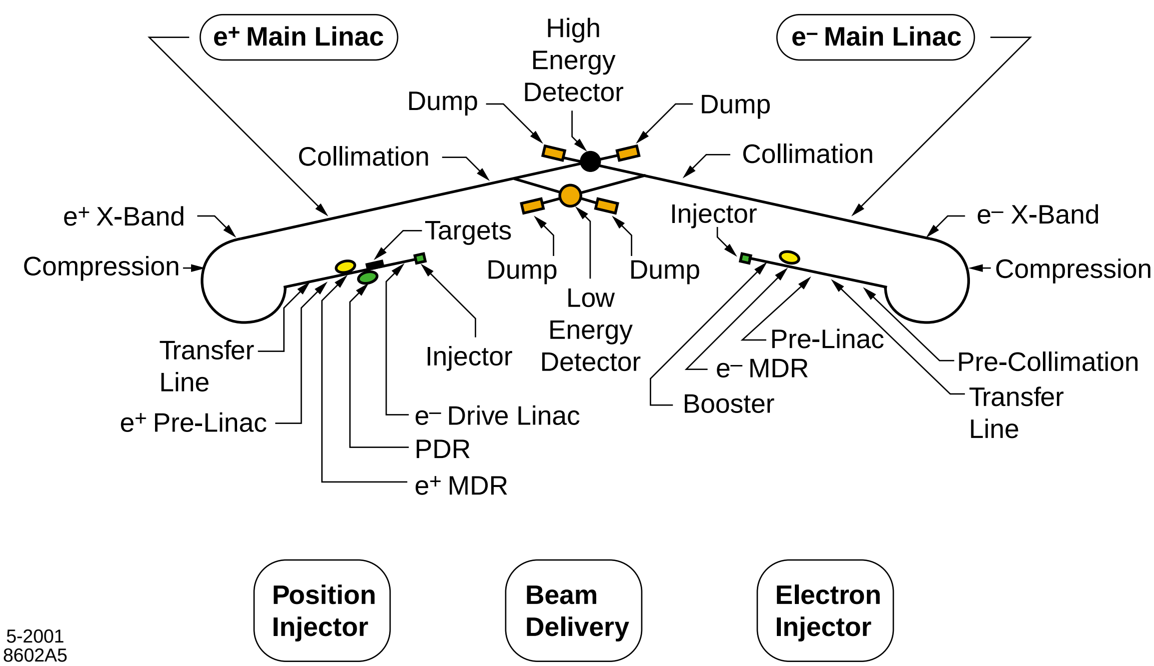

Figure 3.3: NLC Central Injector Schematic Overview

3.3.2 Remote Injectors

Functionally, the NLC has two independent injector complexes, one for electron beam production and one for positron beam production. As there are two main linacs in the NLC, separated by 30 kilometers (18 miles) at their far ends, the two injector complexes are naturally remote from each other and from the center of the site where the experimental halls are located. The NLC remote injector schematic is shown in Fig. 3.4. The electron and positron injectors are positioned immediately adjacent to the compression bend arc at the beginning of their respective main linacs. This configuration is the least expensive and is preferred for the California site 135 and any site where land costs at the ends of the linacs are not prohibitive. The remote injection complexes will be configured to house several beam lines in common housings and will be located at or near grade level. Utility equipment vibration and cultural noise associated with the remote injectors is isolated from the experimental halls by displacement dispersion of at least 15 kilometers (9 miles) each way. For the 135 site, each of the remote injector complexes is near an available access road and is at the same elevation as to the main linac, reducing complexity and cost. Remote injectors have only 180° of beam compression arc housing compared to 360° for the central injector, and they require no beam transport lines in the main linac housings.

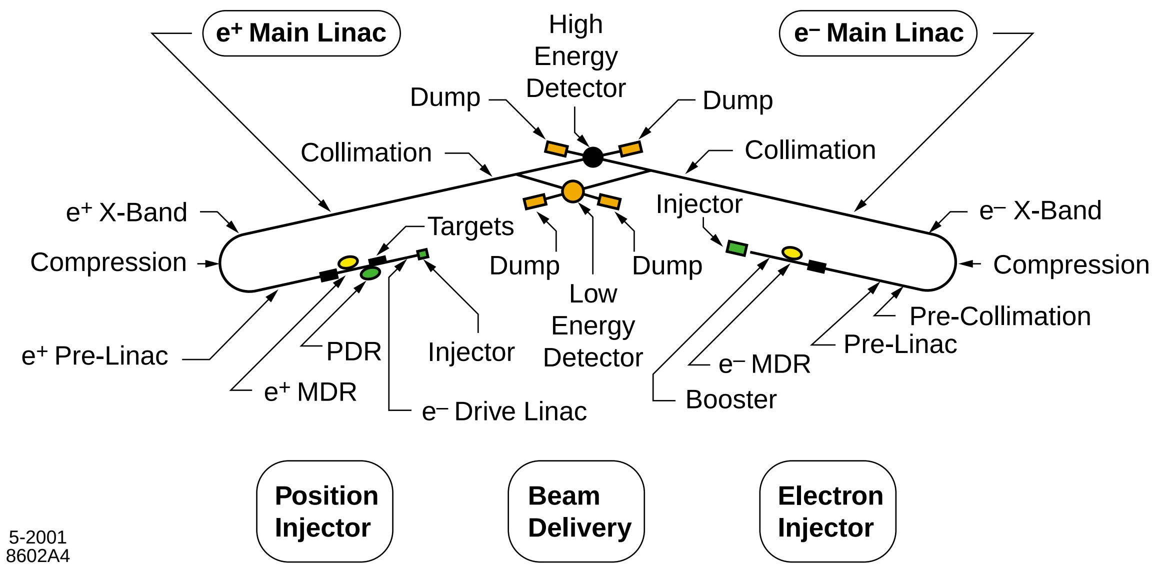

Figure 3.4: NLC Remote Injector Schematic Overview

3.4 Main Linacs

3.4.1 Parallel Deep-Bored Tunnel Configuration

The NLC parallel deep-bored tunnel configuration utilizes two tunnels bored through dolomitic rock at a depth of 30 to 90 meters (100 to 300 feet) below the surface. The optimal depth is a trade-off between tunneling costs and vibration isolation from surface noise sources. The parallel tunnel layout places klystrons and modulators as close as practical to beam-line components to minimize rf losses between them. Each tunnel provides personnel egress to the other tunnel to facilitate hazards management for deep underground occupancy. This scheme is used in most underground transportation tunnels worldwide. Fire separation doors between the tunnels are placed at intervals of 450 to 600 meters (1,500 to 2,000 feet). One tunnel is a support enclosure which houses klystrons, modulators, transformers and piping with continuous access for maintenance personnel.

The other tunnel, shown in Fig. 3.5, is called the beam-line tunnel. It is parallel but offset from the support tunnel by a distance sufficient to protect maintenance personnel from radiation during ‘beam on’ operations. Radiation shielding is provided by the rock between the tunnels. The beam line tunnel houses the DLDS rf distribution system and the beam line with its various technical components. The parallel tunnels are to be constructed with tunnel boring machines, which appears to be both feasible and cost effective. Small tunnel-tunnel penetrations are to be cored. Larger penetrations will be drilled and blasted as needed.

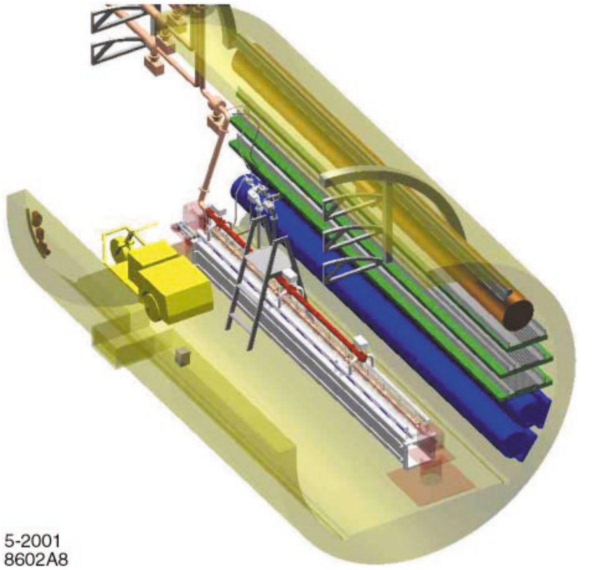

Figure 3.5: Parallel Deep Tunnel View – Beam Housing Tunnel Only

3.4.2 Near-Surface Precast Section Configuration

The NLC near-surface configuration is designed for a cut-and-cover construction technique with precast concrete sections similar to the one employed at FNAL for the Main Injector project. This configuration is shown in Fig. 3.6. Periodic ramps to the surface provide access for conventional surface vehicles along the length of the beam-line housing. The average depth underground of the precast section housings is 10 meters (33 feet), enough to provide radiation safety shielding and diurnal temperature isolation.

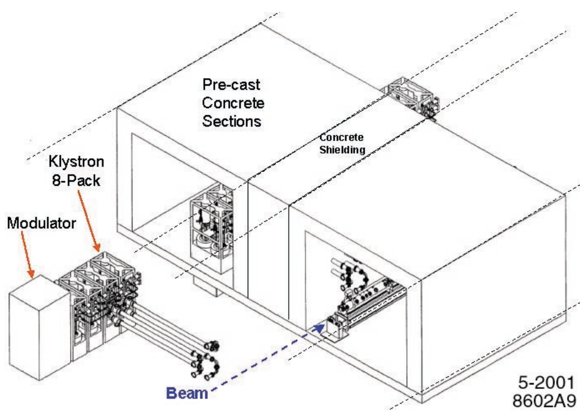

Figure 3.6: Near Surface Precast Section Configuration Line Drawing Section

3.5 Detectors

3.5.1 High and Low Energy Experimental Halls

Two experimental halls are planned for the NLC, one identified as 'High Energy,' and one identified as 'Low Energy,' which are similar in most respects. The two beams that intersect in the high energy hall cross at a 20-milliradian angle. This hall has a floor area of 2,280 square meters (24,500 square feet) with a bridge crane span of 30 meters (98 feet) and travel of 76 meters (249 feet). The Low Energy hall has a detector floor area of 1,080 square meters (11,600 square feet) with a bridge crane span of 20 meters (66 feet) and travel of 54 meters (177 feet). The low energy hall beams intersect and cross at a 30-milliradian angle. Both detector halls are in and on bedrock and, for the remote injector configuration, away from other areas of the NLC having concentrations of utility equipment and noise sources. Figure 3.7 shows the experimental hall with the detector.

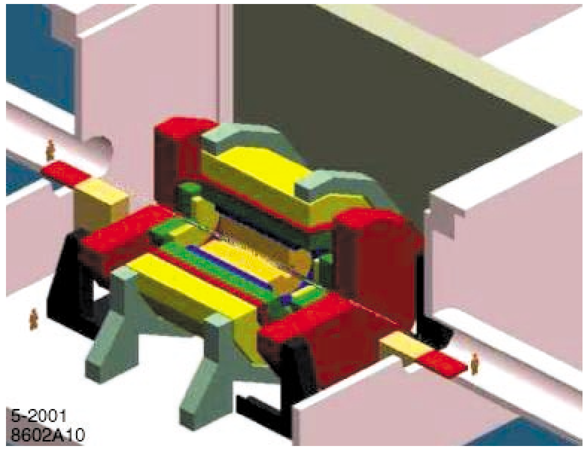

Figure 3.7: Interaction Hall with Detector and Beam Housings

3.5.2 Deep and Near Surface Experimental Halls

The experimental hall detectors have a center bore that is critically aligned to the same elevation as the main linac beam. The main linac beam is planned to be in either near-surface or deep-tunnel housings depending on the NLC site selected and the construction technique used. The detector experimental halls will be at a matching elevation with the linac housing, either 10 meters (33 feet) below the surface or 100 meters (330 feet) below the surface for the two alternatives under consideration. As the total high-energy detector assembly weight is on the order of 11,000 metric tons, moving it, even in sections, will be quite different depending on the elevation differences and the lateral access space available. The near-surface experimental hall alternative offers a clear advantage for moving large, heavy detector components. A vehicle ramp between the detector floor and the surface would allow a single move from the transport vehicle using the detector hall bridge crane. Alternatively, an experimental hall at a deep tunnel elevation may not include a surface ramp as a practical option. A deep experimental hall would likely be more costly to construct and have additional functional complexity for detector assembly rigging operations. Offsetting these apparent shortcomings, a well-designed experimental hall at a deep tunnel elevation would likely have better isolation from surface sources of utility vibration and cultural noise.

3.6 Campus

3.6.1 Central Campus

A central campus on the existing 2,750 hectare (6,800 acre) Fermilab site in Illinois would function to support the NLC through all phases of development, using the laboratory facilities and staff. The preferred North-South site machine alignment would place the NLC immediately adjacent to existing laboratory space, available to be used for construction, testing, installation, operation and maintenance of the technical components. Most of the personnel working on the NLC would be located on the laboratory site.

The beam-delivery housings and the interaction halls would be constructed in bedrock deep beneath the existing site. The central injection complex and the various associated support facilities would be constructed in the glacial till near the surface. All of these facilities would be entirely within the Fermilab site boundaries. Technical support facilities, including machine shops, assembly halls, communication centers and utility control facilities, would be constructed at grade, near the center of the NLC complex. Surface transportation of equipment outside of the laboratory boundaries for installation and maintenance would be largely accomplished through direct tunnel access from the surface at the central campus.

The personnel and the site infrastructure to construct and operate the NLC project at Fermilab includes buildings for administrative and support staff, conference and meeting facilities, computing space, warehousing, machine and preassembly shops, roads, sewers and cooling ponds. Functional analysis of the facility requirements for the NLC has begun and is expected to provide additional planning tools for the design and construction of the conventional facilities.

3.6.2 Distributed Campus

A distributed campus in California would provide support for the NLC. The 135 accelerator site is envisioned to have a minimum of personnel who would be primarily responsible for site operations and maintenance. Operation of the accelerator would be from distributed control rooms, both at the site and in the other laboratories. Most of the personnel at work on the NLC would be located at the existing nearby laboratories in Northern California including SLAC, LLBL and LLNL. The existing laboratory infrastructures for fabrication, measurement, testing and other tasks will become a part of the distributed NLC campus. These laboratories would also provide administration and support staff, conference and meeting facilities, computing space and other functions. The largest single block of new space constructed at the NLC experimental site would be highly flexible warehousing with modular internal occupancies to adapt to the various needs of the NLC project, from planning, through construction, to operations.

References

[1] Corvin, C., “NLC 2001 Configuration Documentation-Conventional Facilities,” *http://www-project.slac.stanford.edu/lc/local/Reviews/Apr2001/Documentation.htm*, May 2001.

[2] Kuchler, V., Corvin, C., “NLC 2001 Conventional Facilities Configuration”, U.S. NLC Collaboration Video Meeting, February 2001.