Digital Technology supporting Nuclear Operation & Maintenance
Erin Joy, Director Digital Nuclear Services GEH
January 2018
125 years of innovation – making the world work better

World's 1st
Central power station
1882

World's 1st
X-Ray tube
1896

World's 1st
Turbo supercharger
1921

World's 1st
LEXAN Transparent plastic of unsurpassed impact resistance.
1953

World's 1st
CF6 Most popular wide-body aircraft engine family
1971

World's 1st
Signa MRI Soft tissue images
1983

World's 1st
World Record Composite fan blade Helps GE90 set Guinness record for most powerful jet engine
1995

1.5 XLE wind turbine Most reliable wind turbine
2008

World's 1st Predix Software platform for Industrial Internet
2013

Tier 4 locomotive First ever built to meet US emissions standard
2015

1879

Light bulb Commercially practical incandescent lamp

World's 1st

1896

Dow Jones Industrial Average Only original company still listed in index 121 years later

World's 1st

1941

Jet engine 1st U.S. jet engine flight

World's 1st

1957

Nuclear power 1st U.S. licensed nuclear power plant

World's 1st

1976

CT scanning World's 1st

World's 1st

1987

F-class gas turbine 1,700+ in operation today in 64 countries World's 1st

World's 1st

2003

Evolution locomotive Most efficient

World's 1st

2009

Vscan Pocket-sized ultrasound

World's 1st

2014

HA Gas turbine Guinness record for most efficient

World Record

2017

CFM LEAP engine Fastest-selling narrow body engine in history

Every 2 seconds a GE powered aircraft takes off

Everyday, GE is helping doctors save 3,000 lives

GE powers over 30% of the world’s energy

GE has remade itself multiple times
A Digital Industrial Company

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

2016 REVENUES

- **POWER**
  - Revenue: $26.8B
  - Employees: 57K

- **AVIATION**
  - Revenue: $26.3B
  - Employees: 45K

- **RENEWABLE ENERGY**
  - Revenue: $9.0B
  - Employees: 12K

- **OIL & GAS**
  - Revenue: $12.9B
  - Employees: 34K

- **HEALTHCARE**
  - Revenue: $18.3B
  - Employees: 54K

- **TRANSPORTATION**
  - Revenue: $4.7B
  - Employees: 10K

- **ENERGY CONNECTIONS & LIGHTING**
  - Revenue: $15.1B
  - Employees: 53K

Where GE operates

Countries: ~180
Employees: ~300,000

US: ~100,000
Canada: ~6,000
Latin America: ~25,000
Middle East, North Africa, Turkey: ~9,000
W Europe: ~74,000
E Europe: ~25,000
Africa: ~2,000
Russia & Commonwealth Independent States: ~2,000
Korea: ~1,000
Japan: ~3,000
India: ~18,000
ASEAN: ~8,000
Australia/New Zealand: ~2,000
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 ...

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 ...
Predix Platform
Faster development, operation and management
Industrial scale analytics
Machine-centric
Secure connectivity
Modular, cloud-agnostic approach

Business Optimization
Portfolio/Fleet

Operations Optimization
Plant/Facility/Train

Asset Performance
Asset

Unique or Niche Solutions & Applications

Industrial Performance Solutions
GE Power Digital Solution Map – Nuclear Specific Tools

**Exelon**

Asset Performance Management

*Nuclear Deployment:*
- 10 Units in 2017
- 12 Units in 2018

Intelligent Asset Strategy (IAS) Templates
- Feedwater
- Transformers
- Condensate System
- Reactor Recirc (BWR)
- Main Steam
- Reactor Coolant Sys (PWR)
- Pressurizer

**Enabling Platform**

**PREDIX**
- Mobility | Cloud Services & Applications | Security | Software Development Kit
- *Predix Edge* Optimizing Controls Applications | Edge Applications

**Lighthouse**
- *Nuclear Development:*
  - Beta Release June 2017
  - 2017-2018
  - User feedback improvements
  - Industry beta customer

**Plant Performance**
- Thermal Models
- Nuclear Start-up

**Cyber Security**
- Baseline | Defend | Prevent

**Refueling Outage Planning & Execution**
- *Nuclear Development:*
  - Eco-System Definition – 2016
  - MVP Definitions 1H-2017
  - MVP 1 Execution 2H-2017
  - Goals: reduce costs & schedule risk

**Digital Twin**

**GE Digital**
PREDIX
Asset Performance Management (APM)
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

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

March: Adv Pattern
Anomaly #1

May: Adv Pattern
Anomaly #2

June: Adv Pattern
Anomaly #5

June: Adv Pattern
Anomaly #6

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

May: Neural Net Alert
Anomaly #4

May: Machine Learning
Anomaly #3

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

Site Action = Late June
Case Management

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

![Image of Case Management software interface]

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

- **Analysis**

- **Scan Group Data**
  - PWIPA_FLOWCTRL_HIC27506_OP: 59.846
  - PWIPA_V02DEX: 3.024
  - PWIPA_PMCPRESS_HIC27508A_OP: 59.834
  - PUMP_EFFICIENCY.CV: 72.108
  - PUMP_SPECIFIC_SPEED.CV: 376.769

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Case Management

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

Identifies Which Analytic/Model Triggered the Alert

- 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
Asset Failure Modes

Failure Mode Risk / Impact

Amount of risk currently mitigated

Asset Failure Modes

Annual cost of the current Maintenance Strategy

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Failure Mode

Mitigation Actions

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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

Data Integration

- SCADA/Historian
- Oil Analysis System
- Gas Analysis System
- GE-SmartSignal
- PMI, Rounds,
- On-Line Doble
- EAM System

Anomaly Twin
- Predictive Analytics

Reliability Analytics

Health Monitoring

Failure Mode Status

Dynamic Risk Status

Failure Mode Tracking

Enterprise KPIs

Failure Modes and Effects
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.