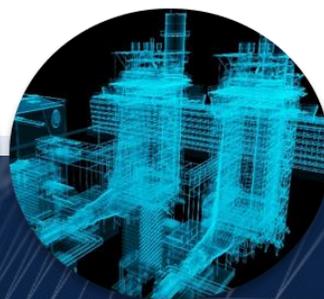
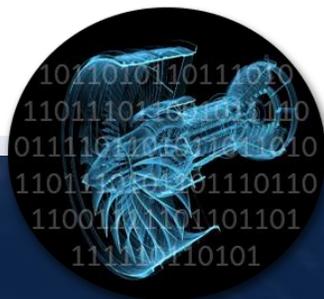




# Industrial Digital Twins & APM



RUSTY IRVING

Digital Twin Platform Leader & Chief Engineer  
GE Global Research

15 May 2019

# Outline

**Industrial Digital Twin** Defined and Explained

**The Path** to Digital Twin

**Digital Twin Examples** and Impact

**Trends and Future Vision**



# What is a Digital Twin?

## Physical Asset



$f(x)$   
TRANSFER  
FUNCTION

## Digital Twin A Learning Digital Model



PHYSICS  
MODELS

+

MACHINE  
LEARNING

- 1 PER ASSET MODEL
- 2 BUSINESS OUTCOMES
- 3 CONTINUOUSLY LEARNS
- 4 SCALABLE
- 5 ADAPTABLE

DIGITAL TWIN INCREASES PRODUCTIVITY AND ACHIEVES  
BETTER OUTCOMES FOR CUSTOMERS



# The Path to Digital Twin



## 1980s

### “BREAK & FIX”

- 1st M&D Systems **answered the question? “What Happened?”**
- Tech: Rule-Based
- Examples: Diesel Locomotive Diagnostics



## 1990s

### “M&D BUILD OUT”

- Systems still Reactive, **answered the question? “What is Happening?”**
- Online centers built out Contractual Service Agreements become the business model
- Tech: Mix of Neural Networks, Case-Based, and other



## 2000s

### “PROGNOSTICS”

- **Answered the question? “What will break?”**
- Examples: Early Warning Systems
- Tech: Prior Methods, Machine Learning, Statistical



## 2010s

### “REMAINING USEFUL LIFE”

- **Answered the question? “When will it break?”**
- Examples: Power Plant OnLine Condition Based Maintenance
- Tech: Prior Methods, Deep Learning, Usage Based Lifting

## 2015+

### “DIGITAL TWINS”

- Now **answering many questions: “Can I run the asset hotter?” “When should I inspect?” “When should I replace?”**
- Enables What-If Scenarios, System Optimization
- Examples: Power Plant Efficiency Optimizer, Aviation Analytics Based Maintenance
- Tech: Prior Methods, Cloud Computing, Learning

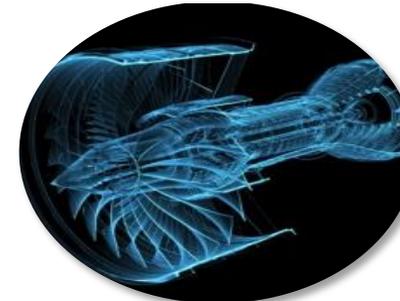
RULES ➤ PHYSICS AND DATA BASED MODELS ➤ PHYSICS MODELS WITH LEARNING ECOSYSTEM



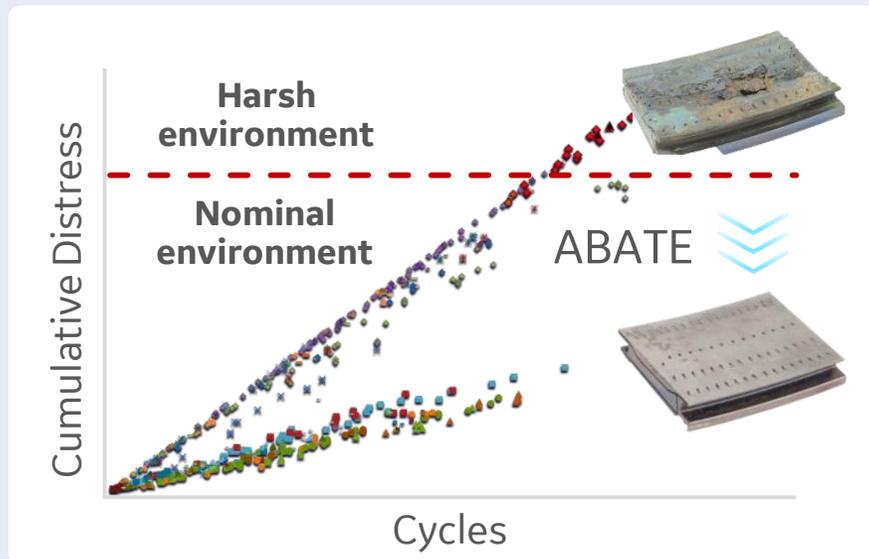
# Continuous prediction Digital Twin – Aviation engine



Environmental conditions  
Per flight data  
Prior condition



**Digital Twin**  
Physics + AI Models



## Optimized Inspection Time and Shop Schedule



INCREASED AVAILABILITY TO CUSTOMER  
SAVES TENS OF \$MM IN UNNECESSARY SERVICE OVERHAULS

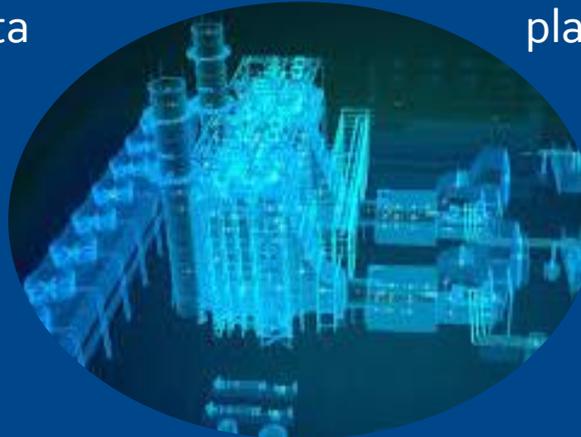


# Optimization Digital Twin – 6FA Turbine Combined Cycle Plant

Plant operational data;  
Weather data



Operational set points for  
plant optimization



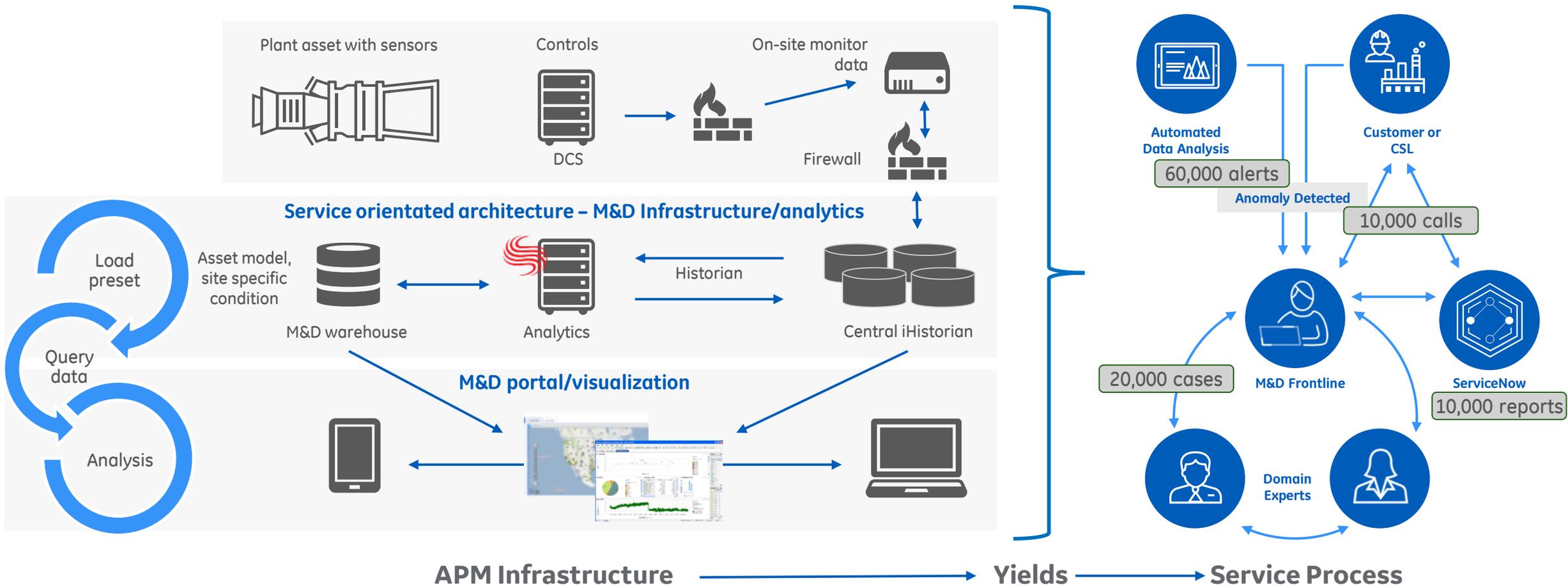
## KEY TECHNOLOGIES

Twins (gas turbines, bottoming cycle)  
Learning  
Optimizer

AUTOMATED OPTIMIZER + TWIN TARGETING 0.5% HEAT RATE IMPROVEMENT



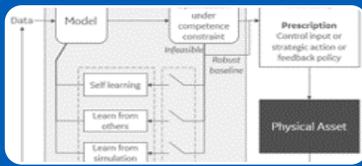
# APM Reference Architecture & Service Process



This Architecture Scales to 6,000 Assets, 400 GW of Power, 3MM Data Points/second



# Current Trends and Next Steps



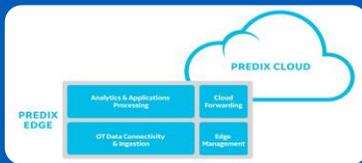
## Humble AI

- Aware of its own competence, can learn, prescribe safe actions
- Fosters operator trust



## Cyber Security

- Digital Ghost technology that works like the human immune system
- Can detect cyber attacks even when operator panel looks ok



## Edge to Cloud

- 5G will provide comm speeds that enable Cloud controlled assets
- Complex models will become realized



## Robotics

- All the above will enable next gen autonomous robots
- Dull, dirty, dangerous tasks will be performed by machines



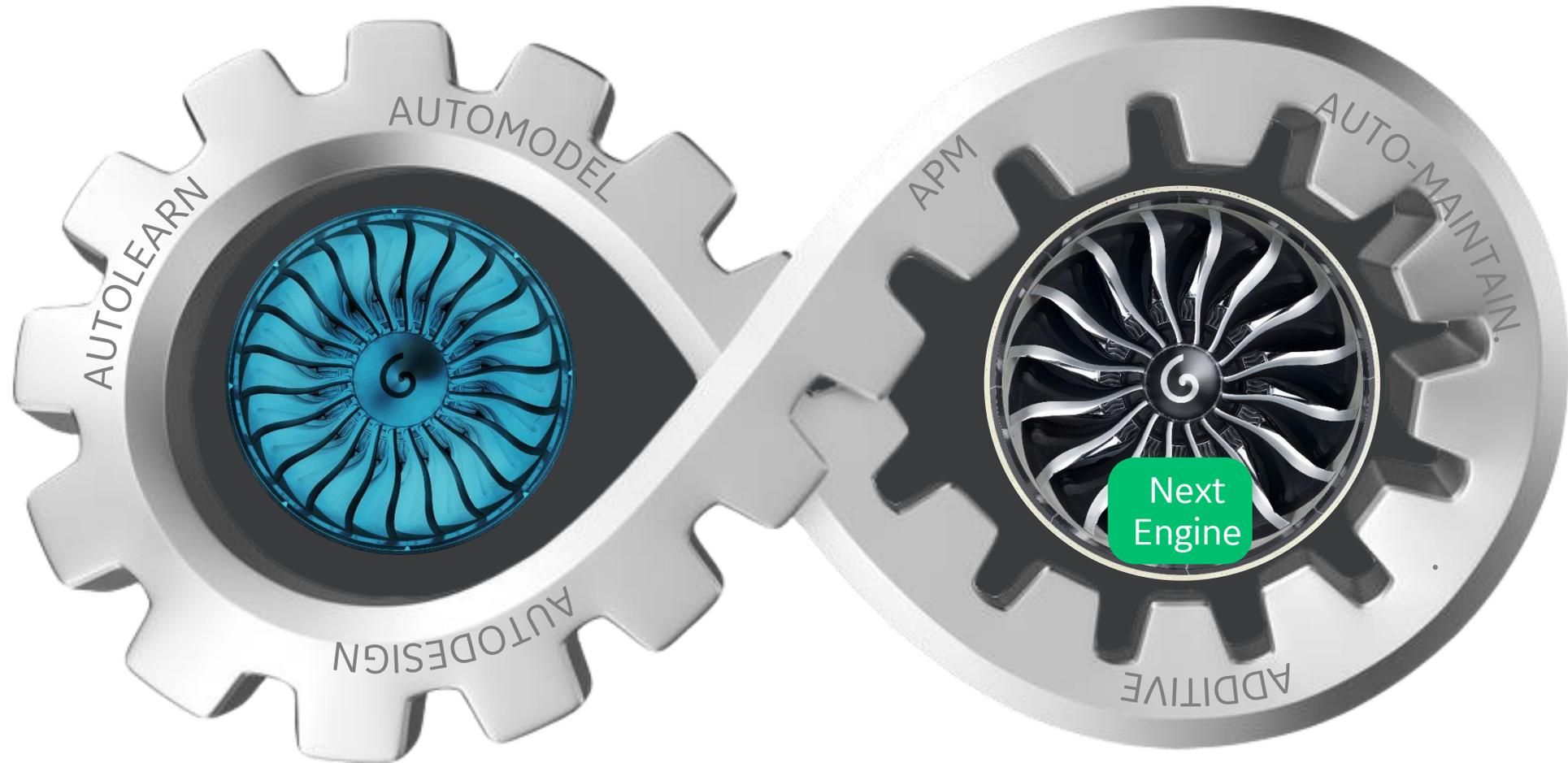
## Additive Manufacturing

- Print parts at the point of care
- Machines will be able to repair themselves

**These Trends Will Enable Trusted Autonomous Operations**



# Ultimate Vision - Immortal Machines



**Continuous linkage provides deep insights and optimized outcomes**

