INTELLIGENT TOOLS FOR COMBUSTION TURBINE HEALTH MONITORING

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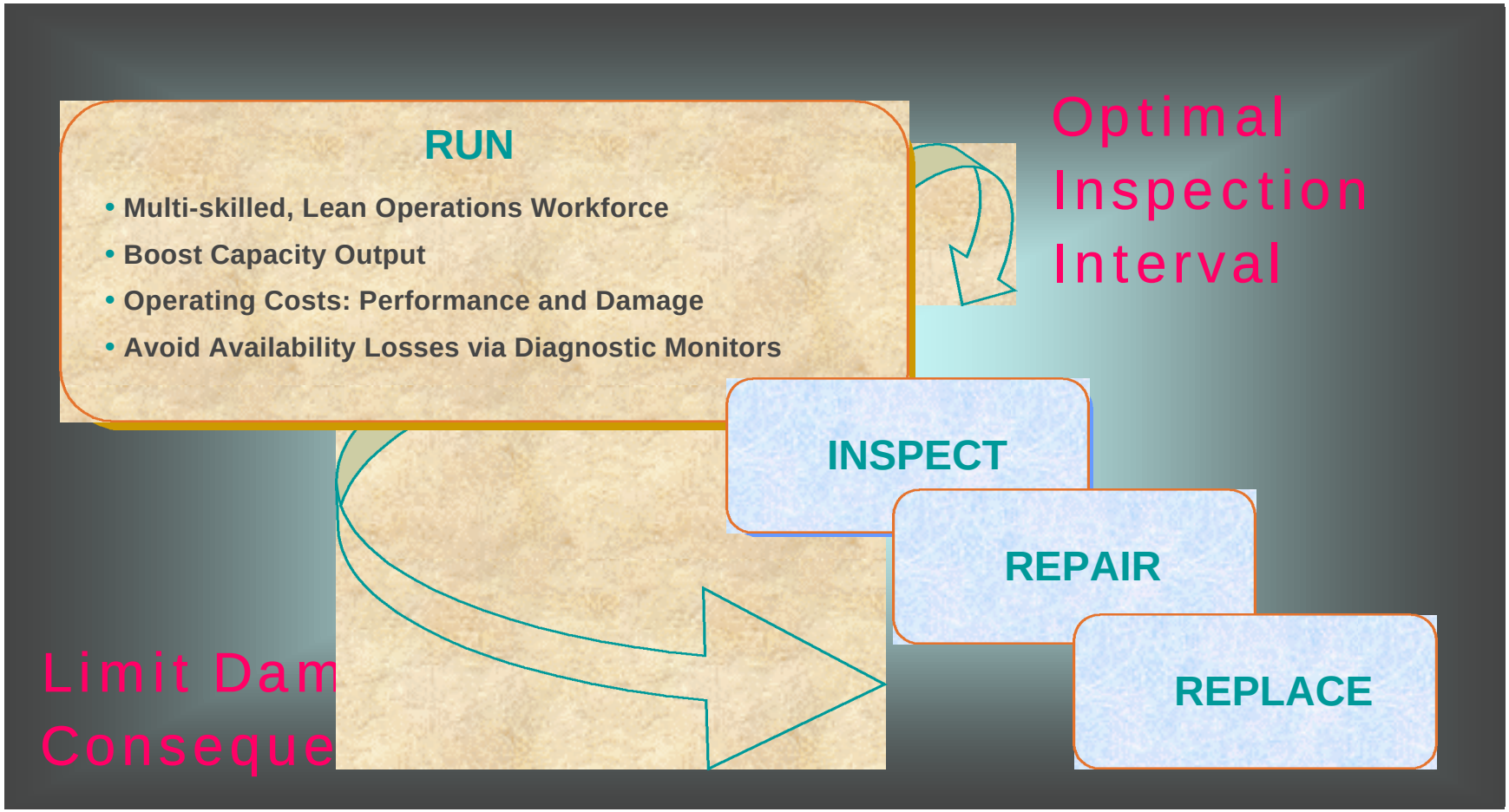
EPRI

Presentation Summary

- Program plan for advanced CT/CC health management
- Primary Equipment (CT, ST and HRSG)
  - ➢ Intelligent software tools for CT health monitoring and assessment
    - ✓Signal processing & model-based sensor validation
    - ✓Fault detection/isolation and diagnosis
    - ✓"Hot section" damage assessment
- Balance of Plant (BOP)
  - ➢ PlantView automation tool for BOP monitoring and assessment of CT/CC plants

CT Life Management Solution



Unmet Needs for Monitoring

- **Limited diagnostic capability.**
- **Often require the assistance of expert interpretation, which devalues their effectiveness as mainstay production tools.**
- **On- line monitoring of component life to allow assessment of when forced-shutdown might occur.**
- **On- line indication of component degradation to alert operators to failures that could propagate through the unit.**
- **On- line risk assessment of extending the outage to determine whether it is possible to operate for extended periods.**

EPRI/DOE CT Diagnostic Health Monitoring Program

- Combustion Turbine (CT)/Combined Cycle (CC) Diagnostic Health Monitoring
- $ 1.6 Million
- 3 years starting October 1, 2001
- EPRI, Impact Technologies, Boyce Consultancy, and Progress Energy (CP&L)
- Leonard Angello, EPRI Project Manager
- Norm Holcombe, DOE Manager

Description of the Technology

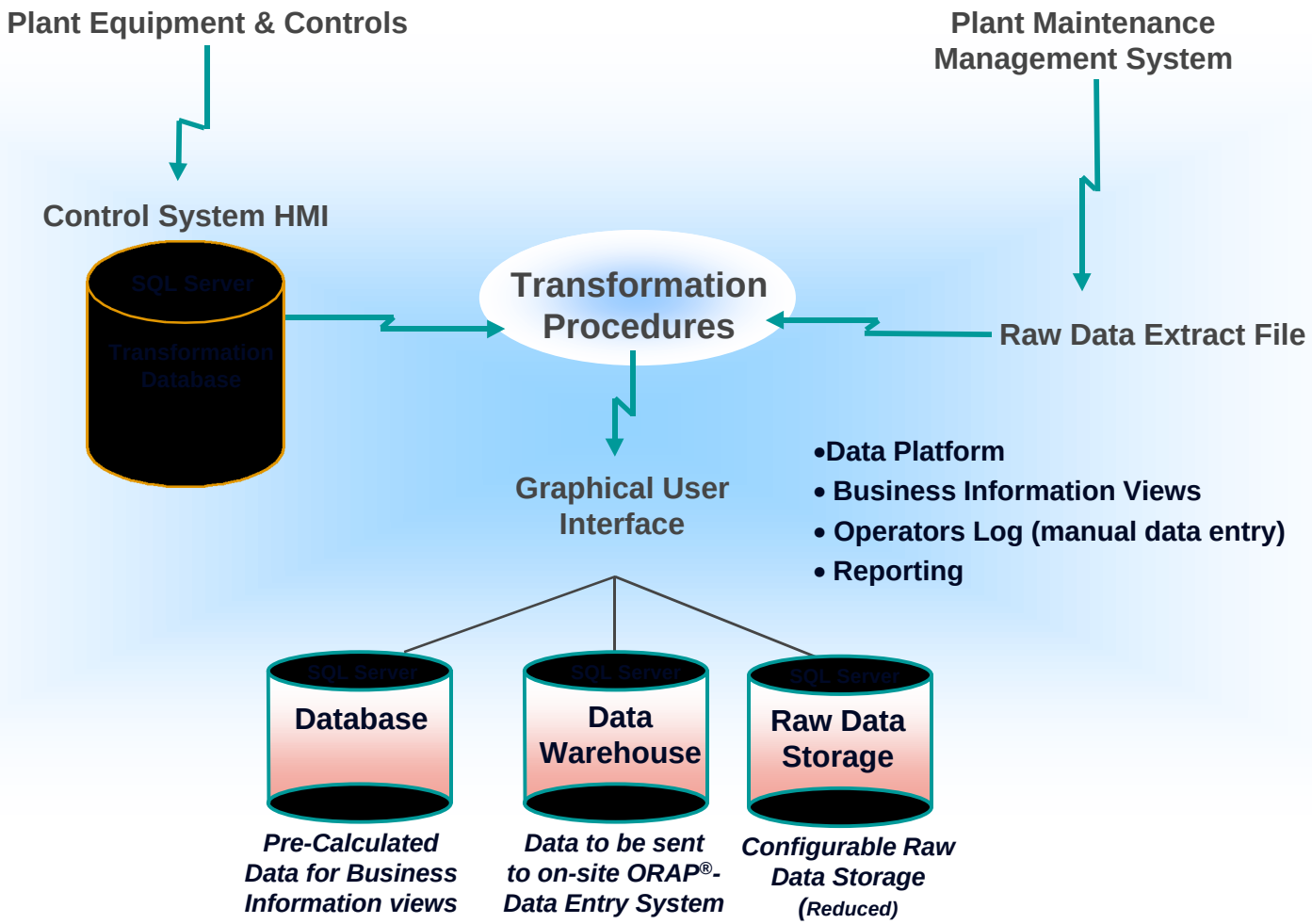
- **The Combustion Turbine Health Management System (CTHM) will consist of a series of dynamic link library (DLL) programs residing on a diagnostic monitoring platform that accepts turbine health data from existing monitoring instrumentation.**

- **The DLL modules will integrate real-time anomaly detection, diagnostics of performance and mechanical faults, and the prediction of critical component remaining useful life (RUL) and turbine degradation.**

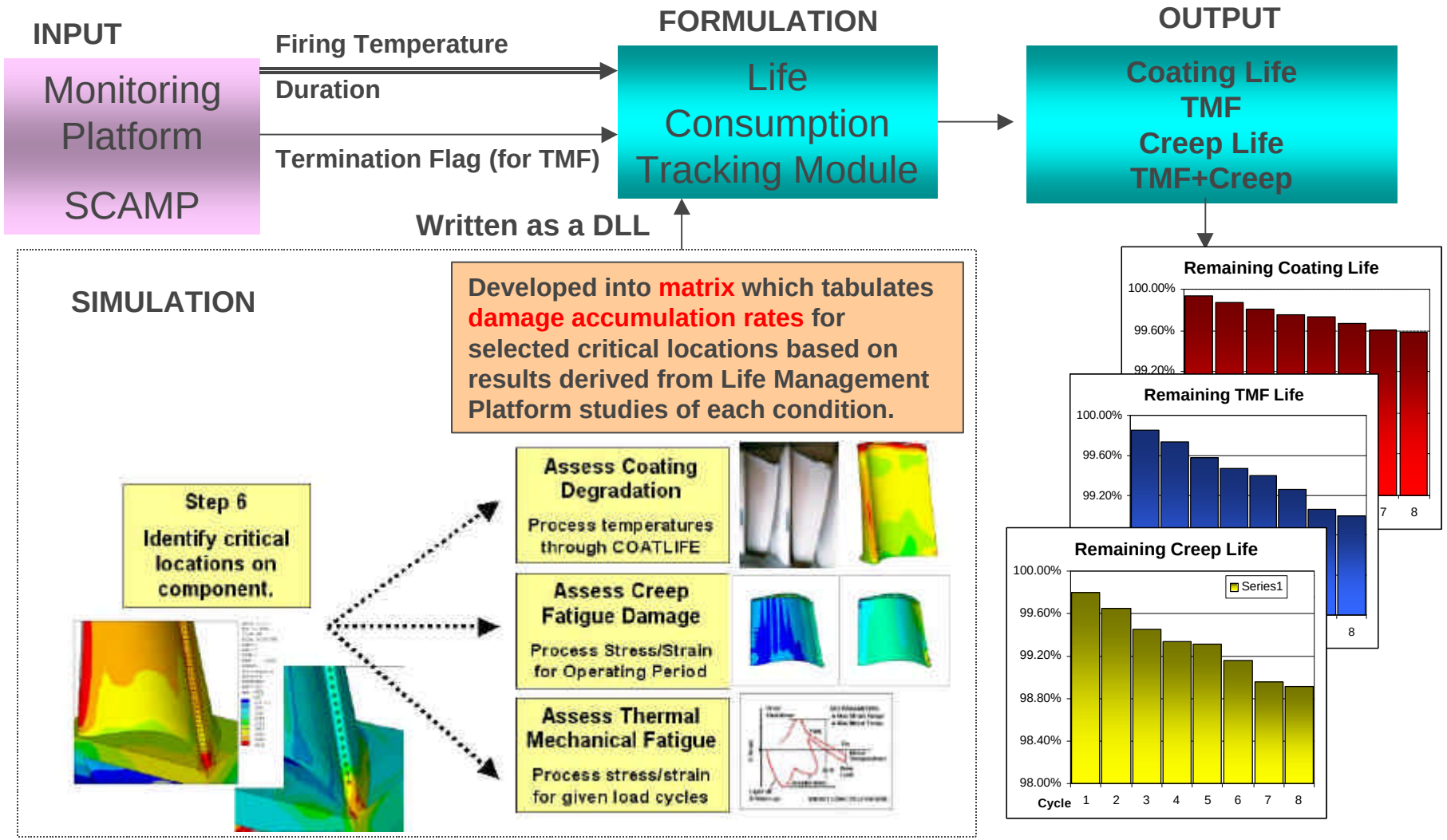
EPRI/DOE - CT Program Work Scope

- Comprehensive CT sensor validation module
  - Model-based and signal processing based techniques
- Performance fault diagnostics module
  - Automated trending and fault pattern classification and fusion
- Combustion process diagnostic module
  - Automated assessment of EGT spread, fuel flow rate, manifold and supply pressures, vibration/dynamic pressure, emissions data.
- Vibration fault diagnostic module
  - Rotordynamic and bearing fault frequency analysis
- Critical component prognostics module
  - “Hot section” RUL projections based on usage profiles and statistical analysis

Online Historical Database



Damage Assessment Monitoring

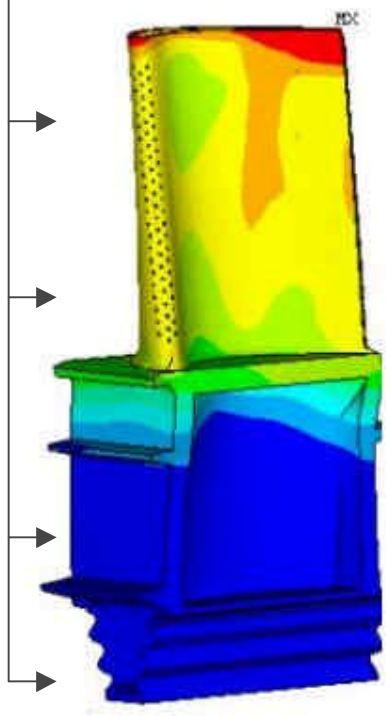


Damage Accumulation Matrix

Monitoring Platform

SCAMP

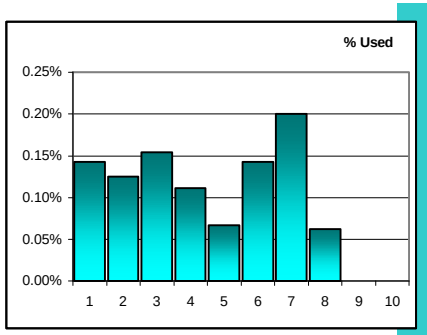
Firing Temperature, Event Type and Duration



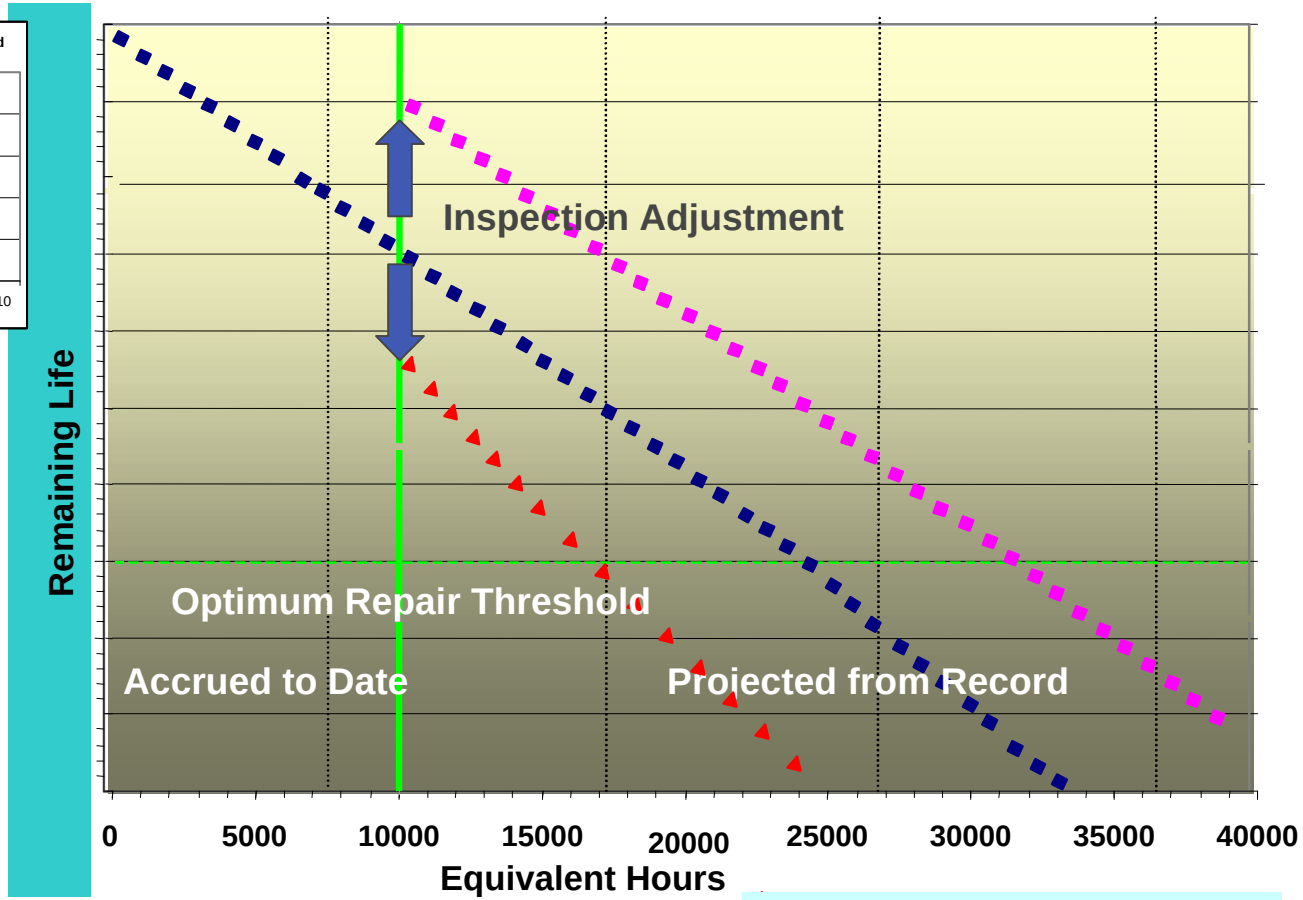
Metal Temperatures, Stress, Strain

DAMAGE ACCUMULATION RATES (DATABASES FROM LMP)								
	Event Type →	Average Load (%)				Type of Start (For TMF only)		
	Critical Location ▼	100	90	80	60	Normal	Fast	Emergency
COATING LIFE	Lead Edge	Estimates of oxidation life (hours) using temperatures derived from LMP aero-thermal analysis						
	Trailing Edge							
	Suction Side							
TMF LIFE	Lead Edge	Estimates of TMF life (cycles) using strain ranges derived from LPM aero-thermal analyses of trips at each of the different load factors and for each of the different types of start-up conditions. Termination flag (signifying type of event) will guide selection of appropriate TMF life from matrix.						
	Trailing Edge							
	Suction Side							
	Cooling Slot							
CREEP	Mid Span Profile –35% bh (Internal)	Estimates of creep (%) using temperatures derived from LMP						
	Cooling Slot							
C+TMF	Cooling Slot	Estimates of Interaction TMF and Creep						

Rate of projected life consumption may be adjusted based on condition observed at any given interval



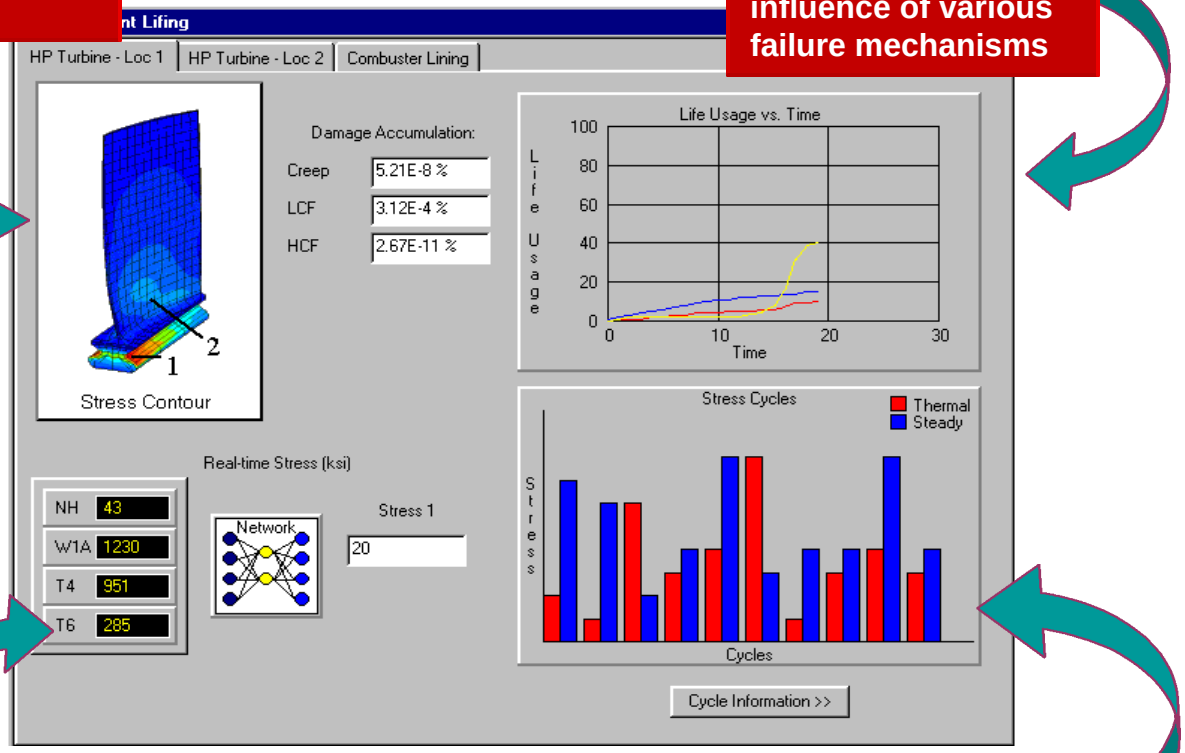
Damage is extrapolated to reflect life consumption based on chronicle of accrued damage.



Health Monitor/Predictor – Lifing Prognostics

Custom critical component life modules show real-time damage accumulation

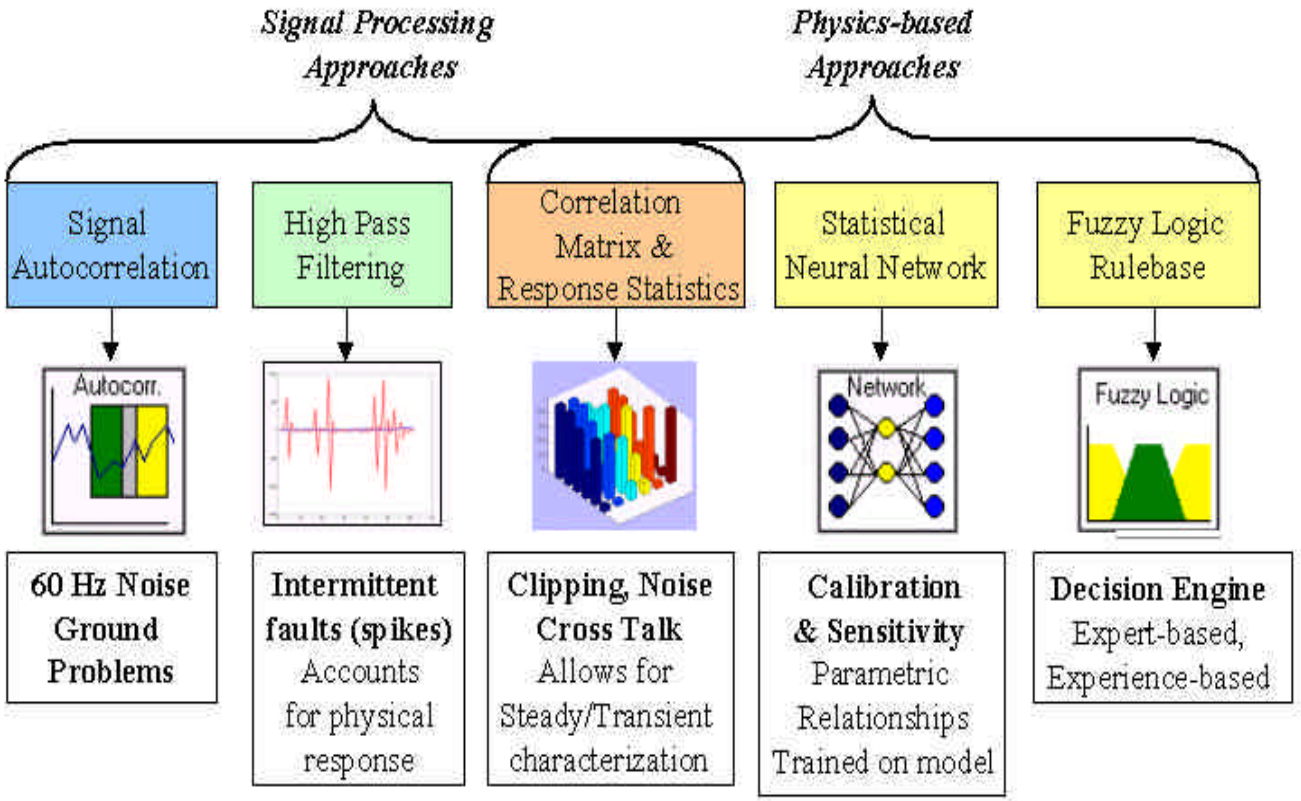
Remaining life chart illustrates the influence of various failure mechanisms



Critical location stresses are virtually sensed with a trained Neural Network

Relevant stress cycles are accumulated

CT Sensor Validation Technologies



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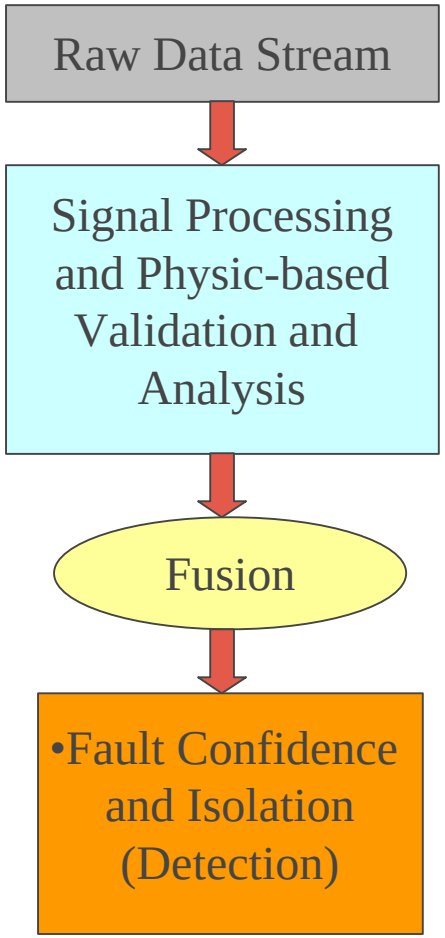
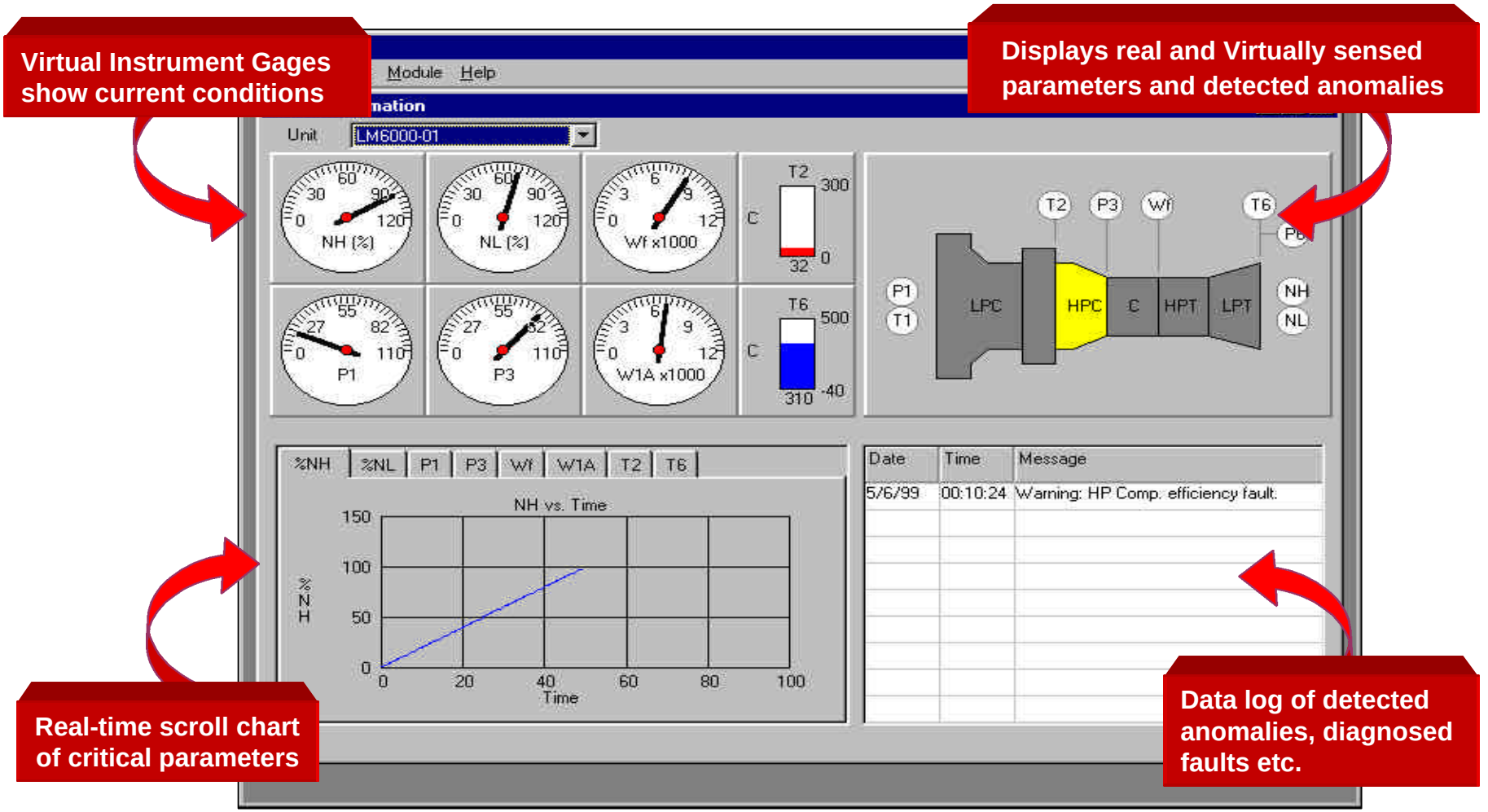
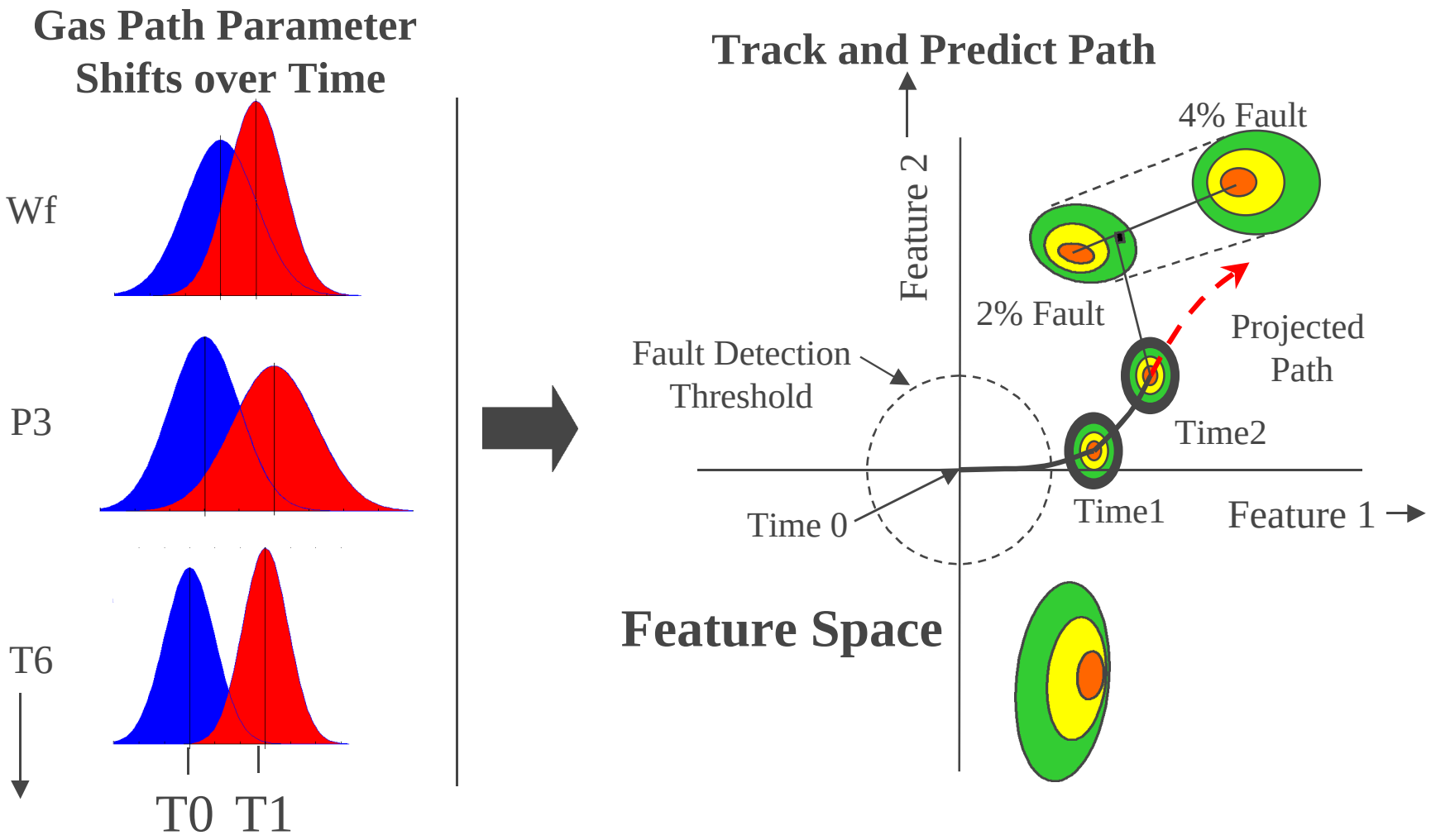


Health Monitor/Predictor – Main Screen



Probabilistic Fault Classifier

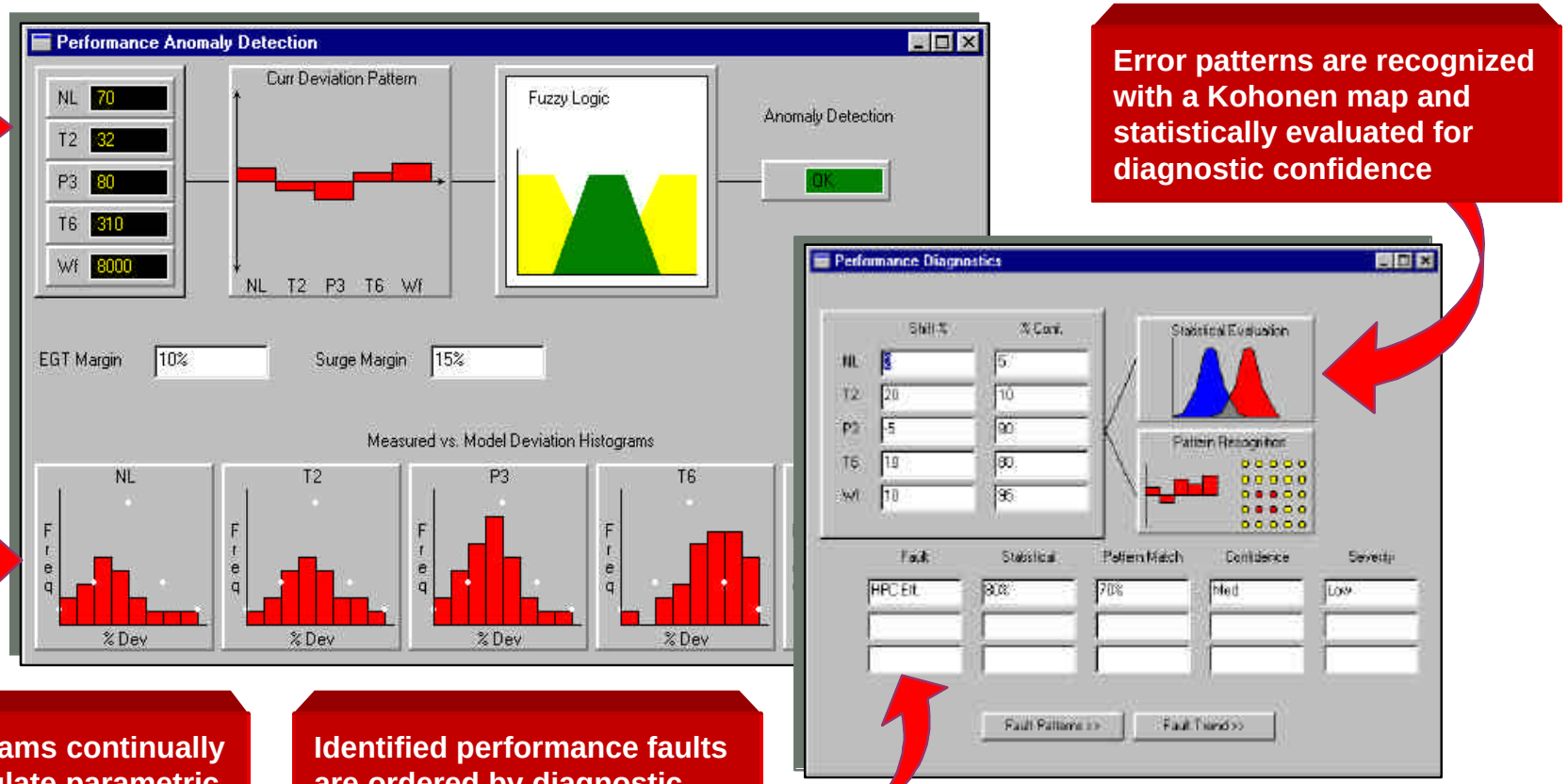


Health Monitor/Predictor - Performance Anomaly Detection & Diagnosis

Current values are gauged against baseline values at the current operating condition

Statistical processing and fuzzy logic evaluate if a performance anomaly is occurring

Error patterns are recognized with a Kohonen map and statistically evaluated for diagnostic confidence



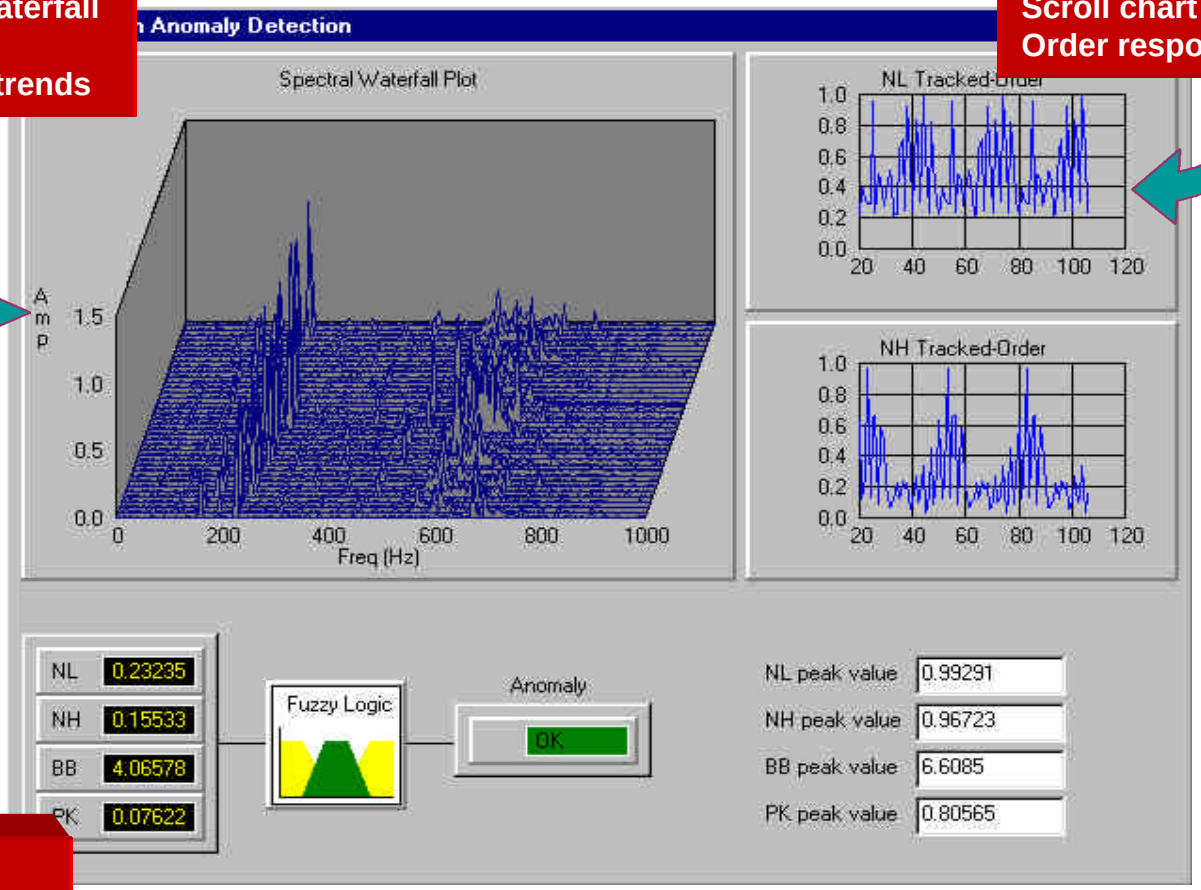
Histograms continually accumulate parametric baseline deviations

Identified performance faults are ordered by diagnostic confidence and severity level

Health Monitor/Predictor – Mechanical Fault Detection

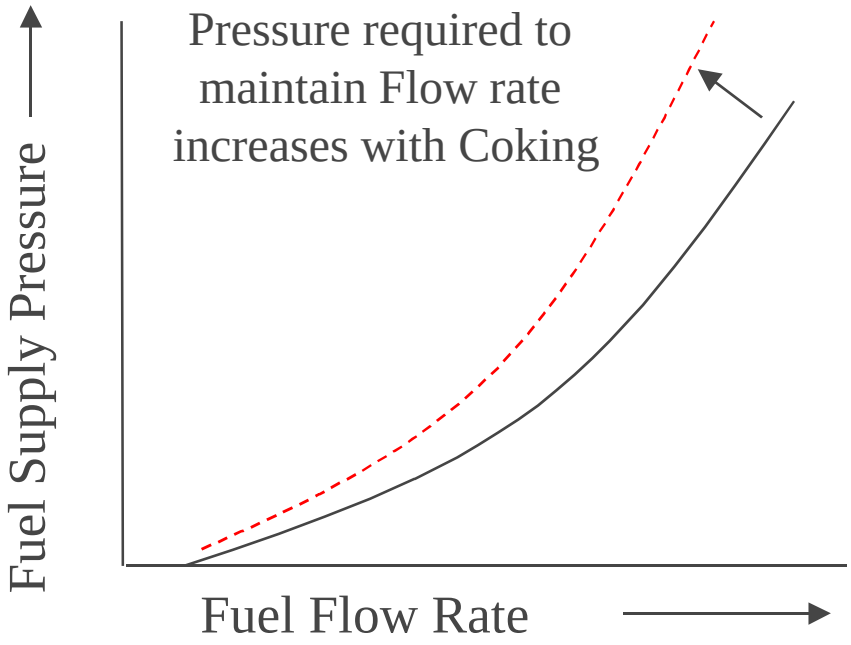
Real-time Spectral Waterfall plot captures speed dependent vibratory trends

Scroll chart of Tracked Order responses

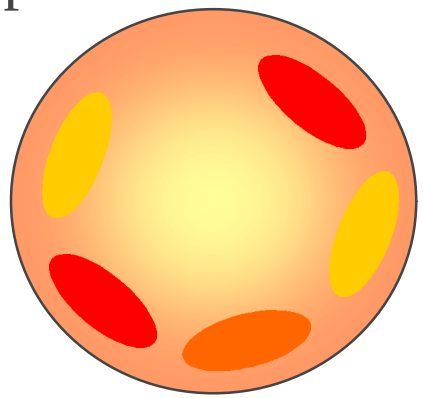


Vibration data is intelligently assessed for mechanical faults

Combustion Process Diagnostics

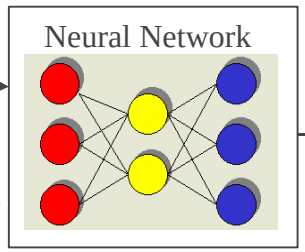


Exhaust Gas
Temperature Distribution



$EGT\_Ave = \Sigma Temps(t) / N$

1) Supply/Flow Rate
2) EGT_Ave
3) Individual Temps



1) Overall Health/Severity
2) Ranked Faults

CP&L and FPC (Progress Energy)

- Various Software Programs to Interface
  - PI, ORAP-LINK, TIGER, EMAP, PassPort, OEM's DCS
- Operating Historical Databases Available for Harvesting
- Various Manufacturers, Types and Models
- 79 Frame Units
- 24 Aero Units
  - GE 7EA (4) Cycled
  - GE 7FA (2) Cycled
  - GE 7FA+e (12) Cycled
  - GE LM6000 (1) Base Loaded
  - West 501AA (11) Peaker
  - West 501D5A (2) Peaker
  - West 501FC (2) Base Loaded (1) Combined Cycle
  - West 501FD (1) Cycled

Module Status

- **Sensor Validation and Recovery Module Complete**
  - **This module will validate the integrity of important gas path sensor signals and predict important parameters that are not sensed in the CT for performance assessment.**
- **CT/CC Performance Module Complete by 10/2003**
  - **This module statistically detects the manner in which performance parameters are shifting over time and then correlate these shifts with degradation issues associated performance.**
- **Remaining Life Module Compete by 03/2004**
  - **This module will utilize models of critical "hot section" components previously developed and put them in a prognostic module architecture that project probability of failure for future operation. Probabilistic models of critical components will monitor the remaining life for thermal-mechanical cycling, creep, and coatings.**

Closing Remarks

- Need exists for monitoring systems that:
  - Optimize performance
  - Define risk of extending operating periods
  - Monitor component degradation
  - Provide early warning of system faults
- The combustion turbine health management (CTHM) system developed under this project will be a dramatic improvement over currently available techniques for turbine monitoring and diagnostics.
- The CTHM will, for the first time, enable real-time anomaly detection and diagnostics of performance and mechanical faults in addition to the prediction of critical component remaining useful life and turbine degradation.