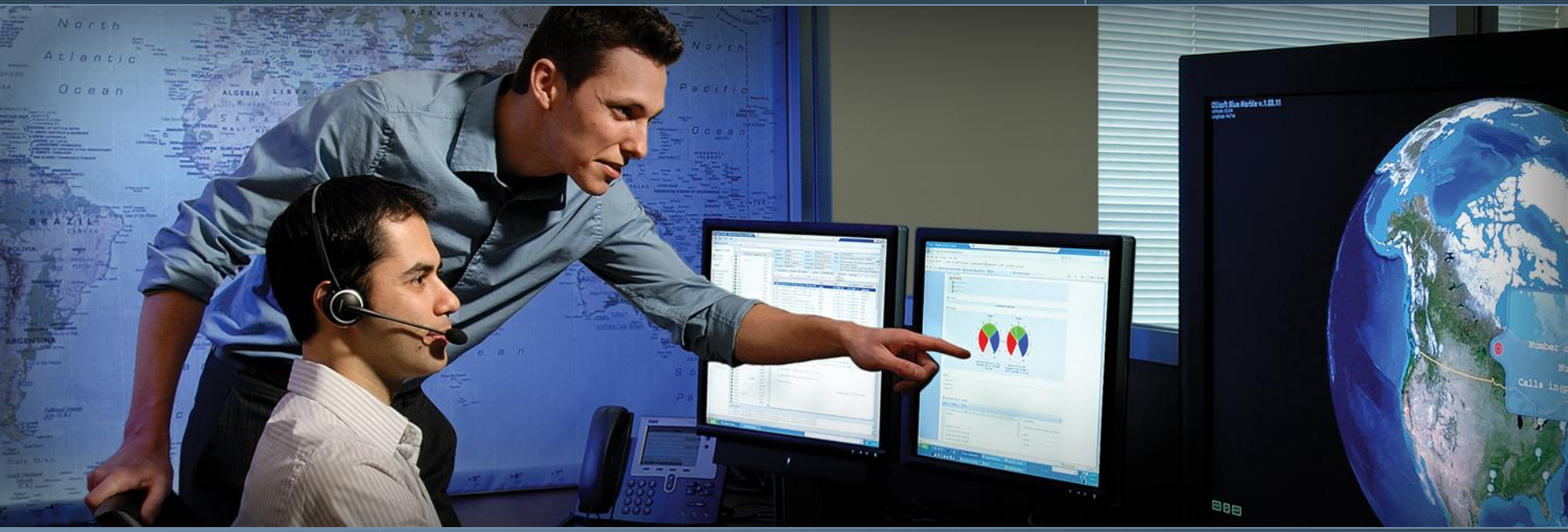
Regional Seminar Series

Denver, CO USA



Condition-Based Maintenance (CBM)

Keith Pierce
Center of Excellence (CoE) Engineer
OSIsoft

19 October 2010

Empowering Business in Real Time.

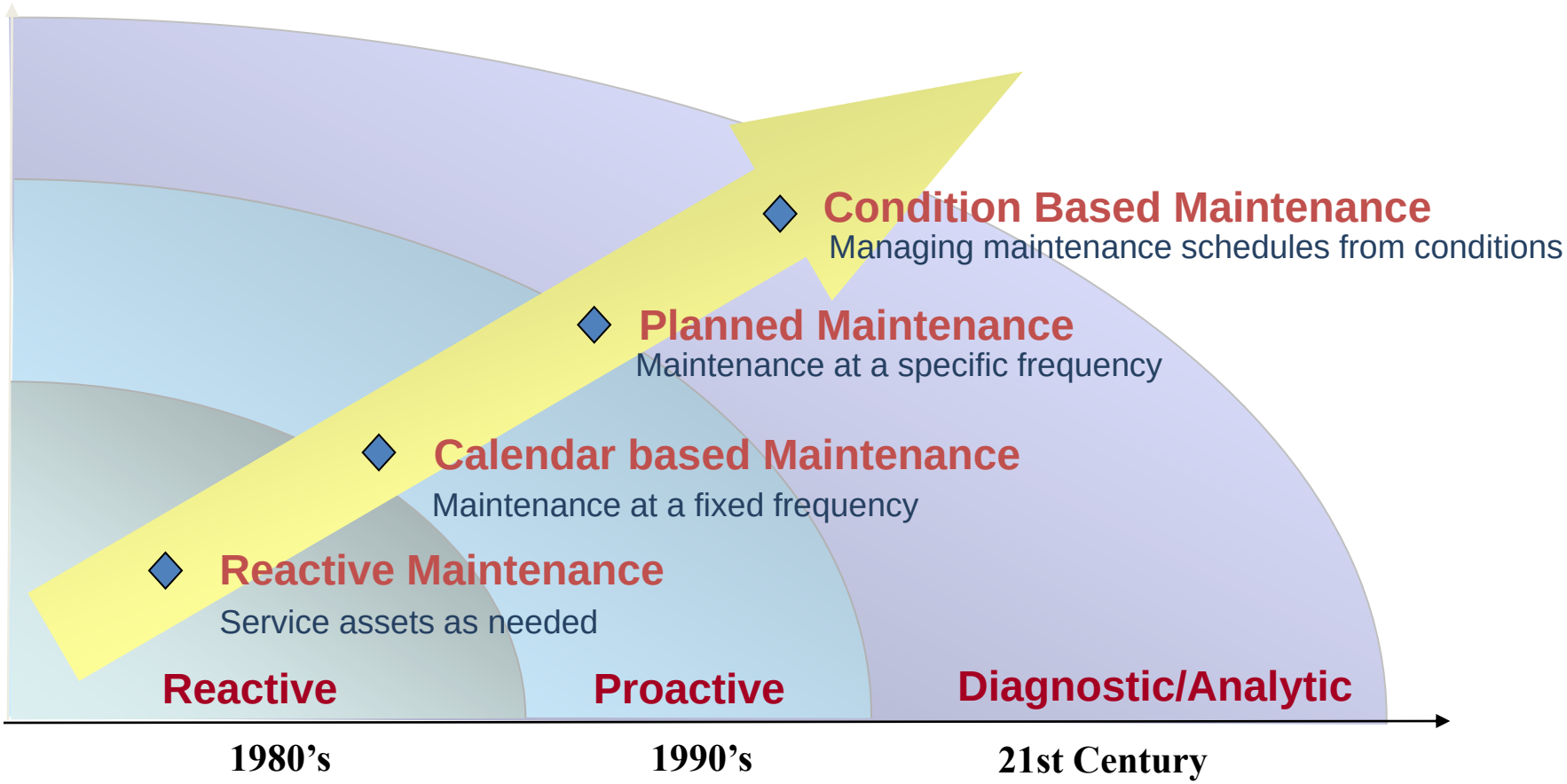
AGENDA

- Condition Based Maintenance – Background
- Condition Based Maintenance – Value Proposition
- Condition Based Maintenance – Business & Technical
- PI System Infrastructure Components
- PSE&G Case Study
- Conclusion
- Q&A

Condition-Based Maintenance

Background

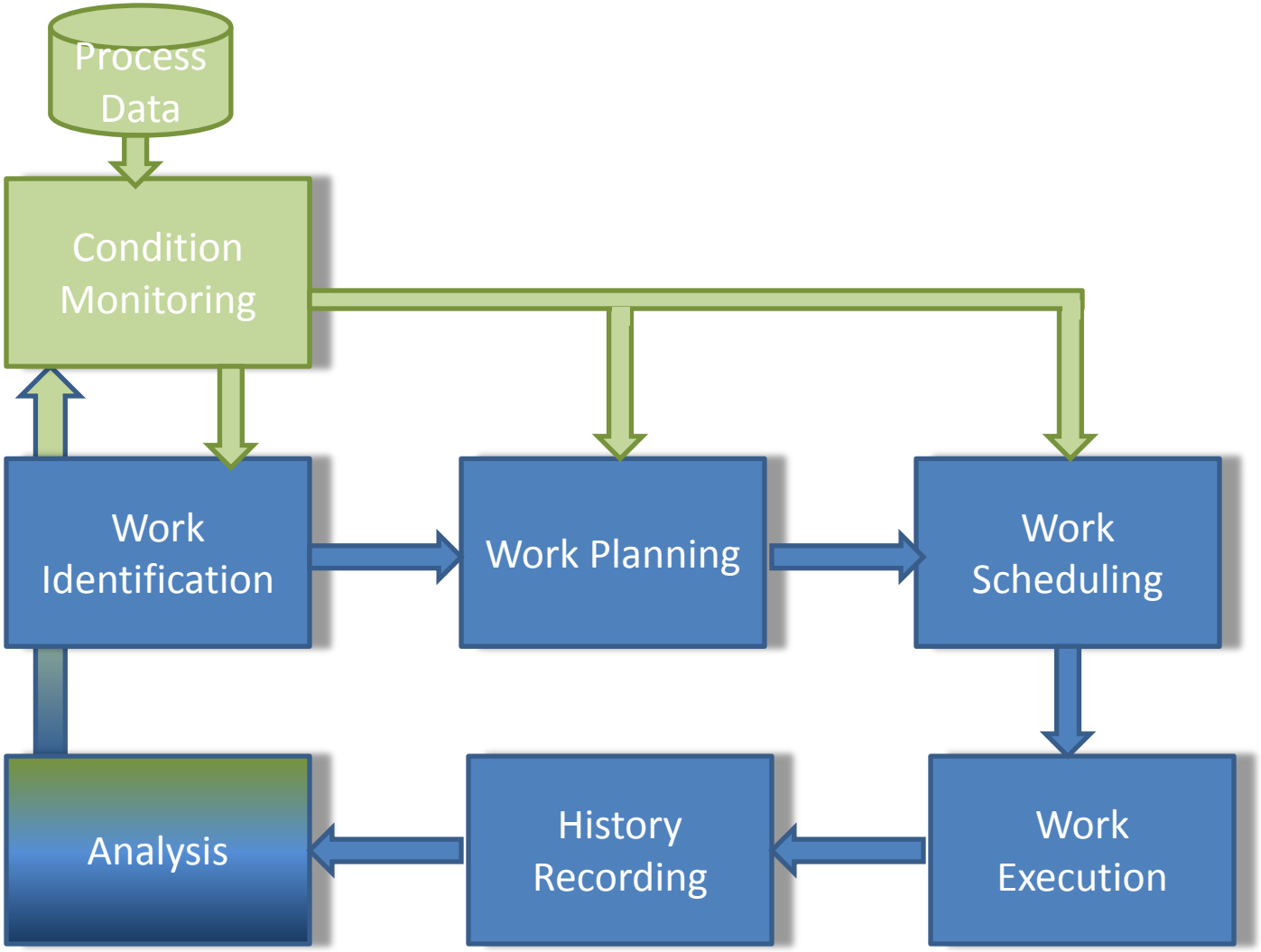
Maintenance Evolution - Reliability



Terms & Definitions

- Predictive Maintenance (PdM)- using a parameter to determine when an asset may fail
- Condition Monitoring (CM) – using a parameter or information about an asset to determine its condition (in regard to that specific parameter)
- Condition-Based Maintenance (CBM)- determining maintenance schedules based on condition type indicators
- Model-Driven Monitoring – based on optimal model for current conditions.
- Reliability Centered Maintenance (RCM) –includes processes to ensure assets perform as required – may involve all of the above plus ancillary functions (training, parts, etc.)

CBM & Maintenance Process



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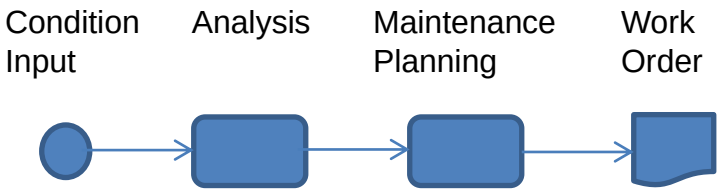
Condition-Based Maintenance (CBM)

- Maintenance Plan Fundamentals
  - Quantitative
  - Qualitative

- Requirements
  - Indicative Data
  - Integration with Work Management



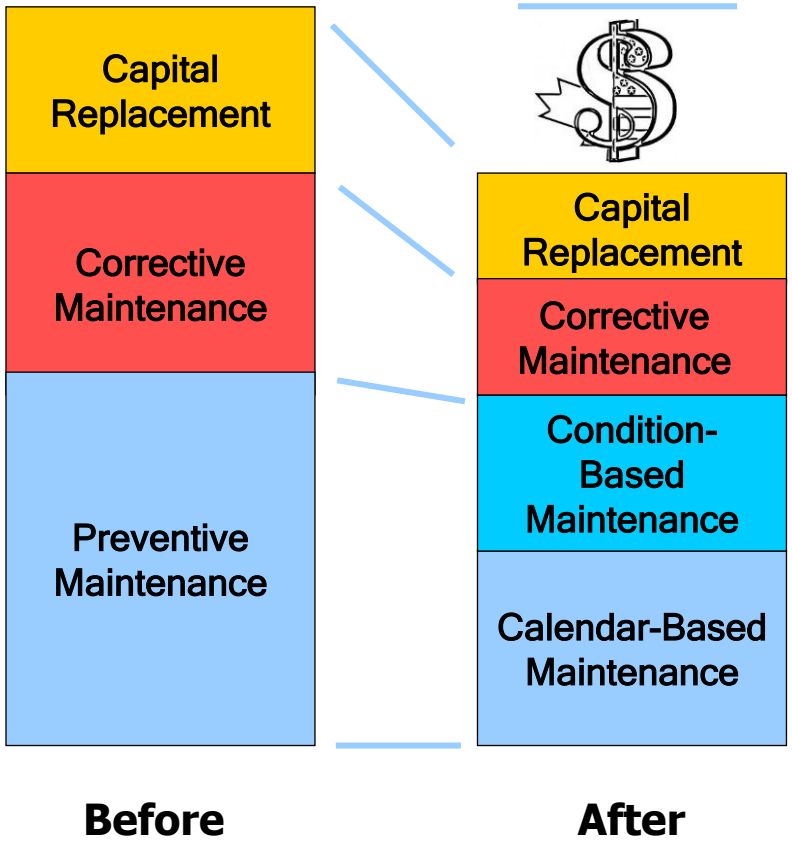
- Implementation Lifecycle
  - It's a journey – very easy to start small
  - Motivate Key Personnel
  - Change Management

Condition-Based Maintenance

Value Proposition

Motivating Factors

- More Effective Maintenance Strategy
  - Do only the maintenance required, when required
  - Fewer outages
  - Fewer induced errors
  - More focused work effort
- Foundation for Decision Support
  - Easily extensible
  - Operations Support
  - Engineering Studies
  - Business Process Integration



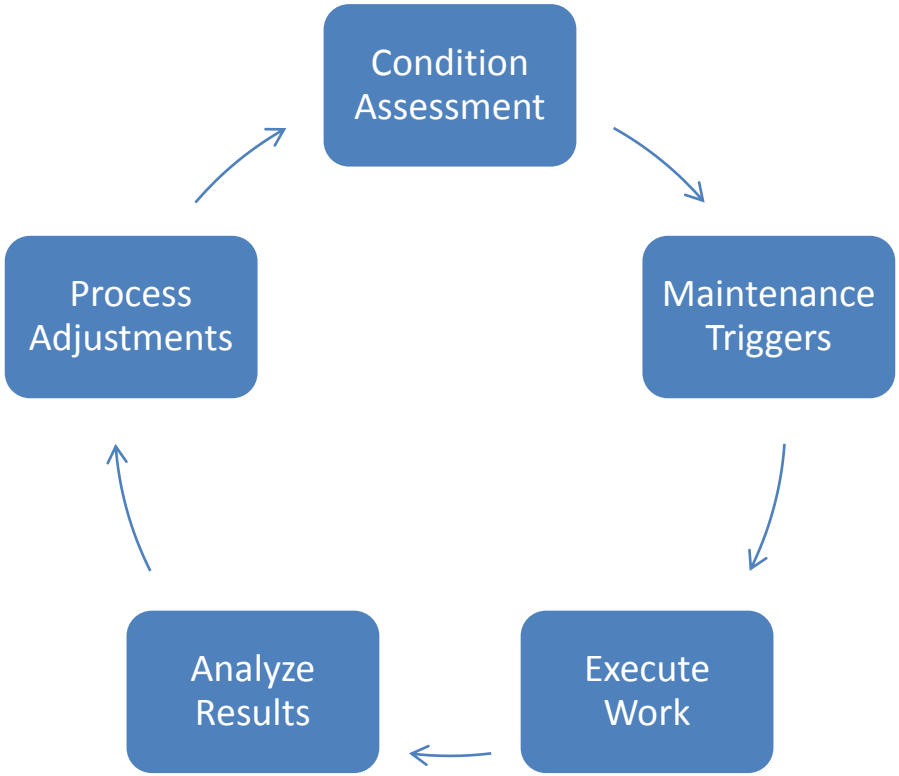
Condition-Based Maintenance

Business and Technical Considerations

Components to Success

- Business Component
  - Leadership and direction - needs a cross-discipline team
  - Where are the costliest failures?
  - What information is available?
  - What information is needed?
  - How would information be integrated?
  - How to measure success?
- Technical Implementation Component
  - Options for data collection
  - Condition Assessment
  - Typical Reference Architecture
  - EAM/CMMS Integration Methods

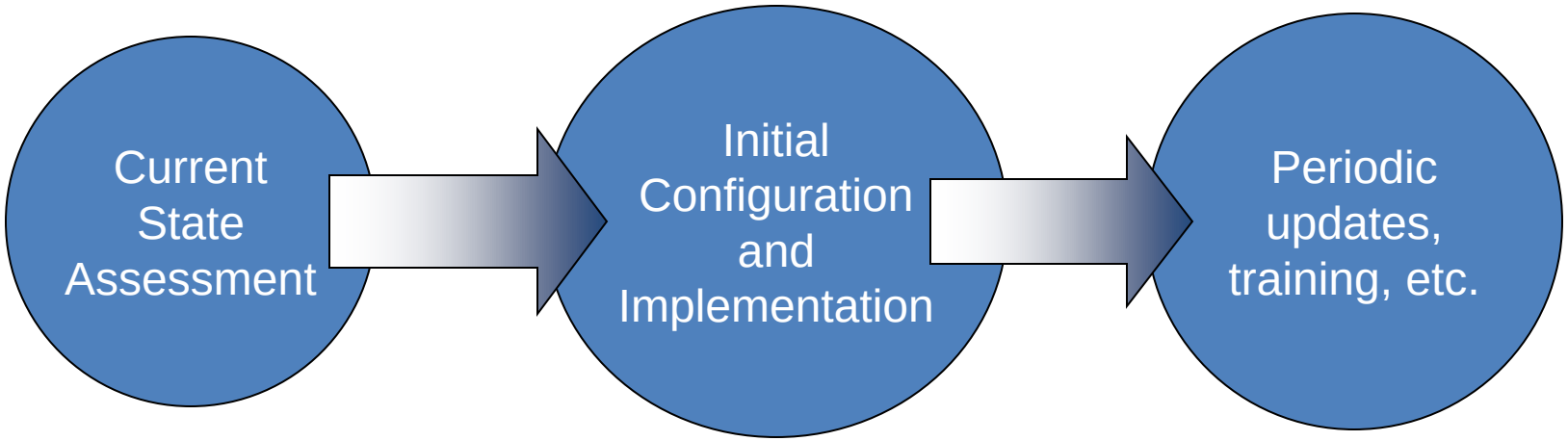
Continuous Improvement Process



- Evolutionary Process
  - Start small but full cycle
- Continuous Improvement
  - Practice in place to improve

Value now. Value over time.

Implementation Approach



- Review Sources of Information
  - Maintenance Management
  - Maintenance Description
  - Data Collection
  - Reporting Systems
- Organizational Review
- Pilot Selection
- Initial business case
- Architectural Diagrams

- Data Context Definitions
- Asset Family/System Content Definition
- Initial User Interface Configuration
- Data mart setup
- Algorithm definition and configuration
- Linking asset performance to maintenance process
- Conduct Pilot
- Business case updates

- Rollout beyond pilot
- Asses effectiveness and improve algorithms
- Implement additional reports
- Improve Data maintenance processes
- Extend to predictive maintenance
- Business case updates

Value now. Value over time.

Technical Challenges

- Acquire Data from a Wide Variety Equipment
- Organize and Classify Equipment for Scalability
- Provide a Configurable Environment for Rule Building and Knowledge Capture
- Support Exception-based Rule Processing and Notification of Maintenance Alerts
- Facilitate Timely Access to both Real-Time and non-Real-Time Equipment Information
- Integrate with the work management (EAM, CMMS, etc.)
- Provide visualization of benefits realization

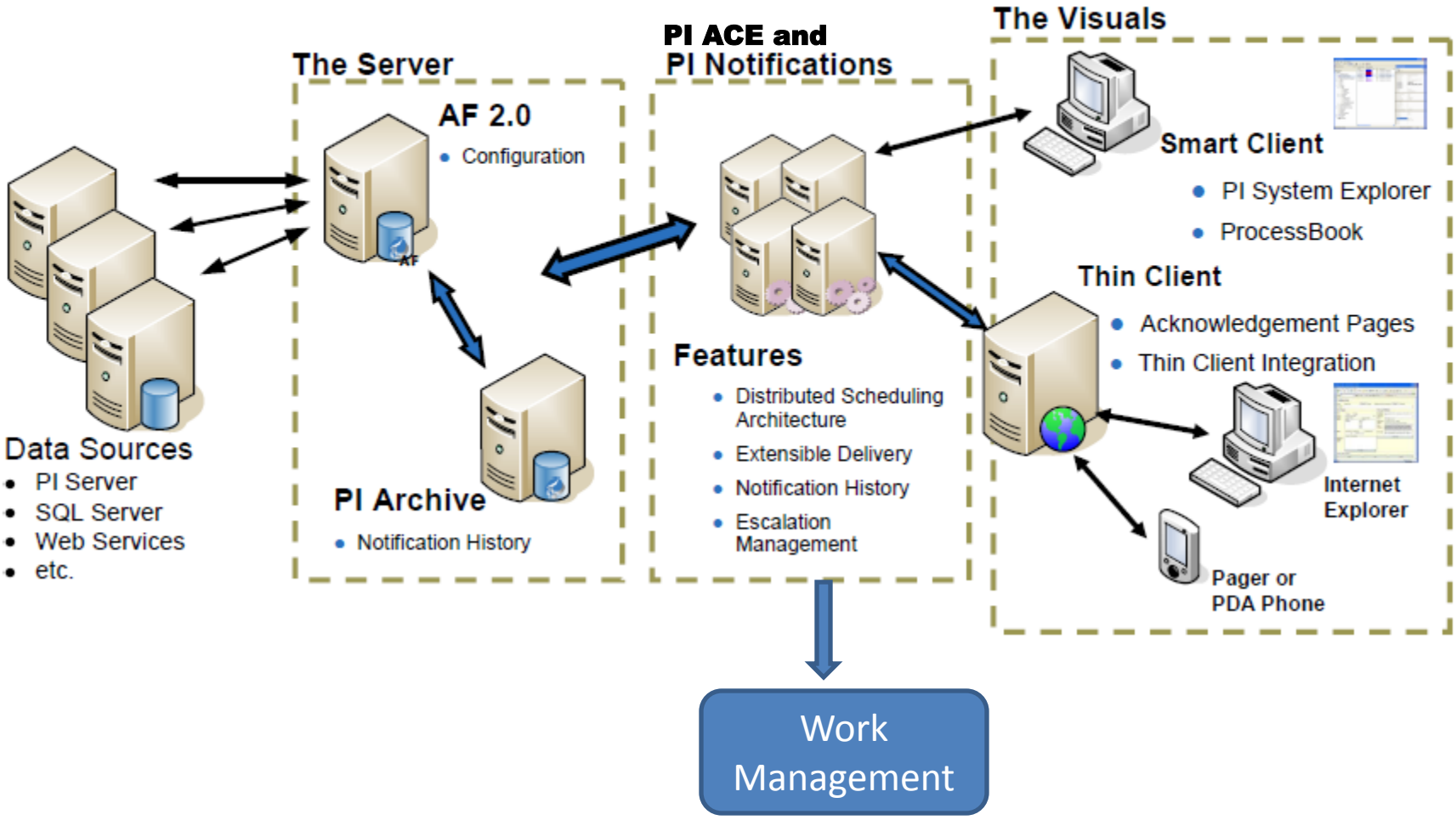
Conceptual CBM Model

Collect	Context	Analyze	Act
Sensors, Indicators, PdM, SCADA, PLC, etc.	Asset Hierarchy, System Model, Peer Groups, Calculation Model	Condition Algorithm, Prioritization, Health Status, Rate of Change, etc.	Visualize, Integrate, Notify, Improve
PI Interfaces, PI Manual Logger, PI Data Acesss	PI Asset Framework (AF)	PI Advanced Computing Engine (ACE), PI Notifications	PI Notifications, PI Data Access, PI Web Parts, PI ProcessBook, etc.

Condition-Based Maintenance

PI Infrastructure Components

CBM PI System Infrastructure Components



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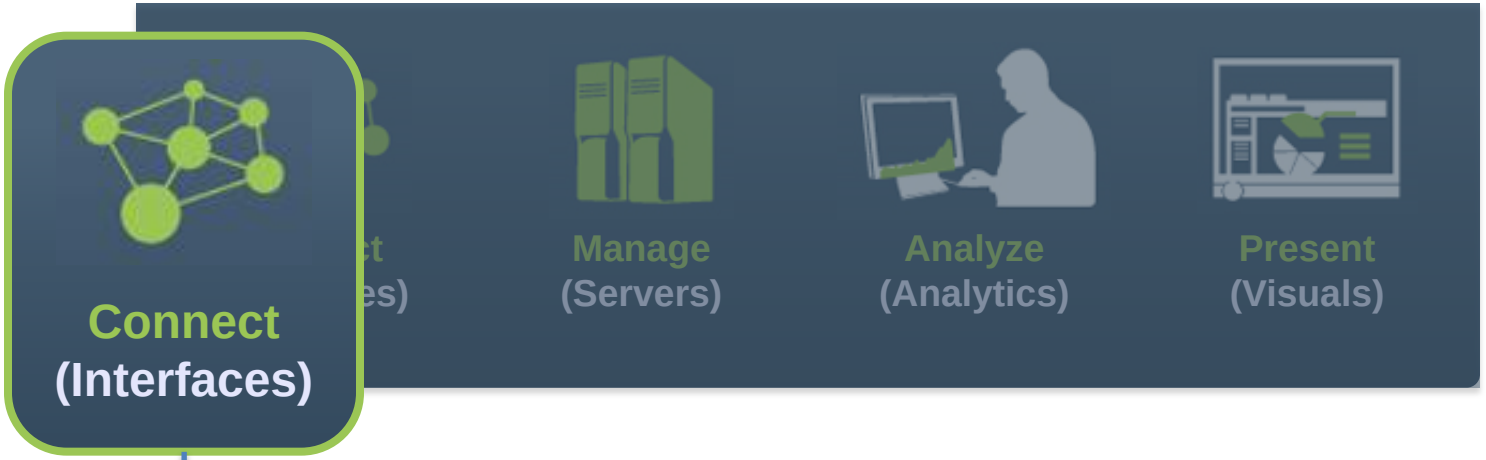
The PI System: Connect



Real-time
- DCS
- PLC
- SCADA
- OPC DA/HDA
- 3rd Party
- COM
- Connector

Custom
- SDK
- API

Relational
- OLEDB
- ODBC/JDBC
- ORACLE
- SQL

Smart Grid
- E&G Meters
- Water Meters
- Synchrophasors/PMU
- Intelligent Electronic Devices

Web Services
- Enterprise Bus
- SOA

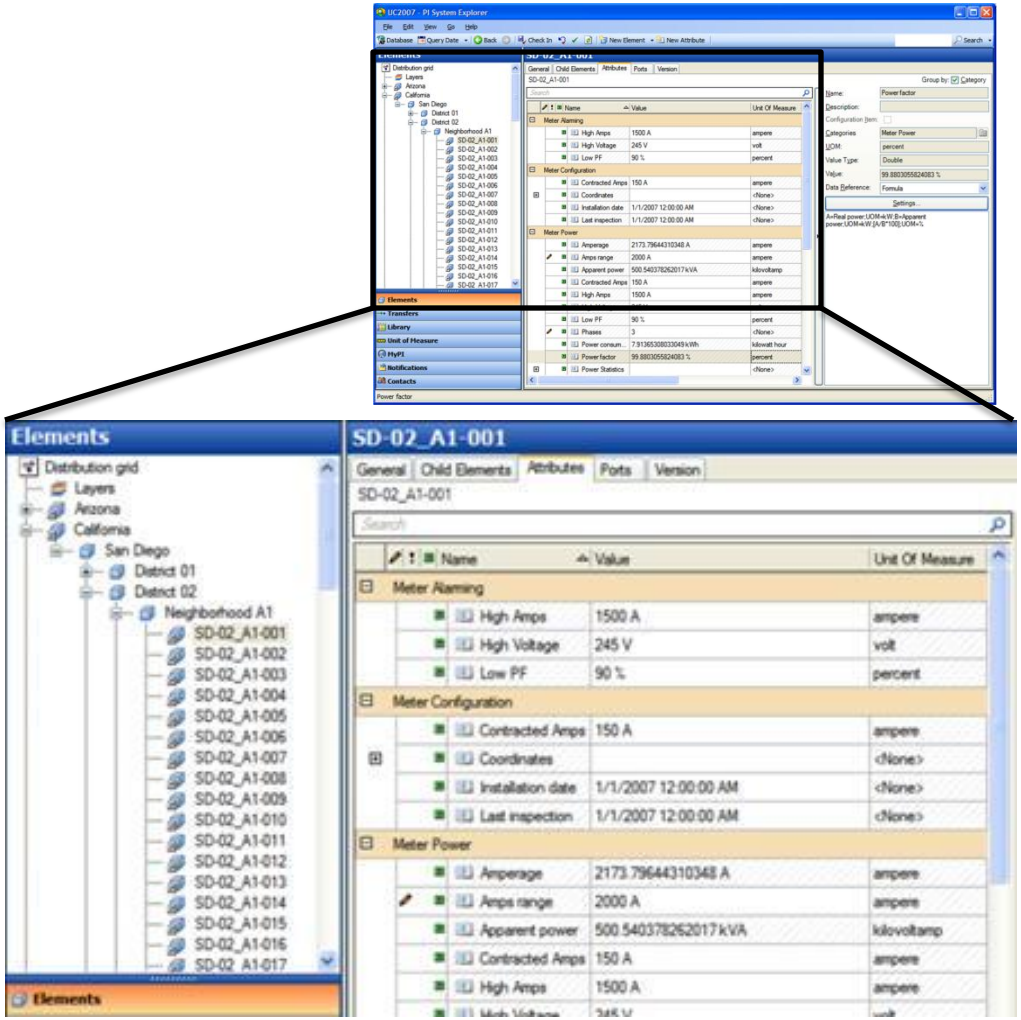
ERP
- OLEDB
- Web Services
- .NET

IT
- MCN Health Monitor

Value now. Value over time.

PI Asset Framework (AF) : Context -

- **Templates** allow quick creation of meta data structure for assets
- **Hierarchical structure** allows for logical browsing for equipment information
- Use of **Element Relative Displays** makes for more consistency in displays and reduces time spent creating displays
- Built on a **SQL Server platform**, resulting in scalability and reliability



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AF - Putting AF into Best Practice

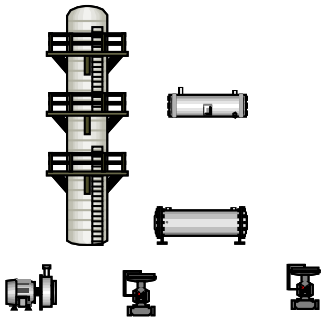
Shaping your data by:

1. Defining types of assets
   Schema of typical asset definition
   » Templates

Condensor
Heatexchanger
Column
Valve
Pipe
Pump

2. Association to a “real” asset
   Created from Template
   » Elements

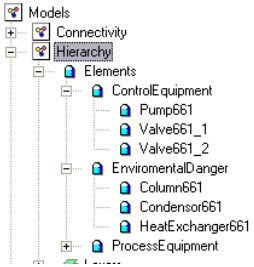
Column661
Condensor661
P661_1
P661_2
HeatExchanger661
Valve661_1
Valve661_2



3. Describing the “real” asset
   Having Units Of Measure (UOM)
   Data references from everywhere
   » Attributes

OpeningGrade	**PI Point:** \\MOBILEVBC\Valve661_1.OpeningGrade
InspectionResult	**Table Lookup:** SELECT InspectionResult FROM …
LastInspection	**Table Lookup:** SELECT LastInspection FROM …
SerialNumber	**Table Lookup:** SELECT SerialNumber FROM …
XZY	**Formula:** A=OpeningGrade;[A*0.98]

4. Physical/logical asset structure
   » Hierarchy



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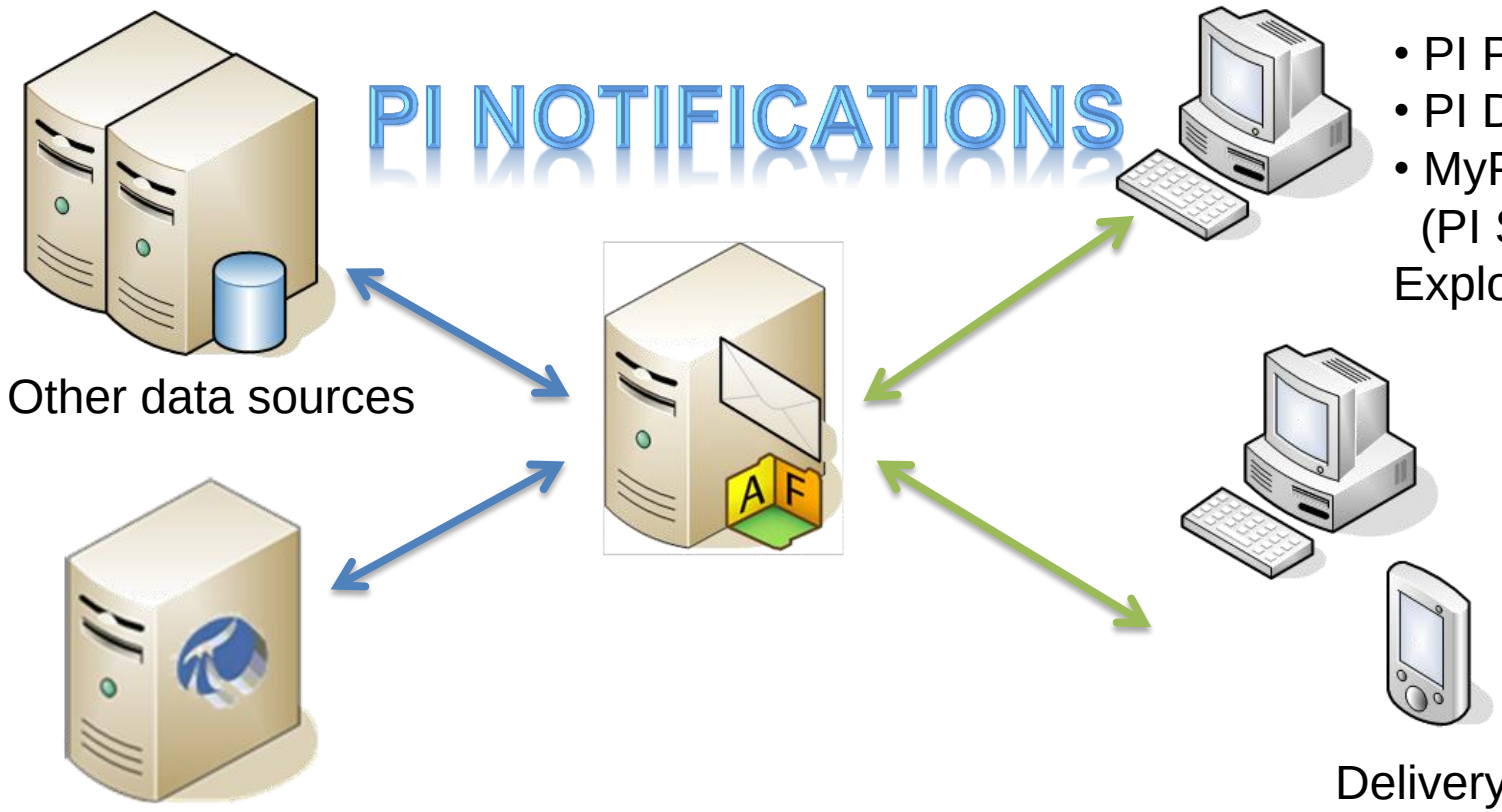
Analysis Options

- AF – Asset Framework
- PI Subsystems
  - Totalization
  - Performance Equations
- PI Advanced Calculation Engine (PI ACE)
  - Schedule Options
    - Natural
    - Event
  - Visual Studio Add-In
  - Flexible and Extensible – Models in MDB

PI Notifications

Configure custom alarms based on any data source by leveraging the flexibility of PI AF



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PI Notifications Benefits

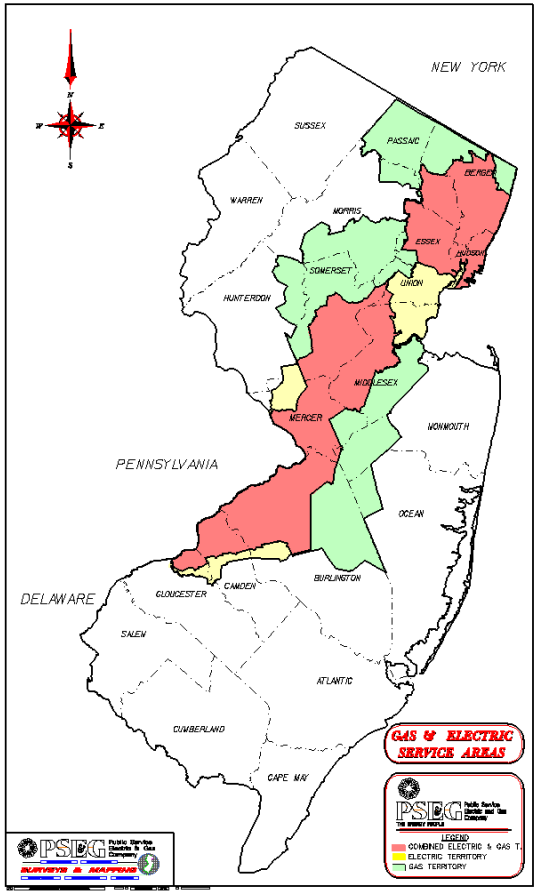
- **Disparate Data Triggering**
  - Use multiple disparate data sources to develop and trigger custom alarming conditions and notifications
- **Escalation Management**
  - Notification delivery to the chain of command
- **Auditing**
  - Supports reporting audit trail through notification lifecycle
- **Cross-System Messaging**
  - Programmatically extend notification delivery to seamlessly integrate messaging to third party applications (e.g., workflow, ERP, and asset maintenance systems,)
- **On Demand Visualization**
  - Provide immediate visualizations using PI WebParts, PI ProcessBook and PI DataLink

PSE&G Customer Case Study

Implementing Condition-Based Maintenance for an Electric Utility

PSE&G

- Utility Overview
  - New Jersey Based
  - Total Assets ~ $14 Billion
  - Total Revenue ~ $7 Billion
- Service Territory
  - 70% of New Jersey's population
  - 2.0 million Electric customers
  - 1.6 million Gas customers
  - 2,600 Square Miles
- Delivery Implementation
  - 1999 – SAP
  - 2000 - OMS, GIS & CAD
  - 2002 - CMMS



PSE&G Customer Case Study

Business Challenge / Problems Addressed

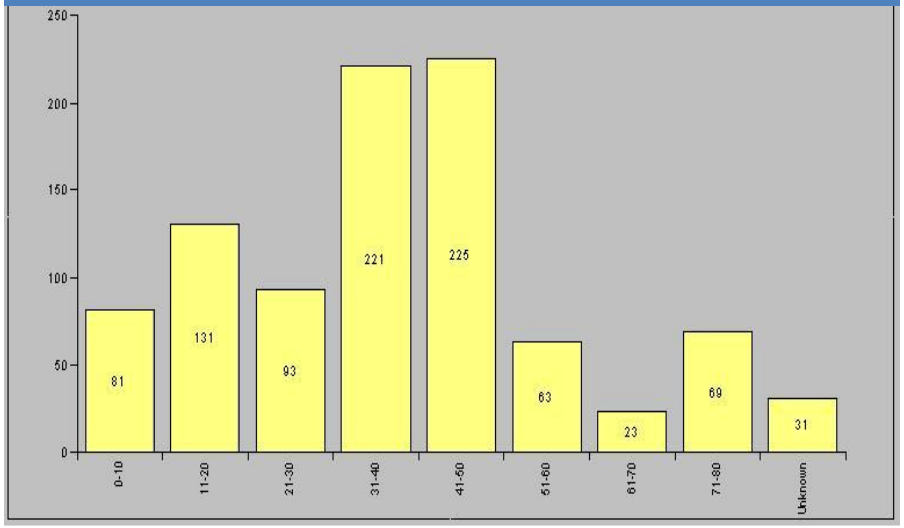
Motivating Factors

- After an equipment failure, sufficient data collected to determine why
- No formal capital expenditure determination plan
- No formal preventive maintenance scheduling program

Challenges

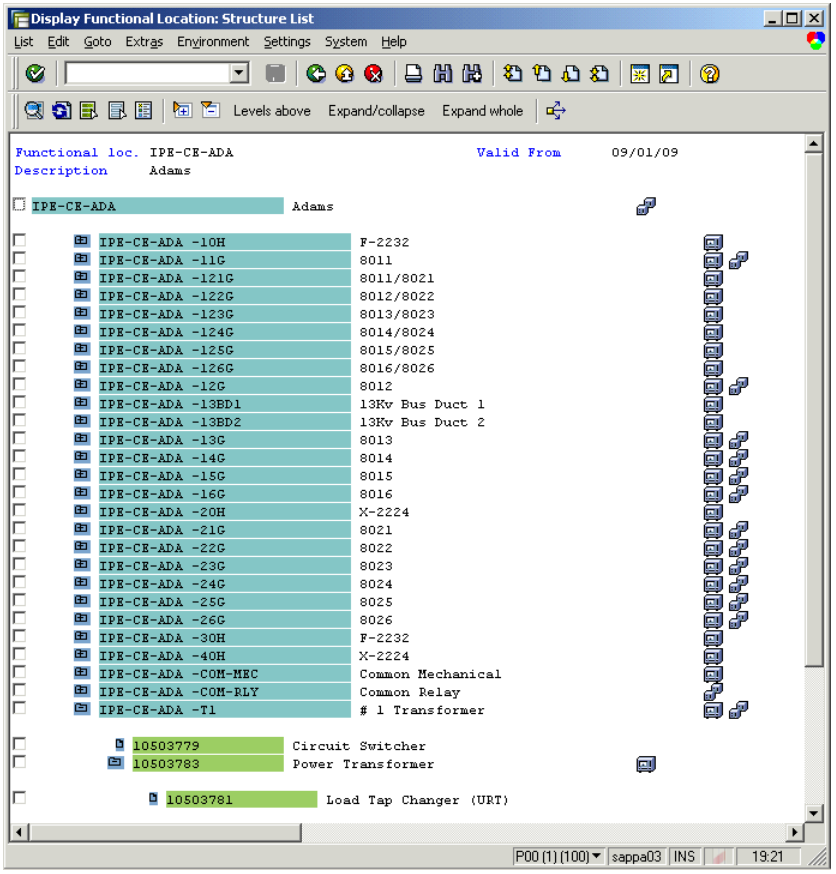
- No predictive maintenance program or strategy
- Significant liability risk and system outage potential from old equipment vulnerable to failure
- Limited assessment tools for determining asset condition
- Decreasing expertise in both field maintenance and engineering
- No formalized capital spending program
- Asset Information in a variety of disparate systems

Asset Population by Division and Age Class Within Equipment



SAP PM for PSE&G Electric Delivery

- Equipment & Locations
  - Class and Characteristics
  - Nameplate
- Maintenance Plans (56k Plans)
  - Calendar-based
  - Counter-based
  - Condition-based
- Notifications
  - Damage and Cause Codes grouped by Equipment
- Equipment Visibility
  - PM Plan Cost/Hours vs. Actual
  - CM Cost



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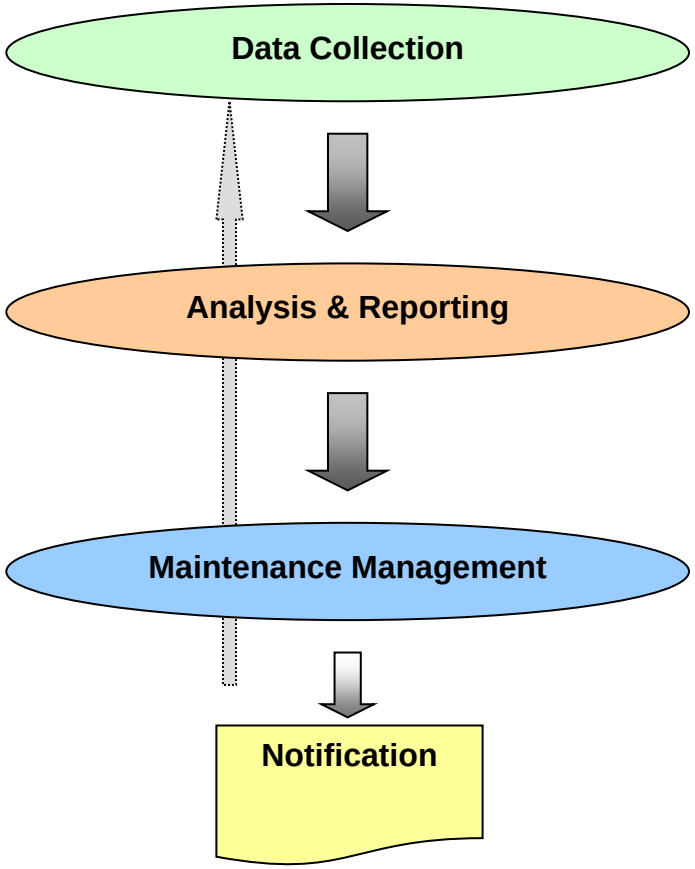
PSE&G Customer Case Study

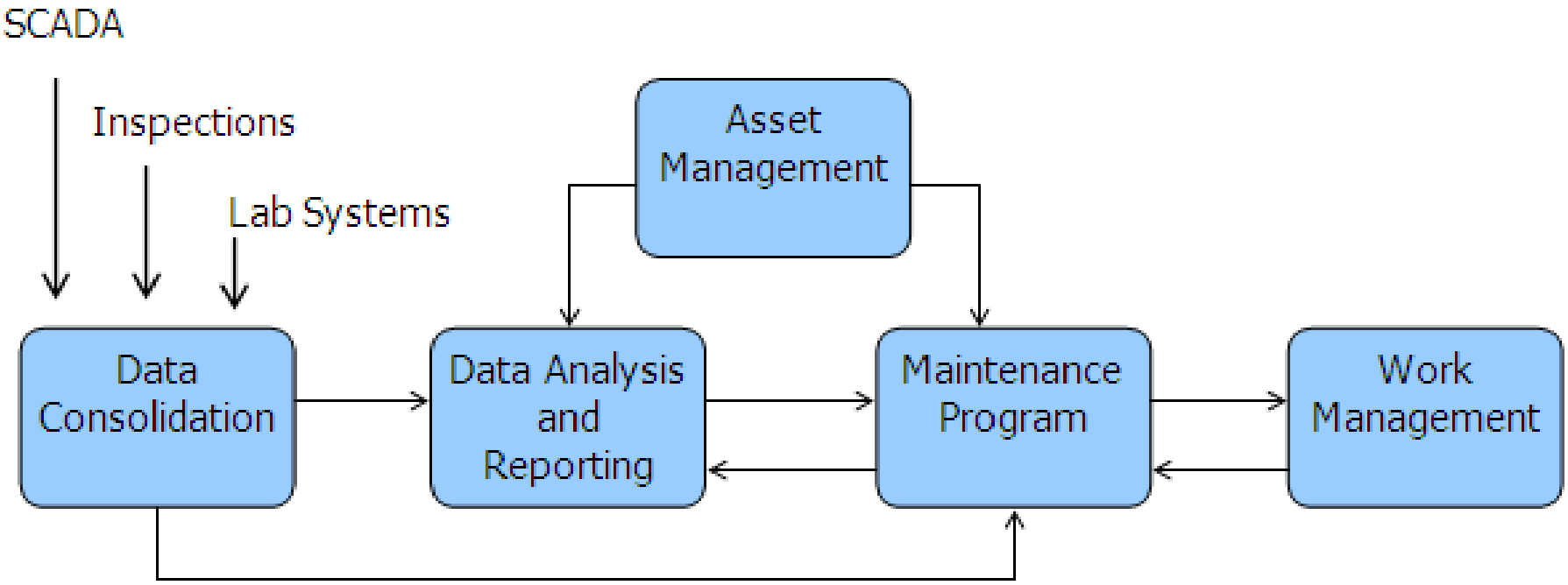
Approach and Solution

PSE&G Functional Areas

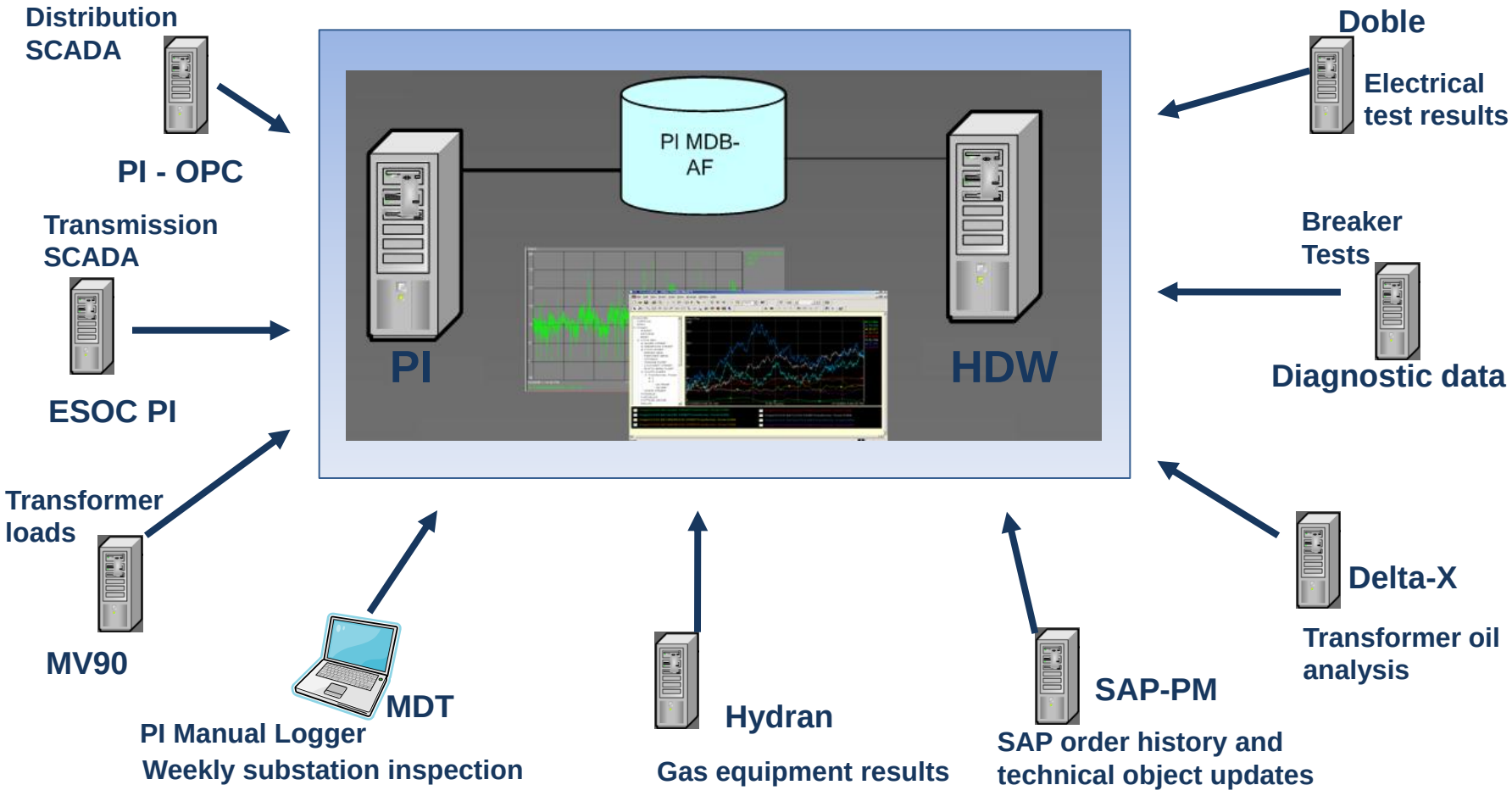
- Data Collection
  - SAP Asset Information
  - Time-Series Data Collection Application
  - Diagnostic and Inspection Data
- Asset Analysis and Reporting
  - Condition Assessment
  - Work Prioritization
  - Alerts / Notifications
- Maintenance Management
  - Measurement Points
  - Maintenance Plan Modifications
  - Notifications



PSE&G Conceptual Model



PSEG System Integration



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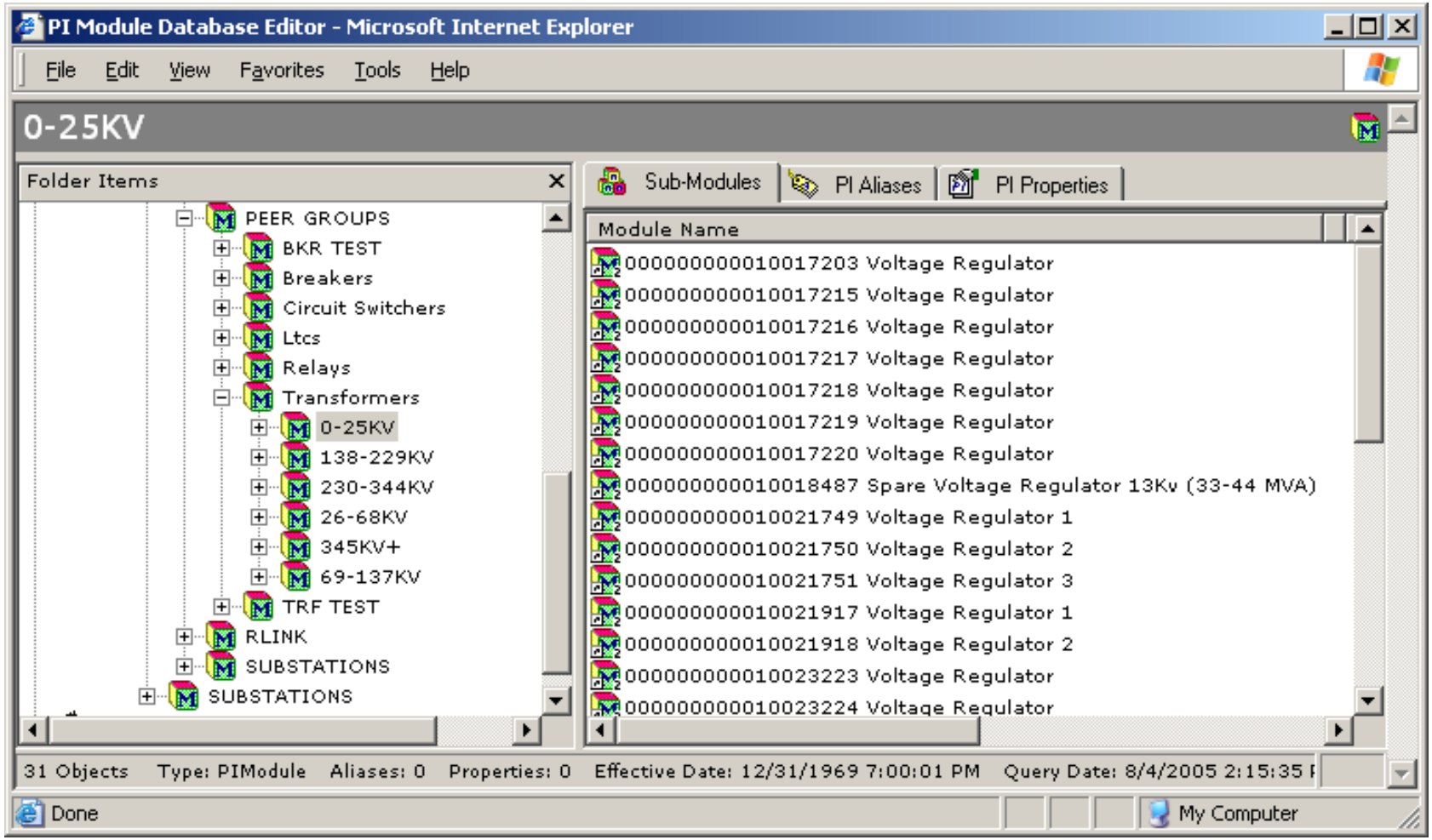
PSE&G Condition Algorithms

- Calculation Structure
  - CA = F1(M1) + F2(M2) + F3(M3) + …
  - Factors driven by data available
  - Example Factors
    - CM Cost & Count for Past 6 Months
    - Operation Count for Past 6/12 Months
    - Gas Analysis – Change over time
    - Average Load over Time
- Peer Groups
  - Apply calculations by peer group
  - Voltage, Class, Type
  - Example Groups:
    - 26KV – 69KV GCB
    - 138KV+ Power Transformer
    - LTC Vacuum Tanks

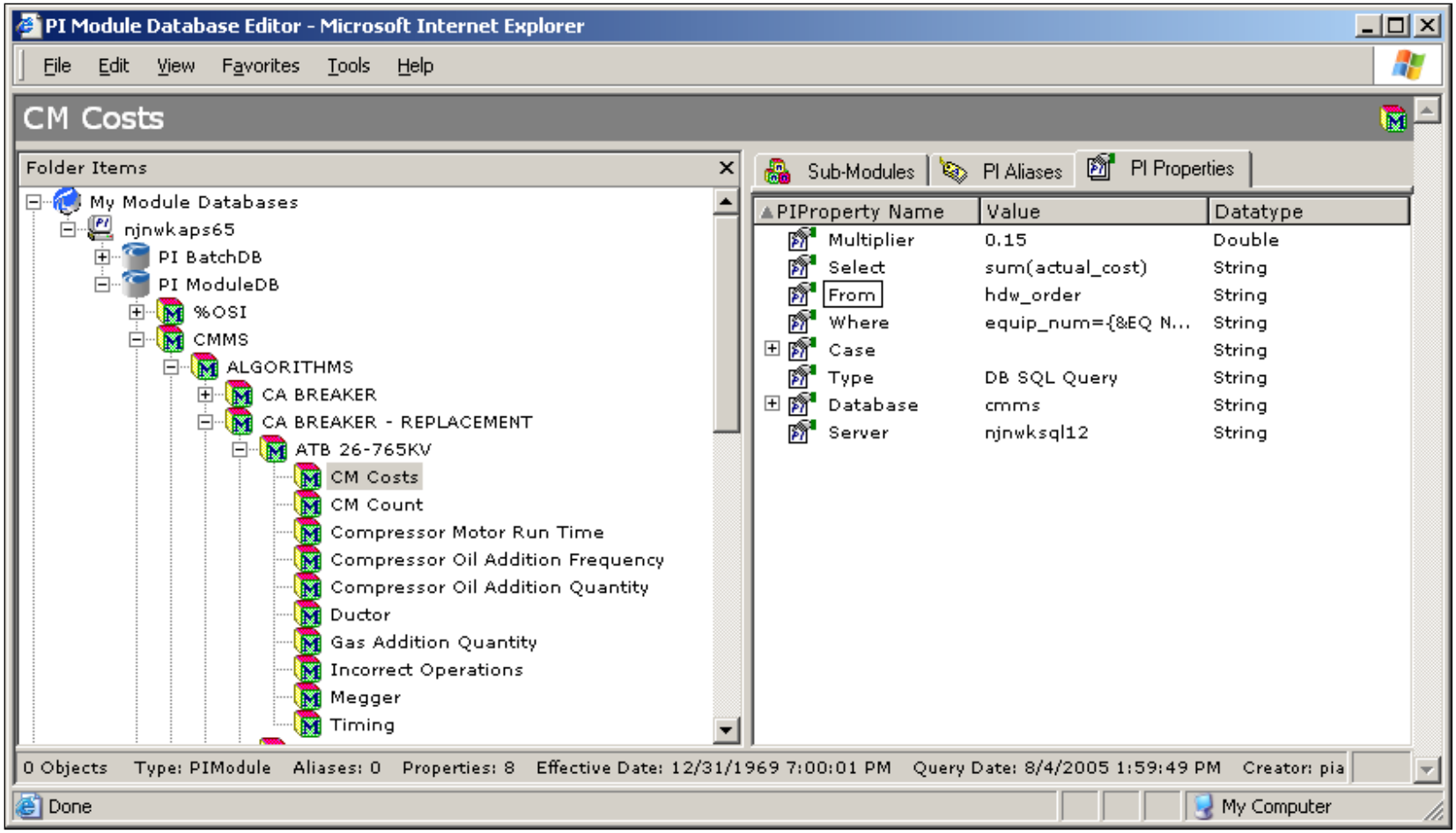
PSE&G Alerts & Notifications

- PI-ACE Algorithms monitor real-time & weekly inspection data
- Creates emails and SAP notification
- Examples:
  - Excessive LTC Operations
  - High GCB Temperatures
  - Low GCB Pressure
  - Low Transformer Oil Tank Levels
  - Low Nitrogen Cylinder Pressure
- Measurement Points updated in SAP

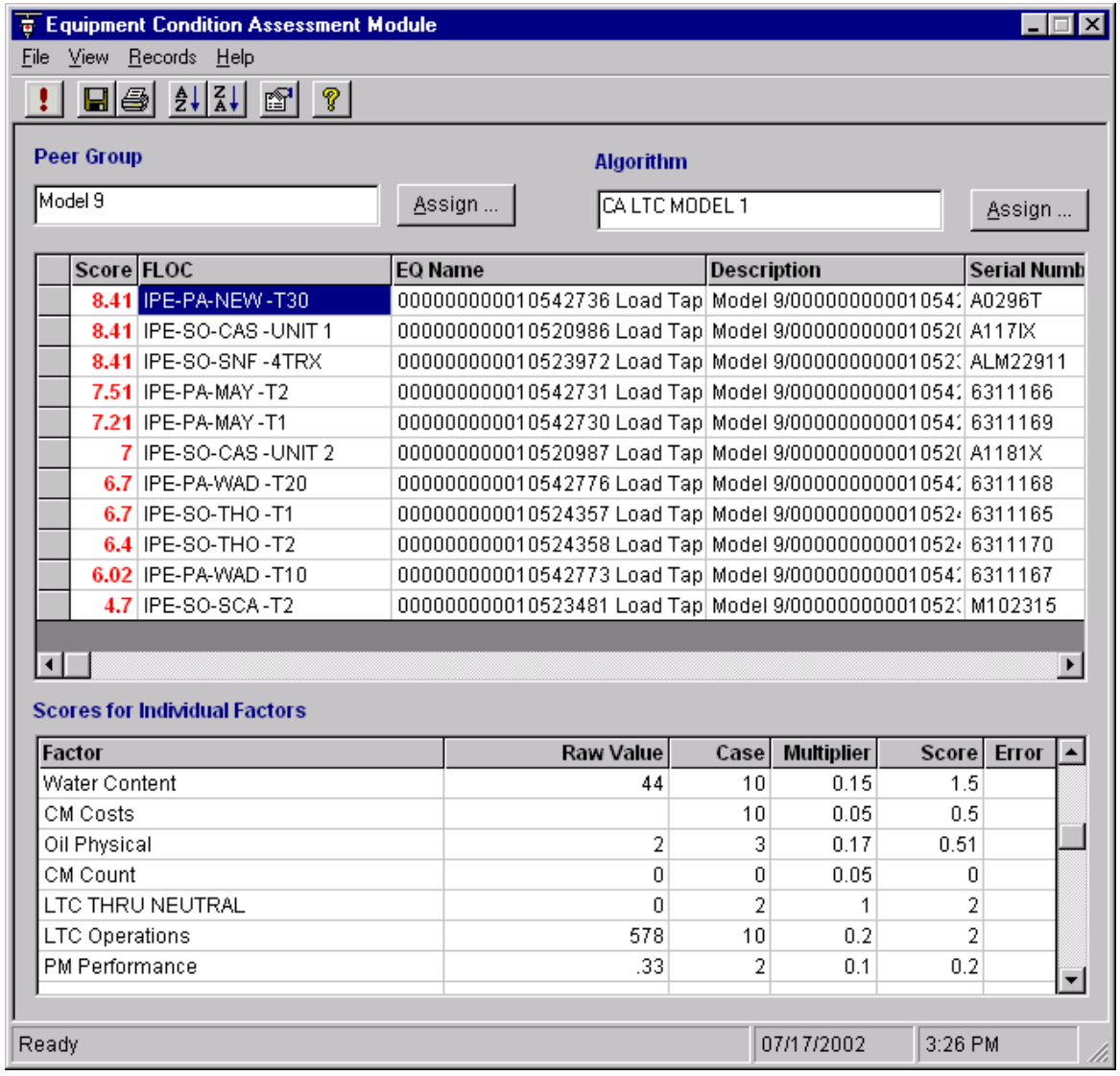
Assets in PI System



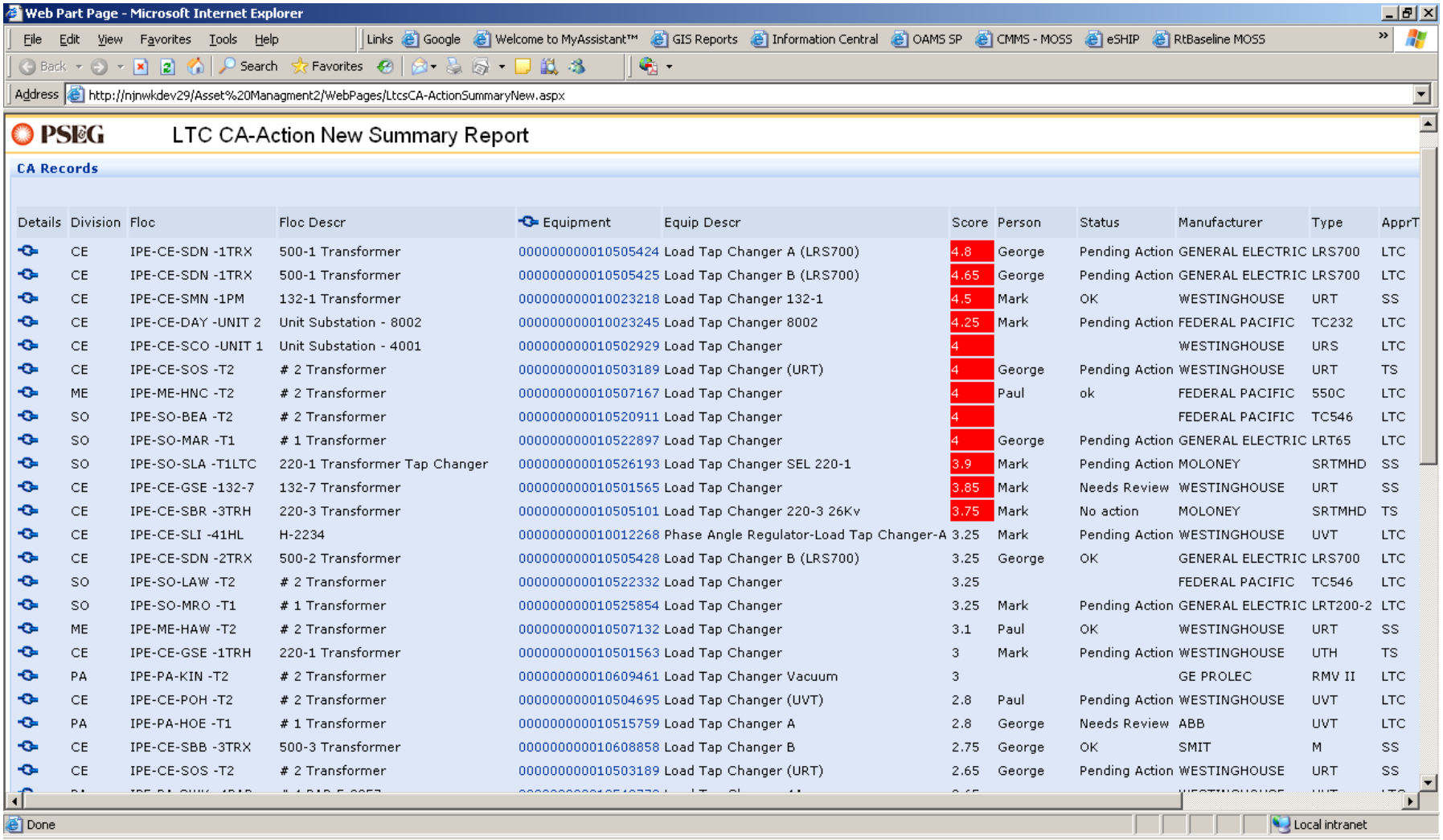
Calculation Models in PI System



Condition Assessment



PSE&G Visualization



Details	Division	Floc	Floc Descr	Equipment	Equip Descr	Score	Person	Status	Manufacturer	Type	ApprT
	CE	IPE-CE-SDN -1TRX	500-1 Transformer	000000000010505424	Load Tap Changer A (LRS700)	4.8	George	Pending Action	GENERAL ELECTRIC	LRS700	LTC
	CE	IPE-CE-SDN -1TRX	500-1 Transformer	000000000010505425	Load Tap Changer B (LRS700)	4.65	George	Pending Action	GENERAL ELECTRIC	LRS700	LTC
	CE	IPE-CE-SMN -1PM	132-1 Transformer	000000000010023218	Load Tap Changer 132-1	4.5	Mark	OK	WESTINGHOUSE	URT	SS
	CE	IPE-CE-DAY -UNIT 2	Unit Substation - 8002	000000000010023245	Load Tap Changer 8002	4.25	Mark	Pending Action	FEDERAL PACIFIC	TC232	LTC
	CE	IPE-CE-SCO -UNIT 1	Unit Substation - 4001	000000000010502929	Load Tap Changer	4			WESTINGHOUSE	URS	LTC
	CE	IPE-CE-SOS -T2	# 2 Transformer	000000000010503189	Load Tap Changer (URT)	4	George	Pending Action	WESTINGHOUSE	URT	TS
	ME	IPE-ME-HNC -T2	# 2 Transformer	000000000010507167	Load Tap Changer	4	Paul	ok	FEDERAL PACIFIC	550C	LTC
	SO	IPE-SO-BEA -T2	# 2 Transformer	000000000010520911	Load Tap Changer	4			FEDERAL PACIFIC	TC546	LTC
	SO	IPE-SO-MAR -T1	# 1 Transformer	000000000010522897	Load Tap Changer	4	George	Pending Action	GENERAL ELECTRIC	LRT65	LTC
	SO	IPE-SO-SLA -T1LTC	220-1 Transformer Tap Changer	000000000010526193	Load Tap Changer SEL 220-1	3.9	Mark	Pending Action	MOLONEY	SRTMHD	SS
	CE	IPE-CE-GSE -132-7	132-7 Transformer	000000000010501565	Load Tap Changer	3.85	Mark	Needs Review	WESTINGHOUSE	URT	SS
	CE	IPE-CE-SBR -3TRH	220-3 Transformer	000000000010505101	Load Tap Changer 220-3 26Kv	3.75	Mark	No action	MOLONEY	SRTMHD	TS
	CE	IPE-CE-SLI -41HL	H-2234	000000000010012268	Phase Angle Regulator-Load Tap Changer-A	3.25	Mark	Pending Action	WESTINGHOUSE	UVT	LTC
	CE	IPE-CE-SDN -2TRX	500-2 Transformer	000000000010505428	Load Tap Changer B (LRS700)	3.25	George	OK	GENERAL ELECTRIC	LRS700	LTC
	SO	IPE-SO-LAW -T2	# 2 Transformer	000000000010522332	Load Tap Changer	3.25			FEDERAL PACIFIC	TC546	LTC
	SO	IPE-SO-MRO -T1	# 1 Transformer	000000000010525854	Load Tap Changer	3.25	Mark	Pending Action	GENERAL ELECTRIC	LRT200-2	LTC
	ME	IPE-ME-HAW -T2	# 2 Transformer	000000000010507132	Load Tap Changer	3.1	Paul	OK	WESTINGHOUSE	URT	SS
	CE	IPE-CE-GSE -1TRH	220-1 Transformer	000000000010501563	Load Tap Changer	3	Mark	Pending Action	WESTINGHOUSE	UTH	TS
	PA	IPE-PA-KIN -T2	# 2 Transformer	000000000010609461	Load Tap Changer Vacuum	3			GE PROLEC	RMV II	LTC
	CE	IPE-CE-POH -T2	# 2 Transformer	000000000010504695	Load Tap Changer (UVT)	2.8	Paul	Pending Action	WESTINGHOUSE	UVT	LTC
	PA	IPE-PA-HOE -T1	# 1 Transformer	000000000010515759	Load Tap Changer A	2.8	George	Needs Review	ABB	UVT	LTC
	CE	IPE-CE-SBB -3TRX	500-3 Transformer	000000000010608858	Load Tap Changer B	2.75	George	OK	SMIT	M	SS
	CE	IPE-CE-SOS -T2	# 2 Transformer	000000000010503189	Load Tap Changer (URT)	2.65	George	Pending Action	WESTINGHOUSE	URT	SS

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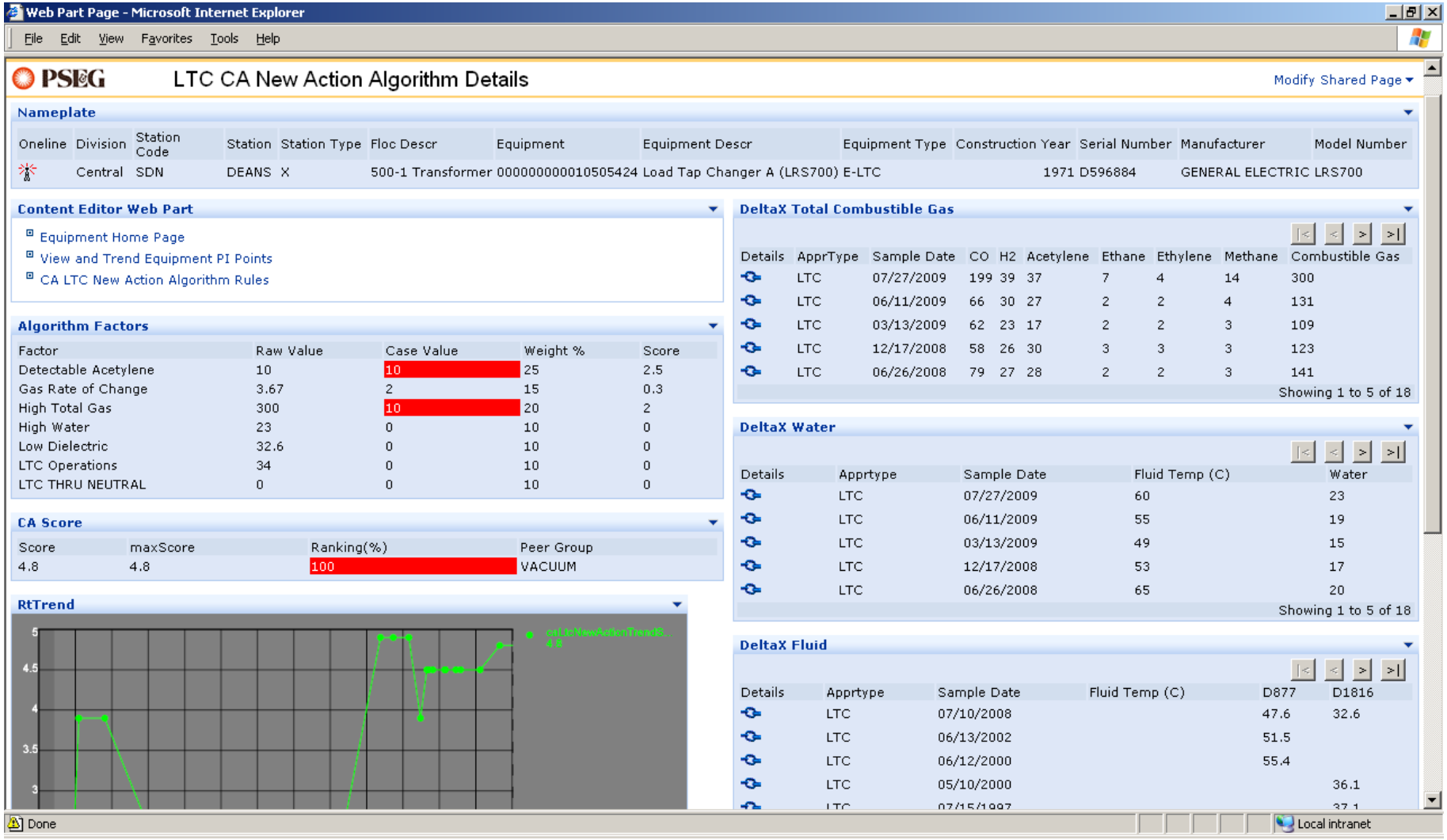
PSE&G Visualization



Empowering Business in Real Time.

OSIsoft Software and Services Used

- PI Server
- PI Manual Logger
- PI Interfaces
  - UFL, OPC, etc.
- PI MDB/AF
- PI ACE
- PI WebParts

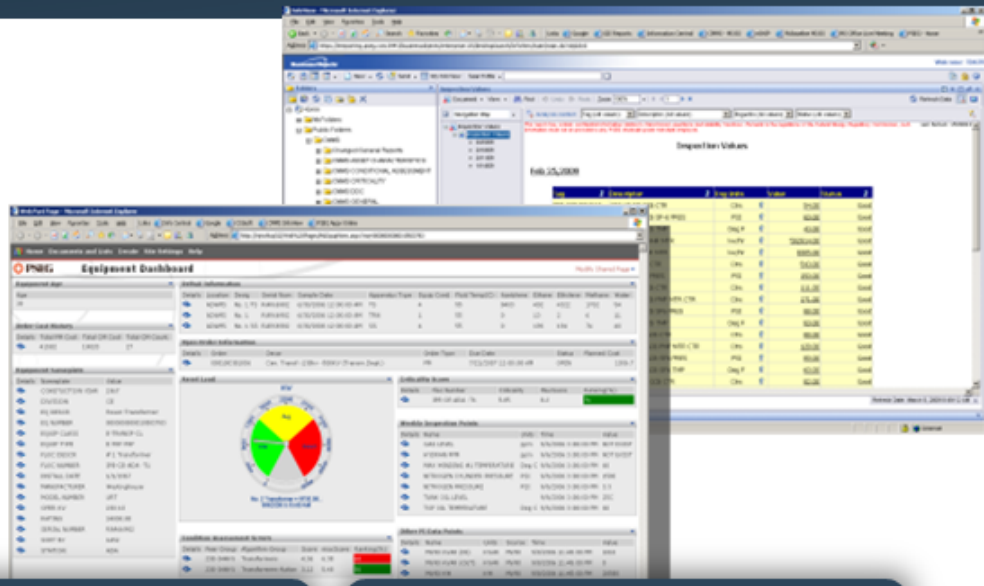
Results

PSE&G: Condition Based Maintenance

"We get a detailed breakdown on equipment costs and man/hours to service that gives us important business benefits. Without the use of the PI System, it would have taken us several months to gather and analyze the information."

Angela Rothweiler, Principal Engineer

PSEG



Customer Business Challenge

- Providing the highest reliability Power Distribution is requirement
- Minimize Maintenance Costs

Solution

- Implemented automatic data collection & notifications to SAP PM
- Setup standard business rules for condition based maintenance using PI - ACE
- Provided focused view into equipment using SAP Portal

Customer Results / Benefits

- Holds Reliability award for Mid Atlantic States for last 7 years
- Focused maintenance expenditures on needed targets
- Last month: LTC stationary & moving contacts burned, next PM due 2015, LTC & transformer would have failed, saved $2M transformer

Empowering Business in Real Time.

Tangible Benefits

- Annually document savings
- 2005 – Approximately $3MM
- Reduced Maintenance Costs
- More targeted and reduced Capital Expenditures
- Failure avoidance

Intangible Benefits

- Platform for many other analytic efforts
- Used for limiting component determination for critical circuits
- Used for Work Prioritization – ensuring the right work is performed
- Results in quicker analysis of failures

PSE&G Lessons Learned

- Right Vision (Business & Technical)
- Organizational Changes to support system
- LOB Control
- Change SME thought process
- Tied success directly to SME and Asset Engineers Goals
- Constantly Measuring Inputs

Conclusions

Conclusion

- Condition Based Maintenance (CBM) is a business imperative
  - Business and Technical Considerations
- PI is the right framework for Condition Based Maintenance
  - Complete path for implementation
  - Provides value now and over time
- Customers have achieved success
  - Many success stories in many industries
  - One of our leading topics in the CoE

Thank you

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