1. Requirements:

The basic requirements of the configuration will be to include accelerator beam housings long enough to adequately provide for one TeV center of mass experimentation in the future even though the longer main linac housings are to be initially outfitted to reach just one-half TeV. The total of enclosed beam line will be ~36.5 kilometers. Two experimental interaction halls are planned. One hall will be a high-energy hall and the other hall will be for low energy experimentation. The two halls will be offset from each other by ~440 meters in Z, and ~20 meters in X. Two alternates are planned for the required 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.

2. Technical Descriptions:

The Conventional Facilities for NLC 2001 will provide accelerator beam and beam support housings, plus related surface support buildings. Also provided will be experimental detector housings, support housings, and related surface support buildings for the detector systems. Access ramps, shafts and penetrations for these, and all associated utilities for power, cooling and life safety systems will be provided.

Two overall approaches to the layout are considered for the NLC. In one, the land area required will be ~3,600 acres, with a layout 0.5 km wide by 30 km long and ~300,000 SF of campus surface buildings. In the other approach there will be roughly twice the beam and support housing space but half the surface buildings and less overall total land area. Electric power for either approach will range from 185 to 195 mega-volt-amperes of metered demand and ~2 million gallons (~7 acre-feet) of cooling water required each day of operations.

2.1 Housing Systems

Beam Housings

The beam housings are below ground so as to use an earth and rock cover for radiation shielding and diurnal surface temperature isolation. The housings have a minimum of either 8 feet of concrete and/or 24 feet of earth/rock covering to shield the beam from the environment. For a single beam housing, with an internal X-Y cross section of 168 square feet, 120 inches of floor width are allocated for the technical systems and 48 inches are allocated for working aisle space. For a multi-beam housing, with an internal X-Y cross section of 207 square feet, 159 inches of floor width are allocated for the technical systems and 48 inches are allocated for working aisle space. At the base of each
side wall of the beam enclosure there is a gutter to collect water. Beam housing drain water is pumped, batched, held, and tested before release to surface drains. Water from inside the beam housings must be controlled as it is potentially radioactive. Water has a half-life of about 20 minutes and decays quickly to benign levels. Access to the beam housing from the surface will be through a combination of ramps, shafts and elevators depending on surface topography and beam housing depth. The average depth below the surface of the beam housing along its length in the cut & cover layout is several tens of feet with a maximum depth in spots of close to 100 feet. The average depth below the surface of the beam housing along its length in the bored tunnel layout is close to 100 feet for a shallow alignment and 300 feet for a deep alignment. The largest heavy object to be installed in the beam housing will be the 23 foot long accelerator support girder assembly. The beam line inside of the beam line housing is to be installed on pedestals spaced at roughly 23 foot intervals. At each pedestal there is a lighting fixture of 100 watts and a 120 volt power receptacle. 480 volt welding receptacles are located at every 3rd pedestal. These will be used for welding, conveyance vehicle electric chargers, and rigging hoists. Telephones for 911 emergency use are located at every 6th pedestal. General communications for personnel will be by personal cell phones. A tunnel antenna system will support these phones. All technical system cabling will be distributed the length of the beam housing in cable tray. Utility circuits will be distributed in conduits as they support life safety systems or the power supply for such systems. These include area illumination, exit lighting, emergency lighting, emergency ventilation, drainage pumping, 120 volt power, 480 volt power, telephones, tunnel electronics enclosures, plus fire smoke detection and suppression.

Multiple sites have been identified as having suitable geology for the beam housings. The beam housings must be structurally stable. Uniform competent rock supporting the beam housing is necessary to achieve this stability. The planned cycle for beam operation is to run for 9 months, from September 1 to May 30 each year. During a 9 month run the beam position is in part controlled with magnet movers located on each magnet pedestal. These movers will position the magnets to account for relative position shifts from all sources including the beam housing floor. Slow drift of the beam housing floor may not exceed a maximum of +1.5 mm during this 9 month period, after which realignment smoothing will take place during a 90 day maintenance interval. As well as structurally stable, the inside of the beam housing must be thermally stable. The air temperature will be close to 95F during normal beam operations. Air within the beam housing will not be circulated or exchanged to the surface environment during beam operations. However fresh breathable surface air will be supplied to the beam housing during personnel access. The ventilating system used for this will also be used for smoke and fire control during emergencies. The beam housing air space will be sectionalized with baffles to control internal wind and to isolate fire and access protection zones. The beam housing will have a smoke detection system, a heat detection system and a water sprinkler fire suppression system. The technical components inside the beam housing will be cooled with low conductivity water supplied at 90F. The accelerator sections in the beam housing operate with an LCW temperature rise of 30F. Returning LCW water piping is insulated from the beam housing air. The accelerator water supply is controlled to = < +0.3F and is pumped from a utility pad on the surface that is displaced at least 300 feet laterally from
the accelerator in the cut & cover layout or between 100 and 300 feet vertically to the surface in the bored tunnel layout to disperse mechanical vibration originating at the utility pad. The beam housing cooling water system is limited to a maximum flow rate velocity of 9 feet per second to minimize mechanical vibration. The cooling water piping is supported and sectionalized with flexible hangers and joints to avoid mechanical resonance and to isolate the piping from the beam housing structure. The beam housing water cooling system piping will transmit 300 or 420 hertz discharge pressure pulses from the LCW pumps on the surface through the beam housing water system supply lines. Hydraulic attenuator canisters will be installed at each flexible hose connection on the supply/return valves at each magnet pedestal to block these frequencies. All utility motors are installed with variable frequency drives phase locked to the beam timing system to run at 3600 RPM. Except for housing drainage sump motors there are no utility motors in the beam housing. All lighting fixtures in the housings are ballast free to avoid 120 hertz vibration. The maximum excursion for utility induced vibration in the beam housing floor directly below the pedestals is limited to 3 nanometers at frequencies above 3 hertz. Various specific frequency amplitude peaks (such as 60 hertz) are to be evaluated on a total spectrum basis. The beam housing floor will be solidly connected to bedrock and will be a solid stable monolithic stone-concrete mass without voids, seams or utility embeds.

Klystron Housings

Klystron gallery housings are below ground and are positioned as close as possible to the beam housings to reduce losses in the transmission of microwave power from the klystrons in the klystron housings, to the accelerator sections in the beam housings. Small diameter sleeves provide for RF feeds from the klystron housings to the beam housings. Klystrons require 24/7 access for routine maintenance by personnel. They are replaced in pairs for depot maintenance and require specialized rigging and conveyance fixtures to handle them. Equipment such as a small electric fork lift must be maneuvered to move the klystron from its operating position to a point of transfer via a surface vehicle. The klystron housing internal cross section is at least 168 square feet, with 120 inches or more of floor width allocated to technical systems and 48 inches allocated for working aisle space. The klystrons are configured in assemblies of 8 klystrons with one modulator. For near surface pre-cast concrete housings these "8-packs" are in turn collected into klystron gallery housings containing nine 8-packs each. The klystron housing is separated from the beam housing by at least 8 feet of concrete shielding. Where the beam and klystron housings are in adjacent parallel bored tunnels, the housing separation is greater to allow for the tunnel construction and for long term tunnel stability. This separation must be between one and two tunnel diameters, about 32 feet maximum for a 16 foot bore. The nine 8-packs in each sector are uniformly distributed along the support tunnel rather than clustered within a klystron housing gallery.

At the base of each side wall of the klystron housing there is a gutter to collect water. Klystron housing drain water is pumped, batched, held, and tested before release to surface drains. Access to the klystron housing from the surface will be through a combination of ramps, shafts and elevators depending on surface topography and klystron
housing depth. The average depth below the surface of the klystron housings in the cut & cover layout is several tens of feet with a maximum depth in spots of close to 100 feet. The average depth below the surface of the klystron housing along its length in the bored tunnel layout is close to 100 feet for a shallow alignment and 300 feet for a deep alignment. The largest heavy object to be installed in the klystron housing will be the 13 foot long modulator assembly. This assembly includes a high voltage oil tank in its base nested in a concrete floor coffin. At each 8-pack there are lighting fixtures that total 320 watts and a 120 volt power receptacle. 480 volt welding receptacles are located at every 8-pack. These will be used for welding, conveyance vehicle electric chargers, and rigging hoists. Telephones for 911 emergency use are located at every 8-pack in the bored tunnel layout or nine 8-pack gallery in the cut & cover layout. General communications for personnel will be by personal cell phones. A klystron gallery antenna system will support these phones. All technical system cabling will be distributed throughout the klystron housing in cable tray. Utility circuits will be distributed in conduits as they support life safety systems or the power supply for such systems. These include area illumination, exit lighting, emergency lighting, emergency ventilation, drainage pumping, 120 volt power, 480 volt power, telephones, electronic rack enclosures, plus fire-smoke detection and suppression.

The inside of the klystron housing must be clean and dry. Routine maintenance of the klystrons includes breaking vacuum and the occasional replacement of klystrons and high voltage components including high voltage insulating oil. The klystron housing air temperature will be close to 78F during normal klystron operations. This is maintained with 45/60F chilled water which is also used to cool totally enclosed electronic equipment racks. Air within the klystron housing will not be exchanged to the surface environment during normal operations. A ventilation system for the klystron housing is included for smoke and fire control during emergencies. The klystron housing will have a smoke detection system, a heat detection system and a water sprinkler fire suppression system. The technical components inside the klystron housing will be cooled with low conductivity water supplied at 90F. This includes the modulators and the klystrons as well as some RF distribution components. The klystron 8-packs in the klystron housing operate with an LCW temperature rise of 65F. Supply and return LCW water piping is insulated from the klystron housing air. The klystron 8-pack water supply is controlled to \( \pm 5F \) and is pumped from a utility pad on the surface that is displaced at least 300 feet laterally in the cut & cover layout, or between 100 and 300 feet vertically to the surface in the bored tunnel layout, so as to disperse mechanical vibration originating at the utility pad. The klystron housing cooling water system is limited to a maximum flow rate velocity of 9 feet per second to minimize mechanical vibration. The cooling water piping is supported and sectionalized with flexible hangers and joints to avoid mechanical resonance and to isolate the piping from the klystron housing structure. All utility motors are installed with variable frequency drives phase locked to the beam timing system to run at 3600 RPM. Except for housing drainage sump motors there are no utility motors in the klystron housing. All lighting fixtures in the housings are ballast free to avoid 120 hertz vibration.
## 2.2 Parameter Table

<table>
<thead>
<tr>
<th>Parameter Table</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Housing Radiation Containment</strong></td>
<td>Minimum of 8 feet of concrete and/or 24 feet of earth &amp; rock for general radiation areas. Beam absorbers, positron sources and damping rings have greater requirements by location.</td>
</tr>
<tr>
<td></td>
<td>All housing drain water is collected, pumped, batched, held, and tested before release to surface drains.</td>
</tr>
<tr>
<td><strong>Beam Pedestal Floor Stability</strong></td>
<td>Slow drift +/- 1.5 mm maximum over 9 month run cycle, followed by 3 month maintenance alignment smoothing.</td>
</tr>
<tr>
<td></td>
<td>Vibration from utility sources to be less than 3 nanometers above 3 hertz, over &amp; above background motion from all non-utility sources. Random motions and various specific frequency amplitude peaks above 3 hertz are to be evaluated on a total spectrum basis.</td>
</tr>
<tr>
<td><strong>Beam Housing Stability</strong></td>
<td>Water cooling circuits in the beam housings are to have a maximum flow velocity of 9 feet per second.</td>
</tr>
<tr>
<td></td>
<td>Except for drainage sump motors, no utility motors are permitted inside the beam housings.</td>
</tr>
<tr>
<td></td>
<td>Utility motor controllers are to be variable frequency drives and phase locked to the 120 hertz beam repetition rate.</td>
</tr>
<tr>
<td><strong>Cooling</strong></td>
<td>Low conductivity cooling water for klystrons and modulators to be 90F supply, +/- 5F, 65F rise.</td>
</tr>
<tr>
<td></td>
<td>Low conductivity cooling water for accelerator sections to be 90F supply, +/- 0.3F, 30F rise.</td>
</tr>
<tr>
<td></td>
<td>Klystron housing air ~78F, +/-10F max w/access</td>
</tr>
<tr>
<td></td>
<td>Beam housing air ~95F, +/-5F max w/access</td>
</tr>
<tr>
<td><strong>Power</strong></td>
<td>No less than 2 site supply sources at 230 kilovolts or higher are required. Power distribution by load type is roughly 78% to RF systems at 2.2 kilovolts DC, 16% to cooling systems at 480 volts, 60 hertz,</td>
</tr>
</tbody>
</table>


and 6% for all other loads at 120/208 & 480 volts, 60 hertz.

Special Maintenance Access Klystrons are to be available for maintenance by personnel 24 hours a day even though they are located as close as possible to beam accelerator sections to reduce RF distribution losses between the klystrons and the beam accelerator sections.

3. Technical Issues:

3.1 Near Field Utility Vibration

Utility equipment vibrates producing noise in the air, water and ground. Isolation and attenuation is necessary to prevent such noise from reaching the beam line components. For deep bored support tunnels containing utility equipment, isolation and attenuation of vibration noise may be very difficult given the close proximity of the support tunnel to an adjacent beam line tunnel. How effective adjacent tunnel vibration attenuation may be over a short distance is not yet fully evaluated.

3.2 Far Field Utility Vibration

A near surface cut and fill construction technique allows vibration sources such as utility equipment to be located on the surface at a distance of 300 feet or more from the beam housings. Combined with other vibration attenuation measures this separation disperses the source noise to low levels when measured at the beam housing floor. How effective the surface separation dispersion may be with distance is not yet fully evaluated but has been shown on other projects such as LIGO to be effective.

3.3 Parallel Tunnel Spacing

A parallel support tunnel is thought to adversely affect the stability of an adjacent beam housing tunnel where the support tunnel is too close to the beam housing tunnel. This is because the near proximity of the void created by the support tunnel upsets the symmetry of ground pressure on the beam housing tunnel. At least one to two tunnel diameters of separation is believed to be needed to prevent the beam housing tunnel from drifting toward the support tunnel housing. The tunnel separation dimension drives costs on other subsystems and would be critical to long term beam floor stability should the separation dimension contribute to tunnel drift over time. Tunnel separation has not yet been fully evaluated.

3.4 Cut and Fill Rebound and Settlement

Use of a cut and fill construction technique with pre-cast tunnel housing sections will include an initial rise in elevation of the bottom of the excavated housing floor trench. Subsequently, after the housings are completed and the excavated fill is placed back on
top of the pre-cast beam housing sections, there will be a subsidence. The extent of the
total excursion in elevation and the period needed to achieve long term stability is not yet
known. Acceptable final settlement has been accomplished on other projects such as
LIGO.

4. Discussion of Configuration Choices:

Bored Tunnel Construction

Parallel bored tunnels are planned as one of two construction technique alternatives.
Several apparent advantages make this alternative interesting. It will minimize surface
disruption and is therefore attractive in an urban environment where land is expensive
and unavailable with limited surface access. Because of their depth below the surface,
parallel bored tunnels also offer the potential for being very stable and quiet depending
on the nature of the utility equipment installed in the adjacent support tunnel. As the
beam tunnel would be only several tens of feet offset from the support tunnel, all
vibration sources in the support tunnel would act to disturb the nearby beam. Avoided
surface land costs must be weighed against the additional cost of boring the support
tunnel and the costs of quieting the utility equipment placed inside the support tunnel.
Tunneling spoils must also be hauled away at considerable expense if long hauls are
required in an urban environment.

Cut and Fill Construction

Cut and fill housings constructed with pre-cast concrete sections are planned as the
second of two construction technique alternatives. Advantages of this alternative are
several. Only the beam housing is constructed over the full length of the main linac with
klystron gallery support housings installed for just 25 percent of the adjacent main linac
beam housing length. This is one-third less total main linac housing when compared to
parallel bored tunnels. As the entire ground surface over the length of the machine must
be opened and then filled back during construction, this approach is only possible in a
very rural location with available land at lower cost than would be found in an urban
location. Rural locations are quieter than urban environments so noise levels generally
found near the ground surface should be more comparable to the noise found at deep
underground locations. The cut and fill construction method retains the cut excavation
spoils for use as backfill reducing material handling costs substantially over those of a
bored tunnel. Near surface cut and fill construction allows long term flexibility in the
machine layout as the near surface pre-cast sections can be literally dug up as needed to
expand the machine at some time in the future. Such flexibility is not as easily available
with a deep bored tunnel. As the cut and fill housings are near the surface, access for
routine maintenance is accomplished every one-half kilometer with ramps up to a parallel
roadway. Access for maintenance through a deep bored tunnel is less direct and probably
slower requiring vertical access shafts placed at several kilometer intervals.