POWERing 2016
The Digital Transformation of Electricity

www.ge.com/digital/power
At GE we consider ourselves a partner with our customers in the digital transformation of electricity. This is never more apparent as when we bring customers from around the globe to collaborate with our engineers and designers in the San Ramon, California Design Center.

The San Ramon office and Design Center has been host to over 580 industrial companies, 75 of which have been from world’s most prolific power producers. These include forward thinking innovators such as Exelon, PSEG and Chubu. Their commitment to understanding how digital can help them advance their business objectives and gain efficiencies and profitability is inspirational to our entire staff as we interact with them at the center.

If you have not yet experienced the excitement of working with our digital team at the Design Center, we invite you to schedule a visit, and hope that you will be similarly inspired.
The Future of Electricity Is DIGITAL

Digital is disrupting and transforming the electricity industry, challenging old models and creating unprecedented opportunities. Over the next decade, there will be ~$1.3 trillion of value to be captured in this transformation. With software and data analytics, combined with advanced hardware, new digitally-enhanced power generation will deliver greater reliability, affordability and sustainability, helping lower costs, improve efficiencies, create growth opportunities and lower carbon output.

As part of GE, GE Power Digital Solutions is the largest contributor of GE’s $5 billion digital portfolio. Launched in 2015, we are building on our 130-year-old foundation with new investments, new technology and new teams to help lead this transformation in the energy space as the digital industrial leader.

At GE, CEO Jeff Immelt is leading our own digital-industrial journey, from the way we work, to our products and solutions, to how we engage with customers. Now, with the addition of the Alstom software portfolio and new GE businesses, we are bringing new digital solutions that span the entire electricity value chain.

Our customers recognize the momentous change taking place in the industry and are seeking solutions and partners in the new age of digital. There are new and old competitors leveraging digital technologies, new policies creating new requirements and new business models that are challenging traditional revenue sources and creating new growth opportunities.

We invite you to explore our comprehensive portfolio of purpose-built digital solutions for our industry that span from Controls to Cloud. The portfolio includes a suite of software applications — our cloud-based Industrial Internet platform Predix, Advanced Controls & Edge Computing and Cyber Security solutions.

We want to be your partner in your digital transformation.

Ganesh Bell
Chief Digital Officer, GE Power
Our COMMITMENT

THE ELECTRICITY INDUSTRY IS UNDERGOING A RADICAL DIGITAL TRANSFORMATION, AND GE IS YOUR PARTNER

Our future realizes the goal of ubiquitous access to clean, reliable, sustainable and secure electricity, while fostering economic growth through the creation of a new energy ecosystem. The convergence of the digital and physical brings this within reach, and GE is your partner for this transformation:

• Edison would not recognize our world today. GE has been innovating across power generation, transmission and distribution for 100+ years. Today GE is still building solutions aligned to market dynamics — intermittent renewables, the need to improve sustainability and resiliency, consumers becoming producers (“prosumers”).

• The energy industry has one of the largest opportunities for digitization. GE equipment powers 25% percent of the world. Utilities with these assets are forecast to spend $90B on Industrial Internet by 2020.

• Data & analytics enable transformation. With more than 13,000 power engineers and data scientists, GE Power has more than 5,000 patents, and offers digital solutions built with deep domain expertise. GE monitors 50 million data points and 10 million sensors, delivering $1 trillion in value to the industry.

At the end of 2015, validated by market momentum, we took a step forward in supporting the entire electricity value chain. We formalized the GE Power Digital Solutions business in conjunction with GE Digital, a strategic move to unify all current software and analytical capabilities.

Our mission is to be the strategic partner of choice for our customers to derive new value, new insights, new revenue and business models from digital assets. A digital company can’t do this. An industrial company can’t do this. Only a digital industrial company can do this.

>7B connected devices producing ~25 exabytes of data per year

GE Monitors:
50MM Data Points
10MM Sensors
$1TN Asset Value

100+ Years Energy Experience
> 25% or 1.5 TW of World's Electricity
> 13,000 Power Engineers & Data Scientists
> 5,000 Patents
By 2020, costs of sensors down ~ 50%
3,100 sensors & actuators in HA plant
The Path to Digital TRANSFORMATION

As with any innovation, there will be early adopters who will forge the path forward, testing the limits of new technology, proving components that offer benefits and dispensing with those that don’t. Each power organization will be approaching the use of data and analytics from their own point of reference, technology maturity and propensity for change. However, there exists a clear ground swell of sentiment that digital is the way of the future, with a stunning 94% of power generation executives believing that it will transform their industry in the coming year.

For most organizations the introduction of digital starts with attaching and monitoring core assets. In fact, many organizations have been performing asset level monitoring with point solutions, for some time. Taking the next steps to consolidate and manage data across plants and fleets, applying analytics to gain insights, implementing predictive analytics and optimizing performance is where the industry is focused in 2016. Understanding where to begin, next steps and mapping the course to digital success requires working with a partner who shares this vision, can support it with appropriate solutions today and has a roadmap for innovation growth in the future.

Connect — Provides the foundation to leverage analytics by enabling the collection of machine sensor data from assets and processes data, as well as management of that data to derive value.

Monitor — Focuses on understanding the performance and health of your assets and processes, and visualization of events.

Analyze — Determines the root cause of issues based on historical and real-time data to understand relationships, correlations, and trends, and facilitates effective problem resolution.

Predict — Provides foresight into impending problems to avoid issues before they occur and drives greater process consistency and asset uptime.

Optimize — Maximizes the performance and profitability potential of assets, plants and fleets to achieve the best possible outcomes. Allows simulation modeling to test “what if” scenarios.

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1 Source: “Industrial Internet Report for 2015” GE and Accenture
THE DIGITAL FOUNDATION

DIGITAL Power Plant

To help customers realize the potential of digital, GE has developed the concept of the Digital Power Plant (DPP). The DPP is grounded in a set of technologies and software that meet customers where they are today in their adoption of digital, and provides the environment to innovate and grow in both sophistication and breadth of solutions.

“We have to look to innovation in emerging technologies.”
— Mike Kurzeja, Emerging Technology, Exelon Corporation

Challenges Facing Power Leaders

Power generation leaders are facing significant challenges with the introduction of renewables, variable fuel costs and an aging workforce. Automation holds the key, but data is not currently leveraged across silos. Significantly, less than 2% of data is captured and that is primarily done in spreadsheets. The inability to identify a pending issue early, the level of operator errors due to unguided actions, energy that is never reaching the consumer, results in a shortfall of nearly $10B annually to the power industry.

Efficiency/heat rate of power plants unchanged since 2003
Failures in generation that can be predicted
40%

Abnormal events that can be attributable to operator error
Central generation still a mainstay in 2025
95%

Energy produced that never reaches the consumer
Annual amount of lost production cost. Unexpected disruptions cost ~8% of capacity
8%

$10B

$230MM* for new plant

$50MM* for existing plant

$75B** in industry value today

*Value of digital power plant over life for an average 500MW plant
** Based on GE estimate calculations of average value per plant site
To address these issues and to enable power leaders the opportunity to increase profitability from machine data and analytics, GE developed the DPP, delivering capabilities in the following areas:

**Software Defined Machines:** Unlike traditional operations machines, where applications for that equipment were built into firmware and notoriously difficult to connect to the Industrial Internet, new breeds of assets autonomously connect to the Industrial Internet, execute native or cloud-based machine applications, analyze collected data and respond to changes in that data.

**Predix™, the Cloud Platform for the Industrial Internet:** GE’s platform for the Industrial Internet, combines best of breed technologies for massive data ingestion, analytic modeling and execution, asset libraries and a sophisticated User Interface (UI). Predix machine is an on-site gateway for data cleansing and communications and for executing analytics at the edge, required for near real-time response. This environment was industrial built to manage the data and analytics required for power companies to gain operational benefits and action-based recommendations.

**Digital Twin:** An organized collection of physics-based methods and advanced analytics used to model the present state of every asset in a Digital Power Plant. GE applications use the Digital Twin to model solutions, execute “what if” scenarios and to drive outcomes based on analytic models that mirror and predict the functions of the physical assets.

**Suite of Applications:** Leveraging data from software defined machines and the GE Digital Twin, a complete set of applications designed to improve asset performance and reliability, to increase operation efficiency and to give power business leaders insights that allow them to make more profitable decisions.
GE Digital Twin is an organized collection of physics-based methods, advanced analytics, enabling technologies and new sensor technologies that are used to model the present state of every asset in a Digital Power Plant. The models start by providing guidance on “design limits” of a power generation unit at the commissioning stage or inferring the design limit for an existing plant/fleet by matching the equipment to thousands of other similar equipment in the database.

Included in the Digital Twin models are all necessary aspects of the physical asset or larger system including thermal, mechanical, electrical, chemical, fluid dynamic, material, lifting, economic and statistical. These models also accurately represent the plant or fleet under a large number of variations related to operation — fuel mix, ambient temperature, air quality, moisture, load, weather forecast models, and market pricing. Using these Digital Twin models and state-of-the-art techniques of optimization, control, and forecasting, applications can more accurately predict outcomes along different axes of availability, performance, reliability, wear and tear, flexibility, and maintainability. The models in conjunction with sensor data and sophisticated artificial intelligence techniques, give the ability to predict the plant’s performance, evaluate different scenarios, understand tradeoffs, and enhance efficiency.
Enabling Technologies: A combination of deep physics insights, engineering design knowledge, new inspection technologies and the latest artificial intelligence and analytics experience deliver a Digital Twin of unprecedented fidelity. This powerful combination of digital plus industrial provides the core strength to enable the GE Digital Twin.

<table>
<thead>
<tr>
<th>Technology Category</th>
<th>Function</th>
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<tbody>
<tr>
<td>Pattern Recognition</td>
<td>Pattern recognition capabilities contribute to developing the behavioral Digital Twin of an asset by using various sources of measurement data collected over-time. Early stage pattern recognition allows advance warnings of impending failures, combined with an assessment of the remaining useful life of the asset/component of interest. Pattern Recognition techniques are extensible to multi-modal data such as time-series data, machine-log data, text data and image data, all or any of which can be processed to learn maximum information about the system to build a digital model.</td>
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<tr>
<td>Learning Models</td>
<td>A critical component of the GE Digital Twin is its proprietary modeling platform within which twins of assets are continuously created, validated, monitored, and updated at a speed close to real-time. New data flows in from operational assets in real-time providing a constant window to the instantaneous state of the asset. This data is appropriately preprocessed to improve the signal-to-noise ratio of the relevant information and used to appropriately update the digital model to minimize differences between the physical and the digital personas of the asset. Model performance is used as feedback in Model Updating, where continuous learning technology is used to provide a stream of refinements to the Digital Twin.</td>
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<tr>
<td>Unstructured Data Analytics</td>
<td>Artificial Intelligence (AI) technology is addressing the massive amounts of unstructured data that enterprises must deal with in the lifecycle of a part and asset. It is estimated that 80% of all data will continue to be unstructured, and AI enables machines to read and understand diverse data, connecting to common and shared semantics, and finding mistakes and quality issues that can be automatically correctly.</td>
</tr>
<tr>
<td>Multimodal Data Analytics</td>
<td>The GE Digital Twin is able to handle data from multiple modalities (Ex: temperature, pressure, Raman spectroscopy, Infrared imaging, visible light cameras) in a seamless and efficient way, delivering best-in-class performance using the latest fusion techniques. These include Deep Learning, Ensembles, Bayesian methods &amp; Knowledge Representations, used to combine information from different modality and provide new information not possible from each individual source.</td>
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<tr>
<td>Knowledge Networks</td>
<td>Knowledge Networks complement the traditional social networks within an enterprise because they are ‘purpose’ and ‘task’ driven: best practices can quickly be identified, shared and then digitized for others. Using GE’s unique Knowledge Network capability, experts can easily enter the type of goal they are working toward and find other experts doing the same.</td>
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</table>

Next Generation Sensor Technologies: A high fidelity Digital Twin requires high fidelity sensor data. GE is continuously working to apply next generation sensing technologies to gather data from difficult or harsh environments.

<table>
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<th>Technology Category</th>
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<tbody>
<tr>
<td>New Sensor Application</td>
<td>Compressor rotor health assessment uses magnetic sensing technologies to monitor blades as they are moving at supersonic speeds. It leverages new technology to estimate blade vibration and resonance in real-time to provide estimates of individual blade health. Compressor stator vane health uses high frequency structure borne sound (acoustic emission) to monitor cracking, leaks, rubs and clashing in compressor blades. This technology generates 50 MM samples of data per second and GE employs high frequency data analytics to process this data to build a Digital Twin for monitoring stator vanes.</td>
</tr>
<tr>
<td>Printed Sensors for Creep Detection</td>
<td>A major failure mode that challenges the life of assets is Creep. GE’s solution to this failure mode includes installation of Lifesight creep sensors. These sensors are wire free strain creep measurement devices that are permanently printed to the part surface and scanned for strain measurements. Each sensor is unique with its own bar code.</td>
</tr>
<tr>
<td>Embedded Corrosion Sensors</td>
<td>Often local conditions are prevalent that would cause corrosion issues difficult to predict on a global scale. GE’s compressor corrosion rate sensor displays real time corrosion rate changes and responses to atmospheric and operational changes from a location inside an asset.</td>
</tr>
<tr>
<td>Atmospheric/Weather</td>
<td>Aqueous corrosion in the compressor and hot corrosion in the turbine section is prevalent in coastal and industrial areas. GE has developed a global database of key atmospheric factors in order to manage these failure modes. Many of these factors affect turbo-machinery: SOx, gas, sulfate aerosols, sea salt aerosols, dust, volcanic ash, soot, organic aerosols, humidity, temperature, pressure, wind speed and direction.</td>
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GE POWER Digital Offerings

With a focus on important outcomes that drive our customer’s Key Performance Indicators (KPIs), we have developed a comprehensive set of integrated solutions that meet our customer’s needs where they exist today and help them develop their roadmap for the coming years. These solutions ensure our customers are well prepared to meet their profitability goals with greater reliability, more efficient operations, more profitable dispatch and trading profiles, all operating in a secured and scalable environment.

**CUSTOMER OUTCOMES***

- **3%↑** Fuel Efficiency
- **2%↑** Output
- **5%↓** Unplanned Downtime
- **25%↓** O&M Costs
- **20%↓** Less Fuel on Starts

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**Asset Performance Management:** Transform machine sensor data into actionable intelligence by combining with robust analytics and domain expertise to provide predictive maintenance towards no unplanned downtime. Create the optimal maintenance schedule for increased asset life and use, by moving to a condition-based program for machine repairs.

**Operations Optimization:** Gain enterprise visibility across power plant and fleet-wide footprints, providing a holistic understanding of the operational decisions that can improve efficiencies, reduce emissions, expand capabilities and lower production costs.

**Business Optimization:** With GE’s intelligent forecasting, portfolio optimization and trading, operations teams can make smart business decisions that reduce financial risk and maximize the profitability of the fleet.

**Cyber Security:** GE’s advanced defense system is designed to assess system gaps, detect vulnerabilities, and protect your critical infrastructure and controls in compliance with cyber security regulations.

**Advanced Controls / Edge Computing:** Leverage data and analytics to manage grid stability, fuel variability, emissions, compliance and other challenges that impact machine performance. Execute fast starts and efficient cool-downs to meet dispatch and market demands.

**Predix:** GE combined cutting-edge technology with decades of industry experience to create a Platform-as-a-Service (PaaS) that securely ingests machine-grade data at scale and analyzes it to deliver outcomes for industrial customers.

*Representative customer outcomes are not guarantees of results.*
### GE Power Digital Offerings Drive Real Results

<table>
<thead>
<tr>
<th>Offering</th>
<th>Real Customer Results</th>
<th>Customer Benefits</th>
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<tbody>
<tr>
<td><strong>Asset Performance Management</strong></td>
<td>$10 MM/year from early detection failures and reduced insurance costs</td>
<td>• Improve reliability with advanced proprietary analytics that predict potential equipment failure to effectively plan maintenance</td>
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<td></td>
<td></td>
<td>• Improve availability — accurate diagnosis of equipment issues toward no unplanned downtime</td>
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<td>• Reduce maintenance costs — customize maintenance strategy to reduce maintenance activity</td>
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<tr>
<td><strong>Operations Optimization</strong></td>
<td>Enabled load ramping up to ±50 MW/min, 2.5 times the normal rate, allowing quick response to market demands in ancillary markets</td>
<td>• Additional economic insight into maintenance decisions based on plant operations</td>
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<td>• Higher accuracy in communicating commitment to trader and dispatcher</td>
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<td></td>
<td>• A component-level view of the impacts to fuel efficiency</td>
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<tr>
<td><strong>Business Optimization</strong></td>
<td>Predicted availability 2-3% more accurately — offers trading team the option to bid additional capacity into the market</td>
<td>• Real-time transparency to power production grants additional MW to sell</td>
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<td></td>
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<td>• Avoiding penalties by making offers with confidence to meet delivery commitments</td>
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<td></td>
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<td>• Accurate and profitable fuel purchasing decisions based on data-driven analytics</td>
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<td></td>
<td>• Real-time insights into financial KPIs for executives, traders and plant managers</td>
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<tr>
<td><strong>Advanced Controls / Edge Computing</strong></td>
<td>10% increase in output capacity 2% increase in fuel efficiency Achieved both through AGP flange to flange replacement and GE Advanced Controls / Edge Computing software solution</td>
<td>• Deliver power quickly in response to changing grid demands</td>
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<td>• Eliminate slow, inefficient start-ups and reduce start-up costs</td>
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<td>• Meet more demand within existing markets to increase revenues</td>
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<td></td>
<td></td>
<td>• Manage variable fuel sources with smoother power output</td>
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<td>• Reduce emissions to meet compliance standards</td>
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<tr>
<td><strong>Cyber</strong></td>
<td>Implemented intrusion detection as “hot” install, with no operations impact</td>
<td>• Reduce risk from cyber-attack on key assets, SCADA/ICS systems, and network infrastructure</td>
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<td></td>
<td>Provided immediate visibility to guard against ongoing BlackEnergy malware attack</td>
<td>• Proactive identification of critical vulnerabilities and security events</td>
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<td>Brought the environment within NERC CIP compliance</td>
<td>• Improve operational reliability and reduced risk in business continuity</td>
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<td>• Regulatory compliance for NERC CIP</td>
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<tr>
<td><strong>Predix</strong></td>
<td>Monitored 2,300+ assets across an LNG plant, with full plant-level visibility, enabled with Predix.</td>
<td>• Begin digital transformation by attaching and monitoring major plant assets to the Industrial Internet.</td>
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<td>• Expand to balance of plant assets and grow data using Predix platform to accommodate growth</td>
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POWER Digital Solution Architecture

**Inputs, Functions, Personas and Results**

### Data Inputs
- **EXTERNAL DATA**
  - GT MWhrs Life vs. Base Load
  - Dynamic Fleet Performance Insights

- **ENTERPRISE DATA**
  - Contracts
  - MCM
  - EHS
  - ERP
  - SCM

- **MACHINE & EQUIPMENT DATA**
  - Sensors
  - Controls
  - Fuel Use
  - Plant Profiles

### Software & Analytics
- **Business Executive**
  - Market Intelligence & Forecasting*
  - Fuel Nominations*
  - Portfolio Optimization*

- **Trader**
  - Market Intelligence & Forecasting*

- **Operative Executive**
  - More Profitable Bids/Offer
  - Improved Fuel Purchasing Decisions
  - Better Schedules Based on GT MWhrs Life vs. Base Load
  - Dynamic Fleet Performance Insights

### Recommendations, Outputs & Actions
- **BUSINESS OPTIMIZATION**
  - Market Intelligence & Forecasting*
  - Fuel Nominations*
  - Portfolio Optimization*

- **PROFITABILITY**
  - More Profitable Bids/Offer
  - Improved Fuel Purchasing Decisions
  - Better Schedules Based on GT MWhrs Life vs. Base Load
  - Dynamic Fleet Performance Insights

- **OPERATIONS OPTIMIZATION**
  - Operations Evaluation
  - Plant Optimization
  - Outage Planning*
  - Emissions & Regulatory*

- **PRODUCTIVITY**
  - Reduced Fuel Consumption
  - Increased MW Capacity
  - Lower Operating Costs
  - Lower Emissions
  - Dynamic Plant Flexibility

- **ASSET PERFORMANCE MANAGEMENT**
  - Machine & Equipment Health
  - Reliability Management
  - Maintenance Optimization*

- **RELIABILITY**
  - Reduced Unplanned Downtime
  - Proactive Issue Identification
  - Improved Outage Planning
  - Reduce Maintenance Costs

### Predix Platform
- Advanced Controls/Edge Computing
- Cyber Security

* Scheduled for launch in 2016
Reliability & Availability

**Bord Gáis Energy**

The 445-megawatt Whitegate gas combined-cycle power plant, owned by Bord Gáis Energy, provides power to 10% of Ireland. The implementation of GE’s APM, Advanced Controls / Edge Computing and Predix platform reduced plant downtimes and balance of plant operations costs.

- **€0.08 MM cost savings**
  - Supplementary firing gas flow
  - Condensate extraction pump
- **€2.20 MM cost avoidance**
  - Actual power station turning gear
  - Projected turning gear failure over plant life
- **€2.28 MM cost reduction & avoidance over 1st year**

**Emissions Control**

**Mainova AG**

Mainova AG, one of the largest regional energy suppliers in Germany, is now able to run their gas turbine at competitive levels, leading to a more profitable position in the market. They also now have the ability to set emissions limits and let the turbine control maximum performance within those limits.

- **60% turndown to 40% load**
- **110% emissions compliant peak load**
- **2% fuel savings during part load operation**

**Productivity**

**PSEG**

PSEG improved performance with GE’s Operations Optimization solution, an integrated view that puts the plant manager and their trading counterpart on the same page. Automatic notifications alert the plant manager to any operational anomalies in order to prevent risky operations. Cloud-based visibility, insights and actions keep leadership focused on achieving their continuous improvement initiatives including identifying opportunities to improve thermal performance, increase operational flexibility and reliability.

- **Achieved top quartile in heat rate and reduced production costs**
- **Minimized fuel start costs**
- **Improved reliability by 1%**
- **Year 1 = $2MM Value**

**Profitability**

**E.On**

E.On, one of the UK’s leading power and gas companies, demonstrated 40% faster and 50% less costly combined cycle plant starts with GE’s Advanced Controls / Edge Computing Solutions, resulting in up to 60% more operating hours and starts compared to non-upgraded plants. The solution has been proven in operation on more than 10 units at 5 different sites since 2013, with more than 20,000 cumulative hours and 1,000 starts through December 2015.

- **40% faster combined cycle plant starts**
- **50% less costly combined cycle starts**
- **60% more operating hours and starts over plant without GE solution**

**Security**

**One of USA’s largest power generators with > 50 power plants**

One of the country’s largest generators of electricity from natural gas and geothermal resources, with > 50 power plants, implemented GE’s OpShield solution to detect anomalies in their OT network in order to reduce their exposure to malware, such as BlackEnergy.

- The solution demonstrated the ease of a “hot” install, granting the utility immediate visibility into their OT network to baseline “normal” traffic and establish policies that would highlight anomalies. The set of capabilities brought the environment within NERC CIP compliance, a major goal for the customer.
DIGITAL SOLUTION DESCRIPTION

ASSET PERFORMANCE MANAGEMENT

BUSINESS CHALLENGES

The power industry faces a complex set of market dynamics and emerging disruptive forces to the operating environment — volatile fuel prices, growing renewables, changing workforce, and shrinking budgets. There’s hope in data and analytics, but power operators still face significant barriers that make it difficult to use this data to business advantage. Information and people work in silos, and operator capacity is limited to analyze data that is collected. Moreover, traditional operations consist of multiple systems, each designed to measure and monitor singular machines or small groups of equipment. There has not been the ability to consolidate and provide that “single pane of glass” that operations management and staff need to see how operations are performing — holistically — across the plant and across multiple plants. Today’s operators face:

• Disconnected and conflicting data across assets, sites, regions
• A lack of asset level visibility — not knowing in advance when problems are about to occur
• Unplanned downtime with lost productivity and high cost of emergency repairs
• Costly and often unnecessary routine preventive maintenance that introduces risk and decreases availability
• High spare parts inventory levels for emergency repairs
• Loss of institutional knowledge as the existing workforce approaches retirement
• Delay in critical information reaching those that need to take action — maintenance technicians, operators, etc.

SOLUTION DESCRIPTION

APM is a software application designed to increase asset reliability and availability while reducing maintenance cost. APM connects disparate data sources and uses advanced analytics to turn that data into actionable insights while fostering collaboration and knowledge management across the organization. A commercial cloud solution, built on the Predix® platform, APM also gives organizations the flexibility to develop new analytics and applications, making it adaptable to meet changing needs.

Real Customer Results*

7500+ assets monitored
$3M+ financial benefit in one year
£6MM per year insurance savings

Combined -Cycle Plant Systems

<table>
<thead>
<tr>
<th>EQUIPMENT TYPES</th>
<th>Steam Turbine</th>
<th>Boiler Feed Pump</th>
<th>Generator</th>
<th>Condenser</th>
<th>Feed Water Heater</th>
<th>Transformer</th>
<th>Dewatered Pumps &amp; Fluid Transport</th>
<th>Control Valves</th>
<th>Gear Boxes</th>
</tr>
</thead>
<tbody>
<tr>
<td>BALANCE OF PLANT</td>
<td>X</td>
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Machine and Equipment Health

Providing a unified, complete and accurate view of the asset, it’s state, status and health.

• Connectivity: Gives users immediate visual reference of the status of various plants across geographical locations
• Condition monitoring: Uses sensor analysis, anomaly detection & KPIs to present current operating state & health of assets

Reliability Management

Predicting and accurately diagnosing issues and responding before they negatively impact assets.

• Analytics orchestration: Enables users to combine various analytic techniques for additional derived value (reduced false positives, automated root cause analysis, etc.)
• Analytics catalog: Provides analytics (detection, predictive, forensic, performance, etc.) in a SaaS/PaaS structure, enabling both use of and contribution to an analytics marketplace
• Configurable workflow: Links APM functionality to pre-configured and user-designed workflows, enabling and enhancing customers business process logic

Maintenance Optimization*

Balancing reliability, availability, performance and costs against risk to maximize the value of the asset.

• Asset maintenance strategy: Recommends modifications to preventative maintenance strategies for optimal utilization of assets based on budget and reliability risk constraints
• Financedly optimized strategy: Provides recommendations on maintenance strategies based on operational priorities of cost, performance, and design basis requirements
• Performance benchmarking: Compares “like” assets and “digital twins” to identify opportunities for improved performance

*Customer results are not indicative of guaranteed outcomes.

* For 2016 release.
### CUSTOMER BENEFITS

#### Overall APM Benefits
- **Improve reliability** — Advanced proprietary analytics that predict potential equipment failures with enough lead time to effectively plan maintenance.
- **Improve availability** — Accurate diagnosis of equipment issues that enables faster repairs and shorter outage duration.
- **Reduce maintenance costs** — Customized maintenance strategy that increases plant reliability while reducing the amount of maintenance activity performed overall.
- **Maintain technical expertise** — A unified and accurate view of assets that provides clear guidance to next occurrence as well as asset history, accessible through an intuitive user interface.
- **Deliver continuous improvement** — Build ecosystem that speeds the process by which new analytics are created, enabling operators to draw insights more quickly and drive action.

**Machine and equipment health delivers:**
- Visibility of machine status and issues anytime, anywhere.
- Better decision-making through a single source of truth that crosses organizational silos.
- Wing-to-wing story that brings together real-time data, alarms, events, and other operational data to get a clear picture of asset performance.

**Reliability management helps customers:**
- Reduce unplanned downtime by predicting equipment issues before they occur.
- Collaborate efficiently on issues while automatically capturing best practices.

**Maintenance Optimization will help customers:**
- Develop better maintenance strategies that balance reliability, performance and costs.
- Improve their ability to respond to market conditions as prices, demand and costs fluctuate.

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### DIGITAL SOLUTION DESCRIPTION

#### OPERATIONS OPTIMIZATION

#### BUSINESS CHALLENGES

With the impact of renewables in the electricity mix, volatile fuel prices, and the emergence of competitive markets globally, today’s power generation fleet is expected to run differently than it was originally designed. Understanding the true capacity, output, and performance of a single power plant is hard enough but it’s nearly impossible to scale across an entire fleet. Executives must prioritize new investments in alignment with the best business opportunities which often entails changing the operating model of parts of their fleet. Plant managers focus on meeting daily operations within budget and frequently maintain a buffer zone in their operating model to reduce risk. If the head of operations can’t see the real availability of a plant to meet demand, then money is left on the table. Aiming people with the right data and powerful analytics can improve the return on existing assets and deliver smarter operational results over time.

#### SOLUTION DESCRIPTION

Operations Optimization is designed to help power generators tackle operational issues, meet business demand, align people and systems, and reach “true” plant capacity while still reducing cost and downtime. Operations Optimization isn’t just about expanding current plant capacity—it’s about redefining the future. Now power generation leaders can align operation priorities to business strategy at scale across their fleet, regardless of generation source. Whether the fleet has a portfolio of steam plants like coal, biomass, nuclear or plants that run gas, liquid fuel or renewable sources such as wind or hydro, Operations Optimization delivers results regardless of OEM.

Operations Optimization delivers proactive recommendations by analyzing internal plant data, historical operational data, or external information in order to inform key resources, reduce production costs, and enhance plant flexibility. From plant managers to CEOs, every level of operations can tap into consistent visibility across systems, giving them the insight to act towards operational excellence in compliance with standard regulations and emissions goals.

Operations Optimization is a cloud-based suite that provides Key Performance Indicator (KPI) focused analytics to multiple levels of the customer’s organization. This enables a consistent view of operations, allowing better and faster decision making. It’s built on credible data and advanced analytics, and improves the performance of power plants. Operations Optimization not only shows organizations where they’re performing today, but provides recommendations on operational changes that will influence a more positive outcome over the long term.

**Real Customer Results***

- **2–3% MW output improvement**
- **Up to 3% improved fuel efficiency**
- **Up to $2MM per day in outage reduction**

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### Operations Evaluation

It is imperative for the executive team to align the organization from the boardroom to the plant and drive to strategic objectives. Operations Evaluation provides high-level performance metrics with assignable targets and alarm levels to drive improvements in thermal performance, operational flexibility, and system reliability in order to achieve an overall improvement in return on assets.

**Operations Evaluation Functions Delivered:**
- Performance indicators can better understand the current operating conditions of the fleet in order to align to operating models and business objectives such as thermal performance, operational flexibility, and system reliability to drive improvement.
- Benchmarking can establish and compare ‘ideal’ baselines for performance, availability, reliability, dispatch, emissions and financial performance. This visibility into (near) real-time operations of each plant compared to expected operating conditions or to similar plants in the fleet help central operational teams make better decisions across the entire system.

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*Customer results are not indicative of guaranteed outcomes.

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**GE Asset Performance Solutions give us a heads up on potential problems coming down the pike. We use it to see anomalies before they become alarms; before they become critical issues.”**

— Mike Hartzig, Plant Manager, Griffith Energy
Plant Optimization

To achieve operation excellence, headquarters needs to optimize the portfolio and improve select KPIs for plants that are operating below the business need. Plant Optimization provides the inputs and decision making analysis that could improve production, reduce heat rate and increase operating margin. Plant Managers can achieve production targets and help the plant run more often and improve the company’s return on assets with more accurate offerings that account for operating costs including cycle efficiency, uptime, flexibility and start costs.

Plant Optimization Functions Delivered:

- Thermal Performance helps central operations increase production, improve heat rate and manage operating margins across the fleet. Plant Managers can prioritize workloads and maintenance plans to help them meet or exceed production goals and costs, such as fuel consumption.

- Operational Flexibility provides insights that help Plant Managers identify optimal configuration, process, or operational settings of each major component within the plant to provide better ramping and dispatch options, reduce fuel burn and improve efficiency, especially when the plant is operating at less than full load.

- System Availability shows opportunities for the plant to run more often and improve the company’s return on assets with more accurate dispatch offerings at lower operating costs including cycle efficiency, uptime, flexibility and start costs.

- Dispatch Optimization determines the best configuration to achieve dispatch targets including start up, ramp, and operating costs, and meet or exceed margin goals.

Outage Planning*

Managing outages effectively is the name of the game for Outage Planning. Every day that is removed from an outage duration for a nuclear or coal plant, or just one combined cycle gas turbine (CCGT) could save an organization up to $2MM per day. Improving field service productivity for a wind turbine generator (WTG) could be worth $600K,000 annually. By selecting the best time and conditions for a planned outage, an organization can reduce the risk of failures or expensive events and better manage overall maintenance costs. Occasionally, an organization must evaluate the risks and costs of decommissioning a new plant or reduce scope and decommission a plant.

Outage Planning Functions Delivered:

- Outage Decision Analysis helps a Plant Manager and Outage Planner reduce the length of the outage as well as coordinate and complete the right activities that will potentially prevent failures, avoid unplanned events and reduce downtime before the next planned outage.

- Maintenance Event Management provides an Operations Manager and Outage Planner guidance for outage plans in order to get in order to get more value out of parts in inventory without voiding warranty or putting the plant operations at risk. It can identify the best timing for a planned maintenance outage based on past and current operational paradigms and ‘Lifting Credit Calculations’.

- Commission and Decommission Planning enables managing the steps, work scope and schedule associated with commissioning or decommissioning a plant.

Regulatory & Compliance Management Functions Delivered*

- Emissions Management & Reporting helps Operations Managers to monitor emissions output in compliance with regulatory mandates and saves time in producing necessary reports for audits.

- Emissions Optimization enables the Plant Manager to improve plant configurations, operating controls and parameters in order to reduce controlled emissions.

Customer KPIs Addressed by Operations Optimization

**Performance**
- Full Load MW (Actual vs Predicted)
- Full Load Heat Rate (Actual vs Predicted)
- Full Load ISO Corrected Output
- Full Load ISO Corrected Heat Rate

**Reliability**
- Commercial Availability
- Equivalent Forced Outage Rate
- Equivalent Availability Factor
- Starting Reliability

**Capability**
- Turndown
- Ramp Rate
- Start-up Time (2x1, 1x1, 1x0, etc)
- Start-up Fuel (2x1, 1x1, 1x0, etc)
- Area Regulation Performance

**Dispatch Optimization**
- Predicted Heat Rate vs Ambient Temperature
- Predicted Output vs Ambient Temperature
- Incremental Capability with incremental cost
- Projected Fuel Spend — Fuel Actual

**Customer Benefits**
Operations Optimization helps customers:

- Improve productivity across the fleet with fact-based actions that align to KPIs
- Compare plant performance to historical or to other plants to determine trends, allowing power executives the opportunity to influence change
- Gain operating insights including root cause analysis and system and plant-level diagnostic tools
- See recommended actions and model the impact before changes are made

“Operations Optimization provides us with visibility and the insights to our KPIs and allows us to look at the actions that will improve performance at lower costs.”

— Richard Lopriore, President of Fossil Generation, PSEG Power

Operations Optimization Applicability:

- Gas Fossil
- Steam
- Wind
- Nuclear
- Hydro
DIGITAL SOLUTION DESCRIPTION

BUSINESS OPTIMIZATION*

BUSINESS CHALLENGES
Operating silos between the generation and the trading organizations in power companies results in negative financial impacts. Additionally for commercial operations teams in organizations that trade power and fuel there is rarely real-time visibility into the productivity potential of the plants. Beyond these internal issues, renewables integration is leading to significant fluctuations in the reliability of the grid causing more cycling of fossil plants and changing of operating profiles.

With missed opportunities from inefficient capacity planning, suboptimal fuel purchases and ill-timed maintenance windows, the bottom line takes a hit and a power producer can become a price taker as smarter, more competitive organizations leverage data and analytics to solve these issues and become the price setters.

What is needed is a more accurate way to predict output capacity and improve operating insights to intelligently make dispatch and trading decisions for the most financially positive outcomes possible. GE’s Business Optimization solutions bring the ability to forecast both plant capability and market trends to lead to production with refined accuracy, resulting in incremental revenues and margin.

SOLUTION DESCRIPTION
Business Optimization is a cloud-based suite designed to help power producers to take full advantage of predictive analytics to make improved decisions around power trading, fuel purchases and portfolio management. The solution is comprised of the following three modules:

Market Intelligence & Forecasting — Forecast plant capability and market behavior to maximize revenue
- **Power Forecasting:** Assess future MW and duct burner capability, heat rates and potential fuel burn of power plants based on ambient conditions for day ahead and real time operations and trading
- **Availability Calculator:** Create optimal balance between asset life and profitable offer strategies. Visibility and insight solution that allows GE customers to make short and long-term decisions to increase plant profitability. The GE Digital Twin dynamically reviews the operation of the GT’s to adjust operating conditions and key set points that permit banking of MWhrs during turn down market conditions. The GE Digital Twin monitors the customer outage time line, ensuring that the future outage date will not change, while delivering the visibility to the maximum total available output between intervals.
- **Fuel Price Forecasting:** Project fuel prices (Gas, Coal) for use in power plants to optimal commitment and fuel/power purchasing decisions.

Portfolio Optimization — Schedule the portfolio for optimum profitability
- **Optimal Scheduling:** Allow traders to dispatch units in the portfolio according to the economic factors to meet the demand set by load and market prices for bids and offers
- **Optimal Outage Planning:** Based on predictive and conditioned based maintenance, market production needs and asset life considerations, schedule optimal timing of planned outages to improve revenue

CUSTOMER BENEFITS
- **Real-time transparency to power production levels** by block for additional MW to sell, generating greater revenues
- **Avoiding penalties** by making offers with confidence that can meet delivery commitments
- **Accurate and profitable fuel trading and purchase decisions, based on data-driven analytics**

**Contract Optimization, Storage Optimization:** Optimize long-term power & fuel contracts and storage against constraints of market forecasts, production expectations and projected fuel costs, and power demand, and transportation and transmission constraints.

- **Achieve balance between banked MWhrs and profitable offers based on availability**
- **Gain an understanding of real-time portfolio dynamics and financials, leading to improved planning capabilities, with dynamic historic and operational data**

**Up to $1MM annual revenue increase with additional power sold based on time-of-day demand and market prices**

* Business Optimization is currently in Beta, scheduled for General Availability release in late 2016.
PREDIX PLATFORM

BUSINESS CHALLENGES

Investment in the Industrial Internet of Things (IIoT) is expected to top $60 trillion during the next 15 years. And by 2020, over 50 billion assets will connect to the Internet. The amount of industrial data generated will be significant in terms of volume, velocity, and variety. In fact, industrial data is growing twice as quickly as any other sector. Yet today, less than 3% of that data is tagged and used in a meaningful fashion. In order to extract insight from the data and gain a competitive advantage, every power company will need to become a software company to thrive.

But harnessing that data potential from scratch presents challenges. Datasets can be fragmented and even siloed between organizations such that power leaders are unable to take advantage of this information in any practical way. Operational Technology (OT) and Information Technology (IT) functions are often operated separately, leading to duplication and fragmentation as these roles converge. The sheer volume of machine data presents obstacles, to be able to collect, manipulate, analyze and use vast volumes of machine data.

The imperative for power industrial IoT is a secured environment with capacity to grow at the speed of machine data and the technical infrastructure to apply sophisticated analytics that drive insights for more profitable business decisions for power companies.

SOLUTION DESCRIPTION

Predix is a comprehensive, modern platform with components that span from the machine to the cloud to enable industrial use cases. The primary components of Predix are:

• **Predix Machine**: The software layer responsible for communicating with the industrial asset and the Predix Cloud, as well as running local applications, like edge analytics. This component can be installed on gateways, industrial controllers and sensors.

• **Predix Connectivity**: Designed for scenarios where a direct Internet connection is not readily available. The service enables machines to talk to the Predix Cloud via a virtual network comprised of cellular, fixed line, and satellite technologies.

• **Predix Cloud**: A global secure cloud infrastructure that is optimized for industrial workloads and meeting regulatory needs.

• **Predix Services**: Industrial services that customers can use to build, test, and run Industrial Internet applications. It also provides a microservices marketplace where developers can publish their own services as well as consume services from third parties.

Predix Machine

Predix Machine provides a number of core capabilities in industrial scenarios, including edge analytics. Industrial scale data — which can be massive and is often generated continuously — cannot always be efficiently transferred to the cloud for processing. Edge analytics provide a way to pre-process the data so that only the pertinent information is sent to the cloud.

• **File and data transfer**: File and data transfer allows data to be pushed to the cloud by continuous streaming, scheduled batches or file uploads

• **Store and forward**: Store and forward provides support for intermittent connectivity loss (for example, when a locomotive travels through a tunnel). Data must be collected locally, and then forwarded to the cloud once connectivity is reestablished

• **Local data store and access**: This capability allows data about machines to be stored on the device so that, for example, a service technician can access the data directly

• **Sensor data aggregation**: Predix Machine can connect to multiple sensors and then push an aggregated 'fingerprint' to the cloud, which reflects the data gathered from all of the sensors

• **Edge analytics**: The edge analytics capability enables computational algorithms to be run directly on the data that is streaming off the machine

• **Certificate management**: In order to provide end-to-end security, Predix Machine supports certificate management to provide SSL-based connections to the Predix Cloud

• **Device provisioning**: When Predix Machine is installed on an edge device, it can 'phone home' to the Predix Cloud to register itself for further management and software upgrades

• **Device decommissioning**: When Predix Machine is taken offline, it can notify the Predix Cloud that it no longer needs to be managed

• **Configuration management**: Configuration management allows remote configuration of the Predix Machine and the tracking of configuration changes over the lifetime of the machine

Predix Connectivity

Predix Connectivity provides fast, secure cloud connectivity from Predix Machine to the Predix Cloud. The service eliminates the long lead times and the expensive proposition of designing and operating a custom and potentially sub-optimal connectivity infrastructure. Predix Connectivity also provides a secure and readily available global virtual network that fulfills Internet requirements in a repeatable fashion and is transparent to the enterprise. The virtual network includes cellular, fixed line, and satellite technologies.

Predix Connectivity is available today through several partners and is offered across the globe. Same day activation and provisioning, combined with continual proactive monitoring support, troubleshooting, and automatic business alerts, are available. Together with Predix Machine, Predix Connectivity provides plug-and-play, secure, and reliable connections to the Predix Cloud.

Predix Cloud

The Predix Cloud is central to enabling the Industrial Internet. It consists of a scalable cloud infrastructure that serves as a basis for Platform-as-a-Service (PaaS), which is what GE and power company developers can use to create Industrial Internet applications. It also provides an entry point for industrial enterprises to take advantage of new software technology without having to make massive hardware and software commitments.

GE has created a Software-Defined Infrastructure (SDI) that fulfills Internet requirements in a repeatable fashion and provides a secure and readily available global virtual network to facilitate dynamic automation and to apply SLA mappings to the underlying infrastructure. This is especially useful when an application requires an underlying hardware configuration. The provisioning management and pooling of resources can be done at a granular level, allowing for optimal resource allocation and ultimately driving costs down and value up.

The Predix platform is based on Cloud Foundry (CF), an open source PaaS that supports multiple developer frameworks and an ecosystem of application services. Cloud Foundry makes it faster and easier for application developers to build, test, deploy, and, perhaps most importantly, scale applications. Because Predix leverages CF, application developers gain access to the vibrant CF ecosystem and an ever-growing library of CF services. Additionally, because it is open source, CF can be customized for Predix workloads.
Predix Security Profile

GE has combined security certifications, hardware, software, expertise and sound practices to create an environment of trust for industrial companies.

Platform Hardening
- The platform and the underlying infrastructure are hardened to remove unnecessary services, applications, and network protocols, configure OS user authentication and to configure resource controls appropriately
- Automated and manual controls are deployed to identify and patch system vulnerabilities
- Common and layer identity for users, devices, software and data are enforced
- Unified and clean run-time environments are provided

Secure Industrial Applications
- Capability to validate and trust apps. Experts in OT/IT security designs that can help reduce time to deploy secure apps.
- SAST, DAST, artifact integration and automation
- Code vaulting and vetted delivery
- Routine Predix ‘Red Team’ assessments
- DevOps security evaluations for platform base code

Continuous Monitoring for Visibility
- End-to-end platform and infrastructure visibility to ensure trust
- Full Security Operations Center (SOC) and tooling
- Automated isolation and monitoring of incidents
- App-to-app behavioral evaluation
- Maintain chain of custody for data communities

Predix PaaS Security Responsibilities
- Physical security for hardware infrastructure
- Isolation of customer environments
  - To ensure business environment and data are hidden from other customers
  - To protect customer privacy

- OS security
  - Hardening and maintaining base OS images for provisioned Virtual Machines based on Predix hardening standards and related guidelines developed to comply with ISO27002:01 and SSSAE16 SOC 2 standards and industry best practices
  - Hardware security
    - Architect and securely deploy hardware for the cloud infrastructure based on Predix hardening standards and related guidelines developed to comply with ISO27002:01 and SSSAE16 SOC 2 standards and industry best practices
  - Secured storage
    - Providing encrypted block and object storage with associated services
  - Secured data in transit within the cloud network
  - Securing the network (using IPSec and SSL/TLS protocols) based on controls defined in Predix hardening standards and related guidelines
  - Federated identity management
    - Tools to use existing identity stores and remove the burden of identity management
  - Secure single sign-on (SSO) services for access to Predix cloud
  - Vulnerability and patch management
    - Test and update software/hardware based on security advisories and regular vendor patch releases utilizing proper change management procedures
  - Monitoring and logging
    - Actively searching for network intrusion, malicious activities, and compliance policy violations that are a threat to the infrastructure
    - Communicating and remediating any incidents
  - Rigorous risk assessments against the cloud infrastructure
  - Perform penetration testing and compliance scanning to detect any vulnerabilities and compliance violations and quickly remediate them
  - Perform assessments against security controls and procedures

Predix Services

Key Predix cloud services can be broken down into two categories, each with its own sub-categories.

Operational Services
Operational Services enable application developers to manage the lifecycle and commercialization of their applications:
- DevOps Services: Services to develop and deploy industrial Internet applications in the cloud.
- BizOps Services: Services that enable transparency into the usage of Industrial Internet applications so that developers can ensure profitability.

Industrial Services
Industrial Services provide the core capabilities required by Industrial Internet applications:
- Asset Services: Services to create, import and organize asset models and their associated software, capabilities, processes and personnel that are leveraged across multiple customers, raising the overall assurance that their critical data assets are protected and secured.
- Data Services: Services to ingest, clean, merge and ultimately store data in the appropriate storage technology so that it can be made available to applications in the manner most suitable to their use case.
- Analytics Services: Services to create, catalog and orchestrate analytics that will serve as the basis for applications to create insights about industrial assets.
- Application Security Services: Services to meet end-to-end security requirements, including those related to authentication and authorization.

CUSTOMER BENEFITS

Predix delivers the following benefits to power companies:
- Speed to Implementation and Innovation: The ability to rapidly develop and deploy solutions means a competitive edge and the ability to speed business benefits. With Predix, power leaders have a ready platform for deployment, without delays of on-premise design, procurement, setup, testing and production hardening.
- End-to-End Security: Industrial companies need assurance that their critical data assets are protected and overall risk reduced. GE has made investments in security software, capabilities, processes and personnel that are leveraged across multiple customers, raising the overall security profile.
- Lower Capital Expenditures: Traditional approaches to systems implementations require IT teams to purchase and configure hardware with large up-front capital outlays. For the industrial IoT space, volume of machine sensor data can scale economically as new operating assets are connected for monitoring on Predix.
- Lower Support Costs: Requirements for on-site support can be costly, especially for multi-site implementations. Incremental personnel for maintenance of large-scale IoT environments, including 24/7 IT support, security personnel, administrators and supervisory support can be defrayed by leveraging GE’s cloud experts.
- Ability to Scale: With advances sensor technologies, analytic data science and networking capacity, the possibilities with industrial IoT are expanding at a rapid pace — a pace that on-premise systems will be challenged to match. With the Predix “service delivery” model, customers can specify the right amount of compute and platform resources needed, and scale rapidly, as requirements dictate.
- Ubiquitous and Global Visibility: One of the key requirements of an Industrial Internet platform is its ability to support a global model so that data can be aggregated and analyzed across operating geographies in order to enable more valuable business decisions. A cloud environment enables such cross-location visibility by providing access from anywhere to the common data store.
The Predix™ cloud solution is projected to extend the life of RasGas assets, as well as lower operating costs through greater efficiencies. This ‘Software Defined Operations’ will provide RasGas with deeper insights into their plant operations to enable more forward looking decisions, in turn providing inputs for how to manage their business operations.

— RasGas Company Limited, one of the world’s premier integrated Liquefied Natural Gas (LNG) enterprises, established in 1993

For more information on Predix: www.predix.com

**DIGITAL SOLUTION DESCRIPTION**

**ADVANCED CONTROLS / EDGE COMPUTING**

**BUSINESS CHALLENGES**

The demand for energy is continually growing, and while needs and priorities differ from application to application, the desire for reliable and efficient power remains constant. With flexibility at the forefront of our technology innovation, GE is focused on delivering products that enable gas turbine power plants to operate seamlessly with renewable energy resources.

Operational flexibility is a total plant system capability — each component must complement and enable the capabilities of the others and all must work together to achieve high levels of efficiency. As a manufacturer of all major power plant equipment, GE is uniquely qualified to develop plant-level solutions that carefully consider the capability of each component to satisfy the demand for plant-level flexibility.

**SOLUTION DESCRIPTION**

**OpFlex: Flexibility Without Sacrificing Efficiency**

GE’s position as an OEM enables the use of strong domain expertise to differentiate turbine and plant performance and operability with controls. High-fidelity physics-based models of the plant components are embedded within the controls logic to run in real time, and are the backbone of adaptive control strategies that protect assets and enhance operation. Features and benefits of this model-based control strategy include:

- **Startup agility**, providing fast, reliable, repeatable starts with low emissions
- **Combustion versatility and improved turndown**, providing robust operation during variations in weather, fuel and grid
- **Load flexibility**, for load range expansion, and improved efficiency and responsiveness
- **System reliability enhancements** for reliable, cost-effective operations

**Fast and Reliable Startup**

The fast start capabilities of our gas turbines enable power generation in response to sudden demand. With the ability to go from cold iron to full power in as little as five minutes, and to start and stop in short cycles, our gas turbines accommodate fluctuating supply or demand with high efficiency.

**BaseLoad Efficiency**

Some gas turbines are required to operate under baseload conditions at certain periods of time. GE’s gas turbines are among the most efficient in the industry, reducing fuel costs when providing the maximum amount of power needed by the grid.

**Turndown for Emissions and Cost Control**

This capability extends low emissions operation to lower load levels, enabling reduced fuel consumption and lower total emissions at minimum loads. This translates to improved economics to remain online during off-peak demand periods to alleviate shutdown and startup costs. This enhanced turndown capability also extends the available load range for operation, improving dispatch flexibility and enabling greater participation in regulating reserve markets.

**Reliability**

This capability provides added reliable, cost effective operations, slows performance degradation, recovers lost performance and extends availability of assets. A new set of analytics reduces false alarms and system trips, thereby reducing overall downtime for trip recovery and improving plant productivity.
The ability to protect, control, monitor and improve performance of the entire plant is critical to realizing its greatest value. GE’s Mark VIe based control system unifies and simplifies protection, control, and monitoring of the entire plant to enhance performance and deliver predictable operation.

Using a modular Predix machine-enabled platform, the Mark VIe control system provides a flexible and scalable architecture for applications ranging from turbine-level to plant-level control. This modular approach facilitates future technology upgrades and protects against obsolescence.

To simplify plant operations and maintenance, the plant control system includes the following primary elements that share common architecture, software tools, and operator interfaces:

- Mark VIe Turbine Control Panels for each gas turbine and steam turbine
- Mark VIe Distributed Control System (DCS) platform for HRSG and plant control
- Mark VIe Safety Controller, a locked configuration, when required for SIL certification
- ActivePoint® HMI with enhanced visualization, alarm rationalization, and server-based thin client deployment

ActivePoint HMI (Human Machine Interface)

To improve worker efficiency, reduce operating costs, and deliver a superior power plant user experience, GE engineered the ActivePoint HMI in close collaboration with more than 100 operators globally. The ActivePoint HMI is in compliance with ISA 18.2, the High Performance HMI Handbook, and other industry standards. It is a total solution enabling system monitoring and controlling from any device, anytime, anywhere. HMI screens for all GE power generation equipment will conform to this new design guideline to provide a common interface across the entire plant and to create a user experience that is visually appealing and enhances situational awareness.

Alarm and Protection Rationalization

GE’s new alarm management system is fully integrated into the ActivePoint HMI. Alarms are now directly represented and actionable within both HMI screens and dedicated lists, and are based on GE’s three-step alarm rationalization process (Design, Categorization, and Alarm Prioritization). By applying common philosophies and rationalization rules across all equipment within the plant, enunciated items are categorized as Events, Diagnostics, Alerts, or Alarms (levels 1, 2, and 3) to greatly improve operator responsiveness.

Actionable alarms can be reduced by as much as 80 percent and are organized into parent-child hierarchies to simplify determining root causes. The alarm management system details the urgency, consequences, potential causes, and suggested actions. Using the Mark VIe distributed control system (DCS) for controlling the entire plant enables enhanced alarm configuration and presentation capability, as well as an integrated operating experience across GE equipment.

Similar to alarm rationalization, GE developed a consistent process for rationalizing the controls protection system associated with plant equipment (Trips, Shutdowns, Runbacks, Pre-Start Checks, and Permissives). Trip optimization reduces or eliminates nuisance trips. Startups are streamlined through the categorization of pre-start checks (not required for startup) and permissives (required for startups).
“Our fleet, including at our other two combined-cycle power plants in Cassano and Sermide, will reap the benefits of GE’s advanced software solutions.”

— Valerio Camerano, CEO, A2A

CUSTOMER BENEFITS

- Deliver power quickly in response to changing grid demands
- Overcome equipment limitations that prevent you from capitalizing on emerging market opportunities
- Eliminate slow, inefficient start-ups and their associated costs
- Stay online more cost effectively
- Meet more demand within existing markets
- Generate revenue through ancillary markets
- Reduce emissions “events,” and potentially costly compliance penalties that can result in financial loss
- Expand your operating window

F-Class

- 40% reduction in start up fuel consumption (for combined cycle plant hot start)
- 50% reduction in start up time (for combined cycle plant hot start)
- 3x increase in fuel variation handling capability
- +2.5% increase in peak output to meet short-term demands
- 50% reduction in start-up NOx emissions
- 2.5x increase in loading/unloading rate — up to ±50MW/min

E-Class

- 8% potential increased output to meet short-term demands
- 10 minute starts for 7EA (<15 min. for 9E) vs. 30 minutes normally
- 50% trip avoidance
- 50% reduction in start-up CO₂ emissions
- 40% per minute fast ramp to base load

DIGITAL SOLUTION DESCRIPTION

CYBER SECURITY

BUSINESS CHALLENGES

The impact of a cyber attack to power operations has the potential to be catastrophic, to the power business, as well as employee and public well-being. More and more, utilities are a growing target for cyber criminals keen on making political statements or simply as criminal misdeeds. Government organizations, such as the Department of Homeland Security, continue to advise power executives to take proactive steps to protect physical assets, software systems and network components of their operating environment.

Additionally, as the power industry has become a more challenging operating environment, leaders are forced to be creative in business planning, and the associated risk management to that business plan. As part of an enhanced risk management program, forward thinking power leaders are putting the right programs in place to assess their vulnerability, to protect their systems and proactively defend their environments. However, the challenge is significant. The nature of security attacks are ever-evolving and require continuous vigilance to combat. Due to the specific nature of attacks on operating technologies, such as Industrial Control Systems (ICS), unique programs are required above the standard IT security protocols to truly protect the power operating environment.

What’s needed is a partner who understands the security profile of an operating environment, who has a focus on industrial software and technology, offers a comprehensive strategy and software portfolio, and is backed by global security expertise. GE has been serving the power industry for decades in every region in the world and offers a comprehensive set of cyber solutions, built on experience and the Industrial Internet platform, Predix. Together with our customers we are dedicated to protecting the global power infrastructure from those who would compromise power delivery, public safety and the financial health of our customers.

$243 Billion – $1 Trillion:

impact to the US economy of an electricity blackout across 15 US states affecting 93 million people

Source: Lloyds Emerging Risk Report, 2015

225K people lost power in the Ukraine due to a cyber attack (December 2015)
THE PATH FOR MAXIMUM CYBER PROTECTION

It is important to understand the steps required to implement a security strategy. The easiest way to identify and initiate these steps is to review a security maturity model, with clear actions outlined for the power business environment:

Stage 1: Assess

Identify immediate security issues that can impact operations, even if the environment is thought to be “air gapped.” Common findings from expert assessments include unapproved wireless access points or unsafe software—vulnerabilities that attackers can easily exploit. Many of these issues can be fixed quickly and simply to reduce cyber threat risk.

Stage 2: Protect

Implement security monitoring and defensive layers to comply with standards and strengthen the security posture. Lower the risk of security exploits by using technical solutions, such as purpose-built industrial control security equipment. Set up automation and patch management tools to simplify and expedite security administration. Administration change control security equipment. Set up automation and patch management tools to simplify and expedite security administration. Implement cyber training programs, similar to mandatory operations safety programs, to inform internal resources on what to look for and how to respond to cyber activities.

Stage 3: Prevent

For sophisticated organizations, pursue proactive and predictive security measures such as running attack scenarios on cloud-collected data. “Digital Twins” can replicate operating environments and simulate defenses across all stages, it is critical to maintain a constant vigilance to ensure basic security hygiene and the enforcement of cyber security policies.

SOLUTION DESCRIPTION

GE Power Digital Solutions work at any stage of security maturity to bring greater control, less risk and increased reliability to a power business. Depending on the situation, there are impactful people, process and technology actions that can be instituted.

GE’s Digital Cyber Security Solutions include:

Security Assessment Services

Security and assessment testing for operational technology (OT) is a specific and demanding discipline. It requires an industrial mindset, in-depth OT cyber security knowledge and the ability to apply best practices to industrial process environments. GE’s security and test professionals can help power companies plan, design, and build operational resilience into people, processes and technology.

Site Security Assessment is an in-depth, comprehensive evaluation of the operational site facility based on industry standards and best practices, resulting in an individualized report with prioritized mitigation recommendations and strategies. The assessment consists of:

- Site Security Health Check: Rapid overview of the operational site facility providing a baseline of cyber strategy, with recommendations on further analysis as well as economic justifications for remediation.
- NERC CIP Cyber Vulnerability Assessment: In-depth evaluation for electric utilities following the requirements prescribed by NERC CIP. The report includes mitigation plans aligned to NERC CIP as well as other industry best practices.
- IEC Security Practices Certification: Provides certification for system supplier compliance with industry standard security best practices (IEC62443-2-4), covering areas such as hardening, anti-malware, patch management, network, and data security.
- IEC 62443 GAP Assessment: Helps industrial automation manufacturers and system integrators understand potential security gaps in their software development, and aligns their practices to IEC 62443-2-4. Specialists are highly qualified to perform both on-site and remote assessments.

Cyber Asset Protection (CAP)

- Patch Update Service: Monthly subscription service provides vendor approved software security patches.
- SecurityST:
  - GE’s SecurityST provides an integral defense-in-depth solution for turbine, plant and generator controls environments. Employing multiple defensive services and technologies, it supports the reliability, availability, integrity and maintainability of a plant’s critical control system and related networks. The SecurityST solution is designed to support plant operators’ compliance to cyber security regulations, standards, and guidelines such as, NEI 08-09, NERC CIP, WIC, IEC and ISA 99.
  - Intrusion Detection: Monitors the control system network for known attack signatures and unusual network activity and notifies of potential threats.
  - Role Based Access Control: Enforces best practice of every user having a unique user name and password.
- Virtual Zoning: Create logical security policy zones without physically rewire the network (VLAN).
- Graphical Network Topology (real-time): Real time graphical representation of the controls network. Includes unknown device discovery and alarming and SIEM integration.
- Intrusion Prevention System (IPS)/IDS: Accurately detects and prevents cyber attacks to the industrial network. By leveraging Wurldtech’s OT and IT signature set, OpShield offers specific and customized, industrial protection for ICS/SCADA systems and industrial networks. Purpose built for industrial control systems, the inspection engine supports most existing industrial protocols, with the flexibility to easily support emerging proprietary protocols.
- Centralized Management: A single graphical interface to build and deploy security policy and protection profiles. It also offers a network-wide view of alerts and attacks on the industrial network.

Cyber Security Training

A comprehensive portfolio of security training courses for critical infrastructure and Industrial Control Systems (ICS) to increase staff knowledge and awareness.

Managed Security Services**

Remote monitoring and diagnostics of OT control environment security events. Activities are examined on network, ICS and host environments; User and systems accounts are monitored for malicious or compromising events.

OpShield

A purpose-built intrusion detection and intrusion prevention security solution designed to protect critical infrastructure, control systems, and operational technology (IOT) assets. OpShield monitors and blocks malicious activity and minimizes disruptions to enable highly available operations and secure productivity.

OpShield is purpose-built to protect industrial and SCADA operations, offering comprehensive security, simplicity, and visibility. This network security solution monitors and blocks malicious activity and attacks to ensure highly available industrial operations for maximum uptime and secure productivity.

- Virtual Patching: Protects unpatched systems with strong field and perimeter defense capabilities.
- Inspects and Controls: Industry leading threat signatures and granular control over protocol commands.

Cyber Security Training

A comprehensive portfolio of security training courses for critical infrastructure and Industrial Control Systems (ICS) to increase staff knowledge and awareness.

Managed Security Services**

Remote monitoring and diagnostics of OT control environment security events. Activities are examined on network, ICS and host environments; User and systems accounts are monitored for malicious or compromising events.

* GE acquired Wurldtech Q2 2014
** Scheduled for General Availability release in late 2016.
CUSTOMER BENEFITS

Overall Cyber Security Solution Benefits
- Reduced risk from cyber attack on key assets, SCADA/ICS systems, and operational network infrastructure
- Proactive identification of critical vulnerabilities and security events
- Improved operational reliability and reduced risk in business continuity
- Regulatory compliance for NERC CIP, with ability to demonstrate security actions and activities

OpShield Benefits
- Protects unpatched system with strong perimeter and field defense
- Inspects and protects control system network protocols with industry’s leading threat intelligence
- Introduces breakthrough drag-and-drop virtual zoning for segmentation without network disruption
- Displays graphical network-wide industrial security view and integrates with SIEM tools
- Simplifies security administration with easy to use graphical interfaces — no CLI required
- Provides enhanced protection against execution of unauthorized code
- Supports plant management’s compliance to cyber security regulations, standards and guidelines

SecurityST Benefits
- Maintains consistent operations of plant’s critical controls and related systems
- Identifies cyber threats to control systems from external or internal sources
- Provides secured backup and recovery capabilities
- Provides proactive and timely monitoring of applicable software security patches and anti-virus/malware/ intrusion signatures using a centralized patch deployment tool

Cyber Asset Protection (CAP) Benefits
- Provides proactive and timely monitoring of applicable software security patches and anti-virus/malware/
- Protect against employee attrition by educating a broader set of talent
- Proactively stop cyber attacks with a well developed staff, ready to identify and act on suspicious events:

Cyber Security Training Benefits
- Arms personnel to be the front line in the battle against cyber attacks
- Achieve compliance requirements for training and preparedness
- Proactively stop cyber attacks with a well developed staff, ready to identify and act on suspicious events:

NERC CIP Compliance
Many U.S. electric utilities are now federally mandated to comply with the North American Electric Reliability Corporation (NERC) Critical Infrastructure Protection (CIP) standards that dictate industrial security and remediation technology, including required compliance, by July 1, 2016. GE’s products and services assist power generation customers in meeting CIP mandatory standards and reduce the likelihood of a compliance event. An event would result in a fine of $1MM per day.

A WELL DEFINED AND PROTECTED OPERATIONS ENVIRONMENT
IT systems are typically fortified at the edge of the Internet with firewalls, proxy servers and intrusion detection services. However, within the corporate environment, sub-networks exist with much looser security barriers, due to the system and data sharing requirements between departments. The OT environment requires a much stronger vigor to protect against attacks that might come from the Internet:

- The ICS network should be separated from the rest of the corporate network via technologies (firewalls, DMZ) that severely limit traffic allowed between the two to only that with special designation.
- User access to the OT network environment should be controlled and examined frequently to ensure that only those that require access are allowed access. Access lists should be reviewed at regular intervals by senior management — extraneous access and departed employees should be removed immediately.
- Traffic within the ICS “network” needs to be monitored closely with sophisticated intrusion detection capabilities to identify any suspicious activities.

$96K avoidance of unplanned outages (modeled on 500MW Block)

$1MM — the average cost of one NERC CIP violation
IMPLEMENTATION & TRANSFORMATION SERVICES

OUTCOME DELIVERY SERVICES

By choosing GE as your digital transformation partner, you will achieve new business outcomes through 5 simple stages: discovery, deployment, adoption, customer support, and ongoing outcome delivery. You will work through these stages alongside GE teams with decades of expertise in big data and asset management, power plant modeling and operations, analytics, critical infrastructure protection and successful IT/OT digital implementation strategies.

To commence the discovery stage, we encourage you to engage in a Power Digital Assessment Service. Together we will identify achievable business outcomes and the digital solutions that will deliver them. The next stages include software technical deployment, validation of your environment and data, adoption, process mapping, and on-boarding to allow you to take full advantage of the analytics capabilities and integrate them into the day-to-day operations. Customer support, outcome delivery and success are ongoing services in your journey toward better business outcomes. In these, a team of customer success managers and support specialists will continually deliver training and updates, conduct regular health checks and business reviews, and ensure your ultimate satisfaction with our products and services.

Deployment, delivered by GE Professional Services

In the technical deployment stage, GE’s Professional Services coaches and works alongside you as we provision and configure our solutions to meet the specific needs of your operating environment. We work directly with your users and educate them on our solutions to ensure they’re successful in understanding the capabilities and usage of the software applications. Professional Services executes upon a proven deployment methodology derived from deep engineering expertise in analytics configuration and modeling of plant assets. Our teams deploy the applications with a keen focus on protecting critical infrastructure, while managing large operational data sets like historian-based and sensor data.

Advisory Services: Consultancy/Assessments
- IIoT Workshop
- Design Thinking
- Data Science
- Architecture & Blueprint

Customer Support, Delivered by GE’s Technical Support

You will have access to several simple, accessible channels to get in touch with GE as part of our customer support commitment to you. You can access support as your time allows through a self-service model with access to a knowledge base of FAQ and expert tips. In addition, GE offers assisted support with access to live support engineers. As a GE customer of our Software as a Service solutions, you have instant access to our digital innovation and power domain expertise through frequent software releases.

Ongoing Outcome Delivery, Delivered by GE’s Customer Success

With GE as your partner on your digital journey, GE’s Customer Success is your trusted resource to ensure you’re making the most out of your digital investments. It will continue to work with you after the initial deployment to incorporate new product capabilities into your operations and achieve your desired business outcomes. From leveraging tools, to best practice coaching, to health checks and business reviews, GE’s ongoing Customer Success services will help you make sure your team uses their analytics capabilities to their full potential and achieves optimal reliability, productivity and profitability objectives.

- Named Customer Success Manager
- Regular Business Outcome Reviews
- Ongoing Adoption Services
IMPLEMENTATION & TRANSFORMATION SERVICES

HOW TO PURCHASE

When engaging with GE, you have a choice of how you’d like to purchase digital solutions to achieve business value and outcomes. We understand your challenges and priorities are diverse, so we provide a flexible way to contract and deliver our solutions to you. Below are the three options:

Application Subscription Model

Purchase our digital offerings through an annual application subscription model. You will have direct access to our applications, built on Predix, such as Asset Performance Management to improve your reliability, and Operations Optimization to improve productivity. This may be the model for you if you:

• Are considering building M&D capabilities
• Need to measure if assets meet your business needs, or are considering buying new assets
• Have traders or schedulers dispatching plant capabilities
• Need to make timely and informed decisions around reliability and costs
• Have most efficient allocation of CAPEx tied to fleet capability and competitive position

Predix Platform Subscription Model

For customers that are looking for applications outside of GE’s portfolio, or desire the ability to extend our applications internally, we can provide a subscription to Predix as a Platform. Customers can choose from four Predix Developer Packs based on usage and services needs — Starter, Standard, Professional and Premium. This may be the model for you if you:

• Run large, multi-fuel fleets
• Have significant headquarter software engineering capabilities
• Operate a fleet M&D center
• Are a business savvy CIO with clear understanding of generating business value

• Want to extend function in GE applications and build your own internal applications
• Experience existing infrastructure complexity, limitations, growing costs with OT integration
• Have limited value of analytics due to lack of IT/OT integrations and data quality
• Need to deliver innovations and analytics expertise to real time applications
• Have specific business outcomes driven by machine data and analytics
• Want to monetize on your industry best practices through the GE Store

Bundled Hardware and Software Model

GE offers a bundling of hardware and software to deliver you an increase in overall fleet or company performance. This may be the model for you if you:

• Are open to and innovative business models with GE
• Are ready to leverage data and analytics to catapult your business
• Are pursuing a multi-year digital strategy and roadmap
• Are seeking to elevate company performance through incremental improvements across your fleet

• Are a company executive with clear incentives to improve your business
• Engage in a significant relationship with GE — M&D and beyond

IMPLEMENTATION & TRANSFORMATION SERVICES

GETTING STARTED

No matter where you are in your digital journey, GE has as team of experts to help expedite your business to the next level of value and outcomes — powerful outcomes like minimized downtime and improved productivity.

To get started, reach out to your local sales representative and ask for a Power Digital Assessment Service at any time. GE experts will partner with your key stakeholders throughout the service engagement.

This simple Power Digital Assessment Service, performed by GE’s power generation, digital and cyber security experts, helps to identify areas of improvement for a single plant, with an eye to scaling the findings across your fleet. There are two focus areas for the assessment, depending on your goals:

Plant Performance

Challenge
Changes in the current power market create challenges for power generators. In order to compete in the industry, while supporting customer needs, power generators are driven to become more flexible, responsive, and cost-effective in their operation.

Benefits
• Quick analysis of potential improvements around equipment reliability
• Better understanding of how reliability improvements can reduce overall equipment downtime
• Potential improvements in plant efficiencies
• Recommendations for improving value in more flexible operations

Cyber Security

Challenge
Industrial controls systems (ICS) networks are increasingly targeted for cyber attack and system operators are experiencing cyber incidents at an ever-expanding rate. Operators need to understand their current security status and develop a plan to improve their security posture. They may also require justification and support for additional budget to conduct a more in-depth assessment.

Benefits
• Provides a rapid security snapshot to quickly identify and understand potential risks that can impact critical production systems
• Improves overall security by evaluating people, architecture and technology to identify weaknesses and mitigation strategies
• Justifies further security efforts with support from documented recommendations

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Who Needs to Participate

**Your Leadership**

- Executive Sponsor
- Division/Plant Operations
- Division/Plant Engineering
- Plant Information Technology
- Plant Maintenance
- Supervisors/Operators

**GE Team**

- Account Executive
- Power Generation Solutions Architect
- Power Operations Subject Matter Expert
- Cyber Risk Management Expert

**Workshop Deliverables**

- Alignment of your organization’s goals and objectives to plant performance
- Recommended actions and remediation to improve performance
- Delivery plan and roadmap for actions
- Business value and estimated ROI

- **Prepare**
  - Discuss Customer Outcomes (Goals & Vision)
  - Review Workshop Agenda, Concept & Process

- **Collaborate**
  - Full Group Discussion
    - Validate Outcomes (Goals & Vision)
    - Discuss Key Metrics
    - Discuss Operations & Barrier to Success
  - 1-on-1 Discussions
    - Discuss Department-Specific Challenges

- **Advise**
  - Present Results & Validate GE’s Understanding of the Business
  - Discuss GE Recommendations & Solution Value Proposition
    - Proposed Solution Recommendations
    - Proposed Reference Architecture
  - Develop Action Plan (Next Steps & Timeline)

San Ramon Design Center Visit

As part of the Assessments outlined above or as a starting point to begin discussions of where your organization might begin to leverage digital, we invite you to visit our design center in San Ramon, California. There you will find a hub of analytic development and software talent ready to understand your particular business situation and collaborate with you on next steps forward.

The Design Center is a collaborative space where cross-functional teams meet to engage deeply with customers, and to discover and test innovative solutions for them in a workspace unlike any other at GE. This intentionally designed, state-of-the-art environment features:

- Flexible workspaces containing a mix of digital and analog creation, annotation, and capture capabilities
- Sophisticated video-collaboration tools
- An impressive 270-degree immersive environment, which helps workshop participants directly connect to a user’s workplace experience

Available resources at the center include software developers, data scientists, database engineers, UI experts and power industry trained personnel to help build your roadmap from connecting assets through plant and fleet optimization.

Additional Resources

Please visit GE’s websites at ge.com/digital/power to learn more about our offerings, customer successes and new innovations by exploring videos, data sheets and customer reference stories of power generation companies who have implemented Predix and GE’s suite of applications. You will discover the value and outcomes that global power leaders are capturing — outcomes like improved plant and equipment reliability, visibility into plant performance and market conditions, and effective security policies that defend against cyber threats.
OUR CUSTOMERS DETERMINE OUR SUCCESS

We look forward the opportunity to serve you in your digital transformation
Visit us at www.ge.com/digital/power

ACRONYMS

API – Application Program Interface
APM – Asset Performance Management
APT – Advanced Persistent Threat
CBM – Condition Based Maintenance
CMMS – Computer Maintenance Monitoring System
DDoS – Distributed Denial of Service
DPI – Deep Packet Inspection
EAM – Enterprise Asset Management
IaaS – Infrastructure as a Service
IAST – Integrated Application Security Testing
IoT – Industrial Internet of Things
IoT – Internet of Things
IPS – Intrusion Prevention Solution
MSSP – Managed Security Services Program
OaaS – Outcome as a Service

OT – Operational Technology
PaaS – Platform as a Service
PM – Preventive Maintenance
RCM – Reliability Centered Maintenance
SaaS – Software as a Service
SOA – Service Oriented Architecture
SOC – Security Operation Center
UI – User Interface
UX – User Experience