GEH Digital Solutions for Nuclear Power Plants

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Companies will shape the future of their industries

AVIATION

- Global leader in propulsion and systems
- Most competitive and innovative engine value proposition …
- efficiency, reliability and lifecycle economics
- Youngest and largest commercial fleet … most diversified services portfolio

HEALTHCARE

- At the nexus of most care pathways
- Leading equipment complemented by high margin services
- Diagnostics, interventional imaging, life care, therapy planning and digital

RENEWABLE ENERGY & POWER

- World's most powerful wind turbines and most efficient gas turbines
- Tech to modernize and digitize
- Grid and electrical infrastructure
- Carbon-free power sources, including **nuclear**, hydro and hybrids

GE will be an aviation-focused company[a)]

Tax-free spin-off … in early '23

Integrating Renewable Energy, Power and Digital; tax-free spin-off … in early '24

BUILDING A WORLD THAT WORKS … SOLVING THE BIGGEST CHALLENGES IN FUTURE OF FLIGHT, PRECISION HEALTH, ENERGY TRANSITION

(a – Includes any remaining stakes in AerCap and Baker Hughes and, upon close, expected 19.9% of go-forward Healthcare, as well as other assets and liabilities of GE today, including run-off Insurance operations

GE Hitachi Nuclear Energy

HITACHI

ADVANCED NUCLEAR | FUELS | FIELD SERVICES | PLANT SOLUTIONS

+ GE Digital
+ GE Research

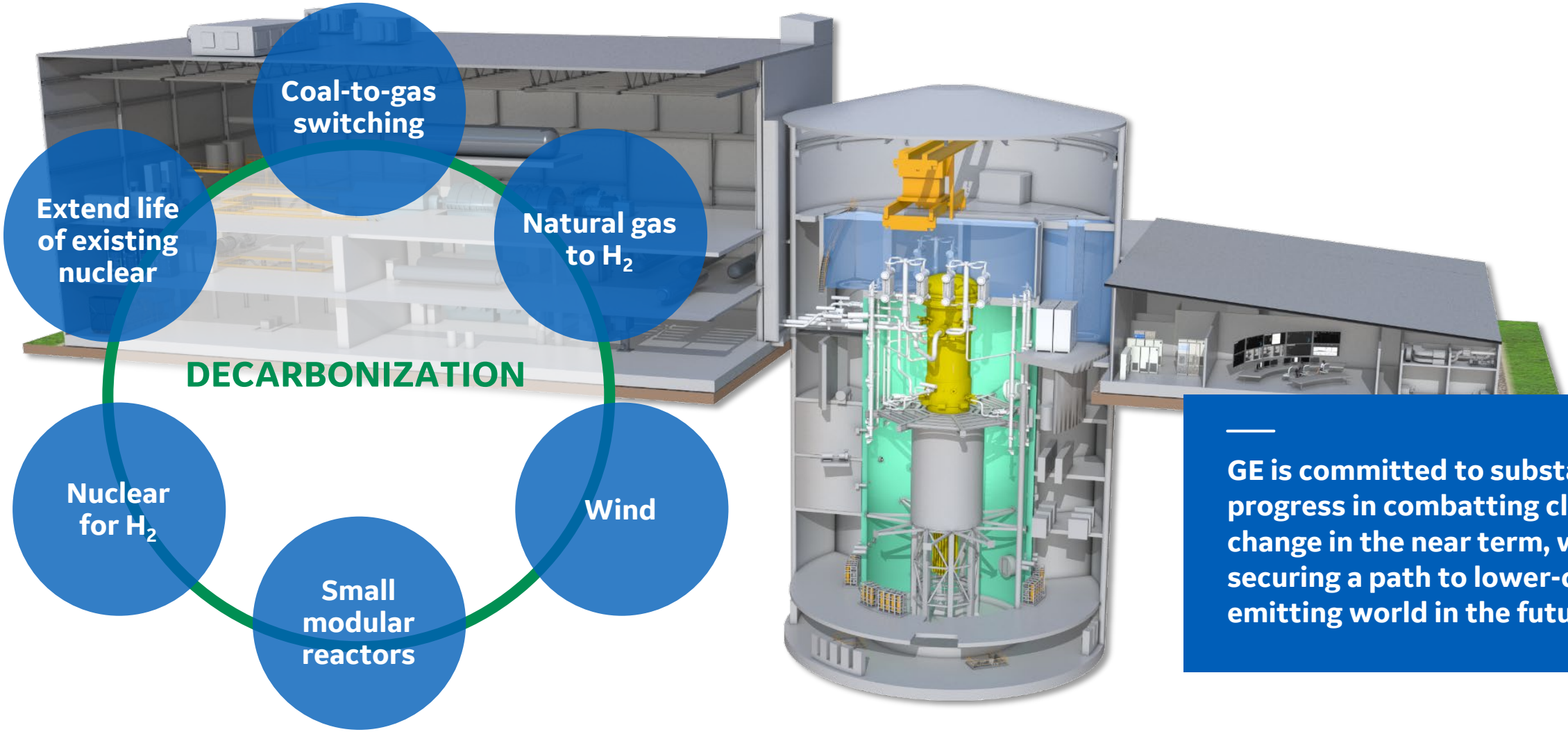
Compute | Algorithms | Fleet Data | Domain Expertise

Necessary but not sufficient ...

Essential to deliver value

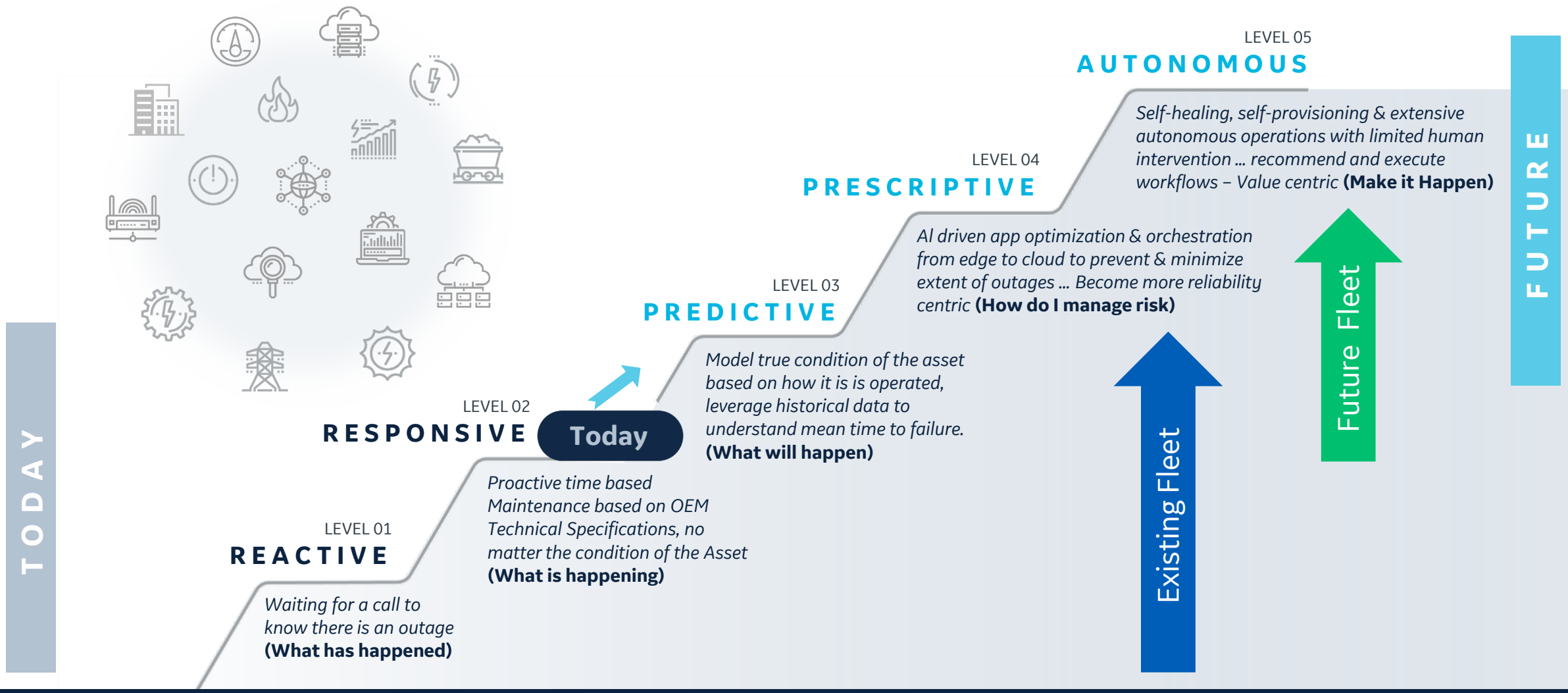
WE BUILD ON OUR LEGACY, BOLDLY INNOVATING TO PROVIDE RELIABLE CARBON-FREE POWER TO THE WORLD

Decarbonization is front and center in GE's strategy for energy transition



GE is committed to substantial progress in combatting climate change in the near term, while securing a path to lower-carbon emitting world in the future

The journey to digital transformation



Digital solutions for existing fleet

"As a Nuclear Plant Operator, I must reduce O&M costs from $31/MWhr to $20/MWhr to stay competitive"

– Voice Of Customer

"**My workforce** is aging and retiring."

"**Need M&D** to proactively id risks and reduce costs."

"**Do I have the right sensors** to use APM?"

"How can we learn from our **historical information**?"

"**Compliance and HC** drive most of my costs."

"**My data is "no good"** – I don't trust that I have the right data."

"I know I need **Digital Technology**, but it's complicated and costly."

O&M cost reduction – What GE is doing with existing fleet

Connect relevant data sources

Assess data quality

Automated reporting

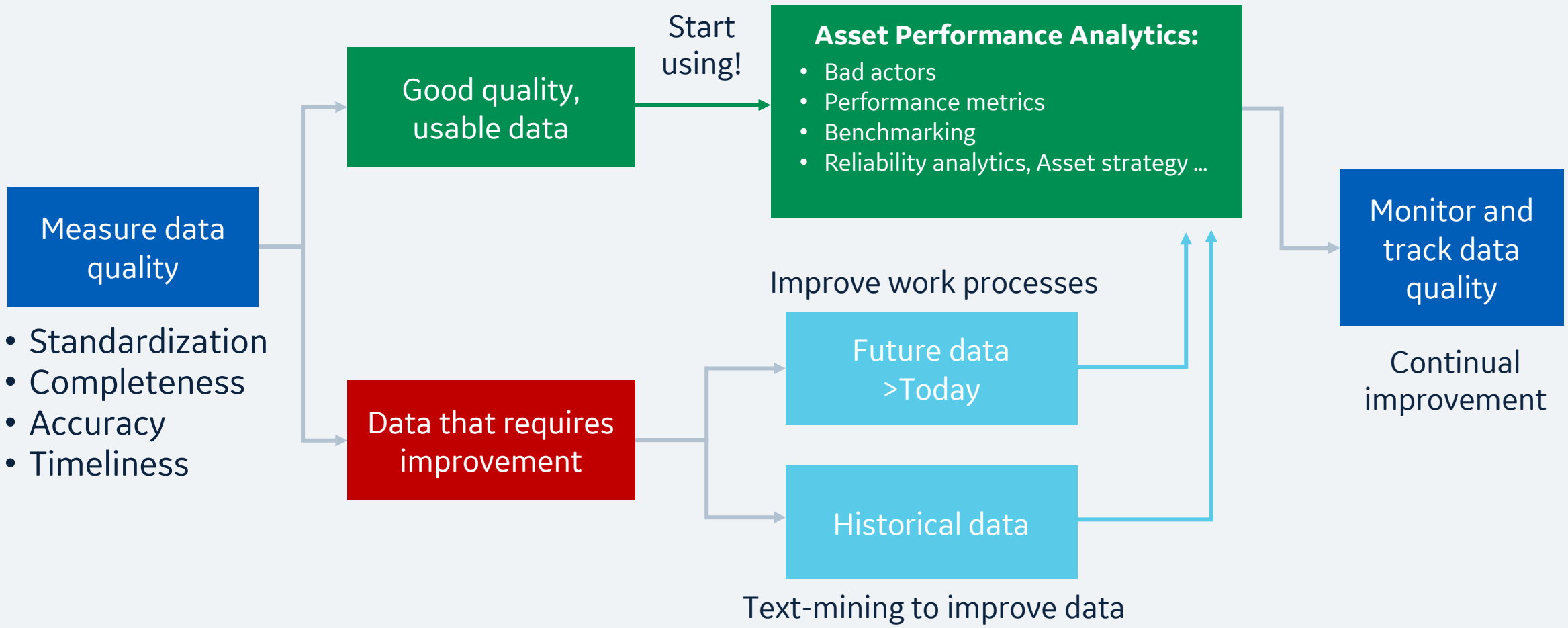
Monitoring and diagnostics

Going from Responsive to Predictive

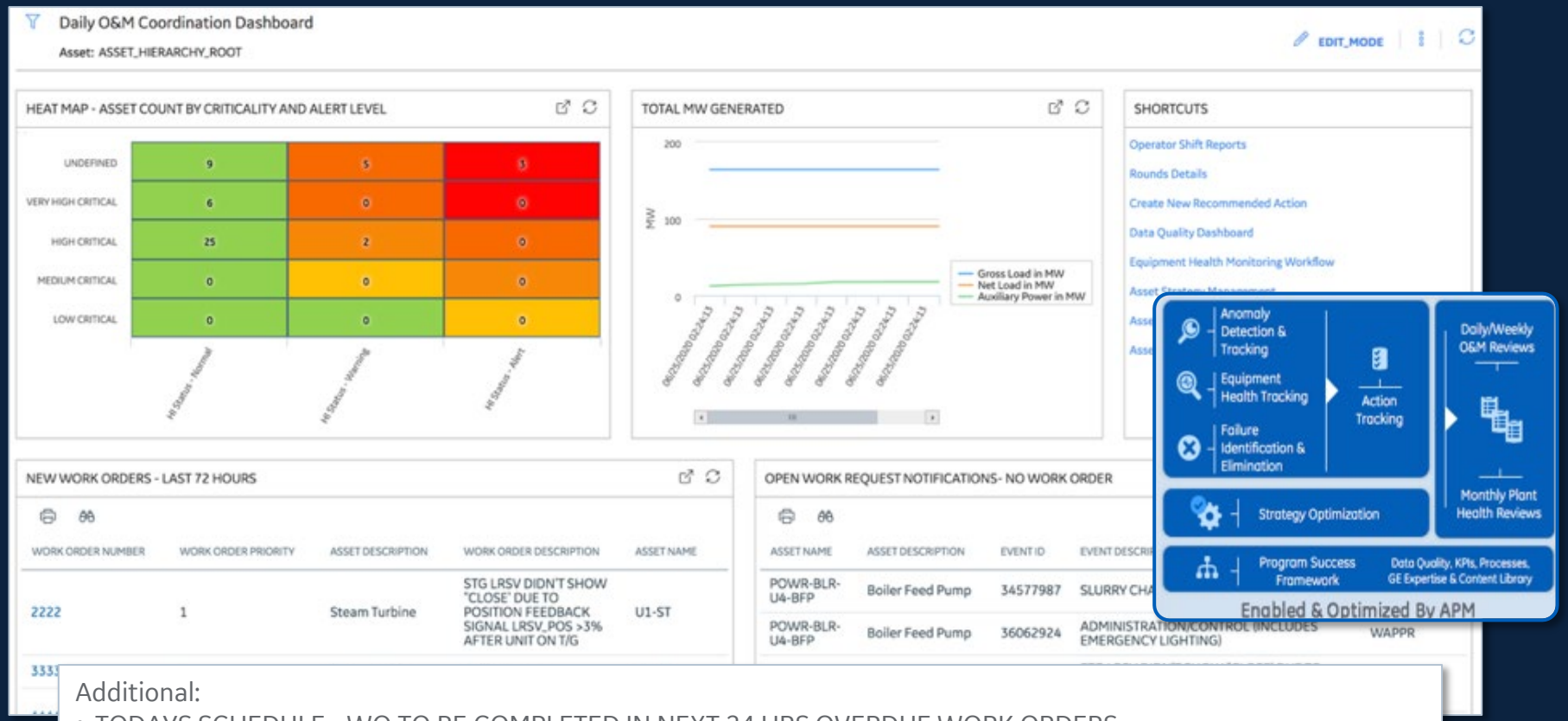
The information, data, or work presented herein was funded in part by the Advanced Research Projects Agency-Energy (ARPA-E), U.S. Department of Energy, under Award Number DE-AR0001290. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Connect relevant data sources

Assess data quality



Automated reporting daily O&M review



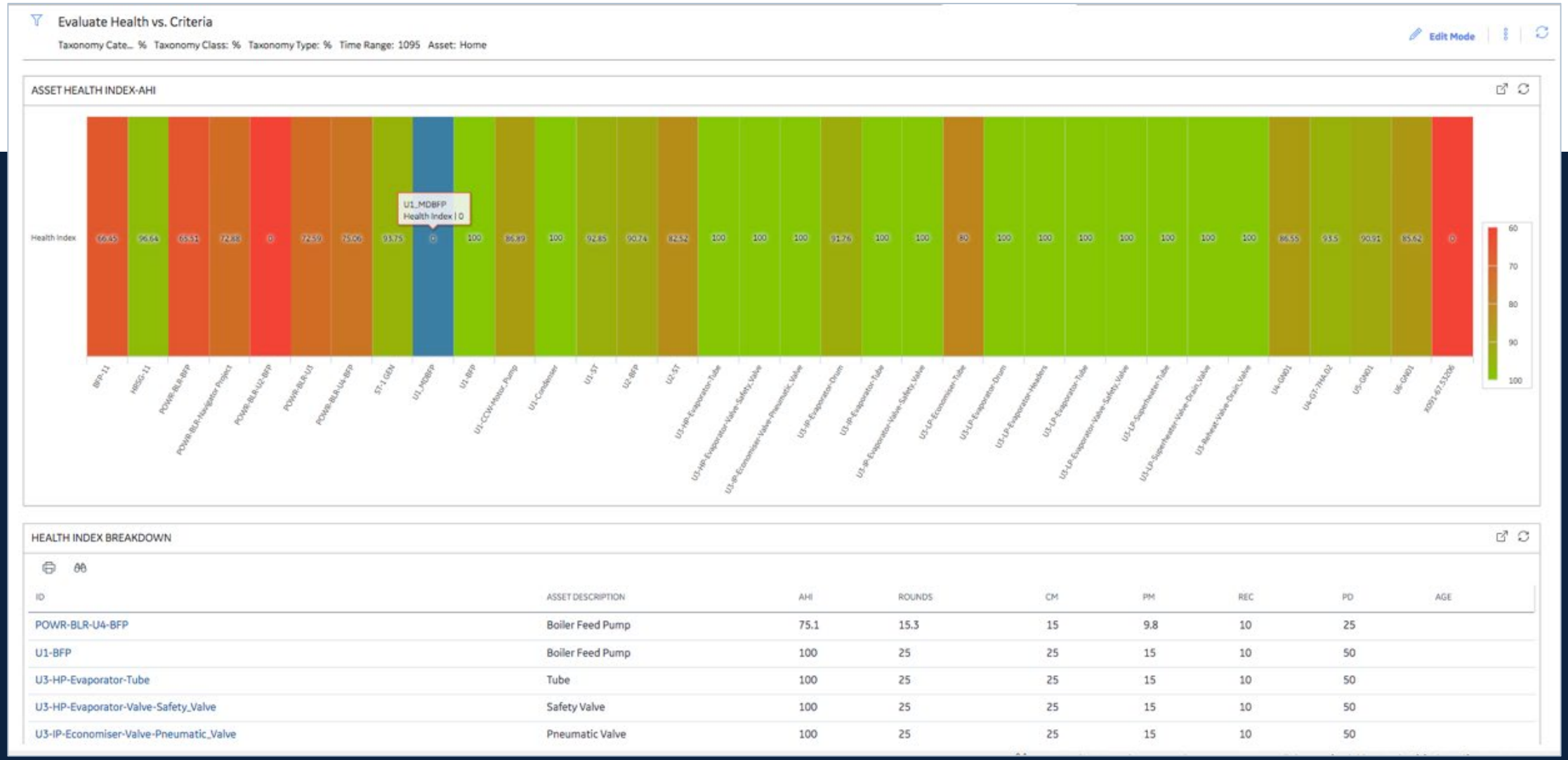
Additional:
- TODAYS SCHEDULE - WO TO BE COMPLETED IN NEXT 24 HRS OVERDUE WORK ORDERS
- WEEKLY SCHEDULE - WO TO BE COMPLETED IN NEXT 7 DAYS
- ROUNDS DEVIATION
- HEALTH INDICATOR RELATED STATUS CHANGE LIST - LAST 72 HRS ANALYTICS DRIVEN ALERT LIST - (LAST 72 HRS)

Key summary dashboards and drilldowns

- Asset Health Heat Map by criticality
- Analytics last 72 hours
- Rounds deviations
- Work Orders by priority and time
- Key shift events
- Overdue actions
- Key operational KPIs

A unified dashboard of O&M status and activities to review and plan daily priorities

Equipment health monitoring workflow (End state)

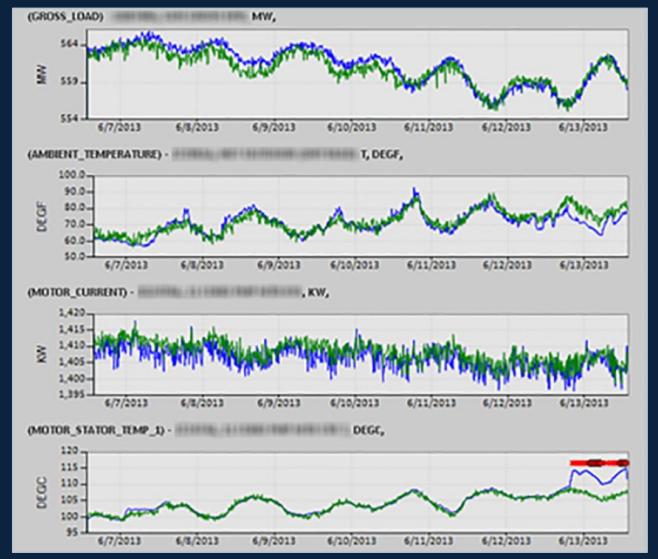


ID	ASSET DESCRIPTION	AHI	ROUNDS	CM	PM	REC	PD	AGE
POWR-BLR-U4-BFP	Boiler Feed Pump	75.1	15.3	15	9.8	10	25	
U1-BFP	Boiler Feed Pump	100	25	25	15	10	50	
U3-HP-Evaporator-Tube	Tube	100	25	25	15	10	50	
U3-HP-Evaporator-Valve-Safety_Valve	Safety Valve	100	25	25	15	10	50	
U3-IP-Economiser-Valve-Pneumatic_Valve	Pneumatic Valve	100	25	25	15	10	50	

Example of existing analytics (GE blueprint)

Failed cooling fan detected on a condensate pump

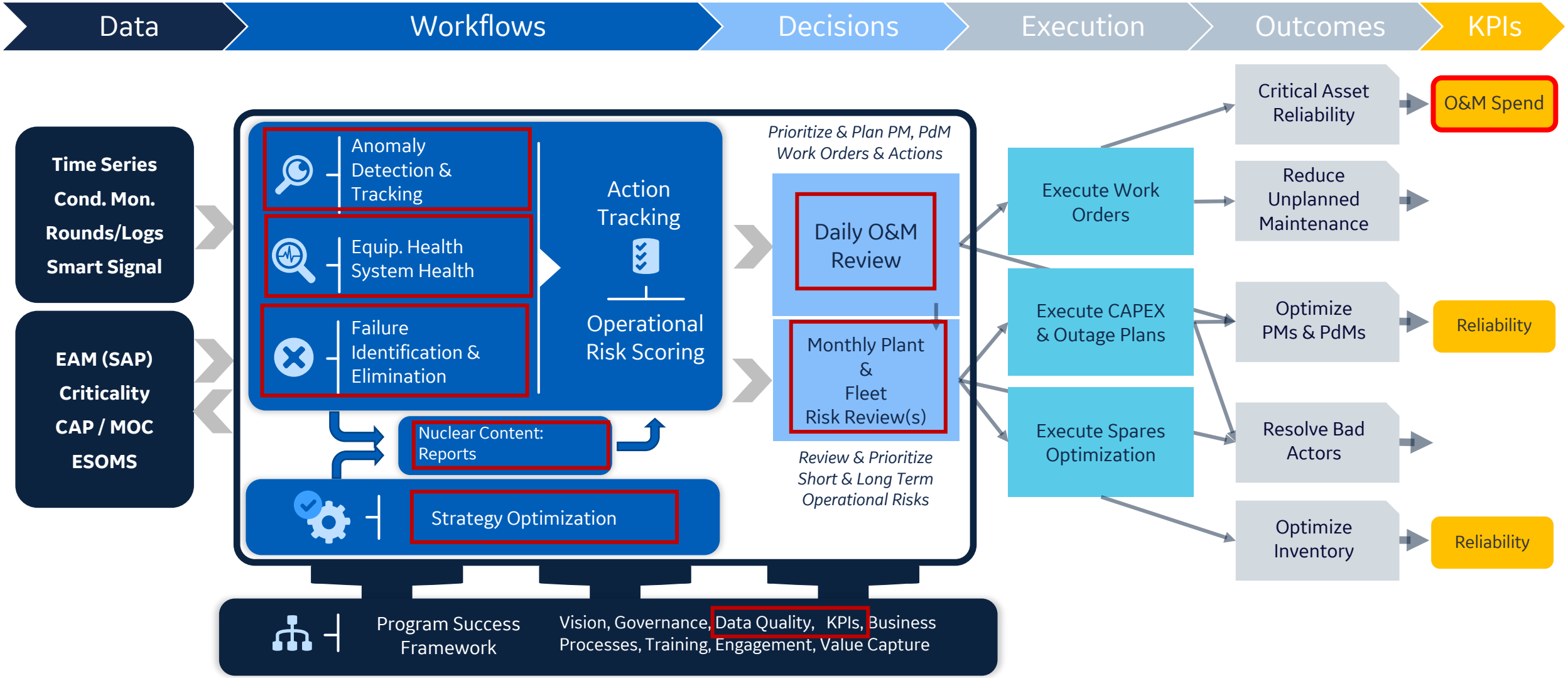
What did our services find?
The stator temperature on a condensate pump motor at a nuclear power plant increased from **222°F to 237°F** (106°C to 114°C) … the plant was not aware of the unusual temperature increase, as it was below the control room's alarm levels.



What was the value to the customer?
The customer engineers were able to address a malfunctioning cooling fan, and they received confirmation that their maintenance action was successful when actual values returned to expected values. If this issue had continued to develop, stator temperatures would have continued to rise, which could have caused a shutdown of the pump.

What was the underlying cause?
Upon investigation, the customer learned that a cooling fan had failed, causing the motor stator temperature to start to rise. The operations team replaced the fan and reset the breaker.

APM operating model (Nuclear)



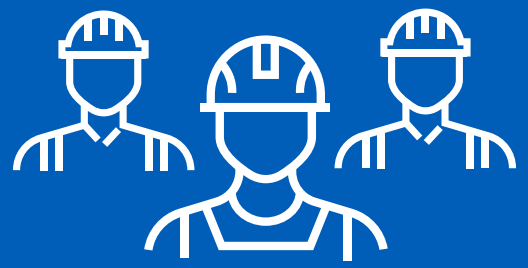
BWRX-300 small modular reactor

- 10th generation Boiling Water Reactor
- Scaled from licensed designs
- Design-to-cost approach
- Significant capital cost reduction
- Capable of integrating with renewables
- Ideal for electricity generation and industrial applications, including hydrogen production
- Constructability integrated into design
- Initiated licensing in the U.S. and Canada
- Operational by 2028

MOST
COMPETITIVE SMR

Digital Solutions for Future Fleet (SMRs)

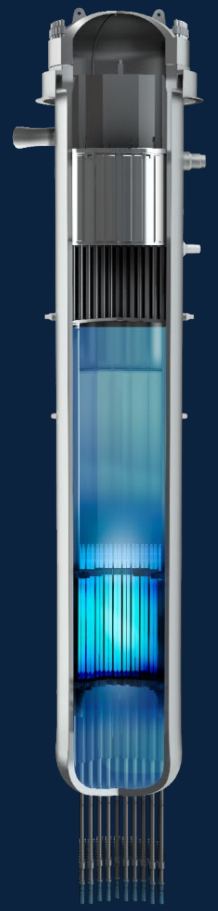
Reducing CAPEX & OPEX in future BWRX-300 Fleet



REDUCED STAFF

DESIGNED TO MITIGATE LOCA

COMPETITIVE LCOE



O&M cost reduction

- **Remote monitoring**
- **Predictive maintenance**
- **Automation**
- **Optimized scheduling and central crews**

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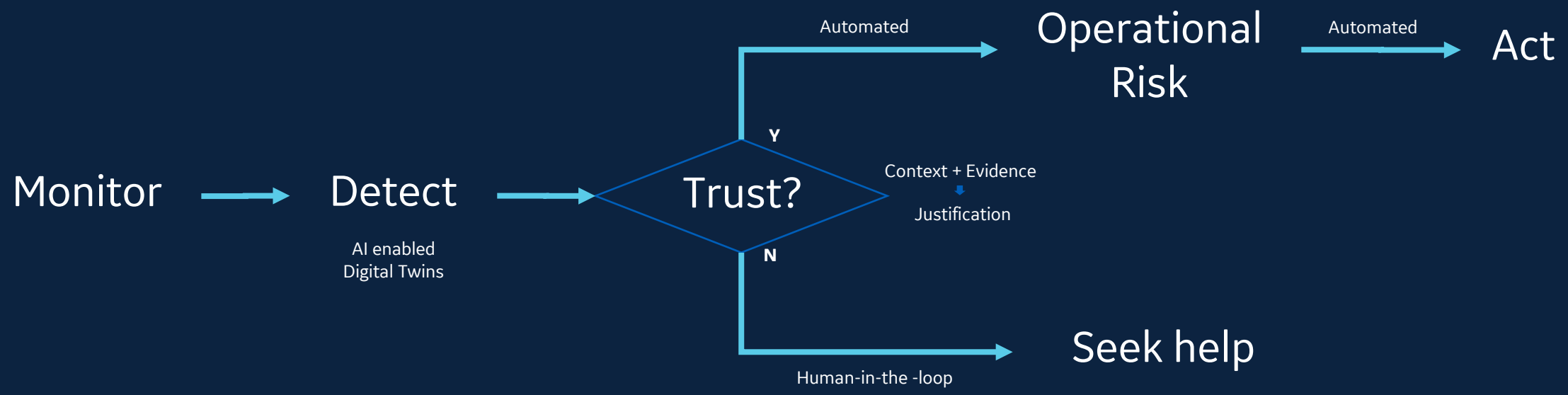
Humble AI

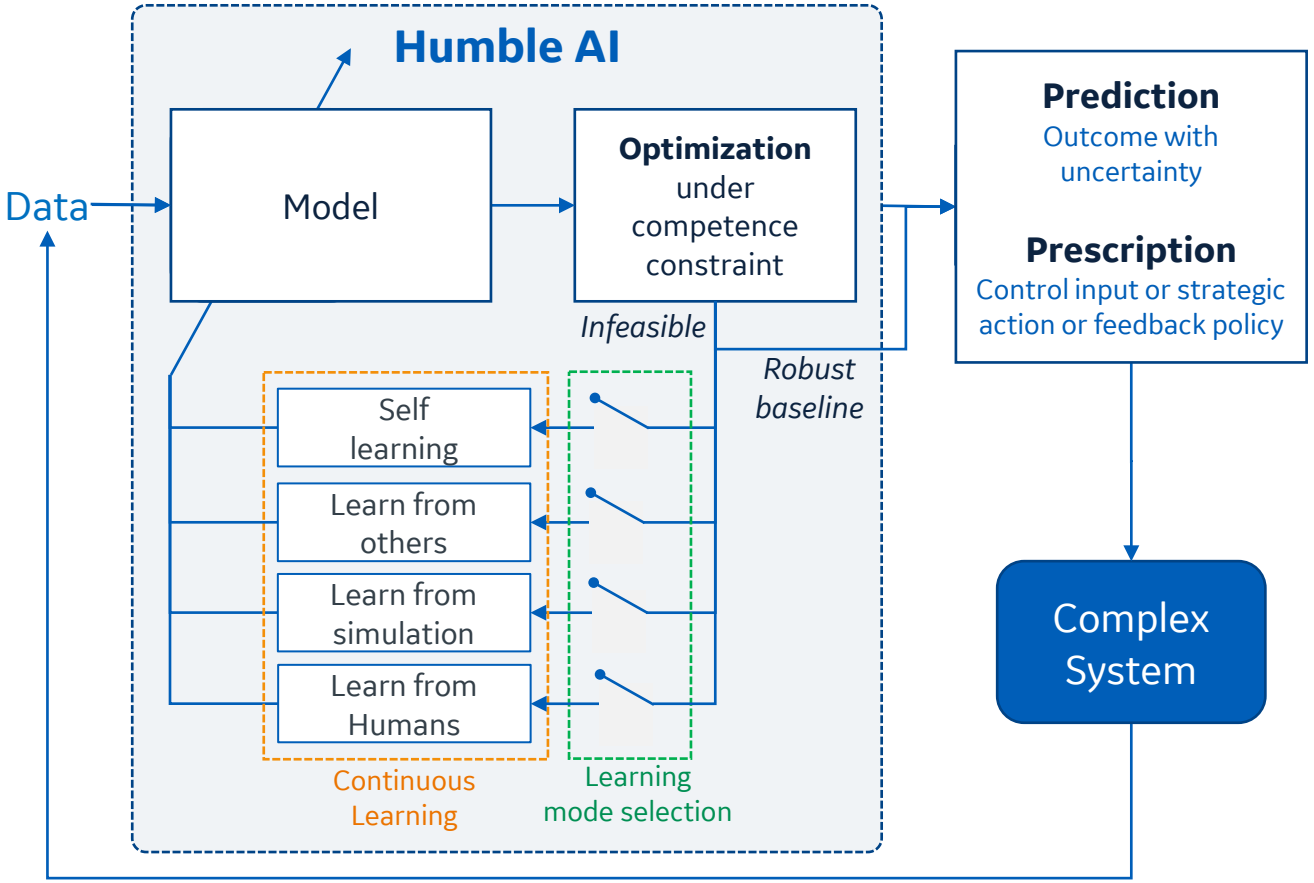
Trust and EXPLAINABILITY
will be key to AI-based decision-making and automation



Humble AI is part of a new lexicon of AI terms emerging, as AI becomes integrated into critical industrial infrastructure where safety, reliability, and performance are paramount

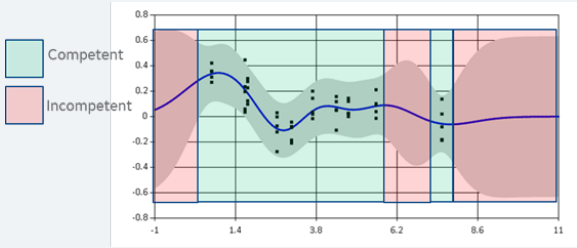
AI for Digital Twin

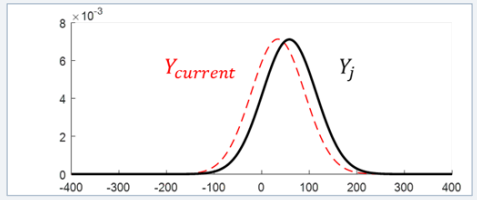
Realizing full value of data-driven analytics by putting information to action



Defining capabilities

- Understand region of trust
- Quantify uncertainty
- Ask for help when incompetent
- Continual learning from multiple sources





Humble AI will **reduce time to value**

Humble AI will **maintain safety**

HUMBLE AI: An AI that is aware of its own competence and improves its competence via learning

AI-enabled Predictive Maintenance Digital Twins

ARPA-e GEMINA

ARPA-e's Mission

- GHG reduction
- Energy independence
- Energy efficiency
- Enhances US Scientific Leadership

We can make carbon free nuclear energy cost-competitive …
We can reduce its cost through AI and automation …
… IF we can mature AI to be trustable for nuclear applications!

Program impact

AI-enabled predictive maintenance for BWRX-300 Advanced Nuclear Reactor **to ↓ O&M labor costs**

Program targets

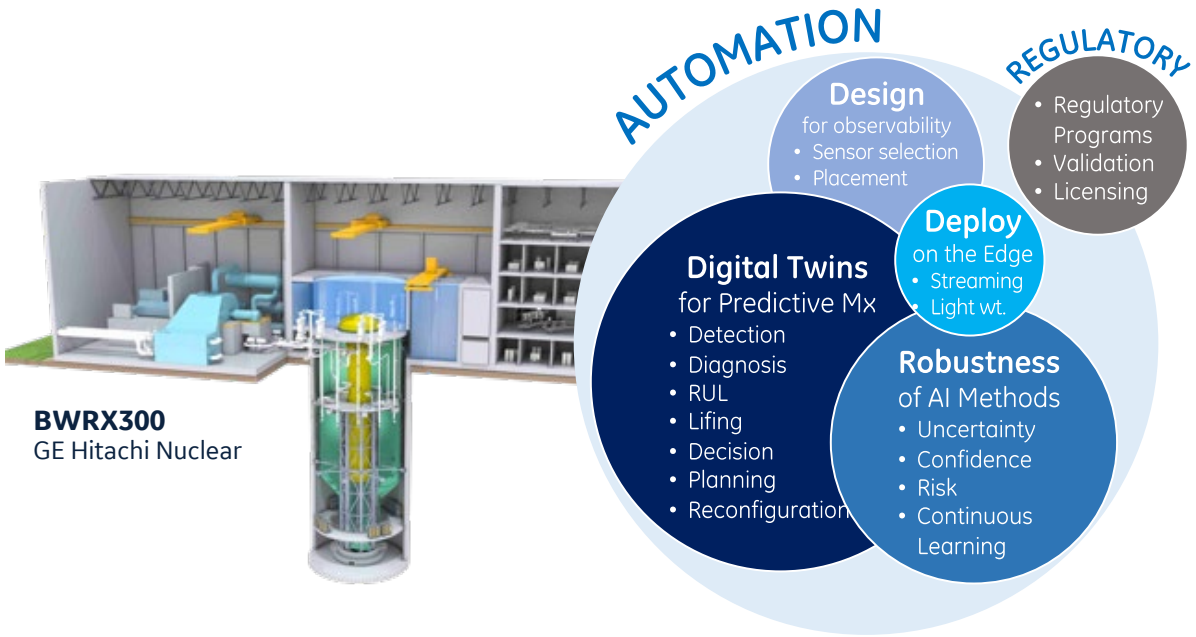
Metric	From	To
Automation ↓ labor costs	*None*	Automated workorders … ↓ Planning staff by 50% (10FTE) Online calibration … ↓ Tech staff 75%, admin 25% (16FTEs)
Predictive Maintenance ↓ labor & mat'l	*Alarms*	↓Forced outages and trips … AI-driven predictive algorithms ↓ Labor headcount 35%
Trust	*Human*	Humble and explainable AI … quantify uncertainty to establish trust in the models and encourage automation

Technology summary

Reactor Operations
Physics-informed machine learning, sensor optimization

Reactor Health
Causal, Humble & Explainable AI for predictive maintenance

Decision Making
Autonomous risk-informed decisions for reconfiguration & maint.



TEAM

THE UNIVERSITY OF TENNESSEE KNOXVILLE

OAK RIDGE National Laboratory

Exelon Generation

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The digital journey

The **existing fleet can leverage its existing data** using GE's Asset Performance Management (APM) software platform.

APM can help identify equipment/system risks to **reduce unplanned maintenance, resolve problem components, and optimize preventative maintenance.**

GE is **developing the predictive and prescriptive models/digital twins for the future fleet using Humble AI** … progress here is expected to benefit existing fleet.

GE continues to evolve its digital technology to help the **existing and future nuclear fleets operate safely and at a reduced O&M cost.**

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