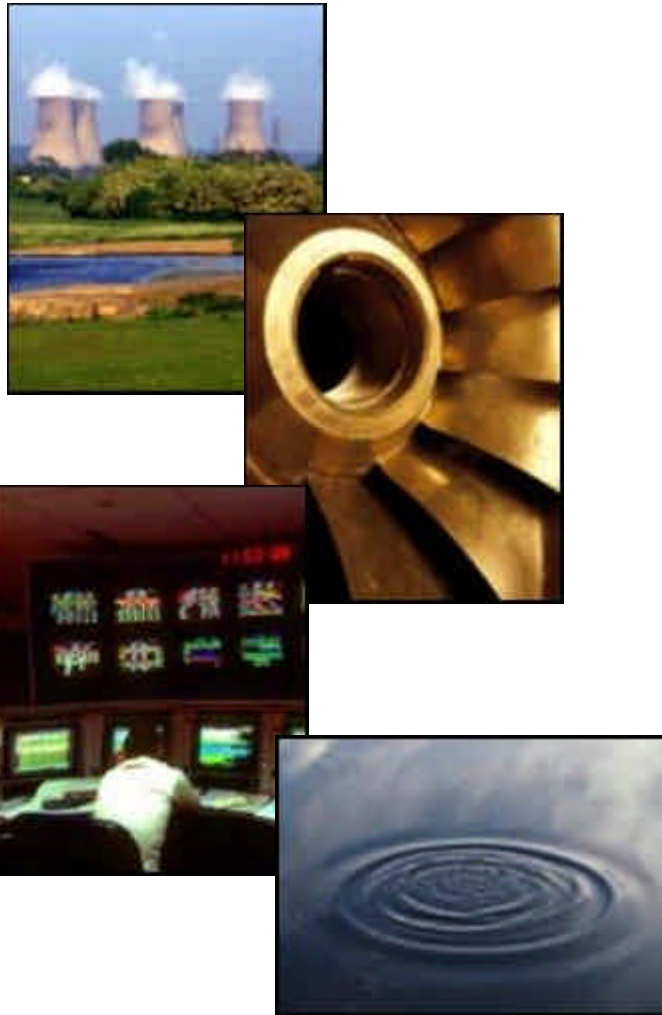


Combustion Turbine R&D at EPRI

**Hank Courtright
Vice President,
Power Generation &
Distributed Energy
Resources**

**CAME – GT Meeting
July 10, 2003
Brussels, Belgium**

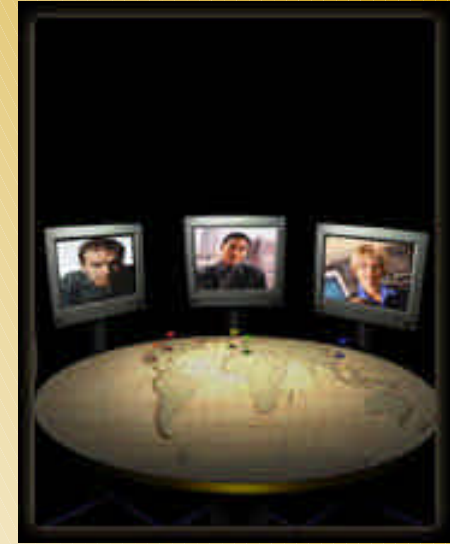
EPRI Mission & Background



- EPRI provides science and technology-based solutions to the energy industry and government
- Non-profit energy research consortium voluntary funded by participants
- Currently serving over 1,000 energy-related organizations, including 150 international participants, in over 42 countries

EPRI Brings Together Strategic Partners

- To maximize the value of science and technology investments
- To solve critical, industry-wide, energy problems that no single organization could solve on its own
- To develop technical solutions tailored to meet individual business strategies
- To open up new business opportunities for the future
- To address the public interest in health & safety and environmental protection



EPRI Worldwide



- EPRI Worldwide SA, established in Brussels, Belgium, to provide science & technology services to clients in Europe, the Middle East and Africa
- Accounts active in Asia and Latin America with new offices established in China and Singapore for supporting Asia

EPRI's Energy Research Program



Power Generation

Distributed Resources
Fossil Steam Plants
Combustion Turbines
Market Analysis
Renewables
Hydroelectric

Nuclear Power

Component
Reliability & Safety
Nuclear Operations &
Asset Management
Nondestructive
Evaluation
Plant Technology

Power Delivery & Utilization

Transmission
Substations
Grid Reliability
Power Markets
Distribution
Power Quality
Energy Utilization

Environment

Air Quality
Global Climate
Change
Electromagnetic
Fields (EMF)
Occupational
Health & Safety
Land & Groundwater
Water & Ecosystems

EPRI CT/Combined Cycle Program

New CT/CC Design and Risk

- Gas Turbine Experience and Intelligence Report
- Durability Surveillance
- Project Risk Framework
- Combined-Cycle Plant Design
- State of the Art Power Plant (SOAPP) Workstation
- CT/CC Environmental Control Issues
- Fuel Supply and Generation Markets

CT/Combined Cycle O&M

- Condition Monitoring and Inspection
- CT Repair Technology
- Hot Section Life Prediction and Improvement
- Operational Flexibility
- Plant Maintenance Management
- Operator Simulator-based Training

HRSG Dependability

- HRSG Cycle Chemistry
- Tube Failures and Life Assessment
- Inspection and NDE
- Application Training Services

CT Life Management Solution

RUN

- Operator Training
- Diagnostic Monitoring
- Operational Flexibility

INSPECT

- Coating Integrity
- Crack Detection/Sizing
- Remote Inspections

REPAIR

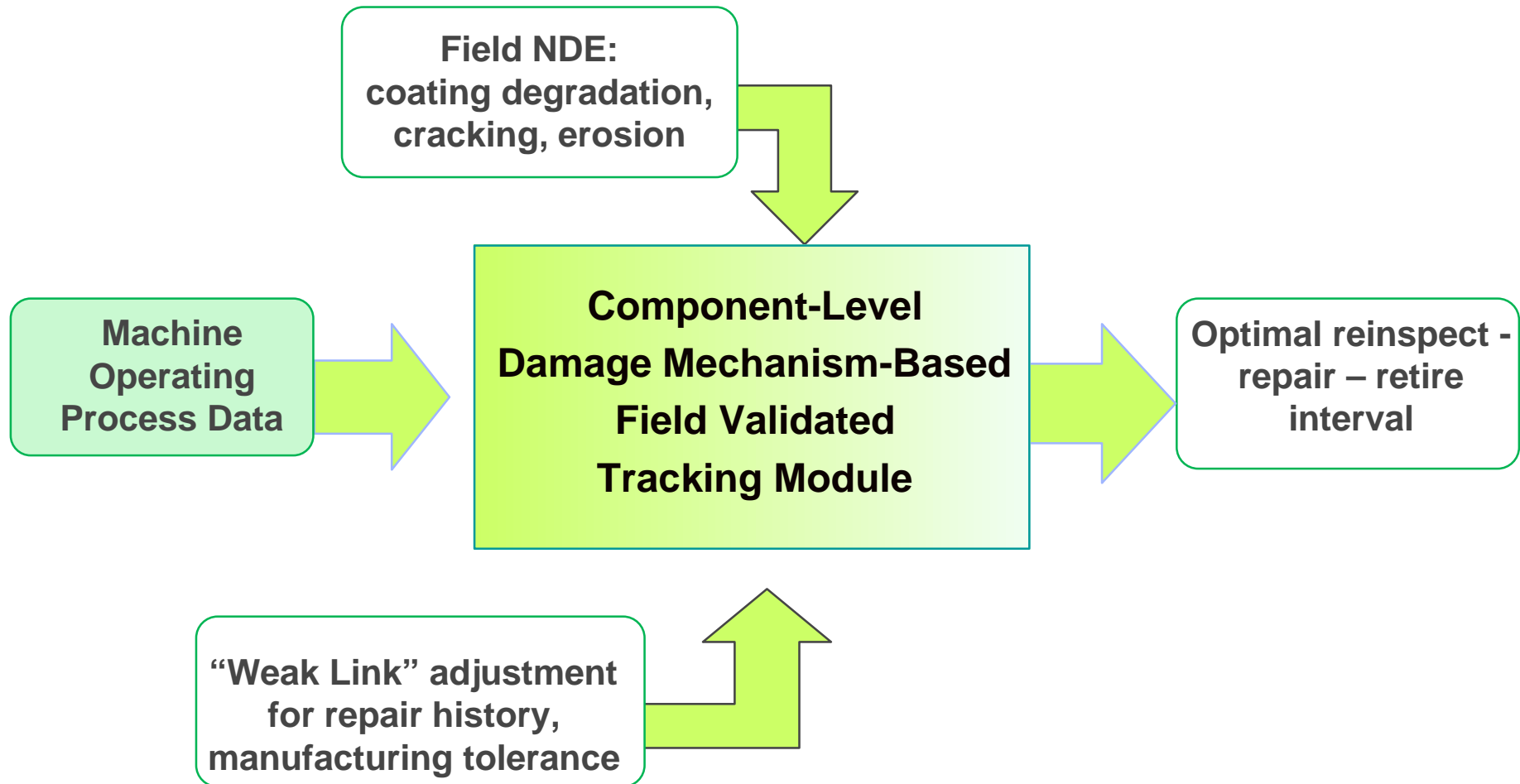
- Model Specific Repair Guidelines
- Advanced Welding/Bonding
- In-situ TBC Repair

REPLACE

- Improved Coatings
- Cost-Effective Design Improvements
- Overhaul Planning (GTOP)

**GOAL: 25%
Reduction in
Life Cycle
Costs**

Managing Hot Section Life Uncertainty



Hot Section Life Prediction and Improvement



- COATLIFE: Proper coating selection and life assessment
- New coatings better suited to machine mission: Fatigue versus oxidation life trade-offs
- Supporting Finnish-Japanese Research consortium addressing more durable multi-layered coating structures
- Need to view coating within context of overall component design, temperature, strain ranges, and fuel factors

Hot Section Life Management Platform

T&S Profile

For Specified Design, Materials and Environment

TMF Cycle

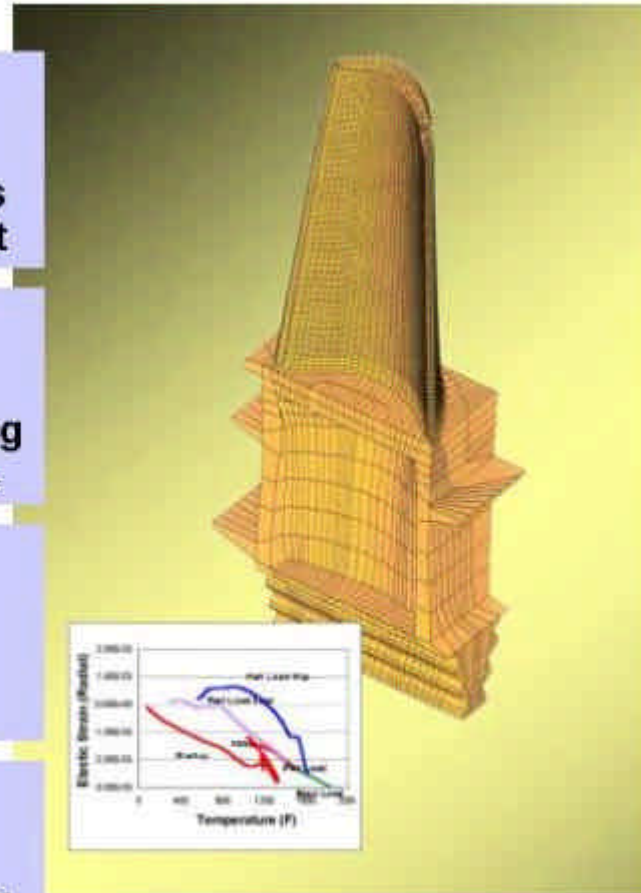
For Specified Types of Operating Starts, Trips etc.

Creep/Coating

For Specified Periods of Operation

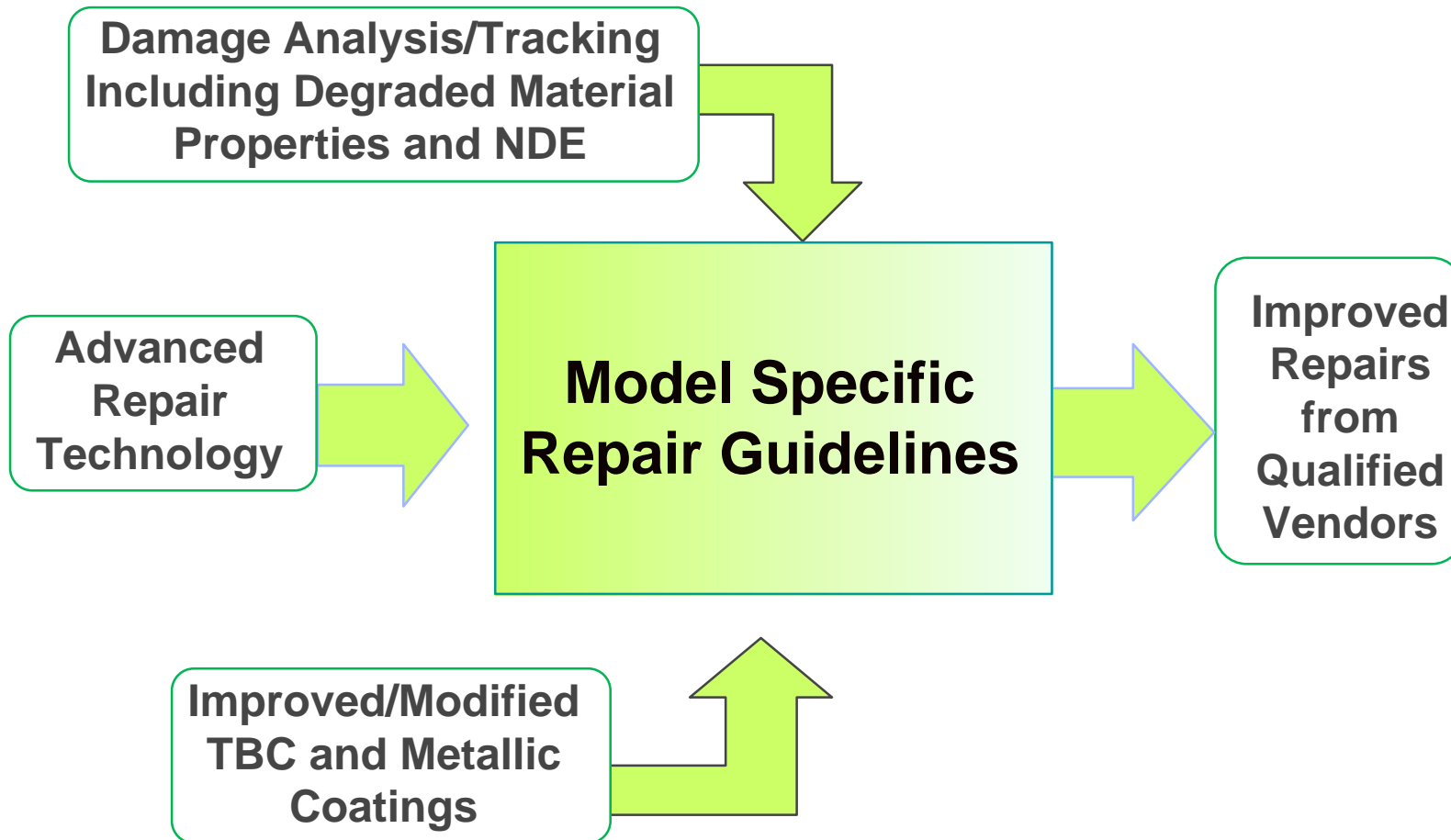
Tech Support

Risk of Failure Based on Specific Operating History

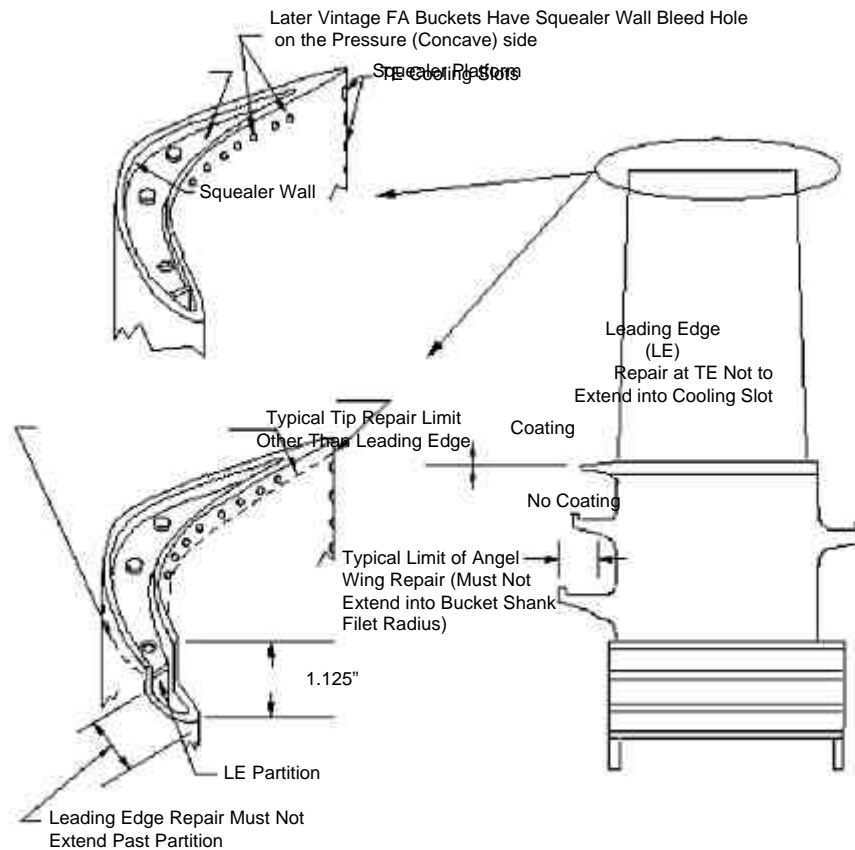


- Provides 3D profile of bucket temperatures and stresses (T&S) under any given operating condition.
- Provides the relative thermal mechanical fatigue (TMF) damage for any given operating cycle or load profile.
- Estimates Creep and Coating Degradation for an operating history.
- Can provide technical information and engineering insight to support run-repair-replace decisions for hot section components.

Maximize Component Economic Life



CT Repair Technology and Guidelines



- Model-specific Guidelines Series establishes acceptable repair procedures to support competitive bidding and follow-on QA
- Advanced Repair Technology
 - Replacement coatings
 - Welding, brazing and bonding technologies
 - Component-specific modifications
- Multi-volume Repair Series covering 7 models to date, including expansion to 50Hz machines

CT Repair and Coating Guidelines



Expanding Repair Guideline Series

- GE MS7001 Model B (1004597)
- GE MS6001 Model B (1006429)
- GE MS7001 Model F/FA (1004340)
- GE MS7001 Model E/EA (1006503)
- Westinghouse W501 Models A thru D (1006509)
- Siemens-Westinghouse W501F (1004341)
- Coating Guideline (1006513)
- 2003+ New Models and Updates including 50 Hz versions

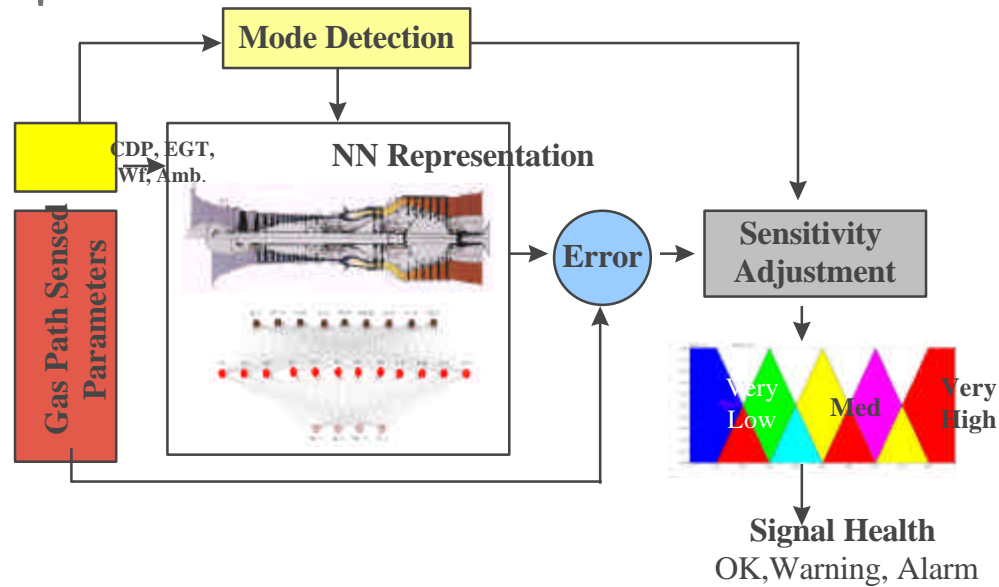
Reduce repair costs and extend service life

CT/CC Operational Flexibility

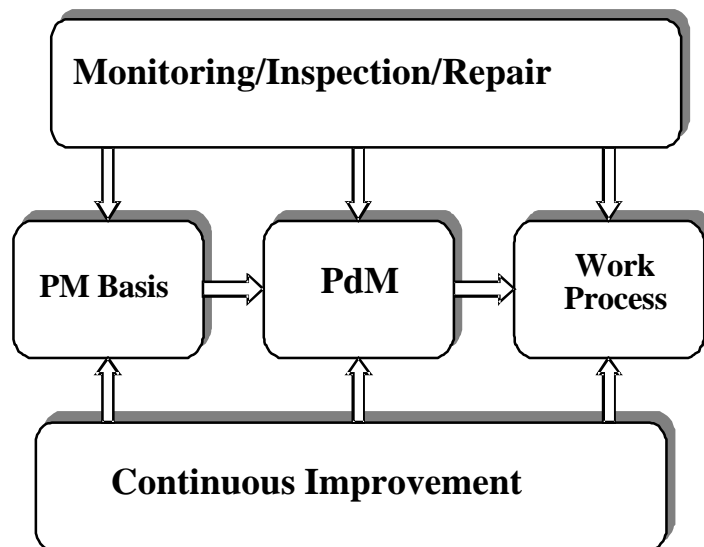


- **Capacity Enhancement Developments:**
 - 2 micron swirl flash nozzle
 - More durable ceramic nozzles
 - Interstage fogging
 - Compressed humid air injection
 - Cheng cycle steam injection enhancements
- **Operational Flexibility:**
 - Burner dynamics, emissions trade-offs
 - Dual-fuel operation
 - Improved seals
 - Stress-controlled trips

CT/Combined Cycle Predictive Maintenance (PdM)

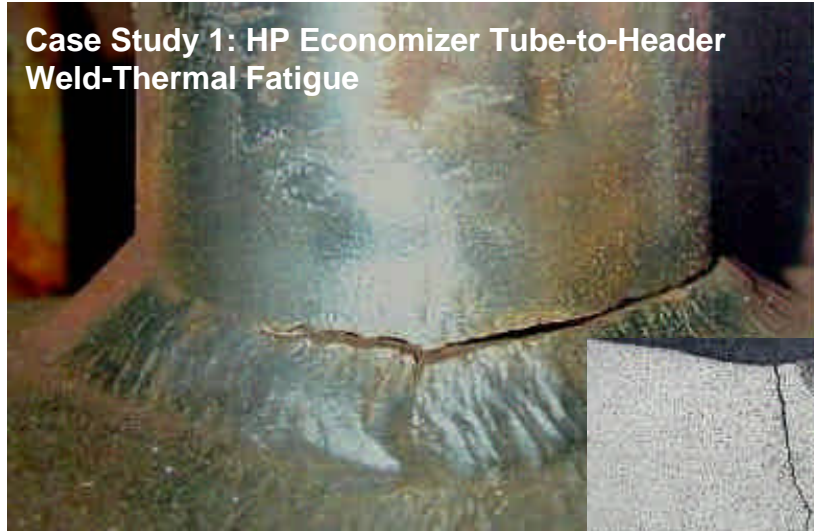


- CT/Combined Cycle PdM Guidelines translates Fossil/Nuclear experience to CT Fleets and Combined Cycles
- CT Diagnostic Monitoring Modules:
 - Sensor Validation
 - Performance anomaly
 - Combustion system
 - Rotordynamic fault
 - Hot section life
- Improved Monitoring Instrumentation & Inspection Techniques



Heat Recovery Steam Generator (HRSG) Dependability

Case Study 1: HP Economizer Tube-to-Header
Weld-Thermal Fatigue



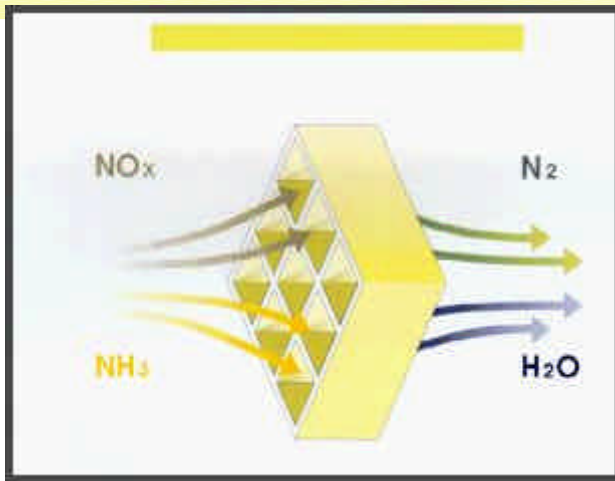
- 19 tube failure mechanisms with possible root causes and solutions
- Comprehensive coverage of most common:
 - Corrosion fatigue
 - Thermal fatigue
 - Flow-accelerated corrosion
 - Under deposit corrosion
- 50% of tube failure related to cycle chemistry (HRSG Cycle Chemistry Guideline)
- Need for remote inspection and repair from tube ID

Operator Training and Advanced Control



- Need to train and enhance front-line competencies
- Simulators and training modules suitable for remote learning
- Pathway for advanced control:
 - Improve operational flexibility
 - Mitigate stress-imposed damage
 - Reduce start-up constraints

CT Environmental Considerations

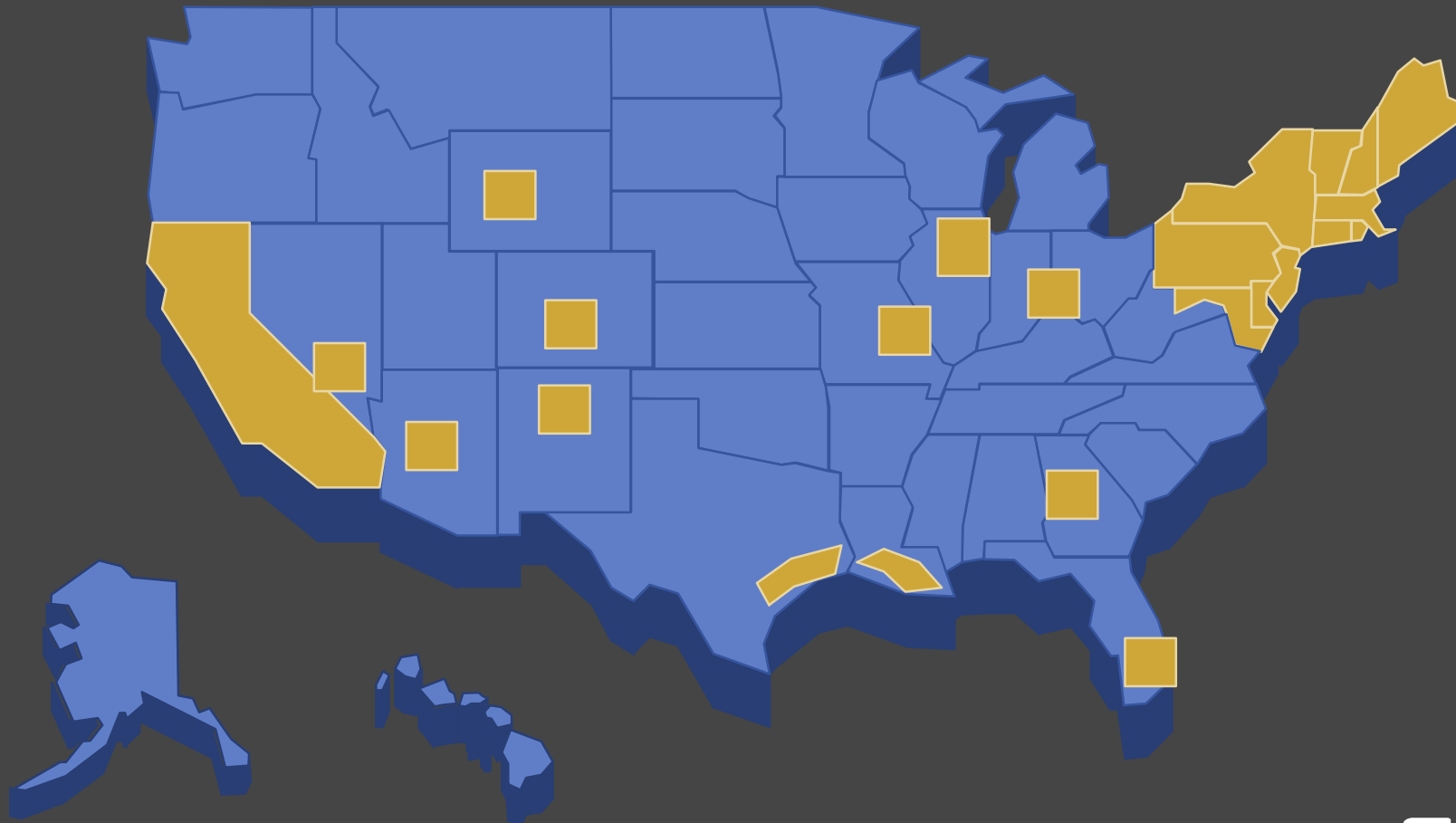


- Assess Emerging Control Technology
 - SCONO_x, zero ammonia slip
- Technology and Issues
 - Simple cycle SCR
 - Ultra-low NO_x limits
 - CO, VOC, HAPS and PM₁₀
 - Catalytic or trapped vortex burner designs
 - Noise control for urban locations
- Challenge to meet natural gas emissions on alternative fuels, including syngas

99-2000

NO_x Emissions Limits

■ > 25 ppm ■ < 5 ppm

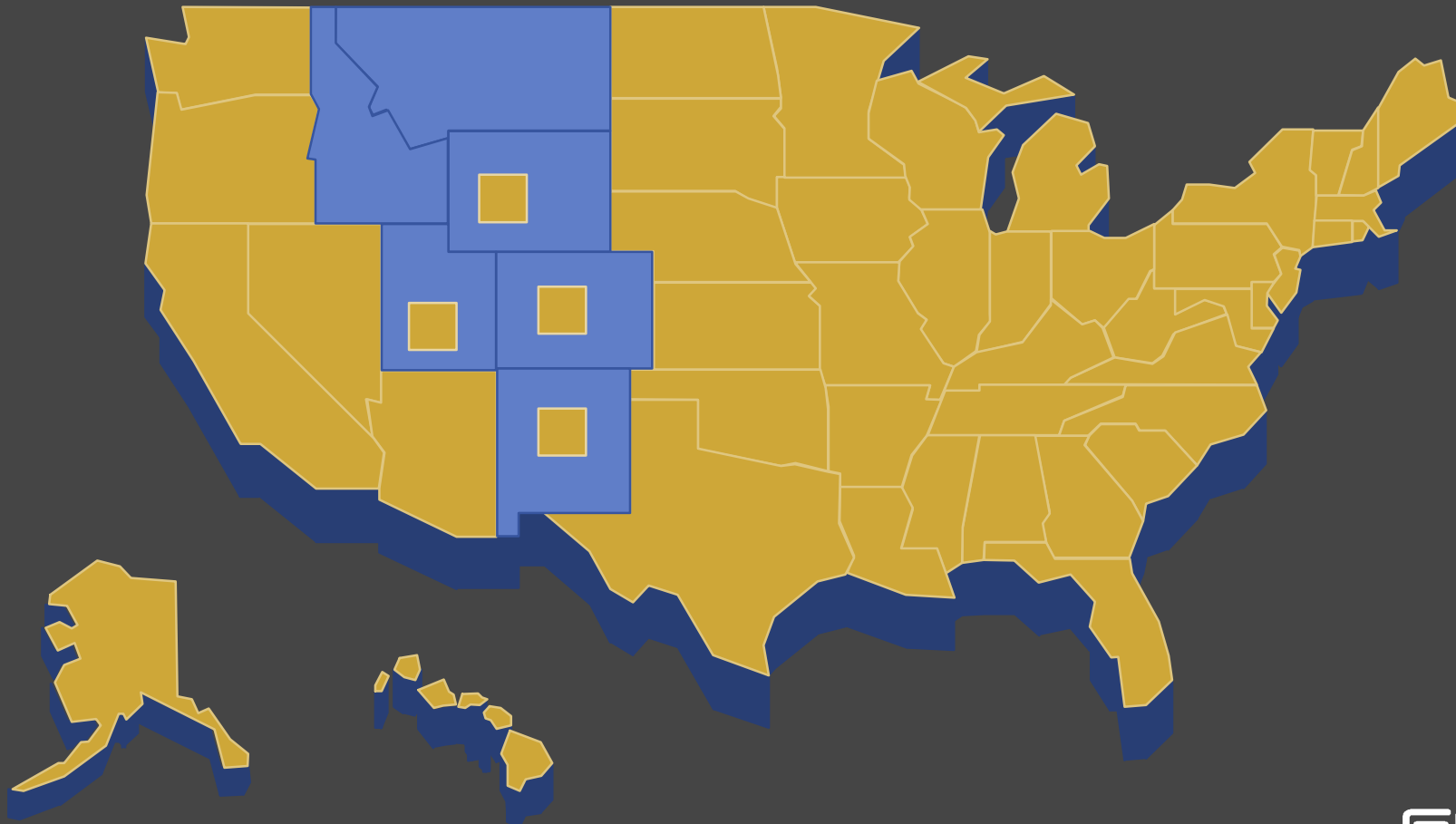


2005

NO_x Emissions Limits

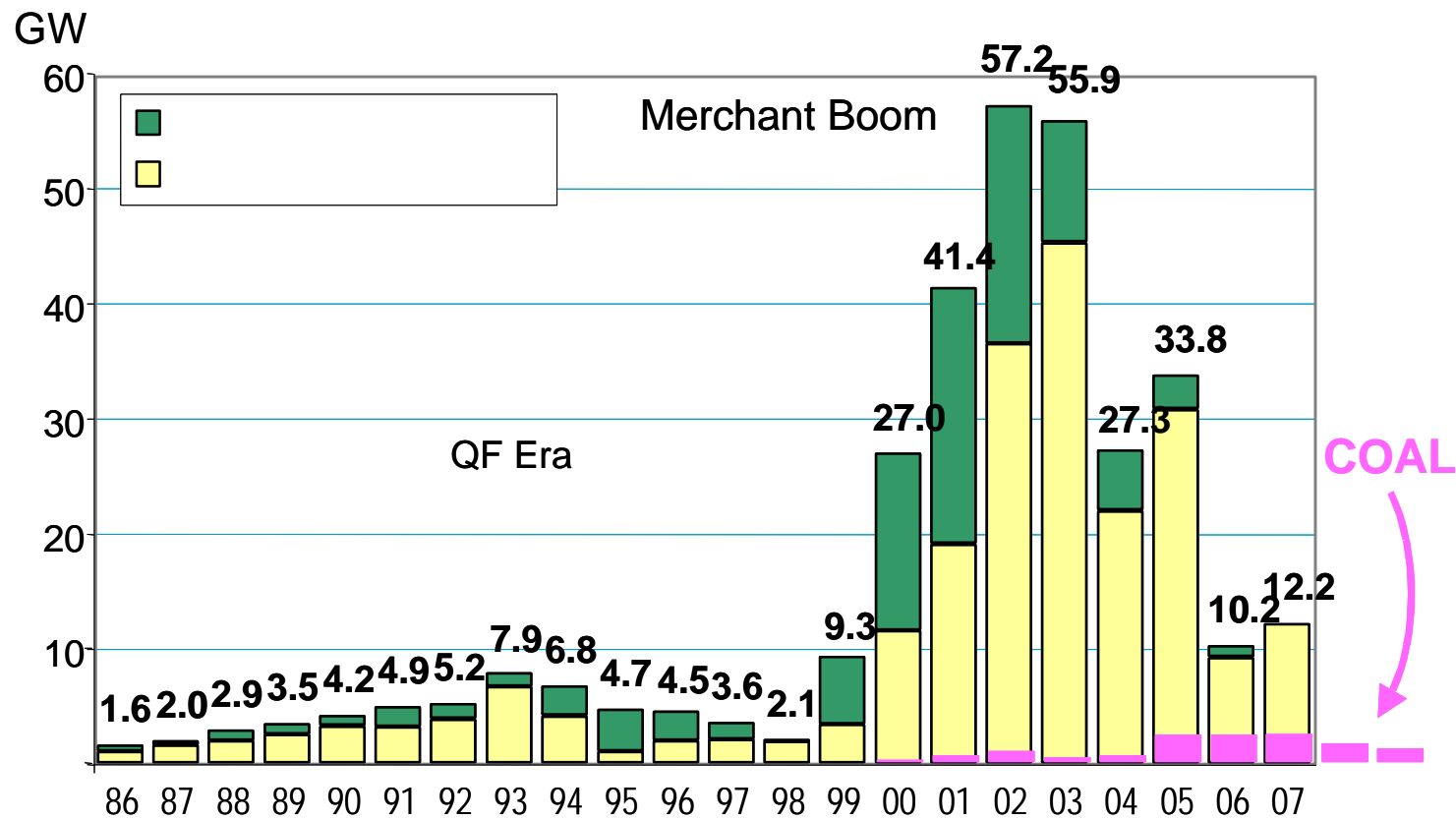
■ > 25 ppm

■ < 5 ppm



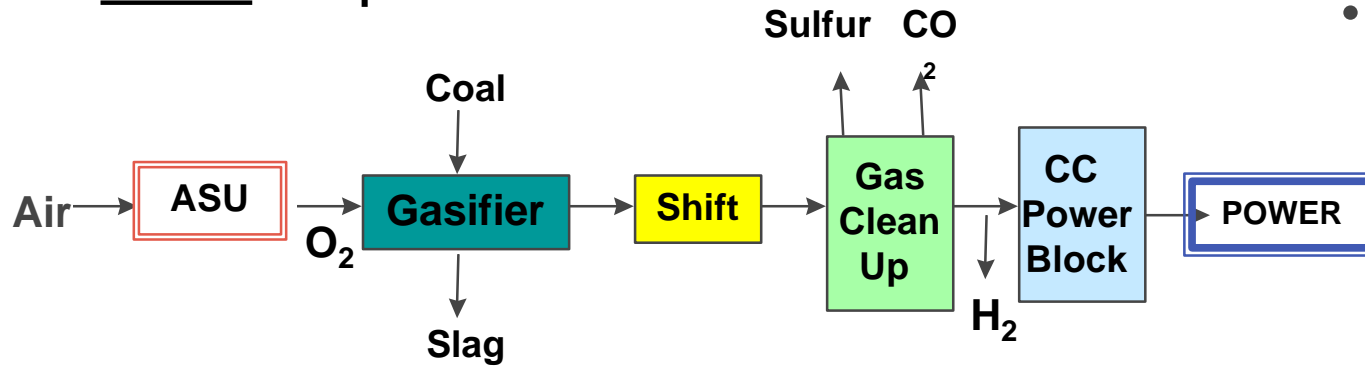
The Boom-Bust Cycle of the US Natural Gas Market

- Based on 1st Q, 2003



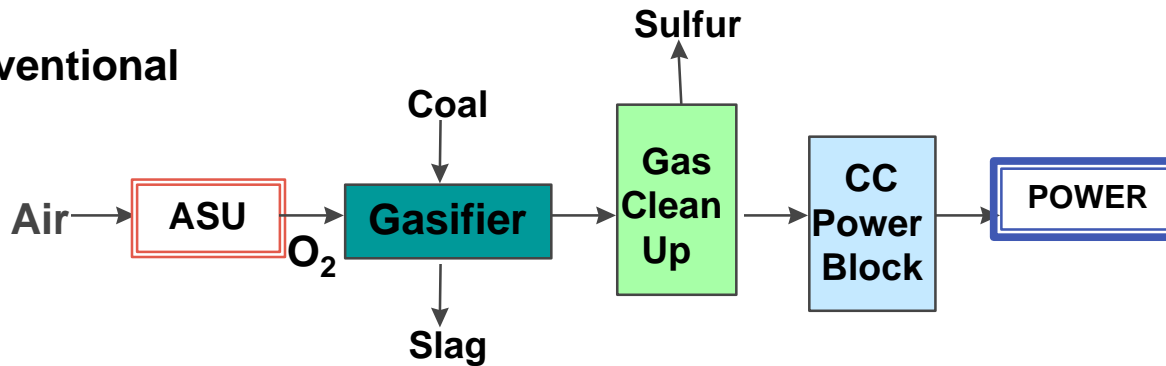
Phased Construction IGCC > CO₂ > H₂

Phased Components



- Why consider it?
 - Provides “real options” for possible CO₂ control or H₂ markets

Conventional



- Low cost pre-investment in:
 - Design area
 - CT/HRSG/ST
 - Air Separation Unit (ASU)
 - Gasifier type & pressure level

EPRI Websites

- To register on INTURB CT Owner's Directory, go to:
www.epriCTcenter.com
- To view EPRI's main website, go to:
www.epri.com

Summary

- EPRI's R&D Program focuses on reducing O&M costs
 - Hot Section Life Management
 - Maximize Component Life
 - HRSG Dependability
- Developing tools for hot section life management allow users to be better informed buyers of maintenance parts and services
- Gas fired CT/CC remains the prime generating platform for the next 5 years
- Where coal resources exist, a transition to IGCC with CO₂ capture is an alternative for carbon management and fuel flexibility
-