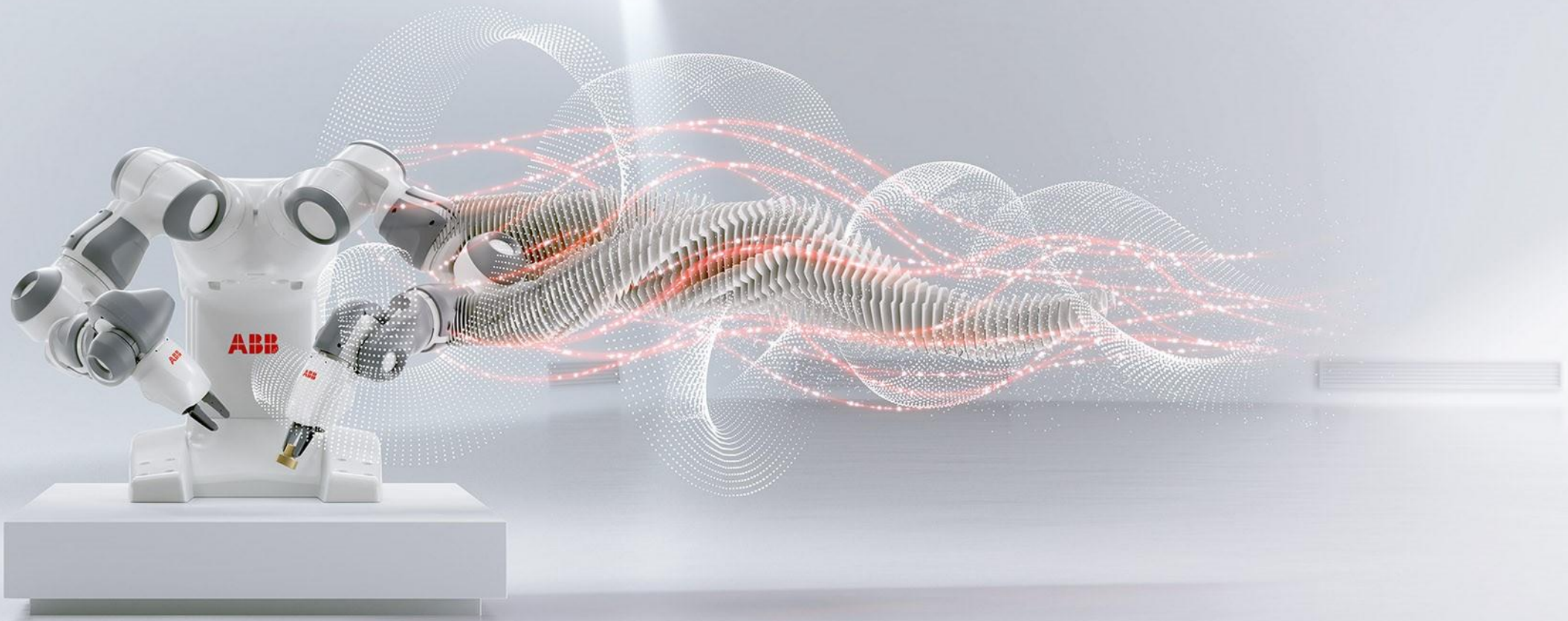


Advanced Predictive Maintenance Program

Chris Flower, ABB IAEN UK Digital Lead

 Document ID.: Rev.:

AI and Training Data

More or Less: Behind the Stats

Advanced Predictive Maintenance Programs

Opportunities and Challenges

Chemicals plants seem like the ideal environment for advanced predictive maintenance – rich data set for machine learning;

- High level of automation
- Rigorous maintenance records
- Overall equipment effectiveness (OEE) losses due to unplanned maintenance range from 3 to 5%

However all is not as it seems for 4 reasons

1. Too little data of failures for machine to learn from
2. Too little time to react to predictions
3. Too little impact because of high degrees of redundancy
4. Too little savings – unplanned maintenance is only half that of planned maintenance (OEE loss of 5-10%)

References:
Predictive maintenance: the wrong solution to the right problem in chemicals: McKinsey & Company

Why Do Predictive Maintenance Programs Fail?

Lack of Vision

- A predictive maintenance program should change the culture, philosophy and workflow of the maintenance department. It is not just the addition of a new technology or tool.

Using a Tool without Understanding Why

- Many facilities purchase a new technology, spend time and money learning how to use the tool, but little time understanding why it is being used.
- The use of the technology as an end in itself without an overall vision of why the technology is being employed

Lack of Consistency

- E.g. failure to commit adequate personnel, lack of proper training, loss of skilled personnel, change in program direction/technology
- Typically results in a lack of faith by the workers and then a reversion back to old patterns

Training and Partnering

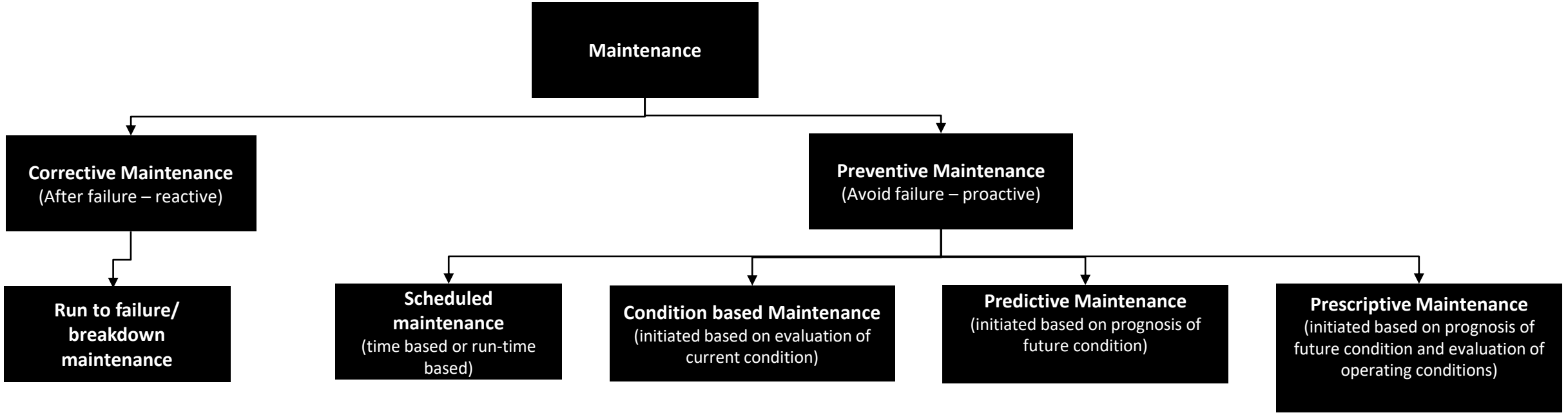
- Onsite training, database reviews, program audits and choosing the correct long-term partner, or service provider, goes a long way to ensuring a successful program

Reference
1. Why Do Predictive Maintenance Programs Fail? Reliabilityweb: A Culture of Reliability

Maintenance and Reliability

Maintenance strategies

Moving towards predictive and prescriptive maintenance



* Based on EN 13306 Maintenance terminology

What causes the majority of failures? Time? No.

The majority of failures are uncorrelated to time or age

Preventive Maintenance (PM): Appropriate for Just 18 Percent of Assets > Yet this has been the focus for most plant maintenance strategies - Doing PM on the other 82 percent can also cause failures!

	Probability curves	**Bromberg (1973)**	**US Navy (ship – 1982)**	**US Navy (submarine – 2001)**	**Nolan & Heap (UAL – 1968)**	**Hyundai Vessel (Electric System – 2016)**
A 	A	3%	3%	2%	4%	0%
B 	B	1%	17%	10%	2%	38%
C 	C	4%	3%	17%	5%	12%
D 	D	11%	6%	9%	7%	3%
E 	E	15%	42%	56%	14%	45%
F 	F	66%	29%	6%	68%	2%

The majority of failures are uncorrelated to time or age, however we still perform maintenance as this is the case

Microsoft's underwater data centre resurfaces after two years

No humans, few failures

Their first conclusion is that the cylinder packed with servers had a lower failure rate than a conventional data centre.

When the container was hauled off the seabed around half a mile offshore **after being placed there in May 2018**, just eight out of the 855 servers on board had failed.

That compares very well with a conventional data centre.

"Our failure rate in the water is one-eighth of what we see on land," says Ben Cutler, who has led what Microsoft calls Project Natick.

The team is speculating that the greater reliability may be connected to the fact that there were no humans on board, and that nitrogen rather than oxygen was pumped into the capsule.

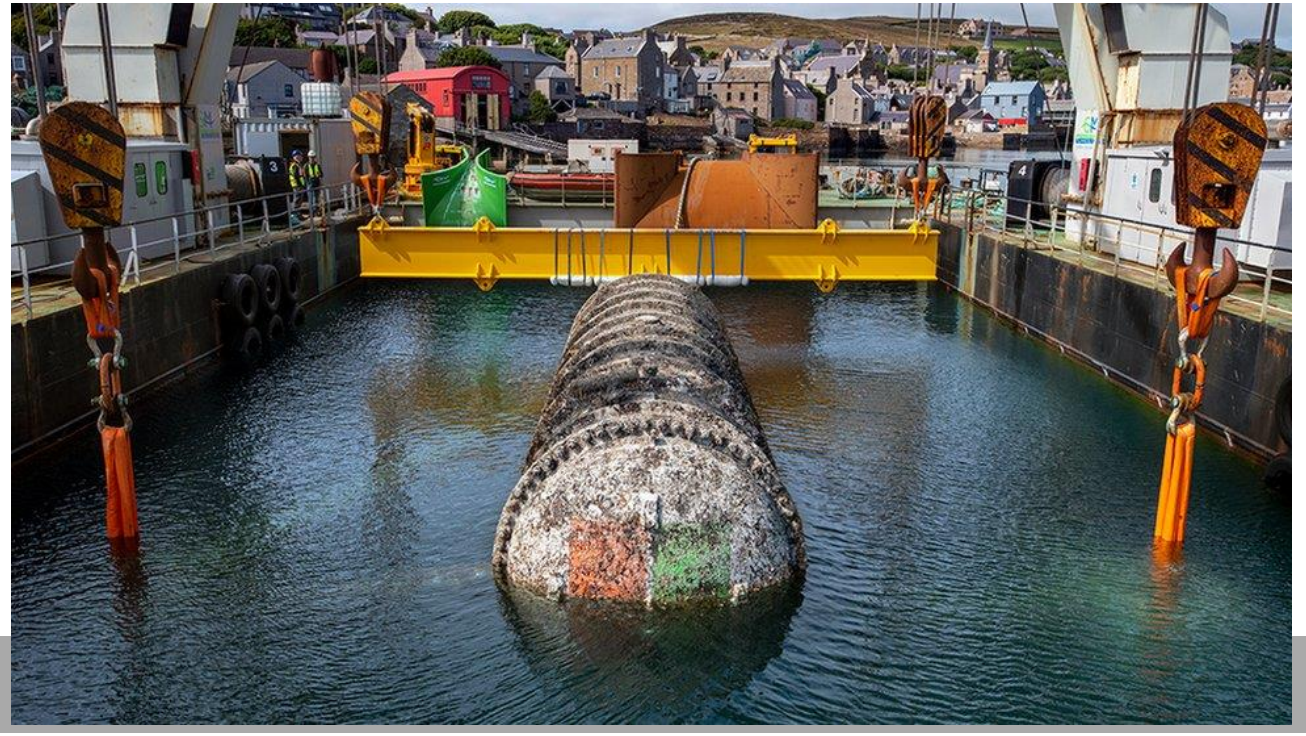


ABB Approach to APM

Six steps to predictive maintenance

Steps to avoid pitfalls

Too little savings

Too little Impact

Step 1

Gain visibility of your data

Lack of Vision

Step 2

Understand the gaps and remediate with added sensing

Using a Tool without Understanding Why

Step 6

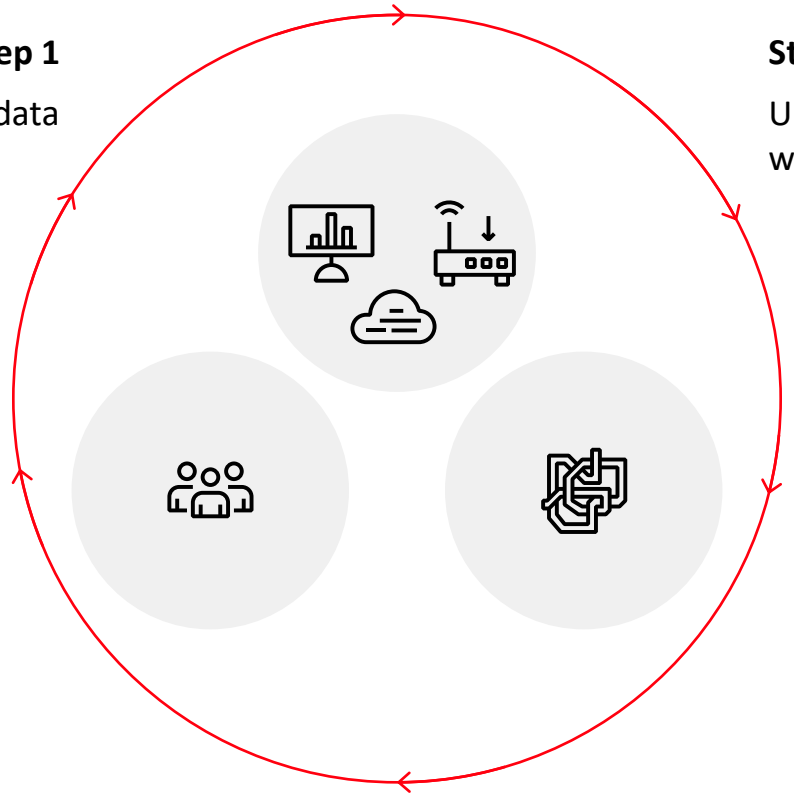
Establishing a reliability culture

Step 3

Too little data of failures

Analyze and understand key trends toward faults

Lack of Consistency



Step 5

Learn and adjust operations

Training and Partnering

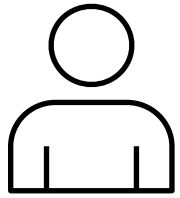
Step 4

Leverage trends to predict faults before they happen and optimize maintenance strategy

Too little time to react

Augmenting the human with information in context

Human



Systems designed by experts

+ Intuition

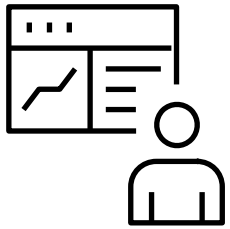
+ Creativity

+ Expertise

– Computation

Augmented

Experts supported by algorithms presented in a context



Amplifying human potential

Artificial

Knowledge learned from data

– Intuition

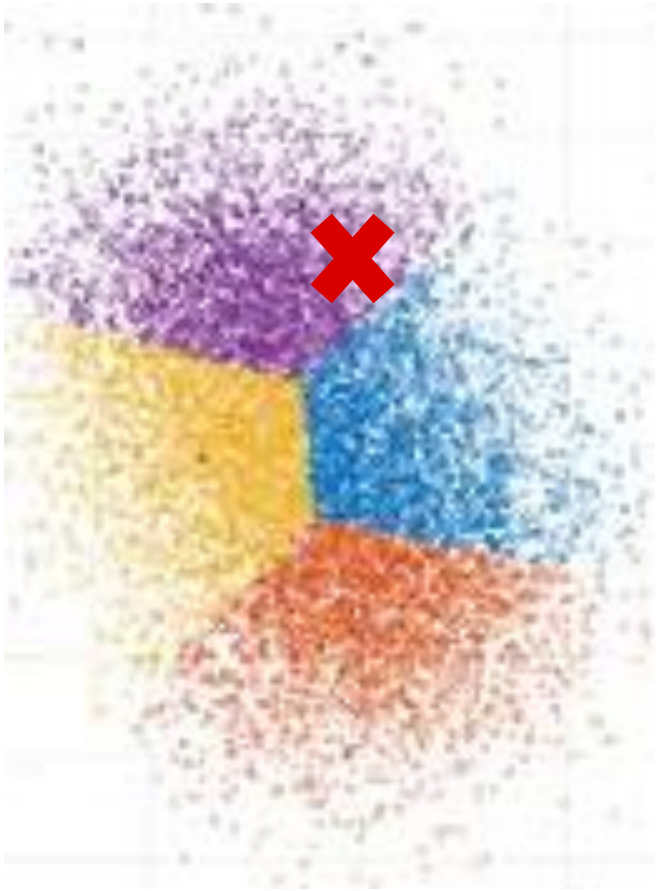
– Creativity

+ Expertise

+ Computation

Modelling Good Health - Less is More

Cluster, Collapse, Squeeze and Compare



Modelling Failure

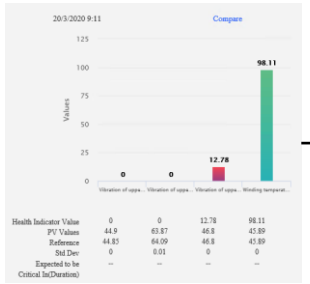
Failure Mode Analysis FM(EC)A

SNo.	Components	Function	Function Failure	Description Of Failure			Failure Effect
				Failure Mode	Failure Mechanism	Detection Of Failure	Local
1	Mechanical Seal	Prevent leaking through shaft	Leaking	eaking	Leaking through sea	Liquid dropping, noise from shaft	-Fluid leakage -Losses of pumping efficiency.
2	Bearing	To bear and hold load from shaft in order to spin	Wrong doing	Vorn out	Shaft and seal will be broken	Vibration and noise on pump	-Excessive pump vibration -Increased in shaft radial movement -Eventual pump shutdown
3	Shaft	Protect shaft from corrosion and erosion on stuffing box	Eroded and corroded shaft	orroded	Corroded	Wrong doing	-Vibration - Possible bearing damage -Eventual coupling failure
4	Impeller	Flow the liquid	Not able to flow fluid	Vorn out	Decreasing pump capacity	Decreasing pressure	- Pump low efficiency - Vibration - Reduce in suction power

Asset Health Modelling

Health Model

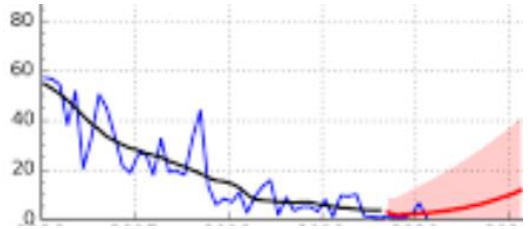
Property Health KDI



Fault Model

Fault Indices FSI/FPI

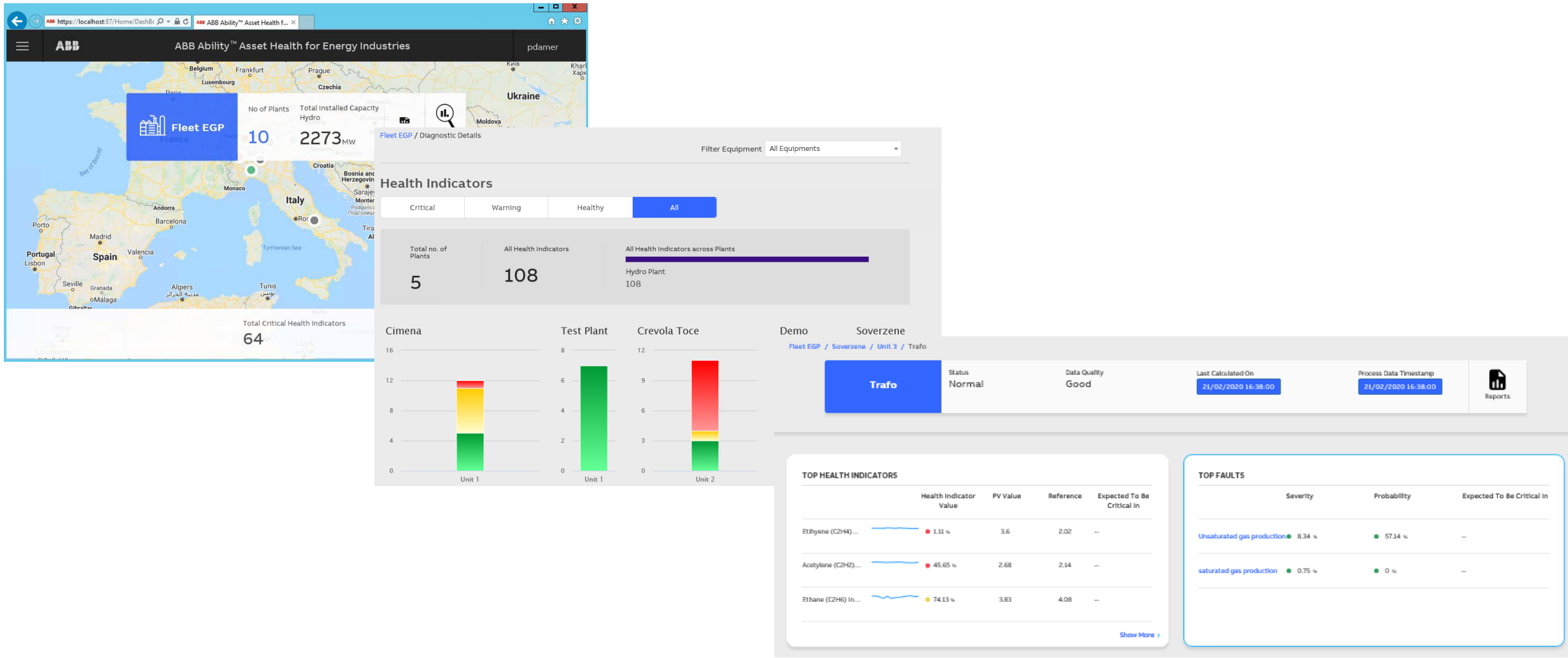
Predict



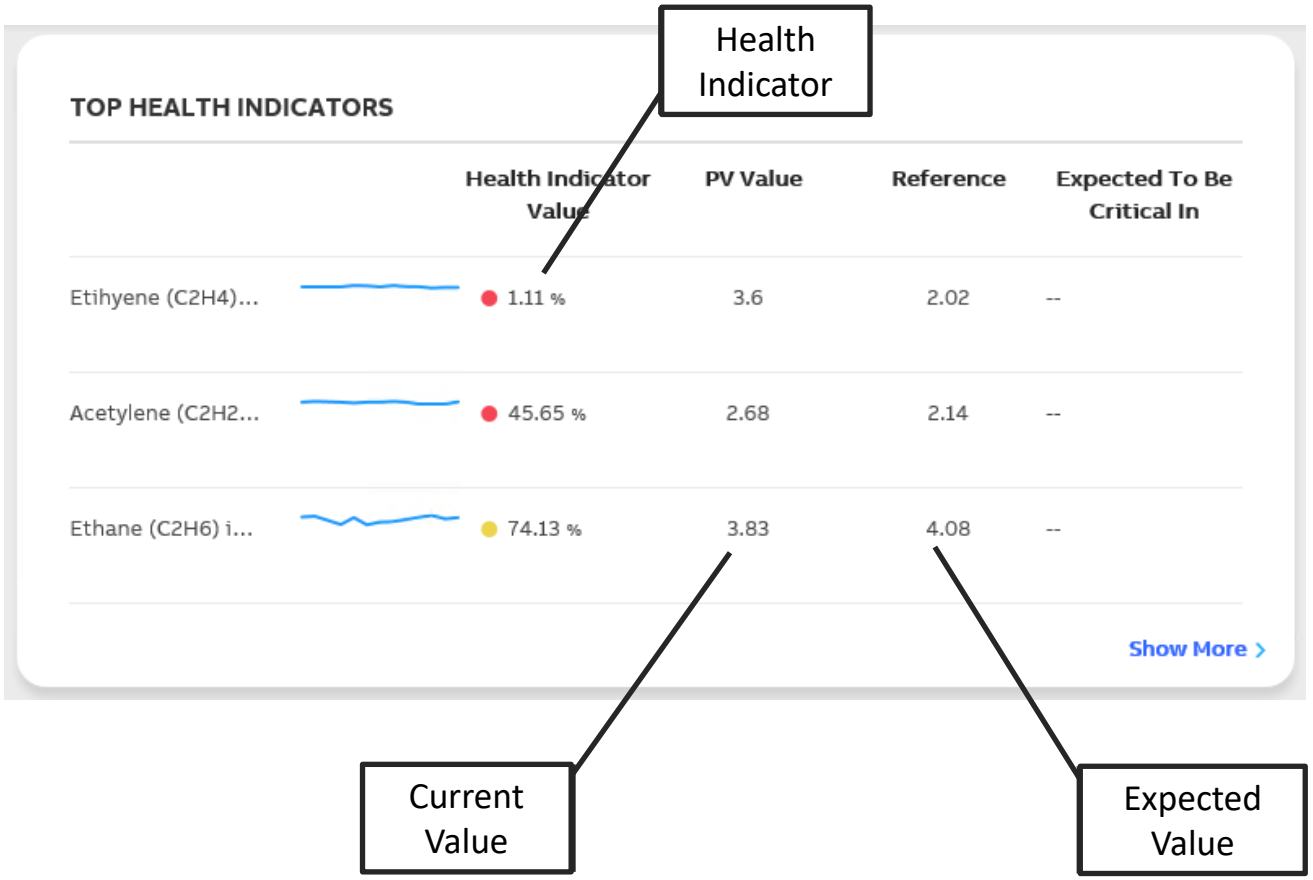
KDI	Key Diagnostic Indicator
FSI	Fault Severity Indicator
FPI	Fault Probability Indicator

Asset Health

Fleet to Equipment



Health Indicators



Faults

TOP FAULTS

	Severity	Probability	Expected To Be Critical In
Fouling on cold side	38.18 %	50 %	--
control valve seat problem	38.18 %	14.29 %	--
Fouling on hot side	0 %	0 %	

Fouling on cold side

	HEALTH INDICATOR VALUE	PV VALUE	REFERENCE	SD VALUE
Heat exchanger - cooling fluid flow	0 %	256	247	0.6
Heat exchanger - cooling fluid outlet t...	85 %	20	20.77	0.19

Indication of a Fault

FAULTS

Fault	Severity %	Probability %	Expected to become critical in	Description	Recommendations	
Fouling on hot side	99.93	100	–	Fouling on hot (shell) side	Strip down exchanger	
Fouling on cold side	99.93	50	–	Heat exchanger fouling on cold (tube) side	Strip down	
control valve seat problem	99.93	14.29	–	Control valve blockage likely	Strip down, clean plug and seat, check pneumatics and spring	

How Severe is the problem

How probable is the problem developing

Final Thoughts

APM programs have the ability to move companies away from scheduled maintenance and gain the OEE benefits from fewer planned and unplanned maintenance activities.

Successful APM programs require consideration of

- People
- Technology (including data)
- Processes

ABB's approach is a hybrid of machine learning and expert knowledge

- Using machine learning to define good health (data rich)
- Expert domain knowledge to identify deviations from good health and produce useful actions


ABB