RWE

Yanqing Li

Integration of Advanced Analytical Models in Value Based Maintenance

Seeq conneqt

Integration of Advanced Analytical models in Value Based Maintenance (VBM)

RWE Generation UK

Information & Analytics

Yanqing Li

Lead Condition Monitoring Engineer

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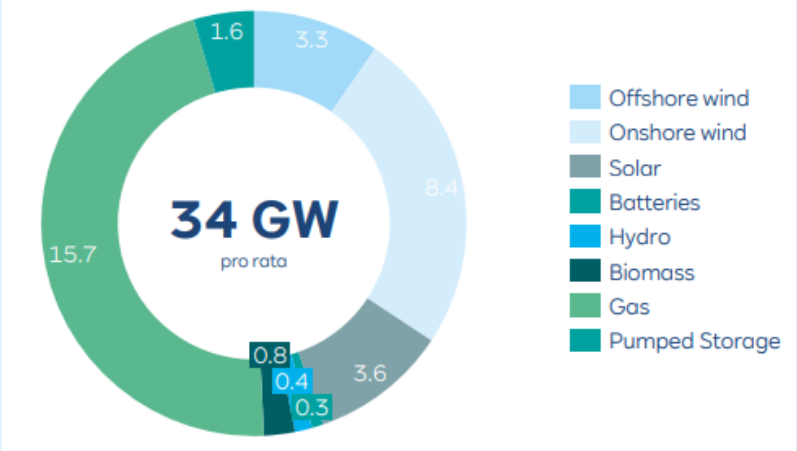
For more than 120 years, RWE has been passionate about generating electricity. Now, RWE is shaping the new energy era.

We aim to be climate-neutral by 2040

- Clear decarbonisation roadmap with further closures of coal activities
- Significant expansion in wind, solar and batteries
- Driving forward green hydrogen
- #2 gas fleet in Europe, 31 power plants
- ‘Energy Company of the Year’ 2023 at Global Platts Energy Awards



RWE Renewables
Offshore and onshore wind power, photovoltaics and storage

RWE Supply & Trading
Energy trading and customer solutions
Gas storage

RWE Generation
Gas, hydropower, biomass and hydrogen

RWE Power
Lignite
Nuclear power

CORE BUSINESS

COAL/NUCLEAR

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Start of our digital journey

Optimized Application Landscape	Making better use of our existing software tool portfolio by creating transparency and providing (improved) training.
Enhanced Remote Working	Ensuring the right equipment, software and training to enable RWEG employees to remotely work from anywhere- also beyond COVID-19.
Data and Digital Platform	Improving the way we manage our data so we make data easily accessible and turn it into a valuable asset – thereby enabling current and future digital opportunities.
Digital Planning	Replace lengthy MTP process by a smarter and shorter, system-based forecast approach with lower granularity. Powered by smart data handling and predictive models.
Digital Reporting	Reduce and highly automate the standard reporting landscape and enable the experts with efficient analysis and visualization capabilities.
Centralised Performance Monitoring	Facilitate centralized performance monitoring by developing and standardising tools & methodologies across Generation.
Remote Operations	Create the opportunity for gradual increase of remote operations by defining blueprint and roadmap; set up GY/LB for remote control.
Value Based Maintenance	Applying advanced algorithms for failure & economic impact prediction to optimize maintenance plans and interventions.

Our journey begins with **eight lighthouses** that cover a broad spectrum of our business.

To be fast and flexible we will transform in an **agile** way starting each new development with a **pilot** and ensure **scalability** across the business.

DIGITALISATION

will enable us to further **maximize the value** of our existing assets and will give us the **competitive advantage** essential for current and future business.

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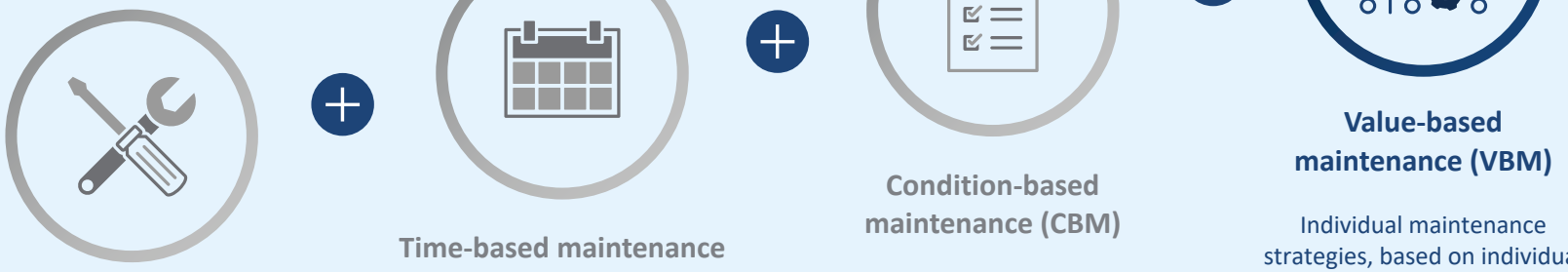
VBM describes a continuous **optimisation** of **maintenance strategies and plans** based on a **regular valuation** of the plant integrity **risks**



Corrective maintenance (CM)

Operation until failure, posterior assessment to decide whether to repair or to replace

Time-based maintenance (TBM) / or cycle-based

Fixed time intervals / cycles for inspection and for certain routine maintenance work stablished, typically OEM driven

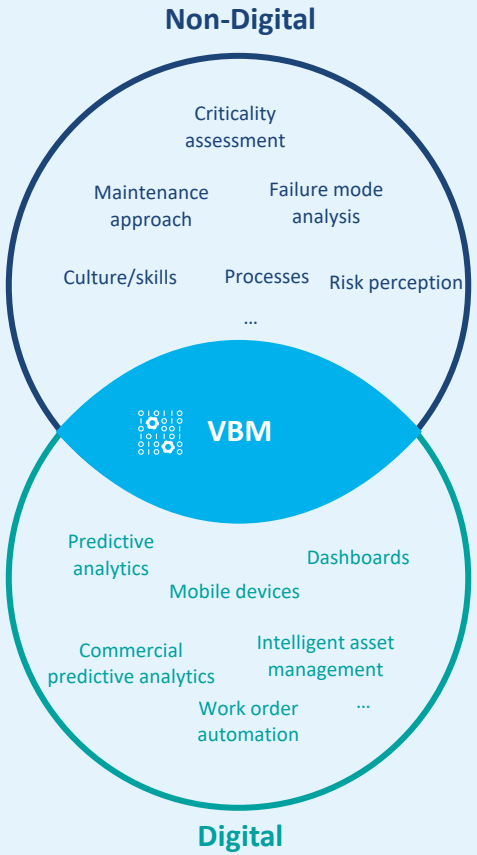
Condition-based maintenance (CBM)

Maintenance activity triggered by estimated condition reaching certain thresholds, i.e. based on data from sensor technology, thermography, ultrasound, oil analysis, history etc.

Value-based maintenance (VBM)

Individual maintenance strategies, based on individual risk and probability assessments

Maintenance activity triggered by predicting the asset health and failure as well as economic impact – up to no action for minor impact/risk



Value Based Maintenance x Data foundation

Equip maintenance teams with the required information to optimise the value derived from maintenance

VBM

Optimization of **maintenance strategies and planning** based on a real time **valuation** of the plant integrity **risks**

€/£

Aimed at the **reduction of high impact failures** and **of over- and under-maintenance**

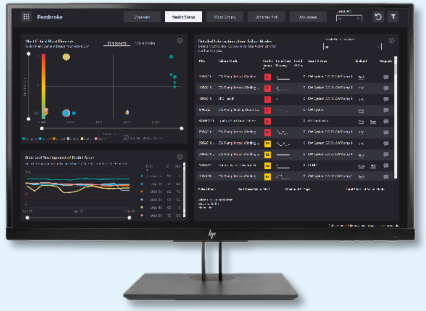
Developed by a **cross-functional team** of maintenance, operations, IT and data engineers

The tool-set consists of **dasboards** and multiple underlying **(ML) models** to compute **integritiy risk level**, **health status**, **failure probability** and **failure impact**

Different dashboards have been developed to present the information **real-time** and from **any device**

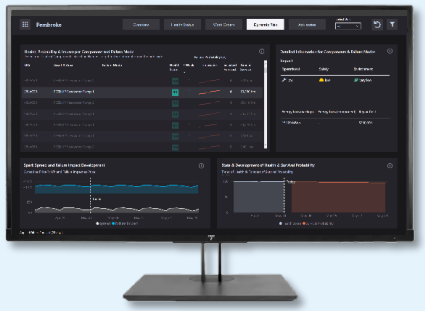
Equipment Health Dashboard

Dynamic overview of equipment health and asset condition



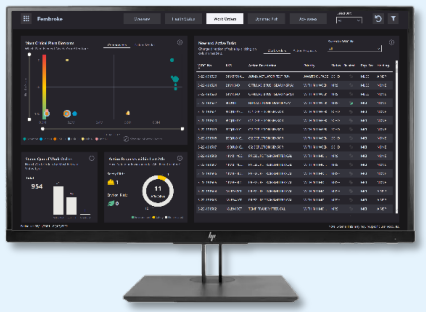
Dynamic Risk Dashboard

Combine technical failure probability and commercial impact data to determine risk level of each component/failure mode



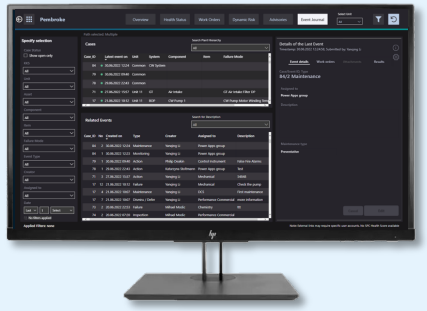
Work Order Dashboard

Prioritise work orders of high risk components while reducing maintenance on equipment with lower criticality levels



Event Journal

Allows to record current topics, link them to data in the cockpit and offer the possibility to link already created historical events



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*"We want to equip our maintenance teams with the required **tools and information** to optimize the **value** derived from **maintenance**"*

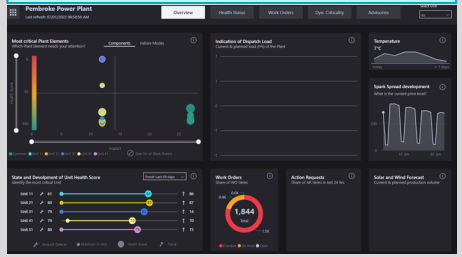
Users

Dashboards

Models

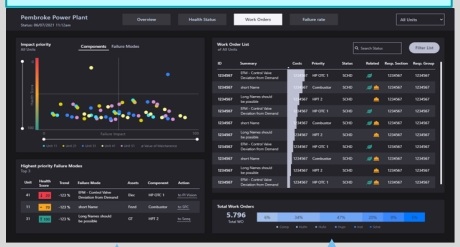
Data

Overview Dashboards

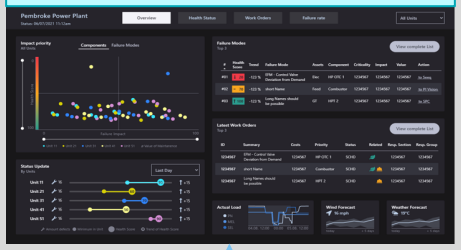


Equipment Health Dashboards

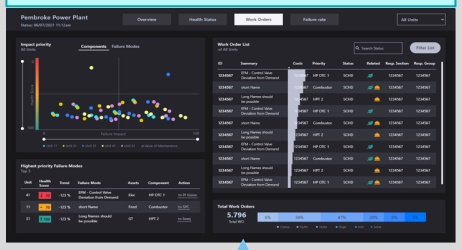
Failure Probabilty & Impact Dasboards



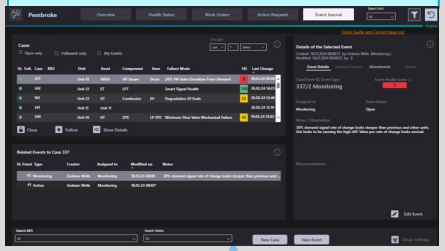
Dynamic Risk Dashboards



Maintenance Dashboards



Event Journal Dashboard



Equipment Health Models

Failure Prob Models

Failure Impact Models

Dynamic Risk Calculation

Work Order Prioritization Models

Collaborative Database

Yuma Datalake

SPC/ Smart Signal/ Seeq

Offline Criticallity Assessment

Reliability Statistics

PI

UK Commercial & Dispatch data

NL/G Commercial & Dispatch data

SAP

PRISM

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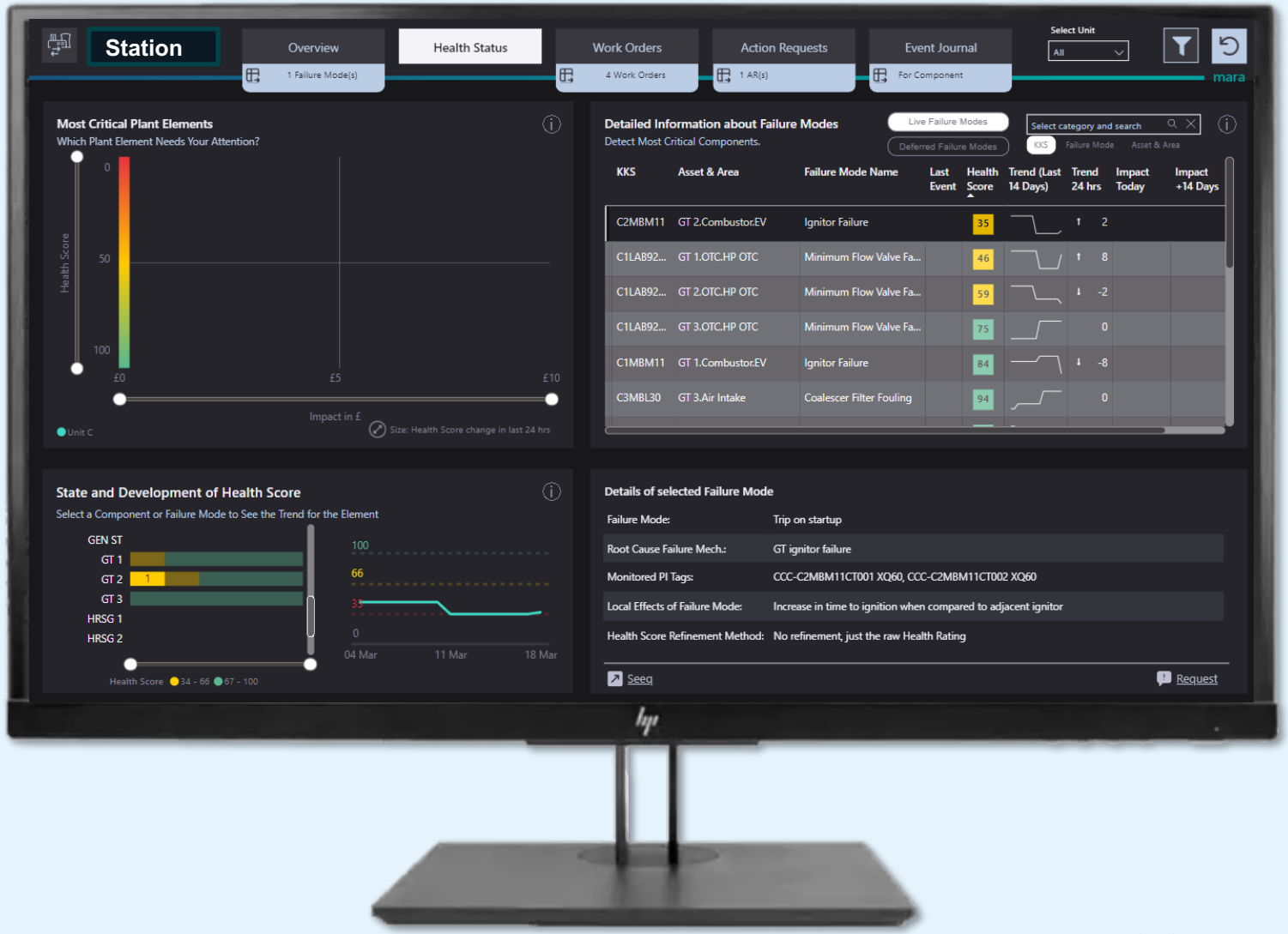
Diagnostic Journey

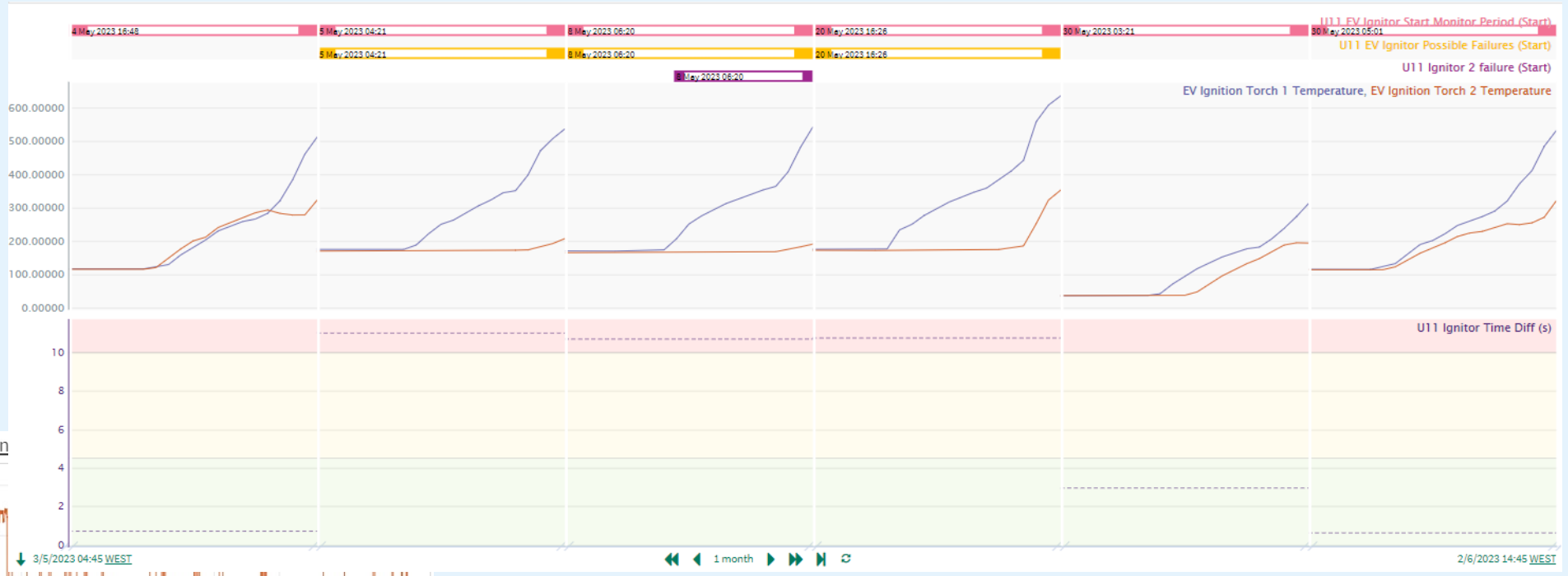
Gas Turbine Ignitor Failure

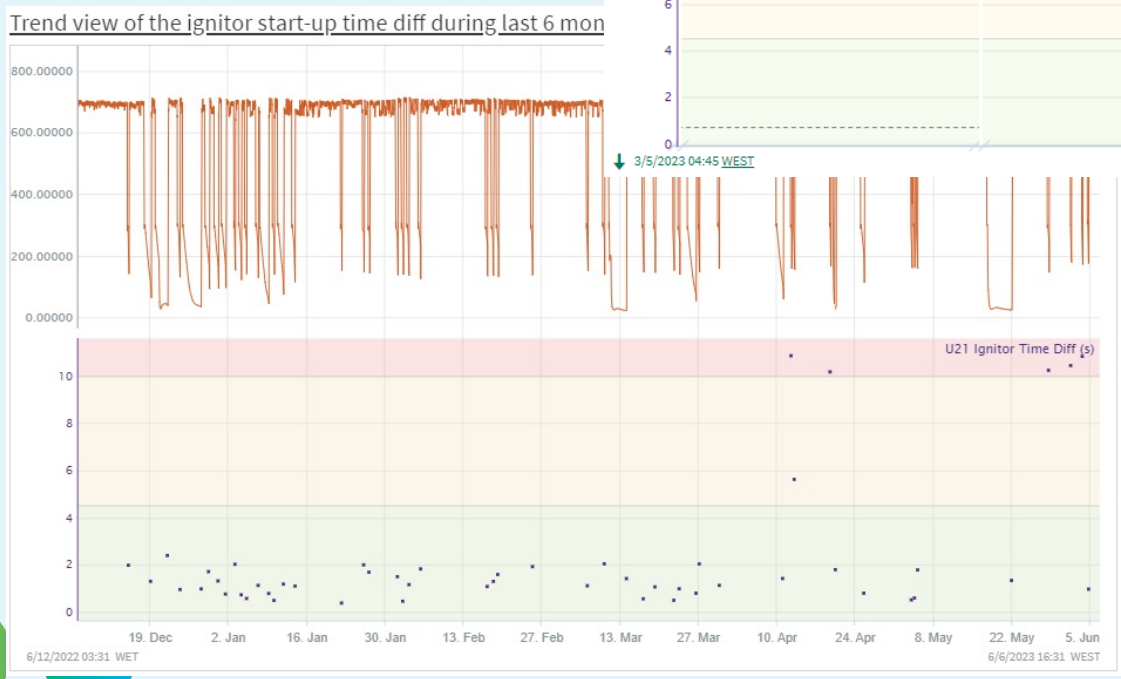
Equipment Health Dashboard
Dynamic overview of equipment health and asset condition

- Reliability Engineer identifies issue with GT ignitor
- Detailed information displayed along with link to Seeq
- Station is aware as there are 4 linked work orders and 1 action request



Seeq Dashboard





- Compares the time difference between the two ignitors when rising 30 deg C above its starting temperature
- A time difference of greater than 4.5 seconds is considered an indication of possible failure
- A failure occurs when one ignitor fails to start in the monitoring period (GT sequence step)

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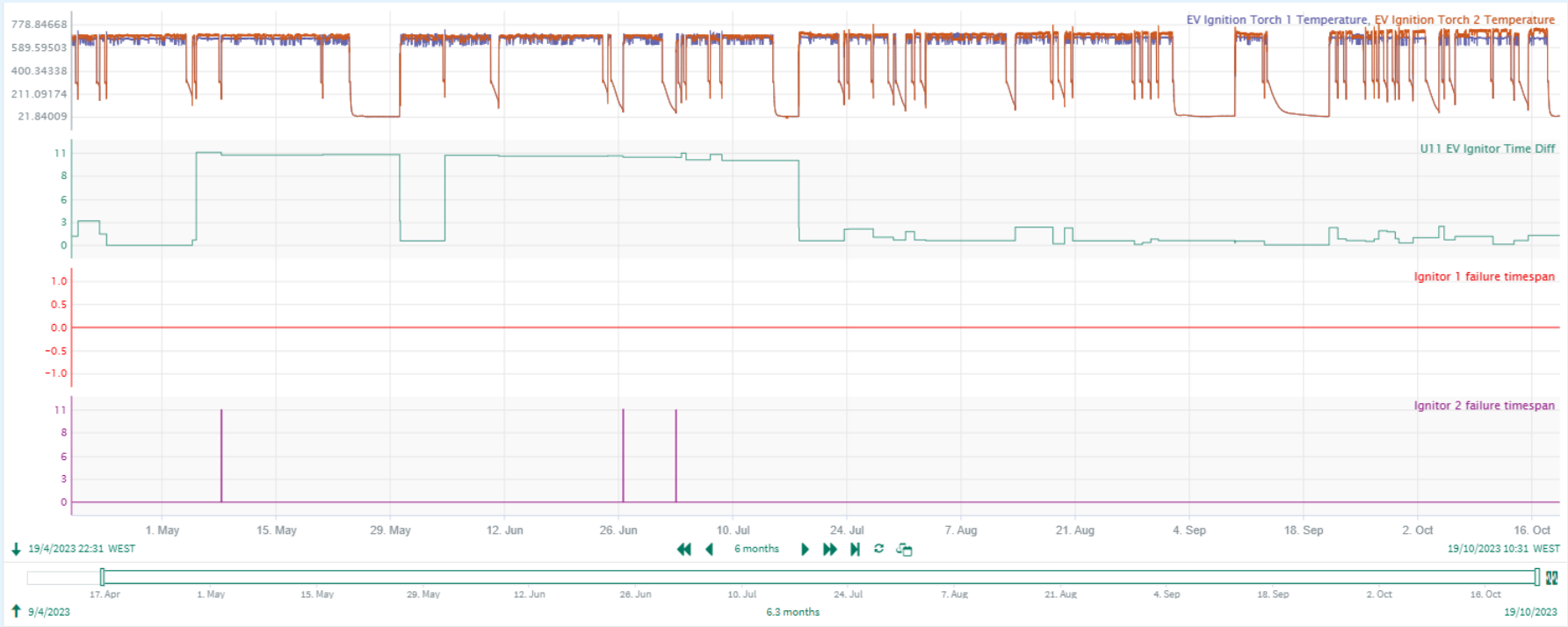
Seeq Model



- Health score calculation takes failure mode indicators:
  - Time Diff, Ignitor 1 and 2 failure timespans
- Indicators are exported to PI

Failed start can cost up to **~£150k** per start

Details

Customize

Name	Asset	Description	Lane	PI P
U11 EV Ignitor Time Diff	GT, EFM - Ignitor Failure	[EXPORT TO "PIserver-PE" AS "PE.Unit 11.GT.Combustor.EV.EFM - Ignitor Failure.Ignitor Start Time Difference" EVERY "15m"]	7	
U11 Ignitor Time Diff (s)	GT, EFM - Ignitor Failure		8	
Ignitor 1 failure timespan	GT, EFM - Ignitor Failure	[EXPORT TO "PIserver-PE" AS "PE.Unit 11.GT.Combustor.EV.EFM - Ignitor Failure.Ignitor 1 Failure Timespan" EVERY "15m"]	9	
Ignitor 2 failure timespan	GT, EFM - Ignitor Failure	[EXPORT TO "PIserver-PE" AS "PE.Unit 11.GT.Combustor.EV.EFM - Ignitor Failure.Ignitor 2 Failure Timespan" EVERY "15m"]	10	
Ignitor 1 Failure Timespan	EFM - Ignitor Failure	Timespan over which Ignitor 1 failed to reach the relative temperature of Ignitor 2	11	\\PI
Ignitor 2 Failure Timespan	EFM - Ignitor Failure	Timespan over which Ignitor 2 failed to reach the relative temperature of Ignitor 1	12	\\PI
Ignitor Start Time Difference	EFM - Ignitor Failure	Time difference between the two ignitors when rising 30 deg C above its starting temperature	13	\\PI
EHM Raw Health Rating (HR)	EFM - Ignitor Failure	Raw Health rating of this failure mode (Equipment Health Model)	14	

EV Ignitor Failure					INPUT
Ignitor Time Diff = 0 (100%)	0	100	%		
Ignitor Time Diff = 4.5 (66%)	4.5	66	%		
Ignitor Time Diff = 10 (33%)	10	33	%	Ignitor Time Diff > 10	
Ignitor failure > 0 (0%)	0	0	%	Ignitor 1 OR Ignitor 2 failure timespan > 0	
Ignitor Time Diff	0.777				
Ignitor 1 failure timespan	0				
Ignitor 2 failure timespan	0				
Health Score (%)	94.13				

- Health score logic written in Excel and coded in Python
- Indicators and raw HS imported back into model for validation

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Health Score Development Process

	Ideation	Design	Implementation	Validation	Deployment
Key Participants	Station Monitoring	Station Monitoring	PI Data Science Team	PI & Monitoring Data Science Team	PI & Monitoring Data Science Team
Key Actions	**Identify, prioritise & select Failure Modes to be developed** **Identify the requirements for the failure mode**	**Create bespoke model in Seeq** **Validate model** **Define and write HS calculation formula logic**	**Establish connection from the failure mode model to PI** **Create Transformer Function & Unit Test**	**Validate new failure mode health score in PI Vision & Seeq**	**Deploy health score to the VBM cockpit**
Key Deliverables	Target Failure Modes 1	Health Score Logic 2	Centralised Data Final Health Score 3	Functioning Test Environment 4	Functioning PROD Environment 5

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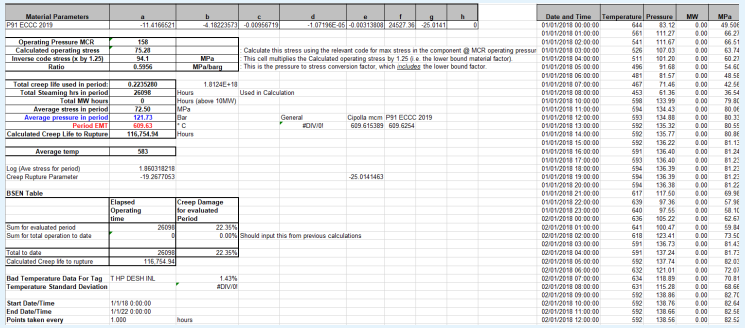
Value Add Examples

High Pressure Pipework Creep Analysis

BEFORE



Material Parameters	a	b	c	d	e	f	g	h
P91 ECCC 2019	-11.4166521	-4.18223573	-0.00956719	-1.07196E-05	-0.00313808	24527.36	-25.0141	0

Operating Pressure MCR	158	
Calculated operating stress	75.28	
Inverse code stress (x by 1.25)	94.1	MPa
Ratio	0.5956	MPa/barg

Calculate this stress using the relevant code for max stress in the component @ MCR operating pressur
This cell multiplies the Calculated operating stress by 1.25 (i.e. the lower bound material factor).
This is the pressure to stress conversion factor, which includes the lower bound factor.

Total creep life used in period	0.2235280	1.8124E+18
Total Steaming hrs in period	26098	Hours
Total MW hours	0	Hours (above 10MW)
Average stress in period	72.50	MPa
Average pressure in period	121.73	Bar
Period EMT	609.63	° C
Calculated Creep Life to Rupture	116,754.94	Hours

Used in Calculation

Average temp	583

		General	Cipolla mcm	P91 ECCC 2019
		#DIV/0!	609.615389	609.6254

Log (Ave stress for period)	1.860318218
Creep Rupture Parameter	-19.2677053

-25.0141463

BSEN Table

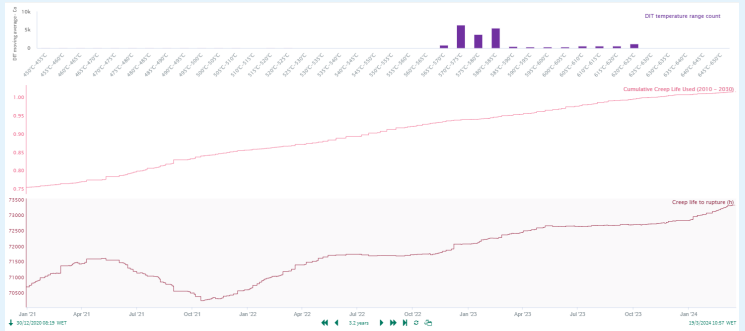
	Elapsed Operating time	Creep Damage for evaluated Period
Sum for evaluated period	26098	22.35%
Sum for total operation to date	0	0.00%
Total to date	26098	22.35%
Calculated Creep life to rupture	116,754.94	

Should input this from previous calculations

Bad Temperature Data For Tag	T HP DESH INL	1.43%
Temperature Standard Deviation		#DIV/0!

Start Date/Time	1/1/18 0:00:00
End Date/Time	1/1/22 0:00:00
Points taken every	1.000 hours

Date and Time	Temperature	Pressure	MW	MPa
01/01/2018 00:00:00	644	83.12	0.00	49.59
01/01/2018 01:00:00	561	111.27	0.00	66.23
01/01/2018 02:00:00	541	111.67	0.00	66.51
01/01/2018 03:00:00	526	107.03	0.00	63.74
01/01/2018 04:00:00	511	101.20	0.00	60.27
01/01/2018 05:00:00	496	91.68	0.00	54.60
01/01/2018 06:00:00	481	81.57	0.00	48.58
01/01/2018 07:00:00	467	71.46	0.00	42.56
01/01/2018 08:00:00	453	61.35	0.00	36.54
01/01/2018 10:00:00	586	133.99	0.00	79.80
01/01/2018 11:00:00	594	134.43	0.00	80.06
01/01/2018 12:00:00	593	134.88	0.00	80.33
01/01/2018 13:00:00	592	135.32	0.00	80.55
01/01/2018 14:00:00	592	135.77	0.00	80.86
01/01/2018 15:00:00	592	136.22	0.00	81.13
01/01/2018 16:00:00	591	136.40	0.00	81.24
01/01/2018 17:00:00	593	136.40	0.00	81.23
01/01/2018 18:00:00	594	136.39	0.00	81.23
01/01/2018 19:00:00	594	136.39	0.00	81.23
01/01/2018 20:00:00	594	136.38	0.00	81.22
01/01/2018 21:00:00	617	117.50	0.00	69.96
01/01/2018 22:00:00	639	97.36	0.00	57.96
01/01/2018 23:00:00	640	97.55	0.00	58.10
02/01/2018 00:00:00	636	105.22	0.00	62.67
02/01/2018 01:00:00	641	100.47	0.00	59.84
02/01/2018 02:00:00	618	123.41	0.00	73.50
02/01/2018 03:00:00	591	136.73	0.00	81.43
02/01/2018 04:00:00	591	137.24	0.00	81.73
02/01/2018 05:00:00	592	137.74	0.00	82.03
02/01/2018 06:00:00	632	121.01	0.00	72.07
02/01/2018 07:00:00	634	118.89	0.00	70.81
02/01/2018 08:00:00	631	115.28	0.00	68.66
02/01/2018 09:00:00	592	138.86	0.00	82.70
02/01/2018 10:00:00	592	138.76	0.00	82.64
02/01/2018 11:00:00	592	138.66	0.00	82.58
02/01/2018 12:00:00	592	138.56	0.00	82.52



Creep Life Consumed	Unit 1
Outlet Manifold	0.6801
Outlet Header	0.6348

AFTER

- Import years of operational data into Excel
- Analysis done on a yearly basis
- Poor operation (or issues) cannot be identified in real time or prevented

- Creep life consumed and time to rupture data in real-time
- Dashboard to enable comparisons
- Allows integration into VBM to identify and resolve issues

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Gas Turbine Air Inlet Filters

CHALLENGE

- Water ingress into compressor due to filter fouling costing **£millions** in consequential damage
- When best to replace filters? Cost vs benefit analysis

SOLUTION

- Calculate condensed water mass flow and trend
- Identify mechanical integrity limit (MIL) for DP
- Allows value-based maintenance approach

RESULTS

- Dashboard showing trend of the current filter total DP
- Predicted overhaul date where the MIL will be reached
- Prevent unnecessary early replacements (vs conventional)

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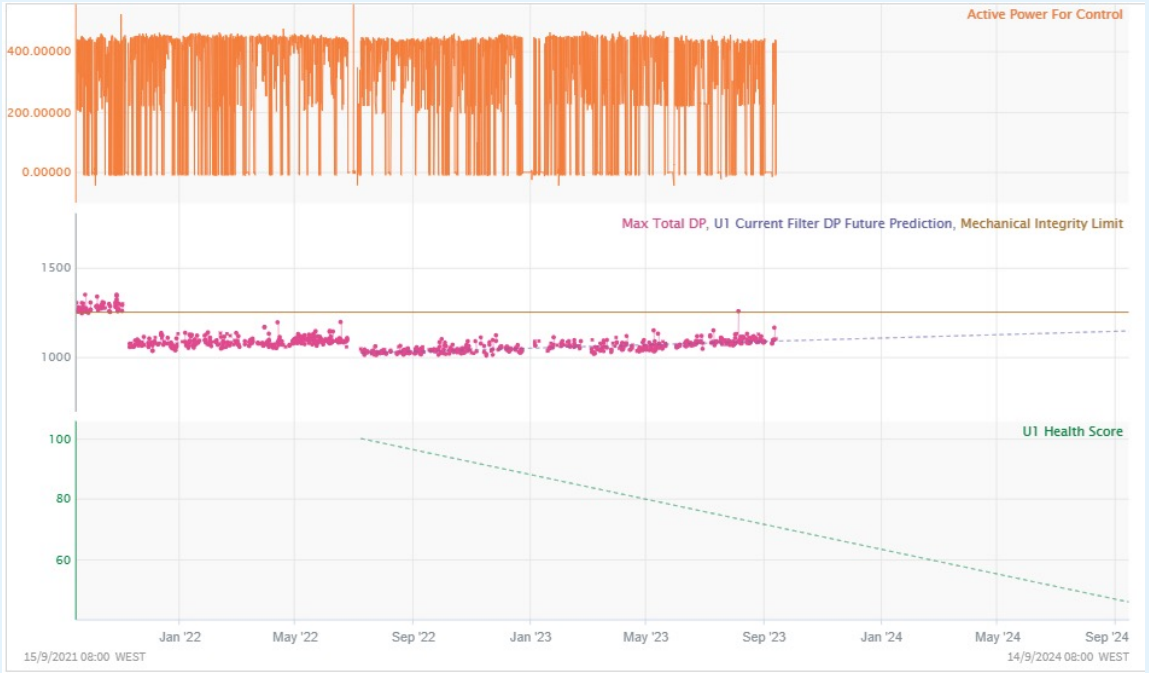
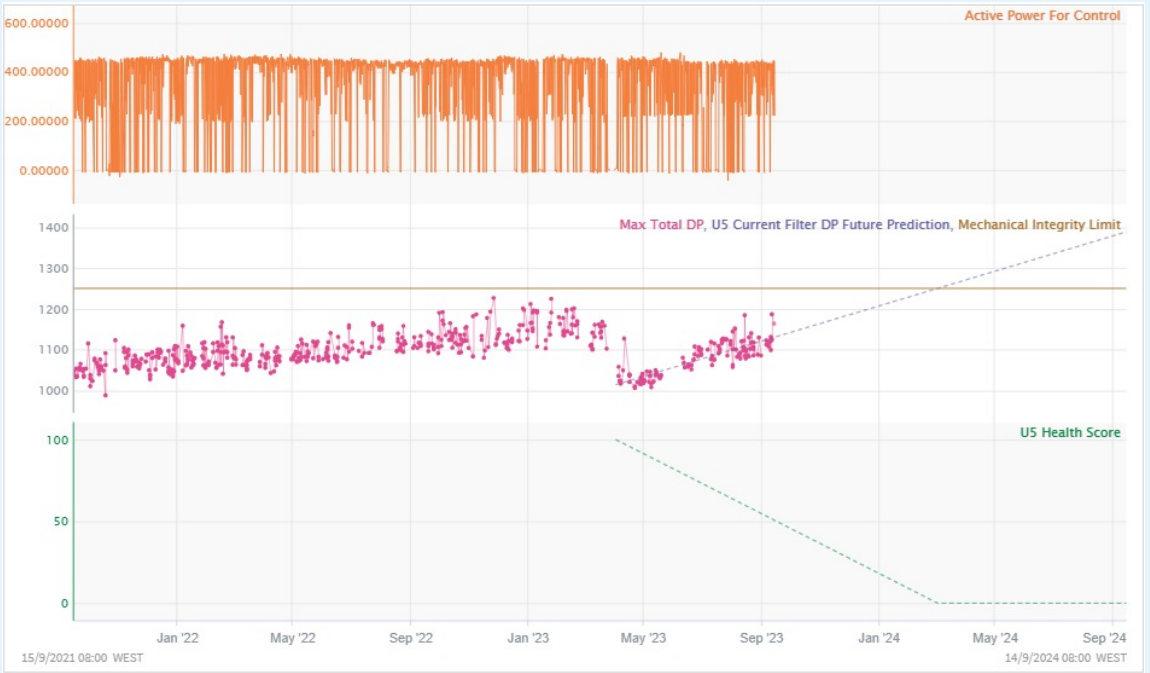
Gas Turbine Air Inlet Filters

Predicted Overhaul Date (Mechanical Integrity)					
U11 Max DP (Mechanical Integrity)	21/07/2026 16:18	U21 Max DP (Mechanical Integrity)	22/06/2025 07:35	U31 Max DP (Mechanical Integrity)	22/06/2024 18:05
U41 Max DP (Mechanical Integrity)	03/03/2024 00:11	U51 Max DP (Mechanical Integrity)	01/03/2024 21:00		





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Stop Ratio Valve (SRV) wear and failure

CHALLENGE

- SRV controls fuel gas entering the GT
- Significant valve wear can render the machine inoperable due to gas leakage

SOLUTION

- Monitor leakage through the SRV during runup, startup and rundown leakage tests
- Allows station to plan replacement before failure

RESULTS

- Each breakdown results in a production loss of **~£1.3m**
- Since model created in 2021, it has prevented 2 further reactive breakdown failures

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Stop Ratio Valve (SRV) wear and failure

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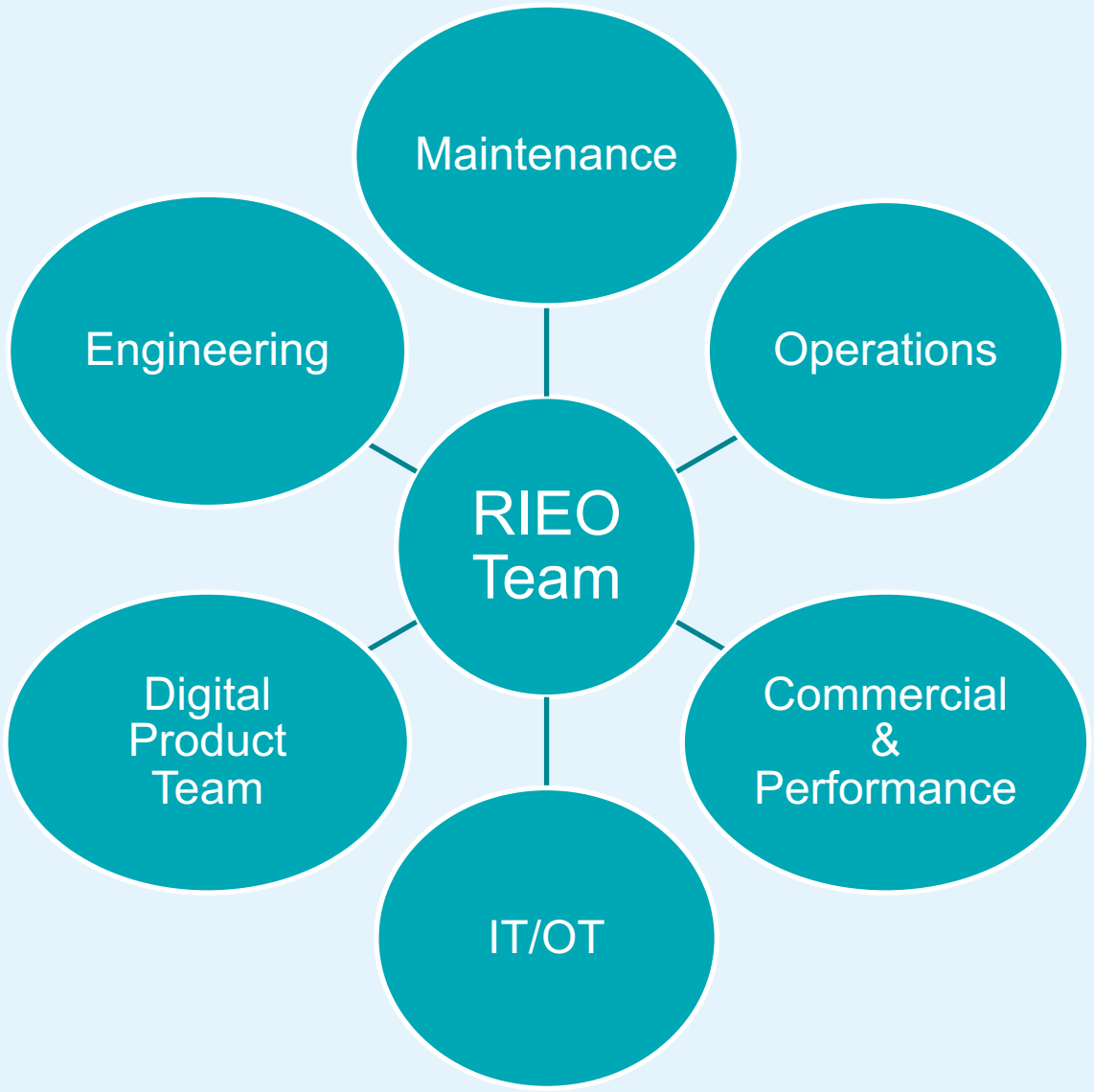
Organisation & Next Steps

Reliability, Integrity & Efficiency Optimisation Team

77
Average Weekly Users

7 Awareness Sessions delivered

73
Users undergone online training



157
support cases raised

3 Fundamental & 3 Advanced trainings delivered

39
Datasource Connections

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Any Questions?