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Roadmapping Workshop on Measurement Science for Prognostics and Health Management of Smart Manufacturing Systems, Nov. 19/20, 2014

NIST
National Institute of Standards and Technology
U.S. Department of Commerce

Manufacturing Machinery PHM

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MFPT

Machinery Failure Prevention Technology Society
www.mfpt.org

TJW09P8

Machinery Maintenance Options

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- ***Preventive Maintenance***
  - ***"Change your oil every 6 months or 6000 miles"***
- ***Condition Monitoring with Condition-Based Maintenance***
  - ***Compare mostly raw data to limits, e.g. OEM or ISO, ANSI, SAE***
  - ***Can become a slice of the "Big Data" pie***
- ***Predictive Maintenance***
  - ***Requires some "analysis", often needs an expert***
- ***Prognostic/ Predictive Health Monitoring: PHM***
  - ***Diagnosis***
  - ***Prognosis***
  - ***If automated, provides critical info to a Plant's "Big Data" stream***

Author's PHM Experience

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- ***Engineering Society: MFPT, STLE, ASME PdM***
  - ***Consider MFPT's PHM meeting in Huntsville AL this coming May***
- ***DoD/ NASA/ Aerospace***
- ***Refineries/ Petrochemical***
- ***Paper Mills***
- ***Energy/ Power Plants (Fossil, Nuclear, Wind)***
- ***Rail (Rapid Transit Trains)***

PHM Needs/ Challenges/ Limits

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❖ Manufacturing PHM Greatest Needs:

- ***Real-time, On-line Monitoring with Actionable Info***
- ***Fabrication/ Machining Precision***
- ***Minimize Downtime***
- ***Minimize Operating & Maintenance (O&M) Costs***
- ***Minimize Energy Requirements***

❖ Greatest Challenges:

- ***Avoid "Too Much Info" (TMI)***
- ***No False Positives***
- ***ROI/ Cost Justification***

❖ Problematic Limits:

- ***Too Much "Human-in-the-Loop" Is Required!***
- ***Many vendors have over-promised: No "Street Cred"***

Methanol Plant Turbine Example

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- ***Background:***
  - Production is $250K/ day in high-demand season
  - The heart of the process is a centrifugal compressor string
  - There were two “strings”, one steam turbine driving each
- ***Problem:***
  - One of the two turbines was exhibiting very high vibration
  - The vibration strangely cycled up and down every 12 minutes
  - The turbine supplier wanted to shut the process down
  - The shut down for “blind repair” would be 6 weeks minimum
  - The Math: Over $5M of lost revenue in peak season!
  - Also: Missed shipments to contract customers (penalties)
- ***Solution:*** Vibration time & frequency data, interpreted by expert human-in-the-loop, determined cause, and predicted machine could keep running till peak season was over.
- ***Question: Can prognosis like this be reliably accomplished without expensive and over-worked experts?***

Options/ Opportunities/ Enablement

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- ***Typical Sensing Options:***
  - ***Vibration, Temperature, Lube Oil***
  - ***Overall Levels, Time, Frequency***
- ***Under-Used Sensing Opportunities:***
  - ***Motor Current: Time & Frequency Statistics***
  - ***Process Conditions! (e.g. Load, Pressure)***
- ***PHM as an Enabler:***
  - ***Vision 1:***

"Take a lickin', and keep on tickin' "
- Eliminate unexpected downtime
- No damaging failures

  - ***Vision 2:***

- Minimal scrap
- Reduced energy utilization

PHM Effects on Re-configurable Processes

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- ***Change (e.g. re-configuration) results in risk***
- ***PHM evaluates risk and predicts outcomes***
- ***PHM can provide real-time data on which machine to "count on":***
  - ***Is my "star running back" tool assigned to the upcoming tight-schedule high tolerance job?***

PHM Progress Over Time

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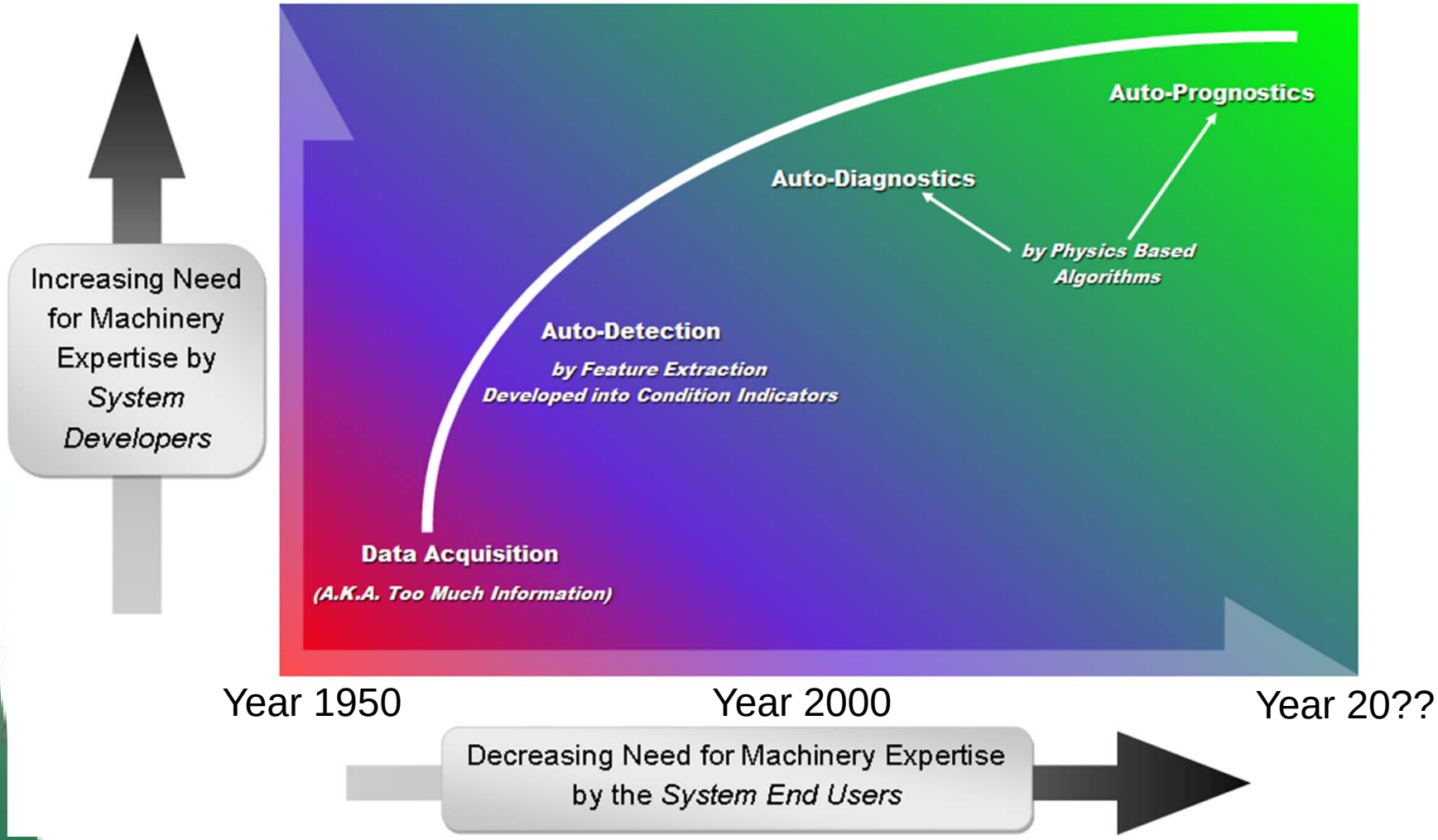

Pump and Compressor System Fault Trending/Diagnosis/Prognosis

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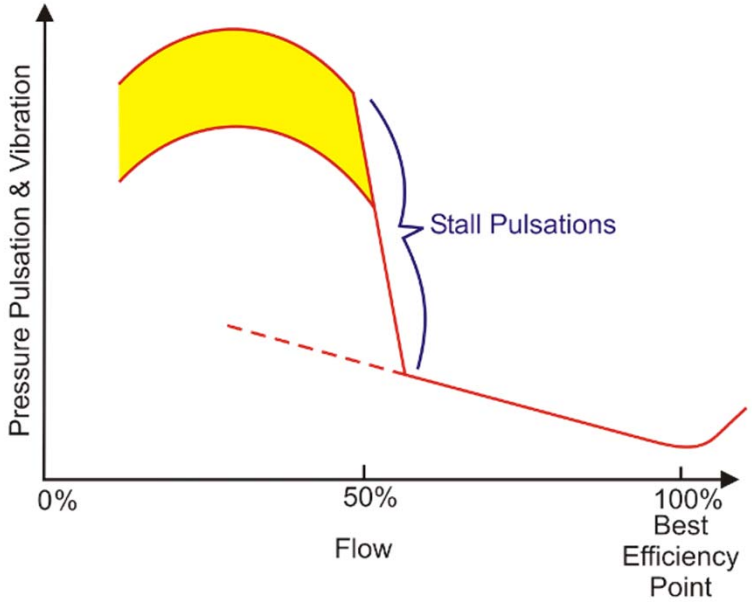
Typical Faults Addressed:

- Imbalance/Misalignment
- Running Off Design Point
- Fluid Issues: Recirc/Stall/Surge
- Pump Cavitation
- Vane Pass Issues: Obstructions
- Seal Damage
- Rolling Element Bearing Deterioration
- Journal Bearing Rub
- Oil Whirl/Whip
- Soft Foot (Loose Connection to Foundation)
- Casing and Foundation Structural Problems
- Motor Rotor Bar Cracked
- Motor Static/Dynamic Air Gap Eccentricity
- Gearbox Deterioration
- Belt Drive Misaligned or Damaged
- Rotor/ Casing Resonant Conditions
- Acoustic Resonance in Piping

Major Effect



Must "crank in" operating load at the time that measurements are made!

Example Physics-Based Evaluation: Rolling Element Bearing Fault Diagnosis

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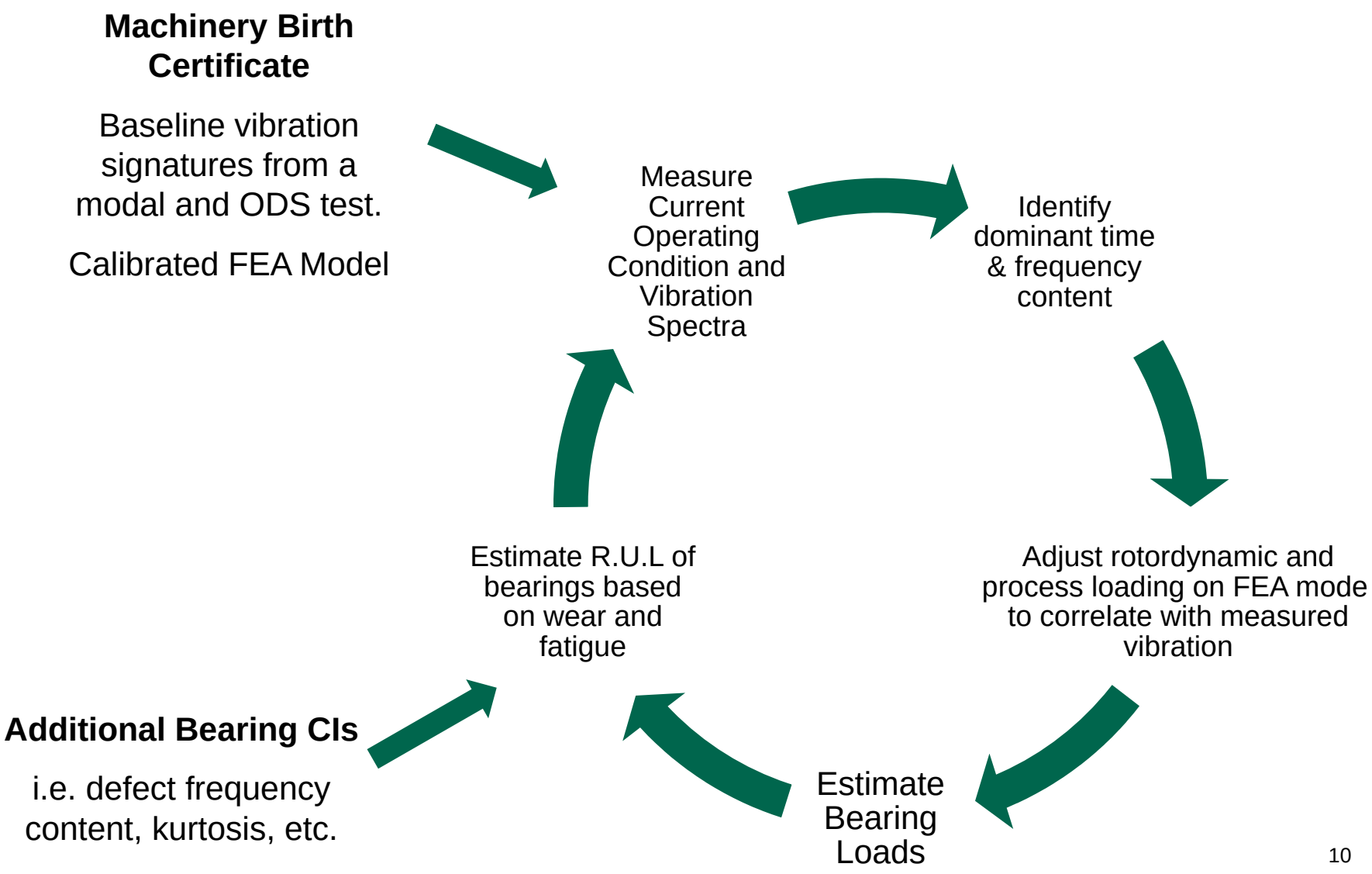

Automated PHM GUI Example: Pumps

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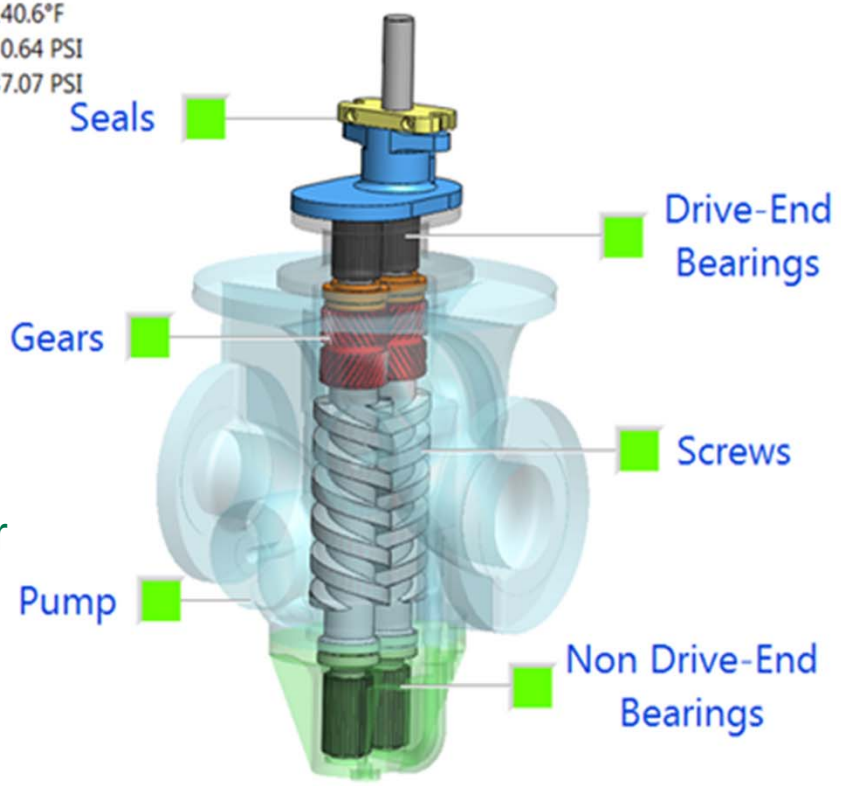
Pump Status

Running Speed:	1800.00 RPM
Motor Stator Temp:	140.6°F
DE Bearings Temp:	140.6°F
NDE Bearings Temp:	140.6°F
Suction Pressure:	10.64 PSI
Discharge Pressure:	37.07 PSI



Keys:

- Visual/ Graphical
- "Bottom Line" at a Glance
- Avoid T.M.I. !!
- Provide "drill-down" info for the experts
- Tie-in to "Big Data"

Final Thoughts

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- ***PHM is crucial for the competitive Lean Manufacturing of the 21st century***
- ***The less Humans-in-the-Loop, the better***
  - ***Advice available real-time***
  - ***Lower cost***
  - ***More consistent results***
  - ***"Too Much Info"? Bring it on!***
- ***Statistical data is a good start, BUT better crank in the machine physics for hi-fidelity PHM!***
- ***Monitoring & evaluation hardware/ software is now up to the task***