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Asset Maintenance From Eye to AI

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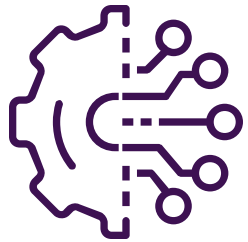
Agenda

- The eye test
- Asset maintenance background
- Usage based maintenance
- CMMS Data Ingress to PI
- Condition Monitoring
- Artificial Intelligence / Predictive Analytics
- PI Data Egress to CMMS



The Eye Test

The Eye Test

Which asset requires maintenance?

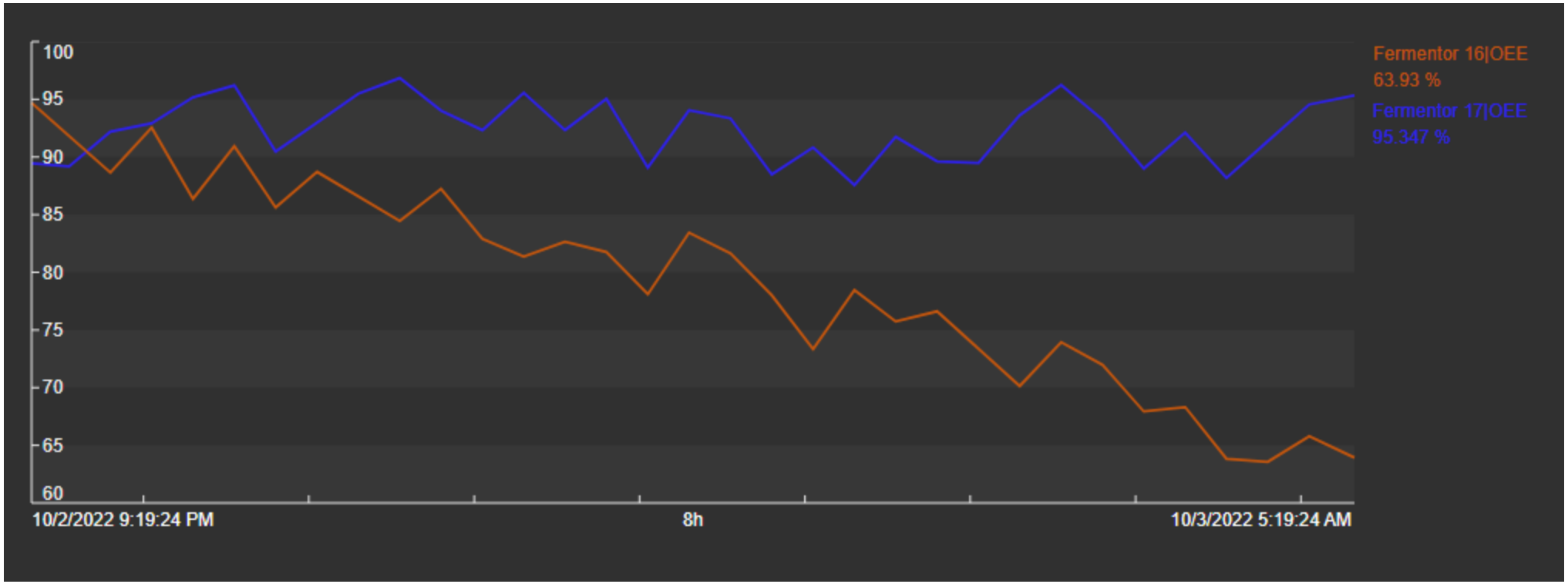
Sometimes it’s obvious

The Eye Test IRL

If only it were that easy…

The Eye Test – digital version

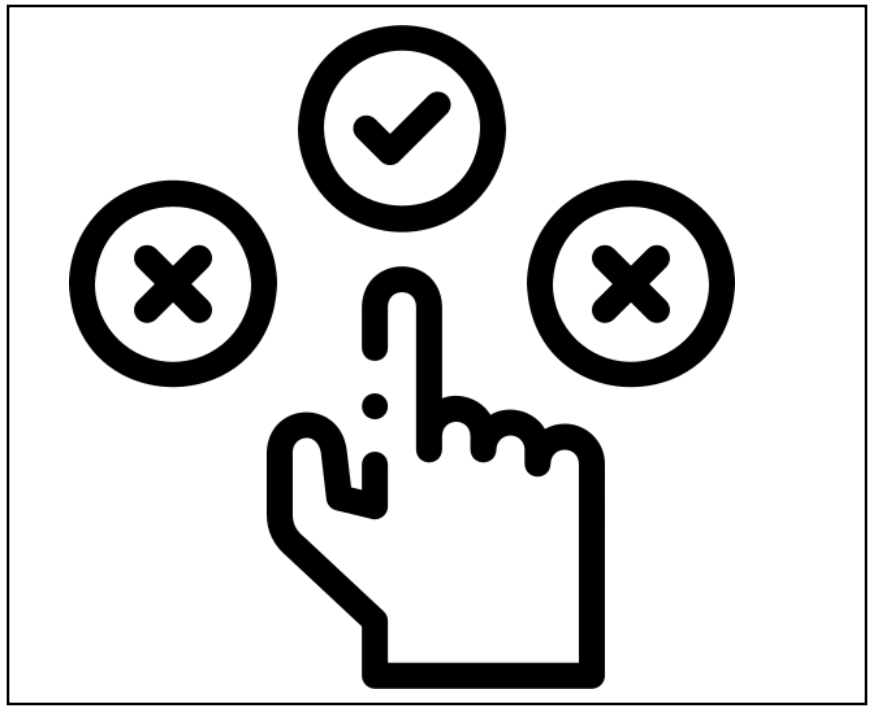
Which asset requires maintenance?



Golden rules of asset maintenance

- Clearly understand the benefit of performing maintenance
  - It must make financial sense and is technically feasible
- Maintenance is perceived as a value rather than a cost
- Understand the impact of equipment failures
  - Operational, Safety, Environment, Brand
- Understanding failure to ensure successful proactive maintenance

The Intelligent Maintenance Plan



'Right Work at
the Right Time,
Done the Right Way,
The First time'

The Plan

(Time Based Maintenance)

Maintenance Methodology

(Condition Based/Predictive Maintenance)

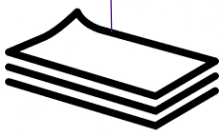
- 100% of work (PM) time/usage based
- Corrective Maintenance

- Preventive, Predictive, Prescriptive
- On Condition Task (Condition Monitoring)
- Scheduled Restoration
- Scheduled Discard
- Failure Finding
- No Scheduled Maintenance

The past, present and future of Maintenance

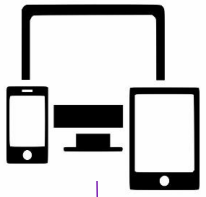
Maintenance in Industry 1.0

- Loosely organized
- Pen & paper
- Not centralized
- No mtce system
- Mtce Routine & Reactive
- No knowledge transfer
- No Mtce technology



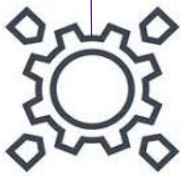
Maintenance in Industry 2.0

- Pen & paper
- Basic digital platforms
  - Spreadsheets
- Formalized procedures
- No centralized system
- Mtce is primary reactive with some preventive mtce
- Limited Mtce technology



Maintenance in Industry 3.0

- Primarily digital, cloud and mobile based
- Formalized procedures
- Centralized Mtce system
- Mtce primarily preventive includes reactive and predictive mtce as well
- Mtce technology used extensively
- RCM, FMEA, TPM encouraged



Maintenance in Industry 4.0

- Relies on combination of different digital systems
- CMMS and IIoT
- Formalized procedures with centralized system
- Mtce is primarily predictive with a balance of reactive and preventive
- Risk Based approach
- RCM, FMEA ,TPM is well established
- Mtce technology fully integrated into all operations

Maintenance in Industry 5.0

- Human-centric approach
- Software, hardware and people work in harmony
- Customizable platforms, integration options that fit company's operations
- IoT to IoE (Internet of Everything)
- Human-machine interaction, decision support systems, collaborative robots
- AI, ML, simulation, Digital twins, augmented, virtual or mixed
- Mtce is primarily prescriptive and predictive
- Cognitive Cyber-physical Systems

AVEVA

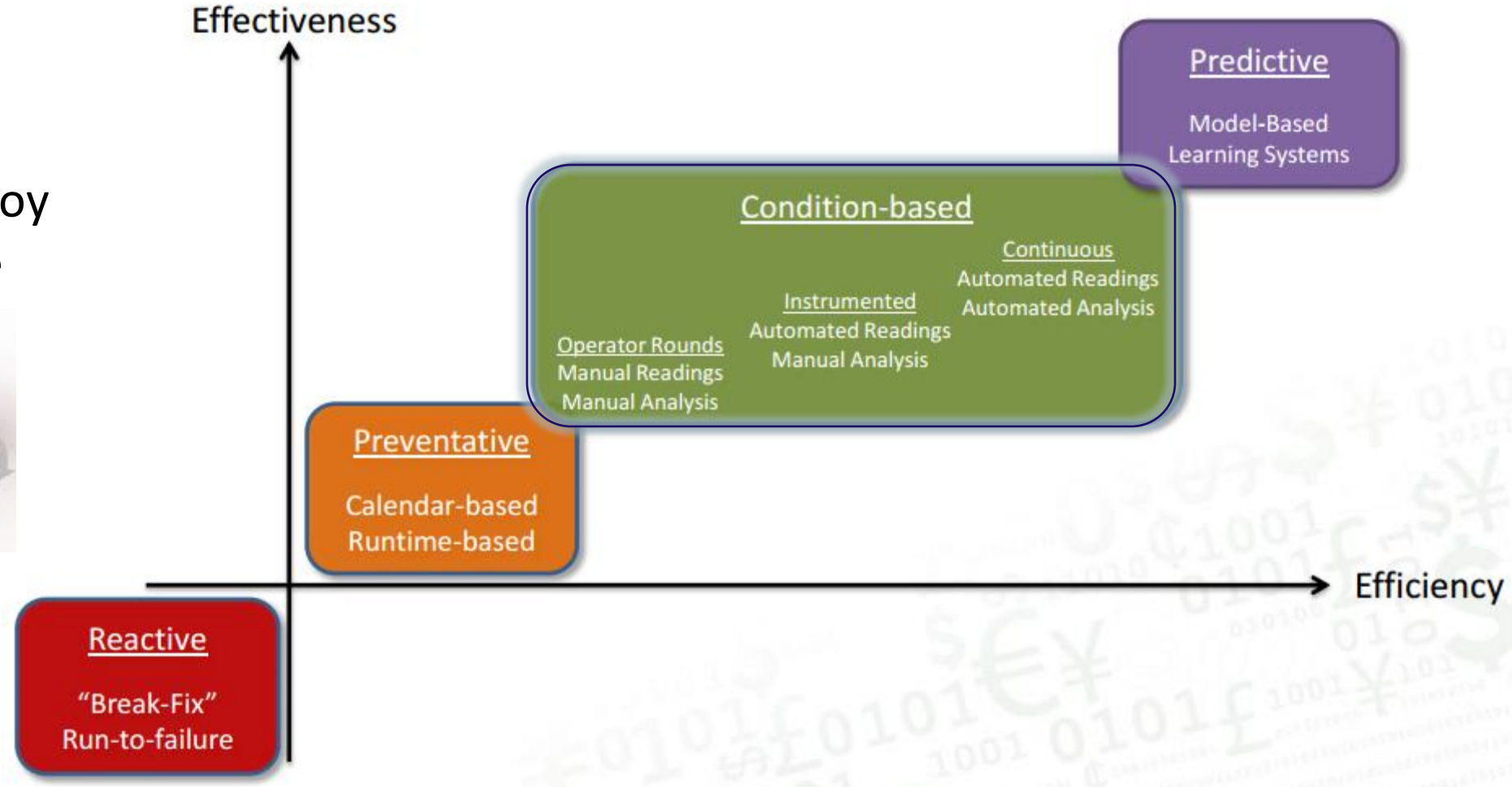
Common Maintenance Strategies

- Reactive Maintenance
- Corrective Maintenance
- Preventive Maintenance (PM)
- Predictive Maintenance (PdM)
- Condition Based Maintenance (CBM)
- Prescriptive Maintenance (RxM)
- Reliability Centered Maintenance (RCM)
- Failure Mode, Effects and Criticality Analysis (FMEAC)
  - Failure Mode and Effects Analysis (FMEA)
- Total Productive Maintenance (TPM)

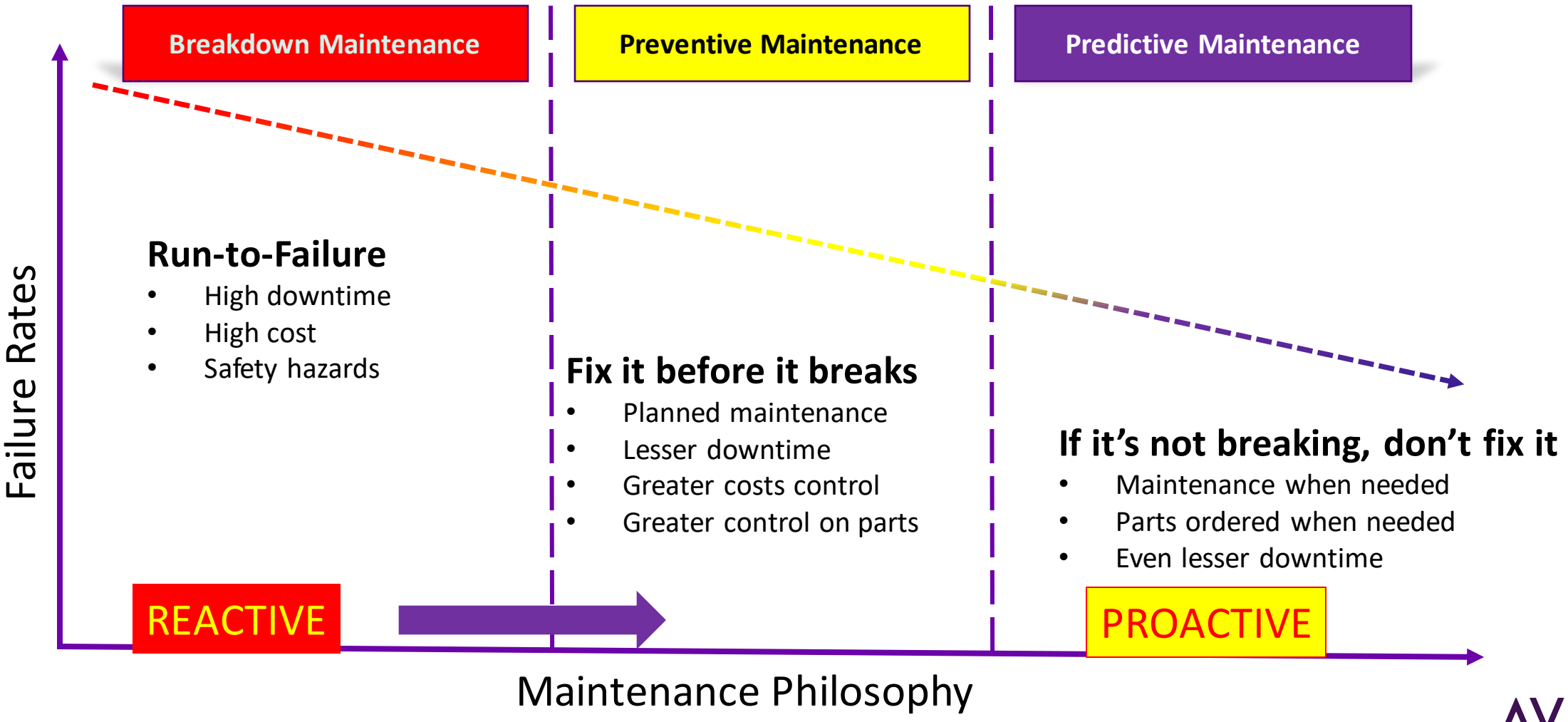
The types of traditional Maintenance

CBM:

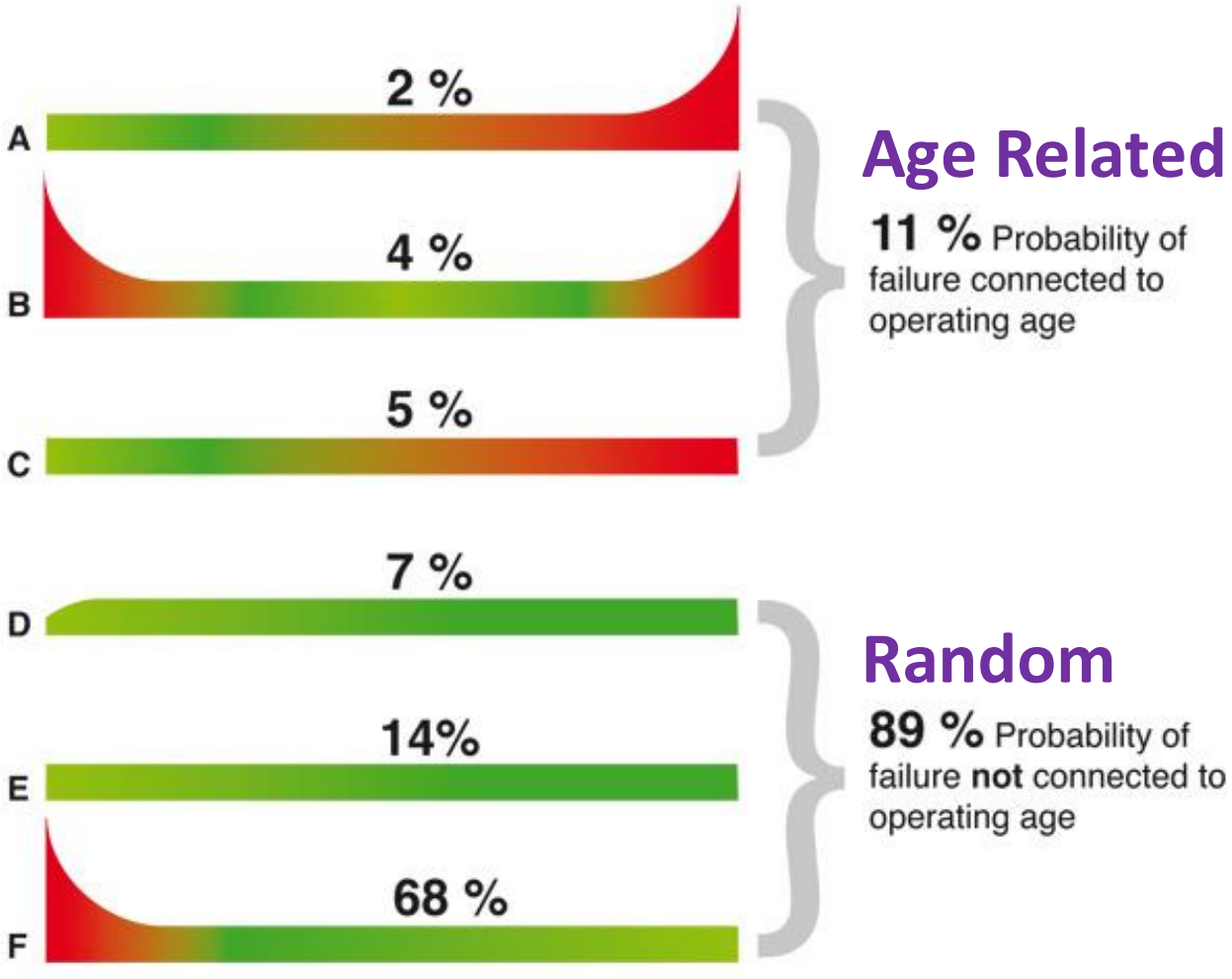
- Simple to deploy
- Greatest Value



Moving from Reactive to Proactive Maintenance



Failure Curves – Age related vs Random



Age Related

11 % Probability of failure connected to operating age

Random

89 % Probability of failure **not** connected to operating age

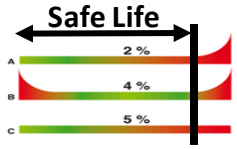
Source: RCM II by John Moubray, Industrial Press Inc, 1992

- Premature random failures
- Often after Human Intervention

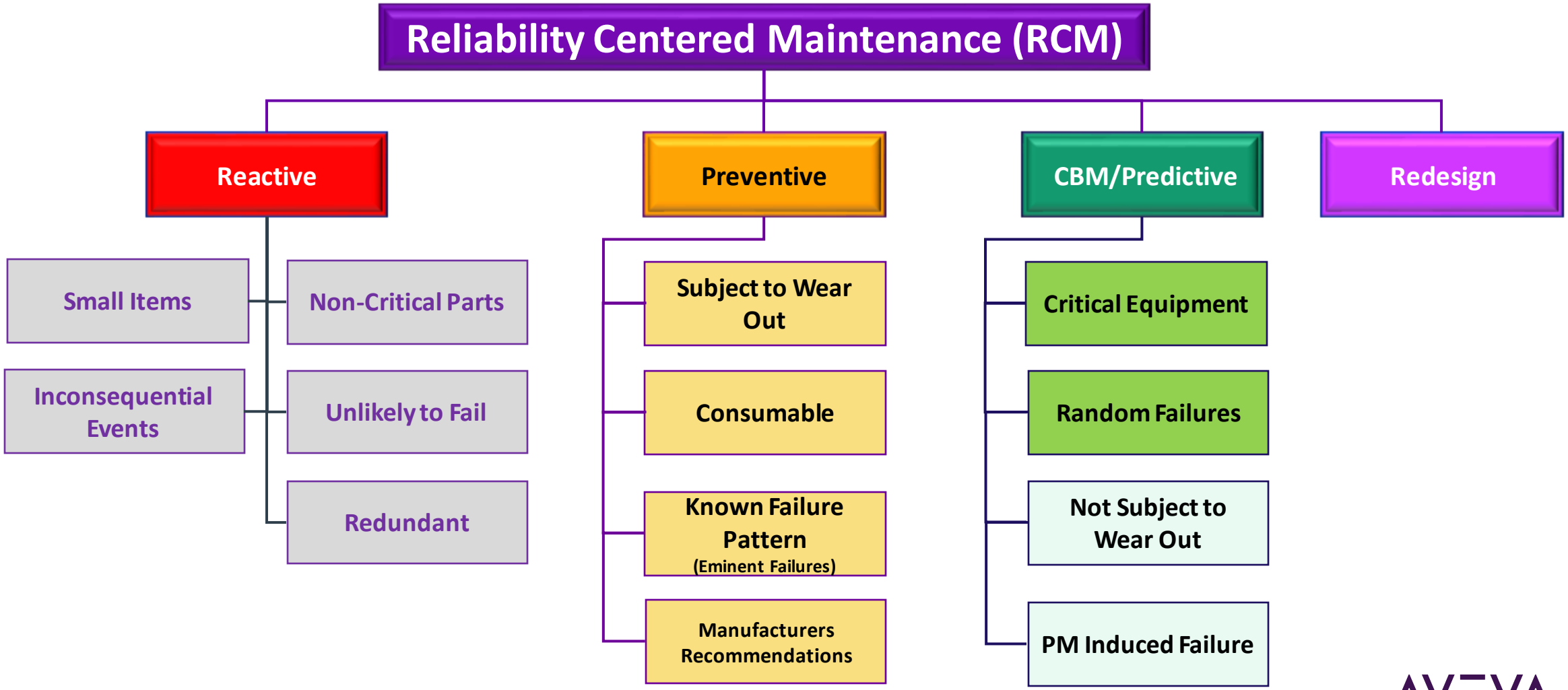
Simple method to determine maintenance strategy

4 Failure Classifications

- Age Related
- Random
- Sudden
- Gradual

	Sudden	***Gradual***
Age Related 11%	**Time/Usage based PM** at "Safe Life Interval" 	**Time/Usage based PM** or **Condition based Maintenance (CBM)**
Random 89%	**Run-to-Failure** with mitigation plans such as ***redundancy*** or ***readily available spares***	**Condition based Maintenance (CBM)** to detect the degradation **P-F Curve** 
	Aveva PI System / Aveva Predictive Analytics	

Reliability Centered Maintenance Approach



Usage Based Maintenance

Usage based maintenance

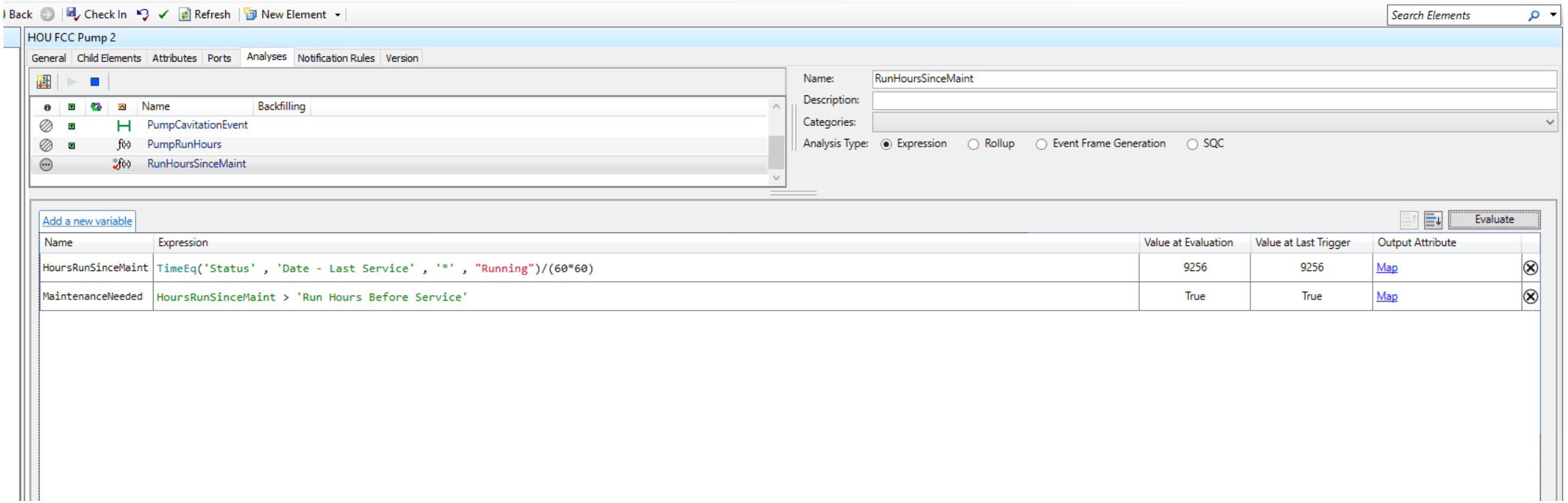
AKA Read the Manual

- Many manufacturers give recommendations for how often to maintain equipment

- Two types
  - Time based
  - Usage based

- Finding the # of run hours is the hard part

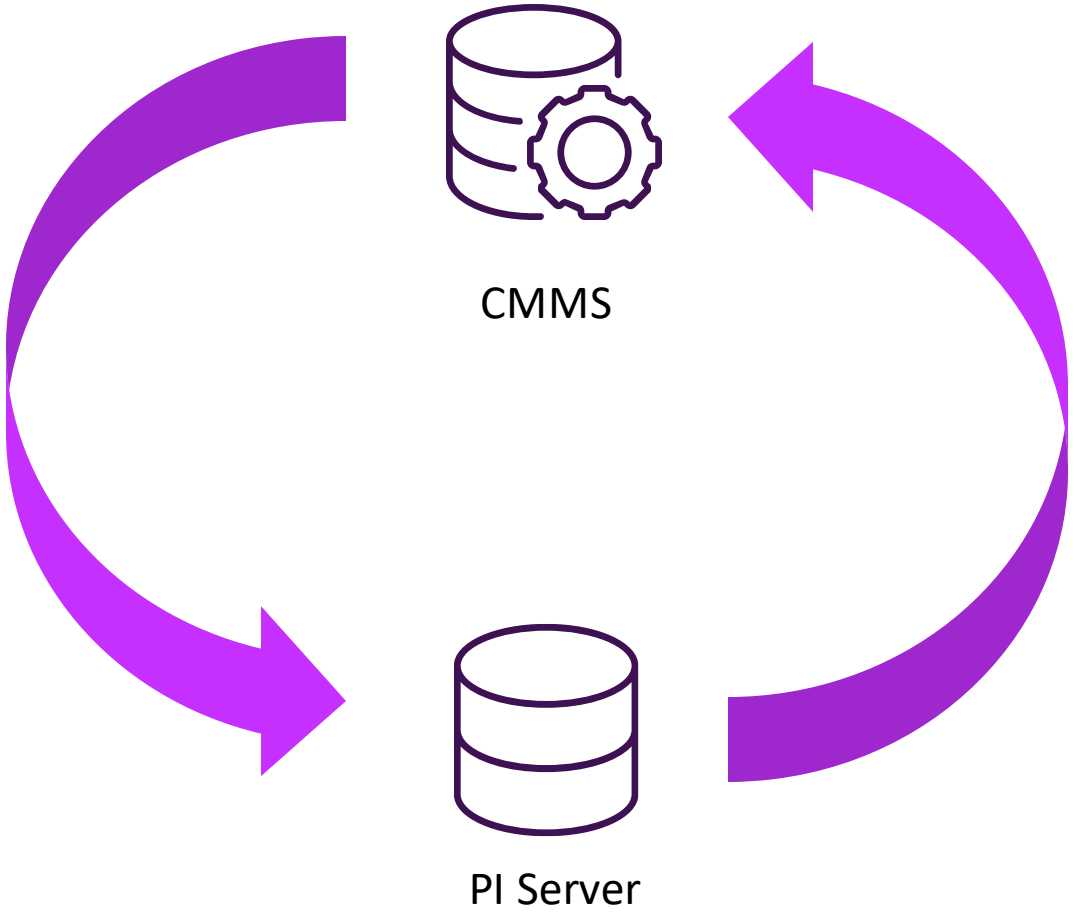
Use Asset Analytics to calculate and trigger



Integration with Maintenance System

Maintenance Systems and the AVEVA™ PI System™

Digital collaboration



Maintenance data ingress

Common approaches

- Manually write in the date to your AF Attribute

- Use Adapter or PI Interface for RDBMS (relational database management system)
  - Stores data as PI Tags

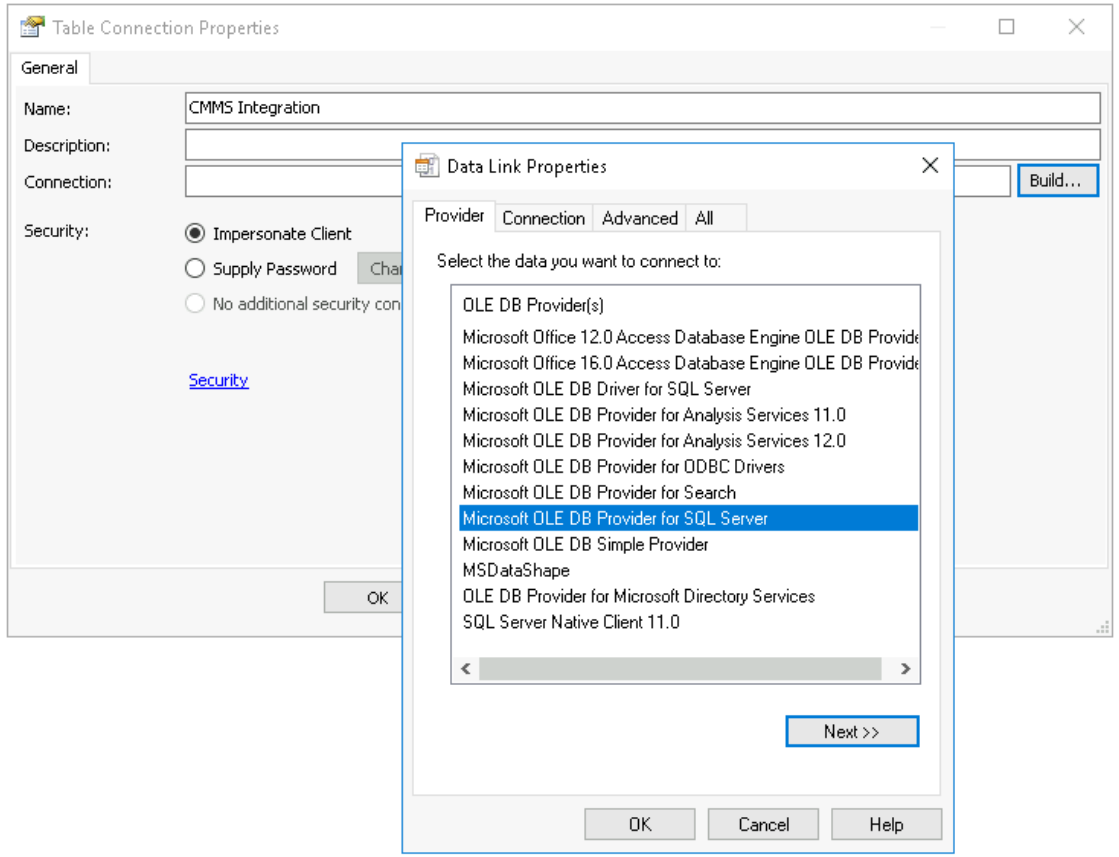
- Use Asset Framework ODBC table connections and attribute table lookups

AF Table connection for CMMS

Single source of truth for maintenance data

- Using the data from the authoritative source

- For best performance
  - Use Parametrized Queries
  - Keep Tables as small as possible



AF Table lookup for CMMS

Single source of truth for maintenance data

- Import data or Link data option
- Query can be a simple “select” statement

AF Table (CMMS data)

CMMS Station Location Equipment

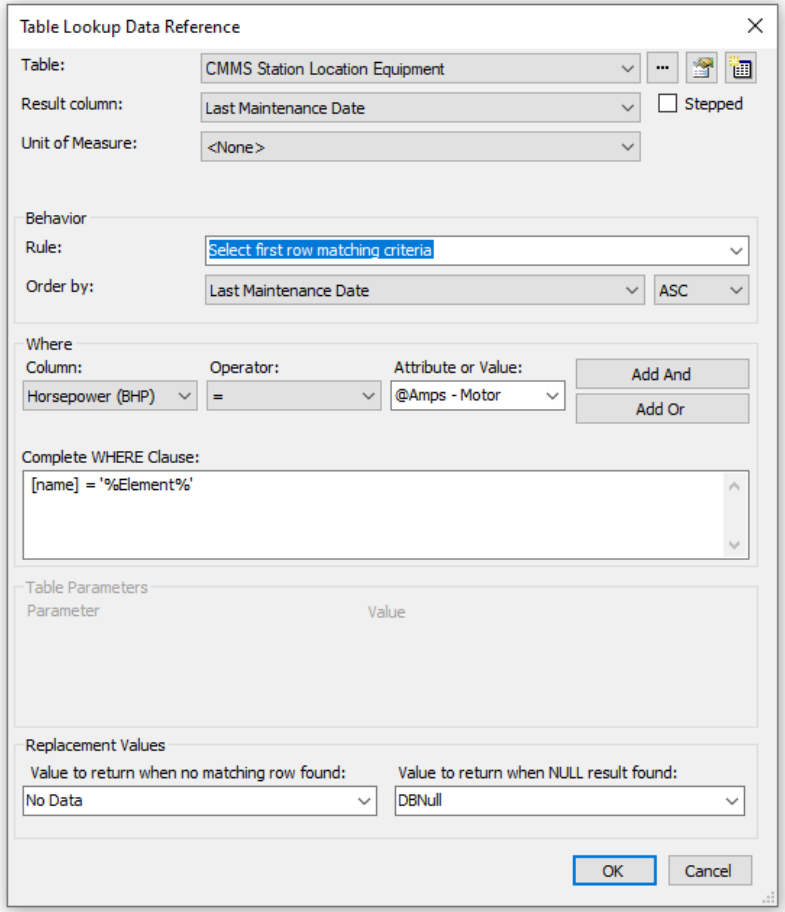
General | Table | Define Table | Version

CMMS Station Location Equipment

Filter

enterprise_id	name	locationid	locationtype	city	region	GPSLatitude	GPSLongitude	LocationStatus	OilContainment	StreetName	StreetNumb	WorkArea	EQUIP_ID
3	TS7:Pickerel	TS7	TS	Rome	York	43.810562066	-79.478469565	IS	SUMP WELL	Dufferin Street	8000	South	1128
4	TS7:Pickerel	TS7E	TS	Rome	York	43.810562066	-79.478469565	IS	SUMP WELL	Dufferin Street	8000	South	1129
5	TS8:Piranha	TS8	TS	Rome	York	43.780209788	-79.542493404	IS	SUMP WELL	Century Place	1	South	1130
6	TS9:Shark	TS9	TS	Rome	York	43.804643049	-79.646716852	IS	SUMP WELL	Rutherford Road	6531	South	1131
7	TS5:Orata	TS5	TS	Vienna	York	43.839901184	-79.417405499	IS	SUMP WELL	Bayview & Highway 7	160	South	1132
8	TS6:Perch	TS6	TS	Vienna	York	43.839911818	-79.416522441	IS	SUMP WELL	Bayview & Highway 7	160	South	1133
9	TS1:Manta	TS1	TS	Athens	York	43.835947766	-79.340634285	IS	SUMP WELL	14th Avenue	3430	South	1134
10	TS2:Marlin	TS2	TS	Athens	York	43.859719536	-79.257314884	IS	SUMP WELL	Hwy 48	7970	South	1135
11	TS3:Moray	TS3	TS	Athens	York	43.84824685	-79.311939307	IS	SUMP WELL	Kennedy Road	7932	South	1136
11	TS3E:Moray Exp	TS3E	TS	Athens	York	43.84824685	-79.311939307	IS	SUMP WELL	Kennedy Road	7932	South	1137
13	TS4:Sturgeon	TS4	TS	Athens	York	43.84399640	-79.3506525	IS	SUMP WELL	Addiscott Court	85	South	1138
17	DS9:Albacore	DS9	MS	Athens	York	43.834197065	-79.340339034	IS	SUMP WELL	14th Avenue	3451	South	1071
18	DS10:Beluga	DS10	MS	Athens	York	43.826011769	-79.423543675	IS		Baythorn Drive	227	South	1072
19	DS12:Bitterling	DS12	MS	Athens	York	43.807079193	-79.419636359	IS	NONE	Morgan Avenue	30	South	1073
20	DS11:Bigeye	DS11	MS	Athens	York	43.819978988	-79.387792591	IS	NONE	John Street	397	South	1074
23	Concord	VMS1	MS	Rome	York	43.803557108	-79.500607968	dc	NONE	Keele Street	7896	South	1077
24	King	VMS8	MS	Rome	York	43.909372558	-79.525264956	IS	NONE	Maloy Street	200	South	1078
25	DS1:Anchovy	DS1	MS	Geneva	York	43.995472312	-79.458651926	IS	NONE	Edward Street	135	South	1079
26	DS2:Angler	DS2	MS	Geneva	York	44.011581532	-79.468867783	IS	NONE	Old Yonge Street	21	South	1080
27	DS3:Arowana	DS3	MS	Geneva	York	43.999582483	-79.495096173	IS	NONE	Bathurst Street	15459	South	1081
28	DS4:Banjo	DS4	MS	Geneva	York	43.965609354	-79.48721361	IS	NONE	Bathurst Street	14025	South	1082
29	DS5:Barbel	DS5	MS	Geneva	York	44.013244596	-79.446138722	IS		Bayview Avenue	15560	South	1083
30	DS6:Barracuda	DS6	MS	Geneva	York	43.99653851	-79.442335764	IS		Bayview Avenue	14778	South	1084
31	DS7:Barreleye	DS7	MS	Geneva	York	44.017594062	-79.419760533	IS	SORBWEB	Leslie Street	15521	South	1085
32	DS8:Bass	DS8	MS	Geneva	York	44.011453785	-79.418300465	IS	SUMP WELL	Leslie Street	15267	South	1086
33	DS301:Blowfish	DS301	MS	Prague	Simcoe	44.40427575	-79.723714319	IS	NONE	Anne Street North	381	North	1087
34	DS302:Bullnose	DS302	MS	Prague	Simcoe	44.33228839	-79.675919854	IS		Saunders Road	169	North	1088
35	DS303:Boga	DS303	MS	Prague	Simcoe	44.355778253	-79.715372393	IS		Ferndale Drive South	202	North	1089

AF Attribute Table Lookup



Condition Monitoring

What is CBM?

- Maintenance strategy focused on preventing asset failures, downtime and unnecessary maintenance practices by monitoring asset health in order to determine what maintenance needs to be completed and when

- Asset Health is based on Real-time or near Real-time assessment of asset condition using different on-condition techniques

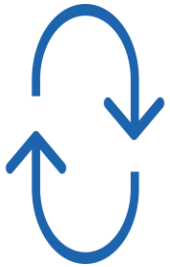
- CBM includes:
  - Condition Monitoring process
  - Corrective maintenance activities

Types of Condition-Monitoring Systems

Two Types: Periodic and Continuous

Periodic Monitoring Systems

- Acquire at selected time intervals (hourly, daily, weekly, monthly patrols)
- Analysis of the collected data is generally performed in the office or laboratory
- Measurements may be on-line or offline, depending on what is being measured and the access required



Continuous Monitoring Systems

- Collect **almost always on-line** the measurement values at selected points on the equipment and this data is continuously compared with pre-established levels or criteria.
- "Set-points" are usually established for the purpose of providing automatic warnings and/or equipment shutdown, depending on the consequence of the impending failure.

Selection of Periodic or Continuous:

- Periodic: time and resource limitations for conducting periodic; on- or off-line monitoring
- Continuous: hardware and installation costs for Continuous, on-line monitoring.

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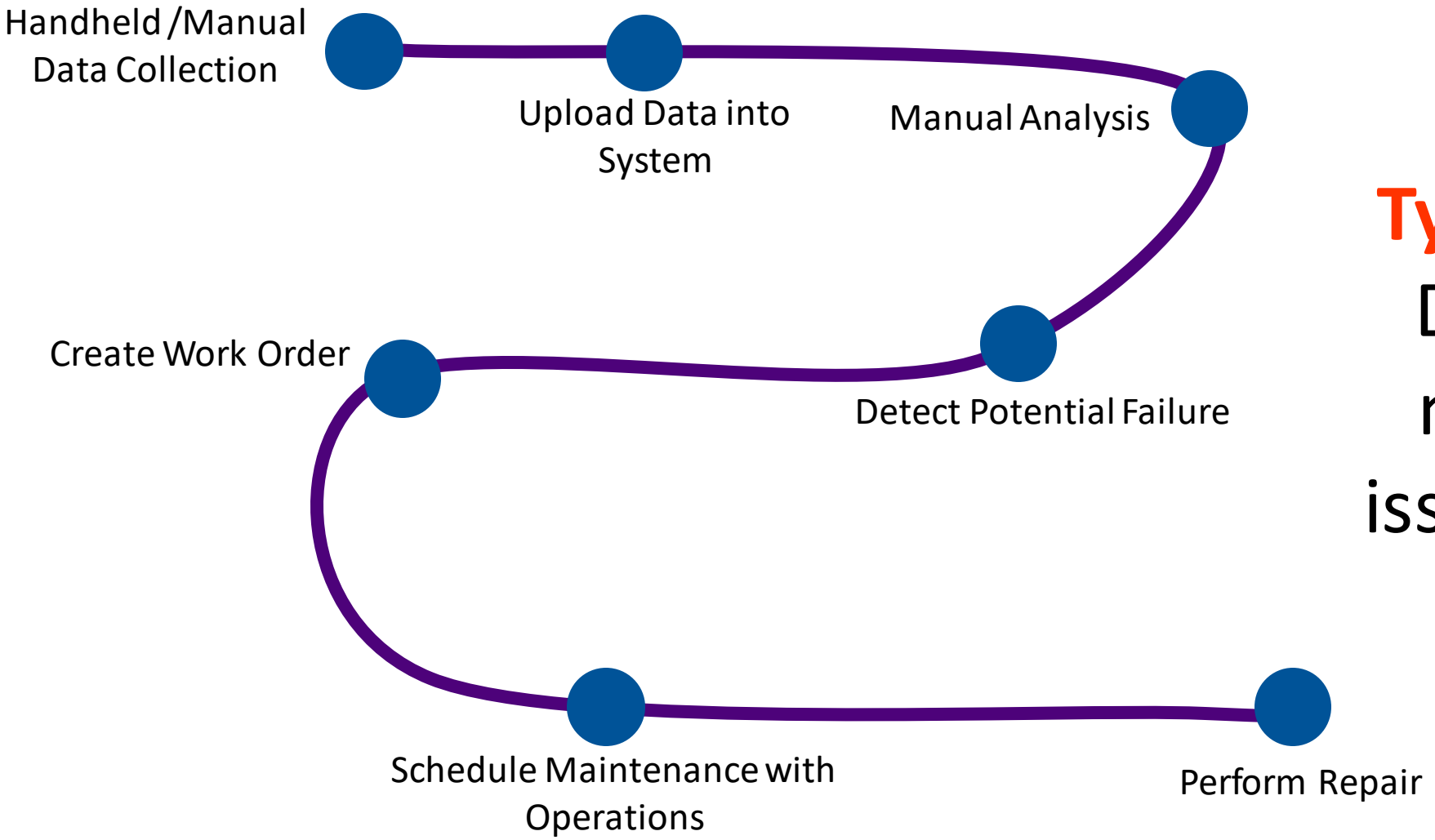
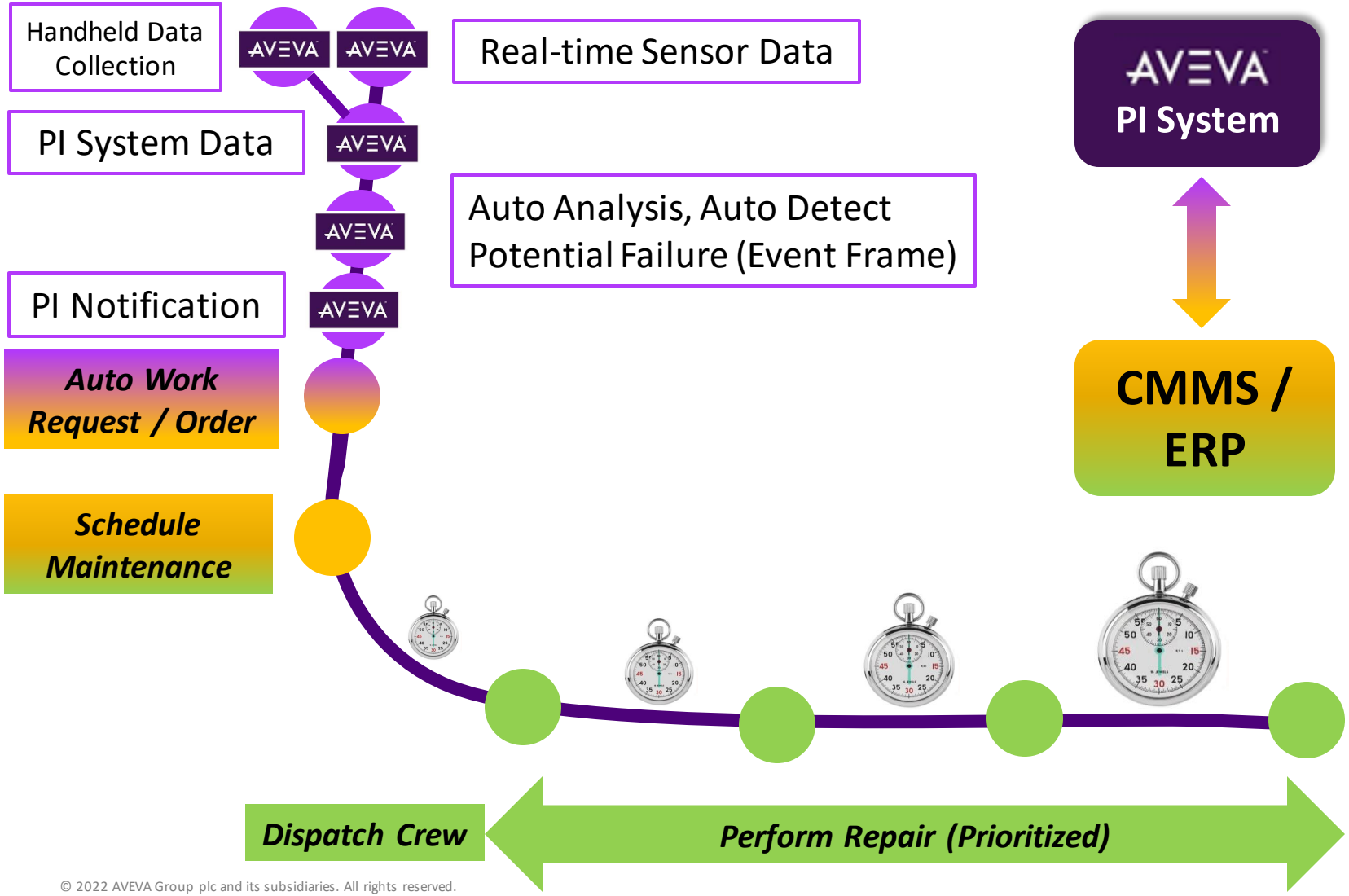
Challenge: Long Gaps Between Measurement and Action



Typical Timeline:

Days, weeks or months before issue is addressed

Solution: Minimize Gaps Between Measurement and Action

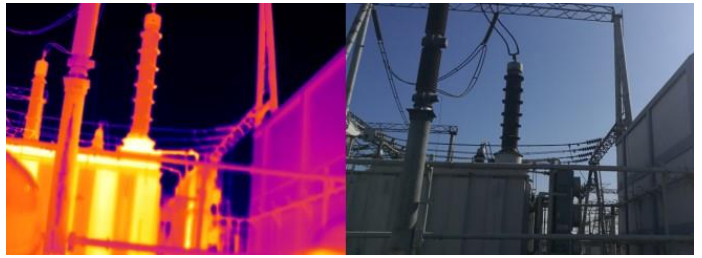


Typical Timeline:

Seconds to Minutes before made aware of issue

Condition Monitoring / Incipient Failure Detection

Condition Scoring Using Potential Failure "PF" Curve



Equipment Condition

1 smooth running

2 minor degradation

P = Change in Condition or Performance detected

3

4 further degradation

Example Condition Scoring Matrix

1 New
2 Used
3 Potential Failure
4 Failed – Schedule Repair
5 Failed – Emergency Repair
6 Failed – Repaired Onsite

Maintenance Task

impending failure

F = Functional Failure

5

6 limited functionality

PF Interval = lead time to failure

Opportunity Window

Time

AVEVA

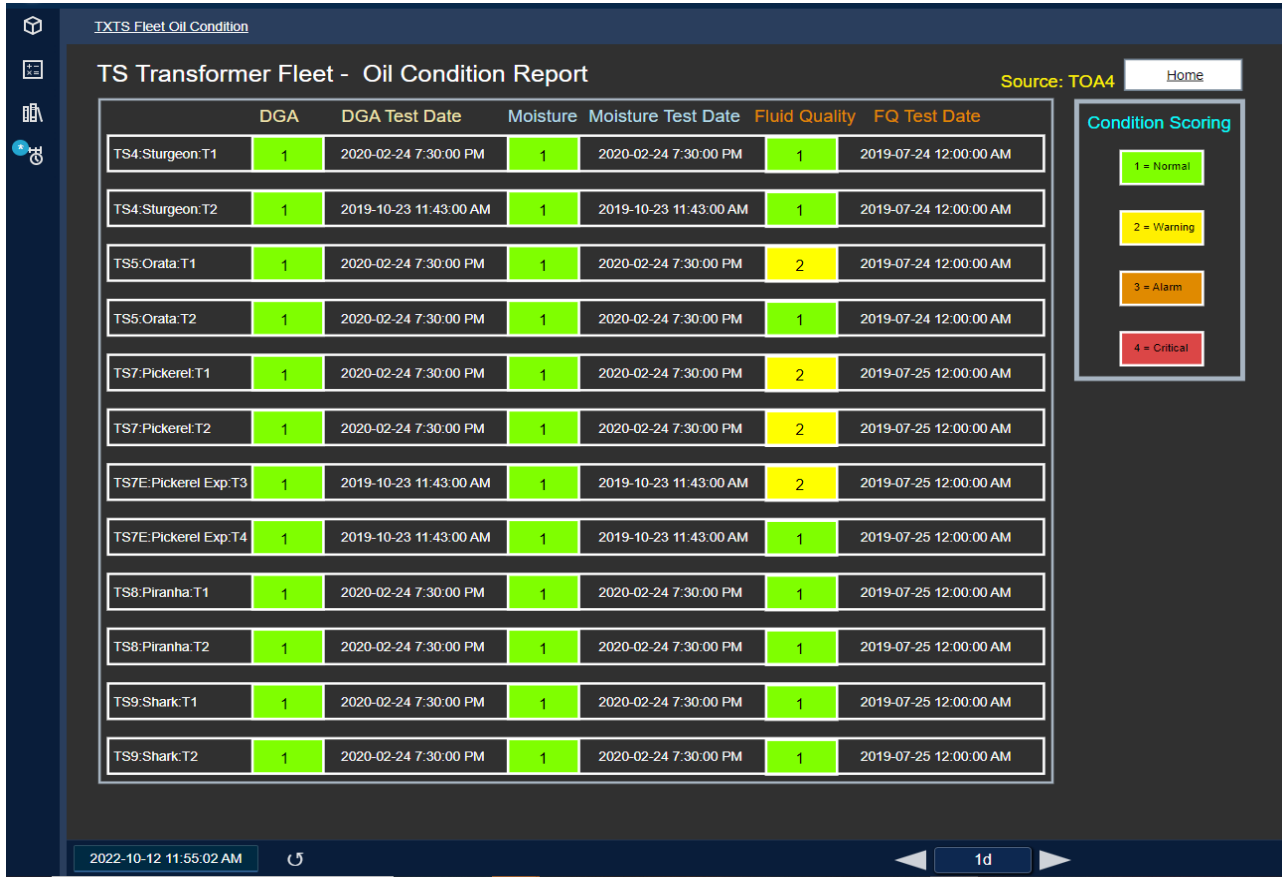
Example PI Vision Report - Condition Scoring

Transformer Fleet Oil Condition Report

Condition Codes

1 – Normal
2 – Warning
3 – Alarm
4 – Critical

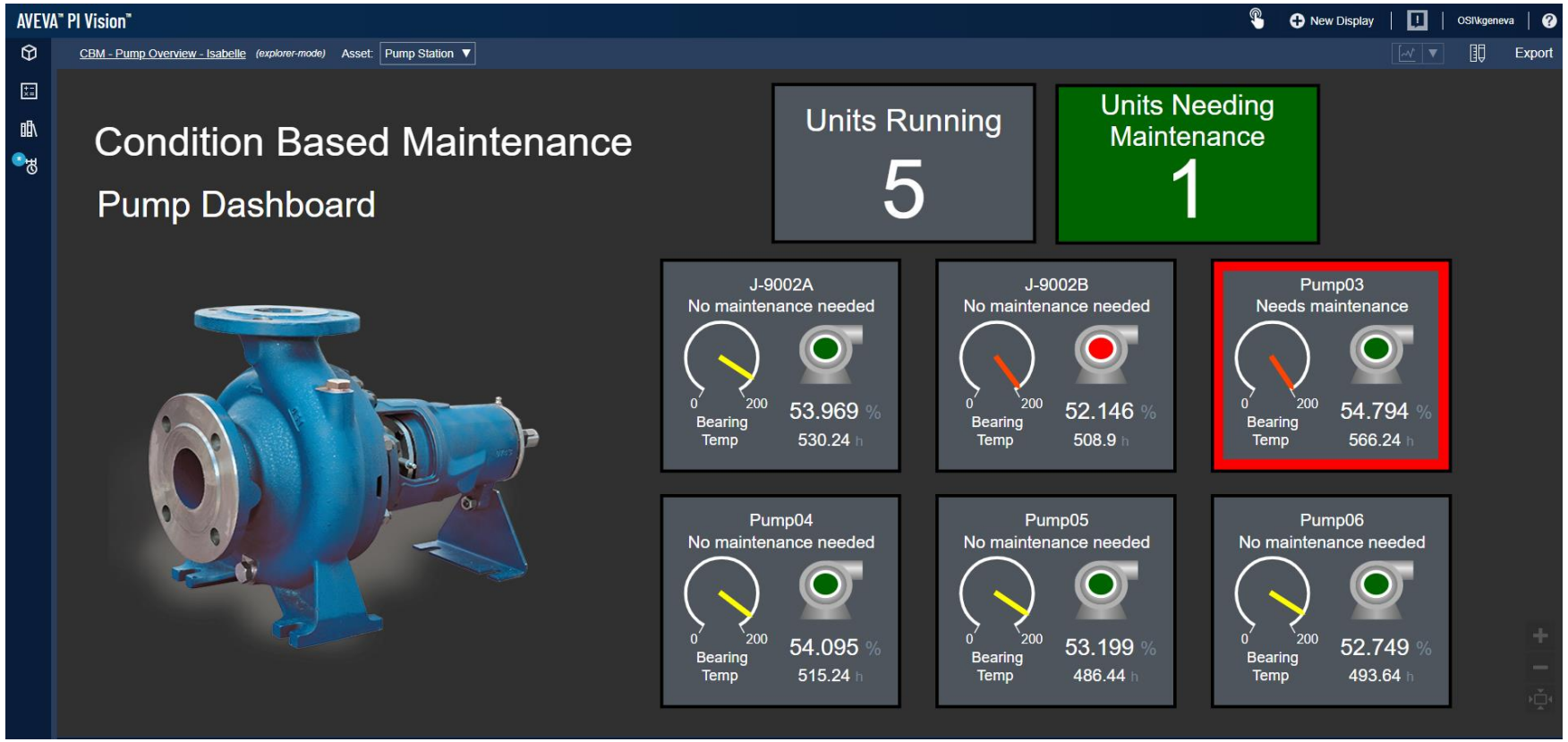
Condition Score	PI Notification	CMMS Alert	CMMS Work Order	Health Score
Code 1	N	N	N	N
Code 2	Y	Y	N	Y
Code 3	Y	Y	Y	Y
Code 4	Y	Y	Y	Y



	DGA	DGA Test Date	Moisture	Moisture Test Date	Fluid Quality	FQ Test Date
TS4:Sturgeon:T1	1	2020-02-24 7:30:00 PM	1	2020-02-24 7:30:00 PM	1	2019-07-24 12:00:00 AM
TS4:Sturgeon:T2	1	2019-10-23 11:43:00 AM	1	2019-10-23 11:43:00 AM	1	2019-07-24 12:00:00 AM
TS5:Orata:T1	1	2020-02-24 7:30:00 PM	1	2020-02-24 7:30:00 PM	2	2019-07-24 12:00:00 AM
TS5:Orata:T2	1	2020-02-24 7:30:00 PM	1	2020-02-24 7:30:00 PM	1	2019-07-24 12:00:00 AM
TS7:Pickerel:T1	1	2020-02-24 7:30:00 PM	1	2020-02-24 7:30:00 PM	2	2019-07-25 12:00:00 AM
TS7:Pickerel:T2	1	2020-02-24 7:30:00 PM	1	2020-02-24 7:30:00 PM	2	2019-07-25 12:00:00 AM
TS7E:Pickerel Exp:T3	1	2019-10-23 11:43:00 AM	1	2019-10-23 11:43:00 AM	2	2019-07-25 12:00:00 AM
TS7E:Pickerel Exp:T4	1	2019-10-23 11:43:00 AM	1	2019-10-23 11:43:00 AM	1	2019-07-25 12:00:00 AM
TS8:Piranha:T1	1	2020-02-24 7:30:00 PM	1	2020-02-24 7:30:00 PM	1	2019-07-25 12:00:00 AM
TS8:Piranha:T2	1	2020-02-24 7:30:00 PM	1	2020-02-24 7:30:00 PM	1	2019-07-25 12:00:00 AM
TS9:Shark:T1	1	2020-02-24 7:30:00 PM	1	2020-02-24 7:30:00 PM	1	2019-07-25 12:00:00 AM
TS9:Shark:T2	1	2020-02-24 7:30:00 PM	1	2020-02-24 7:30:00 PM	1	2019-07-25 12:00:00 AM

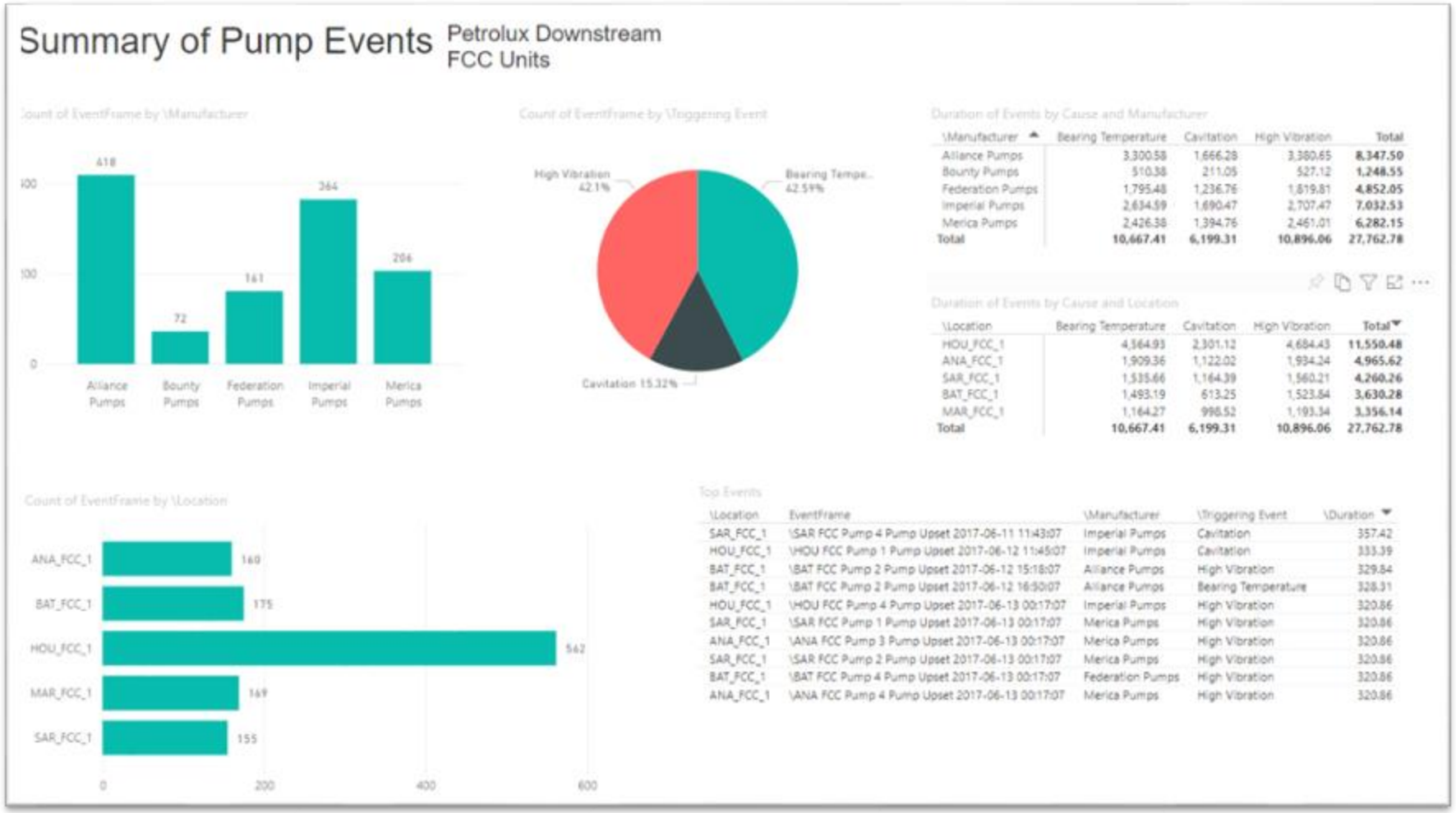
Alert users and close the loop

Notify and alert



Capture poor performance with event frames

Sum and analyze in PI DataLink or PowerBI



Overall Benefits of Condition Based Maintenance

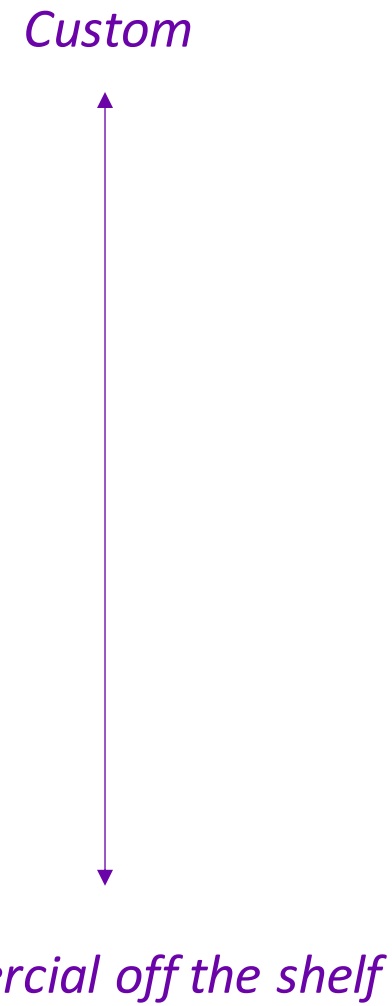
- Reduced Downtime
- Reduction / elimination of Unplanned Failures
- Decreased Maintenance Costs
- Increased Asset Life
- Reduction in Collateral Asset Damages
- Situational Awareness and the ability to Save Precious Time
- Better Understanding of Asset Health
- Prioritization and Planning of Work Orders

Artificial Intelligence - AI

AI – Predictive maintenance

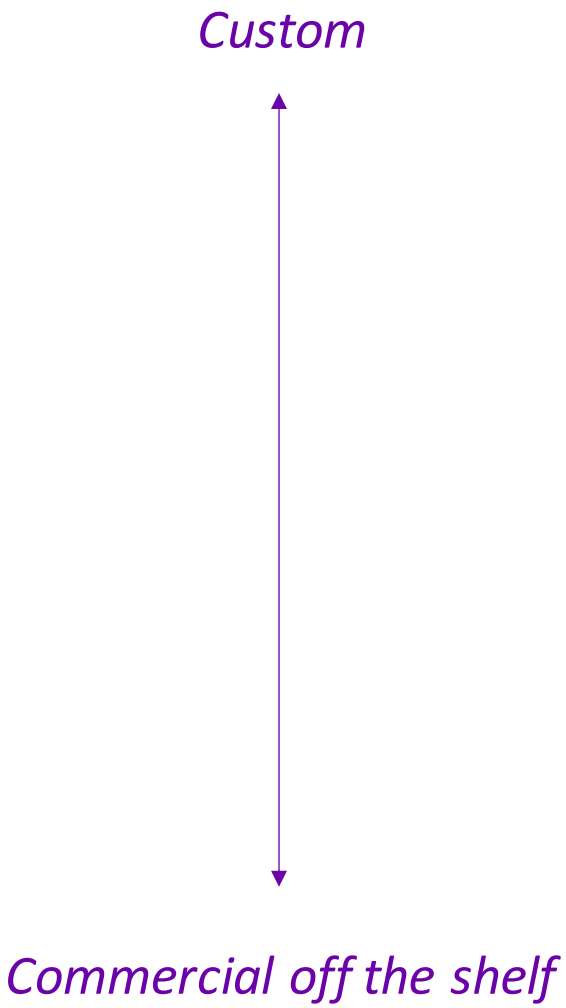
Starts with your people

- Full stack programmers and data scientists
- Only a data scientist
- No data science or programming skills



AI – Predictive maintenance

- PI System Access technologies
- PI Integrator for Business Analytics
- AVEVA Predictive Analytics
- AVEVA Data Hub and data sharing to partners



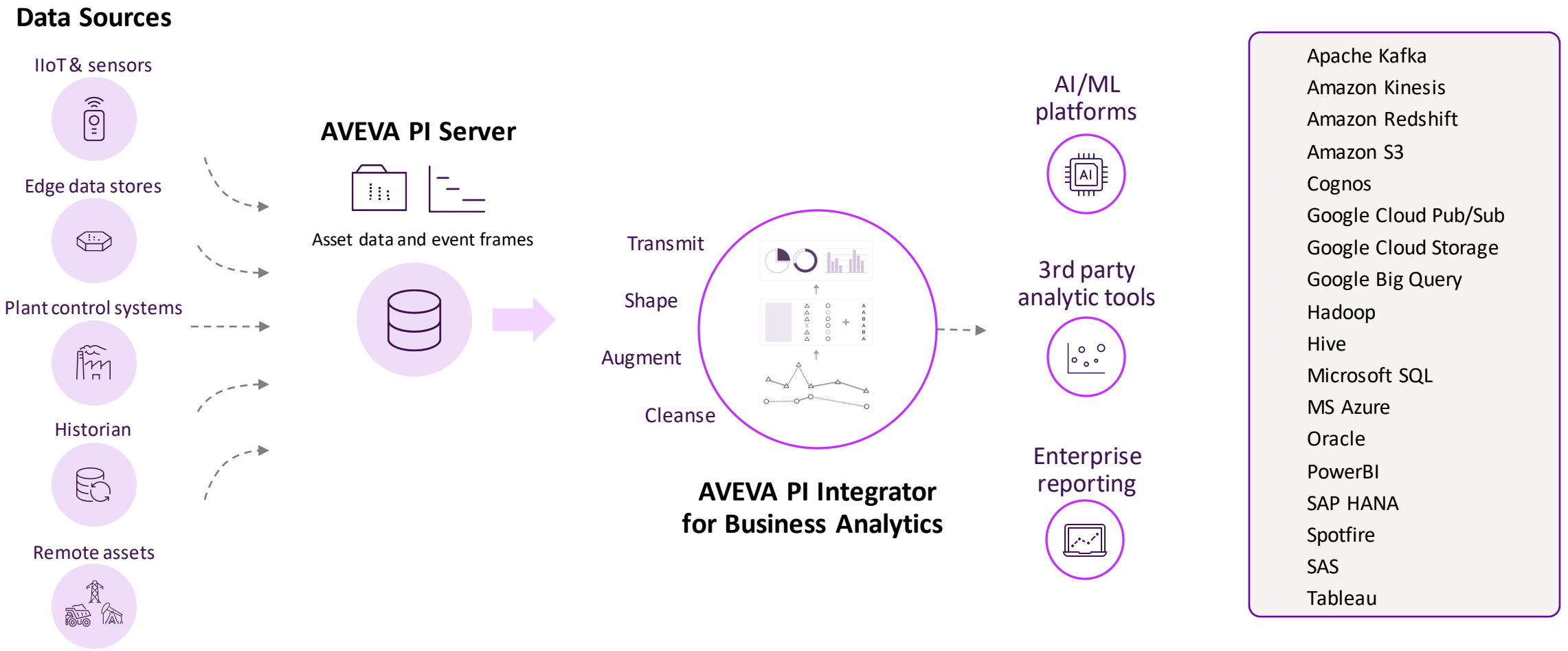
PI Web API

Secure RESTful access to PI Server data over HTTPS

- Send your data to Jupyter Notebooks
- Analyzed temperature control startup data to determine optimal start times for heating and cooling assets at the San Leandro Tech Center
- Findings showed theoretical savings of 5000 run hours per year for these assets

Full presentation here

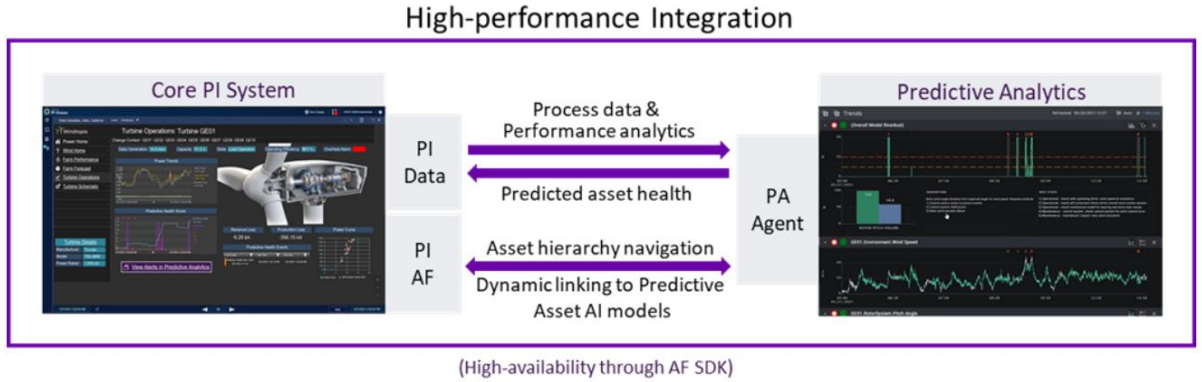
AVEVA PI Integrator for Business Analytics sets foundation to accelerate advanced analytics and business intelligence



AVEVA Predictive Analytics

Prevent Equipment Failures

- Predictive monitoring of industrial equipment assets
  - Compressors, Pumps, Gearbox's, Motors, Turbines, Generators, etc.
- Achieve fast time to value through out-of-the-box predictive monitoring of industrial assets
- Developing unified PI + AI integration



EDF

North America

EDF runs fleet-wide monitoring of solar, wind and energy storage using AVEVA Predictive Analytics combined with PI System operational data management. The solution saved £1.5 million in a single early-warning catch.

Goals

- Combine the PI System™ operations data with AVEVA™ Predictive Analytics to mitigate major asset failures and optimize call-out decisions for maintenance crews.

Challenges

- With 39.1 million customers globally, EDF Group's brand image is closely linked to continuity of service
- Major failures could have been avoided before becoming severe, but the company did not have the capability to detect the early warning signs of future asset failures
- They resolved to create five monitoring centers in order to monitor over 300 fossil, nuclear and hydro plants

Results

- Avoidance of downtime resulting from equipment failure
- £1.5 million saved from a single early warning catch

Industry: Power generation

Solution: AVEVA™ PI System and AVEVA™, Predictive Analytics (formerly PRiSM)

"The PI System is designed to support our goals of operational intelligence. The idea is you build systems that take raw data and turn it into actionable information so you can make smarter decisions"

David Rodriguez Sr., Analytics and Intelligence Engineer, EDF Renewables

LEARN MORE

Duke Energy and Predictive Analytics

46 PI Servers and 11,000 models leveraging over 500,000 data points

- Empower people with early warning notification of equipment problems
- Optimize assets with low-cost sensors and connectivity for high-fidelity data access enabling predictive maintenance
- Improve operations with contextualized insights
- Savings of over $34 million in a single early catch event in 2016.
- AVEVA helps Duke Energy centrally monitor power generation assets with predictive asset analytics software

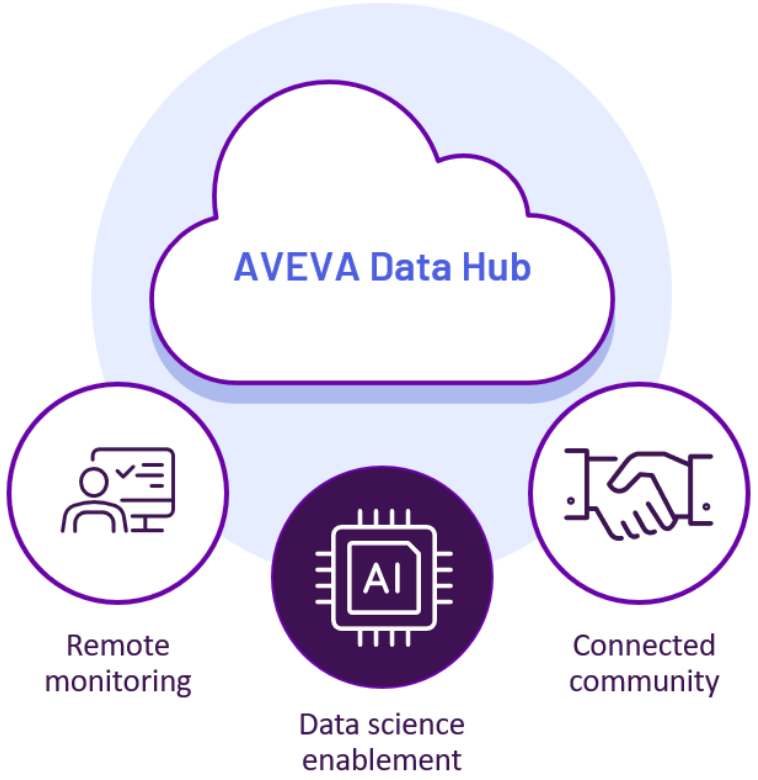
Learn more

AVEVA Data Hub and data sharing

Secure information sharing

- Selectively share operations data with trusted stakeholders
  - Key suppliers, equipment providers, data scientists, enterprise business analysts, and other authorized partners

- Connect external partners without giving network access



Renewable Energy Group (REG) and AVEVA Data Hub

Real-time external analysis on its centrifuge units

- Biodiesel equipment can have many recurring faults, and maintenance costs can also be high
- If this led to unplanned downtime, it could halt production, costing valuable revenue in addition to repairs
- Enabled simple, secure sharing of AVEVA PI System data using AVEVA Data Hub
- Solution can potentially reduce centrifuge downtime by up to 90%

Learn more

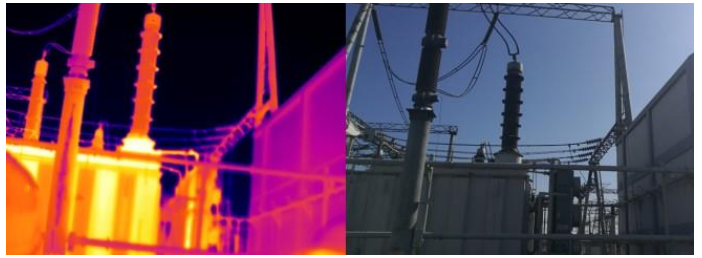
Putting data science predictors back into AVEVA PI Server

- Some predictive models have linear equation outputs
- Use Asset Analytics to create these calculations in PI, writing to future tags
- Notify on discrepancies between real time and predictive data

PI Data Egress to CMMS

Condition Monitoring / Incipient Failure Detection

Condition Scoring Using Potential Failure "PF" Curve



Equipment Condition

1 smooth running

2 minor degradation

P = Change in Condition or Performance detected

3

4 further degradation

Example Condition Scoring Matrix

1 New
2 Used
3 Potential Failure
4 Failed – Schedule Repair
5 Failed – Emergency Repair
6 Failed – Repaired Onsite

Maintenance Task

impending failure

F = Functional Failure

5

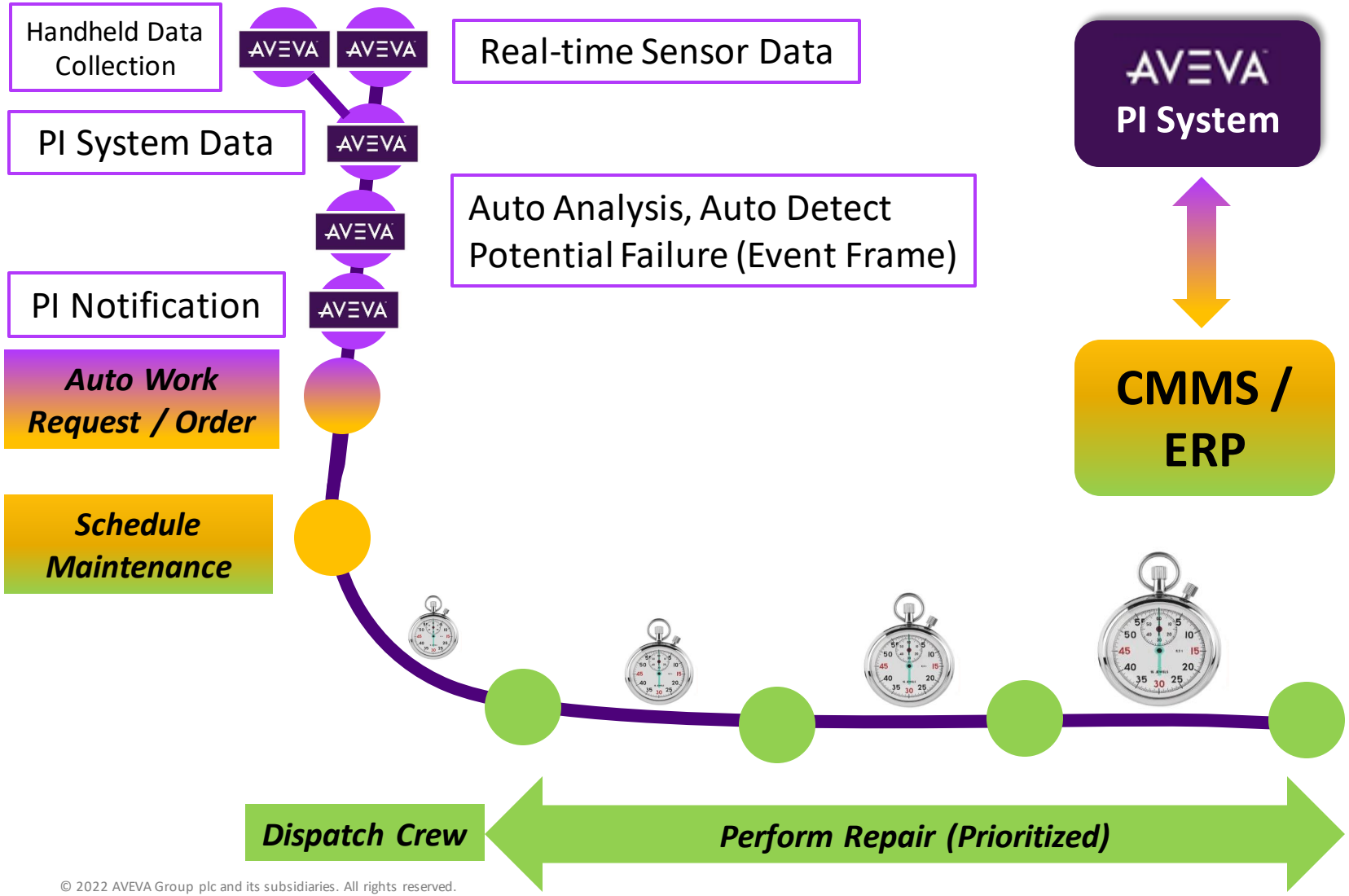
6 limited functionality

Opportunity Window

Time

AVEVA

Solution: Minimize Gaps Between Measurement and Action

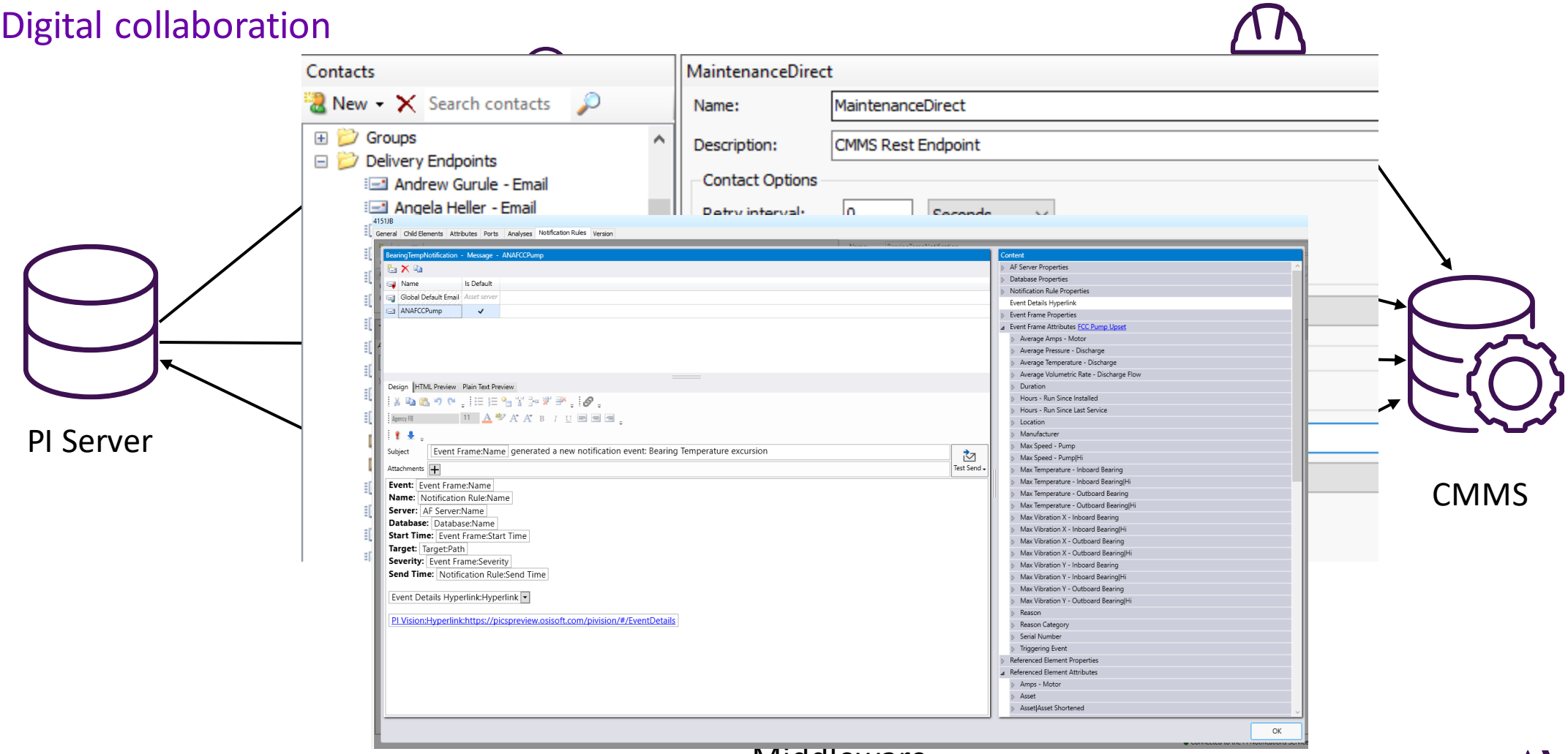


Typical Timeline:

Seconds to Minutes before made aware of issue

Maintenance Systems and the AVEVA™ PI System™

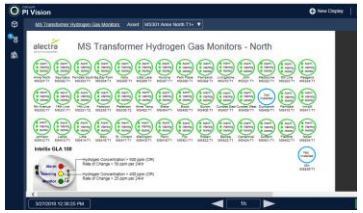
Digital collaboration



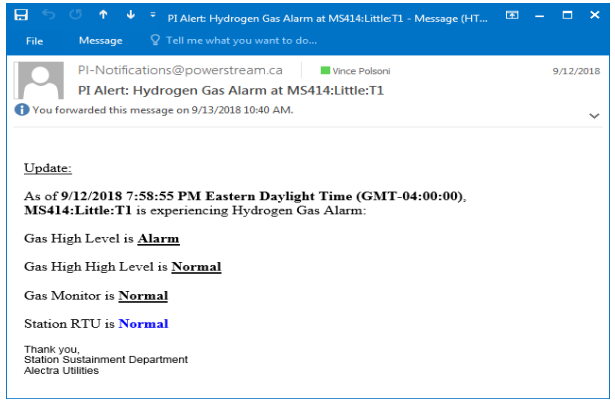
Real Example of CBM with PI System at Work

High Hydrogen Alarm on a 5 MVA Substation Transformer

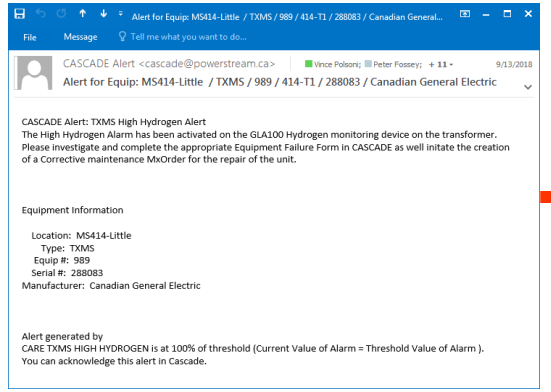
Hydrogen Sensor



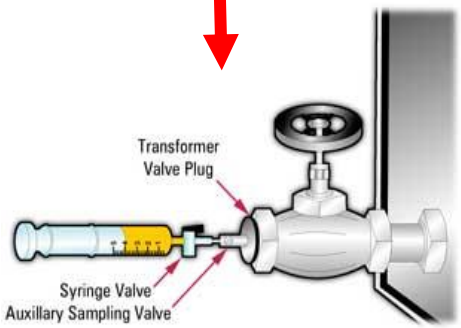
PI Vision Report



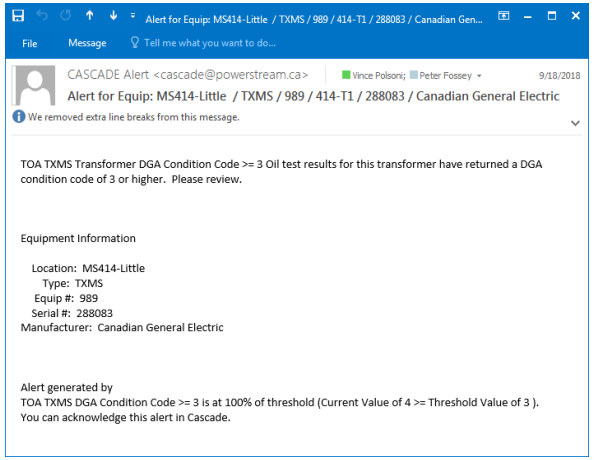
PI Notification – High Hydrogen



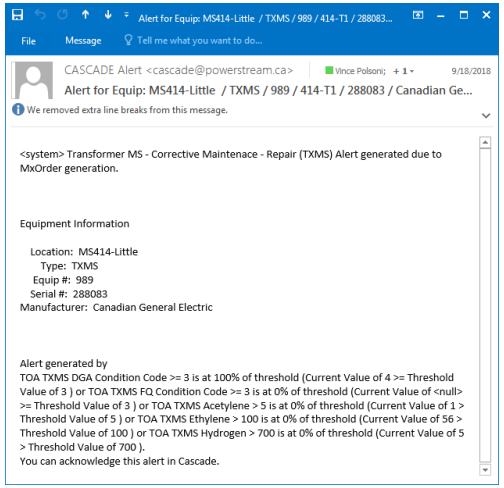
CMMS Alert – High Hydrogen



PI Vision Report



CMMS Alert – Poor Oil Condition



CMMS Auto – Repair Work Order

- Oil sample taken and analyzed by Laboratory
- Lab results entered into TOA4 (Advanced Analytics tool) for analysis
- Auto synch to CMMS and PI System

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Questions?

Please wait for the microphone

State your name and company

Please remember to…

Navigate to this session in the mobile app to complete the survey.

Thank you!

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ABOUT AVEVA

AVEVA is a global leader in industrial software, sparking ingenuity to drive responsible use of the world's resources. The company's secure industrial cloud platform and applications enable businesses to harness the power of their information and improve collaboration with customers, suppliers and partners.

Over 20,000 enterprises in over 100 countries rely on AVEVA to help them deliver life's essentials: safe and reliable energy, food, medicines, infrastructure and more. By connecting people with trusted information and AI-enriched insights, AVEVA enables teams to engineer efficiently and optimize operations, driving growth and sustainability.

Named as one of the world's most innovative companies, AVEVA supports customers with open solutions and the expertise of more than 6,400 employees, 5,000 partners and 5,700 certified developers. With operations around the globe, we are headquartered in Cambridge, UK and listed on the London Stock Exchange's FTSE 100.

Learn more at www.aveva.com

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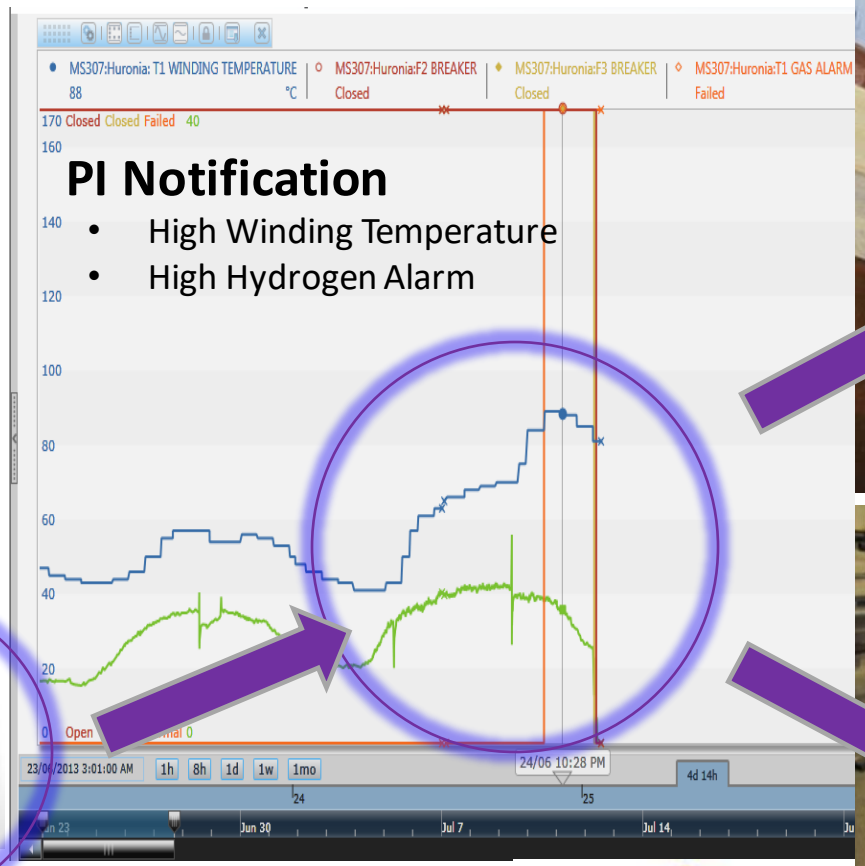
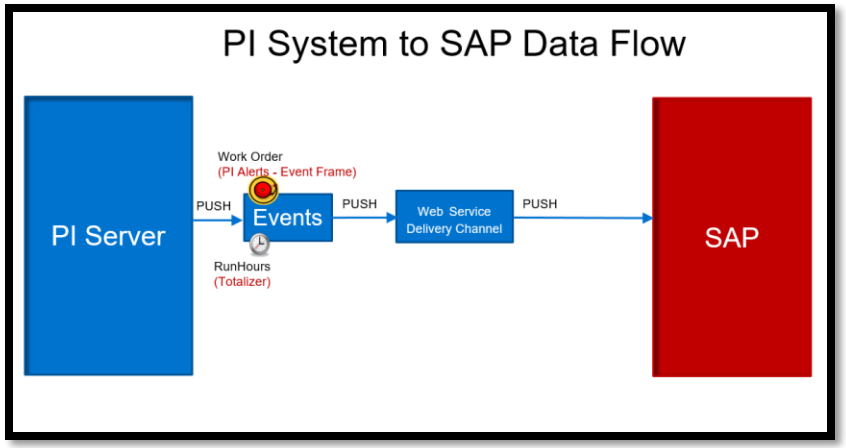
Save - 10MVA 44kV-13.8 kV Transformer

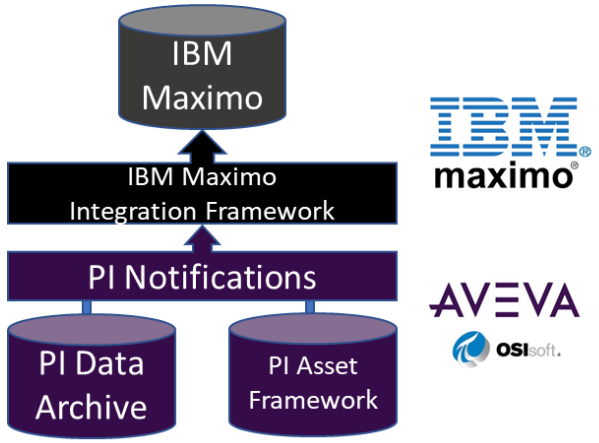


Cost Avoidance: $500,000 averted

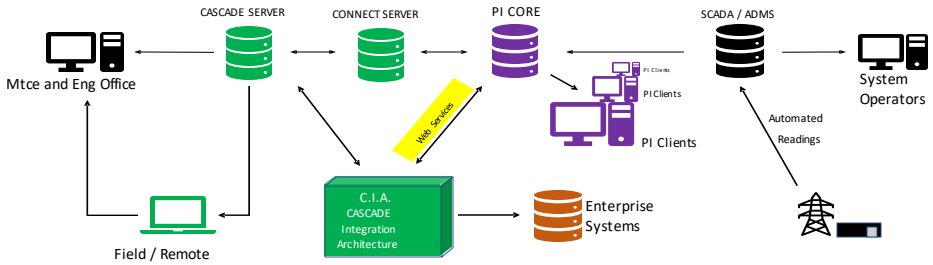
- **Repair Cost: $130,000**
- **No customer outages**
- **Transformer taken out of service before total failure, replaced with spare and repaired**

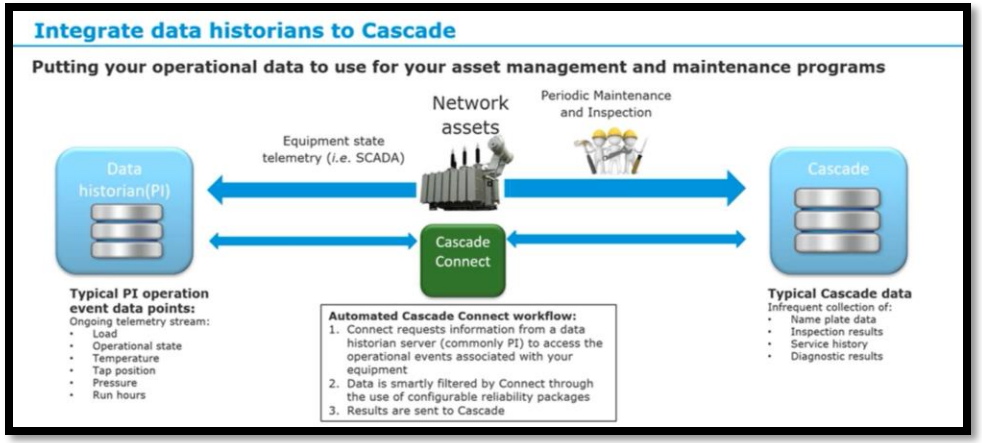
Installed a Hydrogen Gas Monitoring Unit and connected to SCADA (PI and CMMS)





CASCADE CMMS Integration Methods





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PI System to CMMS Data Flow