Asset Monitoring and Condition-based Maintenance (CBM) with the PI System

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Takeaways

- CBM can mean different things – whom do you ask?
- PI System covers major portions of the CBM workflow
  - AF Analytics applied to maintenance/reliability (usage-based, condition-based, predictive)
- As appropriate, include machine condition monitoring data
  - vibration, oil analysis, thermography...
- Get started now – make PI part of the maintenance business process
- Ask about CBM workshops (speak to us or your Account Manager)
- CBM Lab at PI World 2019 - Day 3 afternoon and Day 4 morning

Terms & Definitions

PM/CM

APR

Predictive

APM

RCM

CBM

Condition Based Maintenance

PF

CM

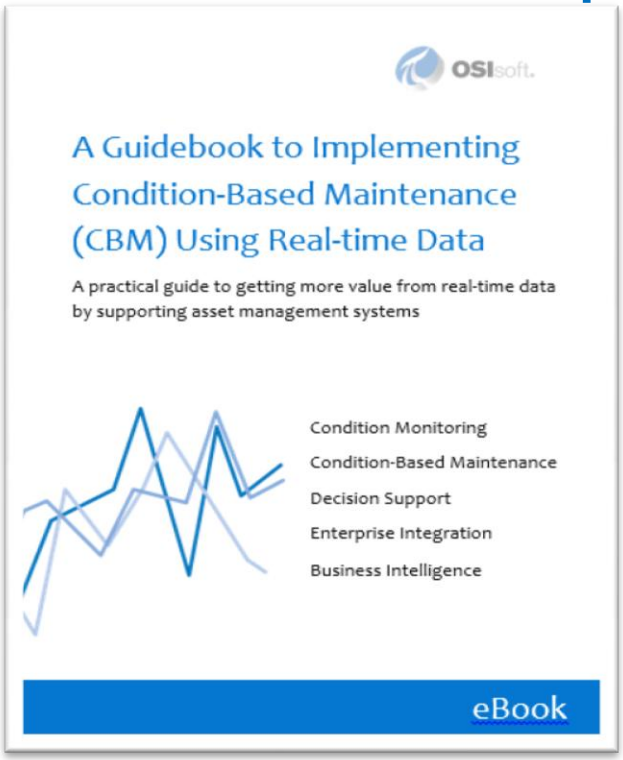
Condition Monitoring

RCA

CMMS

FMEA

CBM Prescriptive Guidance



Terms & Definitions

Implementation Guidance

PI System Overview for CBM

PI System Integration w/ CMMS

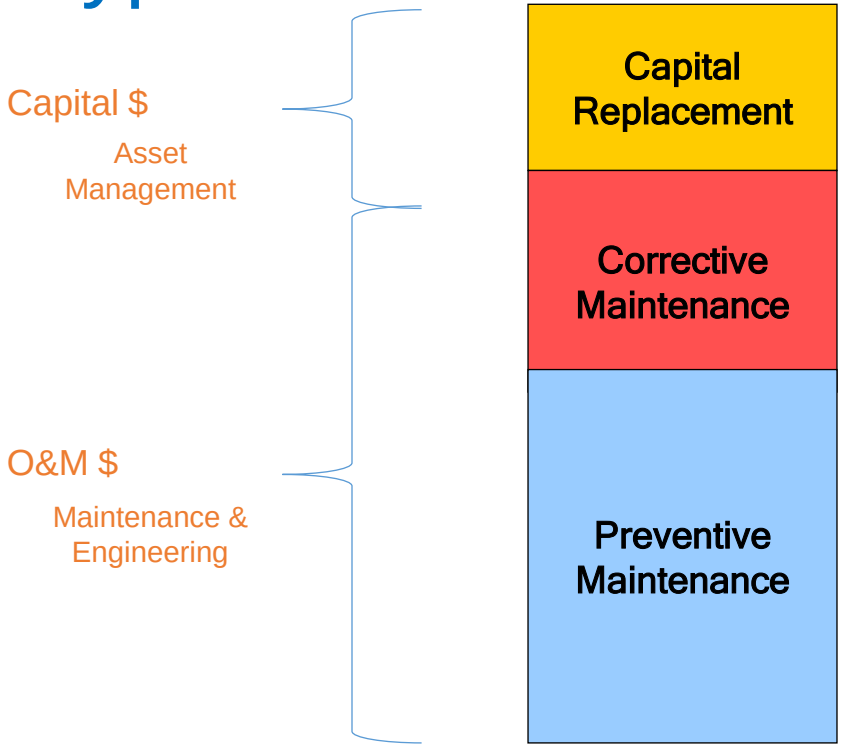
Enabling Opportunities

Solution Examples

Industry References

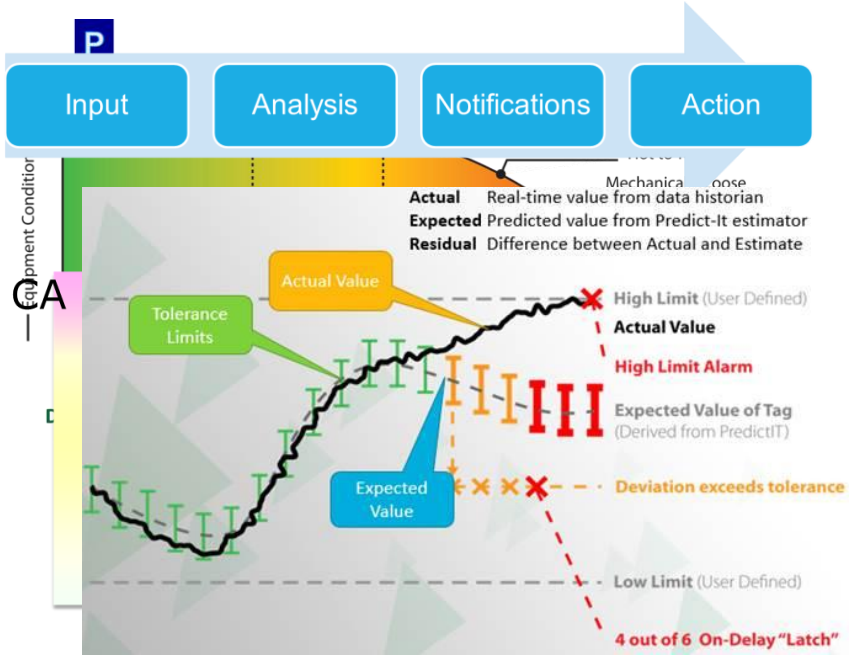
Maintenance Budget & Types

- Capital replacement
  - Replace or rebuild expensive assets
  - Major projects
  - Squeaky wheel gets the grease syndrome
- Corrective Maintenance (CM)
  - Repair a failure or degradation
  - Troubleshoot & Rework
  - Unscheduled often with downtime
- Preventive Maintenance (PM)
  - Usually time-based schedules
  - Clean & Inspect
  - Pack bearings
  - Filter check
  - Diagnostic Measurements & tests



CBM can mean different things

- Condition Monitoring
- Incipient Failure Detection
- Condition Assessment
- CBM Preventive Maintenance
- APR – Advanced Pattern Recognition



It's a journey – not a destination

CBM - Analytics

- Usage assessment - runhours
  - hours, tonnage, starts/stops, …
- Condition assessment - machine or process
  - efficiency, vibration (peak), thermography (hot spot)…
- Predictive - Simple - extrapolate a trend
- Predictive - Advanced and APR models
- Asset Health Score

Run Hours Display

OSIsoft.

Report - Critical Motors - Run Hours

Last Update: 3-12-2016

Equipment	Daily Run Hours	Lifetime Run Hours	During Last Period	Period	Since Last Service	Last Service	Next Service
Agitator 1204	4.51	7,975	0	3mo	387	1/10/2016	11/10/2016
Agitator 1205	23.79	10,119	2,154	3mo	409	2/23/2016	10/3/2016
Agitator 1304	23.49	9,908	2,118	3mo	697	2/11/2016	12/13/2016
Agitator 1305	23.49	9,908	2,118	3mo	697	2/11/2016	12/1/2016
Fan 5163	19.71	8,554	1,174	3mo	2,664	10/1/2015	5/1/2016
Fan 5164	23.97	9,292	2,022	3mo	3,566	10/2/2015	5/2/2016
Fan 8144	14.44	9,839	2,112	3mo	3,635	10/5/2015	5/5/2016
Pump 3809	15.16	8,587	1,949	3mo	3,218	10/10/2015	5/10/2016
Pump 3810	23.97	9,618	2,079	3mo	3,837	9/23/2015	7/1/2016

San Francisco Public Utilities Commission

Results of Pilot

Asset Name	# of PMs: Scheduled Basis	# of PMs: Conditional Basis	# of unnecessary PMs Avoided
PUMP-1149	28	0	28
PUMP-1150	28	12	16
PUMP-1151	28	0	28
PUMP-1152	28	21	7
Totals	**112**	**33**	**79**

100 Main Pumps = $1.8MM Annually

- Over the 28-month simulation, 79 sets of unnecessary monthly Preventative Maintenance procedures were identified.
- Each set of monthly maintenance procedures costs approximately $2100.00
- This equals an annual savings of $71,100.00 for only four assets!

Calculating Expected Heat Rate

TransCanada
In business to deliver

_CoeffType	ECMax
A	3.01916
B	0
C	-140.82336
D	0
E	3431.05804
F	0
G	-39811.23565
H	0
I	226037.87046
J	0
K	-524290.83316
L	0
M	0
N	0
O	0
P	0
Q	0

Lookup curve-fit coefficients from SQL Table (Manufacturer Performance Curves)

Data Reference: Table Lookup

Settings...

```
SELECT CoefficientValue FROM PerformanceCentrifEff WHERE PerformanceModelID = @[PerformanceModelID] AND CoefficientType = @[_CoeffType] AND CoefficientOrder = 1
```

Real-time Streaming Analytics

$$Q = \frac{\Delta P_{DD} * kh}{141.2 \mu B_0 \left\{ ln \frac{r_e}{r_w} - \frac{3}{4} + S \right\}}$$

Category: Nominal Values

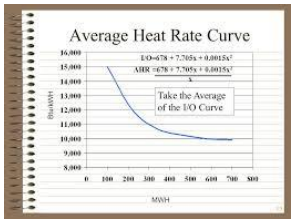
BHP_Nominal	8710.27322604474 BHP
FuelRate_Nominal	71.1036975854648 MCFH
HeatRate_Nominal	8163.19944739005 BTU(LHV)/BHP-hr
PCD_Nominal	205.15303353481 psi
T5_Nominal	1394.59524035539 °F
T7_Nominal	925.386891989674 °F

Apply curve-fit to calculate Nominal Heat Rate

Data Reference: Formula

Settings...

```
S=..\Driver|Steady Speed;A=.|A;B=.|B;C=.|C;D=.|D;E=.|E;F=.|F;G=.|G;H=.|H;I=.|I;J=.|J;K=.|K;L=.|L;M=.|M;N=.|N;O=.|O;P=.|P;Q=.|Q;X=FC_MaxSpeed;[if not(S) then 0 else (A + C*X + E*X^2 + G*X^3 + I*X^4 + K*X^5 + M*X^6 + O*X^7 + Q*X^8)/( 1 + B*X + D*X^2 + F*X^3 + H*X^4 + J*X^5 + L*X^6 + N*X^7 + P*X^8)]
```



Unit_Heat_Rate_Actual	9843.68334570345 BTU(LHV)/BHP-hr

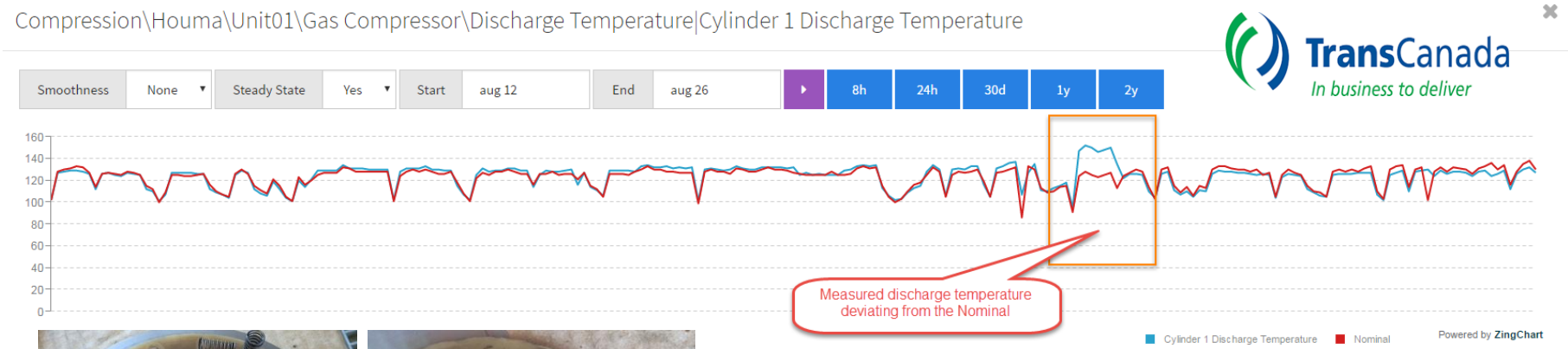
Calculate Actual Heat Rate

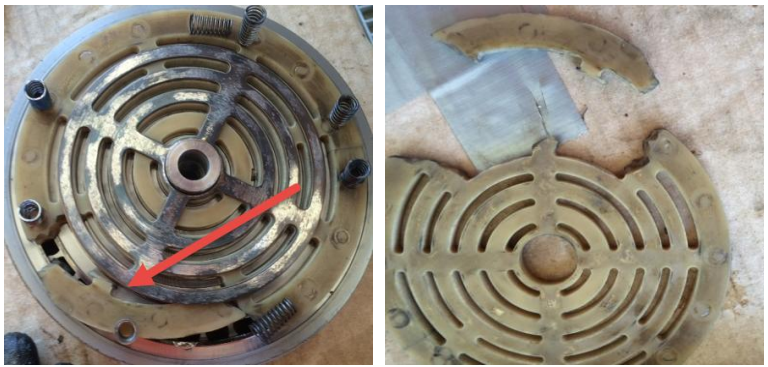
Data Reference: Formula

Settings...

```
A=Unit_BHP;B=Unit_Fuel;C=Unit BTU;[if badval(A) or badval(B) then 0 else if A<=30 then 0 else (B*(1000*C*0.915))/A]
```

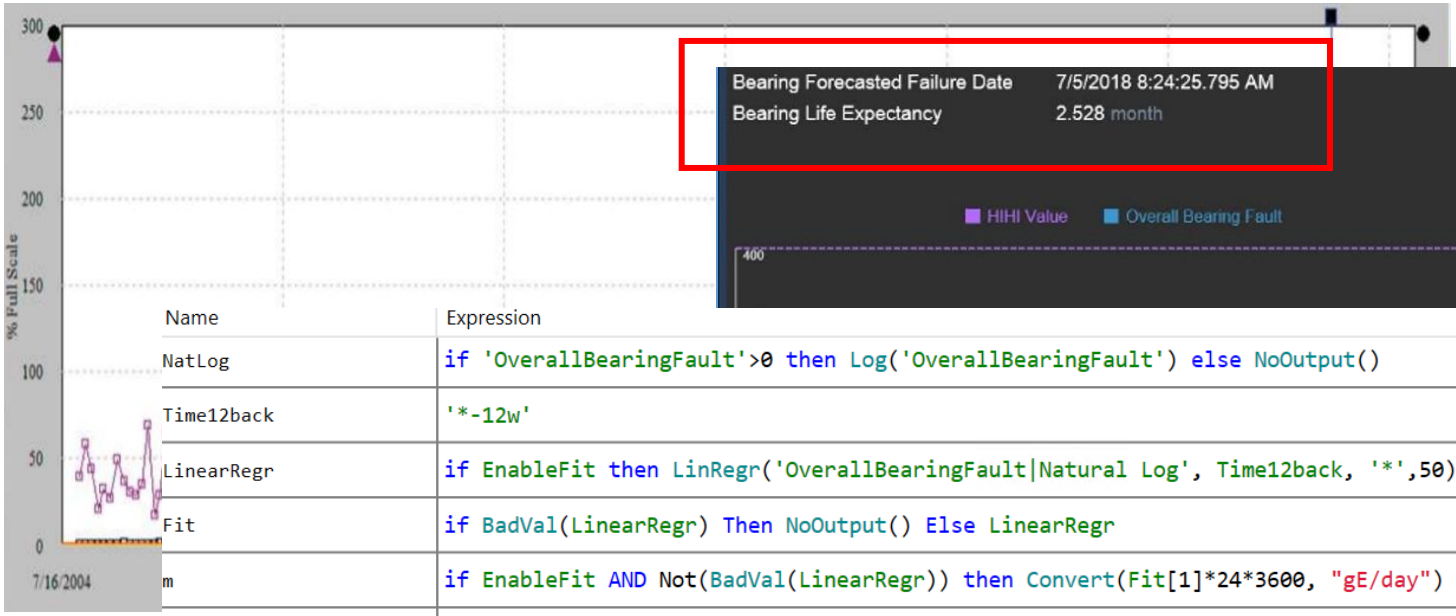
Example of Predictive Analytics in PI AF – Expected vs Actual





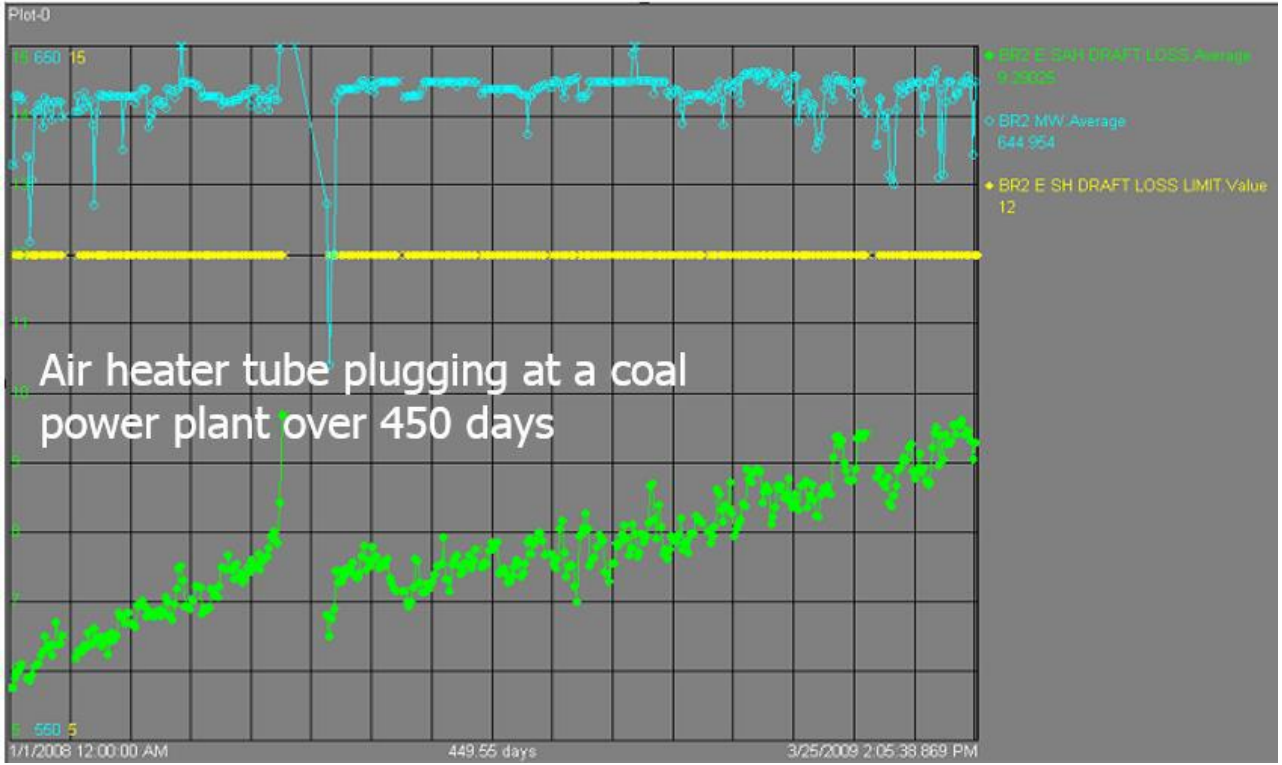
Found partially damaged compressor valve. The valve was replaced in a planned & controlled manner.

Maintenance – Simple Predictive – RUL (remaining useful life)



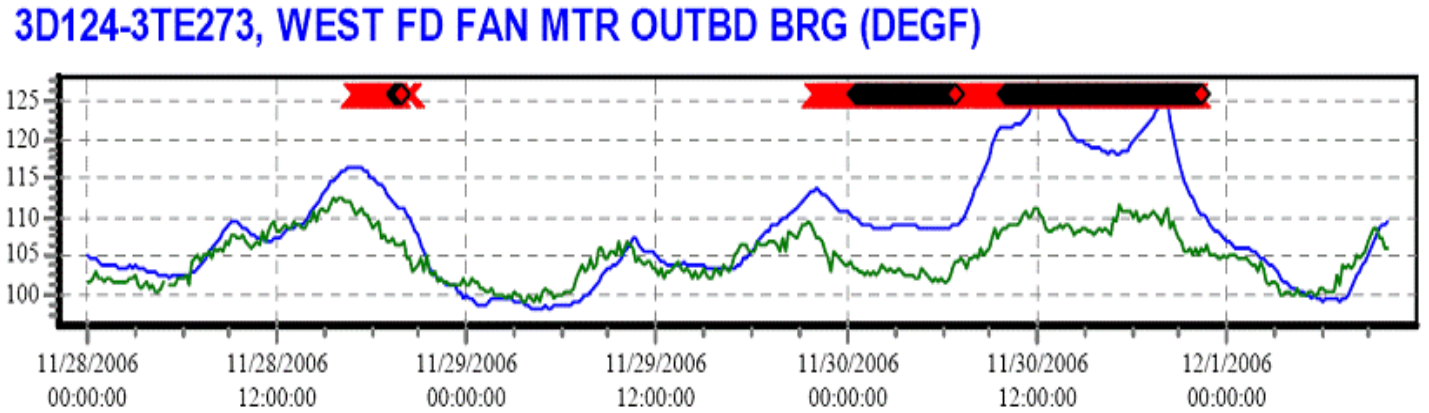
Name	Expression	Output Attribute
NatLog	`if 'OverallBearingFault'>0 then Log('OverallBearingFault') else NoOutput()`	OverallBearingFault|Natural Log
Time12back	`'*-12w'`	Map
LinearRegr	`if EnableFit then LinRegr('OverallBearingFault|Natural Log', Time12back, '*',50) |`	Map
Fit	`if BadVal(LinearRegr) Then NoOutput() Else LinearRegr`	Map
m	`if EnableFit AND Not(BadVal(LinearRegr)) then Convert(Fit[1]*24*3600, "gE/day") e`	OverallBearingFault|m
b	`if EnableFit AND Not(BadVal(LinearRegr)) then Convert(Fit[2], "gE") else NoOutput`	OverallBearingFault|b
rsquared	`if EnableFit AND Not(BadVal(LinearRegr)) then Convert(Fit[3],"ratio") else NoOutp`	OverallBearingFault|r_squared
LifeExpectancy	`if EnableFit AND Not(BadVal(LinearRegr)) and m>0 and rsquared>.400 then Convert((`	BearingLifeExpectancy
ForecastedFailDate	`if EnableFit AND Not(BadVal(LinearRegr)) and m>0 and rsquared>.400 then TimeStamp`	BearingForecastedFailureDate

Simple Predictive - air heater fouling



Advanced Pattern Recognition - Fan Motor Bearing

Temperature movement on FD Fan Motor outboard bearing - about 17 degrees above expected



After detection, the filters were found dirty, replaced, and the real time oil level and temps dropped back to the model expected value.

AGL – Diagnostic Center

Reduce unplanned generation losses across a mixed technology portfolio of > 10,000 MW

CHALLENGE

Improve capability to sense active failure modes at the earliest possible opportunity and take actions to avoid loss

- Data isolated and scattered
- Multiple SCADA technologies in play
- No access to real time data

SOLUTION

Phase #1: Centralise all real time data via OSIsoft PI

Phase #2: Install and commission Advanced Pattern Recognition Technology

- Predict It (APR) technology was fast to install and did not require a large data base (it uses Pi directly)
- A Centralised Operational Diagnostics Centre (ODC) reduced the number of recourses required and increased the level of skills
- ODC also uses PI system for deep dive investigations

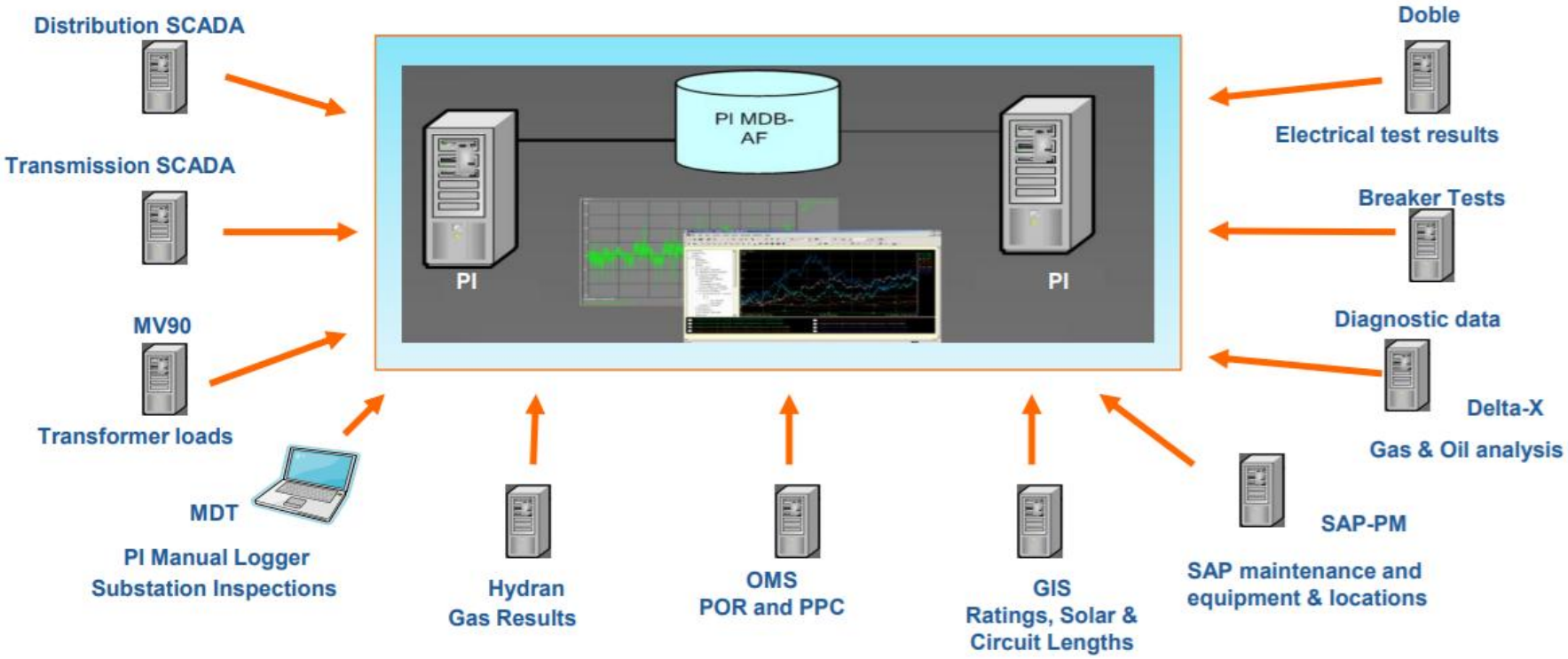
RESULTS

$18.7M of avoided losses in 3 years (from a standing start)

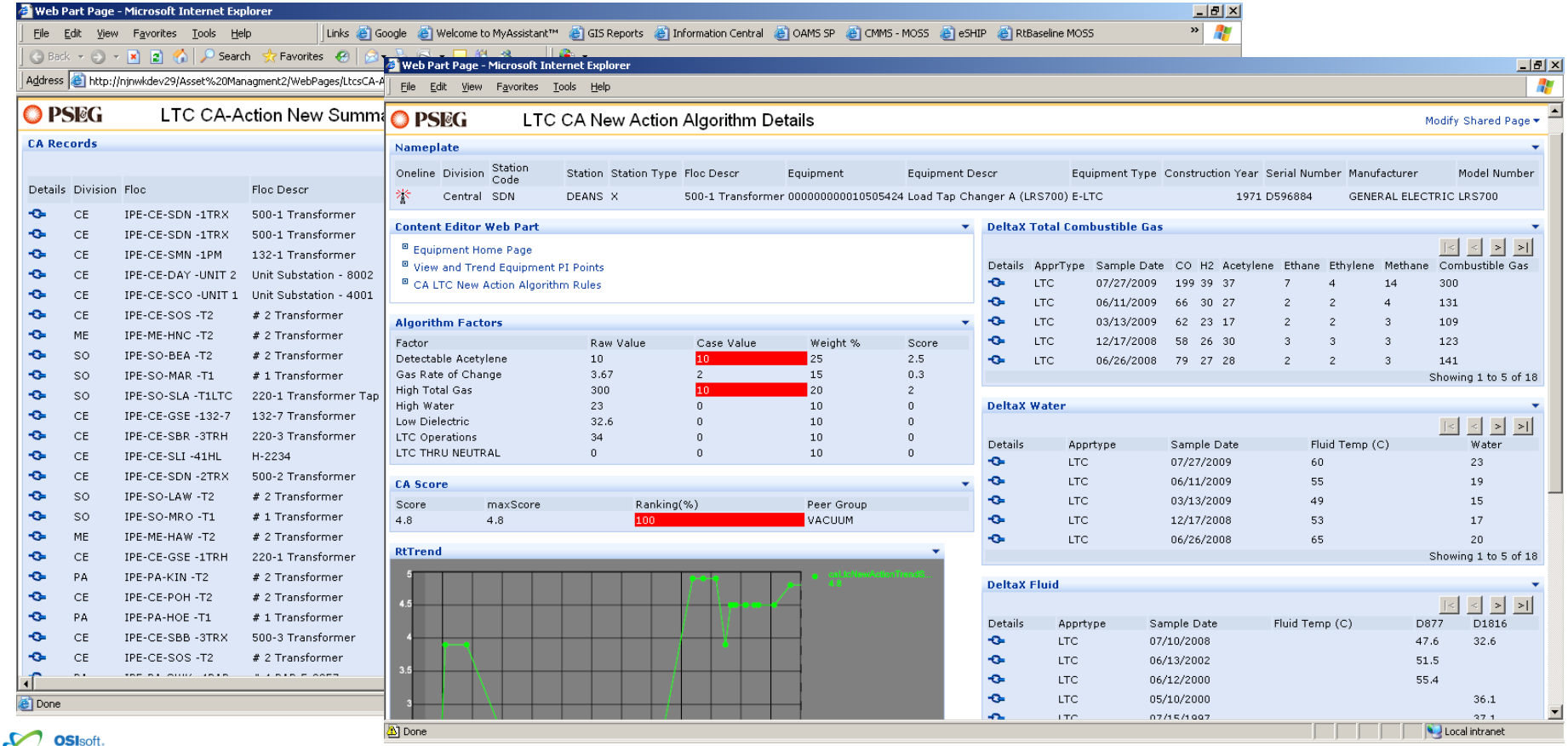
$8.5M of savings last financial year

- ODC delivers significant tangible benefits
- OSISoft PI enables data transformation and the pursuit many other business improvements
- ODC technology now focusing on process safety uplift

PSE&G – Consolidate & Correlate Data

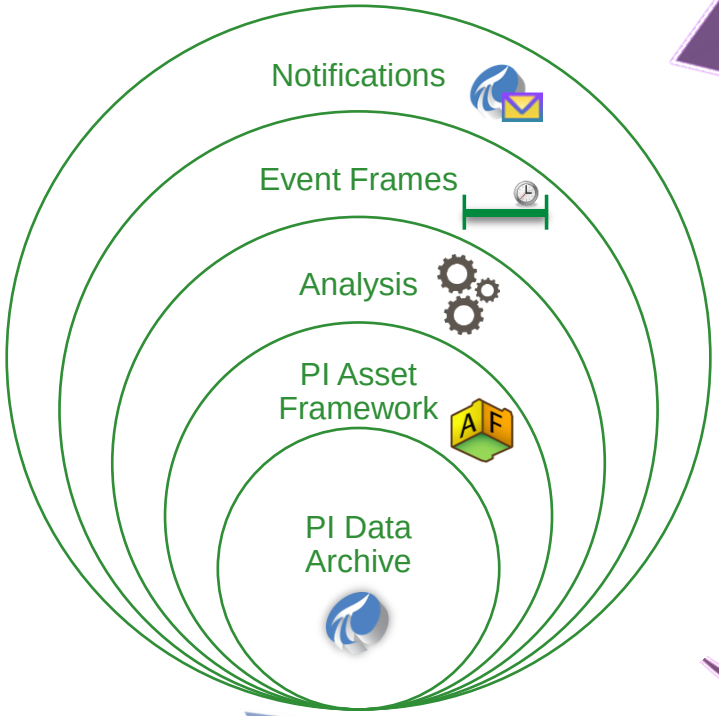


Asset List with Score



PI System's role in CBM

PI Interfaces & PI Connectors



PI Server

PI Integrators & PI System Access

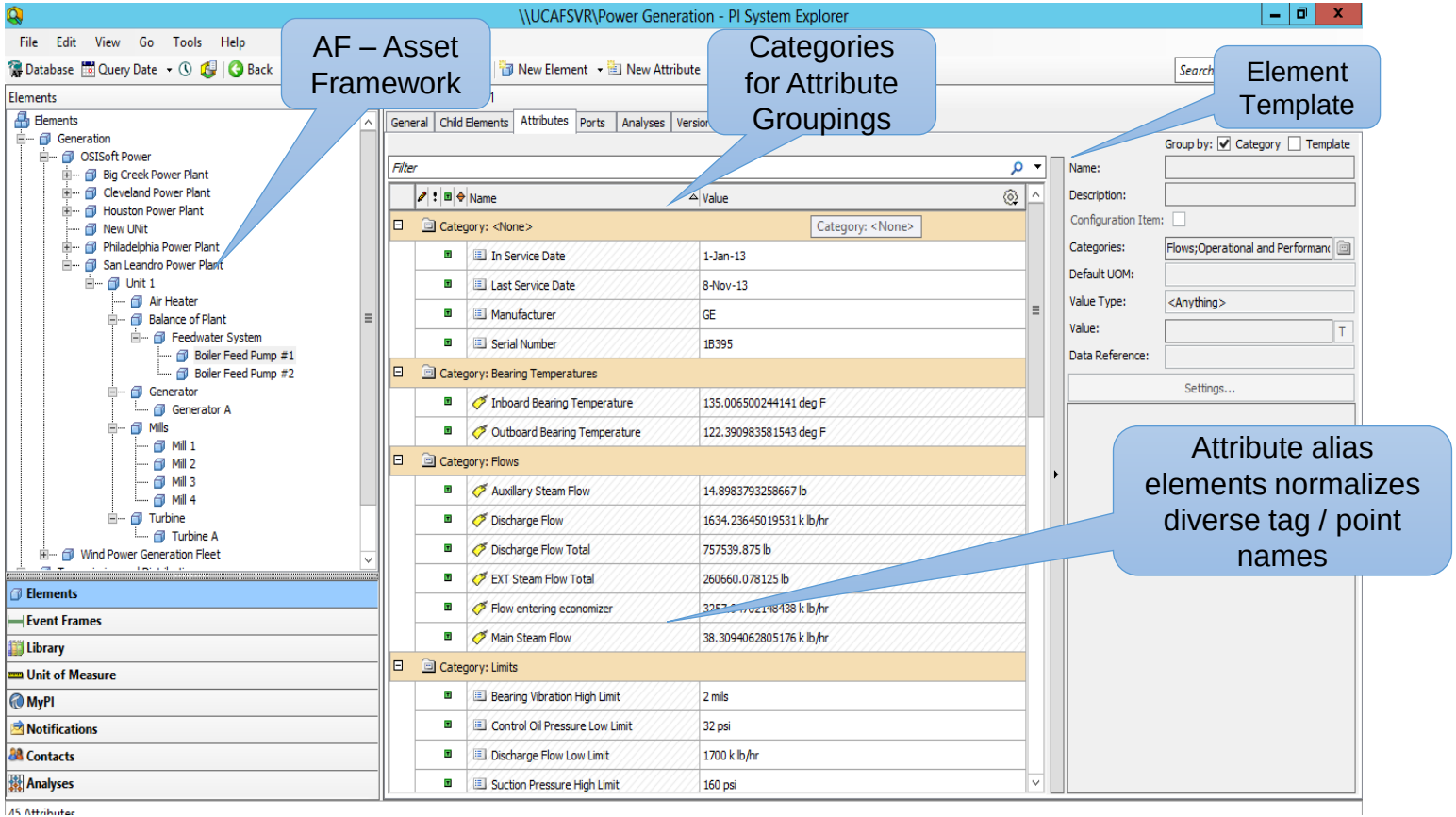
Microsoft SQL Server · infor · sas · SAP · ORACLE · IBM · JDEdwards

1. Connect to relevant sources
2. Collect and archive data
3. Assign context (asset-based)
4. Execute condition monitoring logic
5. Visualize real-time conditions
6. Alert and notify

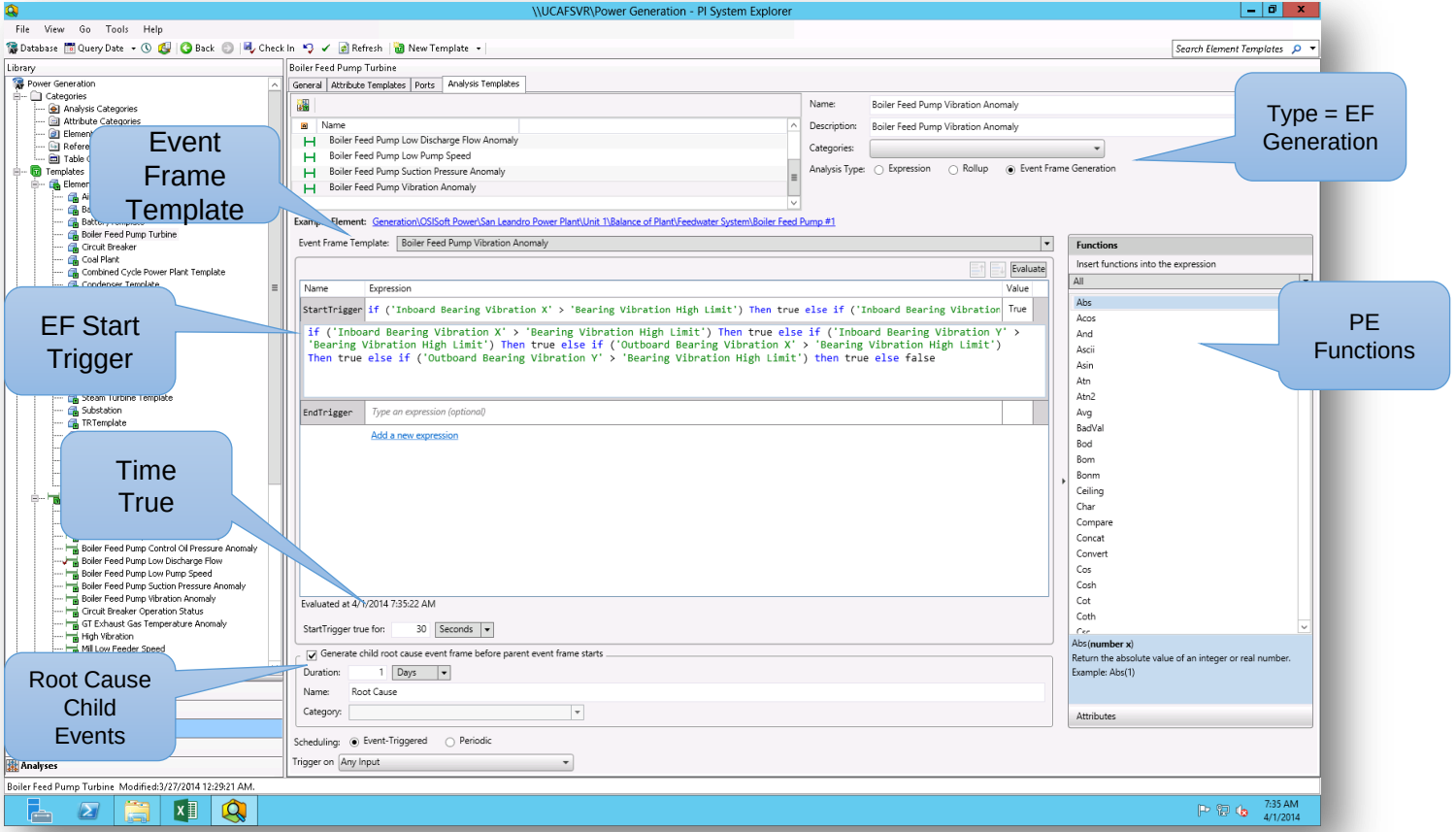
PI Visualization Suite

- PI Vision
- PI ProcessBook
- PI DataLink
- PI WebParts

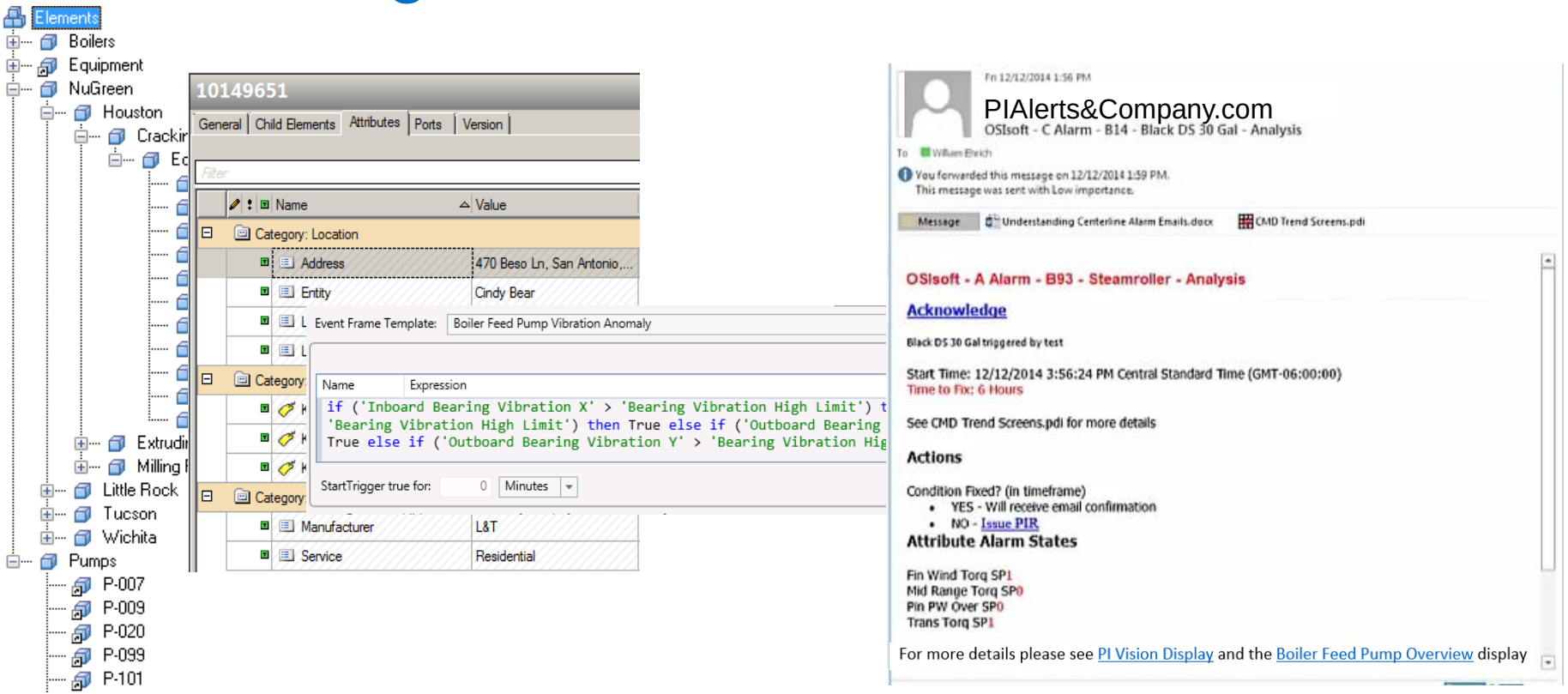
Asset Context in PI AF



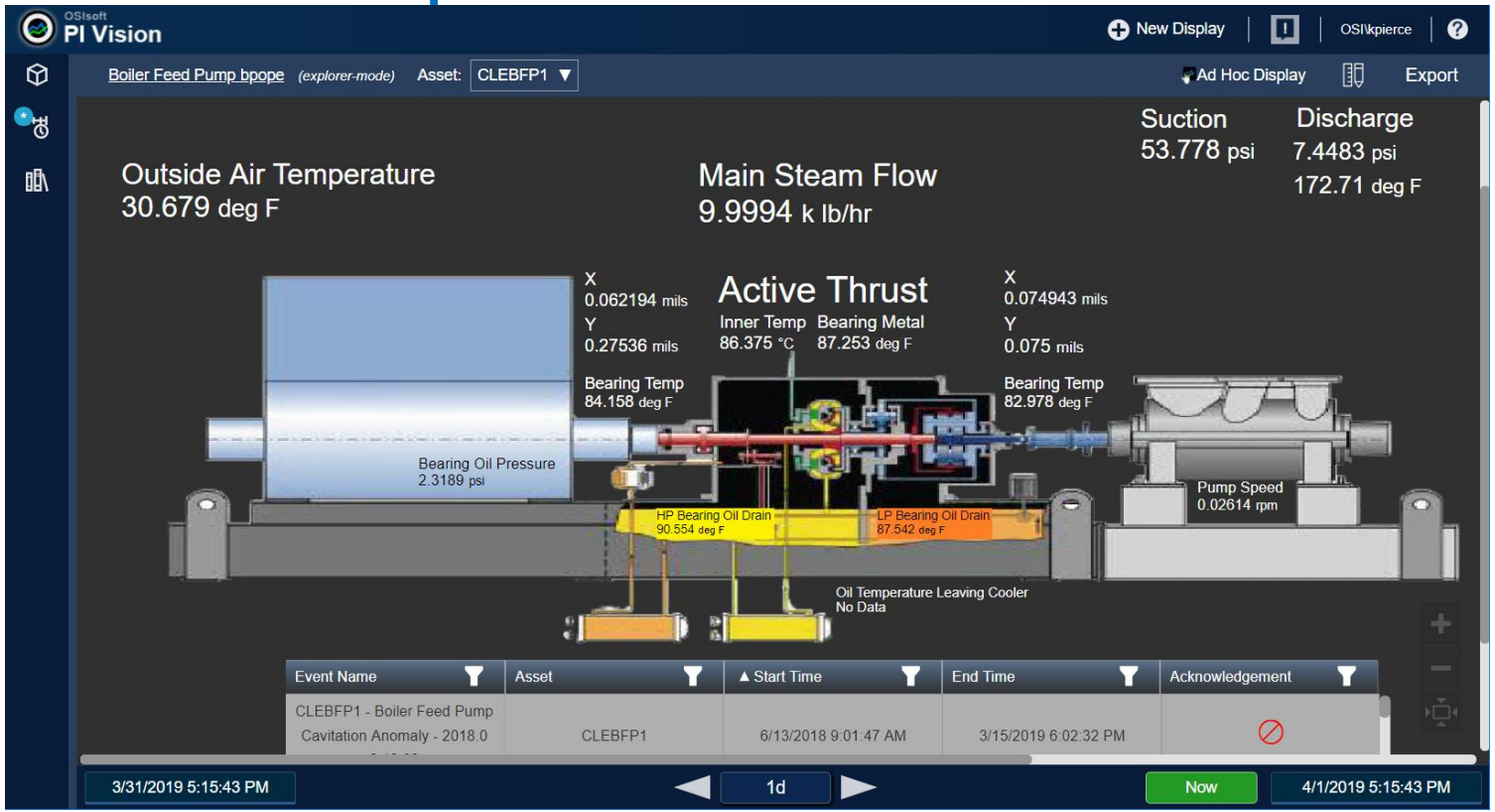
Event Detection



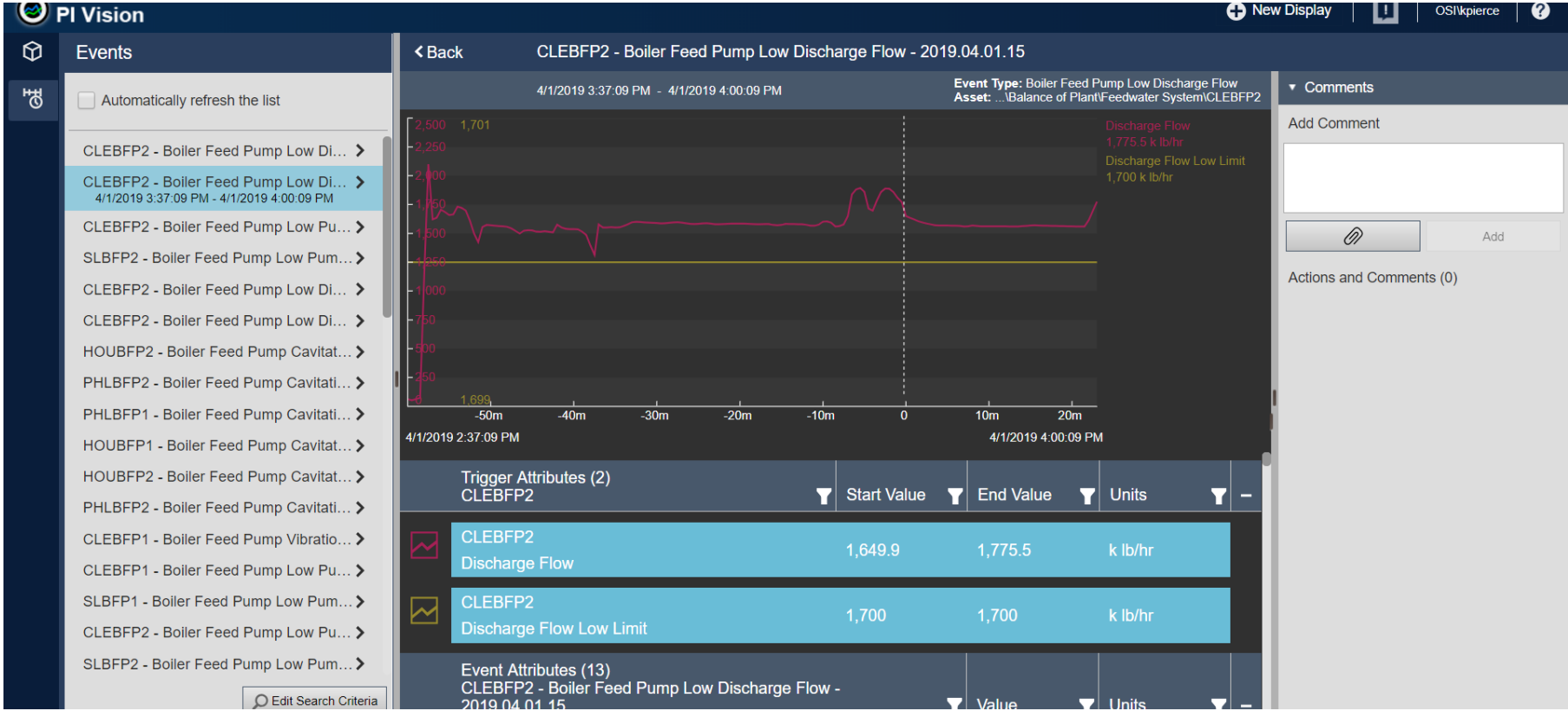
Monitoring Asset Conditions



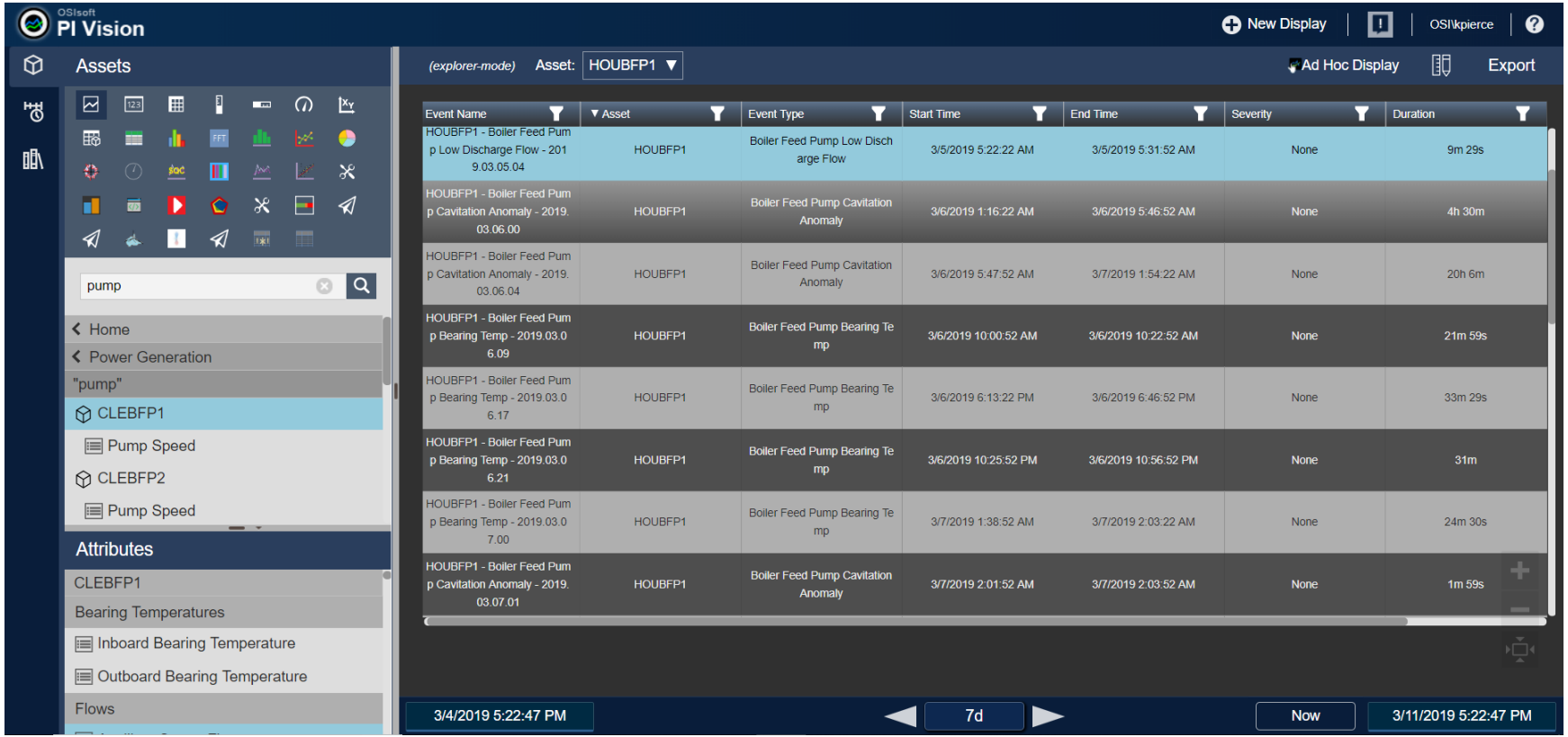
Boiler Feed Pump Overview



Boiler Feed Pump Event Analysis



Event Table Watchlist



Condition Monitoring Report

Time Period

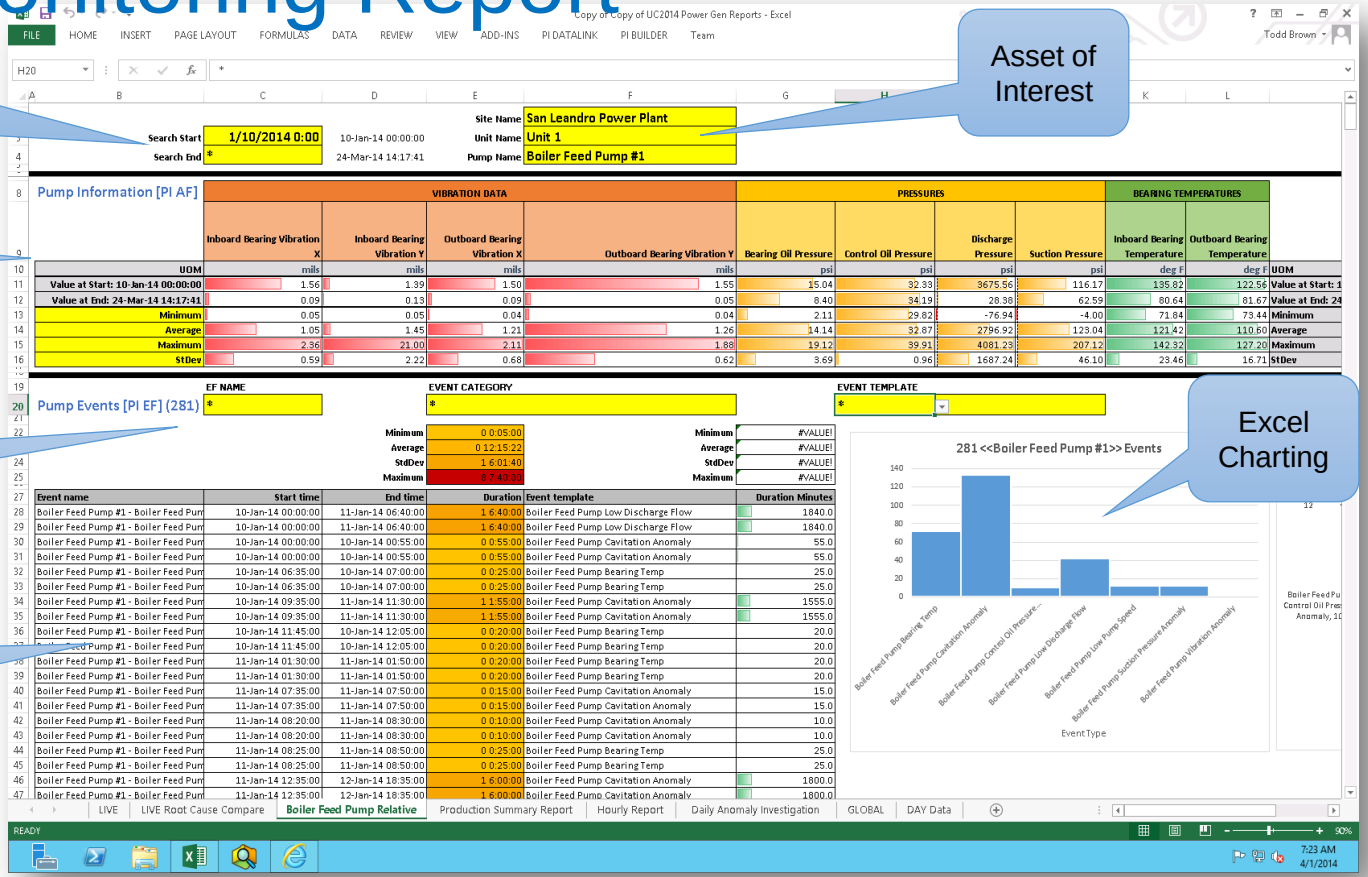
Asset of Interest

Real Time Summaries

Filter Events

Excel Charting

Events



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- PI System covers major portions of the CBM workflow
  - Layers of Analytics applied to maintenance/reliability (usage-based, condition-based, predictive)
- As appropriate, include machine condition monitoring data
  - vibration, oil analysis, thermography...
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PI System - CBM Resources

- Corporate Site – General info and use case search, webinars,…
- CBM Guidebook – Reference material on CBM and Condition Monitoring
- Technical Support – technical resources, downloads, questions,…
- PI Square and CBM – Lots of resources
- PI Community – Peer discussions and OSIsoft moderation, industry groups, development resources, whitepapers, webinars,…
- YouTube – training and introduction videos
- PI Learning – online courses, course materials,….
- Incorporating machine condition monitoring data

Other resources

OSIsoft Users Conf. 2016 TechCon Lab Notes Condition-based Maintenance with PI AF

OSIsoft Users Conf. 2015 Presentation Keeping Assets Healthy – PI System's Role in Asset Maintenance

Calculating Asset Health Score - OSIsoft vCampus 2013 Lab Notes

PSE&G use case showing asset health score http://www.osisoft.com/Presentations/Condition-Based-Maintenance/

http://www.ni.com/condition-monitoring

National Instruments InsightCM™ Enterprise for Condition Monitoring

Allied Reliability Group AR-C10 Data Collector for Condition Monitoring

MetrixSetpoint Condition Monitoring

Emerson Vibration Monitoring

CBM Ideas for Workshop

- Pump / Motor Usage
- Pump / Motor Start – Stop Cycles, Duty Cycles
- Calculate Efficiencies, Anomalies, etc.
- Energy per Unit Processed (e.g. MG/D)
- Predictive / Maintenance Event Detection & Analyses
- SAP, Maximo etc. integration

Asset Monitoring and Condition-based Maintenance (CBM) with the PI System

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Questions?

Please wait for the **microphone**

State your **name & company**

Please remember