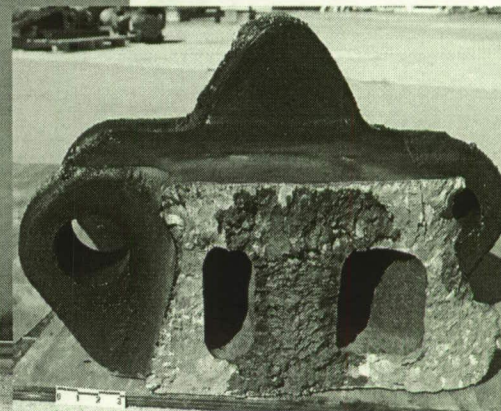


Crawler Shoe Health Monitoring System

Presented by
Michael Schutze

November, 2009



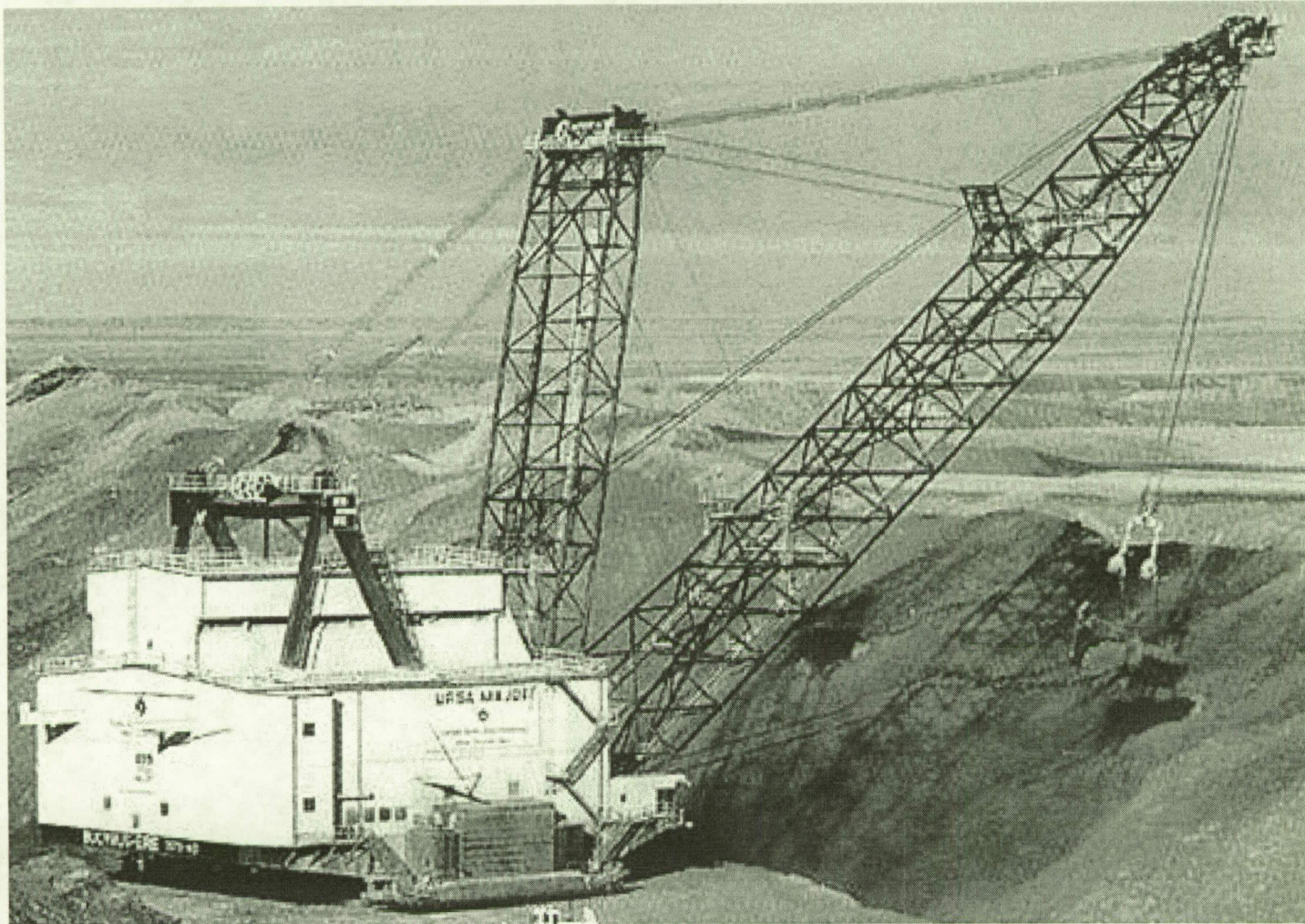
Crawler Shoe Health Monitoring System

- **Crawler Background**
- **Proof of Concept Testing**
- **CTSHM program suite**
- **Conclusions**
- **Questions/Answers**

Crawler History

- **President Kennedy May 25, 1961**
- **1962, VAB to Pad transportation options:**
 - Rail.
 - Barge.
- **February of 1962, a team visited Paradise, Kentucky, to watch a Bucyrus-Erie 2,700-metric-ton (six-million pound) crawler-shovel in action.**

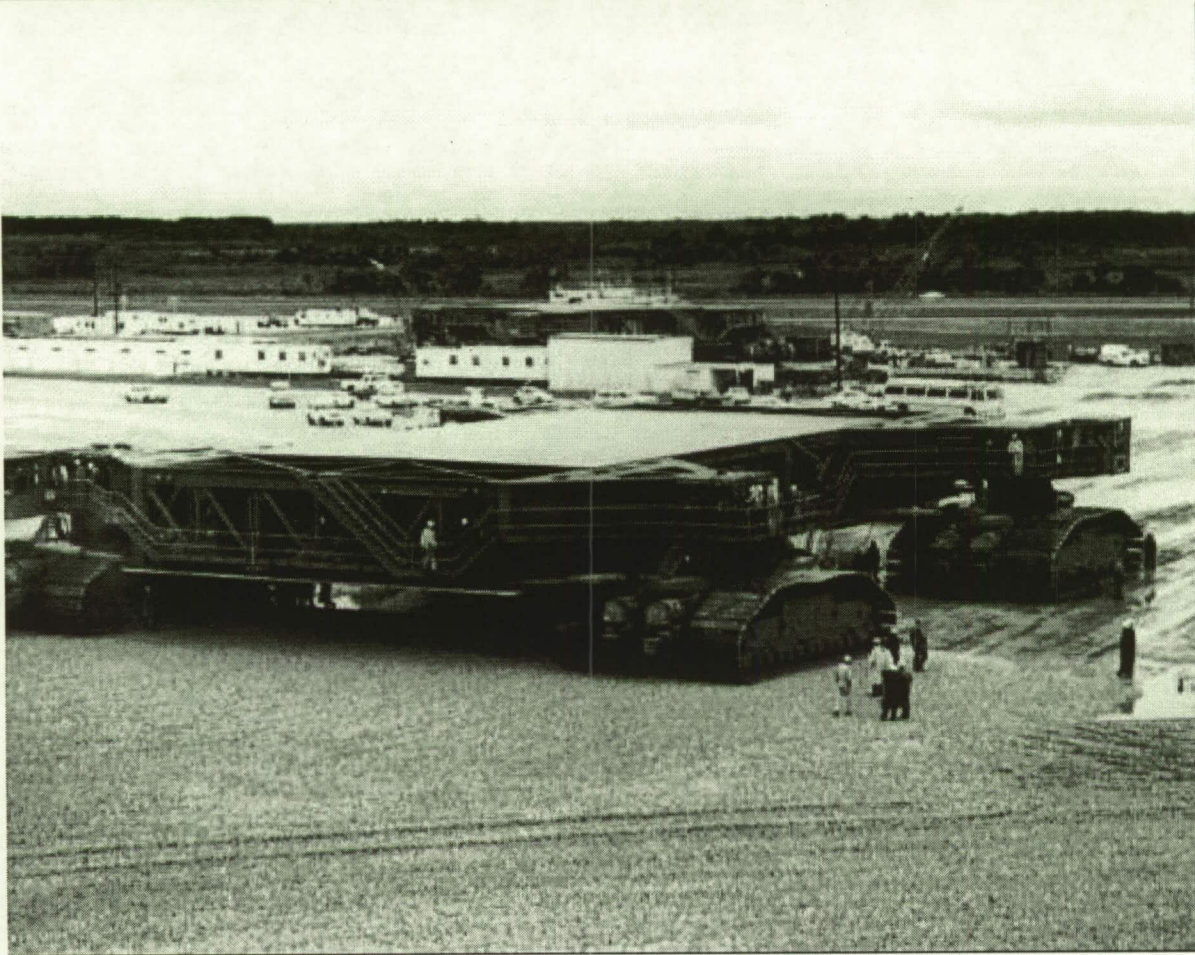
Bucyrus-Erie six-million pound crawler-shovel (1962)



Crawler History

- **July 24, 1965 the crawler moved a launch umbilical tower about 1.6 kilometers.**
- **Test Alabama river rock and crushed granite**

The first crawler-transporter ready for service, January 1966



Recent Crawler History

- **4/25/2006 Shoe Failure**
- **Crawler Transporter Shoe Failure Team Formed**
 - **Recommendations**
 - **Phased Array Ultrasonic Testing**
 - **Modal Analysis Testing – Resonance Shift Analysis Testing**
- **12/2006 Phased Array Ultrasonic's and Resonance Shift Analysis Testing**

Resonance Testing

$$F = [k/m]^{0.5}$$

Where: k= stiffness

m = mass

What is Resonance Shift Analysis?

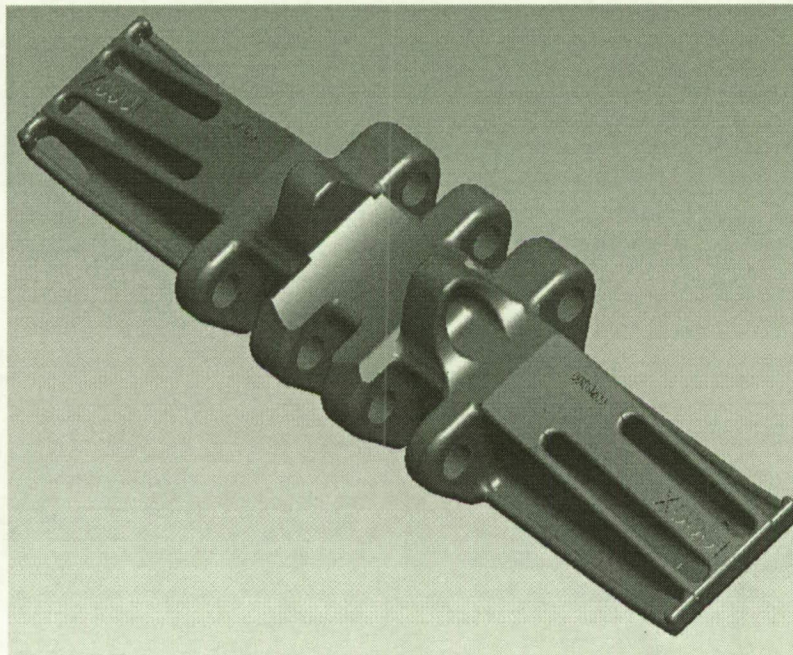
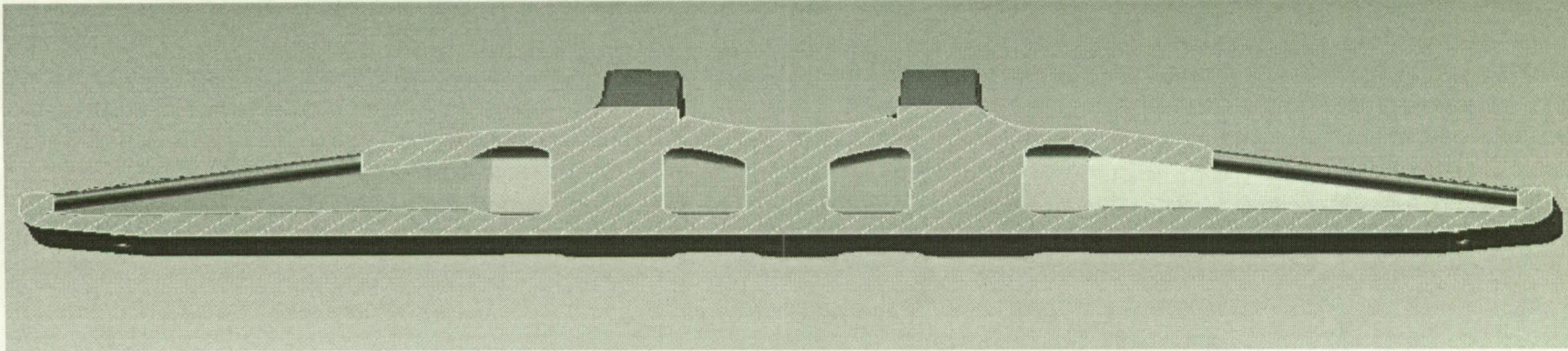
Determination of an acceptable component or area by comparison of known structural resonant frequencies to current/present structural resonant frequencies.

➤ **Known Sources:**

- **Baseline**
- **FEA**
- **Modal Tests**
- **ODP**

❖ **NOT A STAND ALONE TEST.**

Crawler Shoes



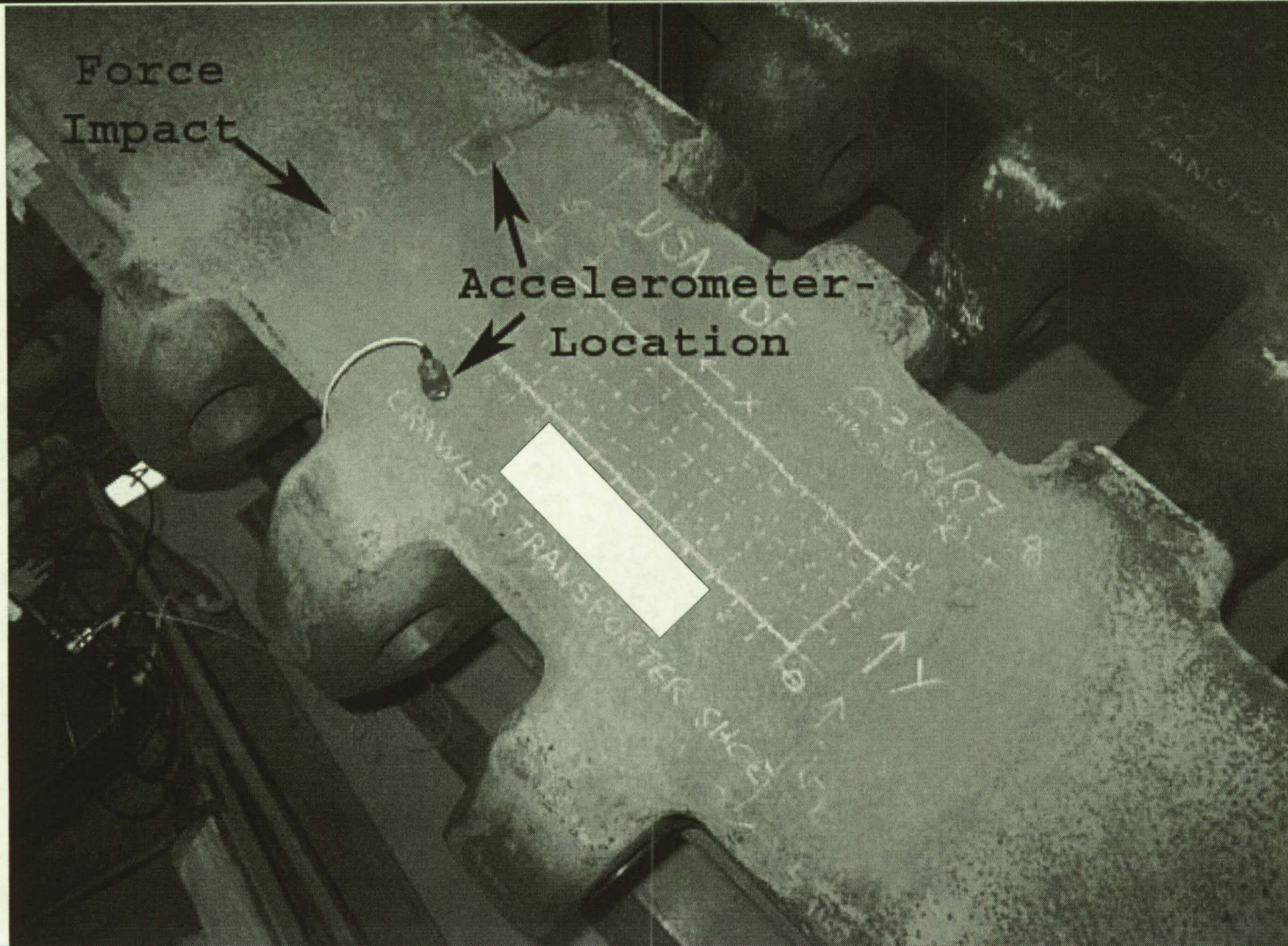
Resonance Testing



Resonance Shift Setup



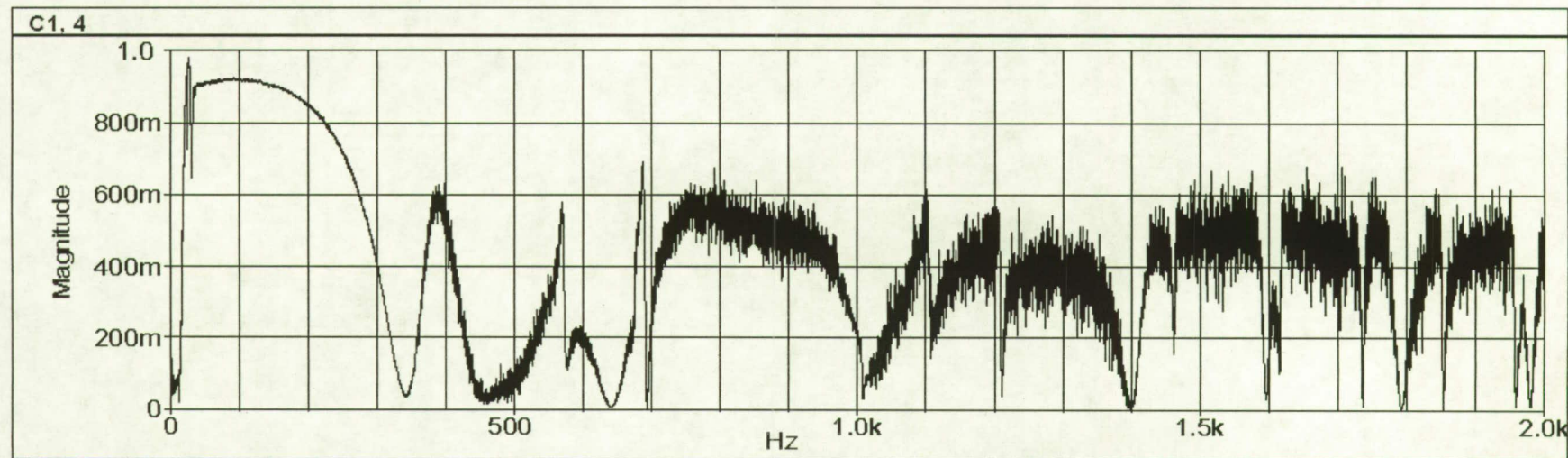
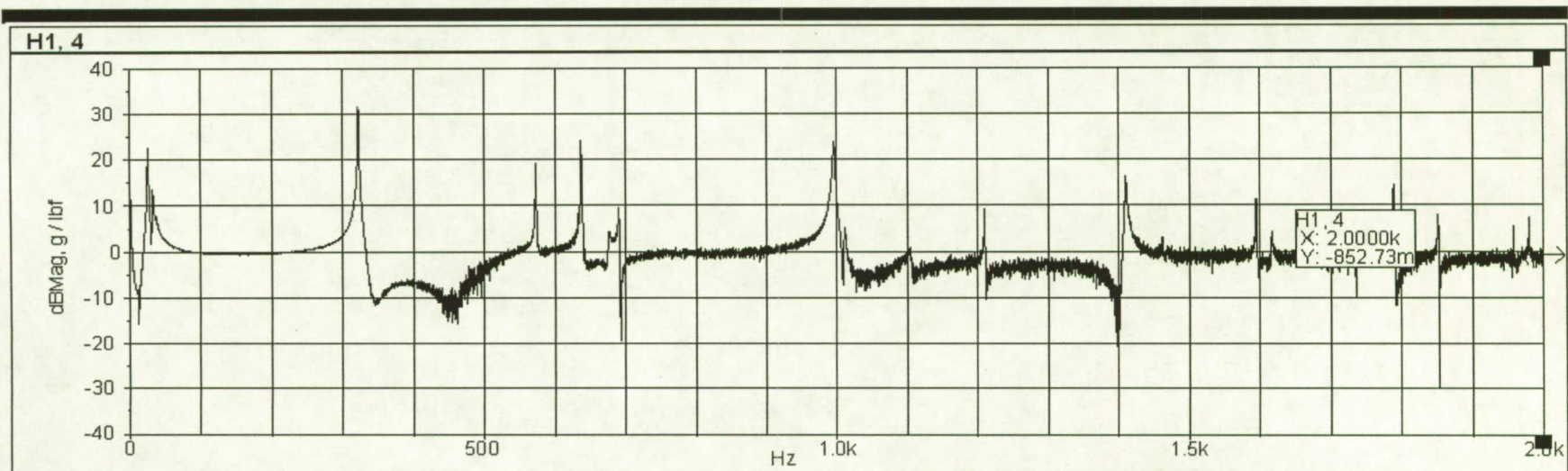
Resonance Shift Setup



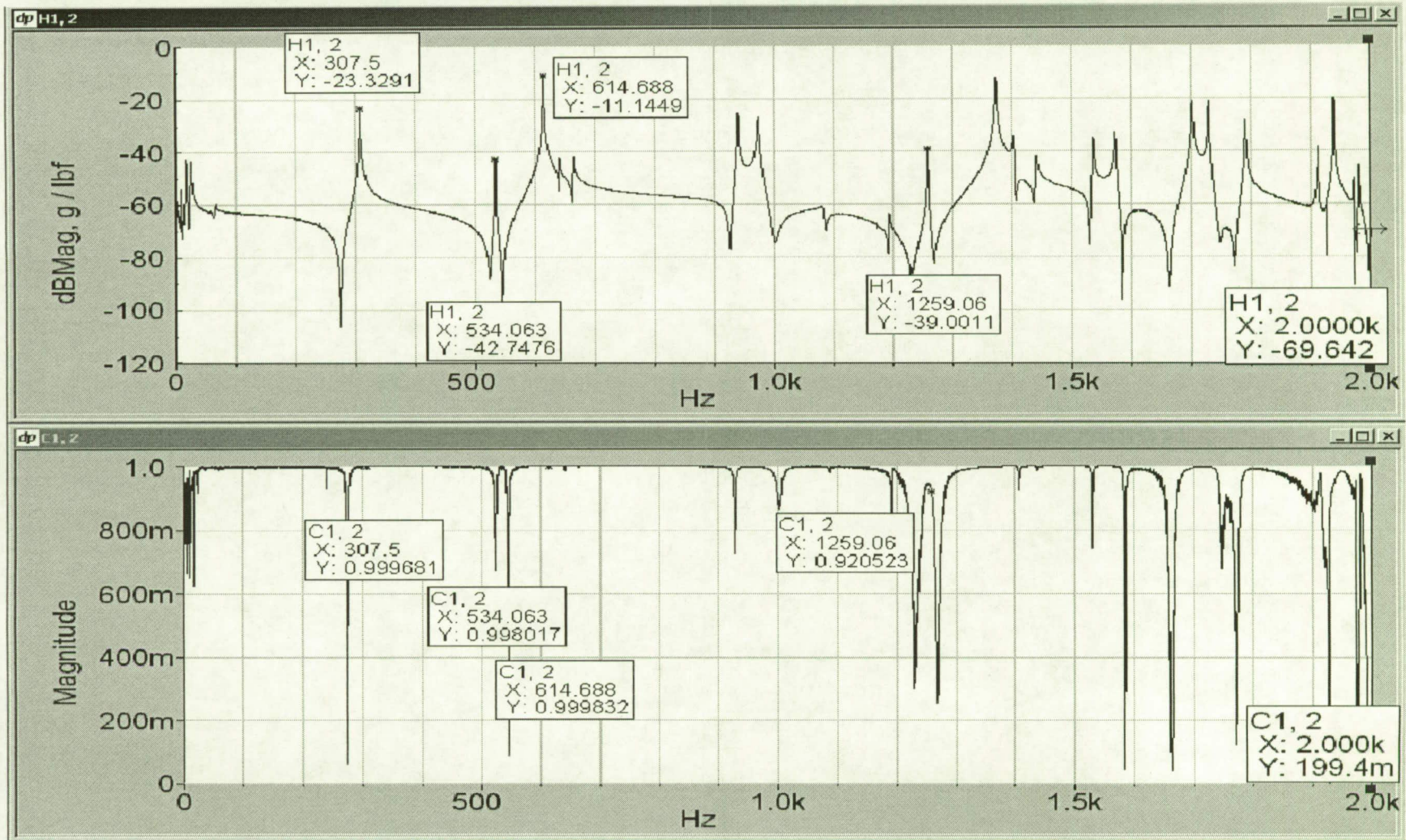
Normal Resonance Shift Testing Problems

- Wires
- Transducers
- Power
- LEAKAGE
 - All the above
 - Resolution
 - Digital Window
 - Frequency range
 - # line of resolution

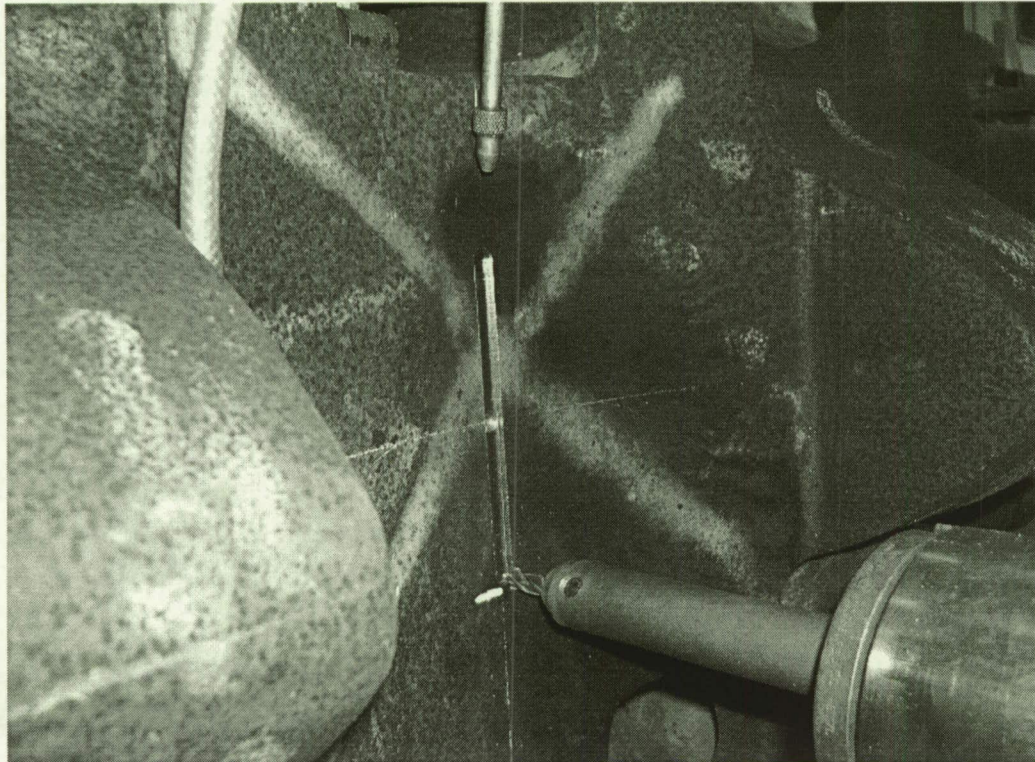
Example of bad Data



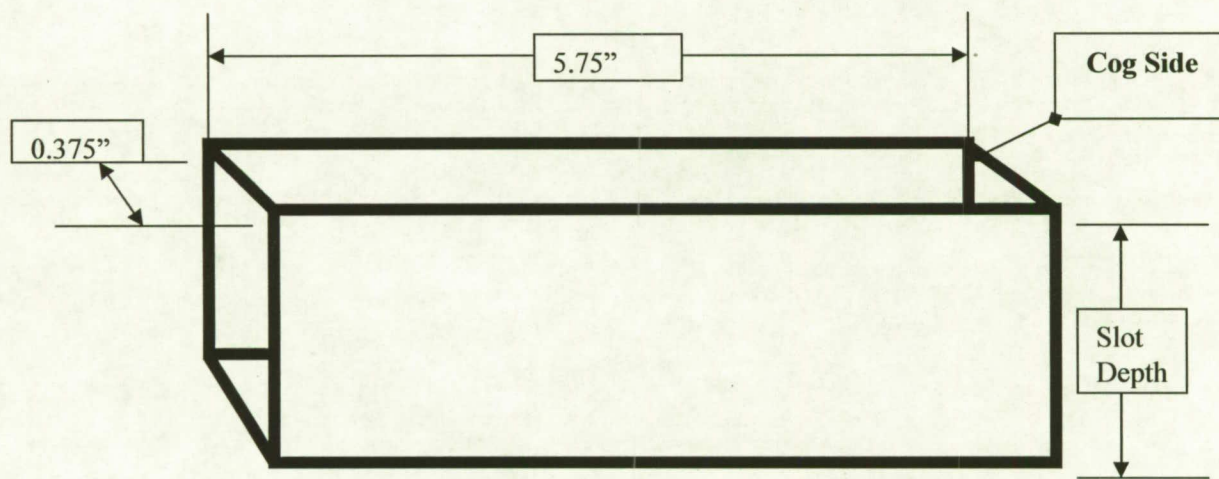
Typical Resonance Shift FRF and COH



Slot in CT Shoe



Slot in CT Shoe



FEA Modes

- **1st bending 307.9 Hz**
- **2nd bending 606.6 HZ**
- **Twisting 524.4 Hz**
- **Twisting 624.7 Hz**
- **3rd bending 963.6 Hz**
- **Axial 1246.4 HZ**

Frequency Difference (Baseline – Current Data)

Frequency Difference							
Slot Depth	0.175"	0.35"	0.52"	0.69"	0.87"	1.045"	1.75"
Baseline Hz	Hz	Hz	Hz	Hz	Hz	Hz	Hz
312.19	0.31	0.69	0.75	0.06	1.88	2.19	4.69
534.06	0	0	0.32	0.32	0.32	0	0
615.0	0	0.31	0.31	0.31	0.31	0.31	0.31
943.13	0.62	0.31	0.33	0.94	0.94	1.25	2.5
984.38	0.31	0.63	1.58	2.82	3.75	5	10
1276.2	0.6	0.7	3.1	4.6	6.5	8.7	17.1
1373.1	0	0.7	0.3	0.3	0	0	0

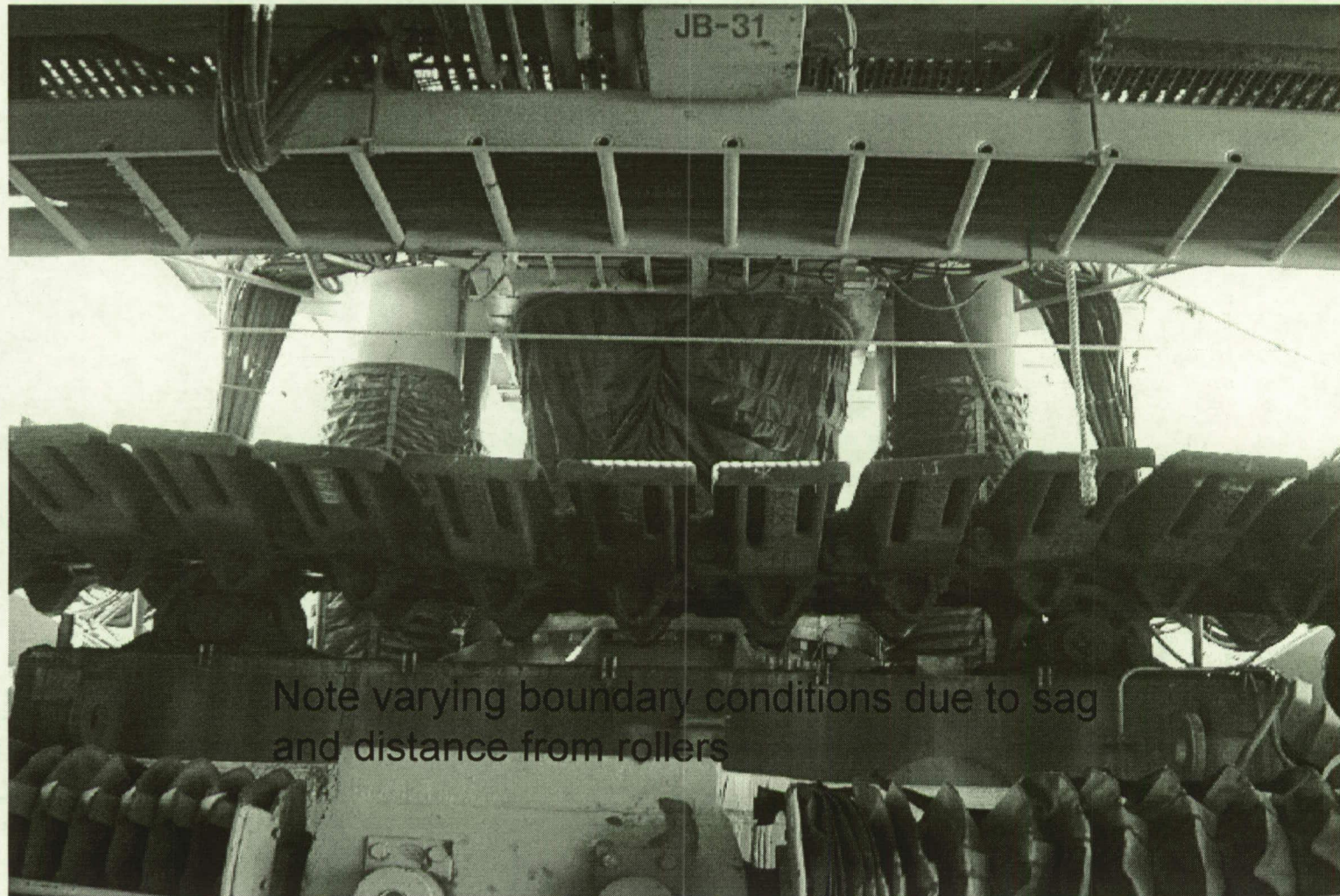
Laboratory Test Conclusions

- **The Resonance Shift Analysis technique will detect flaws 5.7” by 0.375” wide by 0.175” or more in depth.**
- **Requires comparison to each shoe’s baseline.**
- **Takes approximately 3 minutes to interrogate entire shoe.**
- **Can be used for trending the health of shoes on the crawler shoes as well as large commercial Shovels.**

Crawler Shoes Field Testing



Crawler Shoes Field Testing



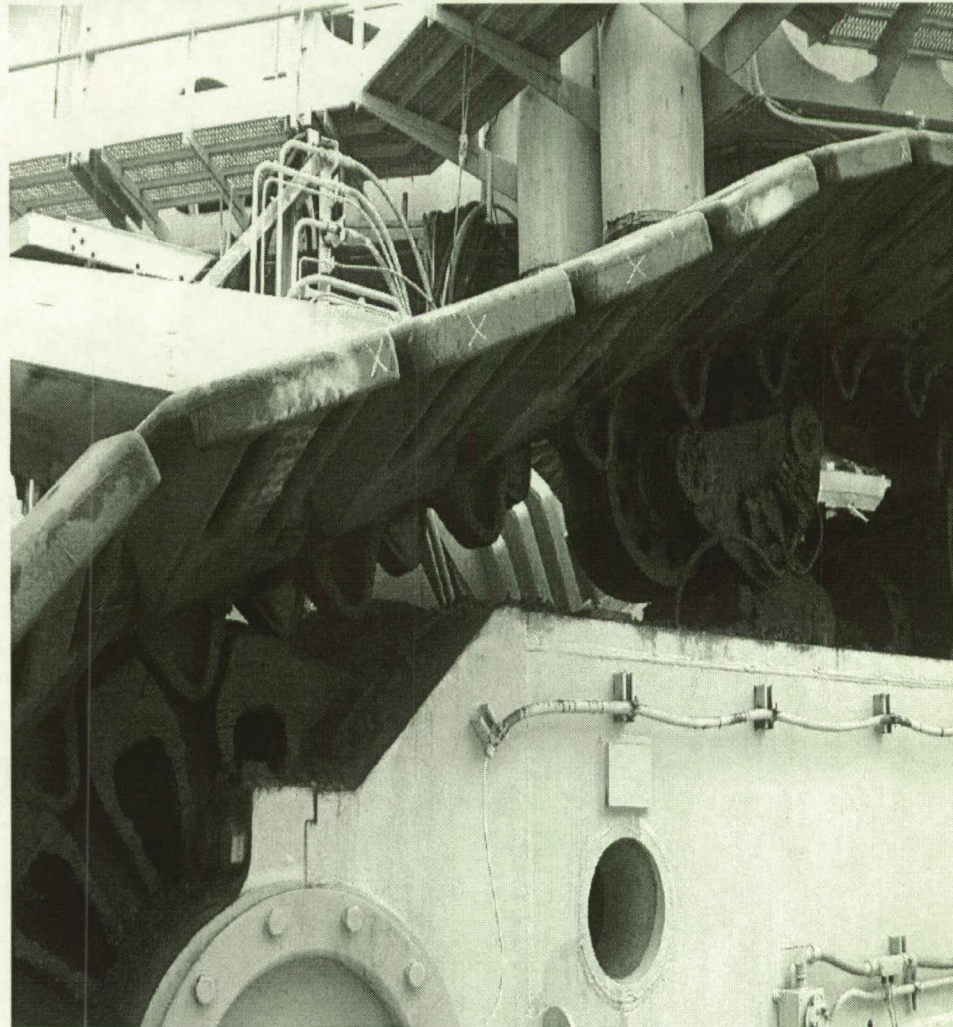
Crawler Shoes Field Testing

Shoe located between the tension rollers and sprocket found suitable for identifying major modes

2 to 3 shoes per location

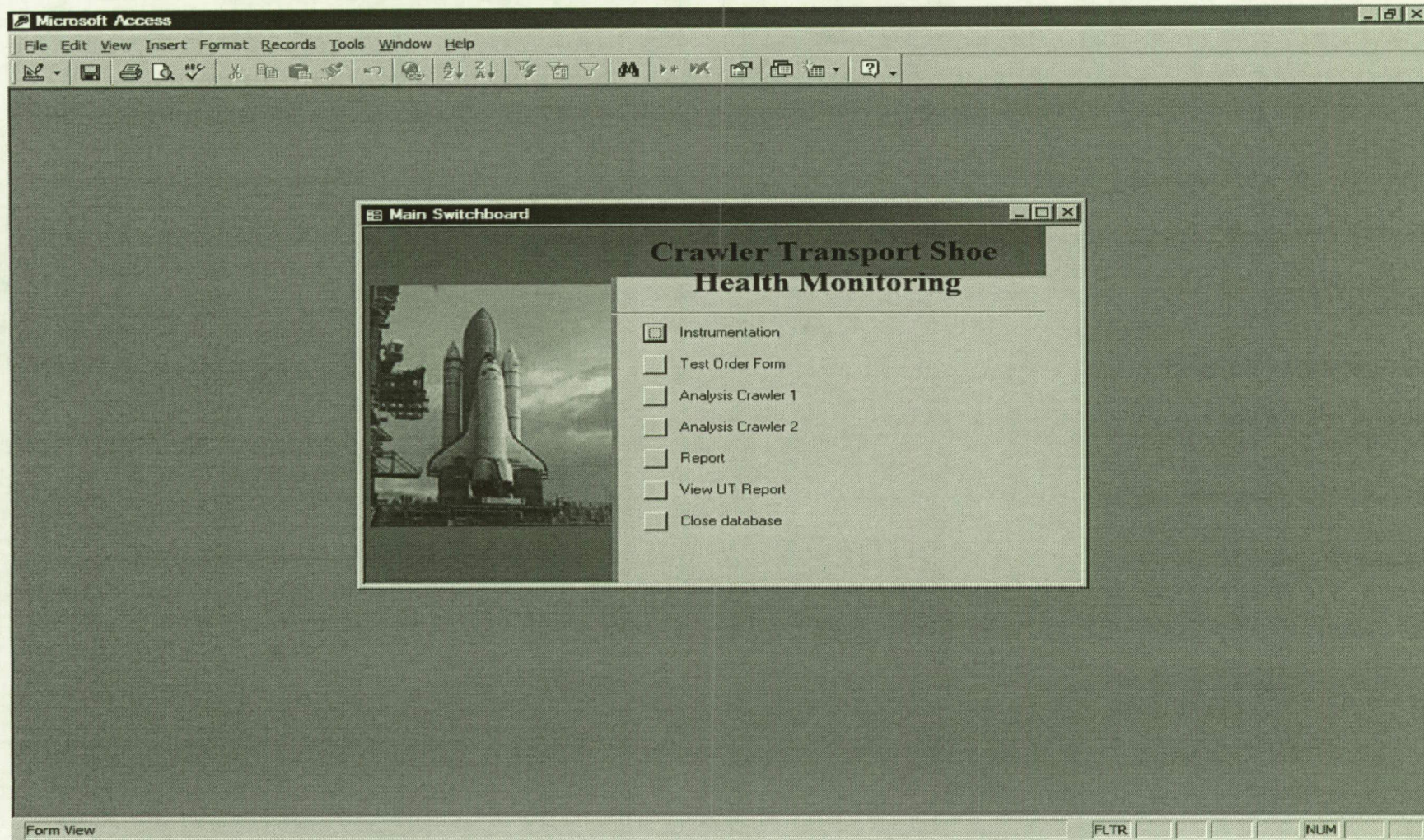
40 to maximum 48 shoes per CT move (120 minutes)

456 shoes x 3 minutes = 1368 minutes (22.8hrs) in 12 crawler moves



- MS Access Database
 - Tracking, Trending, Reporting
- SignalCalc Ace Dynamic Analyzer
 - Data acquisition
- Lab View
 - Analysis, Delta from Baseline

Tracking, Trending, Report



Tracking, Trending, Report - Test Order Form

Microsoft Access

File Edit View Insert Format Records Tools Window Help

TestOrderFRM : Form

Test Coordinator: [] Comments: []

Test Folder: [] Test Instrumentation: []

Crawler Shoe Locations: [] Crawler: Truck: [] Tread: []

16/10/2009 12:13:53 PM

SHOE_NUM	CT_LOC	Co	SET	BASELINE	TEST_NAME	ASCII FILE	HO FILE NAME	SHOE TEMP	IMAGE LOC
			1			ASCII	Hxysv00000		

Record: 1 of 1

Form View

Tracking, Trending, Report - Instrumentation

Microsoft Access

File Edit View Insert Format Records Tools Window Help

TestOrderFRM : Form

Instrumentation FRM : Form

Enter Instrumentation Data

ACTIVE: Active

Work Order: 11520

Test Coordinator: Schutzmg

Test Date: 04/01/2008 6:47:35 AM

Serial Numbers

Accelerometer: 50320

Accelerometer Calibrator: 4192

Accelerometer Conditioner: 27565

Impact Hammer: 11549

Impact Hammer Tip: Teflon Blue

Impact Hammer Conditioner: 22515

Analyzer: 2166117

Computer: 2541264

Record: 1 of 2

Record: 1 of 1

Record: 1 of 1

Form View

SHOE_NUM	CT_LO

SHOE_TEMP	IMAGE_LOC

Tracking, Trending, Report – Shoe Locations

Microsoft Access

File Edit View Insert Format Records Tools Window Help

TestOrderFRM : Form

Test Coordinator: [Dropdown] Comments: [Text Box] 6/10/2009 12:13:53 PM

Test Folder: [Text Box] Test Instrumentation: [Text Box] Crawler Shoe Locations: [Text Box]

Crawler: [Dropdown] Truck: [Dropdown] Tread: [Dropdown]

SHOE_NUM	CT_LOC	Co	SET	BASELINE	TEST_NAME	ASCII FILE	HO FILE_NAME	SHOE_TEMP	IMAGE_LOC
			1			ASCII	Hxysv00000		

CrawlerShoeLocFRM : Form

Record: 1 of 1

Record: 1 of 1

Form View

NUM

Tracking, Trending, Report - Resolution

The screenshot displays the Microsoft Access application window. The title bar reads "Microsoft Access". The menu bar includes "File", "Edit", "View", "Insert", "Format", "Records", "Tools", "Window", and "Help". The toolbar contains various icons for file operations and data manipulation. The main area shows a form titled "PathRangeCrawler1FRM : Form". Overlaid on this form is a dialog box with the following content:

IMPORTANT!
Prior to beginning Any Analysis Check The Resolution, Range and Path.

Title	Definition:	Value
Resolution	Dvision Between Data Points	0.3125

O.K. to Close This Form and Open the Crawler 1 Analysis Close This Form

Record: 1 of 16

View UT Report
 Close database

Form View

Tracking, Trending, Report - Analysis

Microsoft Access

File Edit View Insert Format Records Tools Window Help

Analysis1 FRM : Form

Analyst: Shoe Serial Number: Analysis Crawler: 1

Coordinator Comments: Test coordinator:

Engineering Comments:

ACTIVE	SET	Crawler Number	TRUCK	TREAD	SHOE_NUM
Active	1	1	A	I	<input type="text"/>

CT_LOCATION: BASELINE: BASELINE_FILE:

SHOE_TEMP: IMAGE_LOC:

TEST_NAME	FOLDER	ASCII FOLDER	CD_NUM	HO FILE_NAME	FILE_TIME_DATE
Test	mine	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>

Center Frequency and Delta change from last analysis

Peak 1	Peak 2	Peak 3	Peak 4	Peak 5
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>

Analysis Form

Open LabView Analysis Open Report Form

Record: 1 of 456

Logon ID of person taking data. NUM

Tracking, Trending, Report – Enter Analyst Comments

Microsoft Access

File Edit View Insert Format Records Tools Window Help

Analysis 1 FRM : Form

Analyst [] Shoe Serial Number [REDACTED] Analysis Crawler 1

Coordinator Comments: Test coordinator: []

Engineering Co []

ACTIVE
Active

SHOE_TEMP []

TEST_NAME F []

Test []

AnalysisAccept IQUERY

Shoe Serial Number: [REDACTED]

Analyst Comments []

ACCEPT

UT Required

Analyst [Schutze] DATE_ANALYST: 04/01/2008 9:17:11 AM

Center Frequency and Delta change from last analysis

Peak 1	Peak 2	Peak 3	Peak 4	Peak 5
[]	[]	[]	[]	[]
[]	[]	[]	[]	[]

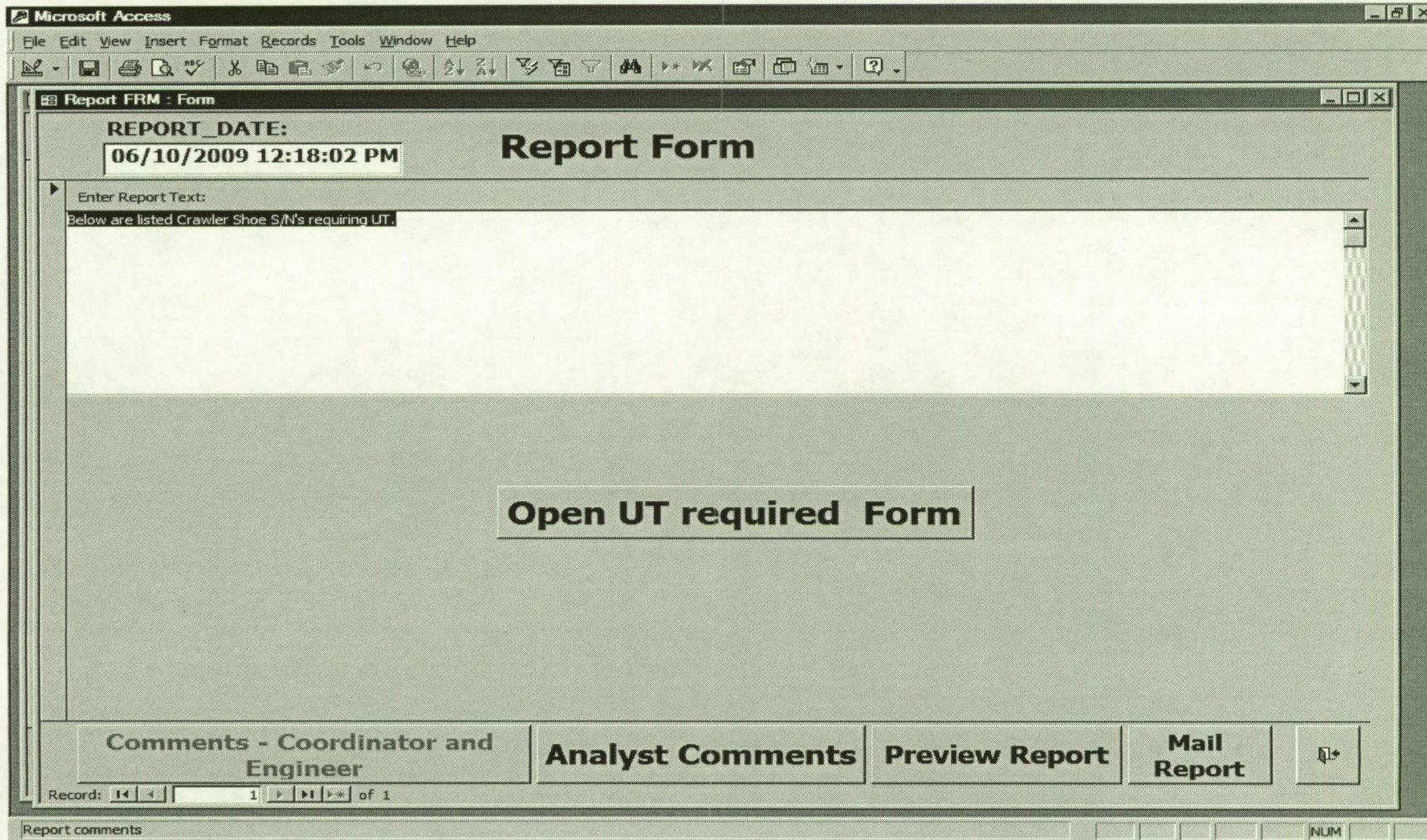
Analysis Form

Open LabView Analysis Open Report Form

Record: 1 of 456

Explain why data is not acceptable. , or any comments.

Tracking, Trending, Report – Report Form



The screenshot shows a Microsoft Access window titled "Report FRM : Form". The menu bar includes File, Edit, View, Insert, Format, Records, Tools, Window, and Help. The toolbar contains various icons for file operations and editing. The main form area is titled "Report Form" and displays the following content:

REPORT_DATE:
06/10/2009 12:18:02 PM

Enter Report Text:
Below are listed Crawler Shoe S/N's requiring UT.

Open UT required Form

At the bottom of the form, there are several buttons: "Comments - Coordinator and Engineer", "Analyst Comments", "Preview Report", "Mail Report", and a button with a plus sign. Below the buttons is a record navigation bar showing "Record: 1 of 1".

Tracking, Trending, Report – Analyst Comments

Microsoft Access

File Edit View Insert Format Records Tools Window Help

Report FRM : Form

REPORT_DATE:
06/10/2009 12:18:02 PM

Report Form

Enter Report Text:
Below are listed Crawler Shoe S/N's requiring UT.

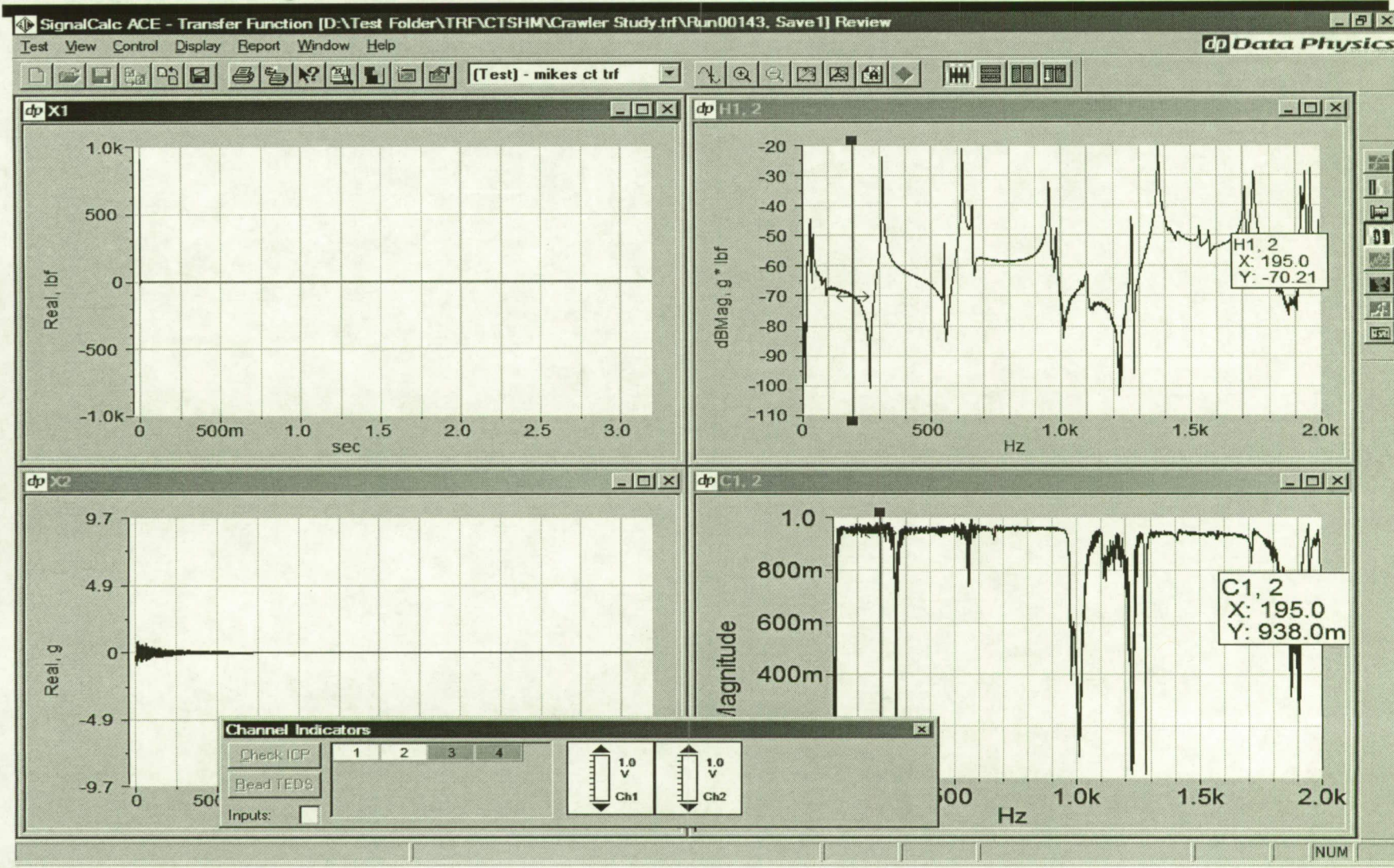
SERIAL_NUMBER	ANALYST	ANALYST	COMMENTS
[REDACTED]	'2008 9:17:11 AM	Schutze	

Record: 14 of 1

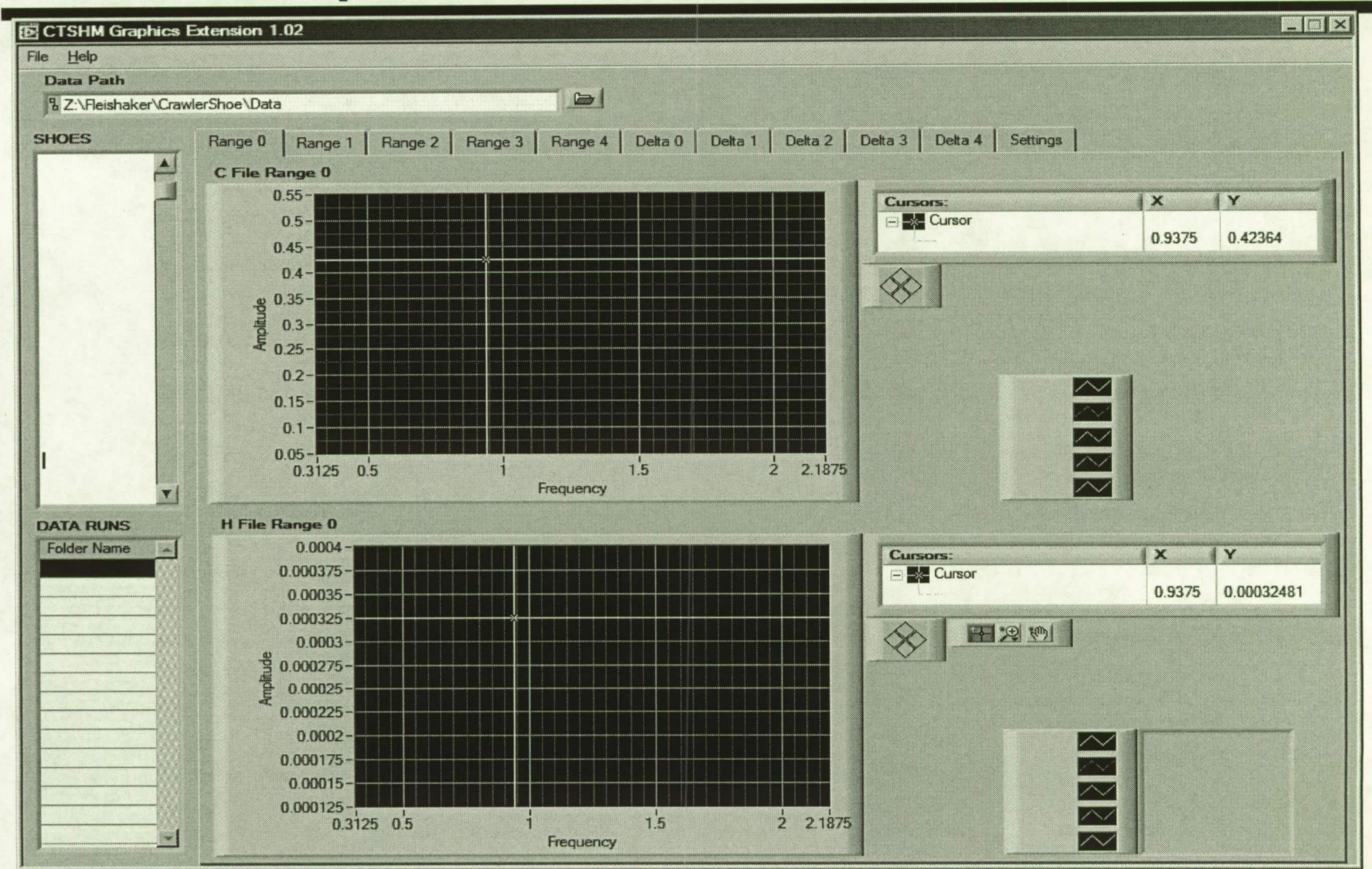
Comments - Coordinator and Engineer Analyst Comments Preview Report Mail Report

Shoe serial number. NUM

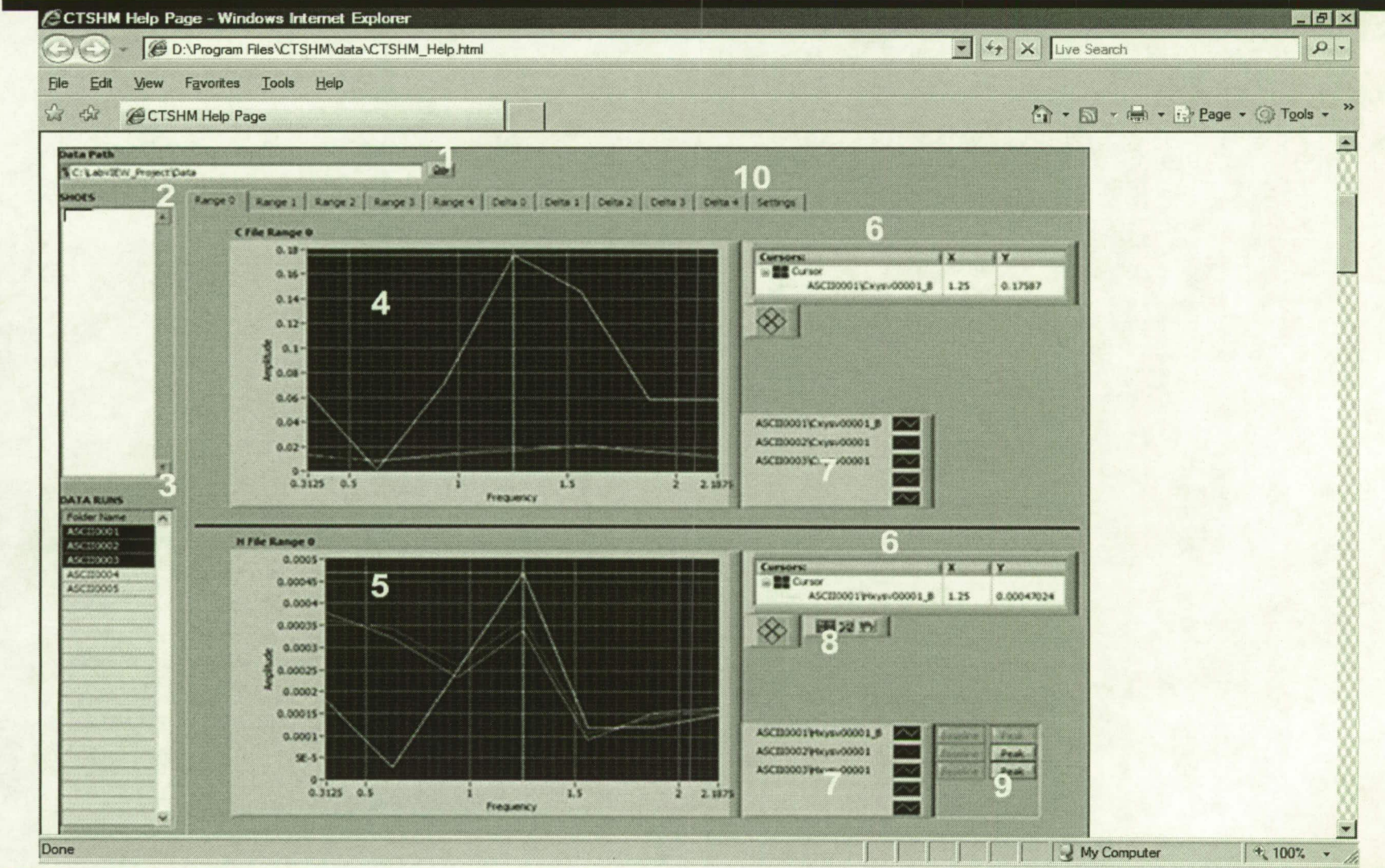
Data Analysis Screen



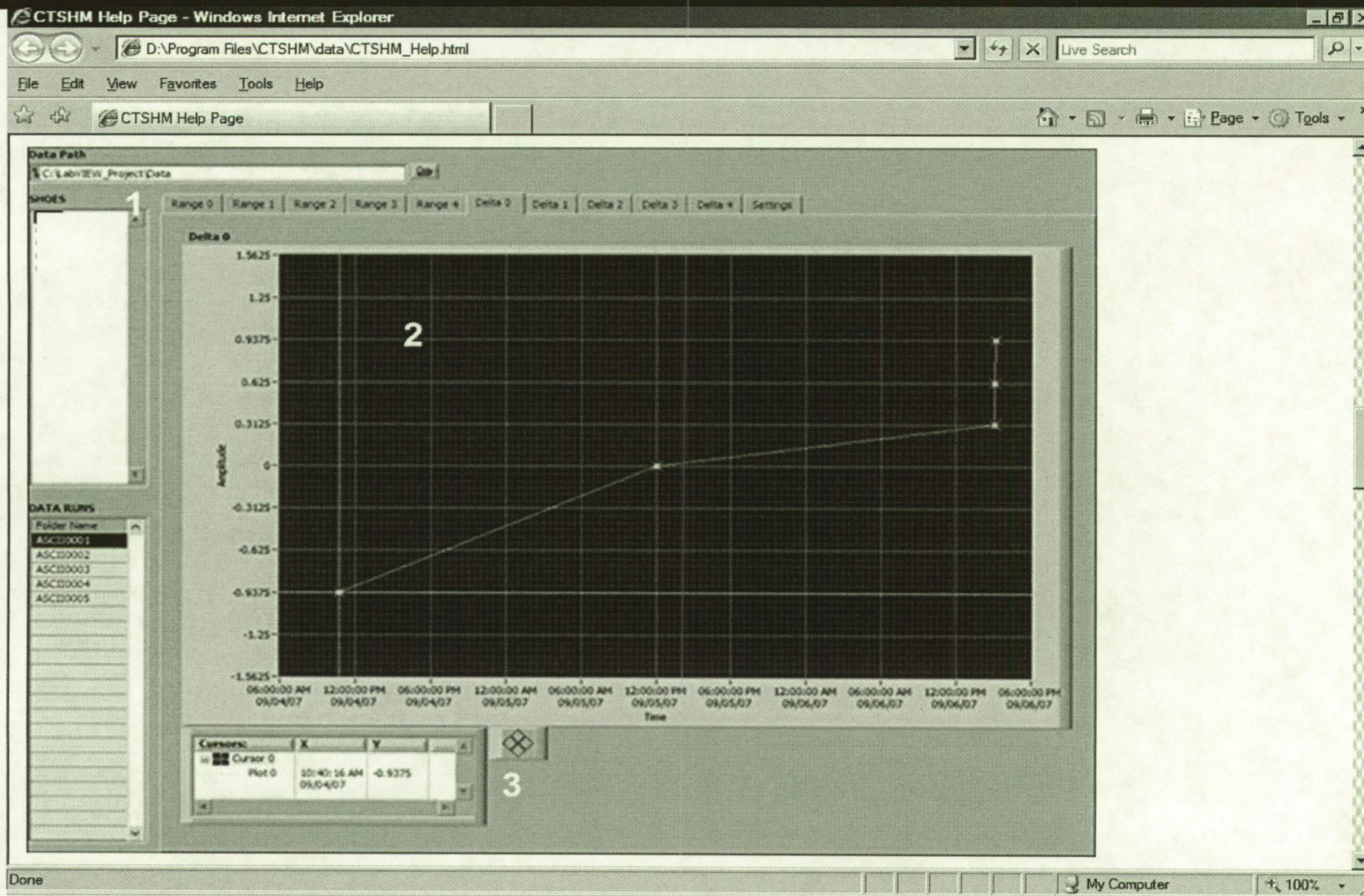
CTSHM Graphics Extension 1.02 – Initial Screen



Tracking, Trending, Report – Frequency vs. Amplitude Trend



Tracking, Trending, Report – Delta From Baseline Trend



Tracking, Trending, Report – Settings Change

The screenshot shows the 'CTSHM Graphics Extension 1.02' application window. The 'Data Path' is set to 'Z:\Feishaker\CrawlerShoe\Data'. The 'SHOES' section has tabs for Range 0-4 and Delta 0-4, with 'Settings' selected. A message states: 'Data items on this page are read-only. Values of Settings are under database control.' The settings are as follows:

- ConnectionString:** DSN=CTSHM_Test (The ADO connection string for the database)
- Resolution:** 0.3125 (Resolution (spacing) of all data points to be examined.)
- CThreshold:** 0.9 (Amplitude threshold for C file data. Any value below this level is considered to be questionable data.)
- Number of tabs:** 5 (The number frequency ranges on the GUI)
- Number of plots:** 5 (The max number of plots on the graph)
- Number of freq ranges:** 3 (The number of frequency ranges to examine)

Data ranges:

LoFreq	LoFreq	LoFreq	LoFreq	LoFreq
0.3125	3.4375	7.1875	7.1875	7.1875
HiFreq	HiFreq	HiFreq	HiFreq	HiFreq
2.1875	5.9375	12.188	12.188	12.188

High and low frequency for every range.

The 'DATA RUNS' section on the left shows a 'Folder Name' dropdown menu and a list of folders.

➤ Summary

- **A viable Resonance Shift Analysis techniques has been developed to monitor the health of the each Crawler Shoe.**
- **Data acquisition time required for 1 crawler is 22.8 hours plus time required for 12 Crawler Transporter moves(7-10 feet each).**
- **Technique is used in conjunction with Ultrasonic Phased Array Analysis.**

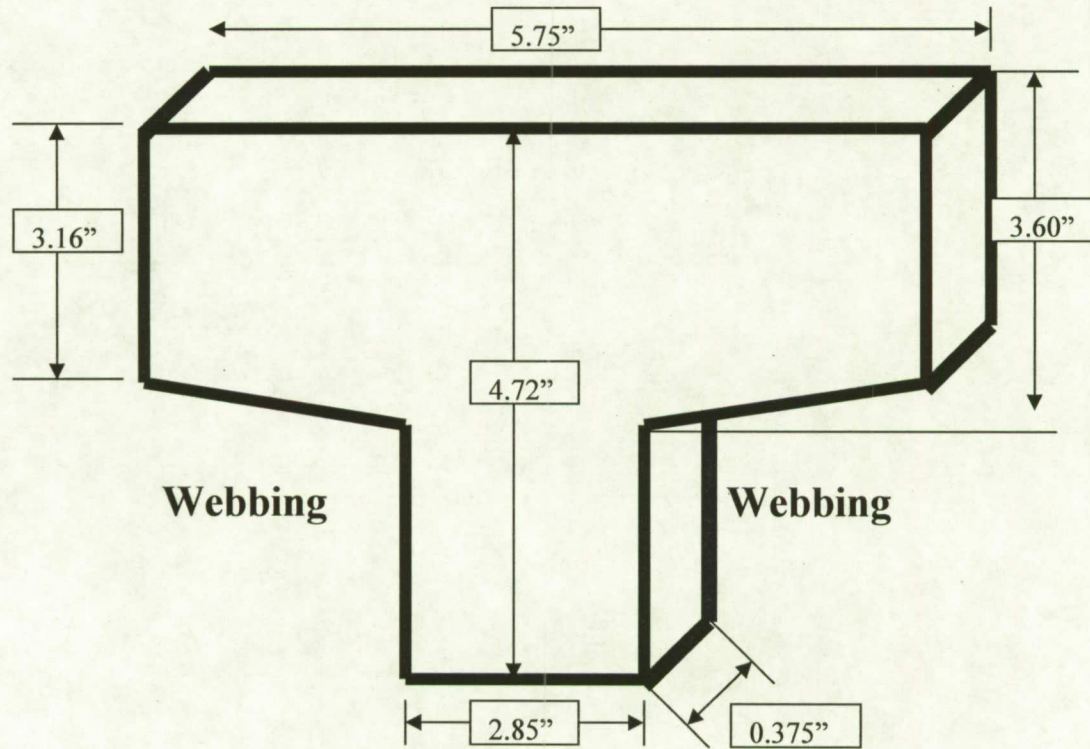
Questions?

Additional Information

Setup

Frequency Range	0- 2KHz
Lines of resolution	6400
Number Averages	6 stable
Trigger	Input
Window	Accelerometer: Response
	Impact Hammer: Force
Analysis Screens	Input Force vs. time
	Acceleration vs. time
	FRF
	Coherence Function channel 1,2

Shoe 2



Shoe 2

			Difference	
Slot Depth	2.63"	4.72"	Baseline - Column 2	Baseline - Column 3
Baseline Hz	Hz	Hz	Hz	Hz
315.31	308.1	305.63	7.21	9.68
622.19	621.88	620.63	0.31	1.56
970.63	966.6	965.6	4.03	5.03
1248.8	1250.9	1245.1	-2.1	3.7
1385.9	1385.0	1381.3	0.9	4.6
1605.3	1604.1	1604.1	1.2	1.2
1741.6	1735.5	1737.5	6.1	4.1
1765.3	1755.9	1754.7	9.4	10.9
“-“ Indicates Baseline frequency was lower.				

Shoe 3

		Difference
Slot	3.0" long x 3.3" deep	Baseline - Column 2
Baseline Hz	Hz	Hz
312.2	311.8	0.4
548.75	549.06	-0.69
620.94	620.94	0.0
954.69	954.38	0.31
1099.4	1099.4	0.0
1287.5	1274.1	13.0
1379.1	1377.5	1.6
1523.1	1523.4*	-0.3
1743.4	1743.4*	0.0
1805.0	1804.7*	0.3
“-“ Indicates Baseline frequency was lower.		
* Indicates COH was less the 0.9.		

Resonant Frequencies

Resonant Frequencies							
Slot Depth	0.175"	0.35"	0.52"	0.69"	0.87"	1.045"	1.75"
Baseline Hz	Hz	Hz	Hz	Hz	Hz	Hz	Hz
312.19	312.50	311.50	311.56	311.25	310.31	310.00	307.5
534.06	534.06	534.06	534.38	534.38	534.38	534.06	534.06
615.0	615.00	614.69	614.69	614.69	614.69	614.69	614.69
943.13	943.75	943.44	942.8	942.19	942.19	941.88	940.63
984.38	984.69	983.75	982.8	981.56	980.63	979.38	974.38
1276.2	1275.6	1275.7	1273.1	1271.60	1269.7	1267.5	1259.10
1373.1	1373.1	1373.8	1373.4	1373.4	1373.1	1373.1	1373.1

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