Best Practices in PHM and Application to Manufacturing

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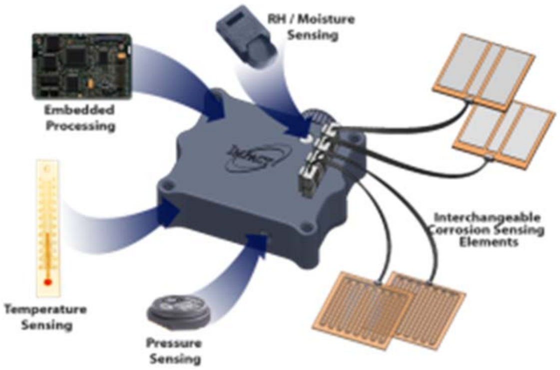
IMPACT CORE TECHNOLOGY AREAS

HARDWARE

Smart Embedded Monitoring Devices

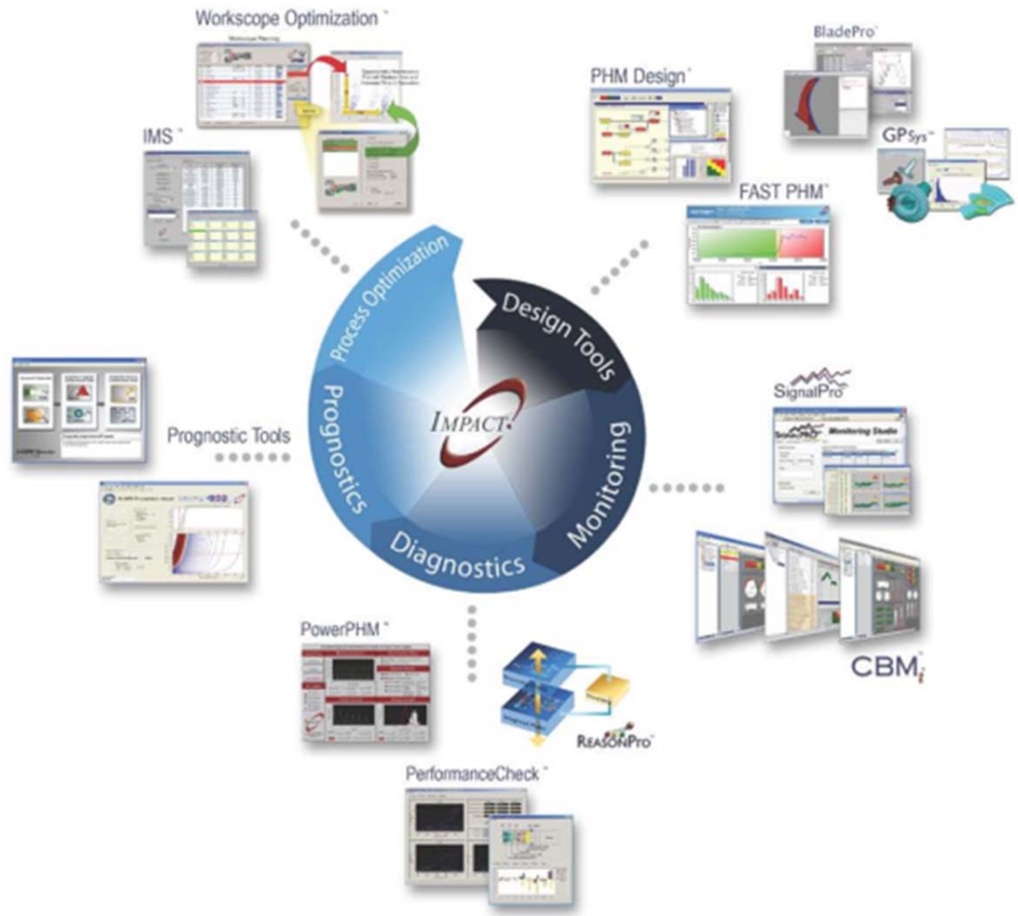


Wired/Wireless Data Collectors

Wireless Vibration Sensor

Fluid Condition and Debris Monitoring

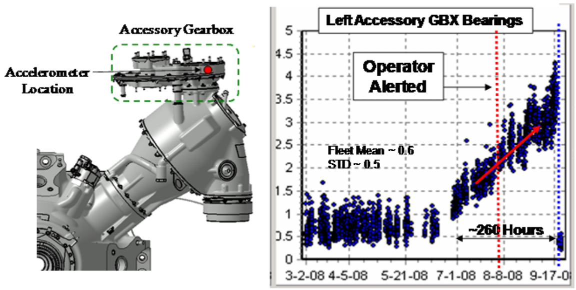
SOFTWARE



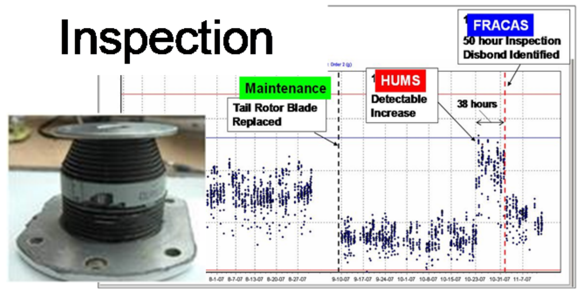
This Page Contains No Technical Data Controlled by the ITAR or EAR.

SOME EXAMPLE PHM SUCCESSES

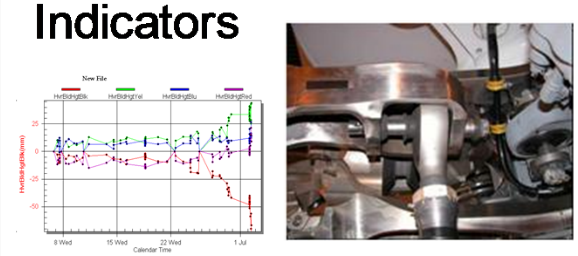
Health Alerts



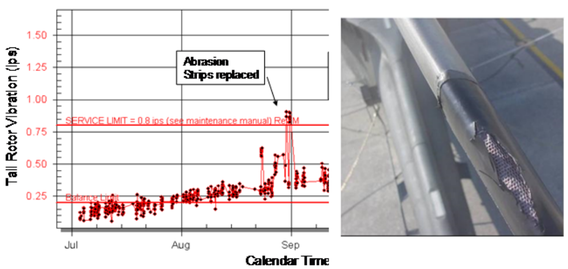
Data Driven Inspection



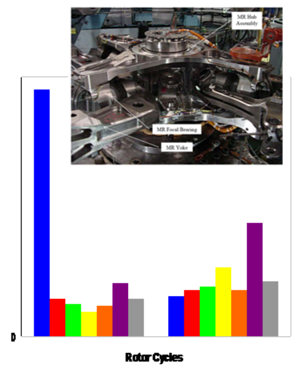
New Condition Indicators



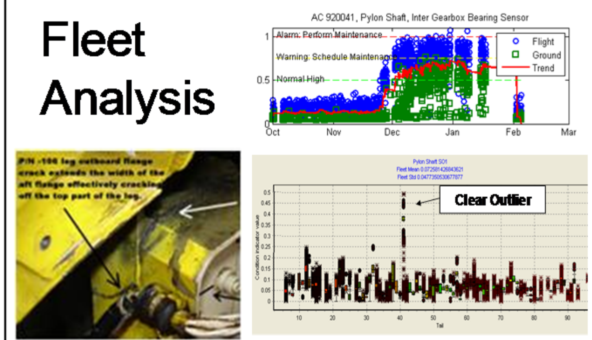
Maintenance Triggers



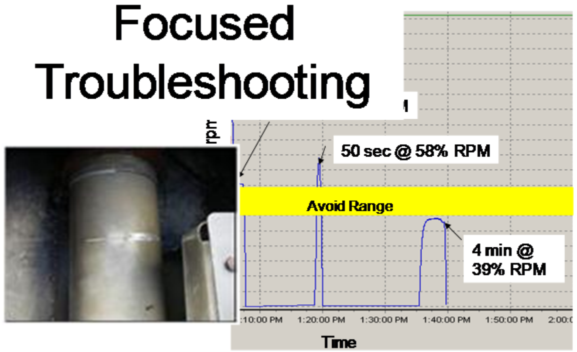
Component Retirement Adjustment S-92 MR Hub



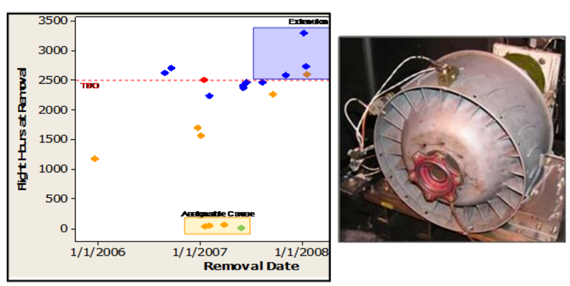
Fleet Analysis



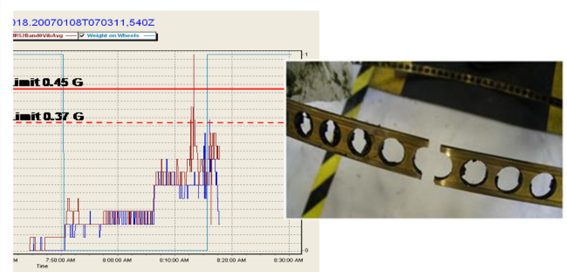
Focused Troubleshooting



TBO Extensions

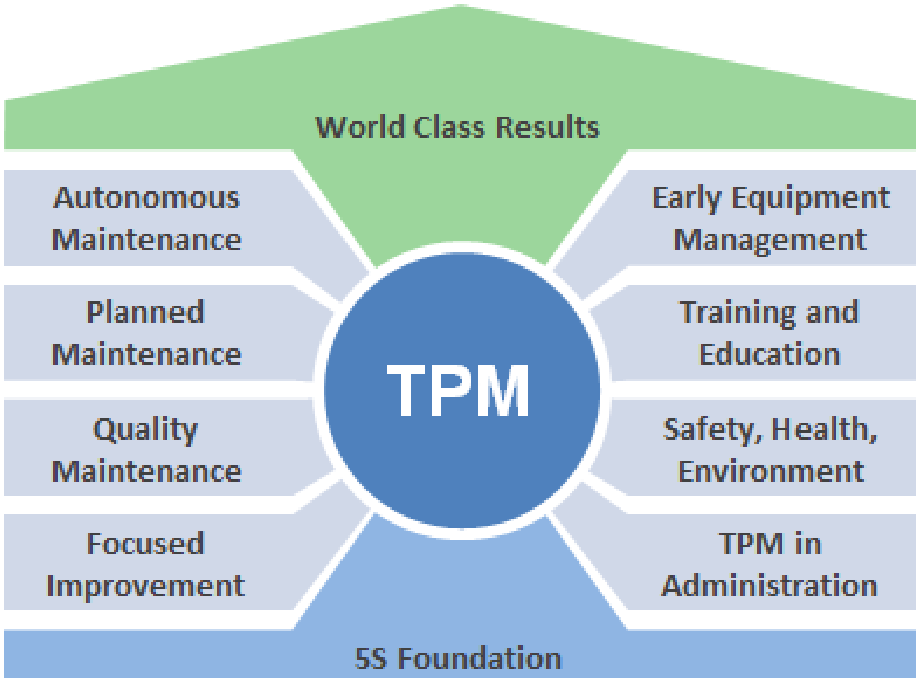


Anomaly Detection



Impact Technologies
A Sikorsky Innovations Company

TOTAL PRODUCTIVE MAINTENANCE



The 5S (or 6S) Foundation

- Sort (eliminate anything that is not truly needed in work area)
- Set in Order (organize remaining items)
- Shine (clean and inspect work area)
- Standardize (create standards for performing above three activities)
- Sustain (ensure the standards are regularly applied)
- Safety (Job 1)

Component	TPM Goal	Type of Productivity Loss
Availability	No Breakdowns	Availability takes into account **Down Time Loss**, which includes all events that stop planned production for an appreciable length of time (typically several minutes or longer).
Performance	No Small Stops or Slow Running	Performance takes into account **Speed Loss**, which includes all factors that cause production to operate at less than the maximum possible speed when running.
Quality	No Defects	Quality takes into account **Quality Loss**, which factors out manufactured pieces that do not meet quality standards, including pieces that require rework.
Overall Equip. Effective. (OEE)	Perfect Production	OEE takes into account all losses (Down Time Loss, Speed Loss, and Quality Loss), resulting in a measure of truly productive manufacturing time. >85% considered WC

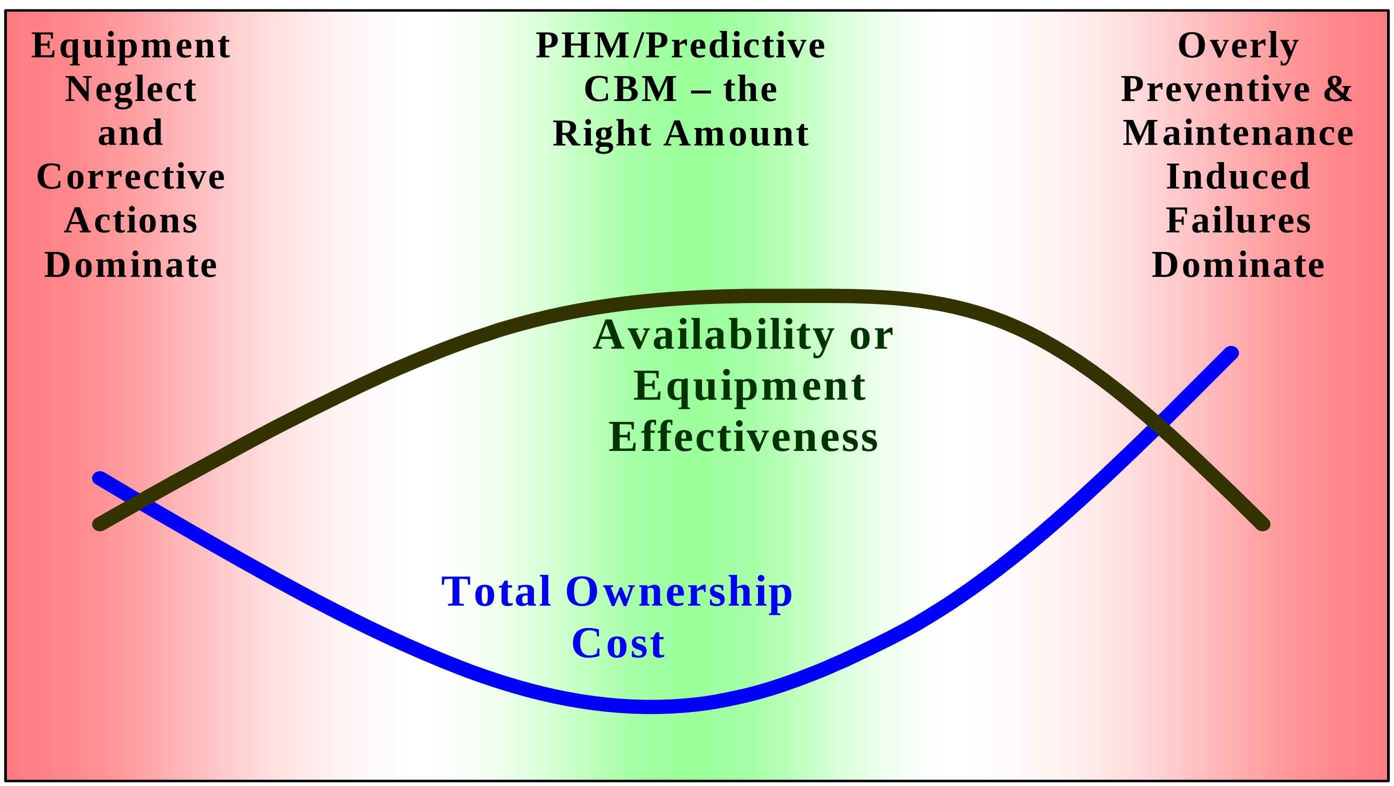
OVERALL EQUIPMENT EFFECTIVENESS

Six Big Losses	OEE Category	Examples	Comments
Breakdowns	Down Time Loss	•Tooling Failure •Unplanned Maintenance •Bearing/Motor Failure	There is flexibility on where to set the threshold between a Breakdown (Down Time Loss) and a Small Stop (Speed Loss).
Setup and Adjustments	Down Time Loss	•Setup/Changeover •Material Shortage •Operator Shortage •Adjustments/Warm-Up	This loss is often addressed through setup time reduction programs such as SMED (Single-Minute Exchange of Die).
Small Stops	Speed Loss	•Component Jam •Minor Adjustment •Sensor Blocked •Delivery Blocked •Cleaning/Checking	Typically only includes stops that are less than five minutes and that do not require maintenance personnel.
Slow Running	Speed Loss	•Incorrect Setting •Equipment Wear •Alignment Problem	Anything that keeps the equipment from running at its theoretical maximum speed.
Startup Defects	Quality Loss	•Scrap •Rework	Rejects during warm-up, startup or other early production.
Production Defects	Quality Loss	•Scrap •Rework	Rejects during steady-state production.

OEE = (Good Pieces x Ideal Cycle Time) / Planned Production Time

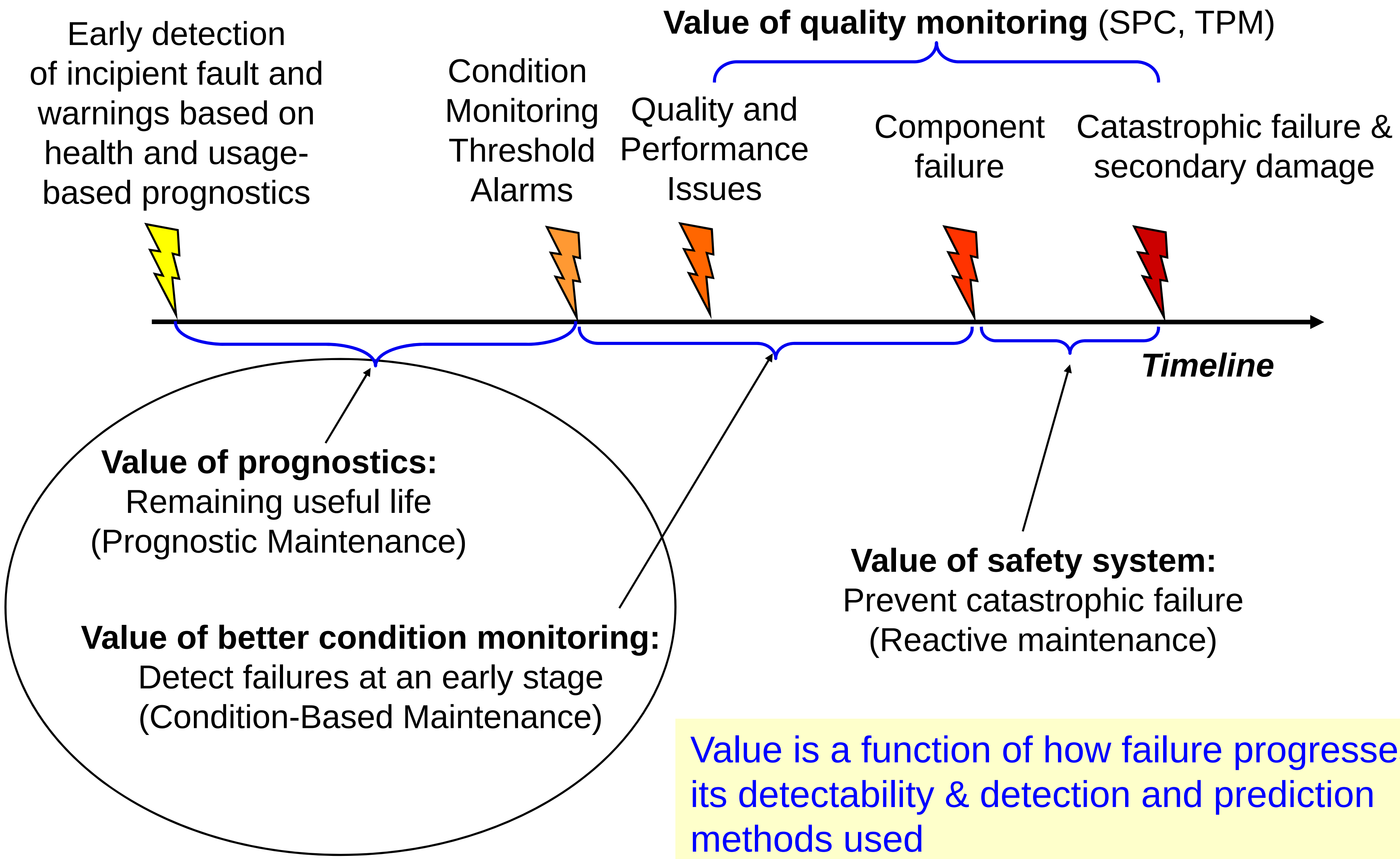
COMPARING PHM/CBM WITH OTHER APPROACHES

Corrective Maintenance | **Condition-based Maintenance** | **Preventive Maintenance**



Number of Maintenance Actions →

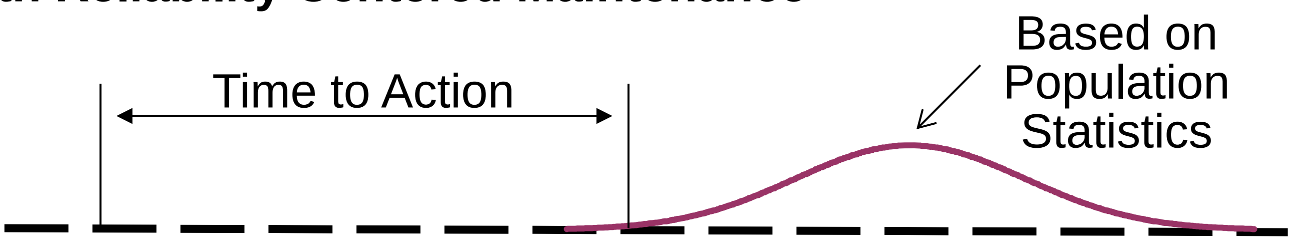
VALUE OF PROGNOSTICS & CONDITION MONITORING



Value is a function of how failure progresses, its detectability & detection and prediction methods used

PROGNOSIS AND CBM

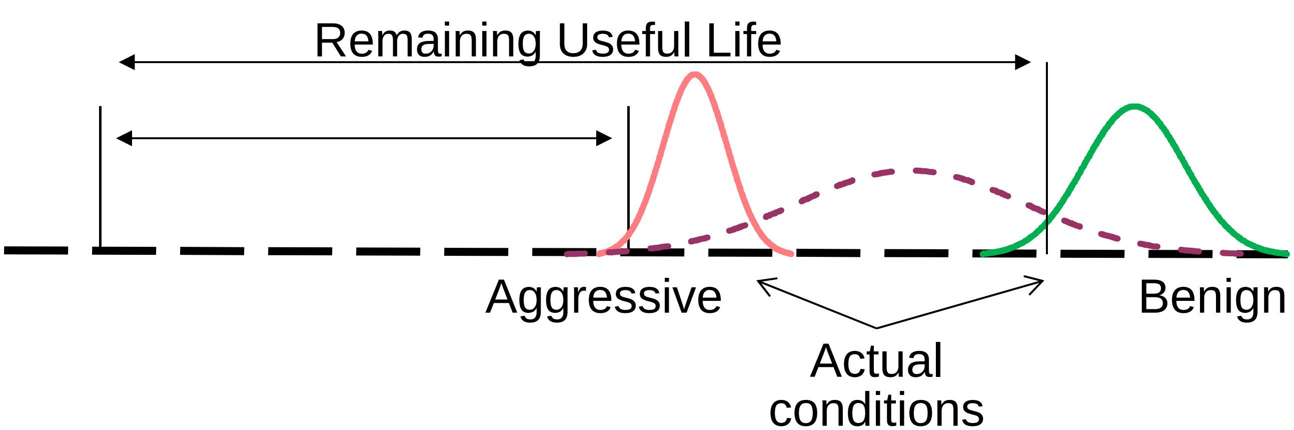
With Reliability Centered Maintenance



Results in:

Scheduled preventative maintenance

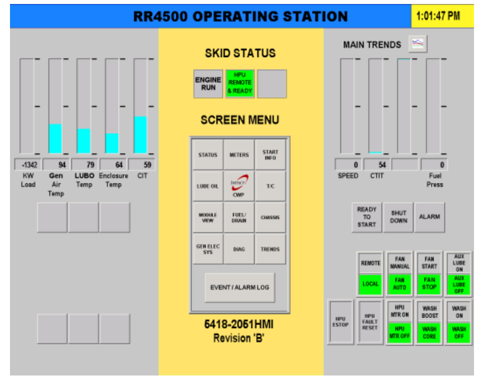
With Condition-Based Maintenance + Prognostics (CBM+)



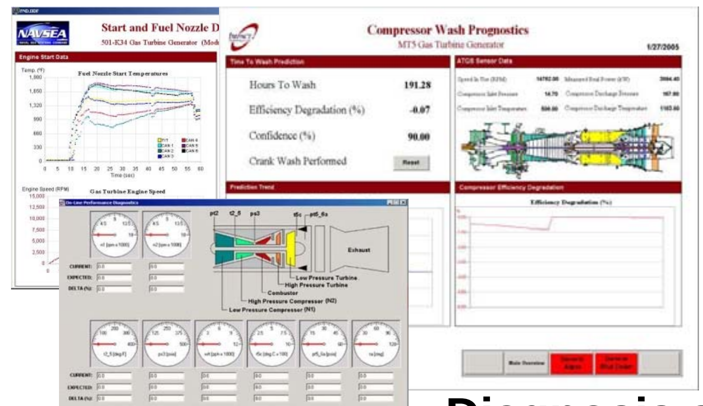
Results in:

Opportunistic maintenance at no additional risk

ELEMENTS OF A CBM SOLUTION

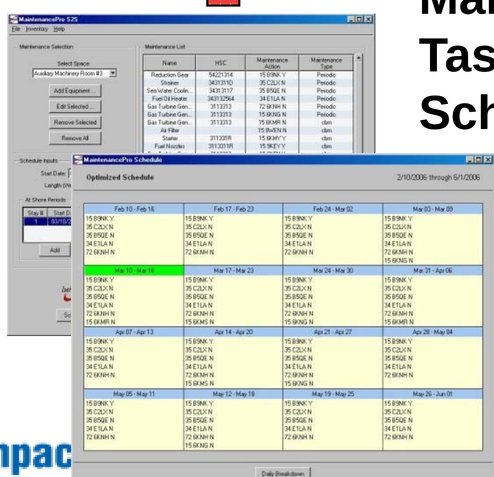


Monitoring and Anomaly Detection

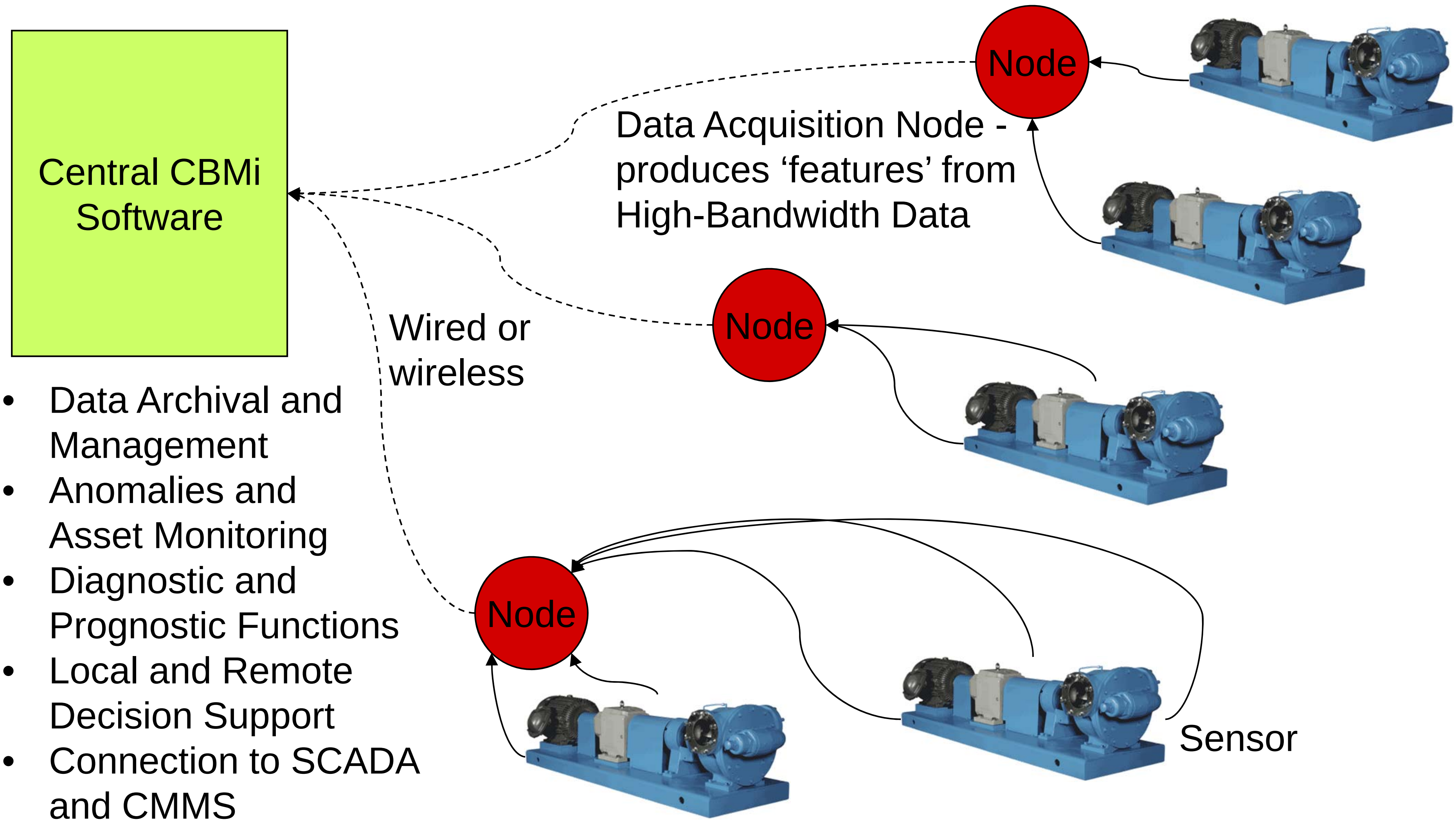


Diagnosis and Prognosis

Maintenance Tasking and Scheduling



A DISTRIBUTED ARCHITECTURE



- Data Archival and Management
- Anomalies and Asset Monitoring
- Diagnostic and Prognostic Functions
- Local and Remote Decision Support
- Connection to SCADA and CMMS

GENERAL PROGNOSTICS CLASSES/APPROACHES

Usage-based Prognostics

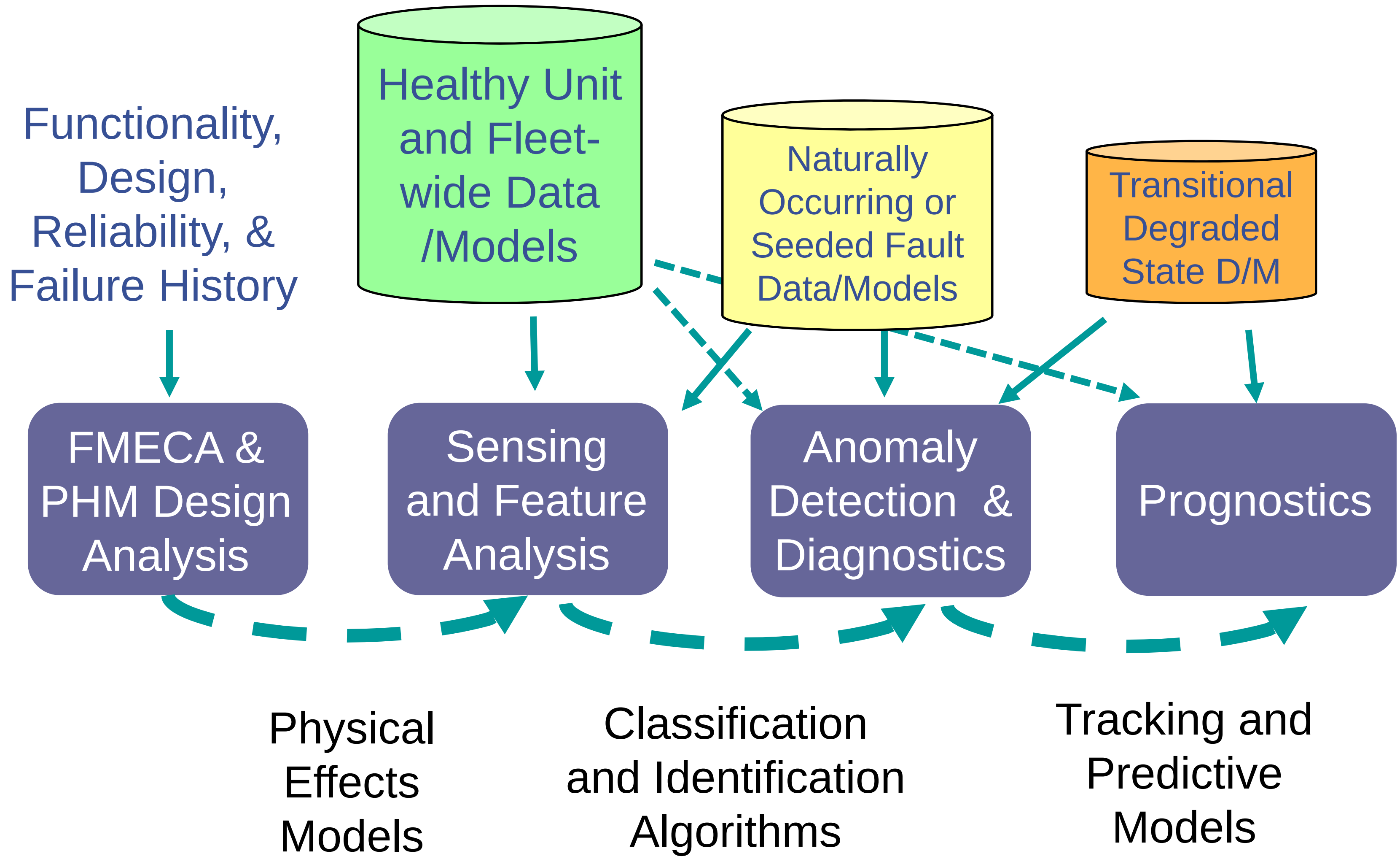
This approach incorporates reliability data, life usage models and varying degrees of measured or proxy data. Forecast based on actual usage when possible. Incipient fault detection may not be available due to sensor or fault mode coverage limitations.

Condition (Health)-based Prognostics

This approach involves utilizing the assessed health or diagnostic fault classifier output to predict a failure evolution. Feature trending or physics-of-failure based prediction may then be used. Incipient fault detection and diagnostic isolation is absolutely necessary.

*Hybrid techniques or fusion approaches may also be used.

DETECTION THROUGH PROGNOSTICS



MAN-PHM SUMMARY AND CHALLENGES

- Typical manufacturing environments have rich data potential to develop greater prognostics using usage, health, and hybrid modeling approaches
- A wide range of prognostic approaches is available with selection depending upon available system information and data quality
- Predicting future events is difficult and the accuracy is highly influenced by multiple sources of uncertainty making a probabilistic approach vital
  - Signal noise, operating modes, actual effective usage capture
  - Condition indicators not fully characterized for failure mode identification
  - Tracking of design life / wear / damage progression
  - Uncertainty in data, system parameters, models, etc.
  - Insufficient data, case studies, diagnostic/prognostic validation
- Combining both physics of failure and health based approaches often aid in managing these limitations and uncertainties
- Goal is to reduce unscheduled maintenance to “near zero” and minimize scheduled maintenance to “truly” on-condition to produce highest uptime at lowest overall maintenance cost
- Translate these capabilities to key manufacturing metrics such as OEE (Overall Equipment Effectiveness) and possibly others?