Predicting Failure in Wind Turbines

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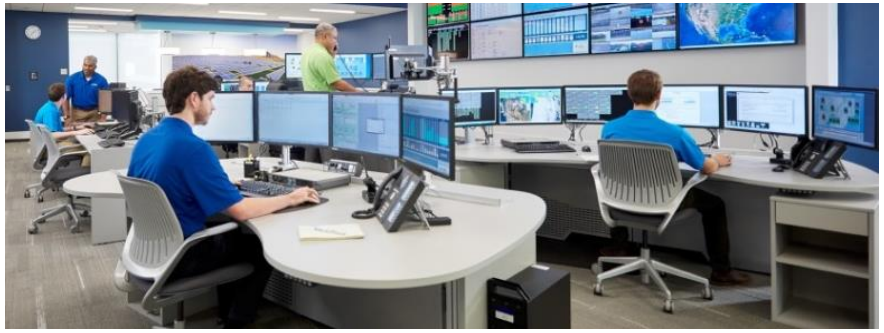
Duke Energy Sustainable Solutions

Commercial Portfolio

DUKE ENERGY®
SUSTAINABLE SOLUTIONS

- Own more than 4.5 GW of wind & solar projects
- Operate & maintain 600+ MW of 3rd party wind and solar projects
- On track to grow Renewables Fleet 3x by 2030



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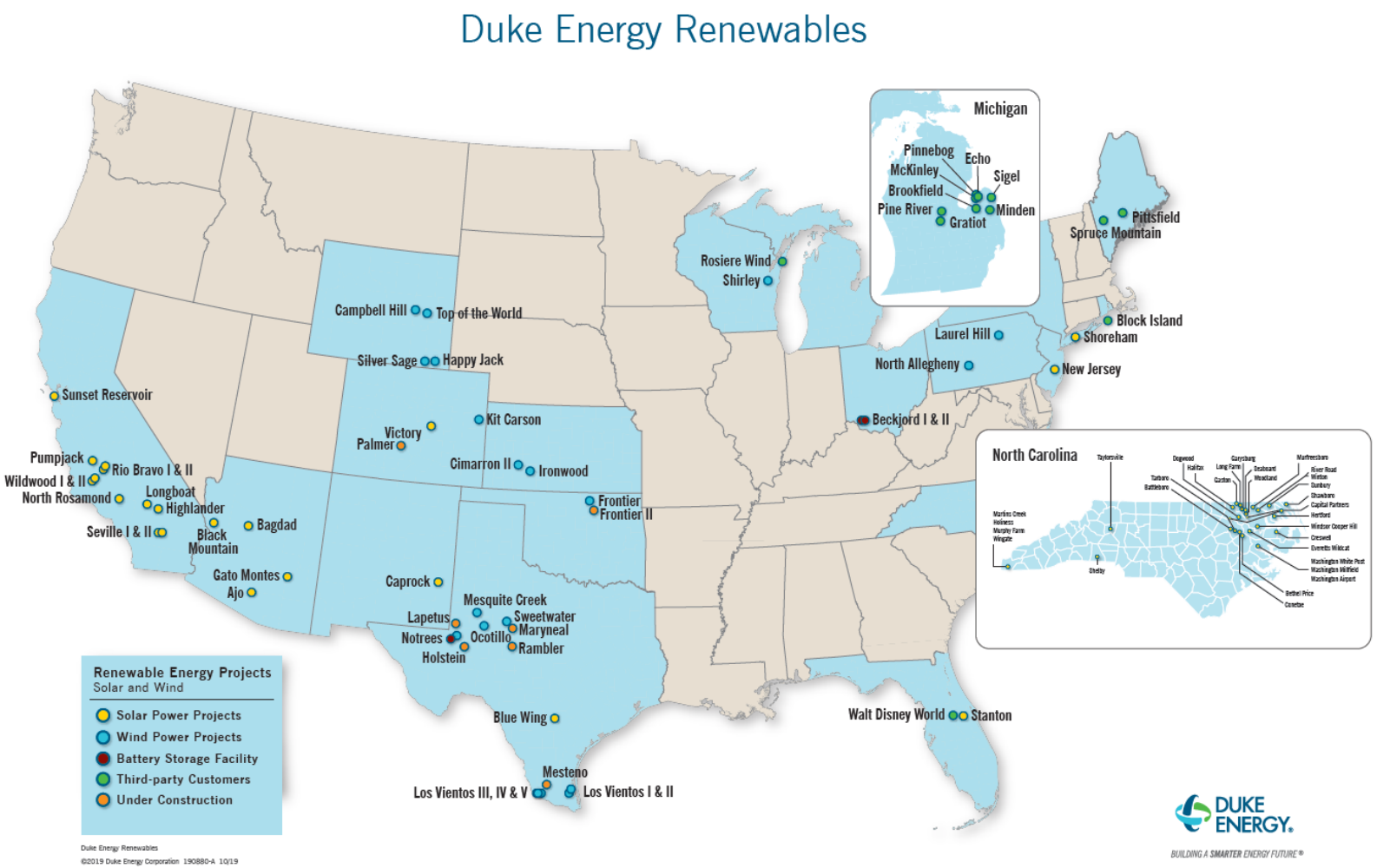
Commercial Portfolio Projects



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BUILDING A SMARTER ENERGY FUTURE®

Wind:

- 23 Sites
- 1,316 Turbines
- 3,091 MW

Solar:

- 61 Sites
- 1,565 MW

Third Party:

- 8 Wind Sites
- 609 MW

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Predicting Failure in Wind Turbines

CHALLENGE

Wind turbine component failures are a leading cause of downtime, lost revenue, and expensive repairs across the wind industry

SOLUTION

Detecting signs of impending failure give an operator the capability to inspect and make repairs on their own timeline

RESULTS

Duke Energy is enhancing visibility across systems and automating alerts, enabling technicians to keep our fleet running better and longer

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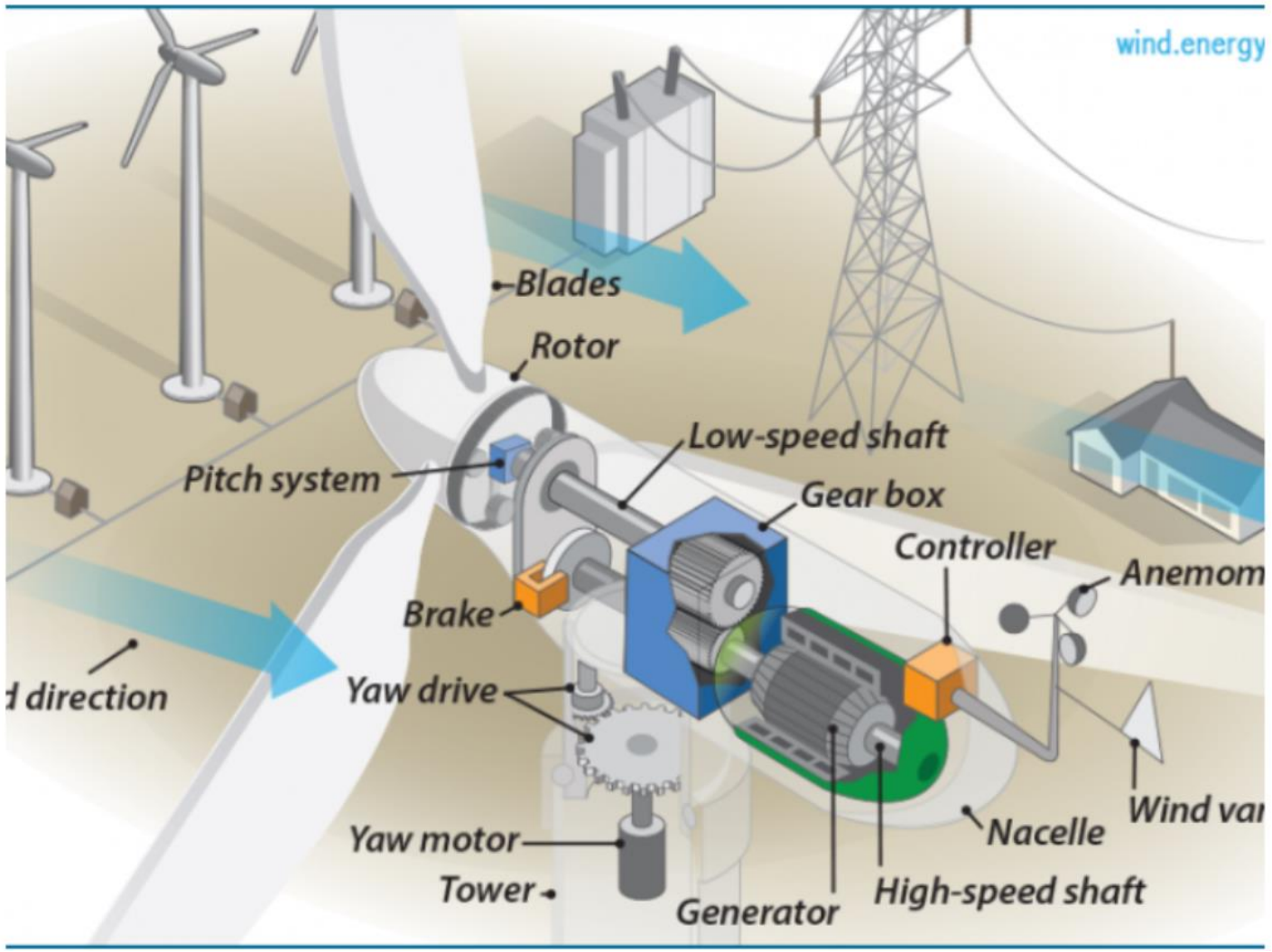
What is the Problem?



Major Components of Wind Turbines

- Blades
- Rotor
- Pitch
- Yaw
- Gearbox
- Generator
- Main Bearing

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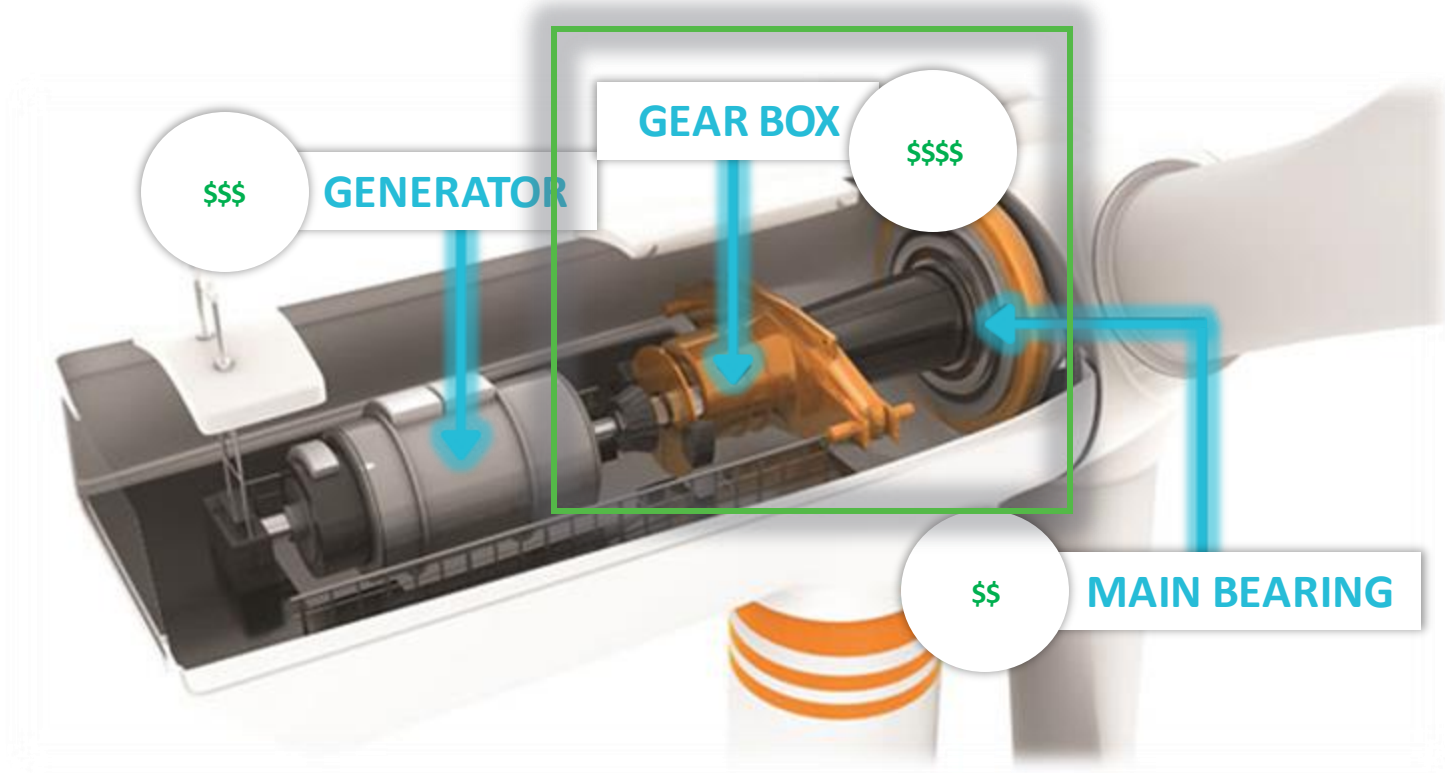
What is the Problem?



Major Components of Wind Turbines

Optimize

- Blades
- Rotor
- Pitch
- Yaw

Predict

- Gearbox
- Generator
- Main Bearing

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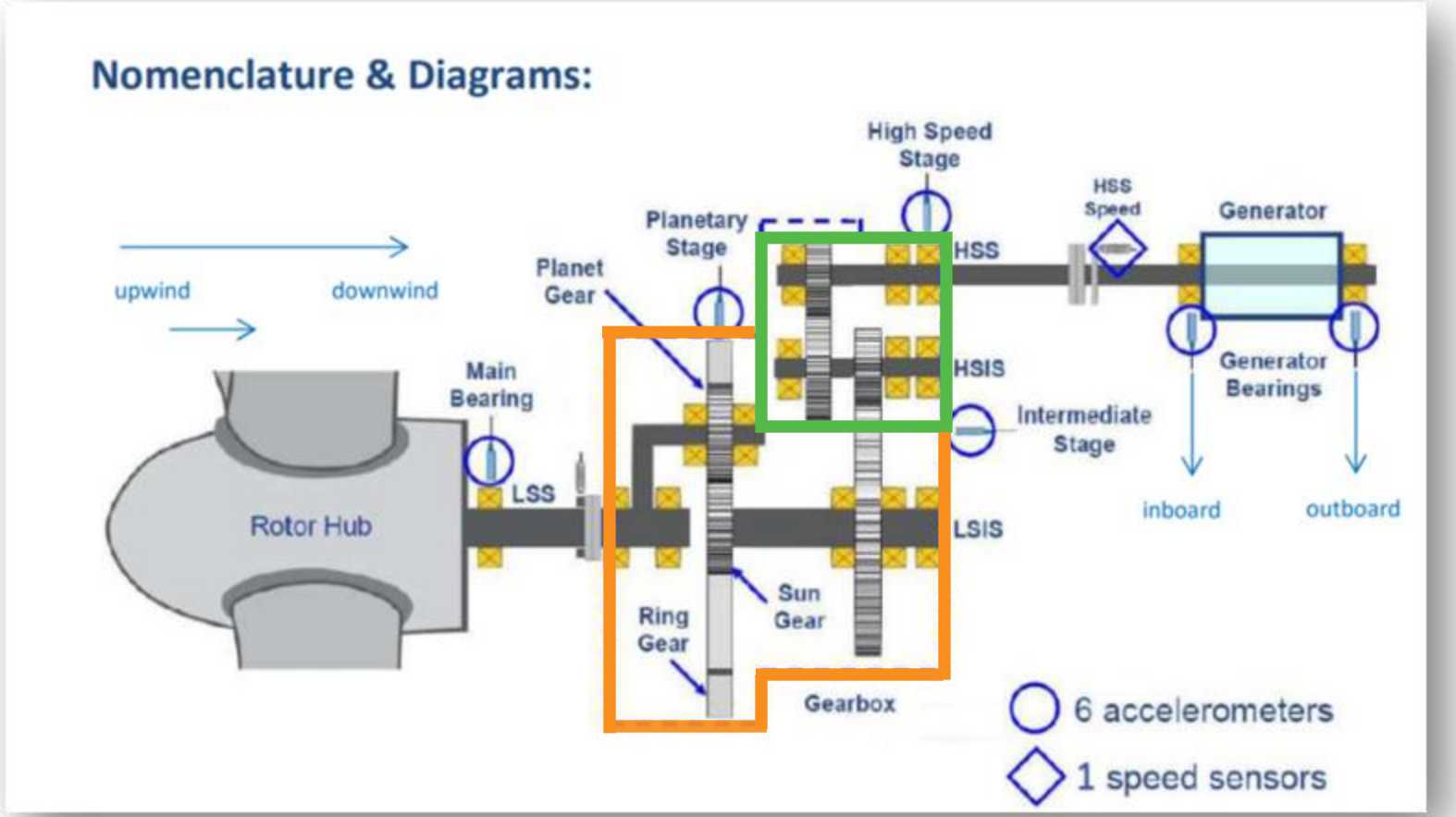
What is the Problem? Benefits of Early Detection



High Speed Stage:

- Uptower replacement
- Avoid full gearbox replacement - $300-500K
- HSIS depends on technology though 85% is repairable uptower

Low Speed Stage:

- Full replacement
- Minimizing risk of gearbox casing split - $30k
- Mitigate potential environmental impacts of oil spill

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Gearbox and High Speed Shaft

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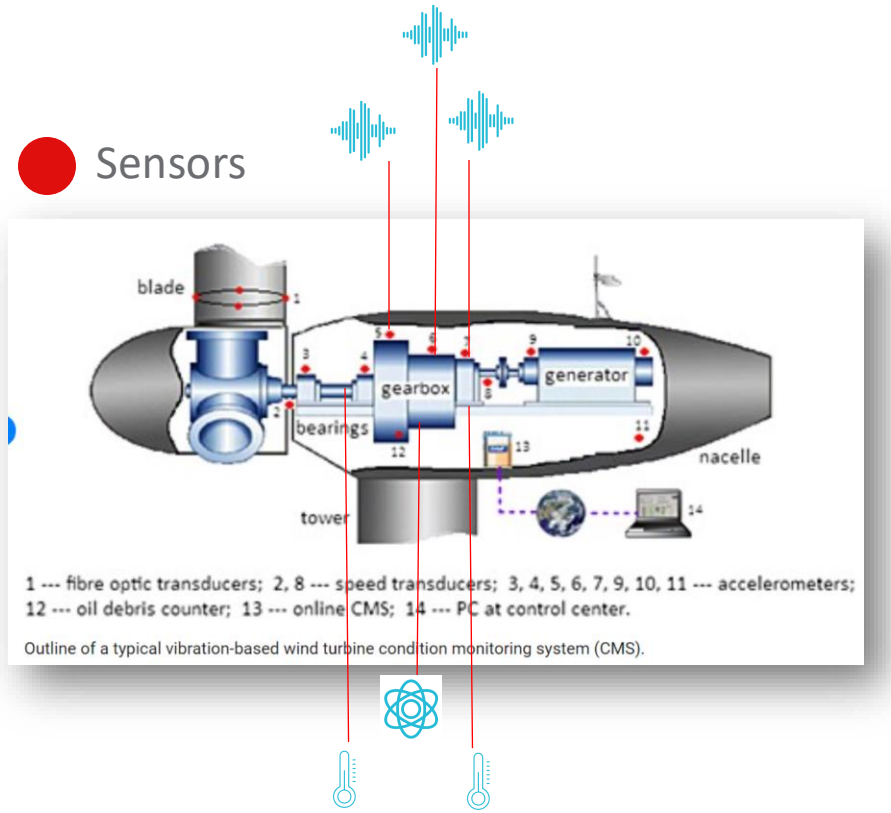
Analytical Approach – Model Determination

KEY SIGNALS

VIBRATION

PARTICLE COUNT

TEMPERATURE



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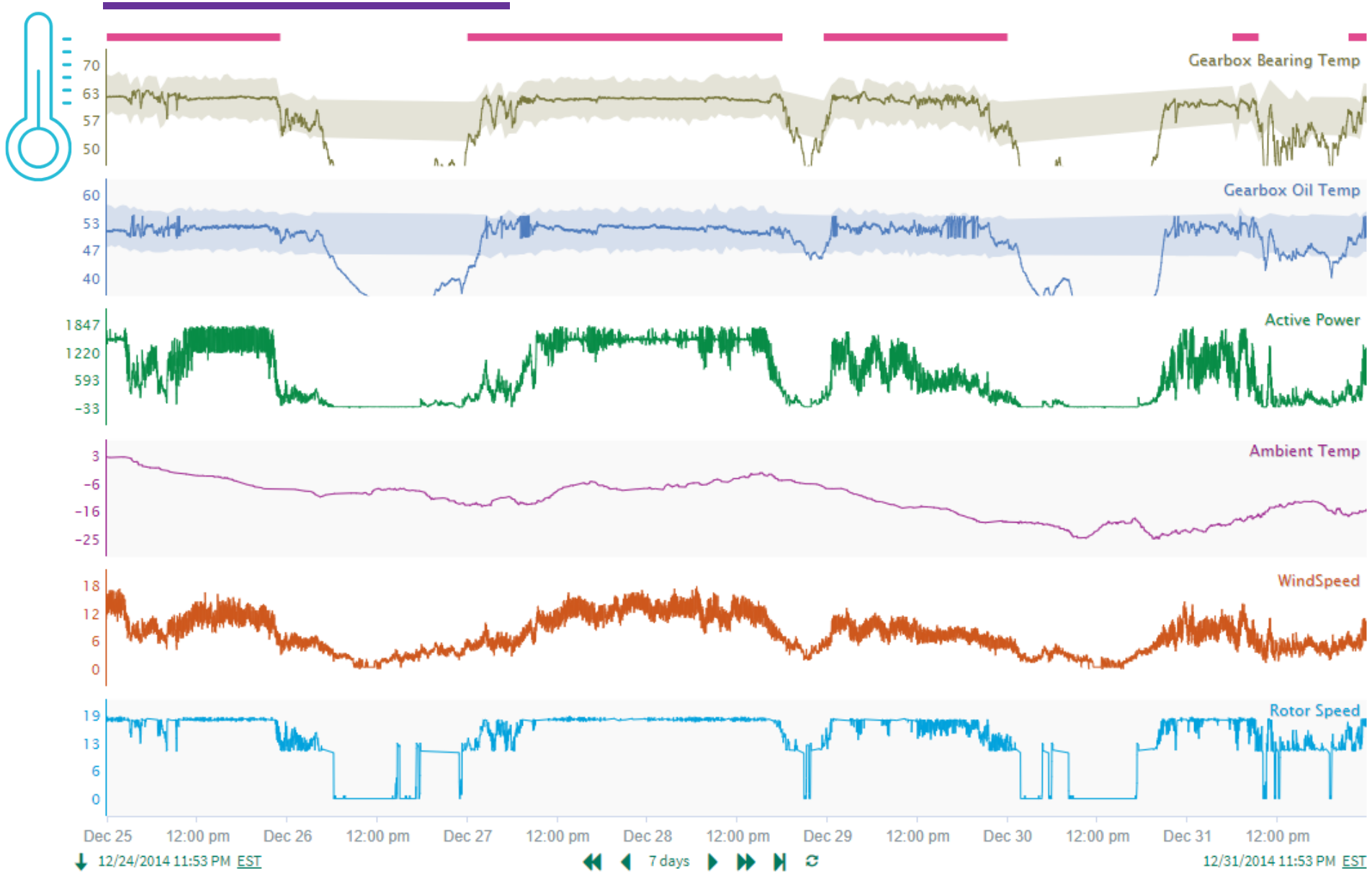
Analytical Approach – Selecting Model Inputs



Training Window

2

Targets

1

Inputs

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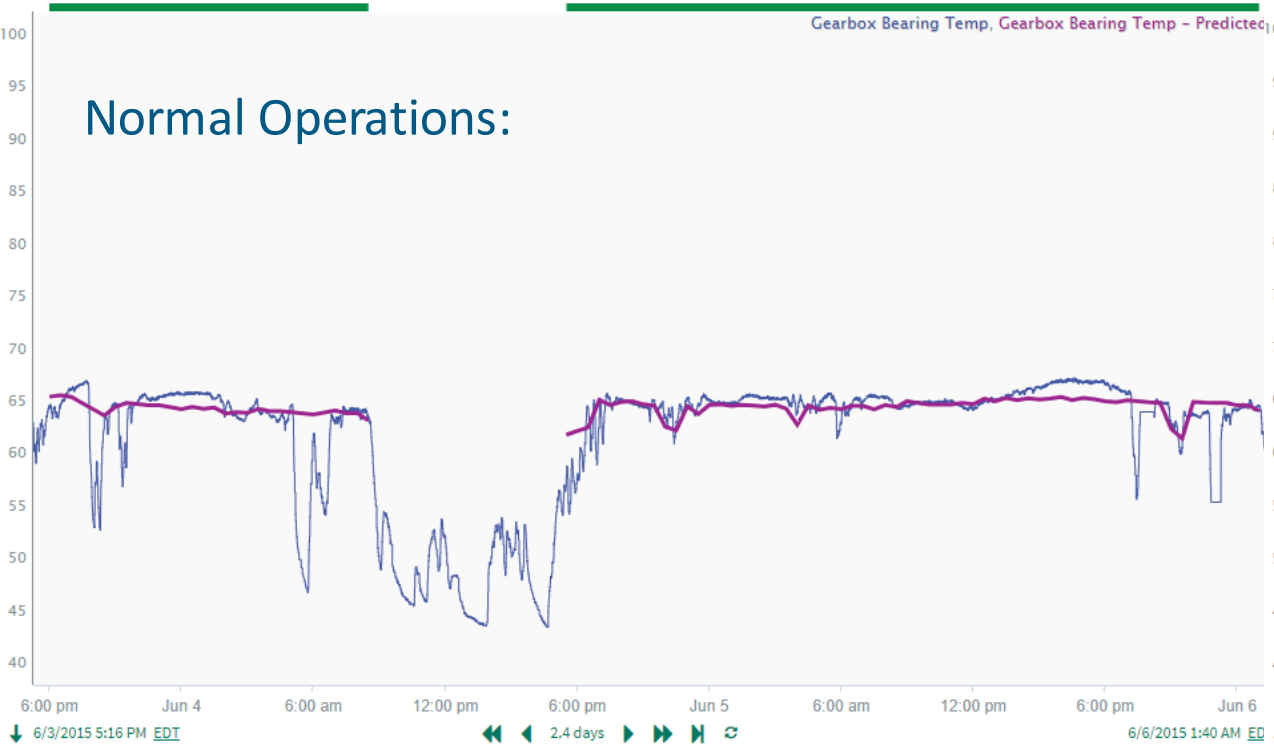
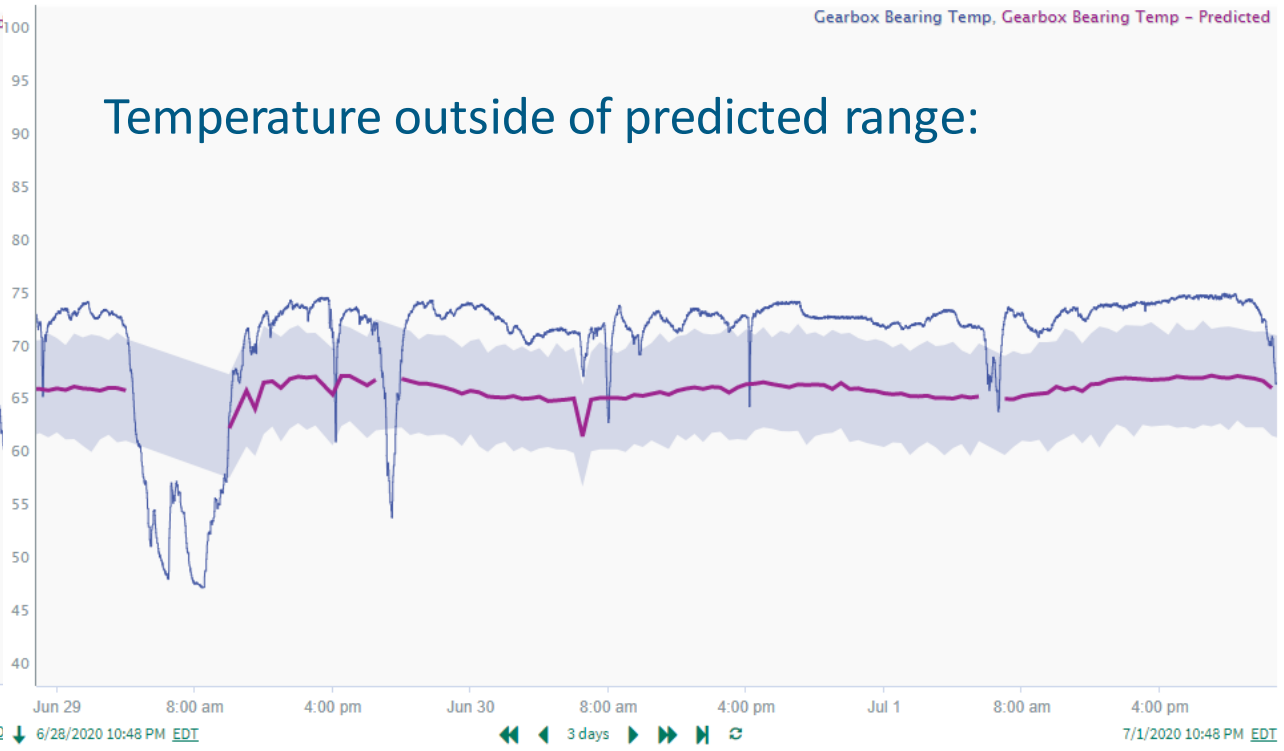
Analytical Approach – Predicting Bearing Temperature

Normal Operations:



Temperature outside of predicted range:



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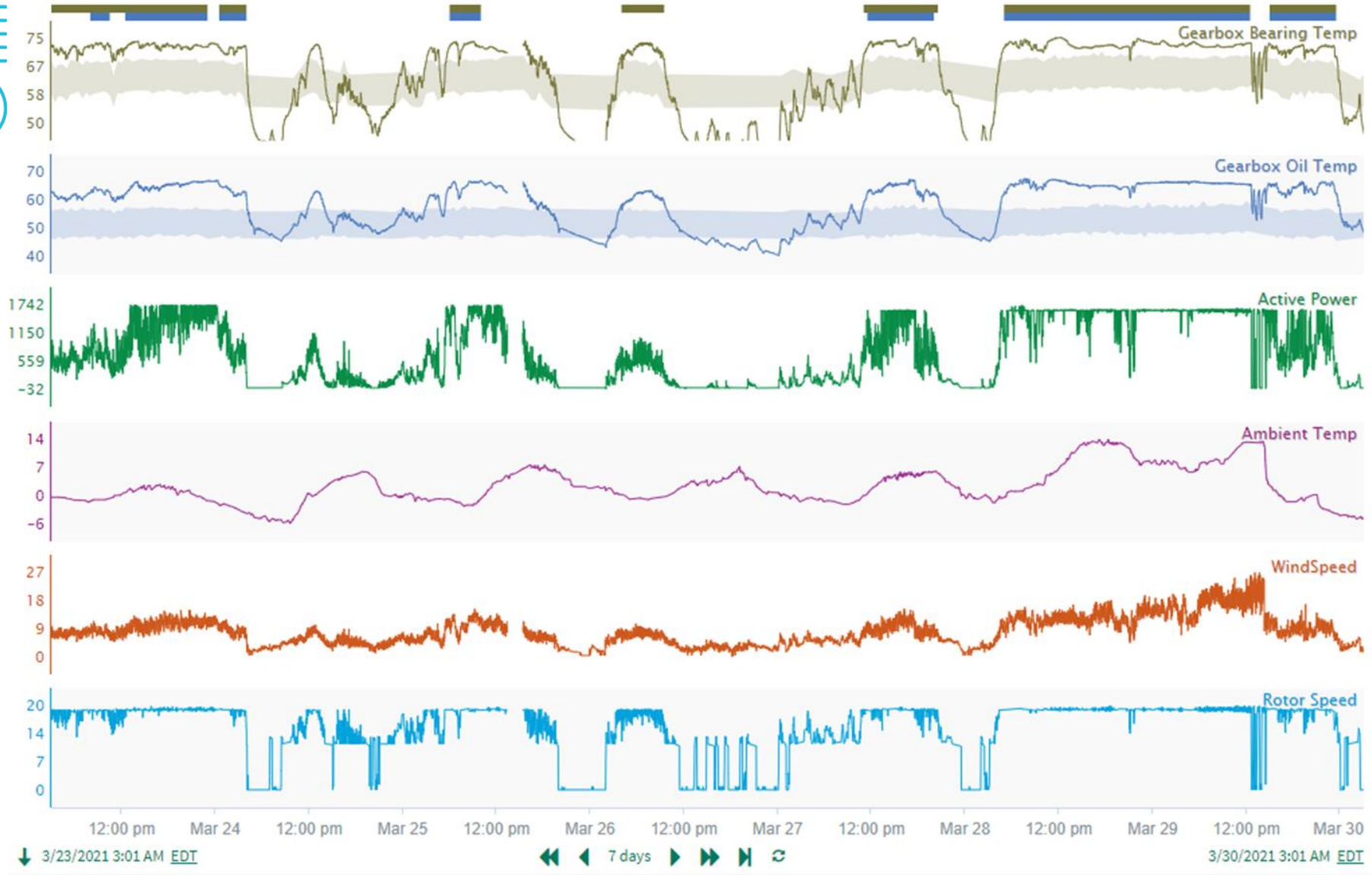
Analytical Approach – Continuous Anomaly Detection



Anomaly Detected

2

Results

1

Inputs

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Analytical Findings: Increasing Failure Indicators Over Time

Wholistic Health Monitoring: Consolidated View

Operational Results

Turbine	Bearing Temp	Oil Temp	Particle	Vibration HSS	Vibration IMS	Vibration PS	Notes
Turbine A			◉	✓	✓		HSS & IMS Vib warnings preceding failure
Turbine B			◉	✓	✓	✓	Warnings from all vibrations, none from temp, particle not available
Turbine C			◉				No warnings preceding failure, particle not yet active
Turbine D	✓	✓	◉		✓		Temp & IMS Vib warnings preceding failure, particle not available
Turbine E	✓	✓	◉	✓	✓		Temp & HSS/IMS Vib warnings preceding failure
Turbine F			✓				Particle warnings peaked 1y prior to failure
Turbine G	✓	✓		◉	◉	◉	Temp warnings only
Turbine H	✓	✓	✓	◉	✓	◉	Temp, particle, & IMS vib warnings preceding failure
Turbine I	✓	✓	✓	✓	✓	✓	All warnings issued preceding failure
Turbine J	✓	✓	✓	✓	✓	✓	All warnings issued preceding failure

Warning present preceding failure **Data not available preceding failure**

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Wind Predictive – Working Smarter

Meeting: Work Week Screening

VS

Monthly CBM Report: PDF through email

× Static
× Manual
× Disparate

✓ Aggregated Data
✓ One User Interface
✓ Accessible Anywhere
✓ Real-Time

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