STATE OF THE ART IN:
SENSING
DATA
ANALYTICS
DIGITAL TWINS

CHRIS PERULLO

Turbine Logic℠
RUN SMARTER

Turbine Logic
RUN SMARTER

Founded 2016

100+ Projects

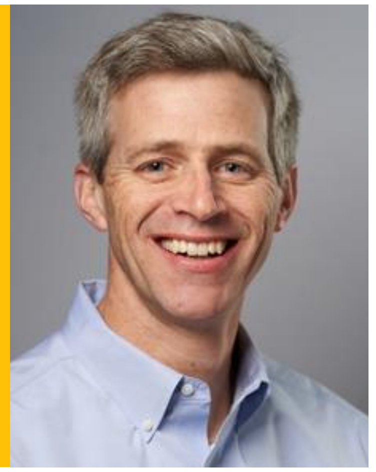
100+Years of Combined Experience

Multidisciplinary Team

www.turbinelogic.com

Jared Kee

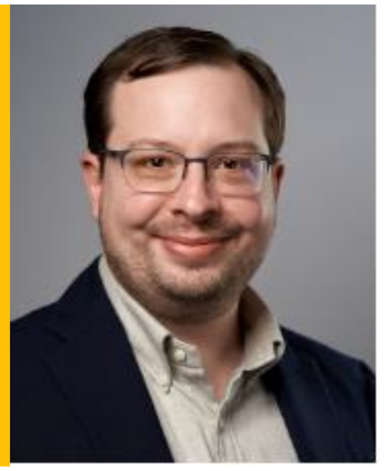
Founder / CEO



Tim Lieuwen

Founder / CTO

Chris Perullo



Director of Engineering

Our Mission

EMPOWER OUR CUSTOMERS TO RUN SMARTER THROUGH THE EFFECTIVE USE OF THEIR DATA

- Run Longer
- Run Cleaner
- Run Stronger
- Run Intelligently
- Empower Yourself

Our Customers

Energy

Power Production
Efficiency
Reliability
Technology

Oil & Gas

Technology
Reliability
CO_2

Research

Research Institutions
Universities
Government

OBLIGATORY DEFINITIONS

DIGITAL TWIN — A Model that learns, adapts, and can represent a **specific** system

SIMULATION — Provides ability to simulate new conditions

MODELING — Models represents the behavior of the system

DATA — Data is required to create a useful model

Turbine Logic
RUN SMARTER

DIGITAL TWINS – CONSUMERS OF INFORMATION

Data Collection

The process of collecting time-series data and metadata, including serial numbers, geographic location, age, and manufacturer details, for building and simulating a model.

Data Preprocessing

Preparing data for simulation models by cleaning, integrating, and transforming it, which may involve removing anomalies and outliers, merging data from different sources, and manipulating it into the required format.

Data Storage

Storage architecture and practices for the large amounts of data used and generated by a digital twin, including considerations like data volume, storage and retrieval methods, format and structure, storage locations, and security.

Modeling and Simulation

Digital twins can include both physics-based and data-driven models. Physics-based models are grounded in physical, theoretical relationships, while data-driven models might use AI/ML algorithms.

Integration

Integration allows for real-time data updates and synchronization between the digital twin and the physical asset, enabling predictive insights and reflecting the asset's current condition.

Analysis Techniques

Involves the use of advanced analytical tools, including AI and ML algorithms, to process and interpret the data. These techniques help in identifying patterns, predicting outcomes, and suggesting optimizations.

Visualization

Concerns the presentation of data and simulation results in an understandable and actionable format. This can include dashboard design, data visualization best practices, and user-friendly interfaces.

Maintenance and Updates

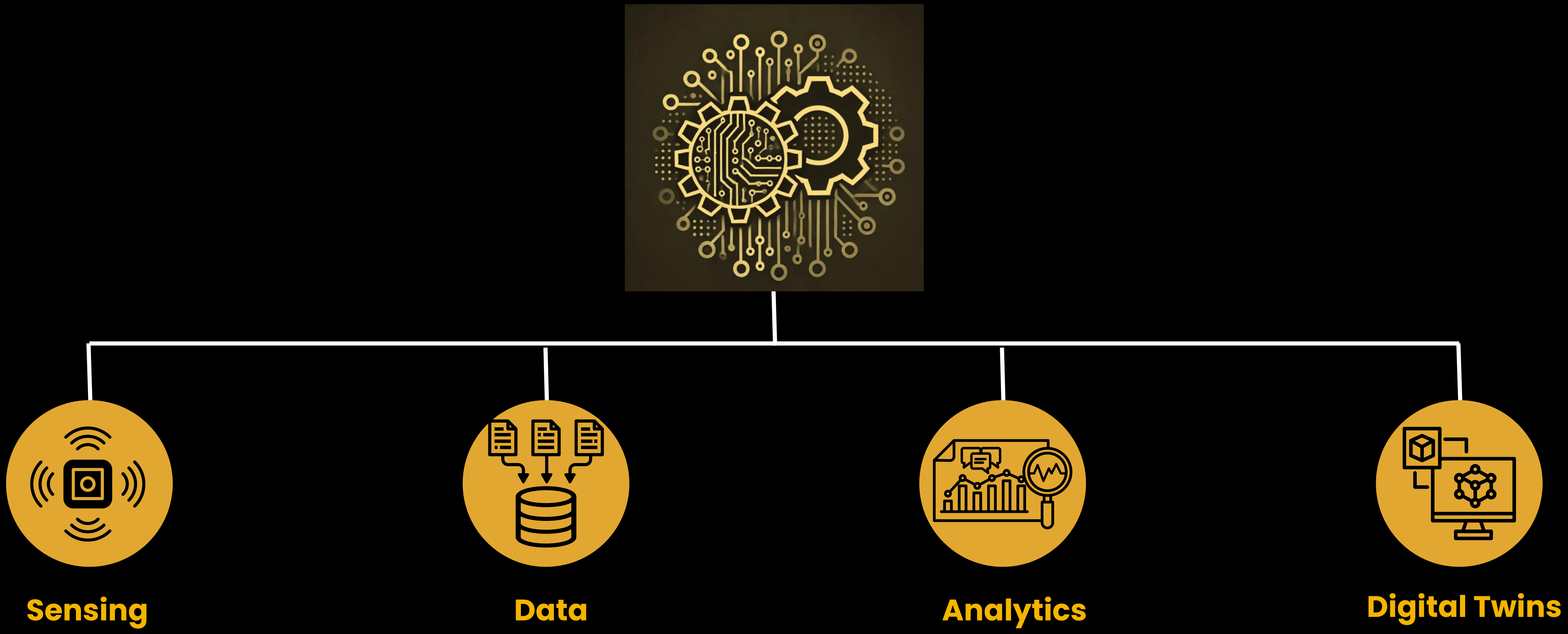
Refers to the processes for version control, model recalibration, tracking model changes, and ensuring models remain accurate over time. This is crucial for the digital twin to remain relevant and useful.

Turbine Logic
RUN SMARTER

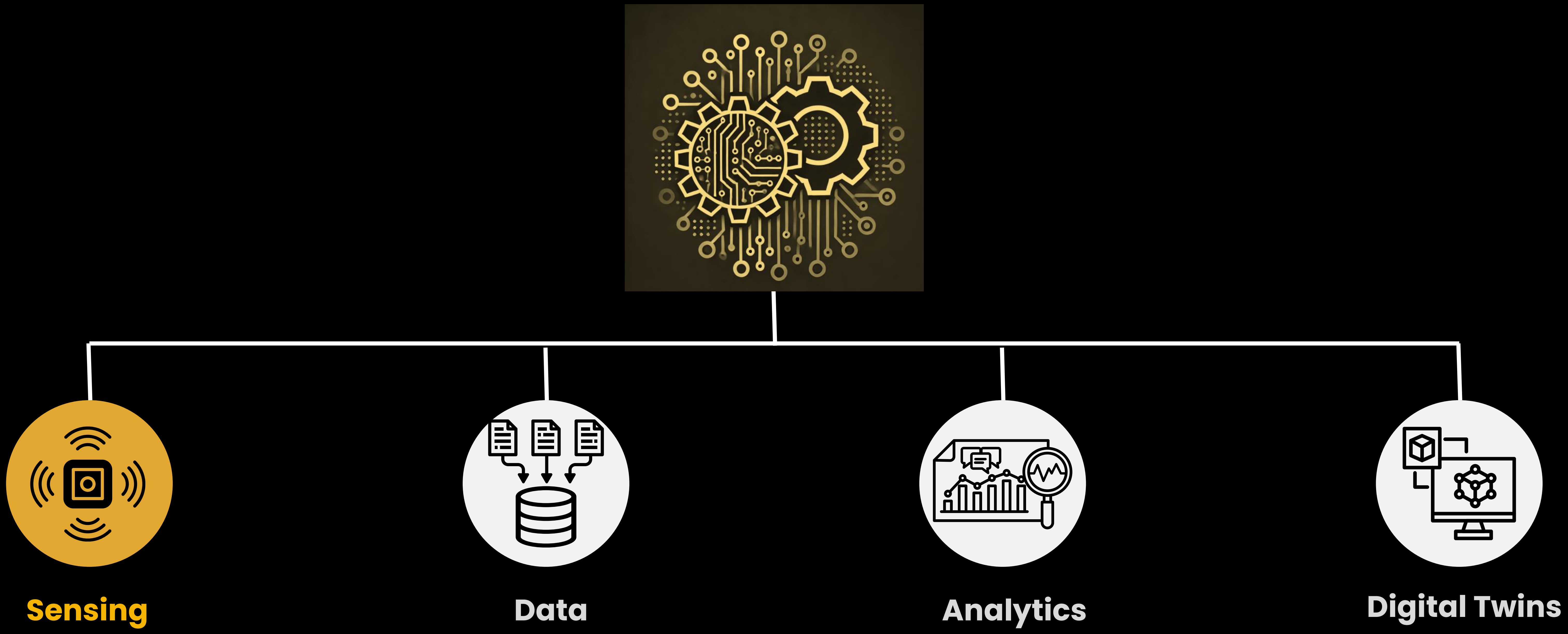
HOW DO WE USE DIGITAL TWINS?

Compare	Diagnose	What-If?
State Identification	Monitor	Observe
	Prognostics	

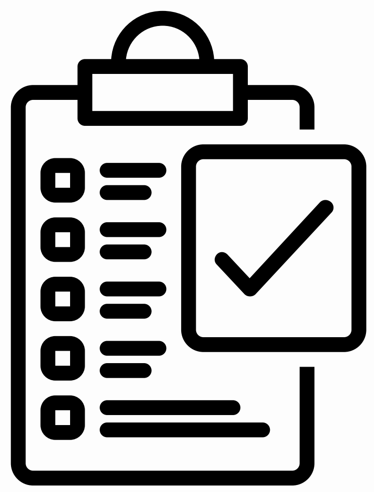
DIGITAL TWINS



DIGITAL TWINS

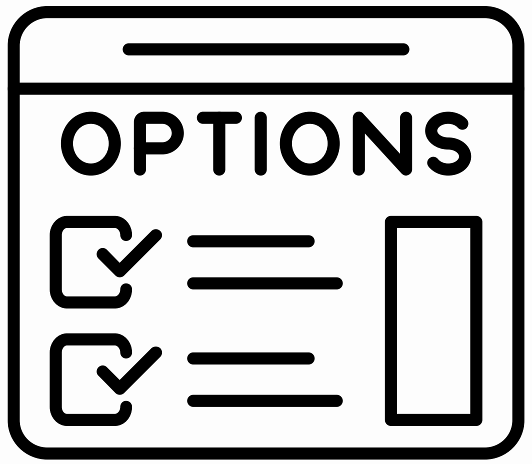


SENSING



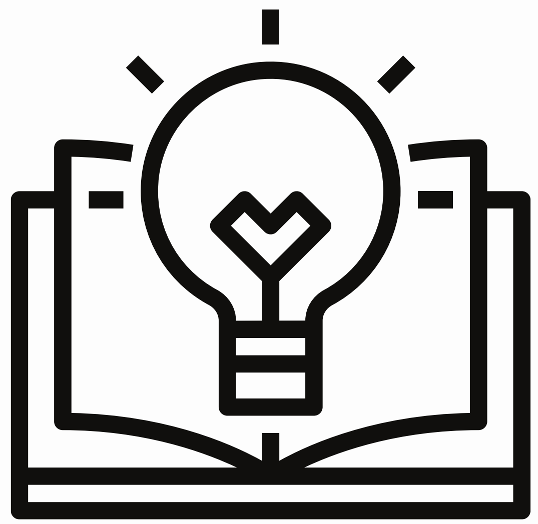
Required

Protection
Control



Optional

Monitoring
Enhanced Control



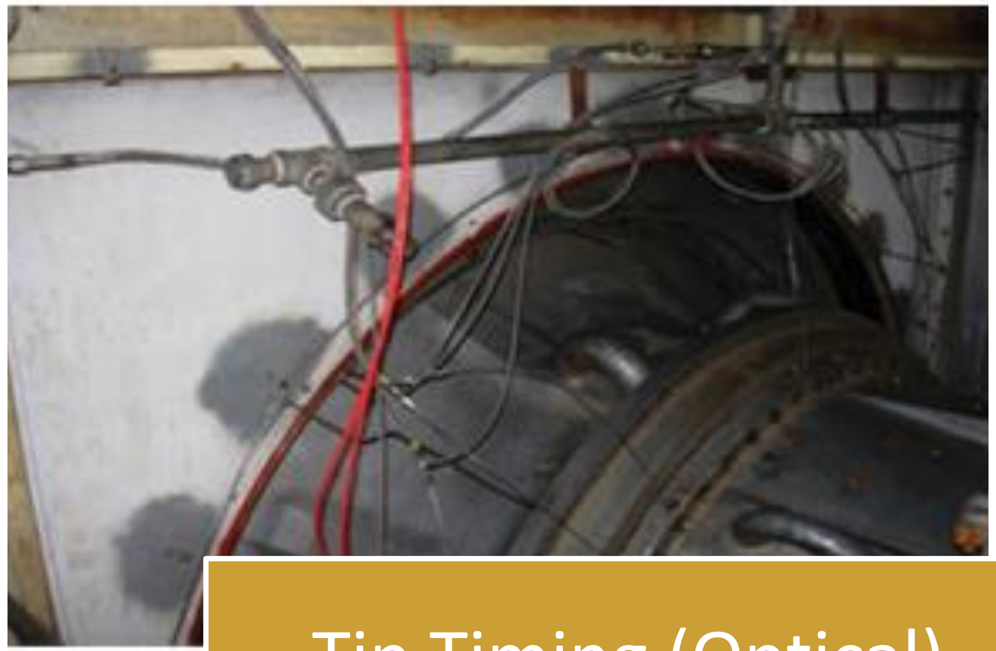
Educational

Temporary?
High ‘Cost’?
High Fidelity?
New Location?

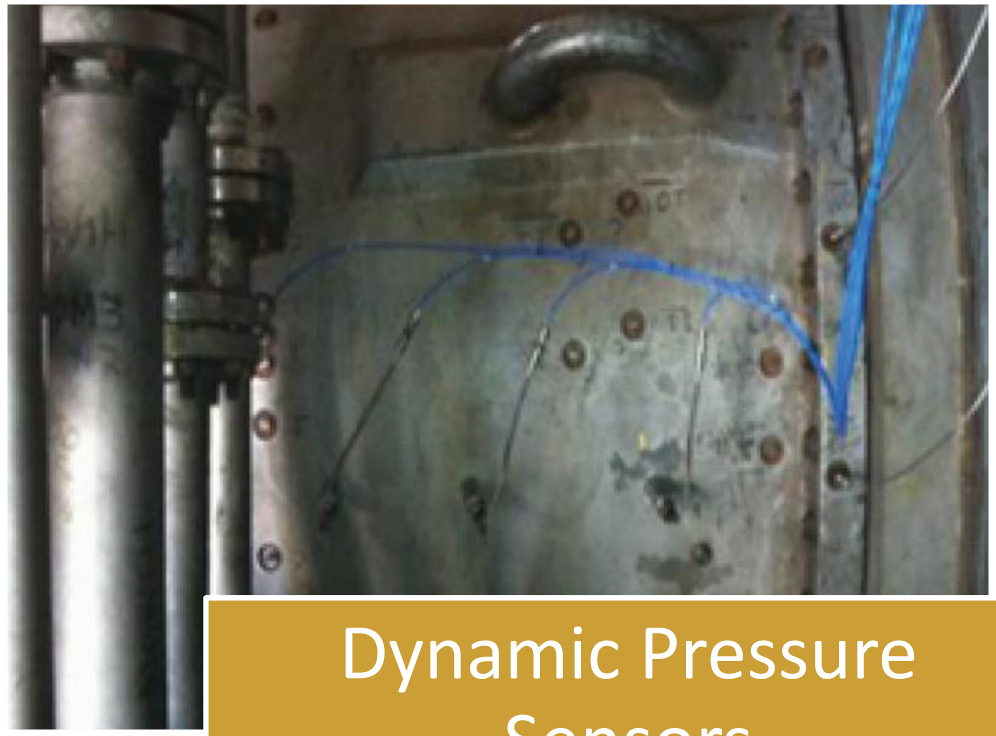
USE INSTRUMENTATION ALREADY AVAILABLE?

CORRELATE TO EXISTING INSTRUMENTATION?

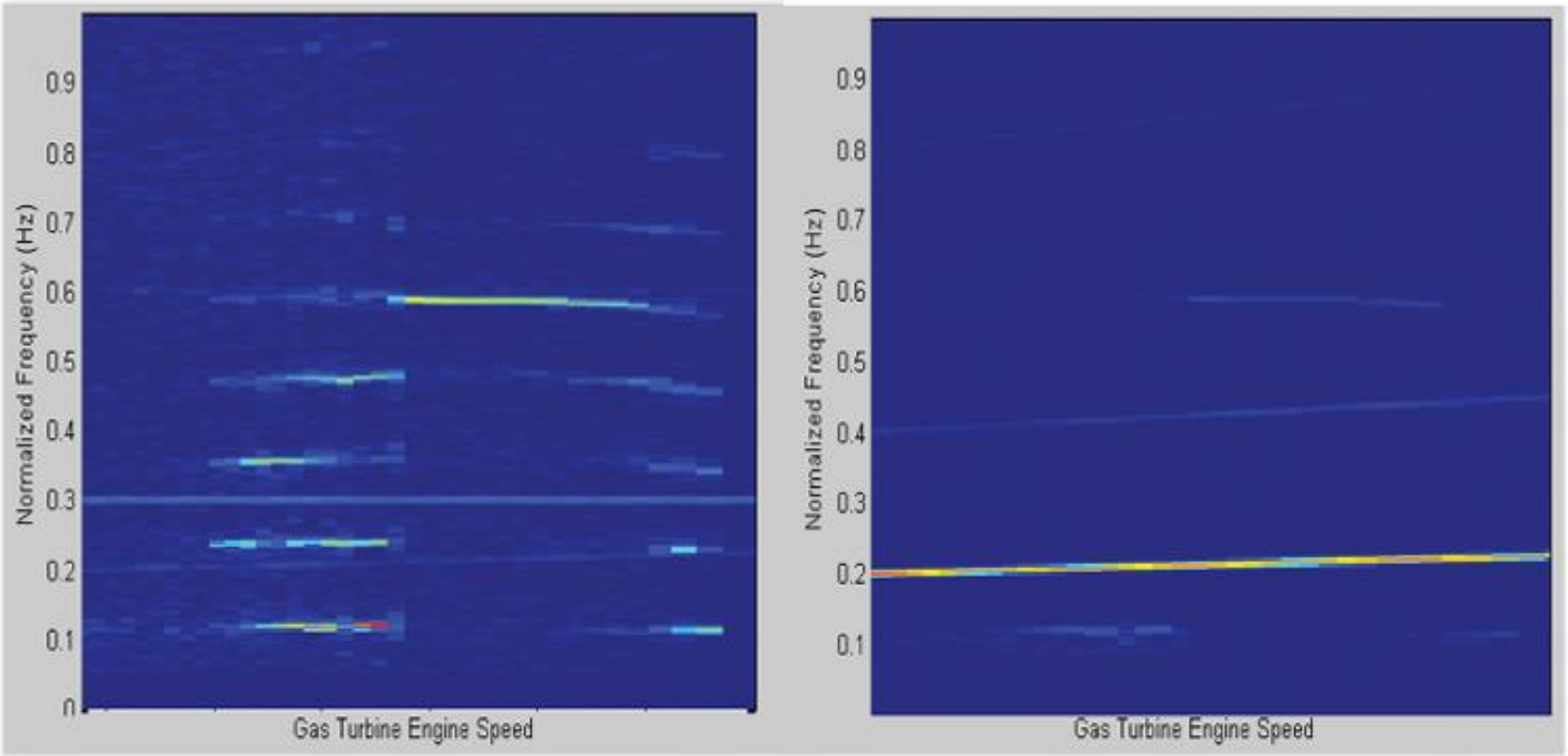
USE CASE (EPRI) – COMPRESSOR ROTATING STALL MONITORING

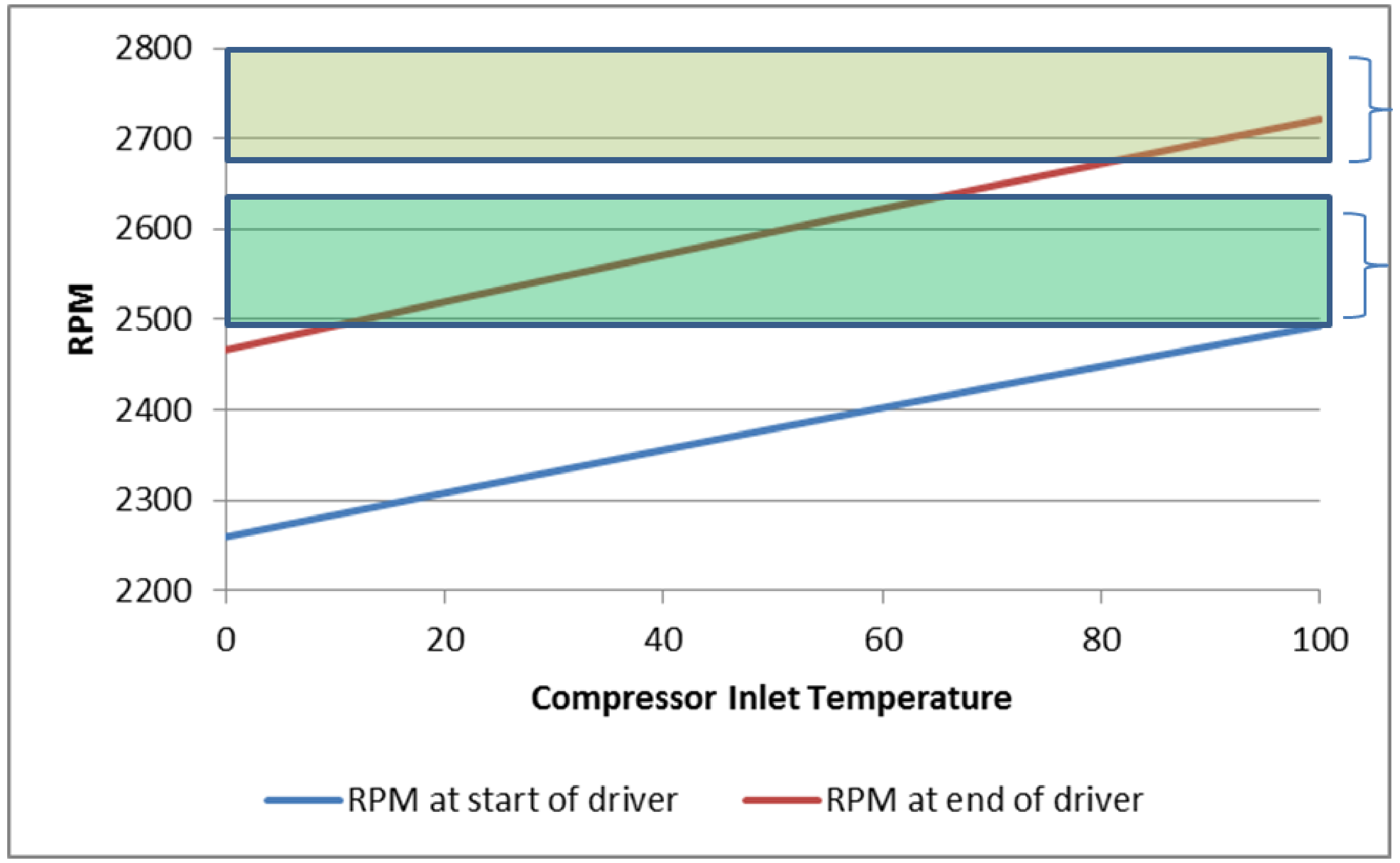


Tip Timing (Optical)



Dynamic Pressure Sensors





-6 ND region

-7 ND region

Turbine Logic RUN SMARTER

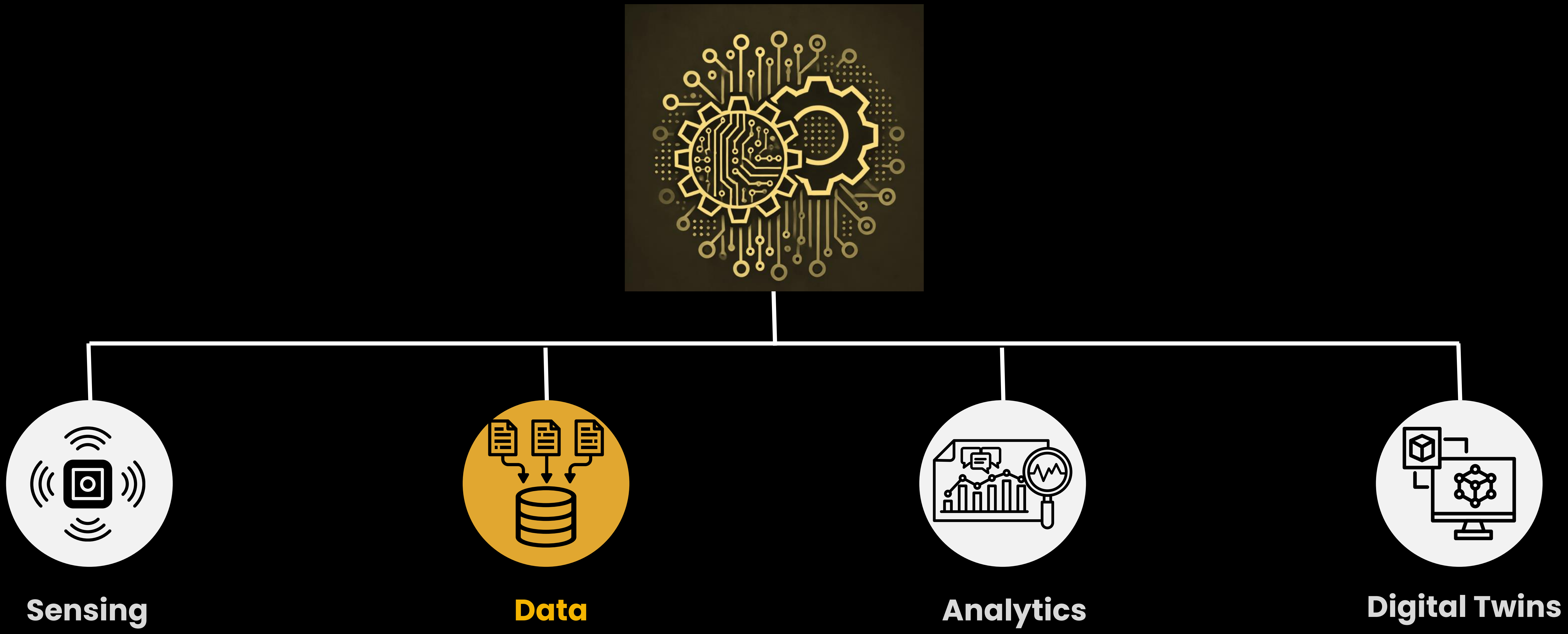
SENSORS AND DIGITAL TWINS

Is It Reliable?

Can It Be Installed

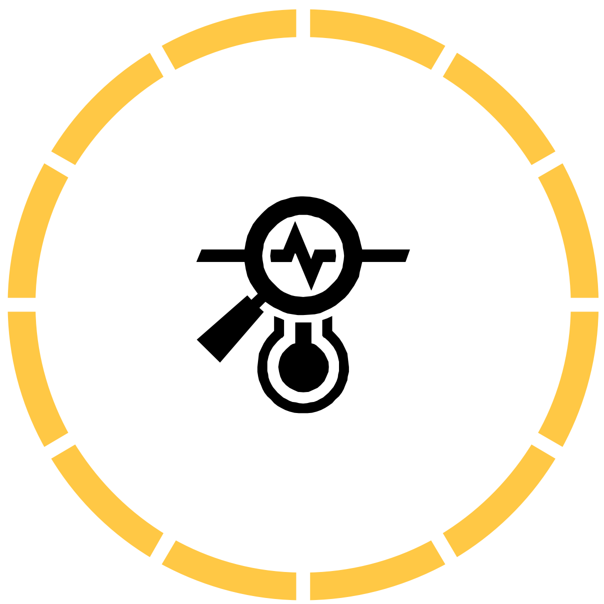
- Without Asset Modification?
- Long term?

DIGITAL TWINS



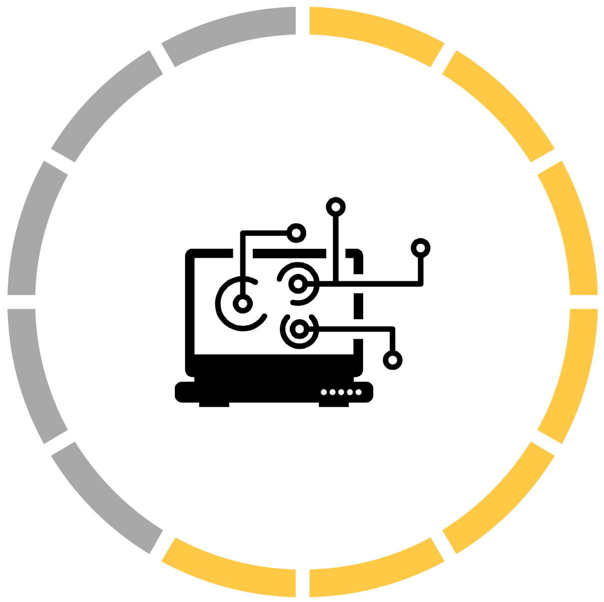
SENSORS AND THE STORAGE CHAIN – IS IT SUFFICIENT?

SAMPLING RATE OF DATA GENERALLY DECREASES



Sensor

20,000 times per second

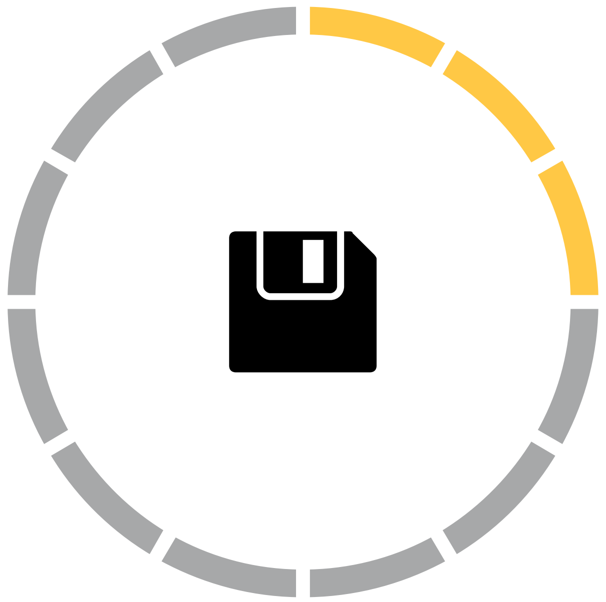


Signal Processing

1,000 times per second

Historian Sample Rate

Once per second?



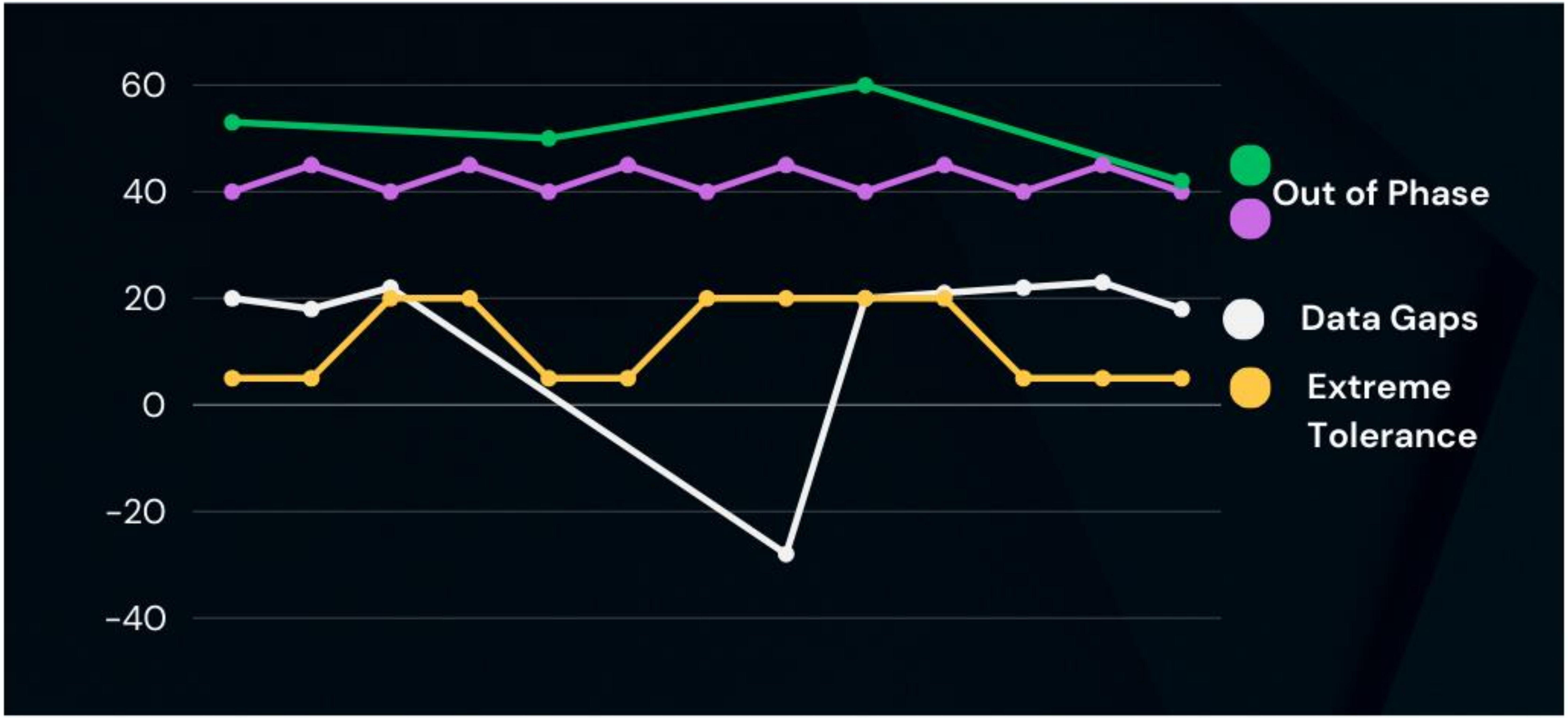
Archived Data Sample Rate

Once per minute?

Fidelity Loss

Turbine Logic
RUN SMARTER

DATA – WHAT CAN GO WRONG?



DATA - CONSIDERATIONS

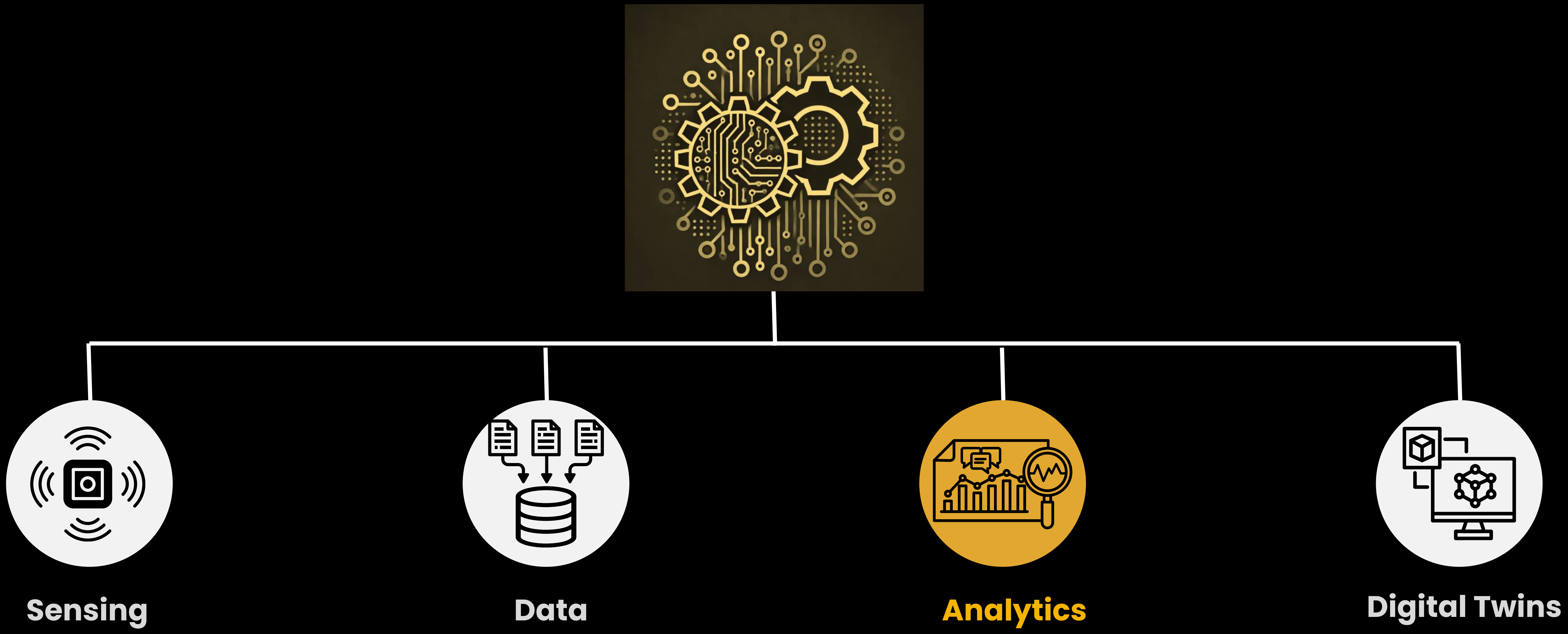
What Existing Sensors Are Being Complimented?

Where and How Will the Data Be Stored?

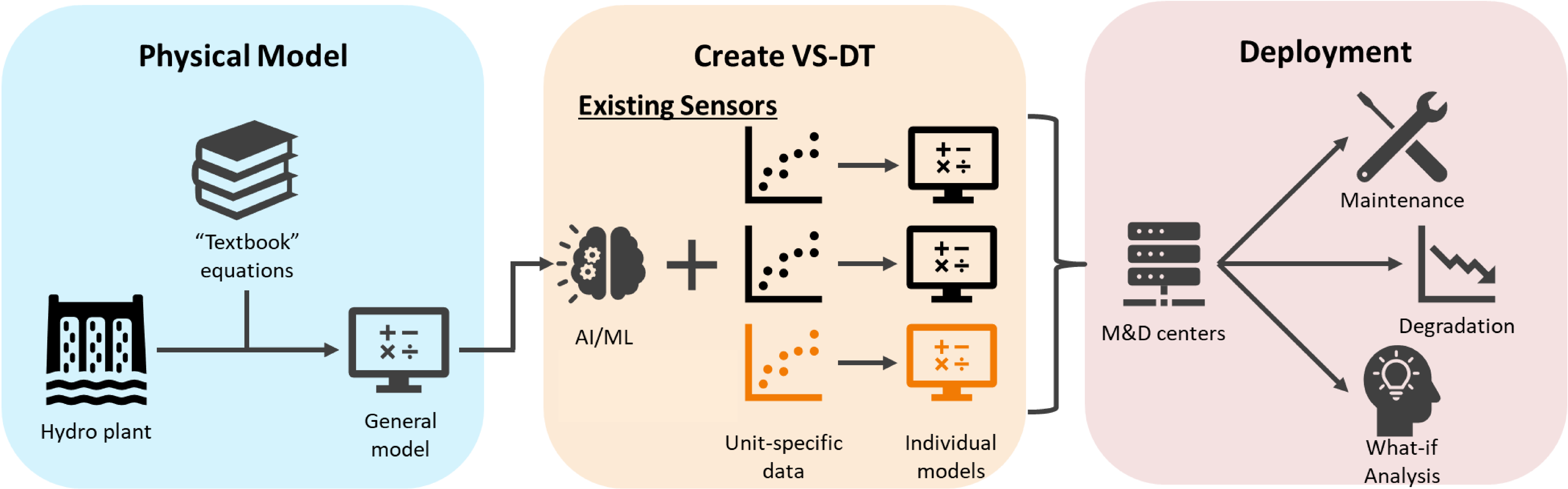
Will the Data Be Accessible?

The Design Is Often Not Completely Known Or Readily Available to End Users

DIGITAL TWINS



ANALYTICS



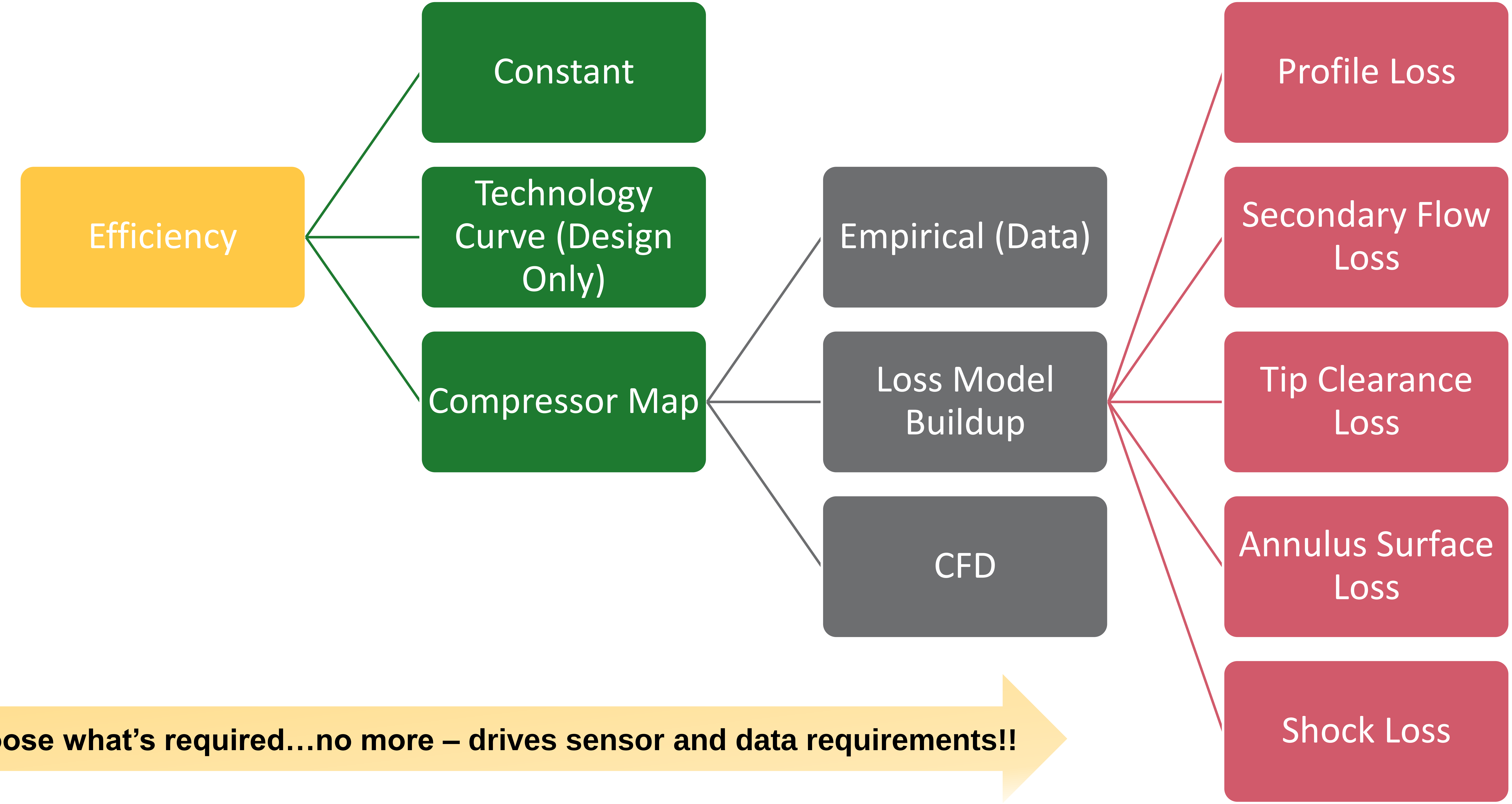
A physics-based model of a physical asset

Tuned to unit-specific data through AI/ML

Providing actionable insight and operational knowledge

Analytics Enable Calibration and Physical modeling

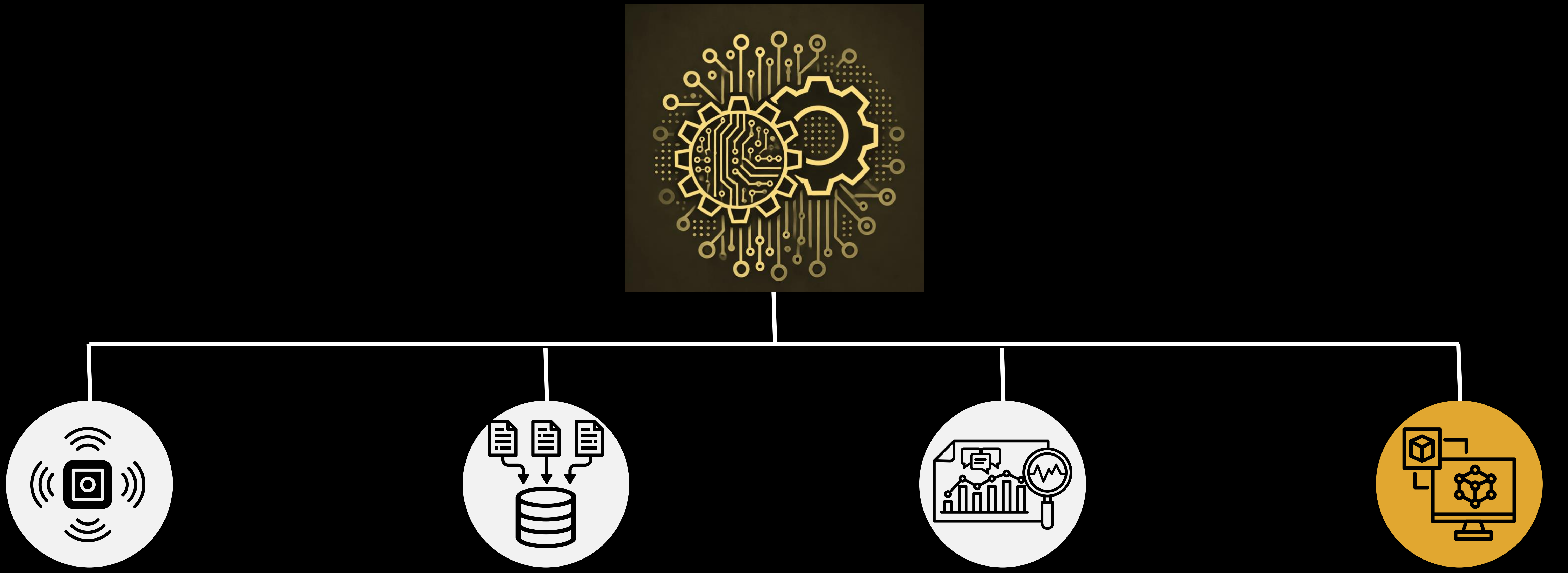
FIDELITY MATTERS…



Choose what's required…no more – drives sensor and data requirements!!

Turbine Logic RUN SMARTER

DIGITAL TWINS



Phase 1

Verification

Conceptual Verification

- Model's theoretical assumptions are sound
- Validation of underlying assumptions and physical models

Implementation Verification

- Code works correctly and is integrated. Data intake, pre-processing, analysis, and post-processing work as intended

Phase 2

Pre-Deployment Validation

Manual Calibration

- Manual adjustment to match 1-2 real world systems
- Testing predictive capability on blind-test systems
- Updating model as needed

Phase 3

Operational Validation

Initial Deployment

- Model deployed
- Significant monitoring and tweaking
- Shows ability to 'twin' early on for target assets

New Use Cases

- Model deployed on new assets with new data
- Model adapts and calibrated properly

Phase 4

Continuous Validation

Continual Improvement

- Model runs 'hands off'
- Pathway exists to improve as new data or behaviors emerge

Long Term Metrics Tracking

- Metrics for accuracy established
- Metrics for accuracy reviewed and acted upon

Turbine Logic
RUN SMARTER

Phase 1

Verification

Conceptual Verification

- Model's theoretical assumptions are sound
- Validation of underlying assumptions and physical models

Implementation Verification

- Code works correctly and is integrated. Data intake, pre-processing, analysis, and post-processing works as intended

Phase 2

Pre-Deployment Validation

Manual Calibration

- Manual adjustment to match 1-2 real world systems
- Testing predictive capability on blind-test systems
- Updating model as needed

Phase 3

Operational Validation

Initial Deployment

- Model deployed
- Significant monitoring and tweaking
- Shows ability to 'twin' early on for target assets

New Use Cases

- Model deployed on new assets with new data
- Model adapts and calibrated properly

Phase 4

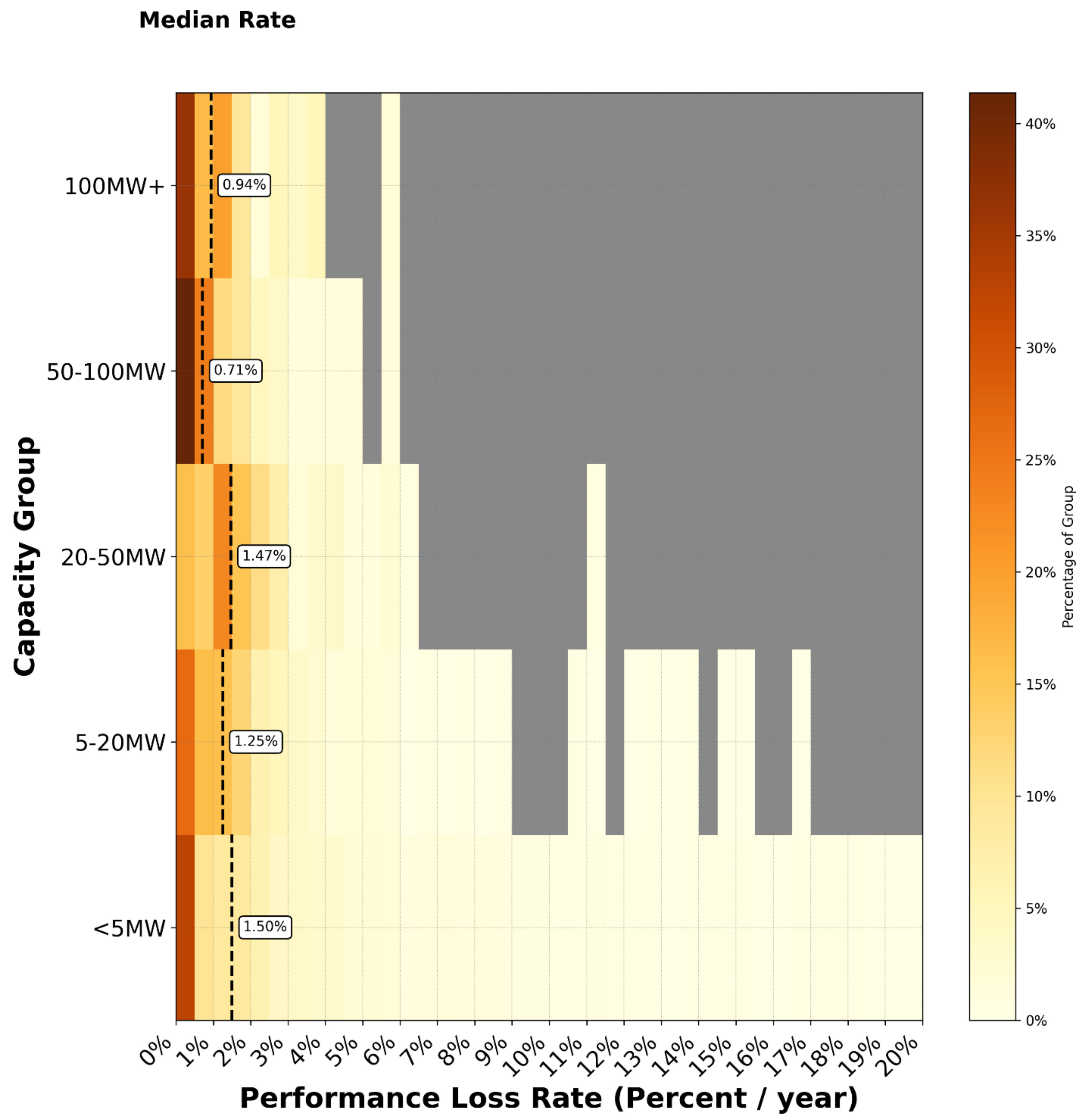
Continuous Validation

Continual Improvement

- Model runs 'hands off'
- Pathway exists to improve as new data or behaviors emerge

Long Term Metrics Tracking

- Metrics for accuracy established
- Metrics for accuracy reviewed and acted upon



Photovoltaic Digital Twin

PREDICT DEGRADATION

USE DT TO BASELINE PERFORMANCE

ACCOUNT FOR UNCERTAINTY IN SUNLIGHT MEASUREMENTS AND DEGRADATION

DIGITAL TWIN CHALLENGES

Model Maintenance

When do you update?
How do you capture continual change?

Uncertainty as a Core Component

Can I trust the model?
Should I trust the model?
What don't I know?

What AI Should Be Used?

LLM
Neural Network
Bayesian
Commercial Offering A/B/C?

Integration Across Tools

Are my tools ready to integrate?
Should I integrate my tools?
Do I have the right tools to begin with?

DIGITAL TWIN CONSIDERATIONS

AI and ML – Use Intelligently and Only to The Extent Required

- If a 2nd order function works – use it
- Great for capturing uncertainty and working with noisy data

Physical Model Required

- Helps 'tie together' noisy data
- Use AI/ML to create reduced order models

Uncertainty

- Should always be included and quantified in the calibration and prediction processes

Empowering the world to *run smarter*