CALIFORNIA INSTITUTE OF TECHNOLOGY

Laser Interferometer Gravitational Wave Observatory (LIGO) Project

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Subject: Information on the seismic effects of various land uses.

This letter summarizes information about possible impacts on the Laser Interferometer Gravitational-wave Observatory (LIGO) caused by activities on the surrounding land. The discussion below highlights criteria concerning man-made sources of vibration that were among the criteria used to choose the Hanford site over other proposed sites in the continental United States.

The LIGO Observatory in Hanford, Washington is a state-of-the-art facility, operated for the U. S. National Science Foundation, that is part of an emerging international network of gravitational-wave detectors. LIGO uses high-precision laser beams to detect the extremely small motions of mirrors caused by gravitational waves created in deep space. Seismic noise (i.e., natural vibrations of the earth) and noise induced by man-made vibrations can hide or mimic the effect of a gravitational wave. Successful detection of the gravitational waves requires that the Hanford Observatory work in unison with its sister facility in Livingston, Louisiana. Thus, a significant increase in the levels of seismic noise and vibration at either of the LIGO observatories could render all of LIGO inoperable for gravitational-wave observations for as long as these increased levels of vibration persist. For this reason, the observatories were located in places with exceptionally low levels of seismic noise and vibration. Following the evaluation of 18 proposed LIGO sites throughout the continental United States, the Hanford site was chosen for LIGO in a national competition, based in part on the low levels of seismic noise and vibration known to exist at this site and the likelihood that these levels would remain low in the foreseeable future.

The site-evaluation committee rated each site according to criteria that reflected LIGO's needs. To evaluate sites on the basis of man-made sources of vibration, an international set of guidelines[1] developed for seismic observatories was used. The guidelines list recommended minimum distances to the nearest source of man-made vibration due to different categories of sources. These recommendations were used to obtain "preferred" and "acceptable" minimum distances to these sources. The sites were then graded according to these criteria. Sample criteria, useful for land-planning purposes are listed below:

1. Reciprocating power-plant machinery, rock crushers and heavy machinery should be located at least 10 miles from the site, with a preferred distance of at least 25 miles.

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1. Manual of Seismological Observatory Practice, P. L. Gilmore, ed., World Data Center A for Solid Earth Geophysics, U. S. Dept. of Commerce, National Oceanic and Atmospheric Administration, Environmental Data and Information Service, Boulder, CO, 80303; Table 2.1.

2. Railways that operate frequently should be at least 6 miles from the site, with a preferred distance of at least 12 miles.

3. Non-reciprocating power-plant machinery and balanced industrial machinery should be located at least 4 miles from the site, with a preferred distance of at least 10 miles.

4. Vehicular traffic should be located at least 0.6 miles from the site, with a preferred distance of at least 3 miles.

Using these criteria, the only serious seismic noise disturbance identified at the Hanford site was vehicular traffic. The Hanford site was given an acceptable rating because the potential disruption due to traffic would be confined to morning and evening rush hours. This was considered to be the only negative vibration-related impact at the site. With assurances from the United States Department of Energy that no significant development was likely within this zone[2], the Hanford site was given a high rating. In selecting the Hanford site for LIGO, the National Science Foundation recognized the anticipated conditions at the site.

We have recently received a final report concerning vibration measurements done for the LIGO site by the Pacific Northwest National Laboratory. Part of the mission of these measurements was to identify possible impacts on observatory operations caused by man-made vibration. The data obtained from this study confirm that the site-evaluation criteria for man-made vibration sources are applicable to the Hanford site.

The effect of traffic was determined with the help of video surveillance equipment and seismometers. Traffic on Route 10 past the LIGO site was observed to cause increased noise at the corner station of the observatory complex. We can say with certainty that large increases in traffic on this road would be disruptive to operations, especially if the weight of vehicles should increase significantly (as would happen if truck traffic increased on this road) or if the quality of the road surface were significantly degraded. We were less sensitive to traffic on Route 240 and Route 4 South, because they were farther from the observatory complex. However, large increases in truck traffic or degradation of the surfaces of these roads could also have negative impacts.

Measurements were also done during a time when there was construction activity near the site. By moving the seismometers we were able to identify how vibrations from construction equipment would lessen with distance away from the site. We found that vibrations from such activities within approximately 8 to 9 miles of the site could cause significant disruptions for as long as such activity persisted.

Similar activities can be expected to be similarly disruptive unless they are situated sufficiently far away. Practical examples of extremely disruptive operations, similar to category (1) above, would be gravel or basalt mining operations, metal-stamping mills and any kind of construction activity that involved backhoes, bulldozers, heavy digging machinery, etc. Continuous operations of this type would render LIGO inoperable if they were located too closely. The equipment in nuclear reactors at Hanford would likely fall into category (3), as would many modern facilities such as biotechnology or semiconductor fabrication plants. Metal or plastics manufacturing using low-impact methods (i.e., no stamping operations) should also fit into this category. The

2. Option to Site A: Laser Interferometer Gravitatinal-Wave Observatory (LIGO), U. S. Department of Energy, Richland Operations Office, March 1, 1991; Section 3.7

operation of facilities like this within the category (3) range would not be deleterious to LIGO, but construction work on these facilities might cause severe disruption. Mechanized farming operations should be in category (4), with activities that disturb the ground (such as plowing) likely to be more disruptive than use of harvesting equipment. With these guidelines, LIGO should be able to respond to any inquiry and to evaluate proposed uses and to identify adverse impacts on LIGO operations.

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