

Field Data Collection Beyond Acceleration

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Field Data Workshop

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Taking on your toughest technical problems



an employee-owned company

Field Data for Transport Packaging

- Collection of acceleration data for characterizing transportation packaging environments is well known
 - Instrumenting vehicles (e.g. truck, rail, air)
 - Provides data on the mechanical environment (shock and vibration) during distribution
 - Can be used to support laboratory simulation (e.g. shake tables)
 - Instrumenting packages
 - Studies of package handling in the small parcel shipping environment
 - Number and severity of drops
 - Monitoring individual shipments of high value items during transport



Field Data for Transport Packaging

- Acceleration is a convenient parameter to measure
 - Sensors consume little power
 - Small physical size
 - Self contained data collection units are practical
 - Internal batteries
 - Internal sensors
 - Internal electronics
 - Generally easy to “package” for a variety of measurements
- But acceleration is not always enough
 - Other physical measurements may be of interest
 - In packaging, it is often **forces** that are needed
 - A wide range of measurements are possible
 - Usually want these other measurements in addition to acceleration

Hardware for Collecting Other Measurements

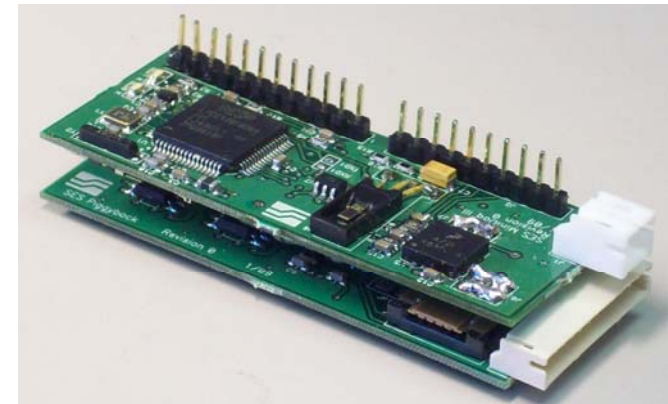
- Sensors

- Mechanical requirements
 - Size
 - Mounting or attachment
- Electrical requirements
 - Power - what kind and how much of it
 - Cabling



- Data acquisition

- Number of channels
- Signal conditioning
 - Ability to mix sensor types
- Physical size and robustness
- Speed, resolution and capacity
- Triggering modes; time based, event based



Unit Load Transportation Case Study

- The Request

- Packaging changes were proposed for a beverage in 32-oz PET bottles
- Top load force experienced by the bottles during transportation and warehousing was an important design input to the overall packaging system, but was not well understood
- Could bottle top load **forces** during transportation be measured?

- Project Scope

- Collect data on bottle forces in a unit load during a truck trip from a manufacturing facility to a regional warehouse
- Continue to collect data during storage at the warehouse
- Try to minimize changes to the unit load to accommodate the instrumentation

Unit Load Transportation Case Study

- Test Design

- Custom pallet constructed to hold instrumentation
- Footprint and deck board pattern of a standard 40 x 48 block pallet
- Data acquisition system, 3-axis accelerometer and batteries contained in boxes replacing wood support blocks
- Cable running to upper deck for connecting extra sensors
- 8 data acquisition channels – 5 load, 3 acceleration



Unit Load Transportation Case Study

- Test Design

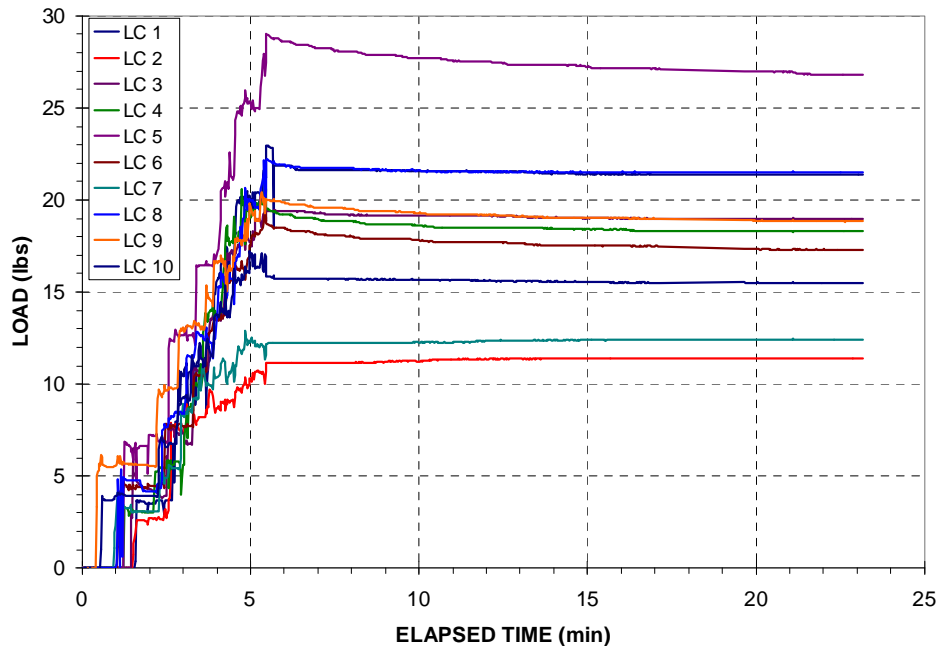
- Small commercial load cells were packaged for placement on top of lower layer of the unit load - five were monitored during trip
- Spacers were placed on all bottles not having load cells to raise them up evenly



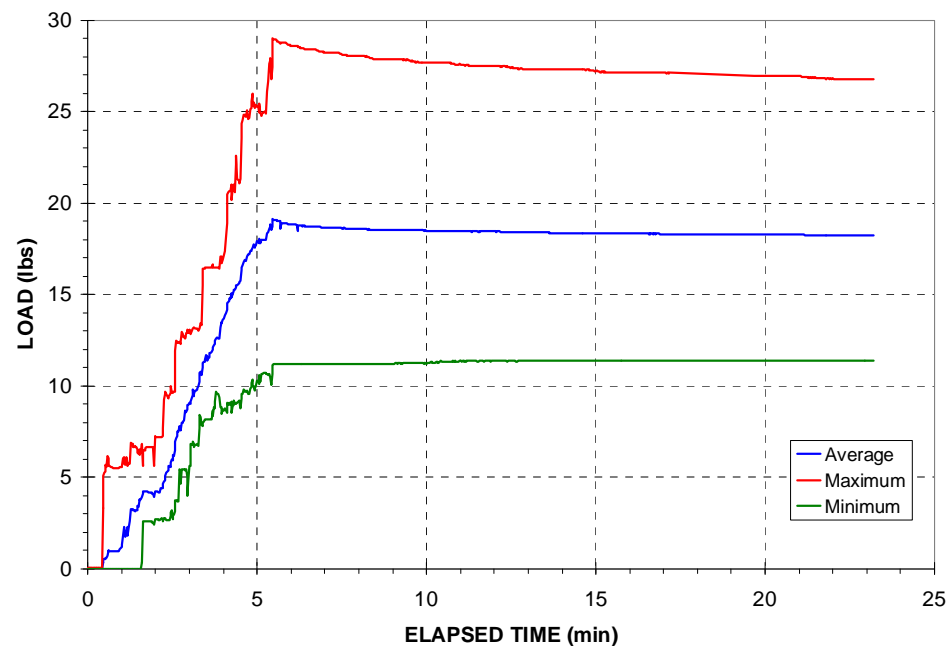
Unit Load Transportation Case Study

- Data Acquisition – Unit Load Assembly

INITIAL PALLET STACKING - All Load Cells



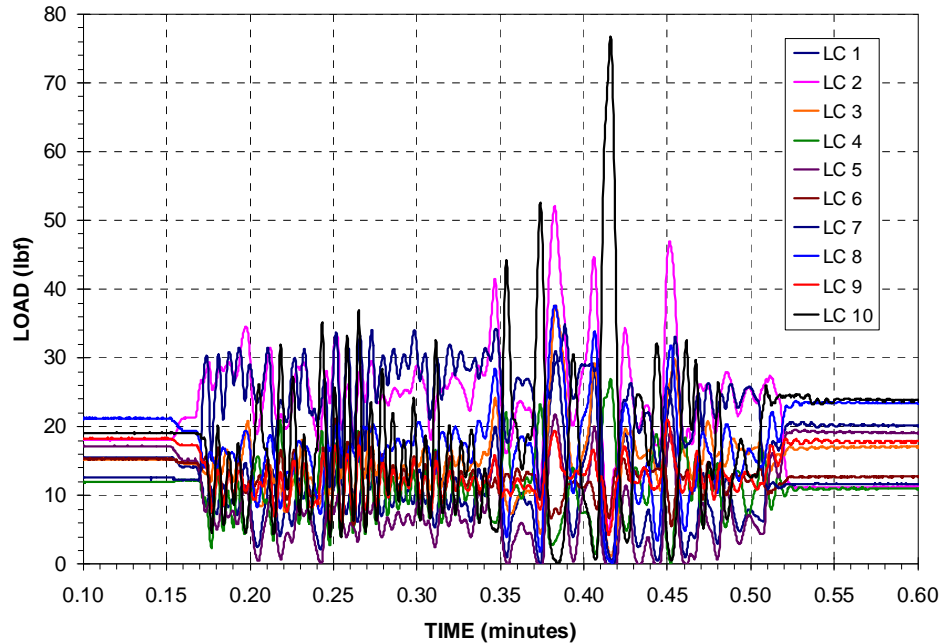
INITIAL PALLET STACKING - Average, Minimum and Maximum Loads



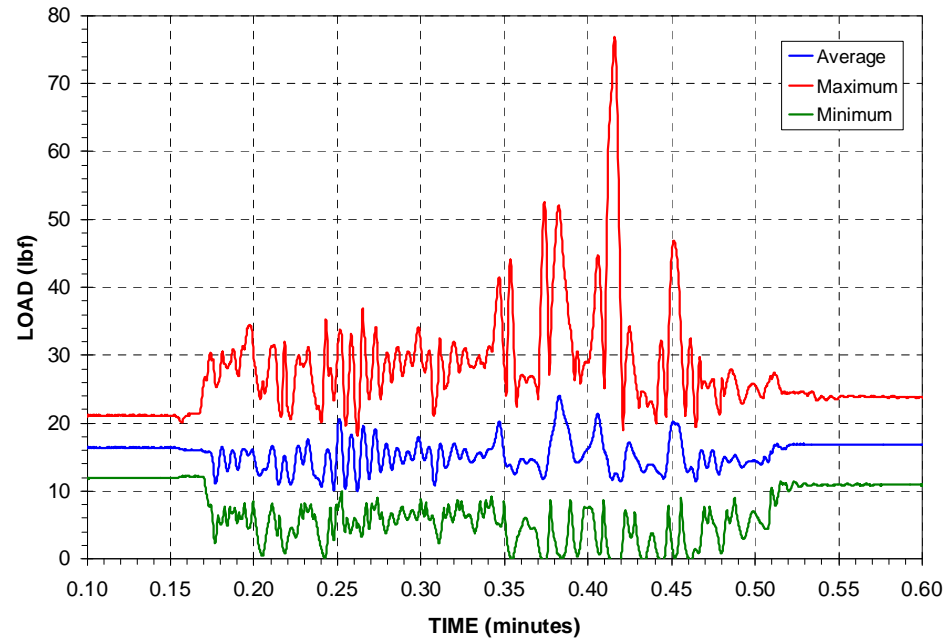
Unit Load Transportation Case Study

- Data Acquisition – Rough Handling Test

Unit Load Rough Handling Test - All Load Cells



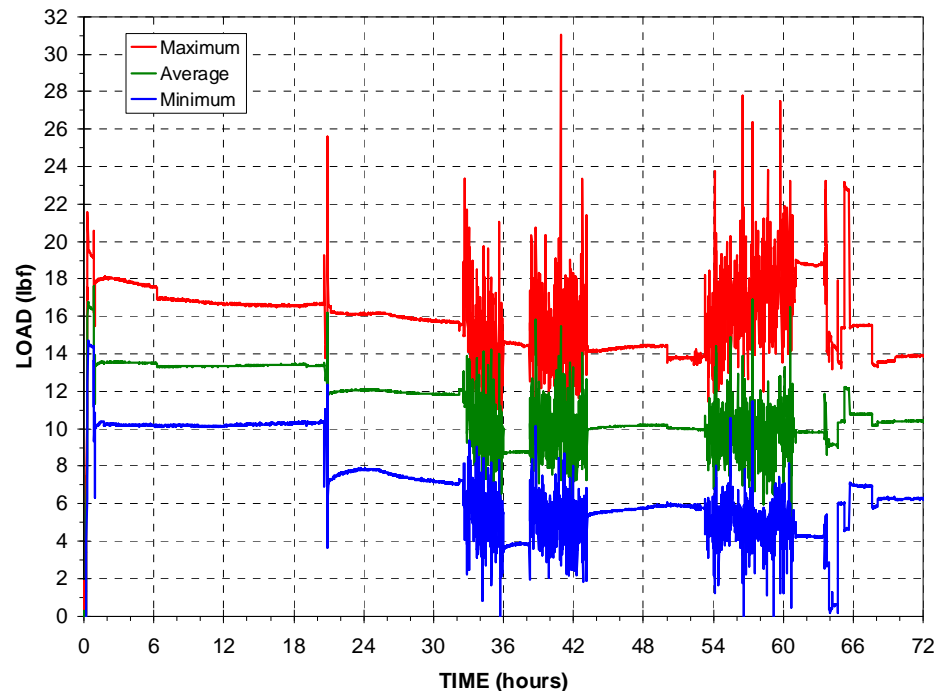
Unit Load Rough Handling Test - Average, Minimum and Maximum Loads



Unit Load Transportation Case Study

- Data Acquisition – Transportation

- Collected bursts of data at fixed time intervals
- Collected bursts of data when triggered by vertical axis accelerometer events
- Collected data for 7 days
- Over-the road travel occurred on days 2 and 3

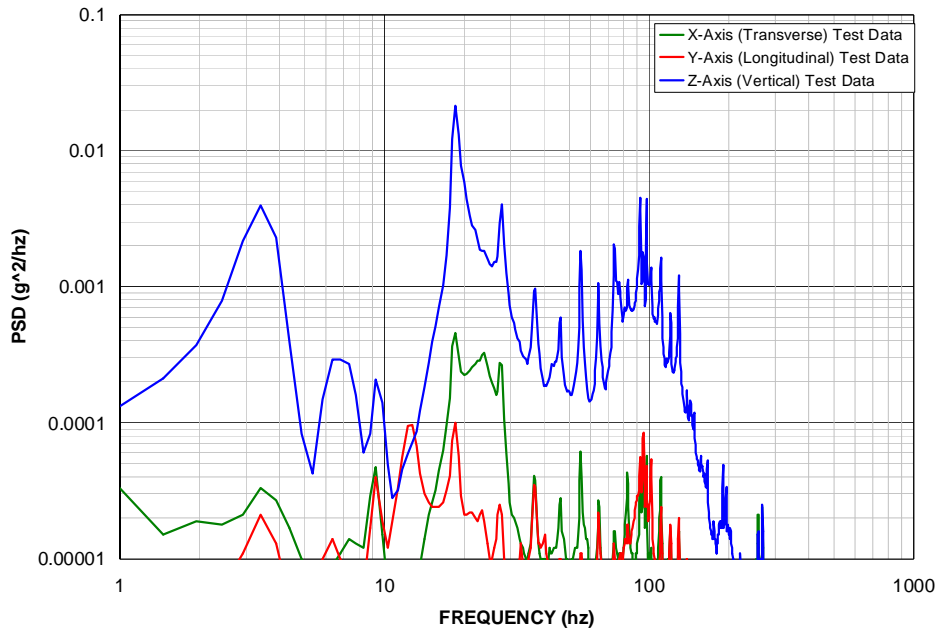


Unit Load Transportation Case Study

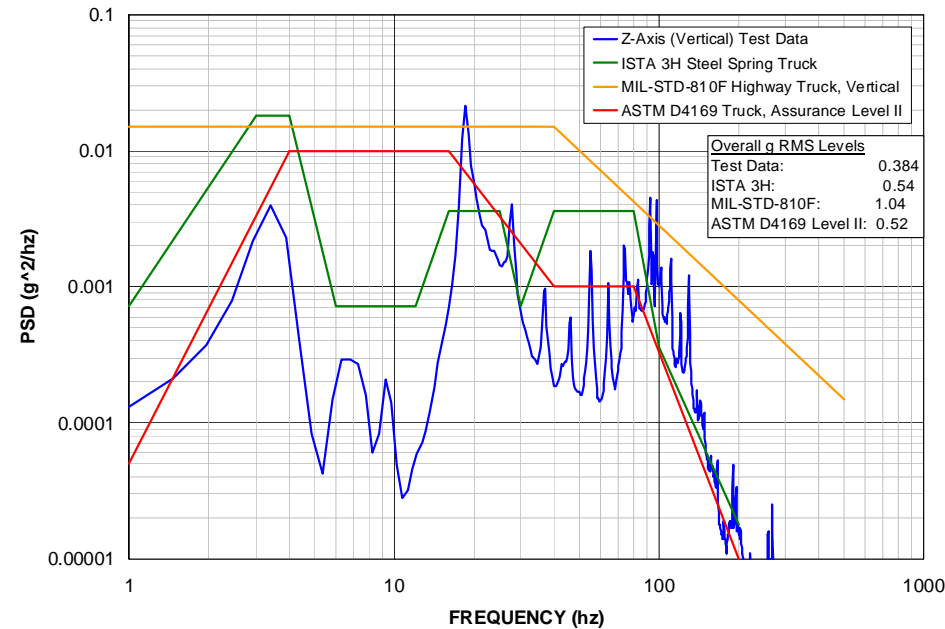
- Data Analysis

- Acceleration PSDs calculated to examine trip severity
- Compared PSD with published standards

ACCELEROMETER POWER SPECTRAL DENSITY
Transit Test X-, Y- and Z-Axis Data



VIBRATION POWER SPECTRAL DENSITY
Vertical Axis Test Data Compared with Published Standards

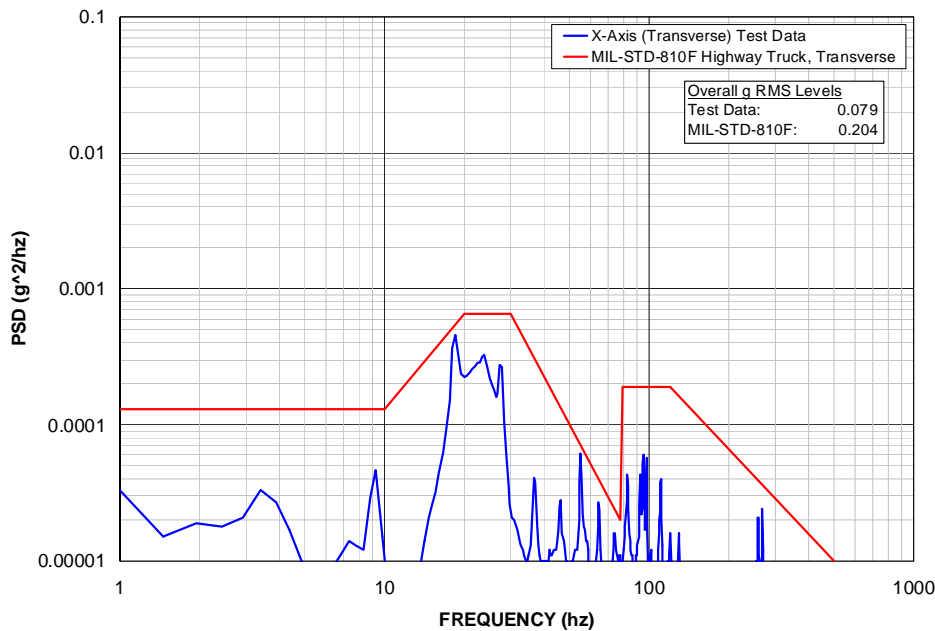


Unit Load Transportation Case Study

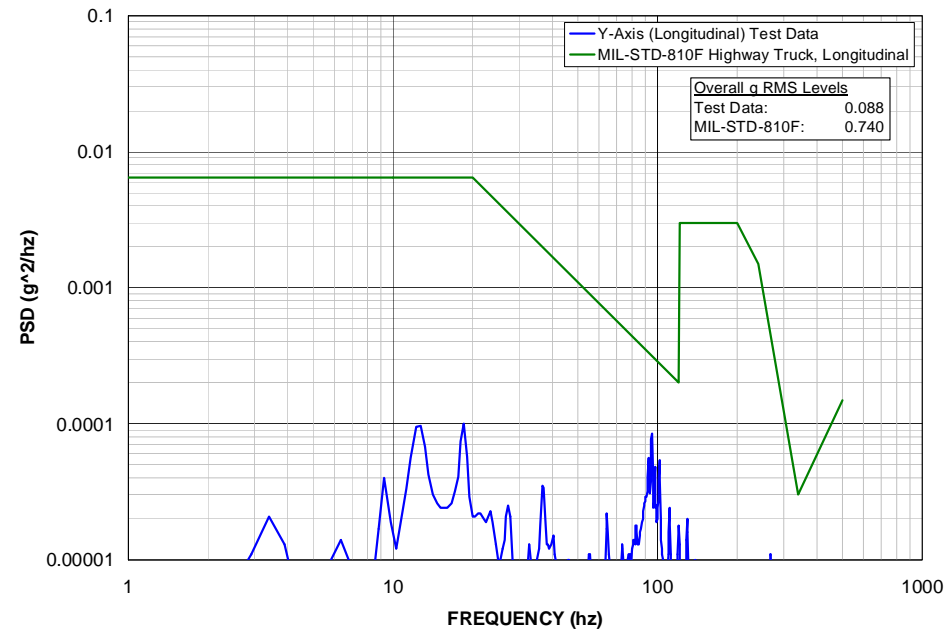
- Data Analysis

- Also interested in horizontal acceleration PSDs

ACCELEROMETER POWER SPECTRAL DENSITY
X-Axis Test Data Compared with MIL-STD-810F Transverse



ACCELEROMETER POWER SPECTRAL DENSITY
Y-Axis Test Data Compared with MIL-STD-810F Longitudinal

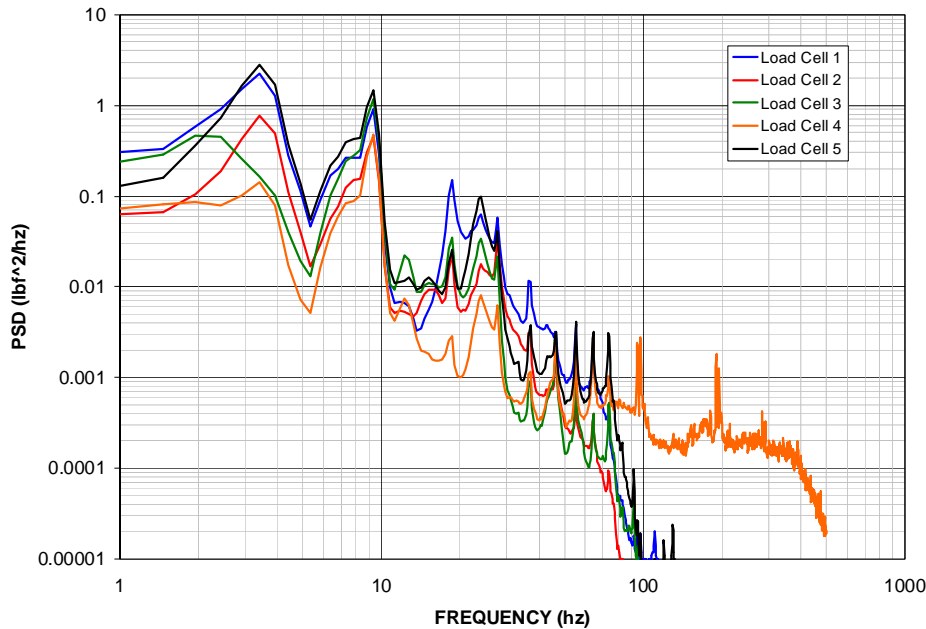


Unit Load Transportation Case Study

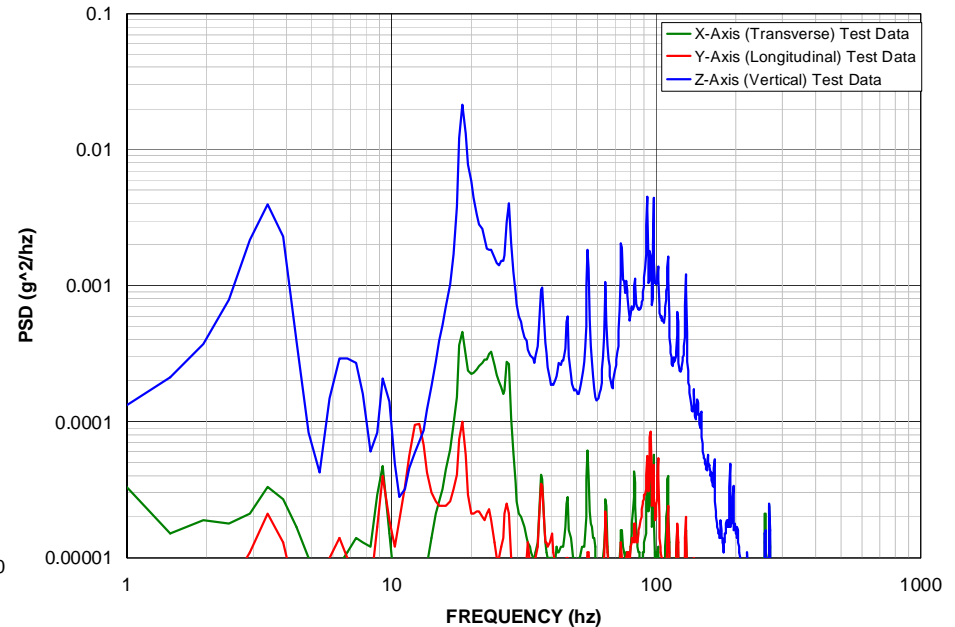
- Data Analysis

- Comparison of force PSD with acceleration PSD
- Compare force and acceleration time histories and frequency spectra

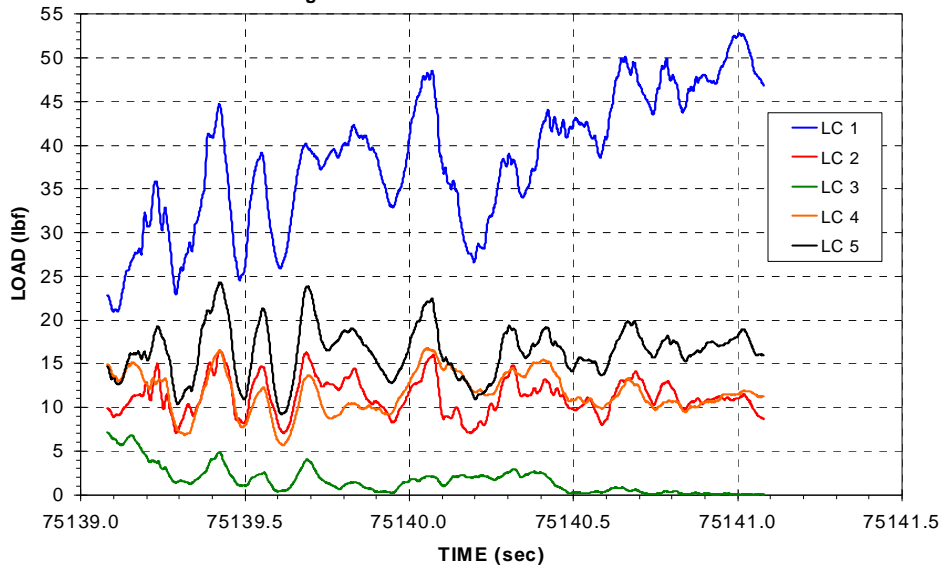
LOAD POWER SPECTRAL DENSITY



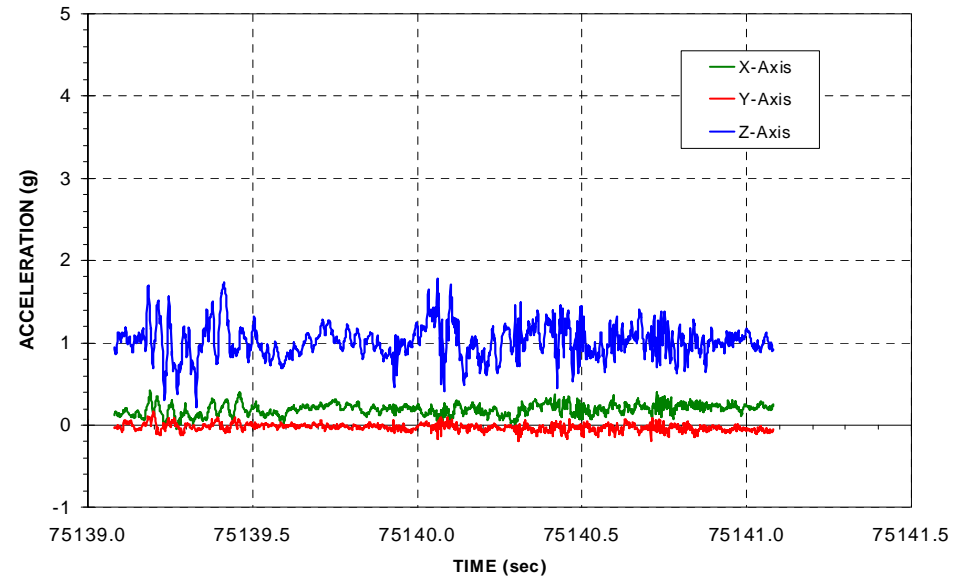
ACCELEROMETER POWER SPECTRAL DENSITY
Transit Test X-, Y- and Z-Axis Data



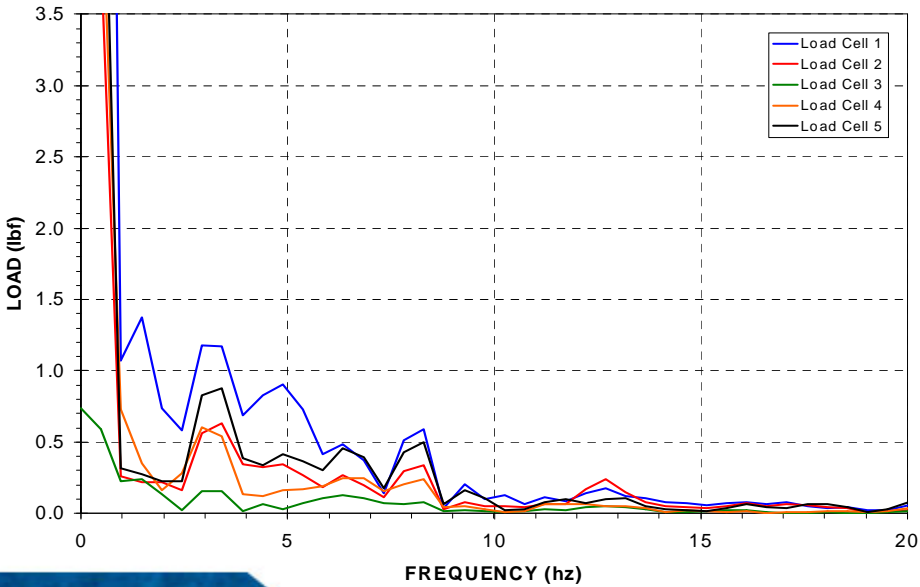
TRIGGERED DATA BURST #19 - LOADS
 Highest Peak for Load Cell 1: 52.8 lbf



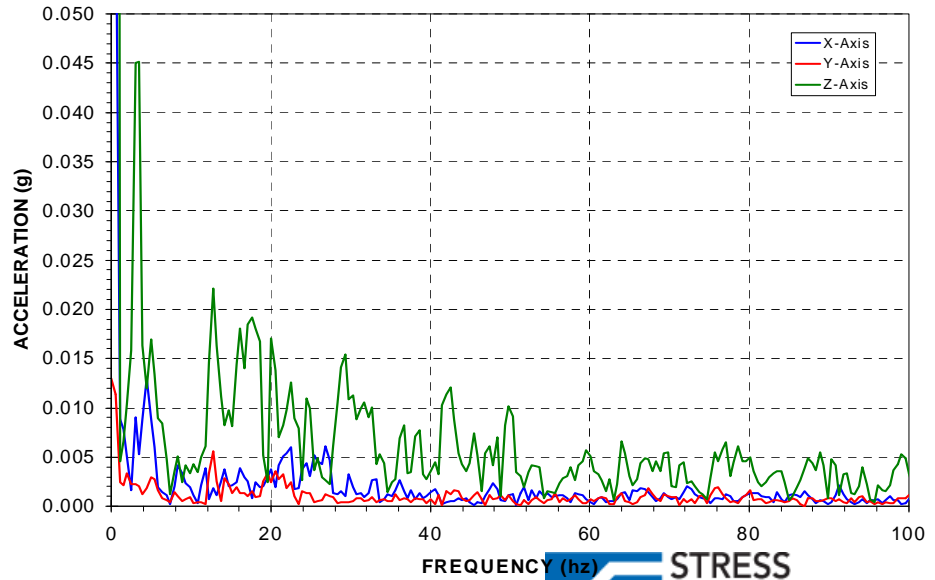
TRIGGERED DATA BURST #19 - ACCELERATIONS



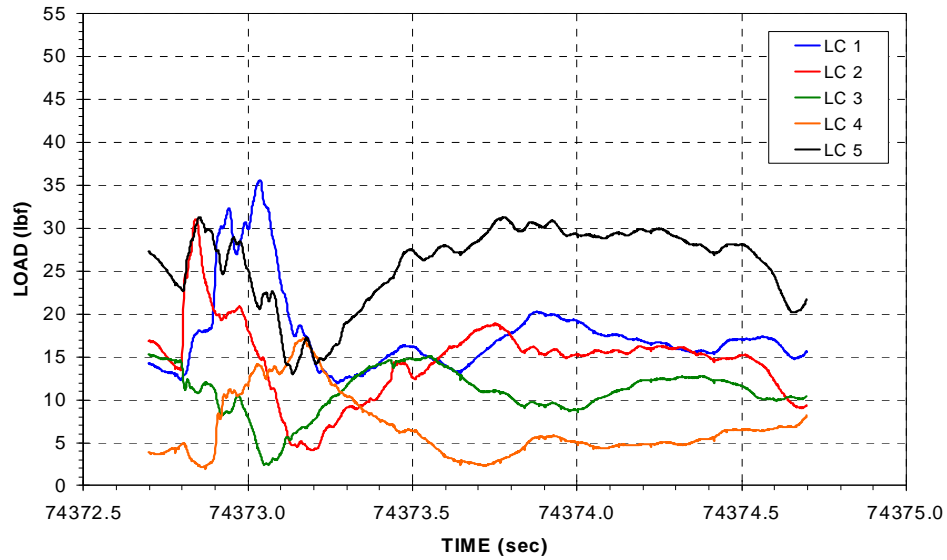
TRIGGERED DATA BURST #19 - LOAD FREQUENCY SPECTRUM



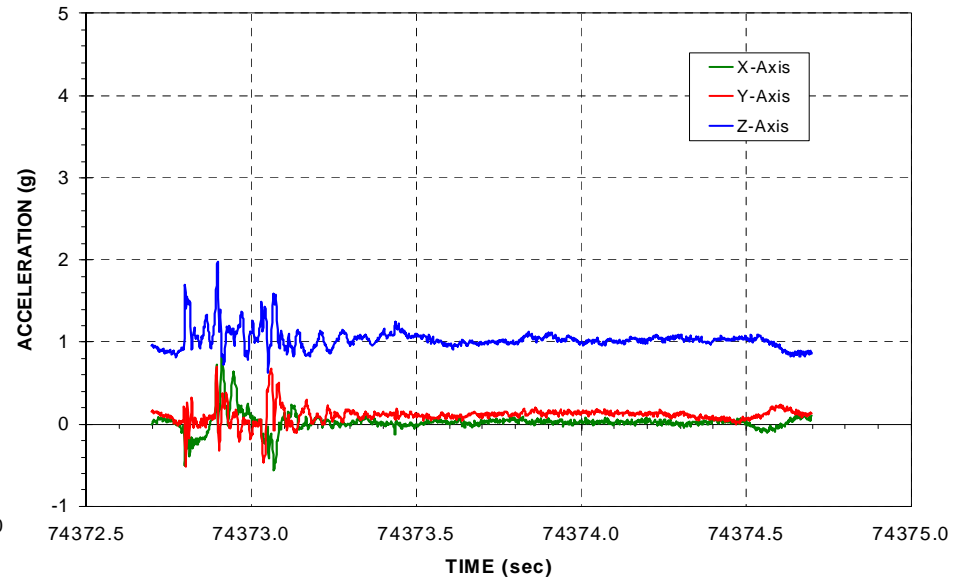
TRIGGERED DATA BURST #19 - ACCELERATION FREQUENCY SPECTRUM



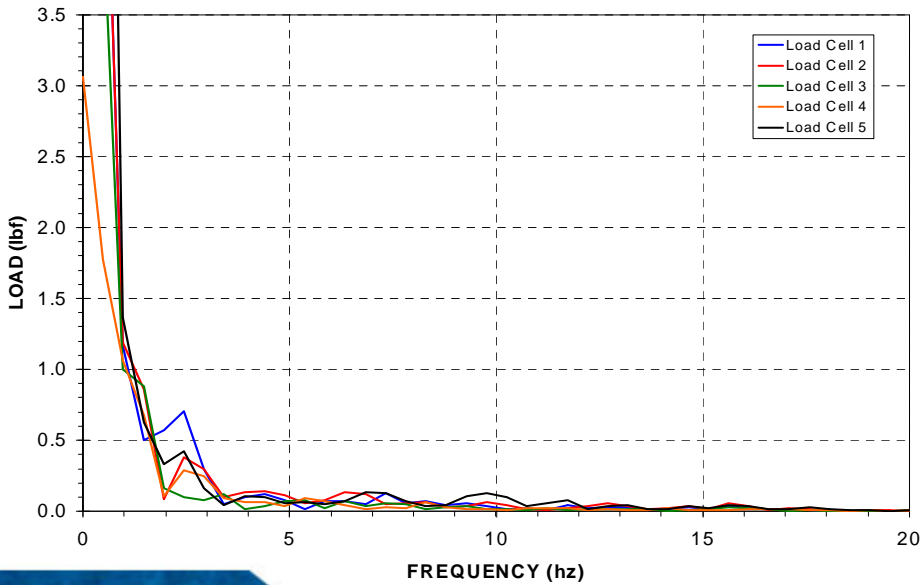
TRIGGERED DATA BURST #10 - LOADS
 Highest Peak for Load Cell 2: 31.1 lbf



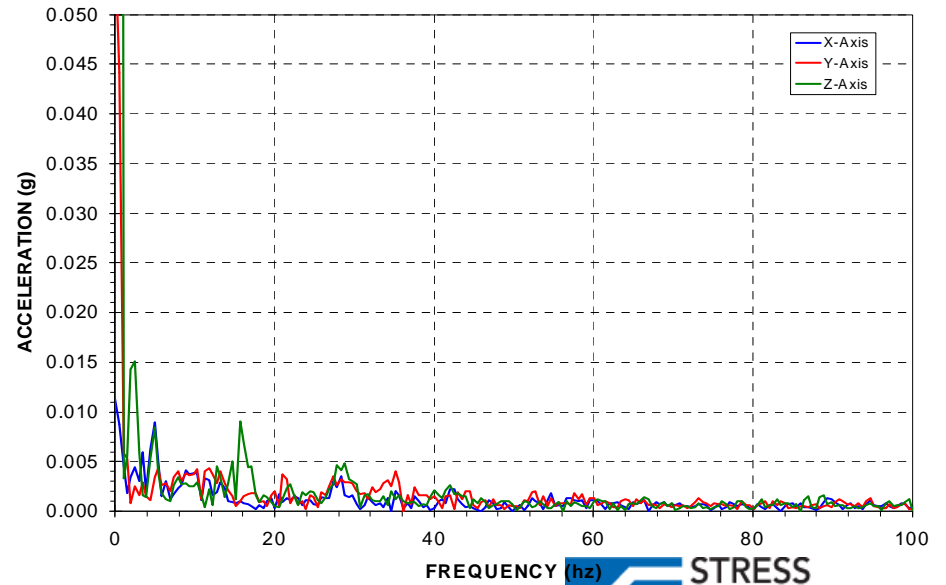
TRIGGERED DATA BURST #10 - ACCELERATIONS



TRIGGERED DATA BURST #10 - LOAD FREQUENCY SPECTRUM



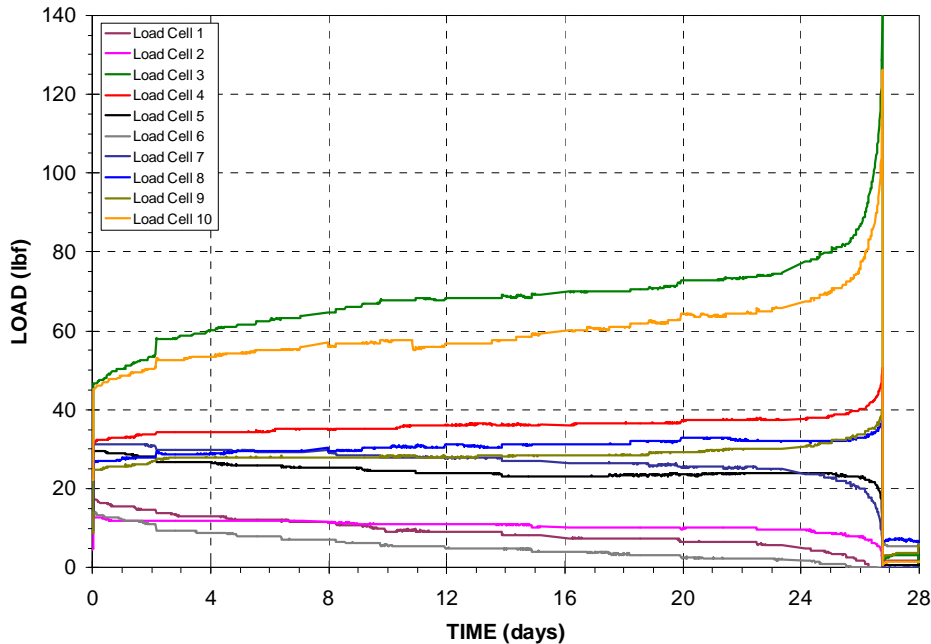
TRIGGERED DATA BURST #10 - ACCELERATION FREQUENCY SPECTRUM



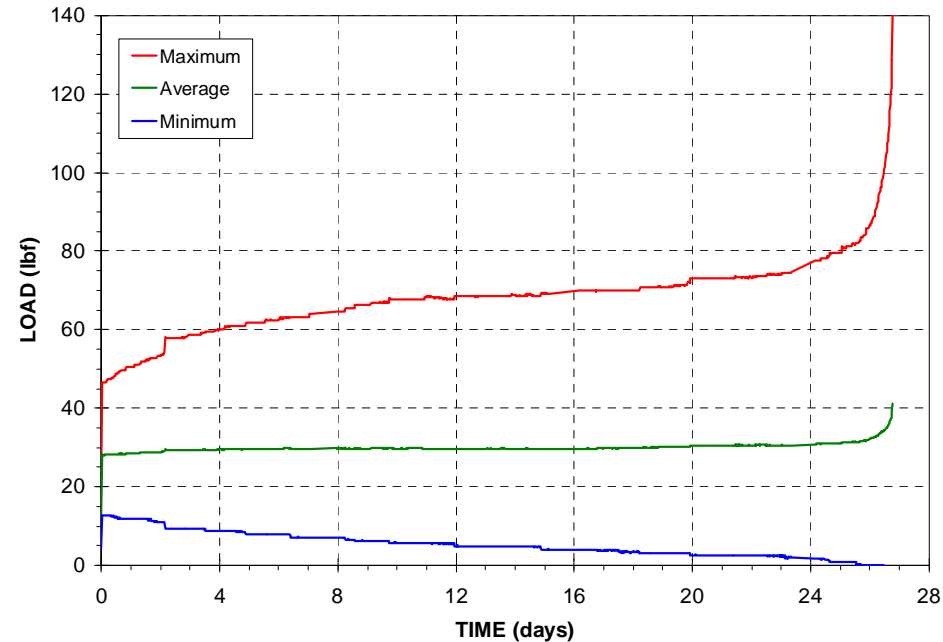
Unit Load Transportation Case Study

- Data Acquisition – Warehouse Stack Test

WAREHOUSE STACK TEST - All Load Cells

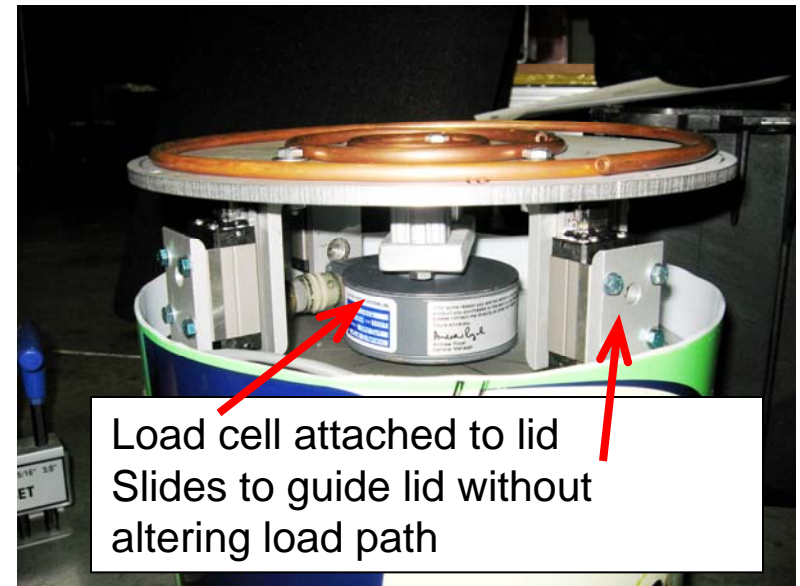
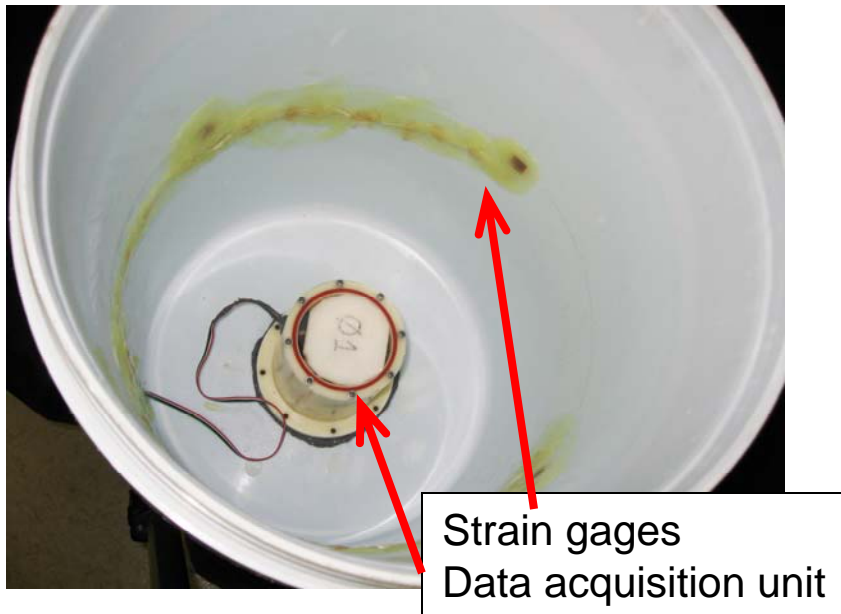


WAREHOUSE STACK TEST - Maximum, Average and Minimum



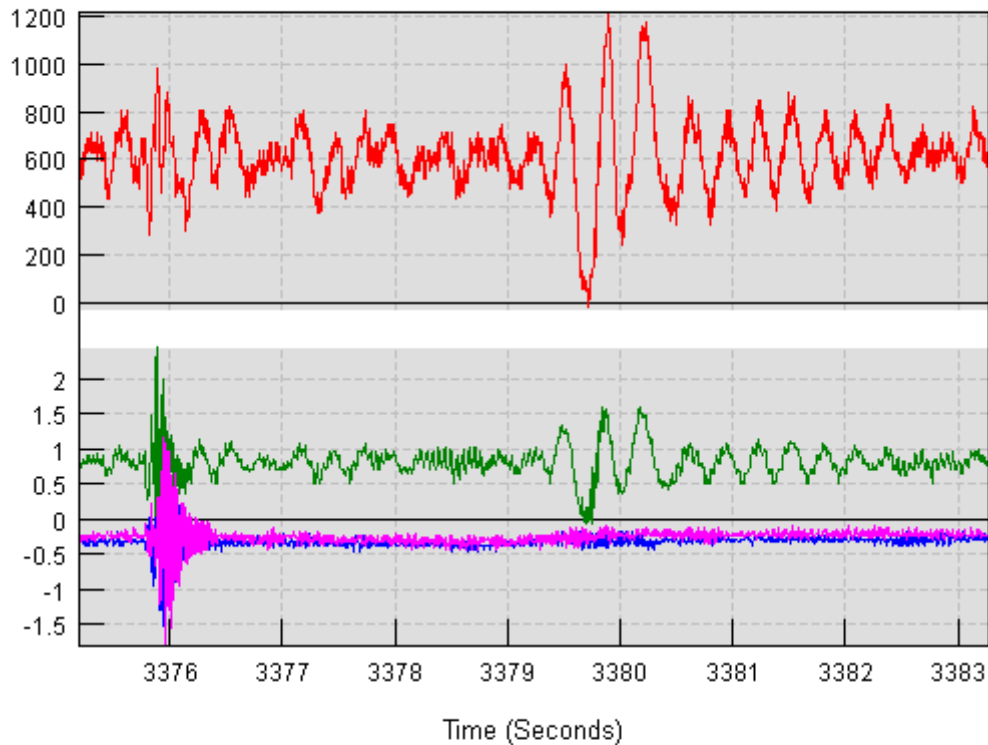
Another Example – Instrumented Pail

- Two approaches
 - Strain gages directly on pail (left photo)
 - Load cell inside pail (right)



Instrumented Pail – Shock vs. Bump

MP Warehouse to Tan Binh Depot; "Mechanical" 18L Bucket; 5 May 2009

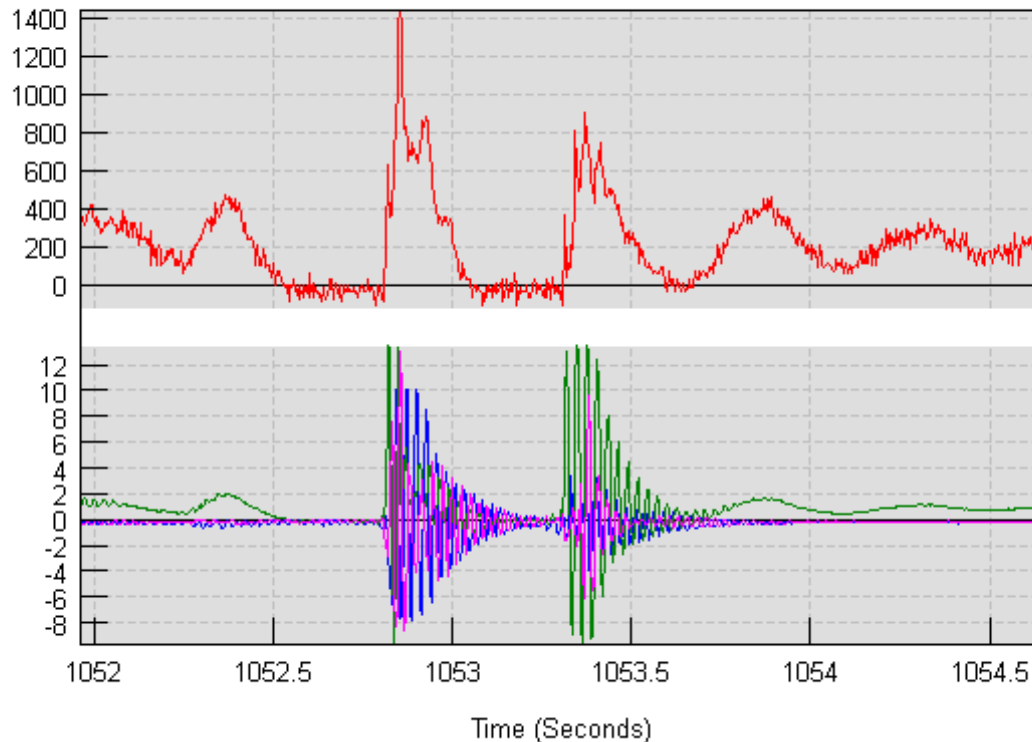


Legend

Marker	Axis	Title	Y Max	Y Min	Y Mean	Y Units
—	A	Ch 1 : LOG4.TXT-Ch1 : Top Load	2414	-402.3	586	N
—	B	Ch 3 : LOG4.TXT-Z-Axis	10.05	-7.942	-0.2977	g
—	B	Ch 4 : LOG4.TXT-Y-Axis	13.41	-10.68	0.8175	g
—	B	Ch 5 : LOG4.TXT-X-Axis	13.41	-9.435	-0.213	g

Instrumented Pail – Road Hazard Impact

MP Warehouse to Mekong Delta Customer; "Mechanical" 18L Bucket; 6 May 2009

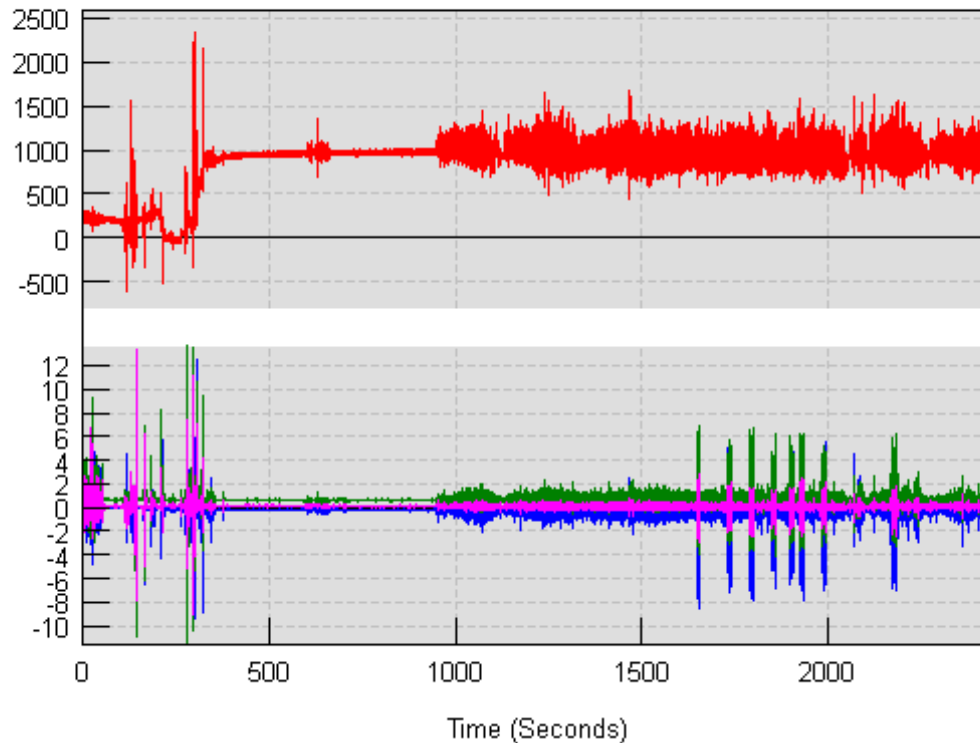


Legend

Marker	Axis	Title	Y Max	Y Min	Y Mean	Y Units
—	A	Ch 1 : LOG4.TXT-Ch1 : Top Load	2638	-223.5	133.6	N
—	B	Ch 3 : LOG4.TXT-Z-Axis	10.14	-7.766	-0.1709	g
—	B	Ch 4 : LOG4.TXT-Y-Axis	13.46	-9.699	0.8259	g
—	B	Ch 5 : LOG4.TXT-X-Axis	13.11	-9.282	-0.1521	g

Instrumented Pail – Handling vs. Transport

MP Warehouse to Tan Binh Depot; "Gaged" 18L Bucket; 5 May 2009



Legend

Marker	Axis	Title	Y Max	Y Min	Y Mean	Y Units
—	A	Ch 1 : LOG4.TXT-Ch1 : Top Load	2349	-611.5	870.3	N
—	B	Ch 3 : LOG4.TXT-Z-Axis	13.14	-10.37	-0.1827	g
—	B	Ch 4 : LOG4.TXT-Y-Axis	13.65	-11.58	0.603	g
—	B	Ch 5 : LOG4.TXT-X-Axis	13.31	-9.1	0.1066	g

Conclusions

- Measuring acceleration provides vital data in dynamic environments
- Other parameters can be important too
 - Some are related to acceleration, some are not
 - Some are dynamic and some are static (or nearly so)
- Tools exist to expand data collection to other physical values of interest
 - Data acquisition units and signal conditioning
 - Sensors
- Additional data can be important to understand complex motions and interactions between system components

Thank You

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