Monitoring & Diagnostics of Power Plant Equipment

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Industry Overview

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# Existing Generation Plants Value Soaring . . .

- Plant Capacity

  - 20GW cancelled or withdrawn

  - 27GW proceeding

- Reliability may be at risk by mid-decade (NERC)

- Natural gas – is it the answer?

- Wind capacity

  - Difficult to launch new coal

  - Coal plants to cycle?

Availability of existing fossil plants is a top industry strategic priority

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Aging of Generation Assets

Exhibit 3
Breakdown of U.S. Coal-Fired Generation Capacity by Age
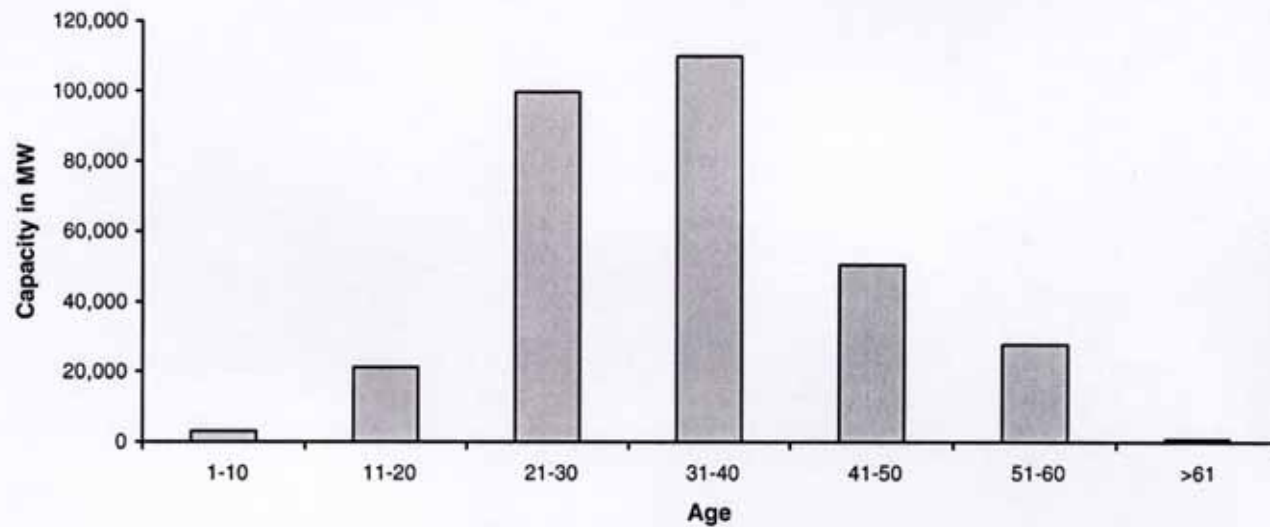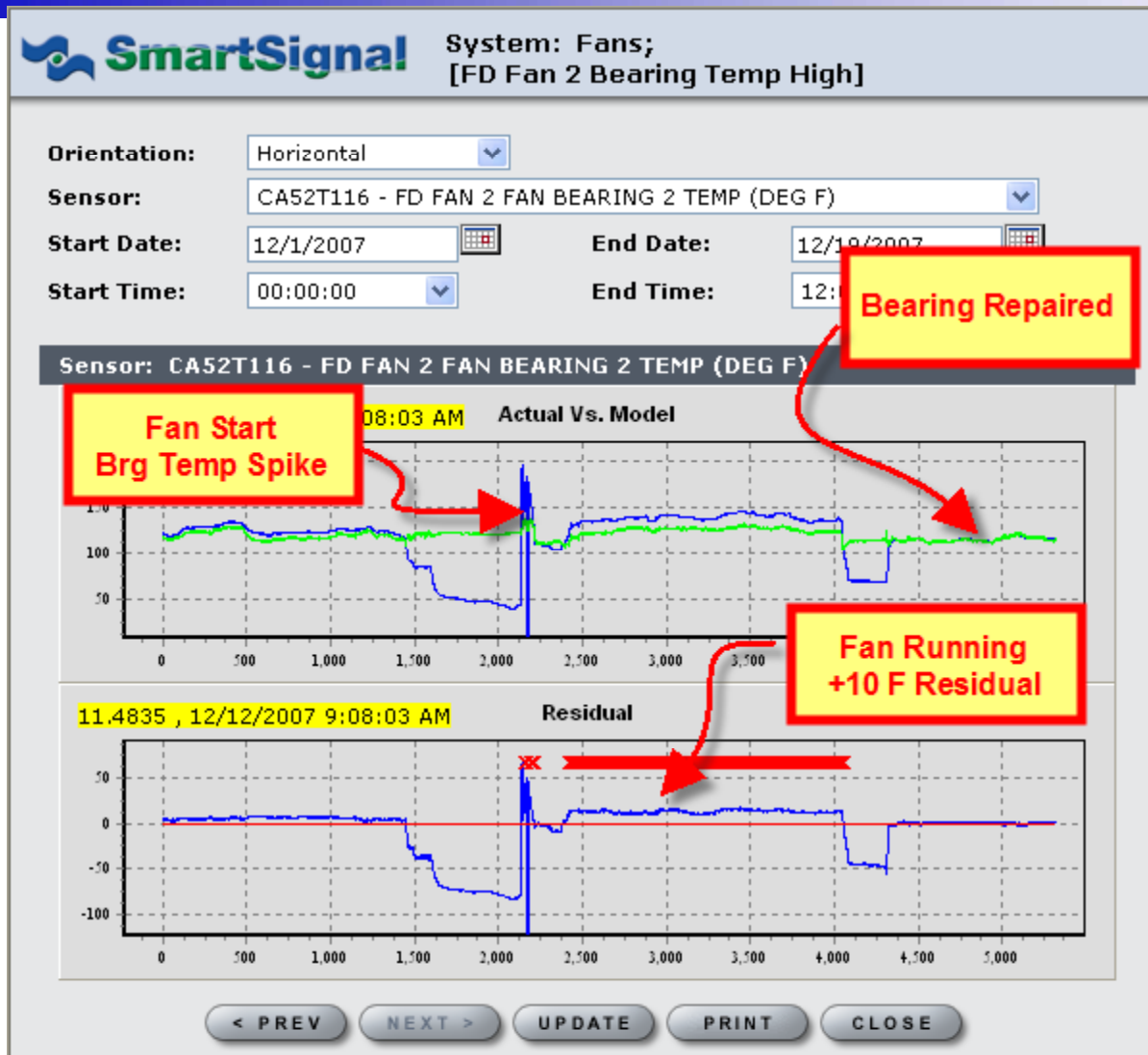
BernsteinResearch, U.S. Utilities: Which utilities are most at risk from pending plant retirements?
April 23, 2008

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Recent Equipment Failure

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Forced Draft (FD) Fan Bearing Failure

An oil sample was taken, but never submitted (too many visible pieces).

A quick vibration analysis was done and indicated a wiped bearing.

Parts were gathered, manpower scheduled, and the fan was scheduled out over for the weekend.

The bearing was replaced.

Bearing Damage

If not for the Condition-Based Maintenance (CBM) Vibration technologist, this would not have been acted on.

He believed there was a potential for a problem based on what was presented, and then confirmed the problem.

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Fleet-Wide Monitoring Centers

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Centralized Monitoring and Diagnostics (M&D) Strategy

- Main thrust is leveraging staff expertise, using technology for efficiency of monitoring, to detect and mitigate potential equipment failures

- Multi-disciplinary staffing with experienced operators, maintenance technicians, and engineers

- Information integration, including connection of plant data historians and enterprise asset management tools to central facility

- Brick-and-mortar facilities in a location central to monitored units

- Executive support for establishing an implementation plan and for communicating the need and benefit across the fleet

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Progress Energy M&D Centers

Carolina's

Fleet Wide Pattern recognition monitoring for Fossil, Combustion Turbine (CT), & Combined-Cycle (CC)
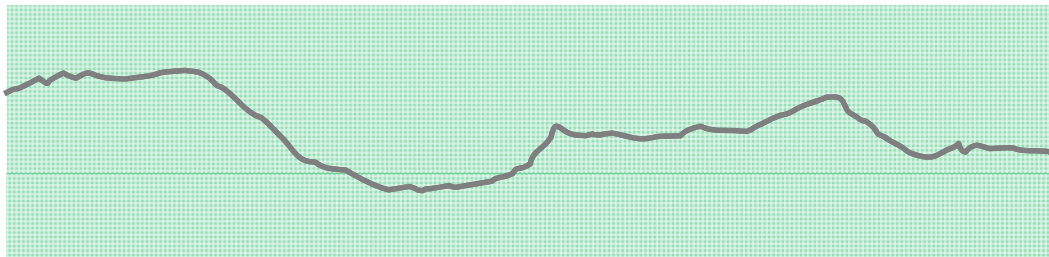
Nuclear & Transmission interested

Florida

Fleet Wide Thermal Performance monitoring for Fossil, CT, & CC

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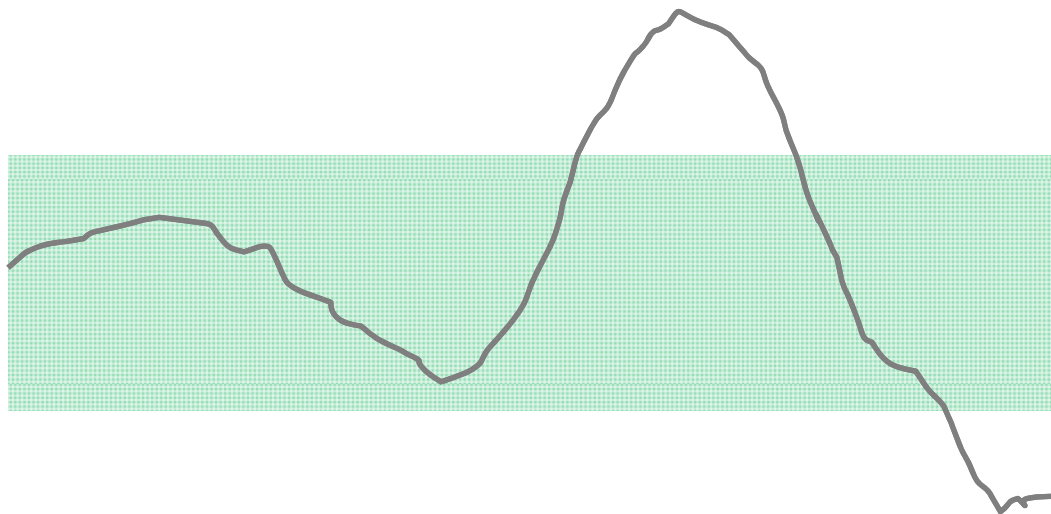
Online Monitoring Basics

Limit Checking

- Normal behavior has normal range

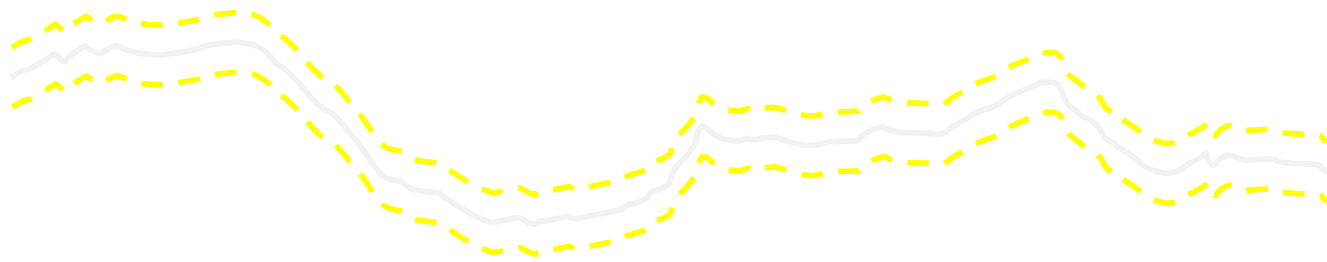

- Abnormal behavior **not** in normal range

- Limits detect unreasonable changes in data values or trends

- Limits might not be sensitive enough for many applications

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Prediction Models

- Predictors provide a **dynamic** reference

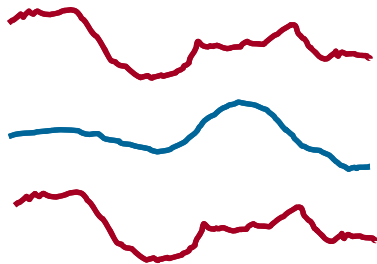- Predictors use **observed** values to infer **expected** values for normal behavior

Predictor

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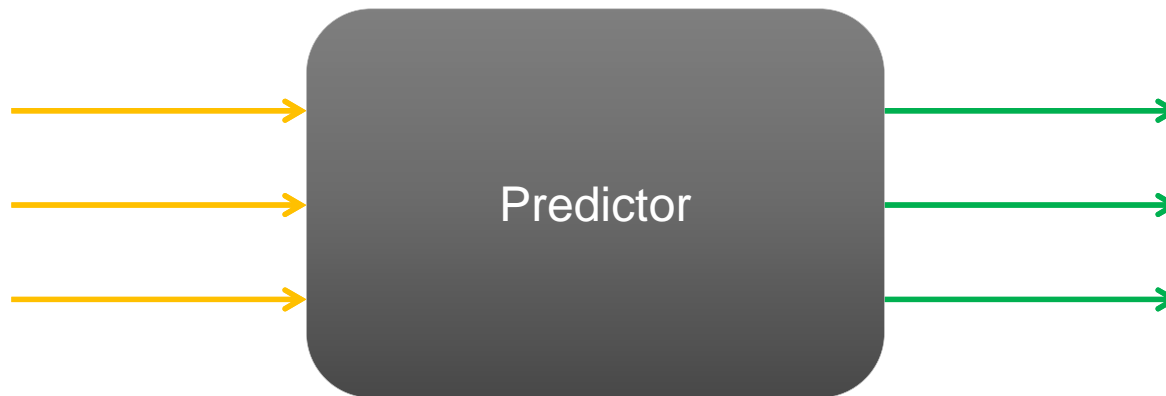
Using Predictors

- Train predictors using **normal** data
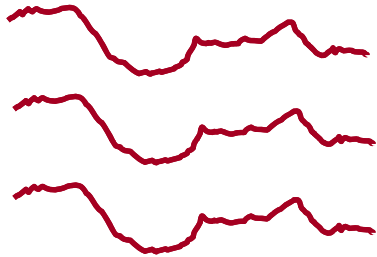
- Pass **corrupted** data to predictor to get **estimate** of un-corrupted values

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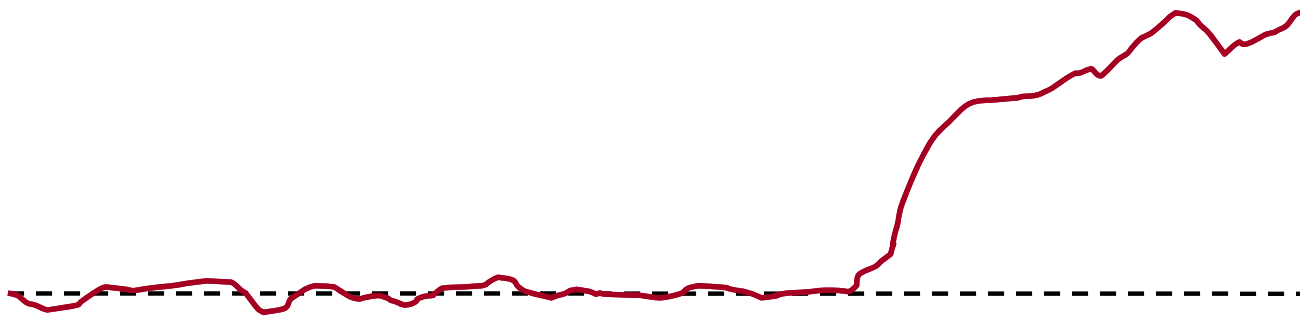
Using Predictors

- Predictor **estimates** follow the expected trend
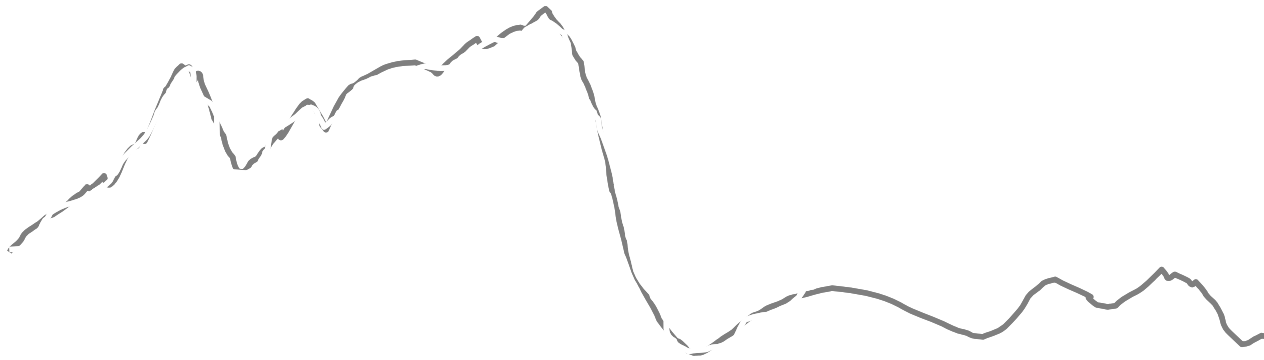
- The **difference** between actual and estimated values identifies the fault

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Prediction Model Examples

- **Univariate** Methods
  - Auto Regression (AR)

- **Multivariate** Methods
  - Multivariate State Estimation Technique (MSET)
  - Inductive Monitoring System (IMS)
  - Principal Component Analysis (PCA)

- **Redundant** Sensor Methods
  - Instrument Calibration Monitoring Program (ICMP)

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Principal Component Analysis

- **Transforms** data into a new coordinate system

- The **principal components** provide the new axes

- Good data will fall within a statistically determined distance from the principal component axes

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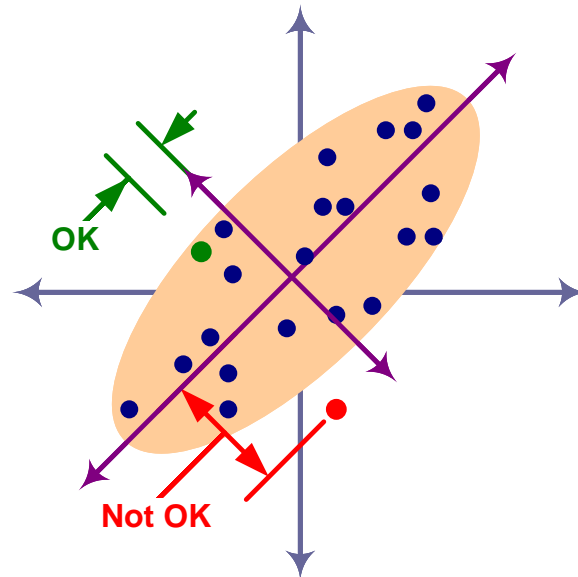
Instrument Calibration Monitoring Program

- Estimate is the **consistency weighted average** of three or more **redundant** signals
- Consistency parameters are derived from training data
- Inconsistent signals are **removed** from the average
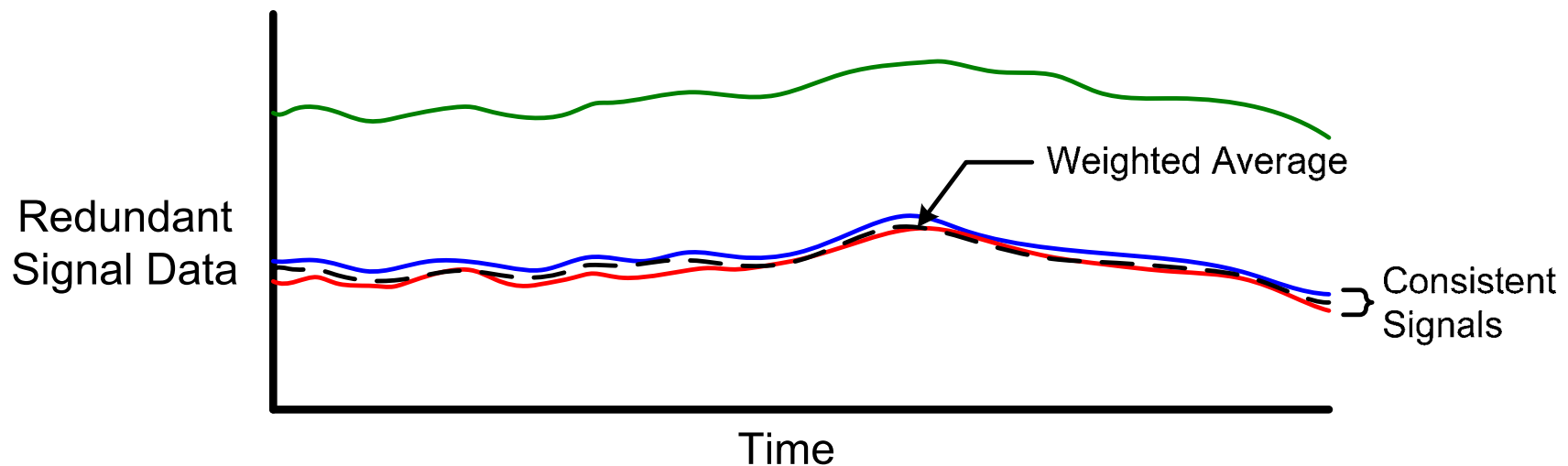
Fault Detection Examples

- Threshold Methods

  – Residual Value Limit

- Hypothesis Test Methods

  – Sequential Probability Ratio Test (SPRT)

- Statistical Process Control (SPC) Methods

  – Mean Test

  – Standard Deviation Test

  – Range Test

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Statistical Process Control

- Used to maintain processes within specific **control limits**

- Compares **sample** mean, standard deviation and range to the control limits to determine abnormal behavior

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Diagnostic Approaches

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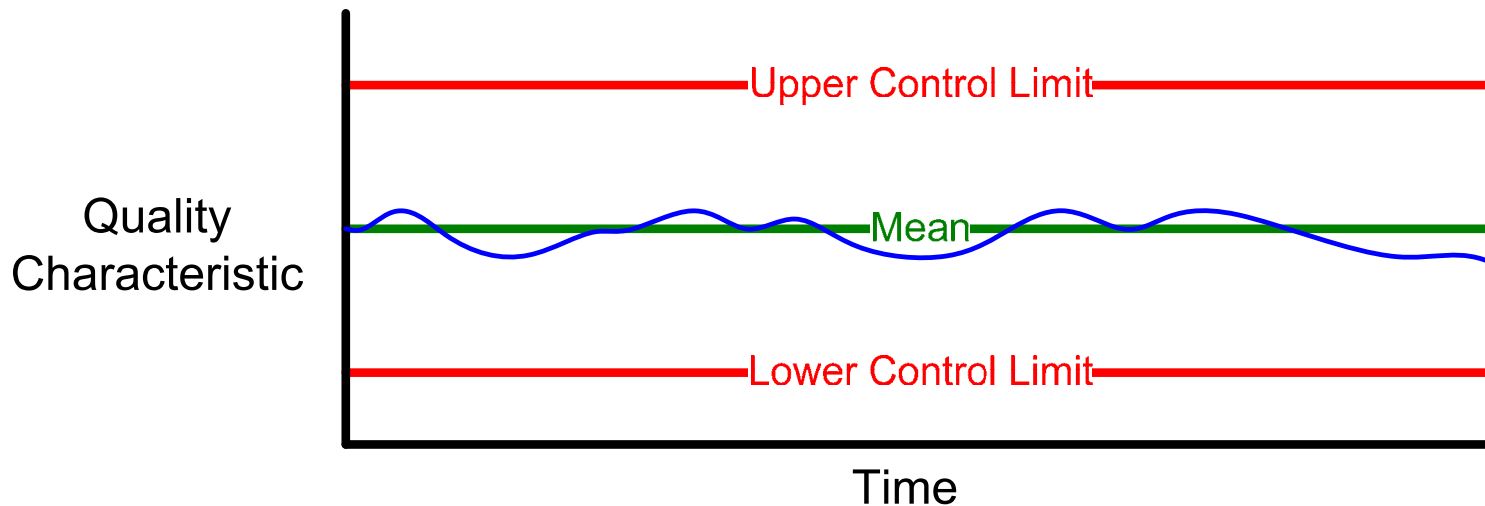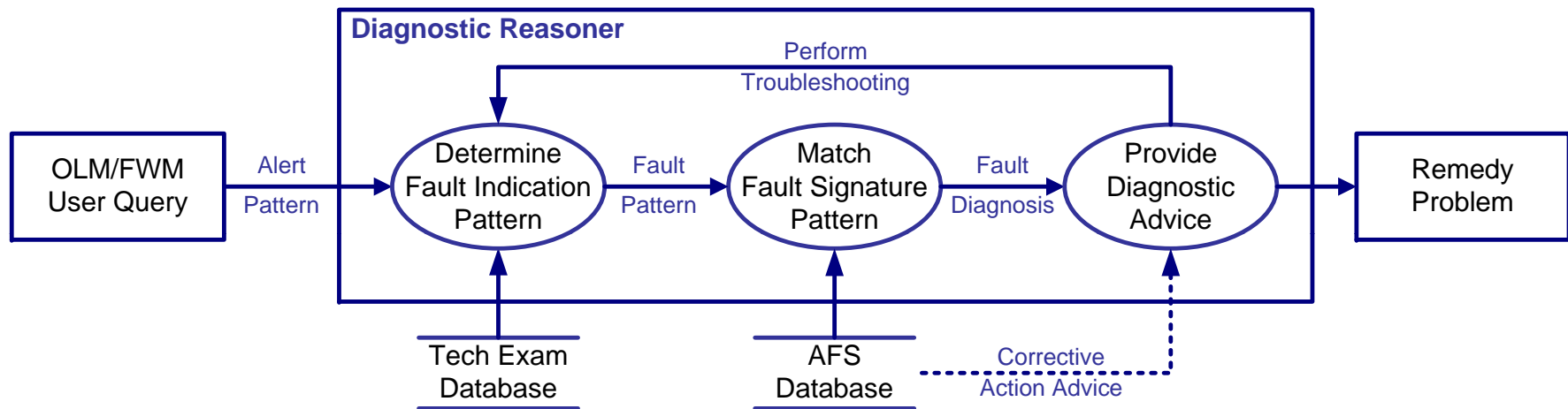
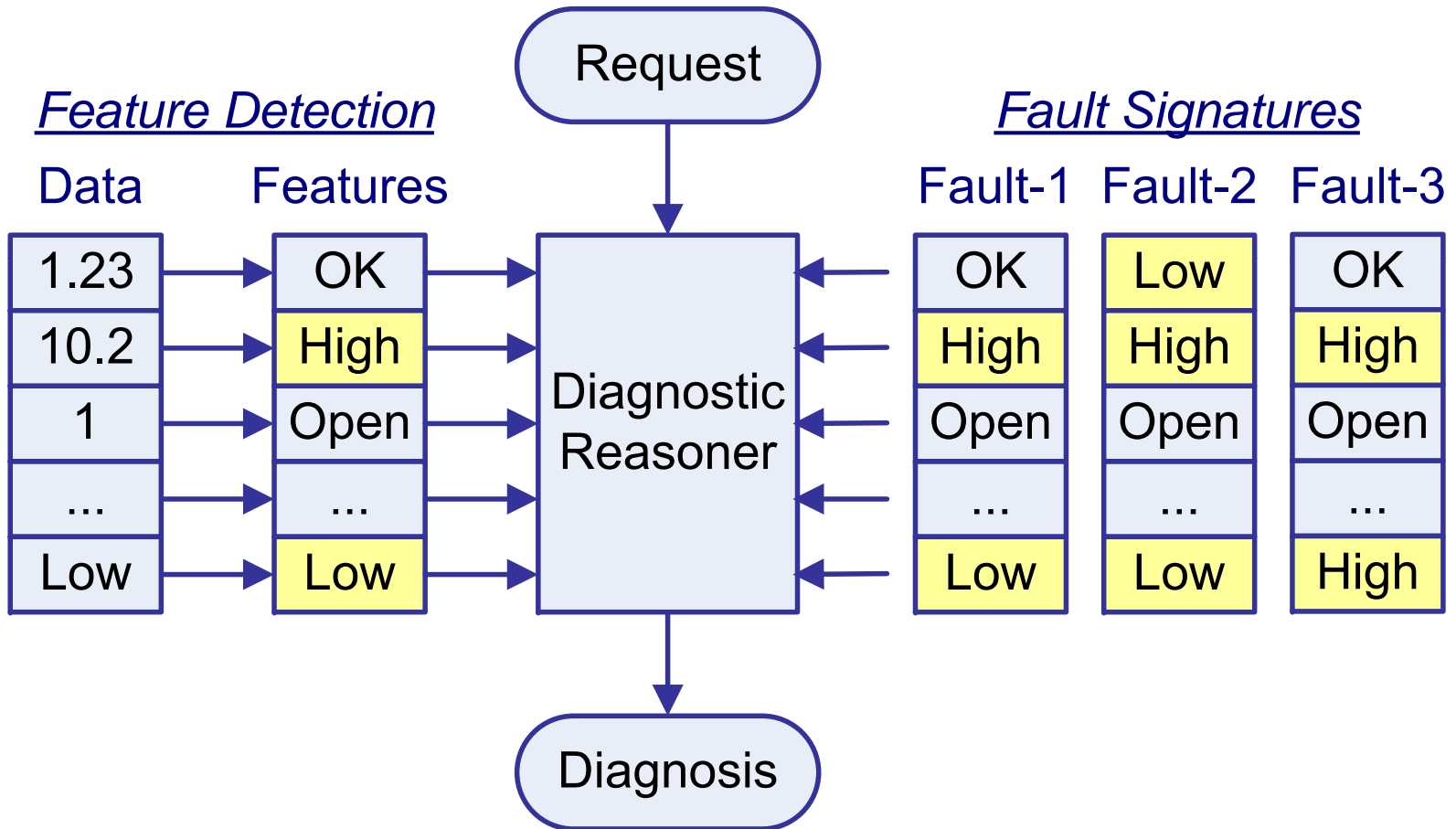# Example Use Case Scenario

- Online Monitoring/Fleet-Wide Monitoring (OLM/FWM) system alert pattern is observed

- Related data for asset are retrieved and a fault feature pattern is created

- Possible matching signatures are retrieved from the Asset Fault Signature (AFS) database and the best match is determined

- Diagnosis is presented, with optional troubleshooting and corrective action information

Diagnostic Advisor Function

Feature Detection

Data | Features

Data	Features
1.23	OK
10.2	High
1	Open
...	...
Low	Low

Request

Diagnostic Reasoner

Diagnosis

Fault Signatures

Fault-1	Fault-2	Fault-3
OK	Low	OK
High	High	High
Open	Open	Open
...	...	...
Low	Low	High

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Conclusion

- Aging power plant infrastructure must continue to supply reliable electricity

- Equipment must be monitored more closely to prevent failures from disrupting plant availability

- Online monitoring technology can be cost-effectively deployed using a fleet-wide approach

- Troubleshooting equipment faults requires practical diagnostic strategies that can reason with partial information

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Questions

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Backup Slides…

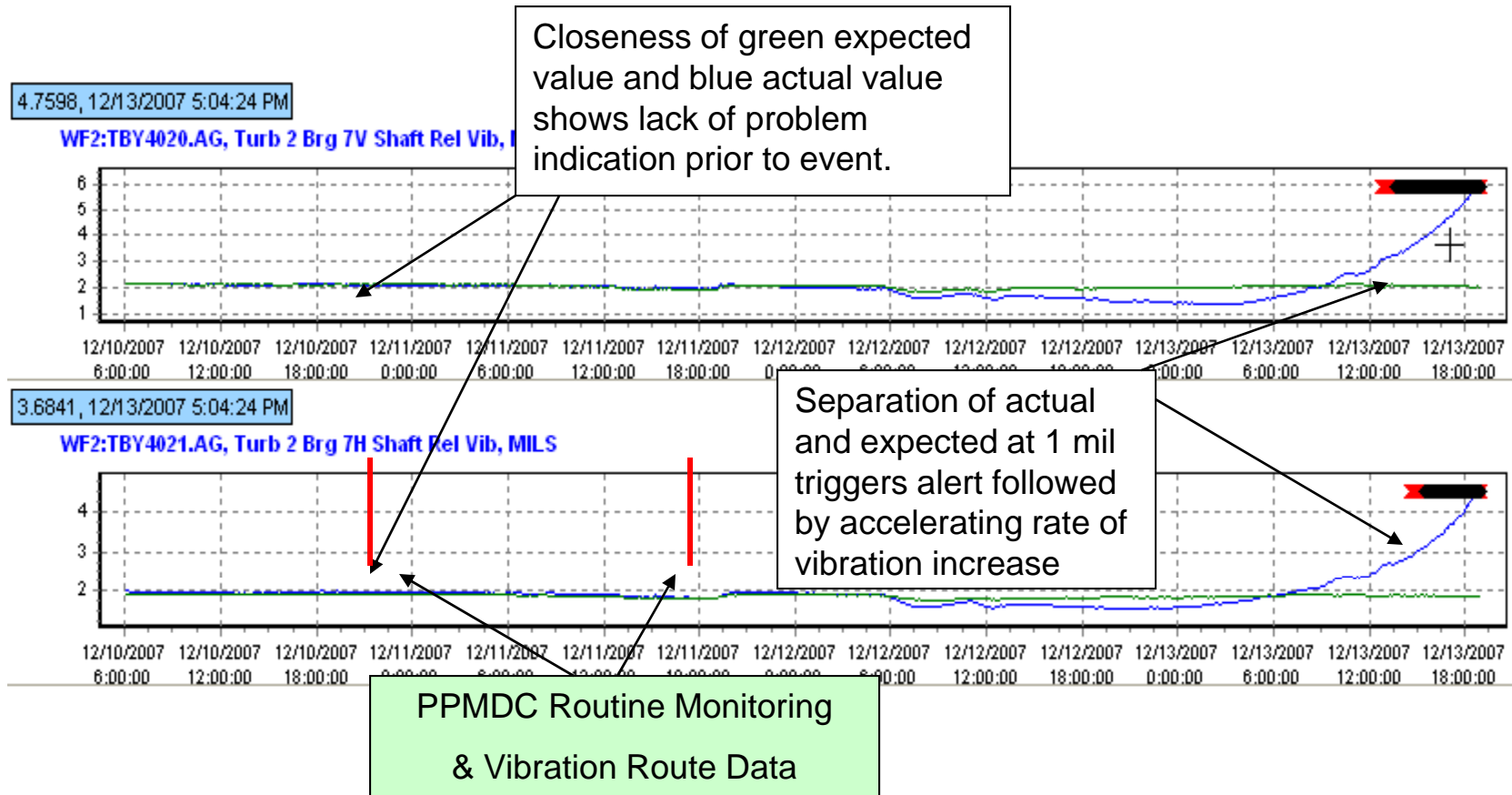EPRI | ELECTRIC POWER RESEARCH INSTITUTE

Generator Rotor Crack

- A few year's ago Entergy Fossil's Performance Monitoring & Diagnostic Center (PMDC) working with the Plant Staff averted a catastrophic failure of their unit generator

- The unit was repaired for a fraction of the $10's of millions the failure would have cost and in a few weeks versus 18-24 months or longer

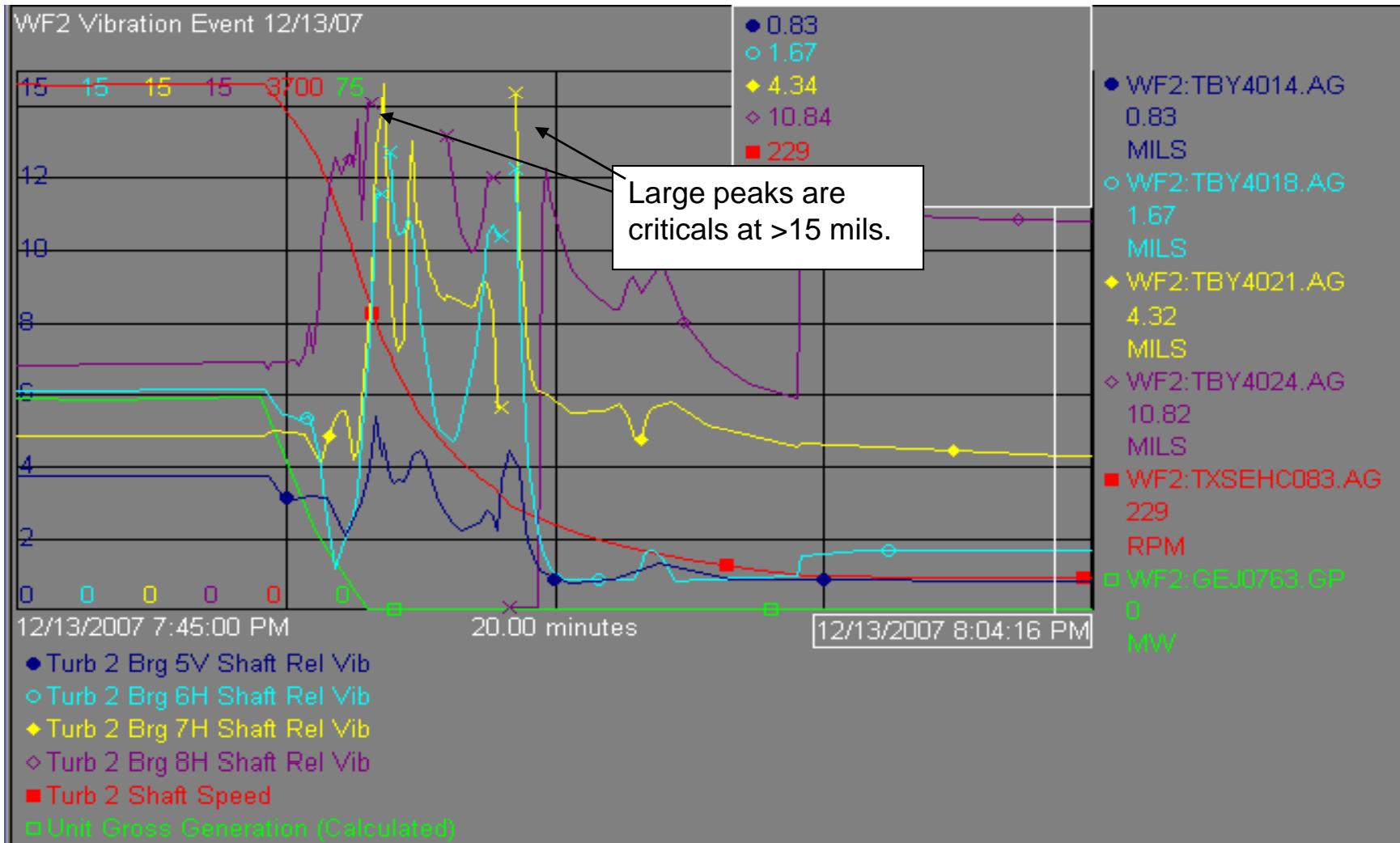EPRI | ELECTRIC POWER RESEARCH INSTITUTE

Prior to Event

- Routine Monitoring of unit was performed

- Included in the routine monitoring was an evaluation of the Turbine/Generator Assets utilizing the Smart Signal / EPI*Center tool and a review of PI data /OIS Displays

- The next slide is representative of the fact that no abnormalities were noted at that time

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SmartSignal Vibration Trend

Closeness of green expected value and blue actual value shows lack of problem indication prior to event.

Separation of actual and expected at 1 mil triggers alert followed by accelerating rate of vibration increase

PPMDC Routine Monitoring & Vibration Route Data

4.7598, 12/13/2007 5:04:24 PM
WF2:TBY4020.AG, Turb 2 Brg 7V Shaft Rel Vib,

3.6841, 12/13/2007 5:04:24 PM
WF2:TBY4021.AG, Turb 2 Brg 7H Shaft Rel Vib, MILS

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Vibration During Coastdown

Crack Location

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Rough Indication of Crack Depth

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Reasoner Tradeoff Study

Technology	When to Use	When Not to Use
Rule-based Model-based	Unambiguous, stable, and narrow problem area, and justification by rule trace is acceptable	*Ambiguous problem area that changes with time or has many operating modes*
Case-based	*Ambiguous problem area with complex structured data changing slowly with time, and justification is required*	When case data are not available or if an exact optimal answer is required
Neural networks	Noisy numerical data for pattern recognition or signal processing	*Categorical data or when justification is required*
Database lookup	Well-structured, standardized data, and simple, precise queries possible	Complex, poorly structured data, and *ambiguous queries required*

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Medical Diagnosis
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♂ male   ♀ female

Male Leg

Foot / Ankle
Foot / Ankle Pain and Swelling

Groin / Hip
Lumps in Groin
Hip Pain

Knee
Knee Pain and Swelling
Swelling / Pain - Back of Knee
Swelling and pain in one joint
Swelling and pain in many joints

Lower Leg
Calf Pain and Swelling
Are my bones weak
Dry skin
Itching With Rash Or Other Skin Changes
Itching With No Skin Changes
Shaking and tremor
Skin infections
Sunburn and aging of the skin

1

- sudden onset of severe pain in big toe
- pain usually begins at night
- red, tender, swollen toe
- most commonly occurs in men
- history of gout or kidney stones in family

Box Number 1

Possible Diseases
Click on a diagnosis below ▼

- Gout
- Pseudogout

Click on possible diagnoses for a brief summary.

Type of Doctor:

- Primary Care Physician
- Orthopedic Surgeon
- Podiatrist

Common Tests:

- metabolic panel
- x-ray of the involved joint

Importance:

- urgent testing and consultation

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