An Overview of Ground Motion and Vibration Studies

Acknowledgements

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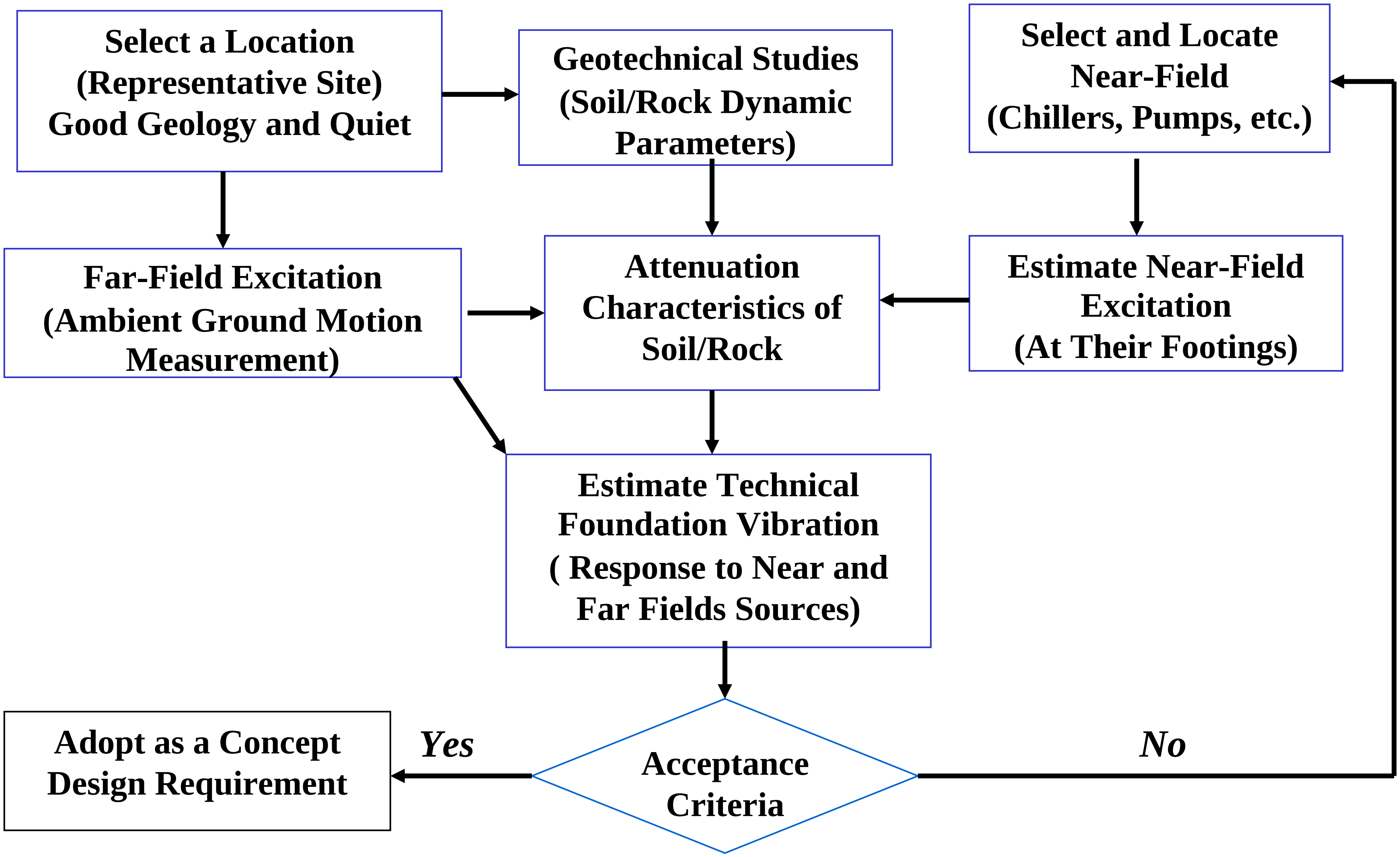
  - Fred Tajirian, Mansour Tabatabaie

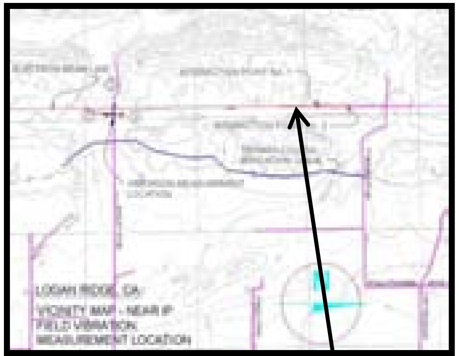
Approach


Select a Location
(Representative Site)
Good Geology and Quiet
Geotechnical Studies
(Soil/Rock Dynamic
Parameters)
Select and Locate
Near-Field
(Chillers, Pumps, etc.)
Far-Field Excitation
(Ambient Ground Motion
Measurement)
Attenuation
Characteristics of
Soil/Rock
Estimate Near-Field
Excitation
(At Their Footings)
Estimate Technical
Foundation Vibration
(Response to Near and
Far Fields Sources)
Adopt as a Concept
Design Requirement
Yes
Acceptance
Criteria
No

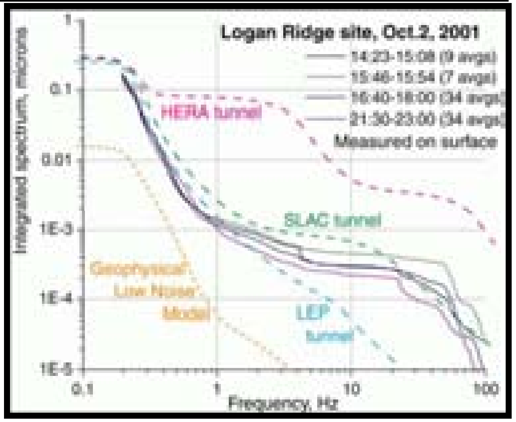
Representative LC Site- Logan Ridge, California

1. View South | 2. View West & Vibration Station | 3. View North

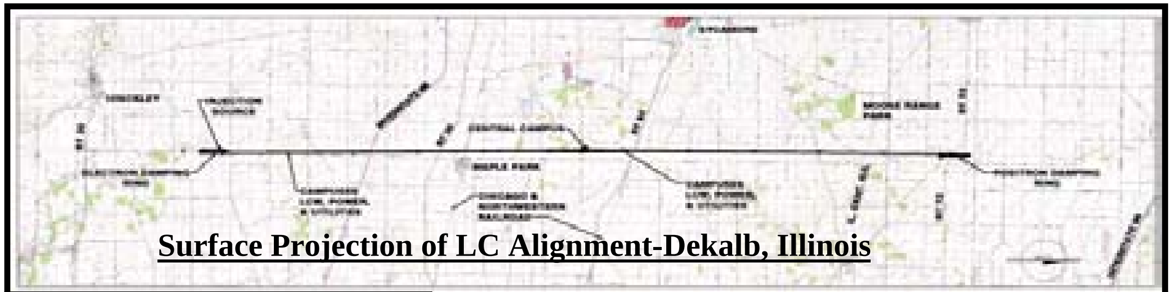
A typical sandstone outcrop at the site is shown below. The near surface rock is soft, competent and well blocked. High tunnel boring machine advance rates are obtainable in sandstone. It is an ideal rock for the LC.



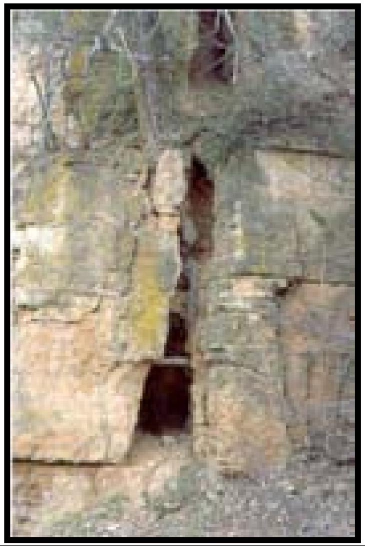
Surface measurements of vibration are plotted below and are comparable with those in the LEP tunnel. They exceed the goals for X-band stability and they can be found in a variety of locations worldwide.

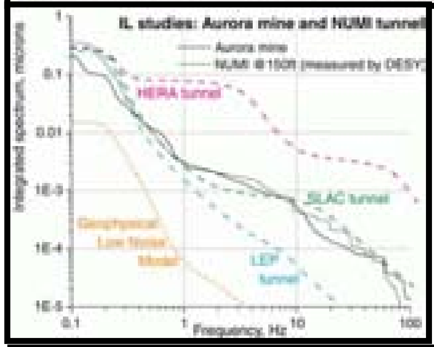


Representative LC Site- Dekalb, Illinois



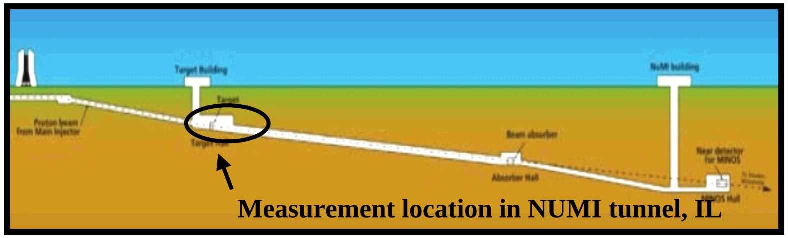
Surface Projection of LC Alignment-Dekalb, Illinois



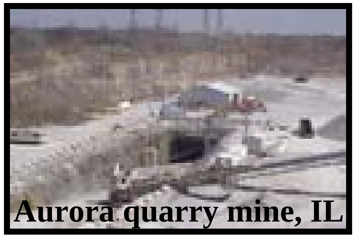


The measurements plotted above are taken in NUMI tunnel at shallow depth and in Aurora mine. Despite the surface being populated and moderately urbanized, the underground locations are relatively quiet.

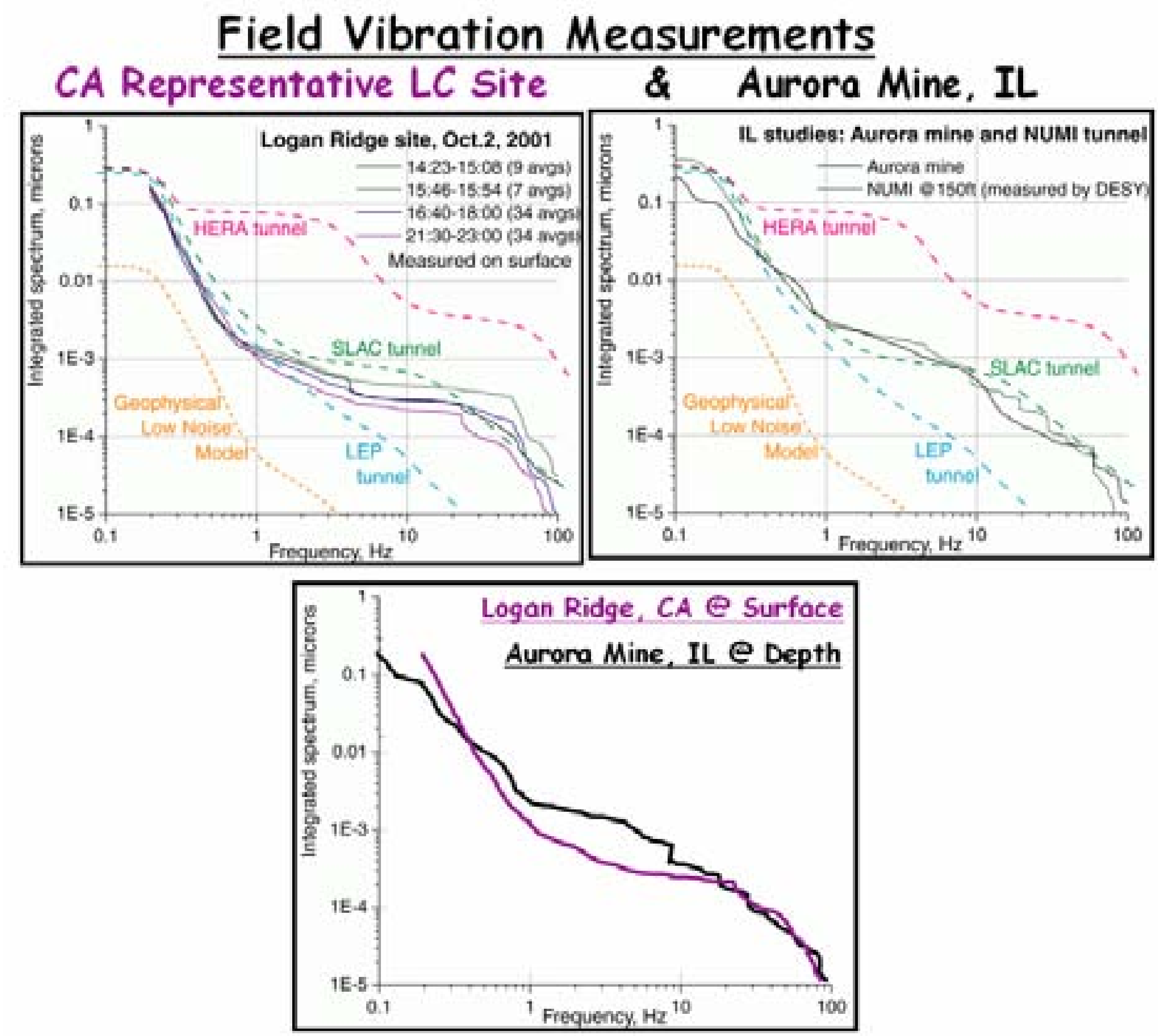
The Galena-Platteville Dolomite is shown above in outcrop. Beneath the DeKalb LC site at a depth of ~300 ft these two units make up a 300+ ft thick, near horizontal, uniform, carbonate unit which has excellent rock mass characteristics that make it an ideal rock for the LC.

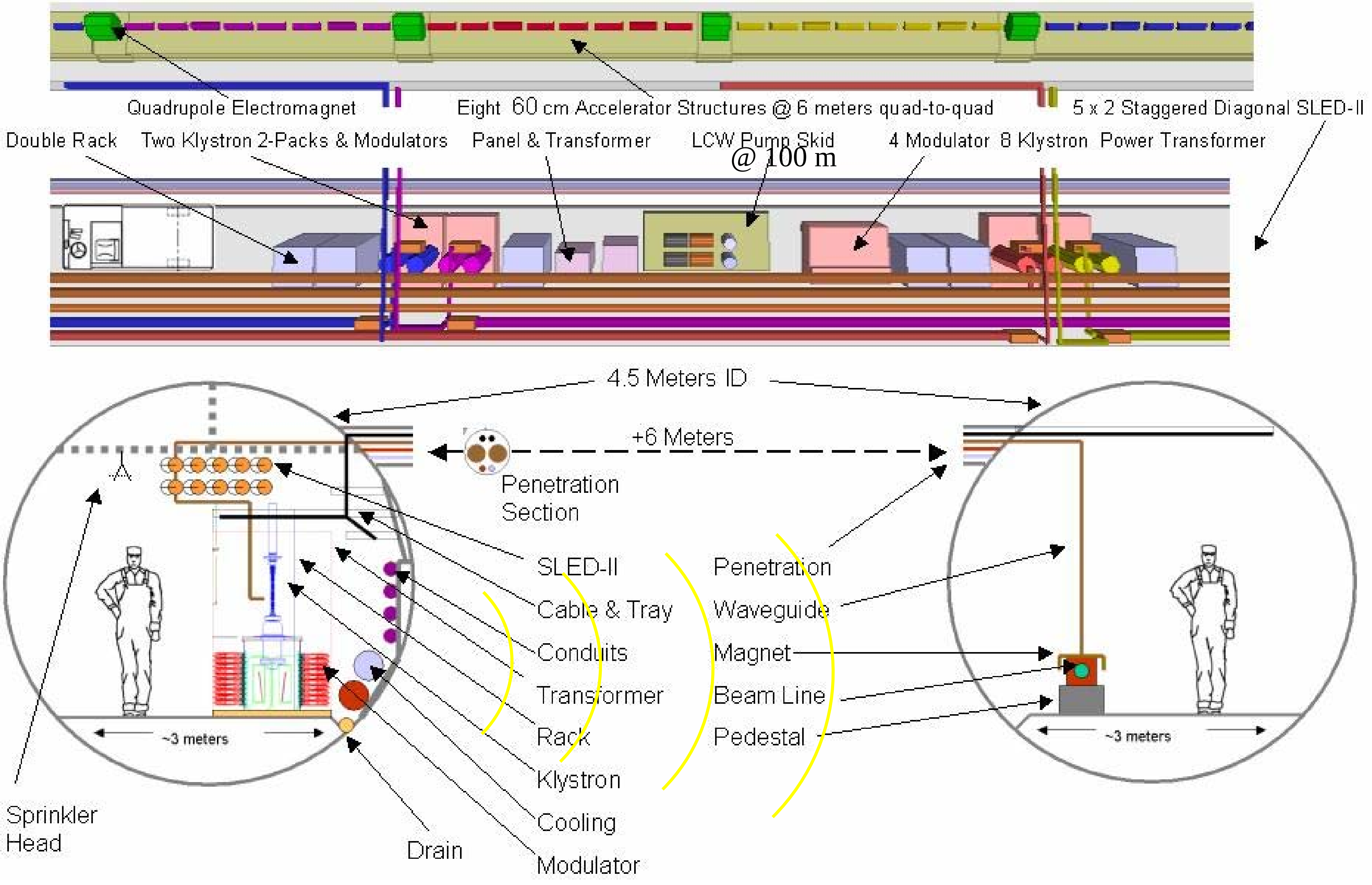


Measurement location in NUMI tunnel, IL

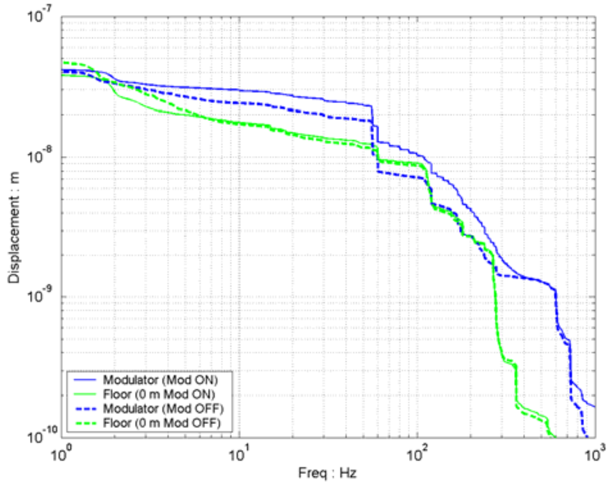


Aurora quarry mine, IL

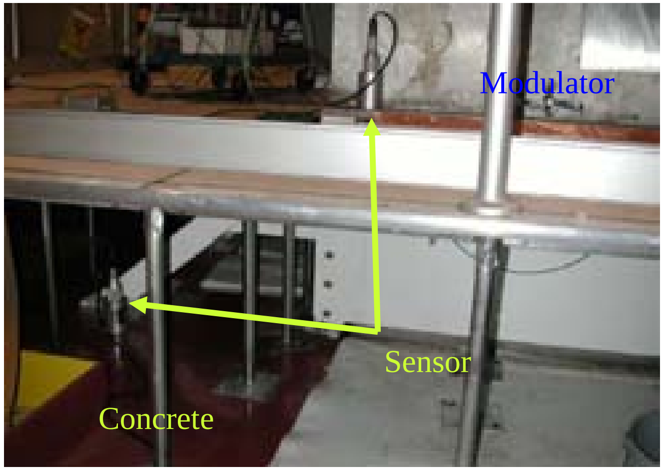

Field Vibration Measurements
CA Representative LC Site
&
Aurora Mine, IL
Logan Ridge site, Oct.2, 2001
14:23-15:08 (9 avgs)
15:46-15:54 (7 avgs)
16:40-18:00 (34 avgs)
21:30-23:00 (34 avgs)
Measured on surface
HERA tunnel
SLAC tunnel
Geophysical
Low Noise
Model
LEP
tunnel
Integrated spectrum, microns
Frequency, Hz
IL studies: Aurora mine and NUMI tunnel
Aurora mine
NUMI @ 150ft (measured by DESY)
HERA tunnel
SLAC tunnel
Geophysical
Low Noise
Model
LEP
tunnel
Integrated spectrum, microns
Frequency, Hz
Logan Ridge, CA @ Surface
Aurora Mine, IL @ Depth
Integrated spectrum, microns
Frequency, Hz

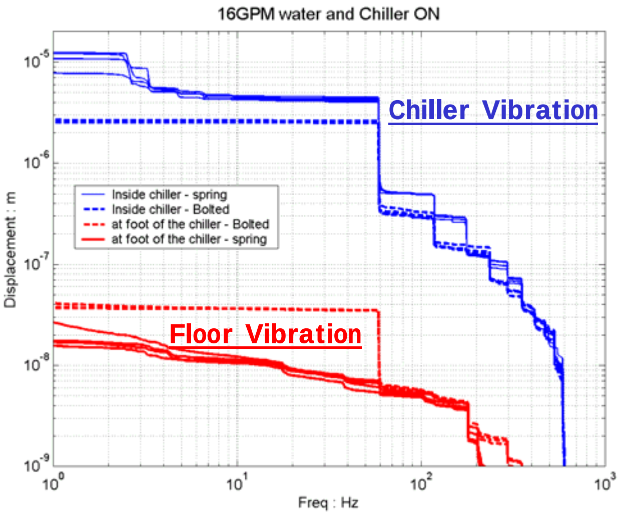

Quadrupole Electromagnet
Eight 60 cm Accelerator Structures @ 6 meters quad-to-quad
5 x 2 Staggered Diagonal SLED-II
Double Rack
Two Klystron 2-Packs & Modulators
Panel & Transformer
LCW Pump Skid
@ 100 m
4 Modulator 8 Klystron Power Transformer
4.5 Meters ID
+6 Meters
Penetration
Section
SLED-II
Cable & Tray
Conduits
Transformer
Rack
Klystron
Cooling
Modulator
Penetration
Waveguide
Magnet
Beam Line
Pedestal
~3 meters
~3 meters
Sprinkler
Head
Drain

Characterization of Vibration Sources in the Support Tunnel



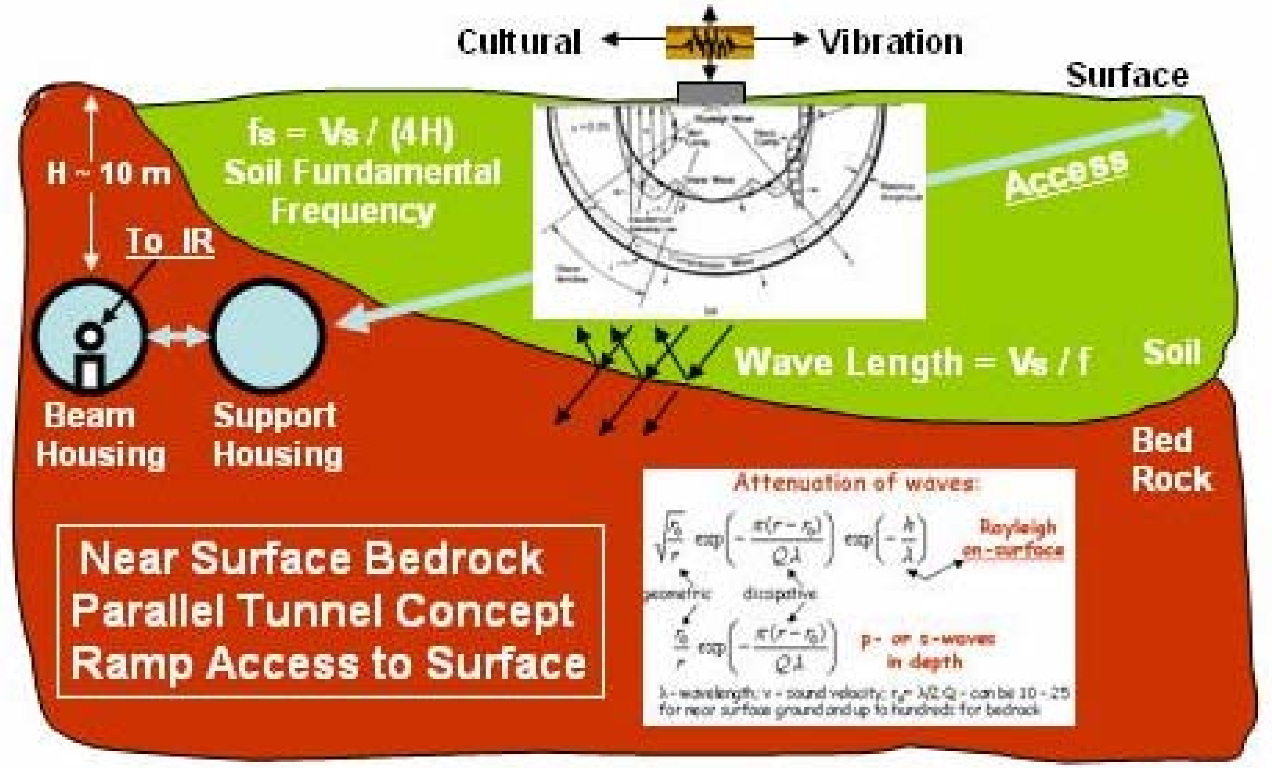
Average integrated displacement at the base of the modulator and near its support.
Modulator pulsed noise @ 60 Hz:
< 30nm on the modulator
< 12 nm on the floor
(within acceptable limit)





The chiller (~700 lb) shown here vibrates by 2-3micron at 59Hz. If mounted rigidly, it transmits ~30nm to the floor near the support. Same chiller mounted on soft spring transmits considerably less vibration to the floor (<nm).

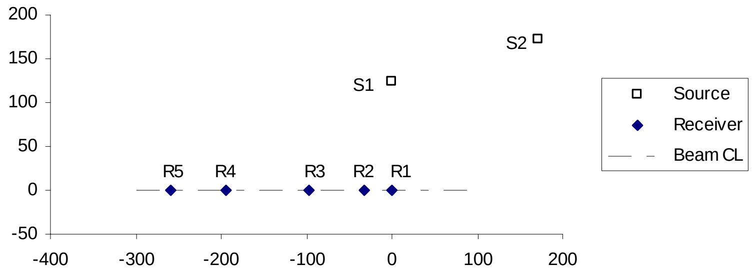
Experimentally determined the vibration transmissibility for two construction methods namely Cut-&-Cover and shallow tunneling



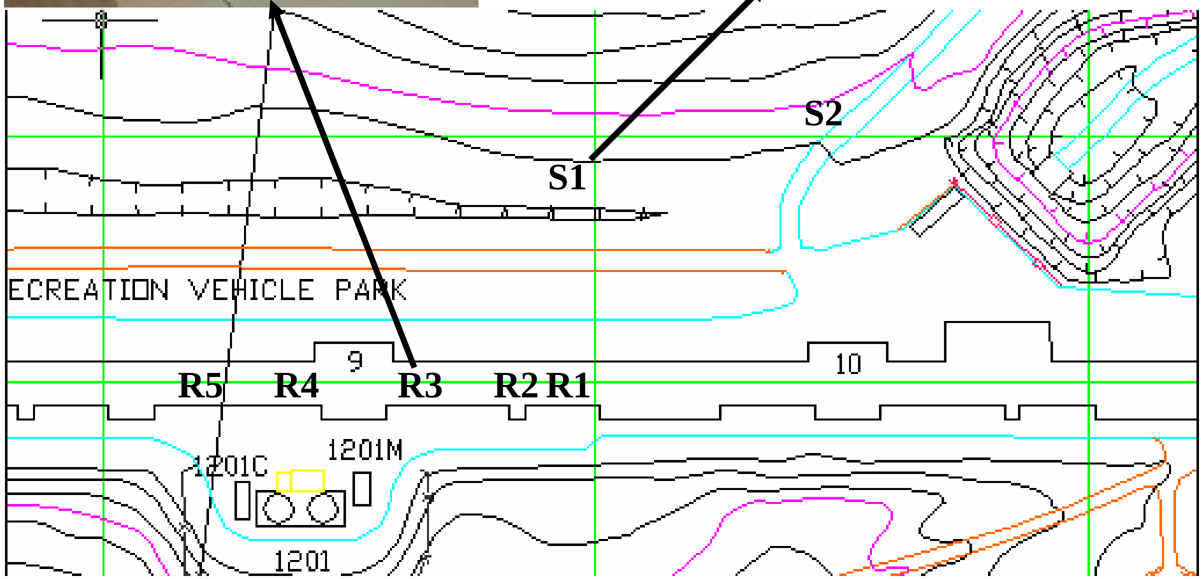
Vibration transmissibility was measured at two locations:

- At SLAC along Sector 9 and 10 for Cut-&-Cover construction method
  - *Eocene sandstone and claystone (shear velocity of ~720 m/se*
- At the Los Angeles County Metropolitan Transportation Authority (MTA) Red Line tunnels near the Universal City Station for shallow tunneling construction method
  - *Miocene sandstone and shale (shear velocity of ~950 m/sec)*

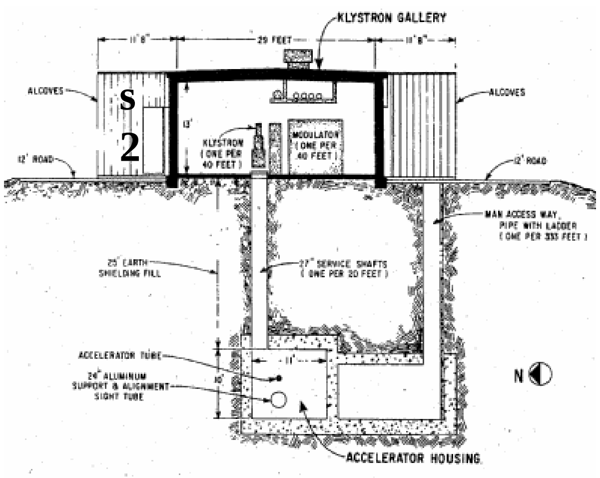
•At SLAC along Sector 9 and 10 for Cut-&-Cover construction method



Location Plan View of Sources S# and Receptors R#

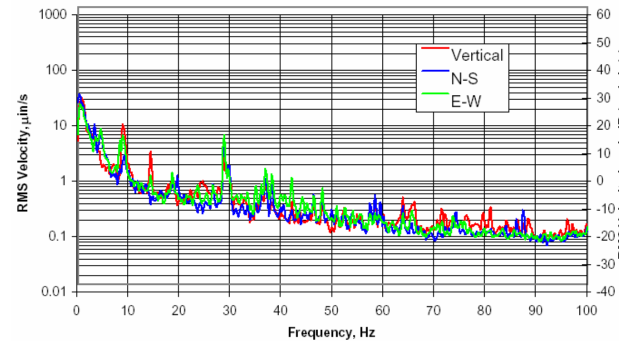


Plan Layout of Sector 9 and 10 at SLAC



Typical Cross Section of Accelerator Housing and Klystron Gallery at SLAC

Source	Receiver	Distance, ft	Attenuation at Given Frequency			
			10 Hz	20 Hz	30 Hz	60 Hz
S1	R1	130	0.014	0.0084	0.012	0.005
	R2	134	0.012	0.012	0.014	0.004
	R3	162	0.011	0.0084	0.006	0.001
	R4	233	0.010	0.004	0.002	0.001
	R5	289	0.005	0.002	0.0009	0.0003

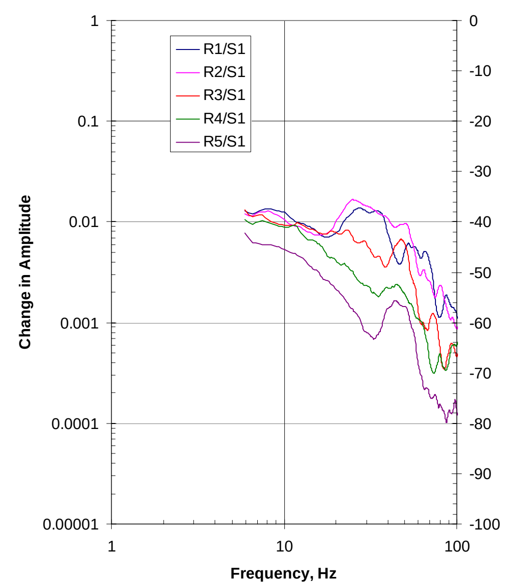


Ambient Vibration at Receiver Location R5

The figures in the above table represent the attenuation Factor for a vibration with its source near S1 propagating along the same path.

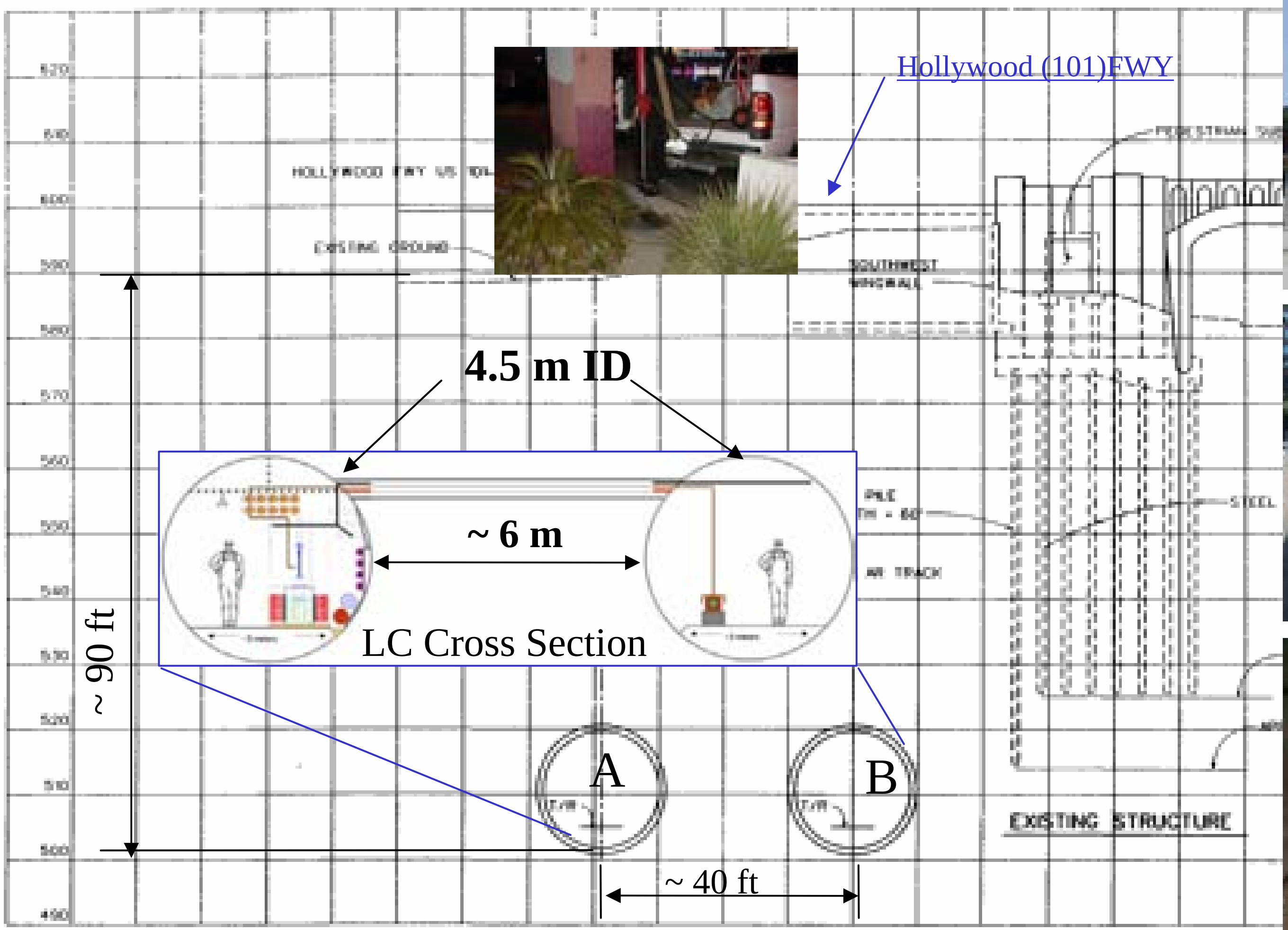
Example 1: Suppose a pump is installed at S1, and it produces a vibration at 60 Hz with an amplitude of X.
The amplitude at 60 Hz that we measure at R5 would be the greater of either ambient or 0.0003X.

Example2: If we want to place a pump at S1 and not to exceed ambient at R5 (0.6μ in/sec), then we need to impose a limit on the resulting vibration at S1 of 0.6/0.0003=0.002 in /sec.

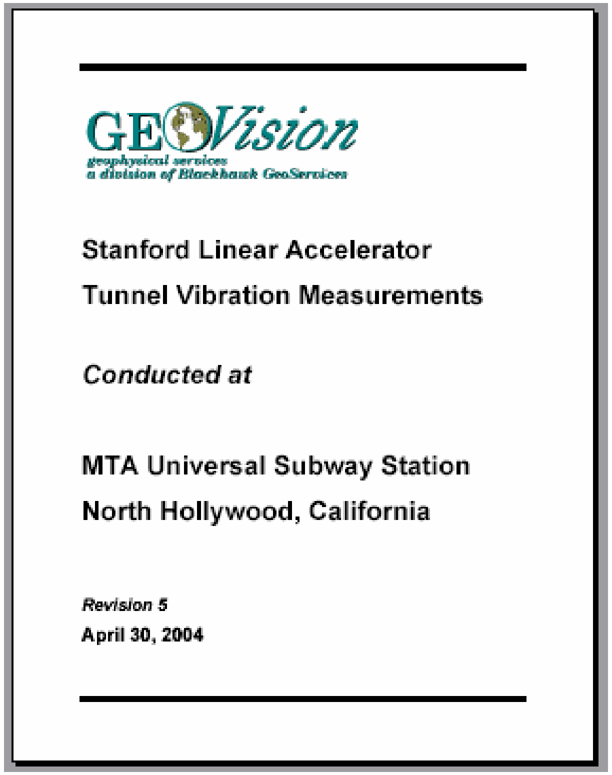


Log Mean Transmission From Drive Point S!

Vibration Measurements in the LA Metro Red Line Tunnels



The LCC-0122 and LCC-0123 have been revised and the revisions are posted:

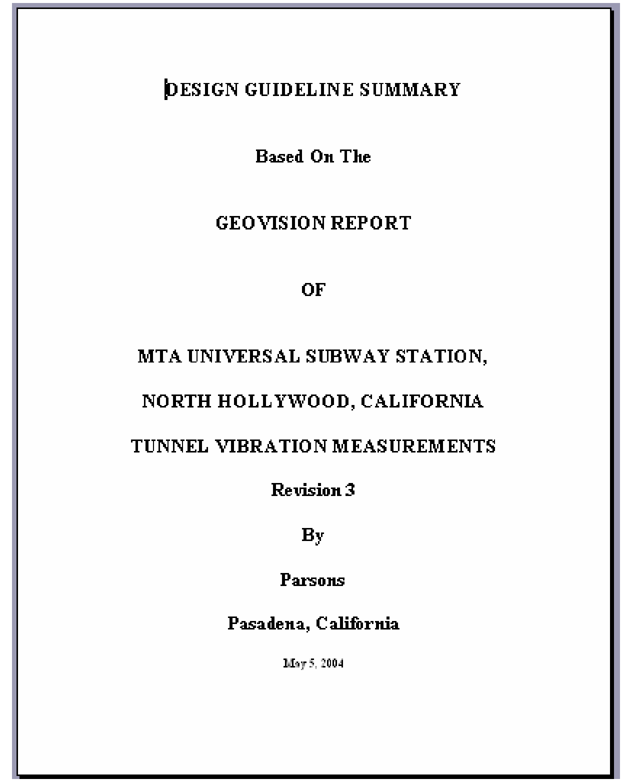

GEOVision
geophysical services
a division of Blackhawk GeoServices

Stanford Linear Accelerator
Tunnel Vibration Measurements

Conducted at

MTA Universal Subway Station
North Hollywood, California

Revision 5
April 30, 2004


DESIGN GUIDELINE SUMMARY

Based On The

GEOVISION REPORT

OF

MTA UNIVERSAL SUBWAY STATION,

NORTH HOLLYWOOD, CALIFORNIA

TUNNEL VIBRATION MEASUREMENTS

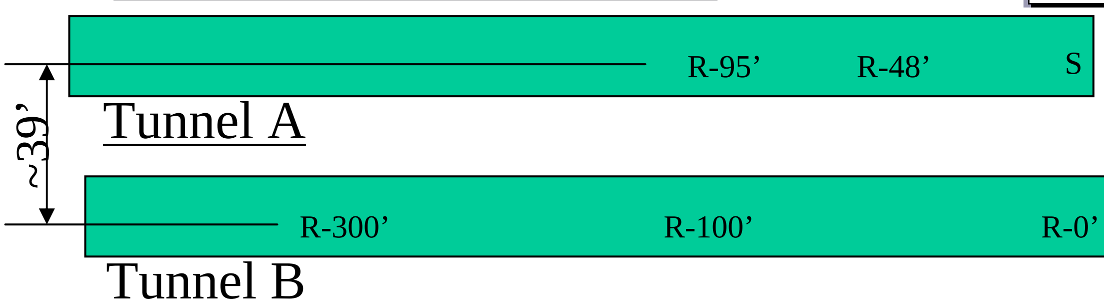
Revision 3

By

Parsons

Pasadena, California

May 5, 2004



“S” Location of the 100-kg drop source

“R” Location of the sensors,

Support to Beam tunnel transmission measured in LA metro tunnels and verified with 3D modeling computer program (SASSI). At 60Hz the mobility across tunnels is ~1 nm/100 Newton's permitting moderate vibration in Support tunnel. If required, vibration due to rotating equipment can be eliminated with standard inexpensive means, e.g. 3Hz springs.

FIG-9-REV-1.PDW

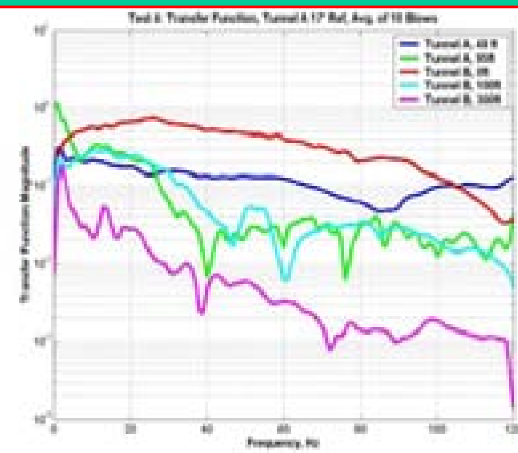
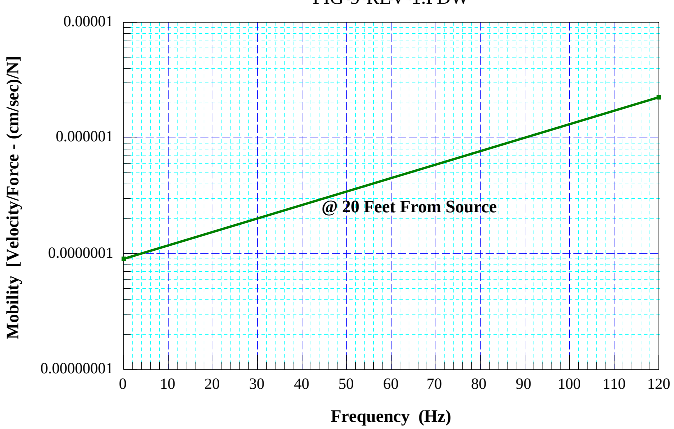
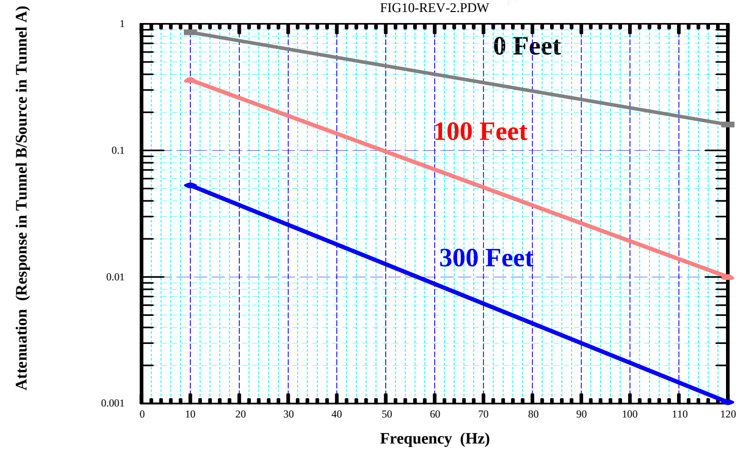
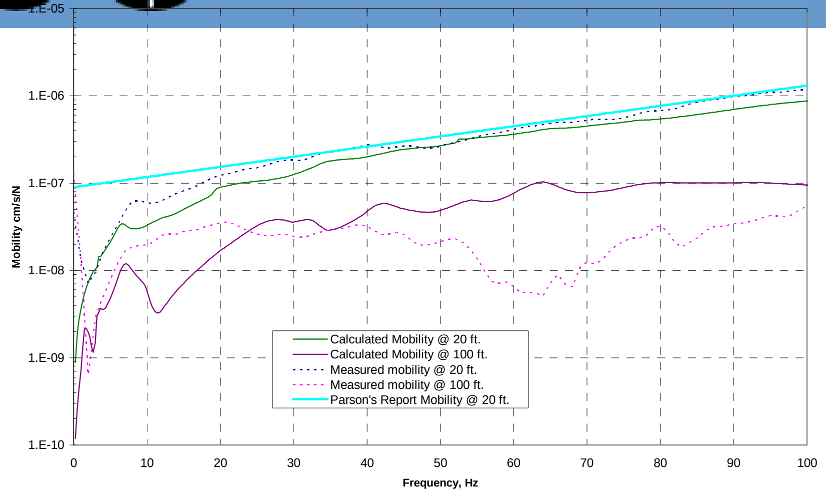


FIG10-REV-2.PDW

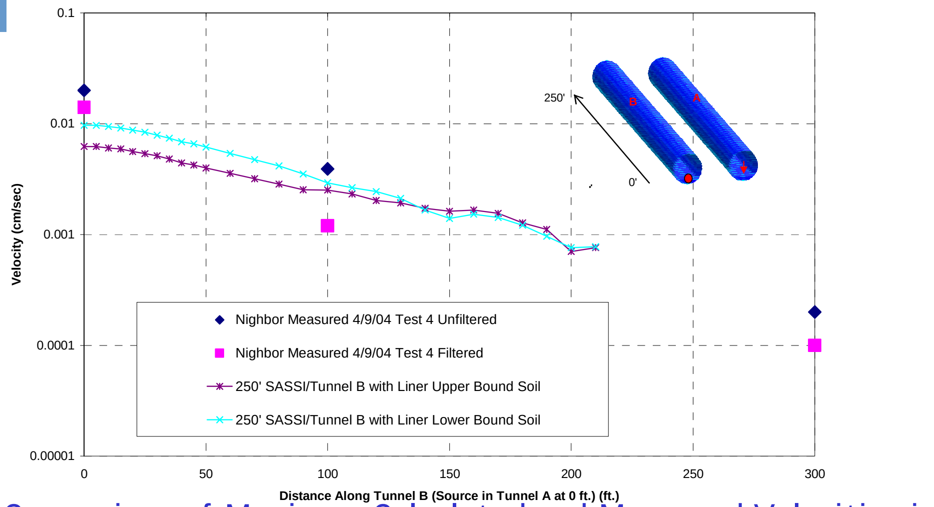




ILC- Snowmass 2005- WG 4



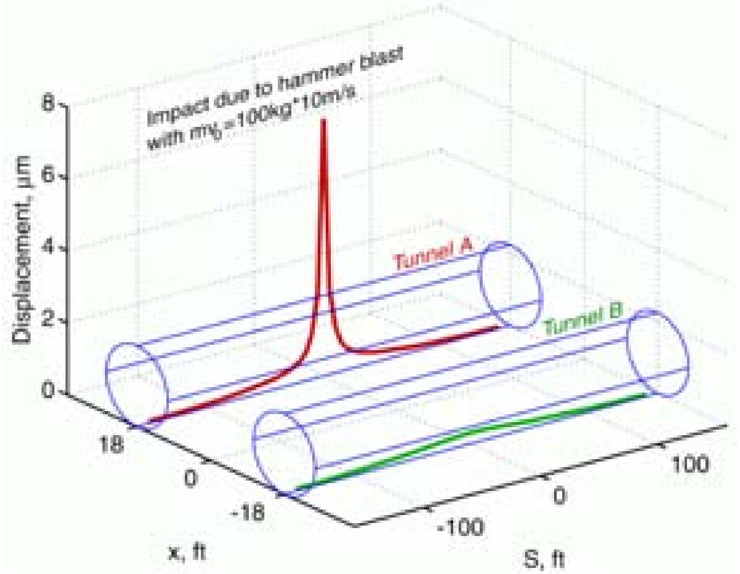
Comparison of Calculated and Measured Mobilities



Comparison of Maximum Calculated and Measured Velocities in Tunnel B, Lower Bound and Upper Bound Soil

- The results of the 3-D computer simulation program "SASSI" and the measured vibration data from the MTA tunnel tests are correlated.

- The SASSI simulation computer program can be used to predict the attenuations of vibration emanating sources in the support tunnel to the vibration sensitive equipment in the beam tunnel.



Science Vibration and Stability Needs for Warm LC

–Assumptions:

The total beam jitter at the IP is 50% of the beam size, with the following uncorrelated contributions:

30% from the main linac, 30% from the beam delivery, 25% from the final doublet, and with 15% injection jitter, RSS is ~ 50%

– Assuming the above jitter budget:

The vertical vibration of the linac quadrupoles needs to be less than 12 nm above several Hz

–Ground stability:

Considering that the normal operations include a 9 month run cycle, followed by a 3 month period for maintenance & alignment,

An annual relative drift rate at the beam pedestal support floor should be less than +/- 2 mm over a distance of 200 meters.

What are the Science Vibration and Stability Needs for the Cold LC?

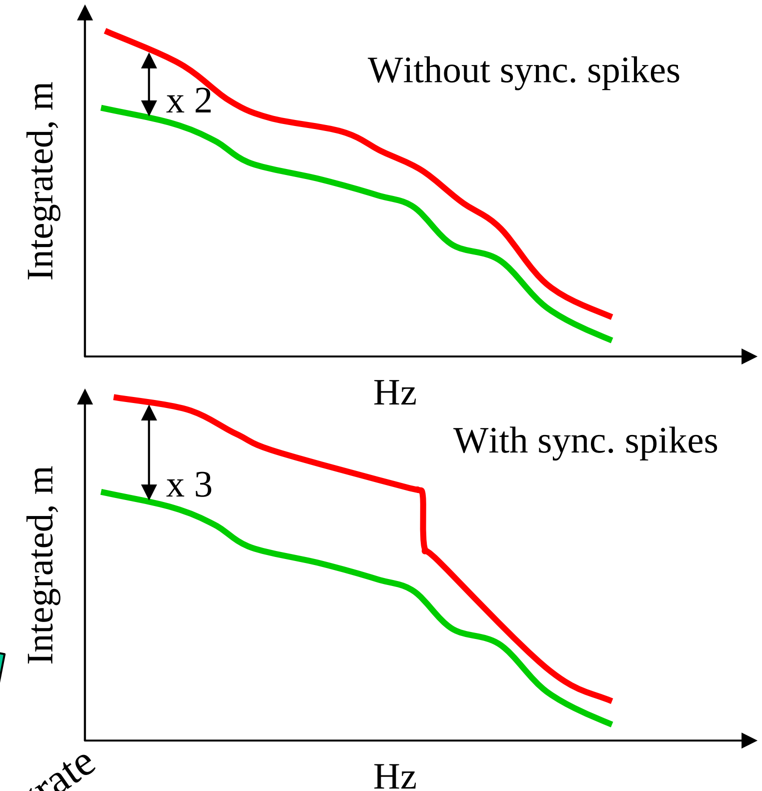
Beam Housing Foundation Vibration Criteria-Warm

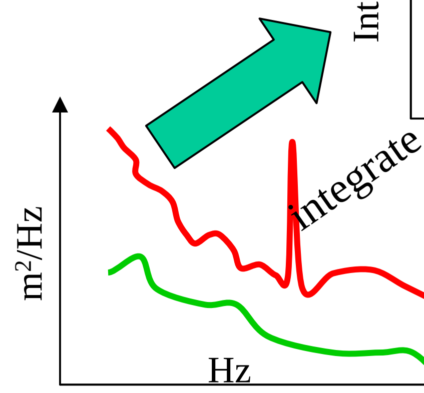
<u>Vibration Criteria at the invert of Beam Housing</u>

The RMS value of the imported (i.e. added) broadband vibration integrated above 3 Hz should be less than a factor of two (2) times the pre-existing ground vibration amplitude, excluding the resonant “spike” vibrations synchronous with collider repetition rate.

With the resonant spikes included, the RMS amplitude above 3 Hz should be less than a factor of three (3) times the pre-existing ground vibration amplitude.

<u>Its assumed that the pre-existing RMS value of the vertical component of ground vibration amplitude is less than two nanometers integrated above 3 Hz.</u>





DRAFTED FROM WARM

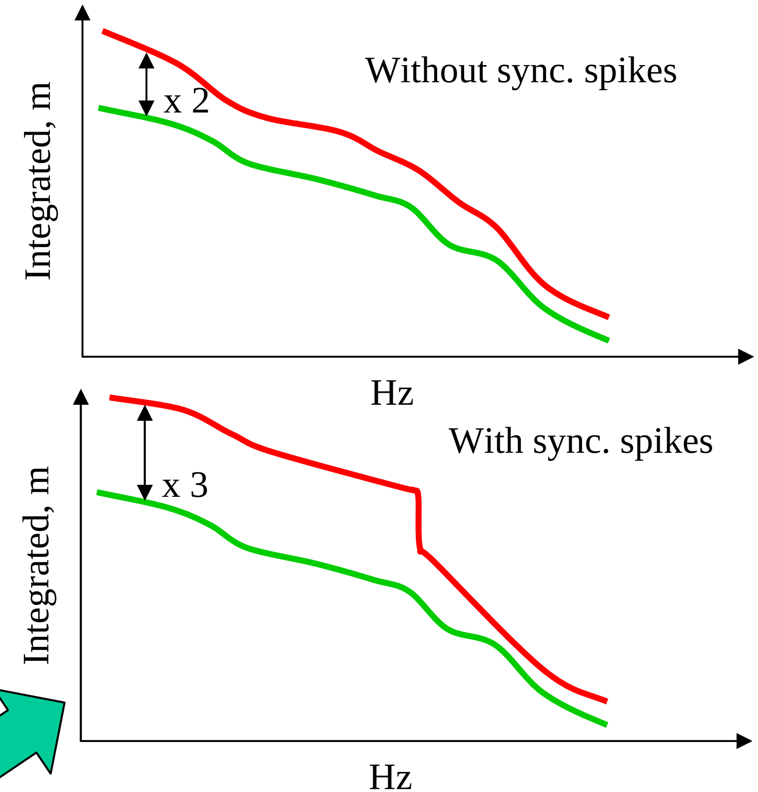
Beam Housing Foundation Vibration Criteria-Cold

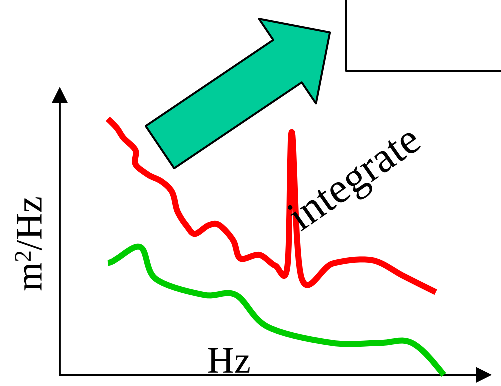
Vibration Criteria at the invert of Beam Housing

The RMS value of the imported (i.e. added) broadband vibration integrated above 3 Hz should be less than a factor of two (2) times the pre-existing ground vibration amplitude, excluding the resonant "spike" vibrations synchronous with collider repetition rate.

With the resonant spikes included, the RMS amplitude above 3 Hz should be less than a factor of three (3) times the pre-existing ground vibration amplitude.

Its assumed that the pre-existing RMS value of the vertical component of ground vibration amplitude is less than 5 nanometers integrated above 3 Hz. and less than 20 nanometers integrated above 0.5 Hz.





What should be done next?

- To measure ambient ground noise (natural, far-field) for the ILC Sample Illinois sites at or near the Interaction Point
  - We are planning to conduct this task
- To identify and to characterize the major vibration sources (cultural, near-field) for the cold machine sub systems
  - Cryogenics systems (Compressors), LCW cooling system, rotating mechanical and electrical equipment (L-Band Modulator)
- To adopt the vibration criteria (goals) and to determined the stability parameters for the cold machine (similar to the one for the warm machine)
  - Vibration budget for the cold machine is higher, but so the imported noises
- To utilized 3-D computer modeling and to modify the parameters for the ILC Sample site
  - SASSI models can be used to parametric predict transmissibility functions
  - Mitigate vibration effects by trying different options, tradeoff
  - This can lead to better optimization of design requirements, as well as to better manage the ILC vibration budget