



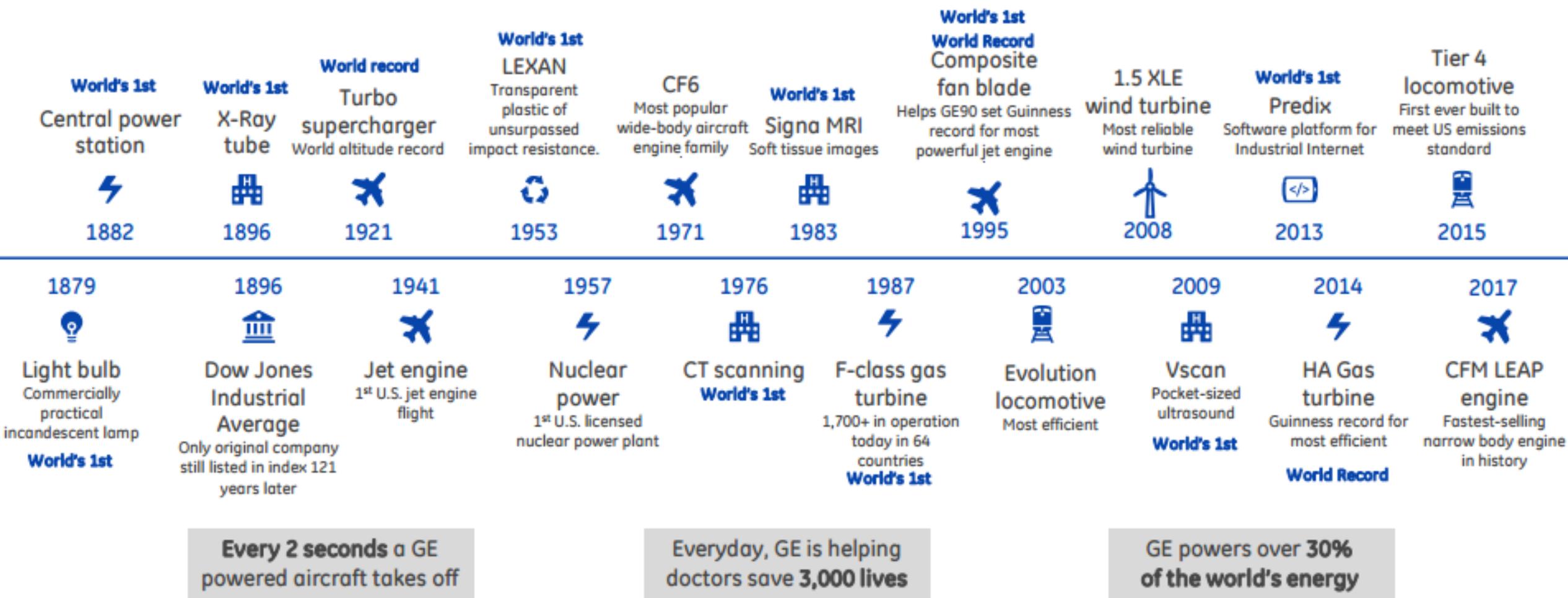
Digital Technology supporting Nuclear Operation & Maintenance

Erin Joy, Director Digital Nuclear Services GEH

January 2018



125 years of innovation – making the world work better



GE has remade itself multiple times



A Digital Industrial Company

\$123.7B in Revenue, 295,000+ people operating in 180 countries

2016 REVENUES



POWER

\$26.8B

**57K
EMPLOYEES**



AVIATION

\$26.3B

**45K
EMPLOYEES**



**RENEWABLE
ENERGY**

\$9.0B

**12K
EMPLOYEES**



OIL & GAS

\$12.9B

**34K
EMPLOYEES**



HEALTHCARE

\$18.3B

**54K
EMPLOYEES**



TRANSPORTATION

\$4.7B

**10K
EMPLOYEES**



**ENERGY CONNECTIONS
& LIGHTING**

\$15.1B

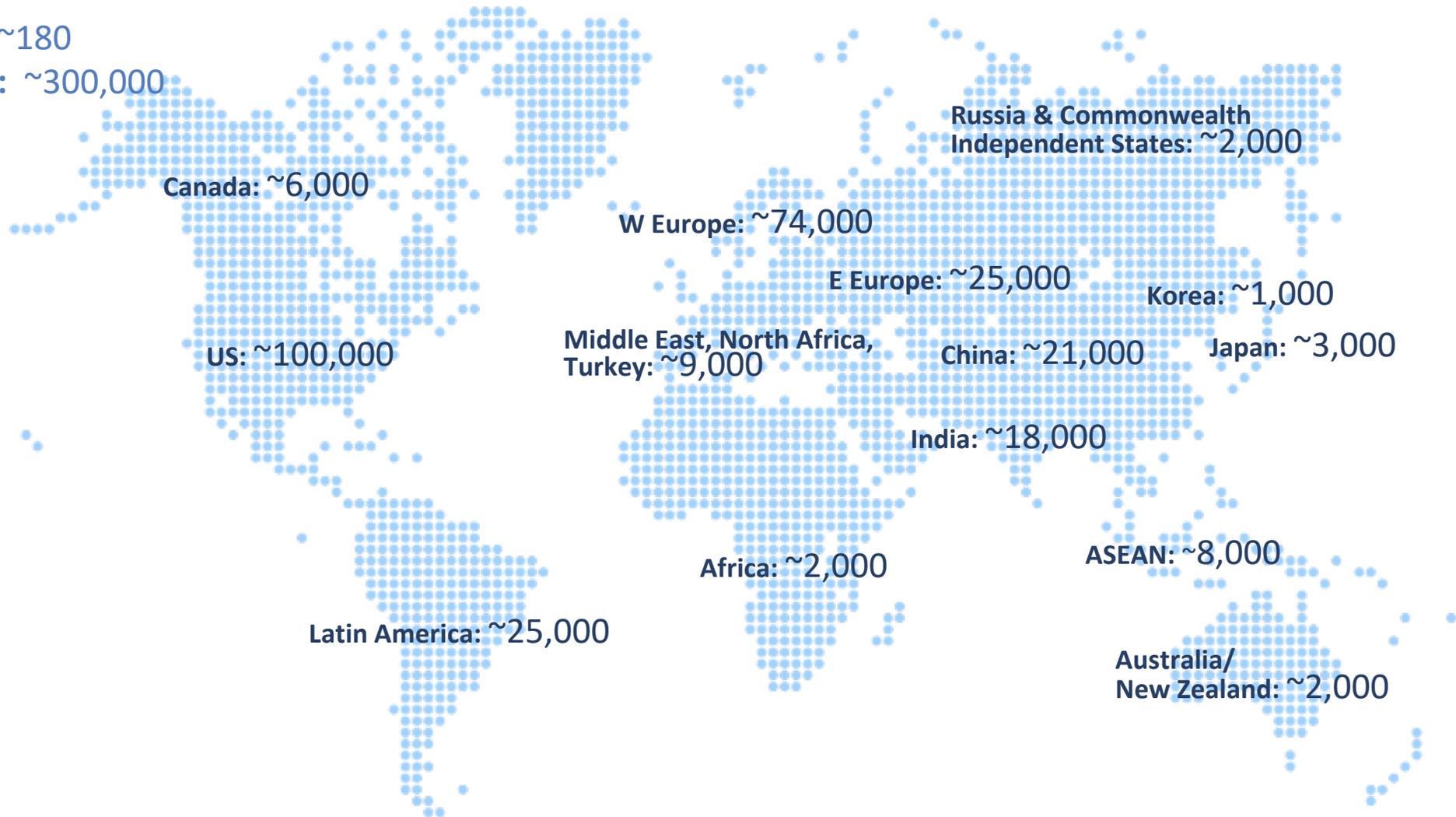
**53K
EMPLOYEES**



Where GE operates

Countries: ~180

Employees: ~300,000

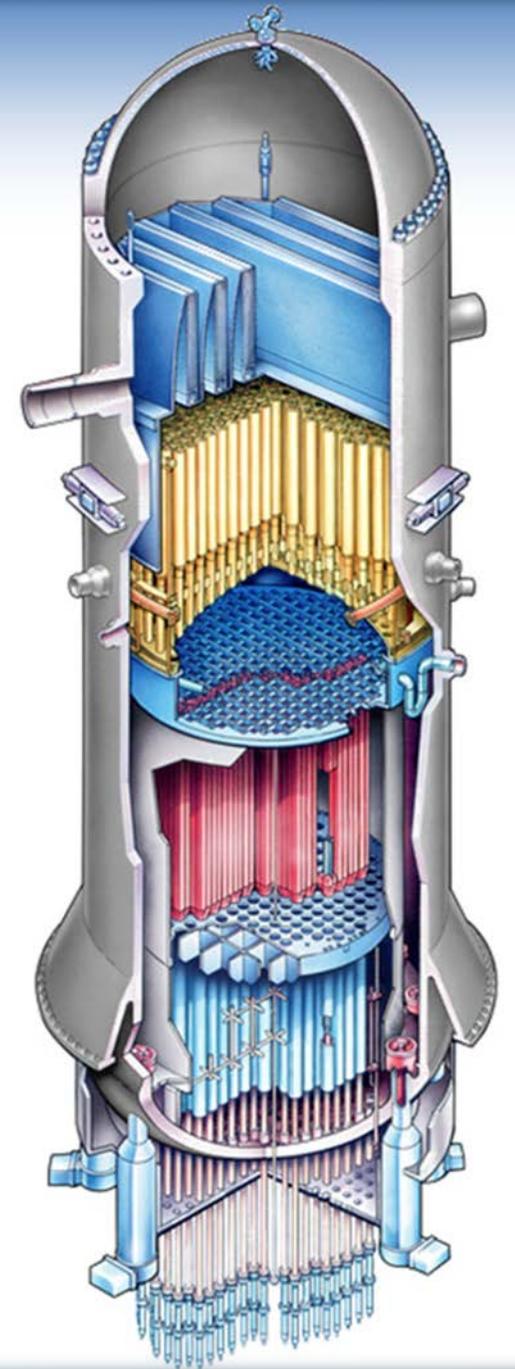


Nuclear – Digital Focus Areas

- ❖ Condition based maintenance – driven by predictive analytics
- ❖ Predicting performance trends to prevent declines
- ❖ Optimization of operational metrics across fleets
- ❖ Outage work scope management & scenario planning
- ❖ Data driven resource planning for training & in-processing
- ❖ Coordinated resources & tooling with analytics
- ❖ Decommissioning planning

Delivering the Nuclear Promise

“The U.S. nuclear energy industry is launching a multiyear initiative to enable its nuclear power plants to generate electricity more efficiently, economically and safely.” <http://www.nei.org/>

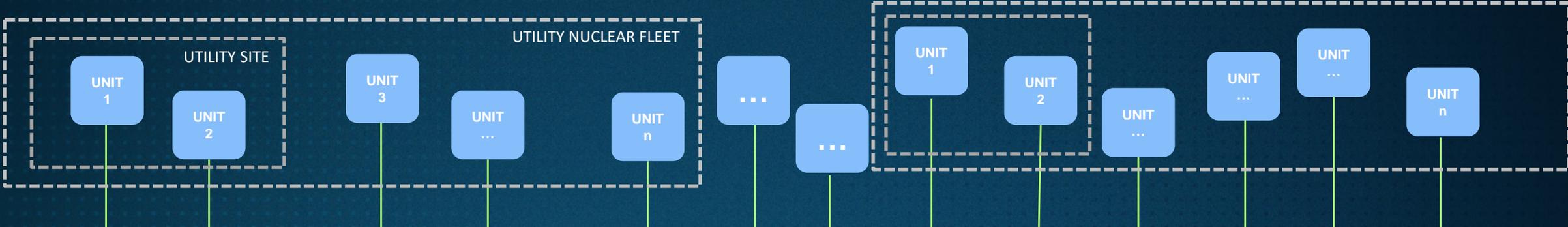




Enabling this Digital Transformation ...

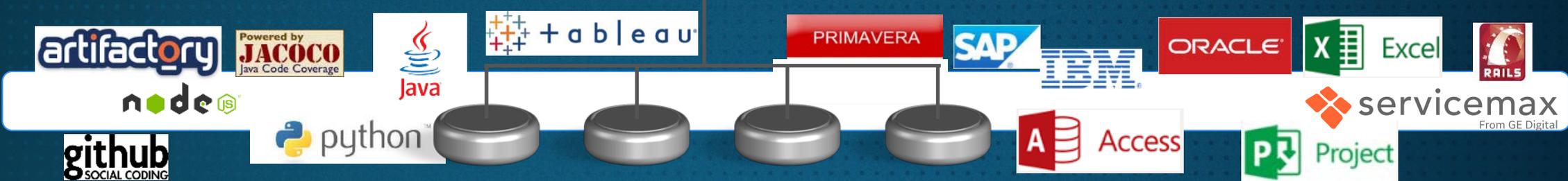
Data Aggregation ...
... nominalized
... No Loss of IP

- Protected
- Secure

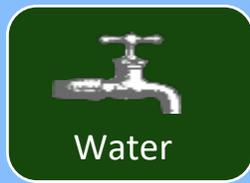


ANALYTICS
Asset Performance Management • Operations Optimization • Purpose-built 3rd party solutions

PREDIX
Open platform - enables ... Innovative Analytics • Analytics Marketplace • Industrial Data Sharing



... Simplified integration with existing IT & operational systems ...



Business Optimization

Portfolio/Fleet



Operations Optimization

*Plant/Facility/
Train*



Asset Performance

Asset



Unique or Niche Solutions & Applications

Predix Platform



Faster development,
operation and management



Industrial scale
analytics



Machine-centric



Secure
connectivity

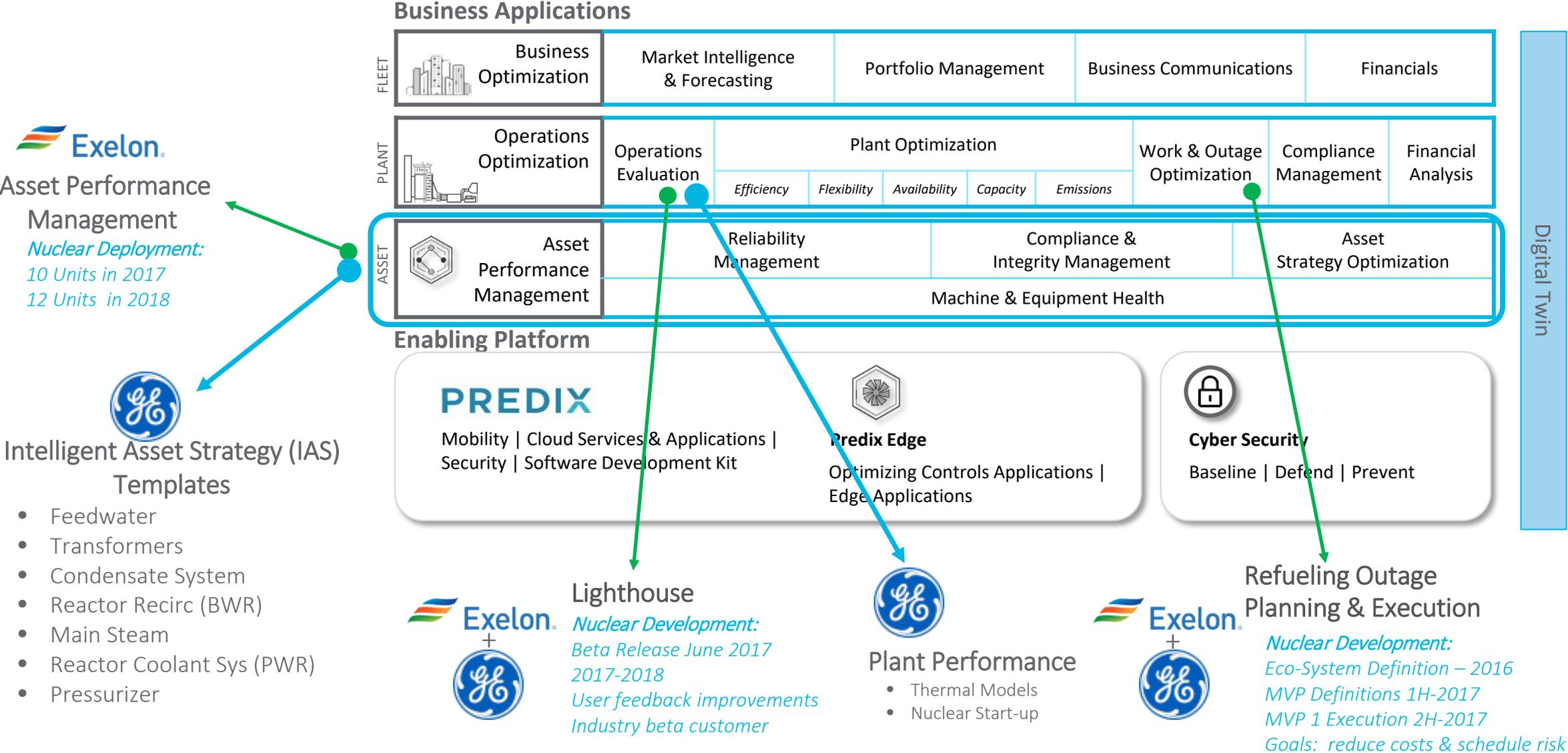


Modular,
cloud-agnostic approach



Industrial Performance Solutions

GE Power Digital Solution Map – Nuclear Specific Tools



PREDIX

Asset Performance Management (APM)



Asset Management View

Departments

- Operations
- Engineering
- Maintenance
- Inspection
- Reliability
- EH&S
- Management
- Finance

Systems

- Health, APR, Historian, Rounds/Logs
- SmartSignal, Design Tools, RCM
- EAM - Maximo, Metrics, Reports
- NDE: Vibration/Oil/Thermography
- KPIS, What-if, Statistical, FMEA
- PHA, MOC, Incident Mgmt, RCA
- Reports, Lean, KPI's, Budget, Excel
- Oracle/SAP, Excel

Asset / Equipment ID

Connected by Assets



Policies
(Operational Risk)

Execution
(Compliance/Tracking)

(Intelligent) Asset Strategies

Site Recommendations/Tasks

Reliability Management

- Predictive Analytics
- RCA
- Statistical Analysis

Asset Strategy Opt

- RCM-FMEA
- Strategy Library
- LCC Analysis

Machine & Equip Health:

- Rounds * E-Logs *
- KPI's-Dashboard * Benchmarking
- Integration to EAM & Key Data Sources
- Criticality, Dashboards, Metrics
- Single View of Asset Data

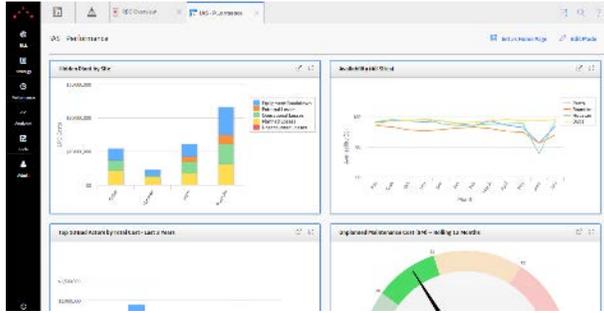
PREDIX



GE APM provides a closed loop process to improve asset performance

Asset Performance Management

1. Visualize



Integration:

- SAP/Maximo/Passport, Operator Rounds, Thermography, Vibration, Documentation, Pictures, Oil analysis, GADS

2. Prioritize

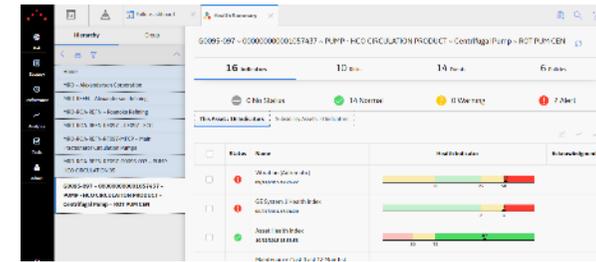
		Consequence				
		Very Low	Low	Medium	High	Very High
Probability	Frequent 5	5	50	500	2,500	5,000
	Probable 1	1	10	100	500	1,000
	Possible 0.5	0.3	3	30	150	300
	Remote 0.1	0.1	1	10	50	100
	Improbable 0.05	0.05	0.5	5	25	50

Mitigated Risk Unmitigated Risk

Equipment Criticality:

- Define Site/Fleet approach
- Establish Asset Criticality... AP 913
- Set Asset Risk
- Visualize unmitigated risk

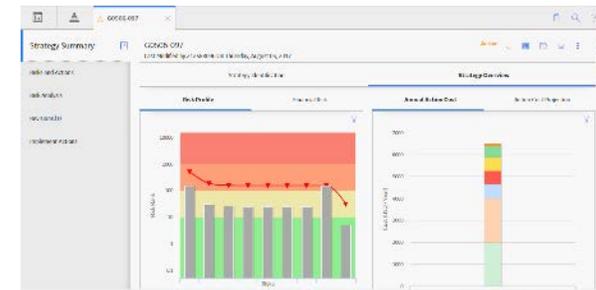
3. Monitor Health



Equipment Health:

- View costs, counts, criticality
- Develop policies
- Send notifications
- Visualized risk based tuning

4. Optimize



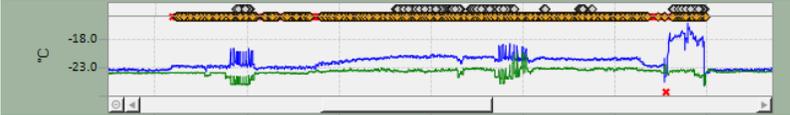
Equipment Strategy:

- What-if Risk & Cost analysis
- Failure mode mitigation
- Site to Site strategy sharing
- A living strategy

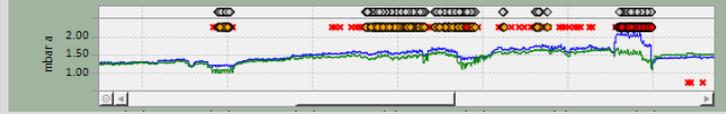


GE Analytics & Advisory Example – The Value of a Strategy

Site Action = Late June



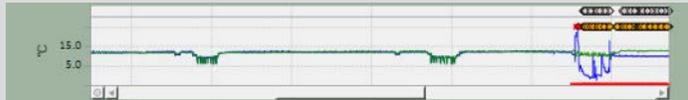
March: Adv Pattern
Anomaly #1



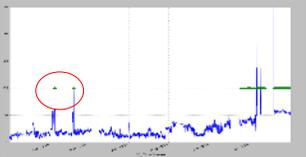
May: Adv Pattern
Anomaly #2



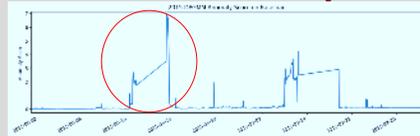
June: Adv Pattern
Anomaly #5



June: Adv Pattern
Anomaly #6



May: Neural Net Alert
Anomaly #4



May: Machine Learning
Anomaly #3

Customer Action Data:

- ✓ Work Order for June Site Action recovered
- ⊗ Work Order detail limited compared to System Engineer interview
- ⊗ Research to find additional Work Orders prior to July ... 2 weeks of effort, none found
- ⊗ Triggering data, not captured
- ⊗ Unable to ID if & when a similar failure occurred at >5 other units ... but they know it has happened
- ⊗ Est Value of reaction to the Failure ~ \$135,000

Method	~ Early Warning
Advanced Pattern	1-6 Weeks
Machine Learning	2-3 Weeks
Neural Networks	2-3 Weeks

Case Management

Knowledge Capture

- Documented History
- Compare Similar Cases
- Analyze the Data
- Connect to Work Orders
- Attach Evidence & Mark-ups

The screenshot displays the GE Case Management interface. On the left is a navigation sidebar with icons for Health, Reliability, Strategy, Integrity, Tools, and Admin. The main area is divided into a list of alerts and a detailed view of a selected alert.

Alert List:

Alert ID	Alert Title	Time Received	Status
4	Overheating PC0005A-097 Alexanderson Refining	10:21	Ready
5	Sensor Dropouts GC0023-097 Alexanderson Refining	10:20	Ready
3	Local Bearing Problem... E0014B-097 Alexanderson Refining	10:19	Ready
4	Control Issue GC0023-097 Alexanderson Refining	10:18	Ready
4	OG_PUMP_S.Pump S... G0001-097 Alexanderson Refining	May 26	In Process
3	OG_PUMP_S.Pump S... G0084-097 Alexanderson Refining	May 26	In Process

Alert Details (Selected):

3 (1680) Pump System Analytics... 26 May 2017 16:16:19 PDT
 G0084-097
 Alexanderson Refining | NA
 000000000001057428

Disposition: None Create Case Timeline View

ALERT INFORMATION

Alert ID	Event Time	Alert Source	Owner
13002	26 May 2017 16:12:13 PDT	SmartSignal	servicemax admin

Density: 48.88

ANALYSIS

[Default Analysis View](#)

SCAN GROUP DATA

Parameter	Value	Parameter	Value
PWIP_PMCRESS_HIC027509B.OP	59.846	PWIPA_FLOWCTRL_FIC027506.OP	67.661
PWIPA_VI02DEX	3.024	PWIP_PMCRESS_HIC27509BA.OP	59.834
PUMP_EFFICIENCY_CV	72.108	PUMP_SPECIFIC_SPEED_CV	376.769

NOTES

4.3.0.0.0 (7642) apmrc.apm.aws-usw02-pr.predix.io 8fe907b3-11d6-429b-b9b0-7467ac47906b servicemax-admin



Case Management

The screenshot displays the GE APM Case Management interface. At the top, there's a browser tab for 'Analysis'. The main header shows the case ID 'G0084-097' and a time range from 08/24/2016 04:40:00 PM PDT to 09/07/2016 04:40:00 PM PDT. Below this, the case title is 'OG_PUMP_S.Pump System Analytics - Pump Performance Loss Pump Performance'. A table lists details: Owner (servicemax admin), Make (-), Asset Type (Equipment), and Analysis Type (Template). A 'SMART SIGNAL' alert is highlighted with a blue arrow pointing to the text 'Identifies Which Analytic/Model Triggered the Alert'. Below the alert, a list of models is shown: '1. PUMP_SPECIFIC_SPEED_CV ()' with sub-points: 'GE SmartSignal – Advanced Pattern Recognition Models', 'Machine Learning – Unsupervised & Mixture Models', and 'Neural Networks – Autoencoders & tuned parameter Models'. A note states: '.... Leverage an extensive catalogue of models and methods'. A line chart at the bottom compares 'Actual' (blue line) and 'Estimate' (green line) values over time from 08/25/16 to 08/31/16. The y-axis is labeled '%' and ranges from 330 to 400. A red horizontal bar is positioned above the chart.

APM Case Management

- Knowledge Capture
- Dig deep into the data
- Attach evidence
- Collaborate across teams
- Record actions
- Trigger work orders
- See past work orders
- See similar cases

SMART SIGNAL ← Identifies Which Analytic/Model Triggered the Alert

1. PUMP_SPECIFIC_SPEED_CV ()

- GE SmartSignal – Advanced Pattern Recognition Models
- Machine Learning – Unsupervised & Mixture Models
- Neural Networks – Autoencoders & tuned parameter Models
- Leverage an extensive catalogue of models and methods

Actual Estimate

400
390
380
370
360
350
340
330

08/25/16 08/26/16 08/26/16 08/27/16 08/27/16 08/28/16 08/28/16 08/29/16 08/29/16 08/30/16 08/30/16 08/31/16 08/31/16

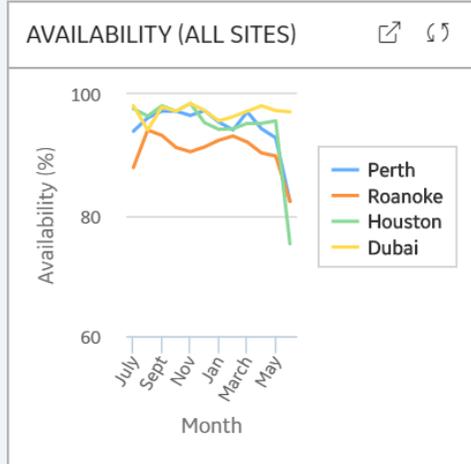
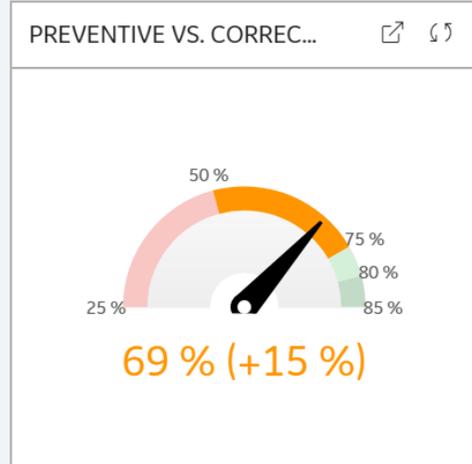
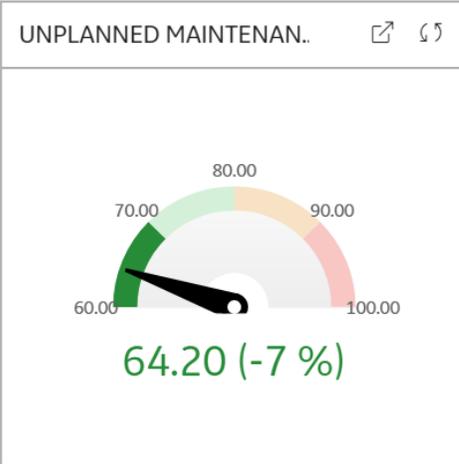
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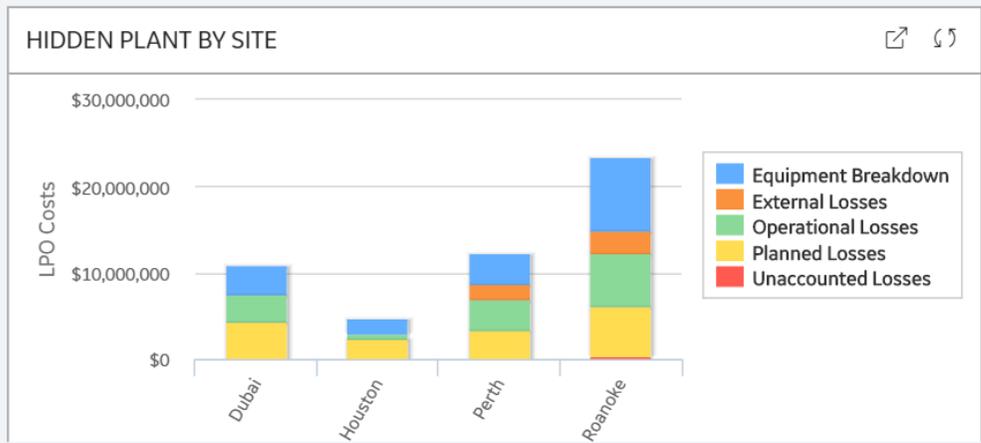
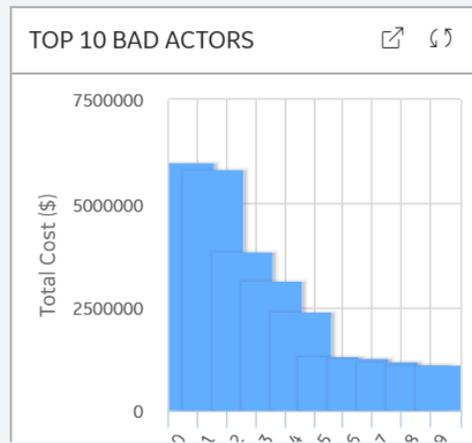
M+M Europe Dashboard

Set as Home Page Edit Mode



MITIGATED RISK HEAT MA..

Frequent	0	160	160	144	0
Possible	0	180	780	270	42
Probable	240	720	1200	972	0
Remote	120	240	360	108	84
Improbable	240	0	0	0	0



GE Logo | ACA Overview | Asset C...analysis | G0084-097

Strategy Details | Asset Strategy | G0084-097 | Criticality: ▲ | 04 Action Changes | Modified | Not Assigned

Risks and Actions | Risk Analysis | Revisions | Implement Actions

Strategy Identification

Risk Profile | Risk Rank (Selected) | Financial Risk

Legend: Active (Dark Blue), Unmitigated (Red with exclamation mark)

Failure Mode Risk / Impact (points to the top red section of the bars)

Amount of risk currently mitigated (points to the green section of the bars)

Asset Failure Modes (points to the x-axis labels 'Risks')

Strategy Overview

Cost Projection

Legend: Active (Dark Blue)

Annual cost of the current Maintenance Strategy (points to the bars)

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GE Logo | G0084-097 | Strategy Details | Asset Strategy | Risks and Actions | Risk Analysis | Revisions | Implement Actions | Failure Mode

G0084-097 | Asset: G0084-097 ~ 000000000001057428 ~ PUMP - RAW... | Criticality: ▲ | 04 Action Changes | Modified | Not Assigned

Risks (11)	Mitigating Actions (4)
<input type="checkbox"/> (LOA) Lubricant Degradation Strategy Mitigated Risk Ra...: 25.1 Strategy Mitigated Finan...: 12500 Source: ASM	<input type="checkbox"/> Change Lubricant Interval: 6 Interval Units: Months Cost: 300.00 Source: ASM
<input type="checkbox"/> (RND) Casing Leak Strategy Mitigated Risk Rank: 53 Strategy Mitigated Financ...: 6250 Source: ASM	<input type="checkbox"/> Digital Twin Predictive Anal... Interval: 1 Interval Units: Days Cost: Source: ASM
<input type="checkbox"/> Cavitation Strategy Mitigated Risk R...: 25.55 Strategy Mitigated Financ...: 6250 Source: ASM	<input type="checkbox"/> Lube Oil Analysis Interval: 1 Interval Units: Years Cost: 100.00 Source: ASM
<input type="checkbox"/> Impeller Wear Strategy Mitigated Risk Ra...: 25.1 Strategy Mitigated Finan...: 12500 Source: ASM	<input type="checkbox"/> Overhaul Interval: 3 Interval Units: Years

Mitigation Actions

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GE Logo | G0084-097 | Criticality: ▲ | 04 Action Changes | Modified | Not Assigned

Asset: G0084-097 ~ 000000000001057428 ~ PUMP - R...

Asset Strategy

What-If

- Turn On/Off an action
- Change a frequency
- Adjust costs

Actions (12) [Apply]

Change Lubricant
Interval: 6
Interval Units: **Months**
Cost: **300.00**
Source: **ASM**

Check Lubrication
Interval: 1
Interval Units: **Weeks**
Cost: **10.00**
Source: **ASM**

Digital Twin Predictive Analytic - Journal Bearin...
Interval: 1
Interval Units: **Days**
Cost:
Source: **ASM**

Digital Twin Predictive Analytic - Oil Cooler Ano...
Interval: 1
Interval Units: **Days**
Cost:

Risk Profile | Risk Rank | Financial Risk

Legend: Active (Dark Blue), Proposed (Light Blue), Unmitigated (Red !)

Risk Rank (Log Scale): 10000, 1000, 100, 10, 1, 0.1

Cost Projection | USD

Legend: Active (Dark Blue), Proposed (Light Blue)

USD: 40000, 20000, 0

See the Cost & Risk impact of your changes

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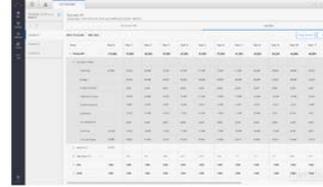
Intelligent Asset Strategy – Digital Twin for Transformers



- Failure Modes Templated – 11
- Anomaly Analytics – 17
- Failure Mode Effects defined – 55
- Identified Recommendations – 46
- Asset Health indicators created – 6-15
- Fault Policies defined per transformer – 9+
- Measurement points identified – 38
- KPIs created for this asset class – 4

Digital Twin

Life Cycle Analysis



Criticality & Risk Assessment



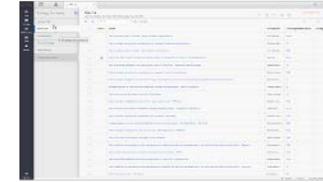
Dynamic Strategies



Enterprise KPIs



Failure Modes and Effects



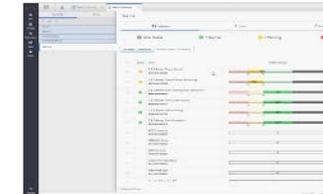
Data Integration

- Data Sources**
 - SCADA/Historian
 - Oil Analysis System
 - Gas Analysis System
 - GE-SmartSignal
 - PdM, Rounds,
 - On-Line Doble
 - EAM System

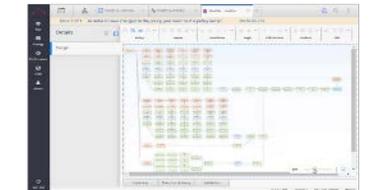
Reliability Analytics



Heath Monitoring



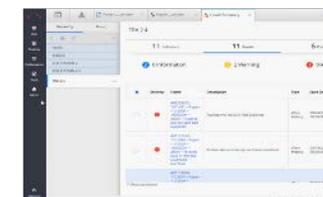
Failure Mode Tracking



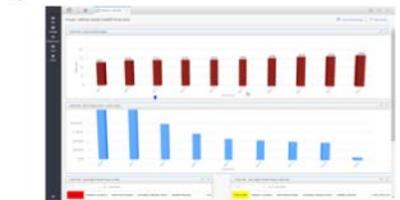
- Anomaly Twin**

 - Predictive Analytics

Failure Mode Status



Dynamic Risk Status



Conclusion

Predix tools for Nuclear enable:

- Knowledge Capture & Transfer
- Easier Access and Analysis of Data
- Shift from Preventive Maintenance to Condition/predictive based Maintenance
- Increased Uptime & Improved Thermal Performance
- Drive increased reliability and performance at the individual asset level.
- Connect assets to people and business processes to drive productivity, efficiency, and availability at the plant level.





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