CHARACTERIZATION OF JOLTING AND JARRING ON OPERATORS OF SURFACE MINE HAULAGE TRUCKS

by Fred Biggs, Richard Miller, and Walter Utt

ABSTRACT

Powered haulage has been, and continues to be, a major source of severe accidents and fatalities at metal/nonmetal surface mines. Between 1986 and 1997, truck drivers accounted for 63% of the lost-time injuries in surface haulage. This project was undertaken to reduce the number and severity of lost-time injuries among operators of these trucks. Work involved measuring shock acceleration at a western surface mine during representative work cycles on two types of trucks and collecting data from cab floors using a triaxial accelerometer and from operator seats using a seat pad accelerometer. NIOSH researchers also used the mine's GPS systems to locate shock events on a mine map in real time. Shock tests were also run at Caterpillar, Inc.'s, proving grounds in Green Valley, AZ, to determine the magnitude of shocks resulting from controlled rock drops onto the bed of a haulage truck.

INTRODUCTION

Powered haulage has been, and continues to be, a major source of severe accidents and fatalities at metal/nonmetal surface mines. Between 1986 and 1997, injuries to truck drivers accounted for 63% of the lost-time injuries.

The objective of this research is to reduce jolting and jarring injuries among operators of heavy mining equipment, particularly haulage truck drivers. Characterization of the magnitude and frequency of jolts and jars will lead to a better understanding of their causes and enable researchers to evaluate different types of engineering controls that could reduce trauma to operators and lower the incidence of back injuries. The research is part of a project called "Engineering Controls for Reducing Jolting/Jarring Injuries in Surface Mines" at the Spokane Research Laboratory (SRL) of the National Institute for Occupational Safety and Health (NIOSH). In this project, researchers are investigating the causal factors of jolting and jarring, what combination of jolts and jars is likely to harm an operator, and the cumulative effects of long-term exposure to jolting and jarring.

FIELD TESTS

Data were collected under actual field conditions during representative work cycles at a western surface mine interested in reducing lost-time injuries among its haulage truck operators. These data were obtained from two types of haulage trucks (truck A and truck B) manufactured by different companies. Jolts and jars were measured using an 8-megabyte Dallas Instruments Saver mounted to the pedestal of the driver's seat with a strong magnet at the point where the seat is bolted to the cab floor. This instrument package has an internal piezoelectric triaxial accelerometer that measures accelerations at the pedestal. A Bruel and Kjaer type 4322 triaxial seat pad piezoelectric accelerometer measures acceleration at the cushion. The three orthogonal directions (x, y, z) were oriented according to ISO 2631 [1]. From the driver's perspective, x is positive forward, y is positive to the driver's left, and z is positive upward.

For truck A, the Saver monitored jolting and jarring for 11 hr, 37 min, between 2:45 p.m. on June 8 and 7:08 a.m. on June 9, 1999. For truck B, the Saver monitored jolting and jarring for 18 hr, 1 min, between 12:47 p.m. on June 9 and 6:48 a.m. on June 10, 1999. The threshold for triggering data collection was determined empirically at 1.5 g's on the z channel of the seat cushion. Seven events above 1.5 g's were recorded on truck A, and five events were recorded on truck B. Other set-up parameters were filter frequency, 200 Hz; range, ±50 g's; samples per second, 512; recording time, 8 sec; and samples per event, 4096. The 12 events were converted from the Saver file format to ASCII and imported into a software program called DADiSP, a product of DSP Development Corp.,[1] for further analysis.

The acceleration shocks for truck A are shown in figure 1 and for truck B in figure 2. Comparing the shocks on truck A with the shocks shown in figure 3 and operators' written logs, the authors determined that shock events A1, A3, A5, and A6 were caused by loading. The other three shock events on truck A (A2, A4, and A7) and all shock events on truck B were caused by rough ground, as determined by comparing figure 4 and operators' written logs. The average peak frequency of the shocks on the seat cushion in truck A was 35 Hz, and the average frequency of the "rough ground" shocks was 1.4 Hz. Interestingly, the average peak frequency of all truck B shocks was also 1.4 Hz.

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[1]The mention of specific products or manufacturers does not imply endorsement by the National Institute for Occupational Safety and Health.

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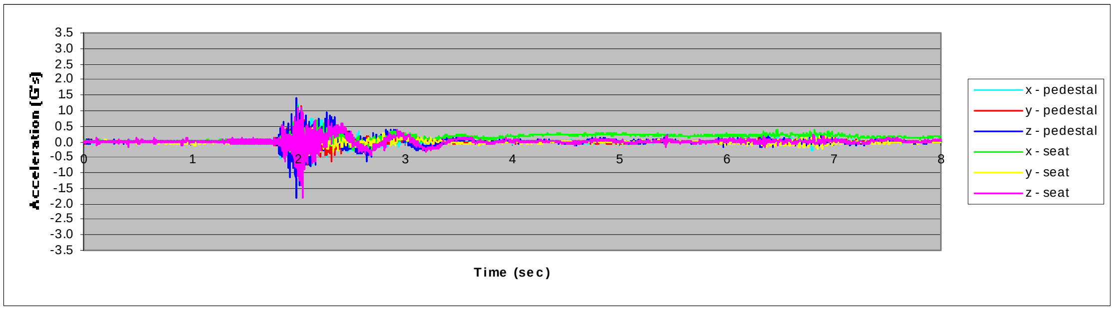

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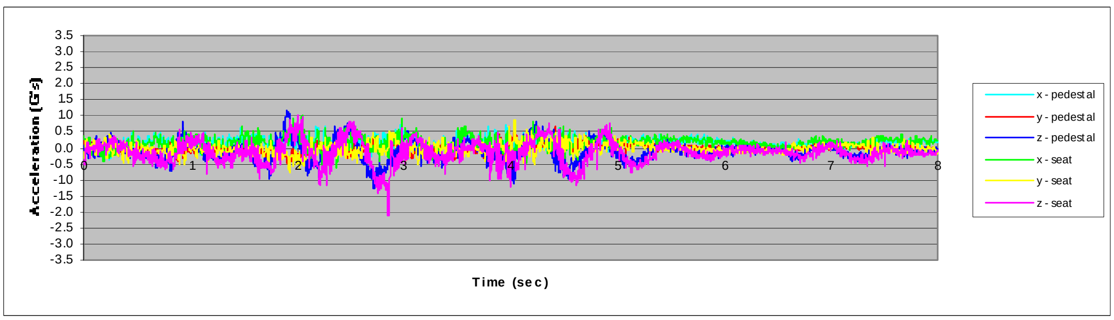

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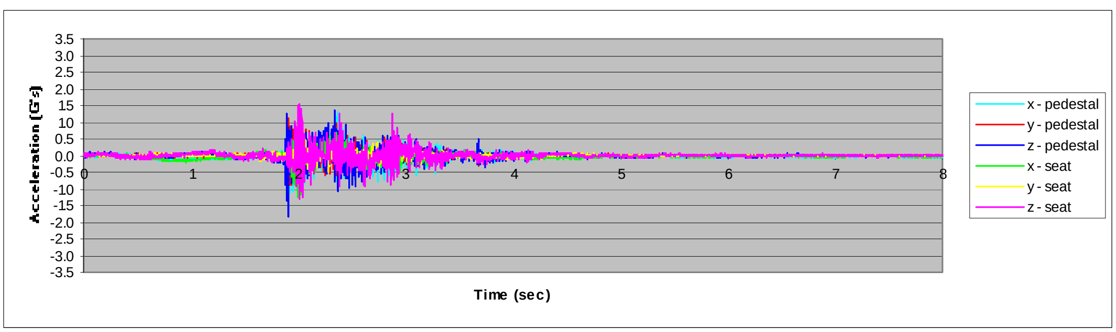

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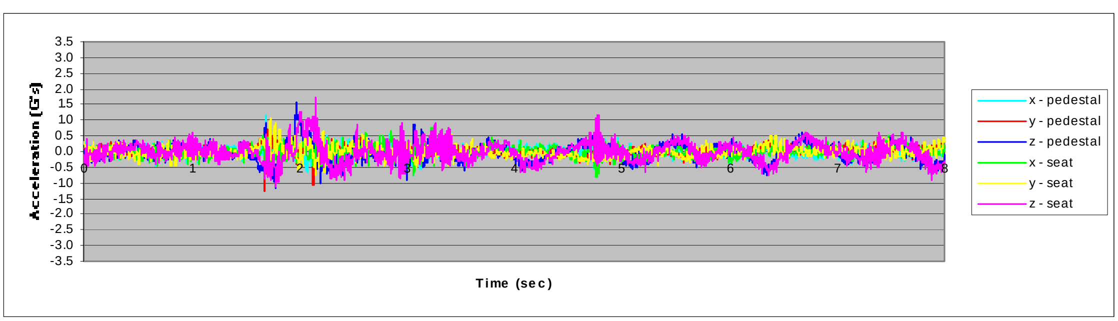

Figure 1.—Truck A shock events. *A*, Loading event, A1; *B*, rough ground event, A2; *C*, loading event, A3; *D*, rough ground event, A4; *E*, loading event, A5; *F*, loading event, A6; *G*, rough ground event, A7.

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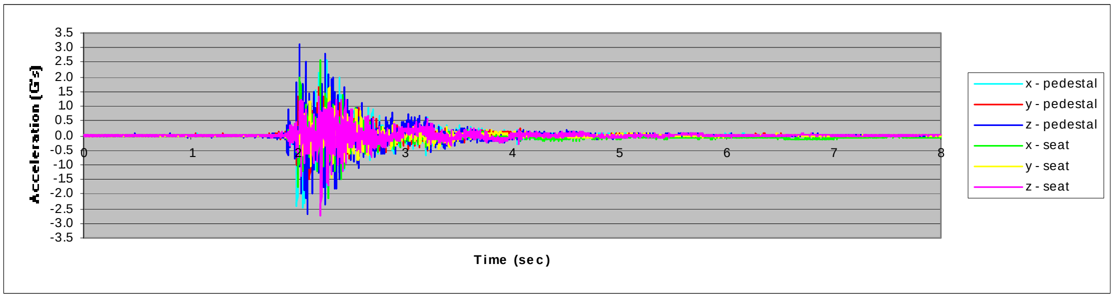

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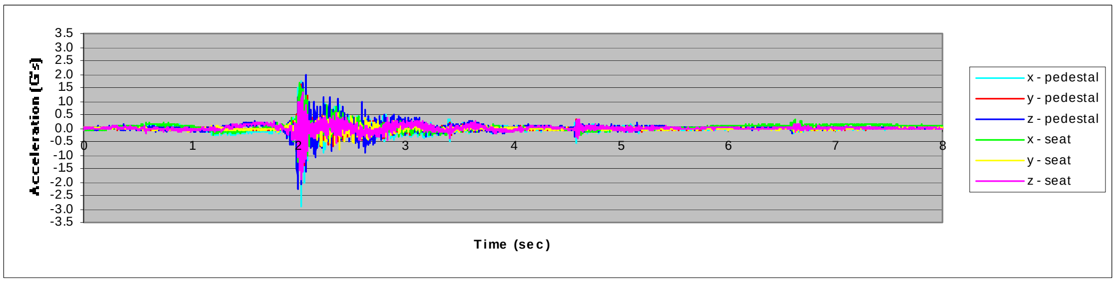

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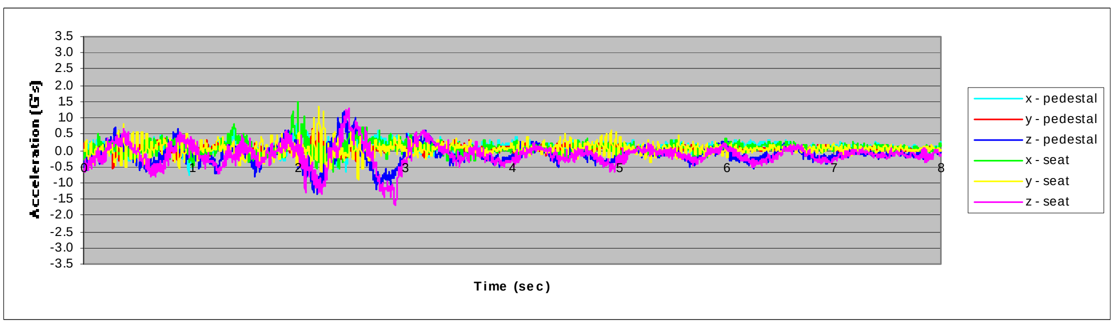
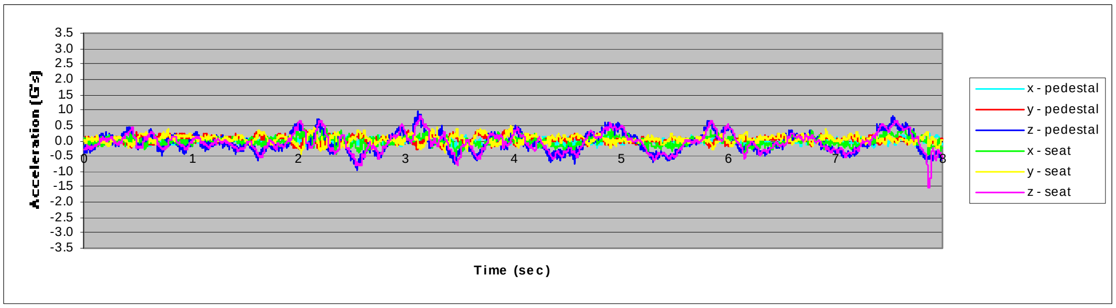


Figure 1.—Truck A shock events (continued). *A*, Loading event, A1; *B*, rough ground event, A2; *C*, loading event, A3; *D*, rough ground event, A4; *E*, loading event, A5; *F*, loading event, A6; *G*, rough ground event, A7.

A



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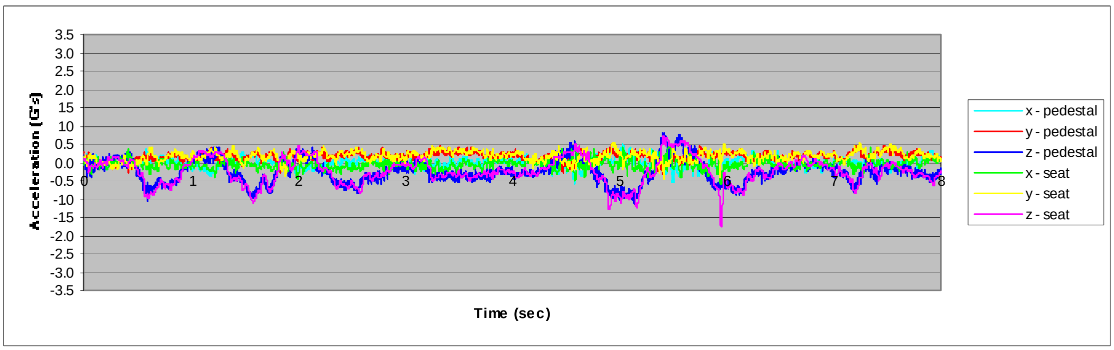

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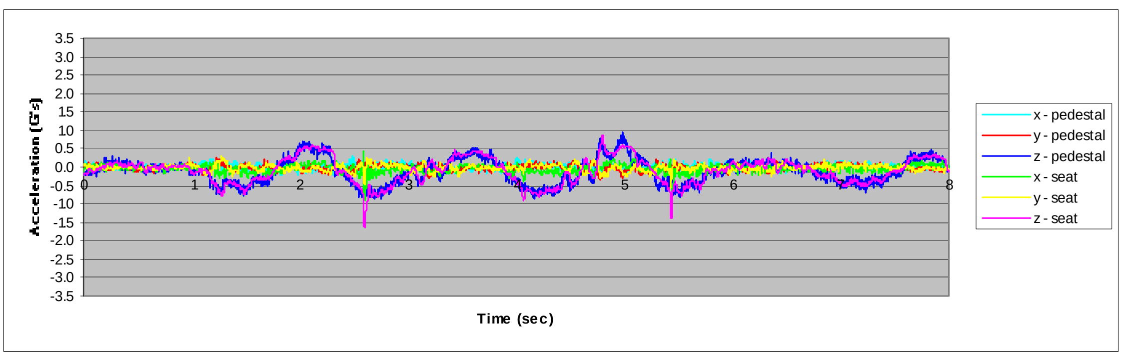

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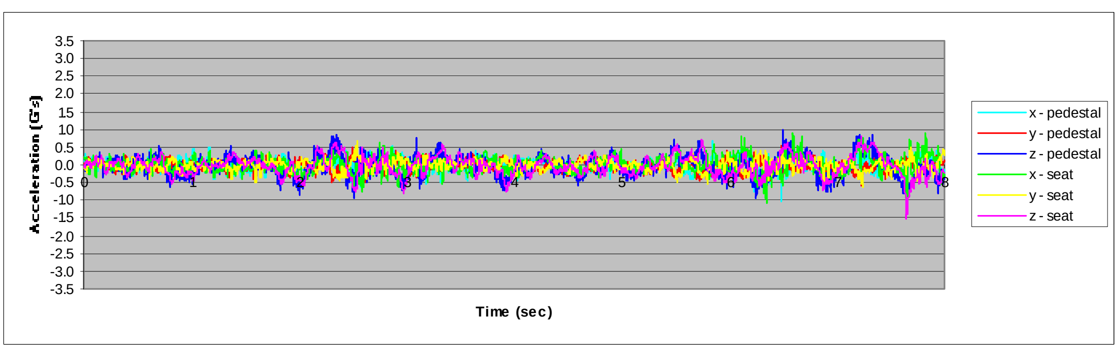

Figure 2.—Truck B shock events. *A*, Event 1; *B*, event 2; *C*, event 3; *D*, event 4; *E*, event 5**.**

E

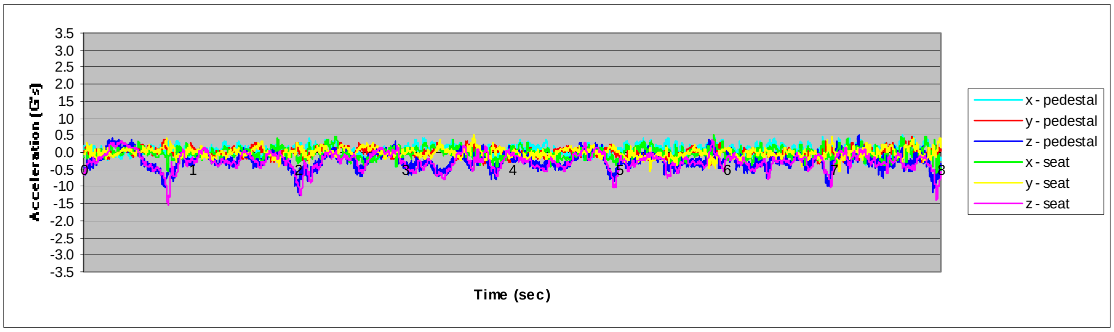

Figure 2.—Truck B shock events (continued). *A*, Event 1; *B*, event 2; *C*, event 3; *D*, event 4; *E*, event 5.

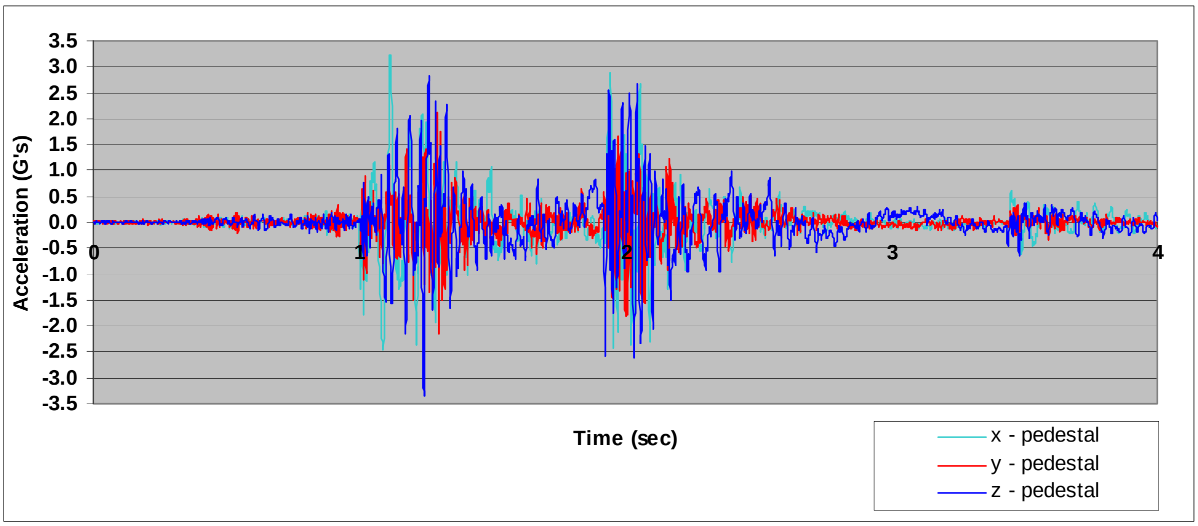

Figure 3.—Acceleration measured after dropping 1-1/2-ton rock from a height of 10 ft onto the bed of a haulage truck.

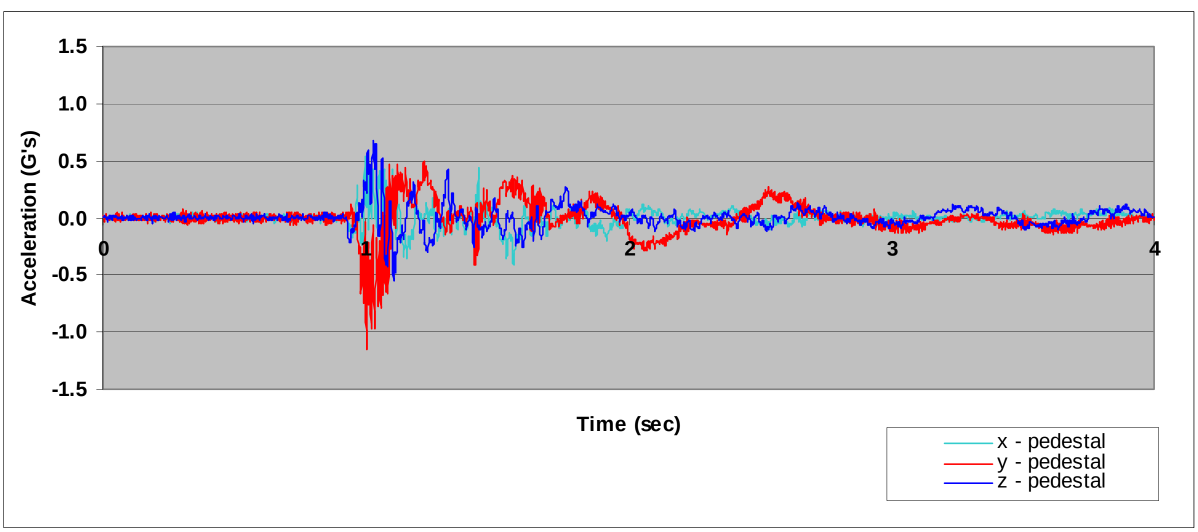

Figure 4.—Acceleration when truck hit in the side by a shovel.

GPS-ACCELERATION STUDIES

A typical epidemiological study involves recording when and where people react to a hazard and plotting the results on a map. To determine the frequency and causes of jolting and jarring, it is necessary to determine when and where these shocks occur, so establishing a relationship between jolt occurrence and location is important. A system that ties acceleration data with Global Positioning System (GPS) data was developed, assembled, and tested to provide an imprint of the jolts on a mine map (figure 5). This information will be of value in providing feedback to truck operators about how their driving affects jolting and jarring and identifying just where haulage road problems are.

Many verbal reports are available from truck drivers concerning where and how they received injuries while driving, but no way has been available until recently to establish where these injuries occurred. However, recent experiments by SRL researchers [2] indicate it may be feasible to mount an accelerometer on the frame of a truck. The accelerometer would send signals to GPS hardware. When the truck is jolted or jarred, the shock would appear on the mine dispatcher's screen in real time. When groups of jolts are seen on the screen, corrective actions could be taken. One such action might be to provide information to a shovel operator that he or she is loading the trucks in a manner that jolts the operator. Or the haulage road in that area could be resurfaced. The GPS could lead to refining information about what conditions most frequently cause or contribute to jolting and jarring. Investigations continue on what software components could allow the display of jolts on a computerized mine map in real time.

Figure 5.—GPS-acceleration data system

The output of the initial SRL experiment was an ASCII computer file containing the location of every jarring event over 2 g's (the minimum threshold the instrument could measure) over the time of the test. Although the truck traveled large sections of the mine without an event over the 2-g threshold, a group of events was recorded for an inclined section of the haulage road. Because the internal frequency filter of the GPS was set at 1000 Hz and the filter of the Dallas Instrument Saver was set at 200 Hz, many more events were recorded per hour using the GPS than were recorded using the Saver.

Using the mine's GPS data, shock events A1 through A6 were plotted onto a mine map (figure 6). These shocks occurred around an area of the mine where the trucks were being loaded. However, shocks A2, A4, A7, and B1 through B5 were caused by rough ground. A better analysis could be made if the locations of the shovels relative to the jolts and jars were known.

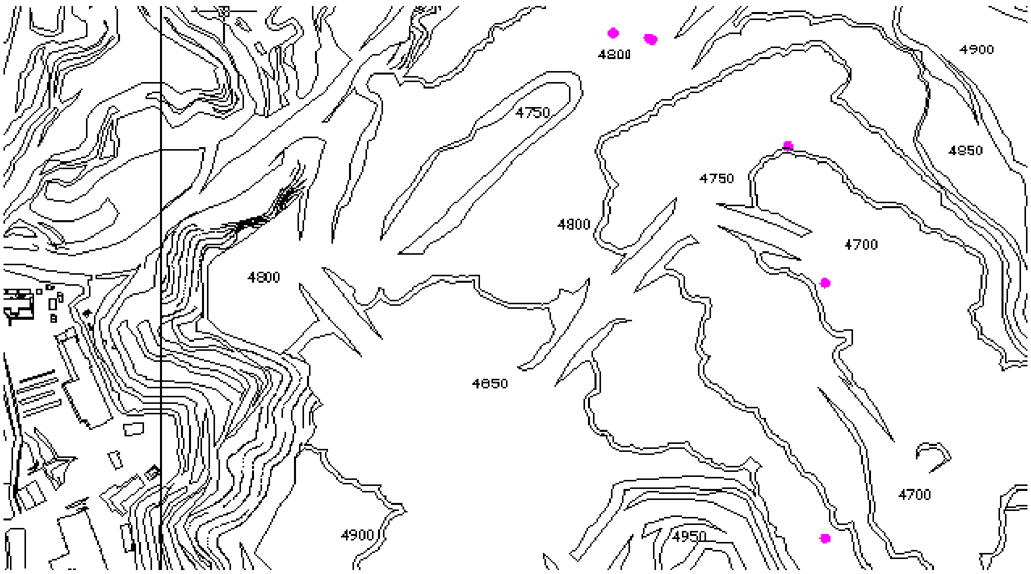

Figure 6.—Shock events A1-A6 plotted on mine map

FIELD TESTS AT CATERPILLAR PROVING GROUNDS

Three sets of experiments were set up at Caterpillar, Inc.'s, proving grounds in Green Valley, AZ. The instruments in the three tests were the same as those used to collect data at the mine. The set-up parameters were threshold level, 1 g; filter frequency, 100 Hz; range, ±20 g's; samples per second, 512; recording time, 4 sec; and samples per event, 2048.

In the first test, a large rock was dropped into the bed of a Caterpillar truck from over 10 ft above the bed surface. The drop produced a distinctive curve (figure 3) in which a significant jolt was registered in the z-direction when the rock struck the truck bed. In the second test, the truck was hit from the side by a loading shovel (figure 4). To measure the magnitude of individual jolts under controlled circumstances, a third experiment was designed that involved a course (dirt road) with a series of bumps positioned randomly along the course. A truck was driven along the course at 5 mph. Figure 7 shows an empty truck going over a bump, while figure 8 shows the same truck going over a bump loaded.

The curve shown in figure 3 was subsequently recognized in the event curves generated at the mine, but the signature of the side hit by the shovel (figure 4) was not. The authors suggest that when these side hits do occur, they put the spine in a vulnerable alignment for any following shock.

Dr. David Wilder,[2] director of the Vibration and Seating Laboratory, Lower Spine Research Center of the University of Iowa, has provided extensive data to this project on what combination of jolts is likely to harm a truck operator. His hypothesis, which he calls the "double-strike effect," suggests that the first jolt sets up the back for the second jolt, and it is that second jolt which could injure the back.

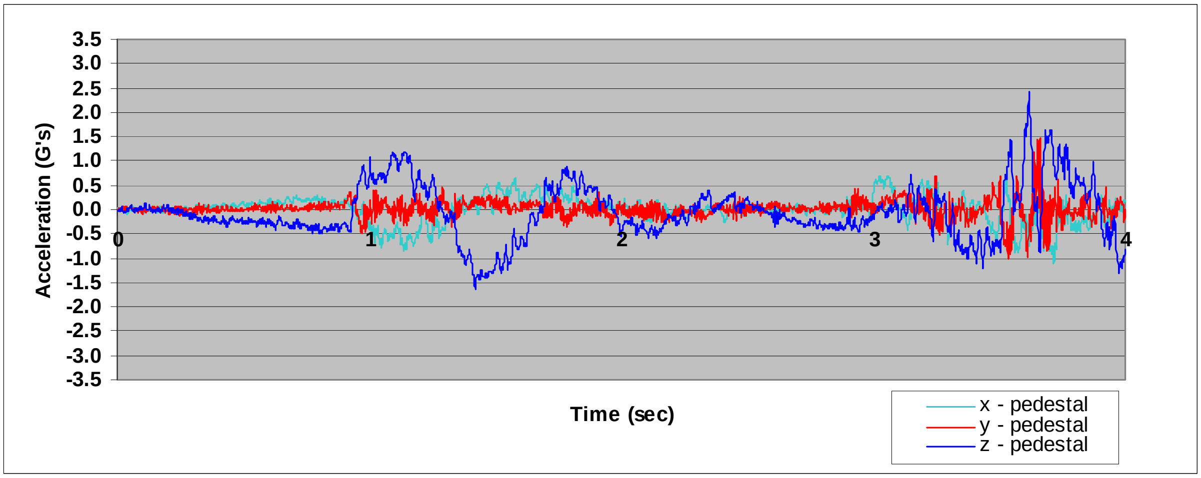

Figure 7—Accelerations on truck going over course empty.

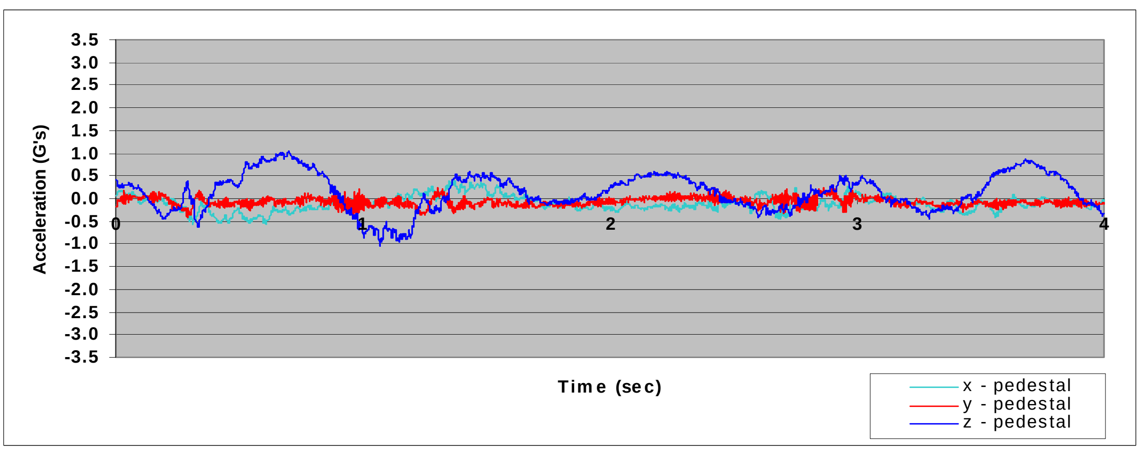

Figure 8—Accelerations on truck going over course loaded.

CONCLUSIONS

1. Rough ground and loading were the primary causes of the jolting and jarring events recorded

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[2]N.B. Fethke, D.G. Wilder, and K. Spratt. "Seated Trunk Muscle Response To Impact." Accepted for presentation at the International Society for the Study of the Lumbar Spine, April 9-13, 2000, Adelaide, Australia.

at the surface mine. Jolting and jarring caused by dumping did not appear in the events recorded.

2. Jolting and jarring from loading were more frequently recorded on truck A than on truck B, but there were no statistically significant differences in the trucks.

3. The double-strike effect, where the first jolt sets up the driver for injury by a second jolt, was not seen in the mine data. However, the possibility of its occurrence is evident in the rock drop experiment.

4. GPS can be used as an epidemiological tool for studying and characterizing jolting and jarring.

REFERENCES

[1] International Standards Organization. 1997. Mechanical Vibration and Shock. Evaluation of Human Exposure to Whole-Body Vibration, Part 1: General Requirements, ISO 2631-1:1997(E).

[2] Miller, R., and others. 1999. Tying Acceleration and GPS Location Data To Create a Mine Management Tool. Presentation SME ann. meeting, Denver, CO, Preprint 99-118.