

The background of the slide is a collage of industrial images. On the left, there are blue electric motors. In the top right, a large metal gear is visible. In the bottom left, a yellow industrial machine is shown. In the center, a worker wearing a white hard hat, safety glasses, and an orange high-visibility vest is looking at a tablet. The entire image is overlaid with a white geometric grid pattern.

**FLUKE**<sup>®</sup>

Reliability

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# Confidence Scoring for Actionable Diagnostics

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February 2024



# Michael DeMaria

- **Director, Azima DLI Product Management**
  - Vibration Hardware, Software, Portal Systems
- **Background Naval Nuclear Power Engineering**
  - Machinery Condition Analysis
- **Joined DLI Engineering in 1995**
  - Engineering Lead / Analyst
  - Program Manager, US Navy
  - Director, Technical Support
  - Director, Training
  - Director, Product Management

# FLUKE®

Reliability

**db**® PRÜFTECHNIK

AZIMA | DLI

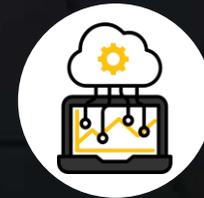
**emaint**™



World-class hardware



Remote condition monitoring services



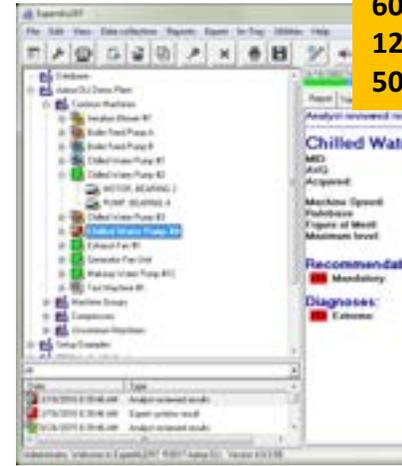
Innovative Software

# Watchman™ System

Remote Setup App



Expert Automated Diagnostic System



Vibration AI

6000+ Trained Diagnostic Rules  
1200+ Identifiable Fault Conditions  
50+ Asset Component Library

## Asset Data Lake

- ### 100,000

Unique Assets
- ### 150,000

Asset Components
- ### 3,000,000

Machine Tests
- ### 150,000

Component Specific Faults
- ### 100 Trillion

Individual Vibration Test Points  
approximately



Vibration Data Sources



Latest Diagnostic Result

Jun 13, 2023, 03:04 PM

**Identified Problems:**

- SERIOUS Pump Bearing Wear

**Confidence:** High

**Completion Profile:** Needs Motor Run, noise average

**Analyst Comments:** Current results continue to show non-synchronous vibration in the high range data with impact detected and some waveform energy at levels that warrant further concern.

**Recommended Actions:**

- IMPORTANT Replace Pump Bearing A/E/S/I - OPEN

**Cited Peaks:** Click [here](#) to view cited peaks

**Analyst:** Jeff Langford



Program Management

Watchman Portal™



Watchman Services

25+ Level 2, 3, 4 ISO Certified  
50k Assets Monitored  
540k Annual Machine Tests



**FLUKE**

Reliability

# Azima DLI History & Milestones



**DLI**  
ENGINEERING  
CORPORATION

Founded

Development of  
Automated  
Diagnostic  
Software

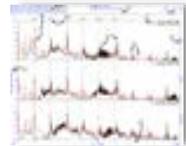


Computer  
Controlled  
Processing



First  
Commercial  
Multi-channel  
Digital Data  
Collector

**ExpertALERT™**  
First Expert  
Automated  
Software



Azima formed



First  
Tablet-style  
Windows® Based  
Data Collector

Launch of  
SPRITEMax



**WATCHMAN**  
Reliability  
Portal™



Strategic Business  
Level Metrics



1966    1976    1980    1986    1990    1995    2000    2005    2012    2015    2017    2019    2023



**Aircraft Carrier  
Contract**



Narrowband  
Vibration  
Analysis



Military Sealift  
Command  
Contract



First Triaxial  
Vibration  
Sensor

AQ-204  
Acquisition  
Hardware

First  
Online  
Diagnostic  
System



10<sup>th</sup> Generation  
ExpertALERT™  
Automated Software



Azima DLI is formed



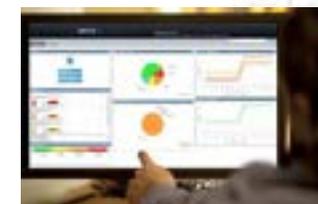
**TRIO®**  
First Modular  
Data Collector



IIoT/AI  
APM Integration

Cloud-enabled complete  
PdM Program Solution

ExpertALERT™  
Cloud-subscription



What can we leverage to improve diagnostic accuracy and confidence?

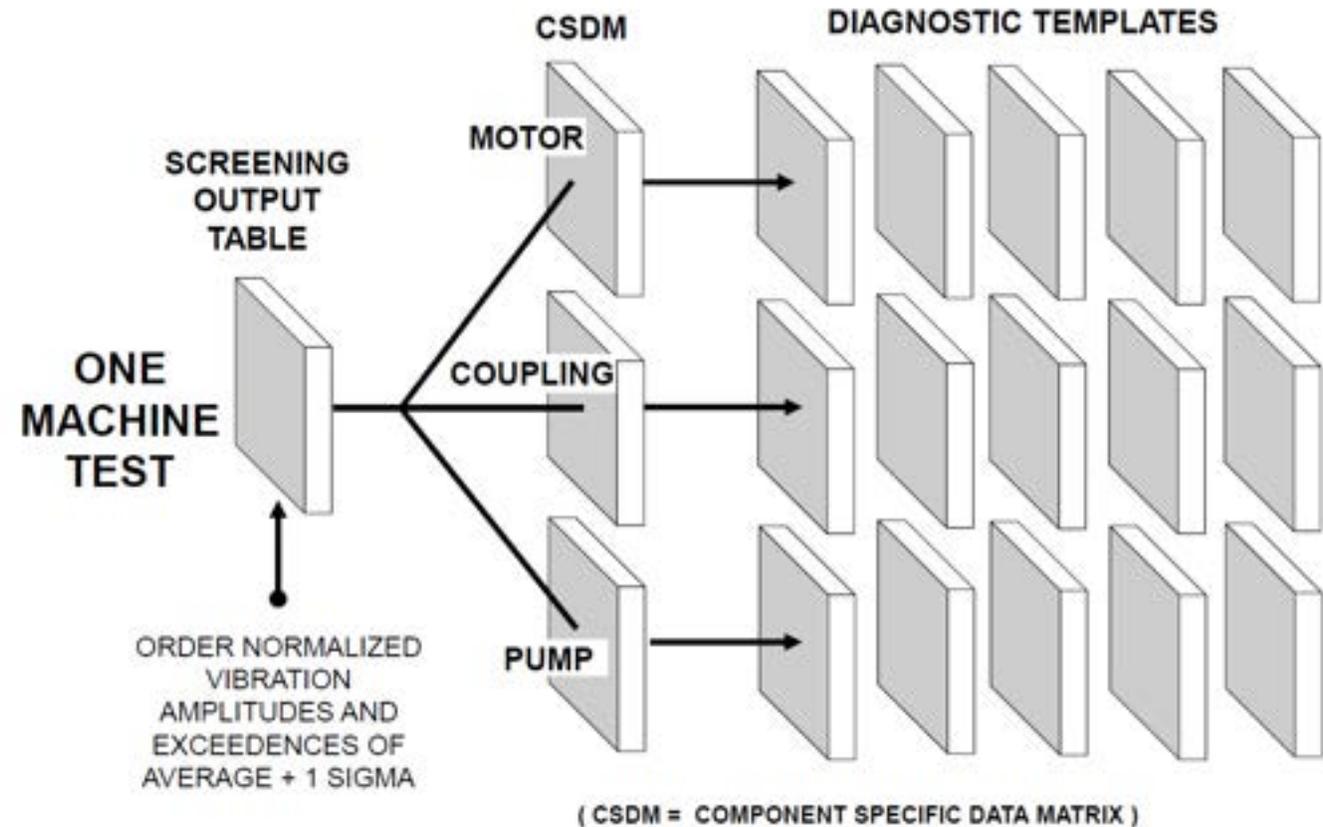
## Agenda

- Expert Automated Diagnostic System
- Contributing Factors to Fault Detection
- Improved Automation
- Delivered Results with Confidence

# Expert Automated Diagnostic System (EADS™)

- Trained Diagnostics
- 6000+ Diagnostic Rules
- 1200+ Fault Conditions
- 40+ Machine Components

## Expert System Flow Path



# Expert Automated Diagnostic System (EADS™)

- Trained Diagnostics
- 6000+ Diagnostic Rules
- 1200+ Fault Conditions
- 40+ Machine Components
  
- Normalized Data
- Prioritized Actions
- Statistical Averages
  
- Supports:
  - Volumetric Analysis
  - Asset Template Leverage
  - Business Level Metrics
  - Data Quality Screening



**Analyst Reviewed Results**

### Main Service Pump #1

MID: 6  
Averages: 4  
Date Acquired: 11/5/2015 3:36:59 PM (UTC)

Machine Speed: 1781 RPM  
Rulebase: 20130322  
Figure of merit: 201  
Maximum Level: 111 (+14) VdB at 1.00xM on Motor Drive End Axial

**RECOMMENDATIONS:**  
<2> IMPORTANT: INSPECT COUPLING AND CHECK SHAFT ALIGNMENT

**DIAGNOSTICS:**  
<2> SERIOUS: **ANGULAR MISALIGNMENT**  
111 (+14) VdB Motor Drive End Axial at 1.00xM  
107 (+11) VdB Motor Drive End Tangential at 1.00xM  
107 (+12) VdB Pump Drive End Axial at 1.00xM  
105 (+12) VdB Pump Drive End Tangential at 1.00xM  
103 (+11) VdB Pump Drive End Radial at 1.00xM  
103 (+ 8) VdB Motor Drive End Radial at 1.00xM  
96 (+ 8) VdB Pump Drive End Axial at 2.00xM

**DISCUSSION BY ANALYST:**  
The vibration has increased over the previous tests.

Analyzed by: Jeremy Smith 11/5/2015 10:27:49 PM (UTC)

Repair Priority

Repair Recommendation

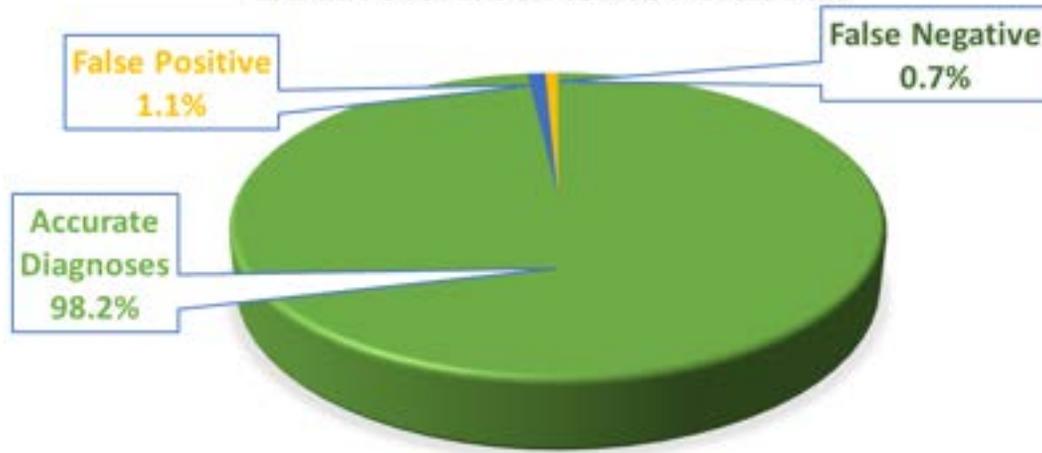
Fault Severity

Fault Diagnostic

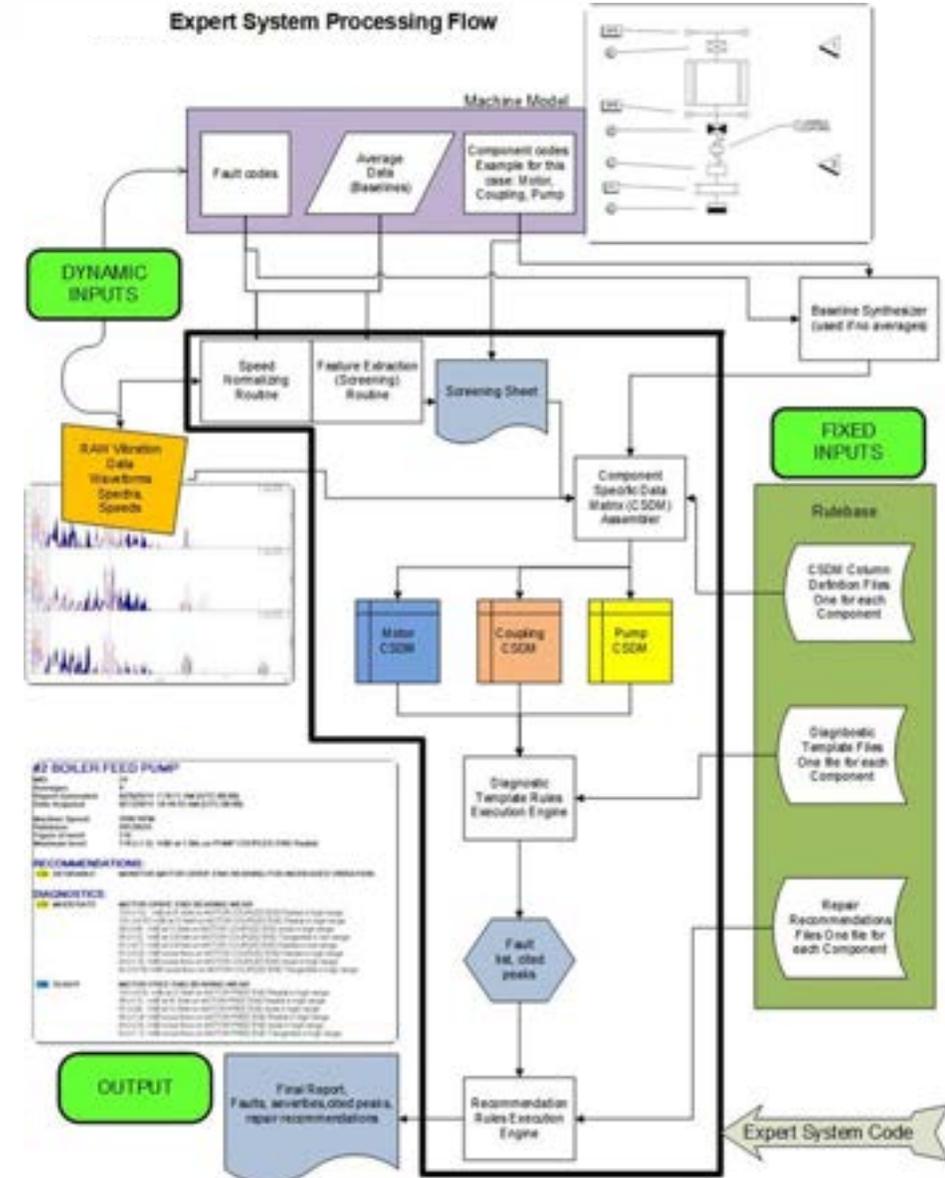
Cited Peaks

# Automated Diagnostics

## Best-in-Industry Automated Diagnostic Accuracy

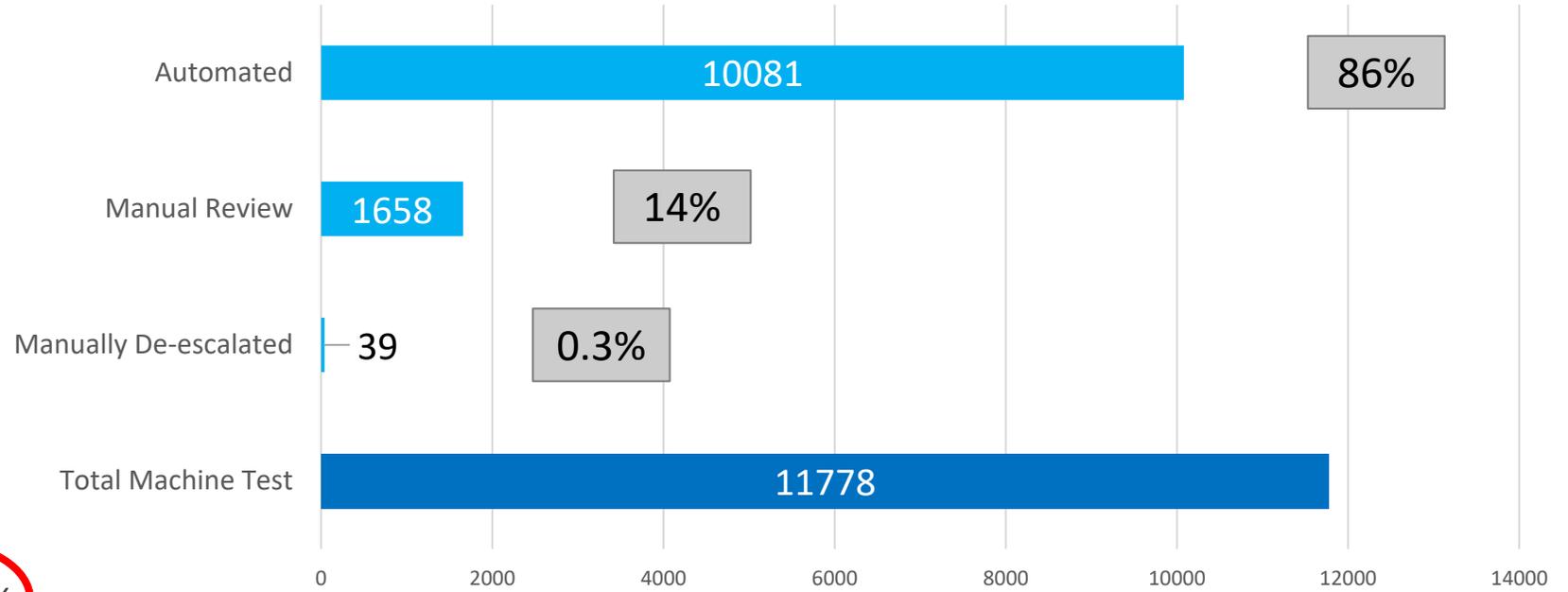


- 6,000 Diagnostic Rules
- 1,200 Fault Conditions
- 150,000+ Component specific faults
- 100 Trillion individual data points
- 150,000+ Unique assets
- 3 Million+ machine tests

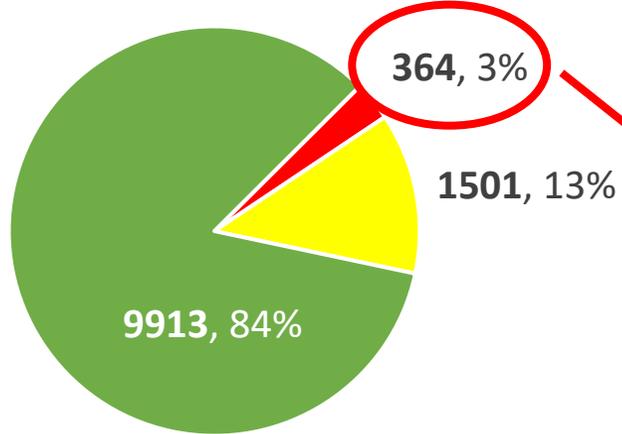


# First Six-Months Program Review

Machine Tests, Oct 2022 - Mar 2023

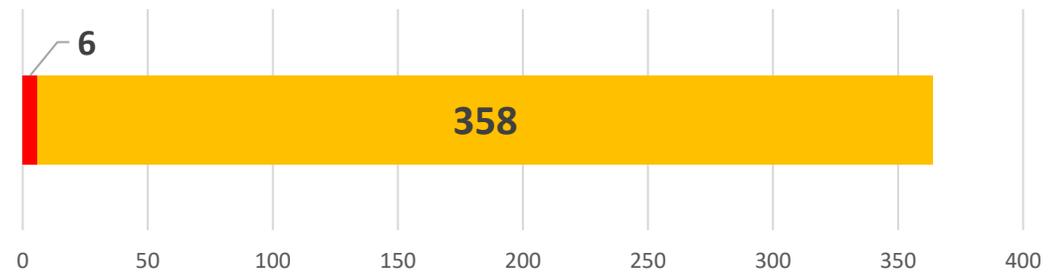


Asset Faults, Oct 2022 - Mar 2023



■ Priority ■ Emergent ■ Healthy

Priority Issues, Oct 2022 - Mar 2023



■ Mandatory / Extreme ■ Important / Serious

# Confidence Level & Completion Score

## Latest Diagnostic Result

Feb 02, 2023, 06:55 AM

### Identified Problems

 **SERIOUS**

Motor Shaft Looseness

### Recommended Actions

 **IMPORTANT**

Check Motor Bearings For Improper Fit  
[ALRT-22996](#) - **OPEN**

 OK

### Confidence

No warnings for this diagnostic result.

 65%

### Completion Profile

Needs Motor Bars, more averages



### Cited Peaks

Click [here](#) to view cited peaks



### Analyst

Manjunath



### Analyst Comments

Fault has increased in severity since last month's reading, prompting an escalation to Important recommended action.

# EADS Result with Confidence

New information available in the diagnostic result

## Expert System Results

### Confidence

MID: 1113  
Averages: 0  
Report Generated: 10/18/2022 9:19:54 PM (UTC)  
Date Acquired: 8/4/2022 4:00:44 PM (UTC)  
Machine Speed: 3580 RPM  
Rulebase: 20221123  
Figure of merit: 687

Maximum level:

MID Completion = 40%: Needs Motor Bars, Pump Vanes, more averages  
Pump looseness diagnostic CONFIDENCE IS LOW with unknown Pump Vanes  
0.38 (+2155%) in/s at 5.00x on PUMP BEARING 3 Horizontal

### RECOMMENDATIONS:

<3> Desirable: Inspect Pump Assembly for Improper Fit.  
<3> Desirable: Replace Pump Bearings.

### DIAGNOSTICS:

<3> Moderate

#### Pump Roller Bearing Wear

0.044 (+2522%) in/s at 3.13xP on PUMP BEARING 3 Horizontal  
0.042 (+2368%) in/s at 16.9xP on PUMP BEARING 3 Axial  
0.032 (+1815%) in/s at 3.13xP on PUMP BEARING 3 Axial  
0.030 (+1682%) in/s at 16.9xP on PUMP BEARING 3 Horizontal  
0.025 (+1404%) in/s at 2.86xP on PUMP BEARING 3 Horizontal  
0.021 (+1221%) in/s at 15.0xP on PUMP BEARING 3 Horizontal  
0.017 (+ 981%) in/s at 12.7xP on PUMP BEARING 3 Axial  
0.012 (+ 690%) in/s at 3.13xP on PUMP BEARING 3 Vertical  
0.011 (+ 617%) in/s at 4.20xP on PUMP BEARING 3 Vertical  
0.007 (+ 395%) in/s at 16.9xP on PUMP BEARING 3 Vertical  
0.0061 (+ 348%) in/s at 12.3xP on PUMP BEARING 3 Vertical

<3> Moderate

#### Pump Shaft Looseness

0.38 (+2155%) in/s at 5.00xP on PUMP BEARING 3 Horizontal

# EADS Result with Confidence

**Example:  
Misdiagnosed  
electrical fault**

## Expert System Results

### Confidence 2

MID: 1106  
Averages: 8  
Report Generated: 10/18/2022 6:45:00 PM (UTC)  
Date Acquired: 10/4/2022 1:08:22 PM (UTC)

Machine Speed: 1777 RPM  
Rulebase: 20221123  
Figure of merit: 459

MID Completion = 90%: Needs Motor Bars  
Motor bearing diagnostic CONFIDENCE IS LOW with unknown number of Motor Bars  
Maximum level: 0.55 (+8330%) in/s at 44.0x on MOTOR BEARING 2 Axial

### RECOMMENDATIONS:

**<2> Important:** Replace Motor Bearings.

### DIAGNOSTICS:

**<2> Serious**

#### Motor Bearing Wear

0.55 (+2448%) in/s at 44.1xM on MOTOR BEARING 2 Axial  
0.45 (+1015%) in/s at 44.1xM on MOTOR BEARING 2 Vertical  
0.29 (+3341%) in/s at 44.1xM on MOTOR BEARING 2 Horizontal  
0.054 (+1368%) in/s at 40.1xM on MOTOR BEARING 2 Vertical  
0.050 (+2212%) in/s at 45.1xM on MOTOR BEARING 2 Axial  
0.025 (+1447%) in/s at 40.1xM on MOTOR BEARING 2 Horizontal  
0.012 (+ 520%) in/s at 3.11xM on MOTOR BEARING 2 Axial  
0.011 (+ 222%) in/s at 3.11xM on MOTOR BEARING 2 Vertical

**<4> Slight**

#### Pump Roller Bearing Wear

0.017 (+ 613%) in/s at 2.30xP on PUMP BEARING 3 Horizontal  
0.012 (+ 439%) in/s at 12.9xP on PUMP BEARING 3 Horizontal  
0.0096 (+ 166%) in/s at 11.7xP on PUMP BEARING 3 Vertical  
0.0094 (+ 193%) in/s at 11.4xP on PUMP BEARING 3 Axial  
0.009 (+ 671%) in/s at 6.45xP on PUMP BEARING 3 Vertical  
0.0081 (+ 226%) in/s at 3.44xP on PUMP BEARING 3 Axial

# Analysis - Automated Diagnostics

## Setup / Input

Asset Details

Install Sensors

Automated Learning



## Diagnostics / Output

Automated Review & Workflow

Analyst Assignment per SLA

Prioritized Actions & Alerting

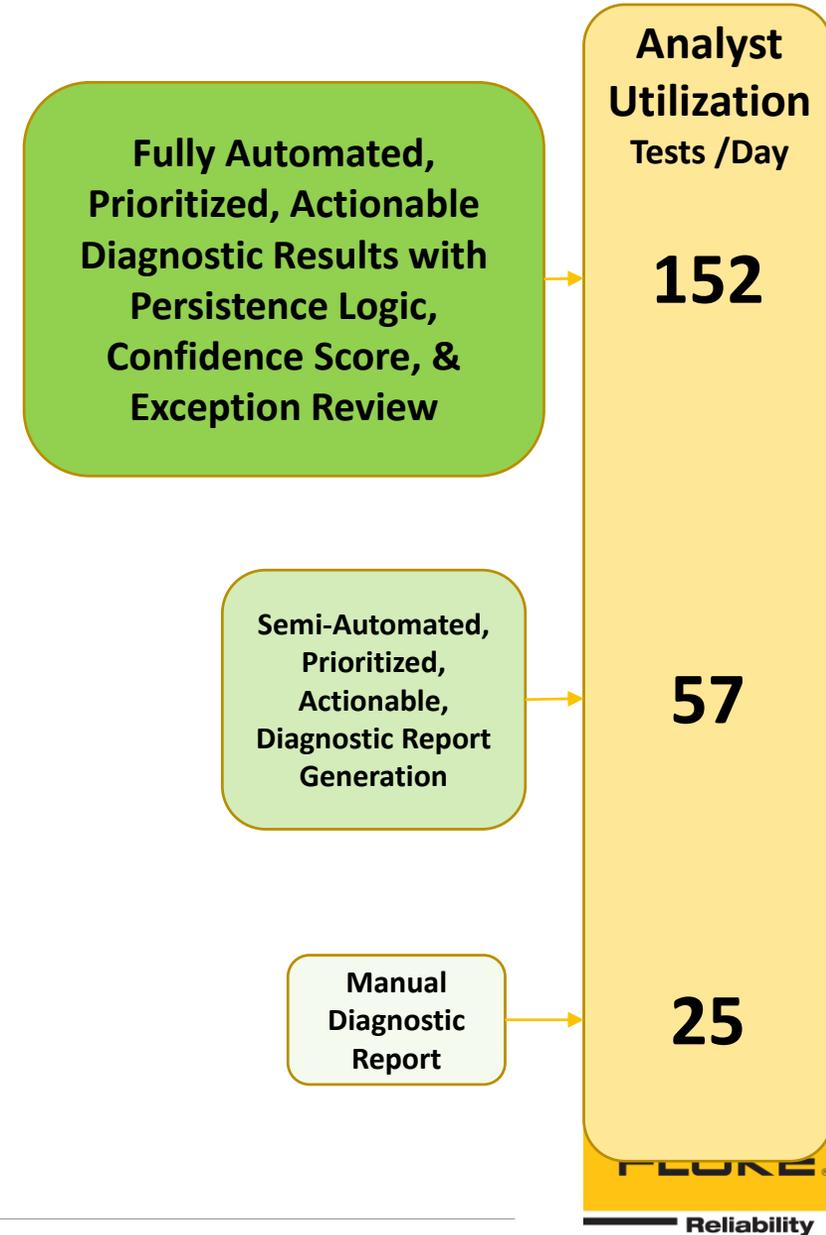
Asset Configuration for Expert Automation

- 6000+ Trained Diagnostic Rules
- 1200+ Fault Conditions
- Automated Baseline Averaging
- Automated Fault Code Finder
- Result Confidence Scoring
- Result Persistence Logic

Workflow Automation for Volumetric Analysis

# Watchman™ Analysis Services

- **~30 seasoned & certified analysts available**
  - Full – Priority Exceptions – Second Opinion – Setup & Coaching
- **Leverage VibeAI Tools, Completion Score**
  - Missing Fault Codes (PV, MB, CV, etc.)
  - Automated Baselineing
- **Volume Analysis Tools**
  - Automated Reviewing
  - Persistence Logic
- **Fault Confidence Level**
  - Results with Low – High Confidence
  - Feedback Loop, KPIs, Metrics
- **Assessment Reporting**
  - Bad Actors, Saves, ROI
  - Program recommendations



## 2023 WATCHMAN Machine Test Results



## 2023 WATCHMAN Machine Test Results by Platform



# What's Needed for Diagnostic Confidence?

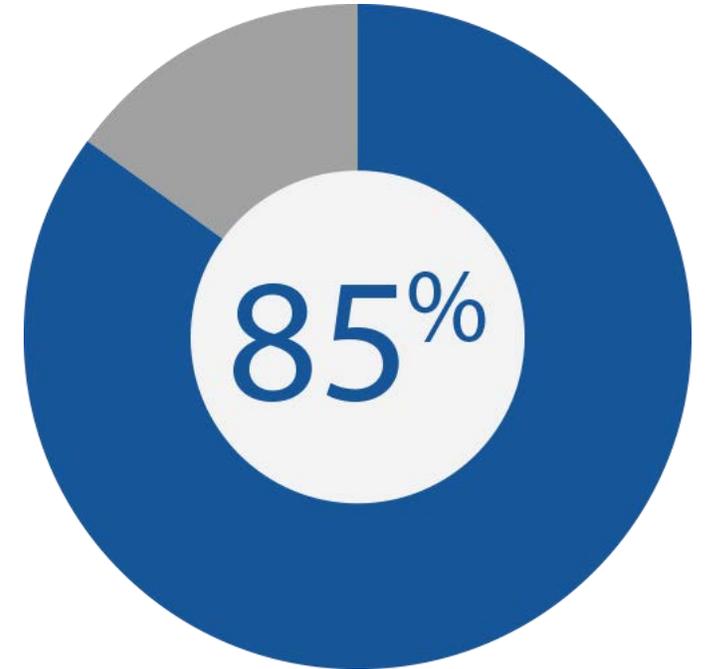
1. Machinery Information
2. Vibration Setup Parameters
3. Diagnostic Comparison Reference
4. Additional Contributing Factors
5. Diagnostic Historical Trends



# How do I complete my asset setup?

## • Asset template completion score

- Evaluate criteria based on component definitions
- Missing or unverified settings are identified
- Improve the statistical average baseline
- Templates can be locked once trained



Initial Setup

Fine Tuning

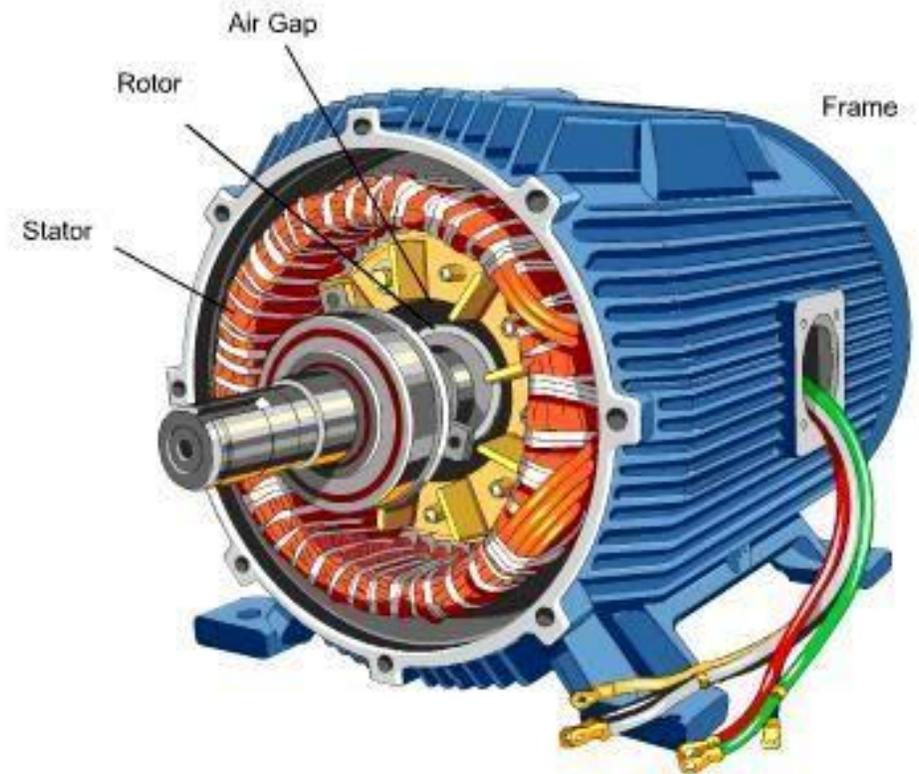
Certified Setup

# Vibration AI: Automated Fault Codes Examples

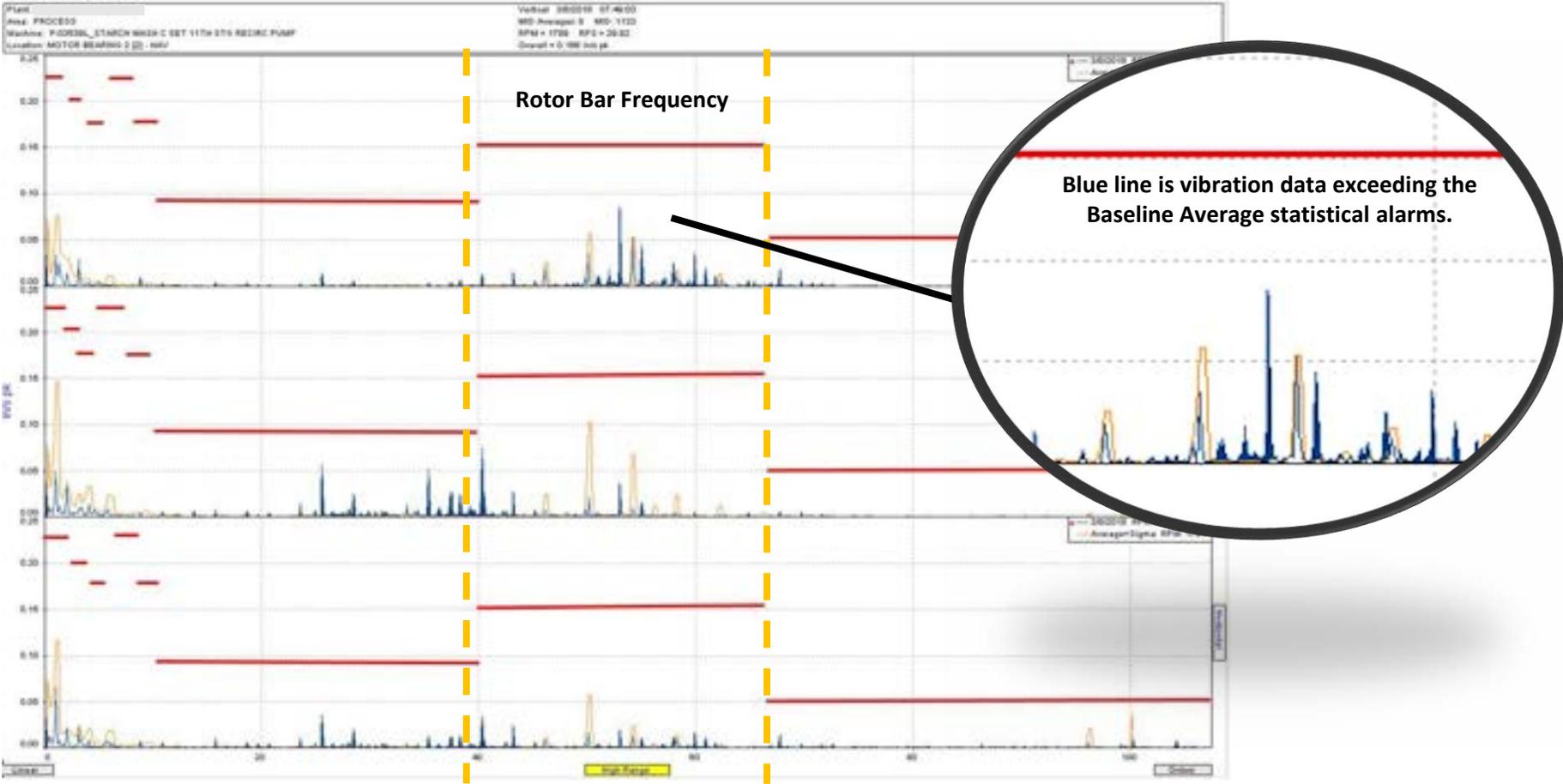
Identifies number of pump vanes



Identifies number of motor rotor bars

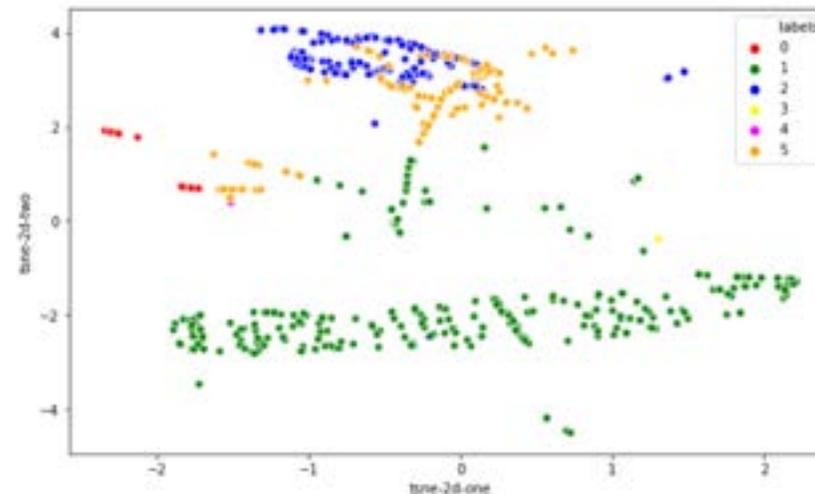
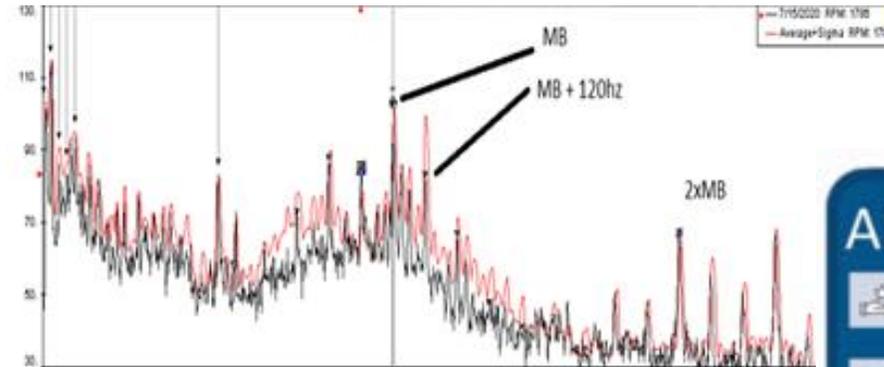


# Band Alarms at rotor bar frequency vs statistical Average Baseline



# AI to Achieve Autonomous Vibration

- AI for machine baselining
  - Find & synthesize baseline
  - Automatically find asset details
    - Motor bars, pump vanes, gear teeth, blade pass, transmission ratio, bearing tones, belt pass
- Unmanned Analysis
  - Feature Extraction from incoming data
  - Compare millions of historical tests
  - Presents diagnostics & prescription
  - User defined workflows and assignments



**APM Data 360**

- 81,000** unique assets
- 148,500** components such as motors, coupling, pumps, etc.
- 2,256,300** machine tests
- 127,632** component-specific faults
- 67 trillion** individual vibration data points

# Feedback to Improve Confidence

- Contributing Factors
- Historical Trends
- Confirmed finding feedback

### Close Alert

Reason\*  
Resolved

Recommended Action Correct?\*  
 Yes  No

Recommended Action Priority Correct?\*  
 Yes  No

Work Order Number  
Enter Work Order Number

Business Impact and/or Production Risk  
Business Impact: 7867567 \$ USD  
and/or Production Risk: Low Medium High

Correct Action Priority?  
MANDATORY DESIRABLE

+ Root Cause Analysis  
+ Action Taken  
+ Repair Completion Date

Cancel Close Alert

# Summary: Building Confidence

- **Determine criteria that defines faults**
  - Ensure complete asset profile
  - Establish proper statistical baseline representation
- **Confidence presented in automated diagnostics**
  - Fault frequencies are noted as AI-based or validated
  - Missing criteria is presented with score
  - Take applicable action





Thank you