INDUSTRIAL TECHNOLOGY RESEARCH

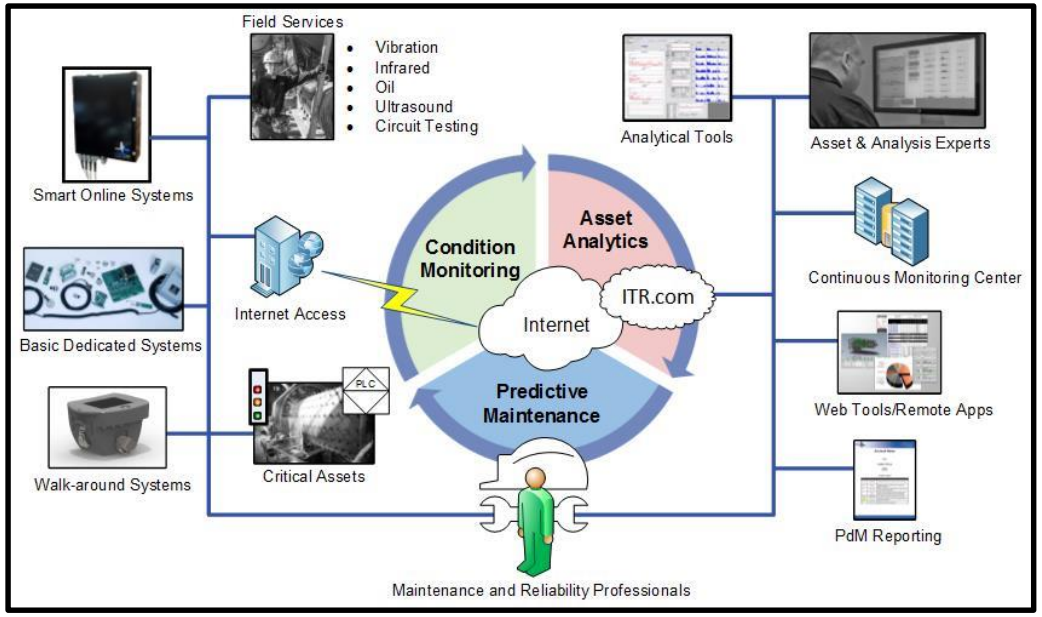
PREDICT TO PREVENT ™

ITR Background

- Founders developed the computerized vibration analysis (CVA) in the 1970's while working for major US Steel R&D organization; one of the original PdM companies, founded 1983
- Today, one of most experienced independent PdM companies in the world provide ongoing monitoring & analysis services to nearly 250 steel mills (44 states, 25 countries on 6 continents)
- First to implement an ongoing vibration program in/to steel
- Hardware, software, and service provider specializing in predictive waveform analytics for complex machinery
- Only independent, hybrid solution provider with >30 years experience with process based on remote diagnostics and prognostics

HYBRID SOLUTIONS PROVIDER

Potential asset failure modes drive monitoring and analysis solutions



Services

- Smart & basic online monitoring
- Vibration analysis
- Oil analysis
- IR thermography
- Ultrasonic testing
- Motor testing
- PdM process management
- Analytics & PdM info training
- Applications engineering
- Data and info (CMMS) integration
- Continuous Monitoring Center

Systems

- Portable systems
- Analysis software
- Smart & basic online systems
- Wireless sensors and monitoring systems
- PdM reporting and information management systems

VIBRATION ANALYSIS LEARNING SESSION

Match the Methods to the Machines

Why is this important?

Too often providers design a monitoring and analysis process based on what is:

- Understood
- Convenient
- Least expensive (upfront, not in the long-term)

Little consideration is often given to the following in regards to appropriateness to the machine and the potential failure modes to be detected:

- **Monitoring methods**: walk-around, continual monitoring, continuous monitoring
- **Analysis methods**: what types of data are necessary, how do we analyze it, how do manage the data and information over time
- **System/human interaction**: degree to which humans are required for success and process to make it work

Goal of discussion: help practitioners understand all important factors so they are considered when designing a process for collecting and analyzing data

Monitoring vs. Analysis

Let's start with understanding the difference…

Monitoring: observing, performing surveillance, comparing data to criteria (one word: observation)

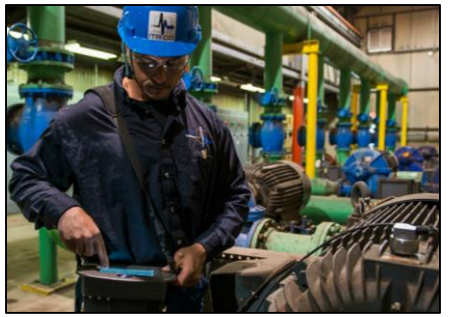
- More equipment, less human
- Often associated with alarms, preventive maintenance
- Front end of process

Analyzing: evaluating data to criteria to seek understanding (one word: evaluation)

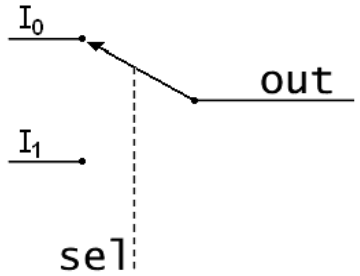
- More human, less equipment
- Often associated with understanding root cause, predictive and proactive maintenance
- Back end of process

Monitoring Methods

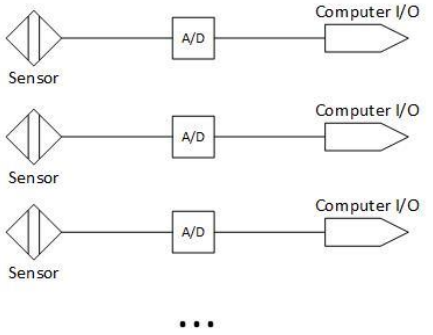
- Portable, walk-around, route-based: mobile system used by one person (at a time) to periodically collect data across many machines



- Multiplexed monitoring: dedicated system where each sensor is sampled periodically and multiple analog or digital data streams are combined into one signal over a shared medium



- Simultaneous monitoring: dedicated system where each sensor is sampled continuously and simultaneously



Monitoring: Pros/Cons

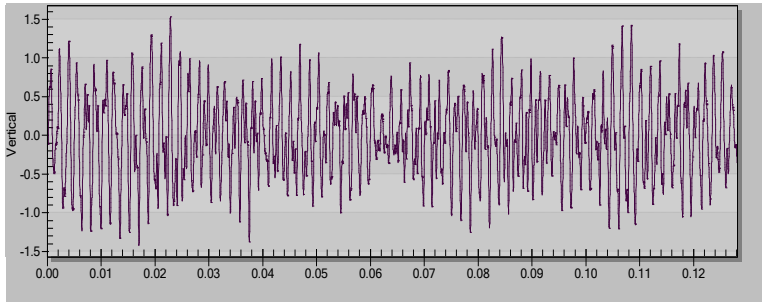
Method	For Consideration…	
	Pros	Cons
Walk-around	▪ Least expensive (10-20 to 1) ▪ Flexibility in measure intervals, locations, testing methods ▪ One system can measure many machines	▪ Monitoring periods are often weeks or months ▪ No opportunity for expert systems (except for 'alarm-based' screening)
Multiplexing	▪ Monitoring periods are often seconds or minutes apart and most failure modes are detectible ▪ Opportunity to apply expert systems ▪ Data and information management much simpler and less expensive than simultaneous	▪ More expensive but not most expensive because of some share resources (A/D) ▪ System limited to one machine or group of machine ▪ Some events may be missed, limited ability to synchronize measurements and data
Simultaneous	▪ True, simultaneous, synchronized data acquisition (no missed events) ▪ Opportunity to apply expert systems	▪ Most expense because of no shared resources ▪ System limited to one machine or group of machine ▪ Data and information management extremely challenging, time consuming, expensive (in engineering time)

Why/when would you use each type of monitoring system?

What is 'Vibration Data'?

Data acquisition

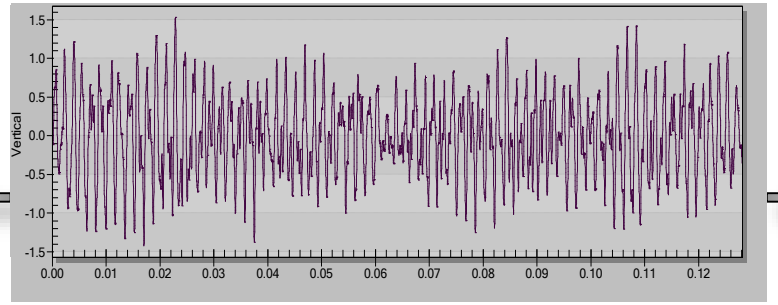
'Raw' waveform data (amplitude vs. time)



- Machine acoustic emissions excite a transducer (e.g. accelerometer)
- Transducer converts electro-mechanical energy of the machine to an analog electrical signal
- Monitoring device converts the analog signal to digital and filters the data (before and after) to fit the data and remove noise/transient events
- Result is 'processed' data: a collection of many, many sine waves

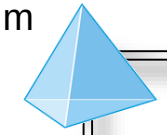
Spectral vs. Scalar Data

‘Raw’ waveform data

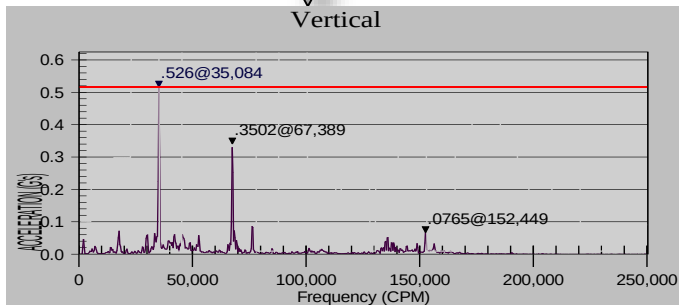


Amplitude vs. Time

Mathematical Spectrum



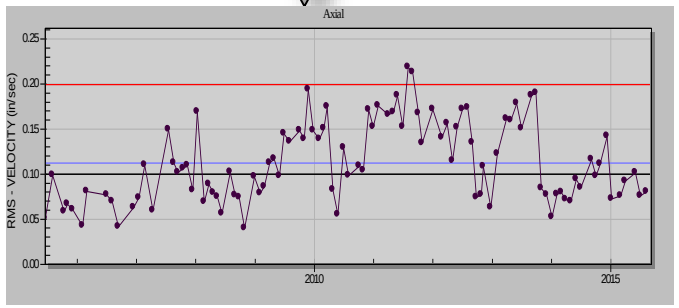
Spectral data



Amplitude vs. Frequency

’Many to one’ data calculations

Scalar data



Amplitude vs. Time

- Similar to a prism for light, broadband vibration is passed through a “mathematical prism” to produce a vibration signature, showing the amplitude of vibration and the frequencies at which they occur
- Vibration frequencies correlate to machine components and provide insights to the analyst regarding machine condition

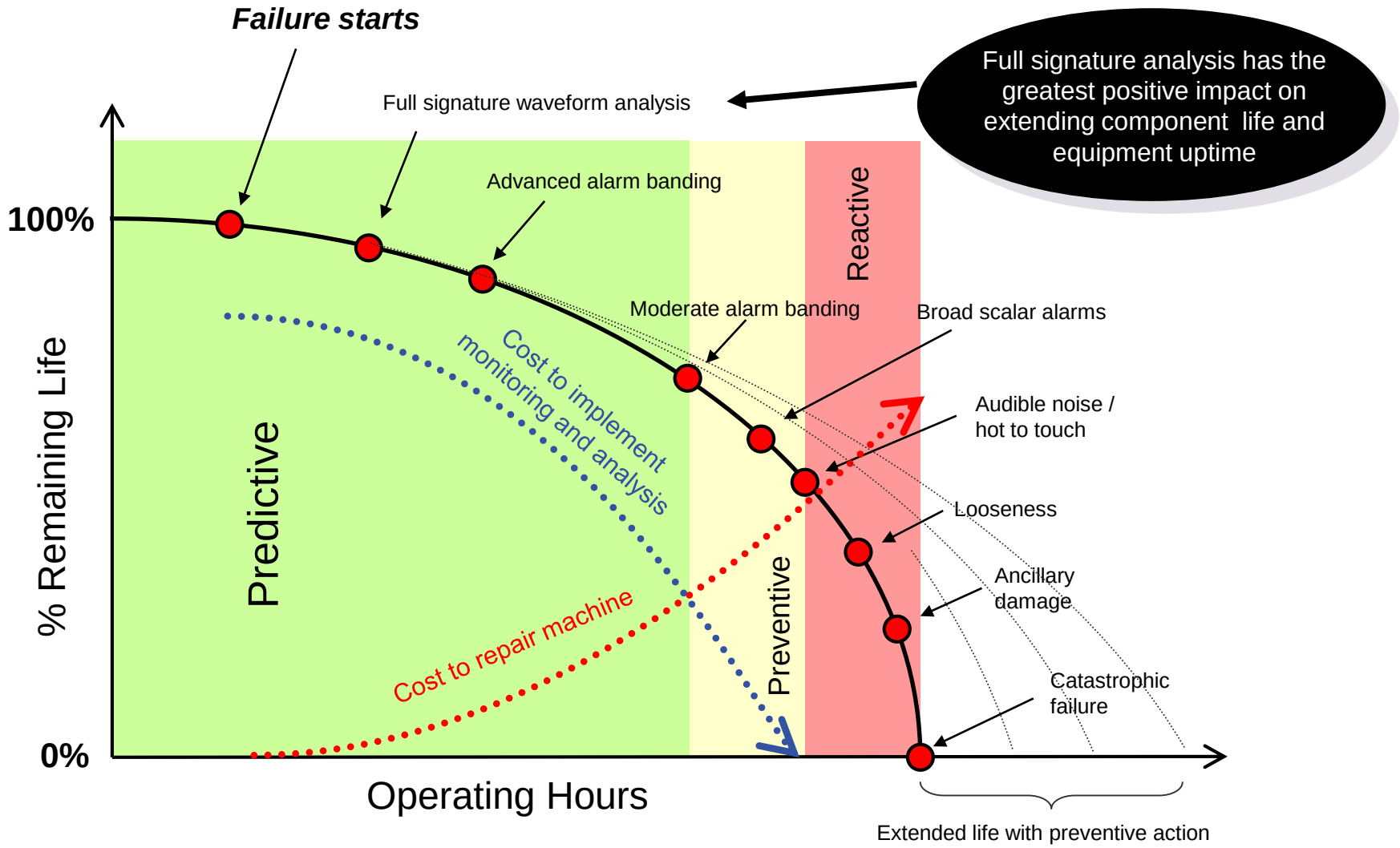
- Numerical techniques to summarize waveform data as ***single value***
- In general terms, represents the ‘energy’ in the data at a given moment in time

Pros/Cons of Different Vibration Data

Data	Common Types	For Consideration…	
		Pros	Cons
Spectral	Time Domain Frequency Spectrum	▪ Rich data set/more info available ▪ Appropriate for complex assets and process conditions ▪ Traceable to machine components	▪ More expertise and time required to analyze ▪ Analysis process ‘costs’ more relative to scalar ▪ Difficult to store and manage large data sets ▪ More difficult to apply expert systems ▪ More difficult to trend over time
Scalar	Overall RMS Banded RMS Crest Factor Intensity Factor	▪ Easy to trend data over time ▪ Easy to apply expert systems and train people to use data ▪ Easy to store and manage large data sets ▪ Analysis process ‘costs’ less relative to spectral data	▪ May lead to false alarms or missed problems with complex process conditions or transient events ▪ Some failure modes ‘masked’ in the data

Why/when would you not use both?

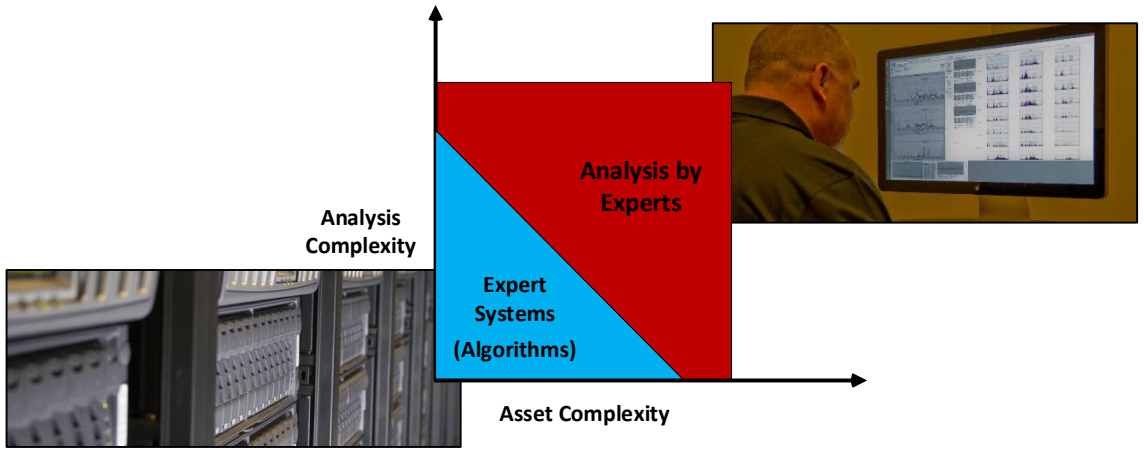
DECISION TRADE-OFFS



Expert Systems vs. Human

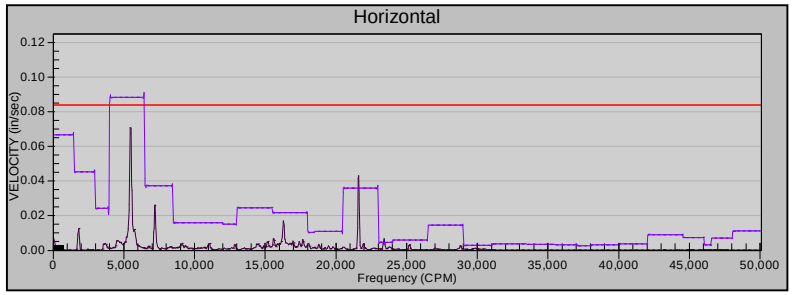
If all analysis was simple, there would be no ‘Analysts’, only computers and programmers…

- Expert systems: rule-based computer programs that use experiential and statistical methods to interrogate data and draw conclusions
- Human analysts: competent individuals that use knowledge, skills, and experience to interrogate data and draw conclusions
- Effective and efficient analysis = “right” combination of both
- For simple assets (constant load/speed), integration is less important
- For complex assets (variable load/speed), integration is essential

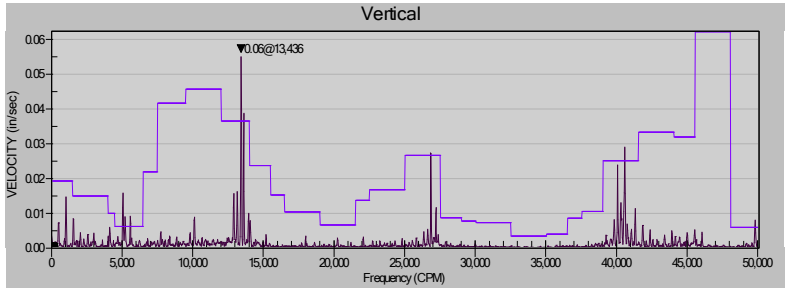


EXPERT SYSTEM/HUMAN TRADE-OFFS

For consideration…



- Constant load/speed motor
- Stable, repeatable data
- 2σ alarm-band is stable and reliable



- Variable speed gearbox (mill stands/cranes)
- Speed varies considerably, so data varies considerably
- 2σ alarm-band does not match data

Notice how the statistical limits 'follow' the spectral data…

What happens when speed changes result in non-linear changes in vibration?

What happens if there are many changing variables with each measurement?

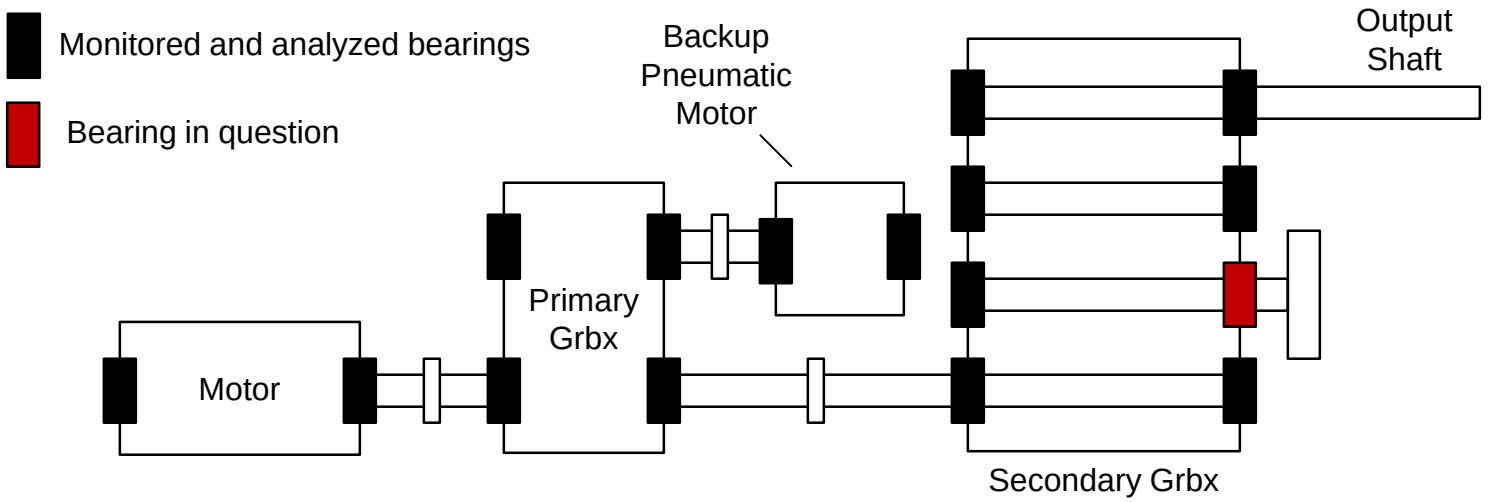
Long Rolling and Process Decisions

Asset	Constant Process Conditions			
	Speed	Load	Product	Other
Hydraulic pumps	✓	✘	✓	✓
Cooling fans/blowers	±	±	±	±
Water pumps	✓	✓	✓	✓
Compressors	±	±	±	±
Main mill drives	✘	✘	✘	±
Roughing mill drives	✘	✘	✘	±
Intermediate mill drives	✘	✘	✘	±
Finishing mill/no-twist mill drives	✘	✘	✘	±
Pinch roll drives	✘	✘	✘	±
Laying heads	✘	✘	✘	±
Shears/saws	±	✘	✘	±
Crane hoist/bridge/main drives	✘	✘	✘	±

✓= yes, ✘ = no, ± = sometimes

Complexity Example

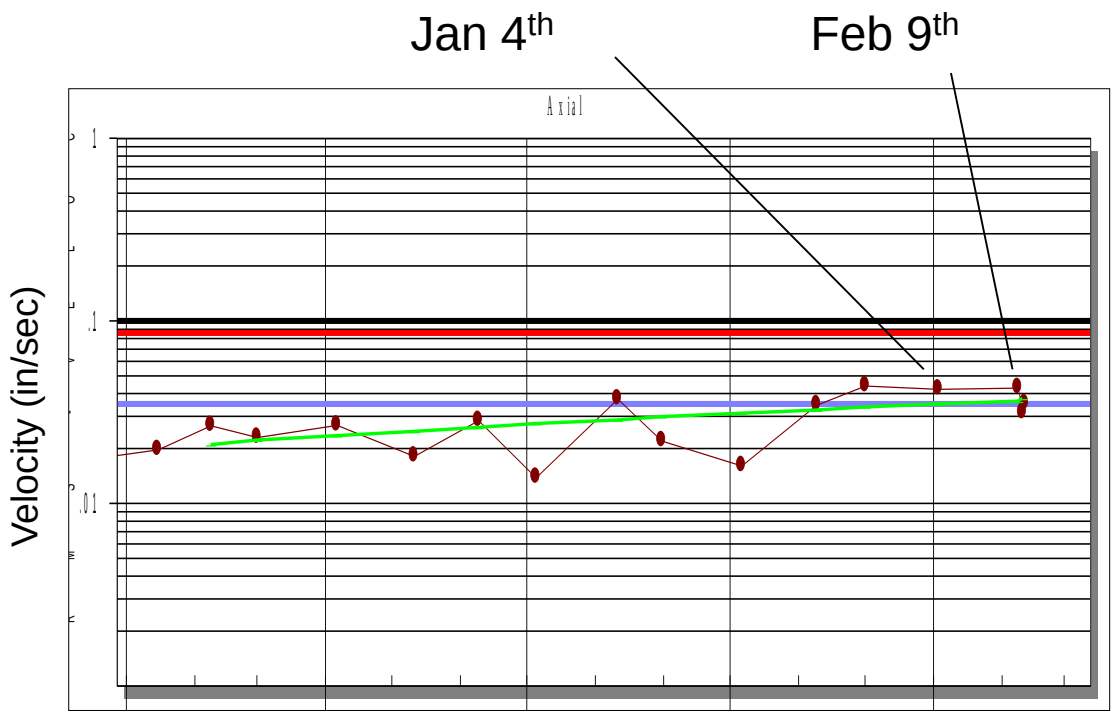
- Multistage gearbox
- Constant load, variable speed, variable product, short cycle time
- System periodically monitored with dedicated system and analyzed monthly
- Bearing in question: secondary gearbox flywheel bearing



Scalar Data Monitoring

Velocity RMS:

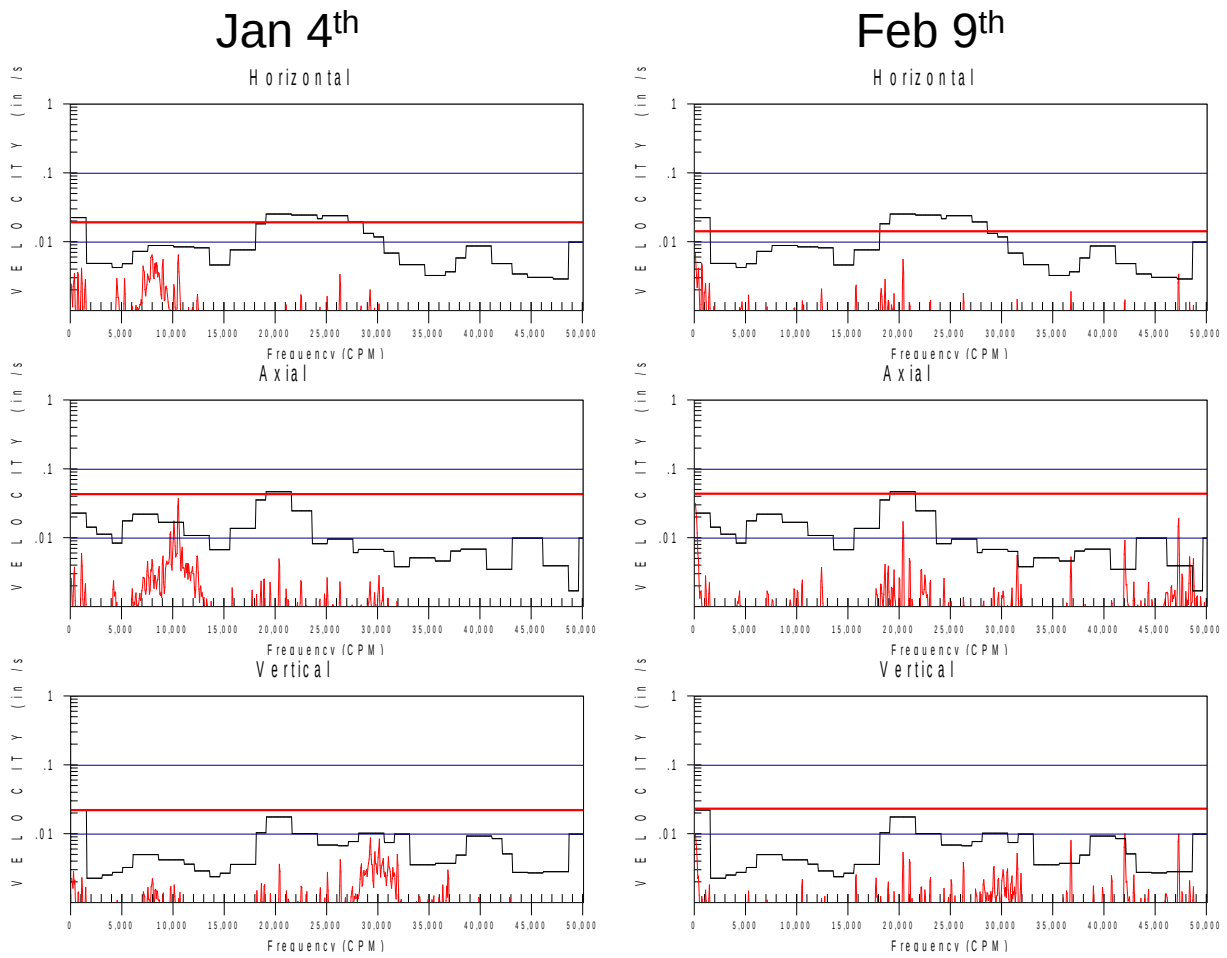
- No significant increase in RMS from Jan to Feb
- Below 2σ limit
- No violation of statistical rules
- Acceleration RMS also shows no significant increase
- Would not “trip” most alarms



Spectral Data Analysis: Velocity

Velocity signatures (low frequency):

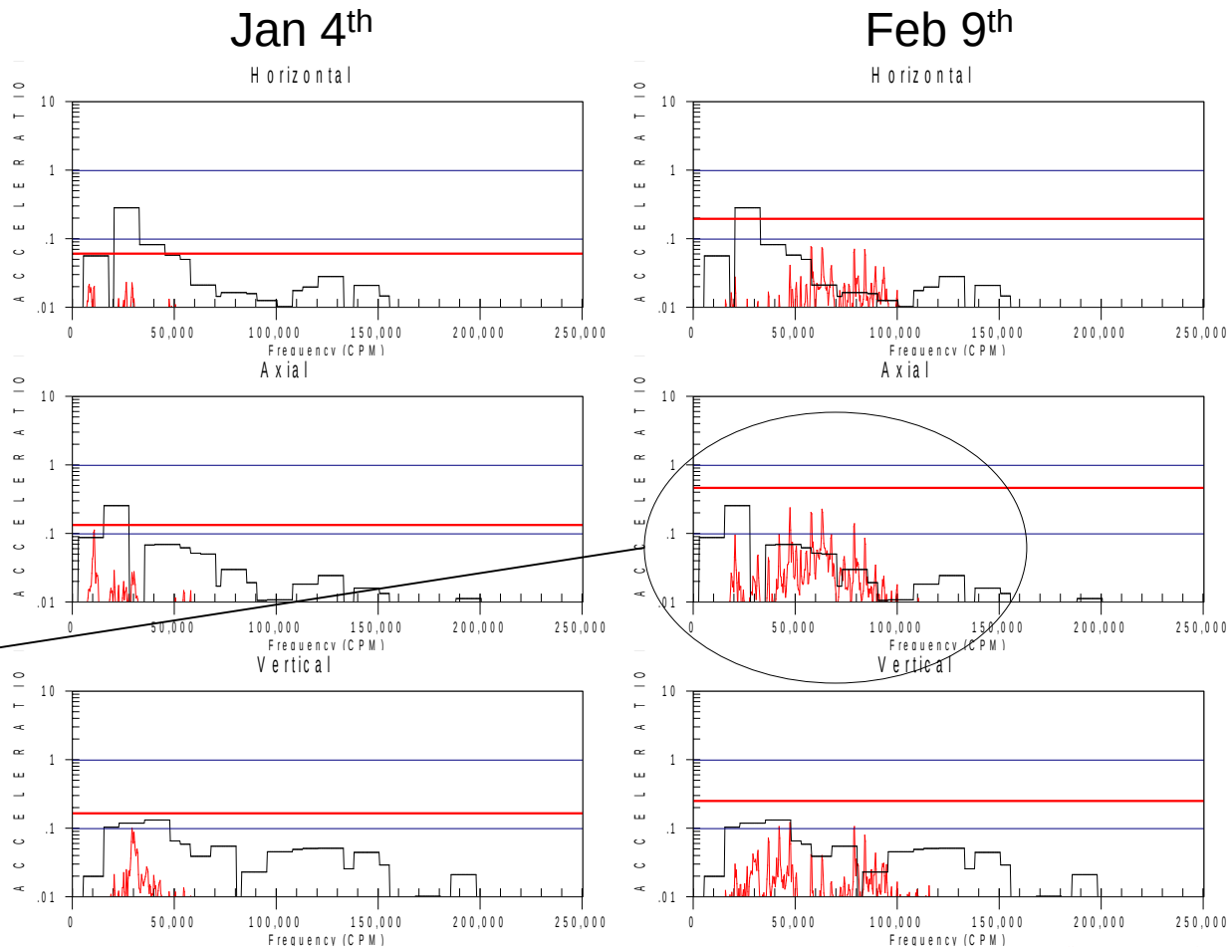
- No significant increase in overall vibration
- Single-banded signature alarms would not “trip”
- Signature shows possible recurring harmonic



Spectral Data Analysis: Acceleration

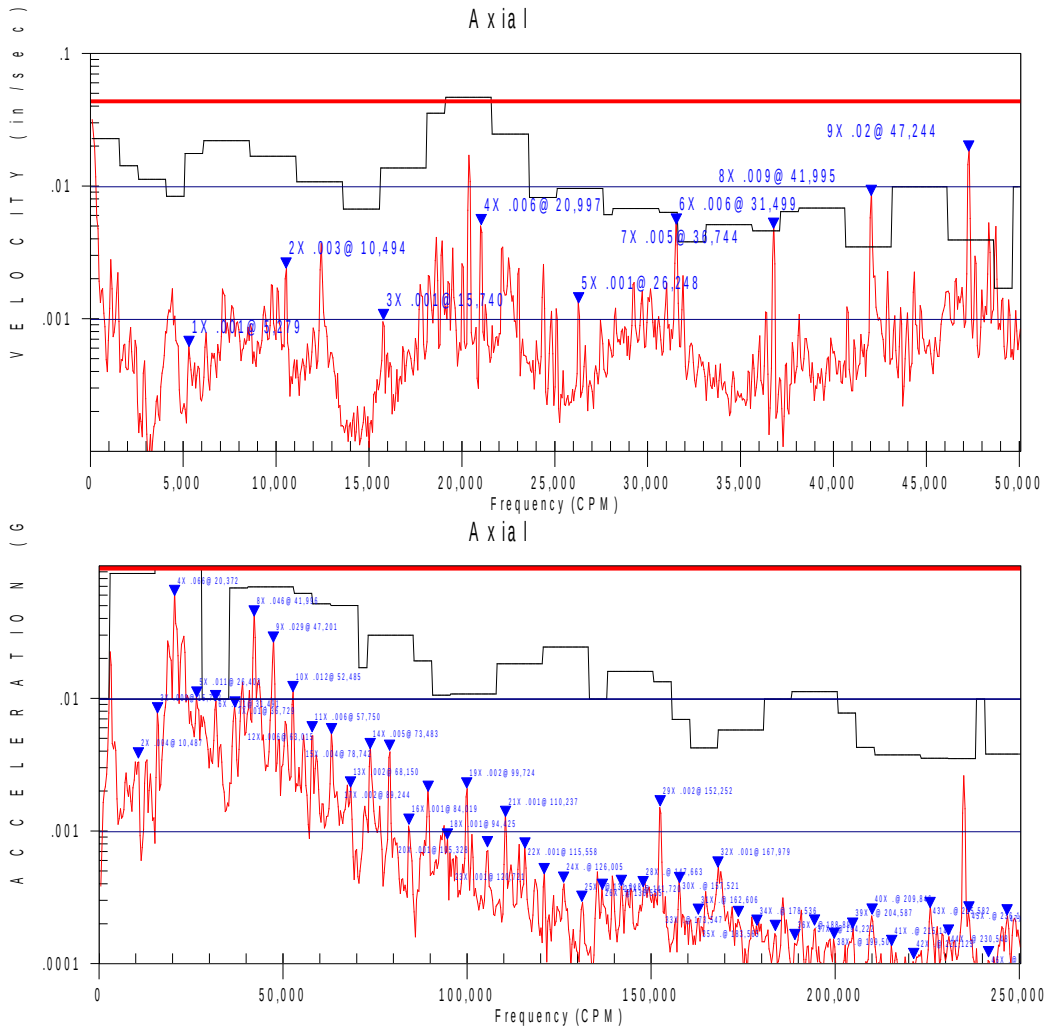
Acceleration signatures (high frequency):

- Some increase in overall vibration
- Single-banded signature alarms may not “trip”
- Extent of possible problem only known with further analysis
- Let’s look further…

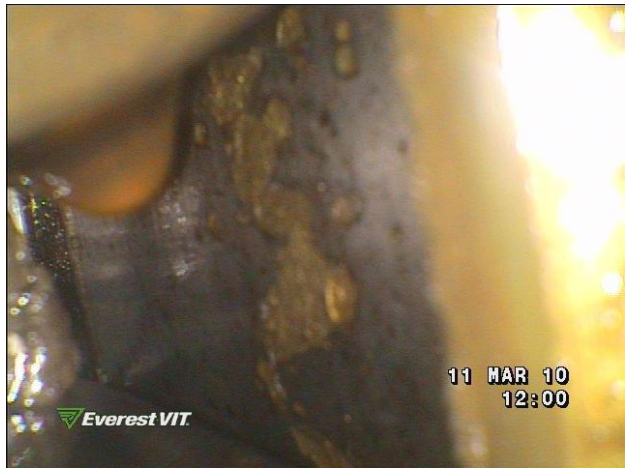


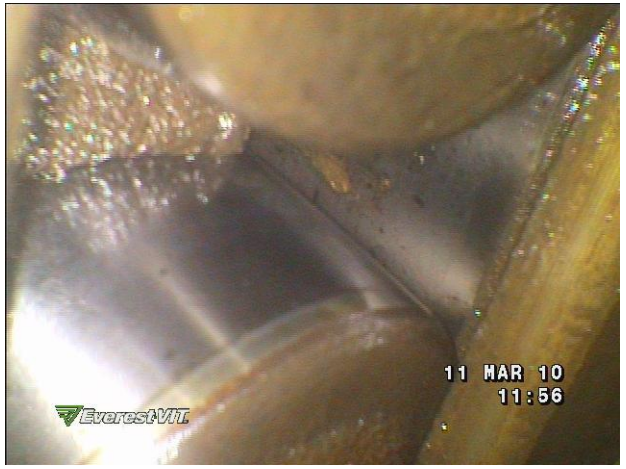
Detailed Signature Analysis

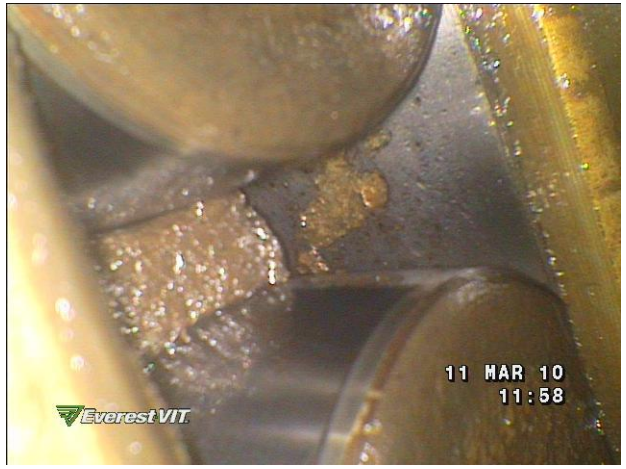
- Blue arrows indicate harmonics of 5251cpm
- 5251cpm corresponds to secondary gearbox flywheel bearing defect frequency
- Problem only identified by human analysis, advanced banding, or advanced signature monitoring
- Analyst(s) update alarms based on new asset knowledge

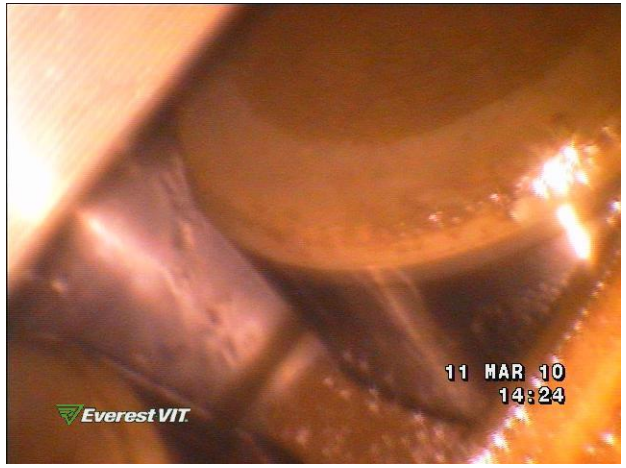


VERIFIED FINDINGS

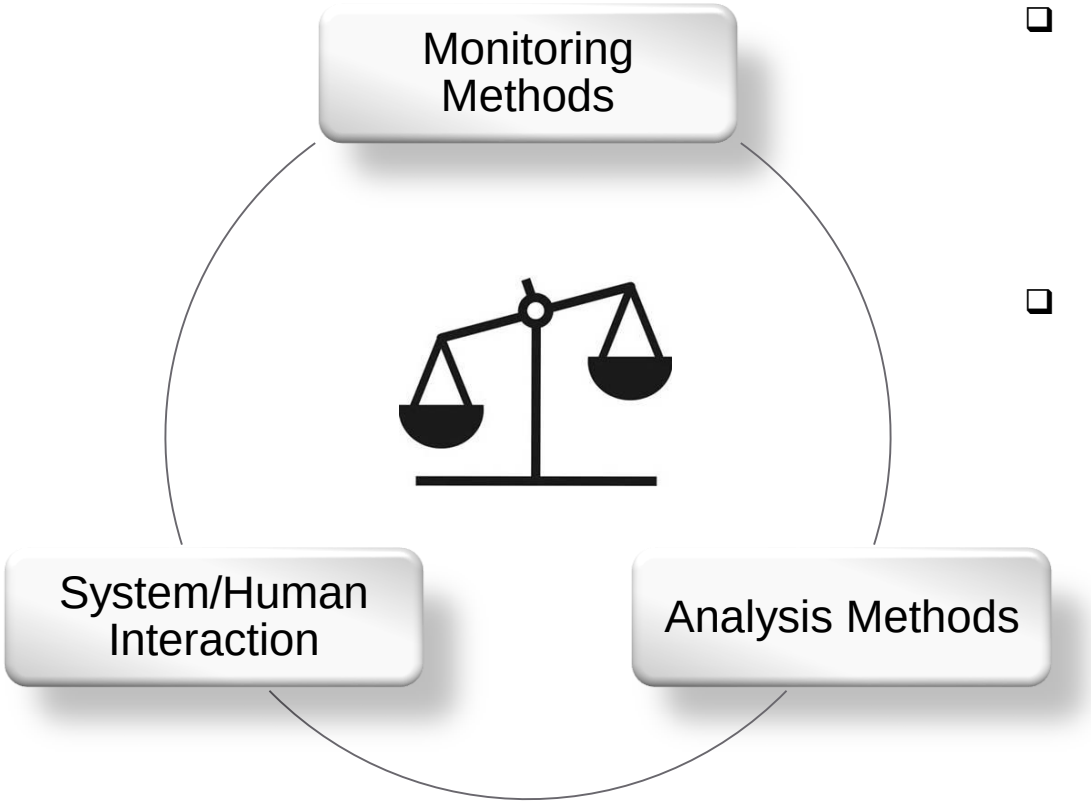








SUMMARY



- Find the right balance based on the machine process conditions and the detectable potential failure modes
- Reminder: PdM is risk management

Thank You