Environmental Control
NLC Snowmass 2001
Housing Stability
Basic Geo-Civil-Structural Objectives

Goal 1: Connect the NLC Beamline (magnet pedestals) to Earth (rock)
   The Beam Housing Floor (Invert) Under the Magnet Pedestals Acts as a Spacer That Functions to Connect: 1) the Earth (rock), to, 2) the Magnet (Pedestal).

Goal 2: Select Good Rock
   The Rock Should Be as Competent, Stable, Homogeneous and Quiet as Possible. It Should Not Be Selected to be At or Near a Noisy Place.

Goal 3: Make a Good Connection Between the Earth & the Magnet
   The Beam Housing Floor (invert) Should be As Good As or Better Than the Rock it Connects To, Ideally an Extension of the Rock. The Floor Between the Magnet Pedestal and the Base Rock Should Have as Few Voids, Seams, Utilities or Imbeds as Practical.
HOUSING STABILITY

• Geology
• Structural
• Electrical
• Thermal
• Mechanical
Next Linear Collider – U.S. Collaboration
SLAC – FNAL – LBNL - LLNL

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- FNAL North-South Bored Tunnel Geology Section View
- Hard Competent Galena- Plattville rock at a depth of ~ 300 feet

- FNAL East-West Cut and Cover Geology Section View
- Softer Glacial Till & Sillurian rock at a depth of ~ 100 feet

Good for Cut & Cover or Tunnel Boring Machine
Environmental Control – Snowmass 2001

California Basement Rocks

- Good Sites in the Green
- Great Valley Sequence
- Soft Competent Rock
- Self Supporting
- Good for C&C or TBM
California Sites & Geology

- N-S along Eastern Slope of Coastal Range
- Near Surface Soft Competent Rock
- Native California Sandstones
- BLM Federally Controlled
- North-South Alignments are Parallel to the Topography
- Base Rock Comes to the Surface in the Foothills
Sample Topography w/ Flat Main Linac Sections & Deep Detector Center
Geologic Map w/ Cross Section - Eastern Slope CA Coastal Range
## Table 4. Variation of Significant Geologic Factors Among the Representative NLC Sites

<table>
<thead>
<tr>
<th>Geologic Survey</th>
<th>Topography</th>
<th>Geology</th>
<th>Seismic Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum elevation</td>
<td>Site 150: 280 ft</td>
<td>Site 135: 180 ft</td>
<td>Site 90N: 240 ft</td>
</tr>
<tr>
<td>Maximum elevation</td>
<td>Site 150: 500 ft</td>
<td>Site 135: 1140 ft</td>
<td>Site 90N: 1060 ft</td>
</tr>
<tr>
<td>Relief</td>
<td>Site 150: 220 ft</td>
<td>Site 135: 960 ft</td>
<td>Site 90N: 640 ft</td>
</tr>
<tr>
<td>Geologic Units</td>
<td>Quaternary deposits (Q): 9%</td>
<td>Tertiary sandstones (Ts): 36%</td>
<td>Cretaceous sandstones (Ks): 3%</td>
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<tr>
<td></td>
<td>Tertiary claystones (Tc): 25%</td>
<td></td>
<td>Cretaceous claystones (Kc): 63%</td>
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<tr>
<td></td>
<td>Strike of bedding: N10W to N15E (20)</td>
<td>Strike of bedding: 5 to 20 E (15)</td>
<td>Strike of bedding: 40 to 70E (30)</td>
</tr>
<tr>
<td>Dip of bedding</td>
<td>N15W to N15E (20)</td>
<td>40 to 60E (20)</td>
<td>20SW to 70NE (90)</td>
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<tr>
<td>Mapped faults crossing alignment</td>
<td>Quaternary active: San Joaquin</td>
<td>Pre-Quaternary: 1 pre-Tertiary</td>
<td>Active faults within 100 km: 5</td>
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<tr>
<td></td>
<td>Nearest active fault: 7.5 km (G V thrust)</td>
<td>Slip rate: 0.1 mm/yr</td>
<td>Peak horizontal ground motion: 0.019 to 0.024 g</td>
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<tr>
<td></td>
<td>Annual: 0.092 to 0.11 g</td>
<td>Ground water: above invert</td>
<td>Reference Materials: Bedrock: 1:13,000 to 1:46,000</td>
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<tr>
<td></td>
<td>25 year: 0.024 to 0.046 g</td>
<td>below invert</td>
<td>Existing mapping: Quaternary active: 1:62,500</td>
</tr>
<tr>
<td></td>
<td>above invert</td>
<td>aerial photographs: 12 flights, 1947 to 1993</td>
<td></td>
</tr>
<tr>
<td>Other Considerations</td>
<td>Sites-Colusa Project</td>
<td>Sites-Colusa Project</td>
<td>Coast Range Tunnel</td>
</tr>
</tbody>
</table>
Typical Site Seismicity in Eastern Slope Foothills

- 25 Year Peak Horizontal Motion ~ 0.1g
- 1 Year Peak Horizontal Motion ~0.02g
- Active Near Fault Slip Rate 0.1mm/yr 7 km Away

- With +/- 1.5mm Magnet Mover Control Range
- Adequate & Acceptable for 9 Month Physics Runs
Magnet Mover Base
Static Adjustment 9 cm
Range in vertical Y, Adjust
as needed at 9 Month
Intervals. X & Z Static
Adjust Range is TBD

Grout ~7 cm Average

Initial Floor Flatness +/- 0.3 cm in Y Over 1000 meters in Z
HOUSING STABILITY

• Geology
• Structural
• Electrical
• Thermal
• Mechanical
Housing Structural Stability

- **Cut & cover construction causes vertical excursions that require time to stabilize**

- **LIGO experience with surface excavation shows that the excursions are predictable and may be corrected in a straightforward manner with overburden and dewatering techniques**
Cut & Cover Vertical Displacement During Construction

Grade

Cut

Cover

Housing

Time to Stabilize ~ Several Tens of Months
LIGO Louisiana Swamp Site
LIGO Louisiana Beam Housing with Parallel Drain Canal
Housing Structural Stability

- Parallel bored tunnels hold x-y position best where the surrounding rock forces on the housings are symmetric and equal.

- Parallel tunnel separation of about two tunnel diameters will maintain balanced forces on each tunnel.

- Parallel tunnel separation for minimum adequate radiation attenuation between tunnels is less than one tunnel diameter, and is 8 feet.
Parallel Bored Tunnel Stability vs. Relative Position

More Stable

Less Stable

8+ Feet

Parallel Bored Tunnel Stability vs. Relative Position
HOUSING STABILITY

• Geology
• Structural
• Electrical
• Thermal
• Mechanical
Electrical Stability

- Primary Electrical Instability is Weather Related

- Secondary Electrical Instability is Wear Related (i.e., Bearing Life)

- Other Factors Include Redundancy, Inspection & Maintenance
Isokeraunic Map

Thunder-Storm Days per Year

5X

40X

90X
Small Bearing Forces w/ Soft Isolated Frame on Slab

Large Bearing Forces w/ Rigid Frame on Slab
NLC Electrical Stability

- 0.995 Electrical Availability on the West Coast is practical with Parallel Redundant Pumpsets and a Ring Bus Power Distribution Configuration

- Availability is 0.950 (.944 actual) Otherwise with Single Pumpsets and a Radial Power Distribution Configuration
Parallel Redundant Pump Set
Each Half Run at 50% Capacity
### Environmental Control – Snowmass 2001

#### Total Availability by Physics Run

<table>
<thead>
<tr>
<th>Lab</th>
<th>Run</th>
<th>Year</th>
<th>Availability</th>
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<tbody>
<tr>
<td>ANL</td>
<td>APS</td>
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<tr>
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<td>Photon</td>
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<td>97.70%</td>
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</tbody>
</table>

**Electrical Utility**
- Availability: **94.4%**

**Total Availability by Physics Run**
- **81.00%**
- **84.53%**
- **80.87%**

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*Note: The table represents data from various laboratories and runs, showing the availability percentages for each.*
HOUSING STABILITY

• Geology
• Structural
• Electrical
• Thermal
• Mechanical
Housing Thermal Stability

- Within a housing, ONE active cooling system is preferred as two or more active systems will tend to destabilize (and fight) each other, be more expensive, and inefficient overall.

- SLC final focus housing measurements led to NO forced air mixing, preferring instead a dead air mass with only minimal convective air movement.
Housing Thermal Stability

- Beam housing components are water cooled with only a very small percentage of the total housing thermal energy going into air. Energy in the air exchanges convectively across the very large surface area of the water cooled (32°C) copper RF distribution system tubes in the upper housing.

- Lower housing air stratifies as desired to isolate the beam in a water cooled (32°C) dead air space.
Ten RF Distribution Tubes in a Pre-cast Concrete Housing

Air Temperature Distribution shown by Color

Beam in Stable Thermal Strata
Ten RF Distribution Tubes in a Pre-cast Concrete Housing

Air Velocity Distribution shown by Colored Vectors

Beam and Dead Air Region
Housing Thermal Stability

- The precision controlled cooling water, 90F +/- 0.3F (32C +/- 0.17C), and the very large total surface area of the copper RF distribution tubes (36 per ML sector), will govern housing air temperature stability.

- Critical high energy components are water cooled, NOT air cooled, so ultra stable air is not critical to performance.
Main Linac Klystron Gallery Utility Pad & KG Berm Cover

- Earth Covered for Thermal, Acoustic, Aesthetic Isolation

- Power & Cooling Utilities Offset on Adjacent Pad Isolating Vibration

- Support Building Contains Klystrons, Modulators, Power Supplies, I&C Racks, Power & Water Distribution
HOUSING STABILITY

• Geology
• Structural
• Electrical
• Thermal
• Mechanical
Mechanical Stability Gremlins

- All Moving Machinery
- Motors - Slip Frequency Sidebands 59 Hz
- Water Pumps - 300 Hz, 420 Hz Impellers
- Ventilation Fans - 10’s of Hz
- Piping Resonance and High Fluid Flow Rates
- Lighting Ballasts - 120 Hz
- Transformers - 120 Hz 1 Phase, 360 Hz 3 Phase
Ugly Floor Noise w/ Water Pumps ON
Beam Housing Floor Utility Vibration Allocation

- Measured on the Floor at the Quad Magnet Pedestal
- 3 Nanometer Excursion Limit, Above 3 hertz
- Specific Frequency Amplitude Peaks (like 60 hertz) are Evaluated on a Total Spectrum Basis
Mechanical Stability - Attenuation & Isolation

- Distance and Depth
- Equipment Balance and Isolation
- Fluid Pressure Pulse Attenuation
- Piping Sectionalizing & Isolation
- Zero Forced Air
Basic utility equipment isolation consists of a stiff skid on spring isolators, on a thick (5 x skid load) foundation bearing on sand and decoupled with a gap from adjacent structures. The net force transmitted from the skid to the foundation is ~ 1% with 3 to 6 hz springs.

Skid forces are minimized (to ~ 0.1g) by equipment balancing (HQ Bearings) and cancellation, (pitch, role & yaw), as well as by selecting higher rpm devices (3600 vs. 1800 rpm).
Pumpset Pair is Mounted on a Floating Concrete Skid

Pitch & Roll Cancel
Yaw Remains
Next Linear Collider – U.S. Collaboration
SLAC – FNAL – LBNL – LLNL

Environmental Control – Snowmass 2001

Pumpset 420hz

Beamline < 100hz

60 hz Fundamental Phase Locked to Beam Timing
Off-skid forces are minimized by polished impellers, flexible piping connections, hydraulic mufflers (420, 300 hz), and baffled surge tanks.

Off-foundation forces are attenuated by dispersive displacement (distance) as well as boundary layer attenuation and ducting (air-soil, soil-rock & rock-rock strata).
Hydraulic Pressure Pulse Attenuators

* Low to High Frequency Transform

* Low Frequency Attenuation

* Matched to System Impedance

Typical Application
Piping Vibration Isolators
Orthogonal Offsets Exploit Depth & Distance

Surface Slab (B) Pressure Contour (p) Attenuation Offset

Beam Housing

Pumps
Environmental Control – Snowmass 2001

**Mechanical System Adaptations**

- TEC, Totally Enclosed motors, no fans, to avoid very low frequency signatures
- Variable frequency motor drives to avoid slip frequency signatures phase locked with linac timing
- Matched pumpset pairs to cancel like signatures & buy redundant reliability
- Precision cast & finished impeller pairs with polished discharge getaways
- COTS Pumpsets aligned on a floating frame, with tuned signature attenuating isolators
- Flexible rubber pump discharge couplings to isolate piping from pumps
- Surge-makeup tanks with baffles & polished discharges
- Piping hung & isolated with flexible supports & segmented off resonance.
Special Notes for Parallel Deep Tunnel Layouts

- RF Feeds w/o Flanges Between Tunnels Require Pullback Space In Larger Tunnel ~ Equal to Separation
- KEK & DESY Abandoned two Parallel Tunnels & Adopted a Single Large Tunnel Alternate.
- Single Tunnel Requires Design Investment (yet to do) for Tight Packaging, Shielding + Thermal & Vibration Stability
- Rotating Equipment, Pumps, Motors, in the Support Tunnel Vibrate to Spoil the Quiet Advantages of the Deep Tunnel
- The LIGO Utility Layout Places Rotating Equipment No Closer Than 300 Feet from the Beam Line.
Environmental Control
NLC Snowmass 2001
Housing Stability
End